ICR Treatment Study Grandfathering Report

Evaluation of Membrane Technology Using Single Element Bench-Tests and Two Stage Pilot-Tests for Compliance with the Information Collection Rule

Conducted during the period of September 1995 to June 1996

Prepared by
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In November 1997

For

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Plant name. Lorton/Occoquan Water Treatment Plant
Plant ICR #. 685

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

SECTION I. CONCLUSIONS AND RECOMMENDATIONS

A comparison of NF fouling rates in integrated membrane systems following MF and conventional pretreatment revealed the increased importance of colloidal materials on NF fouling compared to organic matter under the experimental conditions investigated during this study. MF pretreatment enabled nanofiltration of a surface water with a chemical cleaning interval of approximately one month at 18 gfd flux and 85% feed water recovery for a two stage system. Longer NF cleaning intervals (and lower NF fouling rates) achieved following MF pretreatment compared to conventional treatment suggest that dual-membrane systems could be a method to reduce NF fouling for the Occoquan Reservoir water. Because permeate flux had a stronger effect on NF fouling than feed water recovery, a strategy for retarding NF fouling during surface water treatment may involve a low permeate flux and a high feed water recovery. However, the cost implications of such a strategy would need to be investigated. For a given water source, the feed water recovery may be limited by the solubility of the limiting salt. Hence, care should be exercised when extrapolating these results to other surface waters that may have higher concentrations of divalent ions constituting sparingly soluble salts. Finally, this study showed that nanofiltration of surface water can meet all current and anticipated THM and HAA regulations.

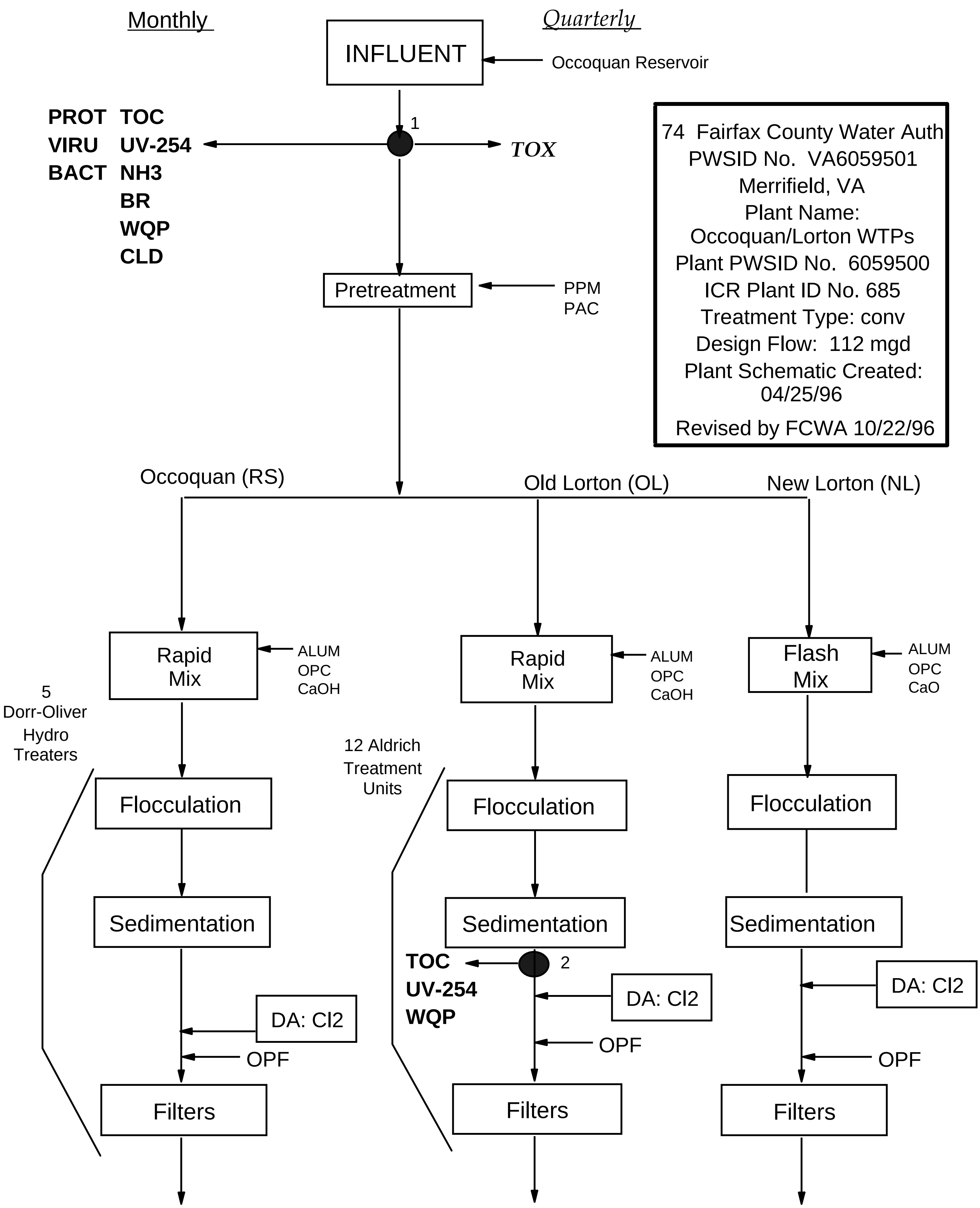
SECTION II. BACKGROUND INFORMATION

Existing Water Treatment Processes. A schematic of the existing treatment processes for the Lorton/Occoquan water treatment plants is given in Figure 1. This schematic was generated earlier during the development of the initial sampling plan for the 18 months of DBP/microbiological monitoring under the ICR. The water for NF testing was obtained following sedimentation and prior to chlorine addition at the Old Lorton Plant (near the sampling location 2 denoted by the red dot).

Basic engineering and chemical feed data for each unit process are summarized in Tables A.2 and A.3 respectively. These tables were also generated earlier using the *ICR Water Utility Database System* (EPA 814-B-96-004) to report the results from the 18 months of DBP/microbiological monitoring under the ICR.

Treatment challenges facing the existing treatment plant. SDSHAA(5) concentrations in the finished water from the existing treatment processes may be higher than the anticipated Stage I maximum contaminant level of 60 µg/L during certain seasons. Further, following high volume precipitation events, the source water turbidity and total organic carbon (TOC) concentrations increase whereas the alkalinity decreases. This combination presents a challenge to the existing coagulation process. Finally, the aging infrastructure of this water treatment facility needs upgrading.

Source and finished water quality. A summary of important source and finished water quality parameters are summarized in Tables 1 and 2 respectively.


