WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT

Demonstration Facility Pilot Study
Microfiltration Membrane
Tertiary Treatment Application
Final Draft Report

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By

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King County

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Technology Assessment Program

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Executive Summary

The focus of these pilot tests was to evaluate a microfiltration membrane process as a tertiary filtration system to produce Class A reuse water. In addition, alum pre-treatment was implemented to determine the impact of a coagulant on total phosphorus (TP) removal. This report summarizes the findings of the microfiltration membrane pilot tests. The testing facilities were designed to supply the microfiltration (MF) unit, manufactured by Pall Corporation, with three different feed streams, each with a water quality different from the other two. Each stream test was designated as a specific test stage:

- Stage 1 – West Point Secondary Effluent (WP SE).
- Stage 2 - Biological Aerated Filter 1 (BAF #1) pilot unit effluent.
- Stage 3 - Biological Aerated Filter 2 (BAF #2) pilot unit effluent.

The performance goals for all three stages were:

- Effluent turbidity <0.5 NTU, 95th percentile, to meet Class A requirements.
- Effluent TOC <2 mg/L, 50th percentile, to meet groundwater recharge criteria.
- Effluent TP <0.05 mg/L, 90th percentile, to meet enhanced nutrient removal goal.
- System Recovery >90%.
- Clean in Place (CIP) interval >30 days.
- Less than 2% long-term flux decline per year.

Table 1 summarizes the MF unit's ability to meet these performance goals.

Table 1. MF Unit Measured Performance

Goal Description	Target	Measured Performance		
		Stage 1	Stage 2	Stage 3
Turbidity Removal	<0.2 NTU 95th Percentile	0.06 NTU	0.06 NTU	0.06 NTU
Filtrate TOC	<2 mg/L, 50th Percentile	Avg: 10.1 mg/L	Avg: 9.8 mg/[	7.5 mg/L
		Max: 11.8 mg/L	Max: 12.9 mg/L	9.6 mg/L
TP Removal	<0.05 mg/L, 95th Percentile	Not measured	1.8 mg/L	Approx. 0.053 mg/L[a]
			No alum pre-treatment	Alum pre-treatment
CIP Interval[b]	>30 days	~ 30 days	~ 30 days	~ 60 to 90 days
System Recovery	>90%	92.5%	89.4%	89.5%
Long-Term Flux Decline	<2% per year	Not measured[c]	Not measured[c]	Not measured[c]

[a] Approximation with only 4 data points.

[b] Observed during extended run tests.

[c] Unable to measure during pilot test duration.

Turbidity Removal

The Pall MF pilot unit provided very good filtrate turbidity quality. For all three stages, the 95^{th} percentile was 0.06 NTU and the performance goal was achieved. During Stage 2, feed turbidity spikes reached 67 NTUs, which increased membrane fouling but did not affect filtrate turbidity.

There was one filter run during Stage 2 where filtrate turbidity escalated above 1 NTU. However, this was an isolated incident attributed to a normally closed valve being slightly opened, which allowed some of the feed to mix with the filtrate.

TOC Removal

The performance goal for TOC removal was <2 mg/L 50^{th} percentile. However, the rejection rate can vary depending on the relative percentages of dissolved and particulate organic compounds. The TOC percent removals in each stage varied widely because the influent TOC varied widely. The performance goal was not achieved during any stage. However, some removal did occur, which indicates there were particulate organic compounds in the influent.

TP Removal

The microfiltration membrane did not meet the TP removal performance goal without alum pre-treatment. This was observed during Stage 2 testing where the 95^{th} percentile TP concentration was 1.8 mg/L (Table 1). However, during Stage 3, alum pre-treatment using a concentration of 50 mg/L resulted in a 95^{th} percentile TP concentration of approximately 0.053 mg/L, which was just above the performance goal level. This result is qualified as approximate because only four data points were collected. The alum pre-treatment resulted in a dramatic reduction in both TP and ortho-phosphate levels in the MF filtrate indicating that the 0.05 mg/L goal is achievable.

Clean in Place (CIP) Interval

In order to accurately determine the expected CIP interval using a pilot system, several months of testing under the same conditions is required. With three unique feed streams to evaluate over five months, there was not enough time in this study to accurately predict the CIP interval for each test stage. Based on the test results, a CIP interval was estimated for each test stage (Table 1). For Stages 1 and 2 the maintenance clean frequency was twice per week. Also, the maintenance clean protocol was modified as testing progressed. Additional testing with the most recent protocol during Stages 1 and 2 might have increased the maintenance clean interval and extended the CIP interval. Without additional data, we assumed that a maintenance clean frequency of twice per week would require a CIP every 30 days.

During Stage 3, the maintenance clean frequency was once per week. However, the increase in TMP was the lowest during this testing, and the maintenance clean interval could have been extended to once every three weeks. It is possible that the CIP interval could then increase to every 60 to 90 days. Therefore, Table 1 indicates an estimated 60 to 90 day interval.

Based on the test results, recommended design criteria for a full-scale implementation are summarized below for each stage.

Stage 1

- Feed source: WP SE.
- Flux-20[1] = 32.5 gallons per day per square foot (gfd) with chlorine feed at a target dose of 5 mg/L.
- Backwash frequency of 15 minutes with a system recovery of 92.5%.
- Maintenance clean frequency of twice per week using chlorine only. Frequency might be decreased (e.g., once per week) if heated water and caustic soda are added to the protocol.
- Estimated CIP interval is 30 days. This could be increased if the maintenance clean frequency is decreased.

Stage 2

- Feed source: BAF #1.
- Flux-20 = 30 gfd with chlorine feed at a target dose of 5 mg/L.
- Backwash frequency of 10 minutes with a system recovery of 89.4%.
- Maintenance clean frequency of twice per week using chlorine and caustic soda with water heated to 38 ºC.
- Estimated CIP interval is 30 days.

Stage 3

- Feed source: BAF #2.
- Flux-20 = 27 gfd with no chlorine feed.
- Backwash frequency of 10 minutes with a system recovery of 89.5%.
- Maintenance clean frequency of once per week using chlorine and caustic soda with water heated to 38 ºC.
- Estimated CIP interval is 60 to 90 days.
- Enhanced Phosphorous Removal. An alum dose of 50 mg/L will produce filtrate TP <0.05 mg/L. Alum addition could decrease the maintenance clean and CIP frequency. If a maintenance clean frequency of once per week is targeted, the flux rate could go up. The flux-20 = 35 gfd was tested for 24 hours and excessive fouling of the membrane was not observed.

[1] Flux-20 is the design flux at 20 ºC.

Each feed stream affected the MF unit in a different way. BAF #2 effluent was a very high quality effluent with the lowest feed turbidity. Even without chlorinating the feed, the TMP slope was the lowest of the three feed streams tested (1.1 psi per day). With alum pre-treatment, the TMP slope was as low as 0.8 psi/day. The WP SE feed proved to be a little more challenging to filter. The TMP slope ranged between 4 and 14 psi per day. Chlorine was added to the feed and the backwash frequency was reduced from 20 to 15 minutes, with a recovery of 92.5%.

The BAF #1 effluent was the most difficult to filter. High turbidity spikes in the feed resulted in several clean in place (CIP) cleans being required. The TMP slopes ranged from 7 to 10.6 psi per day. The backwash interval was reduced from 15 to 10 minutes and the recovery dropped below 90%.

Introduction

The King County Department of Natural Resources (King County) conducted a nine-month demonstration pilot testing project (from June 2001 to March 2002) to assess the performance of eight emerging wastewater treatment technologies. The focus of this project was to assess technologies that had the potential to minimize the footprint, impacts, and costs of producing reclaimed water (Class A or better) at a small satellite facility. This report summarizes the findings of the microfiltration membrane pilot tests.

Description of the Technology

In membrane filtration, raw water is filtered by flowing through a plastic or polymeric material (the membrane layer) that contains millions of small pores. The membrane pores are large enough to allow water to pass, yet small enough to restrict the passage of undesirable materials such as particulate matter and pathogenic organisms. Membrane technologies include reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF). The primary difference between the types of membranes is the size of the pores in the membrane material: the smaller the pores, the smaller the materials removed by the membrane. The driving force for low-pressure membrane filtration is a trans membrane pressure (TMP) differential, which can be either pressure (in pressurized systems) or vacuum (in submerged systems).

A microfiltration membrane has a pore size in the range of 0.1 to 2 μm[2] and operates at low pressures ranging from 3 to 30 psi. Microfiltration is best suited for particulate and turbidity removal and has primarily been used for potable water treatment. However, it has also proven to be an effective wastewater secondary effluent filter to meet effluent turbidity limits for reuse applications. Recently, microfiltration has become a feasible tertiary filtration alternative to conventional granular media filtration.

The microfiltration membrane tested for this project has an absolute pore size of 0.1 μm. Figure 1 is a process schematic for the Pall MF Pilot System. The feed is supplied to a feed tank, where chlorine (sodium hypochlorite) is added at a target dose of 5 mg/L (Cl_2). The feed pump supplies the chlorinated feed to the hollow fiber membrane module.

Water is driven from the outside to the inside of the fibers, and this filtrate is collected in the filtrate line, which is still under pressure from the feed pump. This line can discharge the filtrate to drain, or to a downstream treatment unit, and also fills the reservoir that supplies water for the reverse filtration step.

[2] Micron = 10^{-6} m ~ 1/25,000 inch

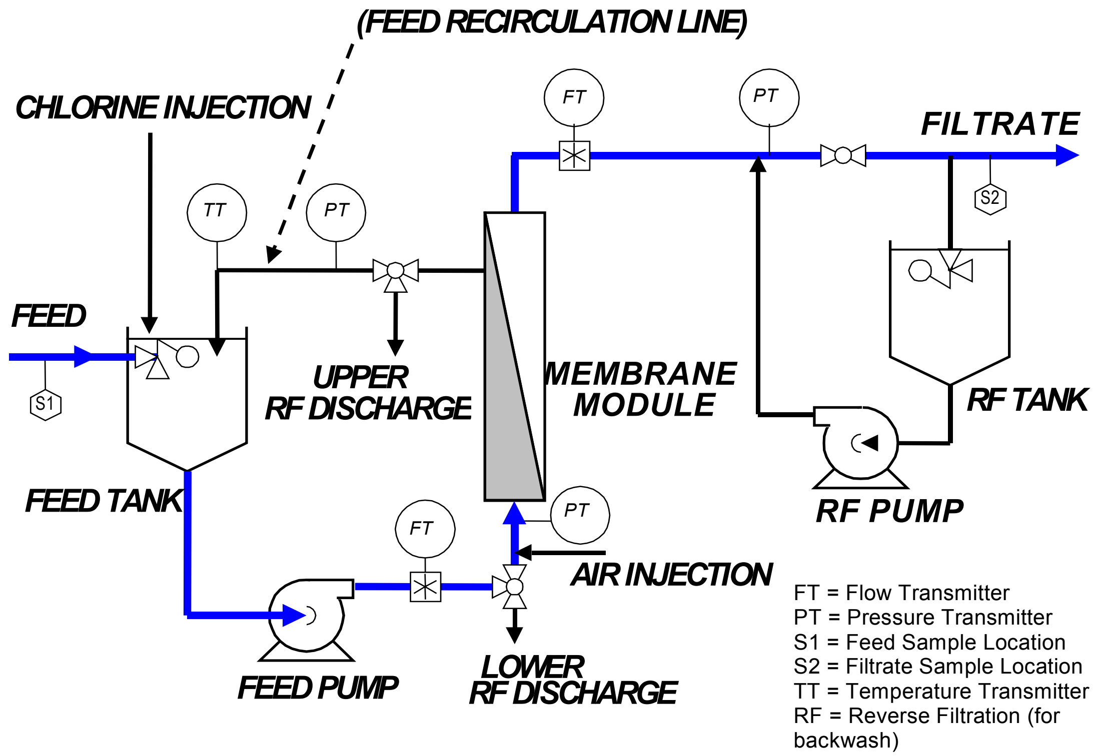

Figure 1. Microfiltration Pilot System Schematic (figure obtained from Pall Corporation).

The single-membrane module is housed in a vertical PVC housing. A small portion of the feed is recirculated back to the feed tank to prevent an air pocket from forming at the top of the housing. Filtration occurs essentially in dead end mode (i.e., no tangential scouring is provided to the membrane surface).

Periodically, the membrane is backwashed to remove solids that build up on the membrane surface and minimize membrane fouling. The backwash step includes a simultaneous air scrubbing/reverse filtration step followed by a reverse filtration (RF) step. The skid is equipped with a separate reverse flow pump and an air compressor. A typical backwash frequency is 15 to 20 minutes. The backwash cycle lasts approximately two minutes.

Since membrane filtrate is used as the backwash water source, which is subsequently wasted, not all of the filtrate produced can be supplied to the end user. The system recovery, defined as the fraction of filtrate available for distribution compared to the total feed water supplied to the membrane system is typically 90 to 95%.

The unit is operated at a constant flow rate. As the membrane fouls, the head loss across the membrane, referred to as the trans membrane pressure (TMP), builds up. The backwash cycle helps reduce the TMP, but it will continue to increase over time. Eventually, the unit will have to be chemically cleaned to remove the fouling material from the membrane surface and restore the clean water head loss.

Chemical cleaning requires taking the unit out of service. The Pall system utilizes an abbreviated clean, referred to as a maintenance clean, and a more rigorous clean, referred to as a clean in place (CIP). Minimizing the CIP frequency reduces operation and maintenance costs. Therefore, one of the major objectives of pilot testing a membrane system is to determine the appropriate maintenance clean frequency to minimize the CIP frequency in a full-scale application. The standard protocols for a CIP and maintenance clean are summarized below.

- CIP: When the TMP exceeds a threshold limit, the unit is taken out of service for 8 to 12 hours. This step requires chemicals and, if available, water heated to 38 ºC (100° F). The cleaning water can be tap water, reverse osmosis (RO) permeate, de-ionized or distilled water. The first clean cycle uses a combination of sodium hydroxide and sodium hypochlorite added to the feed tank. The chemical solution is recirculated for 6 to 8 hours and the system is then drained and rinsed. For the second clean cycle, a heated-water citric acid solution is recirculated for two to four hours. Typical chemical concentrations used are: sodium hydroxide (10,000 mg/L), sodium hypochlorite (1,000 mg/L), and citric acid (20,000 mg/L). For the pilot system, the CIP is a manual operation. The CIP cleaning protocol is included in Appendix A of the report.
- Maintenance Clean: A typical maintenance clean includes only the caustic/chlorine clean step with a total down time of approximately one hour for recirculation and 1 hour for prepping, rinsing, and draining. Typically, only chlorine is used in a maintenance clean. The maintenance clean protocol is included in Appendix A.
- Flux Recovery: After each CIP, the clean water flux was measured and compared to the clean water flux of the membrane when it was new.

Full-Scale Facilities

Following is a list of full-scale Pall MF membrane system installations designed for water reuse in the United States.

- Fountain Hills, CA (2mgd). Feed is aerated pond secondary effluent, chlorinated but not coagulated.
- Fountain Valley, CA (1 mgd). Feed is activated sludge secondary clarifier effluent and chlorinated, but not coagulated.
- Chandler, AZ (1.8 mgd). Feed is effluent from a semiconductor plant and is chlorinated, but not coagulated.
- Charlotte, NC (3 mgd). Feed is activated sludge secondary clarifier effluent, chlorinated but not coagulated.
- State College, PA (3.4 mgd). Feed is activated sludge secondary clarifier effluent and chlorinated, but not coagulated.
- Sonoma County, CA (3.5 mgd). Feed is activated sludge secondary clarifier effluent and is chlorinated, but not coagulated.

Comparison with Conventional Filtration

Compared to conventional granular media filtration, the benefits of membrane filtration are:

- **Smaller Footprint**: For the same footprint, the available surface area of the hollow-fiber membrane configuration is much higher than that for a conventional granular media filter operated under gravity down flow conditions.
- **Reliable Filtrate Turbidity Even With Variable Feed Turbidity**. Since membrane filtration relies on a physical sieving process to remove particulates that are larger than the pore size of the membrane, this technology provides very consistent and reliable filtrate turbidity without the need for chemical addition. However, granular media filtration does require chemical pre-treatment to coagulate, stabilize and flocculate the particulate material so it can be effectively captured within the filter bed. Turbidity breakthrough can occur if the process is not closely monitored, especially during a high feed turbidity incident.

Even though MF has some advantages over conventional granular media filtration, it should be noted that there are higher energy requirements for membrane filtration. Conventional granular media filters are operated using gravity head and there are power costs associated with backwash pumping. However, gravity does not provide an adequate driving pressure to filter water through a low-pressure membrane. Instead, feed pumps are used and there is a corresponding energy cost. The membrane system will also have backwash pumping and air supply energy requirements.

A comparison of granular media filters used by King County at the West Point WWTP and the MF pilot unit performance is provided in the Evaluation of Pilot Results section.

Pilot Testing

Goals and Objectives

The goal of the pilot study was to use the microfiltration process to treat WP SE, BAF #1 effluent and BAF #2 effluent and to determine its effectiveness as a tertiary filter. The pilot study was designed to:

- Determine the sustainable membrane flux limit for each feed stream.
- Evaluate the process based on operational and maintenance considerations such as labor, chemical and energy requirements, and ease and duration of startup.
- Evaluate the potential for long-term membrane fouling (i.e., to determine what is the clean water flux recovery after the CIP).
- Determine the backwashing, maintenance clean, and CIP requirements for each feed stream.

- Evaluate the MF unit for compliance with the State of Washington Class A regulations for turbidity removal. It should be noted that the Class A turbidity removal requirements were developed for granular media filters (<2 NTU 95% of the time and <5 NTU all of the time). Those requirements state that the treatment process must include oxidation and coagulation (i.e., chemical pre-treatment upstream of the granular media filter to ensure reliable turbidity removal) and filtration. However, the small pore size of the microfiltration membrane produces filtrate turbidity levels consistently below 1 NTU **without** coagulant pre-treatment, as long as the integrity of the membrane is intact (i.e., no fiber breakage). The State of California Title 22 Regulations include a separate turbidity removal limit for membranes without the use of a coagulant, which are <0.2 NTU 95% of the time and <0.5 NTU all of the time. Per discussions with the Washington State Department of Ecology, it is anticipated that regulations will be applied to membrane systems in Washington State similar to the Title 22 Regulations in California. Therefore, no coagulant pre-treatment was implemented for this pilot testing during the Class A demonstration tests.
- Evaluate total phosphorous (TP) removal with alum pretreatment.
- Target the following performance goals:
  - Effluent turbidity <0.2 NTU, 95th percentile, to meet Class A requirements.
  - Effluent TOC <2 mg/L, 50th percentile, to meet groundwater recharge criteria.
  - Effluent TP <0.02 mg/L, 90th percentile, to meet enhanced nutrient removal goal.
  - System Recovery >90%
  - CIP interval >30 days
  - Less than 2% long-term flux decline per year

Demonstration Setup

The Pall Microfiltration Membrane pilot unit arrived at the West Point WWTP on September 4, 2001. The unit was on site for a total of 5 months. A Pall startup engineer was onsite in early September to conduct the system startup and train County staff to operate the unit. County staff operated the unit for the 5-month testing duration. Pall had remote access to data logged by the skid which was distributed to the Project Team, as needed, to evaluate system performance. The Consultant team coordinated the pilot testing and provided data analysis.

The pilot unit was located inside the Technology Assessment Facility at the West Point WWTP as shown in Figure 2. The unit arrived on site as a two-skid system. The membrane skid contained the equipment diagrammed in Figure 1 and a SCADA system. The second skid was an air compressor skid. Table 2 describes the physical attributes of the pilot unit.

Figure 2. Pall Microfiltration Membrane Pilot Unit.

Table 2. Summary of Microfiltration Facility Parameters

Parameter	Unit	Value
Membrane Module		
Filtration Surface Area	Square Feet	398
Module Length	Feet	6.6
Module Diameter	Inches	5
Membrane Material	-	PVDF
Module Housing	-	PVC
Feed Tank Volume	Gallon	24
RF Tank Volume	Gallon	24
Feed Pump		
Flow Rate	GPM	0 - 15
Discharge Pressure	psi	10 - 40
RF Pump		
Flow Rate	GPM	0 - 22
Discharge Pressure	psi	30
Air Supply		
Flow Rate	SCFM	3
Regulated Pressure	psig	30

On-line instrumentation measured the following parameters and the data was logged by the SCADA system:

- Feed and filtrate turbidity meters
- Feed and filtrate particle counters (not used for this project)
- Feed temperature and flow
- Feed, recirculation and filtrate pressure (to calculate TMP)
- Filtrate flow

Auto samplers were used to collect 24-hour composite samples on the feed and filtrate at the locations shown on Figure 1. The West Point Process Laboratory analyzed these samples. Grab samples were taken from the same locations and analyzed for low-level constituents (e.g., nutrients, organics, metals) by the King County Environmental Laboratory.

Testing Plan

A testing plan was prepared at the beginning of the pilot study and is contained in Appendix A. As the testing progressed, there were deviations from this test plan, which are summarized at the beginning of Appendix A. The test plan includes a more detailed description of the pilot unit configuration, modes of operation, test phases, sampling and special tests. Following is a summary of key information presented in the test plan:

- For each feed stream tested, baseline operating conditions were first established. Then extended runs were conducted using the test conditions established from the baseline test results.
- At the conclusion of the BAF #2 effluent feed testing, nutrient removal testing was conducted. This included pre-treatment with alum to enhance total phosphorous (TP) removal.
- The pilot test consisted of the following testing stages:
  - **Stage 1 – West Point WWTP Secondary Effluent (WP SE) Feed.** Chlorinated secondary effluent from the main West Point WWTP was piped under pressure into the Technology Assessment Facility to directly supply the MF pilot unit feed tank. The focus for Stage 1 was Class A demonstration on WP SE.
  - **Stage 2 – BAF #1 Effluent Feed.** Effluent from the BAF #1 pilot unit was supplied to the MF unit during this stage. The entire treatment train included West Point WWTP primary effluent (WP PE) supplied to the BAF #1 unit followed by the MF unit. The focus for Stage 2 was Class A demonstration on WP PE using the BAF #1-MF treatment train.
  - **Stage 3 – BAF #2 Effluent Feed**. Effluent from the BAF #2 pilot unit was supplied to the MF unit during this stage. The entire treatment train included WP PE → BAF #1 → BAF #2 → MF. The focus for Stage 3 was Class A demonstration and enhanced nutrient removal with the two-stage BAF system (nitrification) and alum pre-treatment with the MF unit (TP removal).

Results

Operating Data Considerations

The data recorded by the pilot unit data logger were plotted on graphs at 15-minute intervals. Figure 3 is a typical graph that includes this TMP data. The recorded TMP values show a band of operating pressure. The main use for this information is to track the rise in TMP and trigger a membrane cleaning when needed. The rise in TMP is calculated from the estimated TMP slope shown as the clean membrane pressure following a backwash.

The figures in the results section that include the TMP are shown with a time scale that typically spans two weeks. This condenses the 15-minute TMP data for a given day and so the data points appear to be right on top of each other. The graphs do not include a trend line connecting consecutive data points because this makes the figure difficult to read. The TMP trend is used to estimate the TMP slope (psi/day) for a given filter run. The duration between consecutive maintenance cleans, or between a CIP and maintenance clean, is a single filter run.

When evaluating the TMP data, it is important to note that the skid will go into a high-TMP alarm condition when the TMP reaches 35 psi. The unit will continue to operate until the high-high-TMP alarm condition of 38 psi is reached, at which time the unit automatically shuts off. This prevents the TMP from exceeding the pressure rating of the hollow fiber membranes. The

TMP slope for a given feed and test condition is important for determining operating conditions that minimize fouling. It is important to establish the maintenance clean frequency to prevent a high-high-TMP alarm condition, and thus, automatic shut-down.

Membrane Flux

Membrane flux is a key operating parameter evaluated during a pilot study to determine the design flux for a full-scale application. The flux rate is a measure of how much flow passes through the membrane (i.e., filtrate flow) normalized by the active surface area of the membrane. It is calculated as follows:

- Flux (gfd) = filtrate flow (gallons per day)/membrane surface area (sq ft)

The units for flux are gallons per day per square foot, which is abbreviated to (gfd).

Temperature is an important consideration when evaluating the membrane flux for a given feed stream. As the temperature decreases, feed stream viscosity increases. For a constant flow rate condition, a higher feed pressure is required for a colder feed stream. This, in turn, increases the TMP, which will shorten the filter run.

During the Stage 2 and Stage 3 testing, filtrate flow rate was reduced several times because the feed stream temperature decreased as testing continued into the winter months. This reduced the membrane flux. To account for the temperature effect, a temperature correction factor was used, which is calculated as follows:

- Temperature correction factor = $1.03^{(20\,^{\circ}\mathrm{C}\,-\,\text{actual feed temperature}\,^{\circ}\mathrm{C})}$

The temperature-corrected flux is calculated by multiplying the actual flux by the temperature correction factor. In the results section below, the operating data presented include the feed temperature and the temperature corrected flux. The term flux-20 will be used to designate the equivalent flux at 20 ºC.

Backwash Sequence

The backwash sequence includes the following steps:

- Air scrub: The feed pump is shut off and air is introduced into the feed side of the membrane module to scour solids from the membrane surface. The air flow is set at 3 SCFM and the air scrub duration can be adjusted, but is typically 20 seconds.
- Air scrub and reverse filtration: The reverse filtration pump supplies filtrate back through (inside-to-outside) the hollow fiber membranes in conjunction with the air scrub. The duration of this step ranges from 60 to 90 seconds. The reverse filtration flow rate is adjustable and is typically set at 5 gpm.
- Reverse filtration: The air scrub stops and the reverse filtration pump flow rate is increased. The duration ranges from 20 to 30 seconds. The flow rate is adjustable and is typically set at 13 gpm.

The backwash affects the system recovery because it takes the system out of production and the reverse filtration stream is sent to drain.

To minimize fouling, Pall made adjustments to some of the backwash settings which, it turn, affected the system recovery. These adjustments are noted throughout the results section.

Stage 1 – WP SE Feed

The MF unit was supplied with WP SE from September 17 to October 24, 2001. Both operating and water quality data were collected. Also, various maintenance cleans were conducted, along with one CIP at the end of the test stage.

Operating Performance and Chemical Cleans

Table 3 provides a summary of the operating data for each filter run. The table notes if the filter run was conducted during baseline or extended run test conditions along with modifications to the backwash settings, which Pall adjusted remotely during and/or between filter runs.

Table 3. Stage 1 Filter Run Operating Data

Filter Run No.	Test Condition	Filtrate Flow (gpm)	Feed Turbidity (NTU)	Feed Temp (ºC)	Flux-20 (gfd)	Post-Clean [a] TMP (psi)	TMP Slope (psi/day)	Backwash Frequency (minutes)	Recovery (%)
1	Baseline	9	4.1 - 12	18.5 – 20.5	32 - 34	5.5	Initial 1.8[c], Final 1[d] (after BW adjusted)	20 [b]	Initial 94.5, Final 92.5 (after BW adjusted)
2	Baseline	9	4.9 – 6.5	18.8 - 19.8	33 – 34	11	2.5 [c] 5 [d]	20	92.5
3	Extended Run	9	3.7 – 13.1	17.5 – 19.5	33 - 35	10.5	4.3 [c]	20	92.5
4	Extended Run	9	3.7 – 22.4	18 – 19	34 - 35	14	4.8 [c]	15 [e]	92.5
5	Extended Run	9	4.0 – 8.6	15.8 – 18.4	34 - 38	22	10 [c]	15	92.5
6	Extended Run	9	4.2 – 7.4	17.8 – 18.4	34 - 35	20	14 [c]	15	92.5

[a] Post-Clean TMP is the initial TMP for a filter run after a maintenance clean or CIP.

[b] BW settings adjusted: Air scrub + RF duration increased from 60 to 70 seconds.

[c] With chlorine added to feed.

[d] Without chlorine added to feed.

[e] Backwash settings adjusted: Air scrub + RF duration decreased from 70 to 60 seconds. RF only flow rate reduced from 13 to 10 gpm.

Baseline Test Conditions

Baseline test conditions were conducted in the first two weeks of testing (Filter Run Numbers 1 and 2). During that period, the backwash cycle was modified and the impact of not chlorinating the feed was evaluated. Also, the first two maintenance cleans were conducted. Figure 3 is a plot of the key operating data over time for this baseline test. It includes the following parameters: filtrate flow rate, TMP, feed temperature, and feed turbidity.

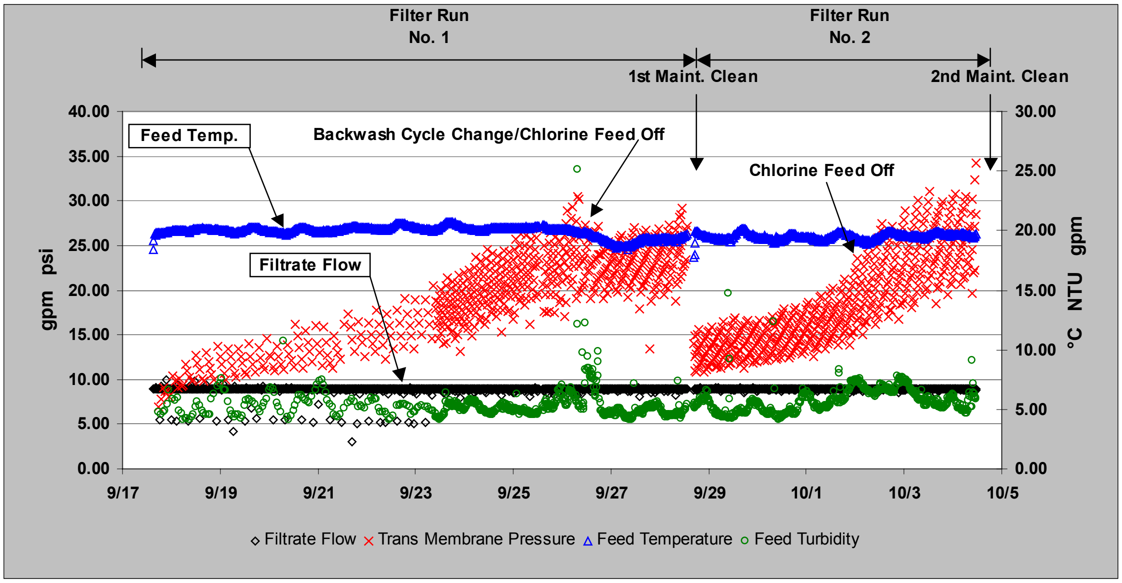

Figure 3. Stage 1 Baseline Test - Operating Data

During Filter Run No. 1, the feed temperature was between 18.5 and 20.5ºC and the filtrate flow rate was 9 gpm (flux-20 of 32 to 34 gfd). The backwash frequency was 20 minutes and the backwash set points were initially:

- Air + reverse filtration (RF): 60 seconds at an airflow rate of 3 SCFM and an RF flow rate of 5 gpm.
- RF only: 20 seconds at 13 gpm.
- The resulting percent recovery for these settings is 94.5%.

