FINAL

PILOT STUDY REPORT

The David L. Tippin Water Treatment Facility Master Plan

June 2018

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Engineers...Working Wonders With Water®

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CITY OF TAMPA

DAVID L. TIPPIN WATER TREATMENT FACILITY MASTER PLAN

PILOT PLANT STUDY

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CITY OF TAMPA

DAVID L. TIPPIN WATER TREATMENT FACILITY MASTER PLAN

PILOT PLANT STUDY

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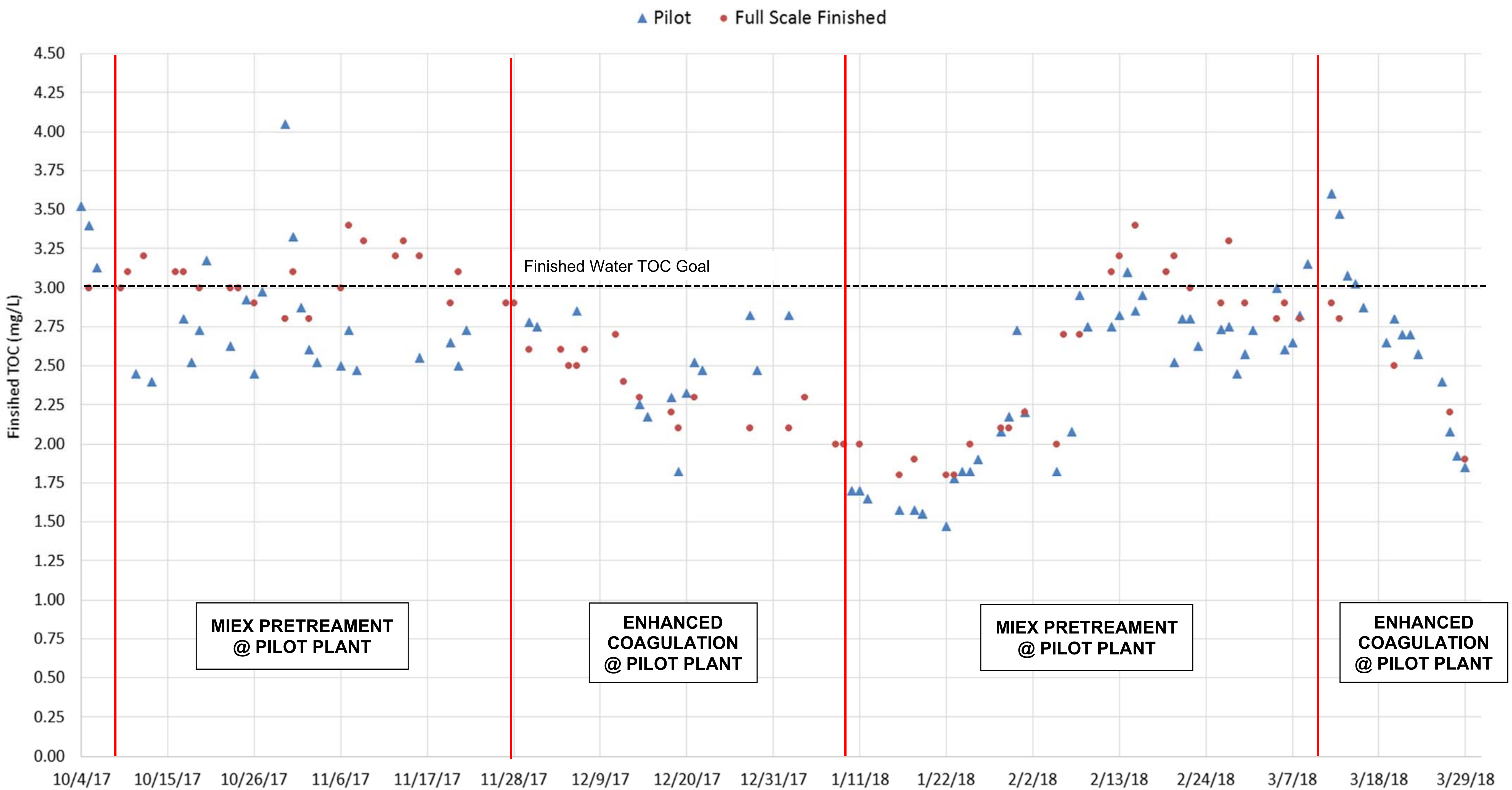
1.0 EXECUTIVE SUMMARY

The City of Tampa Water Department currently owns and operates the David L. Tippin Water Treatment Facility (DLTWTF), which produced about 75 mgd of potable water for its customers (611,000 population; 135,000 service locations) in 2017. The primary source of water for the DLTWTF is the Hillsborough River, while a secondary source is the Tampa Bypass Canal Middle Pool. DLTWTF also uses an aquifer storage and recovery (ASR) system of wells to store treated water in an aquifer during the wet season when river flows are high and recover the water when river flows are low and other supplies are limited. The DLTWTF is permitted to withdraw an annual average quantity of 82 mgd and a maximum daily quantity of 120 mgd.

The City requested that Carollo prepare a comprehensive Master Plan (MP), including a prioritized capital improvement program (CIP). The CIP included the recommendation for a DLTWTF expansion project with implementation of a new 140 mgd magnetic ion exchange (MIEX®) treatment system, to reduce operational expenses (OPEX) and extended infrastructure life within the conventional and Actiflo™ treatment systems without compromising overall TOC removal. Due to uncertainty associated with performance guarantee of such implementation, a pilot study was conducted.

Figure ES.1 shows the average finished TOC for the pilot plant and full scale plant. The results of this study found that the pilot plant produced the same or better finished water TOC as the full scale system (average values less than 3.0 mg/L), whether it was operating with MIEX® pretreatment or mimicking full scale operation with enhanced coagulation. This was imperative to achieve in order to be able to justifiably compare performance and confirm similar results could be expected with full scale implementation of MIEX® pretreatment.

Additionally, it was found that MIEX® was able to significantly reduce the downstream chemical demand, lowering the ferric sulfate dose by an average of 70 mg/L and eliminating the need for sulfuric acid and lime.



FULL AND PILOT SCALE FINISHED TOC

FIGURE ES.1

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Based on the reduced chemical usage and solids processing and disposal, in addition to the costs associated with MIEX® operation, MIEX® is approximately 2.7% less costly over a 30-year life cycle net present value (NPV), as shown in Table ES-1.

Table ES-1 Economic Analysis Summary (in $1,000s)
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Alternative	**1B**	**2A**
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**
Capital Cost	$76,700	$166,200
Annual O&M Cost	$8,200	$5,100
Basin Rehab in 15 yrs (Structural)	$2,900	$-
Basin Rehab in 30 yrs (Structural)	$2,900	$-
Net Present Value (20-Year)	**$242,900**	**$269,000**
Net Present Value (30-Year)	**$337,000**	**$328,100**

Notes:

(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from -15% to -30% and +20% to +50%. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.

The results also indicated that MIEX® is most effective during low TOC season, which has historically been a time where the DLTWTF struggles to efficiently and effectively treat the water, and is likely due to the change in the type of organics. The MIEX® treatment process is known to remove low molecular weight and non-aromatic hydrophilic type organics, while the enhanced coagulation process removes larger, aromatic hydrophobic type organics.

It was confirmed that the MIEX® process is capable of producing low TOC effluent under dynamic conditions of widely varying and quickly changing source water quality. Considering the possibility the DLTWTF may be required to process and treat up to 50 mgd of alternative water supply as part of the Tampa Augmentation Project (TAP) there is potential that *'low TOC season*' could occur year-round. Based on the type of organics in the new water supply, MIEX® pretreatment could then become more effective overall and provide additional cost savings.

In addition to water quality and economic considerations, a number of qualitative considerations were discussed. The results of this study suggest that MIEX® is capable of removing the majority of TOC seasonally, eliminating the need for the currently utilized acid pH depression enhanced coagulation process. This would allow the DLTWTF to operate at a more neutral coagulation pH, which would result in extended useful life for the existing basins in terms of concrete and structural steel integrity. Additionally, City staff could avoid handling the high strength sulfuric acid and reduce the risk of a potentially dangerous spill/accident. The elimination of lime could also save City staff time since lime slaking and slurry systems tend to be labor intensive.

In addition to the benefits realized from the study, there were also a number of risks identified for consideration including potential water quality issues with respect to bromate, chloride, and sulfate. Additionally, due to the DLTWTF's substantial rated capacity, there is inherent risk since full scale implementation of this system would be the largest in the U.S. by more than a factor of 3. MIEX® is a proprietary process and the resin used in this process is currently manufactured in Australia. As such, it could be difficult and expensive to receive virgin resin in a timely fashion should this source of supply become interrupted or unavailable or if the DLTWTF required a complete replacement of the original resin. To mitigate this risk, IXOM has agreed to construct a new resin manufacturing facility to be located in the United States. Confirming this intention, perhaps contractually, with IXOM would be prudent before moving forward with implementation of this technology.

A major benefit originally presented with the MIEX® pretreatment option was the use of a waste brine treatment system in conjunction with a third party to haul away concentrate from this system, with the goal of saving salt costs and maintaining zero-discharge status. There was not enough data collected to statistically confirm this system's effectiveness for salt savings or confirm that the third party vendor could consistently and reliably use the waste concentrate as a viable product. Therefore, there is a risk that the waste concentrate would have to be disposed of in a different manner by the City and the DLTWTF would potentially lose the 'zero-discharge' status.

Biological growth on the resin was witnessed early in the study and required pre-chlorination to prevent resin fouling, ineffectiveness, and carry-over. With pre-chlorination of the raw water there is the risk of formation of regulated disinfection by-products (DBPs), specifically total trihalomethanes (TTHMs) and haloacetic acids (HAAs). DBPs were not monitored during the study; however, due to the raw water TOC levels (up to 25 mg/L) and required chlorine dose (average 2.9 mg/L), it can be assumed that DBPs could be a significant issue. In addition to biological fouling issues, it has recently been observed that there could be long term fouling of the resin. Specifically, it has been found that the resin's ability to de-sorb organics during the regeneration process becomes less efficient over time. This can lead to decreased organics removal performance and eventually inability of the resin to remove organics to the level that was experienced in the pilot.

According to IXOM, resin loss is hard to quantify at the pilot scale level and therefore was not monitored during the study. Resin loss greater than IXOM's assumed value of 1.20 gallons of resin per million gallons of water treated would lead to increased O&M costs at an amount of which is unknown and poses financial risk not shown in the economic analysis.

In regard to the Master Plan report, the intent of this study was to have the ability to finalize the draft recommendation for Alternative 2A (See Chapter 5 for full detail on this alternative) for the Project 4 - DLTWTF Expansion detailed in the prioritized capital improvement plan (CIP) in Chapter 9. The Project 4 recommendation was scoped to include the addition of a new 140 mgd MIEX® system and its supporting equipment among other projects required for expansion. The other apparent option was Alternative 1B that does not include MIEX® and would retain the enhanced coagulation process but also included a majority of the other Project 4 scope items.

With respect to the filters, based on the pilot plant results (unit filter run volumes, solids loading rates, runtimes, and clean bed head losses), it is believed even with MIEX® pretreatment the existing filters can only reliably and efficiently treat at a max loading rate of 2.9 gpm/ft^2 (~92 mgd assuming two large filters out of service) as originally noted in Chapter 3. At this rate, the expansion project would include 48 mgd of new filters. Therefore, it is recommended that the City take a phased approach to filter expansion as to not unnecessarily construct new filters. The City should implement the hydraulic improvement recommendations, as specified in Chapter 4 of the Master Plan first and then proceed with full scale demonstration and testing to witness any impacts to increased filter loading rates, runtimes, and UFRVs. This can be completed independently of MIEX® implementation since this pilot study did not find MIEX® pretreatment to significantly impact or improve filter operations. Filtration optimization with the new implemented hydraulic and process improvements could then help determine the new max loading rates and subsequent finalization of exact quantity of additional filters to meet 140 mgd capacity.

Based on the collective results and observations of this study on water quality, capital and O&M costs, and qualitative considerations, it is recommended that the City implement Alternative 2A that includes MIEX® as a pretreatment system for the DLTWTF; however, with a caveat that the City include the cost of an additional extended (one year) pilot study with MIEX® pretreatment in operation the entire duration. Additionally, mitigation and resolution of the risks identified and presented herein should be wholly resolved through piloting before the MIEX® full scale system is constructed. This pilot would be operated in conjunction with the conceptual engineering design of the full scale MIEX® system.

This recommendation is partly based on the water quality and economic considerations of MIEX®. Water quality and overall process performance for the pilot and full scale systems were very similar, with MIEX® at times providing lower finished water TOC concentrations. Additionally, the economic analysis showed that both alternatives have essentially the same net present values at 30 years, with MIEX® being 2.7% less in NPV life-cycle. Considering this, MIEX® is a viable and promising treatment option for the DLTWTF. However, due to the qualitative considerations and intermittent gaps in data, it is recommended to fully capture an entire year of data, not only in regard to TOC removal, but more specifically to include:

- Resin condition monitoring (RCM) analysis and organics desorption during the regeneration process throughout the year to understand degradation and decrease in organics removal performance over time.
- VSEP treatment runs multiple times per month to gather additional data to fully understand potential salt savings, in addition to multiple sample set deliveries to the third party vendor for confirmation of viable concrete stream usage.
- Collection of ozone dose and demand data, and bromate data (can be completed at bench scale), and consideration of various bromate control techniques. Testing should include blends of raw water from various DLTWTF supply sources including the reservoir and ASR recovery wells.
- Collection of DBP data to determine the impacts of prechlorination prior to MIEX® (can be completed at bench scale)
- Evaluation and mitigation of air entrainment issues associated with the original pilot.
- Piloting of the SIX process simultaneously with the MIEX® process (for the last 6 months).

Additionally, IXOM should provide a performance guarantee for TOC removal as well as documentation supporting their intent to construct a resin manufacturing facility in the United States.

Without full understanding and mitigation of the identified risks, MIEX® cannot be confidently recommended. By conducting additional piloting to confirm risk mitigation approaches in conjunction with the conceptual design, the City and their consultant could better understand the needed customized design of this complex system to fully meet the needs of the DLTWTF while minimizing risks and unknowns.

2.0 INTRODUCTION

The City of Tampa Water Department currently owns and operates the David L. Tippin Water Treatment Facility (DLTWTF), which produced about 75 mgd of potable water for its customers (610,000 population; 135,000 service locations) in 2017. The primary source of water for the DLTWTF is the Hillsborough River, while a secondary source is the Tampa Bypass Canal Middle Pool. DLTWTF also uses an aquifer storage and recovery (ASR) system of wells to store treated water in an aquifer during the wet season when river flows are high and recover the water when river flows are low and other supplies are limited. The facility is permitted to withdraw an annual average quantity of 82 mgd and a maximum daily quantity of 120 mgd.

The City requested that Carollo prepare a comprehensive Master Plan (MP) including a prioritized capital improvement program (CIP) that optimized treatment, improved treated water quality, reduced operating costs, and enhanced treatment and operations through a carefully planned repair and replacement program. The Draft Master Plan was submitted in May 2017 which included the recommendation for Project 4 - DLTWTF Expansion, which was scoped to include the addition of a new 140 mgd magnetic ion exchange (MIEX®) system and its supporting equipment, as well as upgrades to the conventional system, the filtration system, and the solids handling systems. Additionally, pilot testing for MIEX® and conventional system optimization, among other items, were recommended. As a result of these recommendations, the City amended the original scope of work for Carollo to provide services related to pilot plant equipment leasing and support services for a six-month pilot plant study scheduled for start in Fall 2017.

This report provides the pilot plant design, goals, operations, test plans, and results of the study conducted from September 2017 to March 2018. Section 9.0, 10.0, and 11.0 include overall pilot plant performance versus existing full scale facility performance, and details on full scale implementation and other qualitative considerations when considering MIEX® pretreatment. This report is an Appendix to Master Plan Report.

2.1 Acknowledgements

It is essential to acknowledge the work, commitment, and endless hours many of the City's staff, operators, and equipment suppliers put forth for this effort. The success of this study would not have been possible without the City's dedication to the pilot's mechanical and process operations, extensive water quality testing, and optimization of varying treatment scenarios.

2.2 Background

A detailed alternatives analysis was completed as a part of the Master Plan efforts (Chapter 5) due to the existing challenges, need for expansion, and extensive chemical use currently realized at the DLTWTF (because of the enhanced coagulation treatment method detailed in Chapter 3). Five alternatives were evaluated to optimize and/or replace the enhanced coagulation (EC) treatment and solids handling processes while still achieving the City's goals for TOC removal and overall finished water quality.

The alternatives evaluation resulted in the tentative recommendation for Alterative 2A, which would improve and expand the existing conventional treatment trains, retain the existing Actiflo™ treatment trains, and implement a new 140 mgd MIEX® pretreatment system, pending a successful pilot study of the MIEX® system.

As previously described in Chapter 5 of the Master Plan Report, the MIEX® treatment process is a continuous ion exchange water treatment process using MIEX® resin in a fluidized bed. The resin provides high surface area allowing the rapid uptake of dissolved organic carbon, and other anionic contaminants as raw water flows through the bed. The removal of DOC can allow downstream water treatment systems to improve effluent water quality, provide easier operations, and offset chemical usages.

MIEX® resin is regenerated (in a side stream batch process) using a sodium chloride solution. The chloride ions replace the DOC on resin exchange sites so that it can be used in the water treatment process again. To reduce the amount of sodium chloride consumed in the regeneration process, a waste brine treatment process can be implemented to minimize the waste brine volume and provide salt recovery in the system. This option was utilized in the study and is described in detail herein. Additionally, the treated concentrate could potentially be given or sold to a third party, the viability of which was also included in this study.

The results of this pilot study influenced the final recommendations in the master plan including the process evaluation (Chapter 3), the alternatives evaluation (Chapter 5), and the prioritized capital improvement plan (Chapter 9).

3.0 PILOT PLANT DESIGN

The study consisted of four pilot treatment skids; MIEX®, Flocculation/Sedimentation (further referred to as floc/sed unit for brevity), intermediate Ozone, and Filtration. The MIEX® system also included a vibratory shear-enhanced process (VSEP) membrane pilot unit to treat the collected waste brine from the MIEX® system. The MIEX® pilot was supplied by IXOM©, and the remaining skids provided by Intuitech® through Carollo. This section details the specific design for each pilot skid. The pilot plant was located in the DLTWTF's Chemical Building. City staff prepared the room, previously used for polymer storage, to include a drain system, chlorinated water supply, compressed air delivery system, and electrical service. Much like the rest of the chemical building, the room was not air conditioned.

3.1 Process Flow

The overall process flow diagram for the entire treatment train is shown in Figure 1. A detailed process flow diagram for the all the pilot systems are included in Appendix A.

The raw water was supplied at a rate of 10 gpm by an existing air operated double displacement pump and feed piping system, which is pulled from the Hillsborough River and services other areas in the plant. During times when MIEX® was tested, after pumping, the raw water would flow up through the resin filled contactor, through a set of inclined plate settlers (to separate any remaining resin) and through the collection launder pipes before flowing to the break tank and being pumped to the floc/sed unit. After pumping, ferric sulfate and sulfuric acid would be added prior to rapid mixing. Floc aid polymer addition (when MIEX® was off) occurred between the first and second stages of flocculation and caustic was used to adjust pH after settling and prior to ozonation. The settled water was then treated through the ozone unit, followed by filtration in each of the four filters. The filters were operated in biologically active mode to mimic full scale operations. During times when enhanced coagulation was piloted, the raw water flow would was processed through the MIEX® contactor which would be void of resin so no organic treatment occurred through the unit.

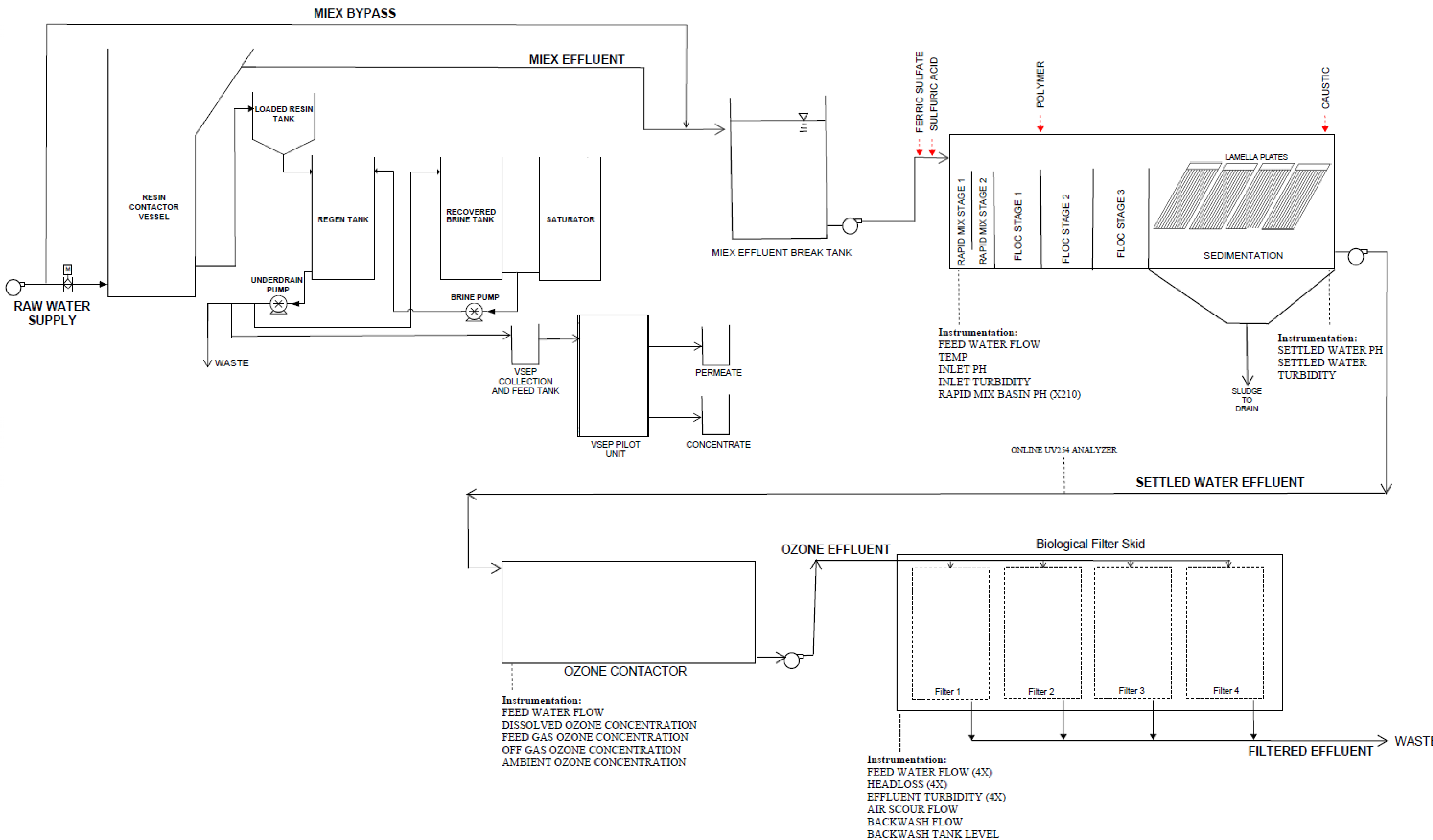

FIGURE 1

CITY OF TAMPA
PILOT PLANT STUDY

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The VSEP system was used to treat brine from the MIEX® system in batches. The permeate was sent back to the salt saturator tank, and samples of the concentrate were sent to a third party for analysis, discussed in more detail herein.

All pilot effluent waste lines were sent to the DLTWTF's existing surge tank (backwash waste washwater), where supernatant was ultimately to be re-treated in the full scale system.

Each of the Intuitech skids included automatic data logging of key parameters, remote monitoring and control using a standard web browser, and email alarm notifications. The City utilized these features throughout the study. Detailed process flow diagrams of each skid are included in Appendix A for reference.

3.2 MIEX®

Table 1 details the components of the MIEX® pilot skid. The skid consists of a contactor tank and mixer where treatment for organics removal occurs, in addition to the regeneration system that includes loaded resin, regen, brine, and saturated salt tanks. The regeneration system also has a regen tank mixer, underdrain pump, and brine pump. Between regenerations, resin loaded with anionic contaminants, referred to as “Loaded Resin”, is transferred from the Contactor Vessel to the Loaded Resin Tank in batches, where it accumulates for a regeneration. A brine solution from the Brine Tank is pumped through the bed in a plug flow manner to reverse the ion exchange process, replacing DOC and other anionic contaminants with chloride making “Fresh Resin”. As the brine is pumped through the bed, an initial set volume is purged to waste to prevent the over concentration of organics in the brine system. The remaining brine is returned to the Brine Tank for reuse. A small volume of a saturated brine solution is pumped from the Saturator to make up for the brine wasted. After a soaking period to ensure the brine completes the ion exchange reversal, rinse water is pumped through the bed to remove the excess chlorides. The resin is then fluidized and stored in the Regeneration Tank where it is transferred back to the Contactor in small batches.

Table 1 MIEX® Pilot Skid Specifications
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Value
Assembled Dimensions	15’ 4” L x 3’ 6’’ W x 8’ H
Maximum Flow Rate	15 gpm
Regeneration System Tanks	4 (Loaded Resin, Regen, Brine, Saturated Salt)
Pumps	2 (Underdrain, Brine) @ 5.0 gpm each
Bed Volume Treatment Range	200 - 1000

Table 1	MIEX® Pilot Skid Specifications David L. Tippin Water Treatment Facility Master Plan City of Tampa
Parameter	**Value**
Regeneration Rate Range	1.67 – 3.00 gallons resin / 1,000 gallons water treated
Resin	MIEX® Gold Resin
Salt	Morton Solar Salt Water Softening Crystals

3.2.1 VSEP

The components of the VSEP skid are shown in Table 2. To minimize the waste brine volume and provide salt recovery in the system, the VSEP waste brine treatment process utilizes a vibrating membrane which minimizes fouling caused by concentration polarization. Manufactured by New Logic Research, Inc. of Emeryville, CA, the nanofiltration (NF) membrane allows a relatively large portion of monovalent ions (e.g. sodium and chloride ions) to pass through the membrane but reject with high efficiency multivalent ions (e.g. dissolved organics).

Table 2	VSEP Pilot Skid Specifications David L. Tippin Water Treatment Facility Master Plan City of Tampa
Parameter	**Value**
Assembled Dimensions	4’ 6’’ L x 3’ 9’’ W x 9’ 2” H
VSEP System Tanks	3 (Brine, Concentrate, Permeate) @ 250 gal each
Pumps	1 (brine feed) at 8 gpm
Clean in Place Chemical Tank	1 at 30 gallons
Bag Filter	1
Membrane	1 nanofiltration membrane at 50 ft^2 area
Max Operating Pressure	600 psi

The waste brine feed is separated into a saline permeate stream and a heavily organic saline reject (concentrate) stream. The clean permeate stream produced by the membrane unit can be reused in the system as salt saturator make-up volume; which saves on overall salt consumption, and a reduced volume of waste to be disposed. The quantity of the recovered volume, as permeate, is dictated by the volume of saturated brine solution used in MIEX® regenerations. Therefore, the VSEP unit must operate at a recovery between 40 and 50% in order to achieve a water balanced saturated brine system.

Samples of the collected VSEP concentrate reject were shipped to BORAC for offsite analysis and testing. BORAC is a third party company that may be able to utilize the concentrate by extraction of organics from the waste into a viable DOC based solid. If BORAC finds the concentrate to be viable, then the DLTWTF would maintain its ‘zero-discharge’ status since the permeate is re-used in the regeneration system and the concentrate would be given to BORAC.

3.3 Coagulation, Flocculation, Sedimentation

The specifications for the floc/sed skid are shown in Table 3. The pilot module consists of a feed pump, two stage rapid mix (run in parallel), three stage flocculation, inclined plate sedimentation, a sludge removal system, and up to five chemical feed systems. Feed flow is maintained through automatic proportional-integral-derivative (PID) flow control. Mixers are variable speed with direct entry of mixing gradient setpoint (in units of sec^{-1}). Inclined sedimentation plates can be added or removed as necessary. Sludge can be removed continuously or intermittently. The sludge pump can also be used to recirculate sludge back into any of the flocculation basins but was not done in this study. Chemical feed pumps could be flow paced with direct entry of chemical dosage, or controlled through a PID loop to maintain the pH.

Table 3 Floc/Sed Pilot Skid Specifications
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Value
Assembled Dimensions	94" H x 163" W x 50" D
Maximum Flow Rate	10 gpm
Rapid Mix Basins (quantity/size)	2 @ 2.5 gal
Rapid Mix Basins (max operation)	1500 s^{-1}
Flocculation Basins (quantity/size)	3 @ 120 gal
Flocculation Basins (max operation)	100 s^{-1}
Settling Plates (quantity/size each)	28 @ 2.8 ft^2
Chemical Feed Pumps (quantity/size)	5 @ 0.01 - 21.7 gpd Range
Sludge Pump Flow Rate Range	0.14 - 1.40 gpm

With the exception of the manually actuated valves, the equipment is monitored and controlled by an HMI (Human Machine Interface). The HMI communicates with the on-board PLC (Programmable Logic Controller), which monitors and controls various instruments and components. In short, the operator monitors the equipment through the HMI, which interacts with the PLC, which in turn activates the various equipment components.

3.4 Ozone

The ozone skid consists of a feed pump, five contact chambers, an ozone generator, and an ozone destruct unit. The specifications for the unit are shown in Table 4. The feed flow is controlled automatically. Contact chambers have twenty-five volumetrically-spaced ports for sampling dissolved ozone. Ozone generator is air-cooled with an integral oxygen concentrator for creating ozone from ambient air, and shuts down automatically if a leak is detected.

Table 4 Ozone Pilot Skid Specifications
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Value
Assembled Dimensions	140" H x 30" W x 120" D
Flow Rate Range	1.6 - 7.0 gpm
Contactors	5 @ 13.9 gal
Ozone Delivery Range	0.13 - 0.58 lb/day
Ozone Dose Range	1.50 – 30.2 mg/L

With the exception of the manually actuated valves, the equipment is monitored and controlled by an HMI which communicates with a small PLC in the control panel that monitors and controls various instruments and components.

3.5 Biofiltration

The Biofiltration skid consists of four constant-rate filters with individual feed pumps, and up to five chemical feed systems. Each filter operates using automatic PID flow control. The module can be operated as four independent filters, or two sets of two filters in series. The air scour and backwash systems are shared by all filters, and also utilize automatic PID flow control. Chemical feed pumps are flow paced with direct entry of chemical dosage. Each chemical pump can be selectively paced to any of the filter feed flows, the combined filter feed flow, or the backwash flow. Backwashing is initiated manually by an operator in the manual mode, or on runtime, run volume, head loss, or effluent turbidity in the automatic mode. Only one filter may be backwashed at a time. The equipment is monitored and controlled by an HMI that communicates with the on-board PLC, which monitors and controls various instruments and components. The specifications for the skid are shown in Table 5.

Table 5	Biofiltration Pilot Skid Specifications David L. Tippin Water Treatment Facility Master Plan City of Tampa
Parameter	**Value**
Assembled Dimensions	136" H x 146" W x 50" D
Flow Rate	0 - 12.0 gpm
Filters	4 @ 6" internal diameter, 117" height
Maximum Media Depth	72"
Filtration Rate Range	2.55 - 15.3 gpm/sq ft
Backwash Rate Range	5.10 - 30.6 gpm/sq ft
Backwash Tank Capacity	150 gal
Air Scour Rate Range	2.55 - 10.2 scfm/sq ft
Chemical Feed Pumps Range	5 @ 0.01 - 21.7 gpd
Chemical Feed Tanks	5 @ 4 gal

4.0 OPERATIONS, MONITORING, AND TEST PLANS

The pilot systems and skids were installed and commissioned in early September of 2017. Training and troubleshooting occurred for the duration of the month. The pilot study and water quality data collection was conducted from October 2, 2017 through March 31, 2018 to evaluate the performance over time when influent water quality varied seasonally and with various chemical and process configurations.

The pilot units were typically staffed Monday through Friday from 6:30 am to 3:30 pm. Remote access and online data logging for the skids were utilized to help facilitate continuous operation overnight and over weekends without the presence of an operator. Plant staff could troubleshoot a number of issues remotely and control skid operation as necessary. A summary of the pilot study test plan is shown in Table 6 and Figure 2 shows this information visually.

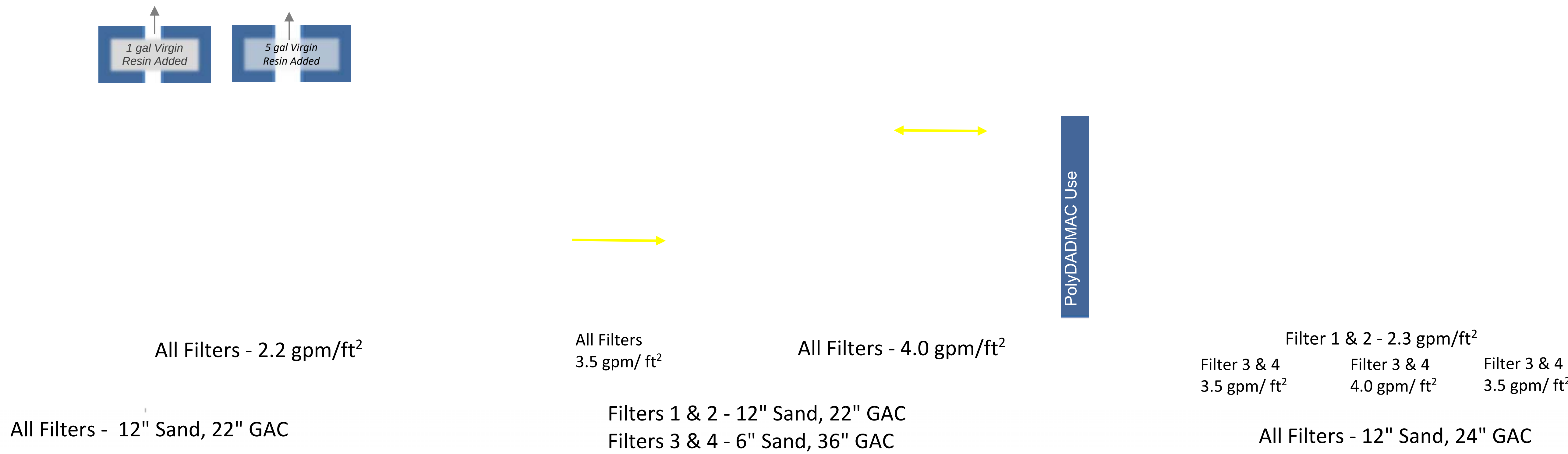
The City also provided a detailed log book which included information on shutdowns, change in operations, mechanical issues, water quality issues, and the like, which is included in Appendix B.

Table 6 Pilot Study Operations Summary
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

<table>
<tr><th>Date</th><th>MIEX®(4)</th><th>Floc/Sed(2)</th><th>Ozone(3)</th><th>Filtration Loading Rate Operation</th><th>Filtration Media Operation</th></tr>
<tr><td>August 28th - September 29th</td><td colspan="5">Installation, Start-up, Commissioning, Training, & Troubleshooting(1)</td></tr>
<tr><td>October 4th - October 6th</td><td>Offline</td><td>Ferric Sulfate, Sulfuric Acid, Caustic, Polymer</td><td rowspan="11">Target Residual of 0.30 mg/L at 5.0 minute contact time to match full scale operations</td><td rowspan="3">All Filters - 2.2 gpm/sq ft</td><td rowspan="2">All Filters - 12" Sand, 22" GAC</td></tr>
<tr><td>October 7th - November 24th</td><td>600 BV</td><td>Ferric Sulfate, Chlorine (starting Oct 31)(6)</td></tr>
<tr><td>November 27th - December 12th</td><td>Offline</td><td>Ferric Sulfate, Sulfuric Acid, Caustic, Polymer</td><td rowspan="5">Filters 1 & 2 - 12" Sand, 22" GAC
Filters 3 & 4 - 6" Sand, 36" GAC</td></tr>
<tr><td>December 13th - December 22nd</td><td>Offline</td><td>Ferric Sulfate, Sulfuric Acid, Caustic, Polymer</td><td>All Filters - 3.5 gpm/sq ft</td></tr>
<tr><td>December 22nd - January 5th</td><td>Offline</td><td>Ferric Sulfate, Sulfuric Acid, Caustic, Polymer</td><td rowspan="3">All Filters - 4.0 gpm/sq ft</td></tr>
<tr><td>January 8th - January 22nd</td><td>600 BV</td><td>Ferric Sulfate, Chlorine</td></tr>
<tr><td>January 23rd - February 15th</td><td>1000 BV</td><td>Ferric Sulfate(5), Chlorine</td></tr>
<tr><td>February 16th - February 28th</td><td>1000 BV</td><td>Ferric Sulfate, Chlorine</td><td>Filter 1 & 2 - 2.3 gpm/sq ft
Filter 3 & 4 - 3.5 gpm/sq ft</td><td rowspan="4">All Filters - 12" Sand, 24" GAC</td></tr>
<tr><td>March 1st - March 8th</td><td>1000 BV</td><td>Ferric Sulfate, Chlorine</td><td rowspan="2">Filter 1 & 2 - 2.3 gpm/sq ft
Filter 3 & 4 - 4.0 gpm/sq ft</td></tr>
<tr><td>March 9 - March 19th</td><td>Offline</td><td>Ferric Sulfate, Sulfuric Acid, Caustic, Polymer</td></tr>
<tr><td>March 20 - March 31st</td><td>Offline</td><td>Ferric Sulfate, Sulfuric Acid, Caustic, Polymer</td><td>Filter 1 & 2 - 2.3 gpm/sq ft
Filter 3 & 4 - 3.5 gpm/sq ft</td></tr>
</table>

Notes:

(1) Online instrumentation for each skid was logging data, however, no water quality samples were taken since treatment was not being optimized during this time.
(2) The floc/sed unit was operated at approximately 9.0 gpm for the duration of the pilot study.
(3) The ozone unit was operated at approximately 3.5 gpm for the duration of the pilot study to ensure adequate ozone dosing. Higher flow rates would significantly increase the needed ozone generator output, which was unnecessary since the filters only required a total of less than 3 gpm for operation at range of loading rates.
(4) The Bed Volume Treatment Rate (BV) is a ratio of water treated and resin regenerated and is used for process control in ion exchange systems. It signifies how frequently resin regenerations occur throughout the water treatment process and therefore how aggressively the system treats the water. Because of this, higher BVs indicated more water treated with less frequent regenerations.
(5) PolyDADMAC was also utilized from February 2nd – 9th, 2018, overdosing of this polymer occurred from February 2nd – 7th, with consistent feed of 1 ppm polymer February 7th – 9th.
(6) Pre-chlorination was implemented on October 31st and utilized when the MIEX® system was in operation due to the suspected biological growth on the MIEX® resin.



PILOT PLANT OPERATIONS SUMMARY

FIGURE 2

CITY OF TAMPA
PILOT PLANT STUDY

Additionally, pre-chlorination on the raw water feed line was used when MIEX® pretreatment was in operation due to the apparent biological growth on the resin. Pre-chlorination began 10/31/2017.

As illustrated in Figure 2, operations were conducted in a manner to fully test a number of treatment scenarios across the entire pilot treatment train throughout seasonal water quality variations. It also denotes shutdowns (whether intentional or unintentional) that lasted longer than one day.

In addition to the water quality parameters monitored continuously on the pilot skids, grab samples were collected and primarily used in the data analysis for this study. The water quality grab sampling matrix that was implemented is shown in Table 7. Filtered effluent samples were taken for each of the four filters. Additionally, the City implemented an online UV analyzer to monitor settled water (floc/sed effluent) which helped forecast expected TOC removal performance thereby allowing for implementation of any needed changes on a day-to-day basis. The City also conducted periodic jar testing to help determine appropriate dosing schemes based on changing influent water quality throughout the study.

The analytical methods are also shown in the Table 7. VSEP water quality samples were collected and processed by IXOM (EOR: end of VSEP run, BOR: beginning of VSEP run). The contents of this report focuses on a number of these water quality parameter results; however, all results are provided electronically as Appendix C.

4.1 MIEX®

The MIEX® skid was capable of monitoring and recording the following:

- Raw Water Flow Rate
- Regeneration Step Number
- Regeneration Tank Level
- Brine Tank Level
- Saturator Level
- Underdrain Brine Conductivity
- Brine Conductivity

Aside from the raw water flow rate, the parameters were recorded online during the regenerations as process control parameters. Reviewing these parameters allowed the operator to interpret from the HMI when regenerations occurred and whether the regenerations were performing optimally.

Table 7 Water Quality Sampling Matrix
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Raw	MIEX® Effluent	Floc/Sed Effluent	Ozonated Effluent	Filtered Effluent	City Conducted Analytical Methods	VSEP (conducted by IXOM)		
							Feed	Permeate	Concentrate
Turbidity	1/day, 5 days/wk	1/day, 5 days/wk	1/day, 5 days/wk		1/day, 5 days/wk	SM 2130 B			
pH	1/day, 5 days/wk	1/day, 5 days/wk	1/day, 5 days/wk		1/day, 5 days/wk	EPA 150.1			
Temperature	1/day, 5 days/wk	1/day, 5 days/wk	1/day, 5 days/wk	1/day, 5 days/wk	1/day, 5 days/wk	Not certified / SM 2550			
Alkalinity	2/wk	2/wk	2/wk		2/wk	SM 2320B			
TOC	2/wk	2/wk	2/wk		2/wk	SM 5310 C			
DOC	2/wk	2/wk	2/wk		2/wk	Not certified / SM 4500.0 G	1/ BOR	1/ EOR	1/ EOR
UV_{254}	1/day, 5 days/wk	1/day, 5 days/wk	1/day, 5 days/wk		1/day, 5 days/wk	SM 5910B			
Magnesium	2/month	1/study	1/study		2/month	Not certified / EPA 200.8 - RL is 0.1 mg/L			
Apparent Color	2/wk	2/wk	2/wk		2/wk	SM 2120B			
Conductivity	1/wk	1/wk	1/wk		1/wk	SM 2510 B	1/ BOR	1/ EOR	1/ EOR
Ammonia	1/month	1/month	1/month	1/month	1/month	DOC 316.53.01501			
Orthophosphate	1/wk	1/wk	1/wk	1/wk	1/wk	EPA 300.0			
Odor (TON)				1/wk	1/wk	SM 2150 B			
Arsenic	1/wk		1/wk		1/wk	EPA 200.8			
Sulfate	2/wk	2/wk	2/wk	2/wk	2/wk	EPA 300.0	1/ BOR	1/ EOR	1/ EOR
Chloride	1/wk	1/wk	1/wk	1/wk	1/wk	EPA 300.0	1/ BOR	1/ EOR	1/ EOR
MIB[(1)]	1/study		1/study	1/study	1/study	SM 6040D			
Geosmin[(1)]	1/study		1/study	1/study	1/study	SM 6040D			
Bromide	1/wk	1/wk	1/wk		1/wk	EPA 300.0			
Bromate				1/month					
Nitrite	2/wk	2/wk	2/wk	2/month	2/wk	EPA 300.0	1/ BOR		1/ EOR
Nitrate	1/wk	1/wk	1/wk	2/month	1/wk	EPA 300.0	1/ BOR	1/ EOR	1/ EOR
Hardness, Total	3/wk	3/wk	3/wk	2/month	2/month	SM 2340C - RL is 1			
BOD (biological oxygen demand)							1/ BOR	1/ EOR	1/ EOR
COD (chemical oxygen demand)							1/ BOR	1/ EOR	1/ EOR
SRP (soluble reactive phosphorus)							1/ BOR	1/ EOR	1/ EOR
TSS (total suspended solids)							1/ BOR	1/ EOR	1/ EOR
TDS (total dissolved solids)							1/ BOR	1/ EOR	1/ EOR
Calcium							1/ BOR		1/ EOR
Silica							1/ BOR		1/ EOR
Sodium							1/ BOR	1/ EOR	1/ EOR
Iron	2/wk	2/wk	2/wk				1/ BOR		1/ EOR
Manganese	2/month	2/month	2/month				1/ BOR		1/ EOR
Fluoride	1/wk	1/wk	1/wk	1/wk	1/wk	EPA 300.0	1/ BOR		1/ EOR

Each day, resin concentration samples were taken from the contactor to monitor the resin bed expansion and the resin inventory. Salt usage was also monitored and was logged manually.

The MIEX® skid was operated as follows:

- Contactor resin concentration: 200 – 250 mg/L
- Resin raw water contact time: 4 – 6 minutes
- MIEX® resin treatment rate: 600 & 1000 bed volumes
- Raw water flow rate: 10 – 15 gpm

Due to biological growth witnessed on the resin, discussed herein, a pre-chlorination step was added October 31, 2017 and used when the MIEX® system was in operation. The chlorine was fed into the raw water line approximately 1 minute (hydraulic detention time) from the raw water sample port and at doses ranging from 0.9 – 7.4 mg/L.

4.1.1 VSEP Brine Treatment

During a test run, the VSEP skid monitored and recorded the following parameters:

- Feed pressure
- Vibration amplitude
- Permeate flow rate
- Concentrate flow rate
- Percent recovery

A sample of the waste brine feed was collected prior to a test run and samples of permeate and concentrate were collected at 10% recovery intervals throughout the test run.

The VSEP was operated under the following conditions:

- Feed pressure: 350 – 400 psig
- Vibration amplitude: ½" – ¾"
- Membrane flux: 17 – 20 gal/ft^2/day
- Percent recovery: 50%

It is possible to run the unit at a higher recovery, but 50% recovery was selected based on the volume balance around the salt saturator, as the permeate is used as makeup water to the saturator. At ~50% recovery, the permeate volume is approximately equal to the amount of saturated salt solution used. Running at a higher recovery would result in a smaller concentrate stream, but there would be excess permeate that would need to be disposed of since it cannot be put back into the system.

The samples were analyzed at IXOM's laboratory for dissolved organic carbon (DOC), sodium, chloride, conductivity, and total dissolved solids to determine the effectiveness of the membrane separation process and to verify assumptions used in evaluating the salt cost savings. As noted, waste concentrate samples were sent to BORAC for analysis to determine if the product was suitable for their use.

4.2 Coagulation, Flocculation, Sedimentation

The floc/sed skid was capable of monitoring and data logging the following parameters every five minutes of operation:

- Date
- Time
- Inlet:
  - Pump Flow (gpm)
  - Temperature (˚C)
  - pH
  - Turbidity (NTU)
- Rapid Mix Basin pH
- Rapid Mixer and Flocculation Mixer Energy (sec-1)
- Settled Water pH
- Settled Water Turbidity (NTU)
- Chemical Pump Flow (mL/min, based on peristaltic pump speed)

Chemical dosing in milligrams per liter was determined by utilizing the inlet flow rate, chemical pump flow, and solution or active concentration of each chemical being fed. The City provided these concentrations as follows:

1. Ferric Sulfate - 1,560,000 mg/L solution concentration
2. Polymer - 2,400 mg/L active concentration
3. Caustic - 1,530,000 mg/L solution concentration
4. Acid - 1,830,000 mg/L solution concentration
5. Chlorine – 115,000 mg/L solution concentration

Therefore, chemical dosage was calculated using the following equation:

$$Chemical\ Dose\ \left(\frac{mg}{L}\right) = \frac{Chemical\ Pump\ Flow\ \left(\frac{ml}{\min}\right) * Chemical\ Solution\ Concentration\ \left(\frac{mg}{L}\right)}{Raw\ Water\ Flow\ (gpm)} * \frac{gal}{3.785\ L} * \frac{1\ L}{1000\ mL}$$

Ferric sulfate solution was collected from the full scale storage system. Polymer was created in batches and mixed manually as needed. Lime was not utilized for settled water pH adjustment in the pilot because it was not feasible to form a consistent slurry at the pilot scale. A temporary feed line from the full scale system was also not feasible since this line would be expected to clog significantly and require constant maintenance. The use of caustic allowed for consistent feed and pH adjustment and therefore was used in lieu of lime. Caustic and sulfuric acid were purchased and delivered in 55 gallon drums for pilot use.

As stated previously, for process control and determination of ferric sulfate dosing, the City utilized and monitored an online UV analyzer which monitored the relative organics across the floc/sed skid.

The coagulation and flocculation mixers were programmed to simulate tapered flocculation and more ideal mixing conditions than what is currently witnessed full scale.

Start of Study through mid-December:

- Rapid mix 1 & 2- 1000 sec^{-1}
- Flocculation Stage 1 - 20 sec^{-1}
- Flocculation Stage 2 - 12 sec^{-1}
- Flocculation Stage 3 - 6 sec^{-1}

The mixing conditions were modified from mid-December through the end of the study, to help mitigate impacts from reoccurring surface sludge (discussed herein), as follows:

- Rapid mix 1 & 2 - 1000 sec^{-1}
- Flocculation Stage 1 - 11 sec^{-1}
- Flocculation Stage 2 - 7.5 sec^{-1}
- Flocculation Stage 3 - 5 sec^{-1}

The sludge pump could be operated continuously or intermittently. The flow and operation of this pump is not continuously logged on this unit. When operated continuously, the sludge became compacted and unable to be removed from the system. Therefore, the pump was operated intermittently for a majority of the study to help control sludge accumulation and blowdown.

4.3 Ozone

The following parameters were monitored and logged on the Ozone skid:

- Inlet pump flow (gpm)
- Dissolved ozone (mg/L)
- Ozone Feed Gas (g/Nm^3)
- Ozone Off Gas (g/Nm^3)
- Ambient Ozone (ppm)

The applied ozone dose in milligrams per liter was calculated using the following equation:

$$Ozone\ Dose\ \left(\frac{mg}{L}\right) = \frac{Feed\ Gas\ Concentration\left(\frac{g}{Nm^3}\right) * Feed\ Gas\ Flowrate\left(\frac{m^3}{hr}\right)}{Raw\ Water\ Flow\ (\frac{L}{hr})} * 1000\ mg/g$$

Off gas is monitored at the top of the ozone contact columns. When ozone off gas is measured, the concentration can be used to calculate the transferred ozone dose which is simply the feed gas dose minus the off gas reading.

Ozone residual readings were manually sampled at two locations in the first two ozone contact columns to help determine required feed gas dose to achieve similar ozone contact time and residual as full scale operations.

4.4 Biofiltration

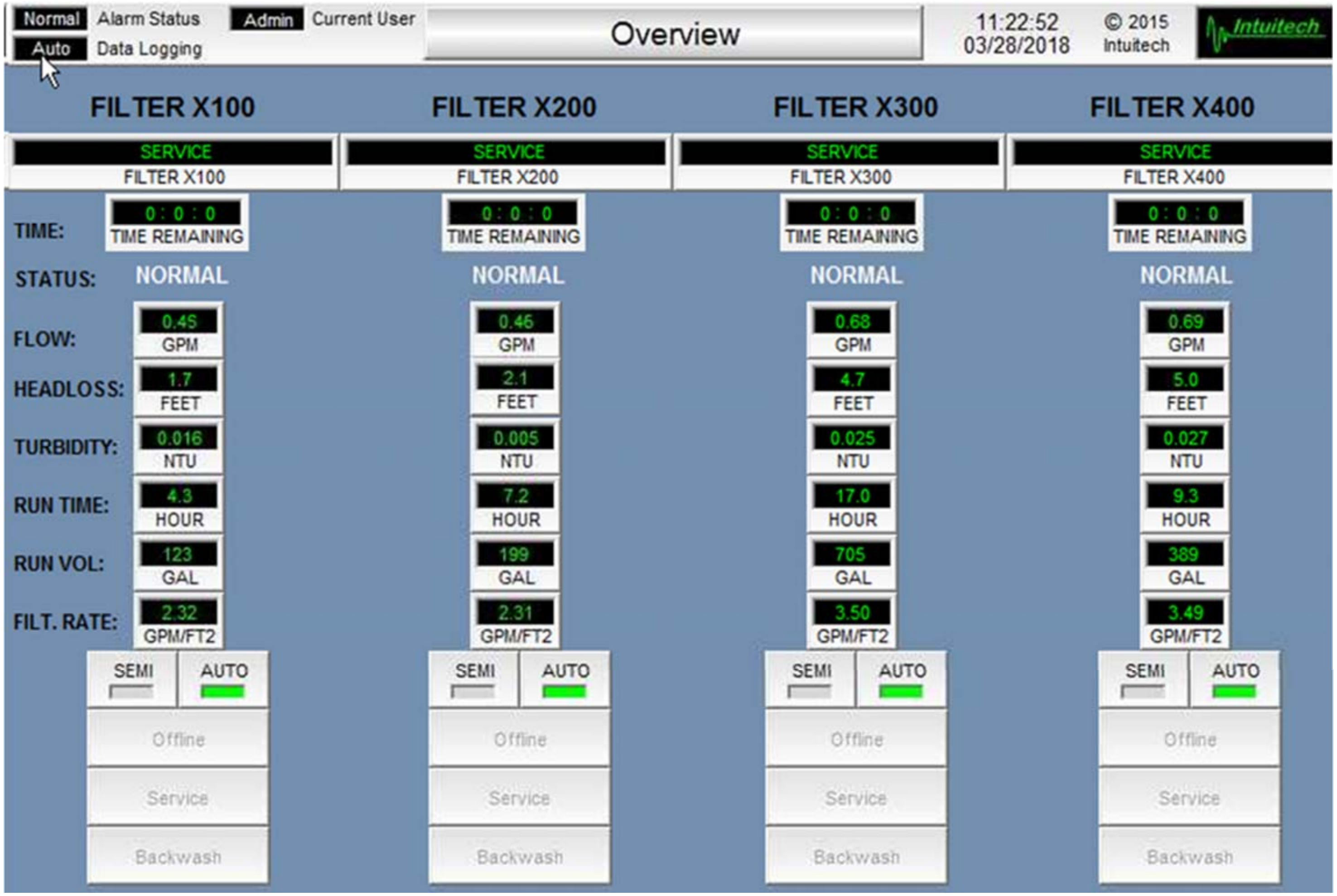
The Biofiltration skid was capable of monitoring and data logging the following parameters for each filter every five minutes of operation:

- Date
- Time
- For each filter:
  - Flow (gpm)
  - Head loss (feet)
  - Filtered Turbidity (NTU)
  - Runtime (hours)
  - Run Volume (gallons)
  - Filter Level (inches)

The skid can also monitor chemical feed but was not utilized since chemicals were not injected as part of the filter process. Figure 3 shows the primary HMI display for the unit, which shows most of the parameters being monitored.

The skid can be operated in semi-automatic mode or automatic mode. With the exception of cleaning, servicing, or intended/unintended shutdowns, each filter was operated in automatic mode throughout the study. When operated in automatic mode, the filter produces water until a backwash is triggered. The triggers for this are manually operator input along with the backwash sequence. Typically, for this study, the programmed triggers and backwash sequences for all filters is shown below:

1. Trigger:
   a. Turbidity Limit - 5.0 NTU
   b. Head loss Limit - 6.0 feet
   c. Run Volume Limit - 1,960 gallons
   d. Run Time Limit - 96 hours *(this was adjusted from November 3rd to December 1st, 2017 to 24 hours, as discussed herein)*
2. Backwash Sequence:
   a. Air Drain Level - Drain to 5 inches above level sensor
   b. Air Scour Step - 180 seconds @ 0.50 scfm *(2.55 scfm/sq ft)*
   c. Simultaneous Air Scour / Backwash Step - Time to fill to 34 inches above level sensor @ 1.03 gpm *(5.25 gpm/sq ft)* and 0.50 scfm *(2.55 scfm/sq ft)*
   d. Low-Rate Backwash - 120 seconds @ 1.03 gpm *(5.25 gpm/sq ft)*
   e. High-Rate Backwash - 360 seconds @ 3.53 gpm *(17.9 gpm/sq ft)*
   f. Low-Rate Backwash - 120 seconds @ 1.03 gpm *(5.25 gpm/sq ft)*
   g. Settle - 15 seconds
   h. Filter to Waste - 600 seconds
   i. Return to service



BIOFILTER SKID HMI

FIGURE 3

CITY OF TAMPA
PILOT PLANT STUDY

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The triggers and backwash sequence were set to mimic existing full-scale operation, with the following differences:

1. Full scale backwash sequence:
   a. Air Scour Step – 90 seconds @ 2.73 scfm/sq ft
   b. No simultaneous air scour/backwash step
   c. Low-Rate Backwash – 30 seconds @ 5.66 gpm/sq ft
   d. Step up to High-Rate Backwash
   e. High-Rate Backwash – 330 seconds @ 15.6 gpm/sq ft
   f. Step down to low rate
   g. Low-Rate Backwash – 30 seconds @ 5.66 gpm/sq ft
   h. Repeat for other filter bay
   i. Return to service after filter to waste

Additionally, the full scale effluent turbidity trigger is set for 0.15 NTU. The pilot was not programmed at this level due to expected variations in the pilot scale due to changing operations, and because the full scale system is hardly ever backwashed on this trigger and almost always on head loss. In order to minimize unnecessary pilot skid shutdowns, the pilot was set at 5.0 NTU.

Filtered effluent was collected in a 150 gallon tank and used as backwash water and therefore was not chlorinated. Filtered effluent not collected in the backwash tank was sent to drain. Biologically active and exhausted GAC from the full-scale filters (collected just after full-scale filter run and before backwashing) and fresh silica sand served as the media for the pilot filters.

4.5 Operational Challenges

During times throughout the study, there were instances of mechanical challenges as well as water quality challenges impacting operations. While this is to be expected at the pilot scale, the issues and subsequent consequences or actions are detailed in Table 8 for reference. The purpose of this table is to show reoccurring challenges or events along with suspected impacts to operations and/or water quality. A detailed pilot log is provided in Appendix B for reference.

The most recurrent and prominent operational issue, not shown in Table 8, was the accumulation of a surface sludge which persisted at various levels of consistency and thickness, and varying time periods throughout the study.

