Cape Hatteras Pilot Plant Study

of the Shallow Groudwater Aquifer

Dare County, North Carolina

performed by:

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of the
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PREPARED FOR

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MARCH 1997

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CERTIFICATION

I hereby certify that this Cape Hatteras Pilot Plant Study of the Shallow Groundwater Aquifer prepared for Dare County, North Carolina, was prepared by me or under my direct supervision.

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Eric T. Weatherly March 28, 1997

Eric T. Weatherly, P.E. Date
Hobbs, Upchurch & Associates, P.A.

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Section I - Summary

Background

Previous studies determined the need for a new water treatment facility serving communities on Hatteras Island from Avon southward. Initial capacity of the water treatment facility would be 1.8 mgd and expandable to 3.0 mgd. The expansion to 3 mgd is expected around the year 2010.

The "Future Water Supply Study" prepared by Boyle Engineers on September 5, 1995, pointed out the feasibility and advantages of a two process water treatment plant (WTP):

- *Conventional Treatment* of groundwater from the shallow aquifier (50' - 70' depth) presently used.
- *Reverse Osmosis Treatment* of groundwater from a much deeper aquifier (300' - 600' depth).

The WTP will initially be capable of producing 1.2 mgd RO and 0.6 mgd conventional treated water expandable to 1.8 mgd RO and 1.2 mgd conventional treated water. Test wells have been constructed to obtain flow and quality data of the deeper aquifer water. Modifications to the existing well field are also underway to improve its flow and quality.

Focus has been directed to the shallow aquifier water. A pilot plant was operated on-site using the existing well water to test a process for removal of the high concentrations of organic matter, color, iron and manganese. The treatment process consisted of anion exchange followed by pressure filtration. This report presents the findings of the pilot plant study.

Outline of Report

The pilot plant results are presented in two sections. The first section addresses the findings of the anion exchange pilot plant for color/organic removal. The second section addresses pressure filtration for iron and manganese removal. Recommendations and cost estimates are presented in each section.

Final Recommendation of the Pilot Study

It was determined feasible to utilize the shallow groundwater aquifer for blending with the RO treated water from the deeper aquifer. The pilot plant verified the anion exchange process, followed by pressure filtration, can provide properly treated blend water.

Pressure vessels containing media treated with anion exchange resins attract and remove the color/organic materials. Chlorine is added to the anion exchange finished water to oxidize the iron and manganese. The iron and manganese can then be collected on a conventional sand/anthracite pressure filter.

Capital cost of the anion exchange treatment facility was estimated at $264,000. Capital cost of the pressure filter treatment facility was estimated at $174,000. The total estimated cost is $438,000, well within previous budgets of $540,000. The estimated cost of operation and maintenance is less than $0.50 per 1,000 gallons based on the pilot plant results.

Section II - Color/Organics Removal

This section discusses the findings, conclusions, and recommendations of the color/organic removal pilot test conducted at Cape Hatteras Water Association's Buxton water treatment plant from December 2, 1996, through March 17, 1997. The following headings are included in this section.

- Background
- Objectives
- Approach
- Pilot Setup and Equipment
- Test Results and Discussion
- Conclusions
- Recommendations
- Cost Estimate

Background

Cape Hatteras, NC, experiences high concentrations of naturally occurring organic materials in their shallow well waters. The well waters also contain high concentrations of iron and manganese. These materials cause the water to be highly colored.

Current water treatment practice in the Cape Hatteras Water Treatment Plant adopts a combination of conventional clarification, which includes air stripping, coagulation/flocculation, sedimentation, and filtration, and cation exchange softening with chlorine disinfection. Treated water quality, however, barely meets the current total trihalomethane (TTHM) regulation, and the color level often reaches to 15 color units.

Proposed disinfectant/disinfection byproduct (D/DBP) rules will require water utilities to lower organic precursors or other chemical compounds that can produce THMs when combined with disinfectants. The Stage 1 D/DBP rule will limit TTHM concentrations to not more than 80 μg/L and total haloacetic acid (THAA) concentrations to not more than 60 μg/L.

Naturally occurring organic materials, often expressed collectively as total organic carbon (TOC), are major precursor material for THMs when they are chlorinated. Therefore, removal of the precursor materials before they make contact with any oxidant/disinfectant is the most logical approach to complying with the proposed D/DBP rule.

Historical THM formation potential (THMFP) in the Cape Hatteras water source ranges from a low of 1,000 to greater than 3,000 μg/L. The raw water color levels often reach over 200 color units; TOC, ranges up to 20 mg /L. In addition, total iron concentration is around 4 mg/L, contributes color to the water.

The anion exchange (ANIX) process was considered for the removal of the organic materials from the shallow well water. Because of the anionic nature of natural organic materials at natural pH levels (pH 6 to 8), ANIX resins have been used for the removal of the organic materials.

This pilot test was designed to demonstrate the ability of ANIX resin to remove organic materials, and ultimately to replace the conventional treatment process which is incapable of meeting the new regulations.

Objectives

The objective of this pilot test was to develop an optimized organic removal process using ANIX resins. To reach this objective, the following is required:

- Compare different types of ANIX resins for their ability to remove TOC and THMFP.
- Determine the capacity of the ANIX resins in terms of BVs throughput.
- Develop a method of determining the timing of regeneration.
- Determine optimum regeneration levels.

Approach

Anticipated treatment processes at Cape Hatteras will be a combination of reverse osmosis (RO), anion exchange (ANIX), and iron and manganese removal processes. The RO treated water will be blended with the ANIX and iron/manganese treated water. The theory behind this treatment scheme is that the RO process will remove most dissolved constituents in the raw water producing a product rich in sodium chloride. On the other hand, the ANIX will remove only nonvolatile organic materials and anions. Hardness causing cations such as calcium and magnesium will not be removed during the ANIX process. Based upon the current estimation, about 66 percent of raw water will be treated with RO, and the rest of the raw water will be treated with the ANIX and iron/manganese treatment processes. By blending the two process waters, the hardness and alkalinity removed during the RO process will be compensated by the hardness and alkalinity present in the ANIX and iron/manganese treated water. In addition, any remaining organic materials present in the ANIX and iron/manganese treated water will be diluted to produce lower THMs in the finished water. A dilution factor of about three for hardness and THMFP will result from blending the treated waters.

Based upon an assumption that the THMFP of RO treated water is very low, a maximum of 300 µg/L total THM can be tolerated based upon the current TTHM regulation of 100 µg/L and three times dilution. Stage 1 maximum contaminant levels are expected to be effective in June 1998, and will limit TTHM concentrations to not more than 80 µg/L. Stage 2 MCLs are expected in June 2004, and may lower TTHM concentrations to not more than 40 µg/L. Therefore, TTHM concentrations of finished water should be reduced accordingly. To comply with the anticipated lower TTHM concentrations in the finished water, the raw water THMFP should be minimized before chlorination.

Pilot Setup and Equipment

Boyle Engineering Corporation (Boyle) partially assembled the ion exchange test equipment in Bakersfield, California and shipped it to the pilot test site at Buxton, North Carolina. The ion exchange portion of the system was assembled on site, and ion exchange resins were charged to the ion exchange vessels. A pilot plant schematic is shown in FIGURE II-1. As shown in FIGURE II-1, the ANIX system consists of three identical vessels. FIGURE II-2 is a photograph copy of the actual ANIX pilot plant. Brine for the regeneration was prepared from a saturated NaCl solution (about 25 % NaCl) provided by the Cape Hatteras Water Association.

The ion exchange vessels selected for the pilot test are made of stainless steel (304 SS) with PVC internals. All the pipings, valves, and fittings used are schedule 40 PVC pipes and some brass. Major equipment and ion exchange resin information are listed in the following TABLE II-1:

FIGURE II-1
CAPE HATTERAS ANIX PILOT FLOW SCHEMATIC

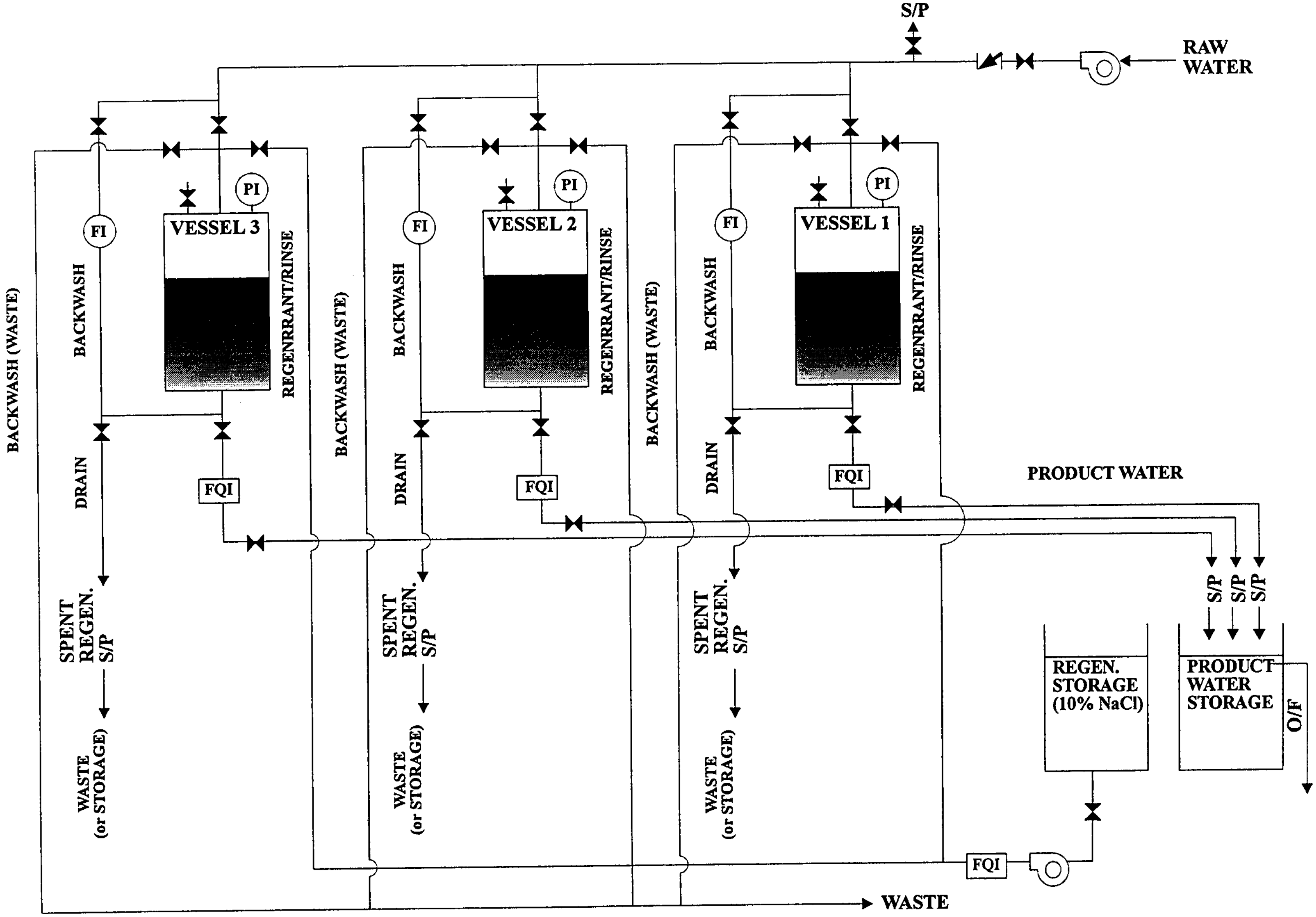


FIGURE II-2
CAPE HATTERAS PILOT TEST
ANIX PILOT PLANT

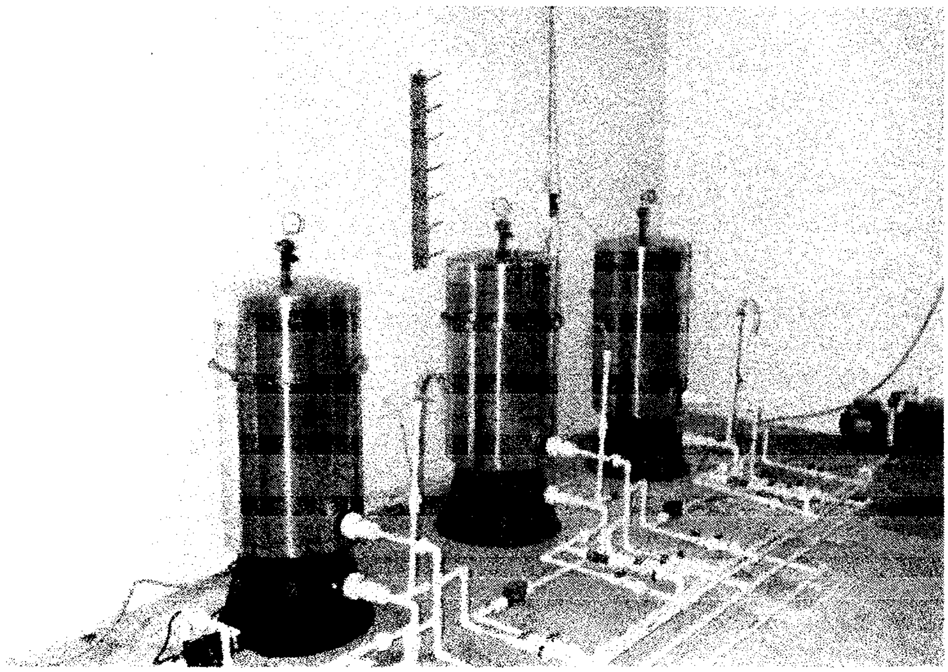


TABLE II-1
CAPE HATTERAS PILOT TEST
MAJOR EQUIPMENT/ION EXCHANGE RESIN INFORMATION

ITEM	MANUFACTURER	DIMENSION/SPECS
Ion Exchange Vessel	American Product SS Tank	18"Ø x 50"H
Raw Water Pump	American Eagle Pump	1 hp (20 gpm @ 35' TDH)
Brine Pump	Cole Parmer	1/25 hp (5 gpm @ 12' TDH)
Electronic Flowmeter/ Accumulator	Cole Parmer	Flow range: 0.3 to 3.0 gpm
Flowmeter	Kobold	Flow range: 2 to 13 gpm
Ion Exchange Resin (strong base anion resin)	ResinTech	SIR-22-HP (acrylic)
	Purolite	Tanex (polystyrenic/acrylic)
	Rohm & Haas	IRA-900-CL (polystyrenic)

The ion exchange portion of the pilot test started producing water from the afternoon of December 4, 1996. Operational parameters of the ion exchange pilot test are listed in TABLE II-2.

The ANIX system was intended to operate in the order of service, backwash, regeneration, and rinse. Backwash, however, was not practiced during the pilot test. Although precipitation of iron compounds on the top of the ANIX vessels was caused by oxidation, no inlet pressure buildup was observed during the pilot test.

TABLE II-2
CAPE HATTERAS PILOT TEST
OPERATIONAL PARAMETERS

PARAMETER	**DESCRIPTION**	**REMARKS**
Quantity of Ion Exchange Resin	3.53 ft^3 (26.4 gal)/vessel	Depth of resin media is 2' @ 18"Ø
Service Flow Rate	2.64 gpm/vessel	EBCT† = 10 minutes
Regenerant	10 % NaCl solution	Prepared from saturated brine(~25%)
Salt Loading Rate	5 lb NaCl/ft^3 resin	Salt loading was not varied.
Regenerant Flow Rate	1 gpm or lower	Soak & pump method
Backwash Rate	4 gpm	Backwash if pressure build up is noticed (~5 psi).

†Empty bed contact time

Test Results and Discussion

A total number of 4 cycles of service/regeneration, including the very short (about 50 bed volumes) preliminary service run, were performed for each vessel during the project period. All three ANIX resins treated a total throughput of over 1,530 accumulated bed volumes (BVs) per vessel. (Bed volume is the volume of ANIX resin contained in a vessel.) In this pilot test, one BV of throughput is equivalent to 26.4 gallons of water.

The salt loading rate of 5 pounds NaCl per cubic foot of resin used during the pilot test is lower than the usual salt loading rate of 8 to 10 pounds per cubic foot, common to other applications. Therefore, as service/regeneration cycle numbers increase, one can expect to experience the following phenomena. Firstly, the high TOC removal efficiencies demonstrated with virgin ANIX resins will probably be reduced as the organic content of the resin increases. Secondly, TOC leakage from regenerated ANIX vessels may also increase, and some color may be detected. Thirdly, service run time may be reduced.

1. VIRGIN RUN

The virgin ANIX resins were initially subjected to a test run. About 50 BVs of throughputs were pumped through each ANIX vessel to check mechanical integrity and to provide a baseline of color and TOC removal. During the test run, three sets of TOC samples were collected, the results of which are presented in TABLE II-3. All three ANIX resins removed color lower than detection limits. Color of influent raw water ranged from about 160 to 230 units.

TABLE II-3
CAPE HATTERAS PILOT TEST
INITIAL TOC DATA & PERCENTAGE REMOVAL

RAW WATER	VESSEL 1 (SIR-22-HP)	VESSEL 2 (Tanex®)	VESSEL 3 (IRA-900-CL)
17.9	0.85 (95.2%)	0.99 (94.5%)	2.22 (87.6 %)
17.9	1.12 (93.7%)	0.99 (94.5%)	1.67 (90.7%)
17.6	1.12 (93.6%)	1.12 (93.6%)	1.88 (89.3%)

1. Measurement unit is mg TOC/L unless otherwise specified.
2. Percent TOC removals are shown in parentheses.

It appeared that Vessel 1 (SIR-22-HP) initially removed the incoming TOC very effectively. As will be shown later, however, the differences in TOC removal efficiencies among the vessels diminished as treated water throughput increased. The relatively high initial TOC leakage observed for the Vessel 3 might have been caused by leaching of some organic materials remaining from the manufacturing processes.

After a brief test run, the ANIX resins were all regenerated by 10 percent brine (10 % NaCl solution). A salt loading of 5 pounds NaCl per cubic foot of resin was used throughout the pilot test.

2. SECOND TO FOURTH RUN

The timing of regeneration of organic-laden ANIX resins was originally planned based on detection of sulfate ions in the effluent from each ANIX vessel. However, no measurable sulfate was present according to the analyses performed using Hach Company's field test equipment. Water quality samples for sulfate were submitted for sulfate quantification, and the results indicated the sulfate content in the raw water was indeed quite low (less than 8 mg sulfate/L).

- Bed Volumes Treated

After a regeneration, the ANIX resin vessels were put back into a service run. In the following TABLE II-4, the service run lengths in BV are presented for each ANIX resin vessel. Note that the timing of stopping the service run for regeneration was determined by the breakthrough of true color (*i.e.*, filtered color) in the treated effluent water.

TABLE II-4
CAPE HATTERAS PILOT TEST
BED VOLUMES TREATED BEFORE REGENERATION

RUN NUMBER	VESSEL 1 (SIR-22-HP)	VESSEL 2 (Tanex®)	VESSEL 3 (IRA-900-CL)
Virgin	53 BV	58 BV	59 BV
2nd	414 BV	416 BV	415 BV
3rd	580 BV	583 BV	583 BV
4th	488 BV	488 BV	489 BV

- Color Breakthrough

Observations and statements made by the pilot operators during the pilot test indicated that color imparted from the oxidation of iron/manganese was significant. The color of ANIX resin treated water intensified as the duration of exposure to the atmosphere increased after waters were sampled. Sometimes the color variations noted by the operators ranged from no color right after the sampling to very dark by the time the samples were subject to the color measurements.

Color was measured in two methods: "true color" and "apparent color." The former is the color of water from which turbidity has been removed. The latter includes not only color due to substances in solution, but also that due to suspended matter.

During the pilot test, the operators used 0.45-μm filter to filter out any suspended material. An operational definition of "dissolved" organic substances in the water includes particles smaller than 0.45 μm in size. Organic substances larger than 0.45 μm in size are, thus, defined as "particulate" organic substances. It is a general assumption that groundwater and interstitial waters would not contain "particulate" organic substances.

The average "true" and "apparent" colors of the raw water were 122 ± 9.6 and 154 ± 20.2 color units, respectively (from 1/14/97 to 1/28/97).

The standard deviation for the "true" colors is much lower than that of "apparent" colors. This larger fluctuation in "apparent" color level is believed to occur due to uncontrolled oxidation of and precipitation of iron when the water was exposed to atmospheric oxygen before the color measurements. Similar fluctuations in "apparent" colors of ANIX resin treated waters were observed throughout the pilot test.

Occasionally, the "apparent" colors of ANIX resin treated water were reduced after membrane filtration for the measurement of "true" color, for instance, 93 to 0 color units. This again confirmed that color breakthroughs encountered were, in many times, caused by colloidal or suspended color bodies which were most likely a result of oxidative precipitation of iron.

An air leak on the raw water feed line was found during the pilot test and later corrected. It is believed that some iron/manganese compounds in the feed water were oxidized and precipitated on the top portion of the ANIX resin vessels. This speculation was proved to be true when the ANIX resin vessels were disassembled and inspected at the conclusion of the pilot test. Backwash of ANIX resin bed before regeneration was not practiced during the pilot test period because no noticeable pressure buildup across the resin bed was noticed.

In the following TABLE II-5, the levels of color intensity measured at termination of each service run are compared. TOC concentrations are also shown in parentheses for reference.

TABLE II-5
CAPE HATTERAS PILOT TEST
COLOR/TOC BREAKTHROUGH BEFORE REGENERATION

RUN NUMBER	VESSEL 1 (SIR-22-HP)	VESSEL 2 (Tanex®)	VESSEL 3 (IRA-900-CL)
Virgin	0 unit (1.12 mg C/L)	0 unit (1.12 mg C/L)	0 unit (1.88 mg C/L)
2nd	6 unit (2.21 mg C/L)	3 unit (2.05 mg C/L)	5 unit (1.90 mg C/L)
3rd	9 unit (2.27 mg C/L)	7 unit (2.41 mg C/L)	9 unit (1.85 mg C/L)
4th	8 unit (4.22 mg C/L)	10 unit (3.46 mg C/L)	13 unit (3.59 mg C/L)

Note: All color measurements were after filtering with 0.45-μm except virgin and 2nd runs.

Generally, the TOC breakthrough pattern followed the "true" color breakthroughs. However, there was an inconsistent relationship between the "true" color levels and TOC concentrations. Timing of filtration for color measurements might have been a factor for the inconsistency. Oxidation of dissolved iron compounds after the filtration might have contributed higher "true" color readings at times.

- <u>TOC Breakthrough</u>

TOC concentrations of raw and treated waters could not be readily estimated by the field test equipment available. All TOC samples were sent to the laboratory for analyses. The TOC data from the second to the fourth runs were compiled and presented in FIGURES II-3 through II-5.