Since the TMP reached 30 psi on September 26, 2001 Pall recommended modifying the backwash cycle to try to reduce the rapid build up in TMP and extend the duration of Filter Run No. 1. At the same time, the chlorine feed pump was shut off. The TMP slope was effectively controlled under these conditions, which was stabilized at around 20 psi until the first maintenance clean was conducted on September 28, 2001. Based on previous experience, Pall has found that chlorinating the feed reduces membrane fouling. Therefore, shutting off the chlorine feed would have an adverse impact on TMP slope. In an attempt to reduce the TMP slope, the backwash cycle set points were changed to the following:

- Backwash frequency: remained every 20 minutes.
- Air only added: 20 seconds at an airflow rate of 3 SCFM.
- Air + RF: increased to 70 seconds at an airflow rate of 3 SCFM and an RF flow rate of 5 gpm.
- RF only: 20 seconds at 13 gpm.
- The resulting system recovery was 92.5%.

The first maintenance clean included a 50-minute chlorine solution recirculation. The post-clean TMP was 11 psi.

Filter Run No. 2 was conducted using the recently changed backwash set points. Chlorine feed was re-started at the beginning of the run. However, in order to confirm the impact of no chlorine feed on the fouling rate, the chlorine feed was shut off the afternoon of October 1, 2001. Figure 3 shows that the TMP slope increased once the chlorine feed was shut off. With chlorine added, the TMP rose at 2.5 psi/day. Without chlorine, the TMP increased at 5 psi/day. The system shut off on a high-high-TMP alarm on October 4, 2001 concluding Filter Run No. 2.

The second maintenance clean, which followed the same protocol as the first maintenance clean, occurred on October 5, 2001. The post-clean TMP was 10.5 psi.

Observations from the Stage 1 baseline test conditions were:

- Increasing the backwash cycle air + RF duration from 60 to 70 seconds and adding an initial air only step for 20 seconds reduced the TMP slope.
- Adding chlorine to the feed reduced membrane fouling rate.
- At a flux-20 rate of 32 to 34 gfd, it appears that a maintenance clean will need to be done twice a week.

Extended Run Conditions

Using the final operating conditions from Filter Run No. 2, an extended run (Filter Run No. 3) on the WP SE feed began on October 7 and continued until October 24. Figure 4 shows the operating data.

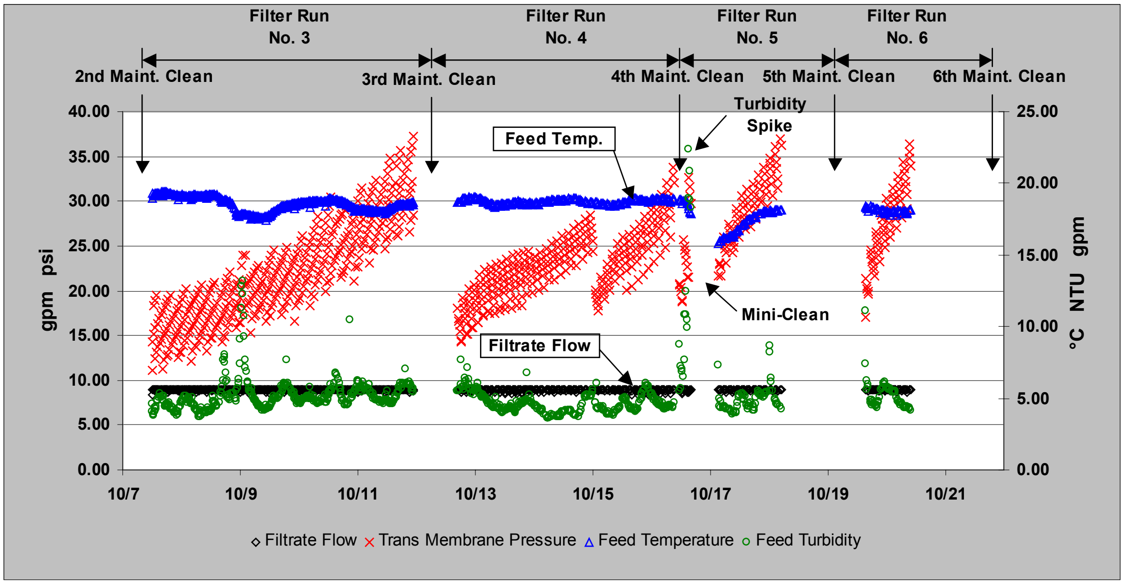

Figure 4. Stage 1 Extended Run - Operating Data

The feed temperature decreased to below 20 °C and towards the end of the run the temperature was 17.5 °C. The feed flow rate was maintained at 9 gpm.

Filter Run No. 3 lasted four days, after which the third maintenance clean was conducted. This was the expected twice-per-week frequency established during the baseline testing. Before starting Filter Run No. 4, the backwash settings were revised to try to maintain a flux rate of 32.5 gfd and decrease the maintenance clean frequency to once per week. The backwash cycle frequency was reduced from 20 to 15 minutes. To maintain a recovery above 90%, the backwash set points were changed to:

- Air + RF: duration reduced from 70 to 60 seconds.
- RF only: flow rate reduced from 13 to 10 gpm.
- The resulting system recovery was 92.5%.

Filter Run No. 4 lasted four days. On October 15, 2001, just after midnight, there was a sudden drop in TMP (Figure 4). This could have been due to an overdose of chlorine in the feed stream, which could have had the effect of a maintenance clean. The Operator log notes indicate the chlorine feed tank was found empty at 8:00 AM on October 15, 2001.

Just after starting Filter Run No. 5, there was a turbidity spike of 22.4 NTU and the TMP also spiked to above 30 psi. The pilot unit was shut off until the feed spike subsided. The high turbidity was a result of a storm event that caused the West Point WWTP to bypass excess flows around the secondary treatment process. Peak flows through the secondary process can also cause some solids carry-over in the secondary clarifiers, which increases the solids levels in the secondary effluent. (Bypassing secondary treatment also increases the organic loading to membranes, which might result in higher fouling potential.)

Once the feed turbidity dropped to below 10 NTU, a mini-clean was performed, as directed by Pall. The mini-clean was an abbreviated maintenance clean that included a 10-minute chlorine solution re-circulation. This was done to prevent having to repeat a maintenance clean cycle, since one had just been completed. Filter Run No. 5 continued, and the post mini-clean TMP dropped to 22 psi (Figure 4). Since the second maintenance clean, the post cleaning TMP increased implying the cleaning effectiveness was declining.

After the mini-clean, Filter Run No. 5 continued for only 26 hours before a high-high TMP alarm caused a shut down. After the fifth maintenance clean, the post-clean TMP was only reduced to 20 psi. Filter Run No. 6 lasted only 19 hours before a high-high TMP condition occurred.

This concluded Stage 1 of the testing and the first CIP was conducted. The CIP protocol is summarized in the test plan (Appendix A). The clean water flux recovery was 97%.

Observations from the WP SE feed extended run test conditions were:

- Maintaining a flux-20 rate of 32 to 34 gfd with a backwash cycle frequency of 15 minutes and a system recovery of 92.5% requires a maintenance clean frequency of twice per week or more.
- The maintenance clean protocol was less effective as the feed water turbidity increased. The latter filter runs began with a TMP as high as 22 psi, which, in conjunction with a feed turbidity in excess of 10 NTU, caused a steeper TMP slope that shortened the filter run. To prevent rapid buildup of TMP, the maintenance clean could be done more frequently than twice per week. Additional testing would be required to confirm this.

Water Quality

Turbidity and TOC concentrations were measured in the feed and filtrate. The turbidity data is presented for both the baseline and extended run testing. The TOC data is presented for the extended run testing only. On September 25, 2001, grab samples of the feed and filtrate streams were analyzed for metals. The feed and filtrate streams were analyzed for organics on September 26, 2001. A few microbiological parameters, along with Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) were also measured and are discussed at the end of this section.

Turbidity

Feed and filtrate turbidity, for both the baseline and extended run testing, is shown in Figure 5. These data were measured by the pilot unit's on-line turbidimeter collected at 15-minute intervals. Also included is the temperature-corrected flux (Flux-20), which was typically 32 to 34 gfd. Feed turbidity was typically between 5 and 10 NTU, with several spikes greater than 20 NTU. Despite these feed turbidity spikes, the filtrate turbidity levels were as follows:

- Minimum: 0.04 NTU.
- Maximum: 0.12 NTU.

- Average: 0.05 NTU.

Figure 6 shows a normal distribution of the filtrate turbidity data, which was 0.06 NTU at the 95th percentile. With a maximum filtrate turbidity of 0.12 NTU, the MF unit met the Title 22 Regulations for filtrate turbidity of <0.5 NTU all of the time.

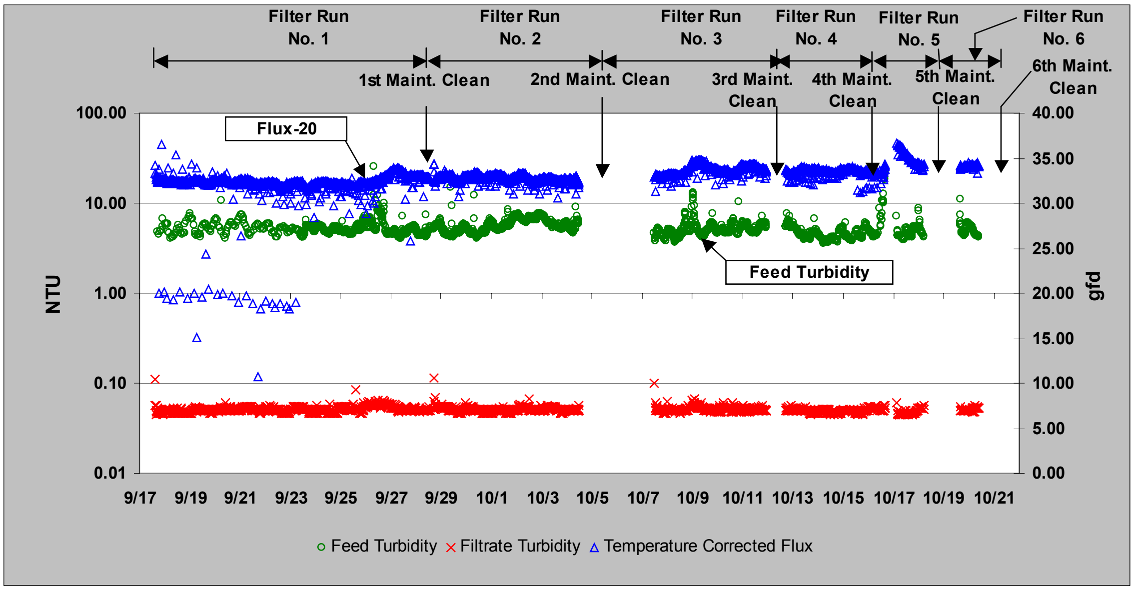

Figure 5. Stage 1 - Feed & Filtrate Turbidity & Temperature Corrected Flux

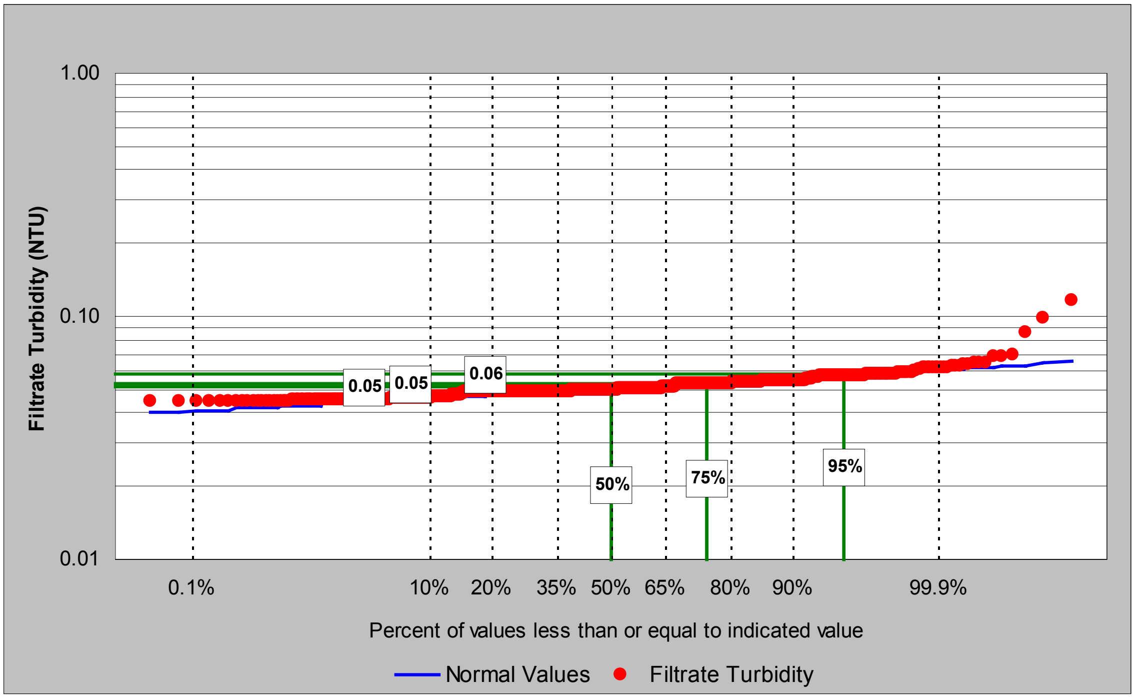

Figure 6. Stage 1 - Filtrate Turbidity Lognormal Distribution

TOC

Figure 7 shows feed and filtrate TOC concentrations. A microfiltration membrane cannot remove soluble organics that are smaller than the membrane pores. Without pre-treatment, such as an addition of a coagulant or powdered activated carbon (which will sorb the organics creating a organic-bound macro molecule rejected by the membrane), the TOC removal is expected to be minimal. Feed TOC levels ranged from 13.8 to 15 mg/L. Filtrate levels were 8 to 12 mg/L.

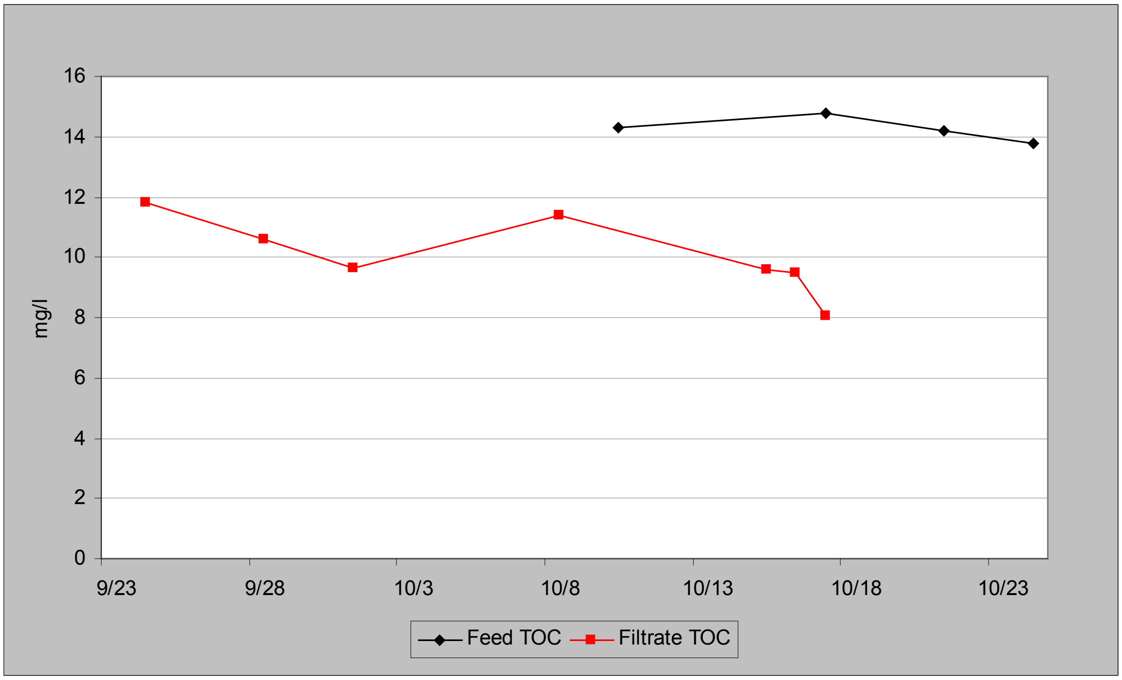

Figure 7. Stage 1 - Feed & Filtrate TOC

Metals and Organics

The MF filtrate was analyzed for metals and organics on September 25th and 26th, respectively. The metals data is presented in Table 4 and the organics data is presented in Table 5. The WP SE feed was not analyzed for metals and organics.

BOD and COD

WP SE is routinely monitored for BOD and TSS to meet the plant's effluent BOD and TSS permit limit of 30 mg/L each. During Stage 1, the plant routinely met the permit limits. Note that the Class A effluent BOD and TSS requirements are also 30 mg/L each.

For this project, the County collected several samples for BOD, COD and TSS analyses on the MF filtrate during Stage 1. The average of these data are presented below.

- Filtrate BOD: <2 mg/l
- Filtrate COD: 232 mg/L
- Filtrate TSS: 2 mg/L

Microbiological

Heterotrophic plate count (HPC) and Total Coliform (TC) were measured three times during Stage 1 on the WP SE. HPC was measured twice on the MF filtrate. The average of these data are presented below.

- WPSE HPC: 560,000,000 CFU/100 mL
- WPSE TC: 52,000,000 CFU/100 mL

- Filtrate HPC: 6 CFU/100 mL

These data show that the microfiltration membrane effectively removed 7 log of HPC from the WP SE.

Table 4. Stage 1 Feed and Filtrate Metals

Parameter	Feed Concentration (mg/L)	Filtrate Concentration (mg/L)	MDL (mg/L)
Aluminum	Not measured	0.0235	0.002
Antimony	Not measured	<0.0005	0.0005
Arsenic	Not measured	0.0018	0.0005
Barium	Not measured	0.00508	0.0002
Beryllium	Not measured	<0.0002	0.0002
Cadmium	Not measured	<0.0001	0.0001
Chromium	Not measured	0.00087	0.0004
Cobalt	Not measured	0.00042	0.0002
Copper	Not measured	0.0284	0.0004
Iron	Not measured	0.12	0.05
Lead	Not measured	0.00179	0.0002
Molybdenum	Not measured	0.0113	0.0005
Nickel	Not measured	0.0036	0.0003
Selenium	Not measured	<0.0015	0.0015
Silver	Not measured	0.00073	0.0002
Thallium	Not measured	<0.0002	0.0002
Vanadium	Not measured	0.0011	0.0003
Zinc	Not measured	0.0361	0.0005
Mercury	Not measured	<0.00005	0.00005

Table 5. Stage 1 Feed and Filtrate Organics

Parameter	Feed Concentration (µg/L)	Filtrate Concentration (µg/L)	MDL (µg/L)
1,1,1-Trichloroethane	Not measured	<1	1
1,1,2,2-Tetrachloroethane	Not measured	<1	1
1,1,2-Trichloroethane	Not measured	<1	1
1,1,2-Trichloroethylene	Not measured	<1	1
1,1-Dichloroethane	Not measured	<1	1
1,1-Dichloroethylene	Not measured	<1	1
1,2-Dichloroethane	Not measured	<1	1
1,2-Dichloropropane	Not measured	<1	1
2-Butanone (MEK)	Not measured	<5	5
2-Chloroethylvinyl ether	Not measured	<1	1
2-Hexanone	Not measured	<5	5
4-Methyl-2-Petanone (MIBK)	Not measured	<5	5
Acetone	Not measured	<2.5	2.5
Acrolein	Not measured	<5	5
Acrylonitrile	Not measured	<5	5
Benzene	Not measured	<1	1
Bromodichloromethane	Not measured	2.18	1
Bromoform	Not measured	<1	1
Bromoethane	Not measured	<1	1
Carbon Disulfide	Not measured	<1	1
Carbon Tetrachloride	Not measured	<1	1
Chlorobenzene	Not measured	<1	1
Chlorodibromoethane	Not measured	<1	1
Chloroethane	Not measured	<1	1
Chloroform	Not measured	12.6	1
Chloromethane	Not measured	<1	1
Cis-1,3-Dichloropropene	Not measured	<1	1
Ethylbenzene	Not measured	<1	1
Methylene Chloride	Not measured	4.2	1
Styrene	Not measured	<1	1
Tetrachloroethylene	Not measured	<1	1
Toluene	Not measured	<1	1
Total Xylenes	Not measured	<1	1
Trans-1,2-Dichloroethylene	Not measured	<1	1
Trans-1,3-Dichloropropene	Not measured	<1	1
Trichloroflouromethane	Not measured	<1	1
Vinyl Acetate	Not measured	<5	5
Vinyl Chloride	Not measured	<1	1

Stage 2 – BAF #1 Effluent Feed

Stage 2 began on November 9, 2001 and continued until January 20, 2002. Feed water quality from BAF #1 effluent exhibited higher turbidity than the WP SE. The MF unit feed piping configuration included a large storage tank between BAF #1 and the MF unit. This tank had been receiving BAF #1 effluent since June 2001, and thus solids collected in the tank bottom. When the stored effluent was first pumped to the MF unit, the unit detected high turbidity spikes that increased membrane fouling and made it difficult to "dial in" operating conditions for an extended run. Furthermore, the feed temperature continued to drop as winter approached, increasing the TMP slope for the target flow rates tested. The filtrate flow rate was reduced to offset this temperature effect. These adjustments and the Thanksgiving holiday shutdown extended the baseline testing duration to four weeks.

After the baseline test data were collected, the MF unit experienced mechanical problems with the reverse filtration pump, which caused the unit to be shut down until just after Christmas. The unit was re-started on January 2, 2002 but the air compressor broke down, delaying testing for another week. With less than two months left in the overall testing schedule, and Stage 3 still to complete, the extended run for Stage 2 was limited to only two weeks to allow the month of February for Stage 3 testing.

Operating Performance and Chemical Cleans

Table 6 provides a summary of the operating data for each filter run. The table notes if the filter run was conducted during baseline or extended run test conditions along with modifications to the backwash settings, which Pall adjusted remotely during and/or between filter runs.

Table 6. Stage 2 Filter Run Operating Data

Filter Run No.	Test Condition	Filtrate Flow (gpm)	Feed Turbidity (NTU)	Feed Temp (°C)	Flux-20 (gfd)	Post-Clean [a] TMP (psi)	TMP Slope (psi/day)	Backwash Frequency (minutes)	Recovery (%)
1	Baseline	8.3	42 - 67	15.7 – 17.0	31 - 33	7.2	na [b]	15 [c]	92.5
2	Baseline	7 initial, then 8.3	7 – 29	13.8 – 15.4	34 – 36	4.6	1 [d] 2.3 [e] 4.3 [f]	15	92.5
3	Baseline	8.3	5 – 12	13.7 – 14.8	35 - 36	10.0	17 [g] 20 [h]	15	92.5
4	Baseline	7	3 – 13	10.7 – 12.5	32 - 33	9.2	8	15	92.5
5	Baseline	7	6 – 23	13.3 – 14.4	30 - 31	4.2 (post CIP)	2.1	15	92.5
6	Extended Run	7	8 - 38	11.8 – 13.8	30 - 33	4	1.7	15	92.5
7	Extended Run	7	8 - 23	13 – 13.4	31	8	Initial 7, Final 3.6 (after BW adjusted)	10 [i]	Initial 92.5, Final 89.4 (after BW adjusted)
8	Extended Run	7	6 - 25	10.8 – 13.2	31 - 33	9.5	10.6	10	89.4

[a] Post-Clean TMP is the initial TMP for a filter run after a maintenance clean or CIP.

[b] na: not applicable. Filter run duration was only 5 hours.

[c] Same settings as Stage 1 Filter Run No. 6

[d] At filtrate flow rate of 7 gpm

[e] At filtrate flow rate of 8.3 gpm, pre-turbidity spike

[f] At filtrate flow rate of 8.3 gpm, post-turbidity spike

[g] Pre-Thanksgiving

[h] Post-Thanksgiving

[i] Backwash (BW) settings adjusted: RF only reduced from 10 to 8 gpm, airflow rate decreased to 180 to 200 SCFM.

Baseline Test Conditions

Figure 8 shows the Stage 2 baseline test operating data. Filter Run No. 1 which started on November 9, 2001 lasted only five hours, at which time the unit shut down due to a high-high TMP alarm. The feed turbidity, believed to be coming from solids scoured off of the bottom of the upstream storage tank, reached 29 NTU. Despite a recent CIP, the membrane immediately fouled. The first maintenance clean for Stage 2 occurred on November 10. Because of the high-fouling nature of the feed, Pall modified the maintenance clean protocol to include heated water (target temperature of 32 °C) for the chlorine solution.

From the results of this first filter run, it was decided to secure the unit for several days to allow time to flush out the storage tank. Also, at the beginning of the next run, the flow rate was initially reduced from 8.3 (flux-20=34 gfd) to 7 gpm (flux-20=29 gfd) for 24 hours to see if the unit could operate for one day without reaching the high-TMP alarm conditions.

Filter Run No. 2 began on November 15 at a feed flow rate of 7 gpm. After operating for over 24 hours with a TMP of 5.5 psi, the feed flow rate was increased back to 8.3 gpm. At that time, it was anticipated that the next maintenance clean would not be needed for one week. However, on November 18, the feed turbidity spiked to 28 NTU. This increased the TMP slope and the filter run lasted just over three days, indicating a maintenance clean frequency of twice per week. During this filter run, the feed temperatures ranged from 13.8°C to 15.4°C. The colder feed temperature also contributed to the increased TMP slope and the decrease in filter run duration.

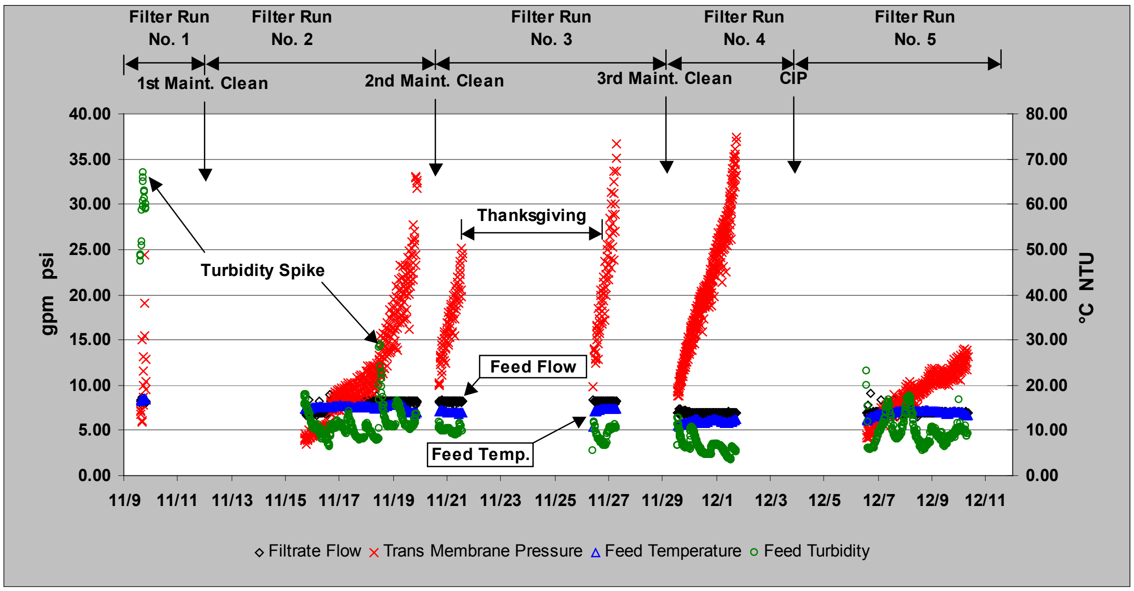

Figure 8. Stage2 Baseline Tests Operating Data

After the second heated-water maintenance clean, Filter Run No. 3 began, and the unit operated for about 21 hours at a feed flow rate of 8.3 gpm before it was secured for the Thanksgiving break. Before it was shut down, a chlorine solution was re-circulated for 20 minutes to mothball the unit for the break. On November 26, 2001 the unit was re-started at the same feed flow rate of 8.3 gpm. Filter Run No. 3 lasted only another 21 hours before reaching a high-TMP alarm condition.

After reviewing the data from the first three filter runs, Pall concluded that for this feed, the system experienced a break point TMP at around 12 psi at a feed rate of 8.3 gpm. (Once this level is exceeded the TMP slope becomes very steep and shortens the filter run.) In order to extend the filter run length before reaching the TMP breakpoint, the feed flow rate for Filter Run No. 4 was reduced from 8.3 to 7 gpm. Also, the post-clean TMP for the second maintenance clean was only 12 psi, compared to the post-CIP TMP of 5 psi. This suggests that the heated chlorine solution maintenance clean was not effectively cleaning the membrane on this feed at a flow rate of 8.3 gpm. One more filter run was attempted at a feed flow rate of 7 gpm before conducting the next CIP.

Filter Run No. 5 lasted only 53 hours. The feed turbidity fluctuated between 6 and 23 NTU. The unit shut down on a high-high TMP alarm on December 1 and a CIP was done. The same CIP protocol was used and the average clean water flux recovery was 94.6 %.

After this CIP, it was anticipated that the extended run testing for Stage 2 would begin. This run is shown on the far right of Figure 8, along with the previous baseline testing data because the MF unit experienced a high filtrate turbidity episode. This incident is discussed in the subsequent Stage 2 water quality section. Because of this incident and subsequent mechanical problems with the skid, the final run in December 2001, Filter Run No. 5 was considered part of the baseline testing.

The following observations were noted:

- The feed flow rate of 8.3 gpm (flux-20 of 31 to 36 gfd) was too aggressive for the BAF #1 effluent feed, given the high feed turbidity coupled with colder feed water temperatures. A filtrate flow rate of 8.3 gpm could not be maintained without having to do a maintenance clean every one to two days.
- The chlorine-only maintenance clean was not effective. After four runs, the post-TMP clean recovery was still above 20 psi, compared to the initial TMP after the CIP of 5 psi. A second CIP was required before starting the extended run testing. Both heated water and caustic soda were added to the maintenance clean protocol to improve its effectiveness.

Extended Run Conditions

The Stage 2 extended run began on January 8, 2002 and continued until January 20. Figure 9 shows the operating data. The unit was operated at a constant feed flow rate of 7 gpm. The TMP was closely monitored with the trigger for initiating a maintenance clean at 12 to 13 psi (just after a backwash cycle) in order to prevent a sudden upward shift in the TMP slope. The goal was to achieve stable operating conditions with a once-per-week maintenance clean.