Table 8 Pilot Operation Challenge Log
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Challenge	Cause	Resulting Action	Operational Impact	Water Quality Sample Impact
September:				
Hurricane Irma	NA	All skids shutdown	NA	NA(1)
MIEX® regeneration tank mixer propeller came loose into tank	Unknown	Reattached propeller	Resin regeneration paused	NA(1)
MIEX® contactor mixer broke	Damaged during installation	Replaced	MIEX® skid shutdown	NA(1)
Filters unable to operate in automatic backwash mode	Faulty and incorrect programming on level transmitters	Replaced all transmitters	Filters required semi-automatic mode, backwashes had to be initiated manually	NA(1)
Ozone analyzer reading unexpectedly high dose values	Faulty ozone feed gas analyzer	Removed, repaired, and reinstalled analyzer	Feed gas ozone not accurately monitored from until September - November 1st, therefore inhibiting the ability to accurately measure ozone dose and demand during this time frame.	Minimal impacts to most water quality parameters. Ozone was controlled by monitoring the online ozone residual analyzer. However, since ozone dose was not able to be measured, the subsequent impact to bromate formation could not be quantified.
October				
Ozone generator pressure not sustained	Malfunctioning pressure regulators (two occasions)	Created backpressure device via tubing and valve	Intermittent Ozone skid shutdowns (resulting in filter skid shutdowns)	None (2)
Raw water flow lost	Raw water pump clogged at river	Cleaned	All skids shutdown	None (2)
No remote access to ozone or filter skids	Firewall blocking filter access and windows 7 needed to ozone access. City IT department blocking access to remote viewing software.	Firewall dropped, City IT resolved, Windows 7 attained through use of Virtual PC.	Inability to remotely monitor operating status and control units	None
MIEX® Resin loss	Biological growth on MIEX® resin	Addition of pre-chlorination step	Loss of resin and need for addition of virgin resin	No impacts to organics removal witnessed, could have improved organics removal due to bulk virgin resin additions
MIEX® regeneration step pausing and resin transfer incomplete or uneven	Level setpoints and program logic not ideal	IXOM corrected logic and transfer setpoints	None. Regenerations were not impacted.	None(4)
Power Failure	unknown	Power automatically restored	All skids shut down	None (3)
Ozone residual increase	Caustic feed tank ran out, allowing pH to decrease	Caustic replenished	Temporary decrease in ozone demand	None(4)
Floc/sed influent pump unable to maintain 9 gpm flow	Unknown	Flushed pump	Intuitech skids shut down	None(4)
MIEX® Skid HMI not functioning	A corrupt development file	Repaired remotely by IXOM	HMI access temporarily unavailable	None
November				
Low Flow to MIEX® system	Raw water pumps shutdown for cleaning,	Placed back online	None	None
MIEX® Mixer shaft broken	Motor not installed properly	Replaced	Limited mixing in contactor	None(4)
Low raw water flow	Clogged wye-strainer	Action taken by full scale operations staff	Limited treatment flow, and intermittent shutdowns of all skids (occurred from 11/11 through 11/17)	None(3)

Table 8 Pilot Operation Challenge Log
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Challenge	Cause	Resulting Action	Operational Impact	Water Quality Sample Impact
Floc/Sed influent pump low flow	High pressure and low flow due to accumulation of precipitated ferric and static mixer, acid feed before flow meter impacting reading	Pump replaced with pump from filter skid, cleared out accumulation, removed static mixer,	Consistent need for flushing, Intermittent Shutdown of intuitech skids during replacement (occurred from 11/14 to 12/5)	None(4)
MIEX® regeneration cycle pauses	Tank level alarm setpoints not properly set	Alarm levels corrected by IXOM	Intermittent regeneration pauses leading to temporary shutdowns	None(4)
Unable to access MIEX® remotely	Transformer wire came loose inside MIEX® panel	Repaired	All skids over weekend shutdown due to inability to remotely control	None(3)
December				
Acid feed line warm and discolored	Improper tubing material	Replaced with proper tubing, fittings and check valve	Temporary shutdown of all intuitech skids	None(2)
Flow meter readings inconsistent	Acid and ferric feed before flow meter impacting instruments readings	Feed points moved to just after flow meter	Temporary shutdown to install new chemical feed points, inaccurate dosing of chemicals since feeds were flow based.	None(4)
Turbidimeters in constant need of flushing	High ferric doses	Not preventable under these operating conditions	Regularly maintain and flush turbidimeters	Sporadic Spikes in online turbidity data, no long term or trend impacts and no impacts to grab samples
February				
Filters stopping during drain stage of backwash	Air valve suspected to be clogged with GAC	Force air to blow out any GAC in all filters, Increased air drain flow from 0.25 scfm to 0.50 scfm	Filter skid shutdown over weekend	None
Ozone smell detected in pilot room	Various leak locations (multiple occasions)	Repaired and Ozone destructor replaced	Ozone feed shut off intermittently	None
Ozone residual reading 0 mg/L	Sensor suspected to be uncalibrated since grab sample measured 0.13 ppm ozone residual	Turned off ozone and zero'd analyzers	Ozone shutdown for 2 hours, ozone residual readings likely inaccurate in late February.	None(4), City utilized grab samples to monitor residual.
Remote access lost to ozone and filter skids	Unknown	Reset modems for each to regain access	Temporary loss of remote control	None
March				
Ozone residual reading 0 mg/L	Sensor suspected to be uncalibrated	Moved ozone residual sample point closer to injection point (on 3/1), Moved back on 3/23.	Ozone residual data likely inaccurate in later February	None, City utilized grab samples to monitor residual.

Notes:

(1) Water quality was not being monitored at this time.
(2) Water quality samples already collected at time of event.
(3) Water quality samples postponed until after treatment restored or to following day.
(4) Water quality samples taken, however, decline or impact on treatment not witnessed

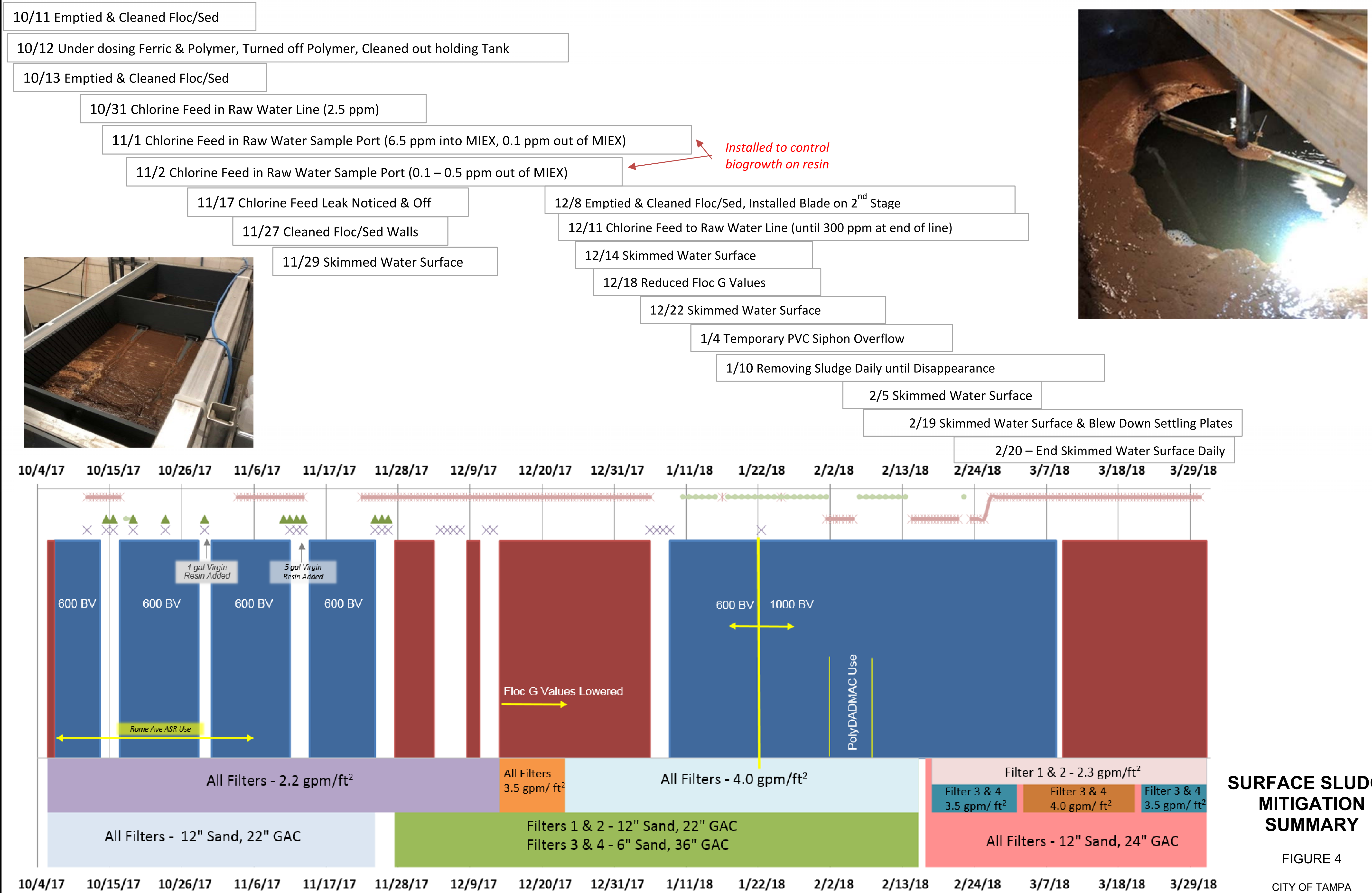
As illustrated in Figure 4, actions taken to mitigate the sludge included:

- Thoroughly cleaned floc/sed skid and holding tank (multiple occasions).
- Lowered ferric sulfate feed (temporarily).
- Lowered and eliminated polymer feed (temporarily).
- Adjusted rapid mixing and flocculation mixing rates (temporarily).
- Complete chlorination of the raw water feed line (up to 150 ppm) (one occasion).
- Intermittent chlorine dosing (0.1 - 0.5 ppm) in raw water supply in pilot room before MIEX® (temporarily).
- Installation of splash deflector on rapid mix weir (temporarily).
- Installation of new raw water pump at river.
- Installation of surface agitators in Flocculation Stages 2 and 3 (permanent).

Most of these efforts did not or only minimally impacted the surface sludge and ultimately the greatest control mechanisms were the surface agitators and City staff manually removing the sludge from the surface on a daily basis when sludge was present. City staff were methodical with this process and conducted sampling to avoid collection unrepresentative data due to any potential impacts when removing the sludge.

The occurrences of the surface sludge could not be verifiably linked to a single cause or source. The sludge events did not correlate with any mode of operation or chemical regime. It occurred during high and low TOC seasons, morning and evening, varying river and air temperatures, and when MIEX® was operating and not operating.

During most occasions, small air bubbles were witnessed in the pilot units. In the floc/sed unit air bubbles could be seen attached to flocculated material allowing it to be carried to the surface. This impact was seen within the MIEX® system as well, and it is suspected that it contributed to excess resin loss (in conjunction with the biological growth) and the need for bulk virgin resin additions early in the study. The resin loss was not believed to have caused an impact on organics removal since the amount of resin loss was not significant. This bubbling and surface sludge phenomenon is not seen full scale. The City recorded dissolved oxygen readings at various locations pilot and full scale as shown in Table 9.



SURFACE SLUDGE MITIGATION SUMMARY

FIGURE 4

CITY OF TAMPA
PILOT PLANT STUDY

Table 9	Dissolved Oxygen Measurements, Full Scale and Pilot David L. Tippin Water Treatment Facility Master Plan City of Tampa			
Date	**Location**	**Time**	**Temperature (˚C)**	**DO (mg/L)**
3/21/2018	Full Scale River (before pumping)	10:46 AM	21.4	7.10
		3:00 PM	20.9	6.27
	Pilot Influent (in pilot room)	11:03 AM	20.7	8.72
		3:10 PM	21.1	8.97
	Pilot Coagulation Effluent (before ozone)	11:15 AM	20.3	7.60
		3:30 PM	20.7	7.38
	Pilot Ozone Effluent	11:35 AM	20.1	9.14
		3:45 PM	21.3	8.62
3/23/2018	River (before pumping)	8:25 AM	19.9	6.79
	Pilot Influent (in pilot room)	9:17 AM	18.5	8.70
	Pilot Coagulation Effluent (before ozone)	9:28 AM	18.6	7.53
	Pilot Ozone Effluent	9:45 AM	18.9	9.42
	Full Scale Basin 5 - Flocculation Stage 1	8:45 AM	18.8	6.85
	Full Scale Basin 5 - Settled Water	8:55 AM	19.2	6.74

As shown, there was an average ~2.1 mg/L increase in DO from the river to the pilot room. When comparing to full scale, the increase in DO in the full-scale was insignificant. Additionally, there was a ~1.3 mg/L decrease through coagulation in the pilot and insignificant decrease in full scale. This decrease is expected since air bubbles were witnessed meaning the dissolved oxygen was supersaturated and coming out of solution, thereby being released and causing decrease in the final dissolved oxygen measurement.

Considering the varying conditions and persistent presence of the surface sludge, it is suspected that there were multiple causes allowing the dissolved oxygen to come out of solution, including, but not limited to:

- Air entrainment from raw water pump and/or supply line.
- Increase in temperature from river source through pilot.

It is thought that algae was not a contributing factor because the sludge occurrence was not diurnal, did not dissipate with chlorination, and because DO would be expected to increase throughout the day rather than decrease as witnessed. Again, this phenomenon is not expected to occur full scale with the implementation of MIEX® pretreatment given its occurrence was not conclusively related to when MIEX® was in operation and is not currently seen in the existing full scale operation.

Despite these operational challenges, there were no significant impacts on the collected data or results of the pilot study. This was because of the diligent and careful efforts by City staff in addressing these issues in a manner that minimized impacts to water quality during sample collection times.

5.0 GOALS AND OBJECTIVES

The overall goal of the DLTWTF is to provide safe drinking water by removing the vast majority of total organic carbon (TOC) and color in order to reduce disinfection by-product formation (DBPs), improve the aesthetic quality of the water by eliminating color, and reduce taste and odor causing compounds. Based on discussions from the Master Plan, the City's finished water goals used to benchmark the performance of the plant are shown in Table 10. These goals are consistently achieved with current operations but at a significant cost stemming from high chemical use, resulting in accelerated wear/corrosion on the exposed surfaces (concrete and equipment), and high volumes of solids/residuals that require processing and disposal.

Table 10 Finished Water Quality Goals
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Units	Value (Min - Max)
pH	units	7.80 - 8.00
Turbidity	NTU	0.01 - 0.08
TOC	mg/L	1.00 - 3.00
Free Ammonia (1)	ppm	0.10 - 0.18
Fluoride (1)	mg/L	0.65 - 0.75

Notes:
(1) After chlorination, before distribution.

In addition to the water quality goals, the following goals were set:

- MIEX® as a pretreatment step to:
  - Reduce coagulant demand (~50 ppm annual avg) at a neutral pH
  - Reduce/eliminate pH adjustment
  - Reduce sludge production
- Waste brine recovery and maintain zero discharge status
- Coagulation:

- Rapid Mix & Flocculation mixing at ‘textbook’ g-values
- Three stage tapered flocculation with ported wall
- Plates settlers

- Ozone:
  - Demand and dose effects from MIEX®/Coagulation

- Filters:
  - Increase loading rates
  - Optimize backwashing
  - Varying media type and depth

Therefore, the overall objective of this study was to evaluate fluidized bed magnetic ion exchange (MIEX®) and resulting performance and operational impacts to the plant's existing coagulation, flocculation, sedimentation, ozone, and filtration systems. Table 11 details each pilot unit process noting each unit objective and target full scale benefits.

Table 11 Unit Process Objectives and Targeted Benefits
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Unit Process	Pilot Objective	Targeted Full Scale Process Benefit (Goal)
MIEX®	Test ability to remove organics and color, and impacts to downstream processes	Influence downstream processes to define changes in chemical use, process operating pH, and solids production without compromising overall TOC removal and finished TOC and color. Maintain zero discharge through use of VSEP system with concentrate brine sold or given to third party
Coagulation, Flocculation, Sedimentation	Optimize chemical dosing scheme during high and low TOC seasons with MIEX® as pretreatment	Benchmark TOC removal seasonally Define reduction in overall chemical usage. Determine additional chemical storage needed for future flows of 140 mgd. Benchmark anticipated solids production and impact to on and off site solids processing facilities
Ozone	Optimize ozone dose and determine demand, evaluate impact on biofiltration and TOC removal	Define ozone dose, understand impacts to specific water quality parameters including bromate and impacts from pH changes, and determine impacts to downstream processes.

Table 11 Unit Process Objectives and Targeted Benefits David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Unit Process	**Pilot Objective**	**Targeted Full Scale Process Benefit (Goal)**
Biofiltration	Test loading rates of 2.2, 2.3, 3.5, and 4.0 gpm/sq ft[(1)] Test multiple media depths	Optimize filter loading rates and media depth Confirm design parameters for the new filters and to determine if the number of new filters required for expansion could be reduced

Notes:

(1) These loading rates assume implementation of the hydraulic and process improvements recommended for the filters as apart of Chapter 3 and 4. Without these improvements that provide an increase in available head, higher filter loading rates may not be possible.

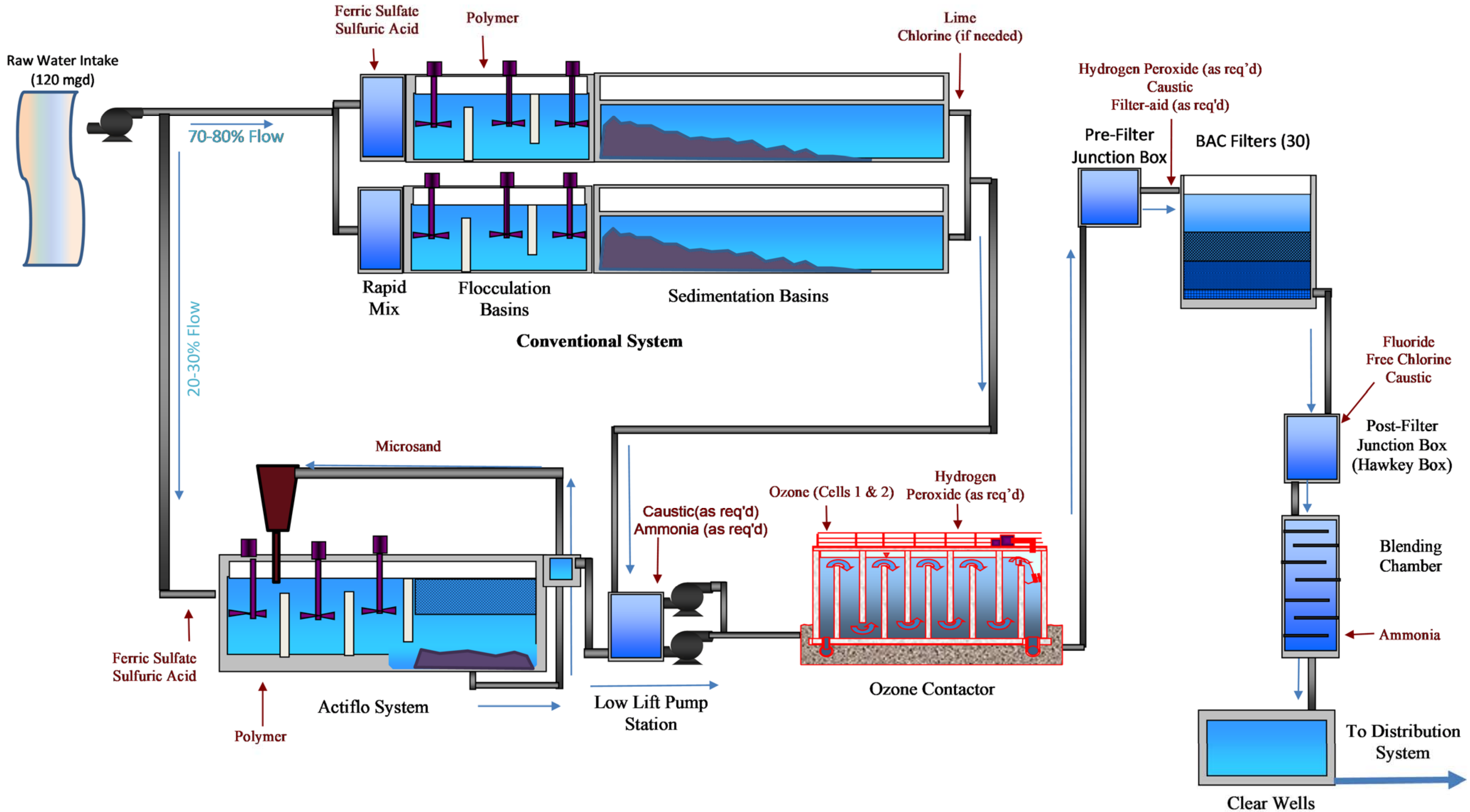
Ultimately the goal of this study was to determine if, with MIEX® as a pretreatment step, OPEX within the conventional and Actiflo™ treatment systems could be reduced without compromising overall TOC removal even with highly seasonal variations in water quality.

6.0 EXISTING FULL SCALE OPERATIONS AND TREATMENT

The Process Evaluation, Chapter 3, of the Master Plan includes more detail on the existing treatment processes and full scale operations currently utilized at the DLTWTF. Some details are reiterated here for ease of reference and to provide more recent operations data, specifically operations and treatment over the course of the pilot plant study.

6.1 Process Flow

Figure 5 depicts the process flow diagram for the DLTWTF. Water withdrawn from the Hillsborough River is screened through a grass bar rack with mechanical screens downstream of this rack for removal of finer debris. The raw water is then pumped to the four conventional treatment trains: Trains 5, 6, 7, and 8. Each train includes coagulation, flocculation, and sedimentation. Together, these trains receive approximately 70 to 80 percent of the total plant flow. The remaining flow is treated through the Actiflo™ Trains 1 and 2. Both systems (conventional and Actiflo™) use ferric sulfate as a coagulant. Before the Actiflo™ and conventional treatment trains, the raw water pH is adjusted using 93 percent sulfuric acid in order to lower the pH to about 3.8 - 4.5 prior to coagulant addition. Then coagulant addition depresses the pH even further to maximize the efficiency of the enhanced coagulation process, specifically for TOC adsorption.



DLTWTF PROCESS FLOW DIAGRAM

FIGURE 5

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PILOT PLANT STUDY

After sedimentation, pH adjustment is required before ozonation. Lime is added to the conventional treatment trains at the combined Trains 5 and 6 and Trains 7 and 8 effluent flumes. Additional pH adjustment occurs at the low lift intermediate pump station before ozonation using caustic soda when the target pH (6.3 to 7.0) cannot be achieved using lime alone (due to high turbidity). The flow is then directed to the ozonation process for primary disinfection. After primary disinfection, the flow is treated with caustic soda to achieve a pH of between 6.5 and 7.3 and then conveyed to the biological activated filtration (BAF) process, which consists of 30 gravity filters. The filters' design maximum hydraulic loading rate is 3.5 gpm/ft^2, and all filters have 12-inches of sand and 22-inches of granular activated carbon (GAC). The water is then chloraminated and the finished water is stored in the clear wells before high service pumping into the distribution system.

6.2 Process Performance

6.2.1 Overall

Chapter 3 of the Master Plan provides great detail on the process performance of the existing full scale system. For ease of reference and because of relevance to the pilot study, some information has been reiterated in subsequent sections of this report.

Historical raw water flow is shown in Figure 6. It can be seen that the total raw flow from January 2016 through March 2017 was relatively consistent; however, from March 2017 to Mid-June 2017 there was a significant decline in flow, which was followed by an overall increase in flow when compared to 2016 values. The City noted that water was purchased at this time to meet distribution system demands.

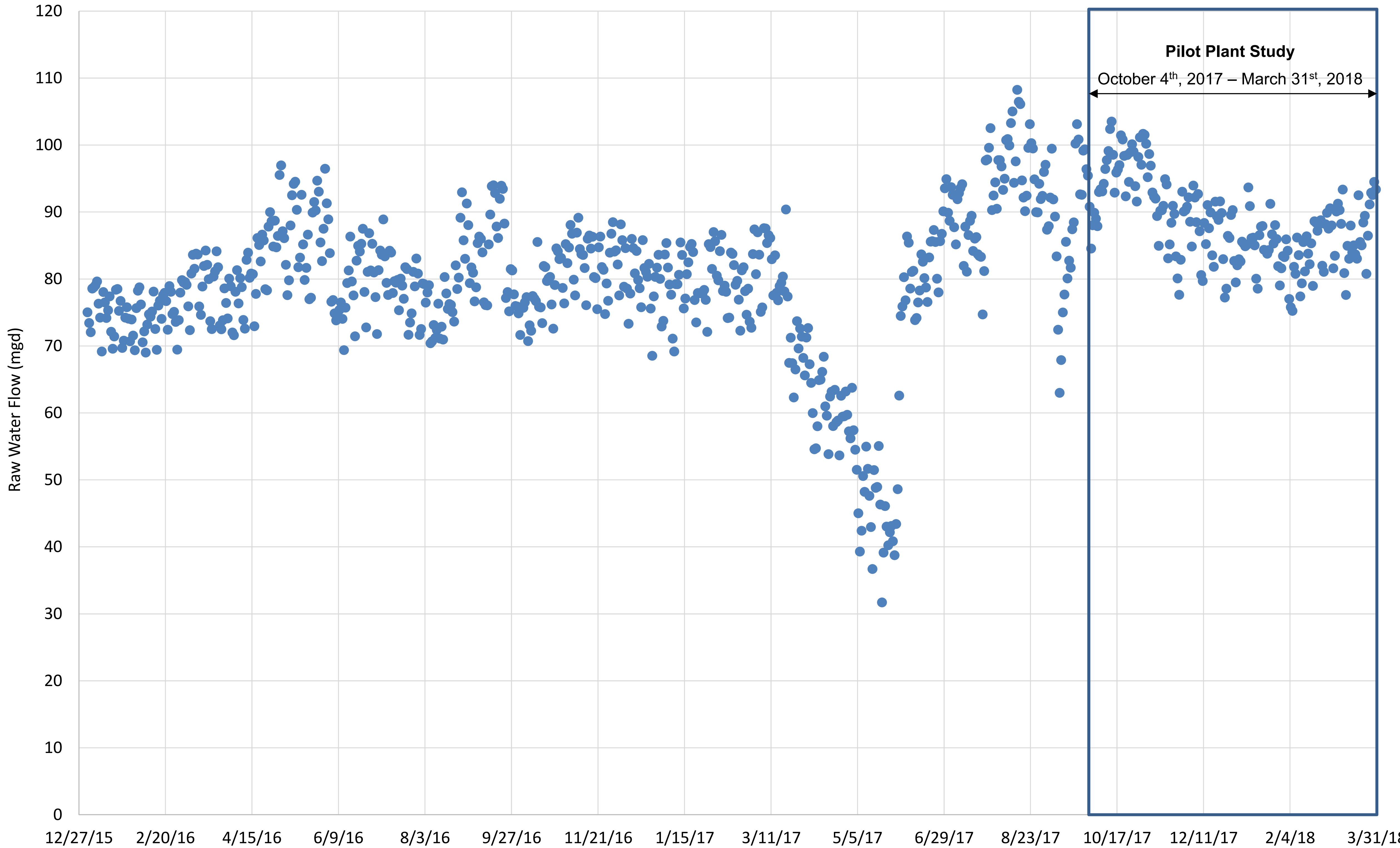
6.2.2 Coagulation, Flocculation, Sedimentation & Actiflo

Due to the goals and objectives of this study, the major focus of this section will be on the full scale systems performance in regard to TOC removal. Comparison with pilot scale performance will be discussed in Section 9.0. Additional information on the overall process performance of these systems can be found in Chapter 3 of the Master Plan report.

The conventional and Actiflo™ treatment trains receive the same raw water source. Based on the flow to each system, average chemical doses and effluent TOC values can be calculated.

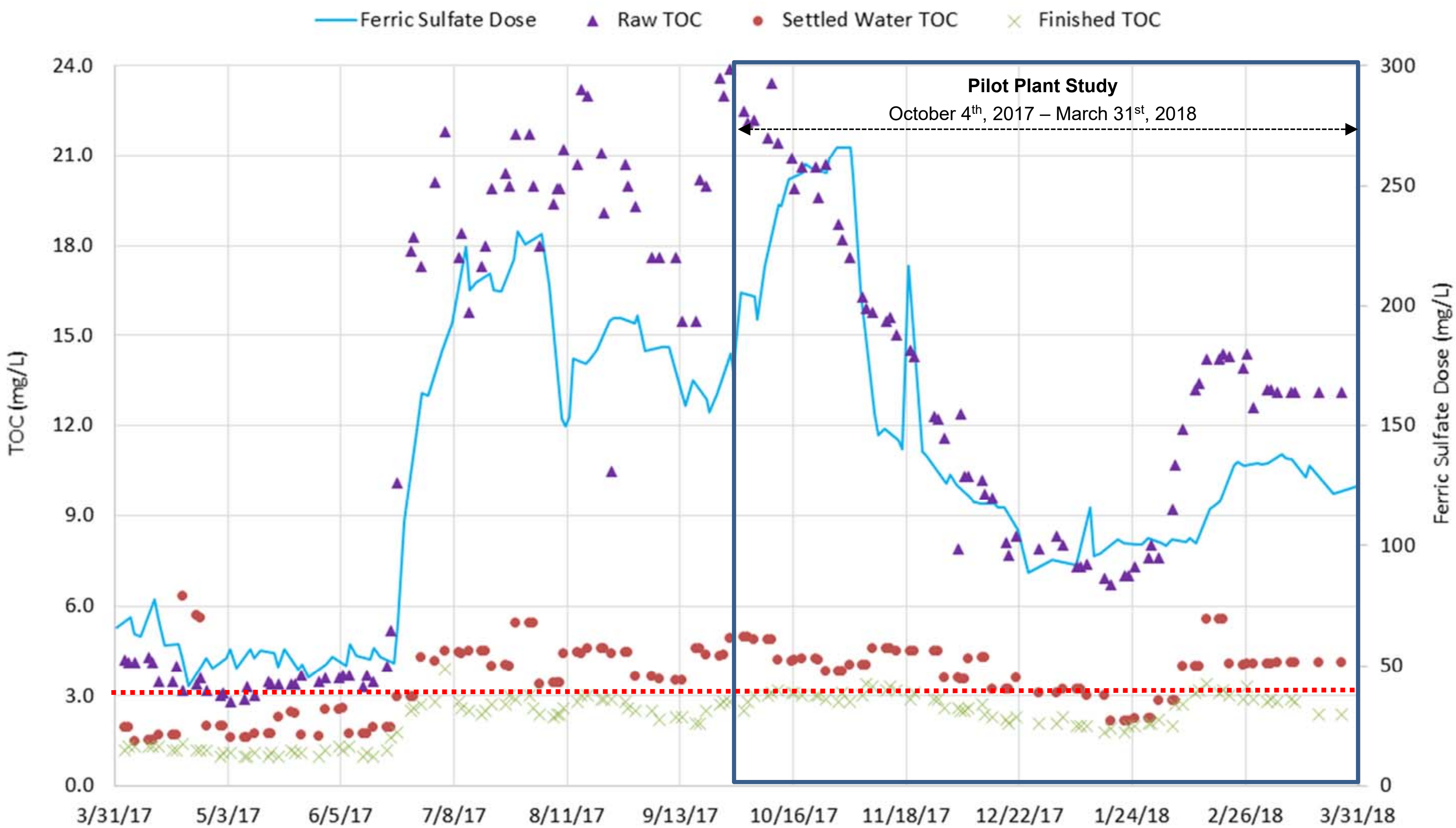
Figure 7 illustrates average raw, coagulation and Actiflo™ (settled water) effluent, and finished water TOC values, as well as applied coagulant dose. The time period shown includes March 2017 to March 2018 in order to show an entire year of seasonal data.

The full scale plant average coagulant dose ranged from 50 to 266 mg/L during the duration of the study, depending on influent TOC concentrations. As shown, a significant amount of TOC is removed through the existing treatment processes and regardless of season, the full scale plant consistently meets the finished water TOC goal (with minor exceedances during higher TOC periods). However, staff have noted that enhanced coagulation treatment becomes difficult during low TOC season.



FULL SCALE HISTORICAL RAW WATER FLOW

FIGURE 6



FULL SCALE TOC AND COAGULANT DOSE MARCH 2017 TO MARCH 2018

FIGURE 7

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Even when TOC is low (below 15 mg/L), a large amount of coagulant is still required and the enhanced coagulation process is less efficient. Based on this data, the average TOC removal during high TOC season ranged from 78 percent to 87 percent, with an average of 83.2 percent, while during low TOC seasons, removal ranged from 67 percent to 82 percent with an average removal of 75.5 percent. It is suspected this is due to changes in the type of organics between high and low TOC seasons. This is discussed further in Section 9.0.

In addition to ferric sulfate, a significant amount of sulfuric acid, lime, and caustic are required. Figure 8 shows these doses from March 2017 to March 2018 on the full scale system. As shown, during high TOC season, no acid addition is required. This is because the ferric sulfate dose is capable of lowering the pH adequately without the need for acid. During low TOC season, acid addition is required and subsequently results in the need for additional caustic and/or lime to raise the pH to the desired range alone before ozonation. Lime use over caustic use is preferential in terms of chemicals costs but due to the high alkalinity and hardness of this water, lime alone cannot be used for pH adjustment during this season. This is because the required dose of lime needed would result in increased turbidity and calcium carbonate precipitation.

6.2.3 Ozone

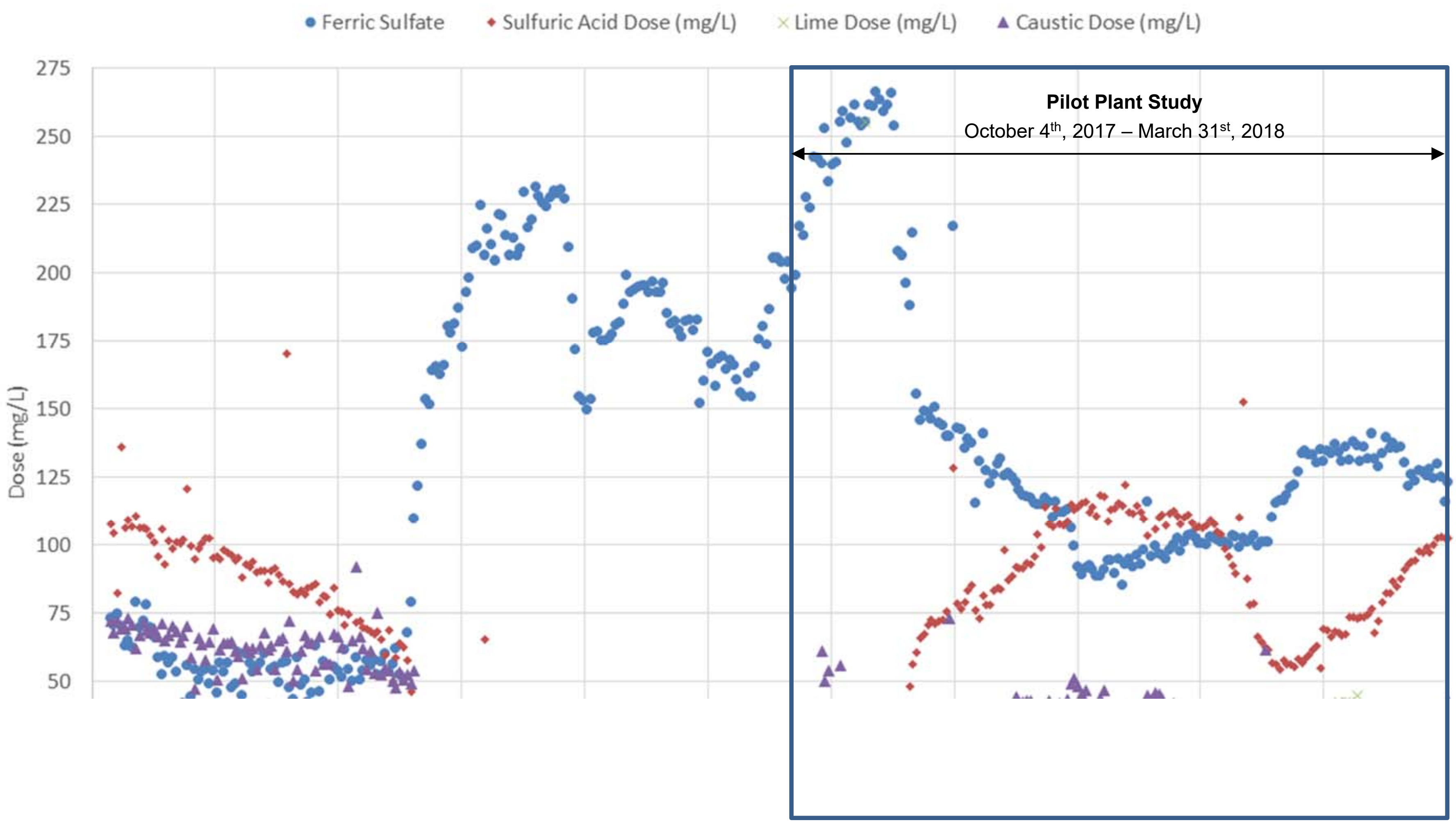
After pH adjustment of the settled water (target pH ~6.3 to 7.0), ozone effectively alters the characteristics of organic compounds and renders them more biodegradable and reduces taste and odor compounds. This can help maximize the efficiency of TOC removal in the biofilters. Ozone also dramatically reduces color by oxidizing the color-causing compounds in the incoming flow stream.

Ozone dose and residual data from March 2017 to March 2018 is shown in Figure 9. During this time, ozone dose ranged from 1.2 to 6.8 mg/L and seems to vary with influent TOC from July 2017 to March 2018. Interestingly, from March 2017 to July 2017 ozone dose was increasing despite TOC concentrations being relatively low. This is likely due to the impact by the significant decrease in raw water flow during this time period. Overdosing was likely occurring and can be assumed since ozone residual levels were also elevated at this time. Ozone residuals ranged significantly from 0.09 to 0.86 mg/L, with a few outlying data points.

6.2.4 Biofiltration

In depth analysis on the existing full scale biofilters is included in Chapter 3 and only parameters relevant to the pilot study will be discussed here and furthermore in Section 9.0.

The City provided average full-scale filter data for the duration of the pilot study (October 2017 to Mid-March 2018) that included average daily total plant effluent, total washwater, and average runtimes. The average filter runtimes and loading rates are shown in Figure 10.



FULL SCALE CHEMICAL DOSING MARCH 2017 TO MARCH 2018

FIGURE 8

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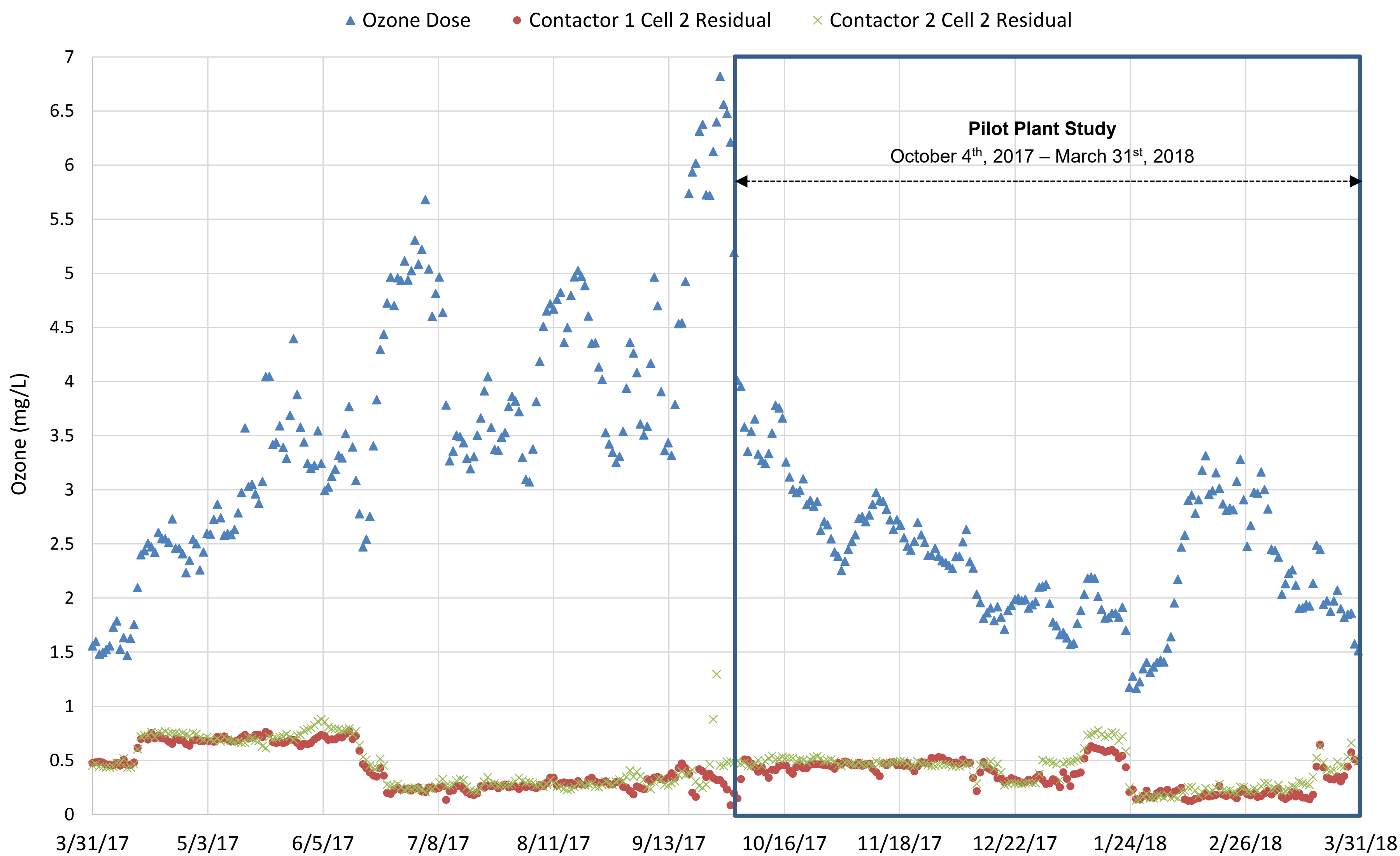

FULL SCALE OZONE DOSE AND RESIDUAL MARCH 2017 TO MARCH 2018

FIGURE 9

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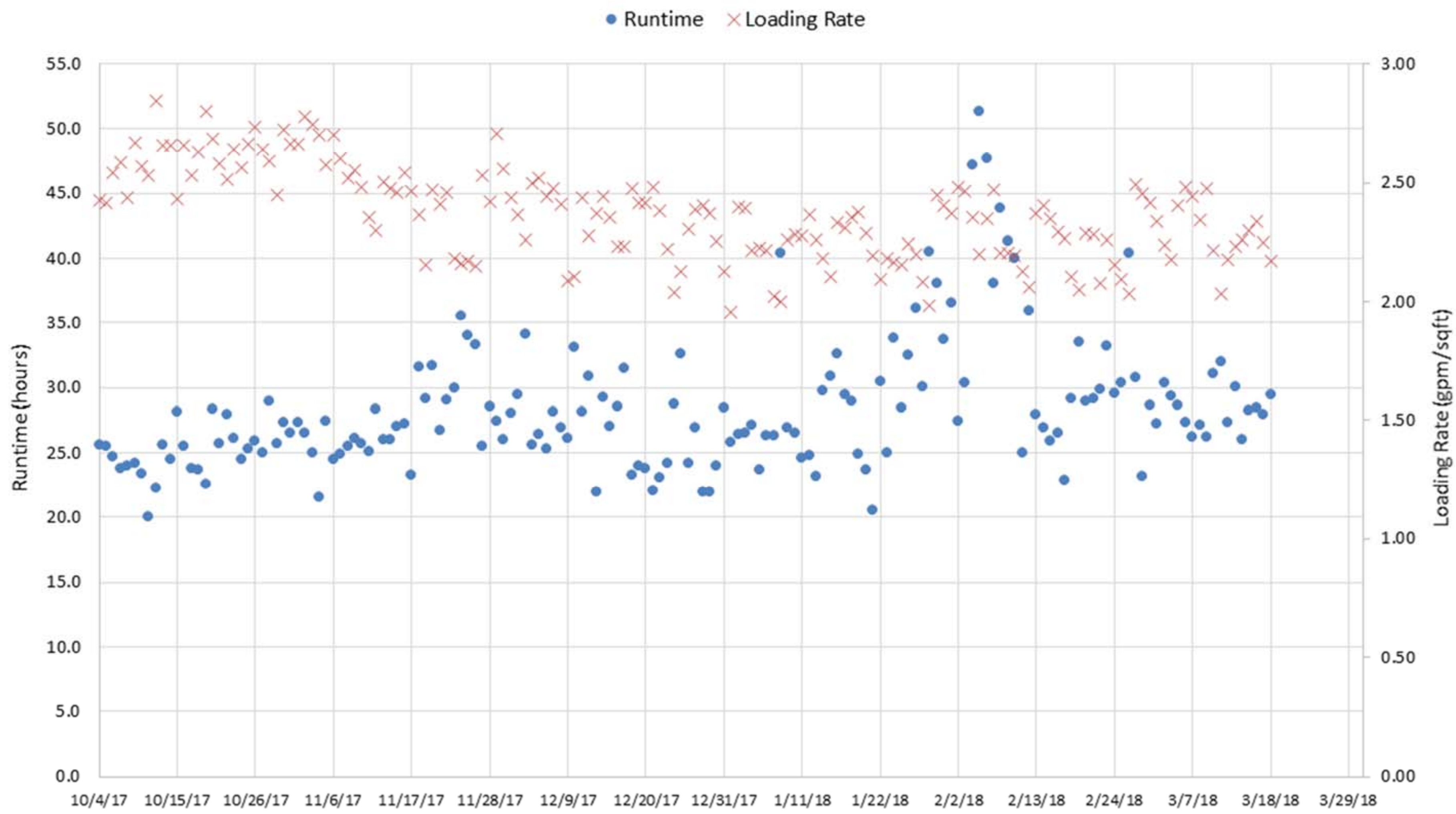

FULL SCALE AVERAGE FILTER RUNTIME AND LOADING RATES

FIGURE 10

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PILOT PLANT STUDY

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The average loading rate was 2.37 gpm/ft^2, which equates to 81.6 mgd of filtered effluent produced by the DLTWTF during the study. Filter runtimes increased temporarily in February.

Considering the full-scale total filter surface area of 23,936 square feet, also provided by the City, unit filter run volumes (UFRVs) were calculated. As shown in Figure 11, the average UFRVs are consistently between 3,500 and 4,500 gallons/ft^2 with the exception of an event in early February allowing for greater UFRVs. The increase in runtime and UFRVs during this timeframe could be due to a number of reasons; however, there was not enough full-scale data provided to verify the causes.

Additionally, full-scale unit filter solids loading rates (UFSLs) were determined. The unit filter solids loading rate (UFSL) is defined as the amount of solids applied to a filter over a specific hydraulic loading rate and time, and is in units of grams of solids per square foot of filter area. This analysis is typically determined using total suspended solids (TSS) data; however, this was not monitored during the pilot study. Therefore, an estimate of the suspended solids based on settled water turbidity was used. Typical conversion ratios of TSS to settled water turbidity ranges from 0.7 – 2.2 mg/L per NTU. A ratio of 1.0 was used for the purposes of this study. Settled water turbidity data was logged daily at full scale, and therefore the total UFSL was calculated as follows:

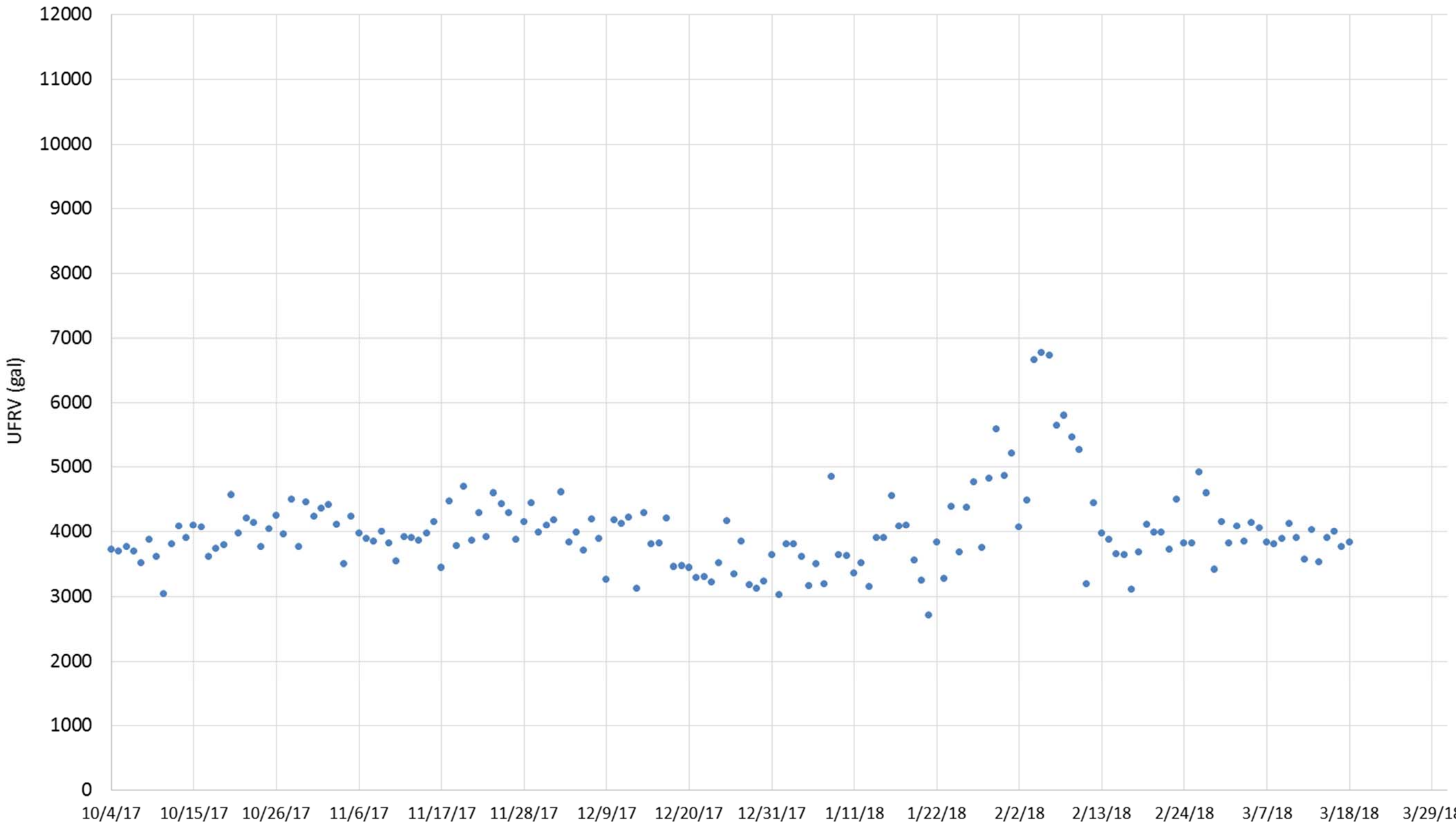
$$UFSL\ \left(\frac{grams}{ft^2}\right) = Settled\ Water\ Turbidity\ (NTU) * \frac{1.0\frac{mg}{L}TSS}{1\ NTU} * Filter\ Loading\ rate\ \left(\frac{gpm}{sqft}\right) * Total\ Filter\ Runtime\ (min) * \frac{3.78\ L}{gal} * \frac{1\ g}{1000\ mg}$$

The results of this calculation are shown in Figure 12. As expected, the USLFs increase with increase in settled water turbidity and were pretty consistent between 20 and 80 grams per square foot of filter area. This parameter is later compared to pilot-scale operations in Section 9.3.

7.0 RAW WATER QUALITY

Most of the raw water quality results detailed in this section were from the time period of the pilot study. Some historical information is included for relevance. All summarized historical water quality data is included in the Introduction Section of the Master Plan.

Typically, the raw water is provided by the Hillsborough River during average and high rainfall seasons, whereas the ASR well supplements flow during the dry season. During the pilot study, one of the three ASR supplies were in use and contributing flow to the DLTWTF, as shown in Table 12.



FULL SCALE FILTER UFRVS

FIGURE 11

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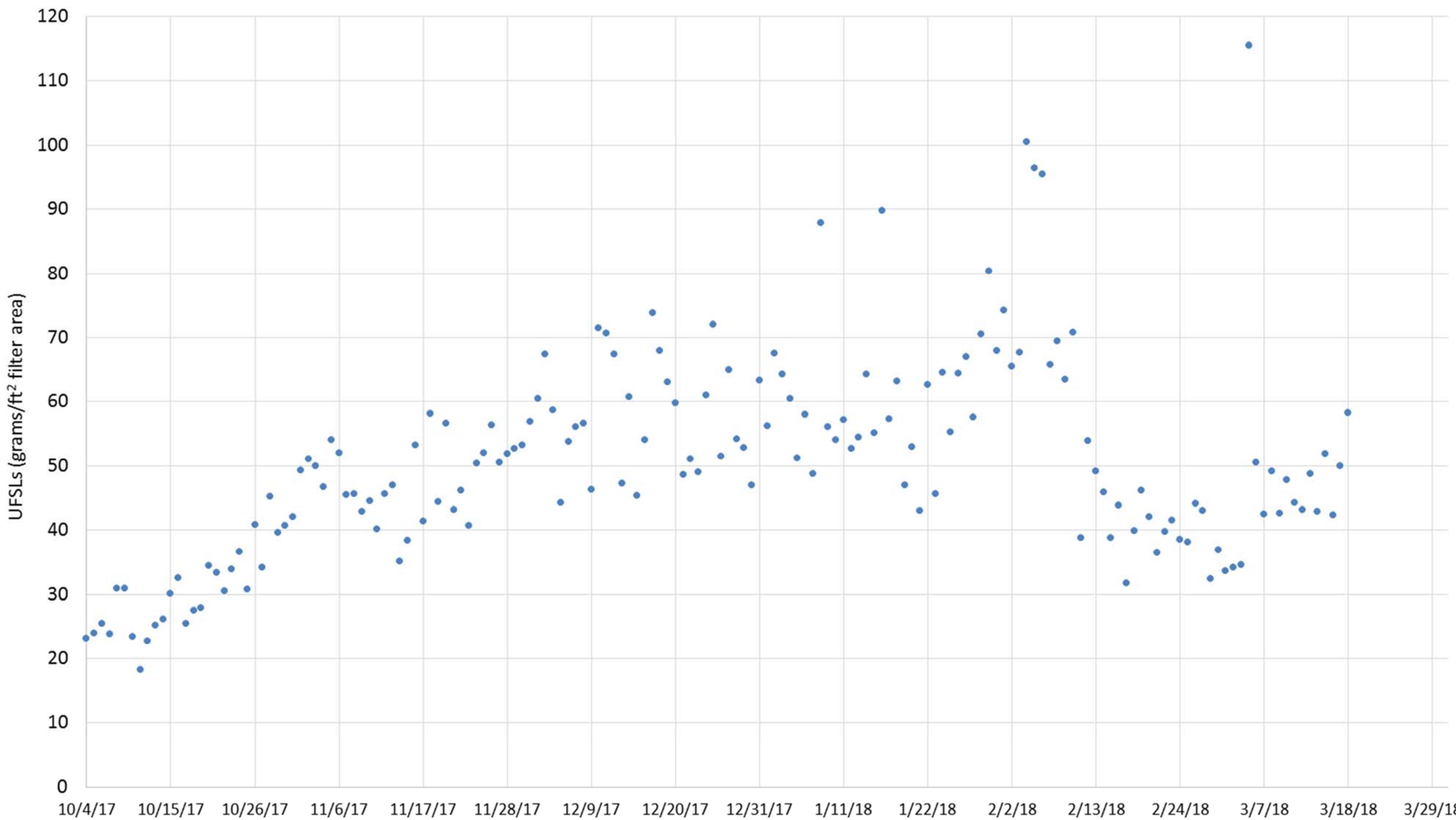


FULL SCALE FILTER UFSLS

FIGURE 12

CITY OF TAMPA
PILOT PLANT STUDY

Table 12	Aquifer Storage Recovery Use During Study David L. Tippin Water Treatment Facility Master Plan City of Tampa	
ASR	**Start**	**End**
TAP 1(1)	7/19/2017	3/6/2018
Rome Ave(2)	No Recovery During Pilot Study	
ASR B	No Recovery During Pilot Study	

Notes:

(1) Recovery Point is located at the Hillsborough River, upstream of the DLTWTF. Provided an average flow of 0.95 mgd.

(2) Recovery point is located at Junction Box 3, which is ultimately conveyed to the plant intake structure. Typically provided an average flow of 10 mgd.

Pilot scale raw water quality from October 4, 2017 - March 31, 2018 is summarized in Table 13. These results were from grab samples, not from the online monitoring systems.

Table 13	Raw Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
Turbidity	NTU	0.50 / 2.20 / 1.23	90
pH (Field)	std. units	6.87 / 8.19 / 7.42	90
Temperature	˚C	10.9 / 27.9 / 20.8	90
Alkalinity	mg/L as CaCO3	64.0 / 153 / 122	90
TOC	mg/L	6.40 / 24.1 / 12.6	90
Filtered UV254	cm-1	0.23 / 1.13 / 0.54	90
Color	pcu	40.0 / 250 / 103	90
Conductivity	µS/cm	214 / 464 / 343	19
Free Ammonia	mg/L as N	0.05 / 0.17 / 0.07	20
MIB(1)	ng/L	3.2	1
Geosmin(1)	ng/L	1.0	1
Orthophosphate	mg/L	/ 0.28 / 0.12	52
Sulfate	mg/L	4.80 / 105 / 20.1	52
Chloride	mg/L	11.9 / 25 / 20.6	53
Bromide	µg/L	50.1 / 81.1 / 66.3	20
Arsenic	µg/L	8.0e-04 / 1.9e-03 / 1.1e-03	19
Nitrite	mg/L as N	BDL	53

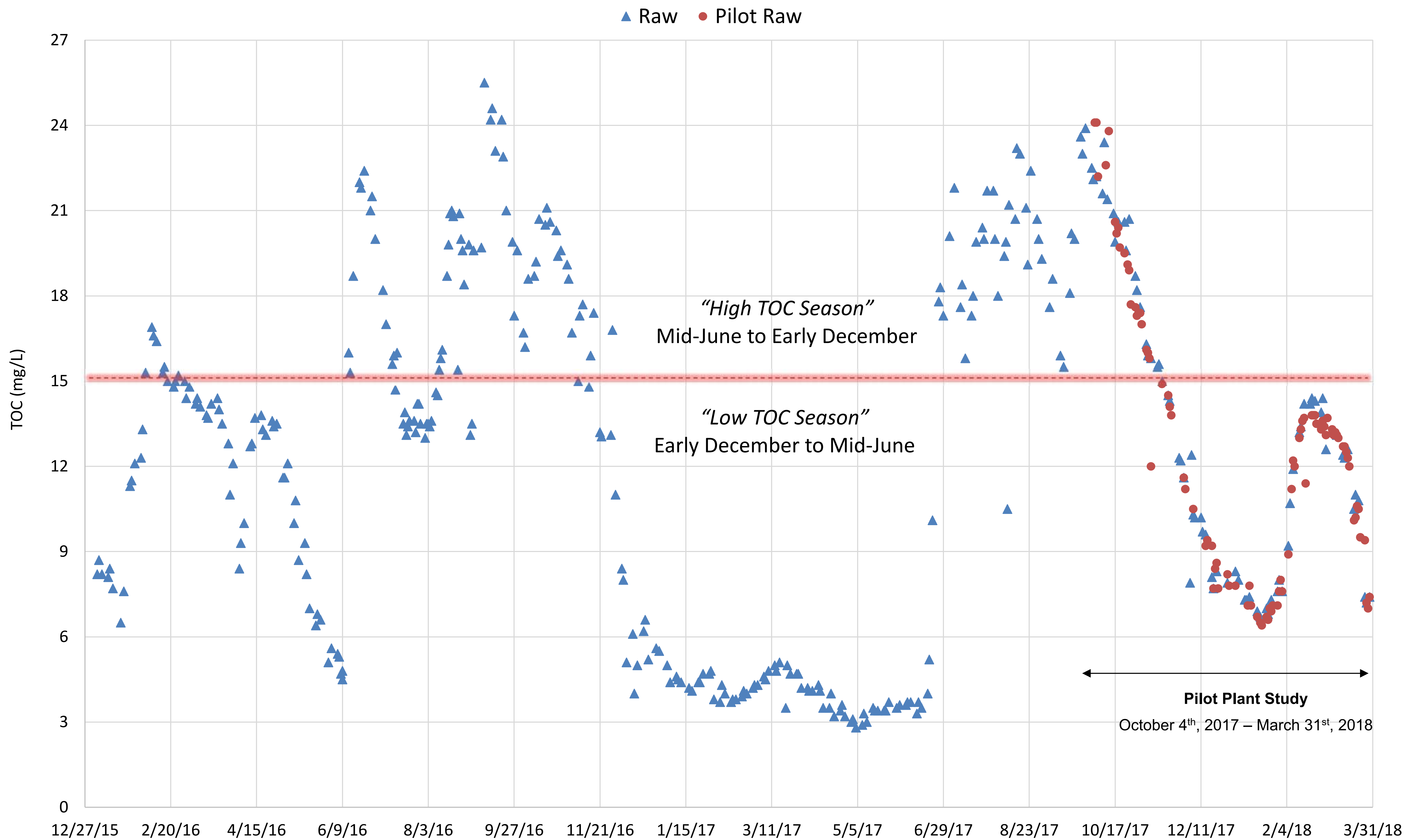
Table 13	Raw Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
Nitrate	mg/L as N	0.025 / 0.394 / 0.131	53
Hardness	mg/L as CaCO3	84.0 / 210 / 156	53
Iron	mg/L	0.082 / 0.481 / 0.226	52
Magnesium	mg/L	2.46 / 5.91 / 4.04	19
Manganese	mg/L	BDL / 0.025 / 0.012	51
Fluoride	mg/L	0.17 / 0.56 / 0.25	53
Notes: (1) One sample taken on 3/28/2018			

Numerous water quality parameters are important to consider for both primary and secondary drinking water standards yet a few parameters deserve additional consideration. The following subsections include further detail on these parameters. Other water quality parameters are discussed in depth in subsequent sections based on their relevance to each process. Additionally, plots of raw, MIEX® treated, settled water, as well as ozone effluent, and filtered effluent monitored water quality parameters are available in Appendix D.

