WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT

Demonstration Facility Pilot Study
Membrane Bioreactor
Final Draft Report

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By

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King County
Department of Natural Resources and Parks
Wastewater Treatment Division
Technology Assessment Program

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Executive Summary

This report summarizes the findings of the membrane bioreactor (MBR) pilot tests. The hollow fiber MBR unit, "Zeeweed" manufactured by Zenon Environmental, Inc., was configured to receive West Point WWTP primary influent and West Point WWTP primary effluent. These studies were divided into several phases in order to test several different combinations of parameters as follows:

- Phase 1a/1c - Nitrification/Denitrification at 10 day Aerobic Sludge Age, 6 gpm.
- Phase 1b – Nitrification/Denitrification at 10 day Aerobic Sludge Age, 8 gpm.
- Phase 2a/2b – Nitrification/Denitrification at 6 day Aerobic Sludge Age, 6 gpm.
- Phase 3a – Biological P Removal at 6 day Aerobic day Sludge Age, 6 gpm flow.
- Phase 3b – Biological P Removal at 6 day Aerobic day Sludge Age, 9 gpm flow.

The focus of these pilot tests was to evaluate the MBR process as a secondary treatment system to produce Class A reuse water. The specific goals for the pilot study were:

- Achieve effluent ammonia concentrations <1 mg/L, 90th percentile.
- Achieve effluent nitrate concentrations < 8 mg/L, 90th percentile.
- Achieve effluent nitrate concentrations < 5 mg/L, 50th percentile.
- Achieve effluent turbidity <0.2 NTU, 90th percentile.
- Achieve effluent TP <0.1 mg/L, 90th percentile.
- Meet Class A reclaimed water standards.

Table 1 summarizes performance goals and measured performance.

Table 1. MBR Unit Measured Performance

Goal Description	Target	Measured Performance
Turbidity Removal	<0.2 NTU, 90th percentile	<0.06 NTU – All Phases
		Average 0.015 NTU – Overall
Effluent Ammonia	<1 mg/L, 90th percentile	0.015 mg/L Average – Overall
		3.6 mg/L Maximum Phase 1c
Effluent Nitrate	<8 mg/L, 90th percentile	6.2 mg/L, 90th percentile – Phase 1b only[a]
	<5 mg/L, 90th percentile	5.2 mg/L, 50th percentile – Phase 1b only[a]
Effluent TP	<0.1 mg/L, 90th percentile	2.7 mg/L, 90th percentile
		0.9 mg/L, 50th percentile
Total Coliform	2.2 CFU/100 mL 7-day median Sample	No detect 12/1 – 3/15[c]
Long Term Flux Decline	<2% /yr	Not Measured[b]
Backpulse Interval	>15 minutes	>90 days

a Effluent nitrate exceeded performance goals in all other phases, see Table 6.

b Unable to measure during pilot test duration.

c Total Coliform average 10^3 CFU/100 mL during Start-up and 10^2 CFU/100 mL during Phase 1a.

Performance for individual process parameters and ability to meet other study goals is summarized below.

Turbidity Removal

The MBR unit produced consistently low effluent turbidities, even under peak flow conditions. For all phases and flows tested, the performance goal was achieved.

Ammonia Removal

The MBR achieved ammonia removal consistently throughout the pilot, with one exception. For a brief period during Phase 1c, ammonia was not completely removed (effluent concentration 3 mg/L), when aerobic tank mixed liquor concentrations dropped below 2,000 mg/L, reducing the population of nitrifiers. Mixed liquor concentrations dropped due to dilute influent waste streams.

Nitrate Removal

Effluent nitrate process goals were not met consistently. The MBR process met the "<8 mg/L 90th percentile effluent nitrate" process goal only during Phase 1b and Phase 1c, when mixed liquor concentration in the anoxic zone were high (>8,000 mg/L). In all other phases, effluent nitrate exceeded process goals.

TP Removal

The MBR unit was not designed to perform biological phosphorous removal. No separate anoxic zone was provided and the anaerobic zone was not designed for phosphorous removal.

As a result, the system did not meet the TP removal performance goal during any phase. Effluent TP was consistently 1 mg/L or less in Phase 1a, 1b, 2a, and 2b. There was no improvement in removal efficiency then the process was modified for biological phosphorus removal for Phases 3a and 3b.

Total Coliform Removal

Effluent total Coliform performance goals were met in Phase 1b, Phase 2 and Phase 3. During Start-up, effluent total Coliform concentrations were as high as 1.7 x 10^3 CFU/100 mL. Effluent Coliform levels dropped in Phase 1a and 1b and no Coliform was detected for the remainder of the study.

Operation at Low SRT

The system operated successfully at a total sludge age of approximately 8 days and an aerobic sludge age of approximately 6 days for more than three months. The system did not have any operation difficulties with high vacuum pressures and complete ammonia removal (<0.02 mg/L) and low effluent turbidities (0.02 NTU average) were achieved during the low sludge age period.

Response to Peak Flows

The system responded well to three four-hour peaking tests where temperature corrected flux was increased to more than 20 gfd. Effluent turbidities remained constant in two of the peaking tests ranging from 0.01 to 0.03 NTU. Effluent turbidity in one test increased over the period of the test (4 hours), but never exceeded 0.09 NTU. In addition, the system operated for 22 days at an average temperature corrected flux of approximately 20 gfd. Effluent turbidity during this period averaged 0.02 NTU.

Long Term Flux Decline

The duration of the pilot study was too short to determine long-term flux decline. However the system operated for more than three months at 15 gfd with no flux decline. Determination of true long term flux decline involves calculation of new membrane clean water flux to the post-recovery clean water for at least four to five consecutive recovery clean intervals. Only one recovery clean was performed in the pilot study. Therefore, it was impossible to determine long-term flux decline.

Backpulse Interval

The MBR successfully operated in relax mode, with no backpulse for more than 90 days in Phases 1c, 2a, 2b, 3a, and 3b, meeting the performance goal.

Introduction

The King County Department of Natural Resources (King County) conducted a nine-month demonstration pilot testing project to assess the performance of eight emerging wastewater treatment technologies. The focus of this project is to assess technologies capable of producing effluent meeting or exceeding State of Washington Class A Reuse Standards.

Description of the Technology

The MBR has been used primarily in small-scale (< 1 mgd) wastewater treatment applications. Recently, it has become a cost effective alternative to conventional activated sludge with filtration for both small and larger scale (up to 5 mgd) treatment facilities when high quality effluent is required or land prices are high.

The MBR is a suspended-growth secondary treatment process. Screened raw water is fed to a series of activated sludge basins and on to a membrane tank. Hollow fiber membranes are submerged in the membrane tank (Figure 1). A vacuum pump draws suction on the submerged membranes to draw effluent through the membranes. No primary or secondary clarifier is used.

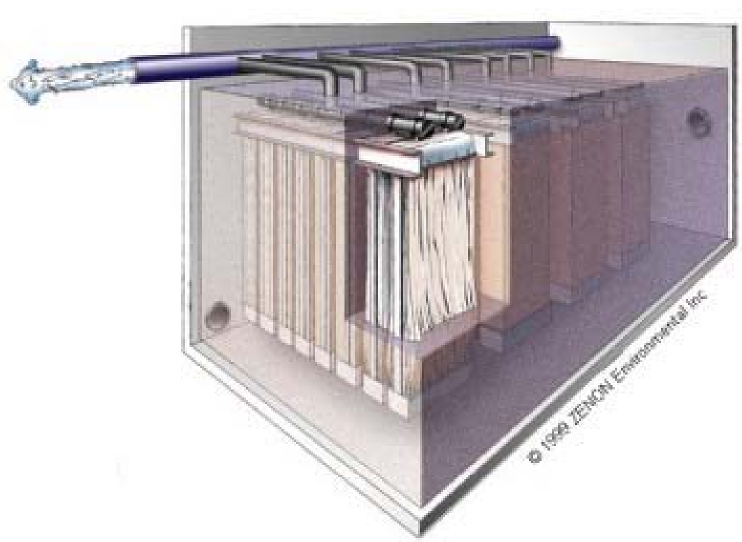

Figure 1. Hollow Fiber Membrane Tank Cross Section (Zenon Environmental Website)

Full-Scale Facilities

The following table (Table 2) is a list of water reuse full-scale municipal WWTP Zenon MBR installations in the United States. Design flows, water source type, start date, upstream bar screen size, mixed liquor concentration, sludge age, process goal and effluent quality information is shown where available.

Table 2. Full Scale Zenon WWTP Installations in the U.S. (Information compiled by Zenon Environmental and HDR)

Location	Design Flow (mgd)	Raw Water Source	Start Date	Bar Screen	MLSS Concentration (mg/L)	SLUDGE AGE (day)	Process Goal	Effluent Quality
Lone Tree WWTP Arapahoe County, CO	1 to 1.5	Municipal Commercial Industrial	August 1998	3 mm*	13,000 to 15,000	24	Nitrification, Phosphorus Removal	<4 mg/L TSS; <4 mg/L BOD; <0.2 mg/L P
Lehigh Acres WWTP Lehigh Acres, FL	0.5 to 0.75	Municipal Commercial Industrial	May 1999	3 mm	13,000 to 14,000	22	Nitrogen removal	<0.2 mg/L TSS; <2 mg/L BOD; <2 mg/L NO_3
Key Colony Beach WWTP Key Colony Beach, FL	0.3 to 0.8	Municipal	January 1999	3 mm	12,000 to 15,000	20	Nitrification	<1 mg/L TSS; <4 mg/L BOD
Anthem WWTP Anthem, AZ	1 to 2.5	Municipal	April 2001	6 mm	12,000 to 14,000	18	Nitrification	<4 mg/L TSS; <4 mg/L BOD
Cohasset WWTP Cohasset, MA	0.4 to 1.0	Municipal	June 2000	3 mm	10,000 to 12,000	>30	Nitrification	<4 mg/L TSS; <4 mg/L BOD
American Canyon WWTP American Canyon, CA	2.5 to 3.8	Municipal	March 2002				Nitrification	
City of Corona WWTP City of Corona, CA	2 mgd	Municipal	January 2002				Nitrification	
Laguna County WWTP Laguna County, CA	0.5 mgd	Municipal	November 2002				Nitrification	
Epping WWTP Town of Epping, NH	0.35	Municipal	February 2002				Nitrification, Phosphorus Removal	

*Lone Tree converted from a 6mm fine screen to a 3mm fine screen after fouling problems on the membrane with hair and other organic debris

Comparison with Conventional Treatment

Compared to conventional treatment, the reported benefits of the MBR are:

- **Eliminates secondary clarifiers**. Because the membranes replace the clarification process, the cost, site space, and settling problems associated with secondary clarifiers are eliminated.
- **Allows operation at high mixed liquor suspended solids concentrations**. Mixed liquor suspended solids (MLSS) can range from 10,000 to 20,000 mg/L compared with 1,000 to 4,000 mg/L in conventional treatment processes.
- **Allows operation at high sludge age without large aeration volume**. Typical sludge ages in the MBR process are 20 to 30 days. Achieving high sludge age does not require a large aeration volume because the solids inventory in the system is high.
- **Creates a small footprint**. Because no secondary clarifiers are used and aeration basins can be smaller, MBR facilities require less site space than conventional treatment facilities.
- **Produces a high quality effluent**. Typical effluent suspended solids are less than 1 mg/L. Typical BOD is less than 5 mg/L. Nitrification, denitrification, and chemical phosphorus removal have been accomplished successfully with MBR systems.

Table 3 shows comparison of effluent quality and operation parameters.

MBR systems also have reported disadvantages compared with conventional treatment processes:

- **Requires more complex chemical facilities**. The MBR requires sodium hypochlorite, sodium bisulfite, and sometimes citric acid addition. Sodium hypochlorite and citric acid are often used in the membrane cleaning processes. Sodium bisulfite is often used to neutralize recovery clean solution. More chemical storage, handling, and delivery systems are required than for conventional treatment.
- **Requires a high level of automation and programming to operate**. The cleaning processes for membranes are almost completely automated. The membrane manufacturer provides instrumentation and the PLC that interacts with a plant SCADA system. The plant SCADA system must be able to handle the numerous inputs from the membrane PLC and track membrane performance.

Table 3. Comparison of MBR to Conventional Treatment

Parameter	Conventional Treatment	MBR
Effluent BOD (mg/L)	10-30	<5
Effluent TSS (mg/L)	10-30	<5
Sludge Age (days)	1-7	7-30
Mixed Liquor Suspended Solids (mg/L)	1,000-4,000	10,000-20,000

Pilot Testing

Goals and objectives

The goal of the pilot study was to use the MBR process to treat West Point primary influent, and to determine its effectiveness to produce reliable, high quality effluent. The specific goals for the pilot study were:

- Achieve effluent ammonia concentrations <1 mg/L, 90th percentile.
- Achieve effluent nitrate concentrations < 8 mg/L, 90th percentile.
- Achieve effluent nitrate concentrations < 5 mg/L, 50th percentile.
- Achieve effluent turbidity <0.2 NTU, 90th percentile.
- Achieve effluent TP <0.1 mg/L, 90th percentile.
- Meet Class A reclaimed water standards.

Other pilot study objectives were:

- Evaluate tendency of membranes to "plug," (i.e., build up head too fast).
- Evaluate potential for long-term membrane fouling (inability to clean membrane completely).
- Less than 2% long term flux decline/yr.
- Backpulse interval exceeding 15 minutes.
- Evaluate the response to peak flows.
- Evaluate operation at high and low MLSSs.
- Evaluate low sludge age operation.

The MBR unit was evaluated for compliance with the State of Washington Class A criteria. Class A requires oxidation and coagulation (i.e., chemical pre-treatment upstream of the granular media filter to ensure reliable turbidity removal) and filtration. Class A turbidity removal requirements were developed for granular media filters (<2 NTU 95% of the time and <5 NTU all of the time). However, the small pore size of the MBR 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 different turbidity standard for membranes without the use of a coagulant, which is <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 adopted for membrane systems in Washington State similar to the Title 22 Regulations in California.

The State of Washington Class A requirement for total Coliform is 2.2 CFU/100 mL for a seven day median sample and 23 CFU/100 mL single sample maximum. This standard applies whether granular filtration or membrane filtration is used.

Demonstration Setup

The Zenon MBR unit arrived at the West Point WWTP in early August 2001. Set up was completed on August 29, 2001. The unit was on site for a total of seven months. Table 4 summarizes pilot unit equipment. A Zenon Start-up engineer was on site in early September to conduct the system Start-up and train County staff to operate the unit.

The pilot unit, as shown in Figure 2, was located inside the Technology Assessment Facility at the West Point Treatment Plant.

Table 4. Summary of Pilot Unit Equipment (Zenon Environmental, Inc.)

Equipment	Unit	Value
Feed Pump	gpm	0-10
Anoxic Tank (operating volume)	gallons	747
Aerobic Tank (operating volume)	gallons	1408
Membrane Module	Micron	0.04 nominal 0.1 absolute
Membrane Tank	gallons	172
Membrane Units	sf	660
Backpulse Tank	gallons	26
Sludge Wasting Tank	gallons	200
Recirculation Pump	gpm	0-45
Permeate Pump	gpm	0-20
Blower for Aerobic Tank	cfm	0-60
Blowers for Membrane Tank (2 blowers in parallel)	cfm	0-25

Figure 2. Zenon MBR Pilot Unit

The schematic of the MBR pilot system is presented in Figure 3. The MBR feed pump is a submersible pump located in a wide spot tank that receives either primary influent or primary effluent from the West Point WWTP. Both primary influent and primary effluent go through a 6 mm fine screen before flowing to the wide spot. From the wide spot, flow is directed through a pneumatic valve to the anoxic tank. The submersible recirculation pump was reconfigured on December 31, 2001 after high mixed liquor readings reflected inadequate mixing. The pump discharge was routed to a spray header in the tank, rather than to the tank bottom.

The aerobic tank is fed by gravity flow from the anoxic tank. A level element in the aerobic tank is interlocked with the pneumatic "feed" valve and the permeate pump to control flows into and out of the process. The permeate pump flow rate is manually adjusted with a valve on the discharge side of the pump. The pneumatic valve is operated to maintain a constant water level in the aeration basin. When water is withdrawn from the system, the water level drops in the aerobic tank, and the feed solenoid opens to bring influent to the anoxic tank. A centrifugal blower provides air to coarse bubble diffusers located in the bottom of the aerobic tank.

A recirculation pump directs flow from the aerobic tank to the membrane tank. An overflow pipe returns flow from the membrane to the anoxic tank during nitrification/denitrification phases. Recycle flows were typically 400% of the permeate flow. The pilot was reconfigured to return MLSS recycle to the aerobic tank during the biological phosphorus removal phases. During the biological phosphorous removal phases, a mixing pump in the aerobic tank directed flow back to the anaerobic tank (anoxic tank) at a rate of 5 gpm. Sludge is wasted from the aerobic tank with a peristaltic pump.

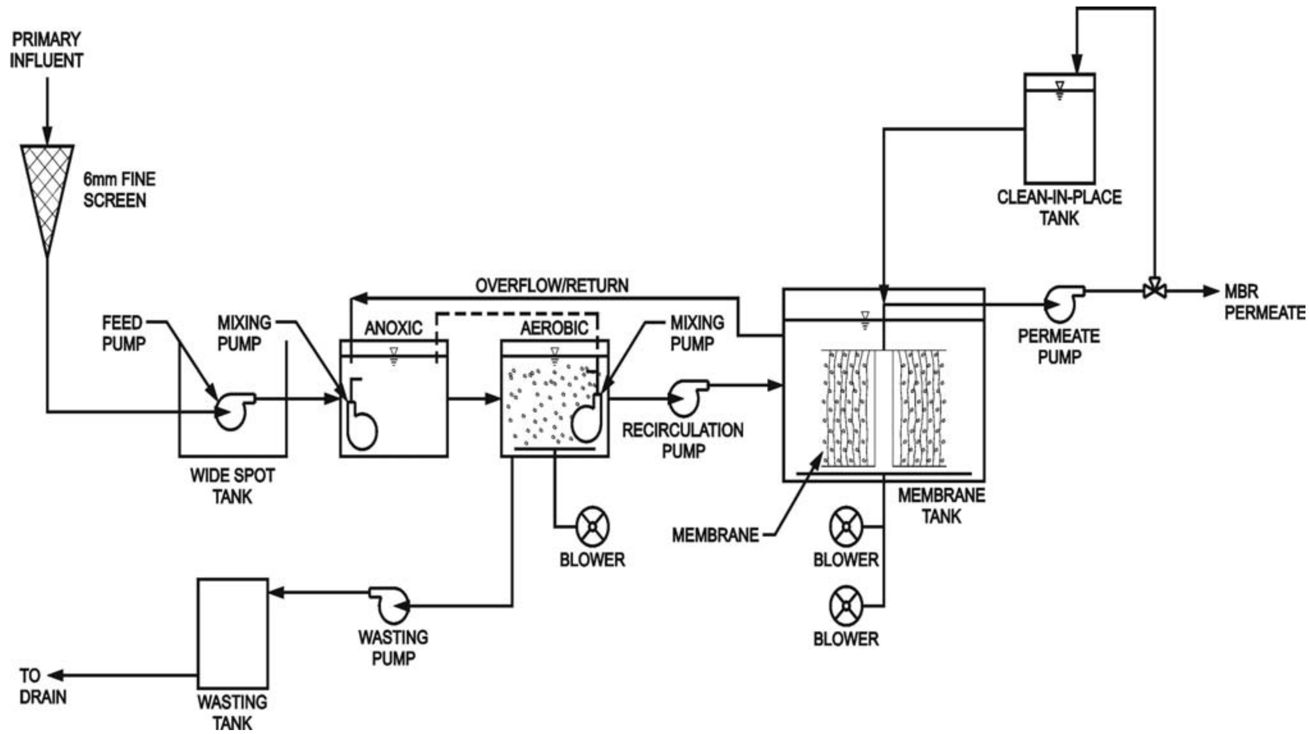

Figure 3. MBR Pilot Configuration (Zenon Environmental)

The membrane module includes a group of submerged hollow-fiber membranes that come together in a manifold. The system is single module model ZW 500c with a membrane surface area of 660 square feet. Each membrane is approximately 6 feet long. The permeate pump draws a vacuum from this manifold at the top of the cassettes and draws permeate through the membranes to drain or to downstream processes. A HACH 1720D turbidimeter measures permeate turbidity.

Vacuum is measured in terms of transmembrane pressure (pressure across the membrane). In this report, the units for vacuum are inches or mercury referred to as (inches Hg). As run time increases solids build up on the membrane surface. At high vacuum (24 inches Hg), the permeate pump shuts off and the tank is aerated without permeate removal.

A blower directs 25 cfm to coarse bubble diffusers in the base of the membrane tank. This blower operates cyclic aeration, on a timer set to 10 seconds on, 10 seconds off. The air is intended to scour the membrane surface.

Membranes must be cleaned routinely to maintain a high flux. There are three distinct types of chemical membrane cleaning – Backpulse/Relax, Maintenance and Recovery. In all three types, air bubbles remove debris from the membrane surface.

- **Backpulse Clean** The backpulse cleaning cycle is a short-term cleaning process (typically 30 to 45 seconds long), initiated every 15 minutes to remove accumulated debris on the membrane surface. Backpulse solution is directed through the membrane in a reverse direction. A calcium hypochlorite solid puck was placed in the clean-in-place tank. The backpulse flow is set at 1.5 times the average flux rate for the system. Automatic valves, controlled by the membrane system PLC, isolate the filtrate line and direct backpulse solution to the membranes.
- **Relax Mode** In relax mode, the permeate pump is turned off during the backpulse period. No solution is fed in a reverse direction. The membranes are suspended with no vacuum (“relax”). The blowers in the tank bottom continue to operate and provide air scour. The majority of Zenon’s full-scale installations operate successfully in relax mode. Operation in relax mode is attractive because system recovery increases if permeate or other water is not required for backpulse. In addition, in full-scale installations, the backpulse solution is a weak sodium hypochlorite solution. Operation in relax mode reduces sodium hypochlorite consumption.
- **Maintenance Clean** The goal of the maintenance clean is to increase the time between recovery cleaning cycles. The pilot goes through the maintenance clean three times a week (Monday, Wednesday, and Friday). During two of the maintenance cleaning cycles, sodium hypochlorite is backpulsed and relaxed alternately at intervals and durations input by the system operator. During one of the weekly cleaning cycles, citric acid is used instead of sodium hypochlorite. The total system downtime for each maintenance clean is approximately one hour.
- **Recovery Clean** The recovery clean process is the most time-consuming cleaning process. When the transmembrane pressure (TMP) increases to 17 inches Hg consistently after maintenance cleaning, a recovery cleaning process may be initiated. During a recovery clean, the membrane tank is drained of all MLSS and the system is removed from service. A strong (1,500-2,000 ppm) sodium hypochlorite solution is placed in the tank and the membrane fibers are soaked for approximately 24 hours.

In addition to the chemical cleaning processes, blowers provide air to diffuser plates located below the membranes.

In this pilot testing, the system PLC controlled the backpulse/relax mode cleaning and the alarms. Maintenance and recovery cleans were completed manually. System data was logged to the facility SCADA system via the system data highway at fifteen-minute intervals for: permeate flow rate, TMP, pre-backpulse relax vacuum, post-backpulse relax vacuum, membrane tank level, and membrane tank temperature. Daily field readings were taken on: wasting rate, recycle rate, membrane tank airflow, aerobic tank airflow, effluent turbidity, pH, and aerobic tank dissolved oxygen.

Automatic samplers collected composite primary influent and permeate for analysis. Composite samples were analyzed for conductivity, BOD, COD, TSS/VSS, TKN, and alkalinity. Grab samples were also taken periodically and analyzed for metals and organics, microbes (heterotrophic plate count, total Coliform), and nutrients (total phosphorous, ortho-phosphorous, ammonia and nitrate).

Testing Overview

The pilot unit ran from August 29, 2001 to March 25, 2002. Table 5 shows the breakdown of phases and operating conditions. A detailed breakdown of daily operating conditions and operator notes is included in Appendix C. Table 6 shows the significant operating events during the study. Figure 4 and Figure 5 provide an overview of system operating conditions throughout the pilot study. Individual process operating and performance parameters are discussed in detail in the following sections.

Startup

During the start-up period, the tanks were filled with sludge from the West Point WWTP aerobic reactor. No dilution was provided. Several problems were encountered during this startup period. Six weeks were required to establish stable operation. No periods of steady-state operation were identified.

Phase 1

In Phase 1 the operational target for sludge age was 10 days. Phase 1 is broken into three sub-phases: Phase 1a (6 gpm); 1b (9 gpm); and 1c (low MLSS). Two four-hour peak flow tests were performed in Phase 1: one at the end of Phase 1a; and, one at the end of Phase 1b.

Phase 2

In Phase 2 the operational target for sludge age was 6 days. Phase 2 is broken into two sub-phases: Phase 2a (6 gpm); and, Phase 2b (permeate pump failure). A 4-hour peak flow test was performed at the end of Phase 2a.

Phase 3

Phase 3 was an operation for biological phosphorus removal with a six-day sludge age. The pilot setup was modified to: return MLSS to the aerobic zone (changing the anoxic zone to an anaerobic zone), add internal recycle in the aerobic zone, and reduce DO in the aerobic tank to create aerobic/anoxic conditions. Figure 4 shows MLSS concentrations in the aerobic tank as well as total and aerobic traditional sludge age throughout the study.

A testing plan was prepared at the beginning of the pilot study and is contained in Appendix A. The pilot testing followed the test plan with one exception; nitrification without denitrification was not investigated. With one month remaining in the pilot study it was decided to skip this test phase and move directly to the biological phosphorus removal phase. In addition, process phases were defined by aerobic sludge age in this report rather than total sludge age, as in the testing plan. After these changes, the actual MBR pilot testing had five phases.

Phase 1a/1c - Nitrification/Denitrification at 10 day Aerobic Sludge Age, 6 gpm. The main objective of Phase 1 was to provide reliable nutrient and TSS removal. A 4-hour hydraulic peaking test at 9 gpm was performed to determine system response to higher flows.

Phase 1b – Nitrification/Denitrification at 10 day Aerobic Sludge Age, 8 gpm. The objective of Phase 1b was to provide reliable nutrient and TSS removal rates at a higher flux than in Phase 1.

Phase 2a/2b – Nitrification/Denitrification at 6 day Aerobic Sludge Age, 6 gpm. The objective of Phase 2a/2b was to determine the lowest sludge age the MBR can be operated at without excessive fouling.

Phase 3a – Biological P Removal at 6 day Aerobic Sludge Age, 6 gpm flow. The objective of Phase 3a is to determine the effect of biological phosphorus removal on MBR system performance.

Phase 3b – Biological P Removal at 6 day Aerobic day Sludge Age, 9 gpm flow. The objective of Phase 3b is to determine how the system operates at high flows for an extended period of time.

The process was controlled by setting the wasting rate to achieve the desired sludge age. Many studies on membrane bioreactors set the mixed liquor concentration, rather than sludge age. Sludge age was chosen because one of the study goals was to evaluate low sludge age operation. Low sludge age operation was investigated because as sludge age decreases, aeration basin size decreases, but at some point, organic material is no longer removed. In addition, lower sludge age mixed liquors are often “sticky” and may be difficult to filter. A goal of the study was to determine if the MBR could be operated successfully with a low sludge age.

