PROJECT MEMORANDUM

HIGHLAND WATER TREATMENT PLANT DBP CONTROL STRATEGIES

JEA

Date:	July 31st, 2019
Project No.:	10557I.00

Subject:	Magnetic Ion Exchange and Fixed-Bed Ion Exchange Bench-Scale Testing Results

1.0 Purpose

Previous work done at Highlands Water Treatment Plant (Highlands WTP) identified Ion Exchange (IX) or Magnetic Ion Exchange (MIEX) as a process solution post aeration to provide removal of organics and mitigate the formation of disinfection byproducts (DBP) in the distribution system to below the Stage 2 DBP Rule limits.

To investigate this potential solution, MIEX jar tests, IX fixed-bed column tests, and simulated distribution system (SDS) tests were performed at the bench-scale at Carollo's applied research lab, Water ARC®. This project memo provides results of all bench-scale testing completed under this effort.

2.0 Test Procedure

2.1 Water Collection

To obtain the most representative water quality for a future IX/MIEX process, water was obtained from a 3/4 inch sample tap downstream of aeration (see Figure 1). Water was collected on June 20th, 2019 in 55-gal poly drums with a liner on the inside and shipped to Water ARC® in a refrigerated freight truck.

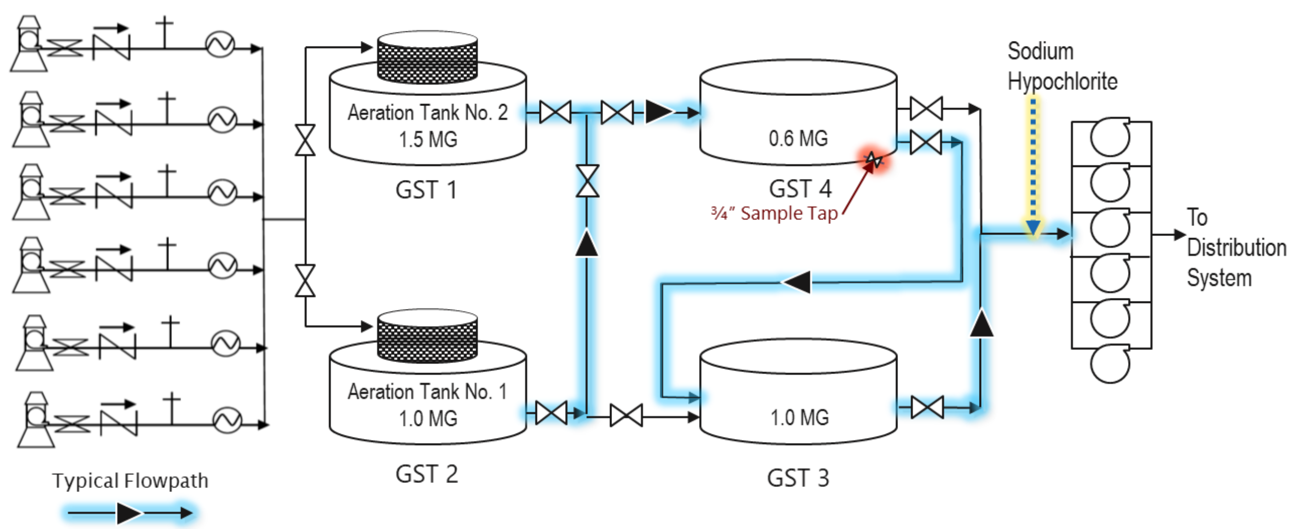

Figure 1 Process Flow Diagram Showing Sample Point Used for Collecting Test Water

2.2 MIEX Jar Test

For each bed volume to be tested, 10 mL of MIEX resin was added to 2L of sample water to get 200 bed volumes rate per cycle. The setup was allowed to mix for 15 minutes at a speed of 150 rpm, followed by 30 seconds of settling. The settled water was sampled for different parameters (i.e., TOC (total organic carbon), UV254, and true color) to record treatment at 200 bed volumes. Following this, 2L of test water was added to the same jar repeatedly to obtain results at 400, 600, 800, and 1000 bed volumes. The composite treated water was sampled for TOC, UV254, true color, alkalinity, bromide, total iron, total manganese, sulfate, and total sulfide.

