ICR Treatment Study Summary Report

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

Conducted during the period of April 14, 1998 through April 13, 1999

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Quindaro Water Treatment Plant, ICR #384

Attachments: 2 diskettes containing the *Data Collection Spreadsheets* and ICR Report

BOARD OF PUBLIC UTILITIES, KANSAS CITY, KANSAS
EVALUATION OF MEMBRANE TECHNOLOGY USING THE SINGLE ELEMENT BENCH-SCALE TEST FOR COMPLIANCE WITH THE INFORMATION COLLECTION RULE

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PART I: CONCLUSIONS AND RECOMMENDATIONS

The use of nanofiltration for the treatment of surface water sources is a rare occurrence. The Missouri River is a highly variable source of water with respect to turbidity and total organic carbon. The Board of Public Utilities of Kansas City, Kansas evaluated the membrane filtration process knowing that it would be a challenge because of the changing source water quality.

In order to produce a test protocol mirroring the potential full-scale installation of a pretreatment system, a system similar to the existing full-scale plant was used. The use of microfiltration prior to the nanofiltration membrane would produce consistent influent water to the membrane but would not be economical. Instead of using a 15% drop in Mass Transfer Coefficient (MTC_w), the allowable membrane pressure and flowrates (as specified by the manufacturer) were used. This protocol produced an average cleaning frequency of 28 days. Although this cleaning frequency borders on the viability of a desirable cleaning frequency of greater than 30 days between cleanings, the difficulties associated with restoring the membrane to its initial MTC_w can be seen in the cleaning tables. Using the average rate of MTC_w decline (0.00164 gfd/psi/day), the membranes would need to be cleaned once every 9.8 days to insure that the MTC_w did not drop more than 15% below the initial MTC_w. This combined with the high dose of sequestering agent (5 mg/L) made treatment costs very high.

The permeate water quality from the membrane was excellent and most water quality parameters of concern had feed rejection rates greater than 90%. This suggests the opportunity for blending of the permeate and the feed water to minimize the capital costs of additional facilities and allow for staged construction. For example, to meet the Stage 1 requirements for THM4 of the D/DBP rule, the blending would consist of 43.6% permeate. For the Stage 2 requirements, the blending would be 72.8% permeate. The blending for HAA5 compliance was lower than that needed for THM4 compliance.

One of the additional benefits of nanofiltration is the removal of calcium and magnesium hardness. The raw water total hardness averages 260 mg/L as $CaCO_3$. This is a moderately hard water. The Board of Public Utilities is interested in nanofiltration from

the perspective of producing a more marketable water with less hardness. To achieve a finished water total hardness of 100 mg/L (a typical softening goal), a blended permeate ratio of 48.5% would be necessary. This is slightly higher than the ratio necessary to theoretically meet the Stage 1 rule (ratio of 43.6%).

The Board of Public Utilities is currently in the process of switching from a river intake to a horizontal collector well for the source water. The utility is excited to continue testing the nanofiltration unit on the new water source which will require much less pretreatment and a much lower cleaning frequency. This source water will be more feasible for membrane treatment than the original river source. The Board foresees this as an opportunity to take the knowledge gained from the Information Collection Rule process and apply it to continued efforts to improve the finished water quality.

PART II: BACKGROUND INFORMATION

The water processing facility is a conventional clarification plant with an average day demand of 28 million gallons per day (MGD) and a maximum day demand of 40 MGD. The facility serves a population of 165,000 in Kansas City, Kansas. It is located on the Quindaro Bend of the Missouri River where it draws water from the river intake to two primary sedimentation basins. The treatment train schematic is shown in Figure II-1.

Prior to the presedimentation basin, an amount (0.3 to 5 mg/L) of cationic polymer is added. After presedimentation, lime, fluoride and activated silica are added in the hydraulic jump between the presedimentation basin and the rapid mix basin. Aluminum sulfate (at an average dose of approximately 17 mg/L) is then added at the rapid mix basin. Flocculation occurs in four flocculation basins after rapid mix, each using four-stage horizontal paddle wheel type flocculators. Flocculation is followed by secondary sedimentation. Chlorine dioxide is added to the water between the secondary sedimentation basins (2) and the final settling basins (3). Settled water is filtered by six dual media filters and stored in a clearwell prior to distribution. Chlorine is added to the treatment train prior to filtration. Additional chlorine is added to the clearwell influent and ammonia is applied to the clearwell effluent before it enters the distribution system to maintain a combined residual.

A summary of the treatment plant processes is given in Table II-1 through Table II-4.

Table II-1: Plant Information

Treatment Plant Name	Quindaro Water Treatment Plant
ICR Treatment Plant ID	384
Treatment Plant PWS ID	KS2020906
Treatment Plant Category	CONV
State Approved Plant Capacity (MGD)	45
Historical Minimum Water Temperature (°C)	1.0
Installed Sludge Handling Capacity (Dry Pounds per Day)	0.00
Blending Indicator	N

Table II-2: River Intake

Water Resource Name	Missouri River
Water Resource Type	Flowing Stream
Intake Name	Intake No. 2 (Water Plant)
Watershed Control	No
Latitude (degrees, minutes, seconds)	+39 degrees 9 minutes 8 seconds
Longitude (degrees, minutes, seconds)	-94 degrees 38 minutes 24 seconds
River Reach Miles	1500

Table II-3: River Intake

Water Resource Name	Missouri River
Water Resource Type	Flowing Stream
Intake Name	Intake No. 3 (Power Plant)
Watershed Control	No
Latitude (degrees, minutes, seconds)	+39 degrees 9 minutes 9 seconds
Longitude (degrees, minutes, seconds)	-94 degrees 38 minutes 15 seconds
River Reach Miles	1500

Table II-4: Treatment Plant Design Data

Unit Process	Process Description
Primary Rapid Mix	Type of Mixer: ME Baffling type: PR Liquid Volume (gal): 2,962 Mean Velocity Gradient (sec^{-1}): 825 Organic Polymer (mg/L): 0.30
Primary Sedimentation	Surface Area (ft^2): 56,706 Liquid Volume (gal): 6,800,000 Baffling Type: AV
Hydraulic Jump	Type of Mixer: HY Baffling Type: UN Liquid Volume (gal): 500 Mean Velocity Gradient (sec^{-1}): 180 Sodium Silicate (mg/L): 0.80 Hydrofluorosilic acid (mg/L): 0.60 Calcium Oxide (mg/L): 8.00
Secondary Rapid Mix	Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 2,244 Mean Velocity Gradient (sec^{-1}): 950 Aluminum Sulfate (mg/L): 17.0 Powdered Activated Carbon (mg/L): 10.0
Secondary Flocculation	Type of Mixer: ME Liquid Volume (gal): 1,773,896 Baffling factor: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474 Stage Sequence Number: 4 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474
Secondary Sedimentation	Surface Area (ft^2): 62,500 Liquid Volume (gal): 10,000,000 Baffling Type: PR
Final Rapid Mix	Type of Mixer: ME Baffling Type: UN Liquid Volume (gallons): 12,000 Short-Circuiting Factor:

	Mean Velocity Gradient (sec^{-1}): 1,107 Chlorine Dioxide (mg/L): 1.0 Chlorine (mg/L): 4.0 Aluminum Sulfate (mg/L): 4.00
Final Flocculation	Type of Mixer: ME Liquid Volume (gal): 1,118,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec^{-1}): 88 Stage Liquid Volume (gal): 1,118,000
South Final Disinfection Contact Chamber	Surface Area (ft^2): 58,914 Liquid Volume (gal): 6,620,000 Baffling type: PR Chlorine: 2.50 mg/L (filter influent)
Filter Building No. 2	Surface Area (ft^2): 6,240 Liquid Volume (gal): 560,000 Total Media Depth (in): 44 Minimum Water Depth To Top of Media (ft): 7.5 Depth from the Top of Media to Top of Backwash Trough (ft):3.0
Clearwell	Chlorine: 3.75 mg/L (clearwell influent) Surface Area (ft^2): 41,268 Liquid Volume (gal): 4,300,000 Minimum Liquid Volume (gal): 2,500,000 Baffling Type: AV Covered Indication Code: Yes Ammonia (mg/L): 1.00

Water quality was a critical portion of the ICR bench study. It determined what pretreatment was needed, and showed how much membrane treatment was needed to meet future regulations. The average source water quality is shown in Table II-5 (7/97-6/98-ICR data). The average finished water quality is shown in Table II-6.

Table II-5: Source Water Quality

Water Quality Parameter	Average Yearly Value	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (°C)	18.5	7.6	31	5
pH	8.18	0.12	8.34	7.9
Turbidity (NTU)	249	482	1754	26
Alkalinity (mg/L as $CaCO_3$)	165	14	190	145
Calcium Hardness (mg/L as $CaCO_3$)	168	16	197	145
Total Hardness (mg/L as $CaCO_3$)	260	24	293	227
Total Organic Carbon (mg/L)	5.2	3.4	13.2	3.1
$UV_{254}(cm^{-1})$	0.093	0.016	0.137	0.076
Bromide (mg/L)	0.05	0.01	0.06	0.03

Table II-6: Finished Water Quality

Water Quality Parameter	Average Yearly Value	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (°C)	17.8	7.4	30.1	7.0
pH	8.2	0.2	8.5	8.0
Turbidity (NTU)	0.15	0.03	0.19	0.10
Total Organic Carbon (mg/L)	3.12	0.37	3.90	2.60
Distribution System THM4 (µg/L)	50.8	14.8	73.7	37.6

PART III: MATERIALS AND METHODS

Pretreatment Process to the Single Element System

The pretreatment system and the membrane unit were located in the existing pilot plant building at the Quindaro Site. The pilot plant building houses an existing two train pilot plant. The filtration unit of the existing pilot plant was used as a portion of the pretreatment for the membrane study. The complete pre-treatment system is shown in Figure III-1. Water was pumped from the secondary basins using two separate pumps and two separate lines for uninterruptible supply. Each pump can provide a sufficient

amount of feed water for the membrane unit. The feed water was withdrawn from this location because it has the least amount of the solids without any oxidant.

The line from the basins entered the wall of the pilot plant building and the flow was measured by a flow meter followed by the UV sterilizer. The paddle type flow meter was checked every few hours to ensure that there was flow from the basins. The UV sterilizer was a model SH-15 made by Ideal Horizons and was rated for 15 gpm.

The water flowed from the UV sterilizer to the existing pilot plant flow splitter for the filters. Within this flow splitter was an overflow which allowed any excess flow to be wasted. The remaining water was processed through three of the six existing pilot plant filters. The dual-media gravity filters are each approximately 5.5 inches in diameter. This provides approximately 0.5 square feet of filter surface area for three filters. The influent flow to the membrane only needs to be 0.4 gpm so the loading rate on the filters would be 1 gpm/ft^2. This is a low loading rate for a dual media filter which allows the filters to run for a longer period of time without the need for washing. Three filters were left out of service so that when a set of filters is dirty, a clean set of filters could be started immediately. The filters were backwashed with tap water with chloramine residuals, and sufficient time was allowed for filter-to-waste to drain the chloramine-containing water to the sewer. This prevented any chloraminated water from entering the membrane, and minimized the risk of exposing the membrane to chloramine.

After filtration (without the presence of an oxidant), the water was pumped to two existing 300 gallon holding tanks. These interconnected tanks allow for storage of filtered water in case of a malfunction of the settled water pump/filtration system. The tanks supply continuous flow to the membrane unit. The holding tanks are equipped with an overflow which discharges any excess water to the sewer. One of the holding tanks has a low level switch which will automatically shutdown the membrane unit upon sensing the low water level in the holding tanks.

Water flows by gravity from the holding tanks to the feed pump of the pretreatment processes of the membrane unit. The feed pump is connected to the SCADA system and

is setup to operate automatically under certain conditions. The feed pump supplies water through the pretreatment process to the suction of the high-pressure pump. A portion of the water was recycled back to the holding tank to keep the feed pump operating properly on its pump curve. The feed water first passes through another dual media filter. This dual media filter is a pressure filter whose media was activated with potassium permanganate to insure that any manganese in the feed water would be removed. The dual media filter is also equipped with a timer which was set to automatically backwash every three days.

After passing through the dual media filter, the water passes through another UV unit. This unit was installed to prevent any biological growth on the membrane. The UV sterilizer was a model SH-15 made by Ideal Horizons. The UV unit is rated at a 99% bacteria inactivation at 15 gpm. The unit is also equipped with a by-pass which allows for use of the nanofiltration unit without the UV unit.