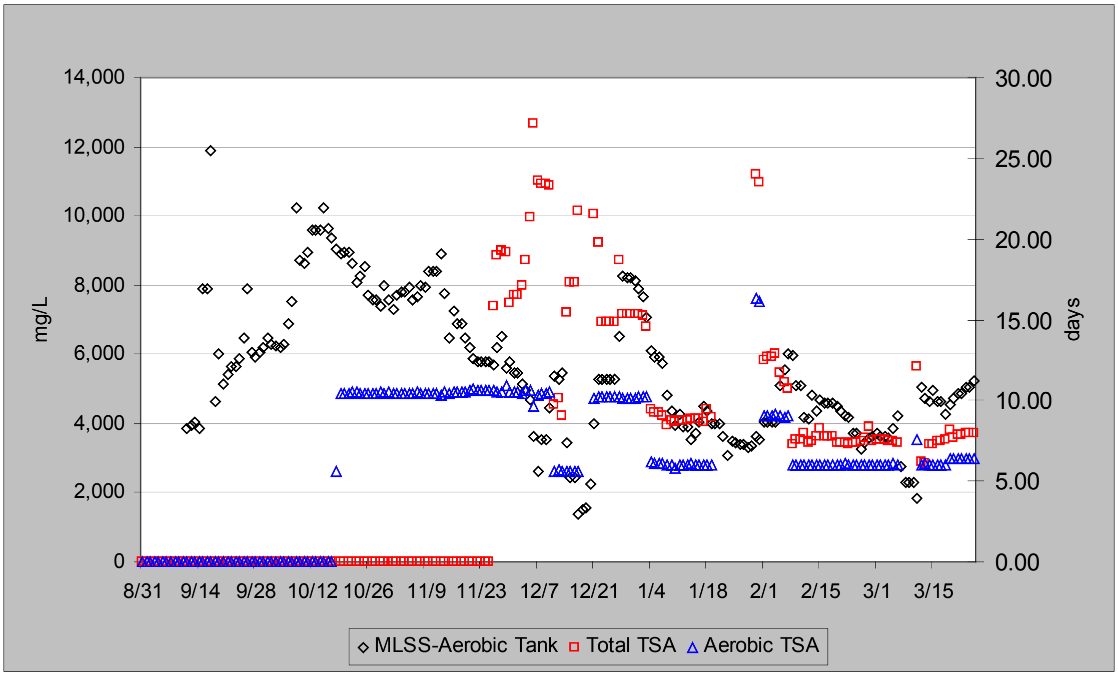

Figure 4. Mixed Liquor Suspended Solids (MLSS) and Traditional Sludge Age (TSA), Total And Aerobic

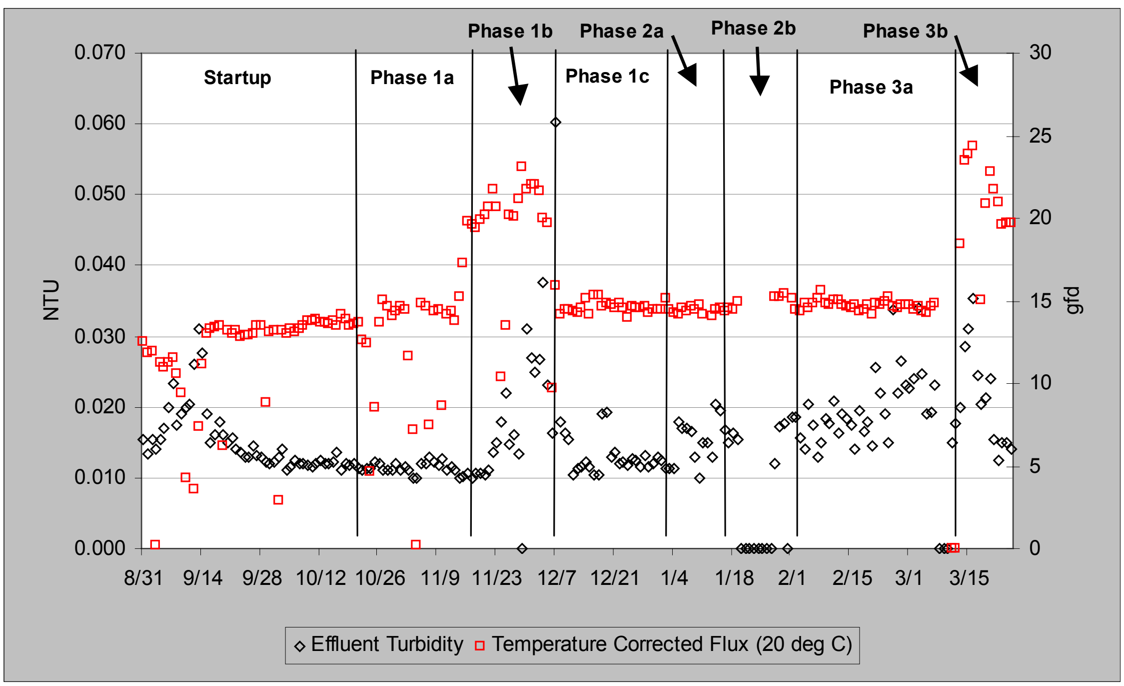

Figure 5. Effluent Turbidity and Temperature Corrected Flux

Table 5. Test Overview

Phase	Process Goal	Feed Source	Wasting Rate (gpd)	Actual Aerobic TSA (days)	Actual Total TSA (days)	Average Flow (gpm)	Average Flux * (gfd)	Relax mode or Backpulse mode	Dates	Comments
Start-up		Primary Effluent 8/29-10/7 Primary Influent 10/8	0	--	--	5.4	11.7	Relax 8/29-9-13 Backpulse 9/14	8/29-10/16 (20 days)	No wasting took place during startup.
1a	Nitrification/Denitrification	Primary Influent	160	10.0	--	5.3	11.5	Backpulse	10/17-11/15 (31 days)	No anoxic MLSS data taken.
1b	Nitrification/Denitrification	Primary Influent	155	10.0	15.0	7.4	16.1	Backpulse 11/16-12/2 Relax 12/3	11/16-12/7 (22 days)	
1c	Nitrification/Denitrification	Primary Influent	176	--	--	5.5	12.0	Relax	12/8-1/3	Wasting was 290 gpd on December 11,stopped wasting from 12/18-12/20, due to low MLSS
2a	Nitrification/Denitrification	Primary Influent	270	5.6	8.5	5.5	12.0	Relax	1/4- 1/19 (16 days)	
2b	Nitrification/Denitrification	Primary Influent	53	--	--	5.5	12.0	Relax	1/20-2/4 (16 days)	Permeate pump failed 1/20-1/28, No wasting 1/20-1/28
3a	Biological Phosphorus Removal	Primary Influent	233	--	--	5.5	12.0	Relax	2/5-3/12 (34 days)	Unit shutdown on high vacuum alarm 3/7-3/9
3b	Biological Phosphorus Removal	Primary Influent	262	6.1	7.4	7.8	16.9	Relax	3/13-3/25 (13 days)-	

*Flux is not temperature corrected.

Operating Events

Table 6 summarizes the significant operating events during all phases of the study.

Table 6. Operating Events

Phase	Date	Mode of Operation	Flux rate (gpm)	Source	Operating Event
Start-up	29-Aug	Relax	6	PE	
Start-up	14-Sep	Back Pulse	6	PE	Changed to Backpulse due to high vacuum pressure.
Start-up	8-Oct	Back Pulse	6	PI	Switched feed source from Primary Effluent to Primary Influent.
Phase 1a	17-Oct	Back Pulse	6	PI	Started wasting at 0245 hrs.
Phase 1a	15-Nov	Back Pulse	9	PI	Performed Peak Hydraulic test. Flux rate increase to 9 gpm for 4 hours.
Phase 1b	5-Dec	Relax	7.3	PI	2230 hrs - process alarmed on low membrane tank level; Lost feed to MBR due to isolation of WS tank # 3; Wasting continued until 0824 hrs (12/6).
Phase 1b	6-Dec	Relax	7.3	PI	Aerobic tank level lowered to 32.7 inches. Process back on line at 1215 hrs.
Phase 1b	7-Dec	Relax		PI	Performed Hydraulic Peaking Test; Flux rate decreased to 5.5 gpm; recirc rate = 22 gpm @ 0709 hrs. During test flux rate = 8.2 gpm; recirc rate = 33 gpm).
Phase 1c	11-Dec	Relax	5.5	PI	Wasting increased to 290 gpd (0916 hrs). Sludge Age = 8 days.
Phase 1c	18-Dec	Relax	5.5	PI	Stopped wasting around 1800 hrs due to low MLSS concentrations. Membrane tank = 1830; Aerobic = 1380.
Phase 1c	21-Dec	Relax	5.5	PI	Resumed wasting @ 1748 hrs; Aerobic = 4000 mg/L TSS.
Phase 1c	31-Dec	Relax	5.5	PI	Modified mixer to improve mixing efficiency, routed pump discharge to distribution manifold located at the top of the tank versus previously discharging to the bottom of the tank.
Phase 2a	4-Jan	Relax	5.5	PI	Increased wasting to 270 gpd; High Vacuum Alarm at 1543 hrs. Membrane air and recirc pump found off following Maintenance Clean ~ 5 hrs.
Phase 2a	10-Jan	Relax	5.5	PI	0118 hrs - Permeate pump failure; 0445 hrs - Stopped wasting; 1030 hrs - Process & wasting resumed. Unit off line - 9 hrs; Unit off line with wasting - 3.5 hrs;
Phase 2a	13-Jan	Relax	5.5	PI	0052 hrs - Permeate pump failure; 0949 hrs - Secured wasting pump; 0950 hrs - Restarted pilot; 1145 hrs - Resumed wasting; Unit off line with wasting – 9 hrs.
Phase 2a	15-Jan	Relax	5.5	PI	Reduced process air to 22 scfm; Target DO = 2 mg/L; Latest average DO ~ 4 mg/L.
Phase 2a	18-Jan	Relax	5.5	PI	Reduced process air from 22 to 20 scfm; Target DO = 2 mg/L; Latest average Do ~ 4 mg/L.
Phase 2a	20-Jan	Relax	5.5	PI	Permeate pump tripped on overload. Unit secured until pump can be fixed.
Phase 2b	22-Jan	Relax	0	PI	Added PI feed; Aerobic tank level 34.3 " to 39.6".
Phase 2b	23-Jan	Relax		PI	Added PI feed; Aerobic tank level 39.1" to 44.2".
Phase 2b	24-Jan	Relax		PI	Added PI feed; Aerobic tank level 43.9" to 49.5".
Phase 2b	25-Jan	Relax			Installed new permeate pump but had problems; reinstalled old pump; Received blower B-3 motor failure alarm YA-3; Will trouble shoot on 1/28.
Phase 2b	28-Jan	Relax	5.5	PI	Unit back in production; only operating with aux membrane blower - 18 scfm; Process air at 19 scfm.
Phase 2b	30-Jan	Relax	5.5	PI	Started wasting at1346 hrs..
Phase 3a	8-Feb	Relax	5.5	PI	Adjusted wasting rate from 180 gpd to 270 gpd @ 1530 hrs.
Phase 3a	15-Feb	Relax	5.5	PI	Stopped maintenance cleans.
Phase	**Date**	**Mode of Operation**	**Flux rate (gpm)**	**Source**	**Operating Event**

Phase 3a	7-Mar	Standby	0		Unit shutdown on VAH-01 Vac High Alarms (0231 hrs); Wasting pump secured @ 1630 hrs; Unit in standby
Phase 3a	9-Mar	Standby	0		Transferred PI feed to pilot. Tank level from 42.5 to 47.5 (1645 hrs).
Phase 3b	11-Mar	Relax	5.5	PI	Unit back on line @ 1310 hrs with membrane air blower @ 24 scfm; Resumed wasting at 270 gpd @ 1537 hrs.
Phase 3b	13-Mar	Relax	9	PI	1302 hrs - Increased flux rate 5.5 to 9.0 gpm; Lowered process air from 15 to 17 scfm.
Phase 3b	17-Mar	Relax	5.5	PI	Shutdown on High Vac 1213 hrs; Power bump at 1100 hrs which kicked out recirc pump; Performed hypochlorite maintenance clean; Returned unit to production at 5.5 gpm (1730 hrs).
Phase 3b	20-Mar	Relax	8	PI	Unable to maintain 9.0 gpm flux rate; Vacuum pressure continues to rise (max 20.7 " of Hg) Lowered flux rate to 8.0 gpm @ 1611 hrs.
Phase 3b	25-Mar				Testing complete.
--	26-Mar				Recovery Clean performed.

Process Data Considerations

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) compared to 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, the liquid viscosity increases. For a constant flow, a colder feed stream requires a higher feed pressure. This, in turn, increases the TMP, which will shorten the filter run. As the pilot testing continued into the winter months and the feed stream temperature decreased, the permeate flow rate was not reduced to keep the biological process stable. To account for the temperature affect, a temperature correction factor was used.

For this pilot study, membrane flux is reported at 20 ºC as the standard temperature. The temperature flux correction factor, 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 following sections, the operating data presented include the feed temperature and the temperature-corrected flux.

All fluxes presented in this report are temperature-corrected to 20 degrees C, unless stated otherwise.

Traditional and Dynamic Sludge Age

Traditionally, sludge age (solids retention time) is the total mass of solids in the system divided by the mass wasted per day. Because the pilot system consisted of three biological reactors with different MLSS concentrations, the total traditional sludge age (TSA) was calculated as follows:

- $$TSA_{total} = \frac{((V_{ab} * MLSS_{ab}) + (V_{an} * MLSS_{an}) + (V_{zw} * MLSS_{zw}))}{(MLSS_{ab} * W)}$$
  - V_{ab} = Aeration Basin Volume (gallons).
  - V_{an} = Anoxic Tank Volume (gallons).
  - V_{zw} = Membrane Tank Volume (gallons).
  - MLSS = Mixed Liquor Suspended Solids in Aeration Basin (mg/L).
  - W = Wasting Rate from aeration basin (gallons per day).

Because of the variation in MLSS concentration and a tendency to build MLSS in the anoxic zone, the aerobic sludge age was also monitored in order to verify sufficient sludge age was available for complete nitrification. Aerobic TSA was calculated as follows:

- $$TSA_{aerobic} = \frac{((V_{ab} * MLSS_{ab}) + (V_{zw} * MLSS_{zw}))}{(MLSS_{ab} * W)}$$
  - V_{ab} = Aeration Basin Volume (gallons).
  - V_{zw} = Membrane tank Volume (gallons).
  - MLSS = Mixed Liquor Suspended Solids in Aeration Basin (mg/L).
  - W = Wasting Rate (gallons per day).

The traditional sludge age calculation is a steady-state calculation. It assumes the system has reached a steady state with minimal changes in wasting rate and mixed liquor concentration. In this pilot setup, the wasting rates and mixed liquor concentrations changed often, sometimes radically. In this scenario, a steady-state equation is no longer valid. As a result, a dynamic sludge age (DSA) was also calculated according to the following equation (Vaccari, 1985):

- $$DSA = \left(DSA_0 - \frac{M_0}{P+K}\right) * \left(\frac{M}{M_0}\right)^{\frac{-P}{K}} + \frac{M}{(P+K)}$$

- DSA_0 = DSA the previous day (for the first data point, the traditional sludge age was used) (days).
- M_0 = Mass in the system the previous day (lbs).
- M = Mass in the system (current day).
- K = M-M_0 (lbs).
- W = Mass wasted (lbs).
- P = K-W (lbs).

For total DSA, M was calculated as:

- M = $\left(\left(V_{ab} * MLSS_{ab}\right) + \left(V_{an} * MLSS_{an}\right) + \left(V_{zw} * MLSS_{zw}\right)\right)$.

For aerobic DSA, M was calculated as:

- M = $\left(\left(V_{ab} * MLSS_{ab}\right) + \left(V_{zw} * MLSS_{zw}\right)\right)$

Because a continuous stream of data is required for these calculations, mixed liquor concentrations over weekend days were calculated as an average of the previous Friday and following Monday concentrations.

Net and Instantaneous Flows

The instantaneous membrane flow is the flow that the membrane actually handles. The net flow, however, is the average flow rate the membrane handles including the time that the membrane is not producing permeate, during backpulse or relax. Flows presented in this report are instantaneous flows. To convert to net flow:

$$Qnet = Qinst * \left(1 - \frac{0.5 \min backpulse / relax}{10 \min}\right)$$

- Qnet = Net Flow (gpm)
- Qinst=Instantaneous Flow (gpm)

Process Data

The following section summarizes process operating data for the duration of the pilot study. MLSS concentration, sludge age, dissolved oxygen, pH and alkalinity data are presented. Process performance and hydraulic performance data are presented in a later section.

MLSS Concentration

Figure 6 shows the MLSS levels in the three-pilot facility tanks; anoxic, aerobic and membrane. MLSS concentrations were consistently higher in the membrane tank than in the aerobic tank because permeate was removed in the membrane tank, concentrating the remaining solids. Mixed liquor concentrations were significantly higher in the anoxic tank than in the aerobic and membrane tanks in Phases 1b and 1c due to poor mixing and wasting from the aerobic tank. The original mixer pump configuration in the anoxic tank discharged to the base of the tank. This configuration did not adequately mix the tank contents. (Mixed liquor samples were not taken from the anoxic zone during Start-up and Phase 1a.) When the mixer pump was modified to discharge to a distribution manifold at the top of the tank, MLSS concentrations decreased and more closely matched concentrations in the aerobic and membrane tanks. When MLSS return was modified in Phase 3a to return solids from the membrane tank to the aerobic tank rather than the anoxic tank, MLSS concentrations dropped in the anoxic tank, as expected.

MLSS concentration dropped in both the aerobic and membrane tanks in Phase 1b and 1c. This drop was largely due to diluted feed attributed to wet weather. Influent BOD was consistently less than 100 mg/L. Typical wastewater influent BOD is 200-300 mg/L.

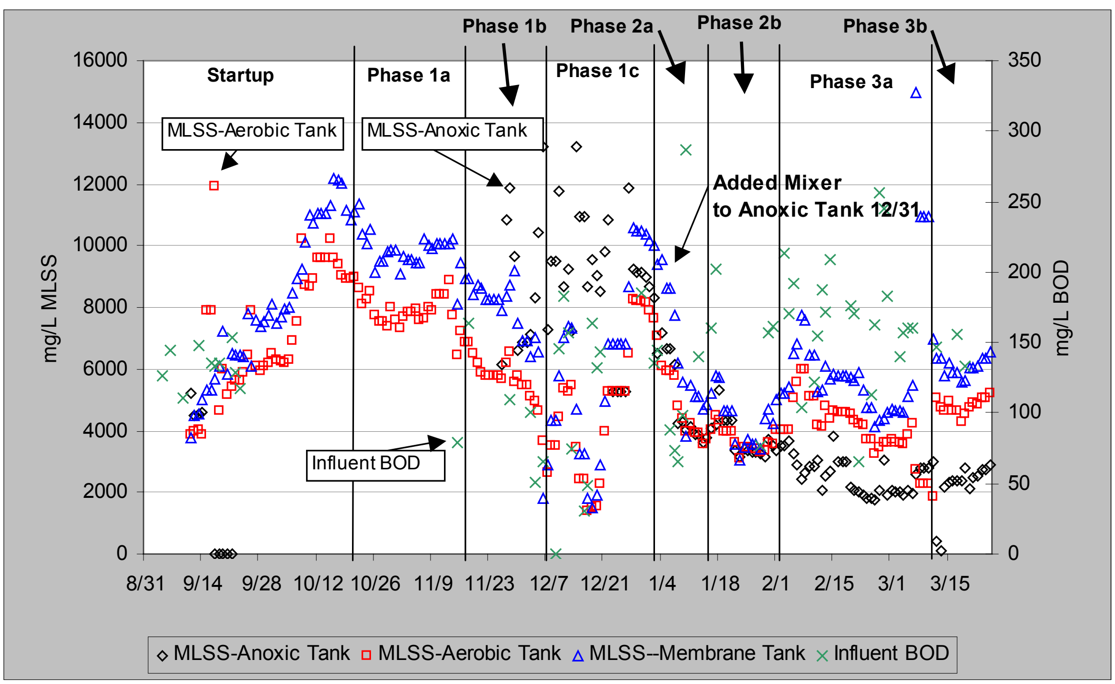

Figure 6. Mixed Liquor Concentrations in Anoxic, Aerobic and Membrane Tanks

Sludge Age

The sludge age target for Phase 1 was 10 days. The aerobic TSA was consistently 10 days throughout Phase 1. Figure 7 shows total TSA and aerobic TSA. Figure 8 shows Total DSA and aerobic DSA. The total TSA (including the anoxic zone) was far above the 10-day target, due to the high mixed-liquor concentrations in the anoxic tank. Aerobic DSA averaged 11 days over Phase 1, with higher sludge ages in Phase 1a and 1b, and lower DSA in Phase 1c, when mixed liquor concentrations in the aerobic tank and membrane tank were low. Total DSA was as high as 25 days.

Operation at lower DSA and TSA in Phase 2a, 2b, 3a, and 3b did not adversely affect system flux and pre-backpulse vacuum, as shown in Figure 25. The system also continued to nitrify effectively during these phases as shown in Figure 17.

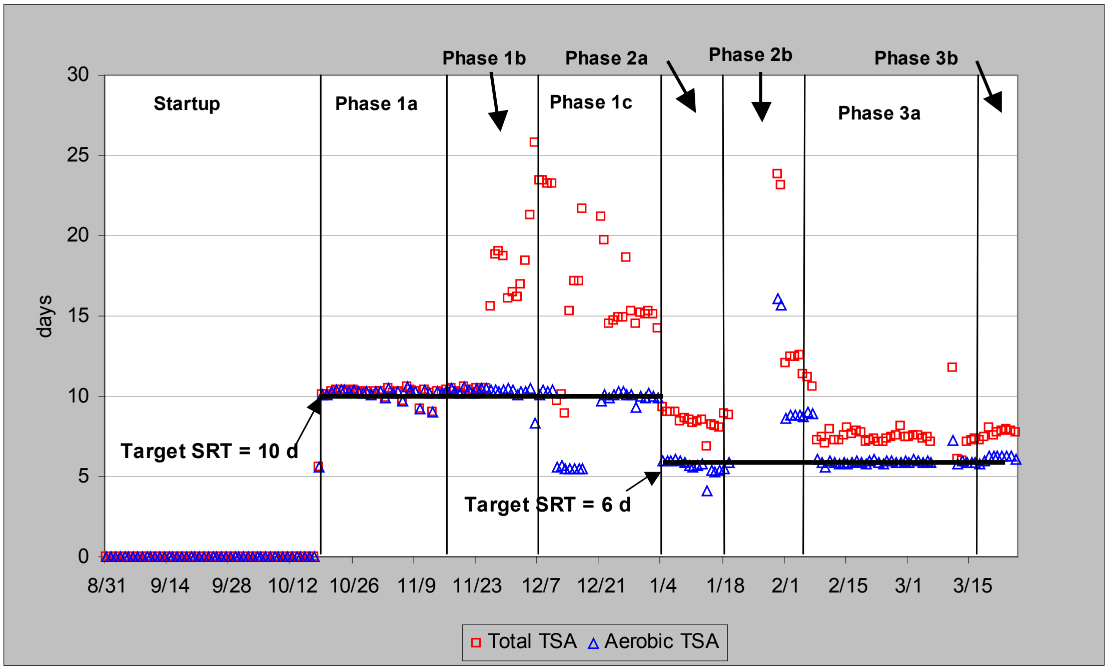

Figure 7. Total Traditional Sludge Age and Aerobic Traditional Sludge Age

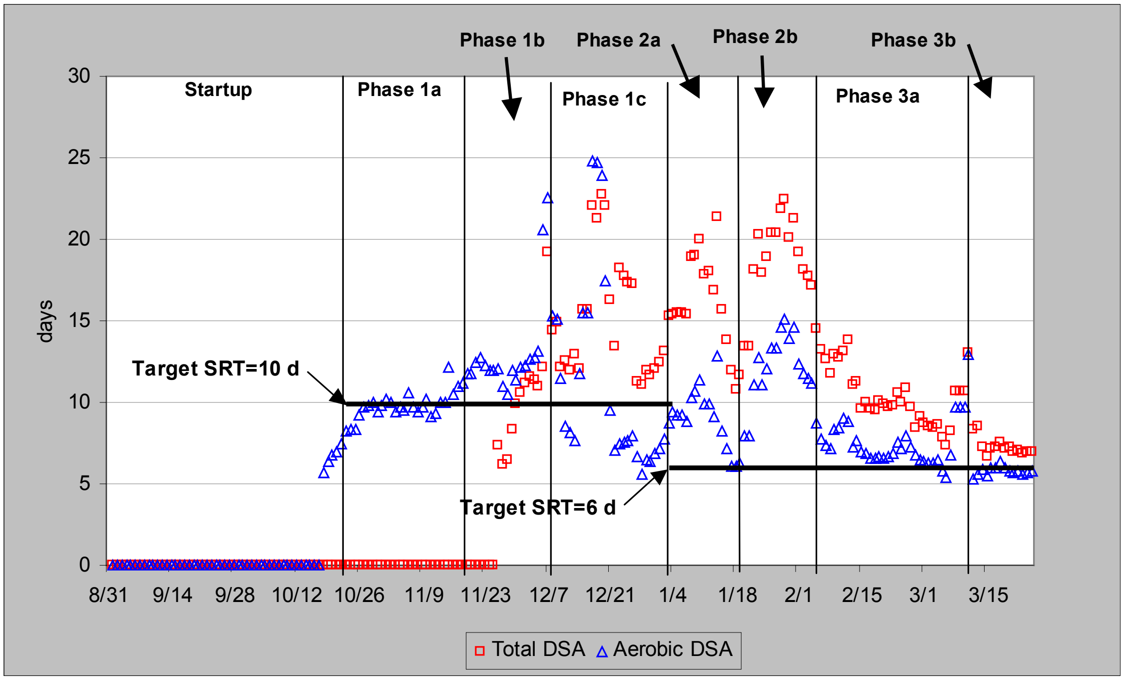

Figure 8. Total Dynamic Sludge Age and Aerobic Dynamic Sludge Age

Dissolved Oxygen

Figure 9 shows dissolved oxygen (DO) concentrations in the aerobic tanks, mixed liquor concentration in the aerobic tank, aeration tank airflow, and membrane tank airflow. DO measurements were taken daily with a handheld DO meter. DO concentrations were consistently above 2.0 mg/L, the typical target for a conventional activated sludge facility. DO varied inversely with mixed-liquor concentration, and concentrations were highest when the mixed-liquor concentration dropped significantly in Phase 1b. Conversely, DO concentration was lowest (around October 12) when MLSS concentration was highest (more than 10 g/L).

During Start-up, the aeration tank received 50-scfm of air with a target DO of 2 mg/l. Over time, due to air filter fouling, the flow capacity continued to drop reaching a max capacity of 27 scfm. Following replacement of air filters on the blower on December 3, 2001, capacity increased from 27 scfm to 52 scfm. On December 4, 2001 the process air was reduced to 28 scfm, as aerobic tank DO levels were high, greater than 10 mg/L. Process airflow was further reduced on January 15, 2002 to 22 scfm.

In Phase 1 and Phase 2 the membrane airflow and aerobic tank air flow were consistently 25 and 26 scfm, respectively. Membrane aeration was cyclic, typically 10 seconds on, 10 seconds off. For Phase 3, (biological phosphorus removal) the airflow to the membrane tank and process tank was lowered further. Because no separate tank was available to act as an anoxic zone, the goal was to reduce DO to below 2 mg/L to induce anoxic conditions within the aerobic tank (simultaneous nitrification/denitrification). During Phase 3, the membrane tank blower failed and the system operated with an auxiliary blower. As a result, airflow into the membrane tank was reduced to 18 scfm and airflow to the aerobic tank was reduced to 20 scfm initially and declined further to as low as 13 scfm. The aerobic tank DO averaged 2.9 mg/L in Phase 3a and 0.9 mg/L in Phase 3b.

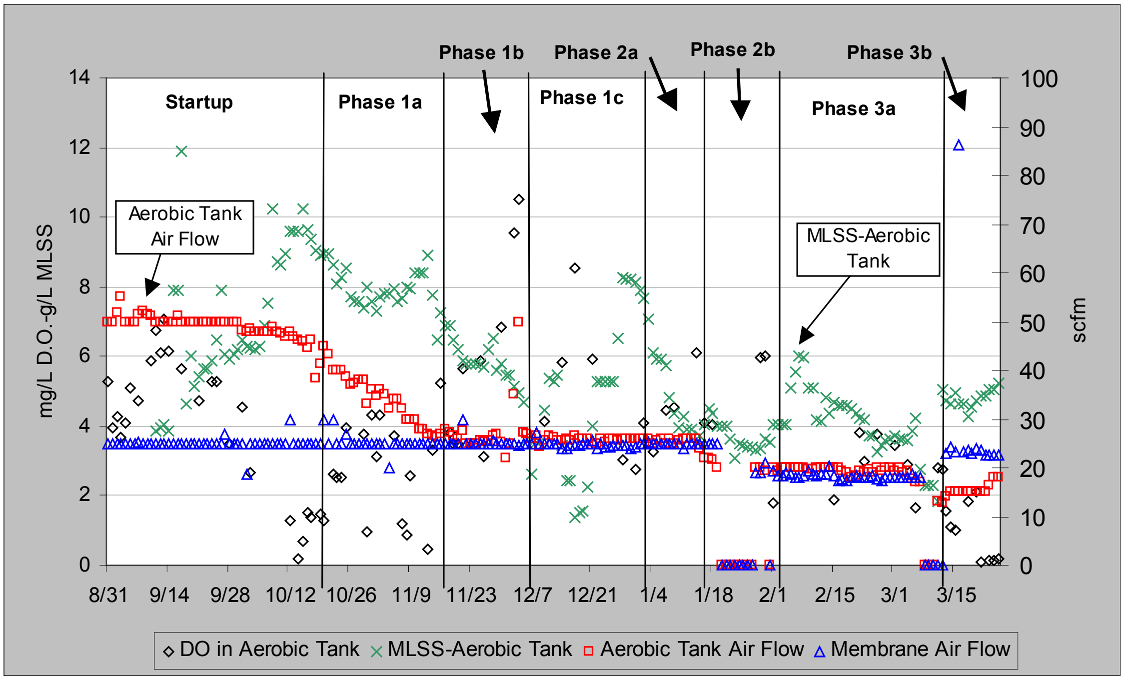

Figure 9. DO, MLSS-Aerobic, Process Air Flow and Membrane Air Flow Data

pH/Alkalinity

Figure 10 shows influent and effluent pH and alkalinity data. Influent pH averaged 7.4 and effluent pH averaged 7.1. pH data are very consistent with little variation over the study. Influent and effluent alkalinity showed more variability. Influent alkalinity was consistently above 170 mg/L during Start-up and dropped during the later phases as winter storms diluted influent flow. Effluent alkalinity was relatively consistent; averaging 51 mg/L.

Nitrification takes up 7.1 mg/L per mg/L ammonia removed. Given that influent ammonia averaged 14.5 mg/L and effluent ammonia was less than 0.02 mg/L, we would expect 104.3 mg/L of alkalinity taken up during nitrification. Nitrification is discussed later in this report. If only nitrification were taking place, the predicted effluent alkalinity would be 65.7 mg/L.

Alkalinity is recovered during denitrification at a rate of 3.5 mg/L/mg/L NO3 reduced. Average effluent nitrate was 7.0 mg/L; therefore nitrogen removal averaged 7.5 mg/L over the study. Therefore, we would have expected the denitrification process to return 22.5 mg/L alkalinity to the system. Predicted effluent alkalinity with both nitrification and denitrification taking place should have been 87.9 mg/L.