As the service/regeneration cycles increased, TOC leakages were also increased as anticipated for all three resin types (see FIGURES II-3 through II-5). Up to the third run, all three resins performed comparably. On the fourth run, however, the TOC leakages from Vessel 1 (SIR-22P-HP) were noticeably higher than the leakages from the other two Vessels 2 (Tanex) and 3 (IRA-900-CL). This difference in the removal efficiency might have been caused by each resin's structural difference.

FIGURE II-3

TOC BREAKTHROUGH PATTERN OF SIR-22P-HP (VESSEL 1)

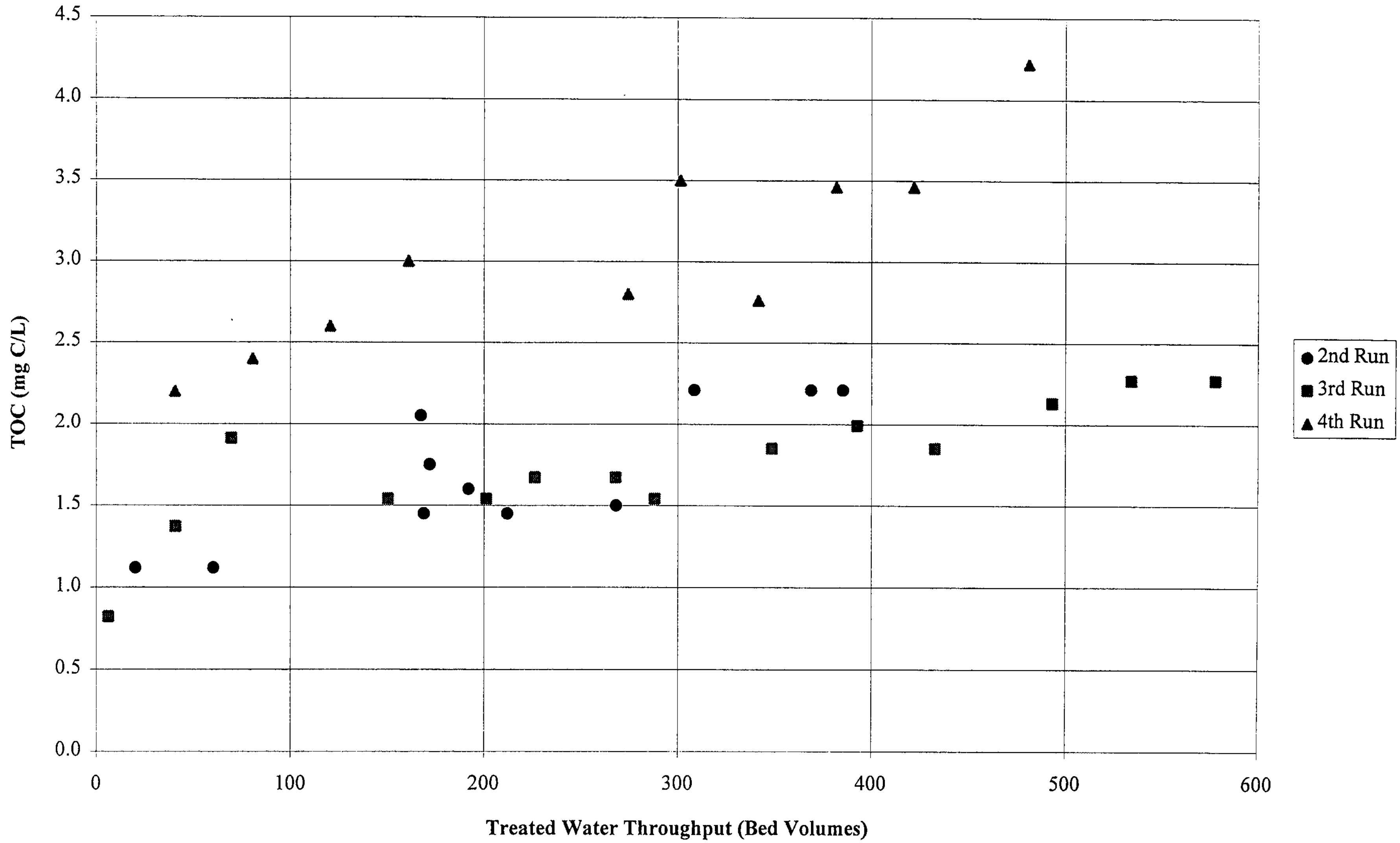


FIGURE II-4
TOC BREAKTHROUGH PATTERN OF TANEX (VESSEL 2)

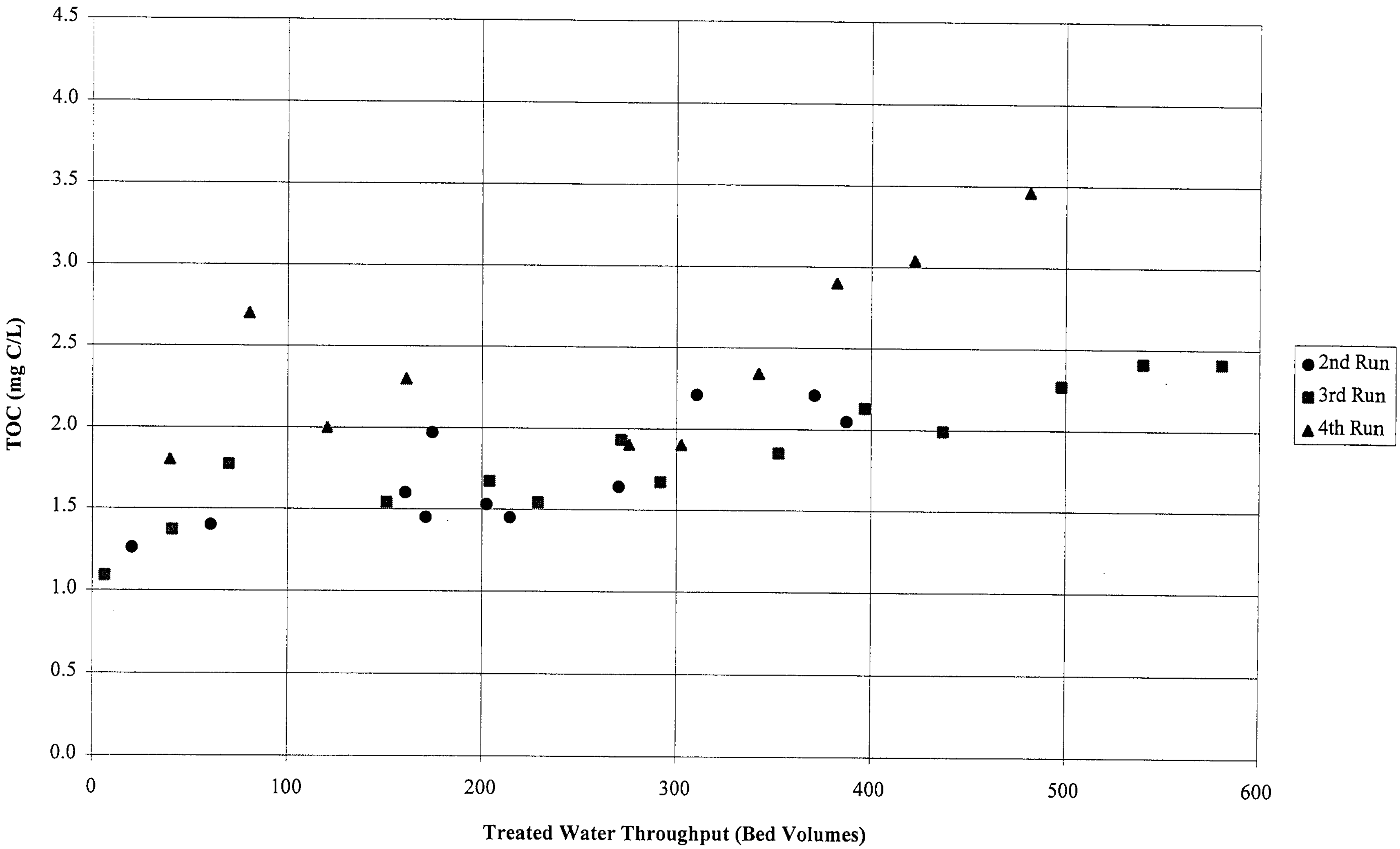
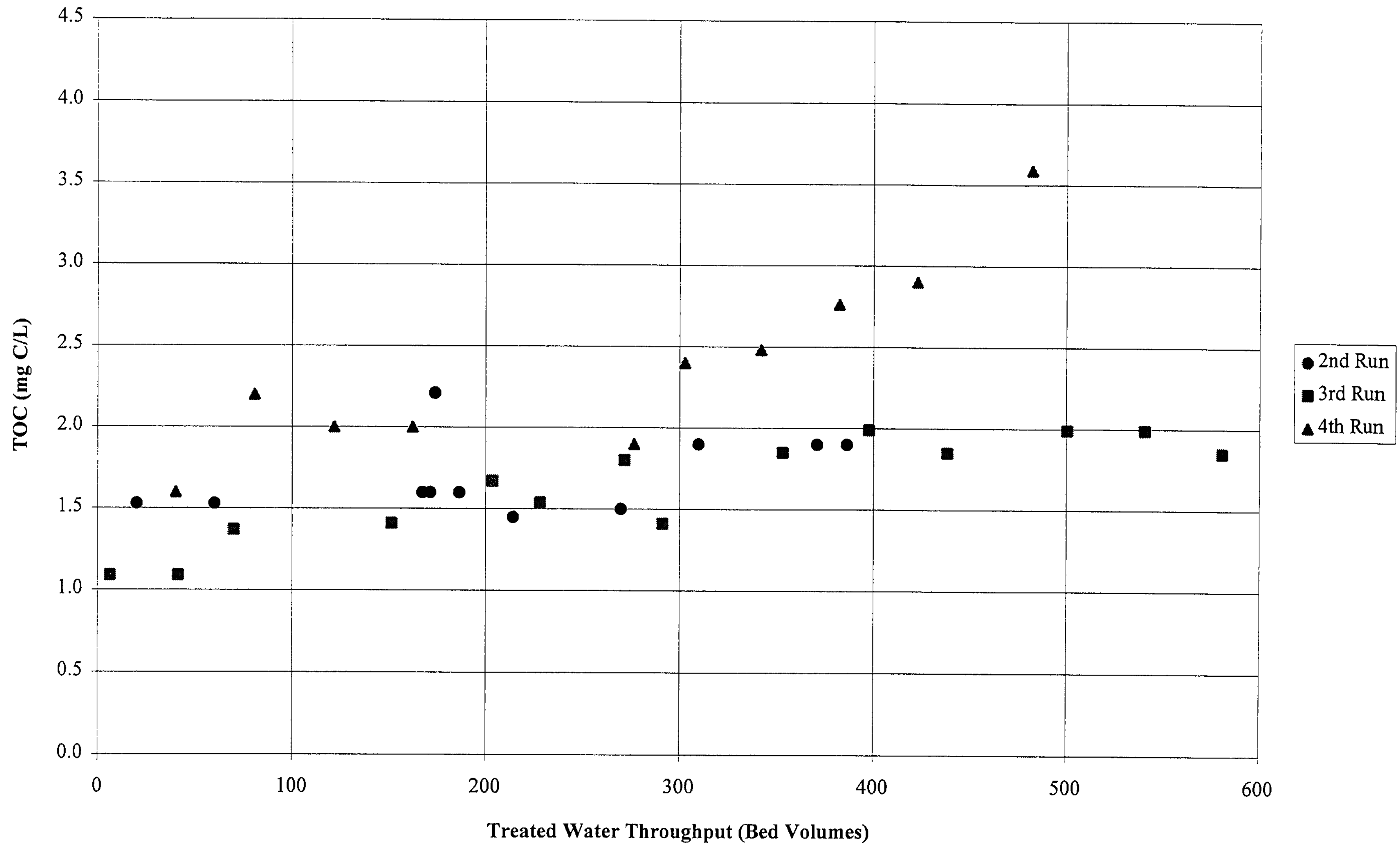


FIGURE II-5

TOC BREAKTHROUGH PATTERN OF IRA-900-CL (VESSEL 3)



As indicated in TABLE II-2, the resin in the Vessel 1 was an acrylic macroporous resin. Acrylic structures are more hydrophilic compared to polystyrenic (Vessel 3) structures, and supposedly exhibit superior regenerability over polystyrenic resins. Polystyrenic resins usually show more affinity for organic materials than acrylic resins. The resin in Vessel 2 was a mixture of resins with acrylic and polystyrenic structures. The mixing ratio of acrylic and polystyrenic resins is not known, however.