2.3 Fixed-Bed IX Test

Two 1-inch glass columns were used for column testing. A strong base ionic resin was used for performing the fixed bed column tests. To prepare the columns, deionized (DI) water was added to approximately 1/3 of the column height. A slurry of DI water and resin was added to the columns to a resin depth of 26 cm, and packing was performed to ensure no air pockets were present. DI water was pumped through the column to verify column packing, and pump flow rate. Test water was introduced at a flow rate of 64 mL/min corresponding to 2.12 minutes of empty bed contact time (EBCT), and the column effluent was collected in a beaker. During operation, several parameters (bromide, TOC, sulfate, UV254, true color, alkalinity, total iron, total manganese, and total sulfide) were tested every 3 hours initially, reducing the interval to every 2 hours once UV254 increase was detected.

2.4 Simulated Distribution System Tests

2.4.1 Chlorine Demand-Decay Test

Prior to performing SDS tests, chlorine demand-decay tests were completed to define the target chlorine dose for SDS tests. For MIEX composite treated water, the required chlorine dose was estimated per the equation below, where DOC equals dissolved organic carbon. In the case of Highlands WTP's raw water supply (and typical of most ground water supplies), DOC is essentially equal to TOC and the terms are often used interchangeably.

$$3\ x\ DOC + 10\ x\ (NH_3 - N)\ x\ Dose\ Factor\ x\ Dilution\ Factor$$

Chlorine solution was added to 40mL of test water in an amber glass bottle based on the equation above and mixed by gently inverting the bottle several times. Free chlorine residual was recorded after 1, 24, 48, 72, and 120 hours.

For IX column tests, instantaneous chlorine demands were measured for the treated test water, and target chlorine dose was adjusted based on MIEX decay results.

2.4.2 SDS Test

For the SDS test, 1.5L of test water was added to a flask, and sodium hypochlorite solution was added to it at a target dose (for MIEX) of 4.5 mg/L CL_2 based on chlorine demand/decay testing. For IX, the target dose was 5.0 mg/L CL_2 based on instantaneous chlorine demand testing and comparison with previous chlorine demand/decay tests. The flask was mixed for 30 seconds, and pH was lowered to a desired level using hydrochloric or sulfuric acid. All prepared SDS bottles were stored in a dark space at room temperature for the required incubation period. At the end of each incubation period, the bottles were measured for free chlorine residual and TTHMs.

3.0 Bench-Scale Test Results

Previous studies performed on Highlands WTP groundwater has shown that in order to meet 80 percent of the MCL (80 µg/L) for total trihalomethanes (TTHMs) in the distribution system, additional treatment must decrease TOC to below approximately 1.0 mg/L. Eighty percent of this MCL, or 64 µg/L, is a reasonable value to adopt as a goal in that it provides a degree of buffer for operations staff. If desired, this value can be revisited by JEA staff during preliminary design. Sections below show results generated from the bench-scale testing performed at Water ARC®, and which treatment method was successful in removing TOC within feasible operating conditions.

3.1 Test Water Quality

Aerated water collected prior to chlorination was analyzed for several parameters as shown in Table 1.

Table 1 Water Quality of Test Water (Post-Aeration Pre-Chlorination)

Parameter	Unit	Value
Alkalinity	mg/L as $CaCO_3$	147.5(1)
Bromide	µg/L	78
Conductivity	µS/cm	483
Monochloramine	mg/L	0.01
Nitrate	mg/L-N	0.047
ORP	mV	211.2
Orthophosphate	mg/L PO_4	0.07
pH	SU	7.395(1)
Sulfate	mg/L	78
Temperature	°C	20.3(1)
TOC	mg/L	3.073(3)
Total ammonia	mg/L NH_3-N	0.39
Total chlorine	mg/L Cl_2	0.01
Total Hardness	mg/L as $CaCO_3$	256
Total Iron	mg/L Fe	0.091
Total Manganese	µg/L	3.5
Total Sulfide	mg/L	ND
True Color	PtCo 50mm	10(2)
Turbidity	NTU	0.34995(1)
UV254	abs/cm	0.218(3)
Zeta	mV	-6.72

Notes:
(1) Average value, n=2
(2) Average value, n=3
(3) Average value, n=4

3.2 MIEX Jar Test Results

MIEX jar testing results for TOC removal at different bed volumes are shown in Figures 2 and 3. TOC removals of 53 percent were observed at 200 bed volumes, which corresponded to 1.428 mg/L. Removal efficiencies dropped at higher bed volumes of 600 and above, which are considered feasible for full-scale MIEX applications without needing to regenerate or recycle the resin. These jar tests indicate that MIEX was unable to meet the 1.0 mg/L of TOC required to mitigate DBP formation for this project. SDS tests performed on MIEX treated water are discussed in Section 3.3. Additional data collected during this test is provided in Appendix A.