However, the pilot study data set is not complete. If we look at a period during which we have at least five data points in a 10-day period, the alkalinity balances. For the period from November 25 to December 4, influent and effluent alkalinity averaged 112.4 mg/L and 53.0 mg/L respectively. Influent ammonia averaged 10.6 mg/L, and effluent ammonia was 0.01 mg/L. Alkalinity would have been 35.7 mg/L if nitrification had been the only process taking place. But effluent nitrate over this period was 5.7 mg/L, and therefore 4.9 mg/L of nitrate must have been removed by denitrification, producing an additional 15.7 mg/L of alkalinity. The 35.7 mg/L from nitrification and the 15.7 mg/L from denitrification should have produced a total effluent alkalinity of 51.4, which is only 1.5 mg/L below the actual measured alkalinity of 53.0 mg/L.

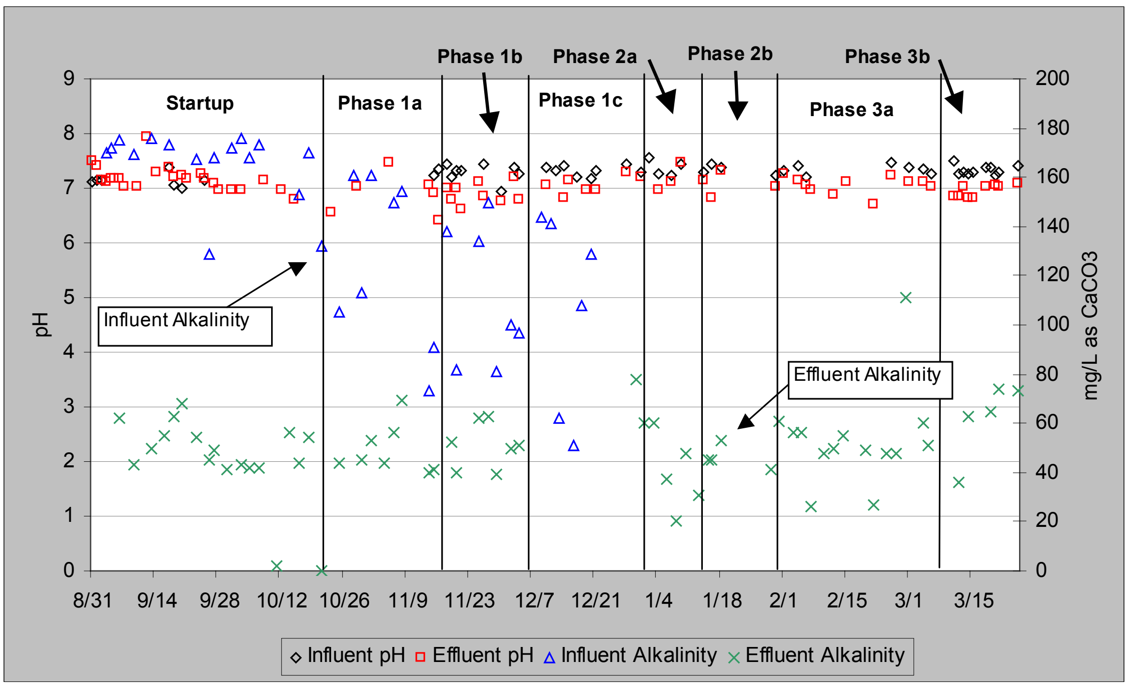

Figure 10. pH/Alkalinity Data

Process Performance

Process performance data are presented in the following section. Data on solids, organics, nutrients, and metals removal are presented along with results from filterability testing. Hydraulic performance is presented in a later section.

Solids Removal

Figure 11 shows effluent TSS, turbidity, and permeate flow for all project phases. Figure 12 shows a probability plot for effluent turbidity. Effluent turbidity was less than 0.1 NTU under all flow and loading conditions tested, meeting the project objectives. The 90th percentile effluent turbidity was 0.02 NTU, an order of magnitude below the 0.2 NTU goal. Turbidity was consistently 0.01 NTU in Phase 1a. Turbidity increased slightly under the higher flux rate

(8 gpm) in Phase 1b – from 0.01 NTU to as high as 0.03 NTU – but returned to 0.01 NTU when flow was reduced to 5.5 gpm in Phase 1c. In Phases 2a, 2b, and 3a turbidity drifted higher to an average of 0.02 NTU. When flows were increased in Phase 3b, higher turbidities were recorded again, with a maximum effluent turbidity of 0.035 NTU. Overall, effluent turbidities and TSS mirrored permeate flow/flux.

Effluent TSS averaged 2 mg/L in all testing phases. During Start-up and Phase 1, effluent TSS was 1 to 3 mg/L. During Phase 1b, under higher flows (higher flux), TSS increased as high as 6 mg/L. On October 10, 2001, effluent TSS was recorded as 23 mg/L. This value is not shown on Figure 11 (to reduce the range of the y-axis scale). Effluent VSS for the same day was 17 mg/L, so an analytical error is unlikely. Because there were no spikes in turbidity during this period and no other data points (even under higher flow rates) that were as high, this data point was recorded as a sampling error. During Phases 1c, 2a, and 2b effluent TSS was higher; averaging 2.0, 2.9 and 3.6 mg/L respectively. At the end of Phase 3a, effluent TSS was 9 mg/L on two occasions. No equipment failures were recorded during this time. During Phase 3b, effluent TSS values were surprisingly low, 1 and 2 mg/L with one <1 mg/L value recorded, and no higher values as in Phase 1b.

Figure 13 shows influent TSS and influent VS:TS ratio. Influent TSS averaged 186 mg/L but ranged from 30 mg/L to 622 mg/L. Average influent VSS to TSS ratio was 0.76.

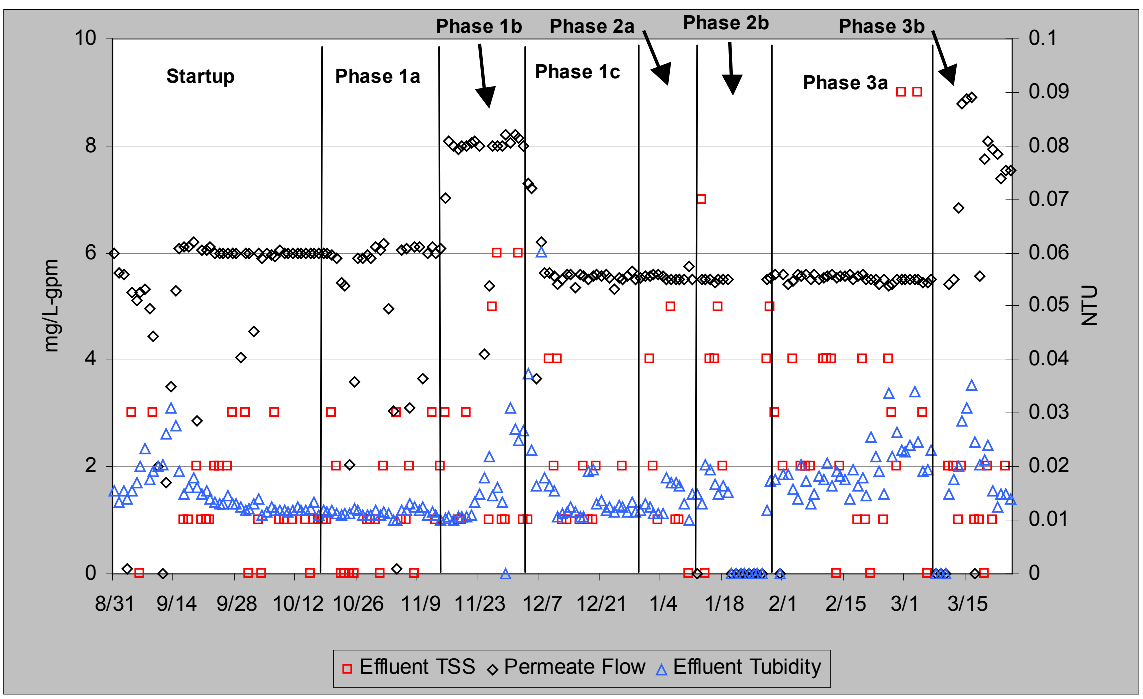

Figure 11. Effluent TSS, Turbidity, and Permeate Flow (Detection limit for TSS is 1 mg/L)

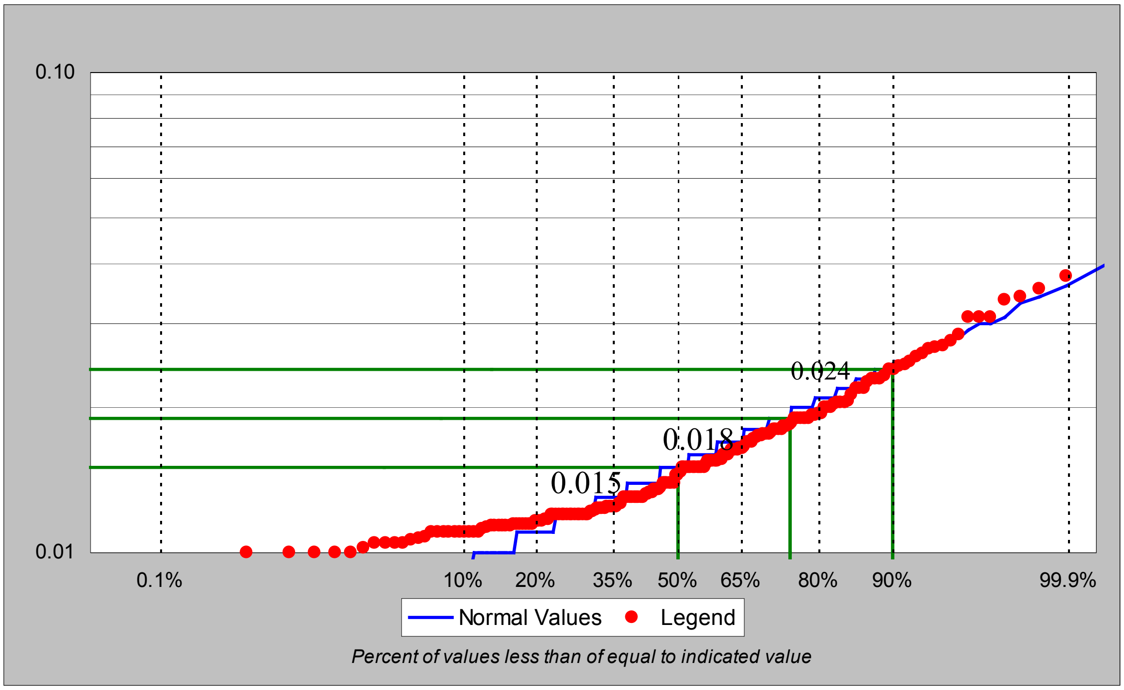

Figure 12. Probability Plot for Turbidity

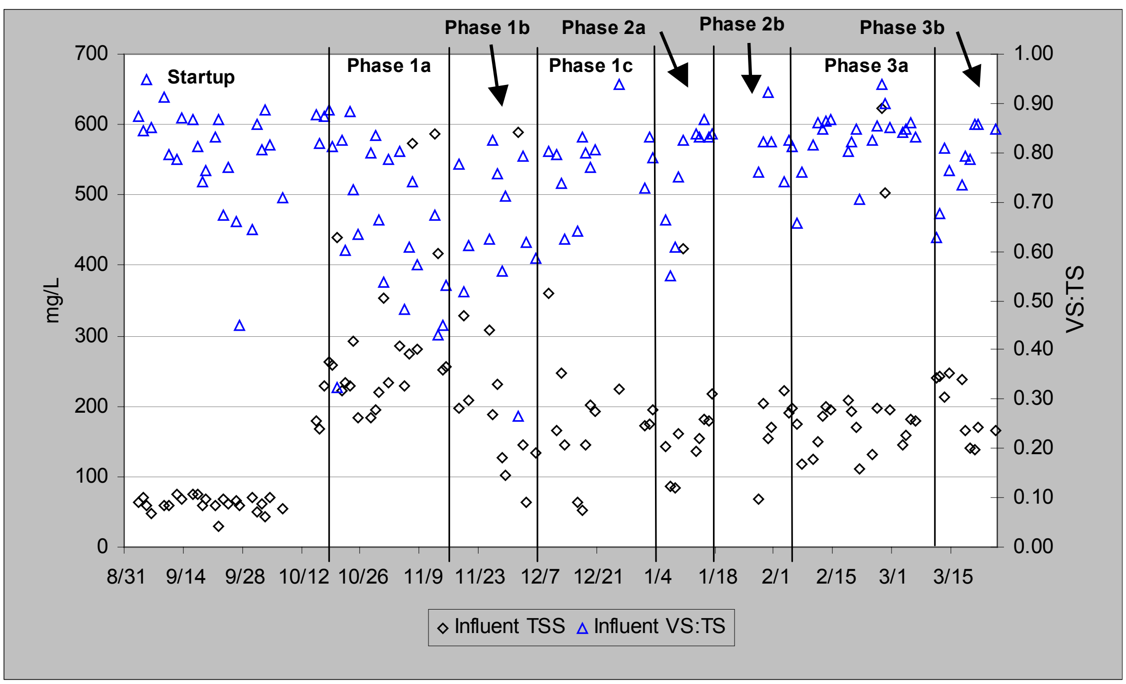

Figure 13. Influent TSS, Influent VS:TS

Organics Removal

The pilot study achieved greater than 99% removal of BOD and greater than 55% removal of COD. Influent and effluent BOD and COD concentrations are shown in Figure 14 and Figure

15, respectively. Influent BOD values averaged 141 mg/L over all phases, and ranged from 31 mg/L to 287 mg/L. Winter season storms caused low influent BODs (<100 mg/L) during Phase 1b, 1c, and 2a. All effluent BOD samples were below the 2 mg/L detection limit, except one sample taken December 31, 2001, which was 4 mg/L. Effluent BOD was not affected by influent BOD concentrations. Effluent BOD sample analysis was stopped after December 31, 2001 due to high sampling load at the process laboratory. Turbidity, COD and TOC were used as surrogate measures for the remainder of the study.

Influent COD concentration was highly variable, ranging from 83 mg/L to 898 mg/L. Average influent COD was 404 mg/L. Average effluent COD was 58 mg/L. A COD balance was attempted but data did not balance.

The Title 22 standard for groundwater discharge is 2 mg/L TOC. Figure 16 shows effluent TOC. Effluent TOC concentrations ranged from 1 to 13 mg/L, and averaged 8 mg/L.

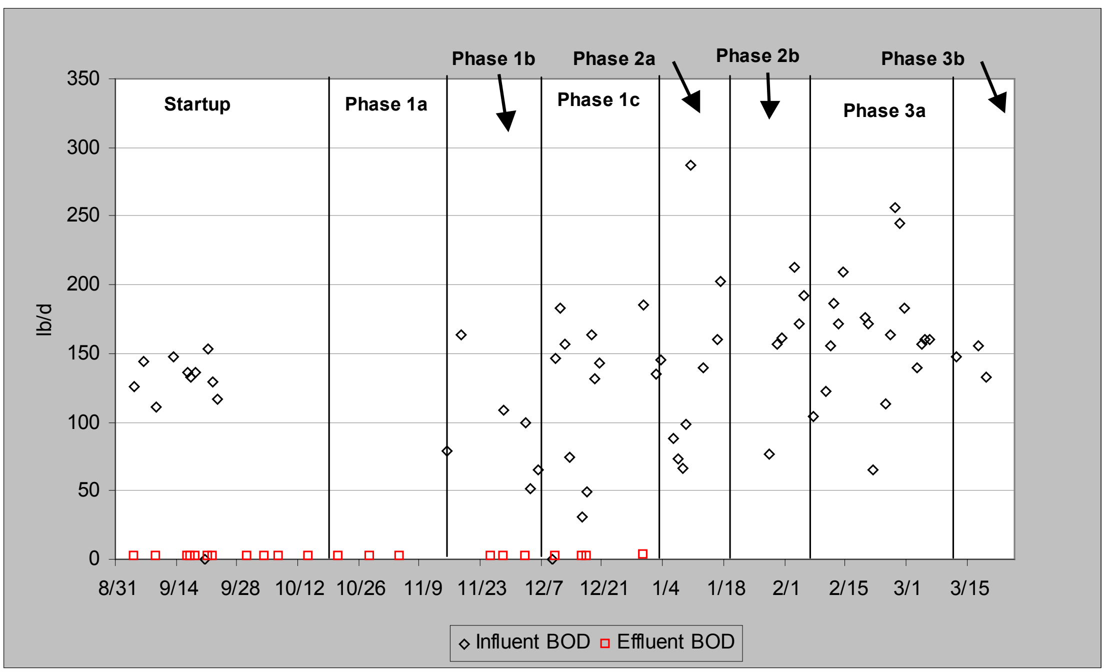

Figure 14. Influent and Effluent BOD Concentrations

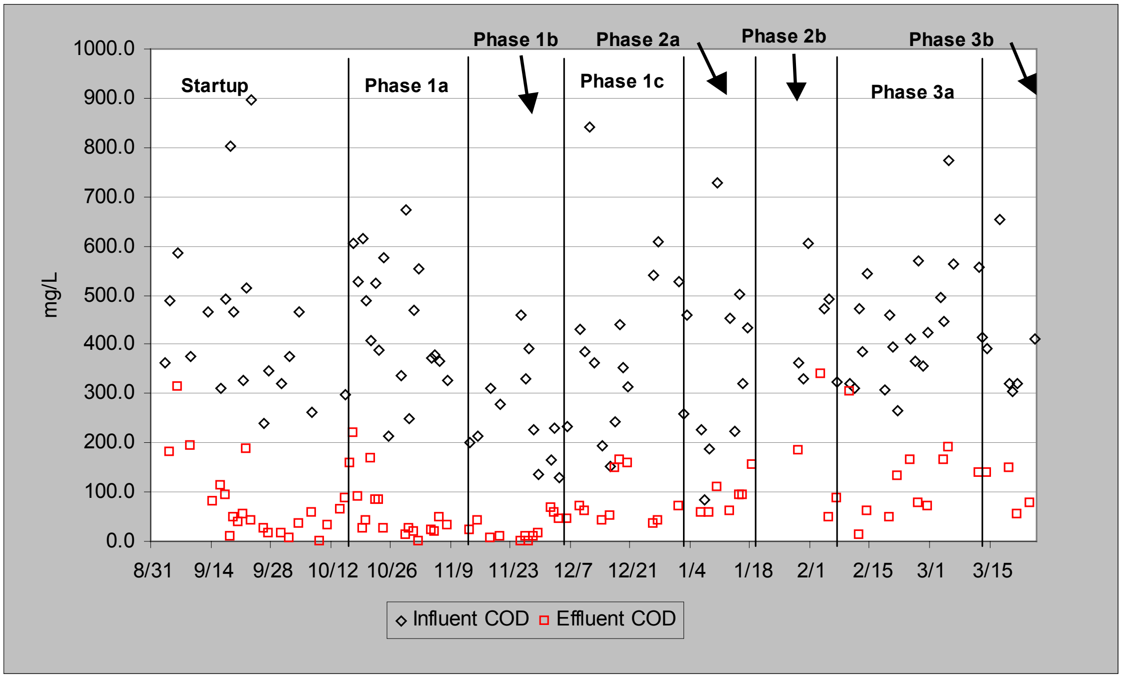

Figure 15. Influent and Effluent COD Concentrations

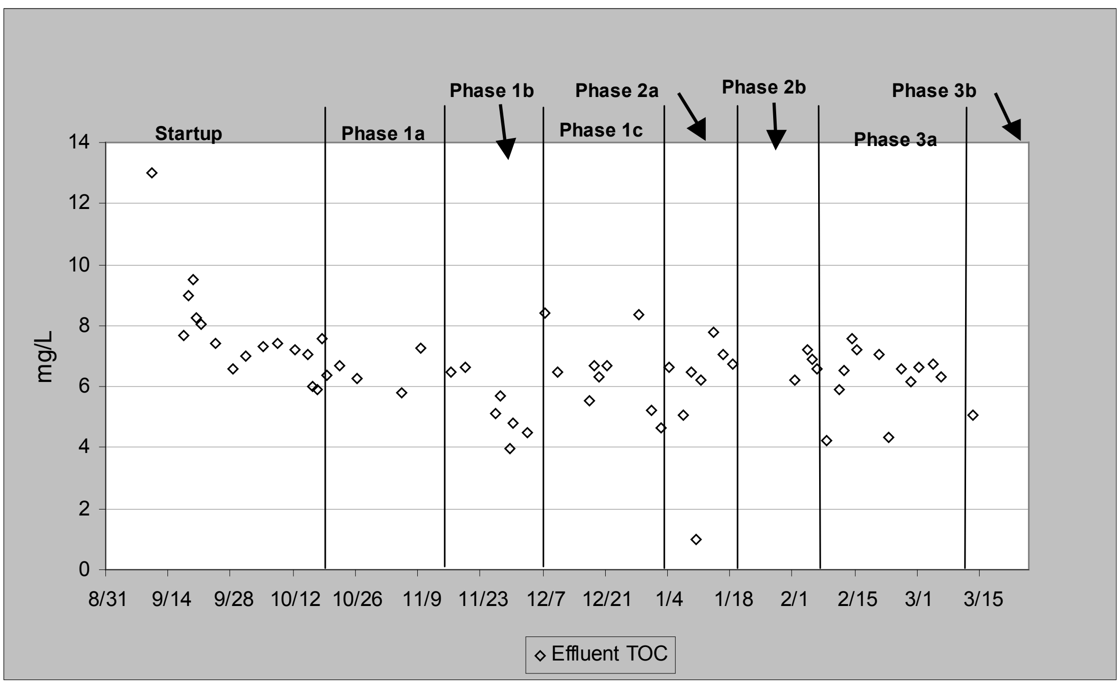

Figure 16. Effluent TOC Concentrations

Nutrient Removal

Nitrogen

Influent and effluent ammonia concentrations are shown in Figure 17. The MBR achieved complete nitrification at all sludge ages and flow rates tested, except for a brief period during Phase 1c, when aerobic-tank mixed-liquor concentrations dropped below 2,000 mg/L, reducing the population of nitrifiers. Effluent ammonia was not affected by influent ammonia concentrations. The 90th percentile effluent ammonia concentration was 0.04 mg/L, well below the 1 mg/L goal. Influent ammonia averaged 14 mg/L with higher concentrations (15 to 25 mg/L) during Start-up and Phase 1a.

Figure 18 shows influent and effluent concentrations of total Kjeldahl nitrogen (organic and ammonia nitrogen). The MBR achieved almost complete removal of TKN during the project. Average influent TKN was 19.8 mg/L. Average effluent TKN 0.4 mg/L.

Figure 19 shows influent and effluent nitrate, anoxic tank mixed-liquor concentrations, and aerobic tank DO. Influent nitrate levels were low, averaging 0.7 mg/L. The source of the nitrate is unknown.

Effluent nitrate levels were greater than expected. The MBR process met the "<8 mg/L 90th percentile effluent nitrate" process goal during Phase 1b and Phase 1c, when mixed liquor concentrations in the anoxic zone were high (>8,000 mg/L). Denitrification took place despite dissolved oxygen concentrations of more than 5 mg/L. The 90th percentile effluent nitrate values were 6.2 and 7.4 in Phase 1b and 1c, respectively. In all other phases, effluent nitrate exceeded process goals. Influent and effluent 90th and 50th percentile values for each phase are shown in Table 7.

Table 7. 50th and 90th Percentile Effluent Nitrate Concentrations

Phase	50th Percentile Effluent Nitrate (mg/L)	90th Percentile Effluent Nitrate (mg/L)
Goal	<5	<8
Start-up	6.9	11.6
Phase 1a	7.9	11.7
Phase 1b	5.2	6.2
Phase 1c	5.9	7.4
Phase 2a	7.4	10.0
Phase 2b	9.4	11.4
Phase 3a	8.5	10.2
Phase 3b	9.5	10.1

Denitrification occurs rapidly in the presence of an organic growth substrate (BOD, methanol, etc.) and is called substrate level denitrification. Denitrification occurs slowly when organisms growth are limited during endogenous decay (low F:M) and is called endogenous level denitrification.

In general, modest levels of nitrogen removal (total nitrogen ≤ 12 mg/L) can be achieved by using BOD in wastewater as a carbon source to achieve substrate level denitrification. However, in order to achieve very low nitrate concentrations, a special strategy is required. This will often require the addition of methanol (or other chemical) to enhance denitrification (raise F:M) in the activated sludge process or in a subsequent process.

The low levels of nitrate removal may be attributed to:

- High food to microorganism (F:M) in the anoxic tank during Startup and Phase 2.
- Cooler influent temperatures in the winter months.
- High DO concentrations in the aerobic tank.

Table 8 shows membrane tank temperature, aerobic tank dissolved oxygen, anoxic tank F:M and specific denitrification rate (SDNR). Anoxic tank DO was measured periodically, and measured 0 mg/L, but no systematic data on anoxic tank DO is available.

Table 8. Membrane Tank Temperature, Aerobic Tank DO, Anoxic Tank F:M

Phase	Membrane Tank Temperature (deg C)	Aerobic Tank Dissolved Oxygen (mg/L)	Anoxic Tank F:M (mg/L/MLSS-day)	SDNR mg NO3/mg MLSS
Startup	20.84	4.28	No data available	
Phase 1a	17.21	2.47	No data available	
Phase 1b	14.07	5.76	0.12	0.024
Phase 1c	13.64	4.89	0.18	0.025
Phase 2a	13.85	4.41	0.36	0.029
Phase 2b	12.61	4.59	0.45	0.030
Phase 3a	13.13	2.89	N/A[a]	
Phase 3b	12.80	0.91	N/A[a]	

[a] In Phases 3a and 3b, the anoxic tank was converted to an anaerobic tank

There are no real 'rules of thumb' identified for F:M ratios or temperatures at which denitrification takes place. SDNR is a function of the F:M ratio and temperature by the following equation:

- $SDNR = (0.03(F{:}M)+0.029)*(1.05^{T-20})$ (Refling and Stensel, 1978)

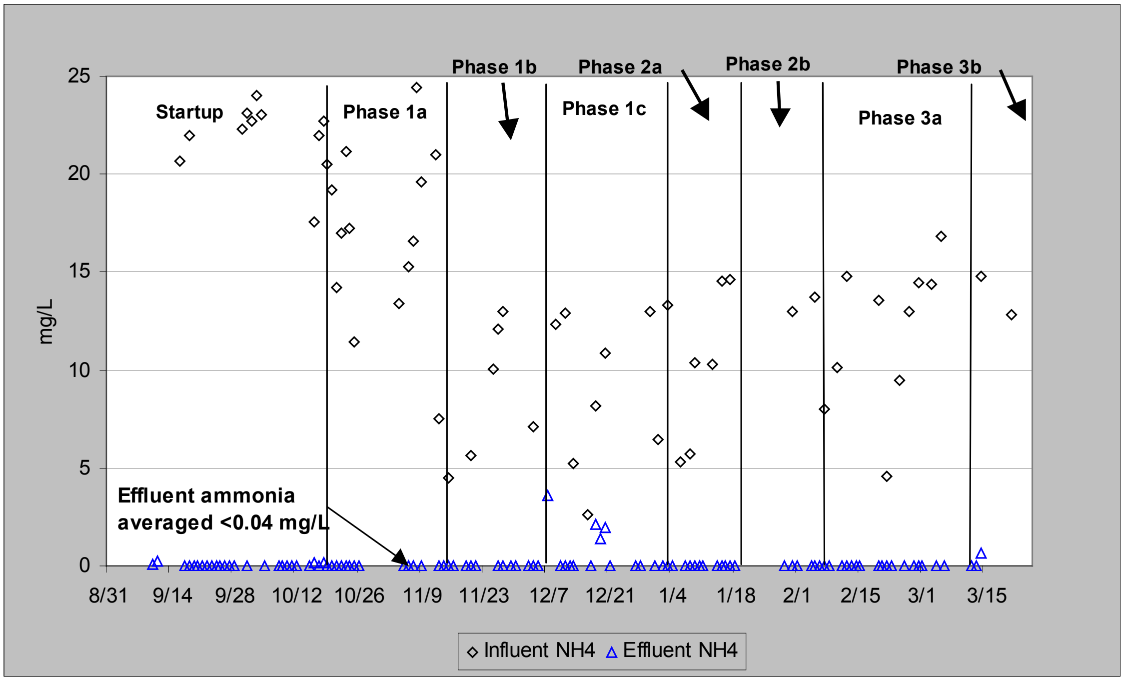

Figure 17. Influent and Effluent Ammonia Concentrations

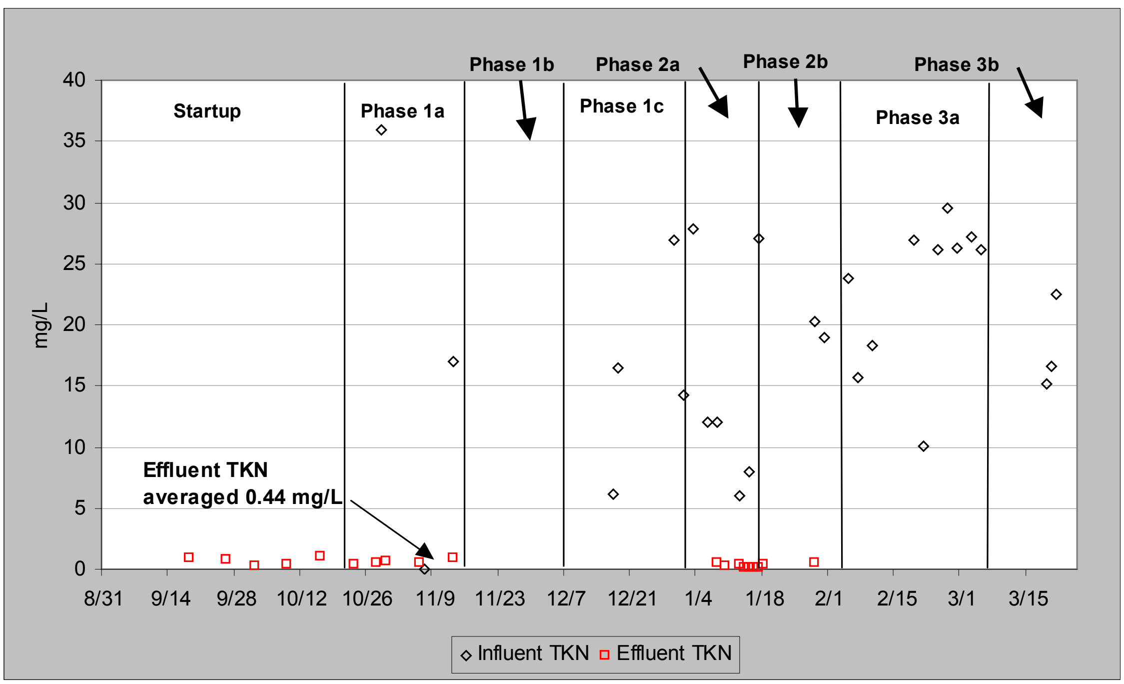

Figure 18. Influent and Effluent TKN Concentrations

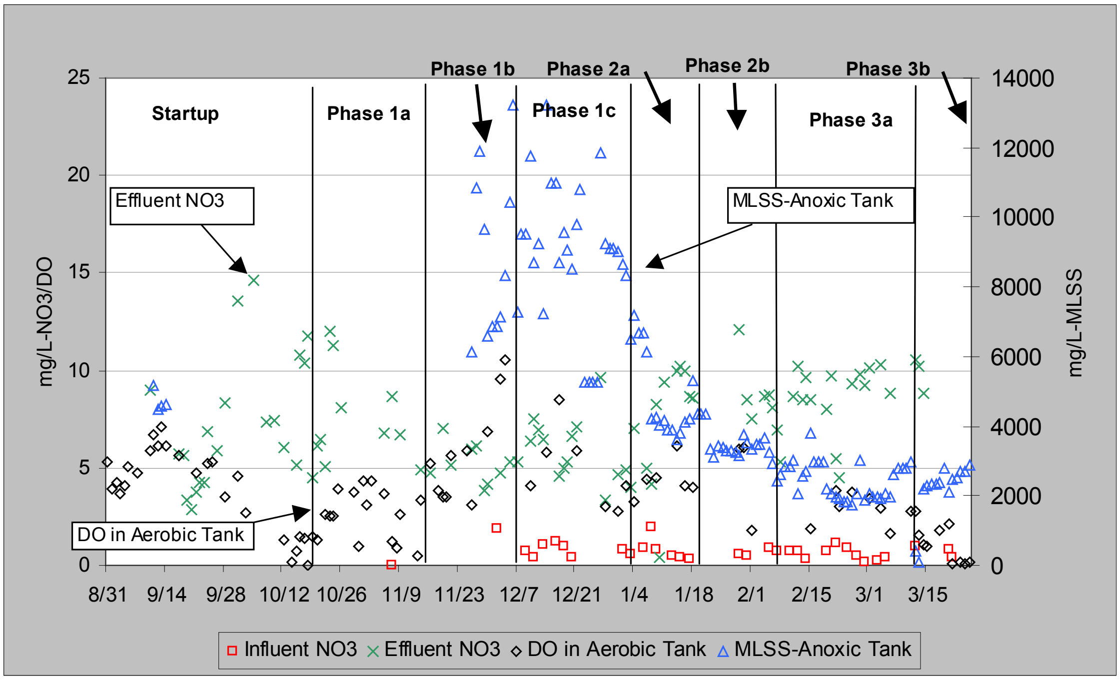

Figure 19. Influent and Effluent Nitrate, DO in Aerobic Tank and MLSS in Anoxic Tank Concentrations