- THMFP Removal

As mentioned earlier, the ANIX treated water will be blended with RO treated water in the future. The future blending practice will dilute hardness and THMFP by a factor of three. Therefore, one THMFP test was performed on the treated water after diluting it three times with an organic free water.

In the following TABLE II-6, the THMFP values of treated water at different BV throughput were compared with TOC data. Although not shown, the level of raw water THMFP is about 2,500 μg TTHM/L.

TABLE II-6
CAPE HATTERAS PILOT TEST
THMFP VERSUS TOC OF TREATED WATER

	VESSEL 1 (SIR-22P-HP)		**VESSEL 2 (TANEX)**		**VESSEL 3 (IRA-900-CL)**	
	THMFP (μg/L)	TOC (mg/L)	THMFP (μg/L)	TOC (mg/L)	THMFP (μg/L)	TOC (mg/L)
2nd Run @414 BV	207	2.0	146	2.1	86	1.9
3rd Run @6 BV	51	0.8	80	1.1	69	1.1
3rd Run @310 BV	152	1.5	126	1.7	114	1.4
3rd Run* @560 BV	50	0.6	43	0.6	32	<0.5
4th Run @121 BV	104	2.6	106	2.0	109	2.0

*Diluted 3 times with organic free water.

There appears to be selective removal of organic materials by different types of ANIX resins. In terms of μg THM produced per mg TOC upon chlorination, the water treated by Vessel 3 (IRA-900-CL, polystyrenic matrix) seems to possess lower reactivities with free chlorine than the other two ANIX resins. All three ANIX resins, however, should be able to meet the proposed D/DBP rules when the RO treated water is blended with the ANIX treated water as proposed in the future.

Conclusions

Based on the results and observations made during the pilot test for the removal of color and organic materials using ANIX resins, the following conclusions can be made:

1. All three ANIX resins performed remarkably well in removing color, TOC, and THMFP.

2. ANIX treatment with RO treatment will produce water that contains low enough THMFP to be free chlorinated without violating the proposed D/DBP rule.

3. Differences in removal of THMFP were observed among the three different types of ANIX resins.

4. As the service/regeneration cycles increased, the TOC leakage also increased as anticipated. The salt loading rate of 5 pounds NaCl per cubic foot of resin seemed to be insufficient to drive off the organic materials from the resin during regeneration.

5. Iron removal demonstrated by the ANIX resin system is thought to be caused by filtration of oxidized and precipitated iron. Some iron compounds might have been associated with the organic materials, and possibly removed during the ANIX process through ion exchange. It is inconclusive what extent the iron-organic interaction contributed to removal of iron by the ANIX system.

Recommendations

Based on the conclusions drawn, the following recommendations are made:

1. "True" color or ultraviolet light absorbency should be used to detect color breakthrough for proper regeneration timing. Sulfate concentration in the raw water is too low to be used as an indicator.

2. To prevent iron from precipitating inside the ANIX system, there should be no air break or leak in the raw water transfer line and well pumps.

3. It is recommended to use higher salt loadings than the pilot tested rate (5 lb NaCl/ft^3) for regeneration. Longer service runs and lower TOC leakages will be experienced as the salt loading rate is raised.

4. Disposal of spent regenerant of ANIX process could possibly be a problem because of its high color and TOC level (minimum of 250 times concentrated compared to raw water color). When the RO concentrate is mixed with the ANIX waste, there will be a concentration factor of about five for color and TOC after mixing those two waste streams. Therefore, it is recommended to open discussion with regulatory agencies for a modification of current discharge permit regarding elevated color and TOC in the waste stream.

Cost Estimate

At the Cape Hatteras water treatment plant, a total of 10 pressure vessels are available. Among those, six vessels (10' Dia. x 6' straight height) have been used for multi-media filters, and four vessels (7' Dia. x 7' straight height) for ion exchange softening. As presented in TABLE II-2, the ANIX system for the organic removal requires an EBCT of about 10 minutes. The EBCT of the current ion exchange softening system is about four minutes. This difference should be noted because much slower kinetics is involved in ion exchange process between the organic materials and the ANIX resins. The organic materials possess much larger molecules compared to hardness' causing cations.

The 4-vessel ion exchange softening system can be used to treat up to 0.6 MGD (according to pilot tested EBCT) with little modification, except the replacement of cation exchange resin with ANIX resin. During the pilot test, shorter EBCTs were not tested for the effect of TOC/color removal efficiencies. Shorter than 10-min EBCT may also be acceptable.

Based upon the current design parameters, to treat the ultimate water flow of 1.2 MGD, either additional ion exchange vessels can be added or the 10' diameter filter vessels can be modified and used. Major modifications may be required, however, to accommodate the ANIX resins; for example, flow distribution/collection replacement, sand blasting and recoating the internals, brine line installation and repiping, and possibly ASME Code receritifications.

In the following TABLE II-7, a cost estimate for probable renovations required to convert existing softening system to the ANIX system is presented.

TABLE II-7
CAPE HATTERAS PILOT TEST
CAPITAL COST ESTIMATE FOR 0.6 MGD ANIX PROCESS

ITEMS	**DESCRIPTION**	**CAPITAL COST**
ANIX Resin Purchase	600 ft^3 @ \$200/ft^3 resin	\$120,000
IX Vessel Modification (motorized valves, etc.)	4 - 7' Dia. x 7' H	\$50,000
Instrumentation & Control	- - - -	\$30,000
Electrical (wiring/conduit for pumps & control valves)	- - - -	\$20,000
Contingency (@ 20 %)	- - - -	\$44,000
TOTAL CAPITAL COST		**\$264,000**

Annual O & M cost estimate is also presented in TABLE II-8.

TABLE II-8
CAPE HATTERAS PILOT TEST
ANNUAL O & M COST ESTIMATE
FOR 0.6 MGD ANIX PROCESS

ITEMS	**DESCRIPTION**	**O & M COST**
Salt (@ \$60/ton)	300 Ton/Yr	\$18,000
Power (@ \$0.09/Kwh)	20 psi loss	\$6,000
Labor (2 hr/day @ \$35/hr)	730 hrs/Yr	\$25,600
Maintenance (@ 2% capital)	- - - -	\$5,000
ANIX Resin Replacement (@ 10%/Yr)	- - - -	\$12,000
TOTAL YEARLY O & M COST		**\$66,600**

Section III - Fe/Mn Removal

This section discusses the findings, conclusions, and recommendations of the iron/manganese (Fe/Mn) removal pilot test conducted at the Cape Hatteras Water Association WTP from December 2, 1996, through January 10, 1997. The following headings are included in this section.

- Background
- Objectives
- Approach
- Pilot Setup and Equipment
- Test Results and Discussion
- Conclusions
- Recommendations
- Cost Estimate

Background

The Background section of Boyle Engineering Corporation's (Boyle) pilot study provided information on the existing treatment system, and organic matter and TTHM information. Boyle's pilot study focused on removal of color/organic matter from the water.

Nearly all Fe/Mn removal methods rely on oxidation followed by clarification and/or filtration. Typical oxidizing agents consist of aeration followed by a stronger oxidizing agent such as chlorine, chlorine dioxide, potassium permanganate and ozone. Oxidation of iron is then followed by filtration using either sand/anthracite or dual media sand/anthracite. Conventional sand or manganese greensand can be used. Greensand media incorporates a charged coating to the sand for enhanced iron and particularly manganese removal.

The purpose of the Hobbs, Upchurch & Associates (HUA) pilot study was to investigate removal of Fe/Mn from the water. The average raw water quality of iron was 3.16 mg/l, and manganese was 0.229 mg/l. The maximum allowable limits are 0.3 mg/l and 0.05 mg/l, respectively. The addition of an oxidizing agent followed by pressure filtration was considered for removal of the iron and manganese from the shallow groundwater.

Objectives

The objective of this pilot test was to develop and optimize Fe/Mn removal processes using oxidation and pressure filtration. To reach these objections, the following is required:

- Determine treatability of Fe/Mn using pH adjustment.
- Analyze the preoxidants: Potassium permanganate, chlorine and chlorine dioxide.
- Analyze treatment with greensand filter media versus conventional filter media.
- Determine operational parameters including chemical feed rate, filter flow rate and filter run length.
- Collect specialty data including: chlorate, chlorite, TTHM and haloacetic acids.

Approach

The Approach section of Boyle's pilot study presented an outline on the total treatment process consisting of RO water blended with ANIX and Fe/Mn treated water. It was further decided the ANIX treatment process would be followed by the Fe/Mn treatment process. In this setup, raw water will be pumped through the treatment process by the well pumps, first through ANIX, then Fe/Mn, blended with RO water and finally to the clearwell.

The theory behind ANIX followed by Fe/Mn removal is to reduce THM formation potentials which would be higher for chlorination prior to removal of the TTHM precursors of the organic-laden raw water.

Pilot Setup and Equipment

A pressure filter pilot plant was set up at the WTP in Buxton, North Carolina. A pilot plant schematic is shown in FIGURE III-1. A scanned photograph of the actual pilot plant is shown in Figure III-2. Water treated by the ANIX process was used as inlet water for the pressure filter. Feed water rate was adjusted using the rate of flow indicator. The pilot plant has the capability of three chemical feel injections. The valving arrangement allows changing from the normal operation cycle to the backwash cycle. Pressure gauges allow monitoring headloss across the filter. The pilot plant specifications are presented in TABLE III-1. Operational parameters of the pressure filter are presented in TABLE III-2.