The chemical feed section of the skid follows the UV sterilizer and includes chemical feed equipment to add acid, polyphosphate, and oxidant scavenger. The acid lowered the pH of the feed water to 6.7 to minimize the amount of dissolved aluminum that will pass through the prefilter and potentially precipitate on the surface of the membrane. Hydrochloric acid was used instead of sulfuric acid to minimize the potential precipitation of barium sulfate. The system was designed to automatically shutdown when the pH was out of the predetermined range (5-8).

Due to the nature of the feed water, an antiscalent/antifoulant was needed to inhibit the formation of scale and reduce particulate fouling within the membrane. Hypersperse AF150 at 5.0 mg/L was recommended by Argo Scientific. Detailed information is given in the Appendix.

A third chemical tank was available to add an oxidant scavenger. This was a back-up system which was installed for a potential situation where the UV sterilizer is inadequate in controlling the microbiological activity and an oxidant is necessary. The addition of an oxidant followed by an oxidant scavenger would only occur in a situation where

biological fouling could not be prevented. The concern with the addition of an oxidant was the formation of disinfection by-products prior to membrane treatment.

Immediately after the addition of the chemicals is a static mixer which mixes the chemicals into the process stream so that the process instrumentation located downstream of the application point will read a thoroughly mixed solution. A pH probe and an oxidation reduction potential probe are located downstream of the static mixer. The pH probe automatically controls the acid feed in order to maintain a pH of 6.7. The oxidation-reduction potential (ORP) probe monitors the presence of an oxidant after the oxidant scavenger has been added to the system. The system is programmed to automatically shut down the membrane unit upon sensing the presence of any oxidant.

After the ORP probe is a temperature indicator. This indicator provides the temperature of the water to be applied to the membrane. The temperature of the water is a critical parameter in determining the normalized flux rate of the membrane.

Following the temperature indication is a cartridge filter. Initially this unit was a 5 μm pore size filter. After some preliminary testing of the system, the cartridge filter was changed to a 1-μm size in an attempt to reduce the silt density index applied to the membrane. A pressure gauge was located before and after the 1-μm cartridge filter so that the headloss across the filter could be measured. The filter was replaced if the differential pressure exceeded 10 psi. The changing of the prefilter from 5 μm to 1 μm did not lower the SDI of the water as expected.

A silt density index test unit was provided off the influent line. This test unit consists of a pressure regulator to maintain a line pressure of 30 psi and a filter holding cell. Using the pressure of the influent pump, the SDI could be directly tested. Downstream of the SDI test kit was the tie-in of the recirculation line of the high-pressure pump, followed by the tie-in of the recycle line. Adjacent and downstream of the recycle tie-in was a pressure switch. The pressure switch sensed the pressure to the suction of the high-pressure pump, and was set to activate upon detection low suction pressure to the high-

pressure pump. If the pressure switch activated, the system would automatically shut down to protect the high pressure pump.

Table III-1 lists a summary of the pretreatment design data of the membrane unit.

Table III-1: Membrane Study Pretreatment Design Data

Unit Process	Process Description
Primary Rapid Mix	Type of Mixer: Mechanical Baffling type: PR Liquid Volume (gallons): 2,962 Mean Velocity Gradient (sec^{-1}): 825 Organic Polymer (mg/L): 0.30
Primary Sedimentation	Surface Area (ft^2): 56,706 Liquid Volume (gal): 6,800,000 Baffling Type: AV
Hydraulic Jump	Type of Mixer: HY Baffling Type: UN Liquid Volume (gal): 500 Mean Velocity Gradient (sec^{-1}): 180 Sodium Silicate (mg/L): 0.80 Hydrofluorosilic acid (mg/L): 0.60 Calcium Oxide (mg/L): 8.00
Secondary Rapid Mix	Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 2,244 Mean Velocity Gradient (sec^{-1}): 950 Aluminum Sulfate (mg/L): 17.0 Powdered Activated Carbon (mg/L): 10.0
Secondary Flocculation	Type of Mixer: ME Liquid Volume (gal): 1,773,896 Baffling factor: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474 Stage Sequence Number: 4 Stage Mean Velocity Gradient (sec^{-1}): 20 Stage Liquid Volume (gal): 443,474

Secondary Sedimentation	Surface Area (ft^2): 62,500 Liquid Volume (gal): 10,000,000 Baffling Type: PR
UV Sterilizer	Rated Flow (gpm): 15 Bacterial inactivation: 99% (at rated flow) Actual Flow (gpm): 4 +/-
Pilot Plant Filtration	Media Type: Dual (Anthracite/Sand) Loading Rate (gpm/ft^2): 1 Backwash Water: Chloraminated Filter-to-waste Period (min): 15 Backwash Frequency: 1/3 days (3 filters at a time with 3 filters in stand-by mode)
Holding Tanks	Number of Tanks: 2 Volume (gal): 300 Retention Time (hours): 26
Dual Media Filter	Number: 1 Diameter (in): 8 Depth of greensand (in): 44 Loading rate (gpm/ft^2): 1
UV Sterilizer	Rated Flow (gpm): 15 Bacterial inactivation: 99% (at rated flow) Actual Flow (gpm): 4 +/-
Aluminum-Control	Chemical Type: Hydrochloric Acid Adjusted pH: 6.7 Dose Rate: Variable (based in influent pH and alkalinity)
Scale-Control	Chemical Type: Hypersperse AF150 Dose Rate (mg/L): 5
Oxidant-Scavenger	Chemical Type: None Dose Rate: None.
Cartridge Filtration	Type: Spun Depth Filter Pore Size (μm): 1 Rated Flowrate (gpm): 10 Actual Flowrate (gpm): 0.4 Replacement: 10 psi of pressure drop or after every cleaning

Schematics and Descriptions of the Process Equipment

A schematic of the nanofiltration unit and associated equipment is shown in Figure III-2.

The high-pressure pump takes the suction pressure and boosts the pressure to a level which will provide the necessary transmembrane pressure. The high-pressure booster pump has a recycle line which allows for recirculation of a portion of the flow back to the

suction side of the pump. This allows for the adjustment of the pressure of the pump such that the pump remains in the proper flow and pressure ranges.

The discharge of the high-pressure pump is equipped with a pressure gauge. This allows for the recording of the operating pressure applied to the membrane. After the pressure gauge is a solenoid valve which closes upon system shutdown to prevent draining of the membrane housing.

The membrane element housing is a 2.5" x 40" element. The housing for the membrane unit is rated at 300 psi. The membrane utilized throughout the testing program was a Fluid System TFC-2540 HR membrane element. The conductivity of the permeate is measured and is connected to the control panel. A pressure gauge and a flow meter are also included in the permeate discharge line. The permeate is piped to a 65 gallon product storage tank. The permeate is used for the chemical feed system make-up and for cleaning the membrane.

The concentrate line from the membrane housing also has a pressure gauge. The concentrate line is divided into two lines which allow the concentrate to either recycle to the inlet of the membrane unit, or discharge to the sewer. The line which recycles to the front of the membrane unit has a needle valve, a flowmeter and a check valve for regulating the return flow.

The line to the sewer has a needle valve with a solenoid bypass valve. The needle valve is to throttle the flow in order to get the correct wastage rate. The solenoid bypass valve is utilized during flushing when it is desirable to push a large amount of flow through the membrane on the feed side and waste the flow to the sewer. The solenoid valve was incorporated into a reject flush system. The control panel upon shutdown would automatically flush the high TDS reject solution from the system and periodically flush the membrane when the system was shutdown to prevent any biological growth. A flow meter and a check valve are also part of the reject flush system. They are used to measure the concentrate flow and prevent backflow from occurring.

The unit also includes a separate cleaning system. The cleaning system utilized the existing feedwater pump. An addition tank was provided for the cleaning solution. A filter for the cleaning solution prevents any recirculation of solids flushed from the membrane back into the membrane system.

The total membrane feed system was equipped with an Allen Bradley Micrologix PLC, elapsed time meter (for measuring the time operational, high pressure feed pump starter, feedwater pump starter, control transformer, pilot lights, audible alarm, system selector switches, fuses, 24 VDC power supply, automatic system flush controls and a membrane cleaning mode selector switch). The control panel was equipped with three flowmeter readouts: the product, the concentrate and the recycle flowmeters. Using these three flowmeters the influent flow could easily be measured. The control panel also was equipped with the pH meter, the conductivity meter and the oxidation-reduction potential readouts. Hand/off/auto switches were available for each of the three chemical feed pumps, the feedwater and the high pressure pump and the UV sterilizer. Alarms were an integral part of the control panel and included a high conductivity alarm, a feedwater ORP high alarm, a feedwater pH out of limits alarm, a pressure fault alarm (low suction pressure to the high pressure pump). An indication light showing a system flush was also incorporated into the control panel.

Experimental Design

After careful thought and deliberation, the Board of Public Utilities in Kansas City, Kansas decided to fulfill the requirements of the Information Collection Rule (ICR) by conducting a single element membrane filtration study. The rationale for conducting a single element study is that the utility felt that a single element study would produce more consistent data than the rapid bench scale membrane treatment system (RBSMT). The utility felt that if they were going to undertake a study of membrane filtration, they wanted to have some data that could be used towards design.

After some preliminary testing/modeling of the membranes available, the Fluids Systems 2540HR membrane was selected for the duration of the study. Due to the high SDI of the

pre-treated feed water and considering the fact that the source was a highly turbid river water, a conservative flux rate of 10 gpd/ft^2 was used throughout the study. A summary of the experimental design information is shown in Table III-2.

Table III-2: Summary of Experimental Design

Season	Membrane	Pretreatment	Water Flux (gfd)	Target Recovery (%)
Spring	Fluid Systems 2540HR	Conventional Treatment w/ Pretreatment System	10	75%
Summer	Fluid Systems 2540HR	Conventional Treatment w/ Pretreatment System	10	75%
Fall	Fluid Systems 2540HR	Conventional Treatment w/ Pretreatment System	10	75%
Winter	Fluid Systems 2540HR	Conventional Treatment w/ Pretreatment System	10	75%

Procedures

The testing procedures followed the ICR guidance manual with the exception of membrane cleaning. The cleaning procedures are listed below:

1. Fill the cleaning solution tank with 30 gallons of permeate
2. Turn the membrane unit off.
3. Switch the valves from P to C. (Permeate to Clean).
4. Utilize the Bioclean 103A. Mix 1 pound of Bioclean 103A for every 5 gallons of permeate. The specific gravity of Bioclean 103A is 1.31, or 10.92 lbs/gallon. For 30 gallons of cleaning solution, 0.55 gallons of Bioclean 103A is needed.
5. Thoroughly mix the solution for 1 minute.
6. From the feed water pump suction, connect to the bottom of the cleaning tank. Connect the reject recycle line into the free standing cleaning solution filter.

The cleaning solution will have a different color once cleaning begins. Waste 3-5 gallons of solution and connect the waste recycle line to the middle feed connection on the cleaning tank.

7. The flow through the membrane unit should be maintained at about 3 gpm. Use the rotameter on the feed water pump to adjust the flowrate. If the flow exceeds 3.2 gpm, use the throttling valve to decrease the flow. Open the reject needle valve all the way. Turn the high-pressure switch to CLEAN and the feed water pump to AUTO. Close the recirculation valve. Turn off all of the chemical feed pumps and the UV light.
8. Allow the solution to clean for 30-60 minutes. If the fouling is excessive, allow the cleaning solution to sit for a period of up to 12 hours.
9. When the Bioclean 103A solution is empty, the pH should read approximately 3. The conductivity will rise dramatically and the ORP level will also increase into the 600 microsiemen range.
10. After the allotted cleaning time, shut the unit off. Remove the middle connection on the cleaning tank and place the stand-alone filter discharge in the sink. Turn the unit back on-line. Allow all of the cleaning solution to discharge to the sink. Allow the cleaning tank to drain as much as possible without cavitating the feed pump.
11. Rinse the inside of the tank with 10 gallons of DI water and turn the unit on again. Drain this to the sink. Whenever discharging any cleaning solution, allow the faucet to run to dilute the waste.
12. After draining the cleaning solution tank, rinse and dump the tank three more times by hand with DI water. Fill the cleaning tank with 10 gallons of permeate water and run the unit in the cleaning mode. The conductivity should decrease to less than 50, the pH should rise and the ORP should fall.
13. Dump all unused DI water, or add more if necessary until the measured parameters stabilize.
14. Rinse the cleaning tank with a small amount of permeate water and dump.
15. Mix 1 pound of Bioclean 511 for every 5 gallons of permeate; or add 0.50 gallons (1.88 liters) of Bioclean 511 to 30 gallons of permeate water in the cleaning solution tank.