Phosphorus

Figure 20 shows influent and effluent total phosphorus (TP) concentrations. Average influent TP was 4.0 mg/L. Influent TP was highest in Phase 1a and dropped off consistently in Phases 1b, 1c, 2a and 2b with winter storm flows. Effluent TP was highest during Start-up (average = 3.6 mg/L) and lowest in Phase 1b (average 0.5 mg/L). Effluent TP was consistently 1 mg/L or less in Phases 1a, 1b, 2a, and 2b. Effluent TP was not directly influenced by influent TP. There was no improvement in removal efficiency when the process was modified for biological phosphorus removal for Phases 3a and 3b. This was likely because the pilot study set-up was not designed for biological phosphorous removal. No separate anoxic tank was provided.

Influent and effluent ortho-phosphate concentrations are shown in Figure 21. Influent ortho-phosphate concentrations parallel total phosphorous trends with higher influent concentration in Start-up and Phase 1a, dropping off through the winter months. Effluent ortho-phosphate concentrations also parallel total phosphorus trends with concentrations less than 1 mg/L in Phases 1a, 1b, 2a, and 2b and no removal improvement in Phase 3a and 3b.

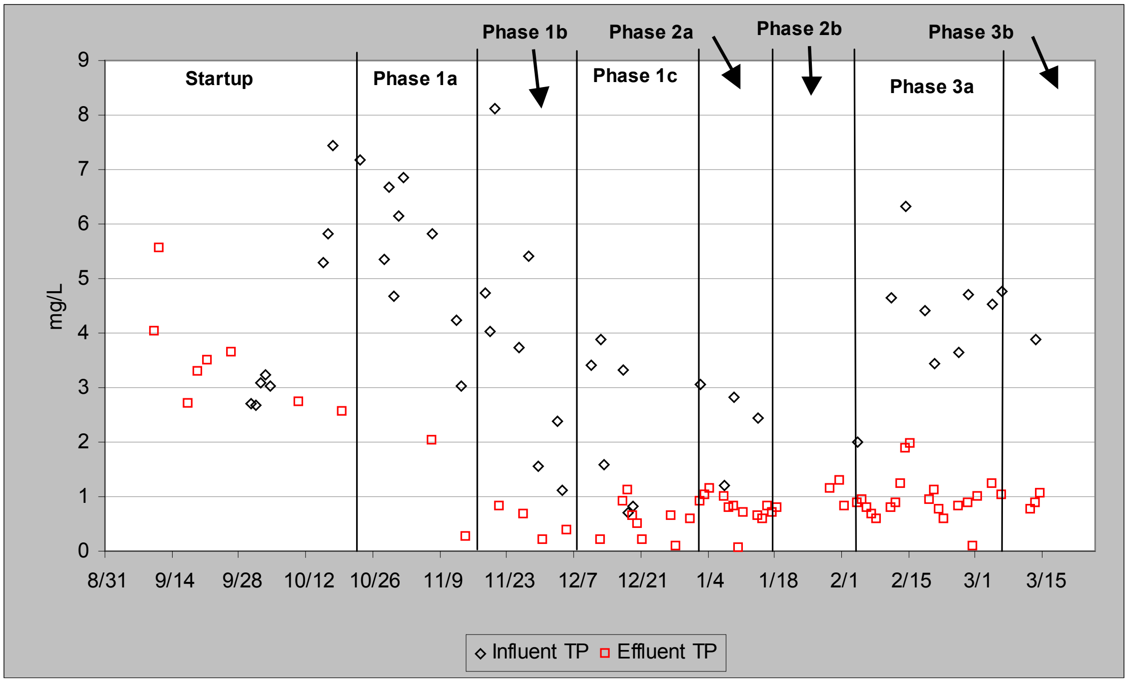

Figure 20. Influent and Effluent Total Phosphorus Concentrations

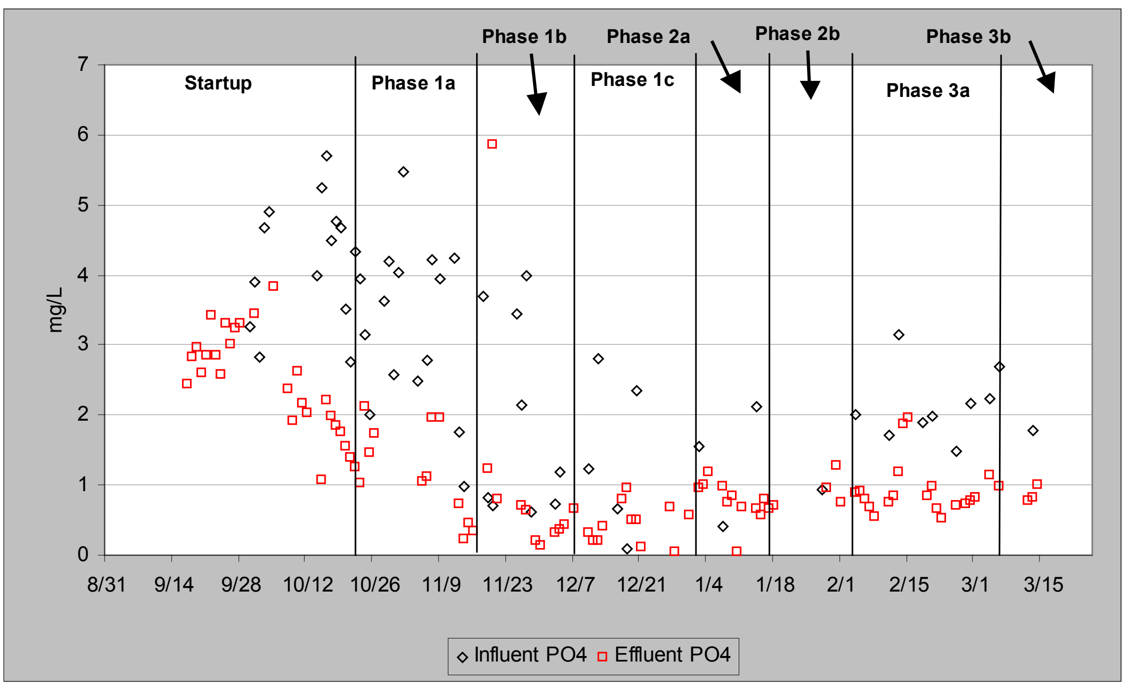

Figure 21. Influent and Effluent Ortho-phosphate Concentrations

Microbial Removal

Figure 22 presents influent and effluent total Coliform and heterotrophic plate count (HPC) data throughout the study. The membrane pore size for the unit was 0.04-micron nominal and

0.1-micron absolute. Bacteria typically range from 0.5 micron to 50 micron (AWWA, 1999). Therefore, we would expect the membrane to completely remove bacteria.

Influent total Coliform levels were consistently 10^6 to 10^8 CFU/100 mL. During Start-up, effluent total Coliform concentrations were as high as 1.7 x 10^3 CFU/100 mL. Several steps were taken to ensure the samples were not contaminated:

- A disinfection clean (a short term recovery clean) was performed on October 15.
- Duplicate samples were taken.
- Samples were taken from an alternate sample tap.
- Sample piping was chlorinated.
- An integrity test and a disinfection clean were performed on October 2.
- A chlorine puck was added to the clean-in-place tank on October 15.
- The membrane tank was chlorinated on November 14.

None of these changes impacted Coliform levels. Effluent Coliform levels eventually dropped in Phases 1a and 1b and no Coliform was detected for the remainder of the study. This improvement in total Coliform removal may be due to pore blocking (debris lodging inside a membrane pore).

Influent HPC levels were approximately one order of magnitude greater than influent total Coliform levels, ranging from 10^7 to 10^9 CFU/mL. Effluent HPC levels were several orders of magnitude higher than effluent total Coliform levels. During Start-up and Phase 1a, HPC data paralleled total Coliform data, dropping from 10^7 at the beginning of Start-up to 104 in Phase 1a. In Phases 1c, 2a, and 2b, effluent total HPC averaged 10^4 CFU/100 mL. However, in Phase 3a, the effluent HPC level increased dramatically from 10^4 to 10^7 CFU/100 mL. Effluent turbidity and TSS concentrations also increased during Phase 3a. These results suggest that the membrane fibers may have been compromised.

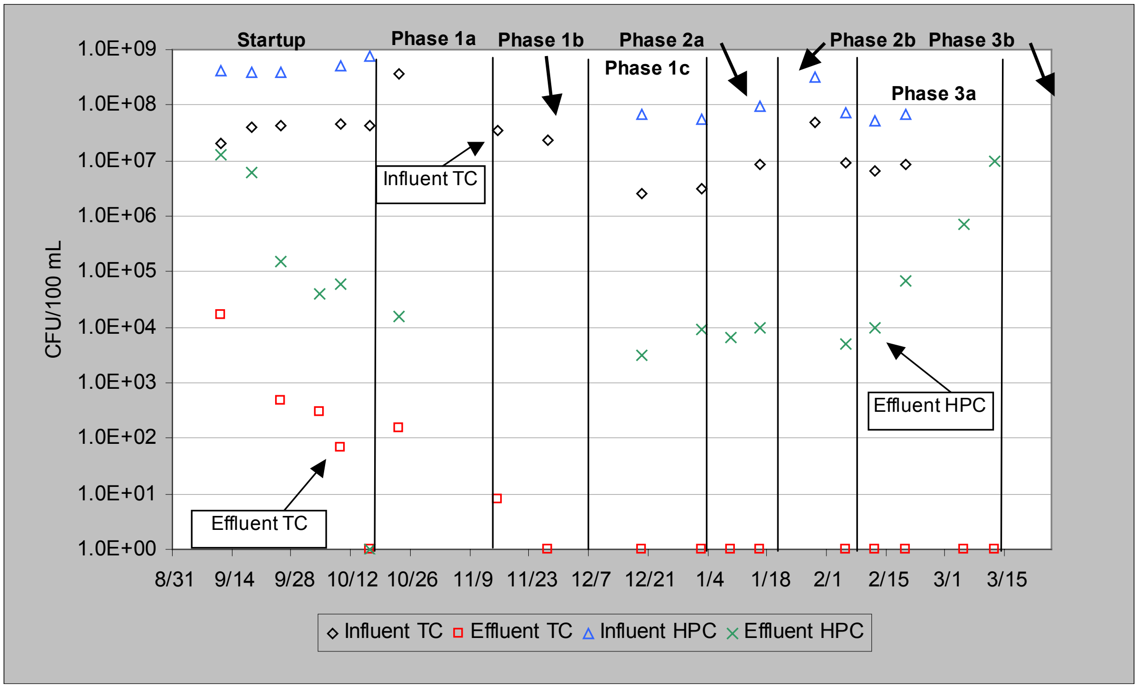

Figure 22. Influent and Effluent Total Coliform and Heterotrophic Plate Count Levels

Filterability

Filterability characteristics of the MLSS were assessed periodically during the study using the sludge volume index (SVI) and the capillary suction test (CST). These tests were used as trouble shooting tools during process upset. CST data for MLSS in the aerobic and membrane tank is presented in Figure 23. CST is shown on the y-axis, mixed liquor concentration is on the x-axis, because CST is a function of solids concentration. Typically, sludge with high CSTs (100 to 150 sec) are more viscous and difficult to filter. Per Zenon, CSTs in the range of 40 to 70 seconds indicate good filterability.

In the aerobic tank, the more dilute mixed-liquor concentrations (3,000-5,000 mg/L) had lower CST values in general than the higher mixed-liquor concentrations (5,000-10,000 mg/L). Higher and more variable CST results were obtained from the membrane tank compared to the aerobic tank. All of the membrane tank CST data were taken during the Start-up phase when the operation was unstable, which may explain the variable data.

Figure 24 presents SVI data for MLSS taken from the aerobic tank. Sludges with good settling characteristics will have an SVI of 80 to 120 mL/g (Fernandez et al, 2000). An SVI greater than 150 mL/g (Jenkins, 1993) is considered high. All the SVI recorded for the MLSS in the aerobic tank, except two points at 145 mL/g, were above this level, indicating very poor sludge filterability. SVI and CST measurements were taken during different periods of testing, so no correlation between SVI and CST is possible. Because samples were taken sporadically throughout the testing, no correlation between SVI or CST and TMP could be determined.

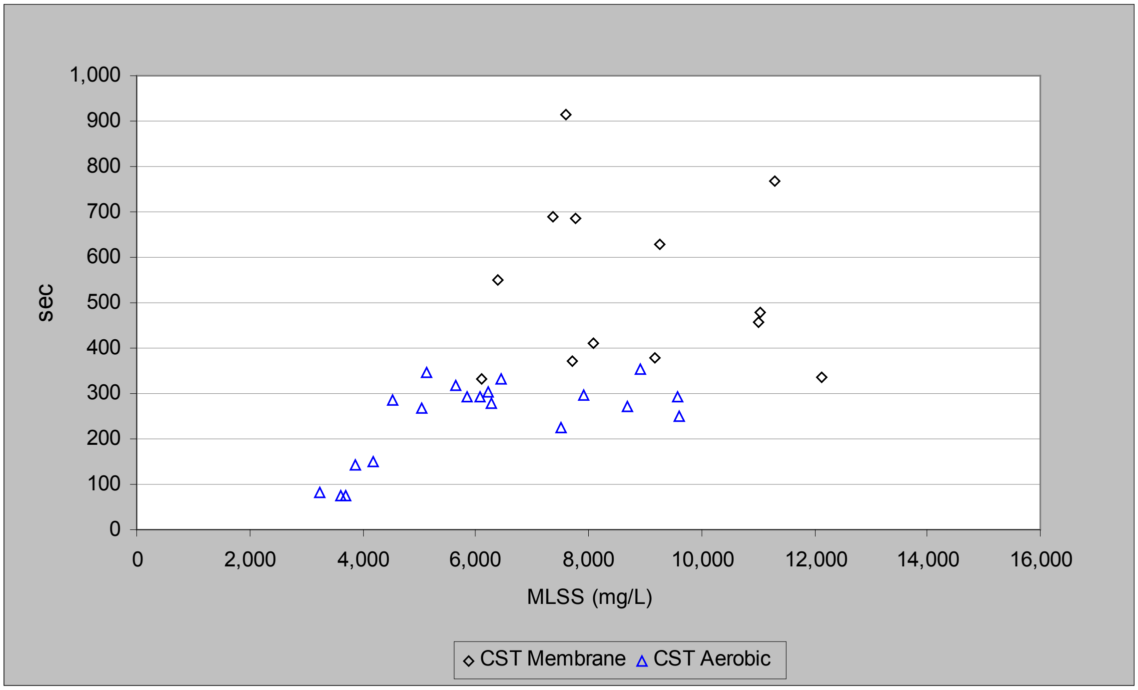

Figure 23. Membrane Tank and Aerobic Tank Capillary Suction Time Data

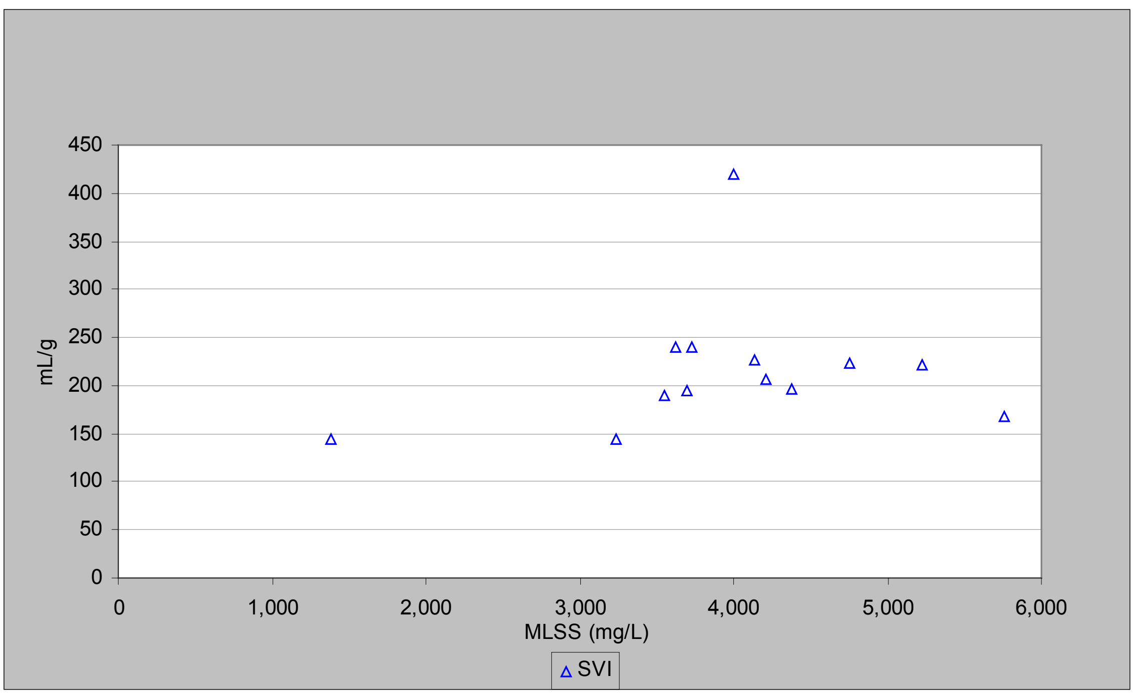

Figure 24. Aerobic Tank Sludge Volume Index Data

Metals

The MBR influent was sampled six times for a range of metals. MBR effluent was sampled four times. Table 9 shows average influent and effluent metals data. The MBR consistently removed some fraction of the metals present in the influent.

Table 9. Influent and Effluent Metal Concentrations

Metal	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	MDL (mg/L)
Aluminum	1.368	0.0151	0.0020
Antimony	0.00078	< 0.0005	0.0005
Arsenic	0.00281	0.0018	0.0005
Barium	0.03353	0.0033	0.0002
Beryllium	0.00016	< 0.0002	0.0002
Cadmium	0.00038	< 0.0001	0.0001
Chromium	0.00580	0.0006	0.0004
Cobalt	0.00084	0.0009	0.0002
Copper	0.05414	0.0078	0.0004
Iron	2.10	0.07	0.05
Lead	0.0153	0.0004	0.0002
Molybdenum	0.0144	0.0139	0.0005
Nickel	0.0058	0.0028	0.0003
Selenium	< 0.0015	< 0.0015	0.0015
Silver	0.0044	< 0.0002	0.0002
Thallium	0.0002	< 0.0002	0.0002
Vanadium	0.0033	< 0.0012	0.0003
Zinc	0.1231	0.0348	0.0005
Mercury	0.0002	0.0001	0.00005

Hydraulic Performance

Flux

The temperature in the membrane tank, TMP, and temperature-corrected flux are shown in Figure 25. System temperature dropped from approximately 20^{o} C at the beginning of the pilot test in August, to 13^{o} C at the end of the pilot in March. Temperature-corrected flux was 11.5 during Start-up and 11.6 during Phase 1a. TMPs were 2.5 inches Hg consistently. During Phase 1b, daily flux was increased to above 20 gfd. The average flux during the period was 16 gfd. Correspondingly, TMPs increased to 5 inches Hg.

The flux was then reduced to 14 to 15 gfd during Phases 1c, 2a, 2b, and 3a. The higher flux rate in these Phases compared to Start-up, and Phase 1b may be attributed to cooler water temperatures and slightly higher flow rates: 5.5 gpm in Phases 2a, 2b and 3a compared with 5.3 gpm in Start-up and 1a. From December 8, through March 12, TMP remained stable at 2.8 to 3.0 inches Hg. This slight increase in system pressures during the later phases of the test may be due to membrane fouling that took place at the higher flux rates in Phase 1b.

During Phase 3b, flux was increased as high as 24 gfd. TMPs increased as well, reaching 21 inches Hg before the unit was shut down. System flux was increased to 18.5 gfd on March 13, 2002. By March 17, system flux was increased to 24 gfd and vacuum pressure was 11 inches Hg. Flux was reduced to 15 gfd March 18 and then increased to 20 gfd for the last seven days of the test. TMPs were as high as 21 inches Hg before the system was shut down.

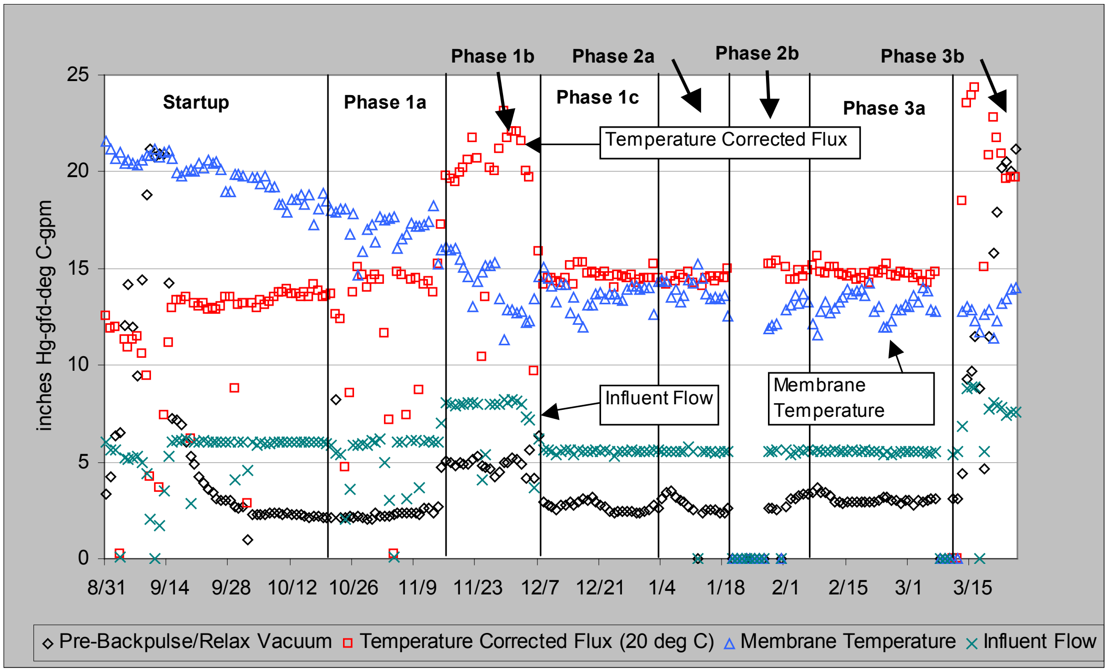

Figure 25. Vacuum, Temperature Corrected Flux, Zeeweed Temperature and Influent Flow

Peak Hydraulic Tests

Three hydraulic peaking tests were performed during the pilot study on November 15 and December 7, 2001, and February 4, 2002. The goal of the peaking test was to determine how the system operated in response to peak flows. Flows were increased 50% for a 4-hour period. Vacuum pressure, dissolved oxygen, and effluent turbidity measurements are taken at approximately 15-minute intervals.

November 15, 2001 Peaking Test

For the peaking test performed on November 15 (during Phase 1a), flow was increased from 6 gpm to 9 gpm for four hours. After four hours, flow was reduced to 8 gpm. Mixed liquor concentration was 8,100 mg/L in the membrane tank. Data from the test are presented in Figure 26. The system was in backpulse mode (10 minute interval, 30 second duration) during this test.

Initial, pre- and post-backpulse pressures were 2.4 to 2.5 inches Hg. During the test, pre-backpulse pressures immediately increased to 6.6 inches Hg, peaking at 8.3 inches Hg by the conclusion of the test. Post backpulse pressure remained relatively constant around 5.5 inches

Hg. When the permeate flow rate was reduced to 8 gpm, system pressures dropped immediately to 5.5 inches Hg before backpulse and 4.5 inches Hg after backpulse.

DO in the aerobic tank dropped from 4.3 mg/L initially to 2.0 mg/L at the end of the test. Turbidity was consistently 0.011 NTU, although a higher reading was recorded after the turbidity probe was removed.

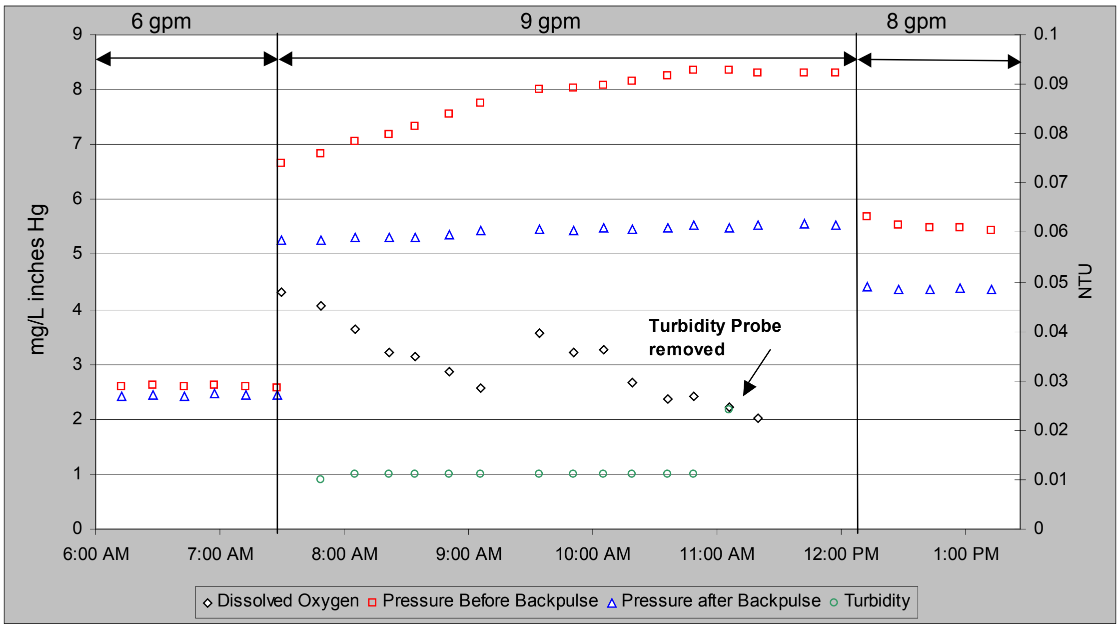

Figure 26. **November 15, 2001 4-hour Peaking Test**

December 7, 2001 Peaking Test

For the peaking test performed on December 7 (during Phase 1b), flow was increased from 5.5 gpm to 8.8 gpm for four hours and then returned to 5.5 gpm. The mixed-liquor concentration in the membrane tank was 2,890 mg/L. Data from the test are presented in Figure 27. The system was in relax mode during this test. Before the test began, system vacuum was 3 inches Hg. When the system flow was increased to 8.2 gpm, vacuum pressure increased immediately to 5.2 inches Hg and then continued to increase to 9.4 inches Hg at the end of the peaking period. This pattern was different than the immediate increase is pressure and constant pressure in the November 15 test. It is difficult to determine if this pattern was a result of operation on backpulse versus relax mode. When the flow was reduced back to 5.5 gpm, vacuum immediately dropped to 5.3 inches Hg. System vacuum continued to decrease and leveled out at 2.9 inches Hg at 9:00 am on December 8.