In mid-December, after the last baseline test run, Pall modified the maintenance clean to include caustic soda (5,000 mg/L) with chlorine (1,000 mg/L NaOCl) in water heated to 38 °C. This revised protocol was used for all subsequent maintenance cleans for Stage 2. It is described in more detail in Appendix A.

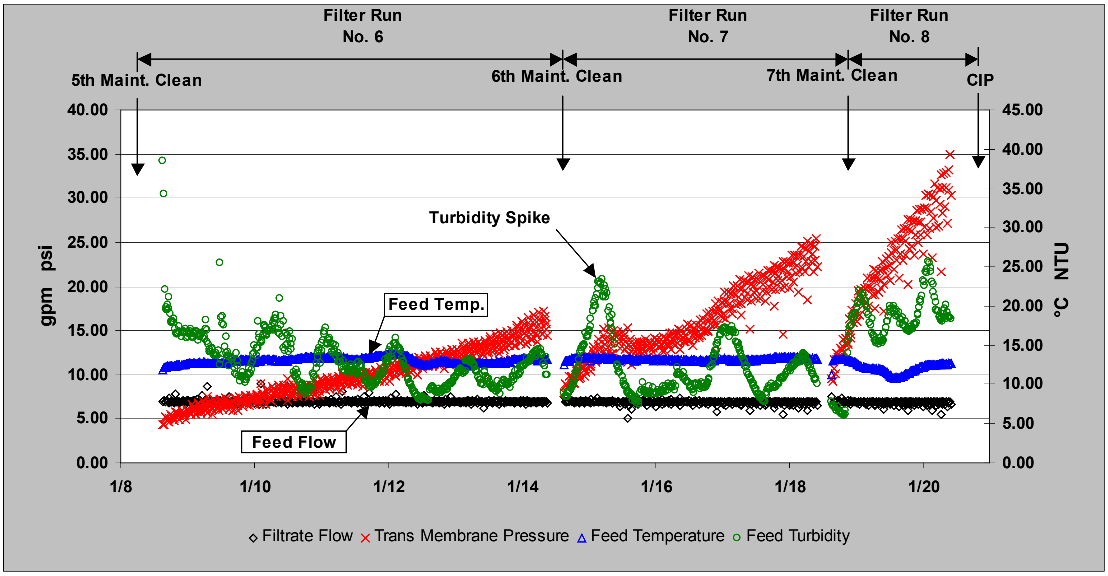

Figure 9. Stage 2 Extended Run Operating Data

Figure 9 shows Filter Run No. 6 lasted six days (January 8 to January 14, 2002). The TMP slope remained constant even beyond the 12-psi break-point level. Just before the maintenance clean on January 14, 2002 the post-backwash TMP was 14.5 psi. With a starting TMP for this run of 4 psi, the average daily change in TMP was 1.7 psi. The feed turbidity fluctuated between 8 and 38 NTU.

Filter Run No. 7 began on January 14, 2002 and lasted four days. After the first 23 hours, the post-backwash TMP had reached 14 psi. This coincided with a feed turbidity spike of 23 NTU on January 15, 2002. Also, the airflow rate during the air-scrub-RF step was too high and reduced the RF pump flow rate during the RF-only step from 11 gpm to 8 gpm. The airflow rate was adjusted from 200 to 250 SCFM to 180 to 200 SCFM. To extend this run duration, the backwash set points were revised as follows:

- Frequency was reduced from 15 to 10 minutes.
- RF-only flow rate remained at the reduced rate of 8 gpm to maintain the same recovery at the more frequent backwash cycle interval.
- The system recovery was 89.4%.

These modifications caused the TMP to immediately decrease by 2 to 3 psi. However, over the next three days (January 16 through January 18, 2002), the TMP increased at a rate of 3.6 psi/day. This was at twice the rate of the previous run.

A final maintenance clean was conducted on January 18, after which time Filter Run No. 8 commenced. The filter run duration was less than two days (43 hours) before reaching a high TMP alarm condition. For this clean, caustic soda concentration was increased to 10,000 mg/L. Also, air scrubbing was added to the final drain step. During this final run, feed turbidity was initially 6 NTU. It then fluctuated between 15 and 25 NTU. TMP increased from 11 psi to 30 psi, which is a TMP slope of 10.6 psi/day. This was more than a six-fold increase in the TMP slope compared to Filter Run No. 6.

During the last day of Filter Run No. 8, County operators noted that the BAF #1 unit had shut down for several hours. With no supply to the storage tank, the withdrawal pump could have scoured the bottom of the tank causing a high-turbidity feed to the MF unit.

The following observations were noted:

- Filter Run No. 6, at a feed flow rate of 7 gpm (flux-20 between 30 and 33 gfd), lasted six days with a final TMP of 17 psi. Unlike the baseline test results at 8.3 gpm, when the TMP exceeded the 13-psi breakpoint level, the TMP did not dramatically increase to high alarm levels when it reached 13 psi. The duration between maintenance cleans therefore increased. The unit could have run for at least one more day achieving a weekly maintenance clean frequency. The run included two turbidity spikes above 20 NTU.
- Filter Run No. 7 did not produce results similar to Filter Run No. 6. It lasted only four days and initially experienced a rapid increase in TMP. One possible explanation was a high turbidity spike just as the run began, causing rapid fouling of the membrane. Also, the backwash efficiency could have declined due to the high airflow rate and reduced RF flow rate. The backwash set points were revised to address this issue after the first day of testing, but the TMP slope continued at twice the rate of Filter Run No. 6.
- Before the final run, Filter Run No. 8, the maintenance clean was revised to include a higher concentration of caustic soda and air scrubbing was added to the final drain step. The post-clean TMP was 8.4 psi. Despite these operating changes, the TMP slope was six times higher than that observed for the Filter Run No. 6 and almost double what occurred in Filter Run No. 7. The intermittent BAF #1 unit operation and fouling characteristics of the solids accumulated in the storage tank had a major impact on membrane fouling.

Water Quality

Feed and filtrate concentrations for the following parameters were collected: turbidity, TOC, ammonia and nitrate. Turbidity data, reported at 15-minute intervals, is presented for both the baseline and extended run testing. The remaining water quality parameters are presented for the extended run testing only. Metals and organics in the feed and filtrate were not measured during Stage 2. Several BOD, COD, and microbiological parameters were measured and the results are presented at the end of this section.

Feed and filtrate TSS monitoring was discontinued during the Stage 2 baseline conditions testing. With filtrate turbidities <0.1 NTU, there were little, if any, quantifiable solids to measure. Instead of TSS, turbidity was the main parameter used to determine solids removal by the membrane.

Turbidity

Feed and filtrate turbidity (collected at 15-minute intervals), for both the baseline testing, is shown in Figure 10. The flux-20 ranged between 30 and 36 gfd. For the three runs in November, 2001 filtrate turbidity was consistently below 0.1 NTU. During Filter Run No. 4 there was one turbidity spike of 0.28 NTU on November 29, 2001. For the remainder of that run, the filtrate turbidity was below 0.05 NTU. Feed turbidity was typically between 10 and 20 NTU, with several spikes greater than 20 NTU.

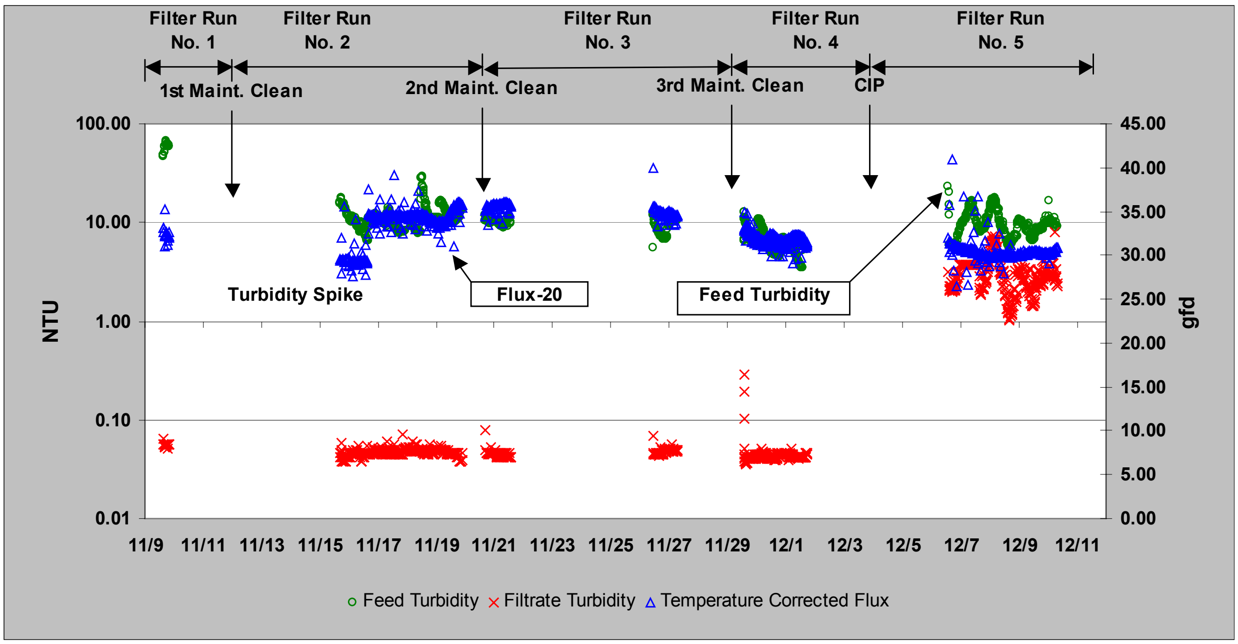

Figure 10. Stage 2 Baseline Tests - Feed & Filtrate Turbidity and Temperature Corrected Flux

A CIP was conducted the first week in December and the next run, Filter Run No. 5, began on December 6, 2001. For this entire run, the filtrate turbidity exceeded 1 NTU. Figure 11 shows the feed and filtrate turbidity for Filter Run No. 5.

The plot of the filtrate and feed turbidity shows that, in general, the filtrate turbidity follows the same trend as the feed turbidity (Figure 11). At the beginning of the run, feed turbidity increased to 17 NTU. At this time, the filtrate turbidity meter recorded constant turbidity levels of 3.7 NTU. The operators observed turbid filtrate water in the RF tank on December 10, 2001 and the unit was shut down, concluding the run.

Pall suggested two possible options for the high filtrate event. The feed could have been mixing with the filtrate or there might have been a fiber breakage. (During a CIP, hand valve (HV) 14 is opened for the cleaning re-circulation step. During normal filtration, this valve is supposed to be closed to prevent the feed from mixing with the filtrate.) It is possible that the valve was left open after the last CIP.

To verify a fiber breakage, Pall asked the County to do a pressure hold membrane integrity test. During the test the unit is shut off, the membrane module is pressurized for five minutes, and the pressure decay is monitored. A pressure decay <0.2 psi per minute indicates no fiber breakage. The test decay rate was 0.26 psi/minute. Pall indicated that a fiber breakage is very rare and requested that the turbidity meters be cleaned with a chlorine solution and recalibrated. Also, HV 14 was confirmed to be closed to prevent mixing the feed and filtrate.

Once these measures were taken, the unit was put back into service and the filtrate turbidity dropped below 0.1 NTU. Subsequent testing showed no additional high filtrate turbidity events, so this episode was an isolated incident that can probably be attributed to HV14 being slightly open.

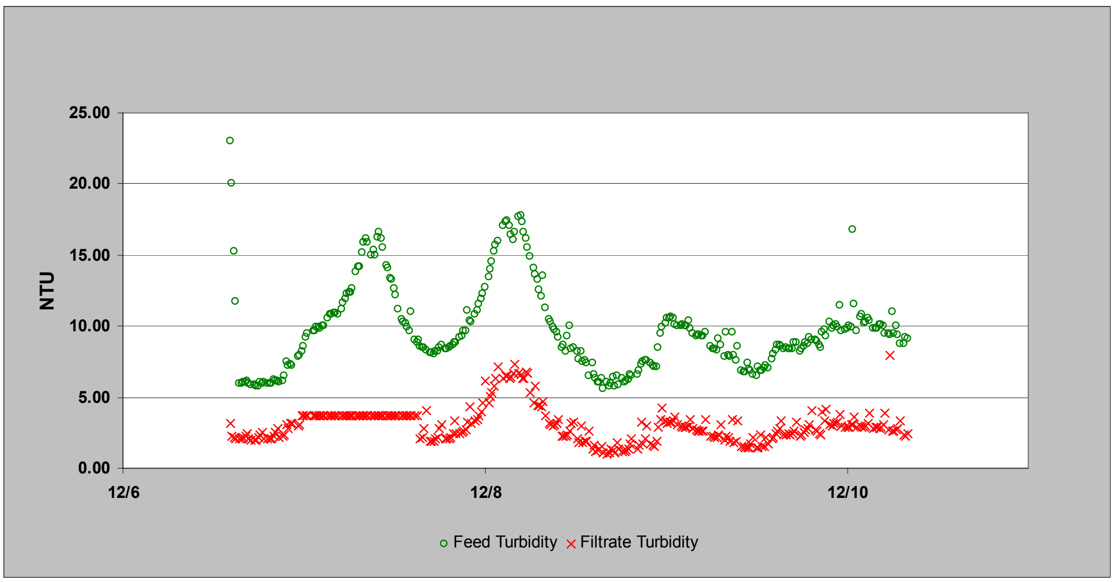

Figure 11. Stage 2 Baseline Test - High Filtrate Turbidity - Filter Run No. 5

Feed and filtrate turbidity for the extended run conditions are shown in Figure 12, along with the temperature-corrected flux. The flux-20 ranged between 30 and 33 gfd. The feed turbidity levels ranged from 6 to 25 NTU with a single turbidity spike of 38 NTU at the beginning of Filter Run No. 6. With the exception of two events, the filtrate turbidity was always below 0.1 NTU.

The filtrate turbidity levels were as follows:

- Minimum: 0.04 NTU
- Maximum: 0.14 NTU
- Average: 0.05 NTU

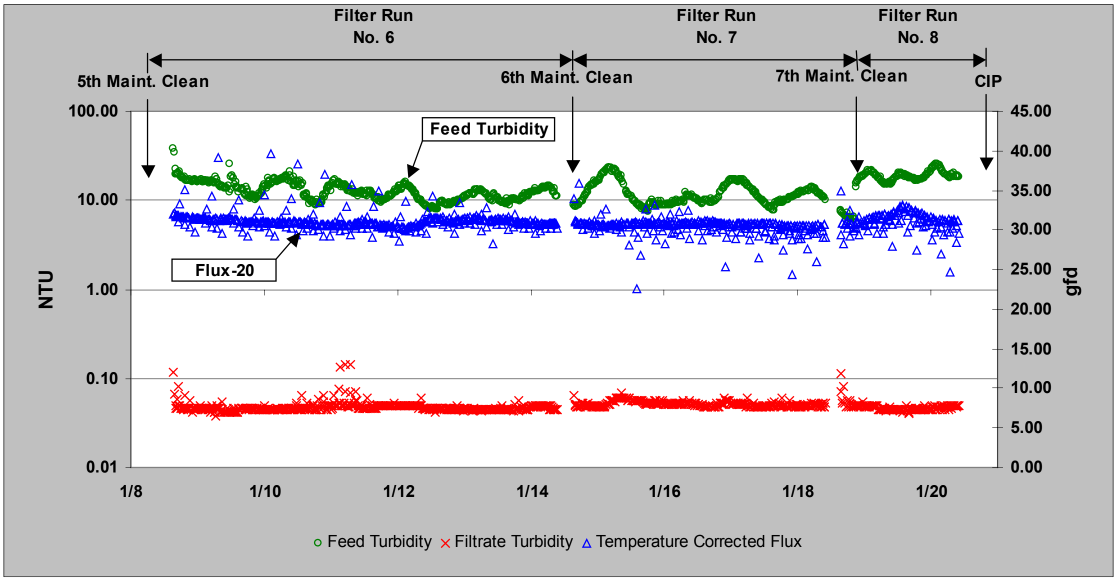

Figure 12. Stage 2 Extended Run - Feed & Filtrate Turbidity and Temperature Corrected Flux

Figure 13 shows a lognormal distribution of the filtrate turbidity data, which was 0.062 NTU for the 95th percentile. With a maximum filtrate turbidity of 0.14 NTU, the MF unit met the Title 22 Regulations filtrate turbidity of <0.5 NTU all of the time.

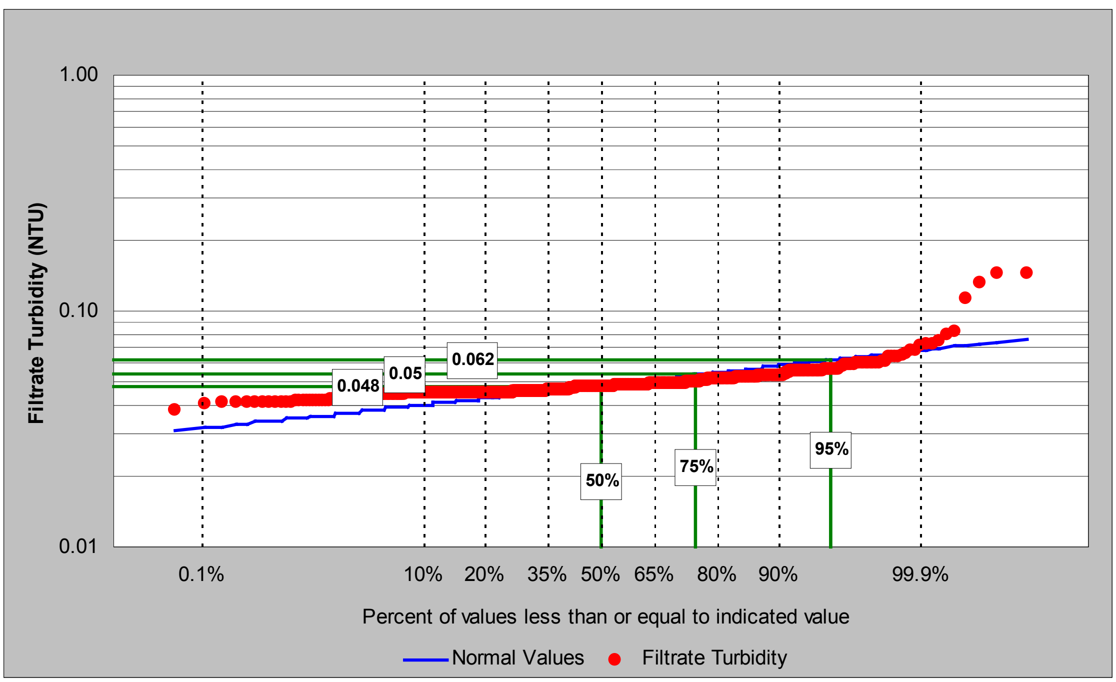

Figure 13. Stage 2 - Filtrate Turbidity Lognormal Distribution

Total Organic Carbon (TOC)

Figure 14 shows feed and filtrate TOC levels. Feed TOC varied between 10 and 20 mg/L. Filtrate TOC fluctuated between 8 and 13 mg/L. On two occasions, the feed and filtrate were sampled on the same day and the membrane removed about 50% of the TOC. On another day with concurrent sampling, the TOC removal was 70%. For this application, the TOC removal will vary depending on the fractions of particulate and soluble organic species; only the particulates larger than the membrane pores will be removed.

Nitrogen Compounds

Figure 15 includes the feed and filtrate ammonia and nitrate concentrations measured during the extended run testing. The filtrate levels for both of these compounds were slightly higher than the feed levels. The microfiltration membrane did not reject these compounds, nor should not increase their concentrations in the filtrate.

This increase in ammonia and nitrate within the membrane system was not anticipated. It could have been caused by a difference in sample-collection methods. The feed samples were 24-hour composites collected by an auto sampler and analyzed by the West Point WWTP Process Laboratory. A grab sample was used for the filtrate analyses, which was conducted by the King County Environmental Laboratory.

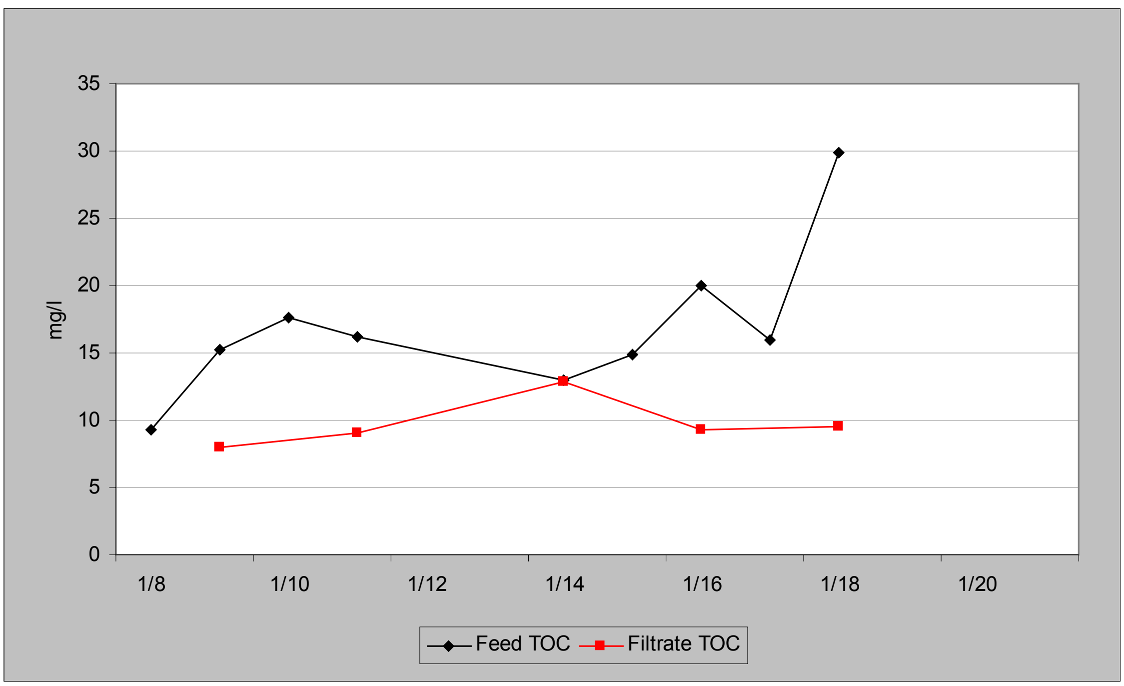

Figure 14. Stage 2 - Feed & Filtrate TOC

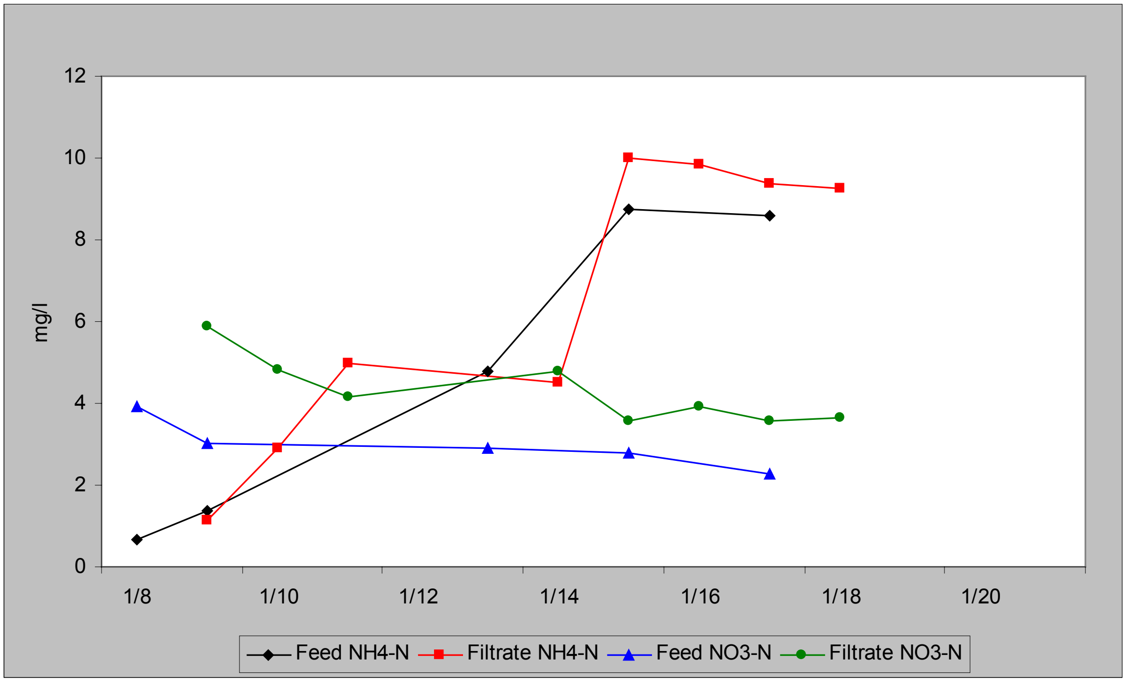

Figure 15. Stage 2 Feed and Filtrate Ammonia and Nitrate

BOD and COD

COD was measured on BAF #1 effluent and MF filtrate during the extended run conditions for Stage 2. BOD was also measured on the BAF #1 effluent. The average values for these data are presented below.

- BAF #1 effluent BOD: 25 mg/L
- BAF #1 effluent COD: 127
- Filtrate BOD: not measured
- Filtrate COD: 108 mg/L

Microbiological

HPC and TC were measured once on BAF #1 effluent during Stage 2. HPC was measured twice on the MF filtrate. The results are listed below.

- WPSE HPC: 33,000,000 CFU/100 mL
- WPSE TC: 490,000 CFU/100 mL
- Filtrate average HPC: 3 CFU/100 mL

These data show that the microfiltration membrane effectively removed 5 log of HPC from the BAF #1 effluent.

Stage 3– BAF #2 Effluent Feed

Stage 3 began on January 29, 2002 and continued until February 27, 2002, at which time the MF pilot unit testing concluded. In this testing stage, the MF unit was part of the following treatment train: WP PE → BAF #1 → BAF #2 → MF → RO. The feed (i.e., BAF #2 effluent) turbidity to the MF unit was lower than the BAF #1 effluent.

The MF unit feed piping configuration included a storage tank (separate from the BAF #1 effluent storage tank) between BAF #2 and the MF unit. Unlike the BAF #1 effluent feed facilities, this configuration did not introduce additional solids in the MF feed. With the turbidity levels of the BAF #2 effluent lower than BAF #1 effluent, there was not a high potential for solids accumulation in the storage tank.

The two-stage BAF train was configured to promote nitrification. With BAF #2 nitrified effluent now supplying the MF pilot unit, there was very little ammonia present in the feed. Under these conditions, chlorinating the MF unit feed at a target dose of 5 mg/L would have produced a combination of mono-chloramines and free chlorine in the filtrate. The downstream RO unit used a membrane module not compatible with free chlorine. To prevent damaging the membrane and avoid a chemical de-chlorination step, feed chlorination was discontinued for Stage 3.

Stage 3 was designed to include several weeks to test alum pre-treatment for enhanced phosphorous removal. With only four weeks to complete Stage 3, there was not adequate time to conduct baseline testing with alum followed by an extended run. Instead, the first three weeks of testing occurred without alum, and the final week of testing included alum. The results from these two test conditions are presented below.

Operating Performance and Chemical Cleans

Table 7 provides a summary of the operating data for each filter run. The table notes if the filter run was conducted during baseline or extended run test conditions along with modifications to the backwash settings, which Pall adjusted remotely during and/or between filter runs.

Table 7. Stage 3 Filter Run Operating Data

Filter Run No.	Test Condition	Filtrate Flow (gpm)	Feed Turbidity (NTU)	Feed Temp (ºC)	Flux-20 (gfd)	Post-Clean [a] TMP (psi)	TMP Slope (psi/day)	Backwash Frequency (minutes)	Recovery (%)
1	Baseline (w/o Alum)	Initial 7, Final 6	3 – 6	9.7 – 12.7	29 - 34	8	Initial 6.7, Final 1.5	10 [b]	89.5
2	Extended Run (w/o Alum)	6	1 - 8	11 - 12	27 – 28	6	1.1	10	89.5
3	Extended Run (w/o Alum)	6	2 - 4	11 - 13	27 - 28	5.3	1.4	10	89.5
4	Extended Run (w/ Alum)	Initial 6, Final 8	2 - 14	8.6 – 12.8	30 - 38	5.8	Initial 0.8, Final 3.4	10	89.5

[a] Post-Clean TMP is the initial TMP for a filter run after a maintenance clean or CIP.

[b] Backwash (BW) settings adjusted when filtrate flow rate reduced: Air scrub + RF duration decreased to 30 seconds, RF flow rate 4 gpm, RF only duration 25 seconds at flow rate of 9 gpm

Baseline Test Conditions (without Alum)

Figure 16 shows the Stage 3 baseline test operating data. It included only a single seven-day run (Filter Run No. 1). The same backwash cycle set points and frequency (every 10 minutes) used at the conclusion of Stage 2 were used in the Stage 3 base line test.

After the first 18 hours, the TMP slope was very steep (6.7 psi/day). Pall attributed this to the low feed temperature (10 ºC) and no feed chlorination. So the filtrate flow rate was reduced to 6 gpm, which is a flux rate of 21.7 gfd (flux-20 = 28.6 gfd). This flow rate reduction reduced the TMP from 19.5 to 13.8 psi. At this lower flow rate and a backwash frequency of 10 minutes, the backwash set points were adjusted to maintain the highest recovery possible. The backwash set points were:

- Frequency: 10 minutes.
- Air Scrub + RF: 30 second duration, 3 SCFM airflow rate, 4 gpm RF flow rate.
- RF only: 25 second duration, flow rate 9 gpm.
- Recovery: 89.5%.

After these changes, the unit ran for another six days. Over this period, the TMP slope was 1.5 psi/day. Just before the first maintenance clean, the TMP was only 20 psi. The maintenance protocol established during Stage 2 continued to be used in Stage 3. This included a heated caustic soda (10,000 mg/L)/chlorine (1,000 mg/L) solution. The post-clean TMP was 5 psi.