16. Thoroughly mix the solution for 1 minute.
17. Follow the same procedure as for Bioclean 103A, except wasting the initial 3-5 gallons of cleaning solution is not necessary. The system will be full of permeate water which will need to be wasted.
18. The pH of the water should rise to approximately 10, the conductivity should increase and the ORP should drop to double digits.
19. Utilize this cleaning solution for 1 hour.
20. Follow the same waste rinsing procedures.
21. In normal operation mode, allow the entire system to flush with feed water, opening the recycle and reject wide open until the conductivity reaches below 30.
22. Place the unit back in service.

Two additional operating memorandums are included in the Appendix. These two memos correspond to the operating flow requirement, the calculation of MTC_w (mass transfer coefficient), chemical feed application, and a summary of monitoring and sampling requirements. All of these protocols meet the requirements of the ICR study and are included for reference only. An additional memo is included which discusses responsibilities of the project team.

Analytical Methods

The analytical methods utilized during the ICR study are a critical portion of the testing. Table III-3 shows the laboratory used, the dates of service and the analyses performed.

Table III-3: Summary of Laboratories Conducting Analyses

Laboratory	Dates of Service	Analyses Performed
Board of Public Utilities Laboratory	4/16/98 – 4/16/99	Chlorine Residual, TDS, Temperature, Turbidity
Montgomery Watson	4/16/98 – 4/16/99	HAA6, THM4, Alkalinity, TOC, UV_{254}, Bromide, Ammonia, Calcium Hardness, Total Hardness, Magnesium, TOX

The analyte as well as the method and the minimum reporting level (MRL) are shown in Table III-4.

Table III-4: Summary of Analytical Methods and MRL's

Analyte	Method	Minimum Reporting Level
Chlorine Residual	SM 4500-Cl D	0.2 mg/L
Total Dissolved Solids	SM 2510 B	5.0 mg/L
Temperature	SM 2550 B	Not Applicable
Turbidity	SM 2130 B	0.05 NTU
BCAA, BDCAA, DBAA, DCAA, MBAA, TCAA	ML/S6251	1.0 µg/L
CDBAA, MCAA,	ML/S6251	2.0 µg/L
TBAA	ML/S6251	4.0 µg/L
$CHCl_3$	EPA 502.2	5.0 µg/L
$CHBr_3$, BDCM, DBCM	EPA 502.2	0.50 µg/L
Total Organic Halogen	ML/9020/SM5320	25 µg/L
Alkalinity	SM2320 B	2.0 µg/L
Bromide	EPA 300.0	0.020 mg/L
Calcium, Total ICAP	EPA 200.7	1.0 mg/L
Calcium Hardness as $CaCO_3$	EPA 200.7	5.0 mg/L
Total Hardness as $CaCO_3$	SM 2340 B	7.0 mg/L
Ammonia Nitrogen	EPA 350.1	0.050 mg/L
UV_{254}	SM 5910	0.009 cm^{-1}
Total Organic Carbon	SM 5310C	Variable (0.5-0.7 mg/L)
pH	SM 4500H-B	0.0010
Magnesium, Total	EPA 200.7	0.10 mg/L

In addition to the laboratory at the Quindaro Water Treatment Plant, an outside laboratory was used during the ICR Treatment Study. Information on this laboratory is listed below:

Laboratory Name: Montgomery Watson Laboratories
Mailing Address: 555 East Walnut Street
Pasadena, California 91101
ICR lab number: ICRCA013
Contact name: Jim Hein
Phone number: 1-626-568-6489
Fax number: 1-626-568-5324

PART IV: RESULTS AND DISCUSSION

Due to the large amount of data that is recorded in the ICR treatment study spreadsheets, a less extensive results and discussion section is included in this report, as directed by EPA. Included in this section are study observations, average feed water quality for each of the four seasons of the study, and a discussion of the impacts of seasonal variations in source water quality on the process performance.

Study Observations

Below is a list of important conditions and observations which are not included in the spreadsheets. These factors should be considered during the interpretation of the study results.

- On 4/6/98, the silt density index (SDI) was 4.48. Problems occurred with the flowmeter on the permeate water.
- On 4/7/98, reject was accidentally shut off for one night.
- On 4/13/98, orthophosphate (Argo AF 150) was diluted below manufacturer's recommended dilution so the chemical feed holding tank was cleaned weekly using permeate water to prevent microbiological growth.
- On 4/23/98, blew the influent hose off of the membrane unit.
- On 5/8/98, automated acid feed – pH reading was unstable.
- On 5/15/98, membrane was cleaned unsuccessfully (pressure remained high after cleaning). The membrane was cleaned because permeate flow could not be maintained.
- On 5/17/98, a fuse was replaced on the feed water high-pressure pump.
- On 5/18/98, the dual media filter (DMF) backwash line was fixed. A cleaning bypass was installed which does not allow cleaning solution through the DMF.
- On 5/19/98, the unit pressures were okay.
- On 5/31/98, there were some problems with pH control.
- On 6/4/98, the membrane was cleaned again only 15 days after the previous cleaning. It's likely that the membrane was not fully cleaned the first time.
- On 6/5/98, the turbidimeters were cleaned.

- On 6/8/98, the polyphosphate pump stopped pumping due to air binding.
- On 6/9/98, SCADA was reprogrammed.
- On 6/12/98, the pressure increased to 175 psi. This was probably due to failure of the polyphosphate pump. Membrane was washed with anti-scalant before cleaning. It was then cleaned with Bioclean 511 and Bioclean 103A. Effluent did not look nearly as bad as before. It was a good clean color. A green solution resulted when 103A was pumped through the DMF. This could be due to biological growth.
- On 6/17/98, there was a high oxidation-reduction potential (ORP) of 180. This was probably because the chemicals were prepared with tap water. The SDI was 5.8-6.2
- On 6/22/98, the ORP was 200.
- On 6/26/98, The membrane was cleaned. The pressure after cleaning was 85 psi, and there was a very low level of solids in the spent cleaning solution.
- On 6/28/98, another cleaning was conducted. The membrane was cleaned for two hours in each of the solutions. The pressure after cleaning was 70 psi.
- On 7/3/98, the pH tested normal.
- On 8/17/98, the membrane was cleaned.
- On 9/11/98, a pressure regulator was installed on the membrane system.
- On 10/7/98, water was lost from the basins. Also, a new 5 μm cartridge filter was installed. The facility lost power on this day.
- On 10/8/98, there was no flow to the membrane unit.
- On 10/9/98, the nanofiltration process was shutdown due to a leak at the pressure regulator.
- On 10/29/98, the system was cleaned.
- On 11/4/98, the acid feed pump was off for 24 hours.
- On 11/6/98, a high pressure cleaning of the membrane was performed.
- On 11/18/98, the system was shut down for 10 days to recalibrate the flowmeters.
- On 12/12/98, the membrane was cleaned. Pressure after cleaning dropped to 140 psi.
- On 1/6/99, the membrane was cleaned, and the pressure dropped to 110 psi.
- On 1/13/99, the membrane was cleaned again.
- On 2/23/99, the membrane was cleaned.

- On 3/1/99, there was a flow problem; however, there was no interruption due to sufficient holding tank storage.
- On 3/5/99, low pH (= 2.5) due to problems with automatic pH control.

Average Pretreated Feed Water Quality

The following table shows the average values of various water quality parameters in the feed water. These are not broken down by season because an evaluation of seasonal variability is only required for quarterly bench-scale tests and year-long pilot studies.

Table IV-1: Average Feed Water Quality

Water Quality Parameter	Average (SD)
Temperature (°C)	24.40 (5.8)
pH	6.87 (0.28)
Turbidity (NTU)	0.31 (0.14)
Alkalinity (mg/L $CaCO_3$)	133.17 (27.0)
Calcium Hardness (mg/L $CaCO_3$)	177.13 (18.8)
Total Hardness (mg/L $CaCO_3$)	273.27 (30.8)
Bromide (µg/L)	62.07 (17.42)
TOC (mg/L)	3.51 (0.51)
UV254 (cm^{-1})	0.09 (0.04)
SDS-THM4 (µg/L)	138.45 (47.7)
SDS-HAA5 (µg/L)	60.62 (27.5)
SDS-HAA6 (µg/L)	70.24 (29.4)
SDS-TOX (µg Cl^-/L)	416.38 (151.8)
SDS-Chlorine Demand (mg/L)	4.48 (0.76)

Recovery Rate

The target recovery rate for the treatment study was 75%. The actual recovery rates deviated a little. The following table shows the actual average recovery rate and the standard deviation over the entire study.

Table IV-2: Recovery Rate

Target Recovery Rate	Average Recovery Rate	Standard Deviation
75%	73%	6%

Feed Rejection Rate

The following table shows the rejection rates for various water quality parameters. In many of the tests, the permeate concentrations of these parameters in the permeate flow were below the minimum reporting level. This presents a problem for reporting the feed rejection rates because rejection cannot be calculated without knowing the permeate concentration. For this study, all permeate samples with parameter concentrations below the minimum reporting level were assumed to have a permeate concentration equal to the reporting level.

Table IV-3: Feed Rejection at 73% Recovery

Water Quality Parameter	Feed Rejection (%)
TDS	92
Ca Hardness	97
Total Hardness	97
Bromide	66
TOC	82
UV254	89
SDS-THM4	95
SDS-HAA5	99
SDS-HAA6	99
SDS-TOX	90

Blend Ratios

Many nanofiltration membranes have very high rejection potential and produce water with contaminant concentrations well below the Maximum Contaminant Levels (MCLs) set by EPA. It is often feasible to blend some of the feed water with the permeate water and reduce operating costs of the membrane facility. Blend ratios can be calculated which represent the necessary ratio of permeate water to total flow that will still meet MCL requirements. These values are calculated in the *Data Collection Spreadsheets*

along with the resulting water quality parameter concentrations. The following table shows the average of each of these values calculated from the spreadsheets.

Table IV-4: Average Blend Ratios and Parameter Concentrations

THM4 Controls		
	Stage 1	Stage 2
Blend Ratio, %	43.6	72.8
SDS-THM4b, µg/L	70.3	35.1
SDS-HAA5b, µg/L	31.1	14.1
SDS-TOXb, µg Cl- /L	204.8	110.5
SDS-CDb, mg/L	2.4	1.3
TOCb, mg/L	11.1	5.5
UV254 b, cm-1	BMRL	BMRL
Bromideb, mg/L	BMRL	BMRL
Alkb, mg/L CaCO3	70.6	41.8
T-Hdb, mg/L CaCO3	111.2	68.1
Ca-Hdb, mg/L CaCO3	76.9	48.6

HAA5 Controls		
	Stage 1	Stage 2
Blend Ratio, %	0*	49.2
SDS-THM4b, µg/L	138.4	64.0
SDS-HAA5b, µg/L	62.7	27.0
SDS-TOXb, µg Cl- /L	417.4	175.6
SDS-CDb, mg/L	4.48	2.2
TOCb, mg/L	3.51	9.5
UV254 b, cm-1	0.09	BMRL
Bromideb, mg/L	62.1	BMRL
Alkb, mg/L CaCO3	133.2	67.6
T-Hdb, mg/L CaCO3	273.3	91.3
Ca-Hdb, mg/L CaCO3	177.1	54.6

The b at the end of each constituent stands for blended concentration.
* A blend ratio of zero indicates that the feed water already meets the requirements for HAA5 concentration. The resulting water quality parameter concentrations in this column are the concentrations in the feed water because membrane treatment is not necessary to meet the Stage 1 requirements for HAA5.
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Mass Transfer Coefficient and Cleaning Interval

The productivity of a membrane is based on the Mass Transfer Coefficient (MTC_w) and the cleaning interval. The cleaning interval is estimated based on the time rate of MTC_w decline between two cleaning events. The following table shows the MTC_w data and the cleaning interval.