Monthly
Quarterly
INFLUENT
Occoquan Reservoir
PROT
VIRU
BACT
TOC
UV-254
NH3
BR
WQP
CLD
1
TOX
74 Fairfax County Water Auth
PWSID No. VA6059501
Merrifield, VA
Plant Name:
Occoquan/Lorton WTPs
Plant PWSID No. 6059500
ICR Plant ID No. 685
Treatment Type: conv
Design Flow: 112 mgd
Plant Schematic Created:
04/25/96
Revised by FCWA 10/22/96
Pretreatment
PPM
PAC
Occoquan (RS)
Old Lorton (OL)
New Lorton (NL)
Rapid
Mix
ALUM
OPC
CaOH
Rapid
Mix
ALUM
OPC
CaOH
Flash
Mix
ALUM
OPC
CaO
5
Dorr-Oliver
Hydro
Treaters
12 Aldrich
Treatment
Units
Flocculation
Flocculation
Flocculation
Sedimentation
Sedimentation
Sedimentation
TOC
UV-254
WQP
2
DA: Cl2
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OPF
OPF
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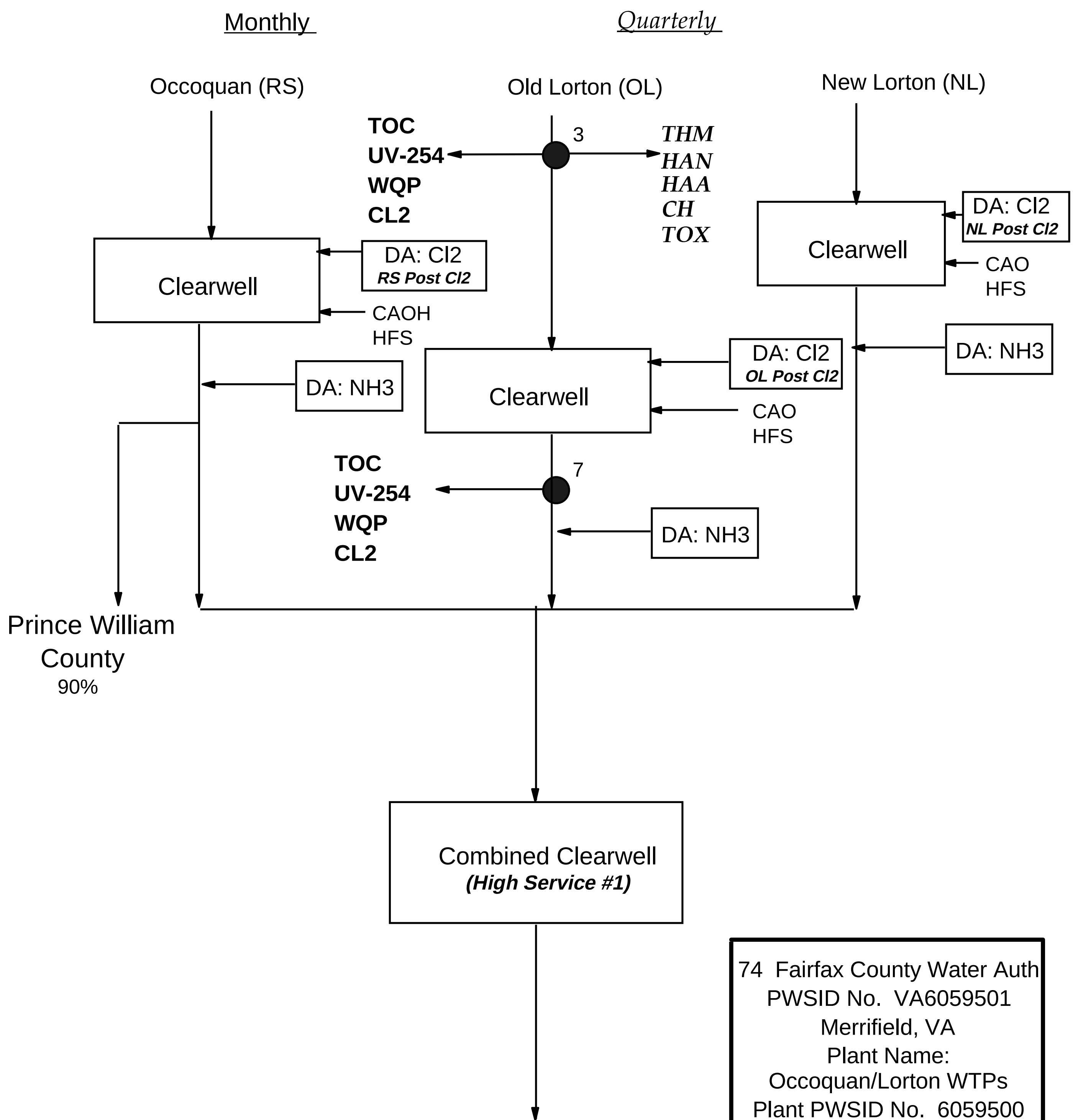
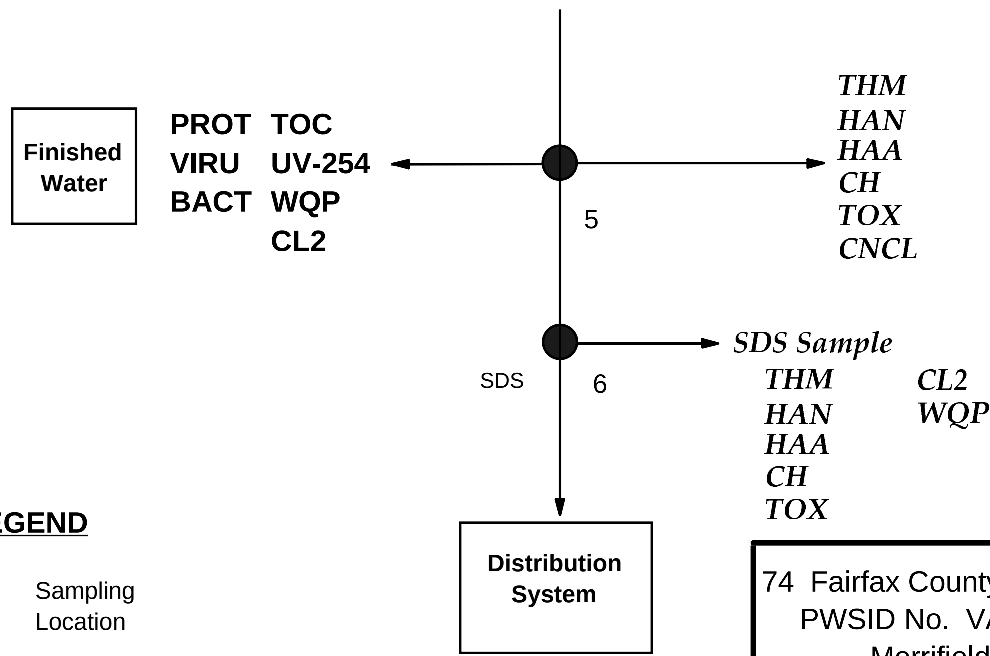
Filters
Filters
Filters



74 Fairfax County Water Auth
PWSID No. VA6059501
Merrifield, VA
Plant Name:
Occoquan/Lorton WTPs
Plant PWSID No. 6059500
ICR Plant ID No. 685
Treatment Type: conv
Design Flow: 112 mgd
Plant Schematic Created:
04/25/96
Revised by FCWA 10/22/96

Occoquan/Lorton



LEGEND

3 Sampling Location

DA: Cl2 Disinfectant Addition Point

WQP
TOX Analyte Groups

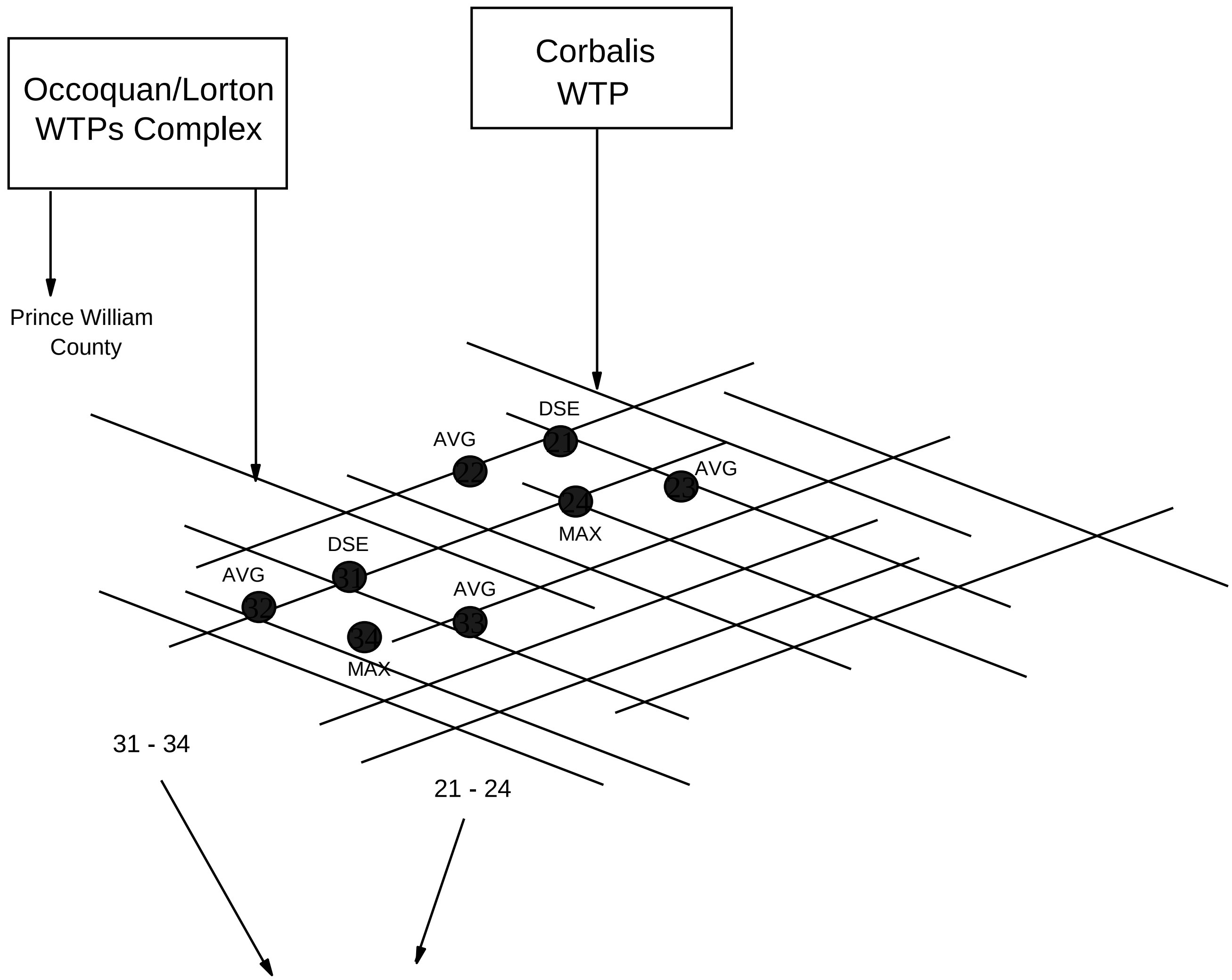
Flocculation Unit Process

ALUM Chemical Added to Unit Process

74 Fairfax County Water Auth
PWSID No. VA6059501
Merrifield, VA
Plant Name:
Occoquan/Lorton WTPs
Plant PWSID No. 6059500
ICR Plant ID No. 685
Treatment Type: conv
Design Flow: 112 mgd
Plant Schematic Created:
04/25/96
Revised by FCWA 10/22/96