Dissolved oxygen decreased from 5.3 mg/L to 4.2 mg/L during the test. Turbidity increased steadily from 0.02 NTU to 0.09 NTU.

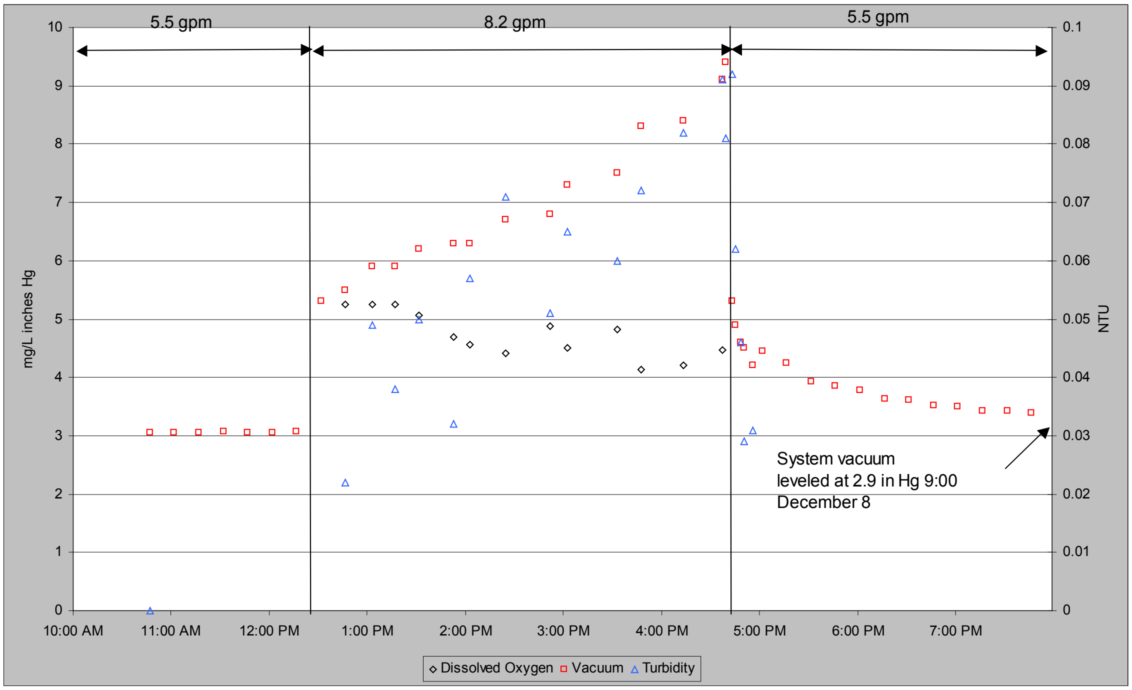

Figure 27. December 7 4-hour Peaking Test

February 4, 2002 Peaking Test

On February 4, 2002 (during Phase 2b), flow was increased from 5.5 gpm to 8.8 gpm for four hours and then returned to 5.5 gpm. The mixed-liquor concentration in the membrane tank was 5,410 mg/L. Data from the test are presented in Figure 28. The system was in relax mode during this test. Before the test began, system vacuum was 3.2 inches Hg. When the system flow was increased to 8.2 gpm, vacuum pressure increased immediately to 5.7 inches Hg and then continued to increase up to 6.5 inches Hg. When the flow was reduced back to 5.5 gpm, vacuum immediately dropped to 3.5 inches Hg. The system operated at a vacuum of 3.5 inches Hg from 1:00 pm to 3:00 pm. At 3:00 pm, a maintenance clean was initiated. After the maintenance clean, the system vacuum stabilized at 3.3 inches Hg.

DO data from this test are questionable because the recorded value spiked to more than 3 mg/L after repositioning the DO probe on two occasions. Turbidity data did not show a consistent increase, as in the December 7, 2001 test. Turbidities were relatively constant ranging from 0.015 NTU to 0.027 NTU.

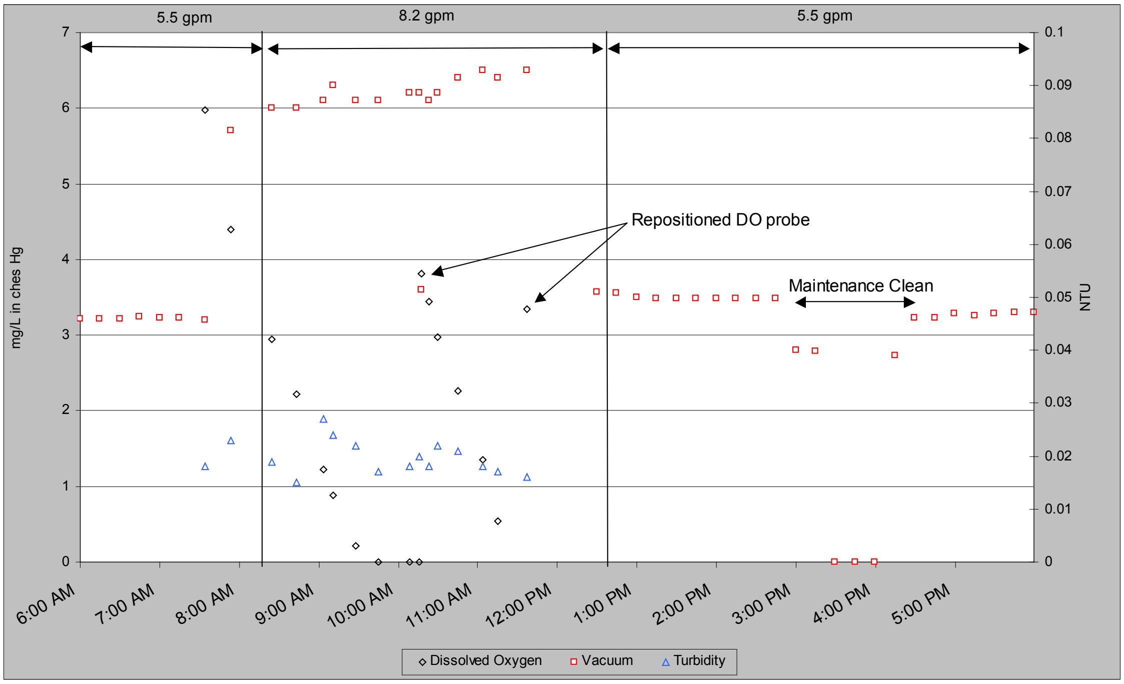

Figure 28. February 4, 4-hour Peaking Test

Relax Mode/Backpulse Mode Operation

The MBR went through Start-up from August 29 to October 16, 2001. The unit was seeded with waste activated sludge (5,580 mg/L TSS) from the West Point WWTP aeration basins, which operates at a sludge age of one day. Figure 29 shows pressures before and after backpulse and the temperature corrected flux.

The MBR went through Start-up in a relax mode of operation. No backpulse (frequent reverse flow through the membrane) was used for cleaning. Instead the permeate pump stopped for 30 seconds every 10 minutes to allow the membranes to relax. Pressures before and after backpulse or relax during the Start-up period are shown in Figure 29.

The unit rapidly developed membrane high vacuums (over 10 inches Hg) over two to three hours. This may be due to seeding with a very young sludge (one-day sludge). Young sludges do not often filter well because they tend to be more “sticky” compared to older sludges, which have a slime layer around the organism.

After two weeks of operation with repeated high vacuum readings, the unit was switched to backpulse mode on September 14, 2001. The unit went though a backpulse for 30 seconds every 10 minutes. With the switch to backpulse mode, the unit rapidly returned to lower and more consistent vacuum readings (2-3 inches Hg). The unit was operated in backpulse mode until December 3, 2001.

On December 3, after several weeks of successful operation in backpulse mode, the unit was returned to relax mode. The unit operated successfully in relax mode for the remainder of the testing period. Cyclic aeration continued in the membrane tank in relax mode. Pressures were consistently 2 to 3 inches Hg at a flux of 15 gfd. When flux was increased above 20 gfd (well above the manufacturer-recommended steady state flux of 13 gfd), and maintenance cleans were stopped, membrane pressures increased and the unit shut down on high vacuum on March 17, 2002.

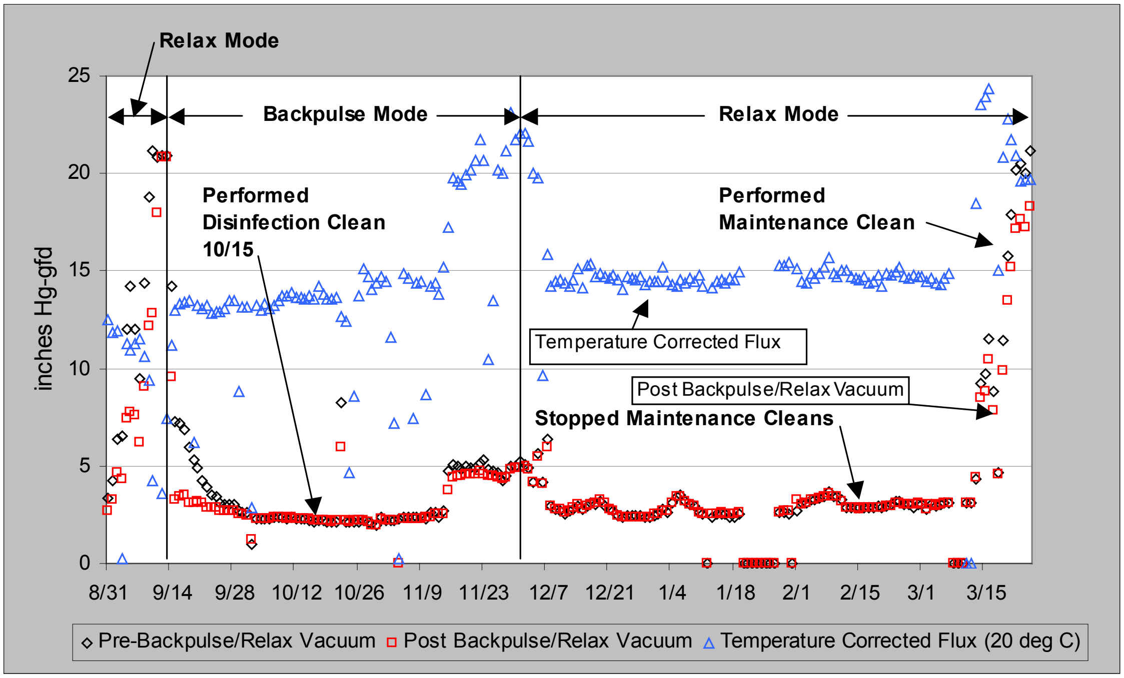

Figure 29. Pressures Before and After Backpulse During Start-up

Maintenance Cleaning

The MBR pilot went through maintenance cleaning three times a week from August 29, 2001 through February 14, 2002. Maintenance cleans are intended to prolong the life of the membrane. Maintenance cleaning during this period did not affect TMPs. Pressure was 2.4 inches Hg both before and after maintenance cleaning. Figure 30 shows the 15-minute data from a typical maintenance clean that took place on October 7, 2001.

From February 25, 2002 through March 25, 2002, (the end of the testing), the unit was run without maintenance cleans. Because the unit was in relax mode and no recovery cleans were performed, the pilot operated with no cleaning of any kind during this period. From February 25 to March 12, 2002, the unit operated with steady TMPs from 2.8 to 3.1 inches Hg. The flow rate during this period was 5.5 gpm. On March 13, 2002, the flow rate was increased to 9 gpm (19.6 gfd actual flux). With the higher flows and system flux, the TMP increased.

A single maintenance clean was performed on March 17, 2002 in response to high vacuum pressures in the system due to higher flux through the membrane. The 15-minute PLC data for March 17, 2002 are presented in Figure 31. During the March 17 clean, TMPs were reduced from 14 inches Hg before cleaning to 8 inches Hg after cleaning. However, flow was reduced from 9 gpm to 5.5 gpm after the maintenance clean so it is unclear to what extent the maintenance clean and/or the flow reduction resulted in the TMP drop. When the flow was increased back to 9 gpm on March 19th, membrane pressure quickly returned to the pre-maintenance clean levels and continued to climb for the remainder of the pilot test.

The maintenance clean interval may be reduced based on the data from the study, however reductions in maintenance clean intervals may have adverse impacts on the life of the membrane.

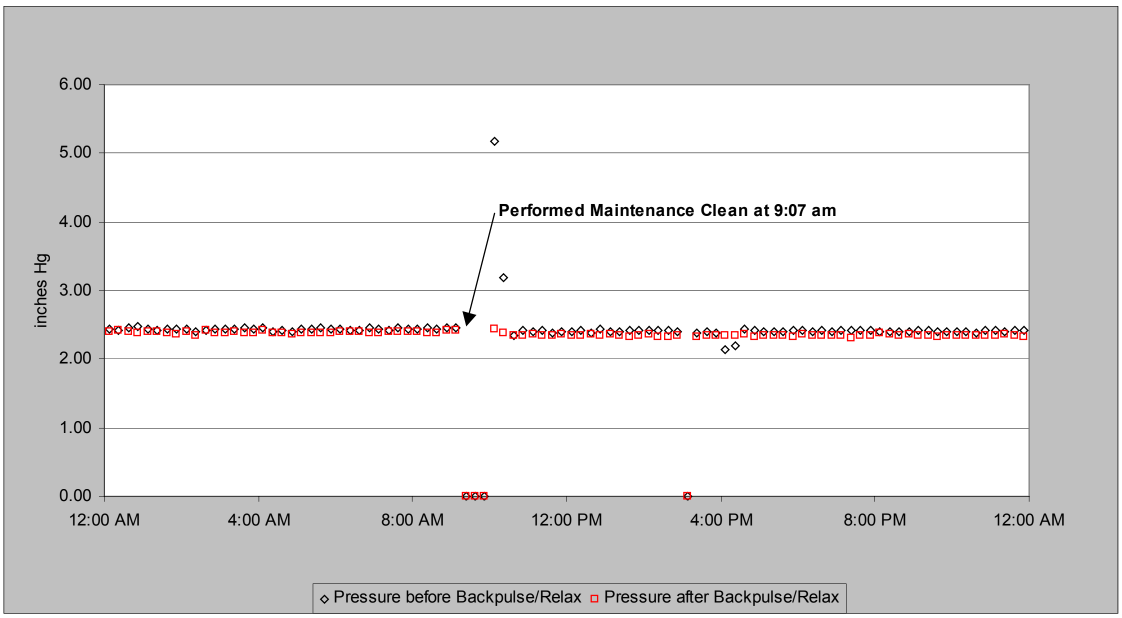

Figure 30. TMPs on October 7, before and after maintenance clean

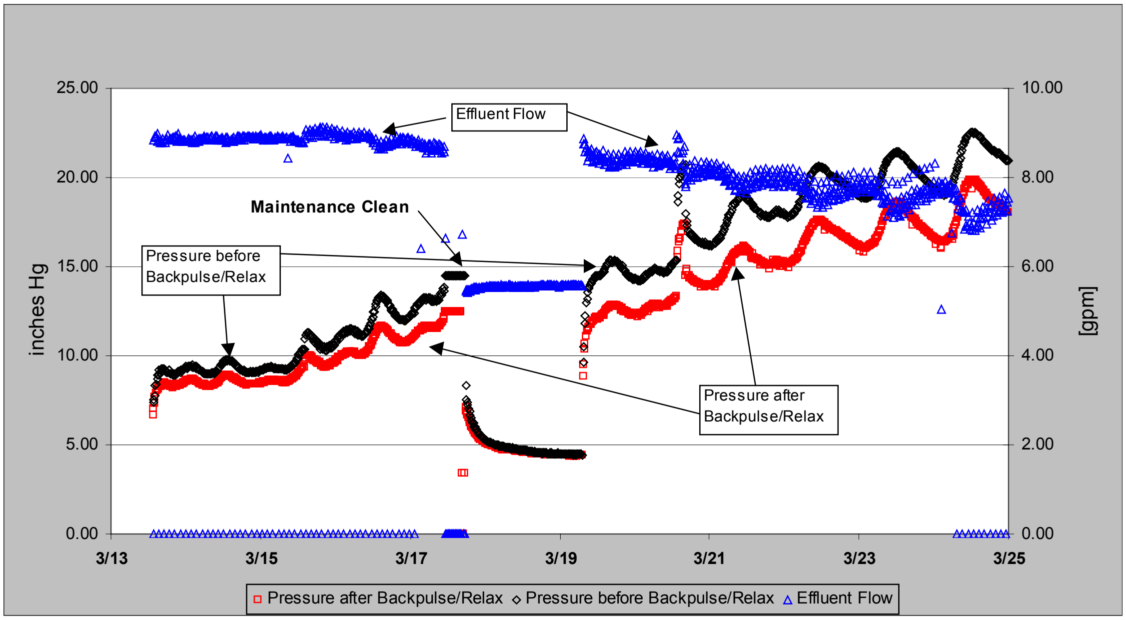

Figure 31. TMPs March 13-March 25, 2002

Recovery Clean

One recovery clean was completed in the pilot study at the end of the study period. In addition, a single disinfection clean, essentially a short-term recovery clean, was performed on October 15, 2001 in response to Coliform counts in the MBR effluent. Figure 32 shows TMPs before and after the disinfection cleaning process. TMP dropped only slightly, from 2.3 inches Hg on average on October 14, 2001 to 2.2 inches Hg on average October 16, 2001.

The disinfection clean took approximately 3.5 hours to complete. The unit was taken out of service at 12:40 pm on October 15, 2001. The membrane tank was drained and the tank was flushed with reuse water for one hour. Then the membrane tank was filled with sodium hypochlorite solution. The sodium hypochlorite was recirculated through the system for 45 minutes. The sprayer pump returned the solution to the membrane tank through a connection at the top of the tank. After 45 minutes of recirculation, the membrane tank was drained and the unit was brought back on line.

The recovery clean was completed on March 26 and March 27, 2002. Test data is summarized in Table 10. The recovery clean included a chlorine soak and a citric acid soak. The recovery clean reduced system vacuum from 11.5 inches Hg (11.1 gfd temperature corrected flux) to 5.1 inches Hg (11.8 gfd temperature corrected flux). Because only one recovery clean was completed and it took place at the end of the study, conclusions about long-term flux decline couldn't be made.

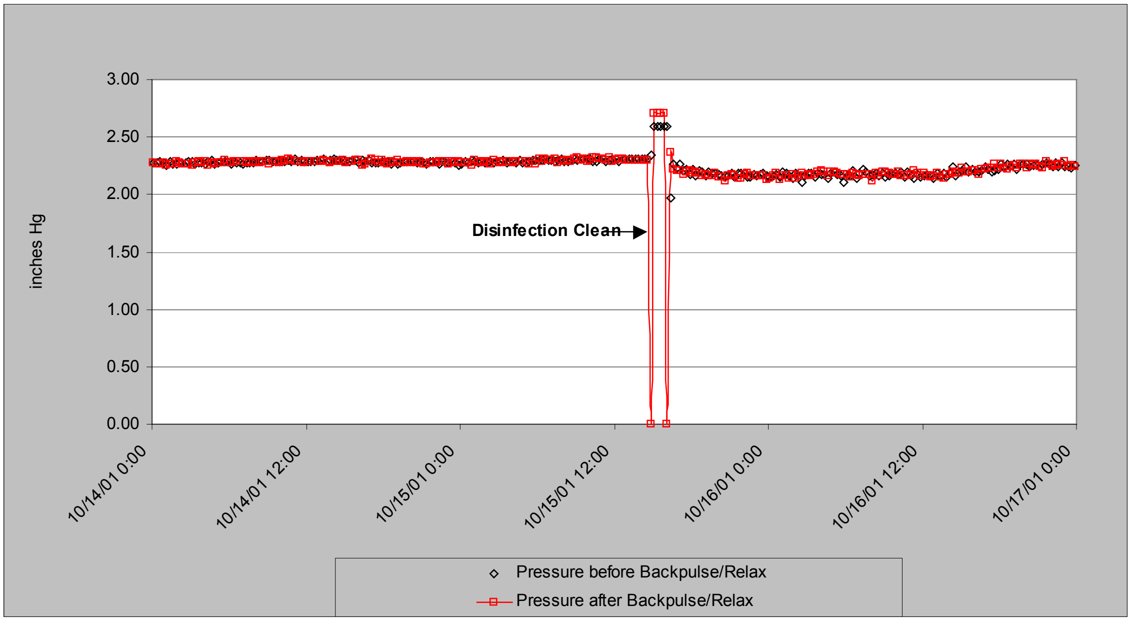

Figure 32. TMPs Before and After Disinfection Clean

Table 10. Recovery Clean Data

Date/Time	Condition	Flux (gfd)	Temp (° C)	Temperature corrected Flux (gfd)	Vacuum (inches Hg)	Comments
3/26/2002	Baseline	9.2	13.3	11.1	11.5	
3/26/2002 13:14	Clean Water	9.1	8.1	12.9	7.7	Complete Flux, chlorine clean at pH 9.06
3/26/2002	2 hr Soak		9.5		6	
3/27/2002 06:00	6 Hour Soak	9.2	9.1	12.7	6	
3/27/2002	Clean Water Flux # 2	9.1	10	12.2	5.9	
3/27/2002	Citric Acid Wash	9	10.3	12.0	5.7	pH= 3.1
3/27/2002 15:17	6 Hour Soak	9	10.5	11.9	5.4	pH = 2.84
3/27/2002	Clean Water Flux # 3	9.2	11.7	11.8	5.1	

Evaluation of Pilot Results

Evaluation of Effectiveness of Technology to Achieve Performance Goals

Table 11 summarizes the operations phases and the process performance in each phase. Table 12 summarizes performance goals and measured performance.

Turbidity Removal

The MBR unit produced consistently low effluent turbidities, even under peak flow conditions. For all phases and flows tested, the performance goal was achieved.

Ammonia Removal

The MBR achieved ammonia removal consistently throughout the pilot, with one exception. For a brief period during Phase 1c, ammonia was not completely removed (effluent concentration 3 mg/L), when aerobic tank mixed-liquor concentrations dropped below 2,000 mg/L, reducing the population of nitrifiers. Mixed-liquor concentrations dropped due to dilute influent waste streams.

Nitrate Removal

Effluent nitrate process goals were not met consistently. The MBR process met the "<8 mg/L 90th percentile effluent nitrate" process goal only during Phase 1b and Phase 1c, when mixed-liquor concentrations in the anoxic zone were high (>8,000 mg/L). In all other phases, effluent nitrate exceeded process goals.

TP Removal

The MBR unit was not designed to perform biological phosphorous removal. No separate anoxic zone was provided and the anaerobic zone was not designed for phosphorous removal. As a result, the system did not meet the TP removal performance goal during any phase. Effluent TP was consistently 1 mg/L or less in Phases 1a, 1b, 2a, and 2b. There was no improvement in removal efficiency when the process was modified for biological phosphorus removal for Phases 3a and 3b.

Total Coliform Removal

Effluent total Coliform performance goals were met in Phase 1b, Phase 2 and Phase 3. During Start-up, effluent total Coliform concentrations were as high as 1.7 x 10^3 CFU/100 mL. Effluent Coliform levels dropped in Phases 1a and 1b, and no Coliform was detected for the remainder of the study.

Table 11 Summary Table of Process Operation and Performance

Phase	Process Goal	Feed Source	Actual Aerobic TSA (days)	Actual Total TSA (days)	Average Flow (gpm)	Average Flux (gfd)	Relax mode or Backpulse mode	Dates	Effluent NH4 (mg/L)	Effluent NO3 (mg/L)	Effluent TP (mg/L)	Effluent Ortho-P (mg/L)	Effluent TOC (mg/L)	Effluent Turbidity (NTU)
Start-up		PE 8/29-10/7 PI 10/8	--	--	5.4	11.7	Relax 8/29-9-13 Backpulse 9/14	8/29-10/16 (20 days)	0.04	6.93	3.64	2.90	7.96	0.02
1a	N/dN	PI	10.0	--	5.3	11.5	Backpulse	10/17-11/15 (31 days)	0.03	7.90	1.62	1.39	6.55	0.01
1b	N/dN	PI	10.0	15.0	7.4	16.1	Backpulse 11/16-12/2 Relax 12/3	11/16-12/7 (22 days)	0.31	5.23	0.52	0.97	5.70	0.02
1c	N/dN	PI	--	--	5.5	12.0	Relax	12/8-1/3	0.40	5.88	0.62	0.52	6.26	0.01
2a	N/dN	PI	5.6	8.5	5.5	12.0	Relax	1/4- 1/19 (16 days)	0.02	7.42	0.73	0.72	5.87	0.02
2b	N/dN	PI	--	--	5.5	12.0	Relax	1/20-2/4 (16 days)	0.02	9.37	1.09	1.00	6.20	0.02
3a	Bio-P	PI	--	--	5.5	12.0	Relax	2/5-3/12 (34 days)	0.02	8.52	0.95	0.92	6.34	0.02
3b	Bio-P	PI	6.1	7.4	7.8	16.9	Relax	3/13-3/25 (13 days)-	0.34	9.53	0.97	0.92	5.05	0.02

N/dn=Nitrification/Denitrification; Bio-P=Biological Phosphorous Removal; PE=Primary Effluent; PI=Primary Influent

Table 12. MBR Unit Measured Performance

Goal Description	Target	Measured Performance
Turbidity Removal	<0.2 NTU, 90th percentile	<0.06 NTU – All Phases
		Average 0.015 NTU – Overall
Effluent Ammonia	<1 mg/L, 90th percentile	0.015 mg/L Average – Overall
		3.6 mg/L Maximum Phase 1c
Effluent Nitrate	<8 mg/L, 90th percentile	6.2 mg/L, 90th percentile – Phase 1b only[a]
	<5 mg/L, 90th percentile	5.2 mg/L, 50th percentile – Phase 1b only[a]
Effluent TP	<0.1 mg/L, 90th percentile	2.7 mg/L, 90th percentile
		0.9 mg/L, 50th percentile
Total Coliform	2.2 CFU/100 mL 7-day median Sample	No detect 12/1 – 3/15[c]
Long Term Flux Decline	<2% /yr	Not Measured[b]
Backpulse Interval	>15 minutes	>90 days

a Effluent nitrate exceeded performance goals in all other phases, see Table 6.

b Unable to measure during pilot test duration.

c Total Coliform average 10^3 CFU/100 mL during Start-up and 10^2 CFU/100 mL during Phase 1a.

Evaluation of Pilot Ability to Meet Other Study Objectives

Operation at Low SRT

The system operated successfully at a total sludge age of approximately eight days and an aerobic sludge age of approximately six days for more than three months. The system did not have any operational difficulties with high vacuum pressures or complete ammonia removal (<0.02 mg/L), and low effluent turbidities (0.02 NTU average) were achieved during the low sludge age period.

Response to Peak Flows

The system responded well to three four-hour peaking tests where temperature-corrected flux was increased to more than 20 gfd. Effluent turbidities remained constant in two of the peaking tests ranging from 0.01 to 0.03 NTU. Effluent turbidity in one test increased over the period of the test (four hours), but never exceeded 0.09 NTU. In addition, the system operated for 22 days at an average temperature-corrected flux of approximately 20 gfd. Effluent turbidity during this period averaged 0.02 NTU.

Long Term Flux Decline

The duration of the pilot study was too short to determine long-term flux decline. However the system operated for more than three months at 15 gfd with no flux decline. Determination of true long-term flux decline involves calculation of new-membrane clean-water flux to the post-recovery clean water for at least four to five consecutive recovery-clean intervals. Only one recovery clean was performed in the pilot study. Therefore, it was impossible to determine long-term flux decline.

Backpulse Interval

The reliability of the MBR successfully operated in relax mode, with no backpulse for more than 90 days in Phases 1c, 2a, 2b, 3a, and 3b, meeting the performance goal.

Reliability Considerations

The MBR process reliability to meet performance goals is summarized in the previous section. For meeting Class A requirements, the MBR's ability to produce an effluent turbidity of <0.06 NTU (the maximum overall turbidity reading) consistently was demonstrated during all test phases. The ability to consistently remove total Coliform was more questionable. However, in a full-scale MBR, disinfection facilities would be located downstream, making the amount of Coliform in the MBR effluent less important.

Operational Considerations

Throughout the testing, county operators recorded detailed comments on the pilot unit's operation. These comments are included in Appendix C. This section summarizes the main observations recorded by the operators.

The system was down on two occasions due to failure of the permeate pump. A survey of full-scale MBR facility operators was conducted to determine how the design of a system design impacts its operation. The survey found that an operator-friendly design has much to do with membrane cleaning. Operators had four main areas where their facility could have been designed more effectively.