Table IV-5: Mass Transfer Coefficient and Cleaning Interval

Average Rate of MTC_w Decline (gfd/psi/day)	Cleaning Interval (days) Average = 28 days	Initial MTC_w (gfd/psi)	Final MTC_w (gfd/psi)	MTC_w After Cleaning (gfd/psi)
0.0034	17	0.107	0.049	0.064
0.0010	8	0.064	0.056	0.089
0.0042	13	0.089	0.034	0.133
0.0012	45	0.133	0.080	0.086
0.0006	71	0.100	0.057	0.077
0.0008	24	0.077	0.057	0.059
0.0013	13	0.089	0.072	0.172
0.0021	31	0.137	0.073	0.088

Note: Instead of using a 15% drop in MTCw to determine the cleaning interval during the membrane study, the allowable membrane pressures and flowrates (as specified by the manufacturer) were used.

PART V: QA/QC SUMMARY

This section summarizes the QA/QC analyses performed during the ICR Treatment Study. The following information is included in this section:

- The results of all laboratory duplicates
- The results of all laboratory fortified matrix sample analyses.
- The results of any independent QC checks (e.g., PE samples).
- A summary of the calibration procedures for the DBP, bromide and TOC analyses.

This QA/QC summary data was provided by Montgomery Watson Laboratories. The data reflects not only our samples, but also those of other bench test utilities (as per agreement with Steve Allgeier of EPA).

Table V-1 shows the results of laboratory duplicates, laboratory fortified matrix sample analyses, and PE samples. Tables V-2 and V-3 summarize the calibration procedures for the DBP, bromide, and TOC analyses.

Table V-1: QA/QC Summary Table

Analyte Identification	Units	Laboratory Identification	Start Service Date	End Service Date	Method	MRL		Count	Average	Std Dev	Percentiles 25th	50th	75th
Bromide	µg/L	ICR-CA013	9/1/97	5/1/99	EPA 300.0	20	RPE of Analytical Duplicates:	192	2.7%	4.9%	0.0%	0.9%	3.9%
							% Recovery for Lab Fortified Matrix:	392	102%	7%	98%	101%	105%
							% Recovery for PE Samples:	5	100%	2%	99%	100%	100%
UV254	1/cm	ICR-CA013	2/1/98	12/31/98	SM5910B	0.009	RPE of Analytical Duplicates:	383	0.2%	0.5%	0.0%	0.0%	0.0%
							% Recovery for Lab Fortified Matrix:						
							% Recovery for PE Samples:	5	96%	3%	95%	95%	96%
TOC	mg/L	ICR-CA013	9/1/97	5/1/99	SM5310C	0.5	RPE of Analytical Duplicates:	758	1.2%	1.7%	0.0%	0.0%	2.3%
							% Recovery for Lab Fortified Matrix:	180	98%	6%	97%	99%	102%
							% Recovery for PE Samples:	5	96%	3%	94%	95%	98%
SDS-TOX	µg Cl-/L	ICR-CA013	9/1/97	5/1/99	SM5320B	25	RPE of Analytical Duplicates:	865	4%	4%	1%	3%	6%
							% Recovery for Lab Fortified Matrix:	883	100%	20%	92%	98%	105%
							% Recovery for PE Samples:	5	88%	8%	85%	86%	88%
SDS-CHCl3	µg/L	ICR-CA013	9/1/97	5/1/99	EPA 551.1	1	RPE of Analytical Duplicates:	254	5%	7%	0%	3%	6%
							% Recovery for Lab Fortified Matrix:	300	112%	74%	93%	100%	113%
							% Recovery for PE Samples:	5	93%	9%	86%	93%	99%
SDS-BDCM	µg/L	ICR-CA013	9/1/97	5/1/99	EPA 551.1	1	RPE of Analytical Duplicates:	250	4%	5%	0%	2%	5%
							% Recovery for Lab Fortified Matrix:	300	99%	30%	90%	98%	103%
							% Recovery for PE Samples:	5	96%	3%	95%	96%	98%
SDS-DBCM	µg/L	ICR-CA013	9/1/97	5/1/99	EPA 551.1	1	RPE of Analytical Duplicates:	203	4%	6%	0%	2%	6%
							% Recovery for Lab Fortified Matrix:	301	103%	36%	93%	100%	108%
							% Recovery for PE Samples:	5	102%	4%	99%	101%	103%
SDS-CHBr3	µg/L	ICR-CA013	9/1/97	5/1/99	EPA 551.1	1	RPE of Analytical Duplicates:	113	6%	9%	0%	4%	9%
							% Recovery for Lab Fortified Matrix:	301	99%	21%	95%	100%	103%
							% Recovery for PE Samples:	4	106%	4%	103%	106%	109%
THM4	µg/L	ICR-CA013	9/1/97	5/1/99	EPA 551.1		Avg RPE of Indiv Anal Dupl:	269	4%	5%	1%	3%	6%
							Avg % Recov for Indiv Lab Fort Matrix:	301	103%	29%	94%	100%	105%
							Avg % Recov for Indiv PE Samples:	4	100%	4%	97%	99%	100%
SDS-MCAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	2	RPE of Analytical Duplicates:	94	11%	12%	3%	6%	13%
							% Recovery for Lab Fortified Matrix:	447	107%	25%	97%	105%	115%
							% Recovery for PE Samples:	5	92%	5%	90%	91%	93%
SDS-DCAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	1	RPE of Analytical Duplicates:	367	4%	6%	0%	2%	6%
							% Recovery for Lab Fortified Matrix:	444	106%	41%	97%	100%	106%
							% Recovery for PE Samples:	5	90%	9%	85%	88%	88%
SDS-TCAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	1	RPE of Analytical Duplicates:	325	3%	6%	0%	2%	5%
							% Recovery for Lab Fortified Matrix:	444	108%	57%	97%	100%	110%
							% Recovery for PE Samples:	5	96%	12%	90%	92%	93%
SDS-MBAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	1	RPE of Analytical Duplicates:	48	10%	12%	0%	7%	16%
							% Recovery for Lab Fortified Matrix:	448	112%	27%	100%	105%	110%
							% Recovery for PE Samples:	5	89%	7%	84%	93%	94%

Table V-1: QA/QC Summary Table (cont.)

Analyte Identification	Units	Laboratory Identification	Start Service Date	End Service Date	Method	MRL		Count	Average	Std Dev	Percentiles 25th	50th	75th
SDS-DBAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	1	RPE of Analytical Duplicates:	199	5%	6%	0%	3%	7%
							% Recovery for Lab Fortified Matrix:	447	105%	24%	97%	100%	106%
							% Recovery for PE Samples:	5	98%	15%	91%	94%	95%
SDS-BCAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	1	RPE of Analytical Duplicates:	325	4%	6%	0%	3%	6%
							% Recovery for Lab Fortified Matrix:	447	103%	19%	97%	100%	105%
							% Recovery for PE Samples:	5	95%	12%	90%	91%	92%
SDS-TBAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	4	RPE of Analytical Duplicates:	11	3%	2%	1%	2%	4%
							% Recovery for Lab Fortified Matrix:	320	113%	24%	103%	115%	125%
							% Recovery for PE Samples:	0					
SDS-CDBAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	2	RPE of Analytical Duplicates:	133	4%	5%	0%	3%	5%
							% Recovery for Lab Fortified Matrix:	407	113%	24%	104%	110%	120%
							% Recovery for PE Samples:	0					
SDS-DCBAA	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B	1	RPE of Analytical Duplicates:	325	4%	6%	0%	3%	6%
							% Recovery for Lab Fortified Matrix:	435	113%	22%	103%	110%	120%
							% Recovery for PE Samples:	0					
HAA5	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B		Avg RPE of Indiv Anal Dupl:	385	5%	5%	1%	4%	6%
							Avg % Recov for Indiv Lab Fort Matrix:	448	108%	23%	99%	103%	109%
							Avg % Recov for Indiv PE Samples:	5	100%	8%	87%	93%	93%
HAA6	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B		Avg RPE of Indiv Anal Dupl:	385	5%	5%	2%	4%	6%
							Avg % Recov for Indiv Lab Fort Matrix:	448	107%	20%	99%	103%	108%
								5	100%	9%	87%	92%	93%
HAA9	µg/L	ICR-CA013	9/1/97	5/1/99	SM6251B		Avg RPE of Indiv Anal Dupl:	387	5%	4%	2%	4%	6%
							Avg % Recov for Indiv Lab Fort Matrix:	448	109%	17%	102%	106%	111%

Table V-2: Calibration Verification and Quality Control Procedures

Performance Criteria	Method	EPA300.0 A, B	SM 6251B	*UV 254*
	Analytes	***Br***	**Haloacetic Acids *(HAA)***	**SM 5910 B *UV 254***
	Target Analytes	Bromide (Br^-)	Monochloroacetic (MCAA) Dichloroacetic acid (DCAA) Dibromoacetic acid(TCAA) Trichloroacetic acid (TCAA) Monobromoacetic acid (MBAA) Bromochloroacetic acid (BCAA)	**UV Absorbance at 254 nm**
1.0 IDC				
1.1 IDLSB	**Method Blank**	< 1/2 MRL	< 1/2 MRL	< 1/2 MRL
1.2 IDA	**QC check sample (external source)**	+/- 20% of true value	+/- 20% of true value	+/- 20% of true value
1.3 IDP				
	No. of replicates	5	5	5
	Spike conc.	Br^- 0 .10 mg/L	20	6.5 mg/L ± 0.5 mg/L DOC (Dissolved Organic Carbon)
	% RSD	< 20	< 20	< 20
	% Recovery	80-120	80-120	80-120
	No. of replicates	7	7	7
	Spike conc.	1/2 MRL	1/2 MRL	0.5 mg/L DOC (Dissolved Organic Carbon) = 0.009 cm^{-1}
	% Recovery	50-150	50-150	50-150
2.0 MRL		Br: 0.020 mg/L	MCAA: 2.0 ug/L Others:1.0 ug/L	0.009 cm^{-1}

Performance Criteria		Method	EPA300.0 A, B	SM 6251B	*UV 254*
		Analytes	***Br***	**Haloacetic Acids *(HAA)***	**SM 5910 B *UV 254***
3.0	**Calibration Verification/ Frequency**		Lowest level std. analyzed at the beginning of each 24 hour- before first sample run Mid level and high level analyzed alternately after 10th sample and after the last sample.	Lowest level std. analyzed at the beginning of each 24 hour- before first sample run Mid level and high level analyzed alternately after 10th sample and after the last sample.	Lowest level std. analyzed at the beginning of each 24 hour- before first sample run Mid level and high level analyzed alternately after every 10th sample and after the last sample.
	Calibration Verification Concentrations and Acceptance Criteria		***Br-***	***MCAA***	***UV254***
			(mg/L) (% rec.)	***(ug/L) (% rec.)***	***(cm^{-1}) (% rec.) (%RPD)***
		Low	0.02 50-150	2.0 50-150	0.009 75-125 </= 20
		Midlevel	0.10 90-110	20 80-120	0.088 85-115 </= 10
		High	0.30 90-110	32 80-120	0.866 85-115 </= 10
				All others	
				(ug/L) (% rec.)	
		Low		1 50-150	
		Midlevel		20 80-120	
		High		32 80-120	
4.0	**Reagent (Method) Blank**				
	Frequency		one per analysis batch	one per analysis batch (one per extraction batch)	Initial zero; Check after each 10 samples
	QC Criteria		< 1/2 of MRL	< 1/2 of MRL	< 1/2 of MRL (<0.0045 cm^{-1})
5.0	**Shipping Blank**	**Travel Blank/ Field Reagent Blank**	NA	NA	NA
	QC Criteria		NA	NA	NA

Performance Criteria		Method	EPA300.0 A, B	SM 6251B	*UV 254*
		Analytes	***Br***	**Haloacetic Acids *(HAA)***	**SM 5910 B *UV 254***
6.0	**LFM**	**Fortified Sample**			
	Frequency		5 % per analysis batch	one sample per extraction batch	NA
	Matrix spike Level		Same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	Same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	NA
	QC criteria		NA	NA	NA
7.0	**Field/Lab Duplicate**				Lab duplicate
	Frequency		5% of the samples per analysis batch	one lab duplicate per extraction batch	all samples analyzed in duplicate
	% RPD				</= 20 % (UV $_{254}$ </=0.045)
	QC criteria		NA	NA	</= 10 % (UV $_{254}$ >0.045)
8.0	**Internal Std.**		NA	1,2-dibromopropane or 1,2,3-trichloropropane in each extract	NA
	QC criteria		NA	+/- 30% of calibration curve AVG IS response	NA
9.0	**Surrogate Standards**		NA	70-130 % 2,3-dibromopropionic acid	NA
9.0	**Surrogate Standards**			or 2,3,5,6-tetrafluorobenzoic acid in each sample	
	QC Criteria		NA	70-130 %	NA