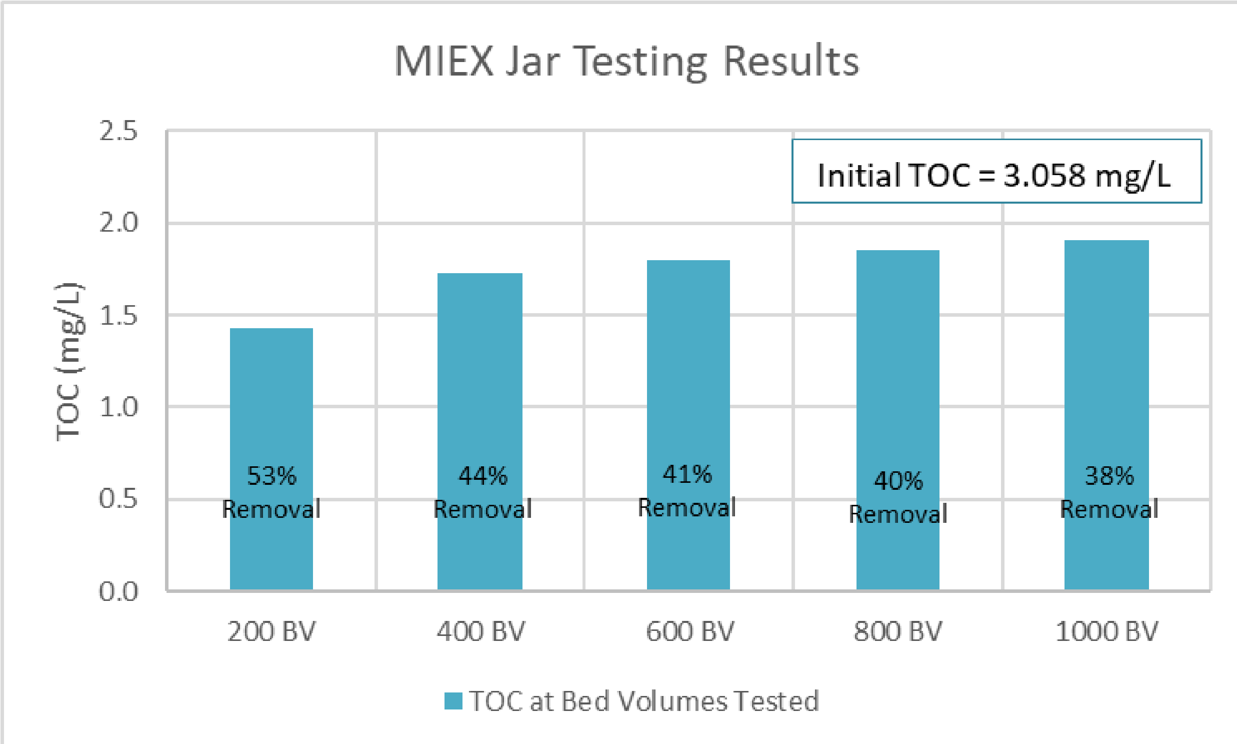

Figure 2 TOC Results at Individual Bed Volumes from MIEX Jar Testing

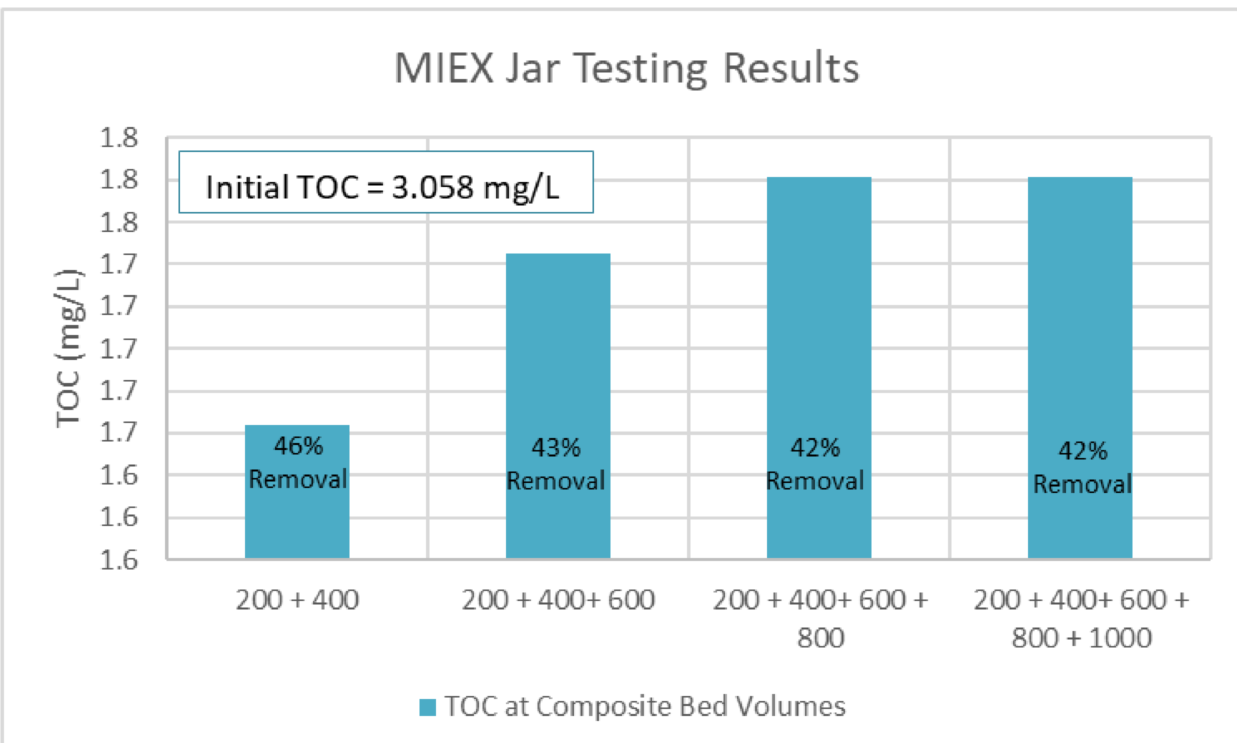

Figure 3 TOC Results at Composite Bed Volumes from MIEX Jar Testing

3.3 IX Column Test Results

TOC breakthrough from the fixed-bed IX column test is shown in Figure 4. TOC is removed to under the 1.0 mg/L target for this project up to 600 bed volumes until peaking, followed by steady removal to under 1.0 mg/L up to 1340 bed volumes. Initial sulfate in the test water (Highlands WTP groundwater) was measured at 78 mg/L which was observed to break through at 600 BV in the column test as shown in Figure 5.