74 Fairfax County Water Auth
PWSID No. VA6059501
Merrifield, VA
System Schematic Created:
08/18/96
Revised by FCWA 10/22/96

Quarterly



THM
HAN
HAA
CH
TOX

CL2
WQP
CNCL(MAX)

LEGEND

● 21 - 24	Sampling Locations
DSE	Distribution System Equivalent--Corresponds to SDS Residence Time
AVG	Average Residence Time in the Distribution System
MAX	Maximum Residence Time in the Distribution System

A.2 -- Design Plant Parameters

Date: 11/7/97

PWS Name: Fairfax County Water Authority
PWS ID: VA6059501
WIDB: 1554
ICR Contact Person: Ms. Jeanne Bailey

Sampling Period: Design
Design Sampling Start Date: 7/14/97
Design Sampling End Date: 12/31/98

Treatment Plant Name: Corbalis WTP
ICR Treatment Plant ID: 684
Treatment Plant PWS ID:
Treatment Plant Category: CONV

State Approved Plant Capacity (MGD): 150.0
Historical Min. Water Temperature (deg C): 2.0
Installed Sludge Handling Capacity (DPD): 190,000.00
Blending Indicator: N

Water Resource Name: Potomac River
Water Resource Type: Flowing stream
Intake Name: Potomac river Intake
Watershed Control: Y
Hydrologic Unit Code:

On River Reach Code:
Latitude (degrees, minutes, seconds): +39°3'45"
Longitude (degrees, minutes, seconds): -77°20'58"
River Reach Miles:

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.
	Influent	INF	1

Process Train Name: Corbalis
Process Train Category: CONV

1	Pre-Treatment	Other Treatment Process	Surface Area (ft2):

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Liquid Volume (gal): Short Circuiting Factor:
2	Reclam. Basin	Washwater Return	2	Washwater Treated: N Coagulation/Sedimentation: N Filtration: N Disinfectant Addition: N Plain Sedimentation: Y Other Treatment: 24 hr average Water flow Returned (MGD): 2.5
3	Reclam. Basin	Washwater Return Sample Point	3	
4	Pre Chlorine	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 2.30
5	Raw Wtr Ctrl Ch	Rapid Mix	4	Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 23,188 Short Circuiting Factor: Mean Velocity Gradient (sec-1): 624.0
6	Basn Rpd Mix Ch	Rapid Mix	5	Type of Mixer: ME Baffling Type: UN

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Liquid Volume (gal): 11,728 Short Circuiting Factor: Mean Velocity Gradient (sec-1): 1,000.0
7	Flocculation	Flocculation Basin	6	Type of Mixer: ME Liquid Volume (gal): 2,084,048 Short Circuiting Factor: Baffling Type: UN Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 100 Stage Liquid Volume (gal): 480,934 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 60 Stage Liquid Volume (gal): 641,246 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 25 Stage Liquid Volume (gal): 961,868
8	Sedimentation	Sedimentation	7	Surface Area (ft2): 138,304 Liquid Volume (gal): 12,414,168 Baffling Type: PR Short Circuiting Factor: Plate Settler Surface Area (ft2):

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:
9	Filtration	Filtration	8	Surface Area (ft2): 19,840 Liquid Volume (gal): 1,558,234 Total Media Depth (in): 51 Depth of GAC (in): 24 Media Type: GACS Type of Activated Carbon: Minimum Water Depth To Top of Media (ft): 6.3 Depth From Top of Media to Top of Backwash Trough (ft): 3.3
10	Post Cl2 #1	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 3.46
11	Filter Clearwll	Other Treatment Process	9	Surface Area (ft2): 23,014 Liquid Volume (gal): 2,410,026 Short Circuiting Factor:
12	Post Cl2 #2	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 1.38
13	Clearwell	Clearwell	10	Surface Area (ft2): 128,629

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Liquid Volume (gal): 13,500,000 Minimum Liquid Volume (gal): 2,000,000 Baffling Type: PF Short Circuiting Factor: Covered Indicator Code: Y
14	Anhydrous ammon	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 1.05
	Finished Water	FIN	11	

Treatment Plant Name: Occoquan/Lorton WTP
ICR Treatment Plant ID: 685
Treatment Plant PWS ID: VA6059500
Treatment Plant Category: CONV

State Approved Plant Capacity (MGD): 112.0
Historical Min. Water Temperature (deg C): 2.0
Installed Sludge Handling Capacity (GPD): 2,880,000.00
Blending Indicator: N

Water Resource Name: Occoquan Reservoir
Water Resource Type: Reservoir/lake
Average Residence Time (Days): 7
Intake Name: Occoquan Resv. Intake - High Dam
Watershed Control: Y

Hydrologic Unit Code:
River Reach:
Latitude (degrees, minutes, seconds): +38°41'58"
Longitude (degrees, minutes, seconds): -77°16'30"
River Reach Miles:

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
	Influent	INF	1	
Process Train Name: New Lorton				
Process Train Category: CONV				
1	Pretreatment	Other Treatment Process		Surface Area (ft2): Liquid Volume (gal): Short Circuiting Factor:
2	Flash Mix	Rapid Mix		Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 14,885 Short Circuiting Factor: Mean Velocity Gradient (sec-1): 29,000.0

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
3	Flocculation	Flocculation Basin		Type of Mixer: ME Liquid Volume (gal): 502,656 Short Circuiting Factor: Baffling Type: UN Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 50 Stage Liquid Volume (gal): 502,656
4	Sedimentation	Sedimentation		Surface Area (ft2): 22,680 Liquid Volume (gal): 2,670,360 Baffling Type: PR Short Circuiting Factor: Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:
5	Chlorine gas	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 10.00
6	Filtration	Filtration		Surface Area (ft2): 5,580 Liquid Volume (gal): 379,086 Total Media Depth (in): 39 Depth of GAC (in):

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Media Type: DUAL Type of Activated Carbon: Minimum Water Depth To Top of Media (ft): 7.0 Depth From Top of Media to Top of Backwash Trough (ft): 2.7
7	NL Post Cl2	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 1.50
8	New Lorton Clwl	Clearwell		Surface Area (ft2): 6,138 Liquid Volume (gal): 750,000 Minimum Liquid Volume (gal): 484,800 Baffling Type: SP Short Circuiting Factor: Covered Indicator Code: Y
9	New Lorton NH3	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 1.00
10	Combination Clw	Clearwell		Surface Area (ft2): 3,840 Liquid Volume (gal): 400,000 Minimum Liquid Volume (gal): 86,000 Baffling Type: UN Short Circuiting Factor: Covered Indicator Code: Y

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
Process Train Name: Old Lorton				
1	Aldrich	Rapid Mix		Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 47,370 Short Circuiting Factor: Mean Velocity Gradient (sec-1): 9,000.0
2	Aldrich	Flocculation Basin		Type of Mixer: HY Liquid Volume (gal): 46,750 Short Circuiting Factor: Baffling Type: UN Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 30 Stage Liquid Volume (gal): 46,750
3	Aldrich	Sedimentation	2	Surface Area (ft2): 4,084 Liquid Volume (gal): 422,620 Baffling Type: UN Short Circuiting Factor: Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
4	Chlorine gas	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 10.00
5	Filtration	Filtration	3	Surface Area (ft2): 9,120 Liquid Volume (gal): 996,732 Total Media Depth (in): 42 Depth of GAC (in): Media Type: DUAL Type of Activated Carbon: Minimum Water Depth To Top of Media (ft): 7.0 Depth From Top of Media to Top of Backwash Trough (ft): 2.0
6	OL Post Cl2	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 2.00
7	Old Lorton Clwl	Clearwell	7	Surface Area (ft2): 9,503 Liquid Volume (gal): 1,070,000 Minimum Liquid Volume (gal): 426,300 Baffling Type: AV Short Circuiting Factor: Covered Indicator Code: Y
8	Post NH3	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Dose Rate (mg/L): 1.00
9	Combination Clw	Clearwell		Surface Area (ft2): 3,840 Liquid Volume (gal): 400,000 Minimum Liquid Volume (gal): 86,000 Baffling Type: UN Short Circuiting Factor: Covered Indicator Code: Y
Process Train Name: River Station/Occoquan				
1	Hydro-Treat	Rapid Mix		Type of Mixer: ME Baffling Type: UN Liquid Volume (gal): 1,852 Short Circuiting Factor: Mean Velocity Gradient (sec-1): 26,000.0
2	Hydro-Treat	Flocculation Basin		Type of Mixer: ME Liquid Volume (gal): 496,672 Short Circuiting Factor: Baffling Type: UN Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): Stage Liquid Volume (gal): 496,672
3	Hydro-Treat	Sedimentation		Surface Area (ft2): 3,848