7.1.1 Dissolved and Total Organic Carbon

Due to the DLTWTF's source of raw water, dissolved and total organic carbon varies seasonally, which is typically dependent on rainy and dry seasons. TOC is a measure of both dissolved and particulate organic carbon, while DOC is only a measure of dissolved organic carbon. For the DLTWTF, dissolved and total organic carbon measurements have a high correlation. Therefore DOC was not monitored as frequently and TOC was used to determine process performance and organics removal.

Figure 13 shows historical raw TOC data from the full scale system. Based on this trend and for purposes of this study, high TOC (above 15 mg/L) season is assumed to occur every year from June 15th to December 1st, and low TOC (below 15 mg/L) season from December 1st to June 15th. Figure 13 also shows the raw water TOC for the full scale and pilot scale systems for the duration of the pilot study to illustrate the similar influent water quality, which allows for TOC removal comparisons discussed later in Section 9.0.



FULL SCALE HISTORICAL RAW WATER TOC

FIGURE 13

CITY OF TAMPA
PILOT PLANT STUDY

7.1.2 UV 254

Similarly to TOC, UV254 provides an indication of the amount of aromatic organic matter present, which also varies seasonally. As shown in Figure 14, there is a correlation between raw TOC and filtered UV254, and therefore the City utilized an online UV254 analyzer for continuous monitoring and process control of the floc/sed pilot unit. The online analyzer samples were not filtered, and settled water turbidities were consistently greater than 1 NTU; therefore, the data was only used to determine relative process performance on a day to day basis.

Also shown in Figure 14 are the settled water filtered UV254 results versus the settled water TOC with and without MIEX® pretreatment. As expected, since MIEX® and enhanced coagulation remove different types of organics, the correlations for each condition are slightly different with MIEX® pretreatment showing a most positive correlation.

7.1.3 Turbidity

The DLTWTF's raw water turbidity is considered low but does vary seasonally. Lack of turbidity can make the coagulation process less efficient when not utilizing enhanced coagulation since the particles necessary for floc agglomeration are minimal.

7.1.4 pH and Alkalinity

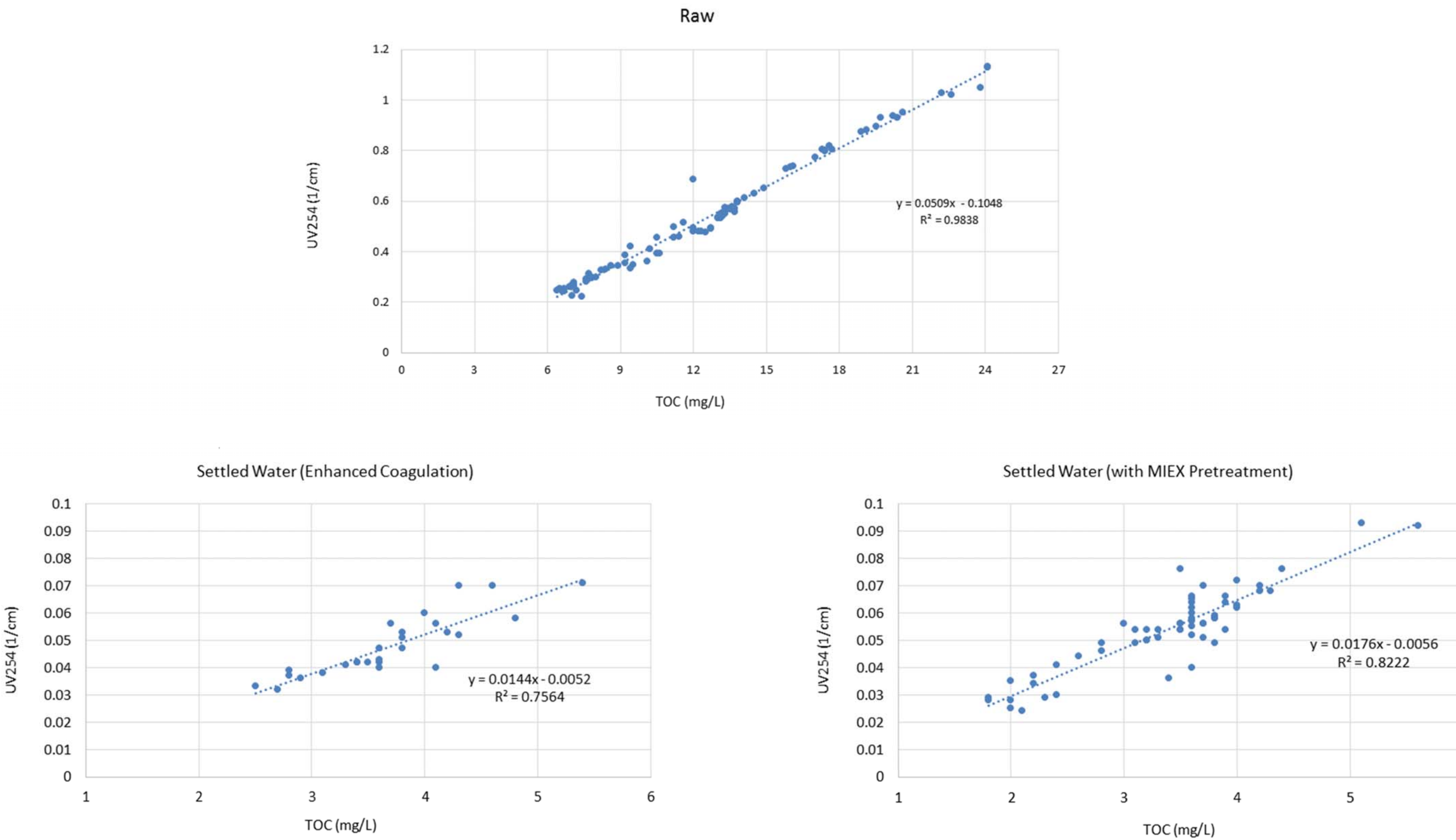
Raw water pH and alkalinity are shown in Figure 15. Since the City's primary treatment process employs enhanced coagulation, influent raw water pH and alkalinity can have major impact on operations. When alkalinity is low, pH can be more difficult to control since the buffering capacity of the water is inhibited. Conversely, when alkalinity is high, additional pH adjustment chemicals (namely sulfuric acid and caustic) are needed to lower and raise the pH to the required level.

7.1.5 Hardness

Hardness, defined as the amount of dissolved divalent cations (magnesium and calcium) in water, seasonally varies, as shown in Figure 16. Staff have noted higher raw water hardness when ASR wells are in recovery. Typically, lime and caustic are needed to adequately bring the pH up before ozonation.

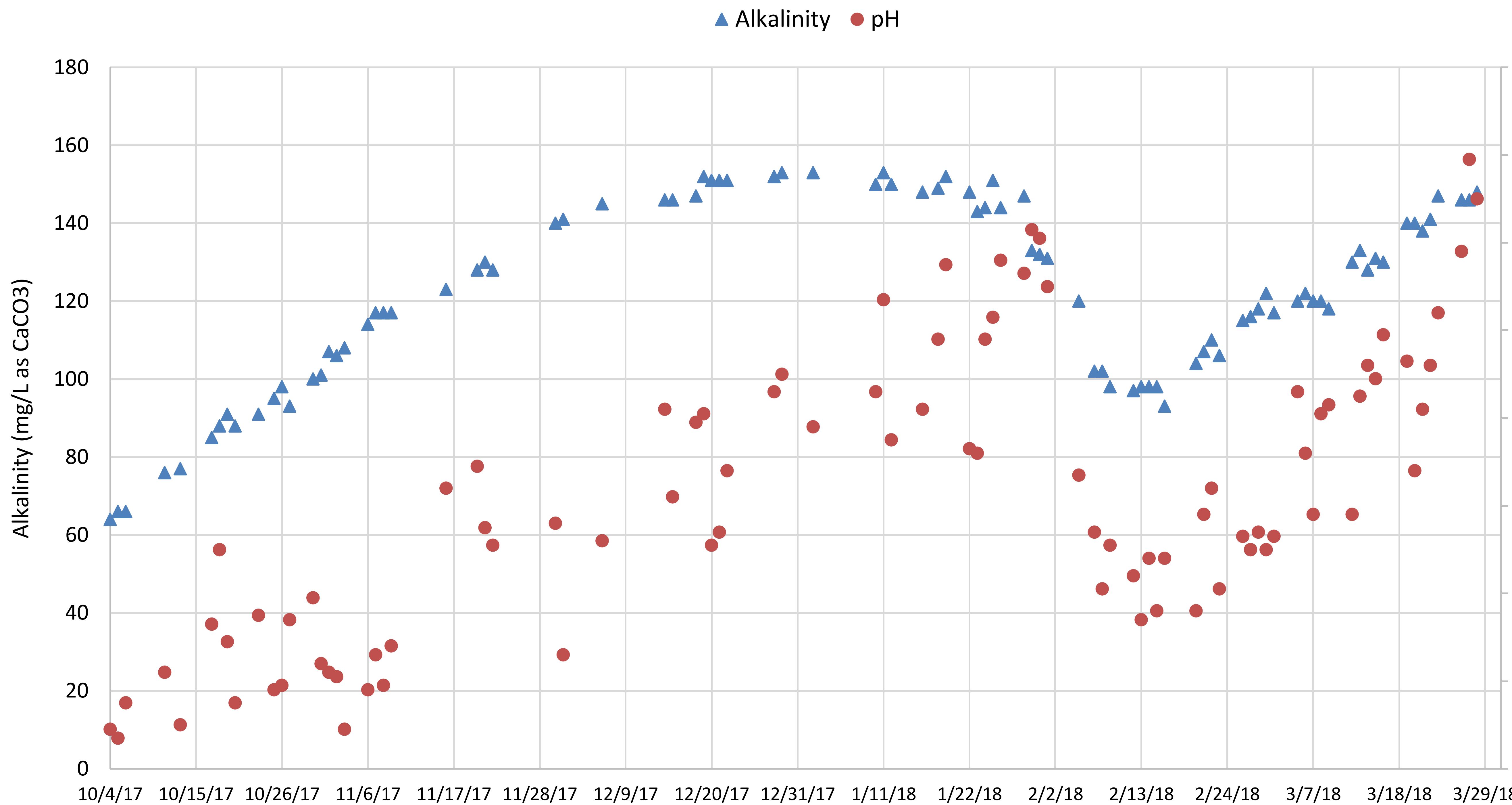
7.1.6 Color

Raw water color over the course of the pilot study is shown in Figure 17. Color is an indication of the organic content of water and includes humic and fulvic acids, natural metallic ions (i.e. iron and manganese), and turbidity. Apparent color is measured on unfiltered samples and true color is measured in filtered (0.45 micron filter) samples. Based on Standard Method 2120B, the City did not filter the samples and therefore all references to color results will be with respect to apparent color.



PILOT SCALE RAW AND SETTLED UV254 VS TOC

FIGURE 14



RAW WATER ALKALINITY AND PH

FIGURE 15

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PILOT PLANT STUDY

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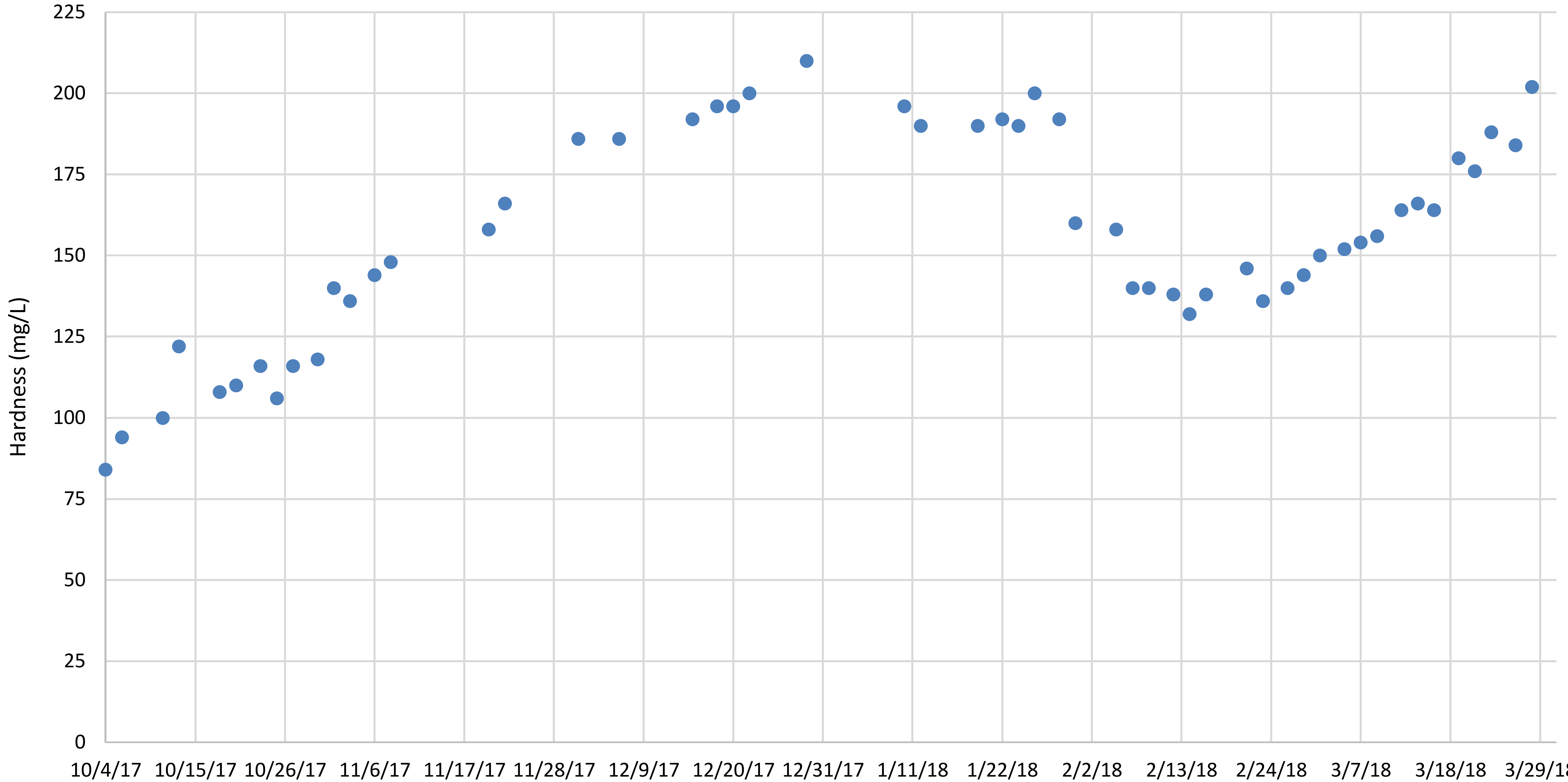

RAW WATER HARDNESS

FIGURE 16

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PILOT PLANT STUDY

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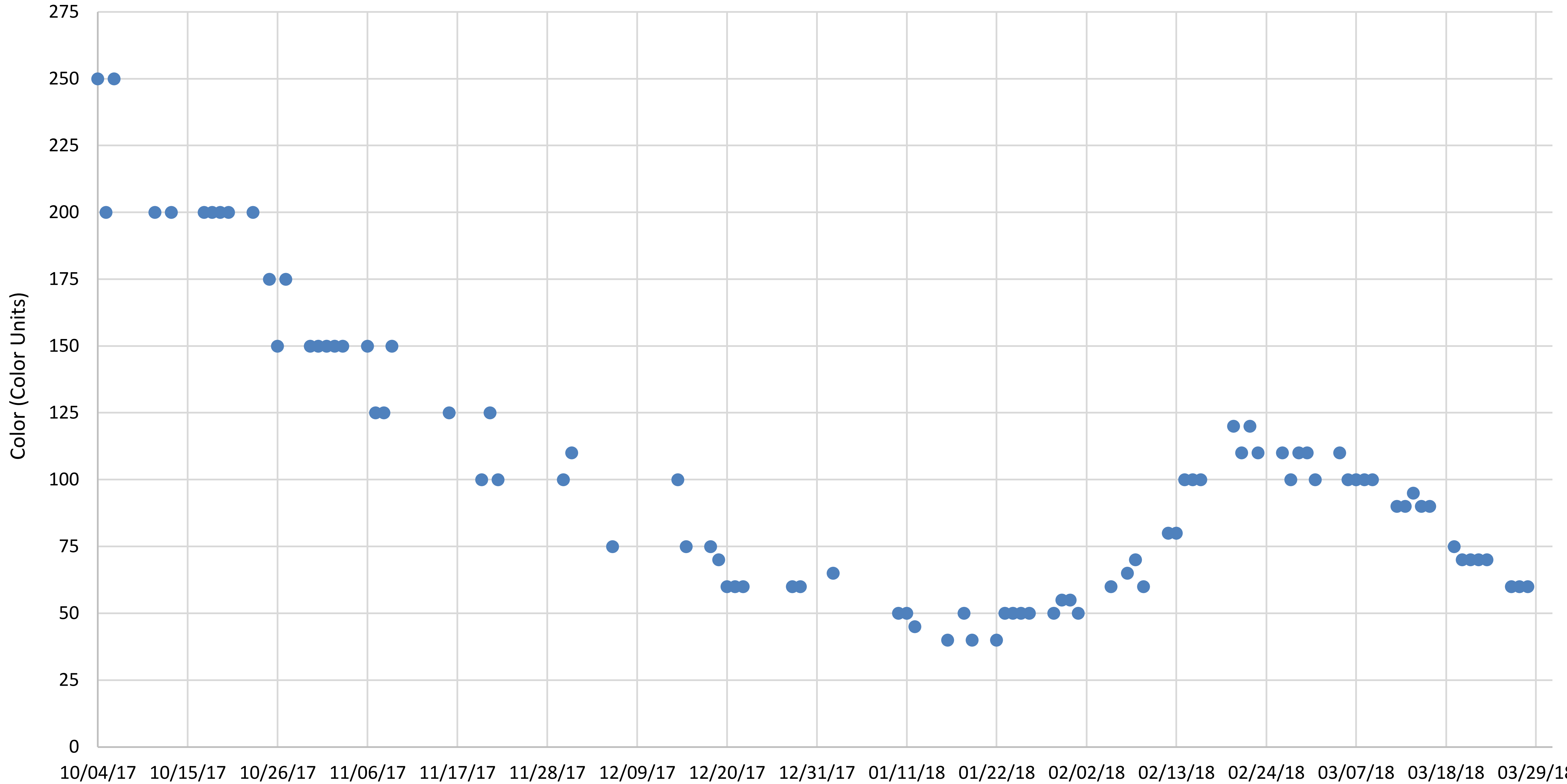

RAW WATER COLOR

FIGURE 17

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PILOT PLANT STUDY

Color has a secondary drinking water standard of 15 color units for aesthetic reasons. Color and TOC fluctuate together seasonally, and similarly color can reach high values (when compared to other surface water plants in Florida) which must be reduced through the DLTWTF's treatment process before distribution.

8.0 PROCESS PERFORMANCE

8.1 MIEX®

8.1.1 Process Operation

The MIEX® system was operated as a pretreatment step to the coagulation process and was operated during times of high and low TOC, as follows:

- October 7th - November 24th, 2017
  - 600 BV
  - Chlorine (started November 1st), Ferric Sulfate
  - High TOC Season
- January 8th – January 21st, 2018
  - 600 BV
  - Chlorine, Ferric Sulfate
  - Low TOC Season
- January 22nd - March 8th, 2018
  - 1000 BV
  - Chlorine, Ferric Sulfate
  - Low TOC Season

Salt usage was also monitored and originally estimated to be 1.5 bags/salt per week of MIEX® operation, however, actual salt usage averaged 2.5 bags/salt per week.

Pre-chlorination was required due to biological growth witnessed on the MIEX® resin. During high TOC season the average dose required was 3.9 mg/L of sodium hypochlorite, and low TOC season required 2.6 mg/L, for an overall average of 2.9 mg/L.

8.1.2 Effluent Water Quality

Effluent water quality data is shown in Table 14 which includes the minimum, maximum, and average values witnessed throughout the duration of the pilot study when the unit was in operation. Additional details on specific water quality parameters of interest will be discussed further in the Performance subsection.

Table 14	MIEX® Effluent Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
Turbidity	NTU	1.00 / 3.00 / 1.84	62
pH (Field)	std. units	6.82 / 7.99 / 7.33	62
Temperature	˚C	11.3 / 27.8 / 21.0	62
Alkalinity	mg/L as CaCO3	64.0 / 148 / 108	62
TOC	mg/L	2.20 / 9.60 / 5.02	61
Filtered UV254	cm-1	0.03 / 0.46 / 0.18	61
Color	pcu	10 / 150 / 52.1	61
Conductivity	µS/cm	233 / 457 / 358	14
Free Ammonia	mg/L as N	0.02 / 0.14 / 0.06	14
Orthophosphate	mg/L	0.01 / 0.21 / 0.07	37
Sulfate	mg/L	1.00 / 17.7 / 6.72	21
Chloride	mg/L	31.7 / 50.5 / 41.0	36
Bromide	µg/L	52.3 / 87.9 / 68.0	15
Nitrite	mg/L as N	BDL	37
Nitrate	mg/L as N	0.025 / 0.343 / 0.122	37
Hardness	mg/L as CaCO3	92.0 / 200 / 148	38
Iron	mg/L	0.09 / 0.47 / 0.22	37
Manganese	mg/L	0.005 / 0.025 / 0.012	36
Fluoride	mg/L	0.17 / 0.28 / 0.21	37

8.1.3 Performance

The primary water quality parameter of interest when discussing MIEX® process performance is organics removal. Therefore, this section will focus on the MIEX® system's ability to remove or reduce TOC, UV254, and color. Additional water quality parameters of interest that will be discussed further are chloride and sulfate. Overall process performance for the pilot and comparative full scale performance will be discussed in Section 9.0.

8.1.3.1 TOC

The MIEX® system operated during the High TOC period from October 10th to November 27th, 2017. During this time frame, the pilot plant ran at a bed volume treatment rate (BVTR) of 600 BV.

Figure 18 shows the raw and MIEX® treated TOC values and percent removal throughout the study when MIEX® was in operation. The raw water TOC ranged from 13.8 to 23.8 mg/L during the high TOC period declining steadily and, despite a declining raw water TOC, the MIEX® unit achieved steady TOC removal with an average removal of 58.1% during this time.

During the Low TOC period, MIEX® was operated from January 8th – March 9th, 2018. Initially, the unit was operated at 600 BV; however, Multiple Load Jar testing was conducted by IXOM on January 11th, and the results showed that there was limited added treatment benefit, in terms of organics removal, operating at 600 BV compared to 1000 BV. Therefore, on January 22nd, the pilot plant BVTR was changed to 1000 BV. During this time frame, the raw TOC ranged from 6.4 to 13.8 mg/L. Despite the change in BVTR, the removal during this time frame was higher (average 65.7% removal) and more consistent across the lower range of raw water TOC concentrations. Although limited in data, the results also show that when the raw water TOC is below 7 mg/L, the MIEX® effluent TOC fell below 3 mg/L, meeting the current finished water goal alone before coagulation and filtration.

These results show that the MIEX® process is capable of producing low TOC effluent under dynamic conditions of widely varying and quickly changing influent water quality. The improvement in performance during low TOC season could be due to the difference in the type of organics during high and low TOC seasons. The MIEX® treatment process is known to remove smaller (low molecular weight humic substances and acid), non-aromatic type organics, while the enhanced coagulation process removes larger, aromatic type organics. During low TOC seasons, it’s likely the former type of organics are present, and during high TOC seasons, the latter.

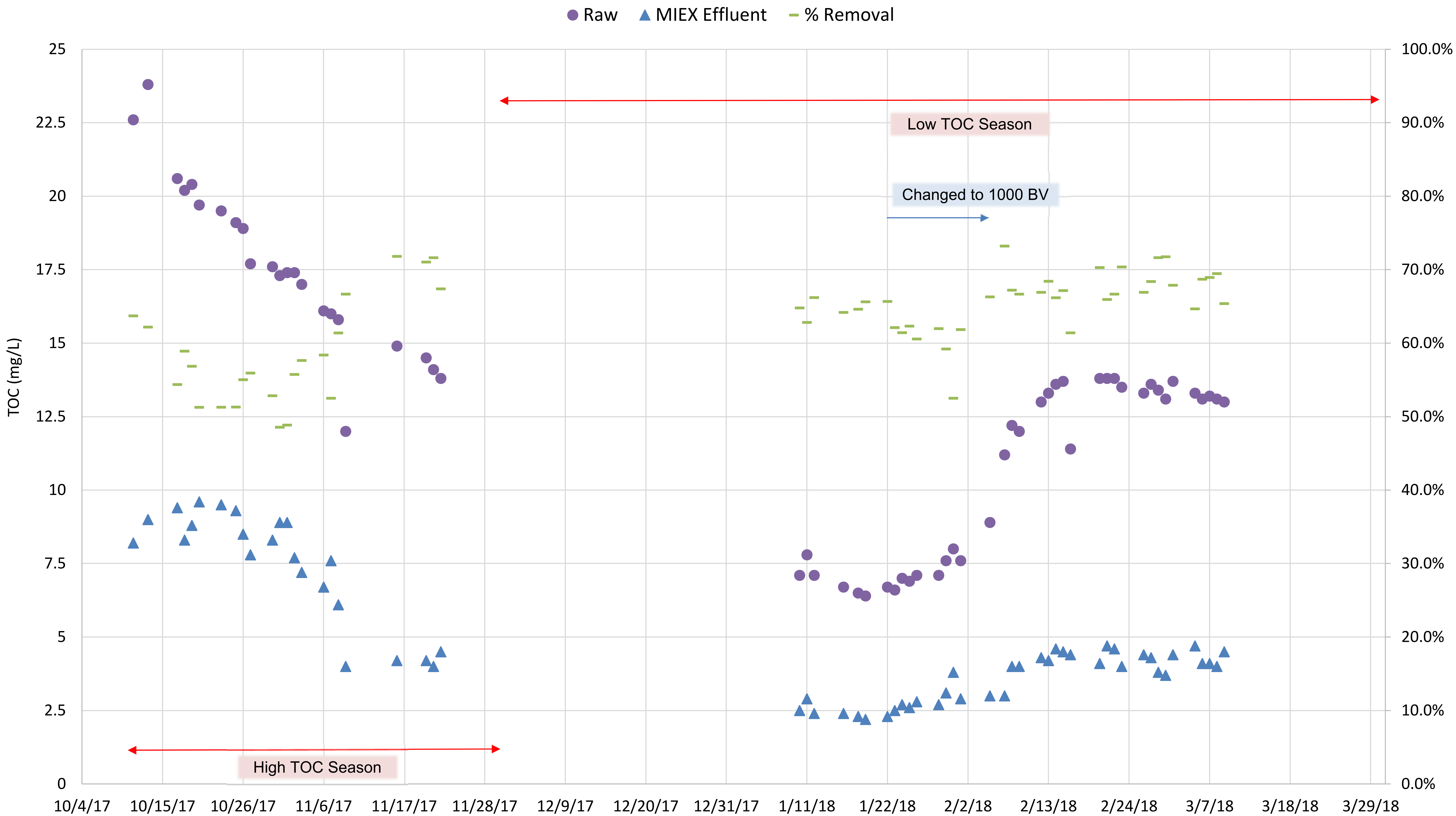
8.1.3.2 Color

Typically, the primary constituent of color is naturally occurring organic matter, which can be removed through the MIEX® treatment process; however, it sometimes can include inorganics like iron and manganese that MIEX® cannot remove.

Figure 19 shows the raw and MIEX® treated water color values (primary axis) and overall percent removal (secondary axis) during times when MIEX® was in operation. As shown, the MIEX® system performed better during low TOC season in regard to percent removal. This suggests that the color causing compounds in low TOC season are more organic in nature, versus high TOC season where they’re more inorganic.

8.1.3.3 Filtered UV254

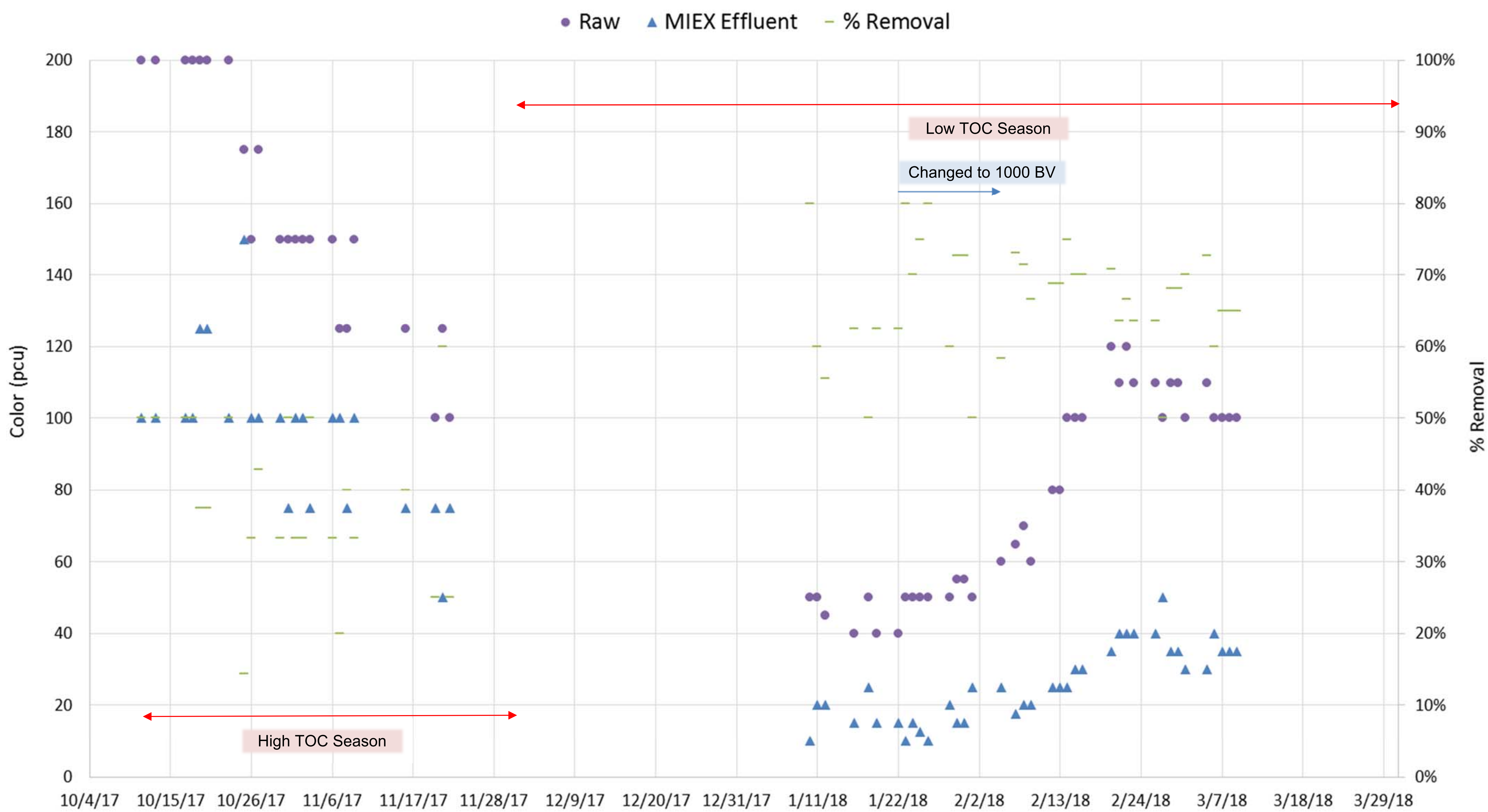
Similarly to color, UV254 can be reduced by the MIEX® treatment process. Figure 20 shows the raw and MIEX® treated effluent filtered UV254 values and corresponding percent removal. Once again, the MIEX® system performed better in regard to percent removal during the low TOC season.



PILOT SCALE RAW AND MIEX TREATED TOC

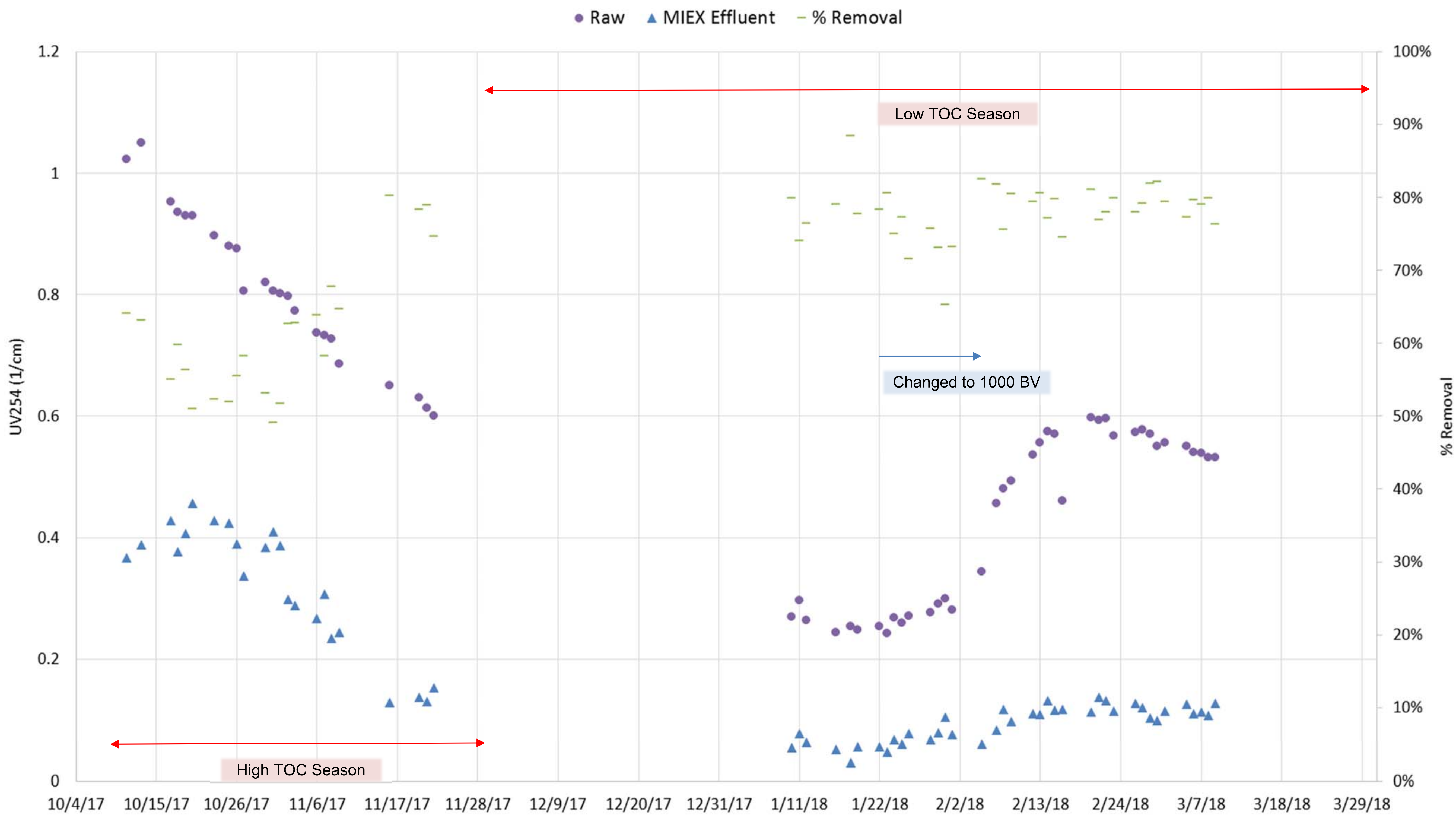
FIGURE 18

CITY OF TAMPA
PILOT PLANT STUDY



PILOT SCALE RAW AND MIEX TREATED COLOR

FIGURE 19



PILOT SCALE RAW AND MIEX TREATED UV254

FIGURE 20

8.1.3.4 Chloride and Sulfate

Since the MIEX® system is an anionic exchange process that exchanges the chloride ion for negatively charged organic compounds, it would be expected that the chloride concentration would increase after MIEX® treatment and ultimately finished water (since it is not removed by ozone or filtration). Additionally, due to the reduced chemical demand downstream of MIEX® (discussed in depth in Section 9.0), the use of ferric sulfate and sulfuric acid is greatly reduced allowing for reduction in sulfate concentration in the finished water. This behavior is illustrated in Figure 21 for the filtered effluent for Filter 1, representing the trend witnessed in all filters.

Also shown on Figure 21 are values for the chloride-to-sulfate mass ratios (CSMR) during times when MIEX® was on and off. It has been found that CSMR values greater than 0.58 can result in lead leaching in distribution systems with lead pipe. As shown, the CSMR is altered and increased significantly with MIEX® pretreatment and therefore could cause serious contamination issues if the City's distribution system has lead pipe. However, City staff has noted that there is currently no lead pipe within the system; therefore, this may not be a major concern if MIEX® pretreatment is implemented full scale.

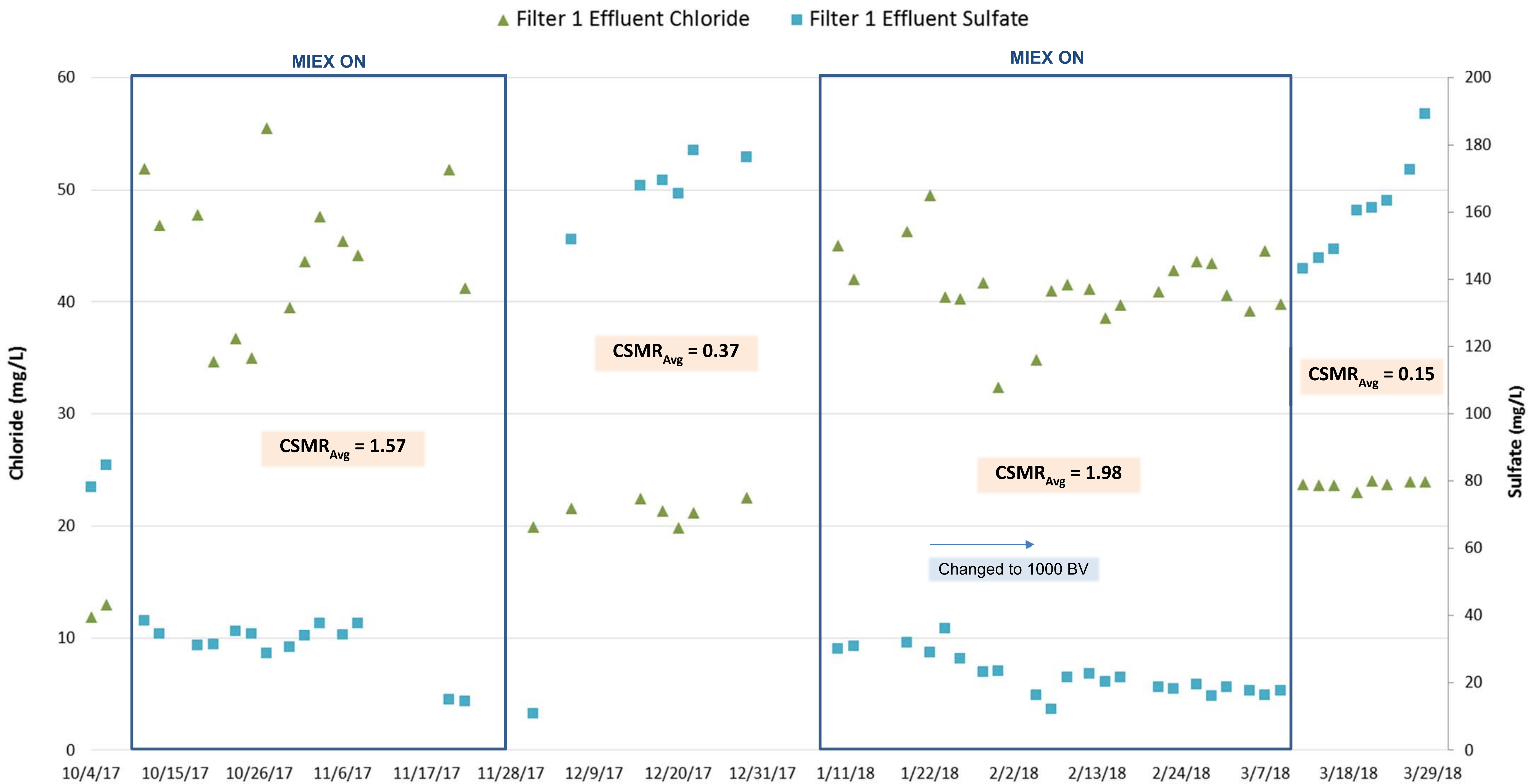
8.1.4 VSEP Brine Treatment

Waste brine treatment batch tests using the VSEP system were conducted by IXOM on January 31st, 2018 and April 9th, 2018. During the January 31st test run, 205 gallons of waste brine was treated and the unit was run to 50% recovery with samples collected throughout. The vibration amplitude was held at ¾" and the feed pressure was maintained at 400 psig resulting in a flux rate of 20.6 gallons per square foot per day.

Table 15 below shows the results at 50% recovery for the January 31st run. The membrane unit accomplished a 98% rejection of the DOC throughout the run, indicating the ability of the unit to reject the TOC and produce a clean saline permeate stream. The unit passed just approximately 50% of the monovalent salt through the membrane, which was anticipated with the NF membrane. The VSEP Data and run log are included in the Appendix G for reference.

Table 15 VSEP Results
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Feed	Permeate	Concentrate
Total DOC (g/L)	2.58	0.124	5.85
Total Salt (NaCl) (g/L)	45.3	46.9	57.3
Total Dissolved Solids (g/L)	67.9	46.7	96.7



PILOT PLANT FINISHED CHLORIDE & SULFATE

FIGURE 21

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PILOT PLANT STUDY

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The resulting sodium chloride concentration in the permeate after waste brine treatment was 46.9 g/L. At this concentration, recycling the permeate to the saturator in lieu of make-up water could result in a 30% salt savings. It should be noted that IXOM reported that due to concentrations of the samples, a dilution of 350 was used for sample analysis and likely impacted analytical accuracy. Additionally, due to the limited data, there is not statistical confirmation that these results would be witnessed full scale.

8.1.4.1 BORAC Waste Disposal

Samples of the collected VSEP concentrate reject were shipped to BORAC for offsite analysis and testing. While waste brine concentrate samples were collected for Borac testing, the limited amount of sample did not allow for process confirmation. IXOM reported that the initial study did show that Borac's treatment process could effectively process the waste brine provided; however, further samples are required to develop confirmatory process parameters and cost benefit analysis.

8.2 Coagulation, Flocculation, Sedimentation

8.2.1 Process Operation

Coagulation using ferric sulfate was the primary mode of treatment within the floc/sed system, regardless of MIEX® operation. Chemical dosing scheme was adjusted to properly achieve conditions for treatment and operations throughout the study were as follows:

- October 4th - 6th, 2017
  - MIEX® Off
  - Ferric Sulfate, Sulfuric Acid, Caustic
  - High TOC Season
- October 7th - November 24th, 2017
  - MIEX® On
  - Chlorine, Ferric Sulfate
  - High TOC Season
- November 27th, 2017 - January 5th, 2018
  - MIEX® Off
  - Ferric Sulfate, Sulfuric Acid, Caustic
  - Mid to Low TOC Season
- January 8th - March 8th, 2018
  - MIEX® On
  - Chlorine, Ferric Sulfate
  - Low TOC Season

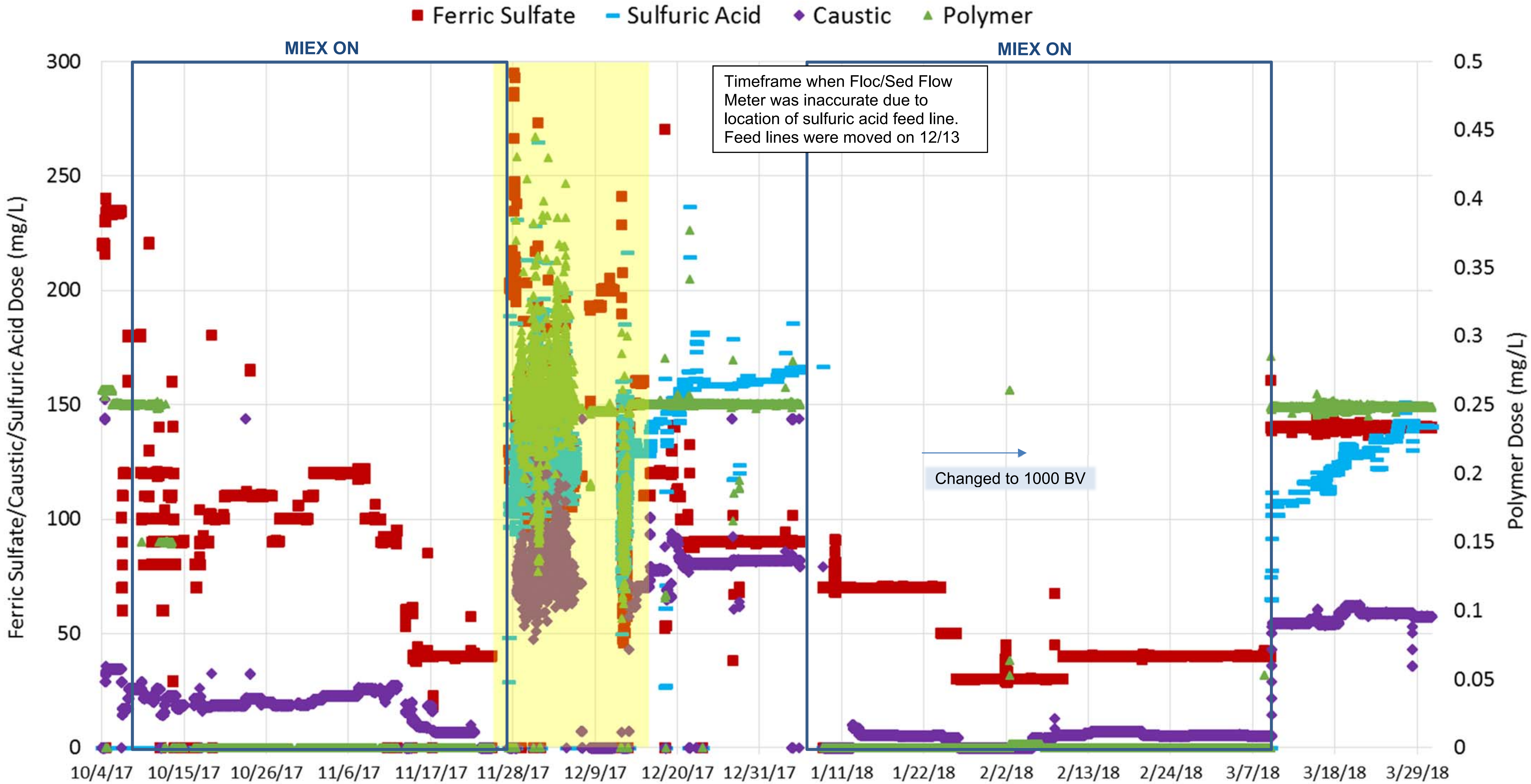
- March 9th - March 31st, 2018
  - MIEX® Off
  - Ferric Sulfate, Sulfuric Acid, Caustic
  - Low TOC Season

The chemical dosing scheme varied according to raw water quality and if MIEX® pretreatment was in use. As stated previously, the City utilized an online UV analyzer on the pilot settled water to help quantify and monitor process performance. The City would increase or decrease chemical dosage based on these readings daily to match the full-scale system. Figure 22 shows the chemical dosing throughout the study from the online chemical feed logger on the floc/sed unit. As shown, sulfuric acid was not required when the MIEX® system was online and there was a corresponding reduced demand for caustic. Additionally floc aid polymer was not utilized during MIEX® operation. PolyDADMAC, a high molecular weight polymer was utilized February 2^{nd}-9^{th} to witness benefits in conjunction with MIEX® pretreatment; however, there were mechanical and subsequent dosing issues that did not allow for consistent feed during this whole timeframe. Furthermore, process performance improvement was not witnessed with the addition of this chemical. Chemical use is discussed further in Section 9.0.

Coagulation pH was also adjusted based on if MIEX® pretreatment was in use. Figure 23 shows the online pH data for the floc/sed unit. As shown, coagulation pH is much lower when MIEX® was offline, as would be expected since sulfuric acid was used. Also, when MIEX® was offline, there was an increase in the variability of the settled water pH. This is due to the addition of acid and subsequent addition of caustic for pH control and associated difficulties in dosing 'just right' to hit a more neutral pH.

8.2.2 Effluent Water Quality

Effluent water quality varied depending on whether MIEX® was in operation or not. The data summarized in this section includes minimum, maximum, and average values witnessed throughout the duration of the pilot study with MIEX® on and off. Additional details on specific water quality parameters of interest will be discussed further in the Performance subsection.



PILOT PLANT FLOC/SED UNIT CHEMICAL DOSING

FIGURE 22

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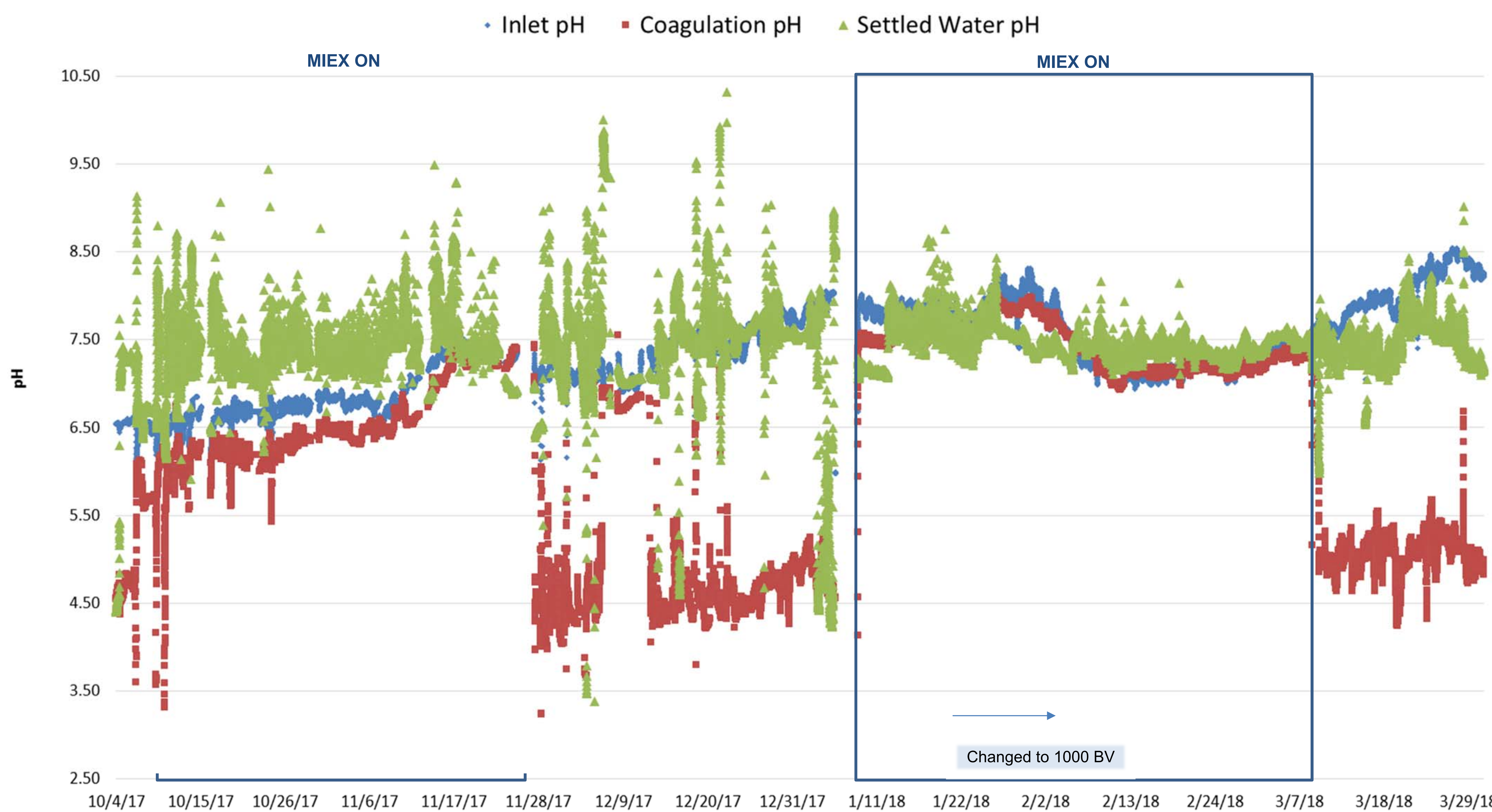
PILOT PLANT STUDY



PILOT PLANT FLOC/SED UNIT PH

FIGURE 23

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PILOT PLANT STUDY

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8.2.2.1 MIEX® On

The effluent water quality from the floc/sed skid when the MIEX® system was running is summarized in Table 16.

Table 16 Settled Water Effluent with MIEX® Pretreatment Water Quality Results
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Units	Value (Min/Max/Avg)	No. of Samples
Turbidity	NTU	0.80 / 3.60 / 1.84	60
pH (Field)	std. units	6.25 / 7.59 / 6.98	61
Temperature	˚C	12.2 / 27.9 / 20.8	60
Alkalinity	mg/L as CaCO3	28.0 / 133 / 90.7	61
TOC	mg/L	1.80 / 5.60 / 3.37	61
DOC	mg/L	1.70 / 4.00 / 2.94	61
Filtered UV254	cm-1	0.02 / 0.10 / 0.06	61
Color	pcu	20.0 / 125 / 46.6	61
Conductivity	µS/cm	304 / 463 / 374	13
Free Ammonia	mg/L as N	0.05 / 0.28 / 0.10	14
Orthophosphate	mg/L	BDL	36
Sulfate	mg/L	12.5 / 38.9 / 25.7	36
Chloride	mg/L	29.5 / 54.3 / 42.1	36
Bromide	µg/L	54.9 / 87.8 / 66.9	14
Arsenic	µg/L	4.6e-04 / 1.4e-03 / 7.2e-04	13
Nitrite	mg/L as N	BDL	34
Nitrate	mg/L as N	0.025 / 0.768 / 0.137	36
Hardness	mg/L as CaCO3	98.0 / 202 / 146	36
Iron	mg/L	1.14 / 3.18 / 1.97	35
Manganese	mg/L	0.005 / 0.025 / 0.011	35
Fluoride	mg/L	0.14 / 0.30 / 0.22	35

8.2.2.2 MIEX® Off

The effluent water quality from the floc/sed skid when the MIEX® system was not running is summarized in Table 17.

Table 17	Settled Water Effluent without MIEX® Pretreatment Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
Turbidity	NTU	1.00 / 9.80 / 4.65	29
pH (Field)	std. units	3.82 / 7.71 / 5.02	29
Temperature	˚C	15.7 / 27.2 / 20.7	29
Alkalinity	mg/L as CaCO3	1.00 / 30.0 / 3.85	29
TOC	mg/L	2.50 / 4.80 / 3.60	28
DOC	mg/L	1.90 / 4.20 / 2.75	29
Filtered UV254	cm-1	0.03 / 0.09 / 0.05	29
Color	pcu	7.00 / 100 / 43.9	29
Conductivity	µS/cm	269 / 519 / 428	6
Free Ammonia(1)	mg/L as N	0.08	1
MIB(2)	ng/L	3.50	1
Geosmin(2)	ng/L	40.0	1
Orthophosphate	mg/L	BDL	17
Sulfate	mg/L	14.8 / 191 / 145	17
Chloride	mg/L	11.6 / 23.9 / 21.2	17
Bromide	µg/L	52.5 / 82.5 / 66.8	6
Arsenic	µg/L	4.0e-04 / 8.5e-04 / 5.2e-04	6
Nitrite	mg/L as N	BDL	17
Nitrate	mg/L as N	0.025 / 0.256 / 0.114	17
Hardness	mg/L as CaCO3	86.0 / 206 / 174	17
Iron	mg/L	0.87 / 4.12 / 2.30	17
Manganese	mg/L	0.010 / 0.020 / 0.014	16
Magnesium(3)	mg/L	2.52	1
Fluoride	mg/L	0.15 / 0.28 / 0.23	17

Notes:

(1) One sample taken on 10/6/2017.
(2) One sample taken on 3/28/2018.
(3) One sample taken on 10/4/2017.

8.2.3 Performance

This section focuses on the performance of the floc/sed skid in regard to the following water quality parameters of interest:

- Alkalinity

- Color
- Sulfate
- Turbidity
- TOC

The remaining results of the settled water quality parameters shown in Section 8.2.2 either 1) did not vary based on MIEX® operation (whether on or off, i.e. similar effluent results witnessed), 2) are not expected to be removed through coagulation, or 3) were not sampled enough for legitimate comparability, and are not discussed in detail here but included in the Appendix for reference: For example, UV254 was used for process control and therefore did not vary significantly regardless of treatment (because a value was targeted and treatment was adjusted to consistently hit that target). These parameters may be discussed in other Sections where applicable and significant.