Access to the Membranes

For clean-in-place systems, walkways with hand railing should be provided on the entire perimeter of the membrane tank to allow the operator the ability to walk all the way around the tank. At two full-scale facilities, walkways were provided only on one or two sides of the membrane tanks.

Space should also be allowed on the floor of the membrane tank to allow an operator to walk around the modules for inspection or to wash them down at closer range. Entry into the membrane tanks at the Anthem, Arizona facility is a confined space entry. In this situation a removable section of handrail and a base for a jib crane should be made to allow for tank entry.

If grating or a checker plate is provided over the membranes, it should be accessible from a safe location and each piece should be small enough to be removed by one operator. At the Cohasset facility, three-foot by nine-foot grating pieces were aligned across all three membrane trains. If one set of membranes was removed from service, the entire grating needed to be removed for access, and removing each piece required two operators. Figure 33 shows the checker plate covering over the membrane tank at Anthem, Arizona. The checker plate covers a single membrane module.

Figure 33. Full Scale MBR at Anthem, AZ

Access to Washwater

All operators surveyed indicated that a good supply of wash water for membrane wash down is required at both the treatment basin and the recovery-cleaning basin. At the Lehigh Acres and Key Colony Beach facilities, 1-inch wash water lines have been removed and replaced with 2-inch supply lines that have 1.5-inch nozzles. Zenon has recommended using a wand in place of a nozzle to fan the wash water over the membrane surface to minimize the potential for damage to the membrane (Thompson, 2000).

Allow Access to Permeate and Airlines

Permeate and airlines are connected to the membrane equipment with cam-lock-type connections. At Arapahoe County, these connections came undone regularly during normal operations, and mixed liquor was discharged through the permeate lines while the vacuum pump continued to operate. The lines were located down in the membrane tank, and no access to the lines at the connection point was provided. Operators needed to reach out over the tank to retrieve the line for reconnection.

The operations staff modified the piping to bring the connection point to the top of the tank where operators could access the connection and changed the cam lock to a 316 SST positive locking connection. Operations staff at the other facilities surveyed also reported that access to the permeate and air lines was hazardous.

Ability to Waste Upstream of the Membranes

At the Anthem, Arizona facility there was one incident where a large volume of clay material was discharged to the sewer system. Because there are no primary clarifiers, and there is no method to waste from the aeration basin upstream of the membranes, the clay material built up on the membrane surface and had to be removed by hand.

While the MBR system is highly automated, the majority of the facilities surveyed provide two to four full-time staff on site during the week and part-time staff on the weekends. Operators report that they spend approximately half their time logging data, collecting and analyzing samples, and monitoring or trending membrane performance. The remainder of their time is spent cleaning, responding and troubleshooting alarms, and performing maintenance. Operators did feel, in general, that the process was easier to operate than conventional activated sludge.

Implementation of a Full-Scale MBR Facility

Design Criteria

The following is a summary of the recommended design criteria for a full-scale facility using MBR.

- Temperature Corrected Flux = 13-15 gfd, 20 ºC.
- Backwash mode operation at a frequency of 15 minutes initially, then operation in relax mode.
- Maintenance clean frequency of three times per week.
- Total TSA = 8 days.

Design flux was determined based on an overview of the temperature-corrected flux data throughout the pilot. The unit operated successfully at 15 gfd for four months during Phase 1c Phase 2 and Phase 3a and at fluxes over 20 gfd during peaking tests; however, Zenon generally recommends operation at 13-15 gfd.

Due to operational problems that surface with startup in relax mode, startup in backpulse mode is recommended. Backpulse mode operation is recommended until the system has operated successfully in backpulse mode and the process has stabilized for two months. The system would be considered stable when the pre-and post-backpulse vacuum was similar and when there were no spikes in TMP. After that the system may be returned to relax mode.

Zenon recommends performing maintenance cleans three times per week. Reducing the frequency of maintenance cleans may have implications for the long-term viability of the membrane and may affect the membrane warranty. The pilot unit operated successfully under high flux conditions during Phase 3 successfully. However, any reductions in maintenance cleans should be reviewed with the system manufacturer.

Design sludge age was determined based on operation in Phases 2 and 3. The system operated successfully at a total TSA of eight days for approximately ten weeks. Operation at a lower TSA may be possible, but nitrification may be compromised at lower TSAs.

Design Features

The following features should be included in a full-scale MBR application for secondary treatment.

- **Fine Screens (2-3 mm).** Fine screens will be required to prevent debris from plugging the membrane modules. A survey of full-scale MBR facilities found that facilities with screens 3 mm or smaller needed fewer-recovery cleans and experienced less membrane fouling. The Arapahoe County MBR facility was originally designed with 6 mm screens upstream of the system. The County operations staff reports that there were significant problems with hair and other organic material binding on the membranes regularly. The County is currently replacing the 6 mm screen with a 3 mm screen in an effort to eliminate the fouling problem. Plants at Key Colony Beach, Cohasset, and LeHigh Acres have 3 mm screens and report no problems with hair or other organic fouling.
- **Monitoring and Process Control.** On-line monitoring of influent turbidity, effluent turbidity, vacuum pressure, run time and other operating parameters required to monitor system performance should be available. The system would perform automated maintenance and recovery cleans, although the operator would initiate both manually.
- **Residuals.** Residuals include screenings and spent chemicals from a recovery clean process. Typically, the spent chemicals from a recovery clean, once neutralized, would be returned to the headworks of the facility for treatment. Screenings would be sent to a local landfill.

Issues not Resolved by Pilot Test Program

The pilot test program could not resolve the following items.

- An accurate determination of long-term flux decline.
- Viability of biological phosphorus removal.
- Viability of nitrate removal.
- Impacts of reducing maintenance clean frequency.

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Appendix A. Test Plan Revisions and Test Plan

Appendix B. Pilot Unit Photos and Operator Comments

Membrane Bioreactor Test Plan Revisions Summary

Introduction

This memorandum is a brief summary of the actual test conditions for the MBR membrane pilot unit. It focuses on changes and modifications from the last version of the MBR membrane pilot test plan, *MBR Test Plan Rev. 6 Draft Date October 4, 2001,* which is also included in this appendix. The intent is for the reader to reference this memorandum in conjunction with *MBR Test Plan Rev. 6.*

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

Operating Conditions

Turbidity was to be measured on permeate. The pilot unit was equipped with a permeate turbidimeter and the PLC logged this data. Periodic turbidity readings were taken throughout the day from the turbidimeters, with a minimum of two readings per day. Lab measurements of turbidity were not performed.

Pilot Test Plan

Overview

Table 2 summarized the proposed phases for the MBR unit and noted that flux (i.e., permeate flow rate) and SRT would vary. Several modifications to the test plan were made:

- The target SRTs were reduced from 15 days and 8 days in the test plan to 10 days and 6 days during the study.
- Phases 1 and 2 in the Test Plan became Phase 1a and 1c in the final report.
- Phase 3 in the Test Plan became Phase 2a and 2b in the final report.
- Phase 4 was not completed.
- Phase 5 was not completed.
- Phase 6 became Phase 3a and 3b.

Sampling

Special Tests

The test plan indicates special tests will be conducted on each of the feed streams. E. Coli testing was recommended. Instead, heterotrophic plate count and total Coliform were measured weekly to determine microbial removal. In addition to SVI, CST was measured several times during the test as a measure of filterability.

Sampling Plan

The sampling plan included in the test plan was an estimation of the schedule and timing for the various parameters that were to be 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.

Membrane Bioreactor Test Plan

MBR Test Plan Rev. 6 Draft

October 4, 2001

Background and Purpose

The Membrane Bioreactor (MBR), manufactured by Zenon is one of eight unit processes being tested during the King County Water Reuse Demonstration Project. The MBR unit was on site and will be ready for operation and testing during the week of August 25, 2001. A total testing period of six months is anticipated for the MBR. The unit will treat primary influent for the duration of the testing. During the first four months the process goal will be nitrification/denitrification. During the fifth month the process goal will be nitrification only. During the sixth month the goal will be nitrification/denitrification with biological phosphorous removal.

The purpose of this document is to outline the proposed testing procedures for the MBR pilot unit that is on site. This test plan will be updated as data is collected and reviewed. This version provides a road map for County staff to begin testing the MBR.

Pilot Testing Objectives

The objectives of piloting the MBR unit process are to:

- Demonstrate the ability of this process to meet Class A water reuse effluent standards.
- Determine overall nutrient removal performance for nitrogen and phosphorous
- Determine membrane cleaning frequency
- Determine typical membrane flux rates
- Evaluate tendency of membranes to "plug," (i.e., build up head too fast)
- Evaluate potential for long-term membrane fouling (inability to clean membrane completely)
- Determine the ability to send effluent to membrane processes
- Evaluate the response to peak flows
- Evaluate operation at high and low MLSSs

The detailed objectives of each phase of testing, as well as performance goals, are included in Tables 4 through 6.

Pilot Unit Equipment and Operation

The MBR pilot unit equipment capacities are summarized in Table 1.

Table 1. Summary of Key Pilot Unit Equipment	
Feed Pump	0 to 10 gpm
Anoxic Tank	1224 gallons
Aerobic Tank	2479 gallons
Membrane Tank	172 gallons
Membrane Units	660 sf
Backpulse Tank	26 gallons
Sludge Wasting Tank	200 gallons
Recirculation Pump	0 to 45gpm
Permeate Pump	0 - 20 gpm
Blower for Aerobic Tank	0 - 60 cfm
Blower for Membrane Tank	0 - 25 cfm

A process and instrumentation diagram of the unit is shown in Figure 1.

The MBR feed pump is a submersible pump located in a wide spot tank that receives either primary influent or primary effluent from West Point WWTP. From the wide spot, flow is directed through a solenoid valve to the anoxic tank. A submersible recirculation pump mixes the anoxic tank. Flow goes by gravity from the anoxic tank to the aerobic tank. A level element in the aerobic tank is interlocked with the solenoid valve, the permeate pump and the recirculation pump to control flows into and out of the process. The solenoid is operated to maintain a constant water level in the aeration basin. When water is withdrawn from the system, the water level drops and the solenoid opens to feed the basin. The flow rate of the unit is therefore controlled by the permeate pump. A centrifugal blower directs 45 cfm of air to coarse bubble diffusers located in the bottom of the tank. A waste line with a ball valve directs MLSS from the aerobic tank to the calibrated sludge-wasting tank. From the wasting tank, waste goes to drain by gravity.

The recirculation pump draws MLSS from the aerobic tank, through a magmeter and feeds the membrane tank. The membrane module includes a group of submerged hollow fiber membranes that come together in a manifold. The permeate pump draws a vacuum from this manifold at the top of the cassettes and draws permeate through the membranes to drain or to downstream processes. As run time increases solids build up on the membrane surface. At 2 inches Hg, the permeate pump shuts off and the tank is aerated without permeate removal.

A blower directs 25 cfm to coarse bubble diffusers in the base of the membrane tank continuously. This blower is on a timer set to 10 seconds on/10 seconds off. The air is intended to scour the membrane surface. An overflow in the membrane tank recirculates flow back to the anoxic tank. The recirculation rate is approximately four times the incoming flow.

The MBR pilot has three types of cleaning processes available; backpulse clean, maintenance clean and recovery clean. For a backpulse clean, permeate is fed from the back pulse tank through the membrane in a reverse direction for a duration of 30 seconds every 10 minutes. The pilot goes through the maintenance clean process much less frequently, only three times a week (Monday, Wednesday and Friday). During two of the maintenance cleaning cycles, sodium hypochlorite is backpulsed and relaxed alternately at intervals and durations input by the system operator. During one of the cleaning cycles, citric acid will be used instead of sodium hypochlorite. The total system downtime for each maintenance clean is approximately one hour. During each maintenance clean, the permeate supply line to the downstream RO unit is disconnected and permeate is routed to drain to prevent free chlorine discharge to the RO membrane.

If the transmembrane pressure increases to consistently 17" Hg, after maintenance cleaning, then a recovery cleaning process may be initiated. During a recovery clean, the tank is drained of all MLSS and the system is removed from service. A strong (1,500-2,000 ppm) sodium hypochlorite solution is placed in the tank and the membrane fibers are soaked for approximately 24 hours.

System Control

With the exception of the influent feed pump, the unit comes equipped with all accessories and equipment required for automated operation. A local control panel allows input and control of mechanical functions and key operating parameters. Alarm conditions and automatic shutdown of the unit are included in the controls to allow unattended operation and protection against failure. Controls external to the MBR PLC allow operation of the influent pump.

SRT/MLSS Control

SRT and MLSS will be controlled by the wasting rate from the aerobic tank. The waste line has manual valve that will be opened daily, 7 days a week, to batch waste to a calibrated waste tank. A peristaltic pump for wasting will be added to give a uniform wasting rate under all loading conditions. The estimated cost for this pump is $1,000.

Under steady state operation, constant MLSS and constant SRT will both give the same operational condition. SRT was selected as the key process control parameter. The base flow to the unit will remain constant throughout the project. The MLSS will increase or decrease based on the SRT target and feed to the unit and calculated from the operating data (MLSS and volume wasted to establish a steady state operating value).

Flow Control

Flow to the unit is controlled by the permeate pump as described above. Permeate flow will be increased by opening the discharge valve on the permeate pump to increase the system flow. This will, in turn, drop the level in the aerobic tank. The level element will send a signal to the solenoid on the discharge of the feed pump to open to compensate. The influent flow to the MBR will impact the membrane flux and HRT in the anoxic and aerobic zones.

Aeration Control

The blower that discharges air to the membrane tank is set on the timer through the MBR PLC. On and off cycles can be entered in minutes. The blower to the aerobic tank is set to operate continuously and is not controlled through the PLC. The goal is to maintain 2 mg/L in the aerobic tank.

Pilot Test Plan

Changes to Original Testing Plan

The initial plan for the piloting of the MBR involved operation of the unit for seven months, with September as the first full month of operation. The MBR unit was started on August 31, 2001. The unit is in shake down to build biomass and establish stable operation under consistent vacuum.

Successful testing is expected in October, approximately one month later than anticipated. For the purposes of this test plan it is assumed that testing will continue to the end of February.

Overview

The pilot testing of the MBR will incorporate six phases. Each phase of the pilot testing proposed above is intended to assess the performance questions and evaluate the unit's ability to meet the performance goals established for the pilot testing project.

An overview of the test plant is shown in Table 2. Based on what is observed during the testing, it may be possible to consolidate periods of testing and/or incorporate additional conditions for testing.

Table 2. Flow and SRT Plan

Phase	Mode	SRT, d	Flow, gpm	Duration, d	WAS, gpd	Month
1	NDN*	15	6	30	287	Oct
2	NDN	15	8	15	287	Nov
3	NDN	8	6	30	539	Nov-Dec
4	NDN	8	8	15	539	Dec
5	Nit	8	8	15	179	Jan
6	BioP	8	8	30	539	Feb

NDN=Nitrification/Denitrification

Test Conditions

General

Testing conditions will be varied during different phases of the testing period. West Point primary influent that has passed through a fine screen will be used for influent to the MBR. Each test period will be run for either 15 or 30 days as shown in Table 2. During weekend periods the MBR should be run throughout the weekend in automatic mode.

A general description of procedures to be used for each period of testing is discussed in this section.

Hydraulic Peaking

The design flow for the MBR pilot (6 gpm) is intended to represent a sustained design flow condition for the unit. Since the application of the process is as a scalping reclamation plant, the flow to the plant will be sustained at the base design load. During periods when a unit is offline for cleaning, the flow to the remaining units must be increased to make up for the loss in capacity. If four units are installed and one goes offline, then the flow to the remaining units increases by 33%.

To test these variable conditions, the flow to the unit will be increased from 6 to 8 gpm for shorter duration testing.

In addition, short term hydraulic peaking is proposed to determine the unit's response to instantaneous peaking. While a rare occasion for a scalping plant, many times these plants are operated with some diurnal peaking. This diurnal peaking is proposed to include a 50% increase in flow for a 4-hour duration. A typical sequence of operation is:

- Week 1 - 3: Base flow condition (6 or 8 gpm)
- Week 4: Peak flow on two days of the week, Tuesday and Thursday – 50% increase in flow for 4 hour. During this period, monitor effluent turbidity and DO.

Phase 1: N/dN, 15 day SRT, 6 gpm flow

The main objective of this phase is to provide reliable nutrient and TSS removal rates under a variety of hydraulic loading conditions. To achieve the target aerobic SRT of 15 days, the wasting rate will be 287 gallons per day.

Phase 2: N/dN, 15 day SRT, 8 gpm flow

The main objective of this phase is to provide reliable nutrient and TSS removal rates under at a sustained higher flux than in Phase 1. To achieve the target aerobic SRT of 15 days, the wasting rate will be maintained at 287 gallons per day.

Phase 3: N/dN, 8 day SRT, 6 gpm flow

The main objective of this phase is to determine the lowest SRT the MBR can be operated at without excessive fouling and to determine how the system responds to a variety of hydraulic loading conditions. To achieve the target aerobic SRT of 8 days, the wasting rate will be 539 gallons per day.

Phase 4: N/dN, 8 day SRT, 8 gpm flow

The main objective of this phase is to determine the lowest SRT the MBR can be operated at without excessive fouling and how the system operates under a sustained higher flux. To maintain the target aerobic SRT of 8 days, the wasting rate will continue to be 539 gallons per day.

Phase 5:Nitrification, 8 day SRT, 8 gpm flow

The main objective of this phase is to determine how the MBR system responds with the anoxic tank removed from the flow stream. A bypass line will be added to allow primary influent to be distributed directly to the aerobic tank. To maintain the target aerobic SRT of 8 days, the wasting rate will continue to be 179 gallons per day.

Phase 6:Biological P removal, 8 day SRT, 8 gpm flow

The objective of this phase is to determine the effect of biological P removal on MBR system performance. Phase 6 will be operated at an 8-day SRT. The anoxic zone will be returned to service, increasing the biomass in the system. The wasting rate for Phase 6 will be 539 gallons per day.

During this Phase, two methods for biological P removal will be evaluated. The first method will be to increase the air-off time in 5 minutes increments and decrease the air on time in five-minute increments and track nutrient removal performance. The goal of this method would be to create localized anaerobic conditions in the aerobic tank. If this method is unsuccessful, a baffle may be added to the existing anoxic tank to create an anaerobic zone.

Sampling

For each phase of testing, influent, effluent and waste sludge are sampled. The waste sludge is a grab sample taken during the batch wasting. MBR influent and effluent are composite samples taken with an automatic sampler. During all the phases of the MBR testing process the sampling will be the same.

Table 3 shows the testing parameters, how often each one is tested and the type of sample taken. E. Coli testing for the MBR effluent was added because E. Coli is a measurement used to determine whether the process meets Class A criteria. In addition, SVI was added to the WAS testing as an indicator of ability to thicken or dewater.

In addition to those tests shown in Table 3, field measurements of pH and temperature will be taken daily on both the MBR influent and MBR effluent. Turbidity will be taken daily in MBR effluent only.

ROLES AND RESPONSIBILITIES

County will operate the unit and collect all samples. County West Point Process Lab will do all analyses, except any special tests. County will maintain the project data management system to include the data obtained for the MBR. The consultant team 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. During the calls, the testing status and review of data occur for the MBR unit. On an as needed basis, the County will coordinate a conference call with Zenon. 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 will participate in these calls.

CONTACTS

The following is a list of the project team members.

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Table 3. MBR Sampling Plan

	Week		CODt	CODs	BOD	TSS	VSS	TOC	TKN	NH4	NO3/NO2	TP	O-P	Alk.	EC	SVI	Metals
Phase 1	1	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
BOD/N/dN		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
15 day SRT, 6 gpm		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
	2	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
		WAS	1	0	0	15	2	0	0	0	0	0	0	0	0	1	0
	3	Influent	5	0	5	5	5	0	0	1	0	1	5	3	0	0	1
		Effluent	5	0	5	0	0	2	1	5	3	1	5	3	5	0	1
		WAS	3	0	0	9	5	0	0	0	0	0	0	0	0	1	1
	4	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
Phase 2	1	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
BOD/N/dN		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
15 day SRT, 8 gpm		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
	2	Influent	5	0	5	5	5	0	0	1	0	1	5	3	0	0	0
		Effluent	5	0	5	0	0	2	1	5	3	1	5	3	5	0	0
		WAS	3	0	0	15	5	0	0	0	0	0	0	0	0	1	0
Phase 3	1	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
BOD/N/dN		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
8 day SRT, 6 gpm		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
	2	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
	3	Influent	5	0	5	5	5	0	0	1	0	1	5	3	0	0	0
		Effluent	5	0	5	0	0	2	1	5	3	1	5	3	5	0	0
		WAS	3	0	0	15	5	0	0	0	0	0	0	0	0	1	0

	Week		CODt	CODs	BOD	TSS	VSS	TOC	TKN	NH4	NO3/NO2	TP	O-P	Alk.	EC	SVI	Metals
	4	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
Phase 4	1	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
BOD/N/dN		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
8 day SRT, 8 gpm		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
	2	Influent	5	0	5	5	5	0	0	1	0	1	5	3	0	0	0
		Effluent	5	0	5	0	0	2	1	5	3	1	5	3	5	0	0
		WAS	3	0	0	15	5	0	0	0	0	0	0	0	0	1	0
Phase 5	1	Influent	3	0	2	5	0	0	0	1	0	2	2	3	0	0	0
BOD/N		Effluent	3	0	2	0	0	2	1	5	3	2	2	3	5	0	0
8 day SRT, 8 gpm		WAS	1	0	0	9	2	0	0	0	0	0	0	0	0	1	0
	2	Influent	5	0	5	5	5	0	0	1	0	1	5	3	0	0	1
		Effluent	5	0	5	0	0	2	1	5	3	1	5	3	5	0	1
		WAS	3	0	0	15	5	0	0	0	0	0	0	0	0	1	1
Phase 6	1	Influent	3	0	2	5	0	0	0	1	0	3	3	3	0	0	0
BOD/N/dN/bio-P		Effluent	3	0	2	0	0	2	1	5	3	3	3	3	5	0	0
8 day SRT, 8 gpm		WAS	1	0	0	9	2	0	0	0	0	3	0	0	0	1	0
	2	Influent	3	0	2	5	0	0	0	1	0	3	3	3	0	0	0
		Effluent	3	0	2	0	0	2	1	5	3	3	3	3	5	0	0
		WAS	1	0	0	9	2	0	0	0	0	3	0	0	0	1	0
	3	Influent	5	0	5	5	5	0	0	1	0	5	5	3	0	0	1
		Effluent	5	0	5	0	0	2	1	5	3	5	5	3	5	0	1
		WAS	3	0	0	15	5	0	0	0	0	5	0	0	0	1	1
	4	Influent	3	0	2	5	0	0	0	1	0	3	3	3	0	0	0
		Effluent	3	0	2	0	0	2	1	5	3	3	3	3	5	0	0
		WAS	1	0	0	9	2	0	0	0	0	3	0	0	0	1	0

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
8/1/2001		Equipment delivered from Irvine CA. Shipper arrived in early afternoon. Following items delivered: std ZW pilot FS121, aux equipment skid, aerobic tank, anoxic tank, wasting tank, small aux blower, large aux blower, recirc pump, 4 boxes of misc equipment. Zenon rep (Patrick Reaume) onsite to receive equipment. New membrane from Ontario arrived on 7/31. All equipment checked by vendor with plan to set equipment tomorrow. Vendor commented that equip has seen lots of modifications in the field - no "as-build" prints with delivery. Vendor (Patrick) having current PID design faxed from Zenon in Ontario. Collected from Zenon eng onsite @ Irvine, Ca.
8/2/2001		New membrane installed using Drying Facility overhead crane. Membrane skid relocated to location in test facility. Installed recirc pump skid, anoxic tank, aerobic tank, and waste tank. Will need to purchase several new hose sections due to facility layout (different than previous @ Irvine ranch). Vendor received PID from Irvine installation, working through install details. Informed that there is folloing equipment requiring additional power sources: air compressor for pneuamatic values - 120 VAC, 10.5 A; feed pump in WS3 - 120 V, 14.5 A; sprayer pump in aerobic tank - 120 V, 9.5 A; recirc pump in anoxic tank - 120 V. 9.5 A; auxilliary blower - 220 V, 13.5 A. Will need to pull new circuits for all items. Original design information from Zenon showed only 480 V, 60A service required. Discovered that main membrane skid panel nameplate states 460 V, 70A service. Cannot connect to facility 460 V, 60 A receptacle. Dennis Okeu (KC- CM-elect) requests that nameplate be changed if possible otherwise new circuit. Vendor spent remainer of day laying out process connections. Vendor

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
8/3/2001		Vendor requesting support on installation. Vendor proposed the following plan: KC contractor finish installation work using "marked-up" PID; return on 8/20 to condition membrane in prep for statup; install new PLC on 8/20; install new PLC on 8/20; seed unit on 8/22 with West Point PAS and support ramp to steady-state (9 days). Informed that new PLC will not be available until 8/8. Vendor is also scheduled for vacation on the week of 8/13. Agreed to propose plan - what are other options? Requested "marked-up" PID to complete mechanical installation. Shinn will initiate early next week.
8/4/2001		
8/5/2001		
8/6/2001		Elect contractor pulling new circuits for additional equipment. Mech contractor working on install of hoses and anchoring equipment. Several bins of parts from Irvine provided. Called vendor to discuss issue with electrical panel nameplate. He is talking to electrical dept later in day. Informed that Zenon bio process type will be onsite on 8/30-8/22. Noted that equipment shipped was not cleaned! Sprayed with residual left in sealed line - opened ball valve.
8/7/2001		Contractors continued installation work. Called again about membrane skid panel nameplate - informed it is in work!
8/8/2001		Received fax from Zenon stating that pilot unit requires a max of 60 A service - 70 A information on nameplate is incorrect. Ok to qire for 60 A service. KC - can elect required nameplate change after reviewing fax memo. Informed Zenon to ship new nameplate. Mech/Elect contractors continuing to install.
8/9/2001		Per request by Zenon, filled membrane tank with potable water and added 3.3 L of 5.25% NaOCl (bleach) to preserve the newly installed membrane. Membrane shipped with glycol coating as preservative. Future reference for preserving/string.
8/10/2001		
8/11/2001		
8/12/2001		

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
8/13/2001		Received new nameplate for membrane skid control panel. Shipped FedEx from Zenon. Handed over the electrical contractor for install. Mechanical contractor continued on install work.
8/14/2001		Electrical contractor provided power to membrane skid control panel. Adapters for 60A fuses would not fit in existing fuse blocks. Elected to leave 70A fuses. Overcurrent protection exists in facility panel @ breaker. 70A fuses acting only as disconnect point.
8/15/2001		Installed work completed. Forwarded DH+ network baud rate (230 k) to Zenon I/C type.
8/16/2001		Installed work completed. Forwarded DH+ network baud rate (230 k) to Zenon I/C type.
8/17/2001		Installed work completed. Forwarded DH+ network baud rate (230 k) to Zenon I/C type.
8/18/2001		
8/19/2001		
8/20/2001		Vendor arrived onsite in late afternoon. Plan is to complete new PLC install following integrity testing of new membrane. Expecting Zenon bio process (Cory Schneider) onsite tomorrow. Shinn finishing brackets for hose sections. Vendor troubleshooting control panel problem - no PLC / panel view power for 2 hours. Found loose fuse block.

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
8/21/2001		Cory Schneider onsite in mid morning. Vendor completed integrity test of membrane. No leaks identified. Meeting to discuss startup/operation: attendees: Patrick, Cory, and Bob. Highlights: pilot control on solid concentration vs. sludge age; expect nitrification in 2 months; cleaning mechanisms are air sensor, maintenance clean, recovery cleaning; no backpulse in pilot relaxation instead (15 min permeate - 30 sec aeration/relaxation); monitor temperature due to its impact on permeability; monitor temperature due to its impact on permeability; in months 8/9 - remove anoxic zone; measure MLSS of membrane tank and aerobic tank 80% of membrane tank; request daily data dumps of DO, TSS, NH4, NO3, TP, for Zenon process monitoring. Discussed new startup schedule with vendor. Comments from Cory Schneider included on test plan.
8/22/2001		Vendor having some problems with 120 VAC fuse in membrane skid panel. Blowing fuse when energizing skid power. He is troubleshooting. Vendor continuing with water checkouts. Several leaks identified. Black and Veatch (Doug and Cindy) onsite for facility walkthrough. Cindy had a chance to talk with Cory about process. See comments in book. Continued discussion of pilot seed source and potential impact on test plan. J.B. provided the following comments, see book. Cory Schneider left in early afternoon.
8/23/2001		Vendor finishing water checkouts and repair of several leaks. Vendor concerned with level of expertise required to install new PLC components. In reality, AB 5/04 will not be installed. Following planned: replace existing AB 5/03 wotj mew;y [rpgra,,ed AB 5/03 from Zenon; Install new analog input card for effluent turbidity; install network adapter RS 232 -> DH+, this required installing power outlet since adapter is DV powered (converter required). Will provide West Point Maintenance electrician on Friday afternoon (overtime work) to complete work. Prim elect (contract electrician) has already spend 40 hrs of T/M to install power for extras pumps/blowers.