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Liquid Volume (gal): 496,672 Baffling Type: AV Short Circuiting Factor: Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): 9,185 Tube Settler Brand Name: Enviropacks
4	Chlorine gas	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 10.00
5	Filtration	Filtration		Surface Area (ft2): 1,400 Liquid Volume (gal): 26,180 Total Media Depth (in): 47 Depth of GAC (in): Media Type: DUAL Type of Activated Carbon: Minimum Water Depth To Top of Media (ft): 9.8 Depth From Top of Media to Top of Backwash Trough (ft): 1.8
6	RS Post CL2	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 2.50
7	River Sta Clwl	Clearwell		Surface Area (ft2): 7,094

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Liquid Volume (gal): 1,700,000 Minimum Liquid Volume (gal): 640,000 Baffling Type: PR Short Circuiting Factor: Covered Indicator Code: Y
8	RS NH3	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 1.00
9	Combination Clw	Clearwell		Surface Area (ft2): 3,840 Liquid Volume (gal): 400,000 Minimum Liquid Volume (gal): 86,000 Baffling Type: UN Short Circuiting Factor: Covered Indicator Code: Y
	Finished Water	FIN	5	

<u>End of Report   A.2 -Design Plant Parameters</u>

A.3 -- Design Plant Chemical Parameters

Date: 11/7/97

PWS Name: Fairfax County Water Authority
PWS ID: VA6059501
WIDB: 1554
ICR Contact Person: Ms. Jeanne Bailey

Sampling Period: Design
Sampling Start Date: 7/14/97
Sampling End Date: 12/31/98

Treatment Plant Name: Corbalis WTP
ICR Treatment Plant ID No: 684
Treatment Plant Category: CONV

Process Train Name: Corbalis
Process Train Category: CONV

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
1	Pre-Treatment	Other Treatment Process				
				Potassium permanganate	KMnO4	1.00
2	Reclam. Basin	Washwater Return	2			
3	Reclam. Basin	Washwater Return Sample Point	3			
4	Pre Chlorine	Disinfectant Addition				
				Chlorine gas	Cl2	2.30
5	Raw Wtr Ctrl Ch	Rapid Mix	4			
				Polyaluminum chloride	Kemira PAX18	3.36
				Aluminum sulfate (Alum)	Al2SO4	46.00

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
				Organic polymer - coagulant aid	Magnifloc 591C	0.09
				Other chemical	Cytec 1986N	0.01
6	Basn Rpd Mix Ch	Rapid Mix	5			
7	Flocculation	Flocculation Basin	6			
8	Sedimentation	Sedimentation	7			
9	Filtration	Filtration	8			
				Organic polymer - filter aid	CYTEC 1986N	0.01
				Organic polymer - filter aid	Magnifloc 591C	0.10
10	Post Cl2 #1	Disinfectant Addition				
				Chlorine gas	Cl2	3.46
11	Filter Clearwll	Other Treatment Process	9			
				Hydrofluorosilic acid	F	0.80
12	Post Cl2 #2	Disinfectant Addition				
				Chlorine gas	Cl2	1.38
13	Clearwell	Clearwell	10			
				Calcium oxide	CaO	10.20
				Sodium hydroxide	NaOH	3.30
14	Anhydrous ammon	Disinfectant Addition				
				Anhydrous ammonia	NH3	1.05

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)

Treatment Plant Name: Occoquan/Lorton WTP
ICR Treatment Plant ID No: 685
Treatment Plant Category: CONV

Process Train Name: New Lorton
Process Train Category: CONV

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
1	Pretreatment	Other Treatment Process				
				Powdered activated carbon	C	10.00
				Potassium permanganate	KMnO4	1.00
2	Flash Mix	Rapid Mix				
				Organic polymer - coagulant aid	Oddessay EC274	0.20
				Calcium oxide	CaO	3.50
				Organic polymer - coagulant aid	Cytec 1986N	0.20
				Aluminum sulfate (Alum)	Al2SO4	40.00
3	Flocculation	Flocculation Basin				
4	Sedimentation	Sedimentation				
5	Chlorine gas	Disinfectant Addition				
				Chlorine gas	Cl2	10.00
6	Filtration	Filtration				
				Organic polymer - filter aid	Odessay EC274	0.01
				Organic polymer - filter aid	CYTEC 1986N	0.01
7	NL Post Cl2	Disinfectant Addition				
				Chlorine gas	Cl2	1.50
8	New Lorton Clwl	Clearwell				

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
				Calcium oxide	CaO	30.00
				Hydrofluorosilic acid	F	1.00
9	New Lorton NH3	Disinfectant Addition				
				Anhydrous ammonia	NH3	1.00
10	Combination Clw	Clearwell				
Process Train Name: Old Lorton						
Process Train Category: CONV						
1	Aldrich	Rapid Mix				
				Organic polymer - coagulant aid	Oddessay EC274	0.20
				Calcium oxide	CaO	4.90
				Aluminum sulfate (Alum)	Al2SO4	40.00
				Organic polymer - coagulant aid	Cytec 1986N	0.20
2	Aldrich	Flocculation Basin				
3	Aldrich	Sedimentation	2			
4	Chlorine gas	Disinfectant Addition				
				Chlorine gas	Cl2	10.00
5	Filtration	Filtration	3			
				Organic polymer - filter aid	CYTEC 1986N	0.01
				Organic polymer - filter aid	Odessay EC274	0.01
6	OL Post Cl2	Disinfectant Addition				
				Chlorine gas	Cl2	2.00
7	Old Lorton Clwl	Clearwell	7			
				Hydrofluorosilic acid	F	1.00

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
				Calcium oxide	CaO	11.00
8	Post NH3	Disinfectant Addition				
				Anhydrous ammonia	NH3	1.00
9	Combination Clw	Clearwell				
Process Train Name: River Station/Occoquan						
Process Train Category: CONV						
1	Hydro-Treat	Rapid Mix				
				Organic polymer - coagulant aid	Oddessay EC274	0.20
				Organic polymer - coagulant aid	Cytec 1986N	0.20
				Calcium hydroxide	CaOH	5.00
				Aluminum sulfate (Alum)	Al2SO4	40.00
2	Hydro-Treat	Flocculation Basin				
3	Hydro-Treat	Sedimentation				
4	Chlorine gas	Disinfectant Addition				
				Chlorine gas	Cl2	10.00
5	Filtration	Filtration				
				Organic polymer - filter aid	CYTEC 1986N	0.01
				Organic polymer - filter aid	Odessay EC274	0.01
6	RS Post CL2	Disinfectant Addition				
				Chlorine gas	Cl2	2.50
7	River Sta Clwl	Clearwell				
				Calcium hydroxide	CaOH	20.00
				Hydrofluorosilic acid	F	1.00

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
8	RS NH3	Disinfectant Addition				
				Anhydrous ammonia	NH3	1.00
9	Combination Clw	Clearwell				

End of Report   A.3 --Design Plant Chemical Parameters

Table 1. Summary of important source water quality parameters

Parameter	Units	Average	Range
Temperature	°C	14.7	2.8 - 24.8
pH	-	7.1	6.3 - 7.5
Turbidity	NTU	16.7	3.5 - 64
Alkalinity	mg/L as $CaCO_3$	34.7	24 - 46
Calcium hardness	mg/L as $CaCO_3$	39.8	22 - 60
Total hardness	mg/L as $CaCO_3$	54.8	37 - 78
TOC	mg/L	5.8	2.9 - 8.6

Table 2. Summary of finished water quality Lorton/Occoquan WTP - 1996

Parameter	Units	Average	Range
Temperature	°C	15.8	4.2 - 24.2
pH	-	7.7	7.2 - 8.3
Turbidity	NTU	0.21	0.11 - 0.35
TOC	mg/L	2.93	1.5 - 3.9
Distribution system THM	µg/L	67	37 - 94

SECTION III. MATERIALS AND METHODS

NF pretreatment. Nanofiltration performance using water following microfiltration (MF) treatment as well as conventional treatment is reported. Skid mounted MF and NF plants were operated at the site of Fairfax County Water Authority's water treatment plant in Lorton, VA. All membranes were operated in a constant flux mode. Details of these pretreatment processes are given in this section.

Microfiltration. A hollow fiber membrane having an outside-inside flow configuration was evaluated in direct flow mode (Table 3). This hydrophobic polymeric membrane was periodically backwashed using compressed air at 90 psi. Three modules were used to generate sufficient water for the two stage NF pilot plant. Pressure gages, flow meters and sample ports were located in the raw and filtrate lines. A valve in the filtrate side was operated manually to change the pressures and flows in the system.

Table 3. MF membrane and system specifications

Parameter	Value
Material	Polypropylene (hydrophobic)
Geometry	Hollow fiber
Flow direction	Transverse flow (outside-in)
Operating configuration	Direct flow (dead-end)
Nominal bubble point	30 psi
Nominal pore size	0.2 µm
Effective inside membrane area per module	15 m^2

MF cleaning. The membranes were operated in constant flux mode and were cleaned when the transmembrane pressure increased to approximately 18 psi. The cleaning solution was prepared by adding three liters of a proprietary solution called MEMCLEAN (a mixture of 0.5% NaOH and surfactants) to water heated to 40 °C. Acid cleaning at a pH of 3 subsequent to cleaning using MEMCLEAN did not provide any additional benefit. The cleaning cycle began by circulating the chemicals on the shell side followed by a short soak period. The chemicals were then drained and the unit was backwashed three times before bringing it back in normal filtration mode. Chemical cleaning required approximately four hours to perform.