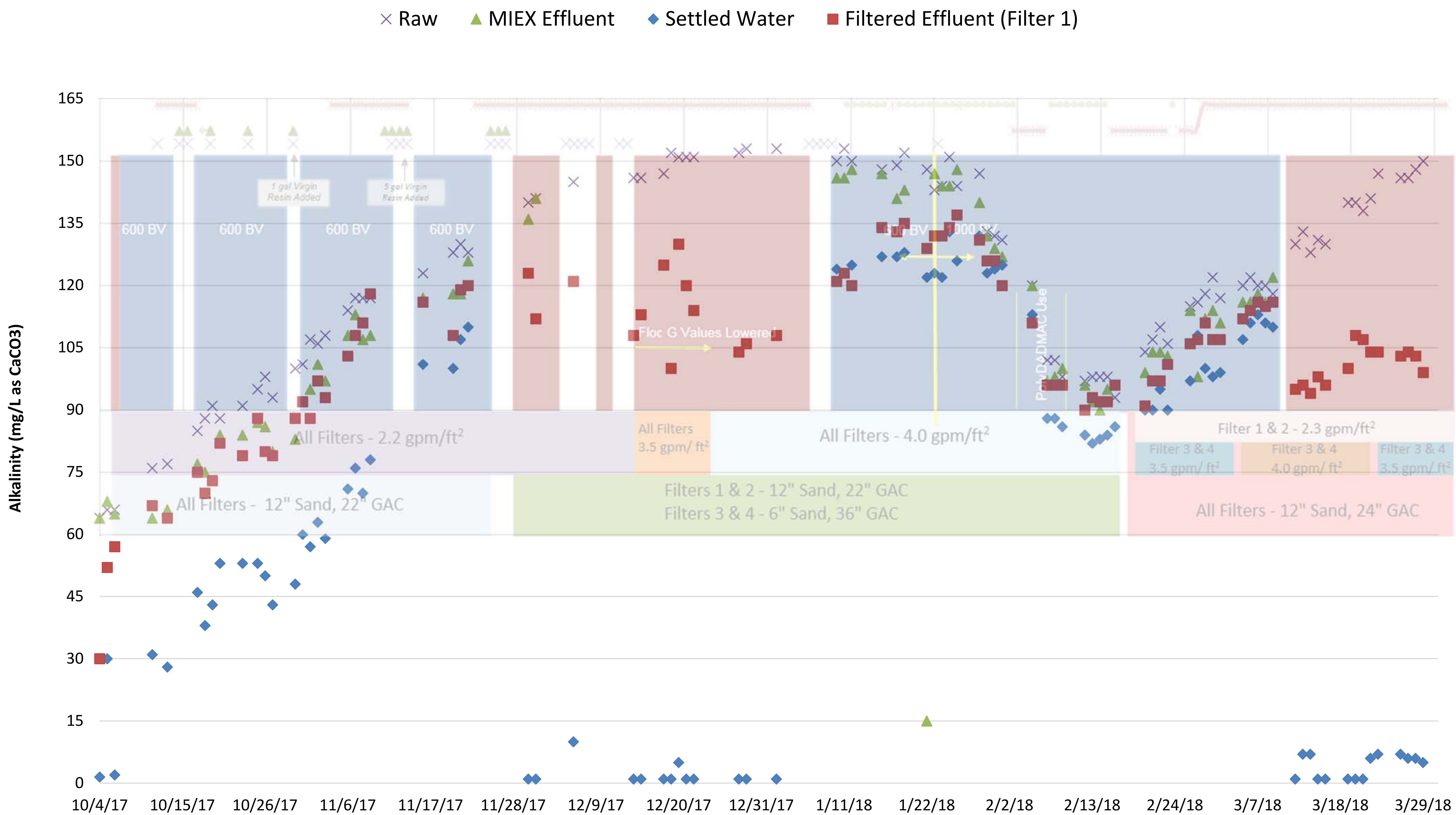
Performance of this unit compared to full scale performance will be discussed in Section 9.0.

8.2.3.1 Alkalinity

Figure 24 shows the alkalinity measured in the raw water, MIEX® effluent, settled water (post coagulation), and filtered effluent (Filter 1) for the duration of the study. It can be seen that when enhanced coagulation was employed (no MIEX® pretreatment), alkalinity in the settled water was less than 15 mg/L due the depressed pH. The alkalinity is ultimately recovered upon addition of caustic and corresponding pH adjustment; however, the total carbonate makes pH adjustment more difficult to control. This can lead to an increase in ozone demand, thereby impacting downstream treatment. Additionally, alkalinity during this type of treatment isn't as adequately restored to raw water levels when compared to implementation of MIEX® pretreatment.

8.2.3.2 Sulfate

Chloride and sulfate levels were previously discussed in Section 8.1.3.4; however, of additional note; Sulfate has a secondary drinking water standard MCL of 250 mg/L and lead to corrosion and black water issues in elevated levels. During periods when MIEX® was off and enhanced coagulation only was employed, significantly elevated sulfate levels are experienced. This is due to the increase in ferric sulfate and sulfuric acid addition required for treatment. Although below MCL levels for the study, sulfate is not removed through ozonation or filtration and therefore should be considered when comparing pretreatment versus no pretreatment, especially during high TOC season when chemical doses are higher.



PILOT PLANT ALKALINITY

FIGURE 24

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PILOT PLANT STUDY

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8.2.3.3 Turbidity

Similarly to the trends witnessed for sulfate, Figure 25 shows how there is an increase in settled water turbidity when MIEX® is not implemented; this is also witnessed in the online turbidity monitoring data shown in Figure 26. This could be due to the high concentration of ferric sulfate and increase in caustic dose required to stabilize pH resulting in higher turbidity readings. Additionally, towards the end of the study, when enhanced coagulation only was employed, the settled water turbidity trends down due to the steady increase in acid use which acted as a coagulant and removed turbidity.

8.2.3.4 Color

Similarly to TOC, color varies seasonally as shown in Figure 27. From October 2017 through the beginning of January 2018, settled water color was relatively consistent regardless of MIEX® operation. However, during January – March MIEX® operation, the color is actually increased through coagulation. This is not expected and could be due to the interference of settled water turbidity since it was marginally higher during this time frame. Measurement of true color rather than apparent color would eliminate turbidity interferences and confirm removal through the MIEX and coagulation processes (which are both widely known to remove color).

8.2.3.5 TOC

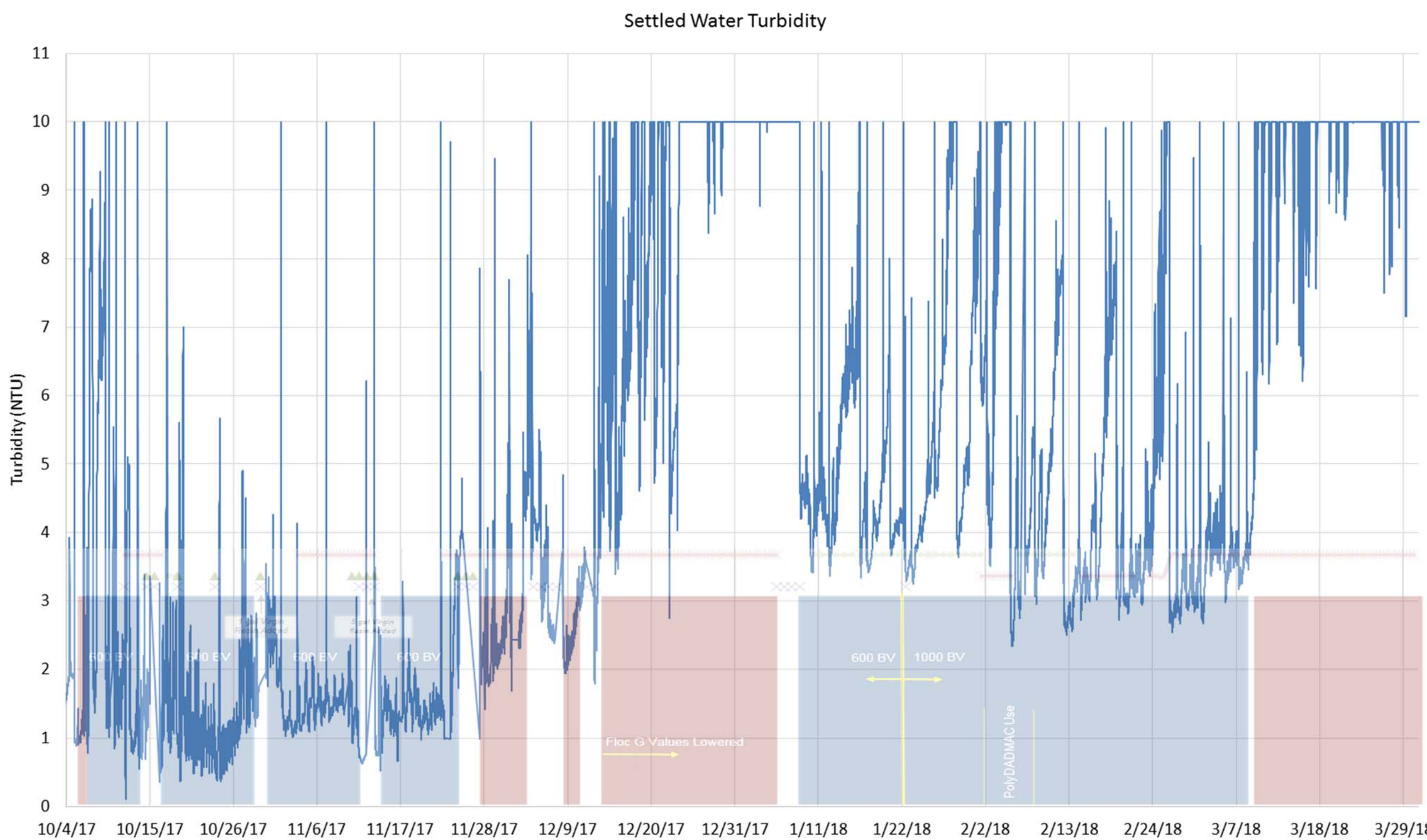
In alignment with the DLTWTF's finished water quality goals, TOC removal is the primary process driver for operations. Figure 28 shows the influent TOC concentrations to the floc/sed skid as well as the settled water TOC.

As shown and as expected, the influent TOC to the floc/sed unit was greater during times when MIEX® pretreatment was not employed (since the influent would be the same as the raw water supply). There is little difference in settled water TOC concentration when comparing MIEX® pretreatment vs no pretreatment. However, when observing high TOC season vs low TOC season it can be seen that the enhanced coagulation process following MIEX® is more efficient in TOC removal in the former, and significantly less efficient in the latter. In fact, the average TOC removal through coagulation during MIEX® operation and high TOC season was 3.8 mg/L (48%), while only 0.5 mg/L (15%) removal in low TOC season.

While chemical dosing was significantly reduced during low TOC season with MIEX® pretreatment and cost savings are realized, the additional 0.5 mg/L removal still comes at a significantly higher cost when considering the dollars spent per pound of TOC removed. Figure 29 shows these values graphically. Therefore, if chemical dosing could be modified to focus on producing a settable and filterable floc, as opposed to removing as much TOC as possible, then additional cost savings could be realized. Conversely, when TOC was high and with MIEX® pretreatment, the unit cost is less than the unit cost for enhanced coagulation only operation. Economic considerations are discussed further in Section 10.0.

PILOT PLANT TURBIDITY

FIGURE 25



PILOT PLANT FLOC/SED UNIT ONLINE TURBIDITY

FIGURE 26

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PILOT PLANT STUDY

PILOT PLANT COLOR

FIGURE 27

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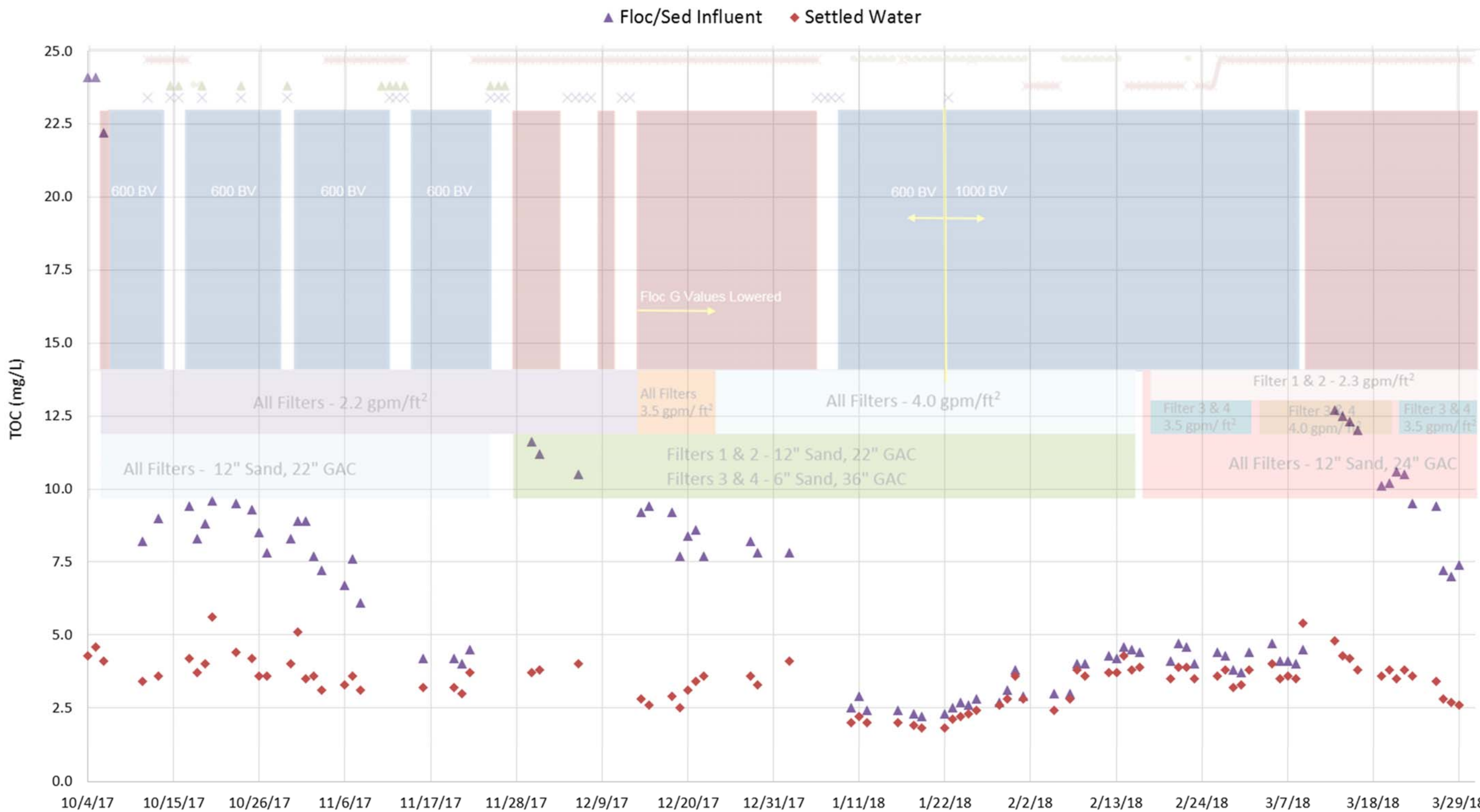
PILOT PLANT STUDY



PILOT SCALE FLOC/SED INFLUENT AND SETTLED WATER TOC

FIGURE 28

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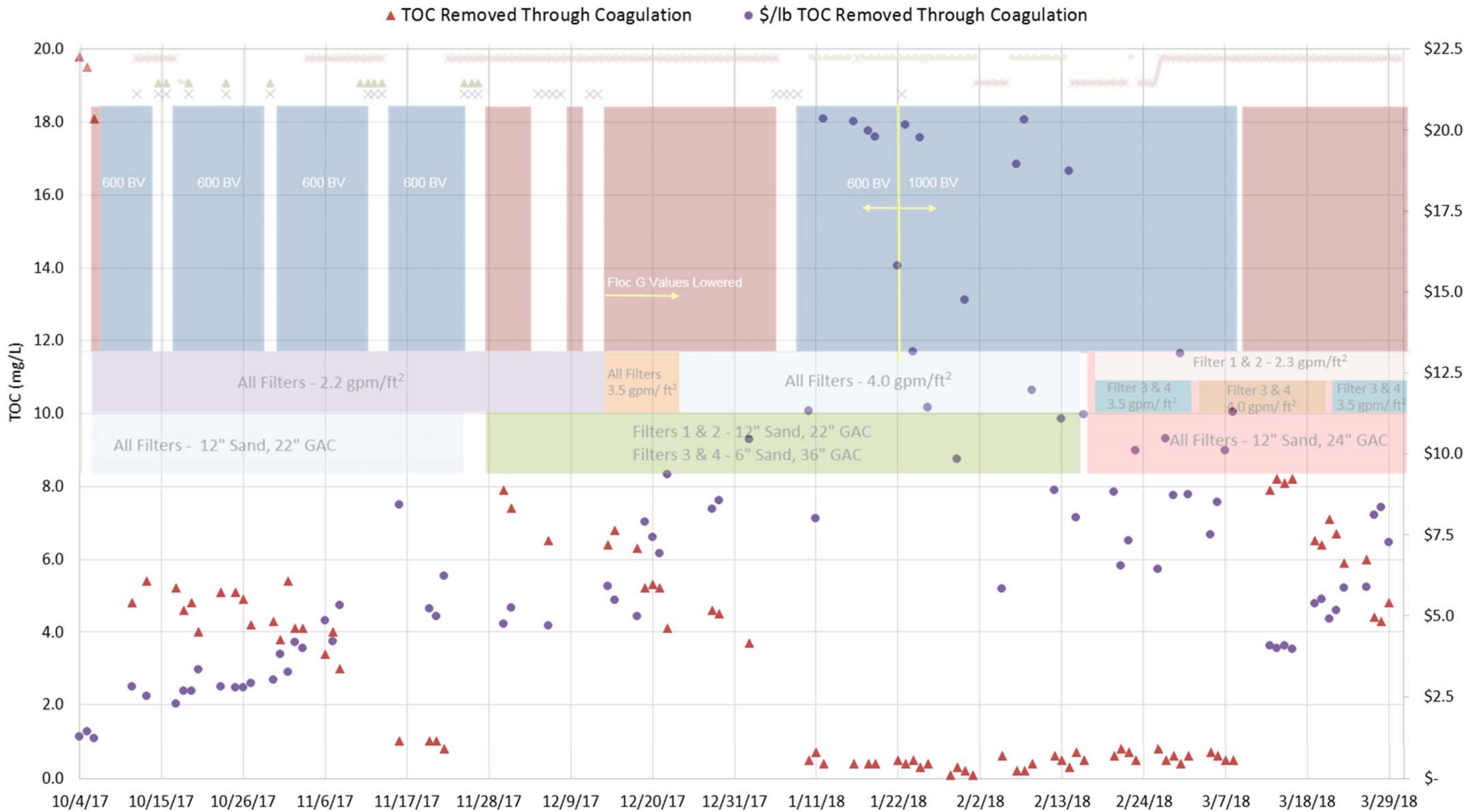
PILOT PLANT STUDY



PILOT SCALE TOC REMOVED THROUGH COAGULATION AND ASSOCIATED COSTS

FIGURE 29

CITY OF TAMPA
PILOT PLANT STUDY

8.3 Ozone

8.3.1 Process Operation

The target ozone residual for duration of the pilot study was 0.30 mg/L at 5.0 minute contact time to match full scale operations. However, ozone demand fluctuated based on the influent water quality to the ozone skid.

During times when influent flow was 3.0 gpm, the residence time at the target ozone dose was 5 minutes, at 3.6 gpm it was 4.1 minutes. The sample line for the ozone residual was relocated depending on flow and intended residence time. As mentioned in Section 4.5, the feed gas analyzer was inoperable through November 1, 2017 and therefore that data is not shown. Although ozone demand data was lost due to this, water quality and dosing efforts were not believed to be impacted since ozone dose was controlled based on the ozone residual at the specified residence times.

pH can significantly influence ozone demand and dose, in addition to impacting bromate formation. Lower pH values can increase the stability of ozone residuals and low alkalinity can decrease stability. Additionally, high pH can cause increased bromate formation and also increase ozone demand due to accelerated ozone decay. Therefore, there must be a balance when adjusting pH prior to ozonation. Influent pH to the ozone system was controlled on the floc/sed skid. As previously shown, the settled water pH (i.e. influent ozone pH) was ~4.5 on average without MIEX® pretreatment and ~6.5 – 7.5 with MIEX® pretreatment. Impacts to water quality from these operational differences are discussed in the process section.

8.3.2 Effluent Water Quality

The data summarized in this section includes minimum, maximum, and average values witnessed throughout the duration of the pilot study with MIEX® on and off. Additional details on specific water quality parameters of interest will be discussed further in the Performance subsection.

8.3.2.1 MIEX® On

The effluent water quality from the ozone skid when the MIEX® system was running is summarized in Table 18.

Table 18	Ozone Effluent with MIEX® Pretreatment Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
pH (Field)	std. units	7.22 / 7.63 / 7.47	14
Temperature	˚C	12.4 / 27.6 / 22.4	14
Filtered UV_{254}	cm^{-1}	0.013 / 0.046 / 0.032	14
Odor	TON	1.00 / 2.50 / 1.79	14
Free Ammonia	mg/L as N	0.05 / 0.20 / 0.08	14
Orthophosphate	mg/L	BDL	20
Sulfate	mg/L	14.1 / 38.9 / 26.3	13
Chloride	mg/L	34.0 / 52.6 / 42.8	13
Bromate	µg/L	1.07 / 35.4 / 15.3(1)	6
Nitrite	mg/L as N	BDL	20
Nitrate	mg/L as N	0.03 / 0.28 / 0.12	14
Hardness	mg/L as $CaCO_3$	102 / 154 / 129	6
Fluoride	mg/L	0.05 / 0.24 / 0.19	14

Notes:

(1) During high TOC season, three samples taken for bromate were 16.3, 35.4, and 33.2 µg/L. During low TOC season, an additional three sample taken measured at 1.07, 2.20, and 3.50 µg/L.

8.3.2.2 MIEX® Off

The effluent water quality from the ozone skid when the MIEX® system was not running is summarized in Table 19.

Table 19	Ozone Effluent without MIEX® Pretreatment Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
pH (Field)	std. units	7.18 / 7.60 / 7.39	6
Temperature	˚C	19.4 / 27.1 / 21.9	6
Filtered UV_{254}	cm^{-1}	0.02 / 0.04 / 0.03	6
Odor	TON	1.00 / 2.00 / 1.33	6
Free Ammonia	mg/L as N	0.05 / 0.16 / 0.08	6
MIB(1)	ng/L	1.40	1

Table 19	Ozone Effluent without MIEX® Pretreatment Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa		
Parameter	**Units**	**Value (Min/Max/Avg)**	**No. of Samples**
Geosmin(1)	ng/L	6.40	1
Orthophosphate	mg/L	BDL	6
Sulfate	mg/L	84.0 / 191 / 150	6
Chloride	mg/L	13.0 / 24.1 / 20.9	6
Bromate	µg/L	1.59 / 16.0 / 5.35	4
Nitrite	mg/L as N	BDL	6
Nitrate	mg/L as N	0.048 / 0.178 / 0.109	6
Hardness	mg/L as $CaCO_3$	86.0 / 196 / 161	4
Fluoride	mg/L	0.18 / 0.28 / 0.22	6

Notes:
(1) One sample taken on 3/28/2018.

8.3.3 Performance

This section focuses on the performance of the ozone skid in regard to the following water quality parameters of interest:

- Ozone Dose and Demand
  - Related to pH, TOC, and Turbidity
- Bromate

Color in the ozone effluent was not monitored throughout the study; however, ozone is an effective process that oxidizes color and produces biodegradable compounds that can more easily be removed through Biofiltration.

Influent odor to the ozone system was not monitored. The average ozone effluent of 1.33 Threshold Odor Number (TON, the dilution ratio at which odor is just detectable) signifies that the compounds causing odor were likely destroyed adequately, being that a very small dilution yielded odor free water. Additionally, although not monitored in the pilot scale raw water, average MIB and geosmin values at full scale have historically been 17.6 and 25.6, respectively. Therefore, the simple sample effluent values shown in Table 20 (in Section 8.4.2) signify the ozone unit was likely destroying these taste and odor causing compounds adequately even before biofiltration.

Approximately 20 samples were taken to measure ozone effluent UV254, based on settled water UV254 at these times, the average reduction was 44.3% with MIEX® pretreatment (based on 14 samples) and 32.3% without MIEX® pretreatment (based on 6 samples).

It appears that UV254 reduction is greater when using MIEX®, although it cannot be said with statistical certainty.

The remaining results of the ozone effluent water quality parameters shown in Section 8.3.2 either 1) did not vary based on MIEX® operation (whether on or off, i.e. similar effluent results witnessed), 2) are not expected to be removed or changed through ozone, or 3) were not sampled enough for legitimate comparability, and are not discussed in detail here but included in the appendix for reference. These parameters may be discussed in other Sections where applicable and significant.

8.3.3.1 Ozone Dose and Demand

Figure 30 shows the ozone skid influent flow, applied ozone dose, and transfer ozone dose. This data was logged continuously on the ozone skid every five minutes. Dose was calculated based on influent flow rate, feed gas concentration, and feed gas flowrate (set at 3 scfh for this study). Transferred ozone dose was calculated by subtracting the off gas ozone reading from the applied ozone dose, utilizing the units conversion equation previously presented in Section 4.3. The ozone demand can be calculated by subtracting the ozone residual from the transferred ozone dose. As shown, due to the feed gas analyzer being offline until November 1st, there is no applied or transferred ozone dose data for this time. This will be discussed further in Section 9.0.

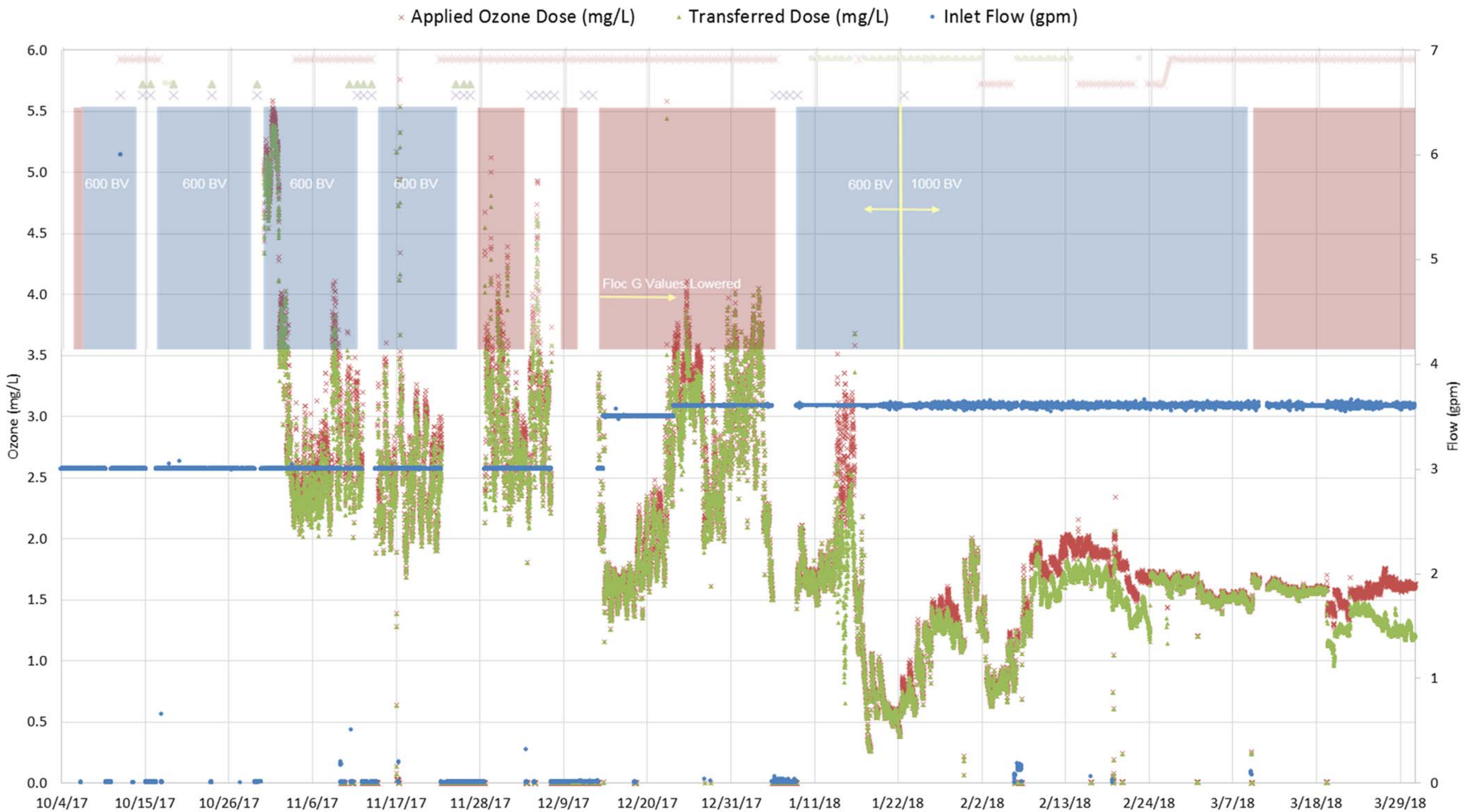
Figure 31 displays the average daily ozone demand throughout the study (with the exception of October – November 1st as previously noted), along with average dissolved ozone residual, and influent and effluent pH values. As expected, demand was higher during high TOC periods, however, even during periods where TOC was dropping and when enhanced coagulation only was employed, the ozone demand was still elevated. In reviewing the pilot plant log, this was likely due to loss of chemical feed (ferric and caustic) to the floc/sed unit, virtually no alkalinity in influent, and the sludge blanket in settling tank being higher than usual allowing for carryover. This would have caused an increase TOC and turbidity thereby impacting ozone demand. Also, it can be seen that when the MIEX® system BVTR changed from 600 BV to 1000 BV, ozone demand increased significantly. Although there was no apparent impact to organics removal through MIEX® and the floc/sed system when the BVTR changes, there is an impact on ozone demand and dose.

Additionally, from mid to late February, the ozone residual was reading zero even though grab samples confirmed residual ozone (0.13 mg/L). Therefore, the actual ozone demand during this time frame could have varied from what is shown.

8.3.3.2 Bromate

Bromate is a disinfection by-product that is formed when ozone reacts with bromide and naturally occurring organic matter with an MCL of 10 µg/L. Factors influencing bromate include ozone dose, pH, bromide concentrations, temperature, organics, ammonia concentration, and alkalinity.

An increase in ozone dose, pH, bromide, and/or temperature will increase bromate formation, an increase in alkalinity, ammonia, or DOC will decrease formation.



PILOT PLANT OZONE OPERATION

FIGURE 30

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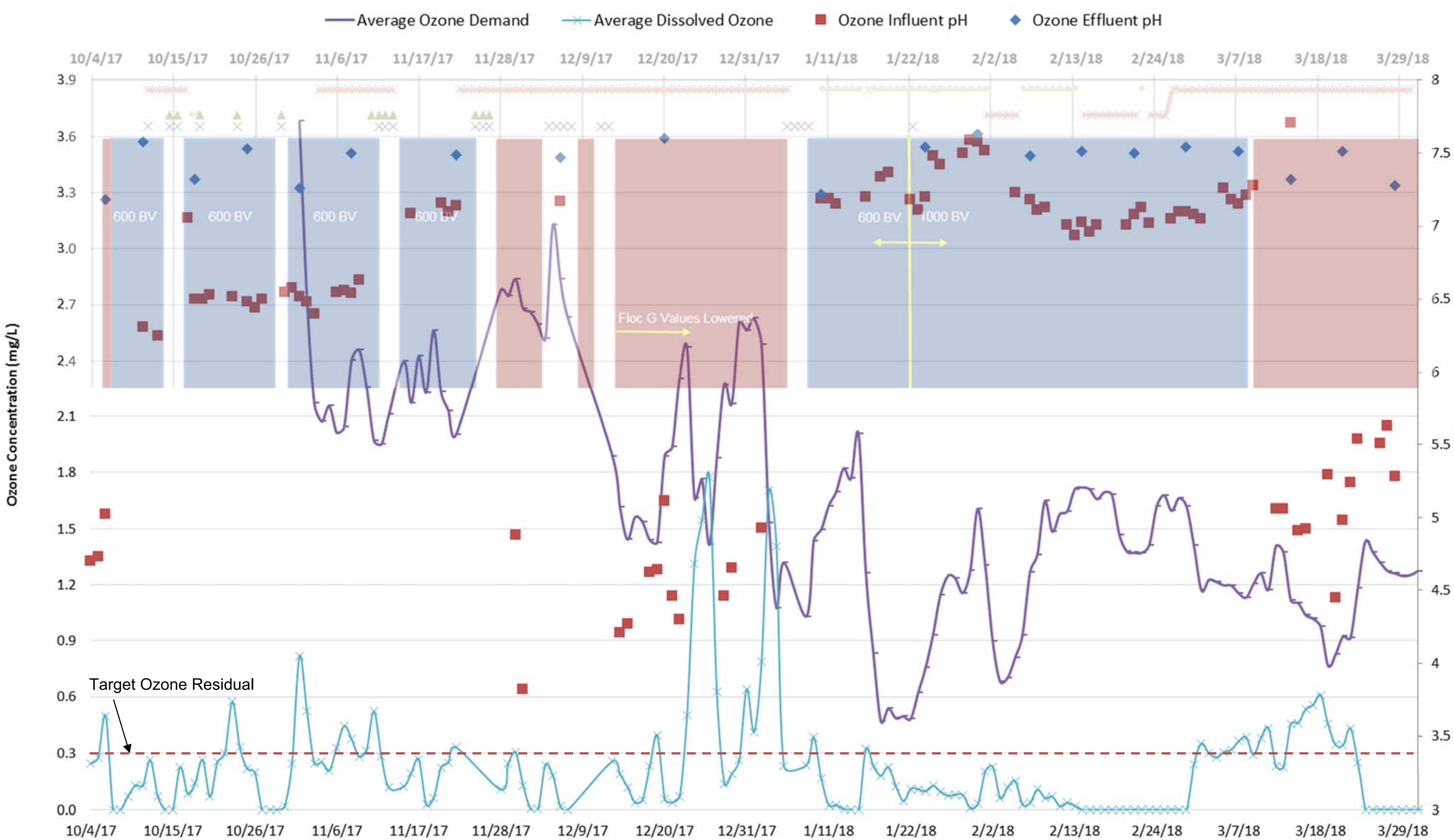

PILOT PLANT OZONE PH AND DEMAND

FIGURE 31

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PILOT PLANT STUDY

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Limited bromate data was collected and the effluent ozone concentrations measured, as shown in Figure 32. Bromate was significantly above the MCL during the month of October. There seemed to be no direct correlation with pH, bromide, TOC, ammonia, or alkalinity, although there is not enough data to statistically confirm this. Influent temperature and applied ozone dose were minimally correlated, being that when temperature and ozone dose decreased, bromate formation also decreased. Additionally, it should be noted that the TAP ASR well was in use which could have impacted bromate formation, although bromide concentrations were consistent throughout the study as shown. Upon further investigation, the City provided full scale data which showed bromate levels of only 1.7 to 2.3 ppb during this time period, confirming the non-correlations stated above.

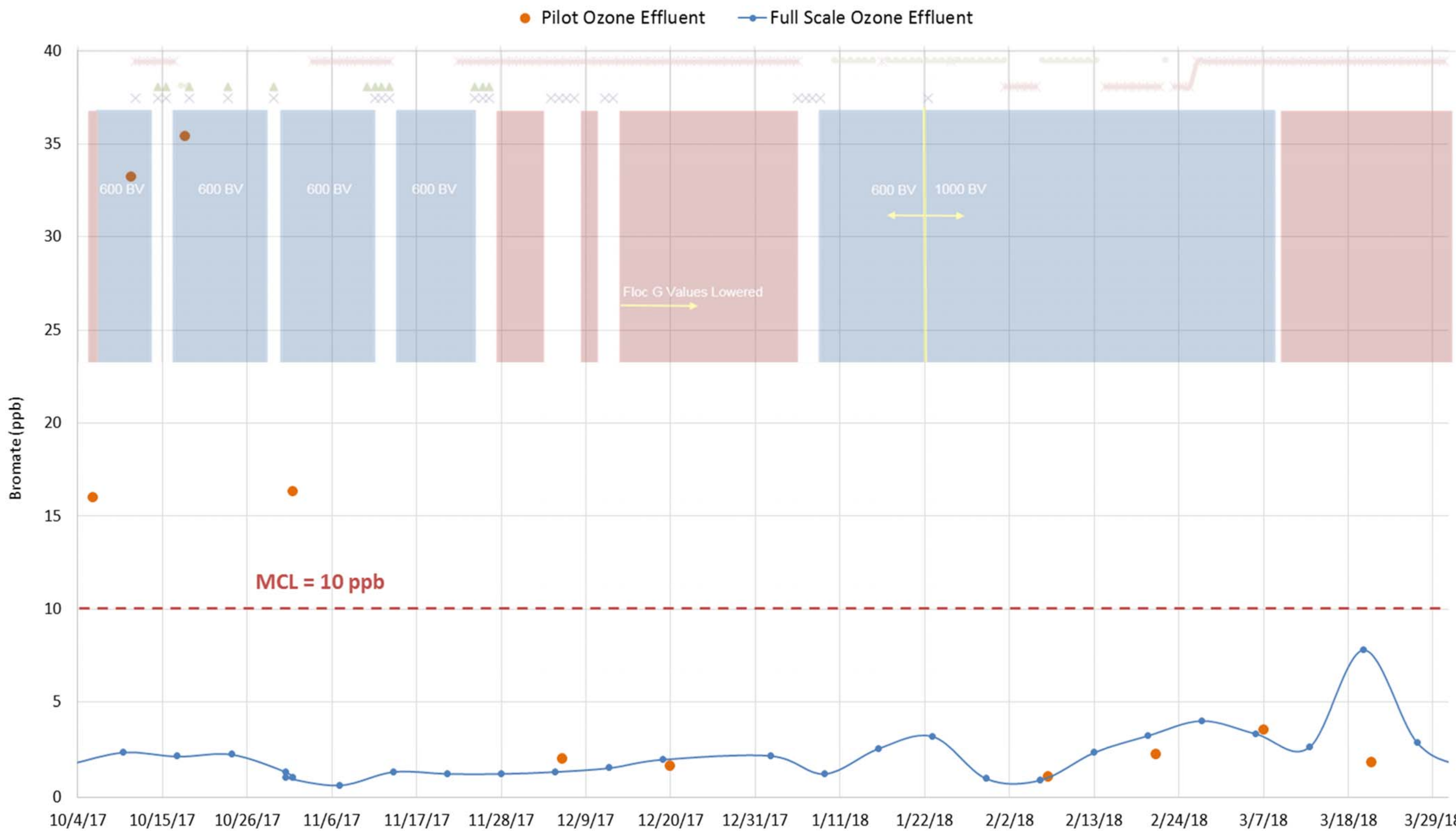
Although ozone dose could not be measured at this time in the pilot, it is believed the ozone demand was higher during this time frame and ozone demand could be increased by MIEX® pretreatment during high TOC seasons. Additionally, Figure 33 shows the pilot scale and full scale bromide levels. It can be seen that, during the time period of high bromate, pilot scale filtered bromide levels measured significantly lower than the settled water values indicating bromide was consumed in the ozone process, leading to bromate formation. Also, during this time, when referring back to the Figure 31, pH is increased significantly after ozone (when compared to low TOC season with MIEX® online), suggesting greater ozone decomposition due to the bromate formation at this time. These findings indicate, with MIEX® pretreatment implementation, bromate could be an issue full scale during high TOC seasons and when ASR is in use, but the limited bromate and ozone dosing data during this time is inadequate to verify this. Additional increase in raw water bromate concentrations could occur with the implementation of TAP as well.

8.4 Biofiltration

8.4.1 <u>Process Operation</u>

The filters were operated at various conditions considering upstream treatment and need for testing higher loading rates. Higher loading rates were tested when MIEX® was on and off to understand the filter's capabilities even with existing treatment processes. As previously illustrated in Figure 2, the filters were operated as follows:

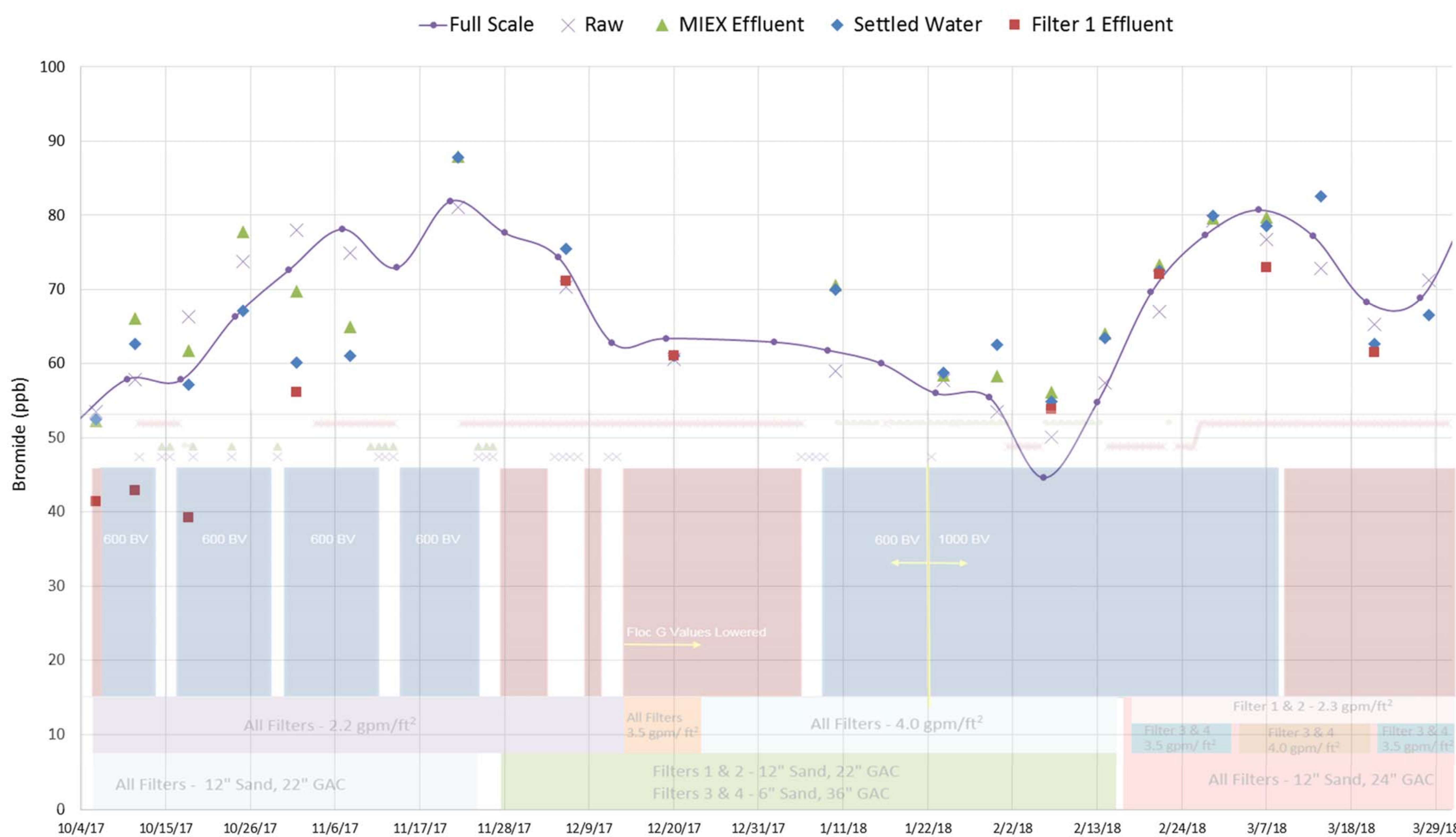
- All Filters - 2.2 gpm/sq ft, 12 inches Sand, 22 inches GAC
  - MIEX® ON
- All Filters - 2.2 gpm/sq ft, Filters 1 & 2 - 12 inches Sand, 22 inches GAC, Filters 3 & 4 - 6 inches Sand, 36 inches GAC
  - MIEX® Off



PILOT AND FULL SCALE BROMATE

FIGURE 32

CITY OF TAMPA
PILOT PLANT STUDY



PILOT AND FULL SCALE BROMIDE

FIGURE 33

CITY OF TAMPA
PILOT PLANT STUDY

- All Filters - 3.5 gpm/sq ft, Filters 1 & 2 - 12 inches Sand, 22 inches GAC, Filters 3 & 4 - 6 inches Sand, 36 inches GAC
  - MIEX® Off
- All Filters - 4.0 gpm/sq ft, Filters 1 & 2 - 12 inches Sand, 22 inches GAC, Filters 3 & 4 - 6 inches Sand, 36 inches GAC
  - MIEX® On & Off
- Filter 1 & 2 - 2.3 gpm/sq ft, Filter 3 & 4 - 3.5 gpm/sq ft, All Filters - 12 inches Sand, 24 inches GAC
  - MIEX® On & Off
- Filter 1 & 2 - 2.3 gpm/sq ft, Filter 3 & 4 - 4.0 gpm/sq ft, All Filters - 12 inches Sand, 24 inches GAC
  - MIEX® On & Off

The applied loading rates of 2.2, 2.3, 3.5, and 4.0 gpm/ft^2 simulated full-scale treatment flow of 80 (current average daily flow), 82 (current permitted with draw average daily flow), 120 (current permitted max day with draw flow), and 140 mgd (future max day flow), in order to understand if new filters would be needed to meet current and future flows.

Additionally, the varying media depths resulted in different L/d ratios, specifically:

- 12” Sand, 22” GAC
  - Total L/d ratio: 1,230
- 6” Sand, 36” GAC
  - Total L/d ratio: 1,320
- 12” Sand, 24” GAC
  - Total L/d ratio: 1,285

This ratio is a dimensionless value that measures relative storage capacity of the filter. The greater the ratio, the greater the storage capacity. The Ten States Standards currently state that filters with L/d ratios greater than 1,000 provide for production of low turbidity water, which is met at each of the media depths mentioned above.

Other than ozonation, there were no chemicals added after sedimentation and prior to biofiltration (i.e., no additional pH adjustment or polymer). On occasion, filters were forced into backwash, specifically when a new testing scheme was employed or when needed operationally. For the duration of the study, a backwash was set to occur if filter head loss was greater than 6 feet. As with the full-scale system, this setpoint was almost always the backwash trigger. However, from November 3rd to December 1st, the backwash triggers were modified to be triggered on runtime greater than 24 hours. This is discussed further in the performance subsection 8.4.3.

8.4.2 Effluent Water Quality

The data summarized in this section includes minimum, maximum, and average values witnessed throughout the duration of the pilot study with MIEX® on and off. Additional details on specific water quality parameters of interest will be discussed further in the Performance subsection.

8.4.2.1 MIEX® On

The average filtered effluent water quality from the biofiltration skid when the MIEX® system was running is summarized in Table 20.

Table 20 Filtered Effluent with MIEX® Pretreatment Water Quality Results David L. Tippin Water Treatment Facility Master Plan City of Tampa

Parameter	Units	Value (Min/Max/Avg)	No. of Samples
Turbidity	NTU	0.10 / 0.53 / 0.14	61
pH (Field)	std. units	7.15 / 7.76 / 7.50	61
Temperature	˚C	13.0 / 28.0 / 21.3	61
Alkalinity	mg/L as $CaCO_3$	64.8 / 137 / 105	61
TOC	mg/L	1.48 / 4.05 / 2.50	61
Filtered UV254	cm^{-1}	0.009 / 0.089 / 0.025	61
Color	pcu	5 / 5 / 5	59
Conductivity	µS/cm	366 / 474 / 407	13
Free Ammonia	mg/L as N	0.05 / 0.14 / 0.08	14
Orthophosphate	mg/L	BDL	36
Sulfate	mg/L	12.5 / 38.5 / 26.0	36
Chloride	mg/L	31.0 / 56.6 / 42.5	36
Bromide	µg/L	38.9 / 74.4 / 56.0	6
Arsenic	µg/L	3.9e-04 / 7.3e-04 / 4.9e-04	12
Nitrite	mg/L as N	BDL	36
Nitrate	mg/L as N	0.025 / 0.345 / 0.150	36
Hardness	mg/L as $CaCO_3$	99.0 / 147 / 129	6
Odor	TON	1.00 / 1.88 / 1.40	14
Magnesium	mg/L	2.84 / 5.14 / 3.93	13
Fluoride	mg/L	0.16 / 0.25 / 0.20	36

8.4.2.2 MIEX® Off

The average filtered effluent water quality from the biofiltration skid when the MIEX® system was not running is summarized in Table 21.

Table 21 Filtered Effluent without MIEX® Pretreatment Water Quality Results
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Parameter	Units	Value (Min/Max/Avg)	No. of Samples
Turbidity	NTU	0.10 / 1.20 / 0.26	29
pH (Field)	std. units	6.27 / 7.67 / 7.19	29
Temperature	˚C	14.9 / 27.9 / 21.4	29
Alkalinity	mg/L as $CaCO_3$	31.0 / 131 / 102	29
TOC	mg/L	1.83 / 3.60 / 2.70	29
Filtered UV254	cm^{-1}	0.013 / 0.048 / 0.030	29
Color	pcu	5.0 / 6.3 / 5.0	27
Conductivity	µS/cm	357 / 686 / 596	6
Free Ammonia	mg/L as N	0.05 / 0.07 / 0.06	6
Orthophosphate	mg/L	BDL	16
Sulfate	mg/L	11.1 / 190 / 143	17
Chloride	mg/L	11.8 / 23.9 / 21.3	17
Bromide	µg/L	41.3 / 70.6 / 58.6	4
Arsenic	µg/L	4.7e-04 / 6.0e-04 / 4.9e-04	6
Nitrite	mg/L as N	BDL	17
Nitrate	mg/L as N	0.053 / 0.270 / 0.149	17
Hardness	mg/L as $CaCO_3$	89.5 / 201 / 160	4
Odor	TON	1.00 / 1.75 / 1.23	6
Geosmin(1)	ng/L	2.38	1
MIB(1)	ng/L	1.00	1
Magnesium	mg/L	2.57 / 5.98 / 4.05	6
Fluoride	mg/L	0.18 / 0.29 / 0.24	17

Notes:
(1) Based on one sample taken on 3/28/2018.

8.4.4 Performance

This section focuses on the performance of the biofiltration skid in regard to the following water quality parameters of interest:

- UV254
- Turbidity
- TOC

In addition, ammonia and orthophosphorus, which are nutrients that can impact biofilter health and performance, were monitored during this study. The data (in shown) indicate that ammonia was not wholly removed (and sometimes increased) through the biofilters. However, nitrate concentrations generally increased through biofiltration. This indicates nitrification was occurring, as would be expected under these operating conditions, but contradicts the ammonia data. Although ammonia was measurable, the accuracy/repeatability of the analytical method used for ammonia is questionable at the low concentrations measured in this study; therefore, conclusions related to the ammonia data cannot be definitely stated. The influent orthophosphorus was below detection limits, which may indicate that the filters are nutrient limited. However, phosphorus addition is not beneficial at this DLTWTF because of the amount of ferric carryover and requirement for pH adjustment in order to be effective. Increasing pH of the filter feed water can improve the bioavailability of supplemental phosphorus in the presence of ferric floc, but is not possible given the current treatment process as it would lead to precipitation of calcium carbonate onto the filters.

In addition to water quality considerations, filter operations were analyzed as follows:

- Filter head loss & run time
- Clean bed head loss & backwashing
- URFVs
- Empty Bed Contact Time (EBCT)
- Solids Loading Rate

The remaining results of the filtered effluent water quality parameters, shown in Section 8.4.2, either 1) did not vary based on MIEX® operation (whether on or off, i.e., similar effluent results witnessed), 2) are not expected to be removed or changed through biofiltration, or 3) were not sampled enough to draw meaningful conclusions, and are not discussed in detail here but included in the Appendix for reference. These parameters may be discussed in other Sections where applicable and significant.

8.4.4.1 Filtered UV 254

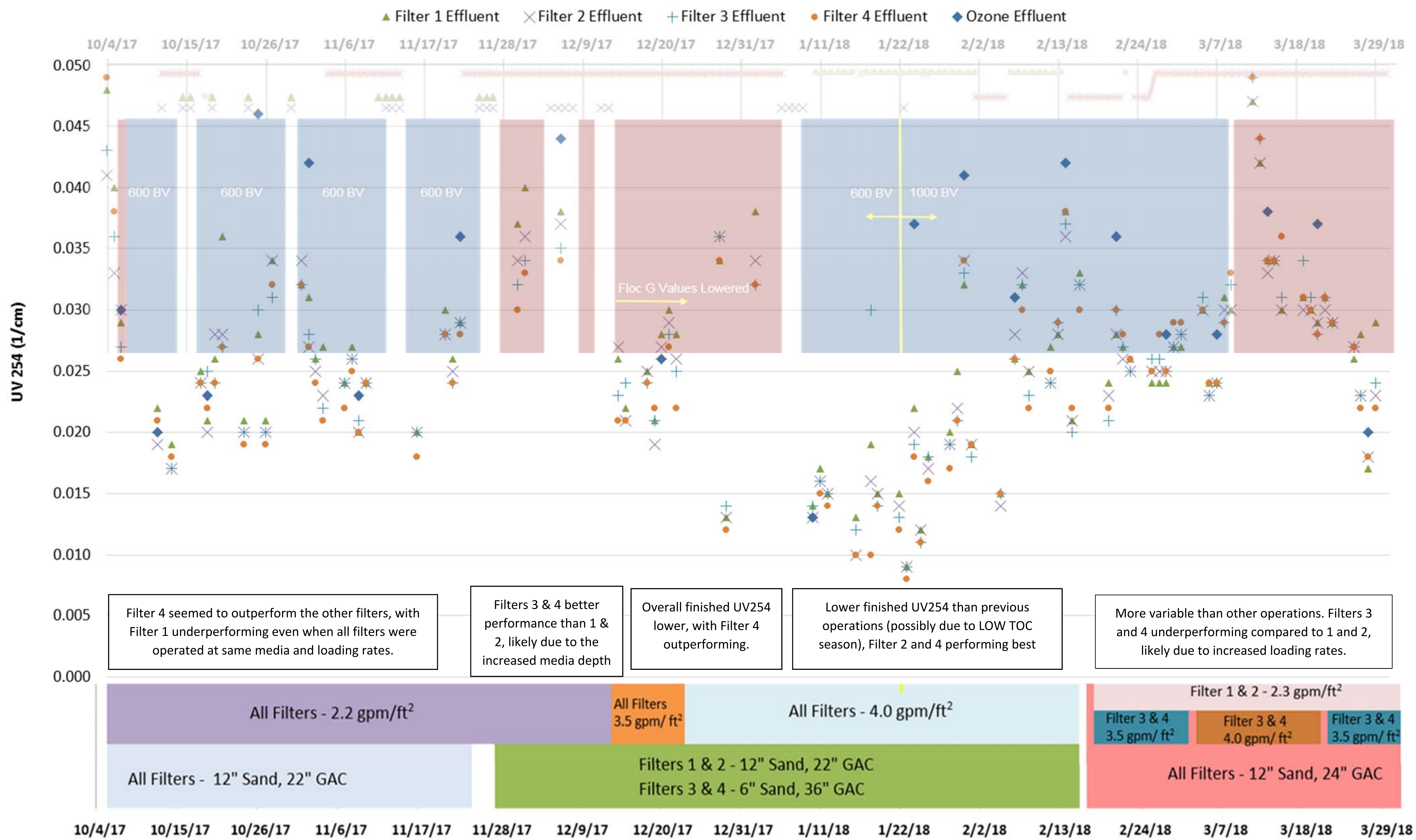
As noted previously, there were limited ozone effluent samples taken for UV254; however, based on the samples provided, the average reduction through the filters was 20.5% and 13.6% with and without MIEX® pretreatment, based on 12 and 5 samples, respectively. However, significant difference in performance cannot be confirmed statistically. Despite this, changes in filtered UV254 based on operational changes can be observed. Effluent UV254 values for all filters throughout the course of study are shown in Figure 34. Also shown is the mode of filter media and depth operation. In general, the filtered UV254 trended based on the effluent UV254 from the ozone skid. Additional observations of note are included in Figure 34.

8.4.4.2 Turbidity

Effluent turbidity for all filters throughout the study is shown in Figure 35. Effluent quality was relatively consistent; however, during times of enhanced coagulation, there was a significant difference in performance. Influent turbidity was higher during this period, and it can be seen that Filters 3 and 4 produced lower finished turbidity than Filters 1 and 2. During these operations, Filters 3 and 4 had increased media depth (6” sand, 36” GAC), while loading rates were equal, which could have been the reason for better performance being the L/d ratio is higher.