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
8/24/2001		Vendor completed checkouts and is currently installing effluent turbidity unit (HACH 1720D). Problem with 1720D - bad. Aquatrend will not recognize turbidity meter. Vendor having new unit shipped. WP Maint Elect (Tim) completed install of all new PLC components. Vendor opted not to work over the weekend. Plan to complete final water checkout on Monday.
8/25/2001		
8/26/2001		
8/27/2001		Discovered leaking 4 in hose between anoxic and aerobic tanks. Plan to order new hose. Completed checkout of new PLC programming with water checkout. Due to ordering of new hose - seeding delayed until Wednesday morning.
8/28/2001		Vendor finishing final checkouts and cleanup. Maintenance cleaning proc will be manual operation. Vendor picked up new hose from supplier. Wrong size ordered 3" instead of 4"!
8/29/2001		MBR unit seeded.
8/30/2001		
8/31/2001	At 1410 hrs flow rate changed: flux from 3 to 9 gpm, and recir from 12 to 24 gpm. MLSS anoxic taken from bottom of tank.	
9/1/2001	DO anoxic readings taken from both tank and bucket, both readings 0. MLSS anoxic taken from top of tank.	
9/2/2001	DO anoxic performed in bucket.	
9/3/2001	At 0920 hrs found primary influent facility feed pump OFF. At 0930 hrs initiated maint clean procedure prior to troubleshooting facility pump. At 0950 hrs primary influent pump tripped and will not restart. At 1000 hrs closed DV6 and opened DV13 to provide primary effluent to MBR for feed source. Plan to replace primary influent pump tomorrow. At 1000 hrs MBR being fed primary effluent. Note: add TSS to sheet.	At 900 hrs discovered primary influent feed offline. Facility pump tripped on overload. Optioned to feed MBR with primary effluent. Closed DV6 and opened DV13 to provide primary effluent to WS3.

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
9/4/2001	Influent feed is still primary effluent.	S12 sampler indicating PPPP - unable to turn off or on, will investigate. Leaking seal around recirc pump; looks like from pump; hosed and will continue to monitor. Still investigating best method for measuring DO from anoxic tank; tried taking readings from bucket and BOD bottle. Sampler S12 troubleshoot: (note 1) according to sampler manual; error message of PPPP or EEEE refers to low battery or failed PROM or RAM check during power up. Switched power packs, sampler appears to be functioning normal, sampler S12 put into service at 1600 hrs.
9/5/2001		S12 sampler collected at 0810 hrs, 17 count. Performed MC1 at 1106 hrs. At 1215 hrs switched feed flow from primary effluent to primary influent. DV6 open, DV13 closed, DV4 throttled. Installed new primary influent feed pump in East Primary.
9/6/2001		MLSS not performed. Putting ice in s12 sampler; heat generated by skid blower heating the area the sampler is located.
9/7/2001		Empty fine screen #1 grit bucket; hosed and raked screen. At 0925 hrs performed hypo maint clean. Recirc pump still leaking, hosed area. Switched feed source from primary influent to primary effluent. Primary influent feed required to operate ActiFlo trailer. Plan to switch feed source back following actiflo trial completions.
9/8/2001		
9/9/2001	At 0955 switched recir pump in operation. Pump #1 leaking at discharge.	Switched operating aerobic to membrane to recirc pumps. Pump #1 off and pump #2 on. Leak on pump #1 discharge line. Noted that pump #1 motor is running very warm. Need to check condition of pump.
9/10/2001	At 1037 hrs adjusted flow to FI-02 rotometer (permeate) 6.1 gpm. At 1725 hrs permeate pump secured for the evening.	At 0947 hrs performed hypochlorite maintenance clean. Talked with Patrick @ Zenon (he actually left message) about high vacuum level. Requested following information: MLSS from ZW tank and aeration tank, DO values, aeration in ZW tank (visual), aeration in aerobic tank (visual), recirc flow correct 6 gpm permeate and 24 gpm recirc, permeate flow? At 1725 hrs Patrick requested that skid permeate pump be secured for the evening. Will maintain aeration in skid.

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
9/11/2001	At 1240 hrs unit back in operation at 6 gpm.	Emailed process weekly report (8/30-9/6) to Patrick Reaume. At 0840 hrs pulled samples from aerobic, anoxic, and ZW tanks for TSS analysis by process lab. At 1055 hrs Patrick Reaume called and left a message. Jeff Penny and Patrick Reaume conference call - Potential causes for fouling: no recirc flow, polymer, sBOD high in effluent. Plan to turn permeate pump back on and allow to run overnight. At 1220 hrs per Zenon, turned permeate pump on at 6 gpm and let stabilize. Interested in ZW vacuum level. ZW Vacuum is 6.2 in Hg. At 1240 hrs per Zenon, left system running overnight. Received MLSS data from process lab (TSS/VSS): Aerobic tank = 3850/3030, anoxic tank = 5190/3990, ZW tank = 2770/2880.
9/12/2001		MBR ZW Vac has returned to 20.8 in Hg. Secured permeate pump at 1135 hrs. Did not perform maintenance clean. Talked with vendor (Patrick) about next step. Leave permeate pump off overnight and startup in morning. Aeration around membrane will continue. Process lab analyzing MLSS samples from all tanks.
9/13/2001	At 1042 hrs turned permeate pump back on. At 1556 hrs permeate pump back on. At 1700 hrs MBR operational at target data sets.	Turned skid permeate pump back on, collected readings. Collected data from previous aeration test - permeate pump off run on 9/10-9/11. Conducted conference call at 1100 hrs with HDR and Zenon. Following topics discussed: expected MLSS in tanks, protential causes of membrane fouling, tests to run as part of troubleshooting, Zenon requested all available data in electronic format. Performing requested tests/checkouts. At 1430 hrs changed cyclic aeration to 10 sec / 10 sec. At 1450-1550 hrs secured permeate pump for 1 hr to allow aeration of ZW tank (data collected after aeration). Aeration flowrates noted 25 scfm and 35 scfm. Checked mixing in anoxic tank, submersible pump is running. Verified (visually) aeration in ZW tank. At 1445 hrs increased permeate flow to maintain 6 gpm and successfully tripped on high vacuum. At 1445 hrs during test to maintain 6 gpm, trip on high vacuum killed 120 VAC power to skid. Problem was blown 15A main 120 VAC fuse. Installed new fuse and abck working. Why is fuse blowing - suspect that alarm annunciator

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
9/14/2001	At 0115 hrs effluent sampler not on. At 1245 hrs switched from relaxation to backpulse mode. 1311 hrs setup is post relax.	At 0900 hrs checked skid - ZW TMP back to 20.6 in Hg. At 0920 hrs recorded all skid settings to support troubleshooting. Conference call with Zenon/HDR, topics as follows: solids (MLSS) in tanks, problem solved; change from relaxation to backpulse mode, no need to reset backpulse flowrate per Zenon, may have to add Chlorine puck down the road puck; now believe problem is caused by sludge characteristics; aeration. At 1200 hrs closed HV25 for precaution (per Zenon). At 1245 hrs switched from relax to backpulse, selected backpulse on main screen. Checked valve changes. At 1249 hrs backpulse complete. Data taken before and after backpulse.
9/15/2001	At 0100 hrs effluent sampler not on.	
9/16/2001	At 1330 hrs S12 sampler started.	
9/17/2001		At 1500 hrs drained water from air compressor and performed maintenance clean.
9/18/2001		At 1420 hrs secured permeate pump to transfer discharge hose to RO feed tank. MBR permeate effluent now flowing to RO skid. At 1510 hrs secured permeate pump to transfer discharge hose back to sampler. RO skid secured.
9/19/2001		At 1110 hrs secured permeate pump to transfer discharge hose to RO feed tank. MBR permeate (effluent) now flowing to RO skid. At 1115 hrs relocated S12 sampler to RO feed tank (MBR effluent feed).
9/20/2001		No comments, continued operation
9/21/2001	At 1843 hrs maintenance clean started, stopped at approximately 1933 hrs.	At 1845 hrs to 1930 hrs completed maintenance clean using HOCl. During maintenance clean, disconnected feed line to RO skid tank. Post maintenance clean allowed MBR permeate to flow to drain for 15 minutes, prior to reconnecting to RO skid. Issue is residual chlorine in ZW tank which could travel to RO skid. Cleaned up area around MBR and moved all electrical cords off floor. Performed single set of CST (s) on ZW tank and aerobic tank sludge. ZW tank 580.3 sec, aerobic tank 346.8 sec, see note three on 9/13 for CST details). S2 sampler left in standby, no sample.
9/22/2001		No entries.
9/23/2001		No comments.

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
9/24/2001		Bleached S2 overflow bucket and sampler line. Performed maintenance clean at 1516 hrs. Disconnected permeate line to RO; found maintenance clean left in Hypochlorite mode. Last maintenance clean occurred on Friday. Sequence would be initiated daily ay 1815 hrs. Returned feed to RO at 1621 hrs.
9/25/2001		No comments.
9/26/2001		Recirculation flow decreasing, at 22 gpm; tweaked discharge valve. Lab error samples throw out; grabs collected.
9/27/2001	Tweaked recirc pump.	No comments.
9/28/2001		Bleached lines and overflow bucket S2; left sampler off for weekend. Performed maintenance clean.
9/29/2001		No comments.
9/30/2001	Sampler started at 0915 hrs.	No comments.
10/1/2001	At 1010 hrs tweaked recirculation pump.	At 1219 hrs performed maintenance clean on unit using hypochlorite.
10/2/2001	At 1220 hrs initiated auto maintenance clean - disabled at 1244 hrs.	Performed integrity test and disinfection cleaning. Note: missed disable of maintenance clean from 10/1, found in middle of clean cycle at 1200 hrs. At 1244 hrs disabled maintenance clean (assume clean started at 1225 hrs). At 1250 hrs secured ZW skid OFF.
10/3/2001	At 0844 hrs adjusted aerobic recirculation rate.	At 1400 hrs effluent turbidity display/meter not working. Talked to Zenon about any previous problems. Instructed to check power supply for loose connections and reset sensor via sensor diagnostics. Checked connections - no apparent problems. Performe
10/4/2001		Sample pulled for micro analysis at Environmental lab. To confirm whether chlorinated clean on Tuesday worked.
10/5/2001		TC result back from Environmental lab - 320 TC/100mL. Next step is to chlorinate the CIP tank continuously - via dosing pump or Chlorine puck. No maintenance clean performed - plan to start again on 3 times per week routine next Monday.
10/6/2001		No comments.
10/7/2001		Plugged unused ports on CIP tank and checked out HOCl dosing pump.

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10/8/2001	At 0845 hrs recalibrated pH meter.	Performed maintenance at 0907 hrs, Hypochlorite. At 1700 hrs switched MBR feed to primary influent. Primary influent pump running in manual. DV13 closed and DV6 open. DV3 and DV4 throttled open on primary influent line - 425 gpm flowrate.
10/9/2001		No comments.
10/10/2001		Performed maintenance clean MCI at 0908 hrs.
10/11/2001		No comments.
10/12/2001		No comments.
10/13/2001		No comments.
10/14/2001	At 0640 hrs DO to waste from aerobic tank on Monday.	No comments.
10/15/2001		S1 grab sample; problems with sampler, reading PPP. Working on chlorination clean and sludge wasting simultaneously. Plan to waste ZW tank = 185 gallons (per Susan) and plan to waste remaining from aerobic tank = 105 gallons. Consultant wants to waste
10/16/2001		S1 sampler plugged with rags, will need to collect grab.
10/17/2001	Wasting 0900-16, approximately 81.6 gallons, wasting down to 4 inches. S1 and S12 samples grab for 10/16.	Setup wasting pump. Using masterflex routed from aerobic tank to waste tank. Will run continuously at rate of 770 mL/min. Checked using 2L graduated cylinder. Need to maintain pump speed at setting 2. At 0245 hrs started wasting. Will monitor through morning. If OK, run continuously... but realize if process is secured, pump must be secured. At 0900 hrs wasted 12 inches from waste tank. Total waste = 16 inches or 80 gallons. (4 inches drain valve.) S1 and S12 samples grabbed. Relocated S1 sampler to wide spot tank #1. Performed MCI clean at 0917 hrs.
10/18/2001		No comments.
10/19/2001	Verified Chlorine puck is still in CIP tank.	Performed Hypo maintenance clean at 1027 hrs. Forgot to turn off recirc pump and membrane compressor until 1104 hrs. Removed permeate to RO at 1133 hrs. Mike Norton indicated that wasting rate should be 155 gallons/day to maintain a 15 day SRT instead of 290 gallons. This would be 413 mL/min. Shut off wasting at 1149 hrs. Drained 23.5 inches from waste tank. Recalibrated pump for 410, pump setting between 1 and 2. Slight change makes a big difference, no touchy. Restarted wasting at 1225 hrs.

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10/20/2001	At 1113 hrs waste tank level 30.5 in L.	Recirc pump #2 starting to leak slightly, will need to have maintenance check on 10/26. Wasting valve on waste tank left open unable to check flow rate. Valve closed, verify Sunday.
10/21/2001		S1 grab; wide spot #1 tank level seems to be fluxing greatly; sampler hose not down in tank far enough; redid hosing. Cleaned facility fine screens. Hosed S2 buildup around recirculation pumps. MBR wasting tank level 30.5 inches at 1113 hrs; wasted to drain.
10/22/2001	Left wasting valve to drain open - closed at 0745 hrs. BP = 18.9. RO down at 1001 hrs.	Left wasting valve to drain open; closed at 0745 hrs. Performed Hypo maintenance clean at 1003 hrs. Initial TMP high (20.1) following a backpulse reduced to typical level of 2.1 in Hg.
10/23/2001	At 1352 hrs wasting tank at 44 inches. Closed at 1538 hrs.	No comments.
10/24/2001	RO planned shutdown at 0955 hrs. Wasting tank level at 30.5 inches at 1112 hrs.	Performed MCI clean at 1003 hrs.
10/25/2001	At 0756 hrs no wasting, possible pump plug.	At 0800 hrs, wasting pump line might be plugged; doesn't appear any wasting occurred since 10/24 at 1112 hrs when last checked. Back flushed wasting lines and replaced tubing; wasting resumed at 1249 hrs.
10/26/2001	At 0944 hrs performed maintenance clean. At 1033 hrs unit secured.	From 0930 to 1030 hrs completed maintenance clean with HOCl. Maintenance (John Bugstrom) repaired leak on recirc pump #1. Put pump #1 into service - pump #2 has bad seal leak. Calling Zenon for mech seal kit. At 1554 hrs checked calibration of wasting masterflex pump. Referencing note 2 from 10.19, wasting rate should be 413 mL/min. 1 minute to graduated cylinder yielded 410 mL/ Emptied wasting tank at 1628 hrs.
10/27/2001		No comments.
10/28/2001	Wasting check performed by Bob Bucher, 425 mL/min OK.	At 0810 hrs wasted from waste tank. Checked accumulation, 425 mL/min, check ok.
10/29/2001	Wasting tank level: 36.5 at 0903 hrs. RO secured at 0907 hrs and back online at 1016 hrs.	Grab S12 sample from HV20 for lab to analyze for CL2 at 1037 hrs. Verified puck still in CIP tank.
10/30/2001	Waste check; 460 mL/min.	At 1530 hrs checked wasting rate. Currently at 460 mL/min. Should be 415 mL/min, did not change setting. At 1611 hrs drained waste tank - predrain level value is 28 inches. At 1656 hrs closed waste tank drain valve.

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Date	Comments (Operator Data Sheet)	Comments (Log Book)
10/31/2001		At 1203 hrs waste tank level at 30.25 inches. Performing maintenance clean, MCI at 1115 hrs. At 1541 hrs closed waste tank drain valve.
11/1/2001	At 0945 hrs secured MBR for blower vane changeout. At 1015 hrs unit back in operation. Check of vacuum, 518 sec remaining = -2 in Hg.	Secured unit for approximately 1 hr (starting at approximately 0935 hrs) in support of maintenance change of vanes on aerobic tank air blower. Maintenance noted 5/16" difference between old and new vanes. Talked with Zenon about new mechanical seals for ML recirc pump. Ordered and expect to have by early next week. Environmental lab micro folks (Karl and Greg) will be onsite Monday (11/5) at 1000 hrs to look over skid and troubleshoot potential routes of contamination. (Elevated TC and HPC counts in permeate S12 grab samples).
11/2/2001	At 0852 hrs opened valve to drain waste tank. 1005 Taken pre-maintenance clean, 1106 taken post maintenance clean.	Primary influent feed pump tripped out on overload at approximately 0145 hrs. At 0900 hrs performed 1 minute MLSS waste pump calibration. Calibrated flow is 410 mL, setpoint of 415 mL. Pump OK, no change required. From 1010 to 1050 hrs completed HOCl (Hypo) maintenance clean. Per Zenon request, checked volume of CIP tank permeate consumed during backpulse. Total volume is 25L. Emailed result to Patrick Reaume.
11/3/2001		No comments.
11/4/2001		No comments.
11/5/2001	Unit left in Hypo maintenance clean mode since 11/2. Maintenance clean from 0958 to 1048 hrs.	No comments.
11/6/2001	On 11/5, feed pump 1 general alarm; 1632 primary influent pump overload. SCADA primary 312 gpm at 810 hrs. At 0800 hrs no flow to wide spot tank 1; adjusted DV4 and valve to Densadeg; may need to monitor and adjust flow to FF, only 2 gpm at 0810 hrs. Need to clean S4 overflow bucket; sampler is not on. S4 and S1 grabs.	No comments.
11/7/2001	At 1350 hrs drained tank. Calibration check of wasting is 420 mL/min, ok!	No comments.

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11/8/2001		At 1355 hrs performed calibration check of MLSS wasting, 420 mL/min (setpoint of 415 mL/min), o.k.. At 1417 hrs drain closed on waste tank.
11/9/2001		Completed HOCl maintenance clean from 0934 to 1030 hrs. At 1515 hrs cleaned permeate turbidimeter and adjusted flowrate.
11/10/2001	At 08544 hrs loss of flow to Wide spot 1 and 3 tank - most likely due to opening outside PI valve to drain. Need to discuss with Densadeg vendor, flow off all night. Note: cyclic air not operating, suspect bad solenoid. At 0946 hrs repaired solenoid (SV-09).	At 0850 hrs discovered no flow to WS 1/3. Reason - Densadeg vendor secured last night included opening of outside PI valve to drain. This provided path of least resistance to drain vs. across fine screen. Fixed today by throttling position should be maintained when the Densadeg is not in operation. At 0940 hrs during this period of SV-9 not functioning, process air was continuously ON at 255 scfm. Noted that cycle aeration not operating. Troubleshooting revealed that solenoid valve (SV-09) operating. Selector valve for cycle air not operational. Solenoid valve block disengaged from electric coil. Repaired and cycle air back in service at 0946 hrs. Need to monitor! At 0947 hrs added new stabilized Chlorine puck to MBR CIP tank.
11/11/2001		No comments.
11/12/2001	At 0945 hrs drained waste tank.	No comments.
11/13/2001		At 0845 hrs discovered no flow to WS 1/3. Unit secured from production. Facility PC showed WS 1 low level alarm at 0843 hrs. At 1630 hours noted MLSS wasting not operational, troubleshooting revealed clog in barb fitting next to masterflex pump, cleaned and back into operation.
11/14/2001		At 1146 hrs secured unit for chlorination clean. Performed clean per 10/15 note 2. (Also secured RO unit during clean.) At 1148 hrs secured MSS waste pump during clean. At 1310 hrs recirc initiated: permeate pump in manual-on; blower in auto-on. At 1416 hrs secured from recirc and drained ZW tank. At 1509 hrs MBR back into service. At 1545 hrs permeate flow reconnect to RO feed tank. At 1700 hrs MLSS waste pump restarted.

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11/15/2001	Testing from 0733 to 1157 hrs. Permeate flow changed to 8 gpm at 1157 hrs.	Perform peak hydraulic load test from 0733 to 1157 hrs. Increased permeate flow from 6 to 9 gpm for 4 hours and monitored DO and NTU. Reduced flow to 8 gpm starting phase 2 testing, permeate flow of 8 gpm.
11/16/2001		No comments.
11/17/2001		No comments.
11/18/2001	At 1155 hrs opened waste tank drain, calibrated check of waste pump = 420 mL/min, this is o.k..	At 0138 hrs noted the in service pump leak by the discharge side. "Slow leak." Need to switch to the standby pump.
11/19/2001	At 1643 hrs closed wasting valve.	No comments.
11/20/2001		No comments.
11/21/2001		No comments.
11/22/2001		No comments.
11/23/2001		No comments.
11/24/2001		No comments.
11/25/2001	Check wasting rate: 410 mL/min.	No comments.
11/26/2001	Note: pump leak and mess on the floor.	No comments.
11/27/2001	At 0909 hrs - no flow to turbidimeter (checked at turbidimeter discharge, opened feed valve HV 21).	No comments.
11/28/2001	Verified chemical puck still in CIP tank.	Performed MCI unit clean. Increase recirc rate from 24 to 32 gpm at 1041 hrs. No flow to turbidity meter.
11/29/2001	At 0730 hrs no flow to turbidimeter.	At 1620 hrs switched recirc pump operation from pump 1 to pump 2. Pump 1 will be rebuilt on Monday (new mechanical seal and repair of discharge side leak).
11/30/2001	At 0802 hrs, effluent turbidity note: had re-established flow on 11/29.	No comments.
12/1/2001		No comments.
12/2/2001		No comments.

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12/3/2001	At 0700 hrs unit secured for maintenance. At 0715 hrs unit to standby, recirc pump OFF. Computer back on at 0850 hrs. Recirc pump back at 0850 hrs.	Maint replacing filters on air compressor; unit in stand by at 0715 hrs, recirc pump off. Compressor back online at 0830 hrs, delivering 52 scfm (previous max capacity of 27 scfm). Recirc pump 2 in service; maint working on pump 1. Maintenance clean started at 0914 hrs - received insufficient CIP volume alarm. At 1110 hrs went to relax mode. Flux rate at 7.3 gpm, previous at 8.0. Called Pat - provided status of recirc pump, requested new impeller. Vacuum pressures pretty stable - increase in NTU has been observed.
12/4/2001	At 0700 hrs reduced recirc rate to 29 gpm. At 0957 hrs reduced process air from 50 to 28 scfm.	Vacuum pressures are remaining stable around 4.2 in Hg. Recirc pump #2 continues to leak. Lowered aerobic recirc rate from 32 to 29 gpm. Main clean left on; went through cycle; again received insufficient CIP volume; will investigate on Wed. Checked wasting rate, approximately 400 mL/min left along. Received 2 voice messages from Pat; recommends lowering process air output to maintain DO in the aerobic tank at 2 mg/L. Pat will be on vacation Dec 4-17, Collin Nash (EXT 3423) is backup. Current DO of aerobic tank around 10 mg/L. Reduced compressor from 50 to 28 scfm. Will have lab check DO meter. Will continue to monitor DO levels. Since switching to relax mode greater variability in turbidities. Need to review NTU data since changes made to the turbidity flow setup. Changes made 11/28? Need to verify.
12/5/2001	S1 sample grab from influent line tap at 0830 hrs.	Performed MCI maintenance clean, no problem with insufficient CIP volume. Lab checked field DO meter; is about 1 to 1.5 mg/L higher than lab DO meter. TSK to replace membrane. Collin Ness (Zenon) left message regarding recirc pump. Andy switch wide spot tank 1 to secondary effluent to trouble shoot fuzzy filter.

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COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
12/6/2001	On 12/5 unit down on low ZW tank level; 2230 S10. At 1526 hrs lost GF1 unable to cycle feed valve; lost turbidity meter; reset GF1. S1 sample not taken due to feed source to WWtk1 being switched to secondary effluent. At 0815 hrs switched WS1 back to primary influent. At 0824 hrs turned off wasting. At 1127 hrs on 12/5 zw tank low level discussed with Collin (Zenon). At 09?? manual open feed valve to ZW tank level above the LLA level of 35; stopped at 0913 hrs to received training. At 1100 hrs 35.1 ZW tank level, manually feed tank until reaches 48.5 level. CIP tank level high at 1145 hrs - drain into bucket using HV14, level at top of CIP HL. At 1215 hrs unit back online, flow to turbidity meter at 1222 hrs. At 1526 hrs no permeate; ZW tank level at 39.8 inches, feed pump indicates on but no flow to tank.	MBR unit alarmed on low ZW tank level at 2230 hrs on 12/5. To help with trouble shooting of the Fuzzy Filter, the wide spot tank # 1 was valved to receive C3. The wide spot Tank 3 was completely isolated. The MBR received PI until the W S tank 3 was completely drained. The MBR went into idle at 2227 hrs(12/5) when the ZW tank level dropped below the low level set point of 35 inches. Wasting continue from the aerobic tank until 0824 hrs(12/6) bringing the aerobic tank level down to 32.7 inches by 0821 hrs. It was necessary to manually feed the anoxic tank to bring the tank level back to 48.5 inches before the process would go into production. The process was back on line at 1215 hrs. Down stream impacts : R/O shutdown when the MBR stopped production. The R/o returned to service at 1217 hrs.
12/7/2001		No comments.
12/8/2001	Received page at 0230 hrs - flex hose to Densadeg leaking; ops isolated at 0130 hrs, increased recirc to 22 gpm.	No comments.
12/9/2001	Started sampler at 0900 hrs.	No comments.
12/10/2001		Decide to hold off on increasing wasting to review TSS data for process.
12/11/2001	Starting new wasting rate of 780 mL/min at 0916 hrs.	0916 hrs - Started wasting @ 780 mls/min for 290 gpd rate to maintain an 8 day SRT.
12/12/2001	Recalibrating wasting pump to 780 mL/min (810 mL/min). At 1600 hrs fine screen 2 cleaned.	No comments.
12/13/2001	Check of wasting rate of = 750 mls/min; Added new stabilized chlorine puck to CIP tank	No comments.
12/14/2001	Initiated maint clean 1430 hrs- end 1515 hrs (actual 1518 hrs)	No comments.
12/15/2001		No comments.
12/16/2001		No comments.

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
12/17/2001	Checked calibration of wasting pump; Ran SVI; 1233 hrs - Shut off recirc & permeate pump to facilitate installation of recirc pump # 1; Unit back on line @ 1313 hrs. Stopped wasting in pm.	No comments.
12/18/2001		1350 hrs - Checked turbidity flow (@0). Troubleshooting revealed pinched feed tubing between plywood and tube steel. Re-routed tubing and re-initiated turbidimeter flow. Secured wasting from aerobic tank last evening (called and requested shift Ops - Mick to secure) Aerobic tank TSS was @ 1380 mg/l on grab sample. Plan to not continue wasting until TSS Increases
12/19/2001		Performed MC1 Maint clean 1454 hrs. No wasting
12/20/2001		MLSS results from 12/19; Aerobic 1550; Anoxic (top) - 7720, (bottom)- 6670; ZW - 1900; Settleometer test ran but aborted; Received calcs from Amanda wants to resume wasting on Friday. Will call on Friday to evaluate based on MLSS results.
12/21/2001	Resumed wasting @ 1748 hrs - 430 mls/min (actual 460 mls/min)	1206- Performed Maint clean. Started wasting @ 160 gpd (429 mls/min) at 1748 hrs. Rate at 460 closest could get; Settleometer ran; no clear interface throughout test. At 67 minutes - SSV = 860 cc/l
12/22/2001		No comments.
12/23/2001		No comments.
12/24/2001		No comments.
12/25/2001		No comments.
12/26/2001		No comments.
12/27/2001	1220 hrs waste check = clogged (430 mls/min)	Working on anoxic tank mixer improvement. Removed hose from discharge of mixing pump and routed directly into tank. Plan to install new taps on spray bar and route mixer discharge through spray bar. Suspect poor mixing due in part to mixer only recirculating locally in the anoxic tank. 1220 hrs- Discovered waste pump inlet clogged. Cleaned and performed check of wasting rate. Waste rate = 430 mls/min ~ 160 gpd
12/28/2001		No comments.
12/29/2001		No comments.
12/30/2001		No comments.

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
12/31/2001	1335 hrs - SV-09 not operating; 1340hrs- Maint Clean initiated; 1420 hrs Maint clean completed	Maint clean (HOCL) completed (1340 - 1420 hrs); 1200 hrs Discovered SWV-09 (cyclic aeration in ZW tank) is not operating. This means that aeration is continuously ON to ZW tank. Working on fix. Completed modification of mixer in anoxic tank. Installed additional sprayers on spray bar and routed submersible pump to discharge to bar. Also installed cover to minimize spray from escaping tank.
1/1/2002		No comments.
1/2/2002		Performed MC1 Maint clean. Unit found still in Maint Clean mode from 12/31. Ran settleometer test. AT 60 minutes, SSV = 980 cc/l; no clear interface;
1/3/2002		No comments.
1/4/2002	High vacuum alarm acknowledged at 1543 hrs; wasting increased.	Performed Maint Clean. Set new wasting rate for 270 gpd to maintain a 6 day SRT based on the aerobic tank MLSS conc (1541 hrs) (710 mls/min); 1543 hrs - High vacuum Alarm - found membrane air compressor & recir pump still off from Maint clean (Maint Clean completed @ 1050 hrs). Acknowledged Alarm and turn on recirc pump & ZW tank air; ZW tank Level Low; No recirc occurring; Put unit in Standby until ZW tank level increased & recirc resumed. Aerobic tank level also dropped to 45.2 ". Permeate production will not occur until the aerobic tank level increased to 48.5". Last pre-BP vacuum - 12.4 in of Hg. After restarting max ~ 8 inches of Hg.
1/5/2002		
1/6/2002		
1/7/2002		Maint clean @ 1011 hrs; back in-service @ 1157 hrs; Checked rate of wasting - 690 mls/min; OK; Performed settleometer test.
1/8/2002		
1/9/2002	0330 hrs - Permeate pump failed; Troubleshooting underway.	Maint clean; Performed settleometer test.