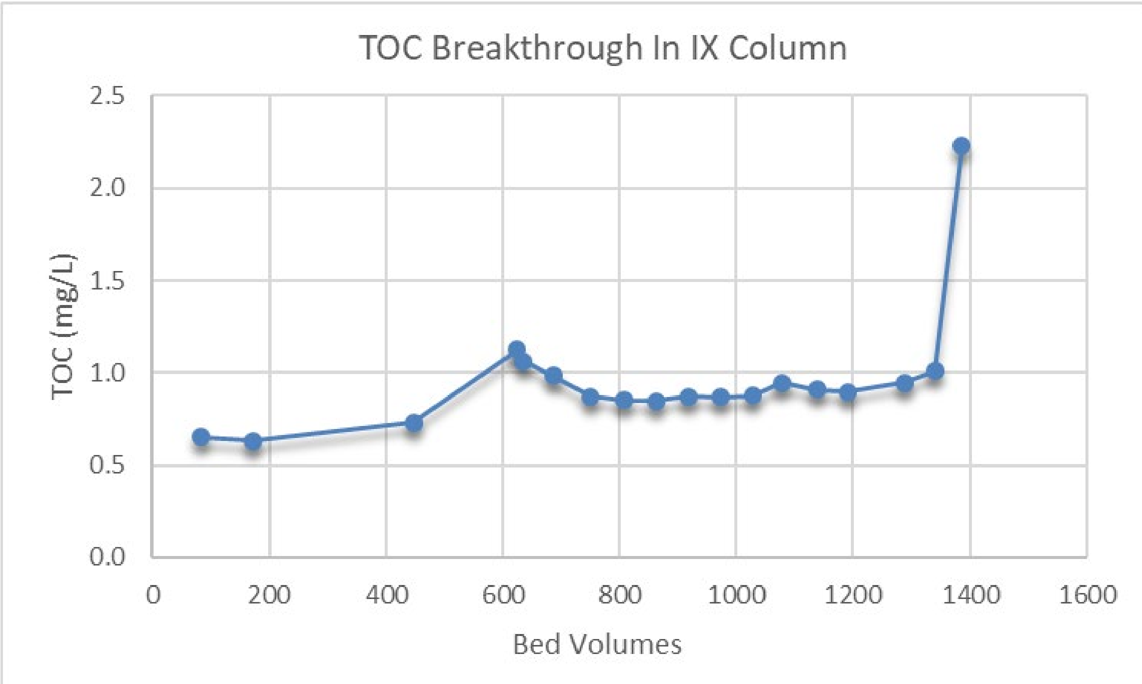

Figure 4 TOC Breakthrough in Fixed Bed IX Column Testing

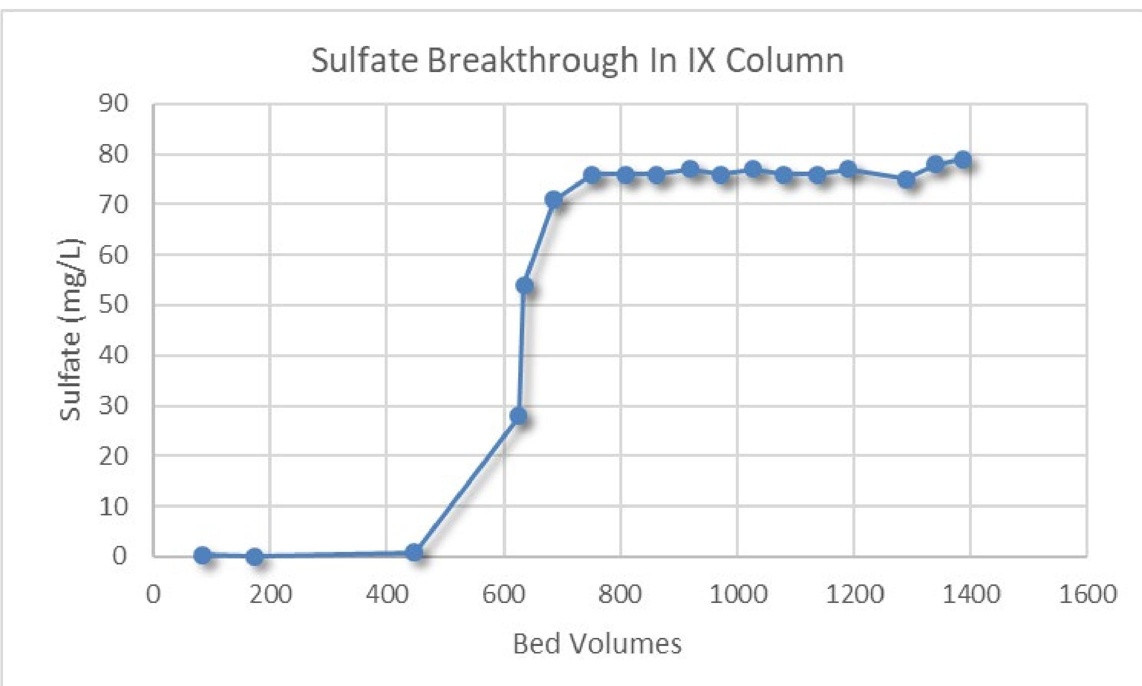

Figure 5 Sulfate Breakthrough in Fixed Bed IX Column Testing

3.4 SDS Tests

SDS tests were performed on a composite sample for MIEX jar testing, and at 100 BV, 1400 BV, and composite sample for IX column testing. Prior to commencing SDS tests, chlorine demand-decay tests were completed to identify optimum chlorine doses which would result in minimum chlorine residual requirements at 120 hours in the distribution system. Table 2 shows chlorine doses used for the SDS tests.

Table 2 Chlorine Dose for SDS Tests Obtained from Chlorine Demand-Decay Tests

Test Water	Chlorine Dose for SDS Test (mg/L)
MIEX Composite	4.5
Thermax 100BV	5.0
Thermax 1400BV	5.0
Thermax Composite	5.0