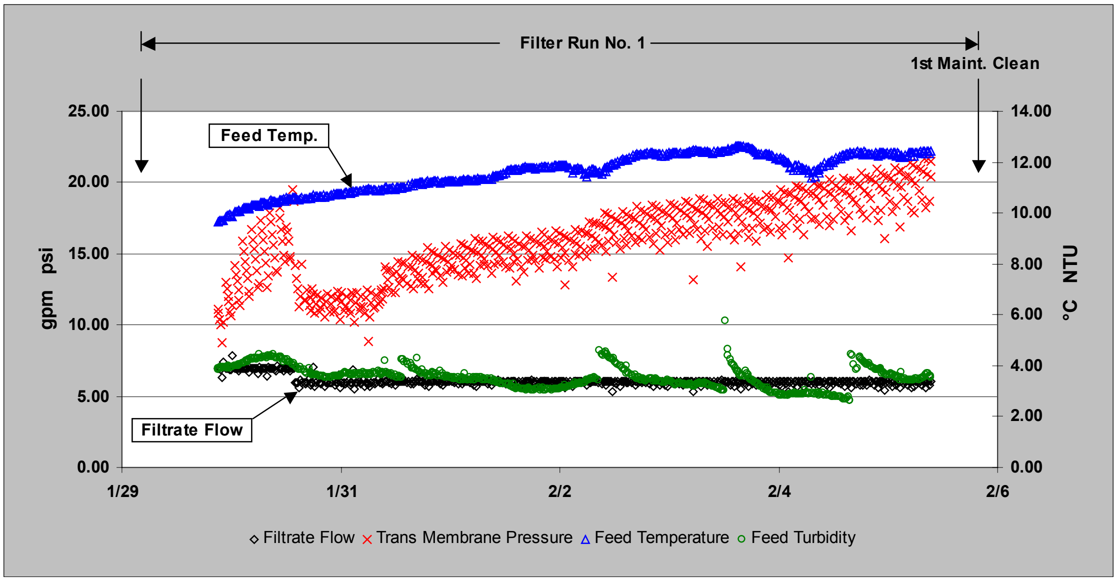

Figure 16. Stage 3 Baseline Test Operating Data - Without Alum

The following observations were noted:

- The BAF #2 effluent is a good quality feed for the MF unit. Feed turbidity was consistently between 3 and 5 NTU.
- Because of the very cold feed temperature and discontinued feed chlorination, the reduced filtrate flow rate (from 8.7 to 6 gpm) was necessary to achieve a seven-day run.
- The maintenance clean was very effective and achieved good TMP recovery (i.e., post-clean TMP between 5 and 6 psi).

Extended Run Conditions (with and without Alum)

Stage 3 extended run testing began on February 5, 2002 and continued until February 27. Three one-week filter runs were conducted with maintenance cleans done once per week. Alum feed (50 mg/L) was added upstream of the MF unit during Filter Run No. 4. Figure 17 shows the operating data.

During Filter Run No. 2, feed turbidity fluctuated between 2 and 8 NTU. The turbidity spikes did not impact the TMP slope. In the last few days of the run, feed turbidity dropped to as low as 1 NTU. The TMP increased at 1.1 psi/day. Feed temperature fluctuated between 11 and 12 degrees C.

Similar results were observed for the Filter run No. 3. Feed temperature ranged between 11 and 13 ºC and feed turbidity was between 2 and 4 NTU. The TMP slope was 1.4 psi/day, slightly higher than the previous run.

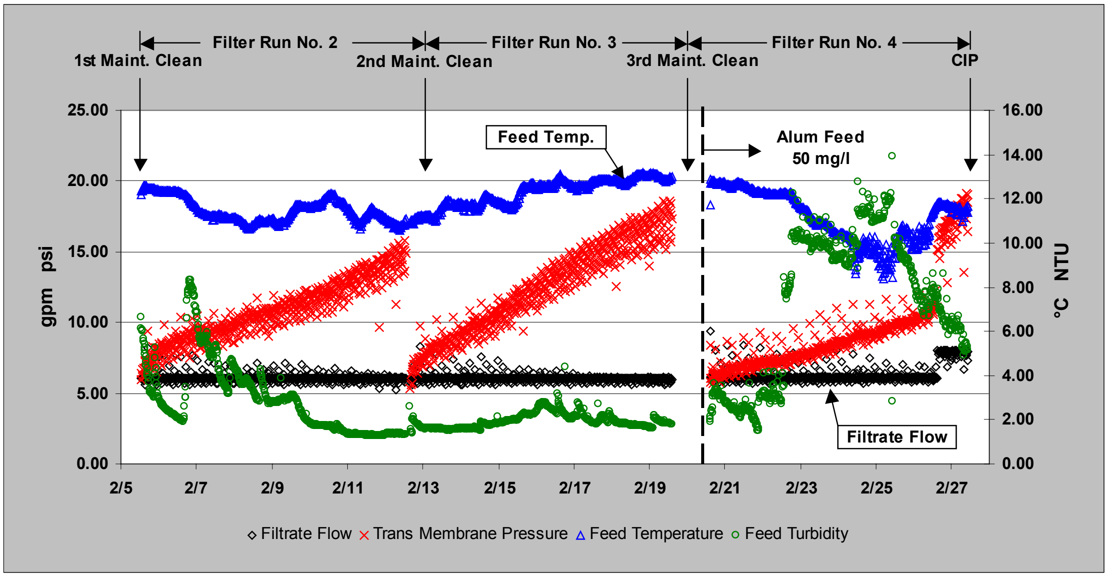

Figure 17. Stage 3 Extended Run Operating Data - Without and With Alum

At the beginning of Filter Run No. 4, alum was added (undiluted stock solution 27% by weight concentration) to the BAF #2 effluent feed at a target concentration of 50 mg/L. The alum injection point was just downstream of the pump supplying BAF #2 effluent to the MF unit. There was a static mixer downstream of the injection point. The contact time between the injection point and MF unit was approximately one minute. For the first 48 hours, feed turbidity fluctuated between 2 and 4 NTU, and it appeared that alum addition was not increasing feed turbidity. Then feed turbidity jumped up to 8 NTU and increased to as much as 14 NTU for the remainder of the test. Feed temperature also dropped to as low as 8.6 ºC. Despite, the higher feed turbidity and low temperature conditions, the TMP slope remained constant at 0.83 psi/day, which was the lowest observed for all stages of the testing.

With such a shallow TMP slope, Pall increased the filtrate flow rate from 6 to 8 gpm for the last 21 hours of the run. This caused the TMP to immediately increase from 11 to 15 psi. The final TMP was 18.4 psi increasing the TMP slope to 3.4 psi/day.

The following observations were noted:

- BAF #2 effluent was a good quality feed for the MF unit. The heated water NaOH/NaOCl clean was effective and provided a post-clean TMP of 5 to 6 psi.
- With a feed turbidity <10 NTU and a filtrate flow rate of 6 gpm (flux-20 between 26 and 28 gfd), the maintenance clean frequency was once per week. At the end of the runs, the final TMP was less than 20 psi, well below the high-alarm TMP setting of 35 psi.
- At 6 gpm (flux-20 between 27 and 30 gfd), alum feed minimized membrane fouling and provided the lowest daily increase in TMP. At 0.83 psi/day, the system might be able to run for three weeks before a maintenance clean. The alum coagulant improves

membrane performance. Possible explanations for this are that the solids produced perform a protective layer on the membrane surface that is very permeable and does not significantly reduce flux. This layer can capture organic solids and is easily removed during the backwash.

- Once the feed flow rate was increased to 8 gpm (flux-20 between 34 and 37 gfd), the TMP slope increased to 3.6 psi/day. If time had permitted and the slope had remained constant, the maintenance clean frequency would have been about once per week.

Water Quality

Feed and filtrate concentrations for the following parameters were collected: turbidity, TOC, ammonia, nitrate, total phosphorous (TP) and ortho-phosphate. This data are presented for both the baseline and extended run testing. Silt Density Index (SDI) and conductivity were measured on the MF filtrate because it was the feed for the RO unit. BOD, COD, and microbiological parameters were also measured and are presented.

Turbidity

Figure 18 shows the temperature-corrected flux, feed and filtrate turbidity for the entire Stage 3 duration. At the filtrate flow rate of 6 gpm, the temperature-corrected flux was between 27 and 30 gfd. At 8 gpm, the temperature-corrected flux was 34 to 37 gfd. Without alum, the feed turbidity was consistently below 10 NTU. With alum, the maximum feed turbidity was 14 NTU.

With the exception of one data point, the filtrate turbidity was at or below 0.1 NTU. On the morning of February 25, 2001 the filtrate turbidimeter recorded a filtrate turbidity level of 1.3 NTU. The 15-minute readings before and after were 0.04 NTU so this data point was considered an outlier.

Excluding this outlier, filtrate turbidity levels were as follows:

- Minimum: 0.04 NTU
- Maximum: 0.11 NTU
- Average: 0.05 NTU

Figure 19 shows a lognormal distribution of the filtrate turbidity data. The 95th percentile was 0.06 NTU. With a maximum filtrate turbidity of 0.11 NTU, the MF unit met the Title 22 Regulations filtrate turbidity of <0.5 NTU all of the time.

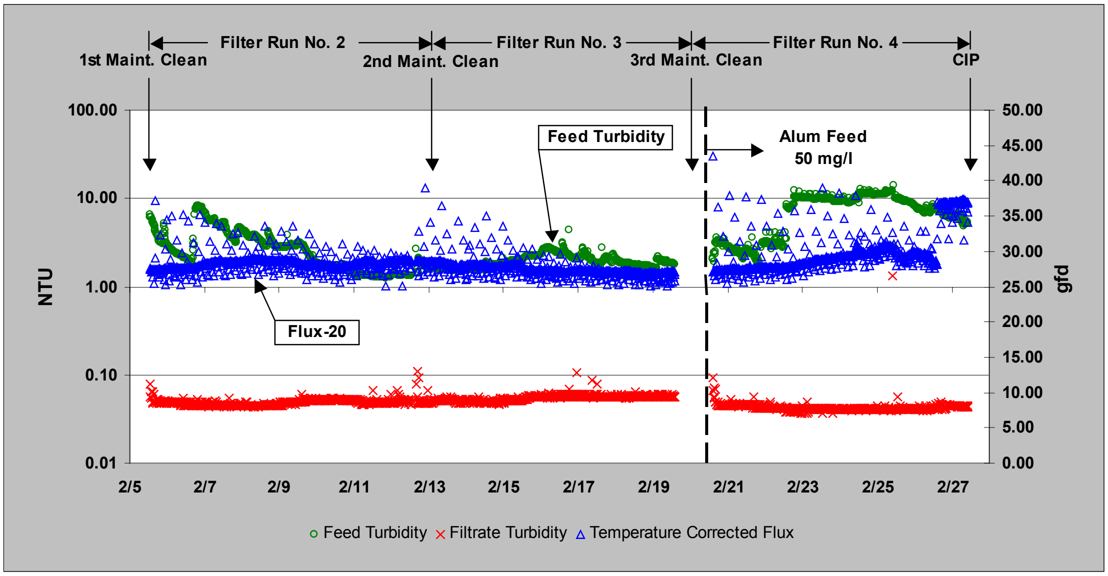

Figure 18. Stage 3 Feed & Filtrate Turbidity and Temperature Corrected Flux

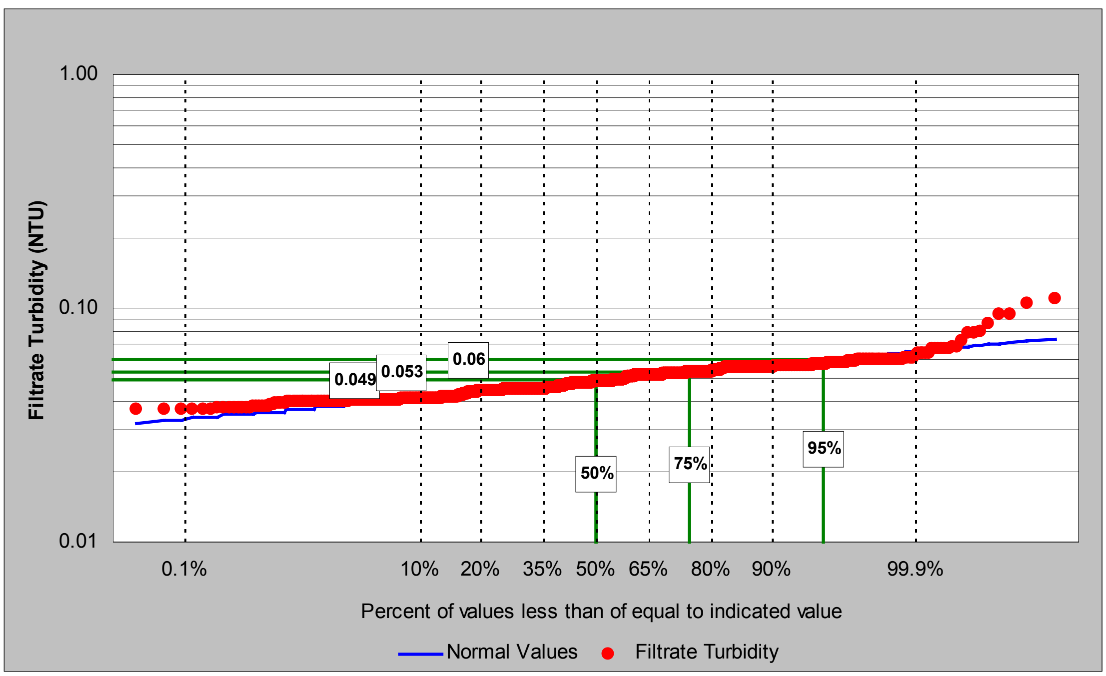

Figure 19. Stage 3 Filtrate Turbidity Log-Normal Distribution

Total Organic Carbon (TOC)

Feed and filtrate TOC levels are shown in Figure 20. Feed TOC varied between 10 and 16 mg/L. Filtrate TOC fluctuated between 4 and 10 mg/L. The percent removal ranged from 21 to 58%. For this application, TOC removal will vary depending on the fraction of particulate and soluble organic species, with only the particulate fraction larger than the membrane pores removed. Alum addition resulted in a slight improvement of TOC removal when similar influent TOC concentrations, with and without alum addition, are compared.

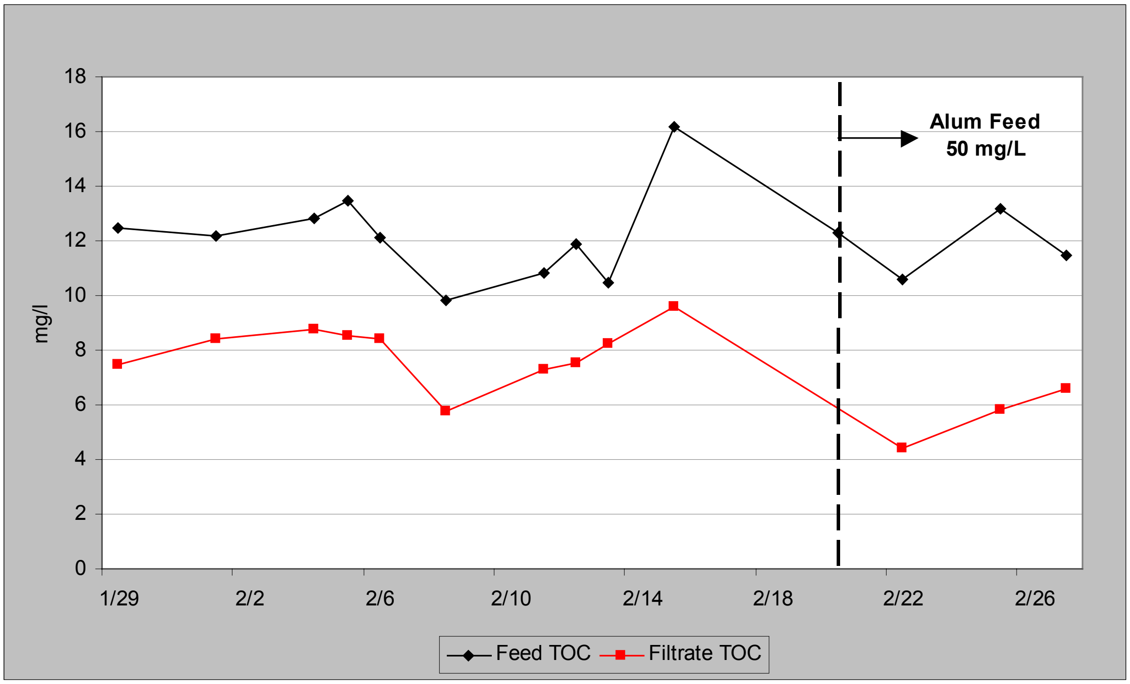

Figure 20. Stage 3 - Feed & Filtrate TOC

Nitrogen Compounds

Figure 21 presents the feed and filtrate ammonia concentrations. In some instances, the filtrate levels were slightly higher than the feed levels. The microfiltration membrane does not reject, nor should it increase, ammonia.

An increase in ammonia within the membrane system was not anticipated. This increase could have been caused by a difference in sample-collection methods. The feed samples were 24-hour composites collected by an auto sampler and analyzed by the West Point WWTP Process Laboratory. A grab sample was used for the filtrate analyses, which was conducted by the King County Environmental Laboratory.

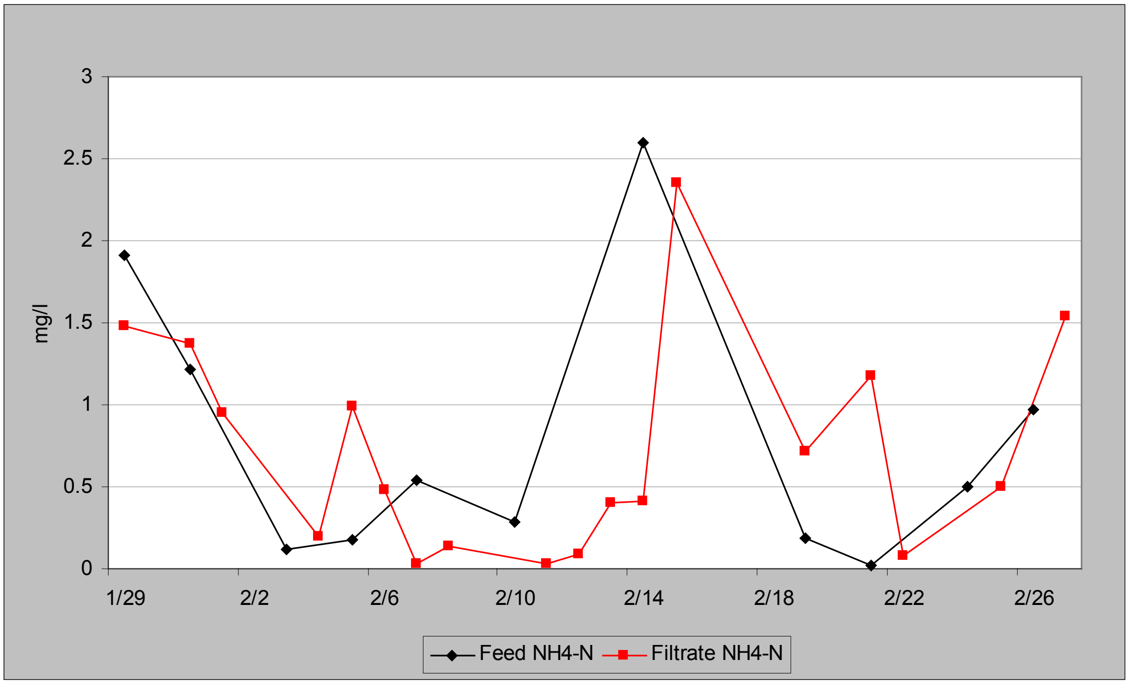

Figure 21. Stage 3 Feed and Filtrate Ammonia

Figure 22 presents the feed and filtrate nitrate concentrations. In some instances, the filtrate levels were slightly higher than the feed levels. An increase in nitrate within the membrane system was not anticipated. The microfiltration membrane does not reject, nor should it increase nitrate.

Figure 23 presents the feed and filtrate TKN concentrations. Unlike ammonia and nitrate, the filtrate levels were consistently lower than the feed levels. The percent removal (based on feed and filtrate data measured on the same day) ranged from 23% to 84%. The microfiltration membrane therefore, appears to reject organic nitrogen. Compared to ammonia and nitrate, organic nitrogen compounds are larger molecules that would tend to be rejected by the membrane.

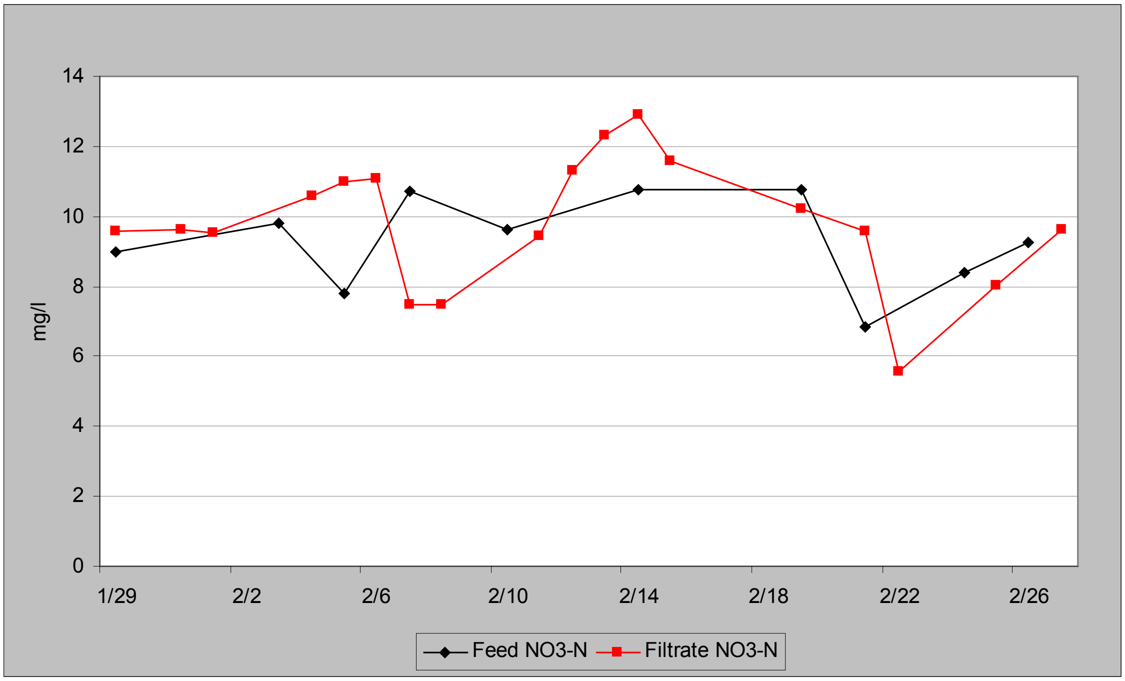

Figure 22. Stage 3 Feed and Filtrate Nitrate

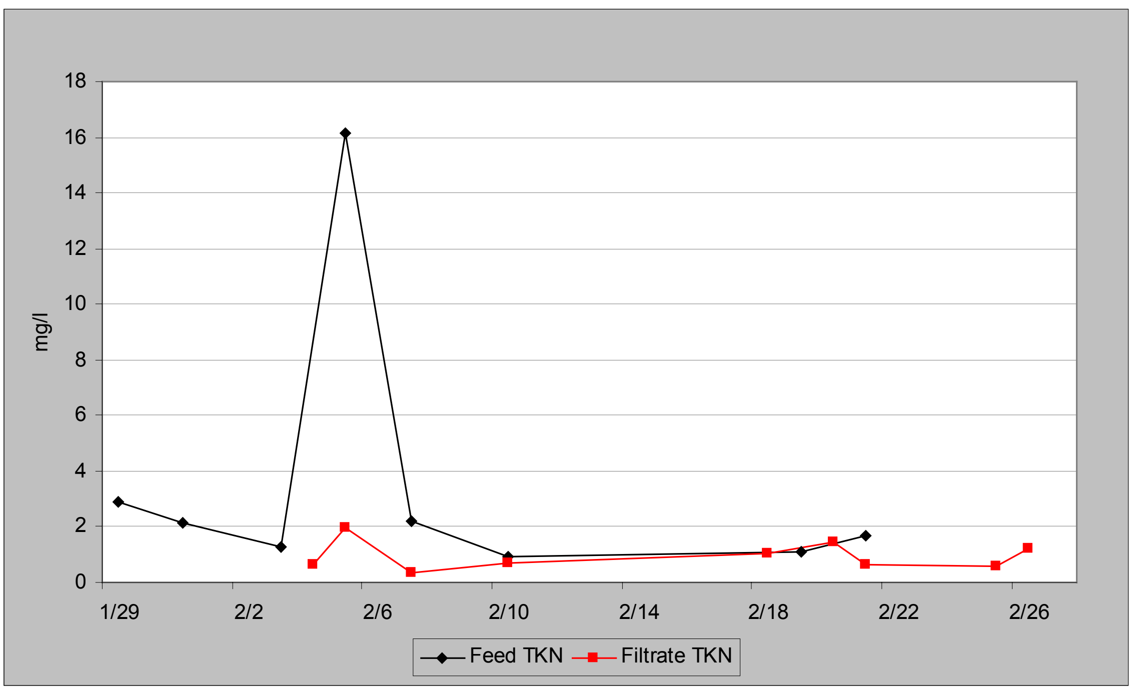

Figure 23. Stage 3 Feed and Filtrate TKN

Phosphorous Compounds

Stage 3 testing showed no rejection of phosphorous compounds by the membrane without alum pre-treatment. However, with alum pretreatment both TP and ortho-phosphate were removed.

Figure 24 includes the feed and filtrate TP data. During alum pre-treatment, four filtrate TP samples were collected. For two of these samples, feed TP was also analyzed, and the concentrations ranged from 0.57 to 1.38 mg/L (Al:P of 6.3 to 15.2). The percent removal, using the concurrent sample data, was 94% and 98%. The four filtrate concentrations ranged from 0.015 to 0.056 mg/L, compared to the test objective of <0.05 mg/L TP, 95th percentile. Generally speaking, with only four data points, feeding 50 mg/L alum achieved the performance goal. Additional data points would be required to confirm this and to determine the optimum alum dosage.

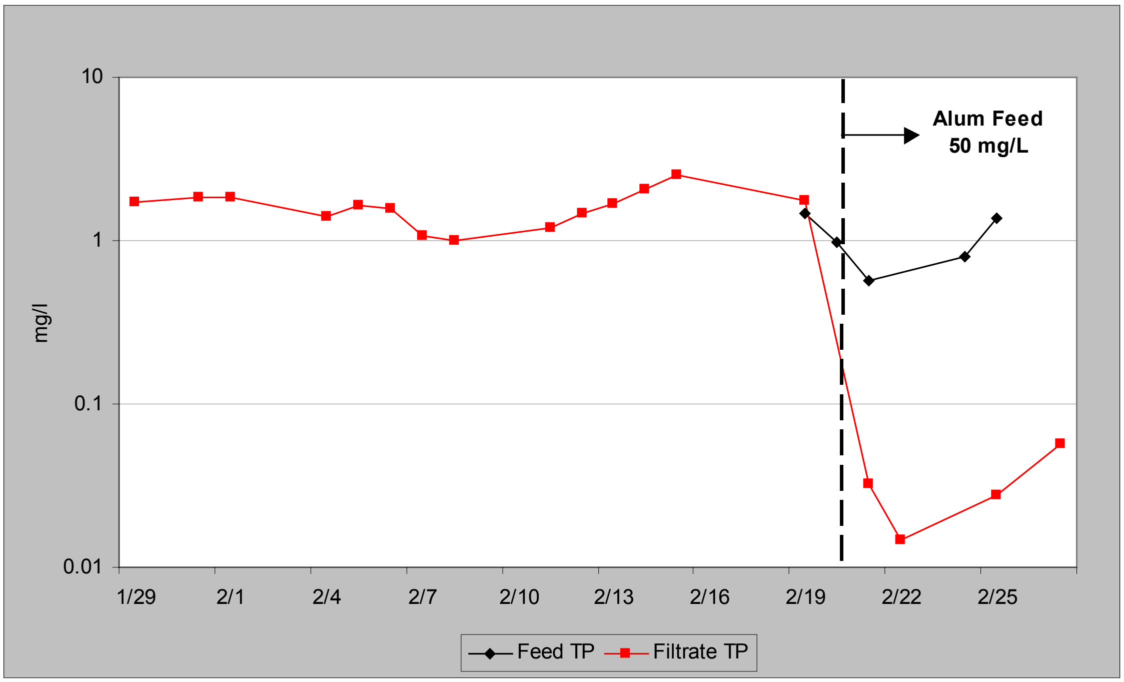

Figure 24. Stage 3 Feed and Filtrate Total Phosphorous

Figure 25 includes the feed and filtrate ortho-phosphate data. During alum pre-treatment, four filtrate ortho-phosphate samples were collected. The filtrate concentrations ranged from 0.002 (less than the lab method detection limit) to 0.009 mg/L. No concurrent feed ortho-phosphate samples were taken. However, note that the pre-alum treatment filtrate ortho-phosphate levels ranged from 0.9 to 2.3 mg/L. Comparing pre- and post-alum feed filtrate levels indicates the alum pre-treatment provided at least a two-order-of-magnitude reduction.

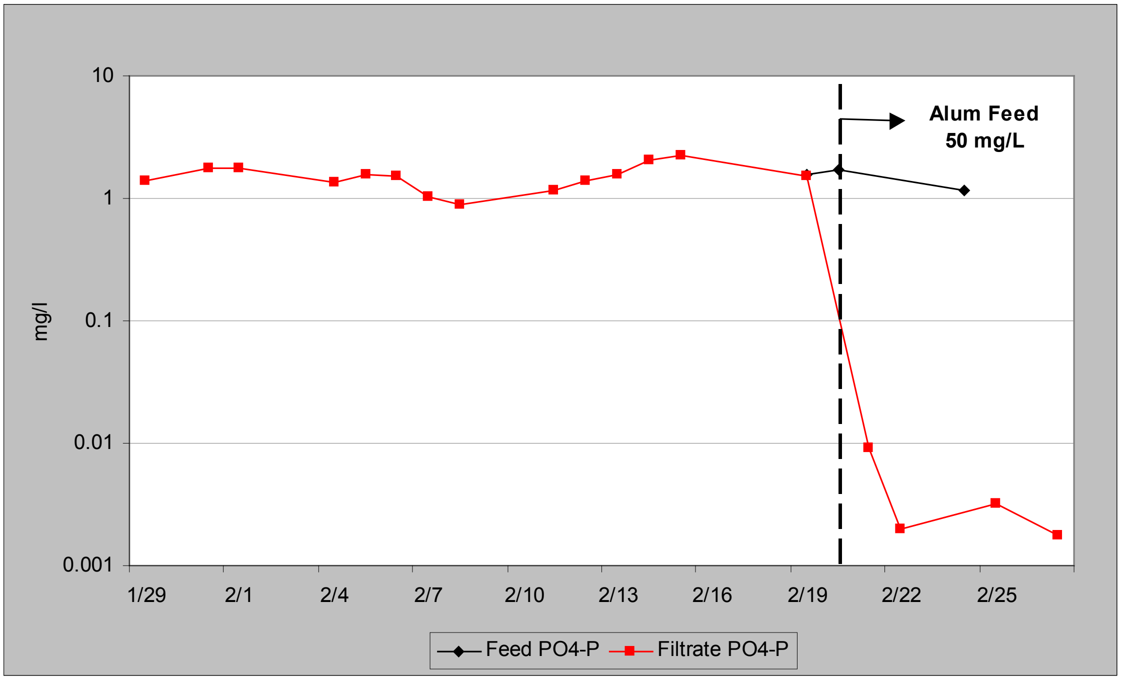

Figure 25. Stage 3 Feed and Filtrate Ortho-Phosphate

Metals and Organics

The feed and MF filtrate were analyzed for metals and organics on January 29, 2002. The metals data is presented in Table 8 and the organics data is presented in Table 9.