8.4.4.3 TOC

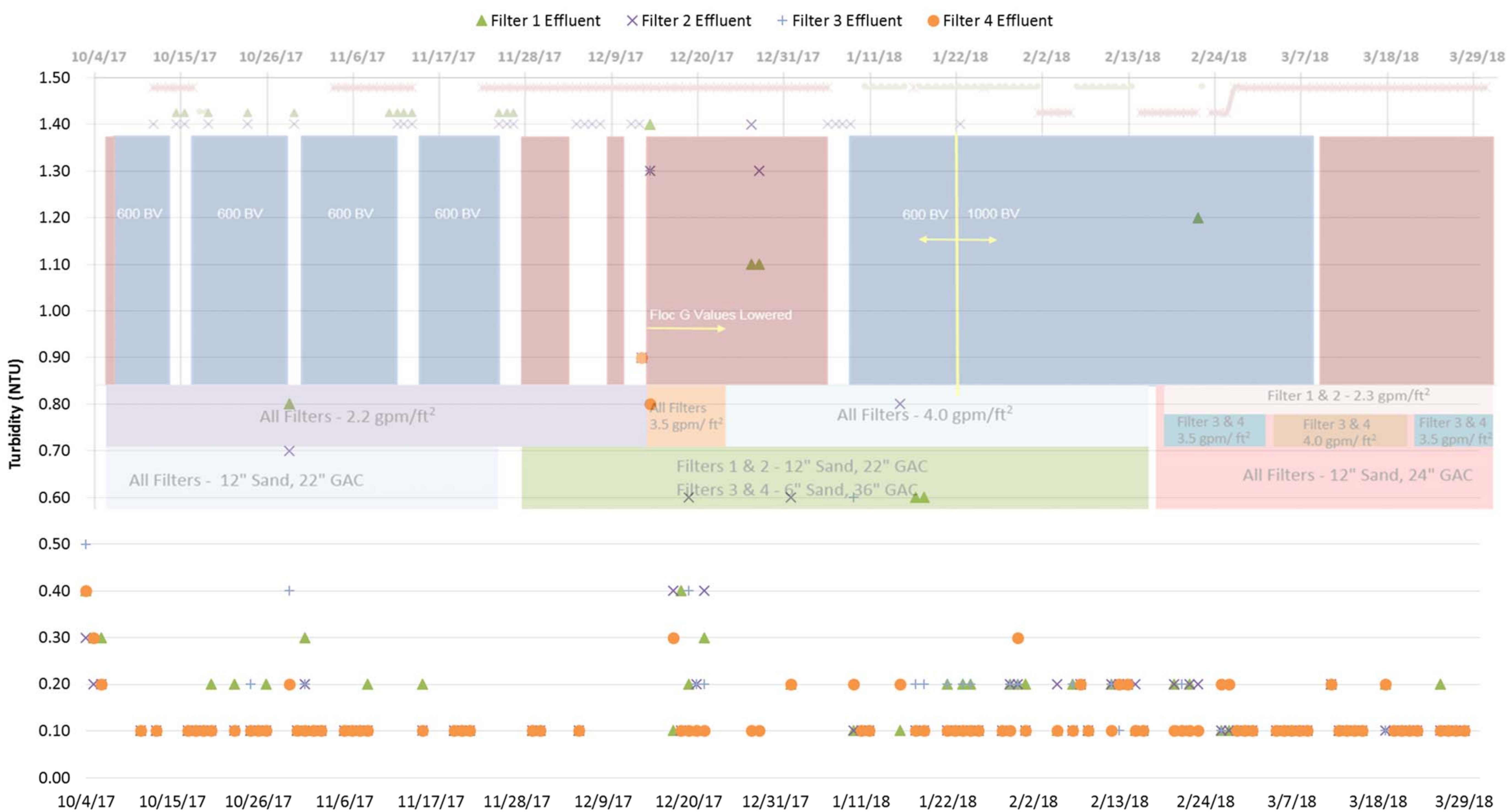
The filters performed similarly in regard to finished water TOC concentrations, as shown in Figure 36. The fluctuations shown in finished water TOC were influenced by settled water TOC from the floc/sed system. Like other parameters mentioned, Filter 4 outperformed during early operations, whereas Filters 1 and 2 performed better during towards the end of the study. Generally, the effluent TOC was below the finished water goal of 3.0 mg/L with a few exceptions. Overall analysis and notes on finished water TOC and pilot plant performance will be discussed further in Section 9.0.



PILOT SCALE FILTERED UV254

FIGURE 34

CITY OF TAMPA
PILOT PLANT STUDY



PILOT SCALE FILTERED TURBIDITY

FIGURE 35

CITY OF TAMPA
PILOT PLANT STUDY

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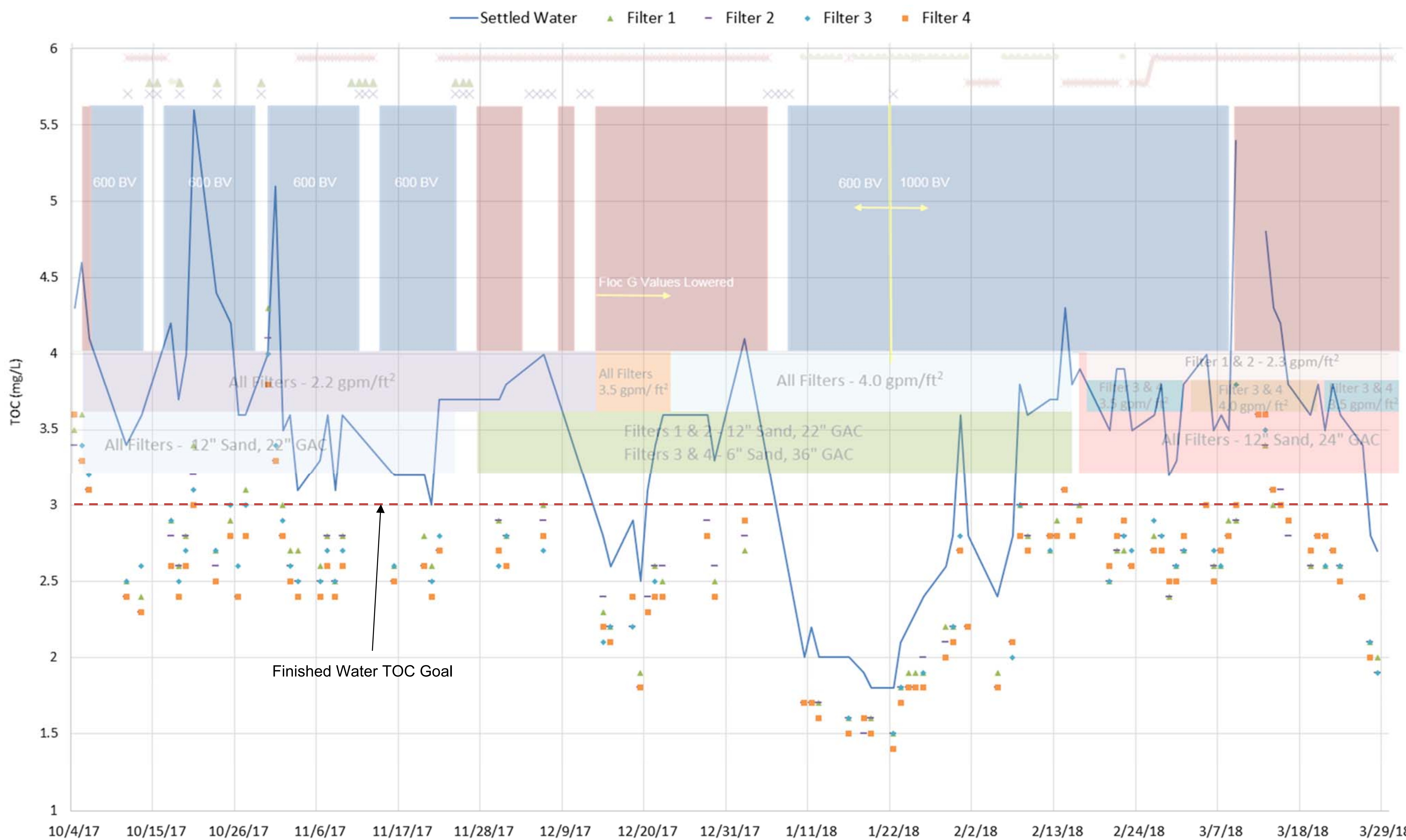


PILOT SCALE FILTERED TOC

FIGURE 36

8.4.4.4 Head loss & Filter Run Times

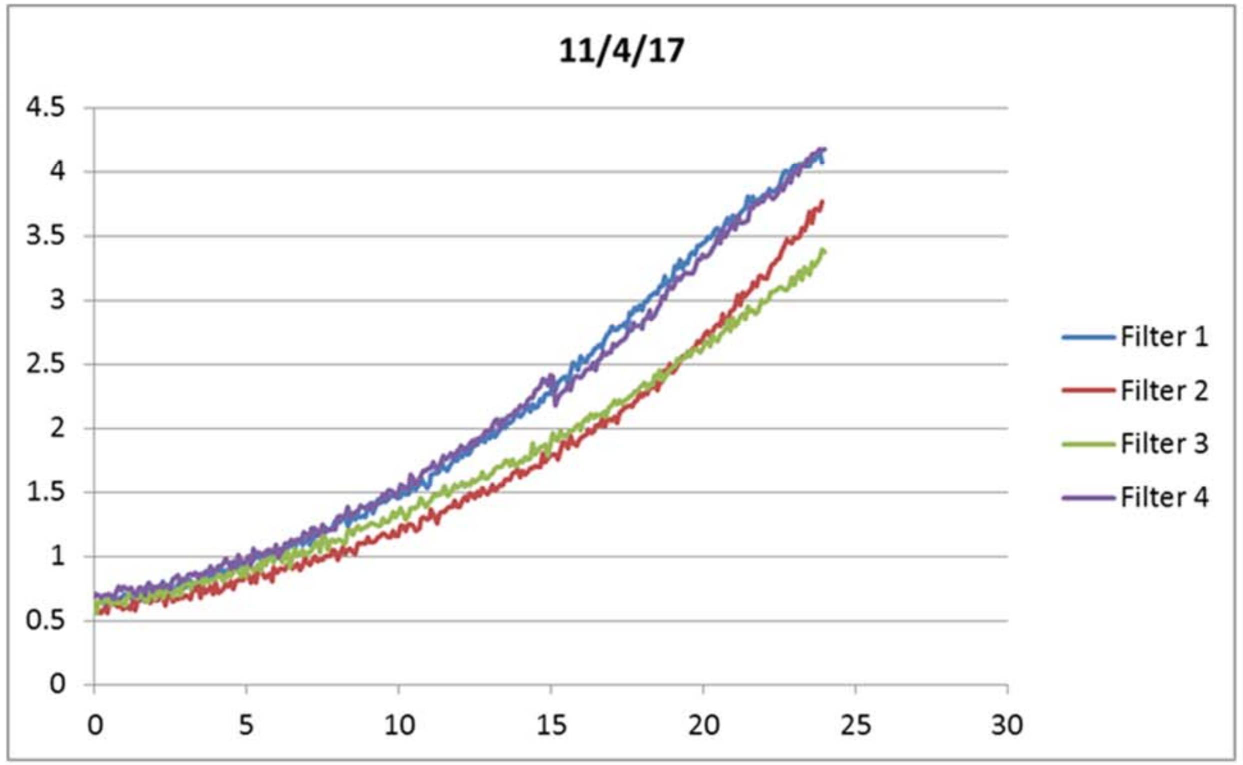
For the duration of the study, a backwash was set to occur if filter head loss was greater than 6 feet. As with the full-scale system, this setpoint was almost always the backwash trigger. As noted previously, from November 3rd to December 1st, the backwash triggers were modified to be triggered on runtime greater than 24 hours (as opposed to 96 hours) in order to record head loss profiles. Therefore, the filters did not reach terminal head loss but instead backwashed when runtime was met. In full scale and as confirmed in pilot scale (see Figure 37), there is a fairly linear relationship between UFRV and head loss (see Chapter 3).

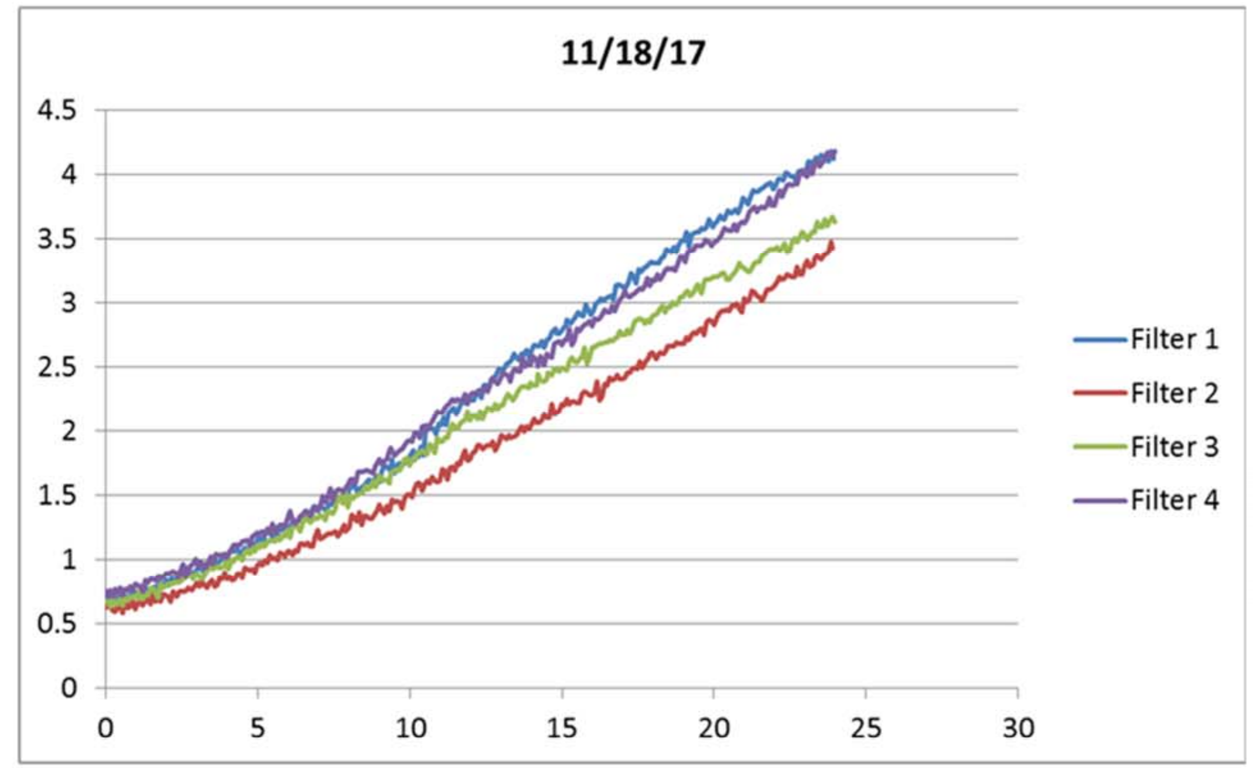
Figure 38 shows the runtimes for each filter when 6 feet of head loss was reached and before a backwash was triggered. From October to early December, filter runtimes were highly variable but consistently greater than 20 hours since the filter loading rates were lower. Starting in early January, runtimes were more consistent among the filters but decreased significantly during times when settled water turbidity was greater.

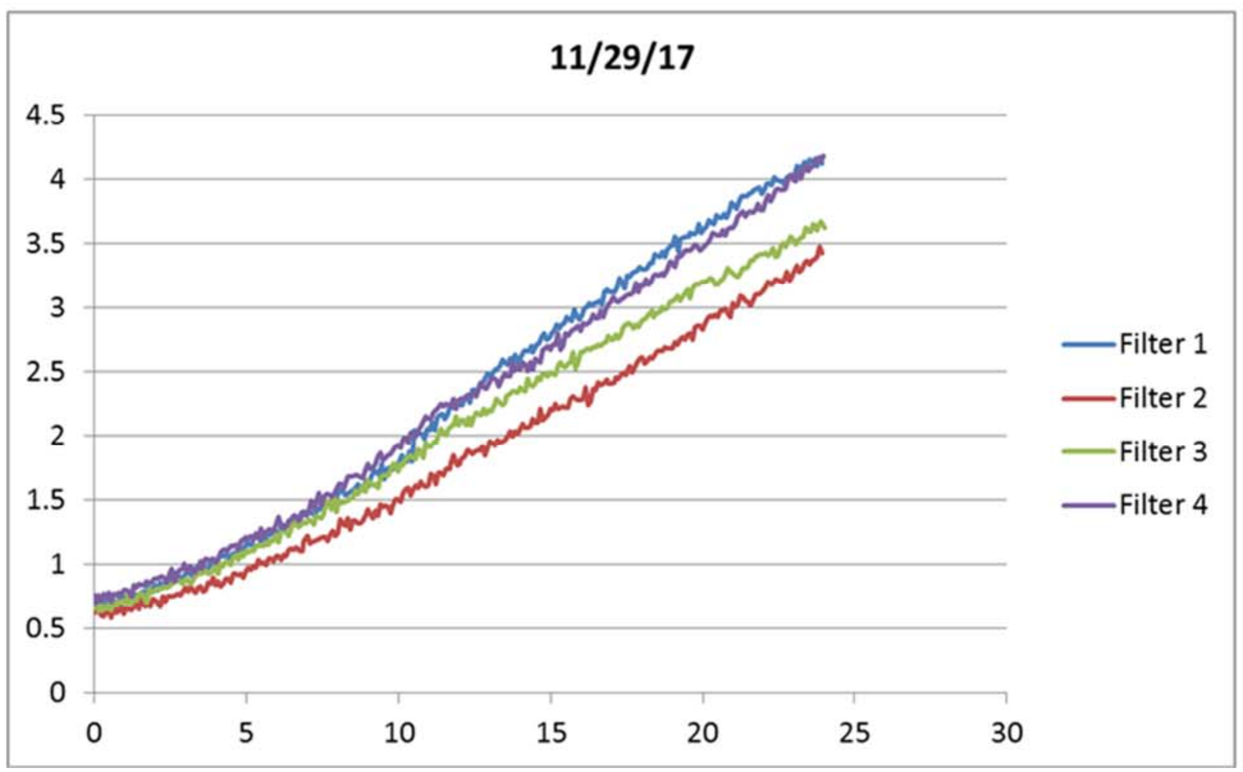
As shown, Filter 1 consistently had the lowest runtimes and Filter 3 the greatest, likely due to differences in media depth during this operation. Filter 4 shows the lowest runtimes despite being operated at the same conditions as Filter 3 during the last part of the study. It is believed the filter was not adequately backwashing as it was witnessed that the bed was not fluidizing during backwash.

In general, as filter loading rates increased, the runtimes decreased. Filters 1 and 2 operated at the same loading rate for Operations 5 and 6 and therefore should perform consistently as shown.

The filter runtimes at higher loading rates are less than desired and are dictated by the available head loss in the filters. Increasing the available head loss would increase filter runtimes as previously mentioned in Chapters 3 and 4 of the Master Plan. Due to the linear relationship between runtime and head loss, a 1-foot increase in available head would be expected to result in an increase in filter runtime of approximately 17%.







PILOT PLANT FILTER HEADLOSS PROFILES

FIGURE 37

CITY OF TAMPA
PILOT PLANT STUDY

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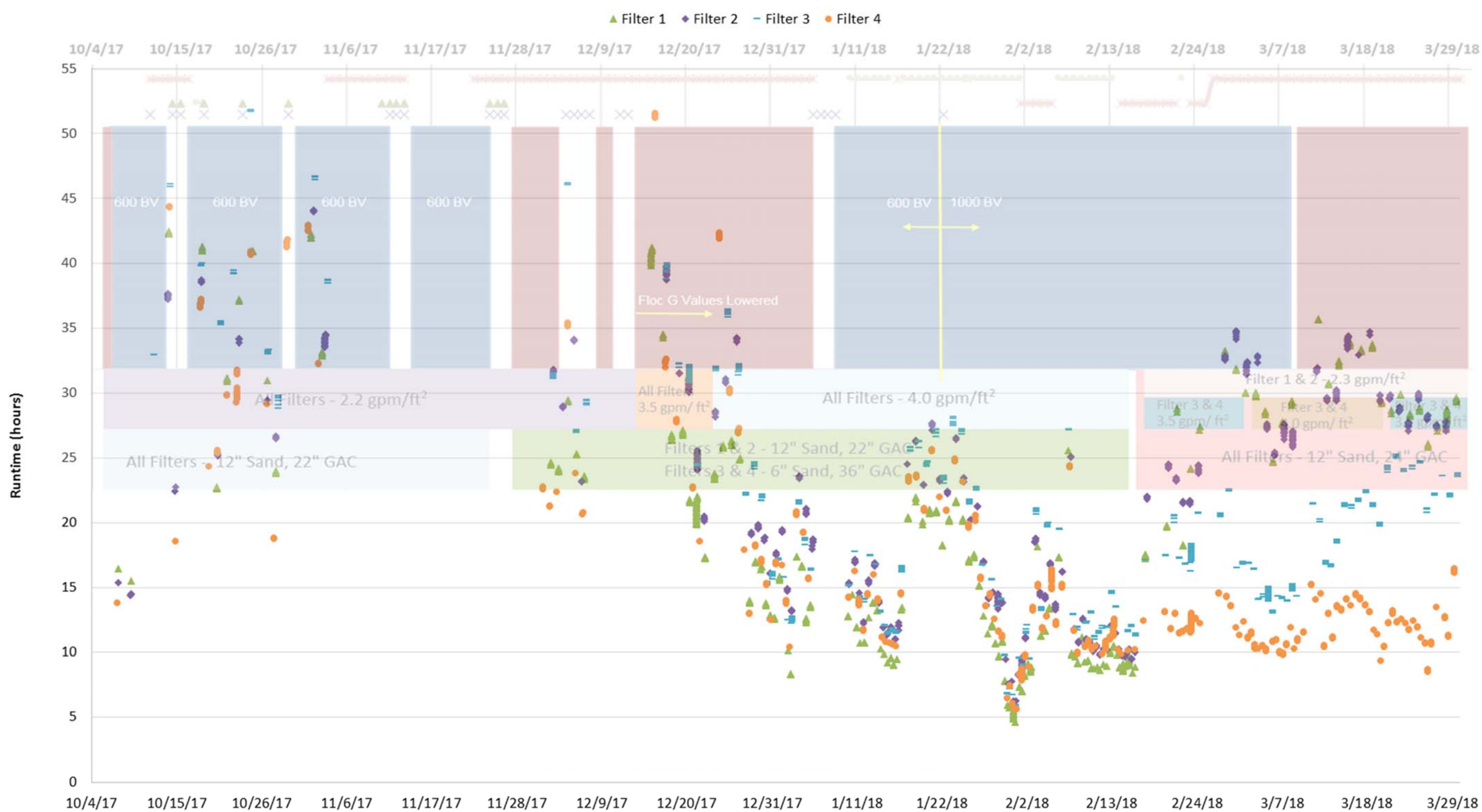


PILOT SCALE FILTER RUNTIMES AT TERMINAL HEADLOSS

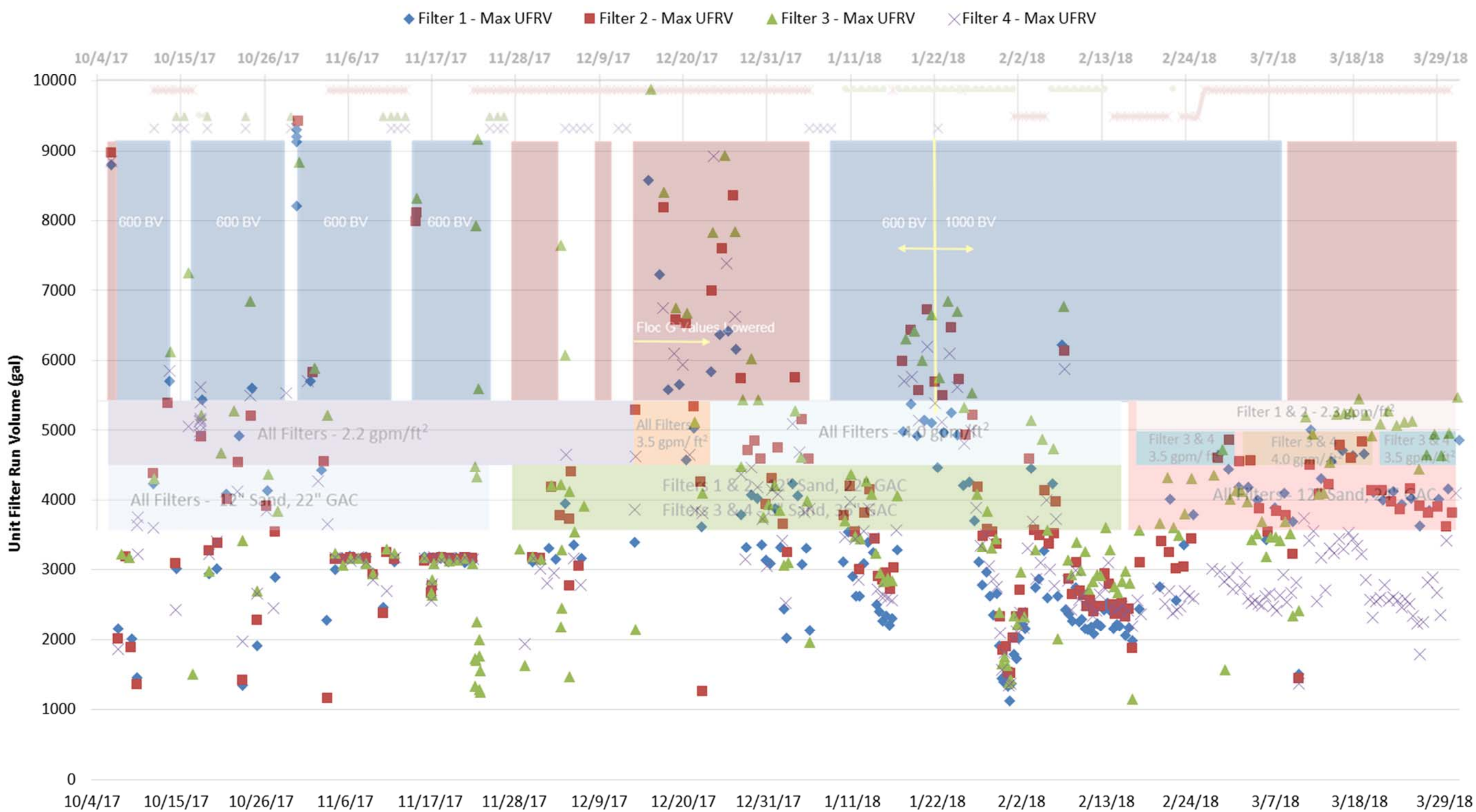
FIGURE 38

8.4.4.5 Unit Filter Run Volumes

Unit filter run volumes were calculated using the filter flow, runtime, and filter area. Figure 39 shows the original maximum UFRVs for each filter throughout the duration of the study. These maximum UFRV values are realized just before a backwash is initiated. In order to have accurate and useful UFRV data, filter flow must be consistent and the backwash must be triggered by head loss, turbidity, or runtime (as set by full-scale operations). As shown, from November 3 to December 1st, 2017 UFRVs are recorded steadily at ~3,100 gallons. This is because backwashes were not triggered by head loss or turbidity, but by time (24 hours as mentioned in the previous section). Therefore, in order to simulate what the actual maximum UFRVs could have been based on head loss, the ratio of the head loss setpoint and head loss at the time of backwash initiation was multiplied by the reported UFRV at the time of backwash initiation. Additionally, there were times when the filters had no low flow situations followed by temporary peaks in flow, while runtime was still being recorded and no backwash was initiated. This would report an inaccurate UFRV so these values were removed from the data set. Finally, UFRV data were removed for any instances where a backwash was initiated but not triggered by turbidity, head loss or runtime. The modified results are shown in Figure 40. Since UFRVs are a function of runtime, a similar trend is witnessed.

It is apparent UFRVs were highly sporadic, even though there were times when loading rates and/or media depths were the same. Despite the high turbidities witnessed during December with enhanced coagulation, the UFRVs were generally (but not consistently) higher. After the new year, UFRV's were more closely grouped but still not ideal. There is an interesting trend from 1/11/2018 to 2/4/2018, during this time the MIEX® was operating. UFRVs averaged around 3,000, then increased to around 5,500, then decreased down to 3,000 gal/ft^2.

There was surface sludge present 1/11 to 1/17, not occurring again until 2/5. Despite the disappearance on 1/17, UFRVs did not consistently improve; conversely, the re-appearance on 2/5 did not negatively influence UFRVs, and therefore it is not likely the surface sludge caused this trend. The MIEX® system bed volumes were changed from 600 to 1000 BV on 1/22, after which a decline in UFRVs was observed. Additionally, ozone demand significantly decreased from 1/15 to 1/25, which could also explain the larger UFRVs followed by an increase in ozone demand and smaller UFRVs. Finally, although Filters 3 and 4 were operated in the same manner, they have significantly different UFRVs from late February to early March.



PILOT SCALE MAX UFRVS

FIGURE 39

CITY OF TAMPA
PILOT PLANT STUDY

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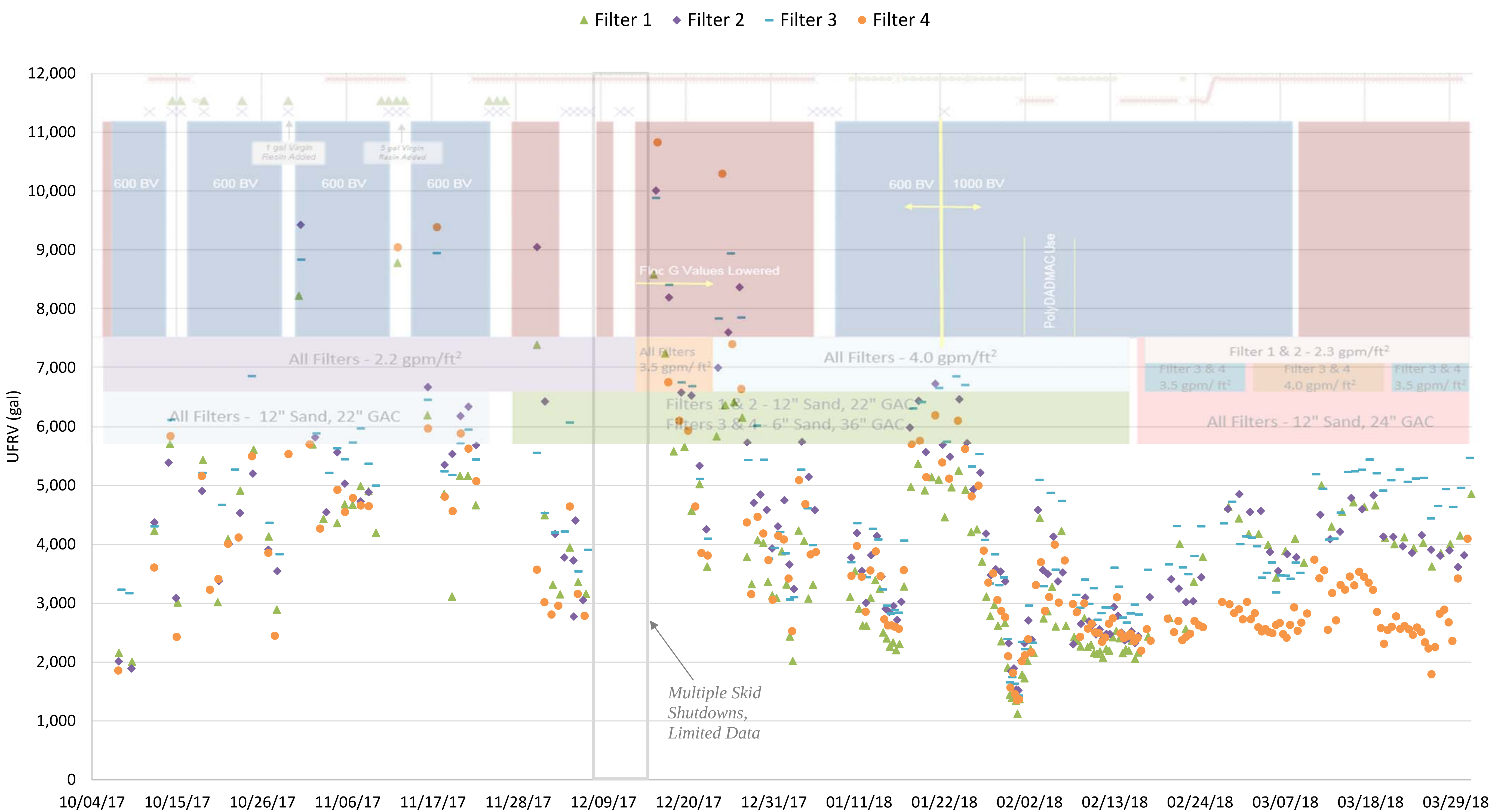

PILOT SCALE MAX UFRVS MODIFIED

FIGURE 40

CITY OF TAMPA
PILOT PLANT STUDY

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8.4.4.6 Unit Filter Solids Loading Rates

At the pilot scale, settled water turbidity data was logged every 5 minutes, and therefore the total UFSL was calculated as the sum of the UFSLs determined every 5 minutes for an entire individual filter run. The equation to calculate the UFSL is shown below.

$$UFSL\ \left(\frac{grams}{ft^2}\right) = \sum Settled\ Water\ Turbidity\ (NTU) * \frac{1.0\frac{mg}{L}TSS}{1\ NTU} * Filter\ Loading\ rate\ \left(\frac{gpm}{sqft}\right) * 5\ minutes * \frac{3.78\ L}{gal} * \frac{1\ g}{1000\ mg}$$

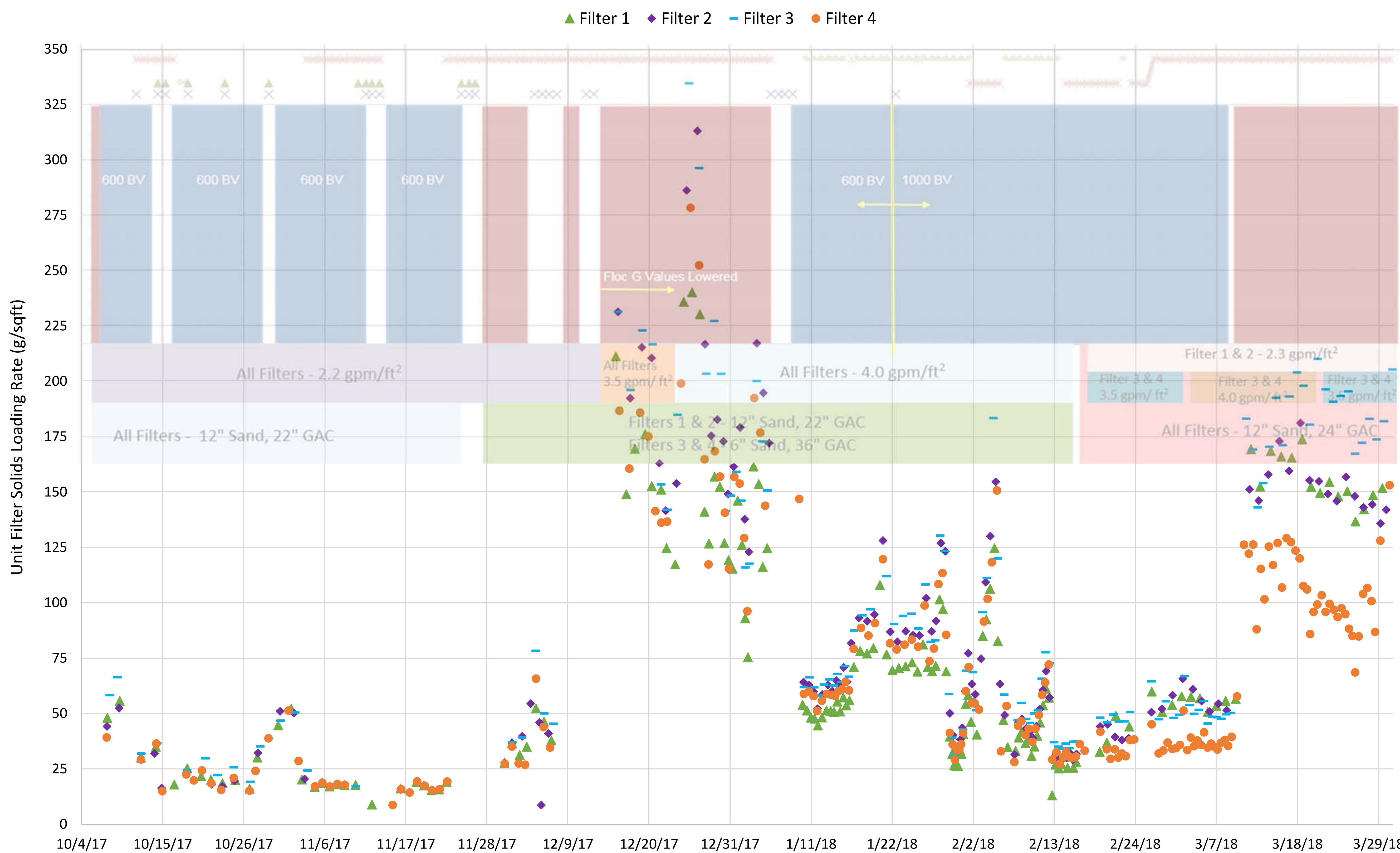
Figure 41 shows the UFSLs for each filter for the duration of the study. As shown, the lowest solids loading rates occurred during high TOC season when MIEX® was in operation. As shown, the UFSLs increase in mid to late December when influent turbidity was high and enhanced coagulation was employed. Conversely, the UFSLs decrease when MIEX® pretreatment is reinstated in early January. When MIEX® system was off again in mid-March, the UFSLs again increased. Filter 3 witnessed higher UFSLs towards the end of the study since runtimes for Filter 3 were longer, despite Filters 3 and 4 having the same media depth and (hydraulic) filter loading rates. In general, the UFSLs were calculated and plotted to help determine if there was any correlation to the varying filter performance in regard to UFRVs. This does not seem to be the case since UFSLs were also high variably (although not correlated).

8.4.4.7 Clean Bed Head Loss & Backwashing

Clean bed head loss for all four filters throughout the study are shown in Figure 42. There is a significant difference in head loss among the different filter operations. This is likely due to increased loading rates of 4.0 gpm/ft^2. Filters 3 and 4 experienced lower clean bed head loss than Filters 1 and 2 during due to the difference in media bed depths (6” sand, 36” GAC and 12” sand, 22” GAC, respectively). Additionally, when Filters 1 and 2 were operated at 2.3 gpm/ft^2, they showed lower head loss than Filters 3 and 4, towards the end of the study. Interestingly, even though Filters 1 and 2 were operated at this loading rate and very similar to the 2.2 gpm/ft^2 operation at the start of the study, there is a significant difference in clean bed head loss compared to the end of the study.

These observations suggest that the backwash procedure was not capable of adequately removing solids or cleaning the filters. This could significantly impact and hinder filter runtimes and UFRVs.

Based on the backwash sequence, approximately 40.3 gallons of backwash water were utilized during a cycle. Considering the area of the filter, this relates to a washwater unit run volume of 205 gallons per square foot, which is typical. Although not taken, turbidity samples taken at the beginning and end of a filter backwash could have indicated if the backwash rate and durations were adequate.



PILOT PLANT FILTER UFSLS

FIGURE 41

CITY OF TAMPA
PILOT PLANT STUDY

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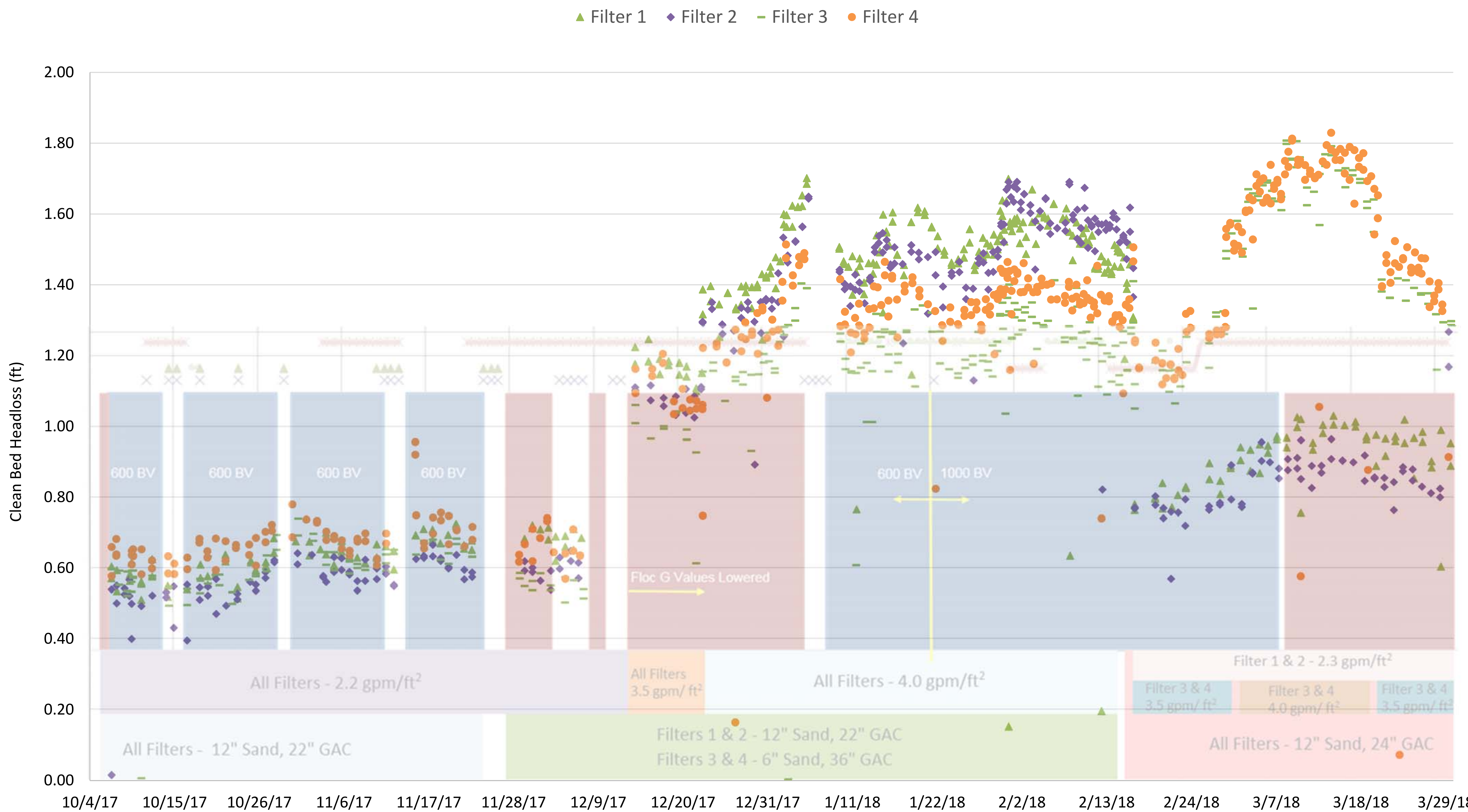

PILOT SCALE FILTER CLEAN BED HEADLOSS

FIGURE 42

CITY OF TAMPA
PILOT PLANT STUDY

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Inadequate backwashing can also be influenced by mismatched media. The sand and GAC utilized (matching full scale) has a significant difference in fluidization rates. This causes the backwash procedure to be less efficient since the media beds were not able to fluidize and provide proper bed expansion. This was witnessed visually, in addition to observing GAC trapped within the sand after backwashing.

8.4.4.8 Empty Bed Contact Time

Based on the flow, area, and media depths the following empty bed contact times for the filters were calculated for each operation:

- 2.2 gpm/sq ft with 12” sand, 22” GAC: EBCT = 9.7 minutes
- 2.2 gpm/sq ft with 6” sand, 36” GAC: EBCT = 12.0 minutes
- 3.5 gpm/sq ft with 12” sand, 22” GAC: EBCT = 6.1 minutes
- 3.5 gpm/sq ft with 6” sand, 36” GAC: EBCT = 7.5 minutes
- 4.0 gpm/sq ft with 12” sand, 22” GAC: EBCT= 5.2 minutes
- 2.3 gpm/sq ft with 12” sand, 24” GAC: EBCT= 9.7 minutes
- 3.5 gpm/sq ft with 12” sand, 24” GAC: EBCT= 6.4 minutes
- 4.0 gpm/sq ft with 12” sand, 24” GAC: EBCT= 5.5 minutes

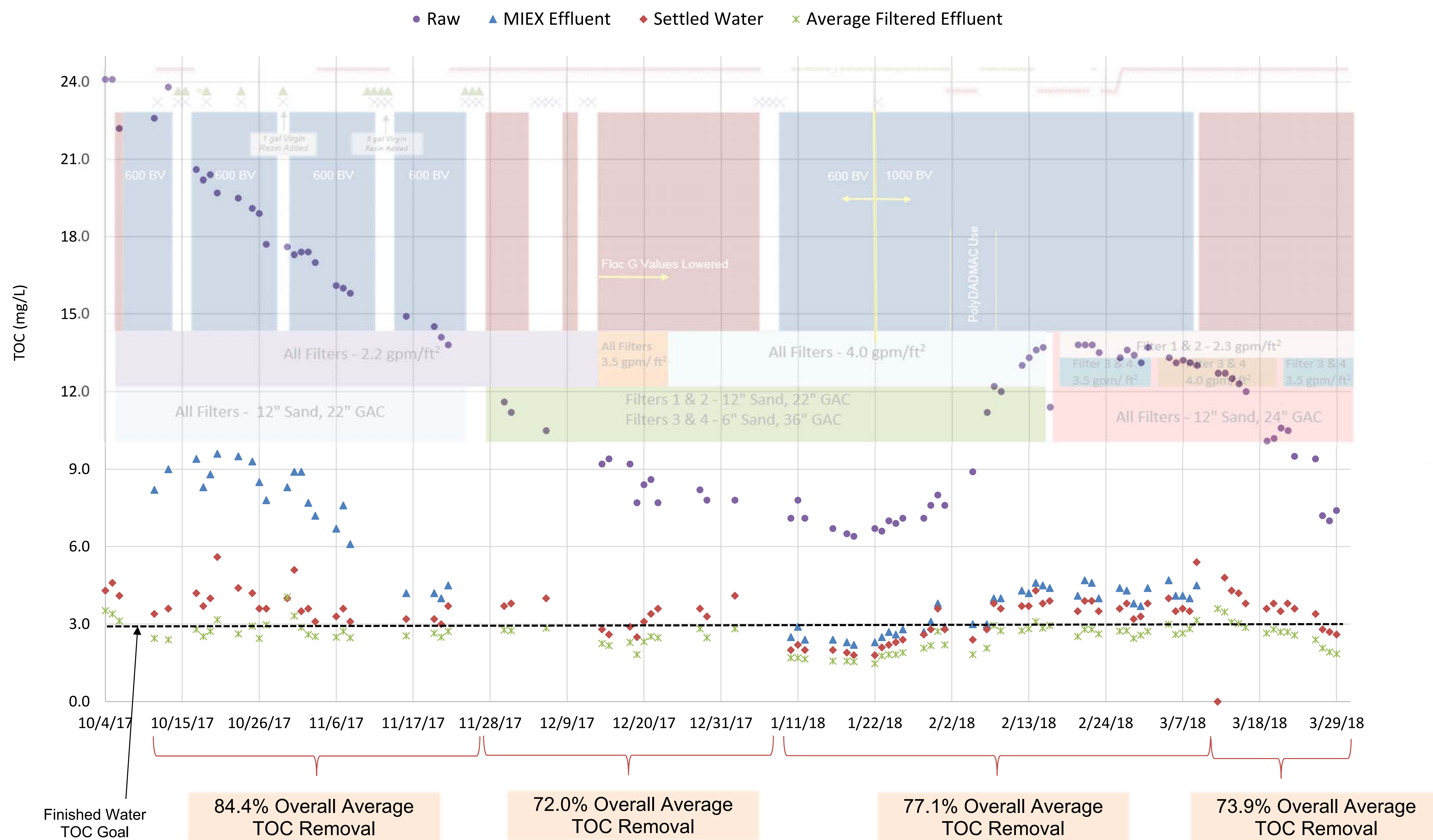
A minimum EBCT of 5 minutes is recommended, which was met during all operations. These values would be consistent with full scale if the same loading rates are applied.

9.0 PILOT AND FULL SCALE COMPARISON

9.1 TOC Removal

An important consideration and driver for this study was the ability of MIEX® pretreatment, in conjunction with coagulation, at a minimum, to provide similar overall TOC removal and finished water TOC concentrations less than 3.0 mg/L.

Figure 43 shows the overall pilot plant TOC effluent per process. Overall, TOC removal was greater during times of MIEX® pretreatment for both low and high TOC seasons. Of significance is also the fact that the MIEX® system removed the vast majority of TOC during low TOC season. Figure 44 shows the percent TOC removal per process and illustrates how during low TOC seasons, the MIEX® system removed 65.7% of the TOC with only an additional 14.6% removal through coagulation on average. This percent reduction related to a less than 1.0 mg/L of TOC removal through the coagulation system.



PILOT PLANT EFFLUENT TOC PER PROCESS SUMMARY

FIGURE 43

CITY OF TAMPA
PILOT PLANT STUDY

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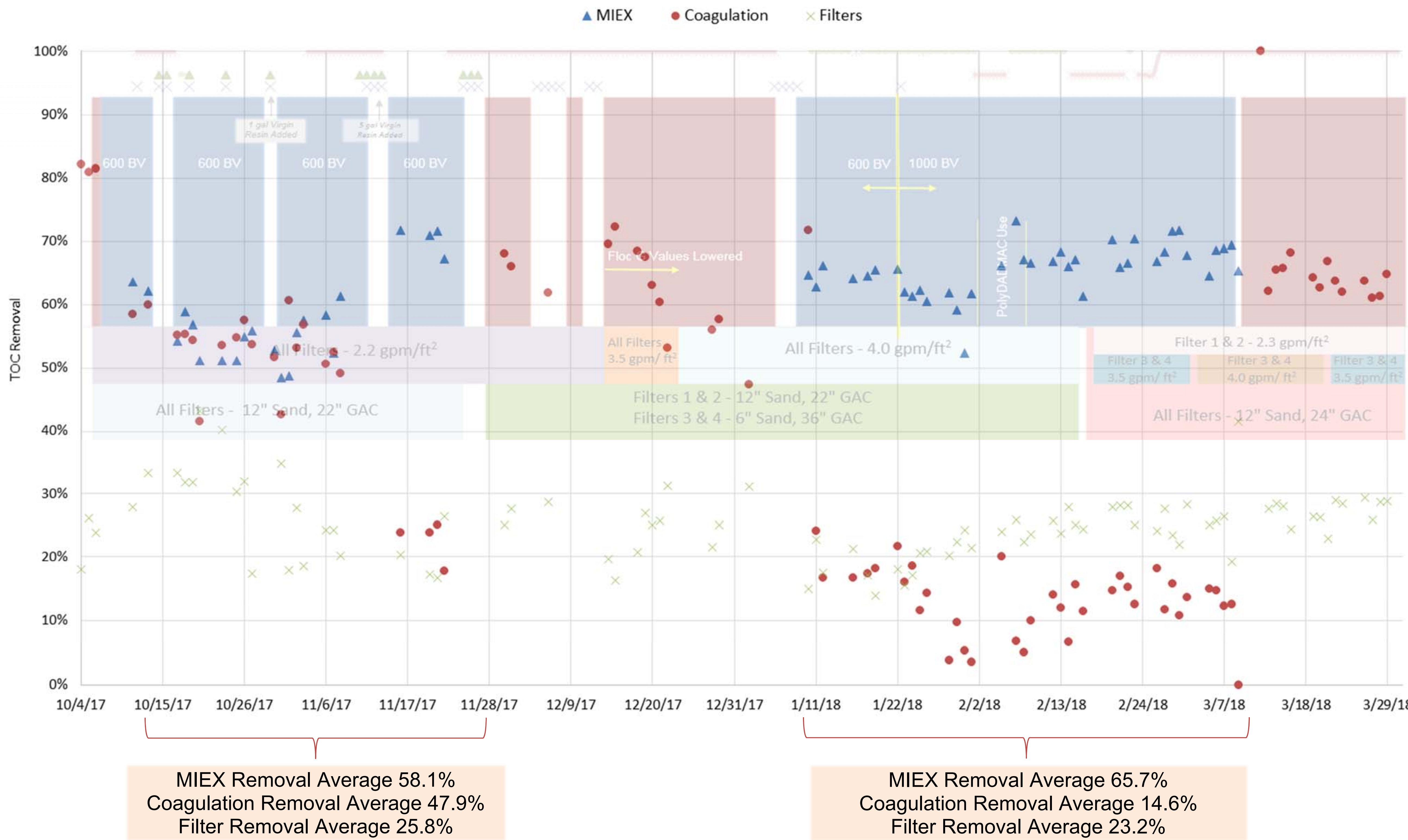


PILOT PLANT TOC PERCENT REMOVAL SUMMARY

FIGURE 44

This is significantly different than high TOC seasons where coagulation removed an average of 47.9% (an additional 3-4 mg/L TOC removal). The filters consistently removed about 1 mg/L of TOC in both high and low seasons. The behavior through coagulation was not originally expected as it was thought that the MIEX® system would be most beneficial during high TOC season, although the pilot study results indicate the opposite to be true. Again, if chemical dosing could be modified to focus on producing a settable and filterable floc during this season, as opposed to removing as much TOC as possible, then additional cost savings could be realized.

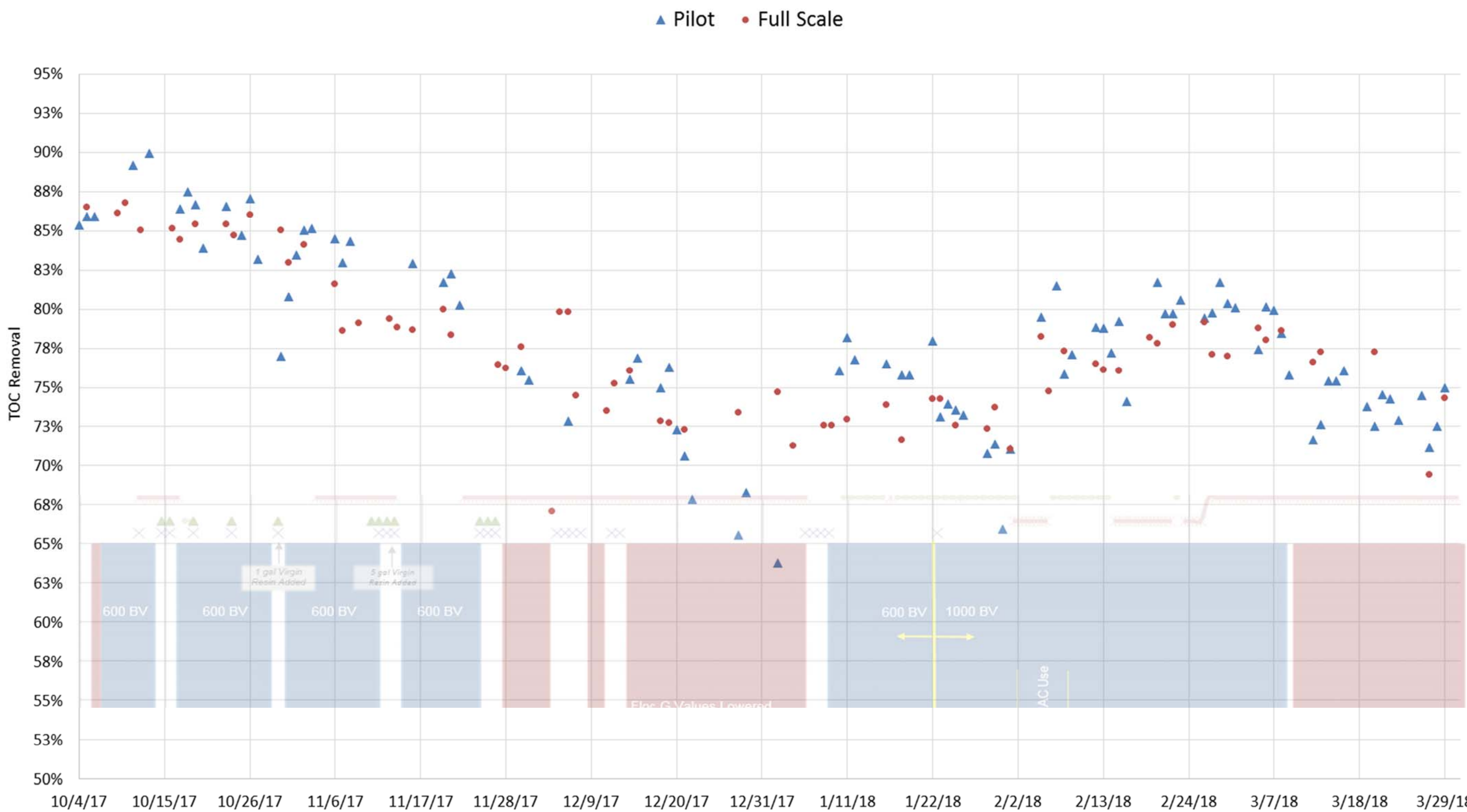
When comparing to existing full scale treatment, Figures 45, 46, and 47 show percent TOC removal, finished TOC, and pounds of TOC removed per day, respectively, over the duration of the study. As shown, finished TOC concentrations were similar in full scale and pilot scale systems, with the pilot performing slightly better, especially during low TOC periods when the MIEX® system was in operation. Overall, the pilot was able to achieve the 3 mg/L goal on average. During periods of high TOC, the pilot was capable of removing over 85% of the influent TOC, and consistently removed more with MIEX® in operation. When considering full scale flowrates and TOC removal in mg/L, an approximate pounds of TOC removed per day could be calculated. These results show a high correlation (R^2=0.90) between pilot and full scale performance. These findings suggest that the pilot plant produced the same or better finished water TOC as the full scale system. Thereby, it would be expected that full scale implementation of MIEX® could warrant similar results.

9.2 Chemical Usage & Ozone

Chemical usage varied seasonally and according to pilot plant operation, as mentioned previously. Figure 48 shows the full scale vs pilot scale comparison on chemical usage for ferric sulfate, sulfuric acid, and caustic.

Full scale floc aid polymer data was not provided (although typically applied at 0.25-0.30 ppm) and the pilot did not utilize lime but did utilize chlorine, therefore they were not compared in this section, although will be considered in the economic evaluation.

As shown, there was a significant reduction in chemical usage when MIEX® pretreatment was in use. When MIEX® was not in use, ferric sulfate dosages closely mimicked full scale. Sulfuric acid dosage was higher than full scale when using enhanced coagulation only. This could have been due to overdosing because of issues with process control at the pilot scale. Additionally, caustic usage was also higher in this mode of operation, but that is due to the fact that caustic alone was used, whereas the full scale facility utilizes lime and caustic. Full scale lime dosing is shown for reference. When MIEX® was in use, caustic alone was capable of adequately adjusting the pH before ozonation and was still lower than full scale caustic use in high TOC and significantly lower in low TOC season. During Low TOC season, in full scale, sulfuric acid is needed to lower the pH in conjunction with ferric sulfate, thereby requiring the use of both lime and caustic for pH control.