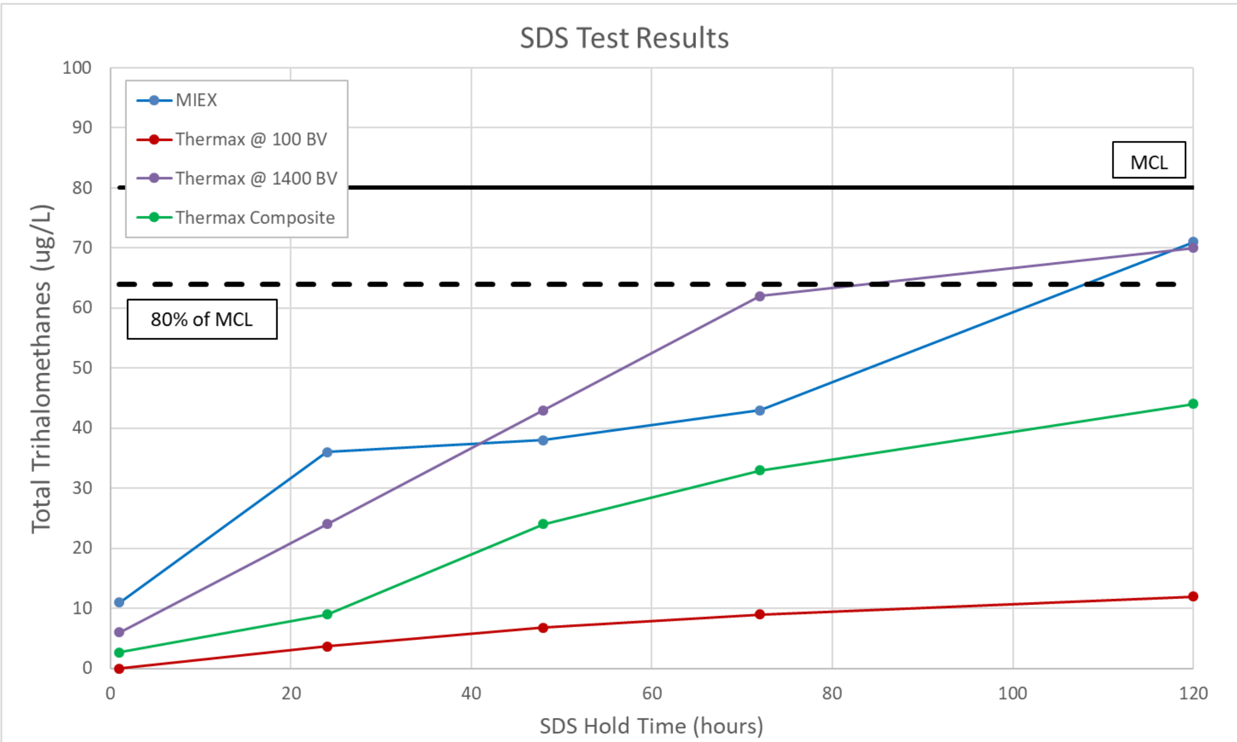

Figure 6 Results from SDS Tests Conducted on MIEX and IX Test Waters

Figure 6 shows TTHM results gathered from the SDS testing for four different test waters. In addition to MIEX composite sample, IX column test water was tested at a low bed volume of 100 (best resin performance), a high bed volume of 1400 (moderate to low resin performance), and a composite sample (to simulate staggered IX vessel arrangement). A staggered vessel arrangement means that the IX vessels will be regenerated in a staggered fashion so that the combined effluent water quality is a composite water quality of vessels that have just been regenerated, are mid-way way through a run cycle, and just about to be regenerated. For example, for 15 vessels and a 3-day regeneration frequency, the staff would regenerate five vessels each day, producing an overall water quality matching the composite sample during testing.

Results from this testing indicate that for a high water age of 120 hours in the distribution system, a strong base anionic resin at 100 bed volumes and composite are well below the treatment target of 80 percent of the TTHM MCL. The MIEX resin composite test water and fixed bed resin at 1400 bed volumes resulted in TTHM formation just above the treatment target at 120 hours of water age. From Figures 4 and 6, it can be concluded that IX operation up to a bed volume of about 1340 can be considered for a full-scale application without the potential for exceeding the TTHM goal of 64 µg/L while allowing some blending. The 1340 BV effluent TOC is 1.0 mg/L (the composite TOC is around 0.96 mg/L) and the 1400 BV effluent TOC is 2.25 mg/L showing a significant increase in TOC and corresponding THMs.

4.0 Design Considerations

4.1 Recommended Treatment Process

Based on the testing conducted during the June/July timeframe, MIEX was unable to meet the water quality goals regarding overall TOC removal (< 1 mg/L), the finished water goal of 64 µg/L, or even the finished water TTHM MCL of less than 80 µg/L. Given the fact that MIEX would require downstream filtration systems (at an added cost) together with a downstream re-pump station, it would need to substantially out-perform a fixed bed ion exchange system in order to be viable – which was not the case based on this testing.

From the bench-scale testing performed and results shown in this memo, the IX resin tested shows efficient removal of TOC to under the TOC treatment target of 1.0 mg/L for this project at sustainable bed volumes. It is therefore recommended that a strong base anionic IX resin be considered for the IX installation at the Highlands WTP for mitigating DBP formation in the distribution system. At the same time, it is also recommended that additional testing of alternate resins for a fixed bed IX system be tested during the preliminary design phase in an effort to optimize both the regeneration rates and bypass flows (as discussed below).