Conventional Treatment. Because chlorine was added to the water prior to filtration at the full-scale plant (to enhance manganese removal and control microbial growth on filter media), water following flocculation, coagulation and sedimentation was pumped to the pilot site. Alum was used as the coagulant and was dosed at approximately 35 mg/L. A dual media filter (12” anthracite and 12” sand) was used to filter the chlorine free water prior to NF. The filter was backwashed when the effluent turbidity reached 0.2 NTU. Sample taps, flow meters and pressure gages were installed in the settled water and filtered water lines. More details on the conventional treatment plant has been presented earlier in section II “Background Information”.

Nanofiltration Experiments. A thin film composite NF membrane having a spiral-wound configuration (FilmTec NF70, FilmTec Corp., Minneapolis, MN) was evaluated. More information on this membrane is provided in Table 4. A 5 µm prefilter was used upstream of this membrane. All experiments were conducted at a pH of 6. Sulfuric acid was used to depress the pH to this value.

Table 4. Description of a membrane element used in this study

Parameter	Value
Membrane designation	NF70
Process	Nanofiltration
Geometry	Spiral wound
Flow configuration	Crossflow
MWCO	200 Daltons
Conductivity rejection[1] (%)	85
Material	Sulfonated polyether sulfone
Measured clean water specific flux at 20 °C ($L/m^2/h/kPa$)	0.086
Temperature correction factor equation (to 20 °C)	$e^{-0.0352(T-20)}$
Fouled membrane cleaning procedure using water at 40 °C	0.5% NaOH

This membrane was chemically cleaned when the specific flux dropped by approximately 20%. Cleaning was achieved by circulating a 0.5% NaOH solution at low pressure (to reduce permeation) followed by a two hour soak. The cleaning solution was reheated to 40 °C and then recirculated. The membranes were rinsed with NF permeate water before bringing them back on-line.

NF with conventional pretreatment. All experiments were conducted using a single four inch diameter (40 inches long) element. Concentrate recycle was employed to control element recovery and crossflow velocity. A schematic of the treatment train employed during this period of testing is given in Figure 2. A summary of experimental parameters investigated in this treatment train are given in Table 5.

[1] measured at 10 gfd flux and 30% feed water recovery

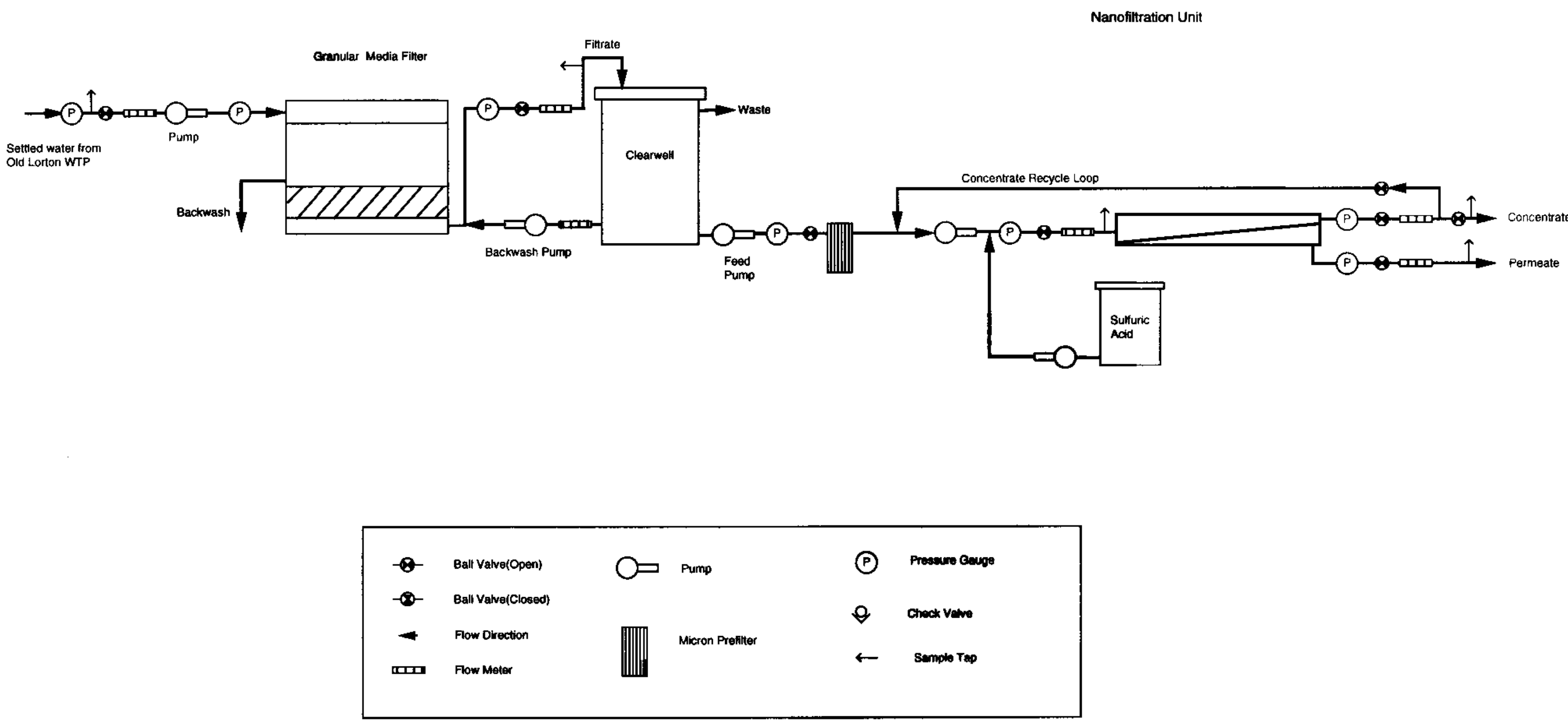


Figure 2. Conventional - Nanofiltration Process Train Schematic

Table 5. Summary of NF experiments following conventional pretreatment

Run #	Date	Flux (gfd)	Feed water recovery (%)	Element recovery (%)
1	1/5/96	9.9	30	10
2	2/26/96	14.76	75	17.5
3	3/22/96	14.69	73	10.9
4	4/9/96	15.84	50	17.5
5	4/22/96	14.77	77	25
6	5/6/96	20.6	75	25
7	5/10/96	10	75	25
8	5/21/96	15	30	17.5
9	5/28/96	15	50	17.5
10	6/3/96	15	75	17.5

NF with MF pretreatment. Pilot testing was undertaken using a two stage array with MF pretreatment. Twelve, 4 inch diameter elements constituted the first stage whereas six elements were used in the second stage. No concentrate recycle was employed during this phase of testing. The first stage consisted of two banks of membranes whereas the second stage had only one bank of membranes. Each bank in turn was composed of two pressure vessels in series. Each pressure vessel could accommodate four membrane elements. Because of flow limitations, only three elements were used in each pressure vessel with a membrane spacer in the lead in each pressure vessel. Thus, a total of eighteen (18) membrane elements were used. All concentrate water was sent to drain. A schematic of the treatment train employed during this period of testing is given in Figure 3. The flux in the first stage was maintained at 20 gfd (at 20 °C). The second stage was operated at a lower flux of 14 gfd (at 20 °C) to achieve an overall system flux of 18 gfd (at 20 °C). The feed water recovery of individual stages was maintained at 60% to achieve an overall system recovery of 85%. This pilot plant was operated continuously for a total of approximately 1,200 hours.

Table 6. Summary of two stage NF pilot plant design parameters

Stage	Permeate flux at 20 °C (gfd)	Feed water recovery (%)
Stage I	20	60
Stage II	14	60
System	18	85

The average transmembrane pressure (P_{tm}) for the nanofilters was calculated using:

$$P_{tm} = \left(\frac{P_i + P_o}{2}\right) - P_p \qquad (1)$$

where P_i and P_o are the pressures at the inlet and outlet of the membrane module and P_p is the permeate pressure.