FIGURE III-1
CAPE HATTERAS PRESSURE FILTER PILOT FLOW SCHEMATIC

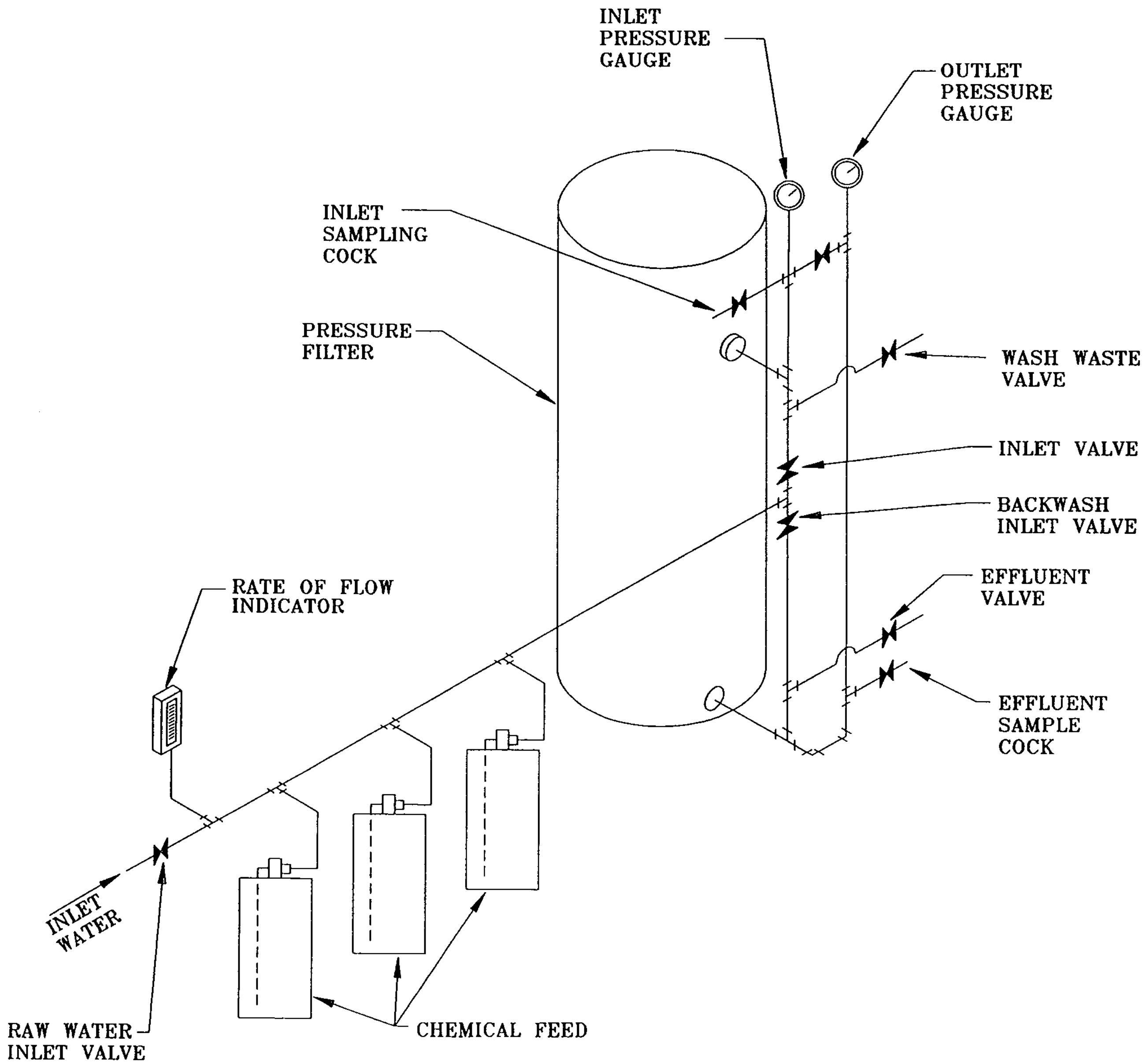


FIGURE III-2
CAPE HATTERAS PILOT TEST
PRESSURE FILTER PILOT PLANT

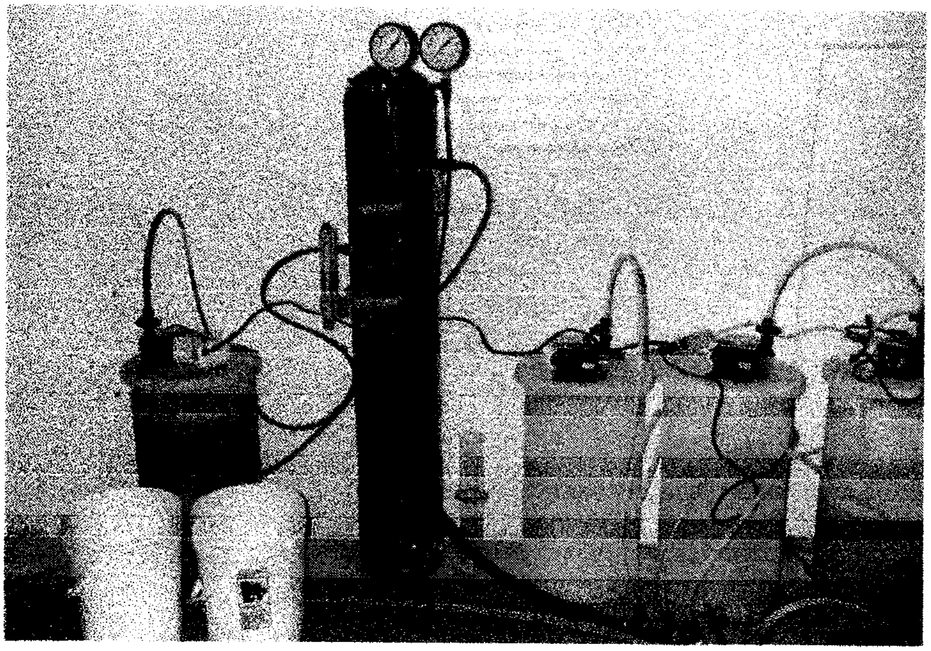


TABLE III-1
CAPE HATTERAS PILOT PLANT
PRESSURE FILTER PILOT PLANT SPECIFICATIONS

ITEM	SPECIFICATION
Pressure Filter	9 1/2" Diameter (1/2 square foot bed area) - 6' Height
Media	
Manganese Greensand	Effective Size 0.30 to 0.35 Millimeters
Conventional Filter Sand	Effective Size 0.45 to 0.55 Millimeters
Anthracite	
Chemicals	Chlorine (Sodium Hypochlorite)
	Chlorine Dioxide (Sodium Hypochlorite, Chlorite, Muriatic Acid)
	Potassium Permanganate
	Caustic
	Soda Ash
	Lime

TABLE III-2
CAPE HATTERAS PILOT PLANT
OPERATIONAL PARAMETERS

FEED WATER	DESCRIPTION
Feed Rate	2 to 6.5 gpm per square foot
	20 to 70 psi
Feed Water	
Maximum Pressure Drop	8 to 10 psi
Backwash Rate	12 gpm per square foot minimum
Backwash Time	10 minutes per each
Chemical Feed Rate	
Potassium Permanganate	Faint orange to pink color in feed water
Chlorine/Chlorine Dioxide	Maintain 0.5 mg/l chlorine

Test Results and Discussion

A series of pilot plant tests were performed to achieve the objectives of the pilot plant. Initial tests analyzed pH adjustment. Tests were then performed to analyze various preoxidants and filter medias. Finally, filter run rates and run lengths were determined for the selected alternatives.

1. GENERAL

During each test, water chemical data was collected from the raw water, water after ANIX and prior to Fe/Mn treatment (resin water) and final product water treated by ANIX and Fe/Mn treatment (finished water). TABLE III-3 contains an outline of the pilot plant test performed. APPENDIX III-A of this study contains water chemical data collected for each test.

TABLE III-3

CAPE HATTERAS PILOT PLANT

OUTLINE OF Fe/Mn PILOT TESTS

No. 1	Greensand Media Flow Rate @ 3 gpm/sf KmNO4 @ 1.0 ppm Continuous Regeneration Feed Cl2 @ 1.5 ppm as Preoxidant Soda Ash @ 3 ppm for pH Adjustment 8 Hour Test Period
No. 2	Greensand Media Flow Rate @ 4 gpm/sf KmNO4 @ 1 ppm Continuous Regeneration Feed Cl2 @ 2 ppm as Preoxidant Lime (7 lbs/15 gal) @ 2.65 ppm for pH Adjustment 8 Hour Test Period
No. 3	Greensand Media Flow Rate @ 4 gpm/sf KmNO4 @ 2 ppm Continuous Regeneration Feed Cl2 @ 1.5 ppm as Preoxidant NaOH(25%) @ 1 ppm for pH Adjustment 8 Hour Test Period
No. 4	Greensand Media Flow Rate @ 4 gpm/sf KmNO4 @ 1.5 ppm Continuous Regeneration Feed Cl2 @ 2 ppm as Preoxidant Soda Ash @ 3 ppm for pH Adjustment 1.25 hr. Test Period
No. 5	Greensand Media Flow Rate @ 6 gpm/sf Cl2 @ 2 ppm as Preoxidant 10 hr. Test Period
No. 6	Greensand Media Flow Rate @ 6 gpm/sf ClO2 @ 1 ppm as Preoxidant 9.75 hr. Test Period
No. 7	Greensand Media Flow Rate @ 8 gpm/sf ClO2 @ 0.8-0.5 ppm as Preoxidant 8.75 hr. Test Period
No. 8	Greensand Media Flow Rate @ 8 gpm/sf ClO2 @ 0.5 ppm as Preoxidant 9.75 hr. Test Period
No. 9	Greensand Media Flow Rate @ 6 gpm/sf ClO2 @ 1 ppm as Preoxidant 2.75 hr. Test Period Raw Water Treated for This Test
No. 10	Greensand MediaFlow Rate @ 6 gpm/sf Cl2 @ 6.5 ppm as Preoxidant Test Run to Breakthrough
No. 11	Greensand Media Flow Rate @ 6.5 gpm/sf ClO2 @ 0.5 ppm as Preoxidant 6.25 hr Test Period
No. 12	Conventional Filter Sand Flow Rate @ 6.5 gpm/sf Cl2 @ 3.5 ppm as Preoxidant Test Period to Breakthrough
No. 13	Conventional Filter Sand Flow Rate @ 6.5 gpm/sf ClO2 @ 0.5 ppm as Preoxidant 5 hr Test Period

During each test, raw water data prior to ANIX treatment was collected. Values for raw water data are shown for each test in APPENDIX III-A. TABLE III-4 contains the average, maximum and minimum values for the raw water.

TABLE III-4
CAPE HATTERAS PILOT PLANT
RAW WATER DATA FOR EACH Fe/Mn TEST

	AVERAGE	MAXIMUM	MINIMUM
pH	7.18	7.21	7.0
Ca Hard	235	289	180
T-Alk	215	238	188
Temp C	13.9	16.3	10.9
TDS	.443	.461	.420
Cond	.879	.887	.850
Fe	3.16	4.31	1.87
Mn	.229	.291	.189
Color	196	225	169
Chloride	92	96	90
Turbidity	5.82	7.2	.46
TOC	18	-	-

During each test, data was collected for water after ANIX treatment and prior to Fe/Mn treatment. Values for this data from each test are seen in APPENDIX III-A. TABLE III-5 contains the average, maximum and minimum values for the ANIX treated water.

TABLE III-5
CAPE HATTERAS PILOT PLANT
ANIX TREATED WATER FROM EACH Fe/Mn TEST

	AVERAGE	MAXIMUM	MINIMUM
pH	6.76	7.3	6.32
Ca Hard	285	289	273
T-Alk	211	238	205
Temp C	13.0	17.1	10.4
TDS	.456	.482	.410
Cond	.886	.963	.790
Fe	2.58	3.63	.70
Mn	.198	.291	.180
Color	14/6	19/5	9/0
Chloride	.012	.012	.012
Turbidity	.89	1.30	<.01
TOC	1.46	-	-

2. SUMMARY OF TESTS

Tests 1 through 4 utilized pH adjustment prior to filtration. Greensand media with potassium permanganate as a regenerate and chlorine as a preoxidant were used for the test. Flow rates were in the 3 to 4 gpm per square foot range. All iron and manganese were removed.

Tests 5 through 8 utilized chlorine and chlorine dioxide as preoxidants and greensand media with potassium permanganate but with no pH adjustment. Test 5 utilized chlorine with a filter flow rate of 6 gpm per square foot. Test 6 utilized chlorine dioxide with a filter flow rate of 6 gpm per square foot. Tests 7 and 8 utilized chlorine dioxide with an increased filter flow rate of 8 gpm per square foot. Each test with varying preoxidants and flow rates performed adequately with all iron and manganese removed. Adjustment to the pH did not effect treatability of the iron and manganese, although adding pH adjusting chemicals did appear to decrease the filter run times. Test 9 offered no new data.