Because of the comparative performance of MIEX versus the fixed bed resins, design considerations are provided below solely for a fixed bed IX system using a strong base anionic resin. Budget costs for both system types (MIEX and fixed bed IX) are summarized in TM-2.

4.2 Bypass Flows

Estimating available bypass flows around the IX system (based on the above test results) can be done after establishing a maximum finished water goal for TTHMs. For example, the finished water goal (discussed above) not to exceed 64 µg/L would allow bypass of about 17 percent of the flows (assuming, based on the tests conducted, 165 µg/L TTHM formation potential in the source water). This formation potential (Figure 5.1 of TM-2) is a somewhat conservative number and there is a potential (given the actual chlorine dose and actual water age in the distribution system) that bypass flows could increase beyond 17 percent and still meet the 64 µg/L goal throughout the distribution system.

The additional testing described above would help identify a safe and reliable bypass flow rate and a corresponding suitable IX system design flow rate. It would also give JEA the opportunity to weigh in on finished water quality goals (i.e., 80 percent of the MCL) and other design and performance criteria, and provide the opportunity to explore alternative resins and at differing TOC concentrations in the raw water.

4.3 Regeneration Rates

Regeneration rates are highly dependent upon the resin type, resin loading (organics) and the hydraulic loading (bed volumes) of the resin/treatment system. While highly accurate estimates of regeneration rates can only be fully quantified after months of testing and regeneration cycles, rates adequate for design can be predicted with reasonable accuracy from short-term testing as was conducted for this study.

For this project we assumed (for TM-2) a frequency of regeneration equating to about 4,300 gallons of brine produced per MG of treated water (excluding any bypass). The single set of tests performed during the June-July test period indicate, however, higher regeneration rates than this assumed value – as much as 50% higher. This higher rate corresponds to about 6,500 gallons of brine per MG of treated water.

Higher regeneration rates means higher salt usage, as well as the higher brine volumes, which will moderately increase the operating cost of the system and also require careful planning for brine disposal. The additional testing suggested earlier could also confirm appropriate design protocol for the full-scale system, and provide better predictions of the anticipated salt usage and brine volumes.

5.0 Summary and Conclusions

MIEX and IX fixed bed bench-scale testing was completed at WaterARC® to identify the best suitable technology for controlling DBP formation in the distribution system of JEA's Highlands Water Treatment Plant by removing organics from the raw groundwater. Results presented in this document conclude the feasibility of fixed bed ion exchange as a process solution to achieve this goal by decreasing TOC to under 1.0 mg/L and finished water TTHMs to less than 64 µg/L (80 percent of the MCL for that parameter).

Additional testing is recommended during preliminary design to better characterize optimum bypass flow rates (potentially reducing the size of the installed IX system) and alternate resin types that could in turn offer lower regeneration frequencies, salt use, and brine volumes.

Appendix A

WATER QUALITY DATA AND METHODS

Table A.1 Water Quality Data Collected During MIEX Jar Tests for Individual and Composite Bed Volumes

Parameter	Raw Water	Individual Jars (BV)					Composite Data (BV)			
		200 BV	400 BV	600 BV	800 BV	1000 BV	200 + 400	200 + 400+ 600	200 + 400+ 600 + 800	200 + 400+ 600 + 800 + 1000
TOC (mg/L)	3.058	1.428	1.723	1.801	1.85	1.907	1.664	1.745	1.781	1.781
UV254 (abs/cm)	0.066	0.0190	0.0264	0.0270	0.0276	0.0300	0.0216	0.0234	0.024	0.0248
True Color	5	2	2	4	2	4	1	2	2	2
pH	7.32	7.51	7.48	7.47	7.52	7.81	7.49	7.55	7.57	7.6
Temperature	20.3	21.4	21.3	21.0	21.6	21.2	20.3	20	20.1	20.3
Turbidity	0.3019	0.3874	0.2754	0.3879	0.4744	0.4688	0.279	0.2652	0.2859	0.2942
Alkalinity	155	130	150	150.0	140.0	140	130	130	140	140
Sulfate	76	50	75	77.0	77.0	77	63	68	69	69
Bromide	81	80	81	78.0	79.0	79	79	80	80	79
Iron, Total	0.0097J	ND	ND	ND	ND	ND	ND	ND	ND	0.0034J
Mn, Total	1.3J	1.4J	1.1J	0.96J	0.93J	0.94J	1.2J	1.1J	1.0J	1.1J
Sulfide, Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table A.2 Water Quality Data Collected During Fixed-Bed IX Column Testing