Simulated Distribution System (SDS) DBP Tests. Water samples were buffered to a pH of 7.5 using a 0.01 M phosphate buffer and then dosed with free chlorine (Cl_2 dose to

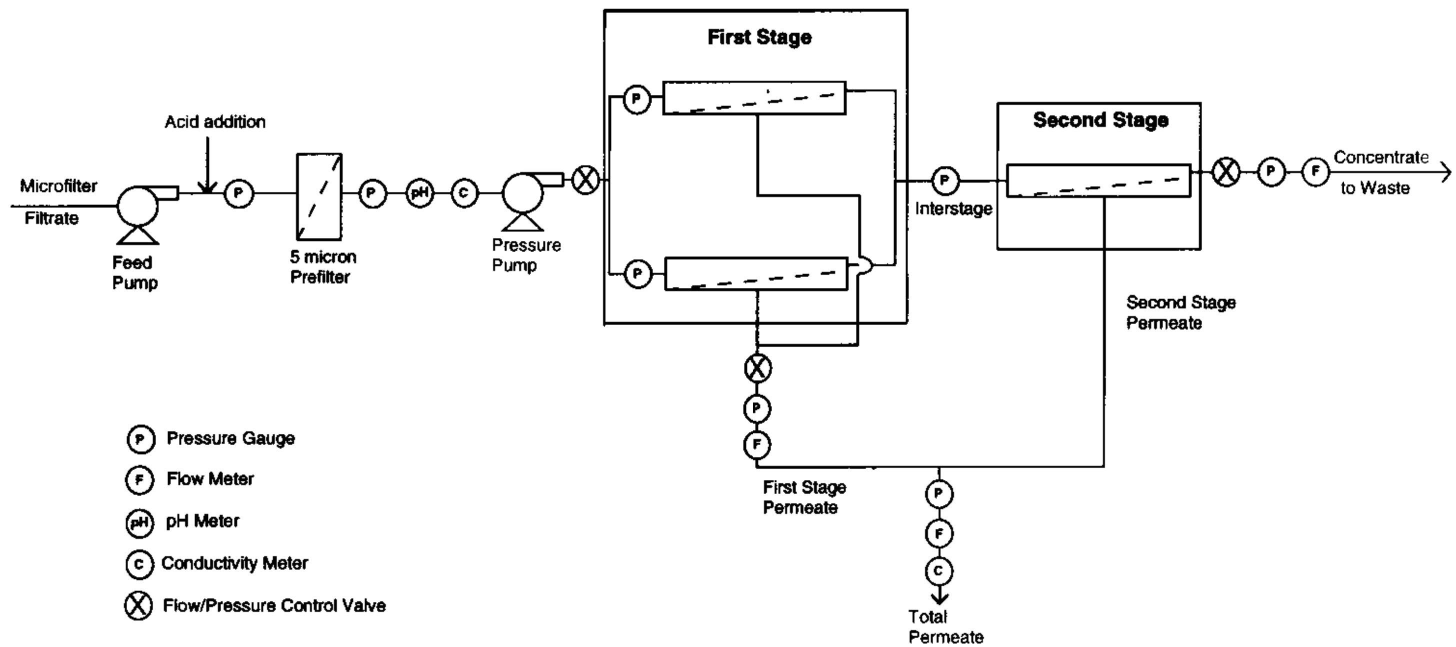


Figure 3. Schematic of the two stage nanofiltration pilot plant.

TOC ratio • 1.6). These were then incubated in the dark at the distribution system temperature. Samples were collected after 72 hours and analyzed for THMs[2] and HAA(6)[3].

Table 7. Summary of SDS experimental conditions

Season	**Temperature (°C)**	**Time (hour)**	**pH**	**Free Cl2 residual (mg/L)**
Spring	18.7	72	7.5	1
Summer	21.2	72	7.5	1
Autumn	20	72	7.5	1
Winter	11.2	72	7.5	1

Silt Density Index. During the silt density index (SDI) test, water was filtered in the direct-flow mode with no crossflow at a constant pressure of 30 psi. The time needed to filter 500 mL initially (t_i) was recorded along with the time to filter 500 mL at the end of the 15 minute test period (t_f). SDI values were measured using disc membranes rated at 0.45 µm (Durapore, Millipore Corp., Marlborough, MA). The SDI was then calculated using

$$\mathrm{SDI} = \left(1 - \frac{t_i}{t_f}\right)\frac{100}{15} \qquad (2)$$

Modified Fouling Index. The modified fouling index (MFI) is based on the assumption of cake filtration (perfect rejection) and that Darcy's law can be used to model the resistance to filtration. The MF membrane used for NF pretreatment had a nominal pore size rating of 0.2 µm. Hence, disc membranes with a smaller pore size rating of 0.1 µm (Durapore, Millipore Corp., Marlborough, MA) were used to measure the MFI. During this test, the cumulative volume of water (V) filtered at a constant applied pressure of 30 psi was measured at predetermined times t. The MFI is the slope of the best fit straight line to the data plotted using V as the independent variable and t/V as the dependent variable. MFI values obtained during this study are reported in units of s/mL^2.

A list of all analytical methods and the minimum reporting levels for each analyte is shown in Table 8. This table also lists the laboratory that performed the analysis as well as the method number. Other information about the laboratories that performed the analyses are given below.

Fairfax County Water Authority Laboratory
ICR ID #. ICRVA002
Address 12015 John Donnelly Street, Herndon, VA 20170
Contact person Ms. Jeanne M. Bailey
Phone number (703) 404-5048
Fax number (703) 404-5076
Montgomery Watson Laboratory
ICR ID # ICRCA013

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[2] THMs denotes the sum of chloroform, dichlorobromo methane, dibromochloro methane and bromoform.
[3] HAA(6) denotes the sum of monochloro, dichloro, trichloro, monobromo, dibromo and bromochloro acetic acids.

Address 555 East Walnut Street, Pasadena, CA 91101
Contact person Dr. Andrew Eaton
Phone number (626) 568-6425
Fax number (626) 568-6324

Table 8. Analytical methods employed during this study

Analyte	Units	Laboratory	Method Number	Minimum Reporting Level
General Water Quality				
Alkalinity	mg/L as $CaCO_3$	FCWA	SM2320B	1
Total Hardness	mg/L as $CaCO_3$	FCWA	SM2340C	1
Temperature	°C	on-site	SM 2550B	NA
pH	-	on-site	SM 4500-H^+	NA
Inorganics				
Iron	mg/L	FCWA	SM3111B	0.020**
Manganese	mg/L	FCWA	SM3111B	0.020***
Bromide	mg/L	MWLabs	ASTM D 1246-88, Vol 11.01	0.020
Nitrogen as Ammonia	mg/L	FCWA	SM4500NH3F	0.05
Particle Characterization				
Total Suspended Solids	mg/L	FCWA	SM2540D	0.1
Total Dissolved Solids	mg/L	FCWA	SM2540C	0.1
Organic Compound Characterization				
Total Organic Carbon	mg/L	FCWA	SM5310C	0.05
UV-254	cm^{-1}	on-site	SM 5910	0.002
Oxidation and Disinfection By-Products				
Trihalomethanes (THMs)				
Chloroform	µg/L	FCWA	EPA524.2	1
Bromodichloromethane	µg/L	FCWA	EPA524.2	1
Dibromochloromethane	µg/L	FCWA	EPA524.2	1
Bromoform	µg/L	FCWA	EPA524.2	1
Haloacetic acids (6) (HAA6)				
Bromochloroacetic Acid	µg/L	MWLabs	EPA552.1	1
Dibromoacetic Acid	µg/L	MWLabs	EPA552.1	1
Dichloroacetic Acid	µg/L	MWLabs	EPA552.1	1
Monoboromoacetic Acid	µg/L	MWLabs	EPA552.1	1
Monochloroacedic Acid	µg/L	MWLabs	EPA552.1	2
Trichloroacetic Acid	µg/L	MWLabs	EPA552.1	1

FCWA - Fairfax County Water Authority Water Quality Laboratory
MWLabs - Montgomery Watson Laboratories
NA - Not Applicable
** Detection limit changed to 0.050 after 3/21/96
*** Detection limit changed to 0.025 after 3/21/96

SECTION IV. RESULTS AND DISCUSSION

Comparison of MF and Conventional Treatment as NF Pretreatment Strategies. The SDI has been used widely as a crude estimator of the potential for colloidal fouling of NF membranes. NF membrane manufacturers typically suggest that NF be employed only for feed waters with an SDI of 5 or less. The median SDI of the MF filtrate was 1.3. The effluent after conventional treatment had higher SDIs compared to the membrane treated waters. The median SDI of the dual media filter effluent was measured to be equal to 5.2 which is four times higher than that of the MF filtrate. These results suggest that NF membranes may foul more rapidly if conventional treatment was employed as a pretreatment and colloidal materials were the primary foulant unless the turbidity and the SDI of the feed water could be maintained at a lower value.

Another tool to estimate the contribution of colloidal materials to NF fouling is the MFI. This has been shown to be a more sensitive tool than the SDI for predicting fouling and cleaning intervals during reverse osmosis of surface water. Hence, MFI experiments were conducted for the raw water and NF feed waters following pretreatment. Thick cakes were formed during the filtration of raw water resulting in high MFIs (median = 0.037 s/mL^2). High removals of suspended solids were achieved by MF. In all cases, the suspended solids concentration of the MF pretreated water was measured to be less than 0.5 mg/L. Because of their low solids content, no cakes were observed on the membranes used to perform the MFI test using MF filtrates. Consequently, no MFIs could be reliably measured for the water following MF treatment. On the other hand, the median MFI for the water following conventional treatment was determined to be equal to 5×10^{-5} s/mL^2. Higher MFI values measured for the conventionally treated water compared to MF filtrates also suggest greater NF fouling following conventional treatment.