Performance Criteria	Method	EPA300.0 A, B	SM 6251B	*UV 254*
	Analytes	***Br***	**Haloacetic Acids *(HAA)***	**SM 5910 B *UV 254***
10.0 Method Calibration Procedures	**Initial Calibration Curve**	Bromide Concentration (mg/L)	MCAA Concentration (ug/L)	NA
	Standard 1	0	2	
	Standard 2	0.02	5	
	Standard 3	0.05	10	
	Standard 4	0.1	20	
	Standard 5	0.3	40	
	Standard 6	0.5	-	
			All others Concentration (ug/L)	
	Standard 1		1	
	Standard 2		2	
	Standard 3		5	
	Standard 4		10	
	Standard 5		20	
	Standard 6		40	

Table V-3: Calibration Verification and Quality Control Procedures

Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
	Analytes	***THM***	***TOC***	***TOX***
	Target Analytes	**Trihalomethanes (THMs)** Chloroform (CHCl3) Bromodichloromethane (BDCM) Dibromochloromethane(DBCM) Bromoform (CHBR3)	**Total Organic Carbon**	**Total Organic Halide (Dissolved Organic Halogen) (DOX)**
1.0 IDC				
1.1 IDLSB	**Method Blank**	< 1/2 MRL	< 1/2 MRL	< 1/2 MRL
1.2 IDA	**QC check sample**	+/- 20% of true value	+/- 20% of true value	+/- 20% of true value
1.3 IDP	**No. of replicates**	5	5	5
	Spike conc.	THM 20 ug/L	TOC 4 mg/L	TOX 250 ug/L
	% RSD	< 20	< 20	< 20
	% Recovery	80-120	80-120	80-120
1.4 MDL	**No. of replicates**	7	7	7
	Spike conc.	1/2 MRL	0.5	1/2 MRL
	% Recovery	50-150	50-150	50-150
2.0 MRL		THM 1.0 ug/L Others: 0.5 ug/L	0.70 mg/L 0.50 mg/L (during treatment studies)	50 ug Cl^-/L 25 ug Cl^-/L (during treatment studies)

	Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
3.0	**Calibration Verification**	**Verification Frequency**	Lowest level std. analyzed at the beginning of each 24 hr before the first sample	Lowest level std. analyzed at the beginning of each 24 hr before the first sample	3 microcoulometer titration cell checks with NaCl std at start of 8-10 hr. work shift. Lowest level std. analyzed before the first sample.
			Mid level and high level analyzed alternately after every 10th sample and last sample	Mid level and high level analyzed alternately after every 10th sample and last sample	Mid level and high level analyzed alternately after every 7th sample and last sample
	Conc. and QC criteria (%rec)		*THM* ***(ug/L) (% rec)***	*TOC* ***(mg/L) (% rec)***	***TOX*** (ug Cl-/L) (% rec)
		Low	1.0 50-150	0.7 (0.5) 50-150	50 (25) 75-125
		Mid-level	20 80-120	4 90-110	200 85-115
		High	40 80-120	9 90-110	500 85-115
4.0	**Reagent (Method) Blank**	***Frequency***	One per analysis batch (one per extraction batch)	One per analysis batch	2 nitrate-washed activated carbon at the start of each analysis batch, then 1 after every 7 samples (run in duplicate)- minimum of 3 per day; Analyze 1 system blank per analysis batch.
	QC criteria		< 1/2 MRL	< 1/2 MRL,< 0.35, or< 0.25	<0.80 ug/Cl-/40 mg of activated carbon; < 1/2 of MRL, <25 or < 12.5
5.0	**Shipping Blank Criteria**	**Travel Blank**	NA	NA	NA

	Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
6.0	**LFM**	***Fortified Sample***			
	Frequency		one sample in each extraction batch	at least 5% of ICR samples in an analysis batch (fortified sample analyzed in duplicate)	at least 5% of all ICR samples analyzed each quarter (fortified sample analyzed in duplicate
	Matrix spike level		same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.	same concentration as cal verification. If no historical data for sample level, rotate low, mid, high as spike conc.
	QC criteria	**% Recovery**	NA	NA	NA
7.0	**Lab (Field) Duplicate**		field duplicate	lab duplicate	lab duplicate
	QC Criteria	**% RPD**	NA	</= 10 % (TOC conc. > 2.0 mg/L) </= 20 % (TOC conc. </= 2.0 mg/L)	NA
8.0	**Internal Std.**		BFB if pentane solvent is used; Optional if MTBE is the extracting solvent	NA	NA
	QC Criteria	**IS Recoveries**	+/- 30% of calibration curve AVG IS response 70-130 % Rec.	NA	NA
9.0	**Surrogate QC Standards**		decafluorobiphenyl in each sample	NA	NA
		Surrogate Recoveries	70-130 % Rec.	NA	NA

	Performance Criteria	Method	THMs EPA 551.1	TOC SM 5310 C	TOX SM 5320B
10.0	**Method Calibration Procedures**	**Initial Calibration Curve**	THMs: CHCL3, BDCM Concentration (ug/L)	Conc. (mg/L)	
	Trihalomethane	**Standard 1**	0.5	0.5	
		Standard 2	1	1.0	
		Standard 3	2	5	
		Standard 4	5	10	
		Standard 5	10	20	
		Standard 6	20		
		Standard 7	30		
		Standard 8	40		
		Standard 9	50		
			THMs: DBCM, CHBR3 Concentration (ug/L)		
		Standard 1	0.25		
		Standard 2	0.5		
		Standard 3	1		
		Standard 4	2.5		
		Standard 5	5		
		Standard 6	10		
		Standard 7	15		
		Standard 8	20		
		Standard 9	25		

To: T.R. Shepard, Board of Public Utilities

From: Vincent Hart- P.E., Burns & McDonnell

Date: March 23, 1998

Subject: KCKBPU - Quindaro Water Processing Plant
SEBST for Compliance with Information Collection Rule
Summary of Monitoring and Sampling Requirements
B&McD Project No. _____

The purpose of this memorandum is to assist you in preparing a schedule that incorporates the monitoring and sampling protocols for the single element bench-scale testing (SEBST) to be conducted at the pilot plant facility. The schedule should reflect the monitoring and sampling requirements established by the EPA in the Information Collection Rule (ICR) along with the monitoring and sampling recommended by Burns & McDonnell.

The yearlong SEBST study to be conducted requires monitoring to be performed on a daily basis **and** sampling to be performed on a biweekly basis. The daily requirements comprise the monitoring of those parameters necessary to assess the routine performance of the system. The biweekly requirements comprise the sampling of certain process streams for parameters which are demonstrative of the effectiveness of the system with respect to productivity and permeate quality (including precursor removal as assessed under SDS conditions).

The daily monitoring requirements are summarized in Table 1. Daily monitoring is separated into those specifically required by the ICR and those recommended by Burns & McDonnell. The ICR states that daily monitoring should be conducted at least once per shift. However, Burns & McDonnell recommends that the monitoring of flow rate, pressure, temperature, and pH be conducted twice daily. Furthermore, Burns & McDonnell recommends that Silt Density Index (SDI) monitoring be performed daily to assess the efficiency of the pretreatment processes. Five (5) different monitoring locations for the SEBST study have been defined by the EPA. These are as follows:

- ***Feed*** - Sample location is immediately following the 5μm cartridge filter and **prior to** the combination of the raw feed stream with the concentrate recycle stream. The analysis of samples from this location allows for the determination of the raw feedwater characteristics.
- ***Permeate*** - Sample location is at the point where the permeate is discharged from the membrane. The analysis of samples from this location allows for the determination of the quality of the effluent from the membrane treatment process.
- ***Concentrate*** - Sample location is following the point at which the concentrate-recycle is separated from the concentrate wasted to drain. The analysis of samples from this location allows for the determination of the quality of the concentrate from the membrane treatment process.
- ***Influent***- Sample location is following the point at which the concentrate-recycle is combined with the raw feedwater prior to entering the membrane. The analysis of samples from this location allows for the determination of the quality of the influent to the membrane

treatment process.

- ***Recycle***- Sample location is following the point at which the concentrate-recycle is separated from the concentrate wasted to drain. The analysis of samples from this location allows fro the determination of the quality of the concentrate recycled back to the influent to the membrane treatment process.

TABLE 1.
Daily Monitoring Requirements - Yearlong SEBST

Parameter	Feed	Permeate	Concentrate	Influent	Recycle
Flow*	none	2D	2D	none	2D
Pressure*	none	2D	2D	2D	none
Temperature*	none	none	none	2D	none
TDS	D	D	D	none	none
pH*	2D	2D	2D	none	none
SDI**	D	none	none	D	none

* Burns& McDonnell has recommended monitoring parameter twice-daily (per shift) rather than the once-daily (per shift) required by ICR.

** Burns & McDonnell has recommended daily (once per shift) monitoring of a parameter not specifically required by ICR for daily monitoring.

D - Once Daily (once per shift)

2D - Twice Daily (twice per shift)

The biweekly sampling requirements are summarized in Table 2. The biweekly sampling requirements can be divided into two (2) areas: those sampling requirements specifically associated with the measurement of those parameters which could affect the performance of the SEBST system and those sampling requirements associated with the testing of Simulated Distribution System(SDS) conditions. The SDS testing for the SEBST is required under the provisions of Information Collection Rule. The attached Environmental Protection Agency fact sheet, describes the procedures for the SDS test.

The data sheet describes four (4) parameters that must be selected to perform the SDS test. These parameters are as follows:

- ***Incubation Time*** used in the SDS test should be equivalent to the average residence time in the main distribution system at the time of the test. In the *Report on Distribution System Residence Time for ICR Compliance* which was performed by Burns & McDonnell in September of 1997, the average residence time in the distribution system (referred to in the report as "Average Average" for a minimum demand day) is 19.02 hours. This residence time of 19.02 is based upon a system demand of 23 MGD. To determine the incubation time necessary for the performance of the SDS test, Burns & McDonnell recommends the use of the following equation:

  Incubation Time (hrs) = 19.02 hrs * Plant flowrate @ day of test (MGD) / 23.0 MGD

- ***Incubation Temperature*** used in the SDS test should be equivalent to the water temperature in the distribution system, at the time of the test, at a location reflective of the average distribution system residence time.
- ***pH Prior to Dosing*** used in the SDS test should be equivalent to the pH in the distribution system , at the time of the test, at a point reflective of the average distribution system residence time.
- Since the Quindaro Water Treatment facility utilizes chloramine as the residual disinfectant in the distribution system, the ***Free Chlorine Residual at the End of SDS Incubation*** should be set at 0.5 to 1.0 mg/L. The residual at the end of incubation should never be less than 0.2 mg/L. Unless the chlorine demand of a particular sample is known ahead of time, the SDS test requires that a chlorine demand study be performed on each sample taken to determine the SDS chlorine dose necessary to produce the desired free chlorine residual in that sample at the end of SDS incubation. Due to the potential high degree of variability in the membrane feedwater quality, Burns & McDonnell recommends that a chlorine demand study be performed for each sample of feedwater taken for the SDS tests. However, since the membrane process produces a consistent permeate quality, the chlorine demand for the membrane permeate should be relatively constant throughout the life of the study. Given that chlorine demand for the membrane permeate can be "estimated with accuracy", Burns & McDonnell recommends that the chlorine demand study be performed only once and the chlorine dose established for the SDS test by this study be utilized for all of the subsequent SDS tests.

These four (4) parameters must be measured and reported in the *ICR Treatment Study Data Collection Spreadsheets* (EPA 815-B-97-002). Furthermore, the analysis on every fifth set of the biweekly samples (from the feed and permeate only) must be duplicated. Sampling results must be reported on Table 5-14 Concentrate Water Quality Parameters and Mass Balance Closure Errors which is located in the *ICR Manual for Bench- and Pilot Scale Treatment Studies* (EPA 814-B-96-003).

In addition to the Biweekly sampling requirements established for the SEBST by the ICR, Burns & McDonnell recommends that **SDI** sampling be performed **once each week** on the effluent from the pilot plant dual media filters. We feel that monitoring the effluent from the dual media filters for SDI values, will aid in preventing membrane fouling due to passage of solids through the filtration process.