Tests 10 through 13 more closely analyzed filter run time and treatability effects of greensand versus conventional filter media.

Conventional filter media performed as well as greensand media. It was determined the filter run time was approximately 13 hours for a 9 psi filter head buildup for both medias. No other significant differences in treatability were seen for chlorine versus chlorine dioxide. Each test removed all iron and manganese.

3. MEDIA

It was determined that the conventional filter sand utilizing chlorine or chlorine dioxide as preoxidants removed iron and manganese as well as greensand media with potassium permanganate feed. Although greensand media does offer stronger treatment abilities, costs are greater for media and chemicals.

4. CHLORATES/CHLORITES

Collection of chlorate/chlorite data was used in the analysis of chlorine versus chlorine dioxide for a preoxidant. Additional monitoring is required by the State for chlorate/chlorite when chlorine dioxide is used as a disinfectant. Stage 1 maximum contaminant levels expected to be effective June 1998 will limit combined concentrations for chlorates/chlorites/chlorine dioxide to not more than 1,000 μg/L.

Four chlorate/chlorite samples were taken: Two samples using chlorine and two samples using chlorine dioxide. TABLE III-6 contains the results of these samples.

TABLE III-6
CAPE HATTERAS PILOT STUDY
CHLORATE/CHLORITE SAMPLE RESULTS

SAMPLE DESCRIPTION	RESULT (μg/L)	
Chlorine		
Chlorate	566	949
Chlorite	769	985
Chlorine Dioxide		
Chlorate	2,210	2,030
Chlorite	1,290	1,250

Utilization of chlorine dioxide exceeded the MCL for chlorates/chlorites. There are no chlorate/chlorite limits when using chlorine; however these values where high also. High chlorate/chlorite levels while using chlorine can be attributed to the chlorine product make-up used for the pilot study in the form of sodium hypochlorite. Utilization of chlorine gas in theory should lower chlorate/chlorite levels.

5. THM - FP

TTHM data were collected for the Fm/Mn treatment product water. THM formation potential for filtered water was 86.4 μg/L. As discussed in Boyle's pilot study, this number can be divided by three due to blending with RO treated water. Stage 3 maximum contaminant levels for TTHM can be met.

6. HALOACETIC ACID

Haloacetic acid was checked in the finished water due to its inclusion in the proposed D/DBP rules. Proposed Stage 1 MCL's are 60 μg/L and Stage 2 MCL's are 30 μg/L. Four samples were taken with results of 1.0, 2.1, 3.4 and 4.4 μg/L, all within the proposed limits.

Conclusions

Based on the results and observations made during the pilot test for the removal of iron and manganese using pressure filtration, the following conclusions can be made:

1. All tests performed utilizing pressure filtration satisfactorily removed iron and manganese from the water.

2. Adding lime, soda ash or caustic for pH adjustment prior to filtration had no effect on iron and manganese treatability, although adding the pH adjusting chemicals did appear to shorten the filter run time.

3. No significant differences in treatability of iron and manganese were seen utilizing greensand versus conventional sand media or chlorine dioxide versus chlorine as preoxidants.

4. Filter flow rates were varied between 4 gpm per square foot to 8 gpm per square foot with no changes to iron and manganese treatability. Filter run times determined during pilot testing were based on manufacturer's recommended maximum allowable flow rate of 6 1/2 gpm per square foot.

5. Optimum feed rates for preoxidant chemicals used were determined to be as follows:

   Chlorine = 3.5 ppm
   Chlorine Dioxide = 1.5 ppm
   Potassium Permanganate = 1.5 to 2 ppm

6. Based on a 6 1/2 gpm per square foot filter flow rate and a 10 psi pressure head buildup across the filter, the filter run time is approximately 13 hours.

Recommendations

Based on the conclusions drawn, the following recommendations were made:

1. Pressure filtration may be utilized to remove iron and manganese from the water.

2. Filter media may consist of sand/anthracite multimedia in lieu of the slightly more costly manganese greensand with potassium permanganate feed.

3. Chlorine gas should be used as a preoxidant instead of chlorine dioxide due to proposed MCL's on chlorite and chlorate.

4. Actual flow rates for the filters may be as high as 6.5 gpm per square foot. It is recommended that flow rate for filter design be based on a maximum of 4 gpm per square foot.

Cost Estimate

As discussed in the Cost Estimate section of Boyle's pilot study, the existing Cape Hatteras WTP has 6 - 10' diameter pressure filters. It is assumed at this time the vessels can be utilized for the proposed blend water project.

Based on 10' diameter, two existing pressure filters will be required to produce the required 600,000 gallons per day initial blend water capacity. TABLE III-7 is a cost estimate for plant upgrades including tank overhaul, media replacement, automatic control filtration/backwash, and new pipe gallery to accommodate four pressure filters and four ANIX vessels.

TABLE III-7
CAPE HATTERAS PILOT TEST
CAPITAL COST ESTIMATE FOR 0.6 MGD Fe/Mn TREATMENT PROCESS

DESCRIPTION	COST
Refurbish 2 - 10' Diameter Pressure Filters (Media, Etc.)	$30,000
Two 6" Automatic Multi-Port Valves	$25,000
New ANIX and Fe/Mn Treatment Layout and Piping Gallery (Expandable to 4 Pressure Filters)	$40,000
Instrumentation and Controls	$30,000
Electrical	$20,000
Total	$145,000
Contingencies (@ 20%)	$29,000
TOTAL CAPITAL COST	$174,000

The annual O&M cost estimate is presented in Table III-8.

TABLE III-8
CAPE HATTERAS PILOT TEST
O&M COST ESTIMATE

ITEMS	**DESCRIPTION**	**O & M COST**
Chlorine (@ $0.50/lb)	6,600 Lbs/Yr	$3,300
Power (@ $0.09/Kwh)	10 psi loss	$3,000
Labor (2 hr/day @ $35/hr)	730 hrs/Yr	$25,600
Maintenance (@ 2% capital)	----	$3,500
Media Replacement (@ 10%/Yr)	----	$2,000
TOTAL YEARLY O & M COST		**$37,400**

APPENDIX III-A

Fe/Mn Removal Chemical Data

TEST 1
Date: December 4

TEST PROCEDURE

Chemicals (Prefilter):	KMn04 @ 1 PPM
	Cl2 @ 1.5 PPM
	Soda Ash @ 3 PPM
Flow:	3 GPM/SF
Head Loss Across Filter:	5 PSI in 8 Hours

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2			280	220	10.9	0.438	0.886		2.96	0.189		210		0.46

Test	Sample Point	10:00	11:00	12:30	2:00	4:05	6:00
pH	Resin Water	6.8	6.8	7.1	7.2	7.0	7.0
	Finished Water	7.7	7.6	7.7	7.7	7.7	7.7
Cl_2 FAC	Resin Water						
	Finished Water	0.2	0.23	0.41	0.41	0.39	0.38
Cl_2 T	Resin Water						
	Finished Water	0.33	0.31	0.43	0.42	0.41	0.41
Ca Hard	Resin Water	280	280	280	280	280	277
	Finished Water	266	263	266	266	266	267
T-Alk	Resin Water	210	205	210	215	216	215
	Finished Water	280	260	280	227	227	223
Temp C	Resin Water	10.4	10.8	11.1	11.2	11.2	11.9
	Finished Water	10.6	10.8	11.2	11.2	11.2	11.9
TDS	Resin Water	0.481	0.466	0.480	0.472	0.471	0.471
	Finished Water	0.451	0.450	0.450	0.453	0.453	0.454
Cond	Resin Water	0.963	0.902	0.901	0.910	0.911	0.909
	Finished Water	0.895	0.893	0.891	0.891	0.893	0.891
ClO_2	Resin Water						
	Finished Water						
Fe	Resin Water	2.76	2.83	2.81	2.83	2.81	2.81
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.173	0.180	0.188	0.183	0.181	0.180
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0.012	0.012	0.012	0.012	0.012	0.012
	Finished Water	0.012	0.012	0.012	0.012	0.012	0.012
Turbidity	Resin Water	<.01	<.01	<.01	<.01	<.01	
	Finished Water	<.01	<.01	<.01	<.01	<.01	

TEST 2

Date: December 5

TEST PROCEDURE

Chemicals (Prefilter):	KMn04 @ 1 PPM
	Cl2 @ 2 PPM
	Lime (7 lbs./15 gal.) @ 2.65 PPM
Flow:	4 GPM/SF
Head Loss Across Filter:	5 PSI in 8 Hours

RAW WATER DATA

pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.4			288	220	11.9	0.438	0.88		2.96	0.203		206		

Test	Sample Point	7:30	9:30	11:30	1:35	3:15	5:30
pH	Resin Water	7.0	7.1	7.0	7.0	7.3	7.3
	Finished Water	7.5	7.5	7.5	7.6	7.6	7.5
Cl_2 FAC	Resin Water						
	Finished Water	0.6	0.6	0.5	0.51	0.53	0.52
Cl_2 T	Resin Water						
	Finished Water	0.61	0.62	0.58	0.58	0.59	0.58
Ca Hard	Resin Water	287	288	288	287	287	288
	Finished Water	270	270	281	282	283	283
T-Alk	Resin Water	210	209	210	210	216	211
	Finished Water	280	280	270	267	277	277
Temp C	Resin Water	11.7	11.9	11.9	11.9	11.9	12.0
	Finished Water	11.7	11.9	11.9	11.9	12.0	12.0
TDS	Resin Water	0.480	0.477	0.478	0.477	0.439	0.440
	Finished Water	0.431	0.441	0.441	0.450	0.450	0.451
Cond	Resin Water	0.901	0.897	0.897	0.893	0.883	0.884
	Finished Water	0.887	0.883	0.881	0.880	0.879	0.880
ClO_2	Resin Water						
	Finished Water						
Fe	Resin Water	2.79	0.279	2.77	2.76	2.76	2.76
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.191	0.192	0.193	0.193	0.193	0.189
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Turbidity	Resin Water						
	Finished Water						

TEST 3

Date: December 6

TEST PROCEDURE

Chemicals (Prefilter):	KMn04 @ 2 PPM
	Cl2 @ 1.5 PPM
	NaOH (25%) @ 1 PPM
Flow:	4 GPM/SF
Head Loss Across Filter:	3 PSI in 8 Hours

RAW WATER DATA

pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.4			289	221	12.0	0.443	0.881		2.97	0.196		199		

Test	Sample Point	8:00	10:05	12:10	2:15	4:15	5:40
pH	Resin Water	7.3	7.3	7.3	7.3	7.3	7.2
	Finished Water	7.5	7.5	7.5	7.5	7.7	7.7
Cl_2 FAC	Resin Water						
	Finished Water	0.5	0.51	0.46	0.47	0.51	0.31
Cl_2 T	Resin Water						
	Finished Water	0.55	0.55	0.53	0.54	0.56	0.34
Ca Hard	Resin Water	288	288	287	288	287	288
	Finished Water	283	281	284	284	289	285
T-Alk	Resin Water	211	210	211	212	211	211
	Finished Water	277	296	277	280	277	270
Temp C	Resin Water	11.9	12.0	12.1	12.1	12.1	12.2
	Finished Water	11.8	12.1	12.1	12.1	12.2	12.2
TDS	Resin Water	0.440	0.440	0.441	0.442	0.449	0.444
	Finished Water	0.451	0.449	0.450	0.451	0.456	0.457
Cond	Resin Water	0.889	0.887	0.883	0.883	0.889	0.883
	Finished Water	0.887	0.887	0.881	0.882	0.882	0.884
ClO_2	Resin Water						
	Finished Water						
Fe	Resin Water	2.88	2.78	2.79	2.78	2.78	2.75
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.183	0.184	0.183	0.183	0.182	0.187
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Turbidity	Resin Water						
	Finished Water						