Another important factor that may influence NF performance is the TOC concentration in the feed water. Percent removal by each pretreatment strategy was calculated based on measurements in the raw and effluent waters made on the same day. Conventional treatment including coagulation, flocculation, sedimentation and granular media filtration decreased the TOC to a greater extent (50%) than microfiltration (5%). Thus, if NF fouling is controlled by the TOC concentration rather than by colloidal materials, conventional treatment may be expected to be a better pretreatment strategy than MF.

Evaluation of Microfiltration Pretreatment. The resistance of the MF membrane to the filtration of water was evaluated. Establishing the membrane resistance over a range of pressures is important because productivity can be affected if the membrane structure compacts at higher pressures. Under the conditions evaluated, the transmembrane flux was found to increase linearly with applied pressure. The membrane resistance was calculated to be 1.33×10^{10} cm^{-1}. The linearity of the pressure-flux profiles indicated that the effects of compaction were negligible in the range of conditions investigated.

MF Membrane Fouling. Microfiltration pretreatment for nanofiltration was evaluated in transverse flow mode at permeate fluxes in the range of 50 - 70 gfd at 20 degrees Celsius. Backwash intervals of 30, 20, and 14.5 minutes were evaluated. In most cases, the specific flux was found to be first order with time (exponentially decay). Exponential curve fits to the data were used to estimate chemical cleaning intervals. The time between two chemical cleaning events under various raw water turbidities and MF operating conditions are given below in Table 9. The decay constants for the specific flux which depict the MF fouling rates are also given in Table 9.

Table 9. Cleaning intervals for selected MF conditions[§]

Start and end dates of run	Raw water turbidity (NTU)	Filtrate flux at 20 °C (gfd)	Backwash interval (minute)	Fouling rate ($hour^{-1}$)	Time to clean (days)
9/13/95 - 10/2/95	5	50	30	0.0022	30
10/5/95 - 10/31/95	18	50	20	0.0018	32
11/6/95 - 1/5/96	17	50	20	0.0007	70
1/24/96 - 3/18/96[†]	30	50	20	NA	50
1/17/96 - 1/21/96	58	70	20	0.0109	4
1/21/96 - 1/24/96	128	66	20	0.0253	2
3/18/96 - 3/29/96	12	65	20	0.0040	12
5/6/96 - 6/4/96	13	65	14.5	0.0014	32

[§] Assuming a maximum TMP of 20 psig
[†] Terminated prematurely for the installation of the third module

The temporal profile of the specific flux exhibited by the MF unit was found to be dependent on the permeate flux, backwash interval and the raw water quality. When the turbidity was approximately 5 NTU, the estimated run length was one month (with a 30 minute backwash interval and 50 gfd permeate flux). For the same flux of 50 gfd, when the turbidity increased to approximately 20 NTU run lengths of approximately one to two months were obtained if the backwash interval was decreased to 20 minutes. As the flux was increased to 65 gfd, run lengths of approximately one month were obtained by decreasing the backwash interval to 14.5 minutes.

MF Membrane Cleaning. MF membranes were cleaned when the P_{tm} increased to approximately 18 psi using a proprietary cleaner called MEMCLEAN. This is a highly basic cleaning agent mixed with surfactants. No additional benefit was observed when an extra acid cleaning cycle at pH • 3 was used. More details on the cleaning procedure have been presented earlier. Table 10 summarizes cleaning efficiency data. In general, chemical cleaning was effective with an average efficiency greater than 97 percent when the unit was operating properly (no leaky valves). These data indicate that the microfiltration foulants in Occoquan reservoir can be effectively removed by chemically cleaning the membrane.

Table 10. Summary of MF membrane cleaning data

Cleaning Date	Initial specific flux (gfd/psi)	Final specific flux (gfd/psi)	Specific flux after cleaning (gfd/psi)	Cleaning efficiency (%)
Oct 2, 1995	11.7	4.2	10.5	90
Nov 6, 1995	10.5	3.5	9.7	92
Jan 17, 1996	9.7	2.8	9.2	95
Jan 21, 1996	9.2	2.7	10.3	112
Jan 24, 1996	10.3	3.6	9.9	97
Mar 18, 1996	10.3	5.2[†]	10.8	105
Mar 29, 1996	10.8	3.6	7.3[§]	68
Apr 3, 1996	7.3	3.6	7.4[§]	101
Apr 5, 1996	7.4	4.0	7.1[§]	96
May 6, 1996	9.9	5.0	10.3	104

[†] Terminated prematurely for the installation of a third module
[§] Leaky valve on the filtrate side resulting in poor chemical cleans

Table 11. Selected Raw Water and MF Filtrate Water Quality Parameters During The Pilot Testing Period

Parameter	Units	Raw Water			MF filtrate			Removal (%)
		Number of observations	Range	Median	Number of observations	Range	Median	
Turbidity	NTU	279	3 - 170	16.3	254	0.05 - 0.25	0.1	99
Alkalinity	mg/L as $CaCO_3$	22	12 - 56	32	20	12 - 56	31	-
pH	-	201	6.17 - 7.1	6.6	204	5.78 - 7.20	6.10	-
TOC	mg/L	34	1.5 - 6.6	5.1	32	3.1 - 6.2	4.4	5.3
Absorbance at 254 nm[†]	-	69	0.119 - 0.455	0.227	69	0.077 - 0.240	0.143	39
Total THMs[§]	mg/L	13	101 - 367	174	13	99 - 206	114	15.5
HAA (6)[§]	mg/L	11	106 - 438	351	13	81 - 297	168	24
True color[†]	Pt/Co units	88	19 - 299	89	74	3 - 58	21	76
Total Fe	mg/L	27	0.25 - 6.04	0.91	32	0.02 - 0.07	0.04	94.6
Total Mn	mg/L	27	0.025 - 0.42	0.086	32	0.02 - 0.144	0.05	54
Total hardness	mg/L as $CaCO_3$	22	84	58	20	27 - 82	58	2.8
SDI[¥]	-	NA	NA	NA	24	0.35 - 1.44	0.75	NA
MFI[¥]	s/mL^2	26	0.026 - 0.067	0.0368	NA	NA	NA	NA

[†] measured after filtration through a 0.45 µm filter

[§] formation after 24 hour free Cl_2 contact time at pH 7.5 and incubation at distribution system temperature

[¥] Measured using a 0.1 µm membrane at 30 psi

Table 12. Selected Settled Water and Dual Media Filter Effluent Water Quality Parameters During the Pilot Testing Period

Parameter	Units	Settled Water			Dual Media Filter Effluent			Removal (%)
		Number of observations	Range	Median	Number of observations	Range	Median	
Turbidity	NTU	232	0.4 - 16.3	5.1	238	0.08 - 1.3	0.21	99
Alkalinity	mg/L as $CaCO_3$	14	10 - 38	18	14	8 - 39	16	47
pH	-	157	5.6 - 7.0	6.2	218	5.74 - 6.97	6	-
TOC	mg/L	28	2.2 - 3.9	2.9	29	1.7 - 3.3	2.4	51
Absorbance at 254 nm†	-	54	0.021 - 0.104	0.042	54	0.022 - 0.056	0.038	83
Total THMs§	mg/L	11	17 - 141	64	13	35 - 125	47	63
HAA (6)§	mg/L	10	7 - 137	75	10	28 - 104	47	70
True color†	Pt/Co units	55	0 - 9	1	66	0 - 8	1	99
Total Fe	mg/L	26	0.05 - 2.75	0.123	26	0.02 - 0.04	0.05	94
Total Mn	mg/L	27	0.025 - 0.135	0.052	26	0.025 - 0.127	0.052	44
Total hardness	mg/L as $CaCO_3$	14	45 - 91	65	14	47 - 120	65.5	0
SDI	-	NA	NA	NA	26	0.54 - 1.94	1.18	NA

† measured after filtration through a 0.45 µm filter

§ formation after 24 hour free Cl_2 contact time at pH 7.5 and incubation at distribution system temperature

¥ Measured using a 0.1 µm membrane at 30 psi

Water Quality. Selected source water and MF filtrate water quality parameters during the testing period are given in Table 11 along with removal percentages. Microfiltration was very effective in reducing the turbidity to approximately 0.1 NTU. High removals of iron and manganese were also observed suggesting that these metals were predominantly in the particulate form. Approximately 6 percent of the TOC was also removed by MF. This translated to a 11 percent removal of SDSTHM precursors and a 24 percent removal of SDSHAA precursors. That a greater percentage of SDSHAA precursors were removed as compared to SDSTHM precursors is consistent with their molecular weights. In general, SDSHAA precursors have higher molecular weights than SDSTHM precursors. Microfiltration did not change the alkalinity and hardness of the water. The median SDI of the MF filtrate measured using a 0.1 µm filter was equal to 0.75.