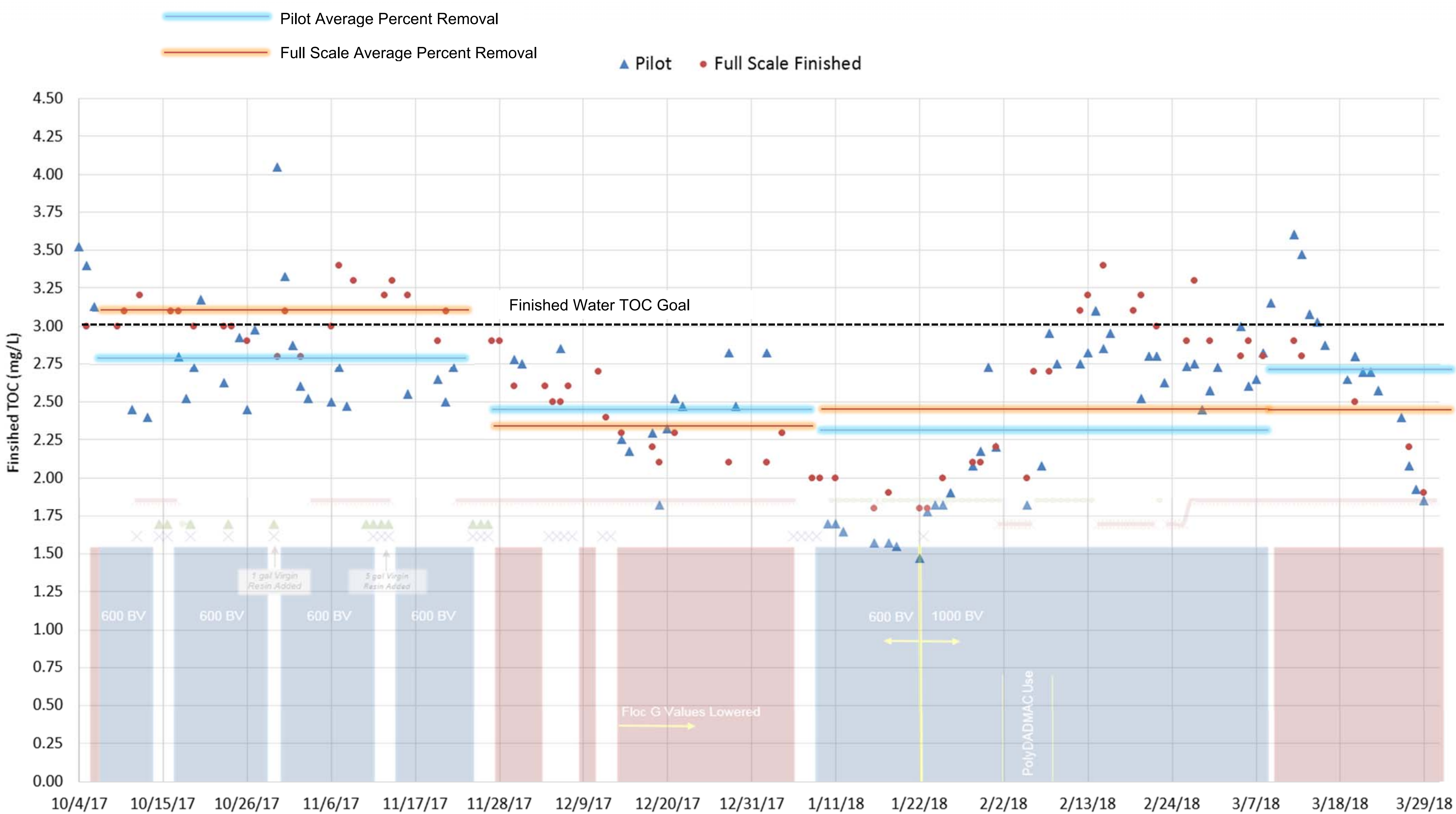


PILOT PLANT OPERATIONS SUMMARY

FIGURE 45

CITY OF TAMPA
PILOT PLANT STUDY

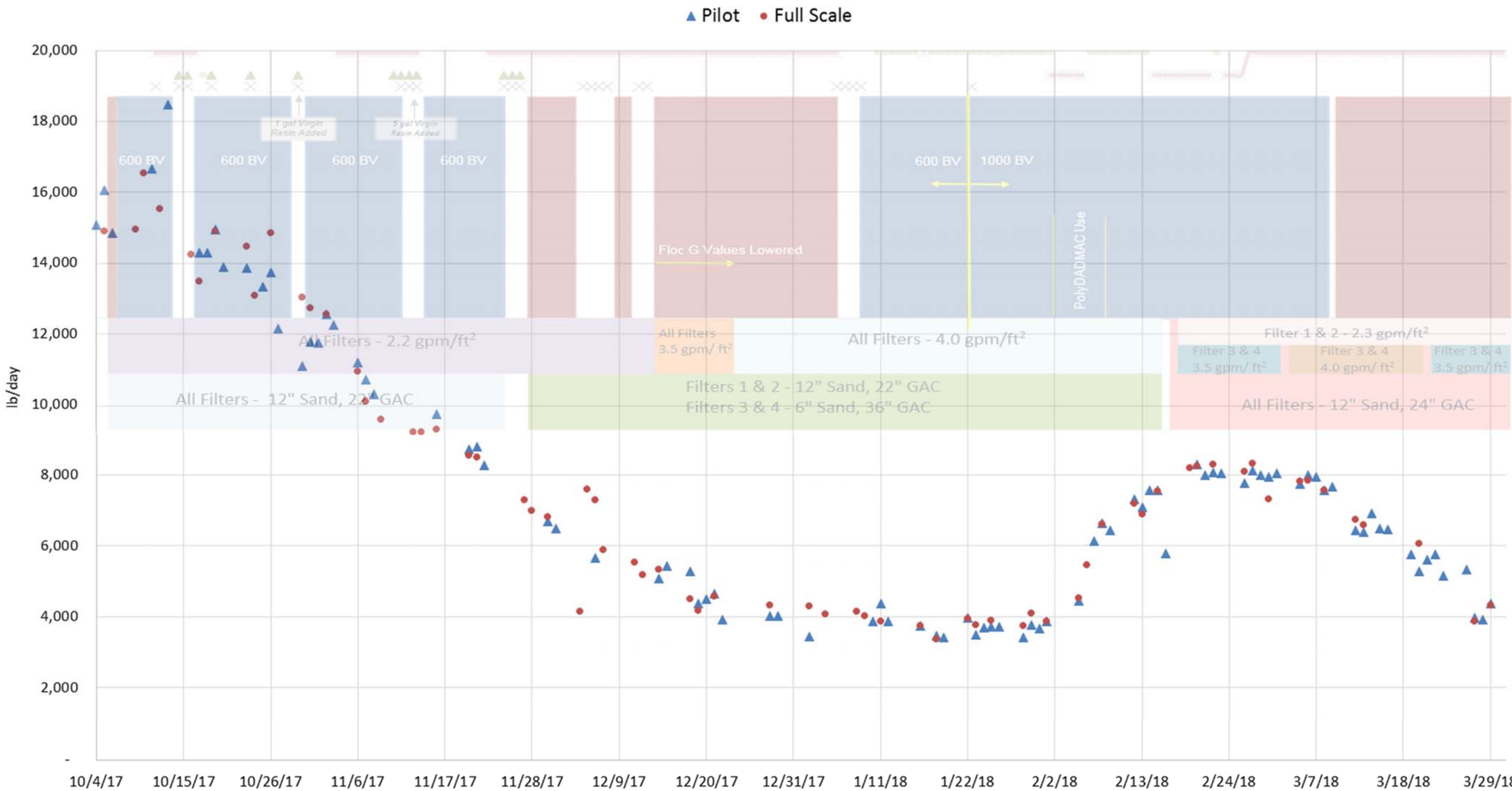
carollo



FULL AND PILOT SCALE FINISHED TOC

FIGURE 46

CITY OF TAMPA
PILOT PLANT STUDY

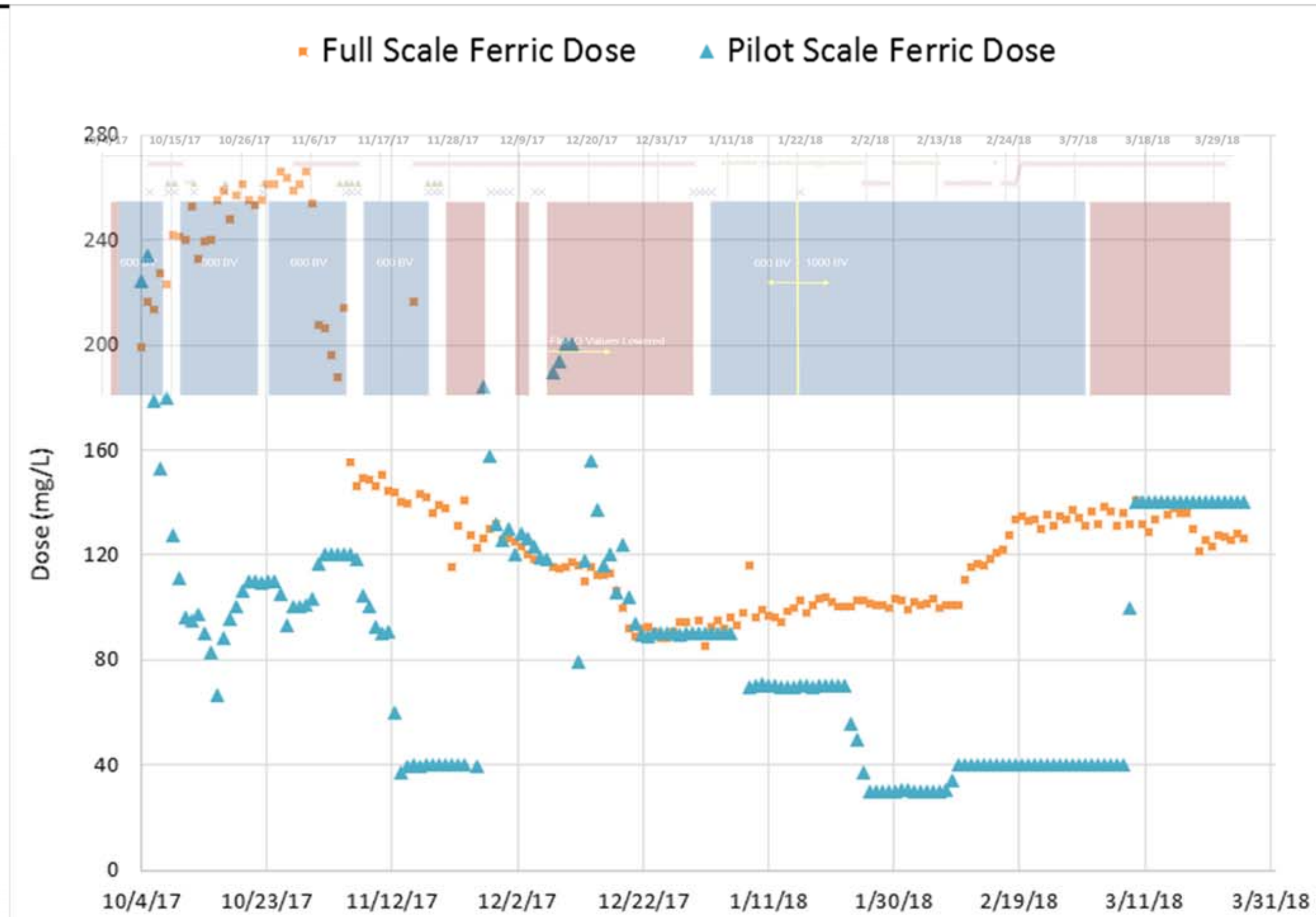


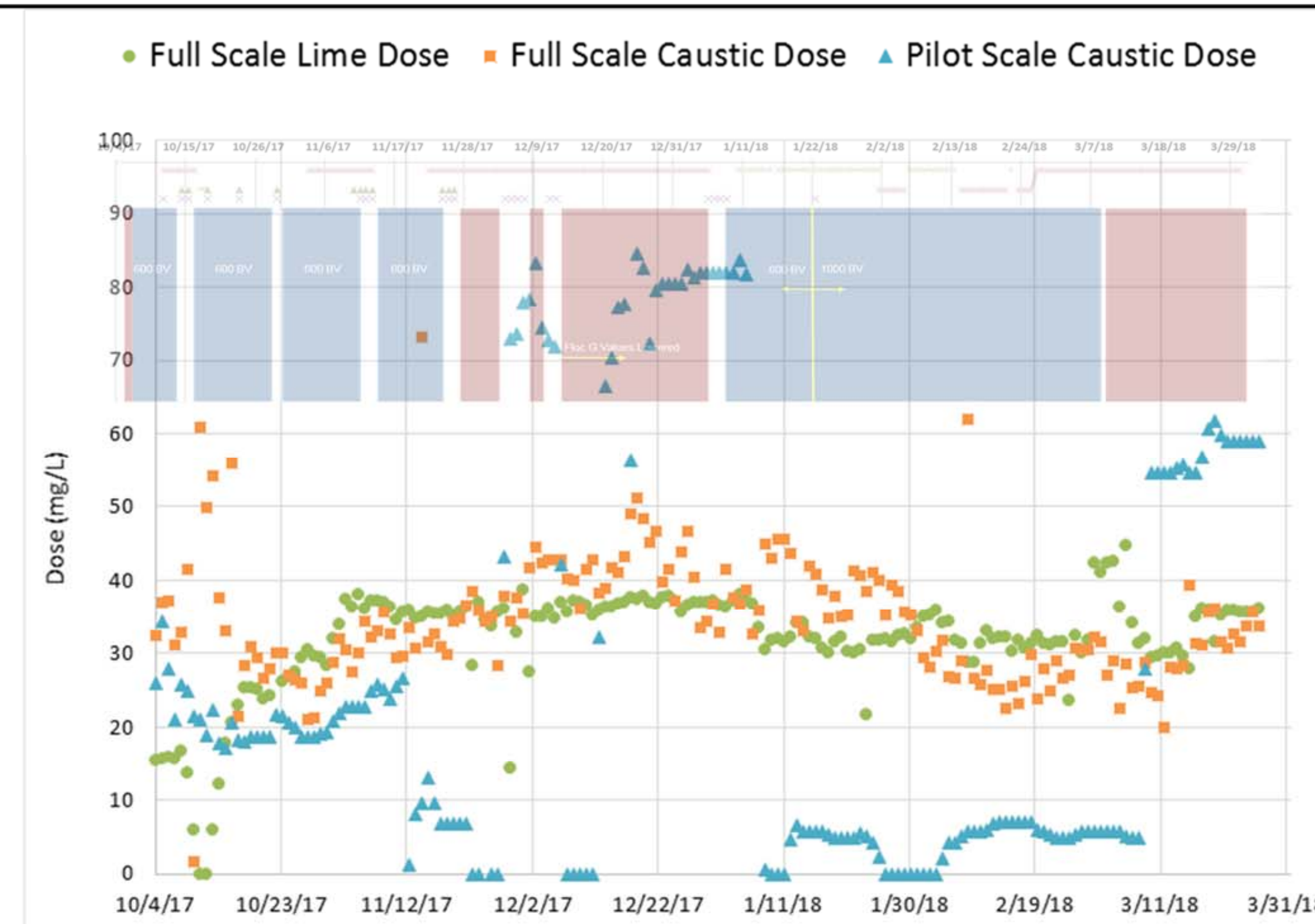
FULL AND PILOT SCALE POUNDS PER DAY TOC REMOVAL

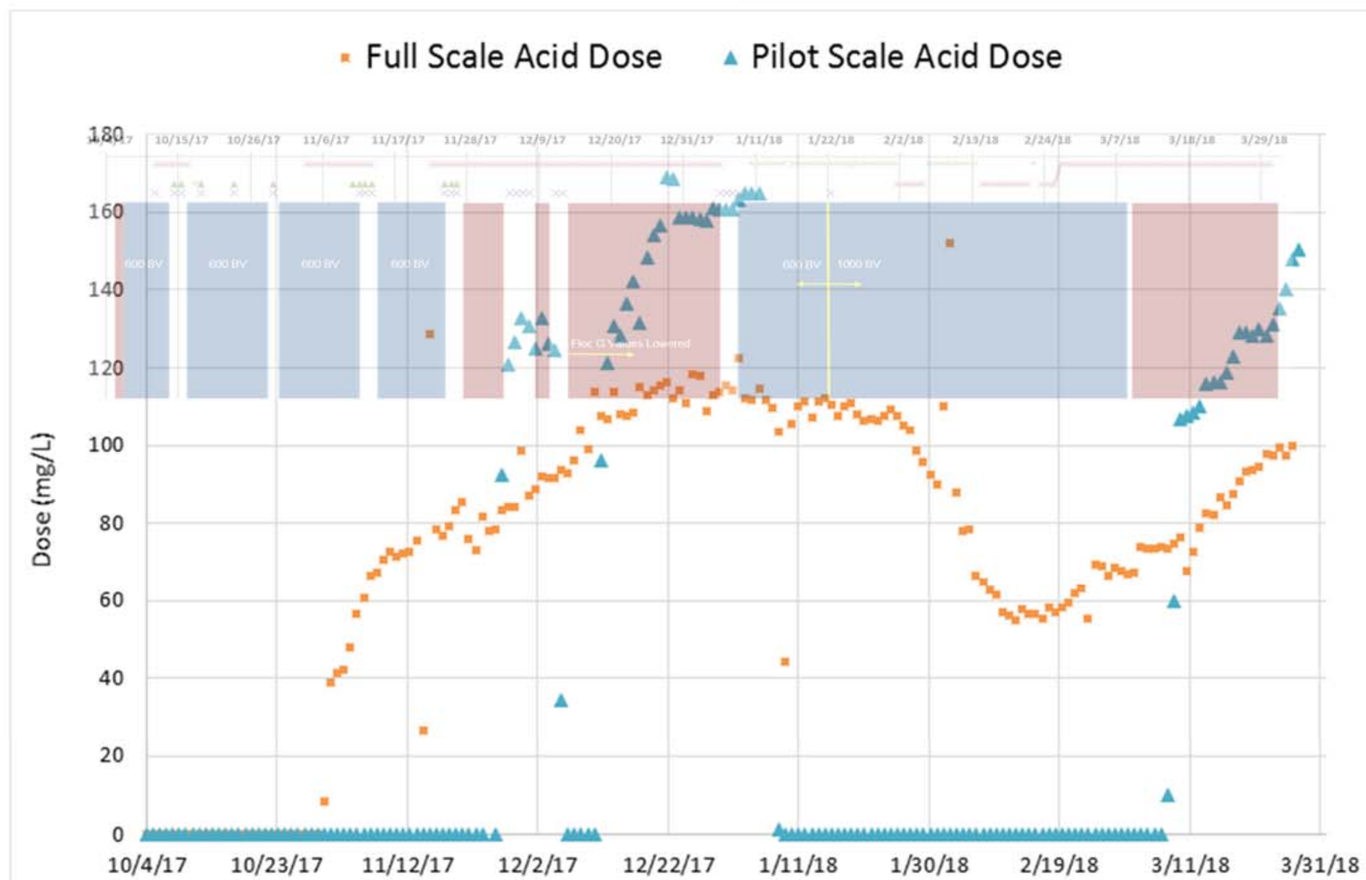
FIGURE 47

CITY OF TAMPA
PILOT PLANT STUDY

carollo







FULL SCALE VS PILOT SCALE CHEMICAL USE

FIGURE 48

The caustic dose when MIEX® was employed during this frame was significantly lower and no lime addition needed. This dosing strategy could be realized in full scale implementation with MIEX® pretreatment, and although caustic is more costly than lime, there would still be cost savings due to the decrease in caustic usage and elimination of lime usage. Additionally, sulfuric acid was not required during times of MIEX® pretreatment due to the change in coagulation method. The pilot scale polymer dose, not shown, was an average 0.25 ppm to match full scale during times of enhanced coagulation. When MIEX® pretreatment was in use, polymer was turned off. MIEX® did require pre-chlorination as previously discussed.

Furthermore, Figure 49 shows box plots for each chemical to illustrate the distribution and variability of chemical addition over the course of a year. Large variations in chemical dosing schemes can lead to difficult process control, albeit the City currently operates extremely consistently given this challenge. Even though this treatment dosing scheme is extremely effective in removing TOC, it comes with elevated operating costs.

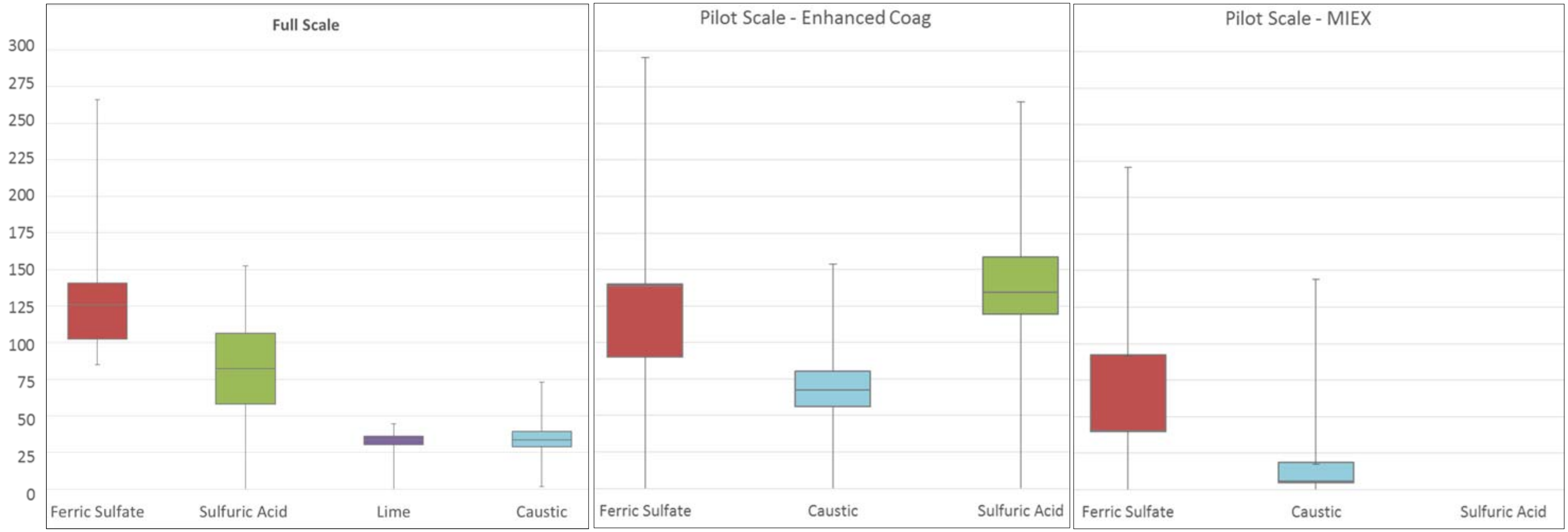
Figure 50 shows the full and pilot scale ozone doses. Since the pilot feed gas transmitter was not online until November 1st, approximate doses were assumed. The assumed increase in ozone due to MIEX® pretreatment during high TOC season was estimated to be 1.0 mg/L. This appears reasonable because even though the dose was around 4.6 when monitoring began on November 1st, it quickly came down because they were able to see and control dose better. Based on the trends shown here, it seems ozone demand is higher with MIEX® pretreatment during high TOC season but lower during low TOC season. Additionally, when the BVTR changed from 600 BV to 1000 BV the ozone demand increased and required additional ozone dose. Even though 1000 BV is adequate for organics removal, operating at this treatment rate has an apparent impact and increase on ozone demand and dose.

Therefore, if MIEX® were to be operated at 600 BV throughout the year then savings on oxygen and power associated with ozone costs would be realized during low TOC seasons. Based on the data collected, the average ozone dose over the course of the study for full scale and pilot scale were essentially the same at 2.37 mg/L and 2.35 mg/L, respectively.

Economic impacts of the reduced chemical usage will be discussed in Section 10.0.

9.3 Filter Performance

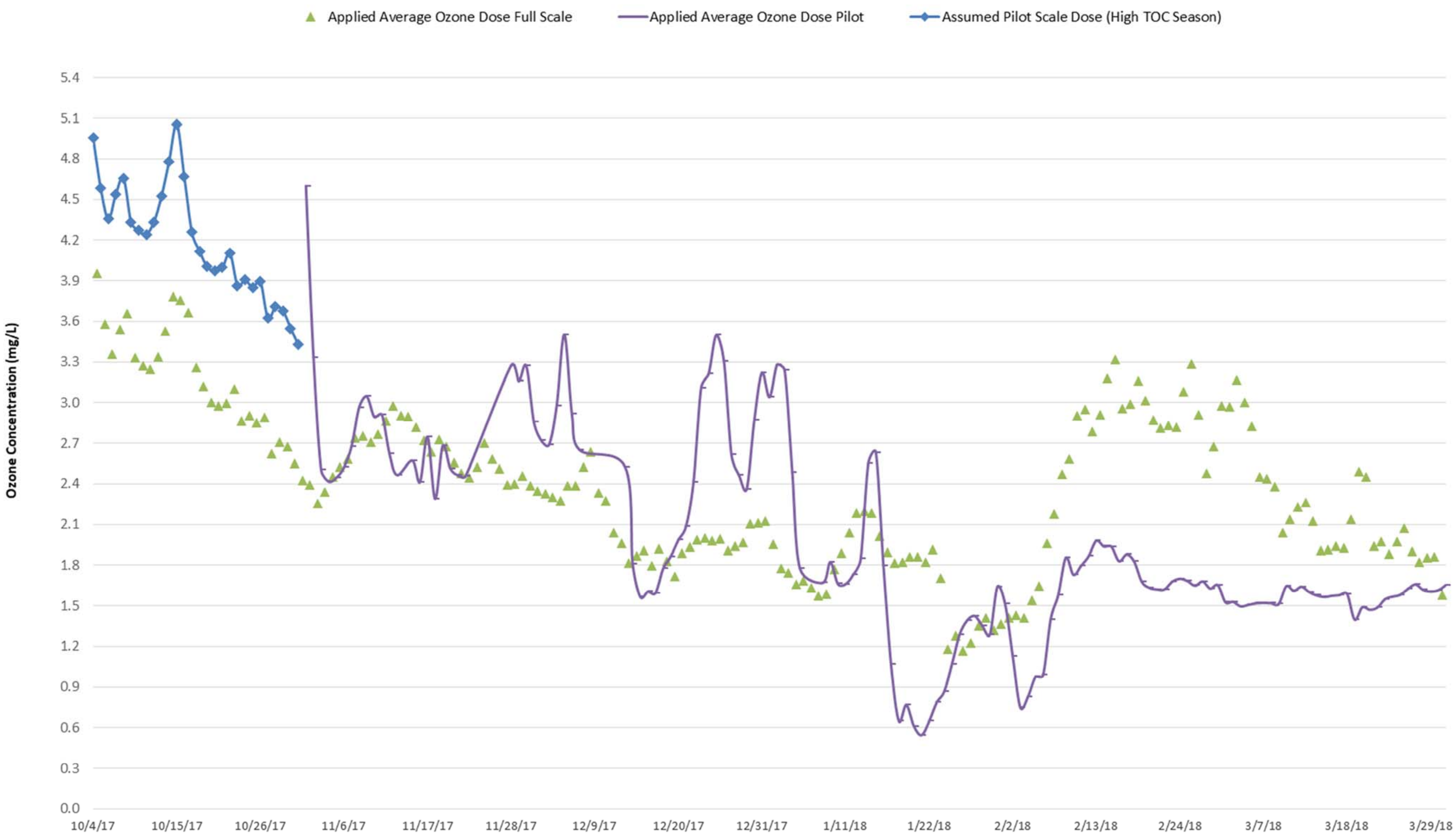
As shown in previous section, the finished water TOC produced by the filters in the pilot was similar or better than the full scale filters. Figure 51 shows the full and pilot scale filter runtimes. The full scale system performed more consistently, which is expected since operations and media depths were not changed. The full scale average filter and pilot filter 1 and 2 seemed to reach similar runtimes at the end of the study when enhanced coagulation only was in place. Being that these filters were operating around the same loading rate as full scale, this would be expected.



PILOT AND FULL SCALE CHEMICAL DOSING BOX PLOTS

FIGURE 49

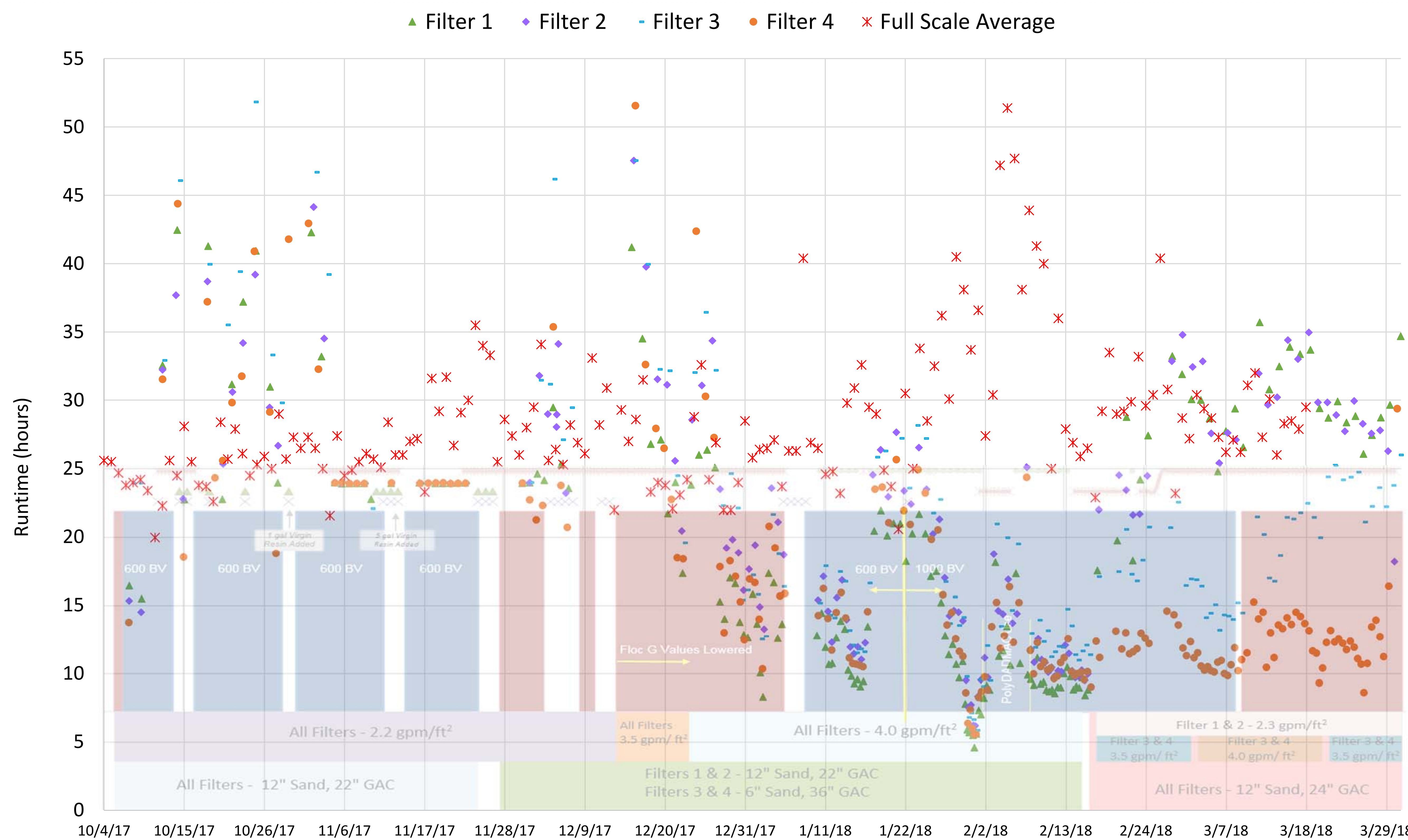
CITY OF TAMPA
PILOT PLANT STUDY



FULL SCALE VS PILOT SCALE OZONE DOSE

FIGURE 50

CITY OF TAMPA
PILOT PLANT STUDY



FULL AND PILOT SCALE AVERAGE FILTER RUNTIMES

FIGURE 51

Alternatively, when MIEX® was in operation during low TOC season, the filter runtimes were similar when the BVTR was 600, but then trended in opposite direction after the BVTR was switched to 1000. As shown in Figure 52, this related to a significant difference in UFRVs (2,000 – 3,000 gallons) during this time frame. It is possible that something was inhibiting the pilot scale filters while the full scale filters were showing extended run times. However, when looking at the trends themselves, it is also possible that the event that lead to a sharp increase followed by a sharp decrease in UFRVs (mid-January to mid-February time frame), was realized first in the pilot scale and a few days later in the full scale. In general, the average UFRVs full and pilot scale were similar (at similar operation), albeit the pilot filters showing more variation since they were not averaged like the full scale filters and experienced varying operational conditions. When comparing USFLs, as shown in Figure 53, it is evident the pilot scale UFSLs were significantly greater and more variable than full scale. This could be due to the fact that full scale data was averaged for all the filters. Individual full scale filter data could have resulted in some instances similar to what was seen pilot scale.

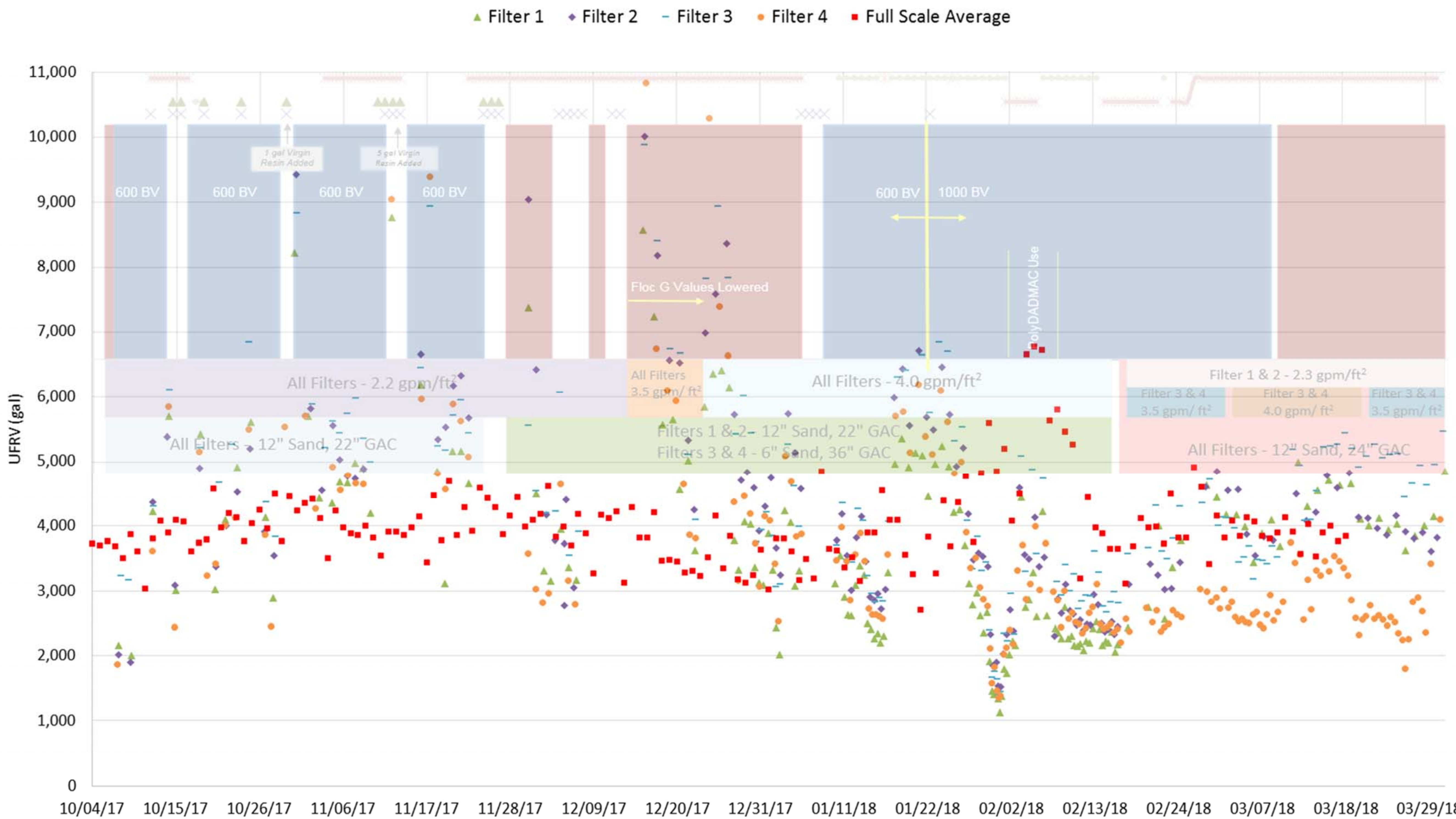
MIEX® pretreatment nor increased media depth did not seem to significantly or consistently provide for an increase in filter runtimes or UFRVs at loading rates of 2.2 or 2.3 gpm/ft^2 when compared to full scale data and would not be expected to improve at higher loading rates. Based on these results and without implementation of hydraulic improvement recommendations in the master plan, it is believed even with MIEX® pretreatment the existing filters can only reliably and efficiently treat at a max loading rate of 2.9 gpm/ft^2 (~92 mgd assuming two large filters out of service) as originally noted in Chapter 3.

10.0 ECONOMIC ANALYSIS

Due to the results of this pilot study, additional economic analysis was required in order to update net present values and overall economic feasibility previously presented in Chapter 5 of the draft Master Plan, specifically in regard to the two major alternatives, 1B (DLTWTF Expansion without MIEX®) and 2A (DLTWTF Expansion with MIEX®). Capital costs for Alternative 2A are greater; however, if chemical costs can be reduced enough, then the payback period could justify the capital expense.

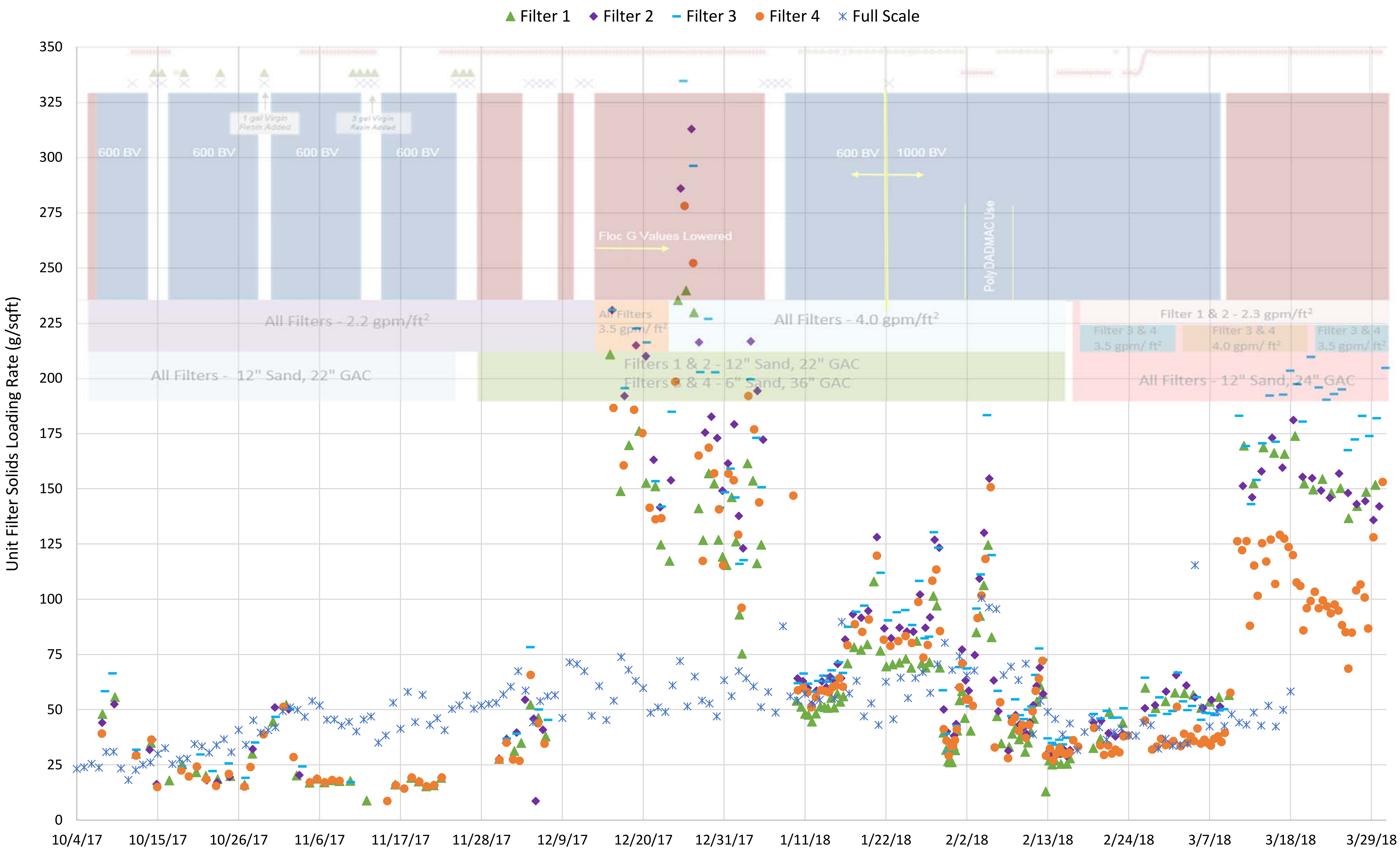
10.1 Chemical Costs

Due to the significant seasonal variations in water quality and subsequent treatment and dosing scheme, the economic analysis conducted considered low and high TOC seasons and costs associated with each. Full scale and pilot scale chemical doses were used in conjunction with the full scale raw water flow rates to calculate a pound per day chemical usage.



FULL AND PILOT SCALE MAX UFRV

FIGURE 52



FULL AND PILOT SCALE FILTER UFSLS

FIGURE 53

Using the assumed chemical costs below, an average total cost for chemicals per day could be determined.

- Ferric Sulfate: $0.08 per pound
- Lime: $0.11 per pound
- Caustic: $0.26 per pound
- Acid $0.06 per pound
- Chlorine: $0.26 per pound
- Polymer: $1.38 per pound

Costs for all other plant chemicals like fluoride, chlorine (for disinfection), ammonia, hydrogen peroxide, and ozone were not included in this analysis since they aren't expected to differ (on average) between MIEX® pretreatment and enhanced coagulation treatment processes.

For MIEX® resin and salt cost per day determinations, the following was provided by IXOM:

- Resin Usage: 1.20 gallons of resin per million gallons of water treated
- Regen Salt Usage (lb/mg): 328.0
- Resin Cost: $43.11 per gallon of resin used
- Regen Salt Cost: $0.06 per lb

The regen salt usage is based on the assumption that the waste brine recovery process will allow for 30% salt savings. It is also based on the assumption that the MIEX® system will operate at 1000 BV during low TOC season. If the waste brine recovery system is less efficient or if the BVTR is operated at 600 BV year round, then the expected salt usage would be greater (up to 437 lb/mg). According to IXOM, salt usage and resin loss at the pilot scale is not comparable or scalable to what would be expected full scale, and therefore that pilot data was not utilized to determine actual salt usage. Additional information on assumptions for salt, resin, and power consumption for the MIEX® system is provided in the Appendix H.

High TOC season and low TOC season were quantified as any days where raw water TOC is consistently above 15 mg/L or below 15 mg/L, respectively. Table 22 shows the costs per day for the existing full and pilot scale operations (with MIEX® pretreatment) during the study, in addition to the relatively cost per day per million gallons treated, in regard to chemical usage. As expected due to the decrease in chemical usage, the chemical costs associated with MIEX® are lower than the existing full scale system employing enhanced coagulation.

Table 22 Seasonal Total Chemical Cost Results
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

		High TOC Season(1)	**Low TOC Season**(2)
Existing Full Scale Operations	Cost/Day	$24,400	$16,900
	Cost/mgd	$258	$221
Pilot Operations (with MIEX® Pretreatment)	Cost/Day	$18,800	$9,900
	Cost/mgd	$176	$117

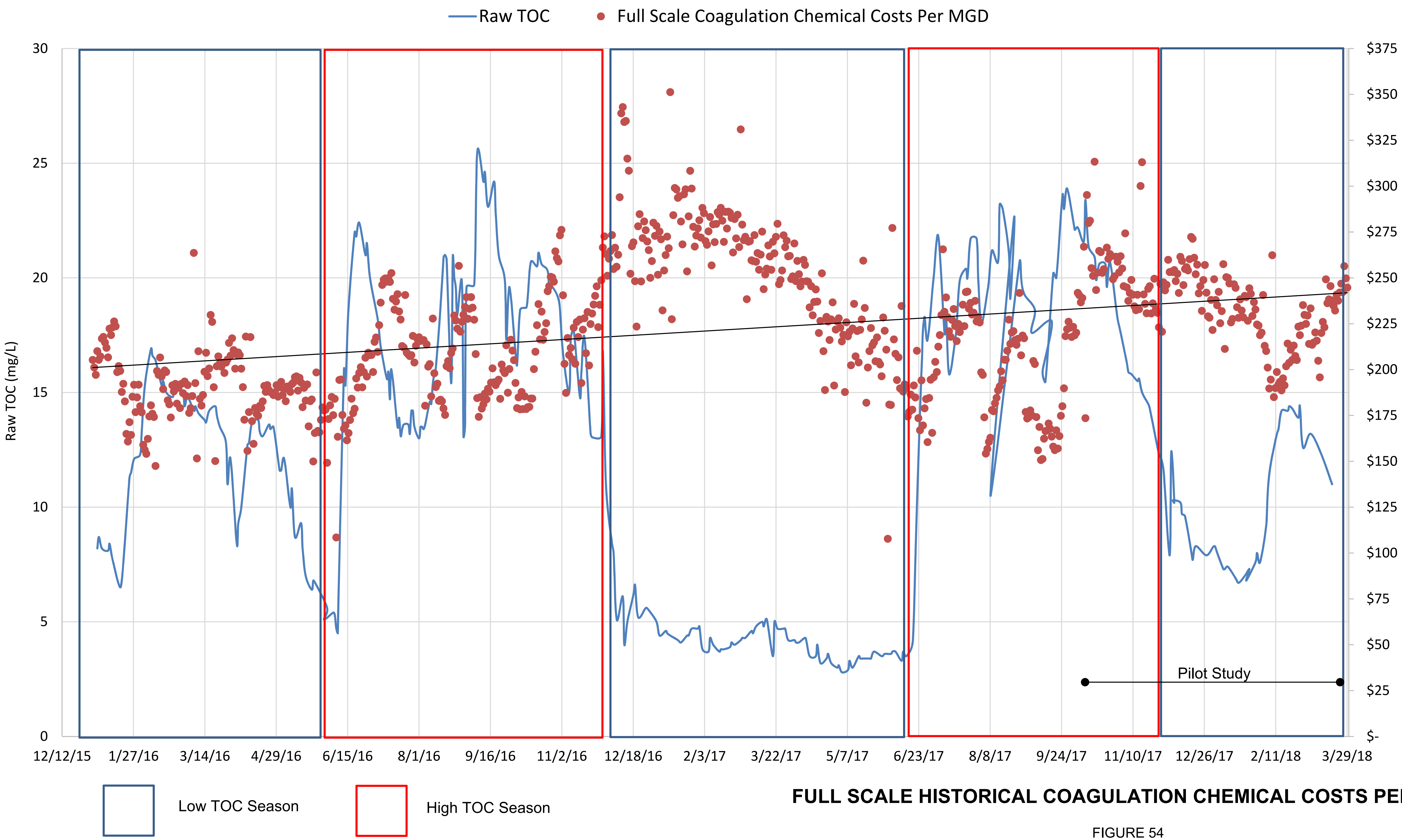
Notes:
(1) High TOC Season Costs from October 6 – November 24th, 2017.
(2) Low TOC Season Costs from January 8th - March 8th, 2018.

It should be noted that, based on the chemical use and TOC data provided for 2016 and 2017, the existing full scale operations costs per day per million gallons has not been this high historically. Table 23 shows the 2016 and 2017 average costs per mgd considering high and low TOC seasons.

Table 23 Full Scale Historical Total Chemical Cost Results
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

		High TOC Season	**Low TOC Season**
Existing Full Scale Operations (Cost/mgd)	2016	$210	$199
	2017	$215	$247

Figure 54 displays the historical raw TOC and associated costs per mgd from 2016 to present. Again, these costs only include chemicals associated with the coagulation system (i.e. ferric sulfate, lime, caustic, sulfuric acid, and polymer). As shown, the costs to treat are seasonal (as expected) but have steadily increased since 2016. The cost to treat during the low TOC season in 2017 was actually higher than the costs to treat during the pilot study. Additionally, more caustic, acid and ferric were used full scale from mid-December 2017 to present when compared to same time frames in 2016 (see Figure 8). Considering this, the costs per mgd shown in Table 23 were deemed reasonable and therefore utilized for the overall economic analysis. The unit costs developed here were used in the overall economic and net present worth analysis.



FULL SCALE HISTORICAL COAGULATION CHEMICAL COSTS PER MGD

FIGURE 54

10.2 Additional Operating and Maintenance Costs

Operating and maintenance costs were developed based on knowledge of the DLTWTF's existing power and chemical costs in addition to annual costs for each alternative. It was assumed that chemicals and power costs will increase at a rate of 3 percent per year, while sludge disposal costs will increase at a rate of 6 percent per year due to the reduction in available land as the population grows. In regard to sludge, it was originally estimated in the master plan that with the implementation of MIEX®, approximately 2 mg/L of additional TOC removal on average would be removed by the coagulation step. This average value was confirmed and therefore original sludge operating costs presented in Chapter 5 are still valid in this analysis.

IXOM provided updated waste brine treatment costs, which assumed a 600 BVTR for a production of 750 gallons of waste brine per million gallons of water treated, at a rate of $8.50 per 1000 gallons. This unit cost covered power and chemicals associated with the VSEP system.

Operating costs were evaluated at average annual daily flows for each year based on the flow projections from the Transmission and Distribution System Master Plan completed by B&V. A life-cycle cost was then calculated to determine the 20-year and 30-year net present value for both options. Operating costs were discounted at a rate of 3 percent to net present value. Similarly to the analysis conducted in Chapter 5, development of capital and O&M costs only included costs that differed among each alternative. Refer to Chapter 5, Section 5.2.1.4 for a list of items not included in this analysis. The 15-year finalized CIP will contain applicable project capital costs that will include the selection of the chosen alternative along with other required expansion project scopes.

10.3 Summary

As previously noted, it was determined that high TOC season typically occurs from June 15th through December 1st (169 days), and low TOC season occurs from December 1st through June 15th (196 days). By utilizing this assumption and actual chemical usage and flow data, an average cost per mgd was calculated (as shown in Table 22). This was then multiplied by the anticipated flows projected to determine average annual chemical costs through 2048 for the net present worth analysis.

Capital costs were developed as a part of the alternatives analysis effort and these values have been maintained, with the exception that the expected costs of new filters have increased based on possibility that the existing filters can only reliably process an average of 2.2 gpm/ft^2 and max of 2.9 gpm/ft^2, even with MIEX® pretreatment. The capital cost for both alternatives has been revised to assume $0.52/gal with 48 mgd of filter capacity required to meet future demands of 140 mgd.

Additionally, the capital cost associated with rehabilitating the existing conventional Trains 5 through 8 due to corrosive conditions because of enhanced coagulation was included for option 1B and assumed to occur in 2033 and 2048. Results of the economic analysis are displayed in Table 24.

Table 24 Economic Analysis Summary (in $1,000s)
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Alternative	**1B**	**2A**
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**
Capital Cost	$76,700	$166,200
Annual O&M Cost	$8,200	$5,100
Basin Rehab in 15 yrs (Structural)	$2,900	$ -
Basin Rehab in 30 yrs (Structural)	$2,900	$ -
Net Present Value (20-Year)	**$242,900**	**$269,000**
Net Present Value (30-Year)	**$337,000**	**$328,100**

Notes:

(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.

Alternative 1B still results in the lower calculated life-cycle costs for 20-year net present value at 10.2% lower than the MIEX® pretreatment option. However, when comparing longer life-cycles, the net present value for Alternative 2A is now 2.68% lower than 1B over a 30 year life-cycle. Since much of the equipment is likely to last longer than 20 years, especially at the DLTWTF, an average 30 year equipment life is reasonable. Additionally, there is a possibility that chemical costs could increase more than 3 percent per year over the span of 30 years. Since Alternative 1B relies heavily on chemical usage, increases in costs above 3% annually would make Alternative 2A more attractive in regard to 20-year life-cycle costs. A sensitivity analysis was completed to attempt to quantify this risk and is discussed in the next section.

10.3.1 Sensitivity Analysis

An economic sensitivity analysis was conducted for various scenarios that examine how changes in assumptions (i.e. increase in chemical costs, higher than expected resin loss, etc.) could impact O&M costs, and subsequently 20 and 30 year net present values, and are discussed herein.

10.3.1.1 Caustic Cost Increase

Table 25 details the expected impacts if the cost of caustic increased by 30% from $0.26 per pound to $0.34 per pound. As shown, the impact with MIEX pretreatment is less significant since the need for caustic for pH adjustment and treatment is reduced.

Table 25 Economic Analysis with Caustic Increase Summary (in $1,000s)
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Alternative	**1B**	**2A**	**Net Change(2)**	
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**	**1B**	**2A**
Annual O&M Cost	$8,800	$5,400	↑$600	↑$300
Net Present Value (20-Year)	$255,900	$273,300	↑$13,000	↑$4,300
Net Present Value (30-Year)	$357,400	$334,800	↑$20,300	↑$6,700

Notes:
(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.
(2) Net change from Economic Analysis Summary displayed in Table 24.

10.3.1.2 Resin Loss

If resin loss was reduced to 0.5 lb/MG from 1.2 lb/MG, then net present values for the MIEX pretreatment alternative are decreased significantly, as shown in Table 26. Alternatively, if the resin loss is increased to 2.0 lb/MG then MIEX pretreatment becomes less viable economically, as shown in Table 27.

Table 26	Economic Analysis with Decrease in Resin Loss (in $1,000s) David L. Tippin Water Treatment Facility Master Plan City of Tampa			
Alternative	**1B**	**2A**	**Net Change(2)**	
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**	**1B**	**2A**
Annual O&M Cost	$8,200	$4,200	-	↓$900
Net Present Value (20-Year)	$242,900	$250,700	-	↓$18,300
Net Present Value (30-Year)	$337,100	$299,400	-	↓$28,700

Notes:

(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are

(2) Net change from Economic Analysis Summary displayed in Table 24.typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.

Table 27	Economic Analysis with Increase Resin Loss (in $1,000s) David L. Tippin Water Treatment Facility Master Plan City of Tampa			
Alternative	**1B**	**2A**	**Net Change(2)**	
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**	**1B**	**2A**
Annual O&M Cost	$8,200	$6,200	-	↑$900
Net Present Value (20-Year)	$242,900	$290,000	-	↑$21,000
Net Present Value (30-Year)	$337,100	$361,000	-	↑$32,900

Notes:

(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.

(2) Net change from Economic Analysis Summary displayed in Table 24.

Finally, being a proprietary resin, there is the possibility that resin costs could increase significantly. Table 28 shows the economic summary for O&M and net present values if the cost of resin increased by 50% from $43.11 per gallon to $64.67 per gallon. Once again, MIEX becomes less economically favorable in this case.

Table 28 Economic Analysis with Increase in Resin Costs (in $1,000s) David L. Tippin Water Treatment Facility Master Plan City of Tampa				
Alternative	**1B**	**2A**	**Net Change(2)**	
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**	**1B**	**2A**
Annual O&M Cost	$8,200	$5,900	-	↑$800
Net Present Value (20-Year)	$242,900	$284,800	-	↑$15,800
Net Present Value (30-Year)	$337,100	$352,800	-	↑$24,700

Notes:
(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.
(2) Net change from Economic Analysis Summary displayed in Table 24.

10.3.1.3 Ozone Usage Increase

Since ozone dose and demand could not be verifiably confirmed during high TOC season, but was expected to be higher with MIEX pretreatment, an economic analysis assuming an increase in dose and use of 50% was conducted. An average cost of oxygen for ozone production of $100 per ton was used for the analysis. The dose was assumed to be 3.45 mg/L which is 50% higher than the existing full scale average of 2.3 mg/L. The results shown in Table 29 signify there was virtually no impact on O&M or life cycle costs within the margin of error, however this analysis does not include in the increased cost of power associated with increase ozone use. When compared to the other sensitivity analysis results, increase in ozone demand impacts is expected to be minor.

Table 29	Economic Analysis with Increase in Ozone Costs (in $1,000s) David L. Tippin Water Treatment Facility Master Plan City of Tampa			
Alternative	**1B**	**2A**	**Net Change(2)**	
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**	**1B**	**2A**
Annual O&M Cost	$8,200	$5,200	-	↑$100
Net Present Value (20-Year)	$242,900	$270,400	-	↑$1,400
Net Present Value (30-Year)	$337,100	$330,300	-	↑$2,200

Notes:

(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.

(2) Net change from Economic Analysis Summary displayed in Table 24.

11.0 QUALITATIVE CONSIDERATIONS

Although cost is important for determining the final recommendation, it is not the only consideration. This section details additional considerations that are less quantifiable and more qualitative based. It includes the benefits and also risks associated with implementing a full scale MIEX® pretreatment system at the DLTWTF.

11.1 Benefits

The results of this study suggest that MIEX® is capable of removing the bulk majority of TOC seasonally and capable of consistently meeting finished water TOC goals below 3.0 /L. This means the current treatment process practiced at the DLTWTF could move away from enhanced coagulation, leading to overall reduced chemical use and solids production. As mentioned previously, enhanced coagulation occurs at a pH between 3.5 to 4.3, thereby requiring a significant amount of pH adjustment chemicals in addition to coagulant. With the implementation of MIEX®, the DLTWTF could operate at a more neutral coagulation pH, which would result in eliminating the use of sulfuric acid and lime. Irrespective of cost savings associated with this, the neutral pH conditions within treatment basins will lead to extended useful life in terms of concrete and structural integrity. Additionally, City staff could avoid handling the high strength sulfuric acid and reduce the risk of a potentially dangerous spill/accident. The elimination of lime could also save City staff time since lime slaking and slurry systems tend to be labor intensive.

It is apparent that MIEX® provides downstream process benefits in terms of TOC reduction, which plays a significant role in minimizing the burden on the existing conventional treatment. More importantly, the results suggest that MIEX® is actually most effective

Table 29 Economic Analysis with Increase in Ozone Costs (in $1,000s) David L. Tippin Water Treatment Facility Master Plan City of Tampa				
Alternative	**1B**	**2A**	**Net Change(2)**	
Description	**Expanded Conventional Treatment**	**Fluidized Ion Exchange Pretreatment**	**1B**	**2A**
Annual O&M Cost	$8,200	$5,200	-	↑$100
Net Present Value (20-Year)	$242,900	$270,400	-	↑$1,400
Net Present Value (30-Year)	$337,100	$330,300	-	↑$2,200

Notes:

(1) Capital and O&M costs were developed in accordance with a Class IV opinion of probable cost of construction as defined by the Association of Advancement for Cost Engineering (AACE).The expected accuracy range is from +30 percent to -15 percent. Class IV budget estimates are typically prepared for master planning and based on preliminary process flow diagrams, main process systems, plant schematic layouts, and major equipment.

(2) Net change from Economic Analysis Summary displayed in Table 24.

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The results of this study suggest that MIEX® is capable of removing the bulk majority of TOC seasonally and capable of consistently meeting finished water TOC goals below 3.0 /L. This means the current treatment process practiced at the DLTWTF could move away from enhanced coagulation, leading to overall reduced chemical use and solids production. As mentioned previously, enhanced coagulation occurs at a pH between 3.5 to 4.3, thereby requiring a significant amount of pH adjustment chemicals in addition to coagulant. With the implementation of MIEX®, the DLTWTF could operate at a more neutral coagulation pH, which would result in eliminating the use of sulfuric acid and lime. Irrespective of cost savings associated with this, the neutral pH conditions within treatment basins will lead to extended useful life in terms of concrete and structural integrity. Additionally, City staff could avoid handling the high strength sulfuric acid and reduce the risk of a potentially dangerous spill/accident. The elimination of lime could also save City staff time since lime slaking and slurry systems tend to be labor intensive.