TEST 4

Date: December 7

TEST PROCEDURE

Short Filter Test Run	
Chemicals (Prefilter):	KMn04 @ 1.5 PPM
	Cl2 @ 2 PPM
	Soda Ash @ 3 PPM
Flow:	4 GPM/SF
Head Loss across Filter:	2 PSI in 1.25 Hours

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2			289	221	11.8	0.444	0.884		2.95	0.205		190		

Test	Sample Point	7:45	9:00				
pH	Resin Water	7.1	7.1				
	Finished Water	7.7	7.7				
Cl_2 FAC	Resin Water						
	Finished Water	0.59	0.58				
Cl_2 T	Resin Water						
	Finished Water	0.62	0.63				
Ca Hard	Resin Water	288	288				
	Finished Water	283	283				
T-Alk	Resin Water	211	212				
	Finished Water	271	272				
Temp C	Resin Water	11.8	11.9				
	Finished Water	11.8	11.9				
TDS	Resin Water	0.441	0.441				
	Finished Water	0.457	0.449				
Cond	Resin Water	0.881	0.881				
	Finished Water	0.884	0.884				
ClO_2	Resin Water						
	Finished Water						
Fe	Resin Water	2.91	2.73				
	Finished Water	0	0				
Mn	Resin Water	0.181	0.180				
	Finished Water	0	0				
Sulfate	Resin Water	0	0				
	Finished Water	0	0				
Color	Resin Water	0	0				
	Finished Water	0	0				
Chloride	Resin Water	0	0				
	Finished Water	0	0				
Turbidity	Resin Water						
	Finished Water						

TEST 5

Date: December 9

TEST PROCEDURE

Chemical (Prefilter):	Cl2 @ 2.0 PPM
Flow:	6 GPM/SF
Head Loss Across Filter:	2 PSI in 10 Hours

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.1			287	228	11.6	0.447	0.887		2.80	0.200		169		

Test	Sample Point	7:20	9:30	11:35	1:40	3:50	5:10
pH	Resin Water	7.1	7.1	6.8	6.8	6.8	6.8
	Finished Water	7.0	7.0	6.9	7.5	7.5	7.6
Cl_2 FAC	Resin Water						
	Finished Water	0.41	0.42	0.43	0.42	0.45	0.42
Cl_2 T	Resin Water						
	Finished Water	0.43	0.43	0.45	0.45	0.47	0.45
Ca Hard	Resin Water	288	288	288	289	291	289
	Finished Water	286	286	287	287	288	288
T-Alk	Resin Water	221	220	221	221	233	234
	Finished Water	231	231	230	240	230	231
Temp C	Resin Water	11.5	11.6	11.6	11.7	11.7	11.8
	Finished Water	11.5	11.6	11.6	11.7	11.8	11.8
TDS	Resin Water	0.477	0.471	0.470	0.429	0.477	0.479
	Finished Water	0.436	0.437	0.439	0.438	0.440	0.440
Cond	Resin Water	0.893	0.896	0.895	0.895	0.895	0.889
	Finished Water	0.881	0.880	0.882	0.888	0.887	0.887
ClO_2	Resin Water						
	Finished Water						
Fe	Resin Water	2.68	2.74	2.74	2.74	2.75	2.77
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.193	0.191	0.181	0.190	0.181	0.186
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Turbidity	Resin Water						
	Finished Water						

TEST 6

Date: December 10

TEST PROCEDURE

Chemicals (Prefilter):	ClO2 @ 1.0 PPM
Flow:	6 GPM/SF
Head Loss Across Filter:	0.5 PSI in 9.75 Hours

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2			288	222	12.1	0.436	0.883		2.91	0.198		172		

Test	Sample Point	7:45	9:35	11:30	1:30	3:30	5:30
pH	Resin Water	6.8	6.8	6.8	6.8	6.8	6.8
	Finished Water	6.9	6.9	6.9	7.0	7.5	7.5
Cl_2 FAC	Resin Water						
	Finished Water	0.2	0.21	0.2	0.22	0.23	0.24
Cl_2 T	Resin Water		0.21				
	Finished Water	0.2	0.21	0.21	0.23	0.24	0.25
Ca Hard	Resin Water	287	287	287	288	288	289
	Finished Water	287	287	286	286	286	286
T-Alk	Resin Water	210	222	213	217	214	217
	Finished Water	210	222	210	212	217	231
Temp C	Resin Water	11.7	12.1	12.1	12.2	12.3	12.4
	Finished Water	11.8	12.1	12.1	12.3	12.4	12.4
TDS	Resin Water	0.480	0.482	0.482	0.480	0.481	0.480
	Finished Water	0.431	0.439	0.441	0.441	0.440	0.440
Cond	Resin Water	0.901	0.900	0.901	0.902	0.910	0.911
	Finished Water	0.887	0.886	0.880	0.881	0.883	0.884
ClO_2	Resin Water	0	0	0	0	0	0
	Finished Water	0.11	0.09	0.11	0.10	0.10	0.07
Fe	Resin Water	2.88	2.78	2.91	2.81	2.68	2.71
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.192	0.187	0.186	0.189	0.187	0.191
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Turbidity	Resin Water						
	Finished Water						

TEST 7

Date: December 11

TEST PROCEDURE

Chemicals (Prefilter):	ClO2 @ 0.8 - 0.5 PPM
Flow:	8 GPM/SF
Head Loss Across Filter:	Negligible in 8.75 Hours

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.0			277	238	16.3	0.461	0.876		1.96	0.193	3	188		

Test	Sample Point	7:30	9:30	11:00	1:30	3:20	4:15
pH	Resin Water	6.8	6.8	6.8	6.8	6.9	6.9
	Finished Water	7.5	7.4	6.8	6.8	6.8	6.9
Cl_2 FAC	Resin Water						
	Finished Water	0.21	0.10	0.11	0.10	0.09	0.08
Cl_2 T	Resin Water						
	Finished Water	0.23	0.13	0.13	0.12	0.11	0.1
Ca Hard	Resin Water	273	273	280	280	283	
	Finished Water	289	289	283	281	280	
T-Alk	Resin Water	230	230	230	232	238	
	Finished Water	248	248	239	231	229	
Temp C	Resin Water	16.2	16.2	16.2	16.4	16.4	16.5
	Finished Water	16.2	16.2	16.3	16.4	16.4	16.5
TDS	Resin Water	0.431	0.431	0.437	0.437	0.456	
	Finished Water	0.451	0.451	0.459	0.454	0.456	
Cond	Resin Water	0.873	0.874	0.884	0.883	0.881	
	Finished Water	0.891	0.891	0.890	0.889	0.881	
ClO_2	Resin Water	0	0	0	0	0	0
	Finished Water	0.09	0.05	0.01	0.01	0.0	0.0
Fe	Resin Water	1.89	1.90	0.93	0.73	0.87	1.02
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.201	0.200	0.194	0.190	0.191	0.187
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	3	4
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Turbidity	Resin Water						
	Finished Water						

TEST 8

Date: December 12

TEST PROCEDURE

Chemicals (Prefilter):	ClO2 @ 0.5 PPM
Flow:	8 GPM/SF
Head Loss Across Filter:	

RAW WATER DATA

pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.1					16.3	0.42	0.85		1.87	0.197	3	184		

Test	Sample Point	7:45	9:30	11:30	1:00	3:00	5:30
pH	Resin Water	6.9	6.9	6.9	6.9	6.9	6.9
	Finished Water	6.9	6.9	6.9	6.9	6.9	6.9
Cl_2 FAC	Resin Water						
	Finished Water	0.03	0.03	0.02	0.02	0.06	0.03
Cl_2 T	Resin Water						
	Finished Water	0.09	0.09	0.05	0.05	0.08	0.07
Ca Hard	Resin Water						
	Finished Water						
T-Alk	Resin Water						
	Finished Water						
Temp C	Resin Water	14.9	16.4	16.2	16.6	17.1	17.1
	Finished Water	14.9	16.4	16.2	16.7	17.1	17.2
TDS	Resin Water	0.430	0.440	0.430	0.420	0.420	0.410
	Finished Water	0.330	0.340	0.330	0.350	0.800	0.290
Cond	Resin Water	0.790	0.840	0.810	0.850	0.850	0.860
	Finished Water	0.660	0.840	0.690	0.680	0.800	0.810
ClO_2	Resin Water	0	0	0	0	0	0
	Finished Water	0.05	0.05	0.03	0.04	0.01	0.02
Fe	Resin Water	0.88	0.89	0.83	0.71	0.7	0.71
	Finished Water	0	0	0	0	0	0
Mn	Resin Water	0.181	0.181	0.181	0.183	0.181	0.181
	Finished Water	0	0	0	0	0	0
Sulfate	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Color	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Chloride	Resin Water	0	0	0	0	0	0
	Finished Water	0	0	0	0	0	0
Turbidity	Resin Water						
	Finished Water						

TEST 9

Date: December 13

TEST PROCEDURE

NOTE: Bypassed ion exchange vessels, treated raw water.

Chemicals (Prefilter): ClO2 @ 1 PPM
Flow: 6 GPM/SF
Head Loss Across Filter:

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2			289	188	17.1	0.46	0.88		3.21	0.214		193		

Test	Sample Point	7:20	8:10	10:00			
pH	Resin Water						
	Finished Water	7.0	7.0	7.0			
Cl_2 FAC	Resin Water						
	Finished Water	0.20	0.21	0.20			
Cl_2 T	Resin Water						
	Finished Water	0.21	0.23	0.22			
Ca Hard	Resin Water						
	Finished Water	287	286	286			
T-Alk	Resin Water						
	Finished Water	184	183	181			
Temp C	Resin Water						
	Finished Water	17.1	17.1	17.2			
TDS	Resin Water						
	Finished Water	0.310	0.300	0.310			
Cond	Resin Water						
	Finished Water	0.840	0.840	0.830			
ClO_2	Resin Water						
	Finished Water	0.05	0.09	0.02			
Fe	Resin Water						
	Finished Water	0.09	0.01	0.03			
Mn	Resin Water						
	Finished Water	0.03	0	0.011			
Sulfate	Resin Water		0	0			
	Finished Water	0	0	0			
Color	Resin Water		0	0			
	Finished Water	1	0	0			
Chloride	Resin Water	0	0	0			
	Finished Water	0	0	0			
Turbidity	Resin Water						
	Finished Water						

TEST 10

Date: January 6, 1997

TEST PROCEDURE

Parameters: Greensand/Chlorine
Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.1	0	0	180	210	14.8	83	41	0.0	4.10	.283	0	199	90	6.9
7.15	0	0	180	210	13.6	86	42		4.10	.291		220	90	7.2