TABLE 2
Biweekly Sampling Requirements - Yearlong SEBST

Parameter	Feed	Permeate	Concentrate
pH	BW	BW	BW
Total Hardness	BW	BW	BW
Calcium Hardness	BW	BW	BW
Alkalinity	BW	BW	BW

Total Dissolved Solids	BW	BW	BW
Turbidity	BW	BW	BW
Total Organic Carbon	BW	BW	BW
UV_{254}	BW	BW	BW
Bromide	BW	BW	none
SDS- Chlorine Demand	BW	Once *	none
SDS-THM4	BW	BW	none
SDS-HAA6	BW	BW	none
SDS-TOX	BW	BW	none
SDS- Cl_2 demand	BW	BW	none
SDI - Filter Effluent **	W	none	none

* Recommended by Burns & McDonnell due to the anticipated consistency of permeate quality produced by the membrane process during the lifetime of the study.
** Additional sampling parameter recommended by Burns & McDonnell.

Should you have any questions or concerns regarding the proposed monitoring and sampling regimes for the Quindaro Water Processing Plant SEBST, please contact me at 822-3362.

To: TR Shepherd, Board of Public Utilities

From: Vincent Hart, Burns and McDonnell

Re: Pilot Plant Guidance

This point in the pilot for BPU is the most critical time during the project. BPU should be running daily SDI's and Burns and McDonnell and BPU should be deciding if the pretreatment for the membrane unit is acceptable. In addition to SDI's particle counts of the filter effluent should be analyzed for relative comparison purposes. The first pump in the unit's process should be running continuously and passing water through the dual media filter associated with the membrane unit. This not only will allow the storage tanks to turn over but it will allow the dual media filter to develop and it can be determined how often the unit will need to be backwashed. This dual media filter can be set to automatically backwash the filter as was demonstrated during the training sessions.

As addressed in my memo to Frank Yau the flow to the pilot plant should be increased and the UV lamp should be fixed by BPU. In addition, SDI's should be run after the 5um cartridge filter to determine what the SDI is after filtration using BPU's portable SDI testing kit. Burns and McDonnell recommends that since the SDI is high up to this point in the study that all filters should be run at the same time and that the rate (gpm/ft^2) be decreased in an attempt to reduce the SDI. In addition, BPU should be running metal ion concentrations to determine what metal ions may be a problem in the pilot testing in terms of fouling the unit.

The following is a list of items that need to be adjusted and tests that need to be done daily to ensure the proper running of the membrane pilot unit:

- The fluid systems membrane, the one currently installed, has an active area of 27 square feet. The filmtec membrane has an active area of 23-24 square feet. As discussed in the ICR manual the membrane should pass anywhere from 10-20 gallon/square ft/day (gfd). Surface waters should be in the 10-15 gfd range. At 15 gfd the flow of product water should be 0.3 gpm (permeate flow). Both membranes can only process 15% of the water passing the membrane. Because of this the influent flow to the membrane should be 2 gpm and the recycle flow should be 1.6 gpm. The wastage rate of the membrane should be 0.1 gpm. All of these flow rates can be adjusted using the respectively needle valves. Although a little bit tricky at first, once all of the flowrates are set the membrane unit should remain constant with only minor day-to-day adjustments necessary. The flowmeters on the pilot plant should be used as an indicator of flowrate, the ICR manual requires that daily measurements of the flowrate should be taken by hand. This can be done by measuring the permeate and the wastage flowrates. The wasteage flowrate is low enough that it needs to be measured without utilizing the flowmeter.

- SDI's need to be done daily.

- To determine if the membrane needs to be cleaned the MTC_w needs to be determined. The MTC is the water mass transfer coefficient. Once the MTC is calculated and a baseline is established then the unit should be checked day-to-day to determine if the membrane needs cleaning. The MTC is calculated using the following procedure:
    1. Record the temperature.
    2. Open permeate sample tap and measure the amount of water/minute. Let the line run for 30 seconds before starting.
    3. Take the flowrate in gallons/day and divide by the active membrane area (in this case it's 27 ft^2.
    4. This is the flux. Normalize the flux utilizing the temperature reading.
        Normal Flux (15 degrees C) = Actual flux x 1.03^(T(15degrees C) – T(actual))
    5. Take the normalized flux and divide by the NDP.
    6. This is the value of the MTC_w. Upon start-up the original valve was 0.1179 gfd/psi.
    7. If the Normalized MTC_w gets below 0.10 gfd/psi (10-15% below the 0.1179 gfd/psi value) then the membrane needs to be cleaned.

- The NDP is calculated as below:
    1. Read in influent pressure to the membrane
    2. Read the pressure of the concentrate
    3. Read the permeate pressure
    4. Determine the osmotic pressure gradient in psi
        a. Record the influent TDS concentration in mg/L (TDS_I)
        b. Record the concentrate TDS concentration in mg/L (TDS_c)
        c. Record the permeate TDS concentration in mg/L (TDS_P).
        d. Plug into the formula $((TDS_I + TDS_c)/2)-TDS_p)x(0.01psi/mg/L)$
        e. It has been estimated that the osmotic pressure gradient should be approximately 12.8 psi but this value should be checked once by testing the actual TDS.
    5. Plug into the formula $((P_I + P_C)/2)-P_P$-osmotic pressure.
    6. The original NDP has been calculated at 123.7 psi after the original startup.

All of these procedures are located in the ICR guidance manual.

The original anti-scalant/sequestering agent concentration and dilution were calculated assuming that the chemical could be diluted as needed (see memo to Frank Yau for more information). 572 mL of anti-scalant/sequestering agent were added to the 30 gallon storage container. This is a 0.5% dilution which is much less than the maxmum dilution of 10% specified by the chemical manufacturer. With the chemical feed pump which can pump a maximum of 12 gallons per day, a feed rate of 3 gpd with a stroke length of 25%. At a dilution of 10% anti-scalant/sequestering the stroke length of the chemical feed pump would be 1.25% of the stroke length. This is probably too low to get reasonable results unless the strokes/min is also turned down.

On March 16, 1998

SDS testing

Sampling and simulated distribution system tests are two of the more important aspects of the ICR requirements. The costs are listed below:

Parameter	No. Per 2 wk	Total # wks	Total #	Cost/unit	Total Cost
TOC*	3	40-52	60 – 78	$60	$2,400
UV 254*	3	40-52	60 – 78	$50	$3,300
Bromide*	2	40-52	40 – 52	$50	$2,000
SDS-THM4**	2	40-52	40 – 52	$160	$6,400
SDS-TOX**	2	40-52	40 – 52	$115	$4,600
SDS-HAA6**	2	40-52	40 – 52	$200	$8,000

Total: $27,900

* Bi-weekly samples of feed, permeate and concentrate

** Bi-weekly samples of feed and permeate

Argo Scientific
A BetzDearborn Company

Bioclean 103A

Cellulose Acetate and Thin Film Composite Membrane Cleaner for Inorganics

Bioclean 103A is a low pH liquid formulation designed specifically to remove metal hydroxides, calcium carbonate, and other similar scales from reverse osmosis (RO) and ultrafiltration (UF) membranes. This highly effective product provides superior cleanings resulting in longer system running time.

Bioclean 103A offers the following features:

- Suitable for use with all thin film or cellulosic membranes.
- Buffered to maintain a pH of 3.0 ± 0.5 over a range of dilutions
- Liquid cleaner which allows shorter mixing time.
- No adverse effects with repeated use.
- Enhanced performance at elevated temperatures.
- Low foam formulation.

PROPERTIES:

Appearance	:	Colorless to amber liquid
Specific gravity	:	1.31 (at 25° C)
pH	:	3.0 ± 0.5 (1 lb:5 gal dilution)
Freeze point*	:	<-5° F (<-15° C)
Minimum storage temp	:	14° F (-10°C)

* At decreased storage temperatures, this product may become cloudy as precipitation occurs. If this should happen, simply warm and stir the liquid until the cloudy solution dissipates.

APPLICATION:

For optimum results, Bioclean 103A should be used in combination with IPA 411, Bioclean 511, Bioclean 107A AES 510 or HPC 307.

PACKAGING:

This product is available in 45# (5 gallon) pails.

DILUTION:

The standard dilution ratio is:

One pound of Bioclean 103A in 5 gallons of water or approximately one gallon of Bioclean 103A for each 45 gallons of water.

CLEANING INSTRUCTIONS:

Specific instructions are outlined on the reverse of this page.

Please do not hesitate to contact Argo Scientific with any questions regarding the use or application of this product.

BIO103A1.SAM
185 BOSSTICK BLVD., SAN MARCOS, CA 92069 (760) 727-2620 FAX (760) 727-3380
03/14/98

Bioclean 103A

Use Instructions

1. Inspect cleaning tank, hoses, and cartridge filter. Install new filter elements.
2. Fill cleaning tank with RO permeate or DI water.
3. Slowly add one pound of Bioclean 103A to the cleaning tank. (1 gallon Bioclean 103A to 55 gallons of water.)
4. Mix solution by recirculating through the cleaning pump.
5. Circulate through each membrane array in the feed direction for 30 minutes. Circulate at the flow rate recommended by the membrane or system manufacture. If the manufacturers recommendations are not available, please reference the cleaning section of the Argo Scientific engineers manual.

In cases of heavy fouling, the first return flow (up to 15% of the cleaning tank volume) should be diverted to drain to prevent re-deposition of removed solids. For optimum results, each array must be cleaned separately in a multi array system.

MEMBRANE TYPE	MEMBRANE DIAMETER	MINIMUM FLOW RATE PER VESSEL GPM (LPM)
SPIRAL WOUND	4"	10 (38)
SPIRAL WOUND	6"	23 (87)
SPIRAL WOUND	8"	40 (151)
HOLLOW FIBER	4"	CONTACT DUPONT
HOLLOW FIBER	8"	CONTACT DUPONT
HOLLOW FIBER	10"	CONTACT DUPONT

6. If solution becomes turbid, discolored from removed material, or the pH level drops below the range recommended by Argo, dump the cleaning tank and prepare fresh solution before cleaning additional passes.
7. Using RO permeate (if possible), rinse before returning system to service.

Argo Scientific
A BetzDearborn Company

Bioclean 511

Polyamide Membrane Cleaner For Organics And Particulates

Bioclean 511 is a high pH liquid formulation designed to remove organics, silt, and other particulate deposits from polysulfone, fluorocarbon, and all polyamide thin film composite reverse osmosis (RO) and ultrafiltration (UF) membranes. This product provides superior cleanings allowing longer run times.

Bioclean 511 offers the following features:

- Optimum results are obtained when used in conjunction with Bioclean 882 and Rogun 881.
- Extremely effective against oils and many other organic compounds.
- Excellent results when used to clean biological matter and eliminate biological slime from the membrane surface.
- Buffered to maintain a pH of 10.5 ± 0.5 over a range of dilutions.
- Enhanced performance at elevated temperatures.
- Liquid cleaner which allows shorter mixing time.
- No adverse effects with repeated use.

PROPERTIES:

Appearance	: Clear, amber liquid
Specific gravity	: 1.18
pH	: 10.5± 0.5 (1:45 dilution)
Freeze point	: < 23° F (-5° C)
Minimum storage temp	: 23° F (- 5° C)*

* At decreased storage temperatures, this product may become cloudy as precipitation occurs. If this should happen, simply warm and stir the liquid until the cloudy solution dissipates.

APPLICATION:

DO NOT USE Bioclean 511 on cellulose acetate membrane. For optimum results, Bioclean 511 should be used in combination with Bioclean 882 and Rogun 881.

PACKAGING:

This product is available in 45# (5 gallon) pails and 500# (55 gallon) drums.

DILUTION:

The standard dilution ratio is:

One pound of Bioclean 511 in 5 gallons of water or approximately one gallon of Bioclean 511 for each 45 gallons of water (18 ml per liter).