Evaluation of Conventional Pretreatment. Selected settled water and dual media filter effluent water quality parameters measured during the testing period are given in Table 12 along with the median percent removals. Approximately 50 percent of the alkalinity and TOC were removed by conventional treatment. High removals of true color and UV_{254} absorbance were also observed. These translated to approximately 65 percent removal of THM and HAA(6) precursors. The median SDI of the dual media filter effluent measured using a 0.1 µm filter was equal to 1.2.

NF cleaning. Chemical cleaning was performed after a 20 percent decline in the specific flux of NF membranes filtering conventionally treated water. Table 13 summarizes NF cleaning efficiency data. In general, chemical cleaning efficiencies were in the range 90 - 108 percent indicating that NF foulants from the Occoquan Reservoir following conventional pretreatment could be effectively removed following a high pH clean.

Table 13. Summary of NF membrane cleaning data following conventional treatment

Run #	Cleaning date	Initial specific flux (gfd/psi)	Specific flux after cleaning (gfd/psi)	Cleaning efficiency (%)
1	1/5/96	0.36	0.39	108
2	2/26/96	0.39	0.35	90
3	3/22/96	0.35	0.34	97
4	4/9/96	0.34	0.35	103
5	4/22/96	0.35	0.34	97
6	5/6/96	0.34	0.31	91
7	5/10/96	0.31	0.34	110
8	5/21/96	0.34	0.33	97
9	5/28/96	0.33	0.30	91
10	6/3/96	0.30	0.29	97

NF cleaning intervals. In all cases, a straight line decline in specific flux with time was observed for the NF70 membrane. Linear regression techniques were used to determine NF fouling rates and corresponding chemical cleaning intervals.

Fouling rate and cleaning interval results are summarized in Table 14 for the two stage NF pilot plant using microfiltered water. Under these experimental conditions (see Table 6), these membranes would need to be cleaned approximately once a month based on a 20 percent drop in the specific flux. It is important to note that longer chemical cleaning intervals would possibly have been obtained if the permeate flux had been lowered.

Table 14. Fouling rates and cleaning intervals for the 2 stage NF System following MF pretreatment

Location	**Fouling rate (gfd/psi/hour)**	**Cleaning interval (days)**
I stage	9.85×10^{-5}	29
II stage	9.85×10^{-5}	27
System	10^{-4}	28

A summary of NF fouling rates and cleaning intervals following conventional treatment is provided in Table 15. These data show that the longest cleaning interval was achieved at the lowest permeate flux and feed water recovery tested for the single element. Thus, at a flux of 10 gfd and a feed water recovery of 30% a cleaning interval of approximately one month was obtained. In the range of conditions tested, NF fouling rates increased with increasing permeate flux. Under these experimental conditions, the rate of fouling was observed to increase exponentially with flux. These data show a strong influence of permeate flux on nanofilter fouling. As the flux was increased from 10 to 15 gfd (R_f = 75%, R_e = 25%), the cleaning interval decreased from 15 to 10 days. As the flux was increased further to 20 gfd (while maintaining R_f and R_e), the cleaning interval was only 3 days. The rate of membrane fouling was observed to increase in a straight line fashion with R_f at constant flux and element recovery. These data suggest that feed water recovery had a weaker influence on membrane fouling compared to permeate flux. The element recovery did not appear to influence membrane fouling in the range 10 % • R_e • 25%.

Table 15. Fouling rates and cleaning intervals for various NF experiments following conventional treatment

Run #	**Fouling rate x 10^3 (gfd/psi/hour)**	**Cleaning Interval (days)**
1	-0.1071	27
2	-0.2909	11
3	-0.3088	10
4	-0.4445	6
5	-0.3012	10
6	-0.8621	3
7	-0.1712	15
8	-0.2201	13
9	-0.3375	8
10	-0.4042	6

Blending studies. One method of decreasing the effective size of a nanofiltration plant employing MF pretreatment is to blend MF and NF filtered waters. Since all of the raw water would be treated with microfiltration, absolute *Cryptosporidium* and *Giardia* removal can be achieved for the entire plant flow. However, it may not be necessary to remove DBP precursors to less than 5 µg/L for all of the microfiltered water. Thus, two MF:NF blending ratios were evaluated: 20:80 and 40:60. These experiments were done in the Winter and Spring are summarized below in Tables 16 and 17.

Table 16. Effect of blending on organic water quality parameters during Winter testing

Parameter	Units	Raw water	MF filtrate	NF permeate	20:80[£] actual	20:80[£] calc.	40:60[£] actual	40:60[£] calc.
TOC	mg/L	5.7	5.4	< 0.25	1.2	1.28	2.1	2.3
SDSTTHM[†]	µg/L	218.8	168.5	1.4	34.6	34.8	74.8	68.2
SDSHAA (6)[†]	µg/L	376	276	3	51	57.6	102	112.2

[†] formation after 3 day free Cl_2 contact time, pH=7.5, T=10 °C

[£] denotes percent of MF filtrate and NF permeate in blended water respectively

Table 17. Effect of blending on organic water quality parameters during Spring testing

Parameter	Units	Raw water	MF filtrate	NF permeate	20:80[£] actual	20:80[£] calc.	40:60[£] actual	40:60[£] calc.
TOC	mg/L	5.22	4.63	< 0.25	0.99	1.1	1.78	2
SDSTTHM[†]	µg/L	174	140	1.1	53	28.9	85	56.7
SDSHAA (6)[†]	µg/L	247	181	1	46	37	81	73

[†] formation after 3 day free Cl_2 contact time, pH=7.5, T=18 °C

[£] denotes percent of MF filtrate and NF permeate in blended water respectively

SECTION V. QA/QC SUMMARY

Laboratory Organization. Fairfax County Water Authority, the Authority, is the largest water utility in Virginia. The Authority serves high quality drinking water to over 1,000,000 people. Located outside the nation's capital, the Authority supplies drinking water to the citizens of Fairfax, Prince William, and Loudoun Counties, the Town of Herndon, the City of Alexandria, Washington-Dulles International Airport, and several federal installations, such as Fort Belvoir.

The Authority's primary sources of drinking water are from an 11 billion gallon reservoir near the town of Occoquan, and from the free-flowing waters of the Potomac River. Less than two percent of the daily water supplied to the service area comes from 9 wells and purchases from other utilities.

The Laboratory is part of the Water Quality and Operations Division of the Authority. The primary function of the laboratory is to assess the quality of the water from its raw source, through the treatment process to the customer's tap. The laboratory is guided by the laboratory manager and directed by the laboratory supervisor. It is composed of six sections: Field Services, Bacteriological, Inorganics, Metals, Organics, and Special Projects. Each section is headed by a lead analyst that is responsible for the work in that area.

QA/QC Summary. The Fairfax County Water Authority's treatment study was performed prior to the promulgation of the Information Collection Rule and the final version of the *DBP/ICR Analytical Methods Manual*. The Authority utilized its internal QA/QC program as a guide to perform the analyses for the treatment study. The Authority also relied on the Draft version of the *DBP/ICR Analytical Methods Manual* for guidance in the analysis of treatment study related samples.

The Fairfax County Water Authority - Water Quality Laboratory. The Water Quality Laboratory is certified by the Virginia Department of Health - Division of Consolidated Laboratory Services. The laboratory certification number is VA00031. [Note: The laboratory is currently an approved ICR laboratory. (ICRVA002)] The laboratory follows the USEPA's guidance for drinking water laboratories as implemented by the Virginia Department of Health - Division of Consolidated Laboratory Services.

Field Duplicates. The Authority's practice is to perform a field duplicate sample on a minimum of 10% of the samples analyzed in each analysis batch.

Laboratory Fortified Matrix Samples. The Authority's practice is perform a laboratory fortified matrix sample on each matrix in an analysis batch. The fortifying concentration will be such that the sample value plus the fortified concentration value will not exceed the highest calibration standard of the calibration curve.

Independent QC Checks. The Authority's laboratory subscribes to the USEPA's Performance Evaluation Study Program. In addition, it is the Authority's practice to analyze a certified sample with each relevant analysis batch.

Calibration Procedures. The Authority follows the calibration procedures described in the published EPA Methods, and the *Standard Methods Manual for the Examination of Water and Wastewater*. It is also a standard practice that the calibration curve bracket all samples analyzed in an analysis batch. Should a sample fall outside of a calibration curve, the sample would be re-analyzed by either 1) dilution, or 2) a new curve would be established that will encompass the sample.

Calibration Check Standards. The Authority's practice is to analyze a calibration check standard at intervals equal to a minimum of each ten samples analyzed in an analysis batch.

Records Handling. All laboratory records are kept for a minimum of the published required time frame for a specific regulation.

Reporting. All values associated with the treatment study were reported after having meet all QA/QC criteria for the specific method to include calibration curves, duplicate samples, fortified matrix samples, calibration check standards, and certified samples unless otherwise specified at the time of reporting.

Overall Treatment Study Analysis. The Authority maintained the highest possible QA/QC standard practices during the treatment study. The Authority utilized the best practices of the Virginia Department of Health - Division of Consolidated Laboratory Services, the Authority's internal QA/QC program, and the draft *DBP/ICR Analytical Methods Manual*.