SDI and Conductivity

SDI and conductivity were monitored for the RO unit feed streams. During Stage 3, the MF unit supplied the RO unit, so these parameters were measured in the MF filtrate. Average values are presented below.

- Filtrate SDI: 1.1
- Filtrate conductivity: 621 µmho/cm

BOD, COD and TSS

COD was measured on BAF #2 effluent and MF filtrate. BOD was also measured on the BAF #2 effluent. The average values for these data are presented below.

- BAF #2 effluent BOD: 7 mg/L
- BAF #2 effluent COD: 140
- Filtrate BOD: not measured
- Filtrate COD: 135 mg/L

Microbiological

HPC and TC were measured on BAF #2 effluent during Stage 3 (four data points). HPC was measured on the MF filtrate (four data points). The average values are listed below.

- BAF #2 HPC: 4,848,000 CFU/100 mL
- BAF #2 HPC TC: 220,000 CFU/100 mL
- Filtrate average HPC: 29,000 CFU/100 mL

This data shows only 1 log removal of HPC from the BAF #2 effluent. This is significantly lower than the results from Stage 1 and 2. HPC represents a wide range of organisms, most of these larger than 1-µm and therefore, higher removals were expected. The reason for the low HPC removal in Stage 3 is not known.

Table 8. Stage 3 Feed and Filtrate Metals

Parameter	Feed Concentration (mg/L)	Filtrate Concentration (mg/L)	MDL (mg/L)
Aluminum	0.0655	0.0239	0.002
Antimony	<0.0025	0.0025	0.0005
Arsenic	0.0018	0.0021	0.0005
Barium	0.00956	0.00755	0.0002
Beryllium	<0.001	0.001	0.0002
Cadmium	<0.005	0.005	0.0001
Chromium	0.0011	0.00078	0.0004
Cobalt	0.00039	0.00026	0.0002
Copper	0.0117	0.00783	0.0004
Iron	0.309	nm	0.05
Lead	0.00064	0.00024	0.0002
Molybdenum	0.00456	0.00405	0.0005
Nickel	0.00369	0.00342	0.0003
Selenium	<0.0075	0.0075	0.0015
Silver	0.00139	<0.0002	0.0002
Thallium	0.001	0.001	0.0002
Vanadium	0.00072	0.00067	0.0003
Zinc	0.0377	0.0292	0.0005
Mercury	<0.00005	<0.00005	0.00005

Table 9. Stage 3 Feed and Filtrate Organics

Parameter	Feed Concentration (µg/L)	Filtrate Concentration (µg/L)	MDL (µg/L)
1,1,1-Trichloroethane	<1	<1	1
1,1,2,2-Tetrachloroethane	<1	<1	1
1,1,2-Trichloroethane	<1	<1	1
1,1,2-Trichloroethylene	<1	<1	1
1,1-Dichloroethane	<1	<1	1
1,1-Dichloroethylene	<1	<1	1
1,2-Dichloroethane	<1	<1	1
1,2-Dichloropropane	<1	<1	1
2-Butanone (MEK)	<5	<5	5
2-Chloroethylvinyl ether	<1	<1	1
2-Hexanone	<5	<5	5
4-Methyl-2-Petanone (MIBK)	<5	<5	5
Acetone	<2.5	<2.5	2.5
Acrolein	<5	<5	5
Acrylonitrile	<5	<5	5
Benzene	<1	<1	1
Bromodichloromethane	<1	<1	1
Bromoform	<1	<1	1
Bromoethane	<1	<1	1
Carbon Disulfide	<1	<1	1
Carbon Tetrachloride	<1	<1	1
Chlorobenzene	<1	<1	1
Chlorodibromoethane	<1	<1	1
Chloroethane	<1	<1	1
Chloroform	<1	<1	1
Chloromethane	<1	<1	1
Cis-1,3-Dichloropropene	<1	<1	1
Ethylbenzene	<1	<1	1
Methylene Chloride	1.2	2.1	1
Styrene	<1	<1	1
Tetrachloroethylene	<1	<1	1
Toluene	<1	<1	1
Total Xylenes	<1	<1	1
Trans-1,2-Dichloroethylene	<1	<1	1
Trans-1,3-Dichloropropene	<1	<1	1
Trichloroflouromethane	<1	<1	1
Vinyl Acetate	<5	<1	5
Vinyl Chloride	<1	<1	1

Evaluation of Pilot Results

Effectiveness of Technology to Achieve Performance Goals

Table 10 provides a comparison of conventional filtration and microfiltration with respect to turbidity removal and system recovery. The West Point WWTP has Dynasand granular media filters that treat a portion of the WP SE to support in-plant activities. PACL is used as a coagulant at a dose between 23 and 40 mg/L. The Dynasand units are operated year round. Table 10 also summarizes the ranges and averages of the performance parameters for the Dynasand filters for monthly average data from January 2001 through March 2002, which was provided by the County.

Data from the Dynasand filters are compared to the Stage 1 extended run MF data. To provide a parallel comparison, the performance data is presented for October 2001 when Stage 1 occurred.

Table 10. Comparison of Conventional Filtration and Microfiltration Performance

Operation / Performance Parameter		Conventional Filtration[a]			Microfiltration (Pall)
		January 2001 through March 2002		October 2001	October 2001
	Units	Range	Average	Average	Average[b]
Secondary Effluent (feed) Turbidity	NTU	2.06 – 7.18	3.88	4.69	5.16
Filtrate Turbidity	NTU	0.22 - 1.79	0.85	1.07	0.05
Turbidity Removal	%	55 - 91	78	77	99
Recovery	%	81 - 96	90	89	92.5

[a] Conventional filtration data is for the West Point WWTP Dynasand filters, which treats a portion of the WP SE to provide in-plant reuse water. Filters use PACL coagulant with an average dose of 26 mg/L. Average hydraulic loading rate is 4.7 gpm/sf.

[b] Microfiltration data is for Stage 1 Extended Run. No coagulant used.

The results in Table 10 show that the MF unit produced a superior effluent turbidity when compared to the Dynasand filter. Effluent turbidity from the MF unit is very low and recovery from the MF unit is better than the Dynasand filter.

Table 11 summarizes target performance goals and measured performance for all three stages for the MF unit.

Table 11. MF Unit Measured Performance

Goal Description	Target	Measured Performance		
		Stage 1	Stage 2	Stage 3
Turbidity Removal	<0.2 NTU 95th Percentile	0.06 NTU	0.06 NTU	0.06 NTU
Filtrate TOC	<2 mg/L, 50th Percentile	Avg: 10.1 mg/L Max: 11.8 mg/L	Avg: 9.8 mg/[Max: 12.9 mg/L	7.5 mg/L 9.6 mg/L
TP Removal	<0.05 mg/L, 95th Percentile	Not measured	1.8 mg/L No alum pre-treatment	Approx. 0.053 mg/L[a] Alum pre-treatment
CIP Interval[b]	30 days	~ 30 days	~ 30 days	~ 60 to 90 days
System Recovery	>90%	92.5%	89.4%	89.5%
Long-Term Flux Decline	<2% per year	Not measured[c]	Not measured[c]	Not measured[c]

[a] Approximation with only 4 data points.

[b] Observed during extended run tests.

[c] Unable to measure during plot test duration.

Turbidity Removal

The Pall MF pilot unit provided very good filtrate turbidity quality. For all three stages, turbidity at the 95th percentile was 0.06 NTU, achieving the performance goal. During Stage 2, feed turbidity spikes reached 67 NTUs, which increased membrane fouling but did not affect filtrate turbidity.

There was one filter run during Stage 2 where filtrate turbidity escalated above 1 NTU. However, this was an isolated incident attributed to a normally closed valve being slightly opened, which allowed some of the feed to mix with the filtrate.

TOC Removal

The performance goal for TOC removal was <2 mg/L at the 50th percentile. However, the rejection rate can vary depending on the proportions of dissolved and particulate organic compounds. This is why the TOC percent removals for each stage varied widely. The performance goal was not achieved during any stage. However, some removal did occur, which can be attributed to the particulate fraction of organic compounds larger than the 0.1 µm membrane pores.

TP Removal

The microfiltration membrane did not meet the TP removal performance goal without alum pre-treatment. This was observed during Stage 2 testing where the TP concentration was 1.8 mg/L at the 95th percentile (Table 11). However, during Stage 3, alum pre-treatment using a concentration of 50 mg/L resulted in an approximate 95th percentile TP concentration of 0.053 mg/L, which was just above the performance goal level. This result is qualified as approximate because only four data points were collected. The alum pre-treatment resulted in a dramatic reduction in both TP and ortho-phosphate levels in the MF filtrate indicating that the 0.05 mg/L goal is achievable.

CIP Interval

In order to accurately determine the expected CIP interval using a pilot system, several months of testing under extended run conditions is required. With three unique feed streams to evaluate over five months, there was not enough time to accurately predict the CIP interval for each test stage. Based on the extended run testing, an estimated CIP interval is shown in Table 11. For Stages 1 and 2 the maintenance clean frequency was twice per week. Also, the maintenance clean protocol was modified as testing progressed. Additional testing with the most recent protocol during Stages 1 and 2 might have increased the maintenance clean interval and extended the CIP interval. Without additional data, we assumed that a maintenance clean frequency of twice per week would require a CIP every 30 days.

During Stage 3, the maintenance clean frequency was once per week. However, in the third stage, the increase in TMP was the lower than for any other part of this pilot study, and the maintenance clean interval could have been extended to once every three weeks. It is possible that the CIP interval could then have been increased to every 60 to 90 days. Therefore, Table 11 indicates an estimated 60- to 90-day interval.

Based on the test results, the design criteria for a full-scale implementation of microfiltration are summarized below for each stage.

Long-Term Flux Decline

Similar to the CIP interval, the long-term flux decline would require several months of testing under extended run conditions to accurately determine the flux decline. This determination involves comparing the new membrane clean-water flux to the post-CIP clean-water flux for at least four to five consecutive CIP intervals. Recovery of the clean-water flux after a CIP indicates the membrane is being effectively cleaned and is not permanently fouled. This is an important consideration in determining the useful life of the membrane.

During Stages 1 and 3, only one CIP was conducted. During Stage 2, there were four CIPs conducted. After each CIP, the clean-water flux was measured at the following flow rates: 8, 9 10 and 12 gpm. The clean water feed temperature was monitored and the flux was adjusted to 20 ºC. Compared to the new membrane clean-water flux-20 values, the flux recovery was calculated for each flow rate tested. Table 12 summarizes the average percent flux recovery for each CIP done.

Table 12. Clean Water Flux Summary

Stage No.	CIP No.	Date	Average Flux Recovery (%)
1	1	11/1/2001	97.2
2	2	12/5/2001	94.6
	3	1/23/2002	85.4
	4	1/29/2002	76.6
	5	1/29/2002	75.8
3	6	2/28/2002	78.3

The tap water used to conduct the clean water flux tests was as low as 8°C in January 2002. Pall suggested using heated water for the flux test, and this suggestion was implemented on January 25, 2002. The flux recovery for CIPs 1 and 2 was greater than 90 percent. However, the recovery for CIP 3 was only 85.4%. Two additional CIPs were conducted before initiating Stage 3 testing to confirm this lower recovery. Recovery rates for CIPs 4 and 5 were all below 80%. The final CIP after Stage 3 testing concluded had a recovery of 78.3%.

Reliability Considerations

The reliability of the MF membrane process to achieve the performance goals is summarized in the previous section. For meeting Class A requirements, the MF membrane's ability to produce a filtrate turbidity <0.5 NTUs all of the time was demonstrated during all three stages of the testing. Fluctuations in feed turbidity caused the membrane to foul quickly requiring more frequent maintenance cleans.

The reliability of TP removal with alum pre-treatment was demonstrated in this pilot study. However, with only four filtrate TP data points collected, additional testing to obtain more data points would increase confidence in this initial finding and is recommended.

The system's ability to reliably achieve the CIP interval and long-term flux decline goals can only be speculated at this time. Additional testing is recommended to collect more CIP interval and post-CIP clean water flux data.

The MF membrane process does not reliably remove TOC.

Pilot Unit Operation Observations

Throughout the testing, the County operators recorded detailed comments on the pilot unit operation. These comments are included in Appendix B. The following summarizes the main observations recorded by the operators. They are focused on level of operator attention and equipment failures.

- The unit was equipped with a remote data logger, which allowed for easy data acquisition.
- The unit was easy to install and startup.
- The unit easily interfaced with the overall facility SCADA system for data acquisition and control.
- Chlorine addition increased the level of operator attention. The feed pump rate and chlorine solution supply had to be checked daily. A loss of chlorine feed would increase the rate of membrane fouling.
- The feed recirculation flow rate drifted during operation. This required frequent adjustment of valve HV5, which was done manually.

- Frequent maintenance cleans increased operator attention because the cleans were not automated on this pilot system. Also, there was not a readily available supply of hot water, which necessitated additional preparation time. A requirement to have hot water available was added to the maintenance clean protocol. With the many revisions to the protocol, it was difficult to keep the total off-line time for the unit to less than 60 minutes. The maintenance clean normally took 2 to 3 hours to complete.
- The CIP protocol was labor intensive and took a lot of time. In some cases, the CIP was done over a period of two days.
- The turbidimeters need to be cleaned frequently to prevent false high readings.
- The system was down for four weeks due to the reverse-filtration pump failure and air compressor failure. This reduced the time available to perform the testing.

Implementation

Design Criteria

The following is a summary of the recommended design criteria for this application. This is based on the extended run results during each stage of the testing.

Stage 1

- Feed turbidity average <10 NTU.
- Flux-20 = 32 gfd with chlorine feed at a target dose of 5 mg/L.
- Backwash frequency of 15 minutes with a system recovery of 92.5%.
- Maintenance clean frequency of twice per week using chlorine only. Frequency might be decreased if heated water and caustic soda are added to the protocol.
- Estimated CIP interval is 30 days. This interval could be lengthened if the maintenance clean frequency is decreased.

Stage 2

- Feed turbidity average <10 NTU.
- Flux-20 = 30 gfd with chlorine feed at a target dose of 5 mg/L.
- Backwash frequency of 10 minutes with a system recovery of 89.4%.
- Maintenance clean frequency of twice per week using chlorine and caustic soda with water heated to 38 ºC.
- Estimated CIP interval is 30 days.

Stage 3

- Feed turbidity average <15 NTU.
- Flux-20 = 27 gfd with no chlorine feed.

- Backwash frequency of 10 minutes with a system recovery of 89.5%.
- Maintenance clean frequency of once per week using chlorine and caustic soda with water heated to 38 ºC.
- Estimated CIP interval is 60 to 90 days.
- Enhanced Phosphorous Removal. An alum dose of 50 mg/L will produce filtrate TP <0.05 mg/L. Alum addition could decrease the maintenance clean and CIP frequency. If a maintenance clean frequency of once per week is targeted, the flux rate could go up. A flux-20 of 34 to 37 gfd was tested for 24 hours and excessive fouling of the membrane was not observed. Since only one alum dose (50 mg/L) was tested, additional testing is recommended to identify the optimum alum dose.

Design Features

The following features should be included in a full-scale microfiltration membrane application for secondary treatment:

- **Chemical Addition Facilities.** Chemical addition facilities, with automated dosing and control features to add chlorine to the feed, will be required to achieve the highest design flux rate. If downstream treatment with an RO unit is implemented, and the RO membrane is not compatible with free chlorine, dechlorination facilities will be required or the MF system will need to be operated without chlorine addition to the feed. This will result in a lower design flux for the MF system. Also, facilities to store and re-circulate heated water solutions with chlorine and/or caustic soda and citric acid will be required to perform maintenance cleans and CIP. The cleaning processes will be automated. To save chemical costs, fresh solutions will be stored and re-used until their cleaning efficiency is diminished. Once this occurs, the chemicals will need to be disposed.
- **Monitoring and Process Control.** On-line monitoring for feed and filtrate turbidity will be included along with standard operating parameters required to monitor system performance. Automatic integrity testing will be provided. The system must be capable of performing automated maintenance cleans, including the use of heated water and the option to use chlorine and caustic soda. A high level of operator attention will be required without automation.
- **Pre-Screening**. Fine screens (2 mm) or strainers (600-µm) will be required to prevent debris from plugging the membrane modules. The screens will have automatic cleaning features to minimize operator attention.
- **Coagulation**. Adding a coagulant (e.g. alum) to the feed could improve membrane operation and possibly offset the need to chlorinate the feed. However, this has not been demonstrated full-scale on a Pall facility designed for effluent reuse. Pall has a full-scale surface water treatment plant (Bakersfield, CA, 20 mgd) that utilizes enhanced coagulation with 25 mg/L ferric chloride.

- **Residuals**. Residuals include screenings, backwash water and spent chemicals. Typically, the backwash water and spent chemicals, once neutralized, would be discharged to the local sewer. Screenings will be sent to a local landfill.

Issues Not Resolved By Pilot Test Program

The following items could not be resolved by the pilot test program:

- An accurate determination of long-term flux decline and CIP interval for all three stages.
- The impact on the maintenance clean interval of using heated water with chlorine and caustic soda for Stage 1.
- The impact of alum pre-treatment on membrane flux rate and fouling during Stage 3.
- Additional data on TP and ortho-phosphate removal.
- The impact of alum pre-treatment on TOC removal during Stage 3.
- Optimal alum dose.
- Cost and performance benefit analyses for various operating options, such as the flux rate, maintenance-cleaning frequency, cleaning-chemical concentrations, backwash frequency, and backwash methodology.

Appendix A - Test Plan Revisions and Test Plan

Appendix B - Pilot Unit Photos and Operator Comments

Microfiltration Test Plan Revisions Summary

Introduction

This memorandum is a brief summary of the actual test conditions for the microfiltration membrane pilot unit. It focuses on changes and modifications from the last version of the microfiltration membrane pilot test plan, *Procedure H-06 Microfiltration Operation Rev. 2 Draft, October 8, 2001*. This memorandum does not replace the test plan. The intent is for the reader to reference it in conjunction with the test plan, which is also included in Appendix C.

The changes and modifications are summarized below. Each major heading corresponds to a section of the test plan affected.

Operating Conditions for Filtration of Secondary Effluent

Table 1 summarized the standard operating set points for the MF unit and noted that flux (i.e., permeate flow rate) is the only parameter expected to change. However, in addition to flux, Pall Corporation actually varied the backwash cycle set points to minimize membrane fouling. These set points are described in the *Microfiltration Membrane Tertiary Treatment Application Memorandum* (MF Report).

Table 1 also noted that particle counts will be measured on the feed and filtrate. The pilot unit was equipped with feed and filtrate particle counters and the PLC logged this data. However, the pilot unit is configured to evaluate microfiltration for both drinking water and wastewater applications. The particle counters are typically used for drinking water pilot tests. Generally, they are not used for wastewater piloting because the feed streams contain a lot of organics that can impact the instrument reading. Also, when treating wastewater, the instruments require a daily inspection and often a daily clean, which is operator intensive. Finally, particle counts are not required for demonstrating compliance with State of Washington Class A Reuse Standards. Therefore, the particle count data was not analyzed, reported or discussed in the MF Report.

Pilot Test Plan

Overview

Table 2 summarized the anticipated test phases and test runs to be conducted. Due to pilot unit mechanical failures, which caused the system to be down for six weeks, only three test phases (referred to as Stages 1, 2 and 3 in the MF Report) were completed. The conditions actually tested are listed below.

- Phase 1 (Stage 1): WP SE baseline conditions test and Run 1.
- Phase 2 (Stage 2): BAF #1 effluent baseline conditions test and Run 2.

- Phase 4 (Stage 3): BAF #2 effluent baseline conditions test and Run 6. An abbreviated Run 7, which was Run 6 with alum pre-treatment, was also conducted.

Extended Run to Demonstrate CIP Interval

This section of the test plan needs some additional discussion as follows.

Routine maintenance cleans (i.e., once or twice per week) will be conducted to prevent a rapid increase in TMP slope, which would reduce the CIP interval. The post maintenance clean TMP will be monitored to determine the effectiveness of the clean. If the TMP is not reduced to a level close to the TMP measured after a CIP, then a CIP will be required.

Peak Hour Flow Test

The peak hour flow testing described in the test plan was not conducted. Per follow up discussions with Pall Corporation, after the test plan was written, it was decided that a peak hour flow test was not required. The sustained permeate flow rate established during the extended run conditions will be used to establish the maximum design flux for a full-scale system. This maximum design flux will be the maximum production rate of the plant under peak hour conditions. Additional membrane units will be installed to maintain peak hour flow conditions at the design flux rate with one unit out of service for a maintenance clean or CIP.

Sampling

Routine Sampling

As discussed previously, feed and filtrate particle counts were measured, but this data was not analyzed or reported in the Main Report.

Feed and filtrate TSS monitoring was discontinued in the third month of testing. With filtrate turbidities <0.1 NTU, there were little, if any, quantifiable solids to measure. Instead of TSS, turbidity was the main parameter used to determine solids removal by the membrane.

Special Tests

The test plan indicates special tests will be conducted on each of the feed streams. However, this was done only for Stage 3 BAF #2 effluent. Per discussions with Pall Corporation after the test plan was written, it was requested that these special tests be included in Pall's overall pilot testing database for possible review at a later date if their membrane experienced a high rate of fouling when testing a feed stream with similar water quality. The Stage 3 special test data is not included in the MF Report, except for aluminum (Table 5 in the MF Report) and VOCs (Table 6 in the MF Report).

Sampling Plan

Conductivity was measured only on the MF filtrate during Stage 3 when the MF pilot unit was supplying the reverse osmosis pilot unit.

The sampling plan included in the test plan was an estimation of the schedule and timing for various parameters measured. However, the actual test schedule changed from week to week. Beginning in December 2001, the actual sampling plan for all of the pilot units was updated by the County weekly and reviewed by the consultant team.

Microfiltration Test Plan

MF Test Plan Rev.2a Draft

October 8, 2001

Background and Purpose

The microfiltration (MF) unit, manufactured by Pall Corporation, is one of eight unit processes to be tested during the King County Water Reuse Demonstration Project. It is being tested as a tertiary filter and will treat various sources of secondary effluent during the overall testing program. The unit arrived on site the week of August 27th. The Pall startup engineer started it up the week of September 3rd. This unit will be on site for six months: months 4 through 9 of the overall testing program.

The *Water Reuse Demonstration Project, Test Plan, Rev. 2, August 15, 2001* depicts the "big picture" testing program for all eight pilots units and the entire nine-month testing program. It summarizes the performance goals for each test unit. This unit-specific test plan provides a detailed road map for operating the MF unit to meet the objectives of the overall testing program.

Pilot Unit Description

The Pall MF pilot system is a skid mounted unit that includes a bag pre-filter, feed pump, a single 5" diameter hollow fiber membrane module, reverse filtration tank, and an air compressor. There is also a reverse filtration pump and a chemical feed pump to dose the MF unit feed with chlorine.

Modes of Operation

The unit operates in the follow modes:

- Forward Filtration: The feed pump (up to 30 gpm at 40 psi) supplies chlorinated secondary effluent to the hollow fiber membrane module. Water is driven from the outside to the inside of the fibers and this filtrate is collected in the filtrate forward line, which is still under pressure from the feed pump. This line can discharge the filtrate to drain or supply a downstream unit and also fills the reverse filtration tank.

  The membrane module is housed in a vertical PVC housing. A portion of the feed is recirculated back to the feed tank to prevent an air pocket from forming at the top of the housing. Filtration occurs in dead end mode (i.e., direction of flow is always perpendicular to the membrane surface).

  The feed is chlorinated using a chemical feed system built into the skid. It includes a chemical feed tank, where neat sodium hypochlorite solution is added and a chemical feed pump injects the solution into the feed line just upstream of the feed tank. The target hypochlorite concentration is 4 – 6 ppm.

- Air Scrub: The feed pump is shut off and air is introduced into the feed side of the membrane module to scour solids from the membrane surface.

- Air Scrub/Reverse Filtration: The reverse filtration pump is turned on to supply 5 gpm back through (inside-to-outside) the hollow fiber membranes in conjunction with the air scour. The reverse filtration stream is sent to drain.

- Reversion Filtration: This step occurs immediately following the air scrub. The air supply is shut off and the reverse filtration flow rate is increased to 13 gpm. The reverse filtration stream is sent to drain.

- Clean In Place (CIP): When the pressure across the membrane module, referred to as transmembrane pressure (TMP) exceeds a maximum threshold limit, the unit is temporarily taken out of service to chemically clean the membranes. This step requires chemicals and if available, water heated to 100° F. The cleaning water needs to be RO permeate, de-ionized or distilled water. The system is drained, rinsed and then re-filled with cleaning water. The first clean cycle uses a combination of sodium hydroxide and sodium hypochlorite added to the feed tank. Heated cleaning water is not required for the caustic clean. The chemical solution is recirculated for 60 minutes and then the system is drained and rinsed. The cleaning water volume is 20 gallons and the rinse water volume is 40 gallons. The unit it is again filled but with heated cleaning water for the second clean cycle. Citric acid is added to the feed tank and the acid solution is recirculated for 60 minutes. Once the system is drained and rinsed, it is ready to go back into service.

  The CIP is a manual operation. The unit is typically off-line for 4 to 5 hours. The total cleaning water volume required is 120 gallons, 60 gallons per cleaning cycle. Typical chemical concentrations used are: sodium hydroxide (10,000 ppm), sodium hypochlorite (1,000 ppm), and citric acid (20,000 ppm).

- Maintenance Clean: In order to increase the duration between CIPs a maintenance clean can be used. It only includes the caustic/chlorine clean step **(chlorine only)** with a total down time of one hour (approximately 45 minutes for recirculation and 15 minutes to rinse and drain). When maintenance cleans are implemented, they are usually done once a week.

Procedures for the CIP and maintenance clean are included in the Appendix.

Membrane Characteristics

The MF pilot unit for this project is using a single 5-inch diameter membrane module, which Pall refers to as Module Type USV-5203. The module consists of 4,800 individual hollow fibers. The bundle of fibers is potted on each end to separate the feed and filtrate streams. The fibers include a membrane on the outside and inside of the fiber. Therefore, the direction of flow can be from the outside in or inside-out depending on the application. For this project, Pall is recommending an outside in direction of flow. This mode uses the outside fiber membrane surface, which provides the highest active filter area. Additional membrane characteristics are listed below:

- Material: PVDF (Polyvinylidene Fluoride)
- Pore rating: 0.1 micron, absolute
- Fiber OD/ID: 1.3 mm/0.7 mm
- Active filter area: 398 square feet (sf)
- Module size: 5 inches wide by 79 inches long
- Housing/Gasket: PVC/NBR

Integrity Testing

An integrity test is conducted after each CIP to see if there are any breaks or holes in the hollow fibers. This involves a pressure hold test. The specific procedure is included in the Appendix. The test lasts about 5 minutes. If the pressure drop during the 5 minute hold duration is <0.2 psi per minute, the module has passed the test. If the drop exceeds this threshold, the Pall startup engineer will come out to the site to do determine which fiber(s) is compromised. That fiber can be taken out of service without replacing the entire membrane module.

Instrumentation and Control

The unit is equipped with an Allen Bradley SLC5/08 PLC automated control system with data logging and remote system monitoring. Continuous monitoring instruments include:

- Feed turbidimeter
- Feed particle counter
  Total >2 micron
  2-5 micron
  5-15 micron
  >15 micron
- Feed temperature indicator
- Feed pressure indicator
- Feed flow meter (rate only)
- Filtrate turbidimeter
- Filtrate particle counter
  Total >2 micron
  2-5 micron
  5-15 micron
  >15 micron
- Filtrate pressure indicator
- Filtrate flow meter (rate only)
- TMP

The unit is equipped with a phone dialup monitoring system so Pall staff can remotely download data for review and analysis.

Operating Conditions for Filtration of Secondary Effluent

Based on previous pilot studies and full-scale systems, Pall has developed a set of recommended operating conditions for using this MF pilot unit as a tertiary filter for this project. These conditions are listed in Table 1.

Table 1. MF Unit Operating Conditions – Tertiary Filtration

Operating Parameter	Range	Initial Setting	How Measured	Comment
FORWARD FILTRATION (FF) MODE				
FEED				
Feed Pressure (psi)	As measured	As measured	Feed Pressure Indicator	
Feed Temp (C)	As measured	As measured	Feed Temperature Indicator(1)	Temperature will affect membrane
Feed Turbidity (NTU)	As measured	As measured	Feed Turbidimeter(1)	
Feed Flow (gpm)	7 - 12.5	9	Feed Flow Meter	
Feed Volume (gallons)	As measured	As measured	Feed Flow Meter x Hours in Operation	
Recirculation Flow (gpm)	See % Recirc.	0.9	Calculated Value Feed Flow - Filtrate Flow	
% Recirculation	10	10	Calculated Value Recirculation Flow/Feed Flow	Pall expects this to stay fixed at 10% to prevent air pocket from forming at the top of the module housing
Particle Counts	As measured	As measured	Feed Particle Counter(1)	
Sodium Hypochlorite Dose (ppm)	4 - 6	5	Feed grab samples	Pall expects this to stay fixed at 5 ppm. Operators should take daily feed tank grab samples and measure chlorine dose.
FILTRATE				
Filtrate Pressure (psi)	As measured	As measured	Filtrate Pressure Indicator	
Filtrate Turbidity (NTU)	<0.5 typical	As measured	Filtrate Turbidimeter(1)	
Filtrate Flow (gpm)	As measured	As measured	Filtrate Flow Meter(1)	
Filtrate Volume (gallons)	As measured	As measured	Filtrate Flow Meter(1) x Hours in Operation	
Particle Counts	As measured	As measured	Filtrate Particle Counter(1)	
TMP (psi)	Up to 35	As measured	Average (feed pressure & recirculation pressure) - filtrate pressure	35 psi set point to trigger a CIP Maximum limit is 40 psi
MEMBRANE FLUX (gpd/sf or gfd)	25 - 45	32.5	Calculated Value Filtrate Flow/Filter Area(2)	For tertiary application, Pall does not expect the flux to exceed 45 gfd
RECOVERY (%)	92 - 98	94	Calculated Value Filtrate Volume/Feed Volume	Impacted by RF rate & duration and Air scour RF rate & duration

Table 1. MF Unit Operating Conditions – Tertiary Filtration (Cont'd)

Operating Parameter	Range	Initial Setting	How Measured	Comment
AIR SCOUR MODE				
Frequency (minutes)	20	20	Coincides with reverse flow frequency	Typically 20 minutes or greater. If <20 minutes, percent recovery
Air Only				
Duration (seconds)	20	20	Designated set point	
Air Flow (scfm)	3	3	Air flow meter.	Pall expects this to stay fixed at 3 scfm. Measured by a rotameter. Operator
Air & Reverse Flow				
RF Flow (gpm)	5	5	RF Flow Meter	Pall expects this to stay fixed at 5
Air Flow (scfm)	3	3	Air flow meter.	Pall expects this to stay fixed at 3 scfm. Measured by a rotameter. Operator records daily.
Duration (seconds)	60 to 90	70	Designated set point	Typically 60 seconds. If increased, RF flow rate during RF no air mode may need to be reduced. RF feed tank volume limited to 17 gallons. Need to make sure the tank does not completely empty.
REVERSE FLOW (RF) MODE (NO AIR)				
RF Flow (gpm)	13	13	RF Flow Meter	This is set to 13 gpm to allow enough volume to purge the membrane housing and remove any solids scoured from the membranes.
RF Volume (gallons)	As measured	As measured	RF Flow Meter x RF duration	
Duration - Air/RF combination (seconds)	20 - 30	20	Designated set point	If increase above 20 seconds, will have to decrease RF flow to prevent emptying the RF tank.
Frequency (minutes)	20	20	Designated set point	Typically 20 minutes or greater. If <20 minutes, percent recovery

Notes:
(1) Parameters routinely downloaded by Pall. Trend plots generated.
(2) Active membrane surface area is 398 sq ft.