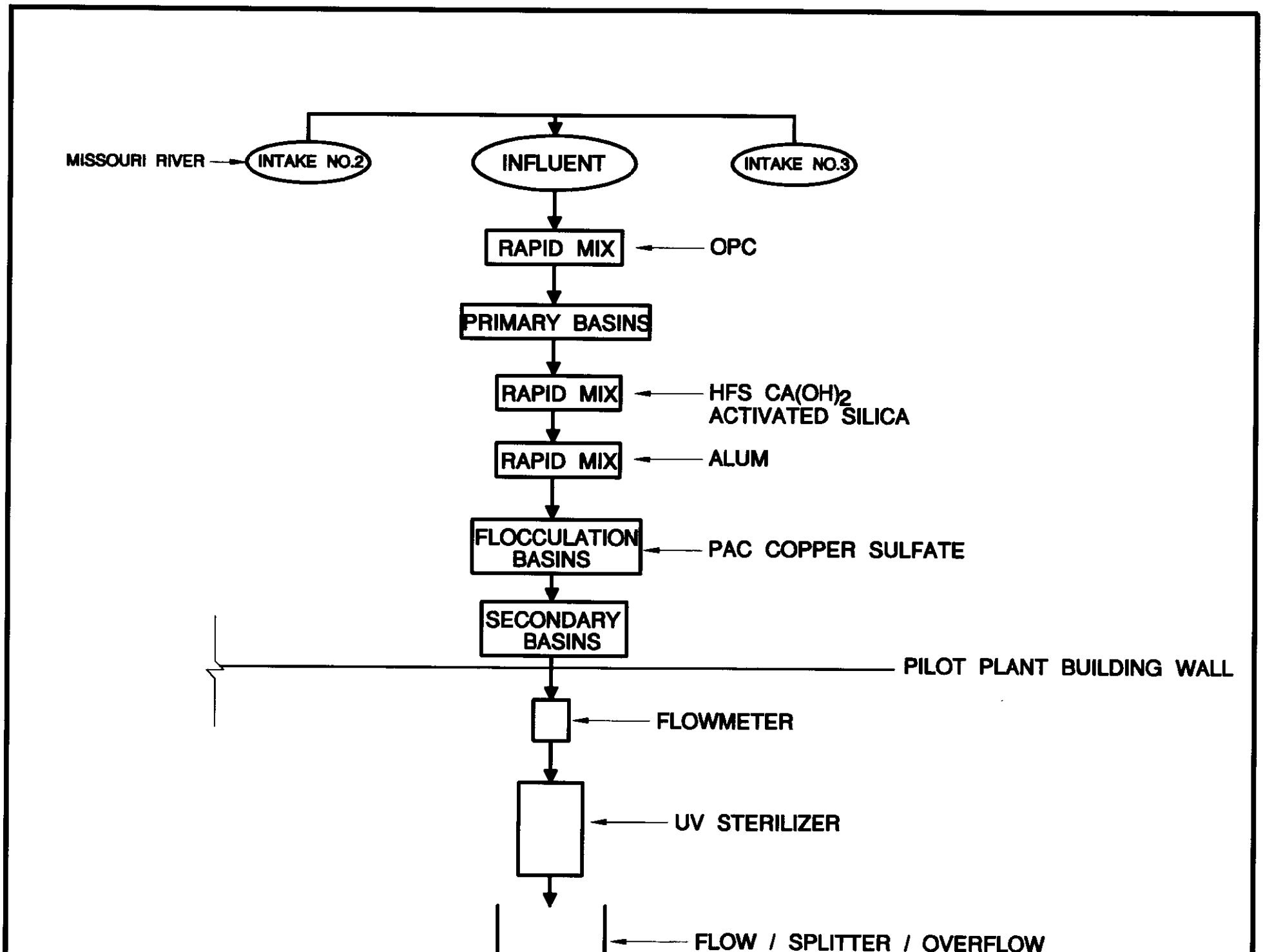
CLEANING INSTRUCTIONS:

Specific instructions are outlined on the reverse of this page. Please do not hesitate to contact Argo Scientific with any questions regarding the use or application of this product.

BIO51101.SAM

02/14/98

185 BOSSTICK BLVD., SAN MARCOS, CA 92069 (760) 727-2620 FAX (760) 727-3380


MISSOURI RIVER
INTAKE NO.2
INFLUENT
INTAKE NO.3
RAPID MIX
OPC
PRIMARY BASINS
RAPID MIX
HFS CA(OH)2
ACTIVATED SILICA
RAPID MIX
ALUM
FLOCCULATION BASINS
PAC COPPER SULFATE
SECONDARY BASINS
PILOT PLANT BUILDING WALL
FLOWMETER
UV STERILIZER
FLOW / SPLITTER / OVERFLOW

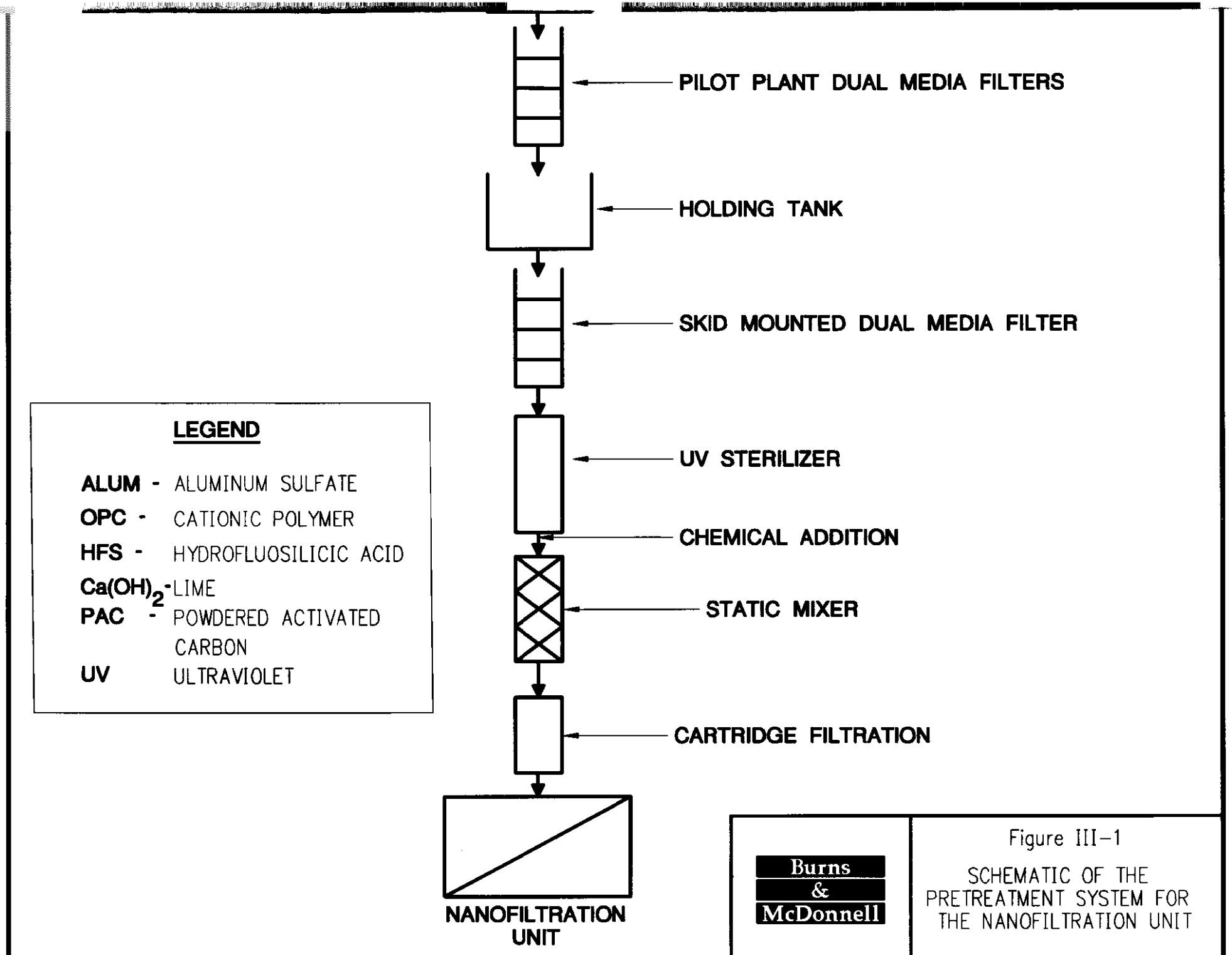
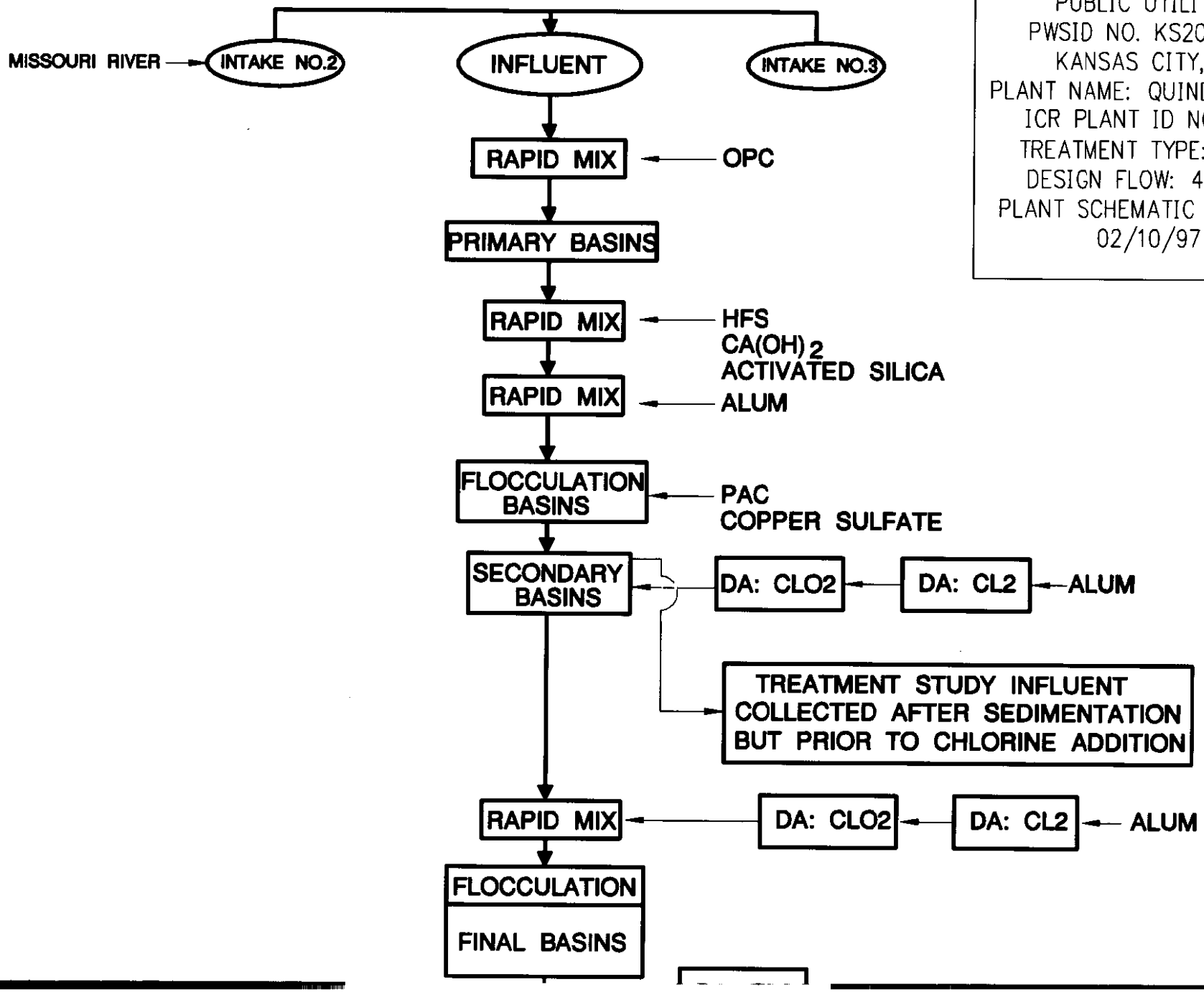