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
1/10/2002		0400 hrs - Discovered unit shutdown on alarm condition : ALARM - YA-4 permeate pump P-4 motor failure on Zenon screen alarm recorded 0118 hrs. 0415 Hrs - Troubleshooting pump failure; On process summary screen previous vac level @ 2.8 "Hg. Tried to restart unit with no luck. Facility SCADA alarm recorded "MBR Permeate Pump Overload " - 0413 hrs; 0445 hrs - Secured MBR wasting pump until unit back in operation. 1015 hrs - CIP tank high level alarm on unit SCADA screen. Drained water from CIP tank via HV14 to floor. Hoping alarm would reset - no luck. Troubleshooting pump electrical - A) Reset overload (tripped) B) Overload set @ 6 Amps C) Motor details : 208 -230 VAC / FLA ^ Amps, service factor = 1.0 continuous duty; 1030 Hrs - Restarted unit (permeate pump operational); Re-initiated waste pump.
1/11/2002		
1/12/2002		2330 hrs- Shift operator noted that WS # 1 & # 3 empty (low level)
1/13/2002	0120 Hrs - P-4 pump failure; Waste check : 720 ml/min	0925 hrs - Discovered MBR shutdown on permeate pump failure - same as 1/10 - Note 1. 0930 hrs - WS # 1 & # 3 have PI in them. Suspect operator adjusted feed control valve; Opened PV4 further to allow more flow - flowmeter showing 225 gpm. This flow is with downstream valves set as is. Opened DV4 under fine screen to increase flow - flowmeter @ 285 gpm. 0940 hrs - Reset permeate pump overload and started skid. Also opened HV14 to drain CIP tank to below high level switch. Due to WS # 1 & #3 empty, Aerobic tank level @ 37.5 " - startup of pilot unit re-initiated feeding. Note wasting was ON during entire down period. 0940 hrs - Secured wasting pump until system back on line. On SCADA, MBR shutdown @ 00:52 hrs on 01/12; 0950 hrs - Depressed ALARM RESET on SCADA panel to re-initiate pilot feeding. 1145 hrs - Re-started wasting pump & check flow rate - 720 mls/min.
1/14/2002		Maint Clean - 1040 - 1130 hrs. Maint removed recirc pump # 2 for rebuild. 1515 hrs - Unit in standby for 5 minutes to checkout re-built recirc pump. Rebuilt pump will remain online overnight for leak check. Performed settleometer test.

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
1/15/2002		Noted that DO in aerobic tank has been around 6 mg/l. The target = 2 mg/l. 0945 hrs - Reduced process air flow to 22 scfm and will measure DO.
1/16/2002	Plant power outage (not feed to facility) 1245 - 1337 hrs.	Maint clean @ 1205 hrs. Performed Settleometer test. Checked & adjusted wasting rate - 720 mls/min. Aerobic tank Do - 4.07 mg/l; Reduced process air blower from 22 to 20 scfm at 1247 hrs. Plant power outage dropped off PI &PE feed pumps to facility : 1245 to 1337 hrs.
1/17/2002		
1/18/2002		Aerobic tank - 4.04 mg/l; Again reduced process air blower back to 20 scfm (1000 hrs); Maint Clean 0920 - 1012 hrs.
1/19/2002		
1/20/2002	1000 hrs - discovered unit shutdown on permeate pump failure; Shutdown until Tues 1/22 - permeate pump failure	1042 hrs - Permeate pump tripped on overload - reset and restarted unit. Can not get unit to restart - will wait for 1 hr and then attempt. Permeate pump has internal thermo trip/reset on motor. 1140 hrs - Still can not restart permeate pump. Unit will remain secured. Flowing operation - process air @ 20 scfm, ZW tank cyclic aeration @ 25 scfm, recirc pump running @ 22 gpm; Wasting pump secured ~2230 hrs.
1/21/2002		
1/22/2002	Unit off line until new permeate pump on Thursday	Aerobic tank level @ 34.3 inches ~ 1500 hrs added 5 inches of PI feed to anoxic tank. Aerobic tank final level = 39.6".
1/23/2002		Added PI feed to anoxic tank. Initial aerobic tank level = 39.1"; final level = 44.2"
1/24/2002		0915 Hrs - Feed PI to anoxic tank - initial level = 43.9 "; final level = 49.5"; 1030 hrs - Received replacement permeate pump via Fed Ex. Used pump from another pilot unit.

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
1/25/2002		West Point maintenance completed installation of replacement permeate pump. Functional checkout (bump of pump) locked pump un - will not move. Plan to remove pump on Monday and install originally removed pump. Note replacement pump also had cracked discharge fitting. Continued troubleshootiing of permeate pump electrical. Discovered PLC not providing discrete output in either auto or manual mode. Jumper around PLC card confirmed that motor starter was OK. Plant to have WP Maint. work overtime on Monday to continue troubleshooting. Noted that blower B-3 motor failure alarm YA-3 appeared. Need to also troubleshoot on Monday.
1/26/2002		
1/27/2002		
1/28/2002		Maint mechanical installed original pump. "Locked" pump taken to Maint for troubleshooting, pump end seized. West Point Maint Electrical continued with PLC troubleshooting. Checking online with laptop computer. Able to force DO for permeate pump ON. Suspect possible issue with alarm interlock. Cleared all alarms and was able to start unit in AUTO. Can not run permeate pump in MANUAL. - no PLC output signal. Permeate pump operating @ 5.5 Amp. After short time in AUTO, process skid blower tripped with alarm as follows "YA-3 Blower B-3 motor failure". Tried restarting with no luck - electrician checked current - attempting to pull 50 A. Pulled leads from motor starter and started pilot unit with only aux blower online. 1115 hrs - Noted with unit in "Production" - no permeate flow. All flow is being routed back into ZW tank. Noted that solenoid YY-03 is not energized - V5 is open to ZW tank and V6 to drain is closed. Need to call Vendor. 1200 hrs - Zenon (Patrick) called about following issues: A) OK to run with 1 blower? B) Why no permeate flow? C) Why no permeate pump
1/29/2002	2230 hrs - Collected "special test" samples for Envir. Lab.	
1/30/2002	Initiated wasting at 100 gpd @ 1346 Hrs.	MC1 maint Clean - 0848 hrs. Perform settleometer test. - 0910 hrs; Started wasting pump per Amanda's recommendation - 100 gpd. @ 1346 hrs.

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
1/31/2002	0850 Hrs - still in Maint Clean Mode	Unit left in Maint Clean Mode from 1/30. Membrane air and Recirc pump turned off -0915 hrs; Unit Alarmed on High Vacuum @ 1102 hrs due to membrane air & recirc pump left OFF. Alarm acknowledged; Membrane air & Recirc pump turned ON @ 1126 hrs; ZW vacuum - 2.5 " Hg.
2/1/2002	S12 - sample a grab.	Maint Clean - 1402 - 1459 hrs; Increased wasting to 180 gpd - 480 mls/min.
2/2/2002		
2/3/2002		
2/4/2002	1320 Hrs - Unit in standby for piping change. 1455 Hrs - Unit back in service.	Ran peaking test - 0730 hrs - 1216 hrs. Increased permeate from 5.5 gpm to 8.2 gpm. Recirc - 2.2 gpm to 33 gpm. Maint. Clean - 1500 hrs
2/5/2002		1437 hrs - Set recycle (aerobic to anoxic) to throttle @ ~ 5 gpm; checked with bucket test : 4.1 gpm 1425 hrs - Missed delivering S12 sample to Process Lab. Emptied existing sample and restarted sampler for tomorrow.
2/6/2002		
2/7/2002	S1- Bleached sampler lines	
2/8/2002		1520 hrs - Check aerobic to anoxic recirc flow using bucket test (setpoint = 5.0 gpm) 5.07 gpm; 1530 hrs - Adjusted waste rate from aerobic tank from 180 gpd to 270 gpd; Current = 410 ml/min; Setpoint = 710 ml/min; checked @ 720 mls/min (dial @ 2)
2/9/2002		
2/10/2002	WS1& WS3 tank empty - adjusted facility valves PV3 & PV4 to provide additional flow.	1245 hrs - Discovered WS1 & WS3 empty. Zeeweed tank level (aerobic tank) @ 42.3" Adjusted facility valves PV3 & PV4 to re-establish flow across screen to WS1.
2/11/2002		
2/12/2002		Performed settlometer test; CST = 150.1 seconds
2/13/2002		
2/14/2002		
2/15/2002		In HDR conference call, reached decision to stop performing maintenance cleans from this point until the end of the project.
2/16/2002		
2/17/2002		

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
2/18/2002		
2/19/2002		
2/20/2002		
2/21/2002	anaerobic pH = 6.45 temp = 12.4; DO = 0; Aerobic pH = 6.7; temp =12.3	
2/22/2002	anaerobic pH = 6.54 temp = 13.3; DO = 0; Aerobic pH = 6.46; temp =13.3	MBR aerobic tank pH has dropped to 6.4; Called HDR (T>B>) to discuss alkalinity addition. Will check again this weekend and potentially add NaOH.
2/23/2002		
2/24/2002		1530 hrs - Checked pH in MBR aerobic and anaerobic tanks. Aerobic = 6.72 & anaerobic = 7.0 Decided not to add NaOH (alkalinity)
2/25/2002		Performed settlometer test; CST = 81.1 seconds & 65 seconds
2/26/2002		
2/27/2002		
2/28/2002		
3/1/2002		Performed settlometer test; CST = 76.6 seconds; Replaced sampler hose on S1 & S12 samplers
3/2/2002		
3/3/2002		
3/4/2002		
3/5/2002		1522 HRS - Per HDR conference call, reduced aerobic air flow from 20 scfm to 15 scfm. 1800 hrs - Installed hose section in anaerobic tank to divert feed flow to bottom of tank. Line terminates approx. 1 ft from bottom of tank. 1805 hrs - Adjusted aerobic air flow to 17 scfm. Recorded 0 mg/l DO @ 15 scfm.
3/6/2002		Performed Settlometer; CST = 143.7 seconds

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
3/7/2002	Unit in standby until 3/8. Aux blower failure.	0745 hrs - Unit shutdown on VAH-01 Vac High Alarm. Noted that aux blower not operating. Suspect lost blower therefore no cyclic aeration on membrane. Received alarm @ 0231 hrs. 0750 hrs - Confirmed blower will not operate. Contacting Maintenance for troubleshoot/rebuild. 1630 hrs - Secured wasting pump. Unit will remain in standby until at least tomorrow. Maintenance will troubleshoot @ 0600 hrs on 3/8. Lab checked calibration of field DO meter. DO readings - Lab : 8.55 mg/l DO; 8.33 mg/l DO compared to Field : 8.60 mg/l DO; 8.44 mg/l DO, respectively.
3/8/2002	Unit secured.	WP Maintenance working on cyclic air blower. Unit can not be repaired - cracked rotor. 1500 hrs - Talked with Zenon about replacement blower. They will ship replacement on Monday - expect delivery on Tuesday morning. Pilot will remain in "Standby" through weekend. Plan to add PE on Monday. Current level @ 42 inches. Will go from 42 to 46 to 50 by Tuesday.
3/9/2002		1645 Hrs - Transferred PI feed to pilot. Start level = 42.5 inches; End level = 47.5 inches. Secured feed pump (pulled power plug) Since WS 1 & WS 3 were near empty. 1600 hrs - Secured facility PI pump by turning OFF @ local control in East Primary. Pump to remain OFF until MBR back on line.
3/10/2002		
3/11/2002	Unit back on line @ 1310 hrs. Resumed wasting @ 1537 hrs.	0930 hrs - Replacement blower arrived via FedEX. Being installed by West Point Maintenance staff. 1310 hrs - Unit restarted with new cyclic air blower operational at 24 scfm. 1500 hrs - Started S1 & S12 samplers; 1537 hrs - Resumed wasting @ 270 gpd - 720 mls/min
3/12/2002		
3/13/2002	1302 hrs - Increased flux rate 5.5 to 9.0 gpm; Recycle rate: 22 to 36 gpm	0940 hrs - significant decline in anaerobic tank TS - investigated; Recycle line plugged; Back flushed & resumed recycle flow. 1136 hrs - Lowered process air 17 scfm to 15 scfm. 1302 - Increased flux rate : 5.5 gpm to 9.0 gpm.
3/14/2002		
3/15/2002		
3/16/2002		

KING COUNTY WATER REUSE TECHNOLOGY DEMONSTRATION PROJECT
COUNTY OPERATOR LOG - ZENON MEMBRANE BIOREACTOR PILOT UNIT

Date	Comments (Operator Data Sheet)	Comments (Log Book)
3/17/2002	Unit shut down on high vacuum. Hypochlorite maintenance clean; 1213 hrs - high vacuum alarm (noted that recirc pump #2 was not operating); 1643 hrs ack alarm and restarted unit; plan to run hypochlorite maint clean; 1650 hrs - Start clean. 1730 hrs - alarm insufficient CIP volume.	1600 hrs - Call from WP operations - unit shutdown on HIGH VAC. 1640 hrs : Troubleshooting cause of shutdown - shutdown occurred at 1213 hrs; Noted that mixed liquor recirc pump # 2 was not operating. Talked with WP Ops and found out that power "bump" occurred shortly after 1100 hrs (3/17). Suspect that power bump may have led to recirc pump shutdown. This would have ultimately caused high vac condition. 1650 hrs - Running hypochlorite maintenance clean and then will return unit to operation @ 9 gpm. also will start recirc pump # 1 (instead of # 2). 1730 hrs - Alarm during maint clean - "insufficient CIP volume". Unit returned to Production after approx 40 minutes of maint clean. Returned system to Production and reduced permeate prod back to 5.5 gpm (vacuum level @ 15 inches with 9.0 gpm). So, permeate = 5.5 gpm ML recirc += 22 gpm. Will discuss next step tomorrow.
3/18/2002		
3/19/2002	0717 hrs - Increased permeate from 5.5 to 9.0 gpm	0717 hrs - Increased permeate 5.5 to 9.0 gpm to support micro sample collection. Also increased recirc 22 to 36 gpm. Plan to let run for 1 hr minimum prior to pulling micro sample.
3/20/2002	1611 hrs - Reduced flux rate to 8.0 gpm	Performed settlometer. CST = 286.8; Replaced batteries in the DO meter. 1330 hrs- Increased flux from 8.2 to 9.0 gpm. Monitored inches of mercury over several production periods. Noted that flux rate drop and membrane pressure peak continued to increase. Max : 20.7 inches of Hg. 1611 hrs - Reduced flux rate to 8.0 from 8.7 gpm.
3/21/2002		1650 hrs - Reduced recyle rate from 36 gpm to 32 gpm.
3/22/2002		
3/23/2002		0945 hrs - Increased process air (aerobic tank) from 15 to 18 scfm based on DO reading of 0.14 This has occurred on 3/21 & 3/23.
3/24/2002		
3/25/2002		0830 hrs - Settleometer; CST = 266.6 ; Unit down, test period complete.

Membrane Bioreactor Pilot Unit Photos

Introduction

The following is a series of photos of the Zenon MBR 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. Zenon Pilot Unit

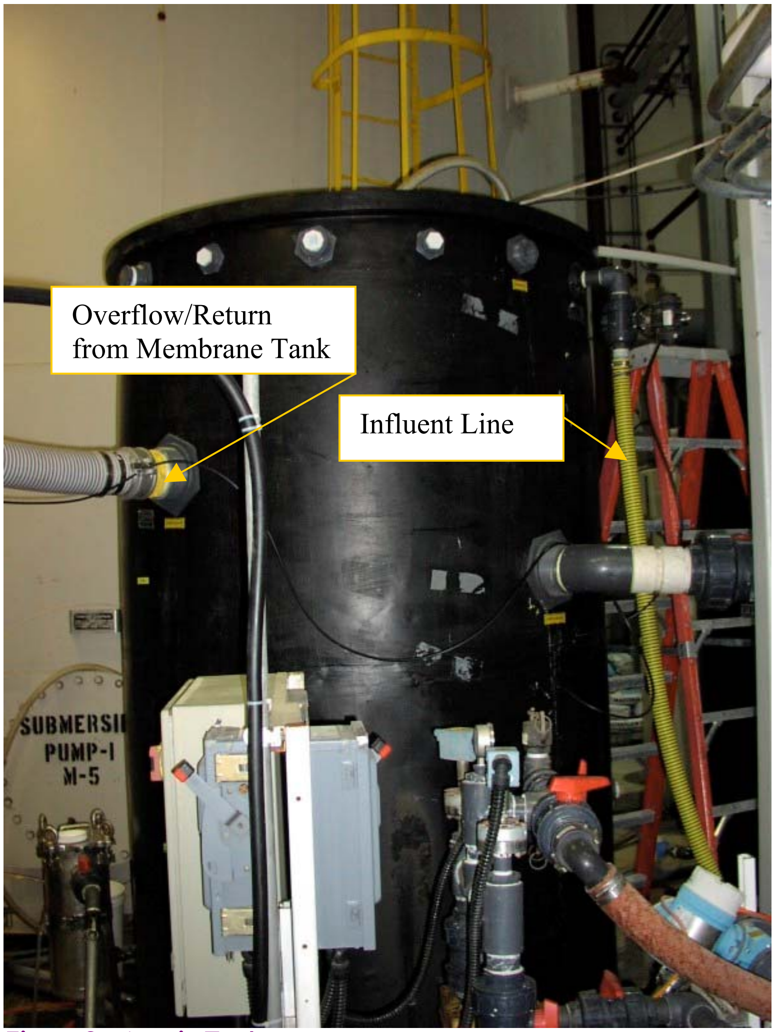

Figure 2. Anoxic Tank

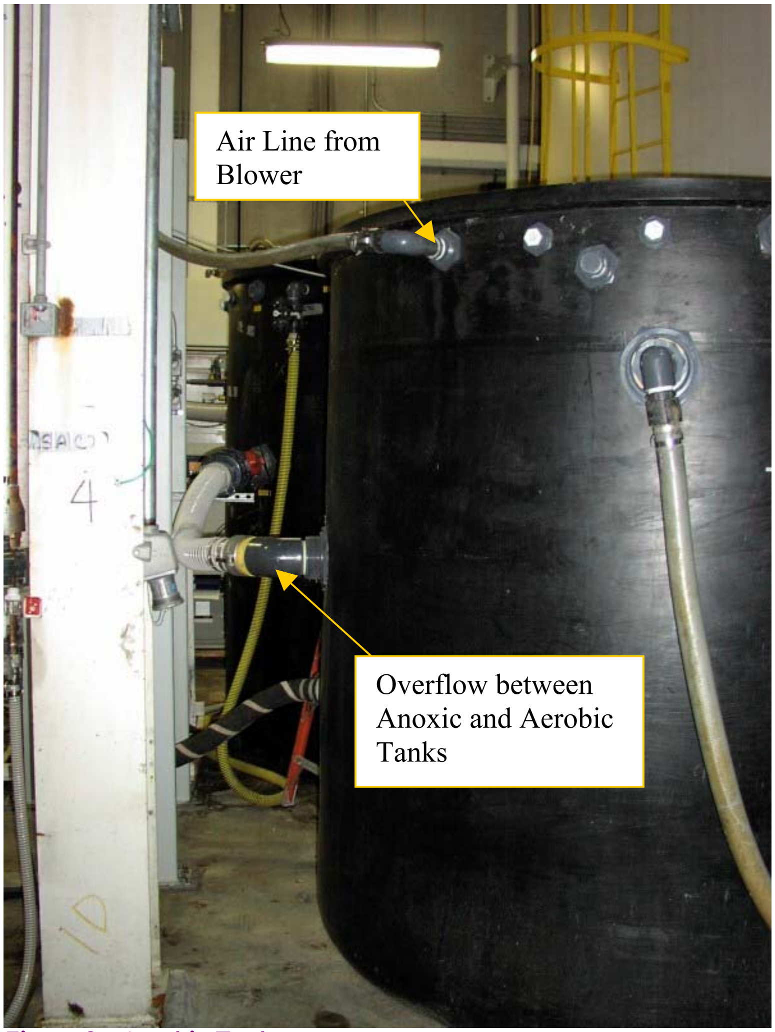

Figure 3. Aerobic Tank

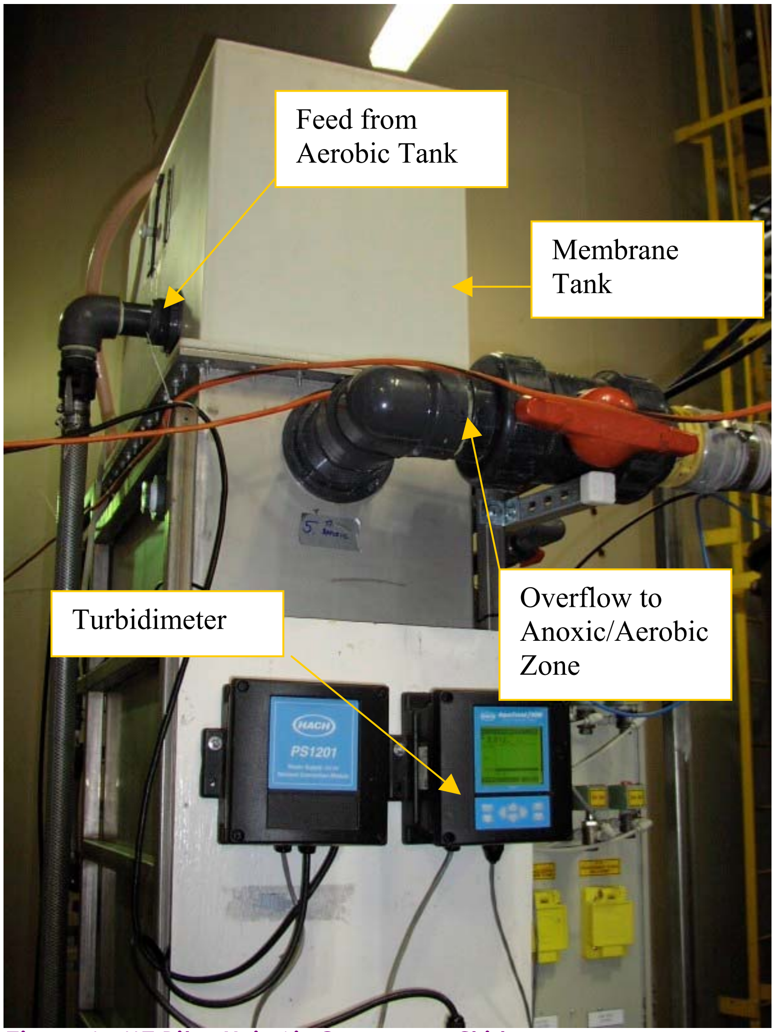

Figure 4. MF Pilot Unit Air Compressor Skid

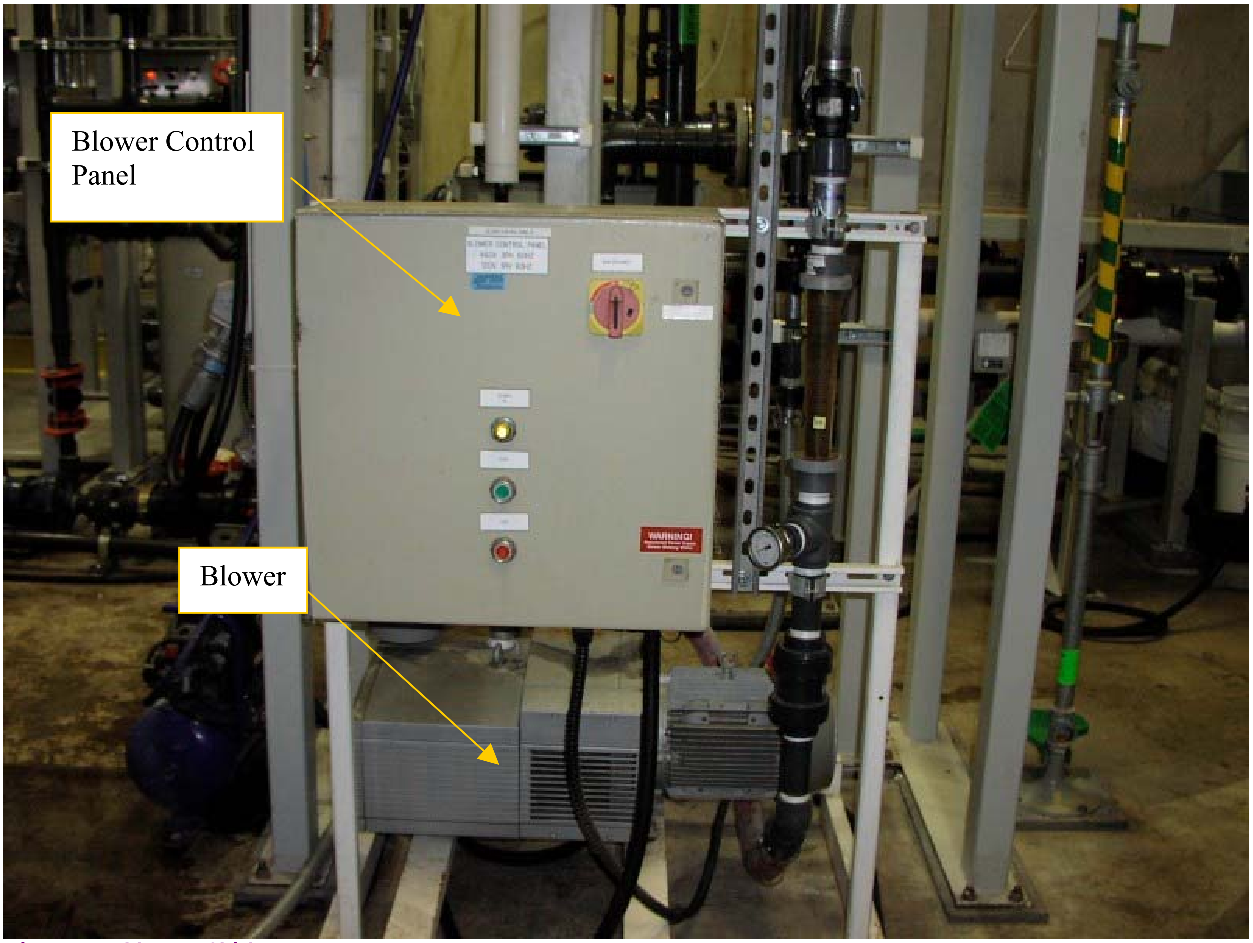

Figure 5. Blower Skid

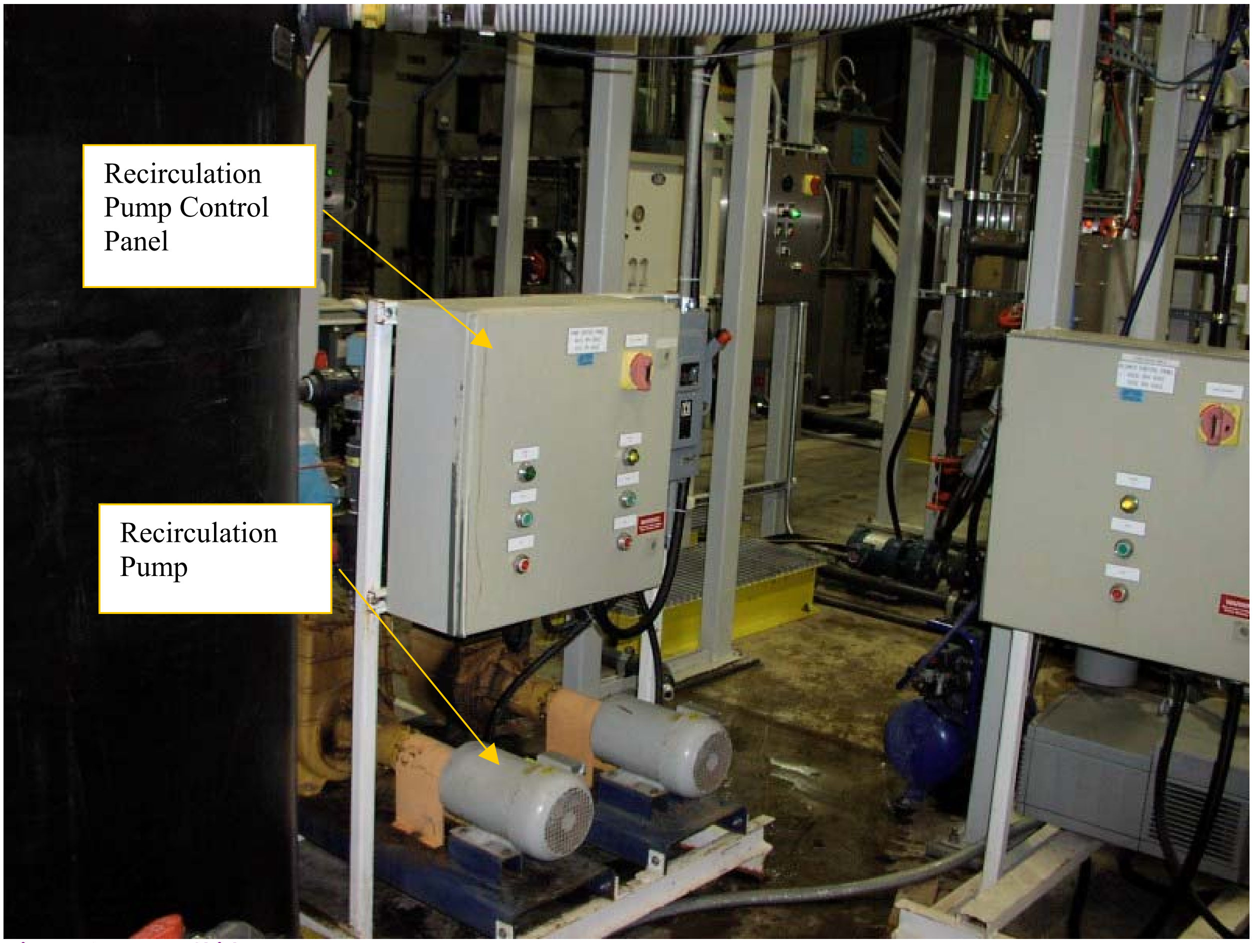

Figure 6. Pump Skid