It is apparent that MIEX® provides downstream process benefits in terms of TOC reduction, which plays a significant role in minimizing the burden on the existing conventional treatment. More importantly, the results suggest that MIEX® is actually most effective during low TOC season, which has historically been a time where the DLTWTF struggles to efficiently and effectively treat the water. The improvement in performance during low TOC season is likely due to the change in the type of organics. The MIEX® treatment process is known to remove low molecular weight and non-aromatic hydrophilic type organics, while the enhanced coagulation process removes larger, aromatic hydrophobic type organics. Due to the relative consistent performance of MIEX® in both seasons, it could be said that high TOC season consists of both type of organics and MIEX® and coagulation work hard together to remove TOC. Whereas in low TOC seasons it’s expected there is very little of the large, aromatic organics, thereby making the MIEX® system more effective and the coagulation process less effective in terms of percent TOC removal.

These results also indicate that the MIEX® process is capable of producing low TOC effluent under dynamic conditions of widely varying and quickly changing source water quality. As mentioned and considered in the Master Plan, the DLTWTF may be required to process and treat up to 50 mgd of alternative water supply as part of the Tampa Augmentation Project (TAP). There is potential that an indirect potable reuse option will become a viable alternative water supply for the City in the future. Therefore, the influent water quality to the DLTWTF may change. It is highly possible that with the implementation of TAP, water quality in terms of TOC could improve and be significantly lower than current raw water TOC concentrations, meaning *‘low TOC season*’ could occur year round. Based on the type of organics in the new water supply, MIEX® pretreatment could then become more effective overall and provide for additional cost savings.

As reviewed in the Regulatory Assessment in Chapter 1, there are a number of contaminants of emerging concern (CECs) that may affect the DLTWTF in the future. Particular constituents of note include strontium, perchlorate, perfluorooctanoic acid/perfluroroocatnesulfonic acid (PFOA/PFOS), and hexavalant chromium, which can be reduced through an anionic exchange process like MIEX®. Toxic organic chemicals (TOrCs), including pharmaceutical and personal care products (PPCPs) and endocrine-disrupting compounds (EDCs), are also of concern when considering IPR. There is currently a study being conducted by Synder Research Group evaluating MIEX® application in potable water reuse (see Appendix F). The proposed study suggests that MIEX® resin was previously reported to attenuate TOrCs by ion exchange and hydrophobic attraction mechanisms. Additionally, Snyder’s group also demonstrated the 70 – 80 % removal of PFOA and PFOS. However, since pre-chlorination may be required with MIEX® pretreatment, Cyantoxins could become a concern since oxidants can lyse cyanobacteria cells and release toxins.

Although there are many benefits to MIEX® pretreatment, there are also a number of risks that should be considered which are detailed in the next section.

11.2 Risk

New treatment processes always pose a certain amount of risk. In order to make a sound recommendation, these risks must be mitigated as much as possible. This section describes possible risks and proposed mitigation strategies (if any) to reduce that risk.

11.2.1 Chloride-to-Sulfate Mass Ratio

Previously discussed in Section 8.1, the differences in CSMR during times when MIEX® was on and off were significant. With the current enhanced coagulation treatment process, the CSMR of less than 0.58 is not concerning in regard to lead leaching. However, this is altered and increased significantly with MIEX® pretreatment and therefore could cause serious contamination issues if the City's distribution system (DS) has lead pipe. City staff understand that there is currently no lead pipe within the system but this should be confirmed. If there is no lead pipe then this may not be a major concern if MIEX® pretreatment is implemented full scale. Conversely, if lead pipe is found to be installed within the DS, then the risk of contamination would increase and cause concerns regarding the use of MIEX®.

11.2.2 Bromate

It is possible that during high TOC periods, MIEX® pretreatment requires additional ozone dose downstream. The type of organics not removed through MIEX® and influent bromide levels in with conjunction ozone application could lead to increased bromate levels, possibly well above the current MCL of 10 ppb. Additional data should be collected and/or researched on this topic since few bromate samples were taken and the actual ozone dose and demand during that time frame were unknown due to feed gas analyzer issues. There are a number of bromate mitigation strategies, including two of which that are already used at the DLTWTF including addition of ammonia and pH control.

11.2.3 Full Scale Implementation – Size and Resin

It is important to note that currently the largest MIEX® treatment facility in the United States is located in Alabama and has a rated capacity of 37 mgd. This is significantly smaller than the DLTWTF's rated capacity and comes with inherent risk since full scale implementation of this system would be by far the largest in the U.S. Additionally, this system could require a significant portion of the DLTWTF's existing open area near the Administration building which could limit future expansions or additional facilities in this location. This risk could be minimized due to the fact that the MIEX® system is of modular design, and therefore scale-up of the design for the contactors and regeneration systems is (comparatively) simpler than other treatment processes.

The MIEX® resin is of proprietary nature and currently manufactured in Australia. Due to this, there is risk of price gauging, higher resin costs associated with shipping and risk of short or unavailable supply. As such, it could be difficult and expensive to receive virgin resin in a timely fashion should this source of supply become interrupted or unavailable or if the facility required a complete replacement of the original resin. To mitigate this risk, IXOM has agreed to construct a new resin manufacturing facility to be located in the United States. This would decrease the cost of resin (already assumed in the economic analysis) but also provide for quick shipments of resin if necessary. Confirming this intention, perhaps contractually, with IXOM would be prudent before moving forward with implementation of this technology.

11.2.4 Brine Treatment and Waste Disposal

A major benefit originally presented with the MIEX® pretreatment option was that the DLTWTF could maintain zero-discharge through the use of a waste brine treatment system in conjunction with a third party to haul away concentrate from this system. This system would also save salt costs by using the high saline permeate within the MIEX® regeneration process. Although the results of the pilot study were promising, there was not enough data collected to statistically confirm this systems effectiveness. Additionally, due to the limited samples collected, the third party vendor could not confirm or deny that the waste concentrate was a viable product they'd be interested in accepting on a full scale basis. Therefore, there is a chance that the waste concentrate would have to be disposed of in a different manner by the City with deep well injection the most likely candidate. Based on IXOM's estimate 750 gallons of waste brine produced per million gallons treated (at 600 BV), this could equate to 61,500 gallons per day of waste brine generated and requiring disposal. Unless additional pilot scale testing is completed to generate more samples for analysis, then there is a risk that the third party vendor could find the concentrate to be unviable full scale, which would cause the DLTWTF to potentially lose its 'zero-discharge' status.

11.2.5 Resin Fouling and Attrition

The results of this study showed that the current source raw water at the DLTWTF is capable of encouraging biological growth on the resin. Without pre-chlorination, this can lead to resin fouling, ineffectiveness, and carry over. With pre-chlorination of the raw water, there is the risk of formation of regulated disinfection by-products (DBPs), specifically total trihalomethanes (TTHMs) and haloacetic acids (HAAs). DBPs were not monitored during the study, but due to the raw water TOC levels (up to 25 mg/L) and required chlorine dose (average 2.9 mg/L), it can be assumed that DBPs could be a significant issue. DBP formation could be tested at bench-scale to address this concern.

In addition to biological fouling issues, it has recently been observed that there could be long term fouling of the resin. Specifically, it has been found that the resin's ability to de-sorb organics during the regeneration process becomes less efficient over time. This can lead to decreased organics removal performance and eventually inability of the resin to remove organics to the level that was experienced in the pilot. This risk is currently mitigated by the fact that resin attrition occurs with the design system which leads to addition of the virgin resin thereby replacing the full inventory of resin overtime. Additionally there are alternative anionic exchange resins, specifically the SIX ion exchange process, which does not experience this type of fouling and also does not use proprietary resin. Additional information on the SIX process is included in Appendix E.

According to IXOM, resin loss is hard to quantify at the pilot scale level and therefore was not monitored during the study. Resin loss greater than IXOM's assumed value of 1.20 gallons of resin per million gallons of water treated would lead to increased O&M costs at an amount of which is unknown and poses financial risk not shown in the economic analysis.

12.0 SUMMARY OF OBJECTIVES AND RESULTS

The overall objective of this study was to evaluate MIEX® as a pretreatment step after raw water screening and before the coagulation process. The pilot study allowed for the observation of overall MIEX® system performance and resulting performance and operational impacts to the plant's existing coagulation, flocculation, sedimentation, ozone, and filtration systems at the pilot. The original goals and objectives set to be accomplished during this study are reiterated and their results discussed below.

Objective:

Use MIEX® as a pretreatment step to reduce coagulant demand to ~50 ppm annual and allow for operation at a neutral pH, thereby reducing or eliminating pH adjustment chemicals and reducing sludge production.

Result: **MET IN FULL**

The average ferric sulfate demand for the pilot system when MIEX® was in operation was 67 ppm. Although this is higher than 50 ppm, it should be noted that the reduction to 50 ppm was developed considering full scale average doses at the time of the draft master plan development, where full scale average dose was 121 ppm. It has since been confirmed that full scale is now operating at slightly higher coagulant doses. Specifically,

- Pilot Plant with MIEX® Pretreatment Average Coagulant Dose
  - High TOC Season – 95 ppm
  - Low TOC Season – 46 ppm
  - Overall Average for duration of study – 67 ppm
- Full Scale with Enhanced Coagulation Average Coagulant Dose
  - High TOC Season – 205 ppm
  - Low TOC Season – 113 ppm
  - Overall Average for duration of study – 141 ppm

Based on these results, the originally set objective of significantly reducing average coagulant dose by 70 ppm was achieved. Additionally, the MIEX® pilot was able to reduced TOC concentrations to level where enhanced coagulation was not required therefore allowing more conventional coagulation at a neutral pH and eliminating the need for sulfuric acid and lime. The resulting reduced TOC and decreased chemical usage in the coagulation system would subsequently result in a decrease in sludge production.

Objective:

Utilize the VSEP waste brine treatment system to produce permeate that could be reused in the MIEX® salt saturator, reducing salt usage, and the concentrate could be pick up and hauled to a third party vendor with the overall goal to maintain zero discharge status at the DLTWTF.

Results: **MET IN PART, ADDITIONAL DATA REQUIRED**

The VSEP system was operated twice during the pilot study and results indicated in the permeate after waste brine treatment was 46.9 g/L and could result in a 30% reduction in salt usage. Additionally, the concentrate was not able to be analyzed due to the limited amount of samples provided to the third party supplier. Due to this, it could not be confirmed that the supplier would be able to utilize the concentrate. Thus there is the risk that the DLTWTF will need to discharge it by other means. Additional data would be required to ultimately confirm that the VSEP system would be beneficial and allow for the City to maintain zero discharge status.

Objective:

Test the ability of the MIEX® system and understand resulting impact to downstream processes in regard to removal of organics and color.

Results: **MET IN FULL**

The raw water TOC ranged from 13.8 to 23.8 mg/L during high TOC period and the MIEX® unit achieved steady TOC removal at an average removal of 58.1%. During the Low TOC period, TOC ranged from 6.4 to 13.8 mg/L, and MIEX® was operated at 600 BV and 1000 BV with no adverse impacts to TOC removal and in fact achieved higher (average 65.7% removal) and more consistent during this time. During periods of high TOC the entire pilot was capable of removing over 85% of the influent TOC. Additionally, in low TOC seasons the, although limited instances, where raw water TOC was below 7 mg/L, the MIEX® effluent TOC fell below 3 mg/L, meeting the current finished water goal alone before coagulation and filtration.

These findings suggest that the pilot plant produced the same or better finished water TOC as the full scale system. Overall these results show that the MIEX® process is capable of producing low TOC effluent under dynamic conditions of widely varying and quickly changing influent, ultimately reducing the pressure on downstream processes to remove organics.

Objective:

Optimize the chemical dosing within the coagulation system with MIEX® as a pretreatment, and operate at 'textbook' mixing g-values, three stage tapered flocculation with ported walls, and plates settlers to see if improved performance could be observed.

Results: **MET WITH EXCEPTIONS**

The coagulation process was highly effective with TOC removals ranging from 40 to 72% with MIEX® on and offline. However, the study did find that during low TOC periods the average percent removal through coagulation with MIEX® pretreatment was only an additional 15%. This was because the MIEX® system removed nearly all the influent TOC only allowing the coagulation system to remove less than 1 mg/L of additional TOC. Based on these results, chemical dosing was optimized during high TOC season, but in low TOC season with MIEX® treatment, chemical dosing could be modified to focus on producing a settable and filterable floc, as opposed to removing as much TOC as possible, which could result in additional chemical use reduction. Furthermore, the persistent presence of surface sludge throughout the study made it difficult to determine if the g-values and floc/sed configuration could benefit the full scale treatment process. If enhanced coagulation is no longer used at the DLTWTF, then mixing and ideal flow conditions become vital to the successful creation of filterable floc. As such, modifications to the existing full scale flocculation and sedimentation basins as previously proposed in the draft master plan are still warranted.

Objective:

Optimize ozone dose and understand ozone demand with MIEX® pretreatment and determine impacts on Biofiltration and water quality, if any.

Results: **MET WITH EXCEPTIONS**

Due to feed gas analyzer issues, there was no data for applied or transferred ozone dose between October 4th and November 1st during the peak TOC season. The average daily ozone dose and demand throughout the study during MIEX® pretreatment (with the exception of October – November 1st as noted), were 1.89 mg/L and 1.62 mg/L, respectively. However, these values could be greater since ozone dose could not be monitored during the highest TOC time frame, when ozone demand is expected to be higher. Also, from mid to late February, the ozone residual was reading zero due even though grab samples confirmed residual ozone (0.13 mg/L). Therefore the actual ozone demand during this time frame could have varied from what is shown. Additionally, it was found that when the MIEX® system BVTR changed from 600 BV to 1000 BV, ozone demand increased significantly. Although there was no apparent impact to organics removal through MIEX® and the floc/sed system when the BVTR changed, there was an impact on ozone demand and dose. Due to these results, the impacts of MIEX® pretreatment on ozone demand during high TOC periods could not be quantified.

Limited ozone effluent bromate data was collected but was found to be significantly above the MCL during the month of October (when ozone dose could not be monitored). After investigations on why this occurred in the pilot scale and not at full scale (despite similar bromide influent concentrations), it is believed the ozone demand was increased due to reasons related to MIEX® pre-treatment during high TOC season. These findings indicate, with MIEX® pretreatment implementation, bromate could be an issue full scale during high TOC seasons and when ASR is in use, but the limited bromate and ozone dosing data during this time is inadequate to verify this. Additional increase in raw water bromate concentrations could occur with the implementation of TAP as well.

Impacts to Biofiltration were not expected as ozone exposure to the filters at the pilot scale and duration of the study was not significant enough to impact filter performance.

Objective:

Test Biofiltration at varying loadings rates and media depths while also attempting to optimize the backwash process, understand any impacts to filtered TOC or turbidity, and understand changes to filter operation (i.e. UFRVs, runtimes, etc.) as a result of MIEX® pre-treatment, with the main purpose of understanding if the DLTWTF needs additional filters to meet current and future permitted capacity.

Results: **MET WITH EXCEPTIONS**

The biofilters were operated at the following loading rates and depths during times of MIEX® pretreatment and times of enhanced coagulation:

- Loading Rates
  - 2.2 gpm/ft^2 to simulate 80 mgd (current average annual daily flow)
  - 2.3 gpm/ft^2 to simulate 82 mgd (permitted average annual daily flow)
  - 3.5 gpm/ft^2 to simulate 120 mgd (permitted max daily flow)
  - 4.0 gpm/ft^2 to simulate 140 mgd (anticipated future max daily flow)
- Media Depths
  - 12” Sand, 22” GAC (existing media arrangement)
  - 6” Sand, 36” GAC (possible media arrangement with hydraulic recommendations implemented)
  - 12” Sand, 24” GAC (possible media arrangement without hydraulic recommendations implemented)

Although there were limited ozone effluent samples taken for UV254, the average reduction through the filters was 20.5% and 13.6% with and without MIEX® pretreatment, based on the samples collected. However, significant differences in performance cannot be confirmed statistically. Despite this, changes in filtered UV254 based on operational changes were observed and expected. Filtered water turbidity was relatively consistent; however, during times of enhanced coagulation, there was a significant difference in performance. Influent turbidity was higher during this period and it was observed that filters with increased media depths performed better. The filters performed similarly in regard to finished TOC and generally, the effluent TOC was below the finished water goal of 3.0 mg/L with a few exceptions.

Filter runtimes were found to be highly variable but consistently greater than 20 hours during times of lower filter loading rates. Starting early January, runtimes were more consistent among the filters but decreased significantly when settled water turbidity was greater. In general, as filter loading rates increased, the runtimes decreased. The filter runtimes at higher loading rates were less than desired but dictated by the available head loss in the filters. Increasing the available head loss would increase filter runtimes as previously mentioned in Chapters 3 and 4 of the Master Plan. Due to the linear relationship between runtime and head loss, a 1-foot increase in available head would be expected to result in an increase in filter runtime of approximately 17%.

UFRVs were highly sporadic, even though there were times when loading rates and/or media depths were the same. Investigation into the reasons for this found that UFRVs were not directly correlated with influent TOC, TOC removed, influent turbidity, turbidity removed, loading rates, or media depths. It was likely a combination of causes that did not allow the URFVs to be more closely related during times of similar operations between the filters. Similar behavior was seen when considering UFSLs, and clean bed head loss values as well. This would significantly impact and hinder filter runtimes and UFRVs. Based on the finds of this study, it cannot be determined with certainty that UFRVs would increase or decrease due to the implementation of MIEX® pretreatment.

The observations related to clean bed head losses suggested that the backwash procedure was not capable of adequately removing solids or cleaning the filters. Inadequate backwashing can also be influenced by mismatched media. This results in a less efficient backwash procedure since the media beds were not able to fluidize and provide proper bed expansion. Different media types and backwash procedures were not tested so it is unknown the positive or negative impact these parameters could have had on increasing filter runtimes or UFRVs.

Based on the operational results, it was found that the existing filters can only reliably operate at an average 2.2 – 2.3 gpm/ft^2, and it was not apparent if MIEX® pretreatment and/or increase media depths could allow for an increase in loading rates. Based on these results and without implementation of hydraulic improvement recommendations in the master plan, it is believed even with MIEX® pretreatment the existing filters can only reliably and efficiently treat at a max loading rate of 2.9 gpm/ft^2 (~92 mgd assuming two large filters out of service) as originally noted in Chapter 3.

13.0 RECOMMENDATION

In regard to the Master Plan report, the intent of this study was to have the ability to finalize the draft recommendation for Alternative 2A (See Chapter 5 for full detail on this alternative) for the Project 4 - DLTWTF Expansion detailed in the prioritized capital improvement plan (CIP) in Chapter 9. The Project 4 recommendation was scoped to include the addition of a new 140 mgd magnetic ion exchange (MIEX®) system and its supporting equipment among other projects required for expansion. The other apparent option was Alterative 1B that does not include MIEX® and would retain the enhanced coagulation process but also included a majority of the other Project 4 scope items.

With respect to the filters, based on the pilot plant results (unit filter run volumes, solids loading rates, runtimes, and clean bed head losses), it is believed even with MIEX® pretreatment the existing filters can only reliably and efficiently treat at a max loading rate of 2.9 gpm/ft^2 (~92 mgd assuming two large filters out of service) as originally noted in Chapter 3. At this rate, the expansion project would include 48 mgd of new filters. Therefore, it is recommended that the City take a phased approach to filter expansion as to not unnecessarily construct new filters. The City, first, should implement the hydraulic improvement recommendations, as specified in Chapter 4 of the Master Plan, first and then proceed with full scale demonstration and testing to witness any impacts to increased filter loading rates, runtimes, and UFRVs. This can be completed independently of MIEX® implementation since this pilot study did not find MIEX® pretreatment to significantly impact or improve filter operations. Filtration optimization with the new implemented hydraulic and process improvements could then help determine the new max loading rates and subsequent finalization of exact quantity of additional filters needed to meet 140 mgd capacity.

Based on the collective results and observations of this study on water quality, capital and O&M costs, and qualitative considerations, it is recommended that the City implement Alternative 2A that includes MIEX® as a pretreatment system for the DLTWTF; however, with a caveat that the City include the cost of an additional extended (one year) pilot study with MIEX® pretreatment in operation the entire duration. Additionally, mitigation and resolution of the risks identified and presented herein should be wholly resolved through piloting before the MIEX® full scale system is constructed. This pilot would be operated in conjunction with the conceptual engineering design of the full scale MIEX® system.

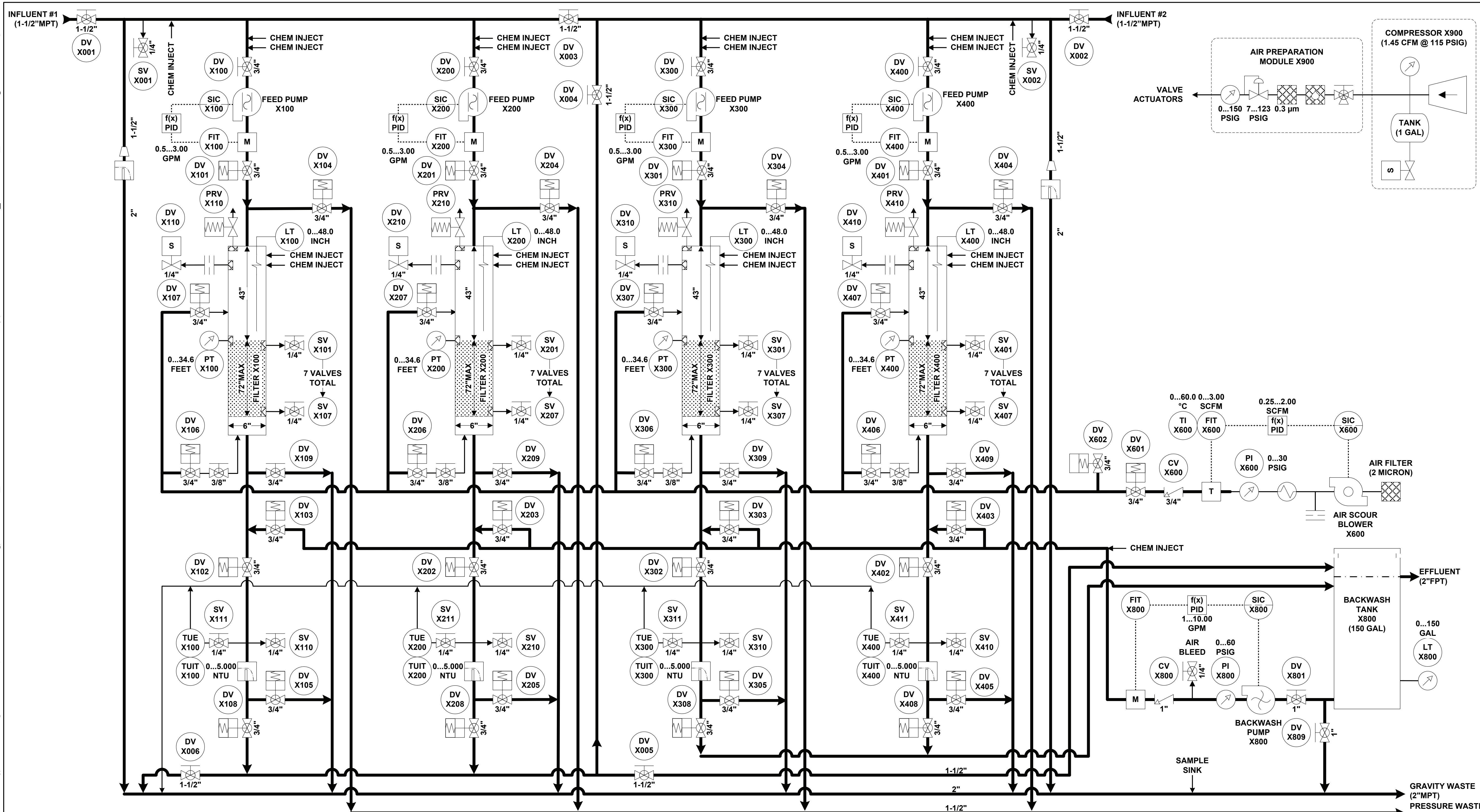
This recommendation is partly based on the water quality and economic considerations of MIEX®. Water quality and overall process performance for the pilot and full scale systems were very similar, with MIEX® at times providing lower finished water TOC concentrations. Additionally, the economic analysis showed that both alternatives have essentially the same net present values at 30 years, with MIEX® being 1.2% less in NPV life-cycle. Considering this, MIEX® is a viable and promising treatment option for the DLTWTF. However, due to the qualitative considerations and intermittent gaps in data, it is recommended to fully capture an entire year of data, not only in regard to TOC removal, but more specifically to include:

- Resin condition monitoring (RCM) analysis and organics desorption during the regeneration process throughout the year to understand degradation and decrease in organics removal performance over time.
- VSEP treatment runs multiple times per month to gather additional data to fully understand potential salt savings, in addition to multiple sample set deliveries to the third party vendor for confirmation of viable concrete stream usage.
- Collection of ozone dose and demand data, and bromate data (can be completed at bench scale), and consideration of various bromate control techniques. Testing should include blends of raw water from various DLTWTF supply sources including the reservoir and ASR recovery wells.
- Collection of DBP data to determine the impacts of prechlorination prior to MIEX® (can be completed at bench scale)
- Evaluation and mitigation of air entrainment issues associated with the original pilot.
- Operation of the MIEX® system at 600 bed volumes throughout the study to determine the impacts on TOC treatment, ozone demand, and filter runs.
- Piloting of the SIX process simultaneously with the MIEX® process (for the last 6 months).

Additionally, IXOM should provide a performance guarantee for TOC removal as well as documentation supporting their intent to construct a resin manufacturing facility in the United States.

Without full understanding and mitigation of the identified risks, MIEX® cannot be confidently recommended. By conducting additional piloting to confirm risk mitigation approaches in conjunction with the conceptual design, the City and their consultant could better understand the needed customized design of this complex system to fully meet the needs of the DLTWTF while minimizing risks and unknowns.

APPENDIX A – PILOT SKID DRAWINGS AND PROCESS FLOW DIAGRAMS



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2			
3			
4			

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DIMENSIONAL TOLERANCES ARE AS FOLLOWS, UNLESS OTHERWISE SPECIFIED

FRAC: ± 1/16 0.XX: ± 0.01
ANGLES: ± 1° 0.XXX: ± 0.005

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DRAWING NAME: 1554-10PP-01.VSD	P.O.:
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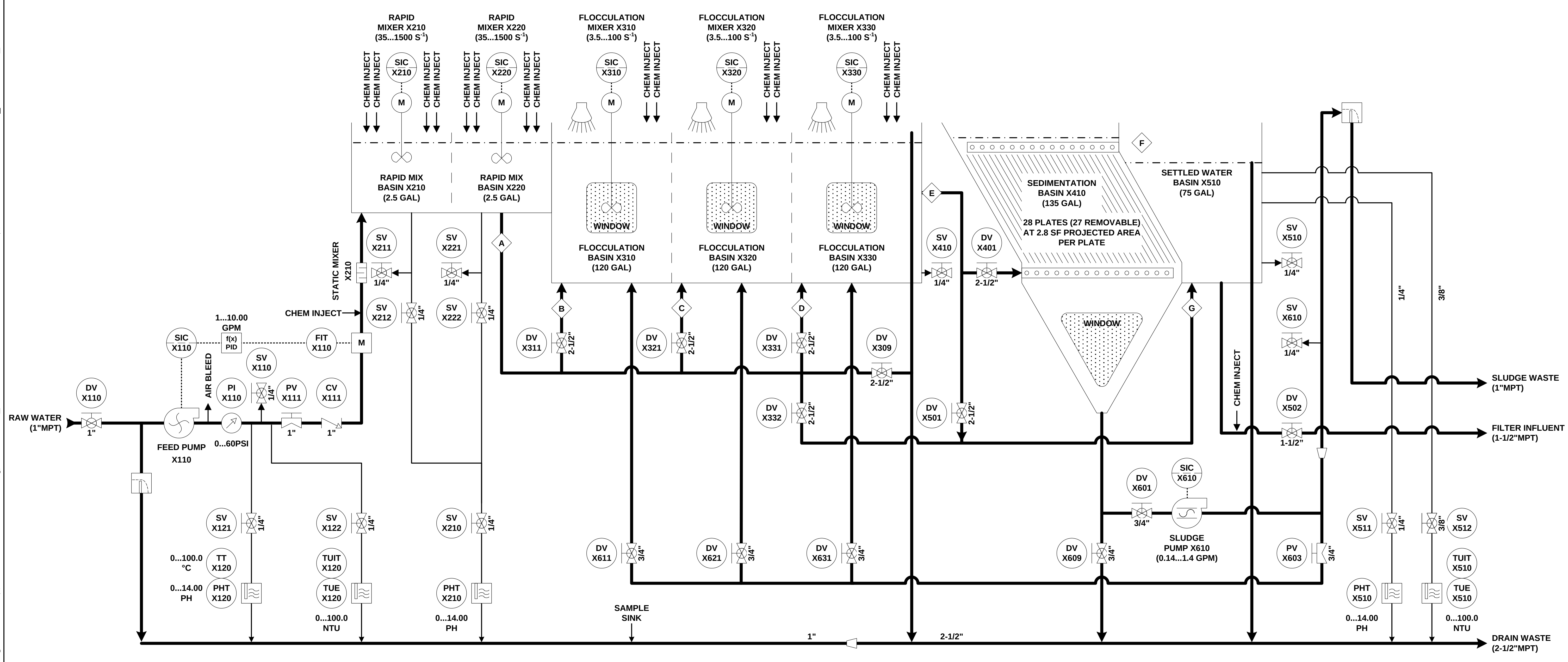

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2			
3			
4			

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FRAC: ± 1/16 0.XX: ± 0.01
ANGLES: ± 1° 0.XXX: ± 0.005

TITLE: FLOCCULATION & SEDIMENTATION MODULE PROCESS & INSTRUMENTATION DIAGRAM - PROCESS	
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DRAWING NAME: 1506-X0PP-01.VSD	P.O.:
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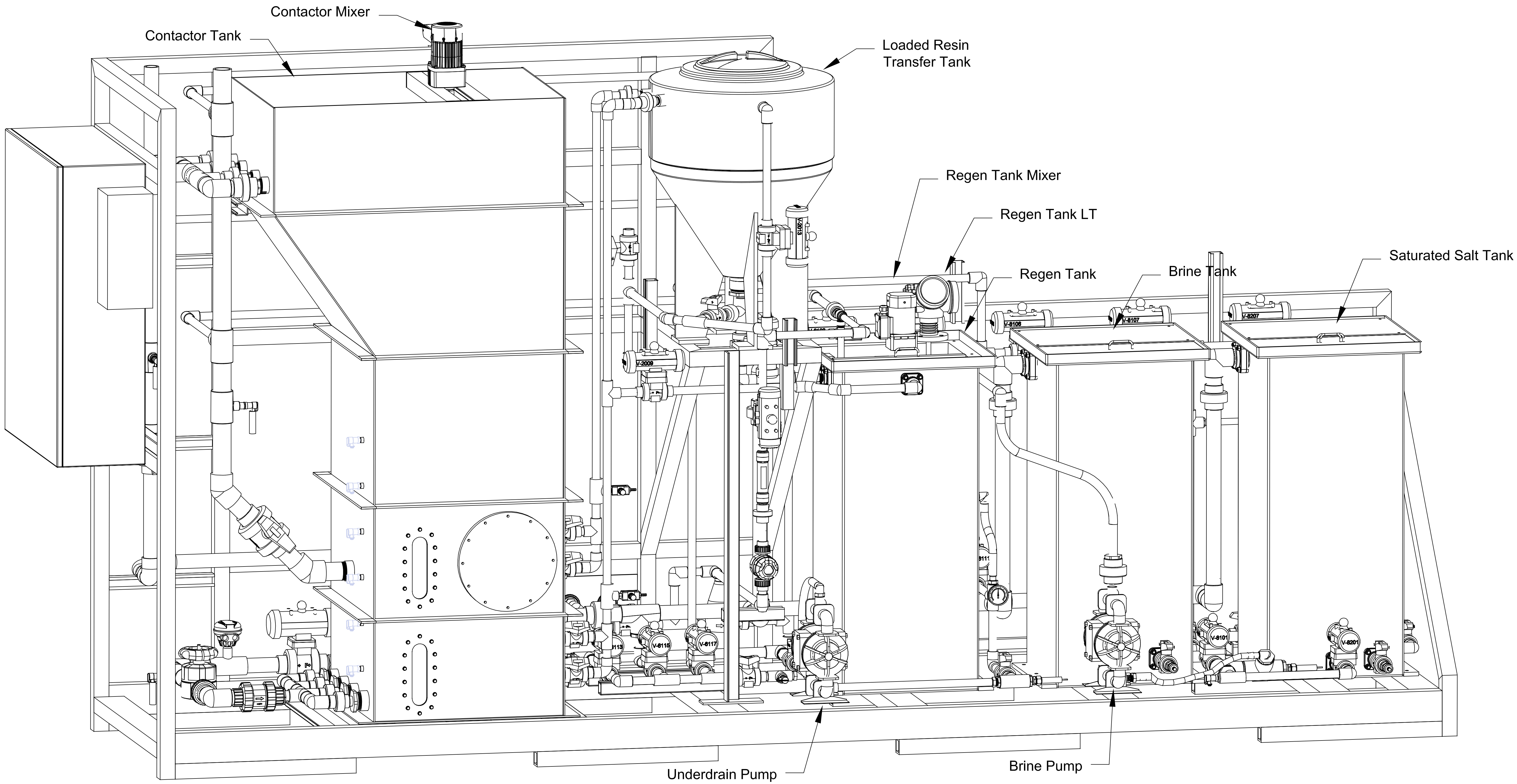

REVISIONS

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0	For Fabrication	07/15/16	T Cooper	S Mitchell	S Mitchell
A	Preliminary Only	02/09/16	T Cooper	S Mitchell	S Mitchell

STAMP

TOLERANCE
FRACTION ± 1/8
DECIMAL .XX ± 0.03
DECIMAL .XXX ± 0.010
ANGULAR ± 1°
FINISH 125

	SIGNATURE	DATE
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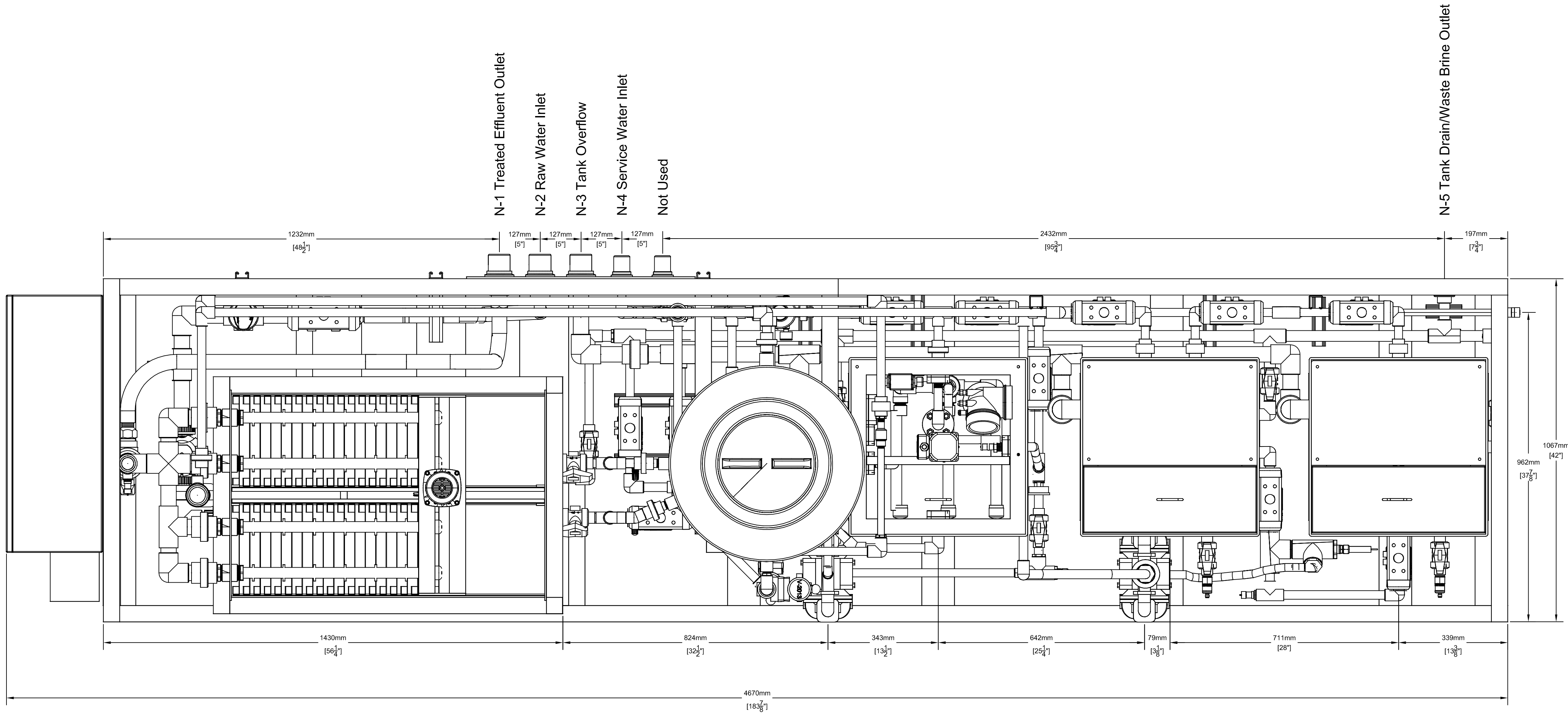
CHECKED BY	S. Mitchell	02/09/17
ENGINEER	S. Mitchell	02/09/17
DISCIPLINE ENGR		
CLIENT		
PROJECT NO.		
PROJECT MGR	S. Mitchell	
FILENAME	NA1700-06-00-001	

IXOM
(FORMERLY ORICA WATERCARE INC.)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

PROJECT Miex 10gpm Pilot Plant
SERVICE MIEX®PRE-TREATMENT
TITLE MIEX®SYSTEM
General Arrangement
Regeneration System

SIZE B | DWG NO. NA1600-05-10-001 | REV 1
SCALE NTS | SHEET 1 OF 3



System Connections

Item	Description	Connection
N1	Treated Effluent Outlet	1 ½" FNPT
N2	Raw Water Inlet	1 ½" FNPT
N3	Tank Overflow Outlet	1 ½" FNPT
N4	Service Water Inlet	1" FNPT
N5	Tank Drain/Waste Brine Outlet	1" FNPT

REVISIONS

REV.	DESCRIPTION	DATE	CHANGED BY	CHECKED BY	ENGINEER
1	As-Built	11/02/16	T Cooper	S Mitchell	S Mitchell
0	For Fabrication	07/15/16	T Cooper	S Mitchell	S Mitchell
A	Preliminary Only	02/09/16	T Cooper	S Mitchell	S Mitchell

STAMP

TOLERANCE
FRACTION ± 1/8
DECIMAL: .XX ± 0.03
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ANGULAR ± 1°

FINISH 125

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CHECKED BY	S. Mitchell	02/09/17
ENGINEER	S. Mitchell	02/09/17
DISCIPLINE ENGR		
CLIENT		
PROJECT NO.		
PROJECT MGR	S. Mitchell	
FILENAME	NA1700-06-00-001	

IXOM
(FORMERLY ORICA WATERCARE INC.)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

PROJECT Miex 10gpm Pilot Plant
SERVICE MIEX®PRE-TREATMENT
TITLE MIEX®SYSTEM
General Arrangement
Regeneration System

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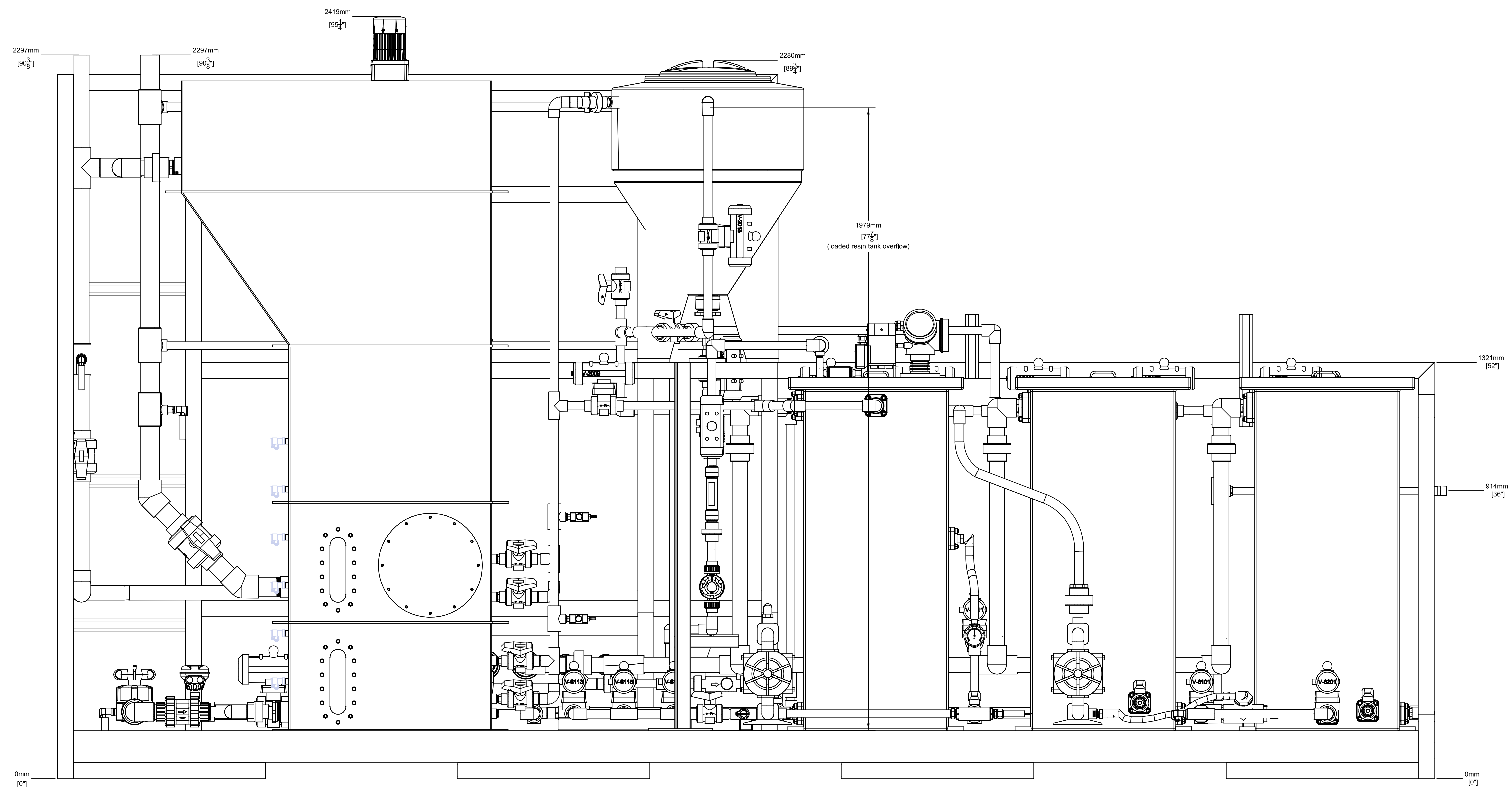
SCALE 3/4"=1' | SHEET 2 OF 3



REVISIONS

REV.	DESCRIPTION	DATE	CHANGED BY	CHECKED BY	ENGINEER
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0	For Fabrication	07/15/16	T Cooper	S Mitchell	S Mitchell
A	Preliminary Only	02/09/16	T Cooper	S Mitchell	S Mitchell

STAMP

TOLERANCE

FRACTION	± 1/8
DECIMAL .XX	± 0.03
DECIMAL .XXX	± 0.010
ANGULAR	± 1°

FINISH 125

	SIGNATURE	DATE
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CHECKED BY	S. Mitchell	02/09/17
ENGINEER	S. Mitchell	02/09/17
DISCIPLINE ENGR		
CLIENT		
PROJECT NO.		
PROJECT MGR	S. Mitchell	
FILENAME	NA1700-06-00-001	

IXOM

(FORMERLY ORICA WATERCARE INC.)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

PROJECT Miex 10gpm Pilot Plant

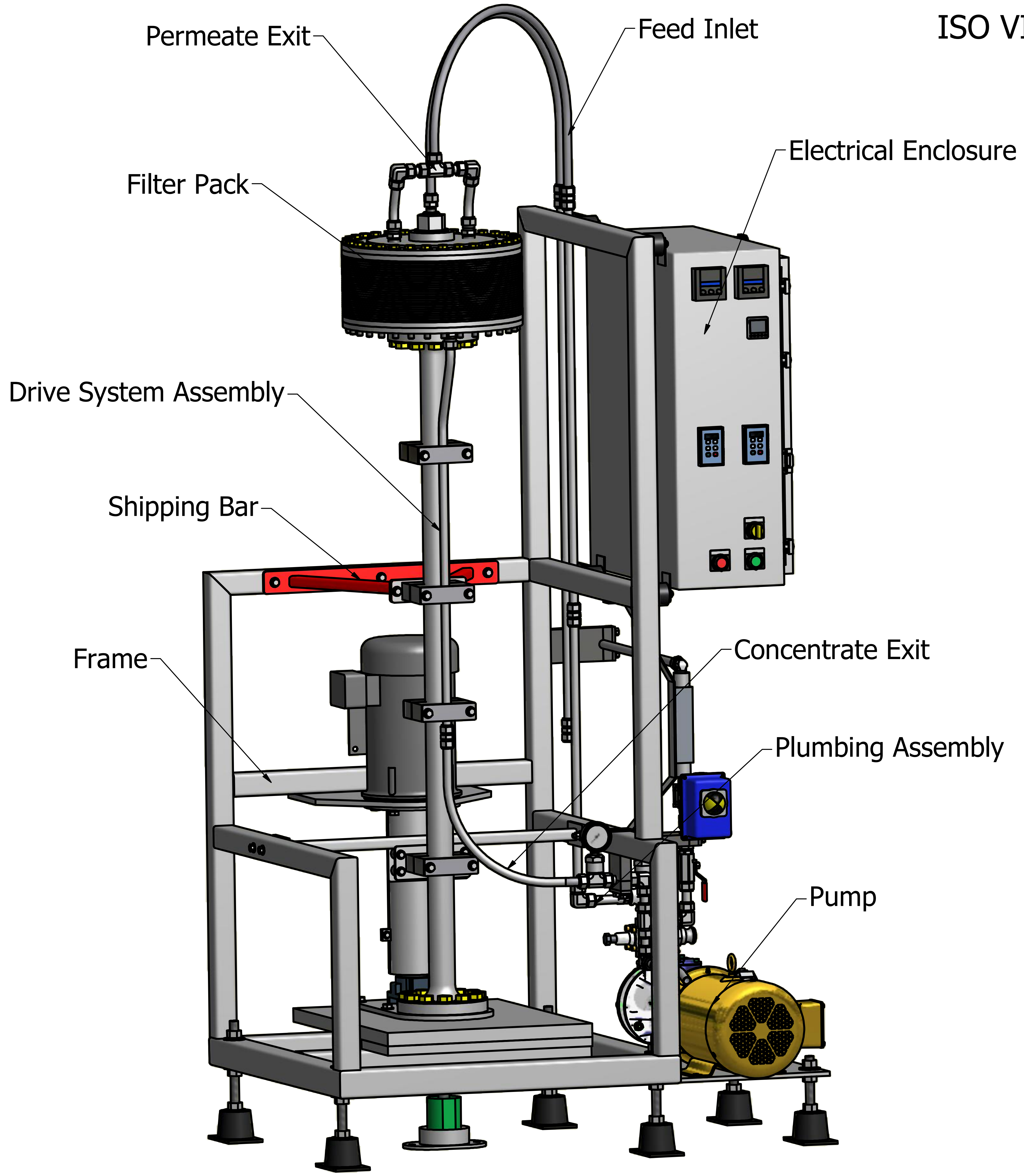
SERVICE MIEX® PRE-TREATMENT

TITLE MIEX® SYSTEM
General Arrangement
Regeneration System

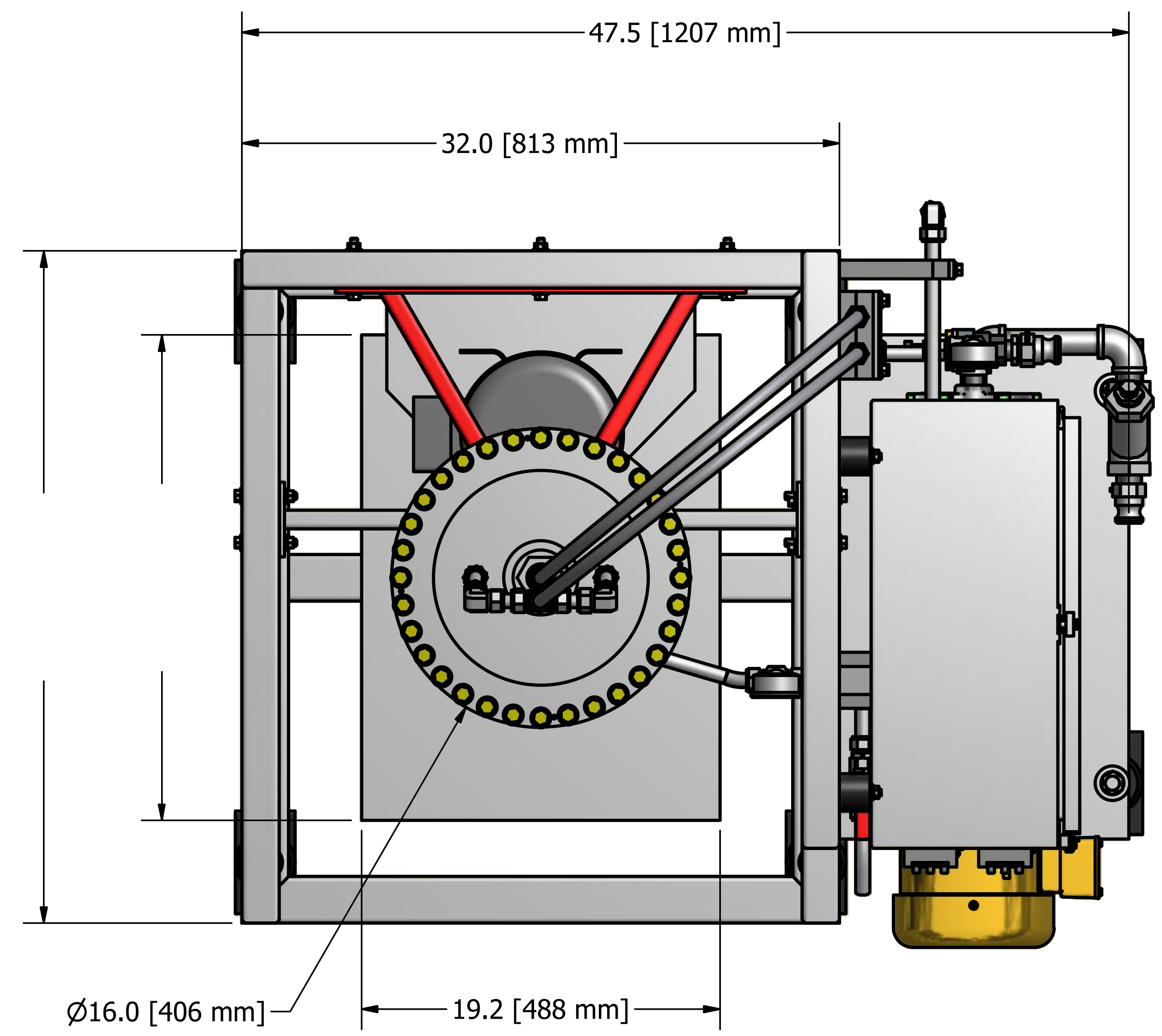
SIZE B | DWG NO. NA1600-05-10-001 | REV 1

SCALE 3/4"=1' | SHEET 3 OF 3

ISO VIEW

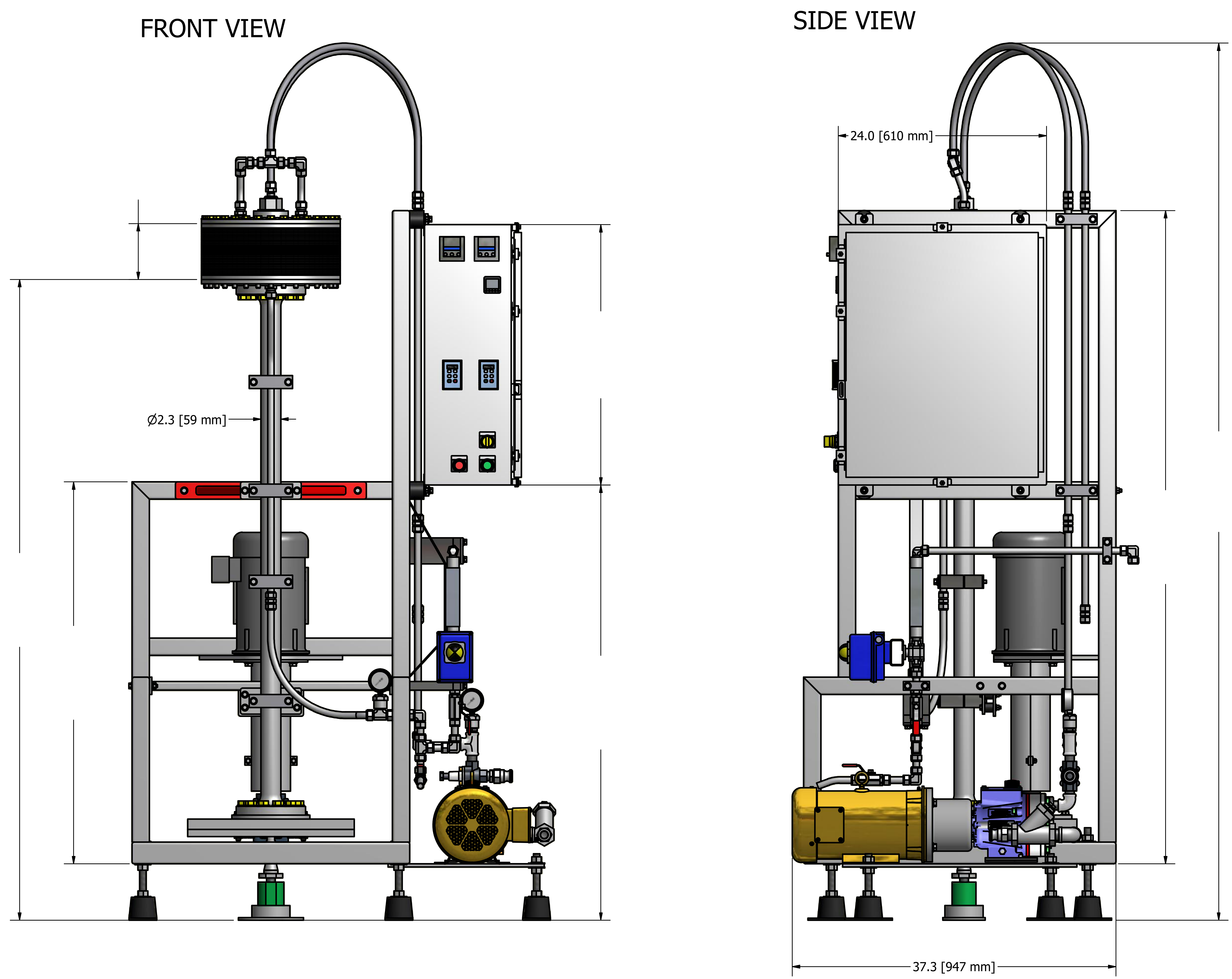


TOP VIEW



Series P50 VSEP System (60 Hz)

NOTES:
1. New Logic Research confidential material.
2. All dimensions are shown in inches [mm]& for references only.
3. Slight differences between drawings and actual system might be attributed to New Logic Research continuously evolving and improving its technology.