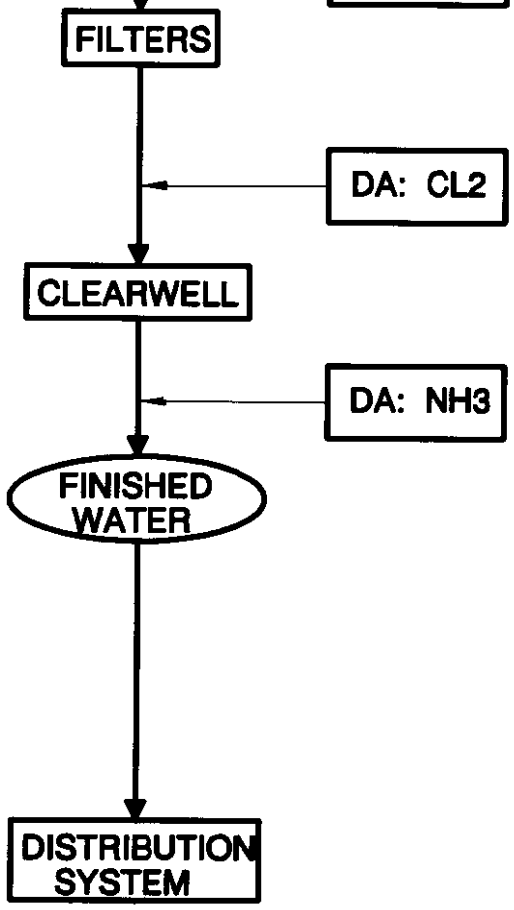
Figure III-1

SCHEMATIC OF THE PRETREATMENT SYSTEM FOR THE NANOFILTRATION UNIT

J:\KCKBPU\880864\KCK2.dwg 0/-12-1999 15:18 MJC

KANSAS CITY BOARD OF PUBLIC UTILITIES
PWSID NO. KS2020906
KANSAS CITY, KS
PLANT NAME: QUINDARO WTP
ICR PLANT ID NO. 384
TREATMENT TYPE: CONV
DESIGN FLOW: 45 MGD
PLANT SCHEMATIC CREATED 02/10/97





LEGEND

DA: CL2 DISINFECTANT ADDITION POINT

FLOCCULATION UNIT PROCESS

ALUM - CHEMICAL ADDED TO UNIT PROCESS

OPC - CATIONIC POLYMER

HFS - HYDROFLUOSILICIC ACID

$Ca(OH)_2$ - LIME

PAC - POWDERED ACTIVATED CARBON

CLO2 - CHLORINE DIOXIDE

CL2 - CHLORINE

ALUM - ALUMINUM SULFATE

NH_3 - AQUA AMMONIA

Burns & McDonnell

Figure II-1

QUINDARO WATER TREATMENT PLANT PROCESS SKEMATIC

J:\KCKBPU\88884\KCK1.dwg 07-12-1999 10:07 MJC

Membrane Autopsy Report

Kansas City Board of Public Utilities

KOCH MEMBRANE SYSTEMS
Fluid Systems

Fluid Systems Corporation
5920 Lakeview
Minnetrista, MN 55364 USA
Tel 612.470.1253
Fax 612.470.1062

T.R. Shepard
KCPBU
3601 N. 12th Street
Kansas City, KS 66104

August 31, 1999

Subject: RMA # 398, 2 ½ " x 40" element

Dear T.R.,

Following is a write up of RMA #398:

Objective: To determine the possible causes for flux loss and poor response to chemical cleaning for a model 2540HR element used for pilot testing.

Tests used to meet this objective:

1. Element autopsy
2. Foulant analysis
   - Loss on Ignition/Ash
   - Scanning Electron Microscope photos
   - EDX of inorganics
3. Membrane cell test following sonic cleaning.

Results:

1. Autopsy:
   There was visible fouling at the feed end of the element. The serial number was washed away. The element was opened. Moderate to heavy fouling was seen on the membrane surface. The foulant was greyish-green in color and sticky the touch.
2. Foulant:
   - Loss on Ignition is 63% (63% of the dried foulant is organic). Ash content is 37% (37% of the dried sample is inorganic)
   - The SEM showed the presence of diatoms (silica skeletons). The SEMs are attached.
   - The EDX analysis of inorganics is attached.

Major Constituents		Minor Constituents	
Si	55.4%	P	7.3%
Ca	11.2%	Al	4.8%
S	7.8%	K	4.2%
Fe	7.5%	Mg	1.9%

3. A membrane sample was cut from the element and cleaned sonically in water. The membrane flux was 29.4 GFD (gallons per square foot per day) versus 28 GFD (+/- 15%) of an average cell test sample in a new element.

Conclusions: The foulant looked heavy and was sticky. An overdose of antiscalant was suspected. A sample was sent to an antiscalant manufacturer for testing. Results confirmed the SEM and EDX. That silica was the major component of the foulant, not antiscalant. Metal silicates and colloidal silica were found. IR showed trace organics.

SEMs of foulants rarely yield much information, but the presence of the diatoms was significant information. The source of the diatoms should be investigated. It is a possible reason for low flux and may not be fully removed during cleaning. Pretreatment should be evaluated. The EDX confirms the SEM , that silica is present and shows it is >50% of the inorganic material on the membrane. Other inorganics are present. Is alum the source of the aluminum? Both iron and alum can cause flux loss. Iron is typically removable with acid cleaning, though.

On the positive side, the foulant was removed fairly successfully with sonic cleaning indicating chemical cleaning should be attainable. The cell test for the membrane was in the range of new membrane flux. The rejection was a little low which is understandable with the increased handling of the sample from an element autopsy.

Please let me know if you have more specific questions. We can work with you more on chemical cleaning suggestions as more questions are answered.

Sincerely,

Madalyn Epple

Madalyn Epple
Midwest Sales Engineer

RMA ELEMENT EVALUATION

Model: 2540 HR **Serial Number:** None **Date:** August 24, 1999

RMA Number: 398 **Customer:** BPU Contact: Epple

1. **Exterior Inspection (as received):** Visible fouling at feed end. Serial number washed away.

2. **Performance Test:** Pressure: N/A Feedwater: N/A

   - Original: GPD: % Rej: Date:
   - Retest: GPD: % Rej: Date:

3. **Dye Test:** N/A

4. **Interior Inspection:** Moderate to heavy fouling. No manufacturing defects found.

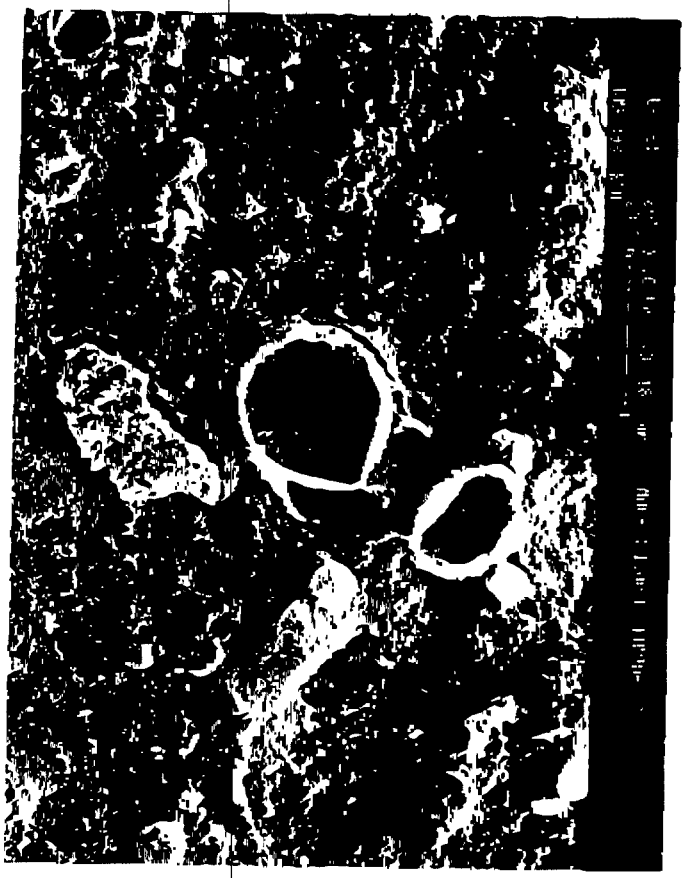
5. **Membrane Test:** 29.4gfd @ 98.7% rej. on 2g/l NaCl, 220 psig. (Ultrasonic-cleaned).

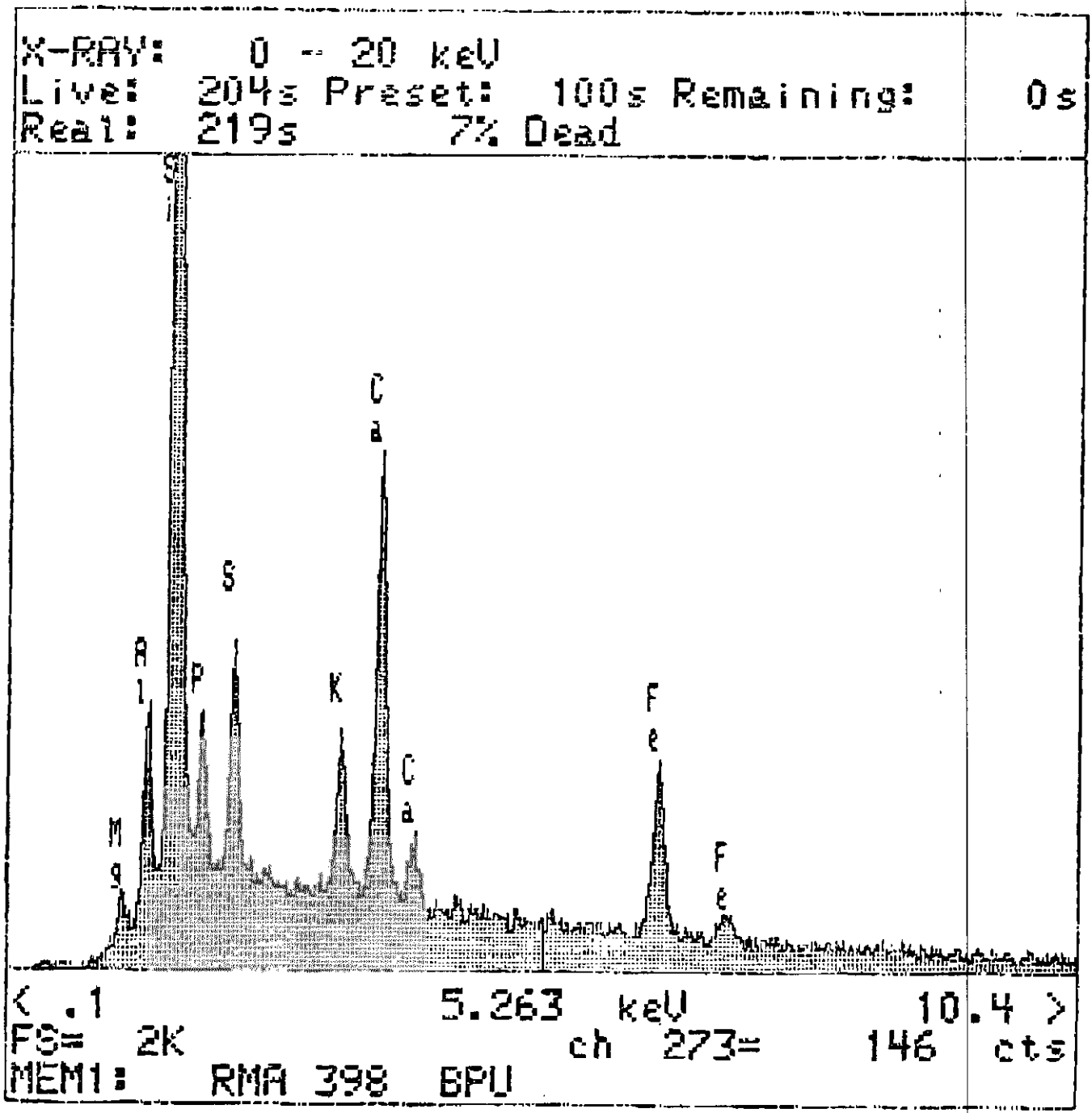
6. **Foulant Analysis:**

   - Appearance: Greyish-green color, sticky to the touch.
   - Loss on ignition: 63% (organic portion) 37% Ash (inorganic portion)
   - EDS:

Major Constituents	Minor Constituents
Si 65.4%	P 7.3%
Ca 11.2%	Al 4.8%
S 7.8%	K 4.2%
Fe 7.5%	Mg 1.9%

Conclusions: Foulant is mostly Silicon. SEM photos (attached) show the presence diatoms which have silica skeletons. Source unknown: DE-treated or naturally occurring in feedwater? Low flow system and frequent cleanings most likely caused by poor pretreatment. Membrane still in pretty good shape: nominal element flux for a new 2540 HR is 28 gfd with 98.8% rej. minimum. EDS report also attached.




X-RAY: 0 - 20 keV
Live: 204s Preset: 100s Remaining: 0s
Real: 219s 7% Dead
Si
Ca
S
Al
P
K
Ca
Fe
Mg
Fe
< .1
5.263 keV
10.4 >
FS= 2K
ch 273= 146 cts
MEM1: RMA 398 BPU