Table 1 notes the operating parameters that remain constant. The only operating condition expected to vary is the flux (i.e., filtrate flow rate).

Pall may recommend adjusting the air scour duration or reverse flow duration and flow rate to lengthen the cleaning cycle. However, this would not be done without first consulting the Project Team.

Pilot Testing Objectives

The pilot testing objectives for the MF unit is focused on the treatment performance to meet State of Washington Class A reuse requirements. Nutrient removal requirements focused on effluent phosphorous limits will also be evaluated.

Key performance questions for the MF unit are:

- Application rate attainable when feeding secondary effluent
- Transmembrane pressure across membrane
- Long-term fouling characteristics
- Backwash requirements

- Impact of alum for phosphorus removal on run time, fouling potential, and backwash requirements

The specific performance goals are listed below.

- Effluent turbidity < 0.5 NTU, 95th percentile
- Effluent total phosphorous (TP) concentration <0.05 mg/L, 90th percentile
- Effluent TOC <2 mg/L, 50th percentile
- Backwash interval >20 minutes
- CIP interval > 30 days
- Less than 2% long-term flux decline per year.

Comparing the initial clean membrane TMP, for a given feed stream, with the subsequent clean membrane TMP for the same flux rate, will assess long-term flux. A clean membrane TMP is defined as the TMP recorded once the unit has undergone a CIP and is put back into service.

Pilot Test Plan

Overview

The MF unit pilot testing will four phases and 7 test runs. These are described in Table 2. With testing beginning September 24th, there is a total of 23 weeks of testing remaining for the MF unit.

Test Conditions

Pall recommends that baseline operating conditions followed by extended runs be conducted for each phase of the testing.

Table 2. Test Phases and Schedule

Phase	Run	Expected Duration	Weekly Schedule(1)	Maintenance Clean
1 - West Point Secondary Effluent (WPSE) Class A Demonstration	WPSE Baseline Conditions	7 days	Week 0: 9/17 to 9/23	
	1	19 days	Weeks 1 - 3: 9/24 to 10/14(2) CIP & Integrity Test on 10/12	28-Sep 5-Oct
2 - BAF 1 Effluent Class A Demonstration	BAF 1 Effluent Baseline Conditions	7 days	Week 4: 10/15 to 10/21	19-Oct
	2 - BAF 1 Effluent. BAF 1 treating WP PE (3)	21days	Weeks 5 - 7: 10/22 to 11/11 CIP & Integrity Test on 11/9 Conduct a peak flow test(4)	26-Oct 2-Nov
3 - BAF 1 Effluent Nutrient Removal	BAF 1 Effluent w/Chemical Feed Baseline Conditions	7	Week 8: 11/12 to 11/18	16-Nov
	3 - BAF 1 Effluent. BAF 1 treating WP PE. Chemical Feed to MF.	14 days	Weeks 9 - 10:11/19 to 11/30	23-Nov 30-Nov
	4 - BAF 1 Effluent. BAF 1 treating DND PE and supplying BAF 2. No Chemical Feed to MF.	14 days	Weeks 11 - 12: 12/3 to 12/16 CIP & Integrity Test on 12/14 Conduct a peak hour flow test(4)	7-Dec
4 - BAF 2 Effluent Nutrient Removal	BAF 2 Effluent Baseline Conditions. BAF 1 treating DND PE and supplying BAF 2.	7 days	Week 13: 12/17 to 12/23	21-Dec
	5 - BAF 2 Effluent. BAF 1 treating DND PE and supplying BAF 2.	7 days	Week 14: 12/24 - 12/30	28-Dec
	6 - BAF 2 Effluent. BAF 1 treating WP PE and supplying BAF 2.	35 days	Weeks 15 - 19: 12/31 to 2/3 Conduct a peak flow test(4) Anticipate 1 CIP	4-Jan 11-Jan 18-Jan 25-Jan 1-Feb
	BAF 2 Effluent w/Chemical Feed Baseline Conditions	7 days	Week 20: 2/4 to 2/10	8-Feb
	7 - BAF 2 Effluent. BAF 1 treating WP PE and supplying BAF 2. Chemical feed to MF.	18 days	Weeks 21 - 23: 2/11 to 2/28	15-Feb 22-Feb

Notes:
(1) Week 1 starts on September 24th. WPSE base line conditions completed by September 24th
(2) Conducted first maintenance clean on 9/28. Will continue weekly every Friday.
(3) Assumes FF1 will not be supplying PE to BAF 1. Still using WP PE to supply BAF 1. BAF 2 will not be ready to supply the MF unit until December.
(4) Peak flow test will occur mid-way between mini cleans, on Monday or Tuesday.
WP PE: West Point Primary Effluent
DND PE Densadeg Unit Primary Effluent

Establish Baseline Operating Conditions

For each feed stream evaluated, baseline conditions will first be established in order to get a handle on the flux rate that will achieve the target CIP interval (i.e., filtration time before a CIP is required). Typically during this part of a test phase, the feed stream water quality is characterized. The water quality parameters of interest are discussed in the sampling section. Specific steps taken during baseline condition testing are listed below.

1. Determine the clean water flux versus TMP at flow rates of 8, 9, 10 and 12 gpm.

2. Generate a plot of flow versus TMP and review this with the project team. Select the starting flow rate for additional baseline condition testing. Usually, the flow rate selected is such that the TMP is less than 7 psi.

3. At the selected flow rate, run the system continuously for a maximum of 7 days. Plot TMP versus time to determine how long it will take to achieve a filtration cycle (i.e., CIP interval) of at least 30 days. The TMP versus time plot will be monitored daily by Pall staff using the remote monitoring system. As it is developed, the project team will review it. During this seven-day test, if the TMP is increasing at a rate that will not meet the 30-day filtration cycle goal (e.g., a TMP increase of more than 1 psi per day), the operating conditions will be modified.

4. Modify an operating condition. This is typically the membrane flux.

5. If an operating condition is modified, repeat step 3 for the new conditions and make additional adjustments as necessary to achieve the 30-day minimum CIP interval.

Extended Run to Demonstrate CIP Interval

The system will now be operated under the final baseline operating conditions to demonstrate that the CIP interval goal of 30 days can actually be achieved. If the goal is not achieved, the operating conditions will be re-evaluated by the project team and the extended run will be repeated for these new conditions.

Class A Demonstration Testing

The MF unit will be evaluated for compliance with the State of Washington Class A regulations during Phase 1. Baseline and extended runs will be conducted.

Nutrient Removal Testing – Chemical Addition

The MF unit will also be evaluated for enhanced phosphorous removal by adding a coagulant (alum) upstream of the unit. In order to establish a baseline alum dose, jar testing will be conducted. The optimum dose should be determined based on filtered supernatant turbidity and ortho-phosphorous.

Peak Hour Flow Test

If time permits, a peak hour flow test will be conducted for each feed stream. The unit will be briefly operated at a higher flow rate to determine any impacts on performance due to an operational peak. In a full-scale system, if one MF treatment train is off line for chemical cleaning, then the remaining trains will have to treat the total plant flow. Assuming a total of three or four trains, the percent increase in feed flow would be 50% and 33%, respectively. The duration of the peak flow would match the typical time frame a treatment train is off line for a chemical clean.

The sequence of testing will be as follows:

- Maintenance cleans will be done once a week on Friday. The peak hour test will be done the following Monday and Tuesday before the TMP has increased to a point where the higher flux rate will trigger the unit's high TMP alarm setting. On Monday, the flow will be increased by 50% for four hours and then returned to the normal operating conditions. On Tuesday, the flow will be increased by 33% for four hours.

- Data to be collected includes on-line operating conditions and influent and effluent turbidity. The increase in TMP will be monitored before, during and after the increased flow condition.

Sampling

Sampling and analysis to track the MF unit performance during each run is presented herein. The sampling efforts include routine sampling and special tests.

Routine Sampling

Routine sampling will include the on line parameters and influent and effluent turbidity, TOC and chlorine residual.

Turbidity

Influent and effluent turbidity will be monitored using on-line turbidimeters. This information will be collected by the testing facility PLC and archived.

Particle Counts

Influent and effluent particle counts will be monitored using on-line particle counters. This information will be collected by the testing facility PLC and archived.

TOC, TSS and COD

Influent and effluent TOC, TSS and COD will be measured in auto sampler 24-hour composite samples. The West Point Process Lab will handle influent samples and the King County Environmental Lab will analyze the effluent samples. TOC will be measured twice a week. TSS and COD will be measured once a week.

TP

During the chemical addition phase, influent and effluent phosphorous concentrations will be measured once a day using auto sampler 24-hour composite samples. The West Point Process Lab will handle influent samples and the King County Environmental Lab will analyze the effluent samples.

Residual Chlorine

Pall would like daily grab samples of the feed tank analyzed for residual chlorine to ensure the dose range of 4 to 6 ppm is maintained. However, it should be noted that the downstream reverse osmosis (RO) pilot unit is testing an RO membrane that is not compatible with free chlorine. However, combined chlorine, at 5ppm or less, is not an issue. So the residual free chlorine and chloramine levels in the MF filtrate needs to be monitored. If it is detected, then a de-chlorination step upstream of the RO unit needs to be implemented.

Reverse Filtration Stream Sampling

A composite sample of the reverse filtration stream could be tested for TSS to determine the solids content in this waste stream. However, rather than go to this effort, a mass balance on the feed and filtrate streams will be done to calculate the solids removed in the reverse filtration waste stream. To do this, influent and effluent TSS will need to be monitored. Therefore, no reverse filtration sampling is anticipated.

Special Tests

During each baseline conditions test, Pall requested that the feed stream be analyzed once for the following water quality parameters.

- Alkalinity
- pH
- Turbidity
- Temperature
- Ortho-P
- TKN
- NH4
- NO3-N
- BOD5
- TDS
- Total hardness
- Sulfate
- Chloride
- Calcium
- Aluminum
- Oil and grease
- Total Coliform
- Fecal Coliform
- VOCs

This list includes TOC, COD, TP and TSS. However, these parameters will already be measured as part of the routine analyses.

Sampling Plan

The sampling plan for each test month is detailed in Table 1 of the Appendix. The table identifies the number of samples for each parameter collected each day. In some cases, the parameters shown in Table 1 are general categories (e.g., all organics). In this case, it is assumed that these analyses will cover the special tests as follows:

- Organics
- Metals
- Conductivity (EC): to be used to measure TDS

- Special: this parameter is assigned to measure total hardness

The sample location labels are as follows:

- MF Influent/BAF 1 effluent auto sampler: S6
- MF Influent/BAF 2 effluent auto sampler: S7
- MF Effluent auto sampler: S10
- Chlorine residual grab samples: feed tank and reverse filtration tank.

For the routine analyses weekly sampling is scheduled for Tuesdays. Bi weekly sampling is scheduled for Tuesday and Thursdays. Special tests are scheduled for Tuesdays.

Appendix Table 1 only covers those test to be done by the West Point Process Lab or King County Environmental Lab. Operators must do daily chlorine measurements using a field test kit.

ROLES AND RESPONSIBILITIES

The County will operate the MF unit and collect all samples. The labs will do all analyses. On a daily basis, Monday through Friday, Pall staff will remotely download the operating data collected by the unit PLC. The schedule for access to the phone line will be coordinated between King County and Pall staff. If the membrane module does not pass an integrity test, the County will notify Pall immediately so the Pall startup engineer can be scheduled to visit the plant, check the module, and isolate any compromised hollow fibers.

The County will maintain the project data management system to include the data obtained for the MF unit. The consultant team (HDR and Black & Veatch) will evaluate the data and distribute the information to the project team. It is anticipated that two conference calls per month will be held to discuss the overall testing program. These calls will include the status and data review for the MF unit. On an as needed basis, the County will coordinate a conference call with Pall. If possible, these calls will include all project team members listed in the subsequent contacts section. However, since it is difficult to coordinate calls for a large group of people, the level of participation may vary to reduce the coordination effort. At a minimum, Bob Bucher and JB Neethling or Michael Norton will participate in these calls.

DATA MANAGEMENT

Data will be automatically collected by the MF unit PLC and remotely downloaded by Pall staff. This same data is also collected in the main PLC data archiving system. County operators will fill out a daily log sheet to record specified operating parameters. A copy of the log sheet is included in the Appendix for reference. The data from the labs will be logged into standard excel spreadsheets that will be kept on the County's network servers for access by County staff. This data will also be transferred into the project data management system (DMS) by County staff.

County staff will send the PLC data to HDR for incorporation into the DMS operation data sheets. There is a microfiltration operation data sheet, a copy of which is included in the Appendix. Note the operation data sheet will only include daily average values for the PLC data. To review the raw PLC data, there is an Excel workbook (not a part of the Excel-based DMS) set up for each pilot unit. The MF unit PLC data viewer file will be set up by HDR and distributed to the Project Team as PLC data is collected. Pall will also have downloaded PLC data available for the Project Team.

Data collected by the County operators will be entered in the microfiltration operation data sheet by County staff. So PLC data (daily averages), lab data, and manually recorded operating conditions will be maintained in the DMS and accessed via the microfiltration operation data sheet.

CONTACTS

Since this testing is expected to require midstream adjustments, it is important to maintain frequent communications between King County and the consultant team (HDR and Black & Veatch). The following is a list of the project team members.

King County

Bob Bucher
206-263-3883, bob.bucher@metrokc.gov

John Smyth
206-684-1774, john.smyth@metrokc.gov

HDR

JB Neethling, Sacramento
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Mike Norton, Seattle
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Mario Benisch, Portland, DMS coordination
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Black & Veatch

Cindy Wallis-Lage, Kansas City
913-458-3603, wallis-lagecl@bv.com

Pall

Scott Caothien, Project Manager, Los Angeles
626-968-4799, ext 226, scott_caothien@pall.com

Paul Morris, Startup Engineer, Los Angeles
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Bill Peretti, Lease Agreement, East Hills, NY
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bill_peretti@pall.com

APPENDIX

CIP Procedure and Pall Checklist

Maintenance Clean Procedure and Pall Checklist

Integrity Test Procedure

Sampling Plan Tables (not included)

Operator Daily Log Sheet (not included)

DMS Microfiltration Operation Data Sheet (not included)

General CIP Protocol

Initiate Clean in Place (CIP) when TMP is 35 psi. The sequence of high pH/low pH cleaning is determined on a case-by-case basis.

1. **Secure test rig:**
   - 1.0 Stop pilot system
   - 1.1 Secure feed valve by manually closing it
   - 1.2 Drain feed tank and permeate tank.
   - 1.3 Rinse feed tank with RO product or potable water
   - 1.4 Change bag prefilter

2. **1% Caustic with 0.5% Chlorine Cleaning:**
   - 2.1 Fill feed tank with RO product water
   - 2.2 Add 40% NaOH (0.5 gal in 20 gal) and 6% NaOCl (1.6 gal in 20 gal)
   - 2.3 Recirculate with 4 gpm permeate and 8 gpm retentate for 6-8 hrs

3. **RO Product or Potable Water Flushing:**
   - 3.0 Fill feed and permeate tanks with RO product water
   - 3.1 Close the manual recirculation valve
   - 3.2 Open the butterfly valve at bottom of modules to drain modules then close
   - 3.3 Flush system with RO product (or potable water)

4. **2% Citric Acid Cleaning for 1 module:**
   - 4.1 Fill feed tank with tap water and permeate tank
   - 4.2 Add citric acid powder (4.2 lbs in 20 gal)
   - 4.3 Recirculate with 4 gpm permeate and 8 gpm retentate for 2 hrs
   - 4.4 Drain feed and permeate tanks.

5. **RO Product Water Flushing:** see section 3 above

Chemical Wash Procedure

1. **Secure Test Rig:**
   1.0 Stop pilot system
   1.1 Secure feed valve by manually closing it
   1.2 Drain feed tank
   1.3 Rinse feed tank with soft, potable water
   1.4 Change bag prefilter

2. **1% Caustic and 0.1% ppm Chlorine Wash:**
   2.0 Open filtrate valve to tank for recirculation mode
   2.1 Fill feed tank with soft water 20 gal
   2.2 Add 6% NaOCl (0.8 L in 20 gal)
   2.3 Recirculate with 6 gpm filtrate and 10 gpm XR for 50 min
   2.4 Secure module rack by closing valve at bottom of rack
   2.5 Drain feed and filtrate tanks

3. **Potable Water Flushing:**
   3.0 Fill feed tank with potable water
   3.1 Close the manual recirculation valve
   3.2 Open the valve at bottom of module to drain module then close
   3.3 Flush system with potable water at 6 gpm permeate and 1 gpm XR
   3.4 Fill feed tank again and repeat flush step
   3.5 Perform an RF

Integrity Test Procedure

1. Start the test rig and run in the forward filtration mode for five minutes to evacuate the trapped air and to ensure complete wetting of the membrane.

2. Drain the feed side of the module while keeping the valve on the permeate line closed. Drain for three to five minutes to remove the bulk of the water. **Caution:** Do not overdrain or drying of the membrane may occur.

3. Close the valve on the retentate line, open the permeate valve, and pressurize the feed side of the module with air at 20 psi.

4. Shut off air supply, and record feed-side pressure decay for five minutes.

5. If the rate of pressure decay is less than 0.2 psi/min, then the integrity of the module is verified.

6. If the rate of pressure decay is greater than 0.2 psi/min, then repeat steps 5.1 – 5.4. If the decay rate is still above 0.2 psi/min, contact the Project Manager for input.

Microfiltration

CIP checklist

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1. Shut down the unit

- ❑ Date:________________ Time:_______________
- ❑ Log ODS sheet "pre-CIP"
- ❑ Wait until the unit is 2 minutes from an RF cycle
- ❑ Stop the unit by pressing **OFF** button on the screen
- ❑ Close the feed water source (valve **DV25**)
- ❑ Turn off **FEED PUMP 2**
- ❑ Bleed feed water pressure at the ¼-inch ball valve located on the top of the bag filter housing (**HV3**)
- ❑ Close manual feed valve (**HV10**)
- ❑ Disconnect feed hose

2. Drain the unit and clean the bag filter

- ❑ Route potable water hose from supply near MBR blower to the skid feed tank
- ❑ Select **MANUAL** operation of the pilot unit screen, clear the alarms if necessary
- ❑ Actuate **V2** valve **to drain** on screen
- ❑ Start feed pump **FP1** at 30%
- ❑ Flush feed tank with potable water while draining
- ❑ Clean bag filter
- ❑ Make sure feed tank is completely drained and stop **FP1** on screen

3. Chlorine Recirculation

- ❑ Collect 20 gal of RO quality from the process lab
- ❑ Fill RO water to feed tank until the water level just touches the bottom of the float valve
- ❑ Submerge heat exchange coil and temperature probe in the feed tank
- ❑ Turn on water heater pump
- ❑ Leave the feed water to heat up for at least 1 hr (80^{o}F)

- ❑ Remove heat exchanger and temperature probe
- ❑ Add 3.0 L of 50% NaOH (2% in solution)
- ❑ Add 3 L of 12% NaOCl (0.5% in solution)
- ❑ Close **HV4**
- ❑ Open **HV5**
- ❑ Open **HV14**
- ❑ Close **HV12**
- ❑ Direct **V2** valve to feed tank
- ❑ Start **FP1** and ramp up to 40%
- ❑ Throttle **HV14** partially closed to achieve filtrate flowrate of 4 gpm
- ❑ 4 gpm filtrate and 8 gpm excess recirc (total feed = 12 gpm)
- ❑ Time start recir________
- ❑ Recirculate for 6-8 hrs
  - ❑ In case unable to recirculate for at least 6 hrs, may shut down the pump and let the unit soaked overnight.
- ❑ Actuate **V2** to drain
- ❑ Drain feed tank completely (may close HV14 to speed up)
- ❑ Stop **FP1**
- ❑ Actuate **V2** to feed tank
- ❑ Open **HV14**

4. RO or potable water flushing

- ❑ Fill feed tank with potable water
- ❑ Actuate **V1** valve to **drain**, hold for **1 min** and return to **feed** position
- ❑ Close **HV5**
- ❑ Open **HV14**
- ❑ Open the butterfly valve at bottom of modules **HV6** to drain than close
- ❑ Start **FP1**, ramp down to **28-32%**
- ❑ Throttle **HV5** partially closed to get **6 gpm filtrate flow and 1 gpm excess** recir flow
- ❑ Recirculate for 10 minutes: Start time: ___________ Stop time: ___________
- ❑ Actuate **V2** to drain

5. **4% Citric acid cleaning**

- ❑ Fill feed tank with potable water
- ❑ Submerge heat exchange coil and temperature probe in the feed tank
- ❑ Turn on water heater pump
- ❑ Leave the feed water to heat up for at least 1 hr (80^{o}F)
- ❑ Remove heat exchanger and temperature probe
- ❑ Add citric acid powder (3.08 kg or 6.8 lbs)
- ❑ Close **HV4**
- ❑ Open **HV5**
- ❑ Open **HV14**
- ❑ Close **HV12**
- ❑ Direct **V2** to feed tank
- ❑ Start **FP1** and ramp up to 40%
- ❑ Throttle **HV14** partially closed to achieve filtrate flowrate of 4 gpm
- ❑ 4 gpm filtrate and 8 gpm excess recirc (total feed = 12 gpm)
- ❑ Time start recir: ________
- ❑ Recirculate for 4 hrs. Time stop:___________
- ❑ Actuate **V2** to drain
- ❑ Drain feed tank completely (may close HV14 to speed up)
- ❑ Stop **FP1**
- ❑ Actuate **V2** to feed tank
- ❑ Open **HV14**

6. RO or potable water flushing

- ❑ Fill feed tank with potable water
- ❑ Actuate **V1** valve to **drain**, hold for **1 min** and return to **feed** position
- ❑ Close **HV5**
- ❑ Open the butterfly valve at bottom of modules **HV6** to drain than close
- ❑ Start **FP1**, ramp down to **28-32%**
- ❑ Throttle **HV5** partially closed to get **6 gpm filtrate flow and 1 gpm excess** recir flow

- ❑ Recirculate for 10 minutes
- ❑ Actuate **V2** to drain

7. Clean water flux test

- ❑ Fill feed tank with potable (leave potable water hose in the feed tank)
- ❑ Close **HV14**
- ❑ Open **HV12**
- ❑ Open **HV4**
- ❑ Go to set up page on screen
- ❑ Enter the flow rate set point = 8 gpm
- ❑ Stop the unit and re-start in auto-mode (must stop the unit first, otherwise the system won't accept the change)
- ❑ Open the potable water valve and adjust the flow
- ❑ Adjust **HV5** to get 10% recir
- ❑ Read TMP and temperature when the flow and TMP is steady
- ❑ Record TMP and temperature in the table
- ❑ Change the flow to 9 gpm
- ❑ Stop the unit and re-start
- ❑ Record TMP and Temperature
- ❑ Adjust the flow to 10 gpm
- ❑ Stop the unit and re-start
- ❑ Record TMP and Temperature
- ❑ Adjust the flow to 12 gpm
- ❑ Stop the unit and re-start
- ❑ Record TMP and Temperature
- ❑ Change the filtrate flow to the desired operating condition
- ❑ Stop the pump

Filtrate Flow (gpm)	TMP (psi)	Temperature (^{o}C)
8		
9		
10		
12		

8. Flush the feed line

- ❑ Turn on **feed pump 2**
- ❑ Open the **DV25** valve to flush the feed line
- ❑ Close the **DV25** valve
- ❑ Reconnect the feed water hose
- ❑ Slowly open the **DV25** valve
- ❑ Open **HV1**
- ❑ bleed air from bag filter

9. Start the unit back up

- ❑ Make sure that HV 14 is closed and HV 12 & HV 4 are opened
- ❑ Select **AUTO** and **START** on the screen
- ❑ Adjust HV5 to get the desire feed and recir
- ❑ Monitor pilot to verity it proceeds through the RF cycle
- ❑ Verify feed tank filling from flow from float valve
- ❑ Verity flows through skid turbidimeter
- ❑ Record time the maintenance clean completion time in log book
- ❑ Log ODS "post maintenance clean"

Microfiltration

Maintenance Clean Checklist

---

1. Shut down the unit

- ❑ Date:_______________
- ❑ Log ODS sheet "pre-maintenance clean"
- ❑ Wait until the unit is 2 minutes from an RF cycle
- ❑ Stop the unit by pressing **OFF** button on the screen
- ❑ Close the feed water source (valve **DV25**)
- ❑ Turn off **FEED PUMP 2**
- ❑ Bleed feed water pressure at the ¼-inch ball valve located on the top of the bag filter housing (**HV3**)
- ❑ Close manual feed valve (**HV1**)
- ❑ Disconnect feed hose

2. Drain the unit and clean the bag filter

- ❑ Route potable water hose from supply near MBR blower to the skid feed tank
- ❑ Select **MANUAL** operation of the pilot unit screen, clear the alarms if necessary
- ❑ Actuate **V2** valve **to drain** on screen
- ❑ Start feed pump **FP1** at 30%
- ❑ Open the air scrubbing valve **V4**
- ❑ Flush feed tank with potable water while draining
- ❑ Clean bag filter (make sure to close the bleed valve and drain valve afterward)
- ❑ Make sure feed tank is completely drained and stop **FP1** and air scrubbing on screen

3. Caustic/Chlorine Recirculation

- ❑ Collect 20 gal of hot potable water from the process lab
- ❑ Fill hot water to feed tank until the water level just touches the bottom of the float valve
- ❑ Add 600 mL of 12.5% HOCL

- ❑ Add 1500 mL of NaOH
- ❑ Close **HV4**
- ❑ Open **HV5**
- ❑ Open **HV14**
- ❑ Close **HV12**
- ❑ Actuate **V2** to feed tank
- ❑ Start **FP1** and ramp up to 30%
- ❑ Throttle **HV14** partially closed to achieve filtrate flowrate of 3 gpm
- ❑ Adjust **HV5** to get 3 gpm filtrate and 6 gpm excess recirc (total feed = 9 gpm)
- ❑ Time start recir________
- ❑ Recirculate for 20 min.
- ❑ Stop **FP1**
- ❑ Actuate **V2** to drain
- ❑ Start pump **P2**
- ❑ Adjust flow to 5 gpm (approx 50% pump capacity)
- ❑ Turn on air scrubbing (**V4**)
- ❑ Adjust air flow to 180 scfh
- ❑ Drain RF tank completely
- ❑ Stop **P2**
- ❑ Actuate **V2** to feed tank
- ❑ Open **HV14**
- ❑ Start **P1**
- ❑ Throttle **HV14** partially closed to achieve filtrate flowrate of 3 gpm
- ❑ 3 gpm filtrate and 6 gpm excess recirc (total feed = 9 gpm)
- ❑ Time start recir________
- ❑ Recirculate for 30 min.
- ❑ Actuate **V2** to drain
- ❑ Open **V4**
- ❑ Drain the feed tank completely

4. First potable water flushing

- ❑ Fill feed tank with potable water
- ❑ Actuate **V1** valve to **drain**, hold for **1 min** and return to **feed** position
- ❑ Close **HV5**
- ❑ Close **HV14**
- ❑ Open the butterfly valve at bottom of modules **HV6** to drain than close
- ❑ Actuate **V2** to feed tank
- ❑ Open **V3**
- ❑ Start **FP1**, ramp down to **20-25%**
- ❑ Throttle **HV5** partially opened to get **4-5 gpm filtrate flow and 1 gpm excess** recir flow
- ❑ Completely drained the feed tank

5. Second potable water flushing

- ❑ Fill feed tank with potable water
- ❑ Actuate **V1** valve to **drain**, hold for **1 min** and return to **feed** position
- ❑ Open the butterfly valve at bottom of modules **HV6** to drain than close
- ❑ Actuate **V2** to feed tank
- ❑ Open **V3**
- ❑ Start **FP1**, ramp down to **20-25%**
- ❑ Throttle **HV5** partially opened to get **4-5 gpm filtrate flow and 1 gpm excess** recir flow
- ❑ Completely drained the feed tank

6. First RF tank flushing

- ❑ Fill RF tank with potable water
- ❑ Actuate **V2** to drain
- ❑ Close **V3**
- ❑ Start **P2** adjust flow to 5 gpm
- ❑ Open **V4**

- ❑ Adjust air flow rate to around 180 scfh by adjusting valve on the rotometer beneath the keyboards
- ❑ After 30 sec., closed **V4**
- ❑ Wait until filtrate tank is completely drained
- ❑ Stop **P2**

7. Second RF tank flushing

- ❑ Fill RF tank with potable water
- ❑ Actuate **V2** to drain
- ❑ Close **V3**
- ❑ Start **P2** adjust flow to 5 gpm
- ❑ Open **V4**
- ❑ Adjust air flow rate to around 180 scfh by adjusting valve on the rotometer beneath the keyboards
- ❑ After 30 sec., closed **V4**
- ❑ Wait until filtrate tank is completely drained
- ❑ Stop **P2**

8. Fill the unit with potable water

- ❑ Fill feed tank and RF tank with potable water
- ❑ Close **HV14**
- ❑ Open **HV12**
- ❑ Open **HV4**
- ❑ Turn on **feed pump 2**
- ❑ Open the **DV25** valve to flush the feed line
- ❑ Close the **DV25** valve
- ❑ Reconnect the feed water hose
- ❑ Slowly open the **DV25** valve
- ❑ Open **HV1**
- ❑ bleed air from bag filter