Test	Sample Point	7:30 AM	9:30 AM	11:30AM	1;30 PM	2:15 PM	3:50 PM		
pH	Resin Water	6.41	6.37	6.33	6.36	6.32	6.36		
	Finished Water	6.50	6.51	6.49	6.52	6.5	6.53		
Cl_2	Resin Water	0	0	0	0	0	0		
	Finished Water	.61	.59	.63	.66	.70	.63		
TDS	Resin Water	100	102	101	103	100	100		
	Finished Water	106	107	109	110	103	105		
Cond	Resin Water	49	49	47	48	49	47		
	Finished Water	53	54	51	52	51	52		
ClO_2	Resin Water	0	0	0	0	0	0		
	Finished Water	0	0	0	0	0	0		
Fe	Resin Water	3.59	3.54	3.49	3.63	3.60	3.59		
	Finished Water	0	0	0	0	0	0		
Mn	Resin Water	.211	.209	.208	.281	.290	.291		
	Finished Water	.090	.003	.001	.000	.001	.001		
Color	Resin Water	19/1	17/2	18/3	19/5	18/3	17/5		
	Finished Water	0	0	0	0	0	0		
Turbidity	Resin Water	1.10	1.10	1.01	1.00	1.10	1.30		
	Finished Water	.50	.32	.23	.17	.10	.10		
Sulfate	Resin Water	1	1	1	1	0	0		
	Finished Water	1	1	1	1	0	0		
Head Loss Across Filter		0	2 PSI	2 1/2 PSI	4 PSI	4.5 PSI	5 PSI		

*NOTE COLOR IS APPARENT/T&A COLOR (4.5 MICROFILTER)

SPECIALTY EFFLUENT SAMPLES (Time Sampled: 9:30/3:50)					
TOC	THMFP	THM	Chlorite	Chlorate	Other
			X	X	

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other

TEST 10

Date: January 7, 1997

TEST PROCEDURE

Parameters: Greensand/Chlorine (3.5 PPM)

Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2	0	0	180	200	14.2	86	43	0	2.91	280	0	188	90	7.1

Test	Sample Point	7:30 AM	9:30 AM	11:30AM	1:20 PM				
pH	Resin Water	6.43	6.39	6.4	6.39				
	Finished Water	6.55	6.61	6.53	6.55				
Cl_2	Resin Water	0	0	0	0				
	Finished Water	.71	.13	.30	.31				
TDS	Resin Water	93	91	100	102				
	Finished Water	097	092	110	109				
Cond	Resin Water	48	44	46	47				
	Finished Water	50	46	50	51				
ClO_2	Resin Water	0	0	0	0				
	Finished Water	0	0	0	0				
Fe	Resin Water	3.6	3.63	2.66	2.51				
	Finished Water	0	0	0	.01				
Mn	Resin Water	.287	.281	.201	.209				
	Finished Water	.001	.001	.001	.010				
Color	Resin Water	16/4	11/6	11	9				
	Finished Water	0	0	0	1				
Turbidity	Resin Water	1.10	1.10	.90	.90				
	Finished Water	.20	.10	0	.10				
Sulfate	Resin Water	0	0						
	Finished Water	0	0						
Head Loss Across Filter		6 PSI	8 PSI	9 PSI	10 PSI				

***NOTE COLOR IS APPARENT/T&A COLOR (4.5 MICROFILTER)**

SPECIALTY EFFLUENT SAMPLES (Time Sampled: 1:30)					
TOC	THMFP	THM	Chlorite	Chlorate	Other
1		1	1	1	

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other
100+	39	0.5	5.1	0	COLOR 200+

TEST 11

Date: January 7, 1997

TEST PROCEDURE

Parameters: Greensand/Chlorine Dioxide (0.5 PPM)
Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2	0	0	180	210	14.3	87.0	43.0	0.0	2.91	0.281	0.0	200	90.0	6.3

Test	Sample Point	1:45 PM	2:30 PM	4:00 PM					
pH	Resin Water	6.38	6.41	6.39					
	Finished Water	6.51	6.54	6.51					
Cl_2	Resin Water	0	0	0					
	Finished Water	.30	.22	.2					
TDS	Resin Water	101	100	102					
	Finished Water	107	109	110					
Cond	Resin Water	47	48	47					
	Finished Water	51	52	52					
ClO_2	Resin Water	0	0	0					
	Finished Water	.09	.10	.10					
Fe	Resin Water	2.52	2.7	2.69					
	Finished Water	0	0	0					
Mn	Resin Water	.211	.203	.201					
	Finished Water	0	0	0					
Color	Resin Water	11/4	12/5	12/4					
	Finished Water	0	0	0					
Turbidity	Resin Water	.9	.9	1.0					
	Finished Water	0	0	0					
Head Loss Across Filter		0	0	0					

***NOTE COLOR IS APPARENT/T&A COLOR (4.5 MICROFILTER)**

SPECIALTY EFFLUENT SAMPLES (Time Sampled: 11:00 AM)					
TOC	THMFP	THM	Chlorite	Chlorate	Other
X		X	X	X	

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other

TEST 11

Date: January 8, 1997

TEST PROCEDURE

Parameters: Greensand/Chlorine Dioxide (0.5 PPM)
Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.2	0	0	180	210	14.3	87.0	43.0	0.0	2.91	0.281	0.0	200	90.0	6.3

Test	Sample Point	7:00 AM	8:50 AM	11:00 AM					
pH	Resin Water	6.41	6.51	6.53					
	Finished Water	6.51	6.6	6.72					
Cl_2	Resin Water	0	0	0					
	Finished Water	.15	.31	.21					
TDS	Resin Water	101	104	101					
	Finished Water	112	112	110					
Cond	Resin Water	46	49	47					
	Finished Water	53	54	51					
ClO_2	Resin Water	0	0	0					
	Finished Water	.20	.21	.20					
Fe	Resin Water	2.71	2.71	2.7					
	Finished Water	0	0	0					
Mn	Resin Water	.213	.194	.196					
	Finished Water	0	0	0					
Color	Resin Water	19/2	12/2	13/2					
	Finished Water	0	0	0					
Turbidity	Resin Water	1.1	1.0	1.0					
	Finished Water	0	0	0					
Head Loss Across Filter		0	0	1 PSI					

***NOTE COLOR IS APPARENT/T&A COLOR (4.5 MICROFILTER)**

SPECIALTY EFFLUENT SAMPLES (Time Sampled: 11:00 AM)					
TOC	THMFP	THM	Chlorite	Chlorate	Other
X		X	X	X	

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other

TEST 12

Date: January 8, 1997

TEST PROCEDURE

Parameters: Filter Sand/Chlorine
Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.1	0	0	190	210	14.1	86	42	0	3.91	.231	0	225	90	6.1

Test	Sample Point	11:15 AM	1:00 PM	3:00 PM	4:00 PM				
pH	Resin Water	6.54	6.53	6.54	6.54				
	Finished Water	6.71	6.72	6.71	6.7				
Cl_2	Resin Water	0	0	0	0				
	Finished Water	.5/3.5	.4/3.5	.15/3.5	.5/3.5				
TDS	Resin Water	100	101	100	101				
	Finished Water	111	110	109	110				
Cond	Resin Water	47	46	47	46				
	Finished Water	52	53	53	53				
ClO_2	Resin Water	-	-	-	-				
	Finished Water	-	-	-	-				
Fe	Resin Water	2.67	2.68	2.67	2.71				
	Finished Water	0	0	0	0				
Mn	Resin Water	.197	.196	0.191	.196				
	Finished Water	0	0	0	0				
Color	Resin Water	17/1	17/1	19/1	19/1				
	Finished Water	0	0	0	0				
Turbidity	Resin Water	.85	.91	.91	1.0				
	Finished Water	0	0	0	0				
Head Loss Across Filter		0	0	0	0				

***NOTE COLOR IS APPARENT/T&A COLOR (4.5 MICROFILTER)**

SPECIALTY EFFLUENT SAMPLES (Time Sampled: ____________)					
TOC	THMFP	THM	Chlorite	Chlorate	Other

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other

TEST 12

Date: January 9, 1997

TEST PROCEDURE

Parameters: Filter Sand/Chlorine
Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.16	0	0	200	210	13.9	86	42	-	4.03	.221	0	192	96	5.8

Test	Sample Point	7:00 AM	9:00 AM	10:20 AM	12:00 PM	1:35 PM	3:00 PM	3:30 PM	
pH	Resin Water	6.59	6.55	6.51	6.50	6.53	6.54	6.52	
	Finished Water	6.77	6.76	6.78	6.76	6.77	6.78	6.75	
Cl_2	Resin Water	0	0	0	0	0.0	0.0	0.0	
	Finished Water	.6/3.5	.5/3.5	.5/3.5	.5/3.5	.5/.3.5	.43/3.5	.41/3.5	
TDS	Resin Water	97	103	101	100	101	101	100.0	
	Finished Water	109	112	110	109	109	110	111.0	
Cond	Resin Water	47	47	48	47	48	47	49.0	
	Finished Water	54	55	55	56	56	55	57.0	
ClO_2	Resin Water	-	-	-	-	-	-	-	
	Finished Water	-	-	-	-	-	-	-	
Fe	Resin Water	2.71	2.91	2.86	2.88	2.78	2.76	2.79	
	Finished Water	0	.01	0	0	0	.01	0.01	
Mn	Resin Water	.193	.192	1.94	.187	.193	.194	0.193	
	Finished Water	0	0	0	0	0	.001	0.0	
Color	Resin Water	13/1	11/0	17/1	10/0	9/0	9/1	11/1	
	Finished Water	0	0	0	0	0	0	0.0	
Turbidity	Resin Water	1.20	1.1	1.0	0.90	.93	.97	0.97	
	Finished Water	0	0	0	0	0	0	0.0	
Head Loss Across Filter		.5 PSI	1 PSI	4 PSI	5 PSI	6 PSI	8 PSI	9 PSI	

***NOTE COLOR IS APPARENT/T&A COLOR (4.5 MICROFILTER)**

SPECIALTY EFFLUENT SAMPLES (Time Sampled: ____________)					
TOC	THMFP	THM	Chlorite	Chlorate	Other
X	X	X	X	X	

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other
100+	43	0.57	5.9	0	Color>300

TEST 13

Date: January 10, 1997

TEST PROCEDURE

Parameters: Filter Sand/Chlorine Dioxide
Flow: 6.5 GPM/SF

RAW WATER DATA														
pH	Cl_2 FAC	Cl_2 T	Ca Hard	T-Alk	Temp C	TDS	Cond	ClO_2	Fe	Mn	Sulfate	Color	Chloride	Turbidity
7.21	0	0	190	220	14.3	86	41	-	4.31	.231	0	205	96	6.2

Test	Sample Point	7:25 AM	9:00 AM	11:00 AM	12:30 PM				
pH	Resin Water	6.4	6.39	6.44	6.39				
	Finished Water	6.7	6.67	6.69	6.67				
Cl_2	Resin Water	0	0	0.0	0.0				
	Finished Water	.20	.20	.22	.20				
TDS	Resin Water	99	101	100	101				
	Finished Water	110	112	112	111				
Cond	Resin Water	47	48	49	49				
	Finished Water	51	52	53	54				
ClO_2	Resin Water	0	0	0	0				
	Finished Water	.12	.09	.09	.11				
Fe	Resin Water	3	2.97	2.98	3.21				
	Finished Water	0	0	0	0				
Mn	Resin Water	.201	.210	.203	.200				
	Finished Water	.001	.000	.000	.000				
Color	Resin Water	16/1	17/0	16/0	13/0				
	Finished Water	0	0	0	0				
Turbidity	Resin Water	1.3	1.13	1.14	1.09				
	Finished Water	0	0	0	0				
Head Loss Across Filter		0	0	0	1/2 PSI				

SPECIALTY EFFLUENT SAMPLES (Time Sampled: 11:00 A.M.)					
TOC	THMFP	THM	Chlorite	Chlorate	Other
X	X	X	X	X	

SPECIALTY BACKWASH SAMPLES					
Turbidity	TDS	TSS	pH	Cl_2	Other