Bed Volumes	pH (SU)	Temperature (°C)	UV254 (abs/cm)	True Color (PtCo 50mm)	TOC (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L as CaCO3)	Total Iron (mg/L)	Total Manganese (mg/L)(1)	Total Sulfide (mg/L)	Bromide (µg/L)
83.00	6.97	20.10	0.005	9	0.651	0.27	86	<0.0026	1.2J	< 0.024	37
173.00	7.93	19.50	0.0080J	< 3	0.631	0.19J	110	<0.0026	1.1J	< 0.024	30
447.00	7.99	20.70	0.0050J	< 3	0.729	0.75	190	<0.0026	1.2J	< 0.024	26
625.00	8.03	20.70	0.011	< 3	1.125	28		<0.0026	1.1J	< 0.024	93
635.00	7.91	21.70	0.013	< 3	1.064	54	160	<0.0026	1.1J	< 0.024	120
686.00	7.91	18.00	0.02	< 3	0.985	71	150	<0.0026	1.1J	< 0.024	130
751.00	7.72	20.90	0.0095	< 3	0.873	76	150	<0.0026	1.0J	< 0.024	120
808.00	7.78	20.40	0.0085J	< 3	0.850	76	150	<0.0026	0.99J	< 0.024	120
862.00	7.79	21.50	0.009	< 3	0.845	76	140	<0.0026	1.1J	< 0.024	110
918.00	7.84	22.10	0.011	< 3	0.872	77	150	<0.0026	1.1J	< 0.024	100
972.00	7.81	21.30	0.018	< 3	0.868	76	150	<0.0026	1.0J	< 0.024	98
1027.00	7.82	20.80	0.009	< 3	0.876	77	130	<0.0026	0.81J	< 0.024	94
1078.00	7.87	20.60	0.017	< 3	0.947	76	150	<0.0026	0.76J	< 0.024	92
1138.00	7.85	20.80	0.015	< 3	0.908	76	150	<0.0026	0.76J	< 0.024	89
1190.00	7.79	21.30	0.0060J	< 3	0.898	77	150	<0.0026	0.67J	< 0.024	88
1288.00	7.83	21.80	0.0070J	< 3	0.948	75	150	0.0026J	0.69J	< 0.024	86
1340.00	7.92	20.10	0.0080J	< 3	1.007	78	140	<0.0026	0.66J	< 0.024	84
1386.00	7.92	20.10	0.012	< 3	2.232	79	140	0.02	2.3	< 0.024	90

Notes:
(1) Qualifier J: The report lab value falls between the method detection limit and method reporting limit.

Table A.3 Analytical Methods Used for Bench Testing

Parameter	Method	Range or MRL	Laboratory
Alkalinity	Hach Method 10280	2 to 200 mg/L as $CaCO_3$	Water ARC®
Bromide	EPA 300.0	MRL: 5 µg/L	Contract Lab
Conductivity	Hach Method 8160	0.01 to 200,000 µS/cm	Water ARC®
Monochloramine	Hach Method 10270	0.04 – 4.0 mg/L-Cl2	Water ARC®
Nitrate	Hach TNT835	0.2 – 13.5 mg/L NO3-N	Water ARC®
ORP	Hach Method 10228	-2,000 to 2,000 mV	Water ARC®
Orthophosphate	Hach TNT 843	0.15 – 4.5 mg/L PO4-P	Water ARC®
pH	Hach Method 8156	2 to 14 S.U.	Water ARC®
Simulated Distribution System Tests	SM5710C	Not applicable	Water ARC®
Sulfate	EPA 300.0A	MRL: 0.5 mg/L	Contract Lab
Temperature	SM 2550B	0 – 50°C	Water ARC®
TOC	EPA 415.3	0.4 µg/L – 100 mg/L	Water ARC®
Total ammonia	Hach Method 10268	0.05 – 1.5 mg/L NH3-N	Water ARC®
Total chlorine	Hach Method 10260	0.04 – 10 mg/L Cl2	Water ARC®
Total hardness	Hach Method 1284	3 – 100 mg/L as $CaCO_3$	Water ARC®
Total Iron	EPA 200.7	MRL: 0.05 mg/L	Contract Lab
Total manganese	EPA 200.8	MRL: 2 ug/L	Contract Lab
Total sulfide	SM4500-S-^{2}D	MRL: 0.1 mg/L	Contract Lab
True color	Hach Method 8025	MRL: 3 PtCo	Water ARC®
Turbidity	Hach Method 10258	0 to 700 NTU	Water ARC®
UV254	SM5910B	MRL: 0.009 AU	Water ARC® and Contract Lab
Zeta	Electrophoretic Light Scattering	-500 - +500 mV	Water ARC®