9. Start the unit back up

- ❑ Select **AUTO** and **START** on the screen
- ❑ Adjust HV5 to get the desired feed and recir
- ❑ Verify feed tank filling from flow from float valve
- ❑ Verity flows through skid turbidimeter
- ❑ Monitor pilot to verity it proceeds through the RF cycle
- ❑ Adjust air flow rate during AS/RF cycle to 150-200 scfh
- ❑ Record time the maintenance clean completion time in log book
- ❑ Log ODS "post maintenance clean"

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
8/27/2001		Pall microfiltration unit arrived on trailer. Delivered by water reources services (Chris Powell). Chris cibtracted by Pall to setup pilot unit. Shinn and Prine working on installation setup. Unit uncrated and prep'ed for placement in facility.
8/28/2001		Moved pilot inot assigned location. Second skid containing air compressor, air dryer, and tornsomer set next to MF skid. Prine required to wire both MF skid and compressor to transofrmer. Shinn installed new C3 (WP secondary effluent) line to column next to skid. Portland Eng looked at DH+ connection. PLC installed is AB 5/05. Need to purchase datalink comm. converter (similar to MBR skid setup) for DH+. Using KC credit card, ordered datalink comm converter.
8/29/2001		Completed mechanical and electrical installs. On hold for DH+ connection until next week. Chris Powell (water resources services) performed functional checkouts on skid. All checkouts satisfactory. Received 5 inch microfiltration module from Pall. Pall sales rep (Bill Peretti) onsite in morning to look over install. Informed that startup individual will be onsite next Tuesday (9/4).
8/30/2001		Chris Powell completed work and left the site midday. Unit secured until next Tuesday.
8/31/2001		
9/1/2001		
9/2/2001		
9/3/2001		
9/4/2001		Paul Morris (Pall startup rep from LA) arrived in afternoon. Following activities completed: -installed new membrane module, performed integrity test, and performed complete checkout of skid. Unit left to run overnight under following conditions: 9 gpm secondary effluent, etc. At 2000 hrs noted pilot unit alarm - HIGH feed pressure. Vendor is handling (monitoring) unit remotely so did not acknowledge. Pulled phone line to allow vendor to monitor via modem. Vendor provided following documents: proposed test procedure and Pall Microza Microfiltration Pilot System Single USV-6203 Microfiltration Module (0.1 pico) Operations and Maintenance Manual.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
9/5/2001		Alarm condition caused by failed solenoid valve. All control valves are pneumatically operated via solenoid. Vendor fixed solenoid and unit back in operation by midday. Vendor continued to operate through evening. Portland Eng installed datalink comm. converter and configured facility PC SCADA for data collection. Phone line remaining in place for remote modem access.
9/6/2001		Conducted training on Operation of pilot. All information provided in Operations and Maintenance Manual. Daily monitoring consist of daily operations sheet and filling of chemical feed tank with household bleach. Pilot feed tank requires Chrloine residual to be maintained. Estimated that pilot will require 20 L/day of household bleach (assumed 5.25 to 6.00 % hypochlorite). Pall plans to monitor (access) pilot unit twice a day during project. Need to maintain phone connection. Vendor will continue to optimize unit until middle of next week. Possible flow change in response to rapid TMP increase. Expect to perform CIP (cleaning in place) in approximately 2 weeks. Will need chemicals to support cleaning (caustic at 50%, citric acid, and NaOCl at 12.5%). Vendor planning to leave in early a.m. tomorrow. Expect to be in contact next week - call every 2-3 days.
9/7/2001		Received HIGH-HIGH feed pressure alarm at 0107 hrs. Unit shutdown received on facility SCADA system. At 0830 hrs acknowledged HIGH-HIGH feed alarm and attempted to restart - no luck. Appears main screen is "frozen" with unit shutdown, all instrumentation still showing run values. At 0900 hrs call Pall for guidance. Talked with Scott in their California office. He suggested rebooting computer. Prior to reboot, recorded setup conditions. Securing control panel in following steps; select utilities, secure RSview project, restarted computer. At 0937 hrs started process backup. At 1430 hrs system stuck in a "filling system" mode. Showing flow at 2 gpm. At 1440 hrs called Scott (Pall) via cell phone to discuss. Discovered that unit must be "tricked" to process from filling mode to forward flow mode. Steps: go to setup and change permeate flow setpoint to 0.5 gpm, unit should switch from fill to foward flow mode, step permeate setpoint back up to 9 gpm in increments (2-4-6-9). Hold for 5 minutes at each step. This tick is not included in the O&M

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
9/8/2001		
9/9/2001	At 0930 hrs system started (manual funtional checkoput of PV-3 valve satisfactory). Top off required! At 1010 hrs low filtrate tank level alarm, reset and filled filtrate tank with potable water. At 1115 hrs same alarm.	At 0730 hrs emailed Paul Morris to inform of current status. Registering new solenoid block. Also cc(ed) Bill Peretti and Jim Gleason. Left voice message with Paul Morris regarding condition as well.
9/10/2001		At 0850 hrs talked to Paul Morris about low level alarm in reverse filtration tank. He suggested reducing RF setpoint down from 12 to 10 gpm. He is also looking into new pneumatic block for the skid. At 0903 hrs started MF unit in AUTO. Reset RF setpoint (in setpoint menu) from 12 to 10 gpm. At 0910 hrs high feed pressure alarm - acknolwedged and restarted. At 0930 hrs high feed pressure alarm - acknowledged and restarted. At 0945 hrs low permeate tank level - acknowledged and refilled tank. Restarted system and reset RF flowrate to 8 gpm. At 1025 hrs discovered that V3 valves showing open on SCADA screen but is physically closed. Solenoid valve not operation - same as Friday checkouts. Secured and performed manual checkout to confirm; yes, not operational.
9/11/2001		Informed that replacement solenoid manifold will be shipped from Pall (New York). Expect later this week.
9/12/2001		
9/13/2001		
9/14/2001		Received replacement manifold via UPS Red. Arranged for Roberto (maint) to install on Monday morning. HDR working on Mf test plan. Expect draft by early next week.
9/15/2001		
9/16/2001		

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
9/17/2001	Startup mode	At 0810 hrs secured skid to remove/replace pneumatic manifold. At 1250 hrs started unit backup (power off to change plug), cannot get alarm "E-Stop/Power Failure E Stop" to clear. Called Paul Morris (Pall) - reset on panel. Solved problem by pressing "Control Power" button. At 1315 hrs functional fheckout problems; 1 of 4 solenoids not energized, all solenoids do not provide air (no valve aeration). Reinstalled old manifold and replaced failed solenoids with solenoids from shipped package. "Salvaged" manifold reinstalled and successfully checked out. At 1500 hrs started up unit in AUTO mode (permeate flow set at 9 gpm). Maintenance (Roberto) determined shipped manifold had spacer installed on air side. Removed spacer and stored unti for future use.
9/18/2001	At 0846 hrs added 4 bottles. Setpoints set, see data sheet.	At 1450 hrs called Paul Morris: estabilished parameters, cleaning/TMP recovery, and hold parameters; doc called King County on C drive; 55 gal drum of HOCl; CIP cleaning onsite - expect 2-3 weeks; clean water flux (compared to original). Phone hookup: 8-10 and 1-2 checks by Pall Corp. Refilled chemical tank with household bleach (5.25% HOCl). Unit continues to operate at 9 gpm filtrate setting.
9/19/2001	At 0400 hrs added 1.4 gal. At 2345 hrs need more chlorax in tank.	Continued operation at 9 gpm filtrate flow. Email from Mike Norton regarding MF operation, see notebook.
9/20/2001	No flow to filtrate turbidimeter and particle counter - suspect SV5 solenoid is bad (will troubleshoot). At 640 hrs resideual chlorine checks: S14 (WP sec eff) 0.61 mg/L, S14F (MF skid feed tank) 8.7 mg/L.	At 0630 hrs noted no flow at filtrate turbidimeter and particle counter. At 1400 hrs time to troubleshoot. Verified that SV10 operating correctly - OK. Adjusted HV10 to proved backpressure to flow through turbidimeter and particle counter, adjustment worked. At 0640 hrs collected samples for residual chlorine analysis (S14 feed water = 0.61 mg/L, S14F feed tank on skid = 8.7 mg/L). Pall requested between 3-5 mg/h Cl- in feed tank. Need to reduce concetration of feed chemical. Will dilute bleach (5.25%) to 50% concentration. Plan to order 55 gal drum of HOCl and install dosing pump to feed system.

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Date	Comments (ODS)	Comments (Log Book)
9/21/2001	Checked wordpad notes from Pall (9/17).	At 1020 hrs call from Paul Morriss - data will be dow nloaded this afternoon and Sunday evening in preparation for Monday conference call leave phone connected. At 1350 hrs stopped process and rebooted computer to establish PC anywhere program. At 1400 to 1530 hrs continued troubleshooting no connection between phone/skid/Pall. Discovered phone had been switched on facility side to other line. Changed and all OK. At 1545 hrs Paul Morris downloaded data and sent via email. Residual Chrloine feed tank empty from 0800-1800 hrs. Ten hours with no additional residual in full tank. Plan to order drum Monday morning - to replace use of household bleach. Setup stock solution 12.5% HOCl for remainder of weekend. (Does not apply on hold until Monday 9/24) fod each container added, add 3 containers full of potable water. Potable water source located next to MBR air compressor.
9/22/2001	759 hrs topped off chemical tank with 3 bottles of bleach.	Added bleach to chemical tank for residual Chlorine.
9/23/2001	At 120 hrs added 3 bleach containers and 3 water containers.	Added bleach to Chemical tank.
9/24/2001	At 1525 hrs added on bottle of bleach.	Added bleach to chemical ank at approximately 0930 hrs and again at approximately 1530 hrs.
9/25/2001	At 1230 hrs MF offline for 1 hr to support new copper line install. At 1400 hrs unit back with high influent turbidity.	At 1230 hrs secured MF skid in support of tie-in of new 2 inch copper to WS1. At 1400 hrs restarted Mf skid. Feed water routed to drain to clean but still dirty water into feed tank. Drained feed tank by (in manual) opening V2 and rad feed pump. Continued operation for approximately 10 minutes. Turbidity peaked at 80 NTU. Put unit into operation after influent turbidity dropped to less than 50 NTU. back in operation at 1430 hrs. Discovered phone line not operation due to water in connection. Need to get new phone cord. Will call Pall this afternoon. Install new phone line tomorrow.
9/26/2001	Secured chlorine dose for today - performing test of membrane with feed at low chlorine residual.	At 0230 hrs added bleach to chemical tank. At 1030 hrs secured chemical tank feed (Chlorine) to unit. Want to run 24 hr test of feed water with no additional Chlorine residual.

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COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
9/27/2001		At 1500 hrs attended a conference call with PALL. Disccused: operating conditions, fouling components, and operation over next week. Resecured chemical metering pump at operation interface screen by un-selecting "P3 chemical addition" on setup screen. Setting up for maintenance cleaning tomorrow. talked to Paul Morris (PALL) about maintenance/checks of particle counters. Two items mention: weekly verify flow at 90-110 mL/min, and clean the inlet lines with laboratory soap. Need to incorporate into checklist. Chemical wash (maintenance clean procedure) provided by Pall in appendix 1 of their test proposal. NaOH will not be utilized in wastewater application. Concern with pH adjustments and potential adverse impacts. Proposed test procedure for chemical wash received from HDR.
9/28/2001	From 1340 hrs to 1630 hrs completed maintenance clean of MF Membrane. At 1630 hrs reinitiated clhorine dosing of feed water. Note: Add 3 containers of potable water with each 1 container of bleach. Bleach is 12.5% NaOCl, not 6%. Potable water tap next to MBR air compressor.	At 1150 hrs working on maintenance clean - talked with Paul Morris about revisions to existing maintenance clean procedure. Revision to step 2.3, Open HV14 and FCV1. Manually turn ON recirc pump to 50%. Adjust HV14 and FCV1 to achieve desired flow. 6 gpm filtrate from HV14 and 10 gpm excess recirc from FCV1. At 1340 hrs secured unit for cleaning. Inspected/replaced bag prefilter, added crystal spring drinking water, and started chlorine recirculation flow. Start time at 1425 hrs, stop time at 1515 hrs. At 1432 hrs low feed tank level alarm - need to close sample valves HV12 and HV4 to turbidity and particle counters. at 1440 hrs added 5 gallons of new water and 200 mL of 6% bleach to make up for loss to drain. At 1543 hrs restarted recirc with potable water (step 3.3 for 10 minute run). Start time at 1543 hrs, stop time at 1553 hrs. At 1550 hrs open turbidity and particle counter handvalves HV4 and HV12 to flush through. At 1610 started second flush cycle (step 3.4) with a start time of 1610 hrs and stop time of 1620 hrs. Also filled RF tank with potable in preparation for step 3.5. At 1625 hrs performed RF by selecting V2 to dra
9/29/2001	At 0445 hrs added 12.5% and 3 containers H2O.	No comments.
9/30/2001	Composite sampler will be started on 10/1 (grab sample on 10/1 for process lab).	No comments.

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Date	Comments (ODS)	Comments (Log Book)
10/1/2001	At 0110 hrs added water/bleach to chemical tank. At 1200 hrs added 1 bottle bleach and 2 bottles H2O; not enough room to add 3rd bottle, will add later today. At 1625 hrs added 1 bottle of water. At 1540 hrs secured Chlorine dosing to feed. Will not operate rest of week.	At 0130 hrs added 3 to 1 ratio of water and bleach, tank is now full. At 1540 hrs secured Chlorine dosing to feed tank: will remain "OFF" for remainer of week.
10/2/2001		At 1000 hrs call from Paul Morris about ability to download data - disconnected. Checked PC - in the waiting mode.
10/3/2001		No comments.
10/4/2001	Shutdown at 1339 hrs on HIGH_HIGH TMP alam. Secured for evening.	HIGH-HIGH TMP alam. System shutdown - will leave overnight and perform maintenance clean tomorrow a.m.
10/5/2001	Chlorine dosing back in operation. Fill tank as required. At 1002 hrs working on maintenance clean setup. At 1300 hrs clean still in progress.	At 1132 hrs initiated maintenance clean. See 9/28 maintenance clean for details. At 1410 hrs reverse filrtration. At 1415 hrs NaOCl pump enabled. Call from Pall about excess flow and HIGH-HIGH YMP alam. HIGH-HIGH alarm at 1459 and 1505 hrs. Looks like WP secondary having problems. Reclean of membrane - per discussion with Pall. At 1545 hrs to 1550 hrs added 100 mL 12.5% HOCl in 20 gallons and recirced for 5 minutes. At 1553 to 1603 hrs, drained recirc water and replaced with potable. Flushed through system for 10 minutes. At 1606 hrs drained flush water and replaced with potable. At 1608 hrs started system back up with 20 gallons of potable water in feed tank. WP secondary online to fill feed tanks. Interesting to note that 10%+ of excess flow has large impact on TMP going up. Talked to WP process. Secondary process stressed over last 2 days - no oxygen for 24 hours. Peark turbidity around 1000 hrs today at 20 NTU. System is now coming down. Will leave MF online but will most likely perform maintenance clean on Monday. At 1655 hrs feed hose to skid leaking; need to replace.
10/6/2001	Secured for weekend At 1655 hrs by Bob Bucher.	No comments.

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Date	Comments (ODS)	Comments (Log Book)
10/7/2001	At 1147 hrs restarted unit after fixing supply hose. At 1000-1200 hrs flushed C3 water feed system prior to restart of skid.	Fixed feed hose to skid. At 1147 hrs restarted skid with Chlorine dosing pump operationl. Feed turbidity running at approximately 6.5 NTU. At 1000 to 1200 hrs, flushed C3 water drain to clean supply piping from WP water reuse header in fallery. Secured flush to WS1 tank after MF unit restarted.
10/8/2001	At 0140 hrs refilled tank.	At 0130 hrs added bleach in 3:1 ratio, tank now full.
10/9/2001	At 0950 hrs added 1 bottle bleach and 3 H2O.	No comments.
10/10/2001	Filled 1 bleach and 3 H2O.	No comments.
10/11/2001		No comments.
10/12/2001	Ar 0137 hrs MF alarm and unit failure. Readings from 1705 hrs before settings change.	SCADA alarm; 0137 hrs MF alarm and unit failure. At 1408 hrs initiated maintenance clean. Completed maintenance clean at 1550 hrs. At 1600 hrs after startup, discovered leak on WP secondary effluent feed hose to skid (second leak in one week). Secured skid and replaced hose. At 1625 hrs restarted skid with new feed hose. at 1703 hrs changed following setting per Pall (Scott). At 1710 hrs AS and RF frequencicies from 20 to 15 minutes, AS (with air) duration from 70 to 60 seconds, RF flowrate from 13 to 10 gpm.
10/13/2001		No comments.
10/14/2001		No comments.
10/15/2001	At 0916 hrs filled chemical tank - no bleach, didn't fill. At 2230 hrs added 2 containers of bleach (2-2).	Suspect Chlorine dosing tank empty from approximately 0800 hrs to 1000 hrs. Assume no longer than 2 hours without chlorine dose. Ordered 55 gal drum of HOCl with expected delivery on Wednesday. In the meantime, use provided bleach. At 2203 hrs add 2 containers of bleach.

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Date	Comments (ODS)	Comments (Log Book)
10/16/2001	At 0145 hrs added 1 container on bleach (1-1). Maintenance clean from 0920 to 1127 hrs.	At 0145 hrs add 2 cotnainer of bleach. At 0400 hrs added one container of bleach. At 0652 hrs HIGH PRESS alarms on unit. At 0923 hrs initiated maintenance clean (see 9/28 note for details). At 0948 hrs Chlorine recirc initiated (stopped at 1038 hrs). At 1042 hrs secured from Chlorine recirc. At 1049 hrs initiated first flush (stopped at 1059 hrs). At 1059 hrs secured from first flush. At 1105 hrs initiated second flush (stopped at 1115 hrs). At 1116 hrs secured from second flush. At 1121 hrs RF performed. At 1127 hrs completed maintenance clean with hookup of WP secondary effluent line. Also adjusted HV5 to get 1 gpm excess flow. At 1630 hrs secured MF skid due to high feed turbidity. West Point secondary problem. Rain throughout day may be contributing.
10/17/2001	At 0150 hrs noted that unit not running. At 0759 hrs lost screen, Bob rebooted. At 1600 hrs added 1 bottle bleach and 3 bottles potable H2O.	At 0210 hrs performed "quick" maintenance clean - see note on 10/5. At 0228 hrs added 200 mL 6% HOCl in 20 gal feed tank filled with potable water and recirced for 10 minutes. At 0246 hrs drained recird water and replaced with potable, flushed through system for 10 minutes. At 0300 hrs drained recird water and replaced with potable. Flushed through system for 10 minutes. At 0321 hrs unit back on-line. Checked with main control to confirm WP secondary at low turbidity level (3.5 NTU). Clean water (potable water) TMP = 16.3 psi, time to RF = 8 minutes. At 0324 hrs turned S10 sampler back on. At 0906 hrs rebooted computer on skid to fix "blackened"screen display. RSLINX.exe - execution error, log being generated. "OK" pressed.

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Date	Comments (ODS)	Comments (Log Book)
10/18/2001	At 0507 Hi-HI d press alarm, reset at 0720 hrs. Alarms: 1401 High TMP, 1603 PTI Hi, 1618 Hi TMP. At 1613 hrs shutdown for the evening until a CIP can be performed.	At 0507 hrs HIHI feed press alarm, reset at 0720 hrs. Paul Morris left message at 1024 hrs (10/17) that modem connection was down. Verified that modem line was OK - hooked modem line into phone - received dial tone. Called Tom at Pall, recommended that computer be rebooted. RSview32 didn't come back up. Tom recommended power off the whole skid. Windows and program came back up. To address high feed pressure manually cycled v, put system in auto, system stuck in filling system mode. Based on notes from 9/7, need to change permeate flow setpoint to 0.5 gpm. System still did not move to forward flow. Tom initiated an Air Scrub (program may have been stuck at a particular step during the reboot and wasn't recongizing any changes). Mode switched to forward flow. At 1613 hrs high TMP alarms, will secured skid until a CIP can be performed.
10/19/2001	Back psi on filtrate down 104-5 psi, PT2. Vendor drained tank at 2105 hrs.	Started maintenance clean at 1245 hrs. Paul Morris indicated that PTS should be moved from 12-13 psi to 4-5 psi.
10/20/2001	At 0722 hrs High TMP alarm.	At 7:22 hrs High TMP alarm. Chemical tank empty, added 1 bottle HOCl and 3 potable water. Raining.
10/21/2001	Unable to confirm original plan to perform a mini maintenance clean; will hold off on clean until 10/22; secured skid.	At 0114 hrs unit shut down on High High TMP alarm. Continues to rain. Unable to confirm original plan for a mini clean with Bobl will hold off until 10/22. Secured skid.
10/22/2001	At 1255 hrs 3 VFD1 F5 over voltage fault. Waiting until after conference call with consultants prior to putting feed to skid. Performed maintenance clean. Started maintenance clean at 1059 hrs. Cl2 cir at 1117 hrs. To drain at 1210 hrs (continues to fill back up through bottom open drain line now flow V2 valves is changing. At 1258 hrs ran P1 at 34 to get 6 gpm feed rate = 13.3, second flush at 1318 hrs. At 1328 hrs widspot #1 high alarm, feed pimp 1 and 2 general alarm, feed pump influent flow meter failure. Appears that RO is back up into MF.	Talked with Mike Norton; Pall will download data and review; conference call scheduled for 10.23 at 0900 hrs to discuss high TMP. Performed maintenance clean; started at 1059 hrs. 50 minute circi completed at 1210 hrs, had problems when trying to empty feed tank; the tank would back fill from bottoml disconnect the drain line from skid - RO back filling? Second flush at 1318 hrs. Skid secured without feed.

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Date	Comments (ODS)	Comments (Log Book)
10/23/2001	Skid online. Secondary effluent has turbidity of 4.71 NTU. Adjusted HV13 valve to achieve 4.5 psi PT2. At 1414 hrs stuck in fill mode; initiated air scrub. At 1551 hrs adjusted HV13 to maintain PT2.	Conference call at 0900 hrs, decisions made: flush feed for 1 hr; hook up feed skid if feed NTU below 8 NTU, run at a flux of 9 gpm for periodof time than lower to 8.3 gpm, run at 8.3 gpm until 10/26, switch to new feed on 10/31. Flushed feed line from 1125 to 1400 hrs. Effluent feed NTU at 1400 - 4.71 NTU. 1400 hrs hooked up feed and started in auto. At 1414 hrs system stuck in fill mode; initiated an air scrub. Lowered permeate setpoint to 0.5 gpm seceral times. Called Paul Morris via modem was able to move to a foward flow mode. Initially had high feed flows; need to close the HV5 completel than open slightly until FT1 is at the desired feed rate (need to put in maintenance clean procedure).
10/24/2001	Added 1 container of bleach (1-3 ratio) at 0155 hrs. At 1120 added bottle of bleach and 3 bottles of potable H2O. At 1555 Hihi TMP. Back online at 1653 hrs.	Paul Morris had lowered flux rate at 2000 hrs (10.23) to 8.3 gpm. At 1515 hrs received call from Morris; believed excess recirc plugged up, trapped air reducing membrane volume; requested HV5 valve open and then adjusted closed; feed NTU approximately 8 to 14. At 1520 to 530 hrs open HV5 valve; adjusted flow to 9.2 gpm. Adjusted HV13 valve to lower PT2 to approximately 5 psi. At 1555 HIHI TMP, feed NTU is 11. Called Morris to set reset and adjust recirc flow and let unit run.At 1614 hrs reset alarm, AUTO start went into filling mode, lowered permeate set point (need to hit ENTER). Reason pervious attempts were not successful. At 1707 HiHi TMP alarm. At 1715 hrs TMP continued to rise.
10/25/2001	At 0544 hrs high-high alarm trans membrane pressures, high high temperature. Skid down.	At 0544 hrs HiHi alarm trans membrane pressure. High Temp (the plant is experienceing high flow and tudbidity high).
10/26/2001	Skid secured.	Unit secured, plant to performed clean-in-place (CIP) on Monday, 10/29.
10/27/2001	Skid secured.	Unit secured, plant to performed clean-in-place (CIP) on Monday, 10/29.
10/28/2001	Skid secured.	Unit secured, plant to performed clean-in-place (CIP) on Monday, 10/29. Maintenance cealn procedure attached to log book for future reference.

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Date	Comments (ODS)	Comments (Log Book)
10/29/2001	Skid secured.	Unit remained secured, preparing for CIP clean. Received immersion heater on Wednesday (10/31). Picked up Citric Acid on Wednesday (10/31).
10/30/2001	Skid secured. Planned CIP.	Unit remained secured, preparing for CIP clean. Received immersion heater on Wednesday (10/31). Picked up Citric Acid on Wednesday (10/31).
10/31/2001	Skid secured. Waiting on CIP.	Unit remained secured, preparing for CIP clean. Received immersion heater on Wednesday (10/31). Picked up Citric Acid on Wednesday (10/31).
11/1/2001	At 0545 hrs CIP initiated, at 1635 hrs CIP completed.	At 0500 hrs settping up for CIP clean per Pall protocol. Drained RF tank by operating skid through RF cycle - then secured. Recirc (NaOCl and NaOH) start time at 0545 hrs. Only able to get 3.5 gpm permeate, 11.7 gpm feed. Initial temperature of 21.2 celcius (0545 hrs). At 0830 hrs check of system: temperature is 32.1 celsius; permeate flow is 3.5 gpm; feed flow is approximately 13 gpm. At 0932 hrs adjusted flow conditions: temperature is 31.9 celsius; permeate flow from 5.6 to 4.4 gpm, feed flow from 13.5 to 12.1 gpm, feed pump speed from 53% to 50%. At 0945 hrs adjusted HV14 to reduce flow from 5.2 to 4.0 gpm. At 1257 hrs secured from 1% caustic and 0.5% chlorine cleaning. Conditions: temperature is 30.9 celsius; permeate flow is 4.0 gpm; feed flow is 12.0 gpm. Total time from 0545 to 1257 hrs, 7 hours and 12 minutes. Flushed system using feed pump and RF pump running at 30% and discharging to drain via V2. At 1400 hrs started 2% citric acid recirc. At 1449 hrs check of parameters: temperature is 23.8 celsius; permeate flow of 4.1 gpm; feed flow of 12 gpm. At 1603 hrs secured from citric acid clean. At 1630 hrs co

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Date	Comments (ODS)	Comments (Log Book)
11/2/2001	Skid offline.	From 0930 to 1100 hrs performed CWF (clean water flux) testing using potable water at flow rates of 8, 9, 10, and 12 gpm. Pall provided excel workbook for calculating CWF and comparing to initial values from pilot skid startup. At 1430 hrs performed checkout of feed pump 2 in preparation for operation using BAF1 effluent in storage tank 1. Noted excess solids in storage tank 1 during checkout. Plan to drain storage tank on Monday a.m. and flush with water. Solids were stirred from bottom of tank by excess recirc flow from feed pump 2 discharge. This will be a normal occurance during operation. Feed pump 2 is ready for operation. Microfiltration skid is secured for the weekend. HDR will notify Pall that skid operation will restart Monday on BAF1 effluent.
11/3/2001		No comments.
11/4/2001		No comments.
11/5/2001	Secured unti until 11/6.	Skid remained secured while storage tank 1 flushed to remove accumulated solids. Plan to startup unit on Tuesday morning.
11/6/2001	Per Pall target operation data set points changed, remotely changed by Paul Morriss. Secured for the evening, problem with control system.	At 1130 hrs setting up for MF operation with BAF1 feed. Feed pump 2 running in HAND at flowrate of 25 gpm. Feed pump 2 discharge to storage tank 1. Set at lowest pressure. At 1135 checked setting on Pall skid per Paul Morris email: flow at 8.3 gpm; SASRF at 15; RF at 15 min; recovery at 90.3%; P2 pump speed at 28% from 38%. From 1150 to 1155 hrs manual ran feed water through unit to drain to checkout feed turbidity which was 11-13 NTU. At 1619 hrs started up unit with BAF1 effluent. RF cycle to AS was -3, time to RF was -19, why is this showing negative values? rebooted computer to reset scren. At 1622 hrs restarted unit with RF cycle to AS and time to RF still decreasing from -3 to -4 and -19 to -24.

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Date	Comments (ODS)	Comments (Log Book)
11/7/2001	At 0945 hrs skid startup with BAF1 effluent, effluent pumps from storage tank 1 via feed pump 2. Shutdown for evening.	At 0845 hrs talked to Pall (Paul Morris) about timer. He suggested securing skid power and then restart (reset of PLC and SCADA system). At 0901 hrs secured MF skid power and restarted. Restart worked, HRF cycle to AS is 1, and time to RF is 15. At 0946 hrs startup initiated in AUTO. Waited for first RF to check new flowrate 4 gpm (28% RF pump speed) vs "old value" of 5 gpm (38% RF pump speed). Also closed HV11 and routed permeate flow through HV10 to drain. This separated the permeate flow from common drain manifold. Adjusted HV5 to establish XR flow of 2 gpm. Feed flow - permeate flow is excess flow. "adjusted" 10.3 - 8.3 = 2, okie! Adjusted HV13 to establish 5.0 psi backpressure on permeate (P12) was running at > 6 psi. Adjusted feed turbidimeter supply valve to maintain adequate flow through meter. At 1552 hrs unit shutdown on low feed tank level. The storage tank 1 must be empty. Secured the unit for the evening. Unit shutdown but P1 pump still operating at 30%. Assume it has operated since unit alarm at 1552 hrs. Only way to get pump OFF was to go to MANUAL and press STOP on pu
11/8/2001	Unit restarted at 0800 hrs. Unit secured after 5 minutes of operation, clogged prefilter bag.	Flushed C2 water and FP2 pumping to drain overnight.
11/9/2001	At 0920 hrs unit still secured. At 2012 hrs H-H TMP alarm caused unti to shutdown, last influent turbidity displaced = 38.2 NTU. MF Cleaning in progress.	At 1458 hrs unit back online. Feed Chlorine dose is 1 container 12.5 HOCl + 3 containers potable water. At 2012 hrs unit shutdown on HIGH-HIGH YMP alarm. Last displaced turbidity was 38.2 NTU. Unit left in shutdown condition until tomorrow.

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Date	Comments (ODS)	Comments (Log Book)
11/10/2001	At 0130 hrs alarm on, panel off.	At 1011 hrs initiated steps for maintenance clean; drained feed and RF tanks; filled feed tank with RO quality water; installed heating element to increase temperature to 90 F; clean bag prefilter. Initiated RO quality water heating at 1046 hrs, setpoint at 90 F. At 1800 hrs continuing with mini-clean; start HOCl recirc at 1818 hrs (stopped at 1908 hrs). Temperature of 34 C, FT1 at 17.5 gpm and FT2 at 6.1 gpm. Started first flush at 1936 hrs, stopped at 1946 hrs. Temperature at 16.5 C, FT1 at 7.4 gpm, and FT2 at 6.0 gpm. Started second flush at 1952 hrs and stopped at 2002 hrs. Temperature at 14.3 C, FT1 at 7.0 gpm, and FT2 at 6.2 gpm. Secured unit by filling feed tank with potable water and leaving in secured operation. Wrote note to Pall on skid PC to discuss need step on Monday morning.
11/11/2001	Unit secured until Tuesday, 11/13.	No comments.
11/12/2001	Unit secured until Tuesday, 11/13.	No comments.
11/13/2001		Conference call with Pall to discuss operation. Plan to clean storage tank 1 and put unit in operation at 7 gpm (for minimum of 24 hrs).
11/14/2001	Unit remains offline while storage tank 1 is cleaned.	Cleaning storage tank 1 using C2 water.
11/15/2001	At 0715 hrs initiated drain of storage tank 1.	From 0830 to 1400 hrs finish flushing storage tank 1. At 1645 hrs started unit in Auto-filtration permeate flow setpoint of 7.0 gpm.
11/16/2001		At 1100 hrs conference call with Pall/HDR plant to increase permeate flow setpoint from 7.0 to 8.3 gpm later this afternoon. At 1535 hrs adjusted permeate flow setpoint from 7.0 to 8.3 gpm.
11/17/2001		At 0230 hrs added 1 container of bleach and 3 containers of water.
11/18/2001	At 0950 hrs adjusted XR flow up slightly, want 10%.	At 0135 hrs filled the chem tank with one container of sodium hypochlorite and 3 containers of water.
11/19/2001	At 0015 hrs unit shut down due to high trans-membrane pressure.	At 1900 hrs checked residual chlorine concentration in feed tank (based on current HOCl addition). Using WP total chlorine kit residual chlorine concentration of 11.4 mg/L! Need to reduce chlorine dosing per the following: dosing pump provides __ ml/min. At 1930 hrs found MF effluent sampler in standby, restarted.
11/20/2001	Mini clean performed. Data taken at 1620 hrs was post maintenance clean.	Unit shutdown on high-high at 21:37 on 11/19. Performed miniclean, clean from 1413 to 1615 hrs.

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Date	Comments (ODS)	Comments (Log Book)
11/21/2001	Secure unit at end of day shift, FP2 off.	At 1335 hrs recirculate with chlorinated water for 20 minutes (from 1400 to 1420 hrs). At 1420 hrs skid secured.
11/22/2001	Secured.	No comments.
11/23/2001	Secured.	At 1000 hrs collected 200 mL sample for alkalinity testing.
11/24/2001	Secured.	No comments.
11/25/2001	Secured.	No comments.
11/26/2001	At 1315 hrs, adjusted feed flow to 9.5 gpm. At 1530 hrs filled up chemical tank.	At 0935 hrs flush unit with potable water, started 1st recirculation at 1003 hrs. Second reciculation started at 1018 hrs. At 1038 hrs started unit back up. Went into backwash at 1042 hrs. At 1052 hrs TMP at 12.1, feed turbidity at 6.7, effluent turbidity at 0.049. This yields a 91.2% efficiency.
11/27/2001	At 0130 hrs filled up chemical tank. At 0720 hrs shutdown on high-high TMP. Secured FP2 at 0900 hrs. At 0240 hrs started upw ith filtrate flow of 7 gpm, post maintenance clean.	Noted at 1000 hrs that unit shut down on high-high alarm at 0720 hrs this morning. Secure the unit until Thursday, conference call with Pall. Will do maintenance clean on 11/28 in the AM.
11/28/2001		At 1110 hrs prep maintenance clean. Started chlorine recirc at 1420 hrs. Clean completed at 1604 hrs. Secured unit after flushing with potable water twice.
11/29/2001		At 1340 hrs started unit up - filtrate from of 7 gpm. At 1356 hrs unit completed backwash. TT1 of 10.8 C, TMP of 8.6 psi, FT2 filtrate flow of 6.9 gpm, FT1 feed of 7.6 gps, AT2 filtrate turbidity of 0.109. At 1520 hrs started autosampler for S10 line.
11/30/2001	At 0804 hrs filled chemical tank.	No comments.
12/1/2001		No comments.
12/2/2001		Unit shutdown at 1800 hrs on 12/1 on a high-high TMP. Feed pump 2 secured at approximately 0300 hrs.
12/3/2001		At 0658 hrs initiated operation (time to RF of 1 min) to perform RF. RF will drain RF tank in preparation for CIP clean. CIP clean performed per note 1 from Thursday, 11/1. At 1000 hrs drain feed and RF tank, cleaned bag filter, and filled up NaOCl bottles.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
12/4/2001		Perforemd CIP, Recir with 0.5 % chlorine and 1% caustic, NaOH 1.5 L, NaOcl 3.6 L, started re-cirt at 14:14 hr, FT1 =12.1 gpm, AT 1=3.6 NTU, PT1=17.7 psi, TT1= 26.8 C, TMP= 0.9 FT 2 = 4.0 gpm, AT2 = 0.348 MTI {T 2= 13.7 psi, PT3=11.5 psi, feed pump 1= 35%. Stopped recir at 14:04 , let soaked overnight
12/5/2001		Drained the unit. Recir with potable water. Recir with citric acid. Performed clean water flux test. Finished at 16:42. Secured the unit-ready to start up tomorrow
12/6/2001		Started the unite back up w/ filtrate flow = 7 gpm, temp 9.s6 C, TMP= 3.1 psi. Log ODS. 9:55 RF tank low, filled with potable water and re-started. 13:40 RF tank low, filled with potable water and restarted- adjusted flow via HV5- stop and re-start. Influent turbidity = 24.5 NTU. Stopped the system, drained the feed tank and flushed the feed line. Still see high feed turbidity.l
12/7/2001		Paul Morris saw high back pressure and high filtrate turbidity. At 11:01, open HV 11, cleaned and adjust flow on the turbidimeter. 12:09 PT2 still high (7 psi) adjust the ball valve above HV11. The turbidimeter light source was out. Found out to be just a loose wire. Fixed the turbidimeter around 15:00.
12/8/2001		No comments.
12/9/2001		Filled chlorine tank
12/10/2001		Paul Morris shut the unit down in the morning due to no backwash flow. Filtrate turbidity very high (3-5 NTU). Visual inspection- filtrate tank very turbid. Checked HV14 valve-found to be closed. Checked the check valve at P2- found working. Blown fuse on pump P2. Paul Morris suggested integrity test. Pressure decay was 1.04 and 0.26 psi/min. Bob Bucher is waiting for electrical print before fixing P2.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
12/11/2001		Replaced fuse on P2. Drained filtrate tank by manuallyrned on P2, closed V3 and drained water through V2. Filled both feed and filtrate tank with potable water. Started the system on auto with filtrate flow set at 7 gpm. Filtrate flow was only 3.5 gpm-the system was stuck in the filling mode. Chenged the filly system fill speed from 20 to 30%. The system filled up and proceeded to forward filtration. Adjusted recir to get feed flow = 7.7 gpm. Log ODS. Adjust HV13 to get PT 2 = 3.9 psi. Turbidimeter for filtrate ir seading neg. value. Verify turbidimeter reading-read 0.675 in 1 NTU standard. Re-calibrated the turbidimeter on filtrate line at 15:06
12/12/2001		Unit is off, due to high-high alarm. Filled up bleach tank. Prep for miniclean. Heating element in the water heater broke. Postpone clean for tomorrow.
12/13/2001	mini clean initiated using hot water (potable) from process lab	Performed maintenance clean. Used hot water from the process lab. During clean water flushing, P1 oscilated between set point (26%) and 63% every 2-3 seconds. Ramped the pmp up to 50%- stop oscillating,but when drop down to 26%- still oscillating. Maintenance clean was completed at 14:30. Logged ODS. Started unit back up with 7 gpm filtrate. TMP was 5.8. Temp = 11.6. Feed turbidity = 8.95 NTU. Filtrate turbidity started out around 5 NTU but went down to 1.7 NTU in approx 5 min and appreared to be going down.
12/14/2001	Shut down in am hours by Pall due to RF pump failure. Suspected fuse.	Filled chlorine tank. Informed via email that pilot secured by Pall after discoveering RF pump not operating. Secured FP2@ local panel. Started miniclean with caustic/chlorine. Couldn't get the filtrate rate up to 6 gpm. Only went as high as 2.8 gpm. After 1 hr- up to 3 gpm. After 2 hours- up to 11 gpm. Stopped recirculation and let the unit soaked.
12/15/2001		Let the unit soaked
12/16/2001		Let the unit soaked
12/17/2001		Continued with maintenance clean

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
12/18/2001		At 11:42 hrs, check CV2 valve, appeared to be working. Cleaned strainer on P2. Staryed system up at 11:42 hrs, the TMP was 6.6 psi. Watched unit going through BW cycle. Pump P2 operated fine. Logged ODS. At 12:02 hrs, the unit went into another RF cycle. P2 failed to work during the BW. Stopped the system. Tried manually activate P2, but still didn't work. At 14:20 hrs, drained the unit and recirculated with chloinated water (0.1 ppm) for 10 min. At 14:50 hrs, secured the skid.
12/19/2001		Unit secured
12/20/2001		Unit secured
12/21/2001		Unit secured
12/22/2001		Unit secured
12/23/2001		Unit secured
12/24/2001		Unit secured
12/25/2001		Unit secured
12/26/2001		MF effluent sampler (S10 borred for use in C3 feed to fuzzy filter unitl. Setting changes under section 7. 120 to 40, 175 to 100, 60 mm to 30 mm.
12/27/2001		No comments.
12/28/2001		From 10:30 to 11:30 hrs, trouble shooting with WP maint. Electricians. Following changes make: fuses (5 fu&6fu) replaced with 10 A fuses. Clamped 2 VFD with max Hz output of 60 (was @ 120). 2VFD max output volts set at 250 (was 230). Suspected that if RF pump was deadheaded the VFD increase beyond 60 Hz which increased current beyond 7.5 A rating on fuses. Still need to Assess requred set oints changes with new VFD settings. For example, RF pump max %speed may have to be increased to get 11 gpm from pump. Secured unit until changes can be discussed with Pall. Left message in their office. Following table are results of check outs
12/29/2001		No comments.
12/30/2001		No comments.
12/31/2001		From 9:30 to 15:30 hrs, operated unit using potable water with no shutdowns.
1/1/2002		No comments.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
1/2/2002		Talked with Paul Morris (Pall) and plan to restart unit this afternoon. At 17:30 hrs, working on unit start up. Beld feed line for 15 min. At 17:45 hrs, rebotted compyter (not responding to start up). Initial operation of unit with high feed turbidity (~ 50 NTU). Operated unit for approximatly 0.5 hrs before shut down on high feed pressure. Troubleshooting revealed that the air compressor had shutdown. Compressor had tripped on thermal overload. Reset and restarted compressor with the same results. Secured the unit for the evening. Call from Ed Kane (Pall contractor working in Eugene, OR) about need to checkout unit. He can be reached @ (541) 988-4942. Informed Ed to hold off until further troubleshooting can be accomplished.
1/3/2002		From 8:50 to 9:20 hrs, bled MF feed line from storage tank 1 in effort to reduce feed turbidity prior to pilot unit startup.
1/4/2002		Unit secured
1/5/2002		Unit secured
1/6/2002		Unit secured
1/7/2002		Unit secured
1/8/2002		Started unit back up after flushing the system with potable water. Unit completed RF cycle.
1/9/2002		At 6:30 hrs, discovered chlorine dosing tank empty. Filled and bled air from line. Chlorine dosing re-established at 6:45 hrs.
1/10/2002		At 15:30 hrs, screen :frozen" on unit. Stopped unit and re-booted computer. Only offline for approximately 5 min.
1/11/2002		At 9:30 hrs, chlorined doing tank empty- refilled and bled air from discharege line. Free chlorine in filtrate was 13 mg/L- will cut chlorine dosing by 2/3.
1/12/2002		No comments.
1/13/2002		No comments.
1/14/2002		At 10:00 hrs, initiated miantenance clean using caustic/chlorine. Pre-maintenance clean TMP = 15.6 psi. Re-cir water temp = 38.2 C. At 14:20 hrs, maintenance clean completed. Unit completed RF cycle. Starting TMP was 5.9 psi. Free chlorine in filtrate = 24 mg/L (16:00 hrs) suspeced that was from maintenace clean.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
1/15/2002	At 10:06 hrs, adjusted the feed flow from 10.2 to 8 gpm)	At 10:00hrs, TMP was 14 psi at 4 min to RF cycle. Observed unit through RF cycle, pump P2 ok, air system ok. TMO right after RF cycle = 12.3 psi. Pall changed RF cycle frequency from 15 min to 10 min in the early afternoon.
1/16/2002		Ar 11:40 hrs, received an email from Paul Morris (Pall) asking to check the air pressure and air flow during SASRF cycle. Stopped the system, opened the V4 valve manually, the pressure was 30+ psi (PT1). Turned the system back on, waited for air scrubbing cycle. The pressure read 1.3 psi. The system was slow to respond to commands, especially when turned off and on. When hit "start" the message "are you sure you want to stop the system" popped up. It took a while to register. The unit was stuck in the filling mode. Had to increase pump P1 from 27% to 30%. Unit proceeded to farward flow then. At 13:30 hrs. checked the system again, AS pressure was bouncing from 1-10 psi. The flow rate was 200-300 scfh. At 15:30 hrs, checked air flowrate during air scouring- duirng AS only, 270 to 300 scfh. During AS/RF= 200 to 250 scfm. Adjusted the flow during AS/RF to around 180-200 psi per Pall's recommendation. PT1 was around 10.7 psi and no longer fluctuating.
1/17/2002		At 13:29 hrs, received email from Paul Morris asking to check the PC. The PC was slow to respond. Closed the window and re-start the program.
1/18/2002	S10, sample a grab, sample hose not down far enough.	At 10:34 hrs, stopped the system- TMP was 22.1 psi, time to RF = 8 min. At 13:30 hrs, started chemical recirculation with caustic concentration increased from 0.5% to 1%. Added air scrubbing step during draining. Added RF flushing (see details in maintenance clean check list). At 15:18 hrs, completed maintenance clean. Started unit back up. Logged ODS "post maintenance clean). Unit went into backwash at 15:22 hrs. Air flow rate during AS = 210 scfh. Adjusted air flow rate during AS/RF to 180 scfm. TMP post RF = 8.4 psi.
1/19/2002		
1/20/2002	At 11:05 hrs, the unit was in High TMP alarm.	Unit secured until Tue 1/22/02
1/21/2002		

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
1/22/2002		At 10:00 hrs, started maintenance cleaning, caustic/chlorine recirculation. After project conference call- proceeded to do CIP instead of miniclean. Added 2400 ml of chlorine to the feed and continure to recirculate. At 16:00 turned of the feed pump and let the unit soaked overnight.
1/23/2002		At 10:00 hrs, continued with CIP. At 11:40 started citric acid cleaning. At 13:45, finished citric acid recir. The control panel wasn't responsive. Performed hard reset-turned power off then back on. At 14:56 hrs, completed CIO and clean water flux test and secured the unit. The clean water flux was only 82 to 88% of the original clean water flux. The temperature was 8.6-8.8 C.
1/24/2002		No comments
1/25/2002		Performed clean water flux test using warmer water (18C). Tested in recir mode (instead of forward flow) due to unable to connect to the warmer water source. The clean water flux was still less than 90% of the original. Pall recommended another CIP with higher caustic and acid concentration (2% and 4%) and longer acid recir (4 hrs versus 2hrs previously)
1/26/2002		No comments
1/27/2002		No comments
1/28/2002		At 10:30 hrs, started CIP with 3.0L caustic and 3.0 L chlorine. Recirculated for 6 hrs, then let the unit soaked overnight.
1/29/2002	At 22:40 hrs, collected "special test" samples for Env. Lab.	Ccompleted CIO. Performed CWF test using hot water from process lab to get water temp around 18-20 C. The recir mode gave CWF about 75 - 77% of the original. Paul Morris pointed out that the CWF in re-cir mode would always be less than the farward flow mode due to the additional pressure. Therefore, should not worry about it and re-started the unit. The unit was started with BAF2 effluent. The water was very turbid. The black solid in water indicated that the the condition at the bottom of ST2 had gone anaerobic, since it had been sitting static for a few days. This should not be an issue once MF is operated continuously. The TMP was 6.5 and the temperature was 9.1 C. The RF cycles to AS and time to RF on the screen were both negatives. Did hard reset.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
1/30/2002		At 14:00 hrs, decreased filtrate from 7 to 6 gpm as advised by Scott (Pall). At 15:50 hrs, adjusted RF cycle as adviced by Pall.
1/31/2002		At 9:44 hrs, Pall couldn't access the skid remotely. The screen was slow responding to commands. The screen froze in RF mode since last night. Rebooted the computer again. At 9:59 hrs, the unit went into BW. Everything seemed to be operating. Adjusted air flow during AS/RF to 180 scfh.
2/1/2002		No comments
2/2/2002		No comments
2/3/2002		No comments
2/4/2002		No comments
2/5/2002	Performed maintenance clean - 1st BAF 2	At 12:35 hrs, completed maintenance clean. Influent turbidity 15 NTU, TMP 5 psi. The unit proceeded through the backwash completely.
2/6/2002		No comments
2/7/2002		No comments
2/8/2002		No comments
2/9/2002		No comments
2/10/2002		No comments
2/11/2002		No comments
2/12/2002	Performed maintenance clean - 2nd BAF 2	From 13:50 to 15:50 hrs, performed maintenance clean, logged ODS. Post-maintenance clean TMP was 4.7 psi, inf. Turbiditey = 4.84 ntu. The unit proceeded through the BW cycle completely.
2/13/2002		No comments
2/14/2002		No comments
2/15/2002		At 12:14 hrs, the screen froze- turned the PC off then started it back on again.
2/16/2002		No comments
2/17/2002		No comments
2/18/2002		No comments
2/19/2002	3rd BAF 2 Maintenance Clean	At 14:00 hrs, performed maintenance clean, then secured the unit. Will start the alum inline feeding tomorrow.

KING COUNTY WATER REUSE DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - PALL MICROFILTRATION PILOT UNIT

Date	Comments (ODS)	Comments (Log Book)
2/20/2002		At 14:10 hrs, started the unit back up with BAF2 effluent. Starting TMP was 5.9 psi, tempertature = 10.1 C. The unit completed BW cycle. At 15:40 hrs, started alum feed at 50 mg/L. The pump stroke = 40, pump speed = 3 (see calculation in the log book pg. 78).
2/21/2002		No comments
2/22/2002		No comments
2/23/2002		No comments
2/24/2002		No comments
2/25/2002		At 10:15 hrs, bob noticed higher turbidity since the weekend- visualy inspect the feed tank. Notice flock accumulating on the tank wall. Currently the infulent turbidity is 11-12 NTU. Cleaned both turbidimeters.
2/26/2002		No comments
2/27/2002		At 11:40 hrs, shutdown the unit and initiated CIP.
2/28/2002		At 13:00 hrs, finished CIP. At 17:30 hrs, performed CWF test.

Microfiltration Pilot Unit Photos

Introduction

The following is a series of photos of the Pall Corporation microfiltration membrane pilot unit system during the pilot testing. Each photo includes a caption and text boxes to point out key pieces of equipment.

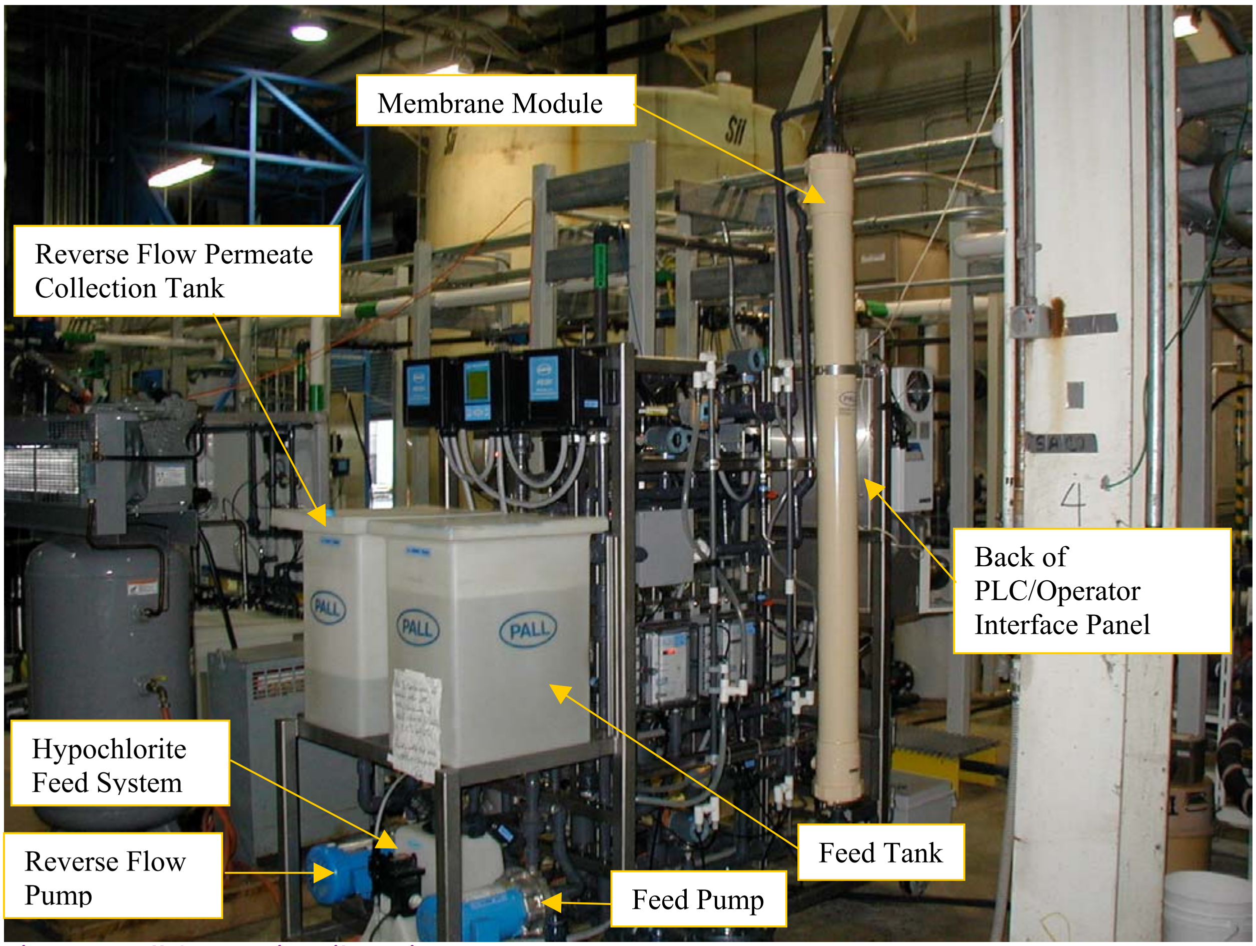

Figure 1. Pall Corporation Pilot Unit

Figure 2. MF Unit PLC and Operator Interface

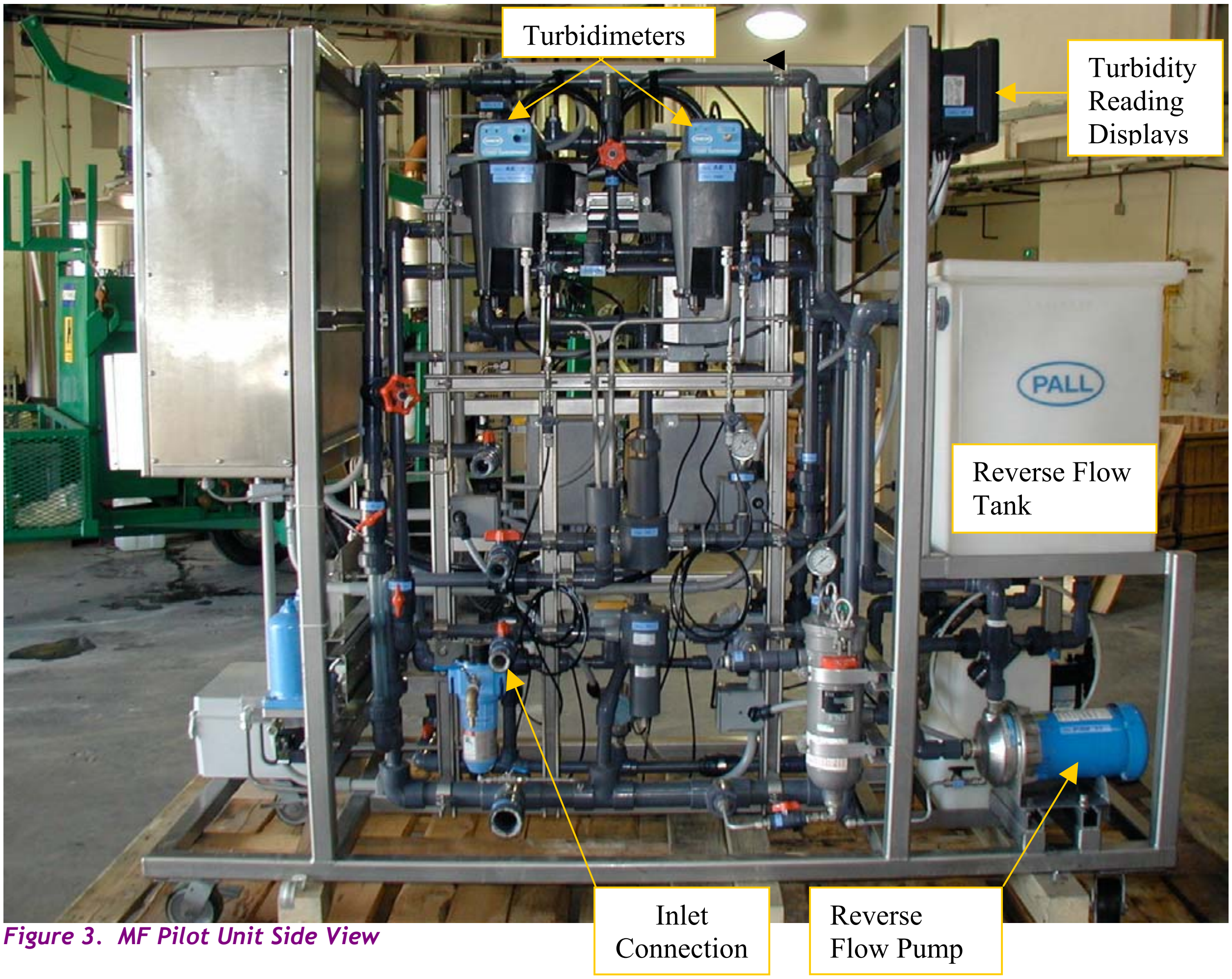

Figure 3. MF Pilot Unit Side View

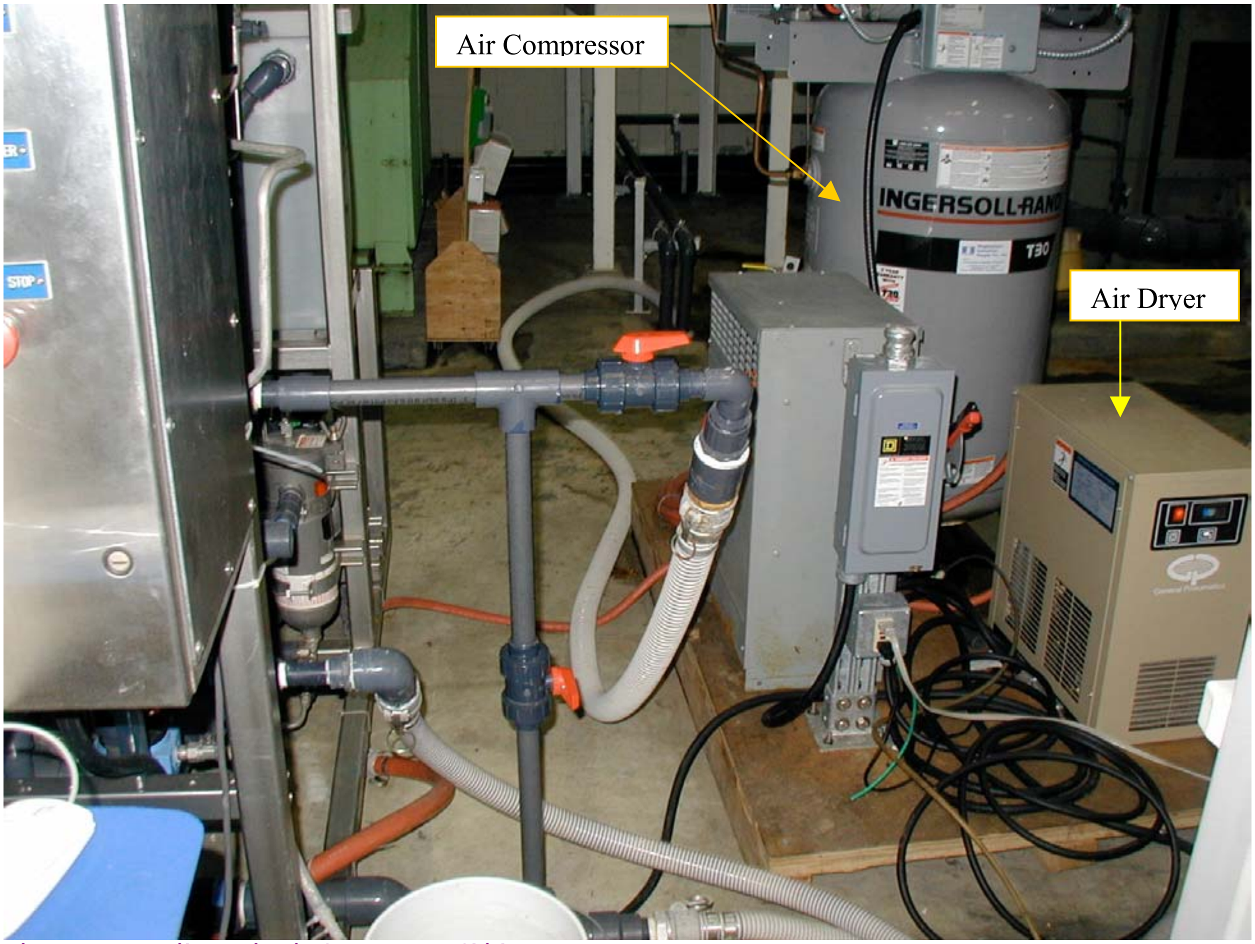

Figure 4. MF Pilot Unit Air Compressor Skid

Figure 5. MF Pilot Unit Pre-Screening Bag Filter