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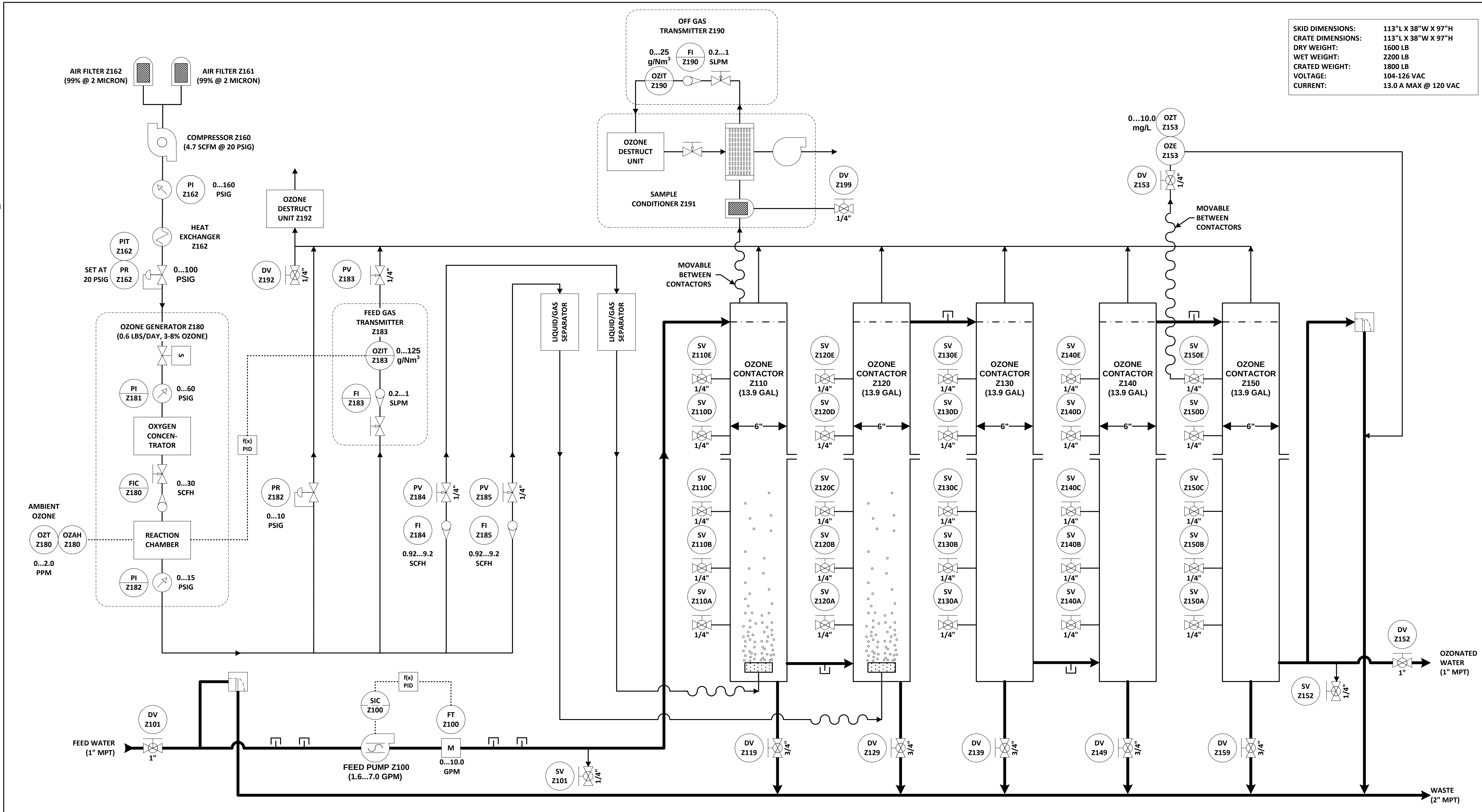
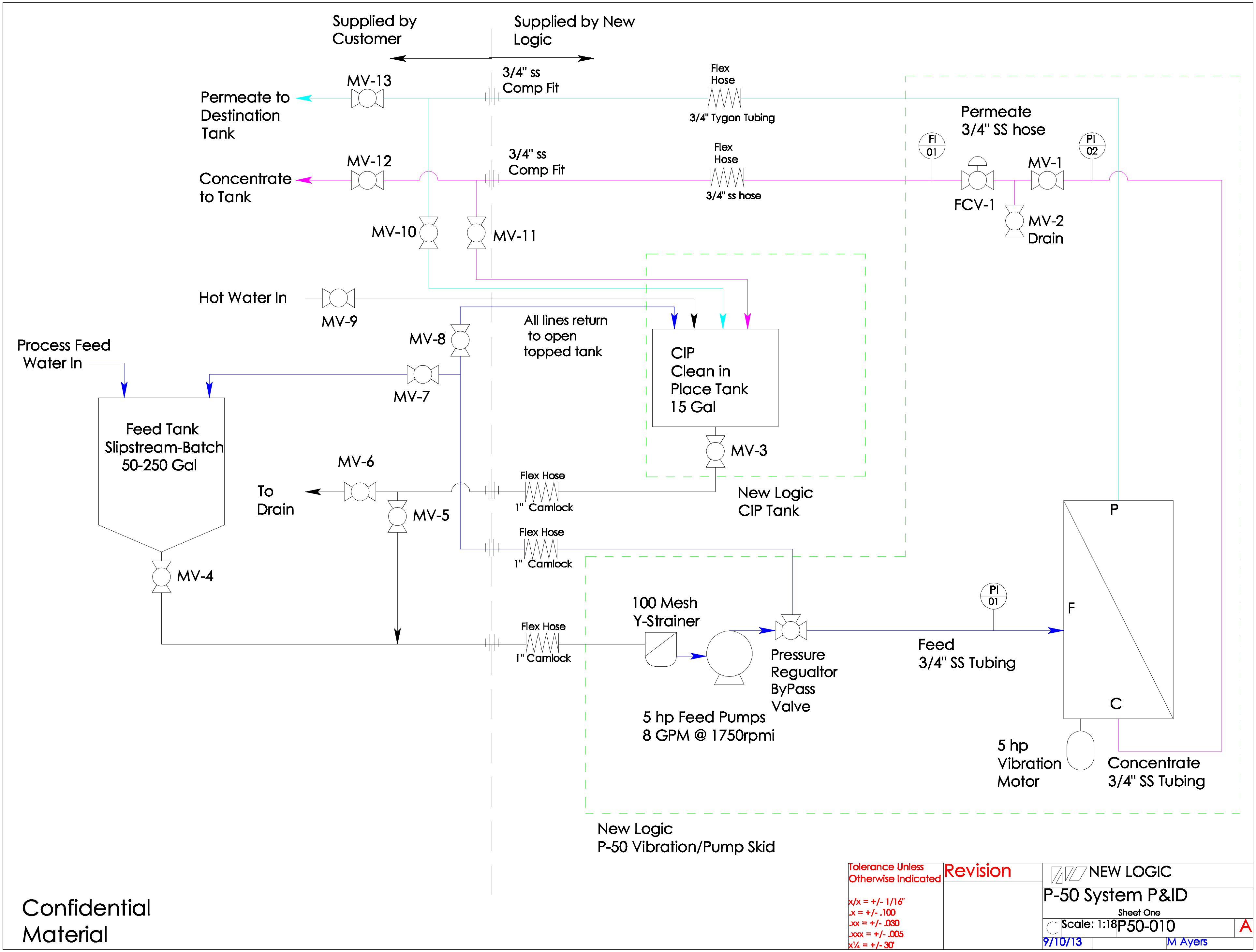


REV	DATE	BY	DESCRIPTION
1	03-21-11	AJB	ADDED DRY / WET WEIGHTS, FEED WATER WEIR, ADDED NEEDLE VALVES ON FEED / OFF GAS TRANSMITTERS, ADDED PIT Z162, CHANGED RANGES ON PI Z182 AND PI Z181
2	1-25-12	REM	CHANGED OZONE GENERATOR PID LOOP CONTROL TO THE FEED GAS CONCENTRATION.
3			
4			

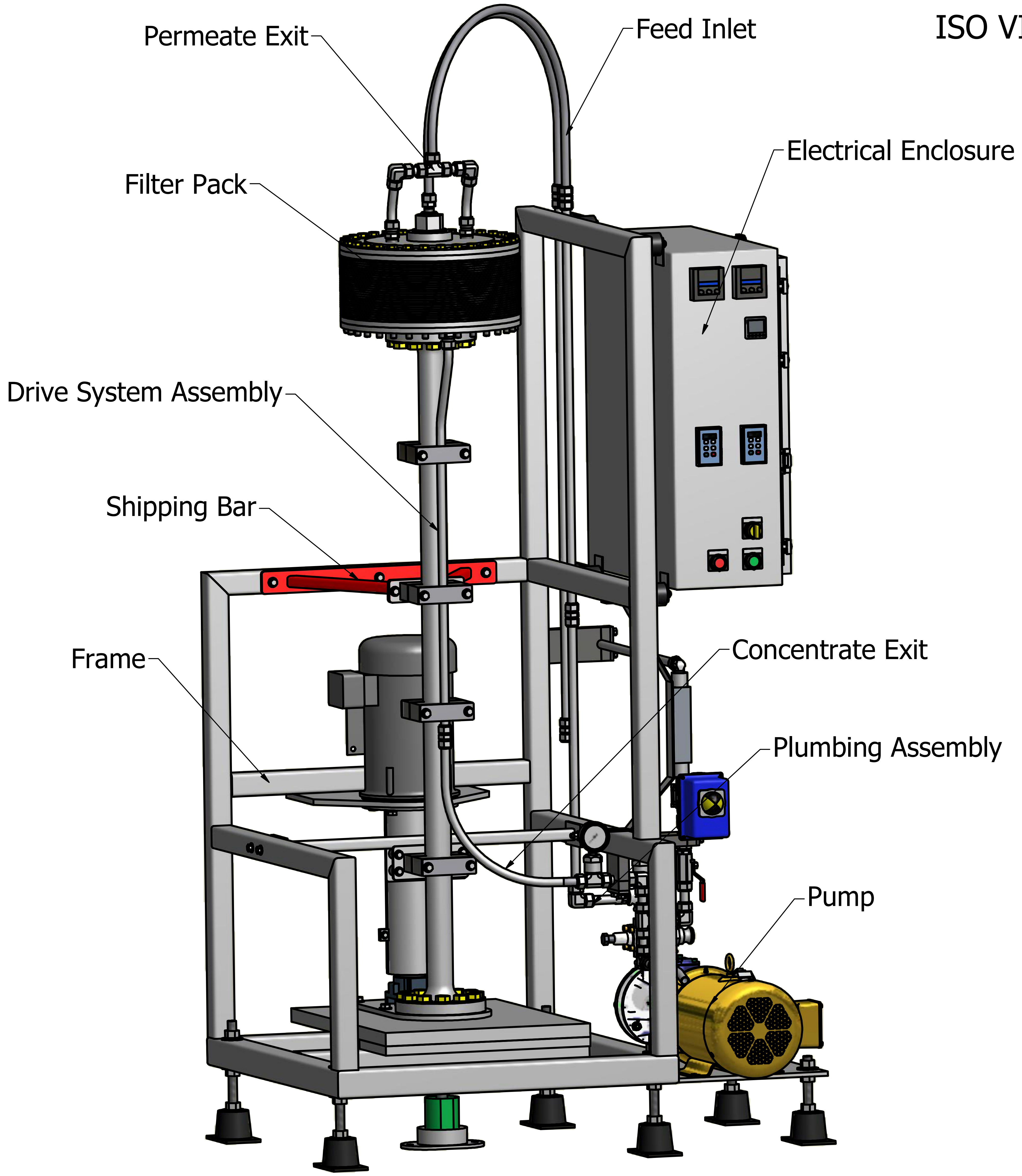
Intuitech®
www.intuitech.com

TITLE: OZONE PILOT MODULE Z100
PROCESS & INSTRUMENTATION DIAGRAM

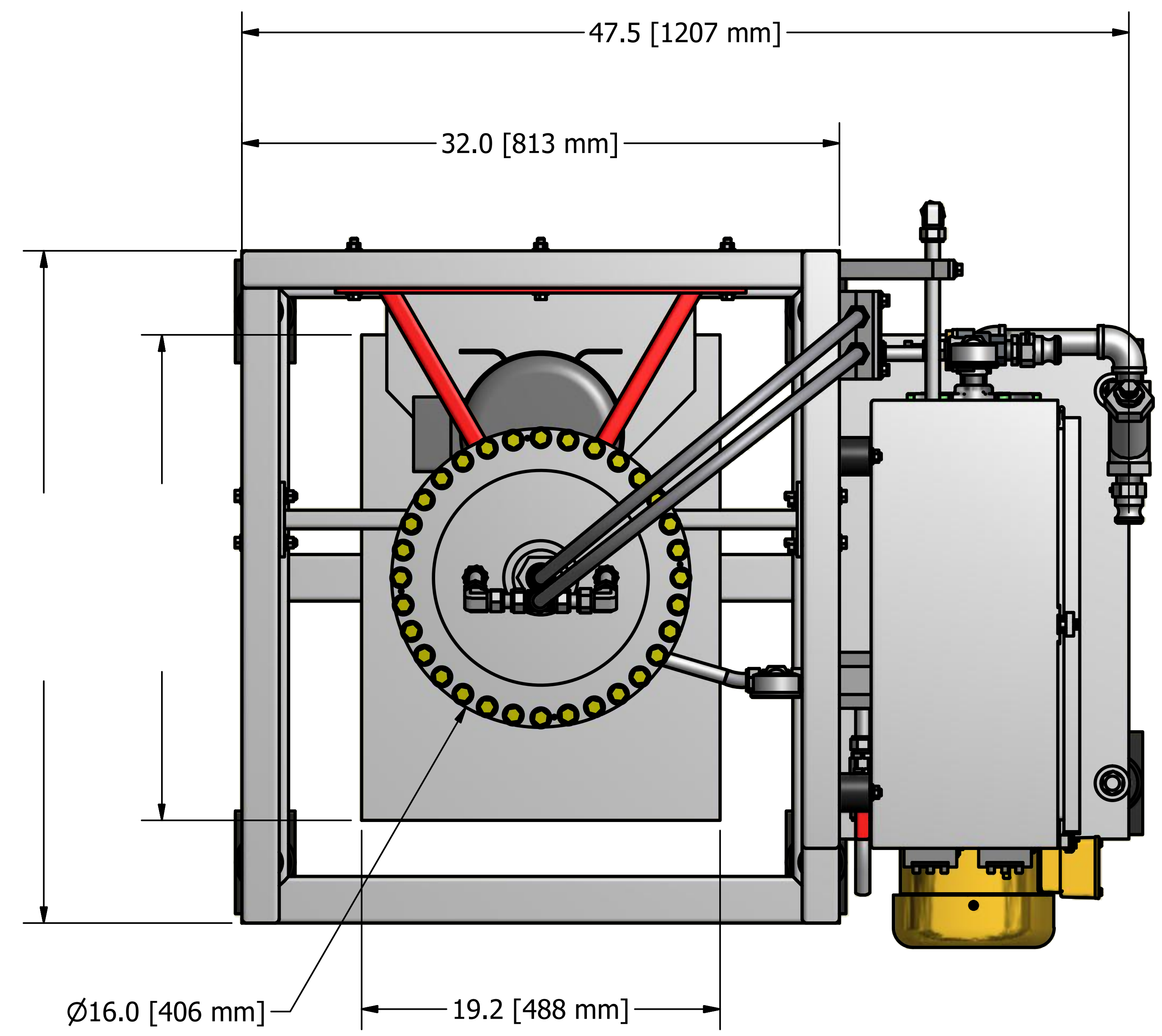
CLIENT: CAROLLO ENGINEERS	PROJECT: 1381
DRAWN BY: AJB	DRAWN DATE: 02-18-11
DRAWING NAME: 1381-Z1PP-100.VSD	P.O.:
SCALE: NONE	REVISION: 1


Supplied by Customer
Supplied by New Logic
3/4" ss Comp Fit
Flex Hose
3/4" Tygon Tubing
MV-13
Permeate to Destination Tank
Permeate 3/4" SS hose
FI 01
PI 02
MV-12
Concentrate to Tank
3/4" ss Comp Fit
Flex Hose
3/4" ss hose
MV-1
FCV-1
MV-2 Drain
MV-10
MV-11
Hot Water In
MV-9
MV-8
All lines return to open topped tank
CIP Clean in Place Tank 15 Gal
Process Feed Water In
MV-7
Feed Tank Slipstream-Batch 50-250 Gal
MV-6
To Drain
MV-5
Flex Hose
1" Camlock
MV-3
New Logic CIP Tank
P
Flex Hose
1" Camlock
MV-4
100 Mesh Y-Strainer
PI 01
F
Flex Hose
1" Camlock
Pressure Regualtor ByPass Valve
Feed 3/4" SS Tubing
5 hp Feed Pumps 8 GPM @ 1750rpmi
C
5 hp Vibration Motor
Concentrate 3/4" SS Tubing
New Logic P-50 Vibration/Pump Skid
Confidential Material
Tolerance Unless Otherwise Indicated
x/x = +/- 1/16"
.x = +/- .100
.xx = +/- .030
.xxx = +/- .005
x¼ = +/- 30'
Revision
NEW LOGIC
P-50 System P&ID
Sheet One
Scale: 1:18
P50-010
A
9/10/13
M Ayers

ISO VIEW



TOP VIEW



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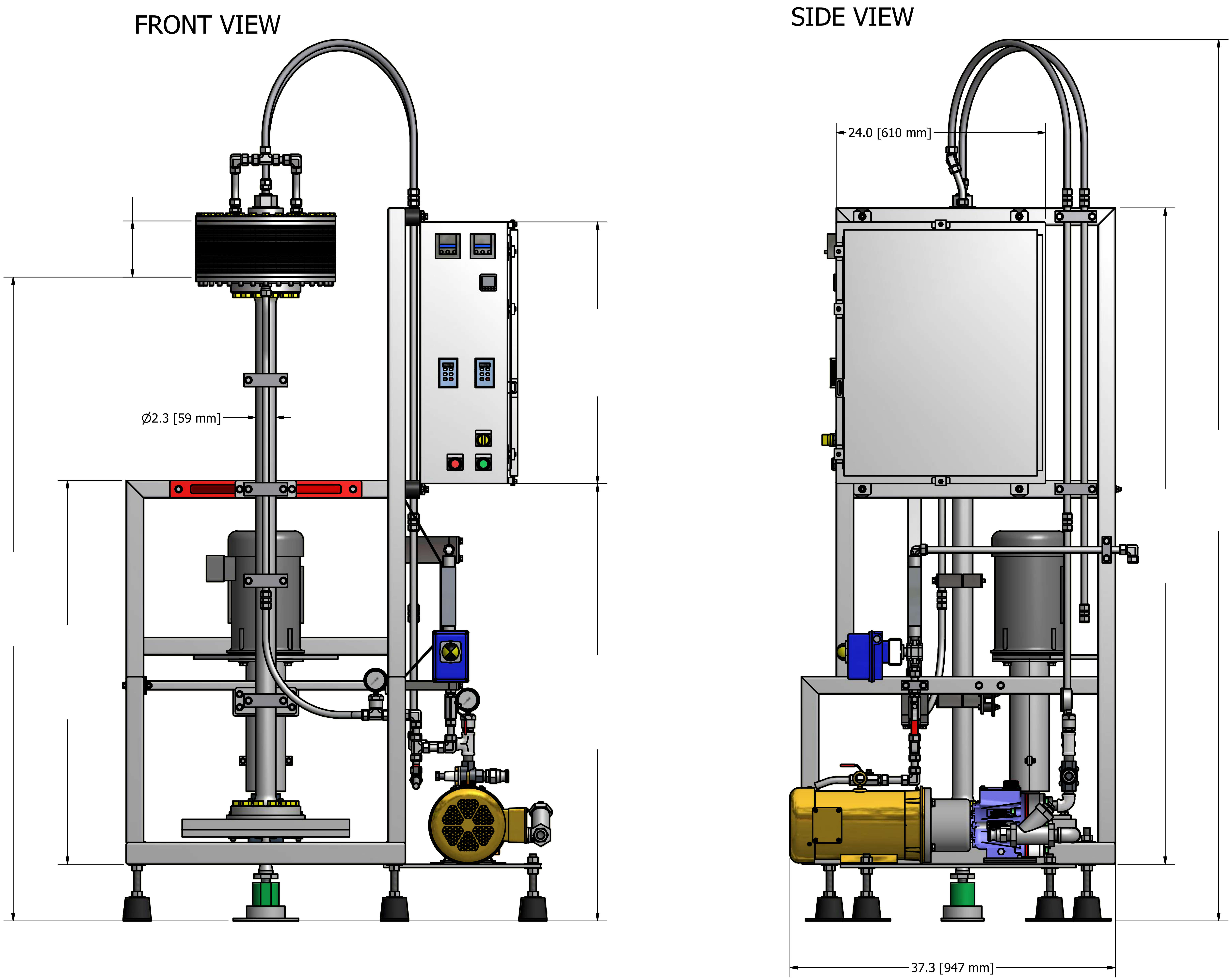
Series P50 VSEP System (60 Hz)



Series P50 VSEP System (60 Hz)

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NEW LOGIC
RESEARCH, INC.
1295 67th St. Emeryville, CA 94608 510.655.7305 510.655.7307 fax www.vsep.com

Pilot Testing

VSEP P-50 Machine Specifications 12/02/2013

Current operating Manual: P-50 Version 4.0

Operating Conditions:

Equipment Rating: Nema 4, Indoor-Outdoor protected from sunlight and rain.
Operating Ambient Temperature Limits: 0-40ºC
Storage Temperature: 0-40ºC
Relative Humidity: 90% or less, non-condensing
Elevation: 3300 ft. (1006 M), without derating.

Filter Pack:

Membrane Area: 50 sq. ft.
Hold Up Volume: Approx. 2.4 Gallons (9 liters)
Maximum Operating pressure: 600 psi (1000psi option available with system modifications)
Maximum Shear Rate: 150,000 Inverse Seconds
Wetted Materials: 316 Stainless Steel, EPDM or Viton

Vibration System:

Drive Bearings: MORSE SEALMASTER RFB 108TF
Vibration Motor: BALDOR Spec: 36A002S042G3, 5HP 3450RPM/60Hz, 460 VAC 3 phase
Vibration Motor Control: AC Tech (ESV402N02TXB)

Feed System:

Pump: HYDRA-CELL D10EKSGSNHMB: 8 GPM @ 1725 RPM
Motor: BALDOR CEM3615T, 5HP 1750 RPM, 460 VAC 3 phase
Pump Bypass Valve: WANNER C22AABBSSEF (Custom material available upon request)

Instruments:

Pressure Gauges: 1 on Process Outlet and 1 on Process Inlet WIKA 233.54
Flow Meter (Acrylic Tube Indicator): COLE-PARMER Model 32445-58
Timers: ATC Long Range Model 365 Timer
Control Valve at Process Outlet: FloTite 310SSFFFL15- 1/2"
Actuator: Indelac R Series Nema 4 Model R4BF03-2

Electrical Power Requirements: Standard Unit (With a 3HP Feed Pump Motor)

(Note: A 5HP Pump can be used but generally does not operate at more than 3 HP in this System)

Standard Voltage: 480 VAC 3 phase 'wye' Power
Normal Full Load Operating Current: 12.6 amps
Power Cord: 8 Ft long with a NEMA L15-30P plug
Required Receptacle: NEMA L15-30, 30 amp circuit recommended

System Size and Weight:

Overall Dimensions: 48" w x 36" d x 81" h
System Weight: 900lbs. (336 kg) approximate

***Custom systems (CSA, CE, Class I Div II, AS3000, etc…) are available on request**

Utility Summary							New Logic Research	
VSEP System								

CLEANING WATER CONSUMPTION

(Use Hot Water for cleaning water >300 uS/cm)

	# /Day	Temp degC	Gallons/Day	GPM	M3/hr
VSEP					
Cleanings	1	50-60	80	0.06	0.0126
Intermittent need of additional cleaning or flush of filter pack	0.25	50-60	100	0.07	0.0158
System Water Totals			**System Totals**	**0.13**	**0.0284**
VSEP Supply Water at 50-60degC and ~7gpm					
VSEP Supply water at 20 psi to open CIP tank					

ELECTRICAL CONSUMPTION

Based on 480VAC, 3 phase, 60hz Input

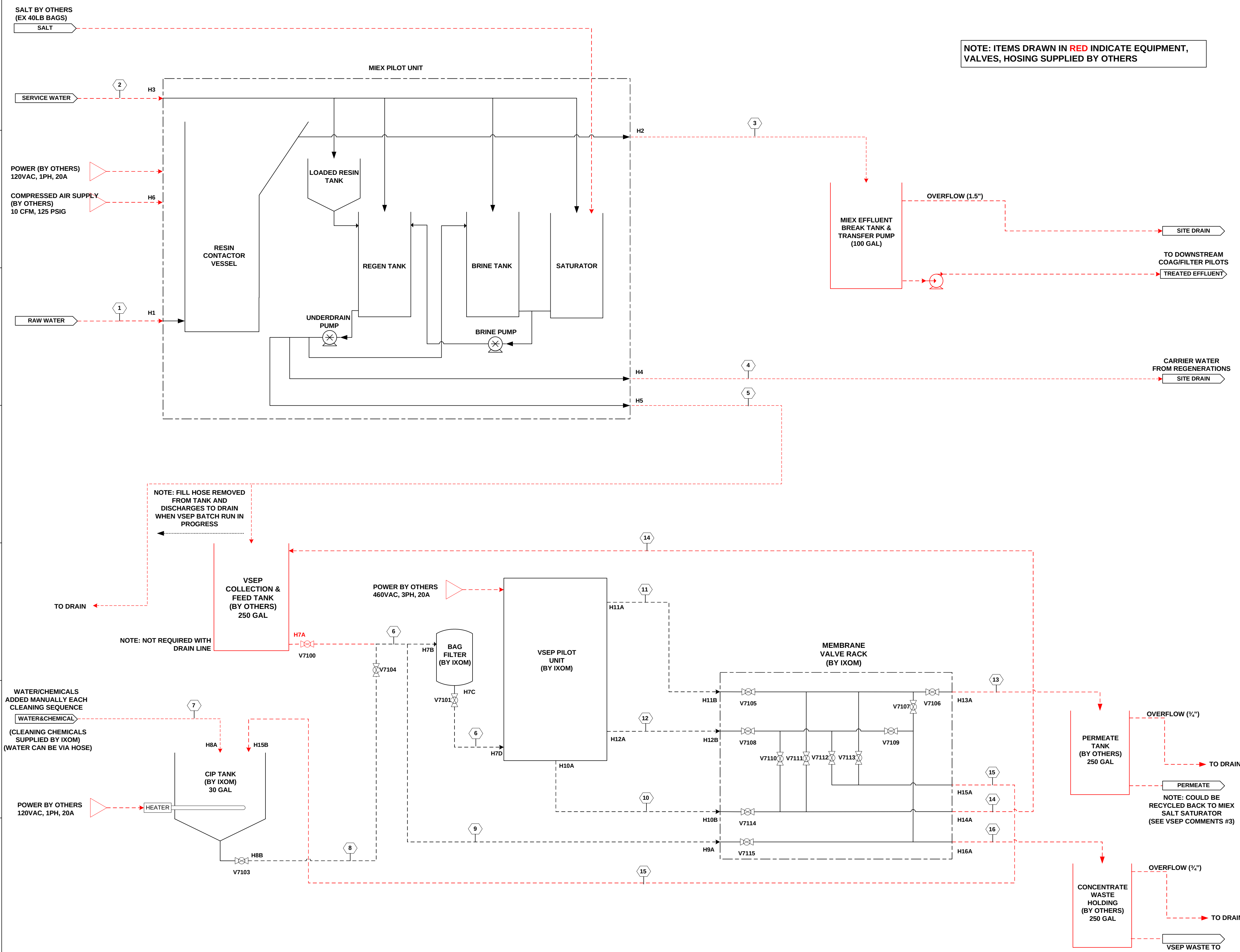
FLA = Full Load Amps = Full Load Drive Output x 1.15x

RLA = Running Load Amps = FLA x .65x

VSEP 240 VAC Motors

	# Motors	HP /ea	kW /ea	Amps /ea	FLA /ea	RLA /ea	Total kW	Total FLA	Total RLA
VSEP Drive Motor	1	3	2.3	8.8	10.1	6.6	2.3	10.1	6.6
VSEP Feed Pump	1	5	3.8	15.0	17.3	11.2	3.8	17.3	11.2
Totals	**2**						**6.1**	**27.4**	**17.8**

Note: These are estimates only based on very preliminary data. These calculations are subject to change and do not include equipment offskid of VSEP system



GENERAL COMMENTS:

A. MIEX PILOT PLANT

1. RAW WATER: 10-15GPM FLOW RANGE. ASSUMED RAW WATER FLOW TAKEN FROM A PRESSURIZED MAINS. IF BEING PUMPED TO PILOT PLEASE ADVISE.
2. MIEX EFFLUENT: GRAVITY FLOWS FROM CONTACTOR VESSEL, WITH LIMITED AVALIABLE SUPPLY PRESSURE/HEAD. MAY REQUIRE A BREAK TANK AND TRANSFER PUMP FOR DOWNSTREAM COAGULATION / FILTRATION PILOTS. IF THE EVENT OF A FAULT, MIEX PILOT MAY AUTOMATICALLY STOP WATER FLOW; NEEDS TO BE CONSIDERED ON DOWNSTREAM PILOTS AND POTENTIALLY OPERATIONAL IMPACTS.
3. SERVICE WATER SUPPLY: MAX. SUPPLY PRESSURE 30PSIG. IF HIGHER, THEN PRESSURE REDUDCTION REQUIRED (BY OTHERS).
4. WASTE BRINE DISCHARGE: DISCHARGE TO A COLLECTION TANK REQUIRED. COLLECTED VOLUME THEN TRANSFERRED TO A VSEP FEED TANK FOR OPERATION AS REQUIRED.
5. CARRIER WATER DISCHARGE: THIS IS INITIAL WATER DRAINED FROM RESIN AT START OF REGENERATION. THIS CAN DISCHARGE TO A SITE DRAIN / RUN-OFF (NOTE: NORMALLLY ON FULL SCALE PLANTS, THIS FLOW IS RETURNED TO THE CONTACTOR VESSEL; CANNOT ON SMALL PILOT AS THE FLOW IMPACTS OPERATION OF THE CONTACTOR.

B. VSEP PILOT PLANT

1. OPERATION: ASSUMED VOLUME OF WASTE BRINE WILL BE COLLECTED AND THEN PROCESS IN BATCHES (200-250 GAL LIKELY). TYPICALLY AFTER EACH OPERATIONAL RUN, HOT WATER CLEAN IN PLACES (CIP) ARE REQUIRED. CHEMICAL CIP'S (ALKAI / ACID) LESS FREQUENT ARE ARE DEPENDENT ON MEMBRANE PEFROMACE.
2. WASTE BRINE: COLLECTED CONCENTRATED WASTE (REJECT) BRINE WILL BE SENT TO BORAC FOR THEIR TESTING.
3. PERMEATE: THE RECOVERED PERMEATE (SALT) COULD POTENTIALLY BE FEED BACK INTO THE MIEX PILOT SALT SATURATOR VESSEL, EITHER BY (1) MANUALLY ADDING LIQUID BACK TO SALT SATURATOR TANK, OR (2) HAVING PERMEATE TANK SLIGHLY ELEVATED TO ALLOW GRAVITY DRAINING TO SALT TANK. OPTIONS TO BE CONSIDERED IF REQUIRED.
4. CLEANING IN PLACE (CIP): AFTER EACH RUN, A HOT WATER CIP WILL BE REQUIRED. CHEMICAL ALKALI CIP'S (ALKALI OAND/OR ACID CIP'S) WILL BE PERFORMED BASED ON MEMBRANE PERFORMANCE AND FLUX RATES.

C. WASTE DISCHARGE TO A DRAIN

SHOULD ASSUME THAT SOME WASTE WILL BE REQUIRED TO DISCHARGE TO A DRAIN DEPENDING ON HOW OFTEN THE VSEP MAYBE OPERATED THROUGHOUT THE PILOT DURATION.

D. POWER SUPPLIES

POWER SUPPLIES AS DETAILED REQUIRED FOR MIEX PILOT AND VSEP EQUIPMENT (PILOT AND CIP TANK HEATER). ELECTRICAL CONNECTIONS ARE PERFORMED BY OTHERS AND AS REQUIRED TO LOCAL CODES. EACH SUPPLY SHOULD COME OFF AN APPROPRIATE ISOLATION BREAKER.

E. COMPRESSED AIR

COMPRESSED AIR SUPPLY REQUIRED FOR MIEX PILOT AS DETAILED. AIR COMPRESSOR NOT SUPPLIED BY IXOM. RECOMMEND AN AIR RECEIVER TANK SIZE OF APPROX. 30 GAL

E. CONSUMABLES

1. MIEX PILOT: MAKE-UP MIEX RESIN FOR THE INITIAL PILOT DURATION WILL BE SUPPLIED BY IXOM. SALT FOR REGENERATIONS SUPPLIED BY OTHERS (USE A COARSE SOLAR GRADE SALT WITH NO ADDATIVES)
2. VSEP PILOT: CIP CHEMICALS WILL BE SUPPLIED BY IXOM.

PROCESS FLOWS AND LINE SIZES

	UNITS	RAW WATER SUPPLY	SERVICE WATER	MIEX EFFLUENT	REGEN CARRRIER WATER	REGEN WASTE BRINE	VSEP FEED	CIP TANK INFLUENT	CIP FEED
		S1	S2	S3	S4	S5	S6	S7	S8
MANNER OF FLOW		CONTINUOUS	INTERMITTENT	CONTINUOUS	INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT
TOTAL FLOWRATE	GPM	15.0	5.0	15.0	5.0	5.0	4.0	N/A	2.0
TOTAL FLOWRATE (AVG)	GPD	21,600	135	21,600	70	18.0	N/A	N/A	N/A
BATCH VOLUME	GAL	N/A	N/A	N/A	N/A	4.8	250	30	30
LINE SIZE	IN	1.5	1	1.5	1.5	1	1	N/A	1
LINE TYPE	N/A	PVC HOSE	PVC HOSE	PVC HOSE	PVC HOSE	PVC HOSE	PVC HOSE	N/A	PVC HOSE

	UNITS	WASTE BRINE DRAIN	VSEP BYPASS	VSEP PERMEATE	VSEP CONCENTRATE	VSEP PERMEATE	VSEP FEED RECYCLE	CIP RETURN	VSEP DRAIN
		S9	S10	S11	S12	S13	S14	S15	S16
MANNER OF FLOW		INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT	INTERMITTENT
TOTAL FLOWRATE	GPM	N/A	2.0	1.0	1.0	1.0	3.0	2.0	N/A
TOTAL FLOWRATE (AVG)	GPD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BATCH VOLUME	GAL	N/A	N/A	75 - 175	75 - 175	75 - 175	75 - 175	30	N/A
LINE SIZE	IN	1	3/4	3/4" OD	3/4" OD	3/4	3/4	3/4	1
LINE TYPE	N/A	PVC HOSE	PVC HOSE	PVC TUBE	PVC TUBE	PVC HOSE	PVC HOSE	PVC HOSE	PVC HOSE

HOSE CONNECTION DETAILS (MIEX PILOT)

EQUIPMENT	HOSE CONNECTION POINT	CONNECTION TYPE	CONNECTION SIZE
RAW WATER SUPPLY	H1	FEMALE NPT	1 1/2"
MIEX EFFLUENT DIACHARGE	H2	FEMALE NPT	1 1/2"
SERVICE WATER SUPPLY	H3	FEMALE NPT	1"
CARRIER WATER DISCHARGE	H4	FEMALE NPT	1 1/2"
WASTE BRINE DISCHARGE	H5	FEMALE NPT	1"
COMPRESSED AIR	H6	PUSH TO CONNECT FITTING	1/2" OD

CAMLOCK CONNECTIONS

MALE CAM-LOCK X HOSE

FEMALE CAM-LOCK X HOSE

HOSE CONNECTION DETAILS (VSEP UNIT)

EQUIPMENT	HOSE CONNECTION POINT	HOSE CONNECTION TYPE	CONNECTION SIZE
FEED TANK	H7A	BY OTHERS	
BAG FILTER	H7B	FEMALE CAMLOCK X HOSE	1"
	H7C	FEMALE CAMLOCK X HOSE	1"
CIP TANK	H8A	N/A - MANUAL ADDITION	
	H8B	FNPT (ASAHI UNION)	1"
	H15B	THROUGH CUT OUT IN LID	
VSEP UNIT	H7D	FEMALE CAMLOCK X HOSE	1"
	H10A	FEMALE CAMLOCK X HOSE	3/4"
	H11A	COMP. TUBE FITTING	3/4" OD
	H12A	COMP. TUBE FITTING	3/4" OD
VALVE RACK	H9A	FEMALE CAMLOCK X HOSE	1"
	H10B	FEMALE CAMLOCK X HOSE	3/4"
	H11B	COMP. TUBE FITTING	3/4" OD
	H12B	COMP. TUBE FITTING	3/4" OD
	H13A	FEMALE CAMLOCK X HOSE	3/4"
	H14A	FEMALE CAMLOCK X HOSE	3/4"
	H15A	FEMALE CAMLOCK X HOSE	3/4"
	H16A	FEMALE CAMLOCK X HOSE	1"
PERMEATE TANK	H13B	BY OTHERS	

VSEP VALVE RACK POSITIONS

O = OPEN, C = CLOSED

OPERATION	V7100	V7101	V7103	V7104	V7105	V7106	V7107	V7108	V7109	V7110	V7111	V7112	V7113	V7114	V7115
START UP	O	O	C	C	O	C	C	O	C	O	O	C	C	O	C
NORMAL	O	O	C	C	O	O	C	O	C	O	C	C	C	O	C
CIP	C	O	O	O	O	C	C	O	C	C	C	O	O	O	C
DRAIN	O	O	O	O	C	C	O	C	O	O	C	C	C	O	O

NOTES:

1. ALL RED DASHED LINES - - - - - - - - - - AND ITEMS DENOTES EQUIPMENT AND PIPING DESIGNED AND SUPPLIED BY OTHERS.

REVISION HISTORY

REV	DESCRIPTION	DATE	CHECKED	ENGINEER
-			-	-
-			-	-
-			-	-
-			-	-
-			-	-
-			-	-
B	UPDATED	08/16/17	-	-
A	PRELIMINARY FOR REVIEW	08/15/17	-	-

STAMP

TOLERANCE	
FRACTION	
DECIMAL: .XX	
DECIMAL: .XXX	
ANGULAR	

	SIGNATURE	DATE
DRAWN BY	M. LARSON	08/15/17
CHECKED BY		
ENGINEER		
DISCIPLINE ENGR		
CLIENT		
PROJECT MGR		
PROJECT NO.	NAXXXX	

FULL FILENAME
L:\WATERCARE\ENGINEERING TEAM\TRIALS\TAMPA, FL 2017\ TAMPA PILOT (PROCESS FLOW DIAGRAM REV B).VSD.VSD

IXOM

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

PROJECT: MIEX® PILOT

SERVICE: MIEX® PRE-TREATMENT

TITLE: 15 GPM MIEX & VSEP PILOT PROCESS FLOW CONFIGURATION

SIZE: B | DWG NO: TAMPA PILOT | REV: B

SCALE: NTS | SHEET: 1 OF 1

APPENDIX B – PILOT PLANT LOG

Master Plan 2016 Pilot Plant Log

8/28/17

- Week of jar testing.

9/8/17

- Went through shut down procedure for MIEX in order to power down equipment in anticipation for Hurricane Irma.
    - Resin transferred to regeneration tank and stored in brine solution.
- All Intuitech skids shut down as well.

9/13/17

- Started up MIEX skid. During startup, noticed propeller of regeneration tank mixer had fallen off into tank. Had to fish it off the bottom, remove the mixer (motor and shaft) from top of container to reattach propeller.

9/15/17

- Back-flushed settling basin in order to break up and drain the compacted sludge.
- Replaced the stator on the sludge pump.

9/20/17

- Noticed MIEX resin not fluidizing. Found out later that the mixer was damaged during setup (but was working) and finally broke.

9/22/17

- Getting license errors on Filter skid.

9/26/17

- Increased MIEX flow >11 gpm to make sure the floc/sed skid doesn't shut down again due to low flow.
- Need to set ozone dose very high to get residual. Ozone feed gas analyzer seems to be inaccurate.

9/27/17

- Tyler got all filters operational after replacing transmitters.

10/2/17

- All skids were shut down due to low flow. Restarted system but pump would not reach set-point (9 gpm). Noticed a thick clump of algae growth in the holding tank. Scooped that out and began taking apart all of the pipe from the holding tank to the rapid mix basin. Flushed out all lines and the pump. Eventually got all of the mess out and got flow back to set-point.

10/3/17

- Kept losing pressure to the ozone generator. Sean talked to Rob with Intuitech and narrowed it down to a malfunctioning pressure regulator. Had to force some tubing onto the drain, attach a valve, and partially shut it to create backpressure.

10/4/17

- Began baseline testing
    - MIEX was "bypassed" by sending resin to the resin regen tank, left soaking in brine solution.

  - Coagulation target was similar to full-scale, ferric dosed enough to get pH to ~4.5, polymer 0.25 ppm, turbidity ~1.0 NTU.
  - Ozone residual at a 5 minute retention time set to ~0.30 ppm
  - All filters running at a 2.2 gpm/sqft loading rate; backwash sequence was set by Carollo but was well out of normal conditions.
- Set up caustic feed.
  - Tubing and peristaltic pump connections were all plugged.
  - Replaced tubing and moved to different peristaltic pump.
  - Initially attempted running tube to drip on the surface of the settling basin so it would briefly mix before the settled water pH meter but the flow wasn't high enough to get the pH to setpoint.
  - Moved the injection point to the ozone feed line coming off of the settling basin (after pH meter) but ran tubing from the ozone line right after the flow meter to the settled water pH meter to monitor.

10/6/17

- Collected final data set for baseline
- Powered down ozone to open up the panel and check if the remote controller Ethernet was plugged into the correct place (and as far as I can tell it was)
  - Purged ozone analyzer with ozone-free gas for 2 hours before zeroing.
- Lost raw water to pilot room; turned out to be clogged pump at the river.
- MIEX put back into operation at 600 BV (1.67 mg/L ERD)
- Coagulation basins set for 100 ppm ferric dose, ozone still targeting 0.30 ppm residual, filters left at 2.2 gpm/sqft loading rate.
- Filter backwash sequence modified to more accurately simulate full-scale with the exception of the high rate backwash which was raised to 18 gpm/sqft to get proper fluidization.

10/9/17

- MIEX did not regenerate any resin over weekend; most likely due to operator error when putting system back into operation the prior Friday.
  - Resin transferred from regen tank back to contactor.
  - Loaded resin dumped into regen tank, forced into regen cycle, and put back into auto.
- Conference call with Carollo
  - Outstanding issues:
    - No remote access to ozone or filters
    - Ozone feed gas analyzer reading very high
    - Broken valve on filter 3
      - Justin will send us new one
- Put in a ticket with T&I to gain access to the Intuitech skids using the VNC software from the work network.

10/10/17

- MIEX regeneration was hung up again and did not regenerate overnight.
  - Talked to Michelle and everything seems to be back to normal.

- Remote Access Issues:
  - Tyler talked to Intuitech and they realized they had a firewall up that was blocking our access to the filter skid. We can now reach it.
  - I spoke to John with Intuitech to work out the issue with ozone remote access.
    - He had me open up the remote control box, unplug the red/black plug next to MDM and plug it back it. He was able to access it after that.
    - I was able to access the ozone skid via Virtual PC in XP mode on my laptop using my phone as a hotspot. I am unable to access it (or any other skid) on the work network.
  - I was able to access the MIEX skid using the phone apps. Need to click on connect in the "OpenVPN Connect" app and then connect to skid in the "Mocha VNC Lite" app. Make sure to disconnect when not using (do NOT allow it to run in the background).

10/11/17

- During sample collection, noticed filter 3 headloss went to zero but then eventually went back to normal. Also, filters 3&4 had no headspace at the top of the column but manual states there should be 4-6". Tyler said this is normal.
- Tyler came by to work out ozone feed gas issues. She was told to zero it for 4 hours. After talking to Keith, we decided to flush it with ozone-free gas overnight before zeroing it.
- We found an ozone gas leak in the connection right after the gas flow meter for column 1. Turned off compressor and generator, put Teflon tape on the connection, tightened it up, put compressor and generator back in service and leak was gone.
- Emptied out entire coag/floc basins in evening and hosed down to get rid of the thick layer of sludge on top of flocculators 2 and 3 and the settling basin.
  - Restarted basins without ferric. Increased MIEX to 2.5 mL/L. Polymer didn't create any floc out of the turbidity. UV254 was ~0.4. Filter turbidity was high. At 10pm, set MIEX back to 1.67 mL/L, turned on ferric at 60 ppm and polymer at 0.15 ppm. Want to get basins dialed in with MIEX pretreatment.

10/12/17

- Still getting sludge layer formed on surface even though under-dosing ferric and polymer.
  - Emailed the group for input.
- Watched MIEX step 35 towards end of run cycle and noticed no resin (only water) being transferred.
- UV254 signals were to the wrong names in SCADA. Yorger switched the signals at 9am.
- Cleaned out holding tank; layer of algae-like growth on inner wall.
- Troubleshot treatment issues with sludge forming at surface.
  - Turned off polymer for a few hours; no improvement.
  - Adjusted mixing rates; no improvement.
- Put system back into normal operation for Friday collection.
- Increased MIEX contactor mixer to 77% to try to get better suspension.

10/13/17

- Emptied out entire coag/floc basins in morning and hosed down to get rid of the thick layer of sludge on top of flocculators 2 and 3 and the settling basin.
- Restarted basins without polymer to determine if the buildup is caused by the poly.
    - Before leaving, surface sludge buildup was already noticeable.
- Replaced broken actuated valve on Filter 3.
- Tyler pulled off the ozone feed gas analyzer and sent to INUSA for repair.

10/16/17

- Power failure on Sunday shut down all systems.
    - MIEX did not resume automatically. Had to jog forward regen step to force regen cycle.
    - Turned mixer down to 70%

10/17/17

- Surface sludge in flocculators thinning out.

10/18/17

- Surface sludge in flocculators nearly gone.
- MIEX
    - Michelle Larson providing training for Sean.
    - The resin in the regen tank gets transferred to the contactor until the level in the regen tank reaches 10% but the mixing blade is around 21% height so Michelle changed that setpoint to make sure resin is always being mixed during transfers.
    - At 5:15pm she put the raw water flow meter in simulation mode to trick it into thinking we're treating more water in order to speed up the cycle.
    - Around 8pm she was making changes to the logic and had to shut down flow which emptied the holding tank and shut down floc/sed. I was able to remote in and turn it back on before ozone and filters shut down due to low flow.
- Conference call with Carollo

10/19/17

- MIEX
    - Regen paused in morning due to high resin level. Michelle had to adjust some setpoints to prevent that from occurring.
    - We discussed adding a free chlorine injection point where the raw water comes into the pilot room. This would give ~1 minute detention time before the sample port pre-MIEX.
        - Would also need to install a new sample port before the injection point to collect our raw water samples.
    - Data log frequency adjusted to give us a week of data instead of just one day.
    - Resin inventory in contactor is low. Will wait until making other changes before adding resin.
- Forced all filters into backwash to get a new headloss profile.

10/20/17

- Filter 1 backwashed during sample collection. Waited for at least 1 hour runtime and for turbidity to come down before collecting that sample set (all other samples were already collected).

10/23/17

- Ran out of caustic to the settlement basin at about 7:00 am causing the pH to drop to the mid to low six range. Consequently, the ozone residual shot up. Caustic feed normalized about 9:00 am so residual should get back to about 0.4 g/Nm^3. Entered by Sean Pitcher
- Set up peristaltic pump X710 on floc/sed basins to feed chlorine to raw water.
- After-hours, maintenance installed new raw water sample port, chemical injection port, and MIEX bypass (in that order) right after the shut off valve where the raw water first enters the pilot room.
    - Had to stop flow to all skids to perform work.
    - When work was completed, I turned on MIEX remotely but it kept wanting to shut down due to low flow while in auto; had to set shutoff valve V2101 in manual.
    - Couldn't remote into filter skid. Sean went to plant in evening to turn all equipment on.

10/24/16

- Regen was paused when I came in due to "#8 Level Transmitter Failure"
    - There was a high level alarm; manually drained regen tank down to 75% and resumed regeneration. It did 2 back to back regens and then returned to normal.
- Put MIEX shutoff valve V2101 back into auto and is working normally.
- Replaced the drain section of the pressure regulator on the ozone compressor feed line. Set it to 20psi.
- Mechanics filled the 50 gal ferric tank.

10/25/17

- Forced all filters into backwash to get a new headloss profile.

10/26/17

- Set all 4 filter turbidimeters to factory calibration at 8:50am.
- Remotely lowered ferric dose in the PM at the request of Larry Elliot.

10/27/17

- Ozone
    - Tyler installed the ozone feed gas analyzer. Let run with ozone-free gas for 3 hours before zeroing and turning up ozone concentration.
    - "Feed Gas Analyzer Error" and "Feed Gas Analyzer Error" on HMI alarm screen.
        - Ozone analyzer showing 36 GNM3 at 50% but HMI showing 0
    - Ambient ozone monitor detecting leak at feed gas ozone analyzer so I set the generator to 0%

10/30/17

- All Intuitech skids were shut down (as of 10/29/17)
    - Floc/sed feed pump couldn't maintain 9 gpm.
        - Sean used hose to flush pump in both directions.
        - Takes 100% to get 9 gpm (as it did previously also)
        - Reduced flow setpoint to 8.5 gpm (95.3%) to prevent another shutdown and to monitor if the percent speed increases over time to maintain 8.5 gpm.

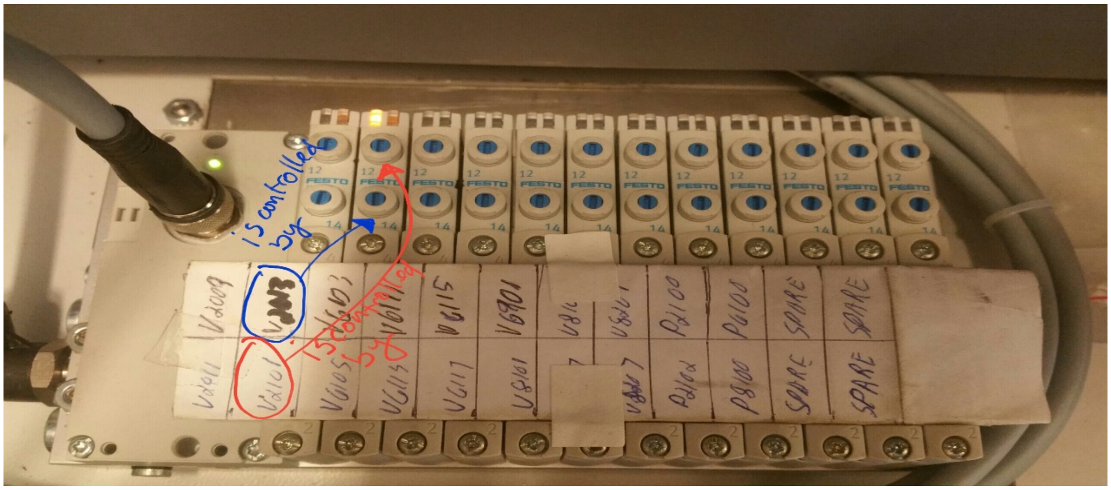
- Mechanic increased pressure in raw water line in order to get MIEX flow up to 15 gpm (could not get flow past 10.5 gpm in AM)
- Ozone
    - Tyler fixed communication problem between ozone feed gas analyzer and HMI.
    - We found and fixed the leaks on the feed gas analyzer
    - Generator was set to start producing ozone again
- Received 10.5% sodium hypochlorite
    - Moved to pilot room
    - Need to find safe way to feed without off-gassing chlorine into room

10/31/17

- HMI on MIEX crashed. Sent email to Michelle Larson. Michelle sent it to Cliff Bottorff who wrote me back that on the desktop if the HMI is not operating there is a "Start Center" which is there always. Pressing "Start" will start back up the HMI
    - Later when trying to select the motor control in the HMI for MIEX it crashed again. Gave it about 10 minutes and it got back to the same screen as above and got back to the HMI.
- Angela from the lab did the sample collection with my (Sean's) supervision today.
- Began feeding chlorine into raw line at 11am (2.5ppm)
    - Leak in PVC fitting at injection port was causing chlorine to short-circuit out of system and very little residual was making it to the MIEX contactor.

11/1/17

- Moved chlorine injection point to the raw water sample port.
    - Was able to get 6.5ppm free chlorine right before MIEX and 0.1ppm coming out of MIEX
- Got remote access to filter skid back on line. The CAT5 cable from the Ethernet hub in the modem was disconnected from the female-female adapter that connected another CAT5 cable (which was also unplugged) to the control box. Reconnected both sides and it worked. The retention tabs on the male ends of the unplugged connectors have been broken.
- Got the MIEX skid HMI functioning properly. Contacted IXOM who tried to reboot the system but could not. Later they found it was a 'corrupt development file' per Clint Bottorff who fixed it remotely. I can now access the LT6100 mixer motor without crashing the system as was the case.
- In the process of fixing the MIEX, it was discovered that at least two the manual overrides for the valves located in the valve manifold (rectangular grey box with small blue flat head screw heads) at the bottom center of the control box are mislabeled. Other controllers were not tested. Please see below pic. Turning these screws will override default behavior dictated to the valves by the operating system in a shutdown or system crash. Turning these screws clockwise 90 degrees forces the valve it controls open.
- Valve override manifold in MIEX skid (next page).



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11/2/17

- Reduced chlorine feed in raw water to maintenance concentration (0.1-0.5 ppm free chlorine) after sample collection.

11/3/17

- Added 0.25 gallon resin into contactor and 0.75 gallon resin into regen tank at 10:30am.
    - Noticed surface sludge in basins came back shortly after.
- Before leaving, set all filters for 24 hour runtime to get a few headloss profiles over weekend.

11/6/17

- Very thick layer of surface sludge in basins.

11/7/17

- Low flow to MIEX contactor.
    - Maintenance had to shut down raw water pumps to clean out Y-strainer.
    - When raw flow stopped, noticed zero mixing in contactor. Looked up top using ladder and saw that the mixer shaft was broken.
        - Don't know how long mixer has been broken.
    - They also increased the pressure a bit so that we can maintain 15 gpm.

11/9/17

- Had to reduce floc/sed flow to 8 gpm because it was running 99.6% speed at 8.5gpm.

11/10/17

- Sean flushed floc/sed raw pump several times because the %speed kept increasing to maintain flow.

11/11/17

- MIEX crashed; had to put control valve in manual and open to keep flow through contactor.
    - Flow was hovering around 7gpm.
    - Set floc/sed to 5 gpm.

11/13/17

- Thick floating sludge still in basins; thick layer of sludge in settling basin difficult to pump out.
- MIEX

- Low flow shut all the other skids down.
- Regen stuck on "drain carrier water" step even though no water in regen tank.
  - Put whole system on Pause.
- Drained down contactor for mechanics to install new motor and inspect the guide shaft.
- Resin inventory about 13.5 gallons in contactor.
  - Not sure of resin volume outside of contactor. Will need to re-evaluate to determine how much resin to add back into system.
- Michelle here for training.
  - Today she's helping get MIEX back up and running. VSEP still being installed.

11/10/17

- Miex shut down about 5:30 yesterday afternoon due to low flow. Flow was about 11 gpm when everything was back up.

11/11/17

- Floc/sed shut down about 12:30am due to low flow again. MIEX was around 7 gpm . Changed Floc skid flow to 5gpm and turned floc/sed back on. Came into plant and the plant was down again. Now Floc skid pump refuses to get to 0.5 gpm and power to pump was 100%. Flushed pump before putting back in service.

11/12/17

- Floc/sed shut down again due to low flow (~5 gpm through MIEX).

11/13/17

- Plant still down from yesterday. Raw flow to Miex now at about 3.5gpm. Mechanic stated that the y-strainer to the plant was "completely gunked up". Regen cycle on Miex on Sunday was very abnormal, LT600 never refilled and the pump from this tank was on but pumping nothing. LT600 was empty of fluid but had some resin at the bottom. No resin was in the upper tank. Contactor was emptied to the level just under the access port. A new motor was put on to drive the contactor mixer and as of 12:30 no flow introduced into the system as resin inventory was to be taken by Michelle before restart.

11/14/17

- Pump on Floc skid failing. Flush pump 3x and bleed of air. Ran for about one hour and then saw degradation of performance. Changed pump to spare pump. Ran for about one hour and started to see some degradation of flow again. Changed this pump with the pump from the filter skid and replaced the filter skid pump with the pump originally on the floc skid. Slowly brought pump to speed and bled air and it performs stably at 8.5 gpm. Finished about 1 pm with switching pumps. Resin loss and adjustment to Miex still being made.

11/15/17

- 7:00 am Pump on floc skid working, Miex adjustments done filters turned on and ozone performing. System fully operating and adjustments made to get system into steady state.

11/16/17

- Approximately 4 pm flow to Miex went down to about 7gpm. Adjusted Floc skid to 4gpm and sludge pump to 0.75gpm. When I left at 6:45pm flow had not gone back to normal.

11/17/17

- Flow still not back. Ozone shut down. Pressure regulator to ozone generator is once again broken. Re-installed the old one which has a tube and flow valve to regulate pressure and the ozone went back into service.
- Pilot still running till 8:00am when low flow to Miex shut down rest of plant. Flow resumed normally about 9:00am when floc inlet pump was flushed and bled of air. Flow resumed normally at 8.5gpm and about 13 psi at pump discharge. After half hour ozone was put on.
- No further VSEP training done as Michelle sheared the bolts tightening plates on the vibrating platform. VSEP out of service till further notice by Michelle.
- Air occasionally getting into MIEX contactor from raw water line. May need to put an air relief valve to prevent this.
- Leak at chlorine pump. No chlorine getting into raw water line.

11/20/17

- Raw water back-feeding into chlorine drum through peristaltic pump. Need a check valve on chlorine line. May not be able to overcome pressure in raw water line.

11/22/17

- Scooped off sludge build up from surface of all tanks in floc/sed basins. Within 2 hours it was back to where light could not penetrate the surface. Floc skid pump was using more power to be at 85gpm than normal so flushed pump ahead of weekend and performance improved.

11/23/17

- From remote connection to MIEX, saw that regen was halted due to high level on LT600. Reduced it remotely below 90% and it happened again. Reduced it to just below 70% and it completed the regen and began working again.

11/24/17

- Remotely saw that MIEX and floc/sed were both down, as MIEX shutting down stopped flow to the rest of the plant. MIEX had the same alarm as on 11/24, but another one saying the 24volt backup was low. Cleared alarms, reduced level of LT600 to below 70% and restarted MIEX. It completed the regen cycle and immediately started another one. This is common for the system when a regen deviates badly from designated parameters. Signed off and let it do its work. Logged into Floc/Sed and turned it on as flow was likely getting through MIEX and had filled flow normalization tank. I decided to let these two systems run for a while to see if they had other hiccups later on.

11/25/17

- Attempted to log into MIEX but it rejected my request. About 2 pm went to the plant and the power to the MIEX skid was down completely. Decided not to mess with it. No through flow available to the rest of the skids as flow through MIEX is controlled by an automatic valve that shuts off when MIEX goes down, so I left those down too.

11/27/17

- Came in and Pilot Plant was as it was left on 11/24. Electrician came in a bit later and tightened down the power wire to the transformer inside the MIEX panel. He said it came loose and was arcing. The wire looks a bit burned, but he said it should function, but maybe we should look at getting a transformer in case this one was damaged. With MIEX power on, opened the valve to allow water through the system and turned on floc/sed operations.

- Pump to floc sed was at 100% and not getting flow past 7.0gpm apx. Stopped and flushed pump 3x and got it to operate. Shut off pump and drained all water from tanks on Floc/sed. Scrubbed down sides of tanks and flushed out surface sludge, now about 2” thick. Began pumping and put skid back into operation.
- Michael found that there was no flow to pH meter for rapid mix and flushed the line.
- Decided to keep MIEX shut down until problems are fixed (need air release valve on raw water line and need to get chlorine feeding again).
    - Transferred all resin into regen tank. In regen tank, drained water to resin level and pumped in fresh brine. Drained that until conductivity stabilized.
- Opened up bypass to have raw water go to floc/sed feed tank.
- Floc/sed unit shut down around 11pm due to low flow.

11/28/17

- Floc/sed had shut down due to low flow at 11 pm the night before. Turned it back on but it went back offline a few minutes later. Reduced flow to 6gpm and it stayed on.
- Found a break in the acid feed line by injection point that was squirting water. Shut down the system to cut the broken part and reattached to valve. Don’t know when this happened because the rapid mix pH line was plugged and not flowing through pH meter.
- Turned floc/sed back on but max flow was at 7.3gpm and pressure at discharge of pump was about 22psi where it is normally at 13psi with a flow of 8.5gpm and about 87% power. Bled pump of air and no change. Flushed pump 3x and no change. With ~10psi difference deduced there must be blockage in flow to rapid mix. Took apart piping and flushed each section, replacing and restarting each time. Upon cleaning in line mixer to the rapid mix basin, large chunks of red material came out. Reassembled and flow at 8.5 gpm at ~87% power and about 15psi at pump discharge achieved.
- Lowered ferric dose to 140 mg/L and started up polymer at 0.25mg/L. Saw that flow to rapid mix pH was again not flowing. Flushed the line and got it to flow. Sampled and tested pH and it was consistent with pH reading.
- Sean flushed the raw pump to get flow back up again.
- Removed sand from filters 3&4 and added GAC. Now have 6” sand and 36” GAC.
    - Noticed filters 1 and 2 have a couple extra inches of sand and just 20” of GAC (though it was a little higher when we started so we must have lost a small amount of GAC).
- Put ozone and filters back in service.

11/29/17

- Floc sed pump back to 21psi at discharge at 7.5gpm flow. This time changed out the static mixer with a new one and pressure down to 11psi on pump discharge at 9gpm.
- Skimmed all water surfaces in floc sed, but the foam is returning.
- Flow to rapid mixers pH meter keeps stopping.

11/30/17

- Foam on basin surface now turned to sludge (different consistency than when MIEX is running). Will leave it alone to see how bad it gets.

- Floc sed pump instantaneous flow swinging wildly but centered at 9gpm. Will speak to Rob at Intuitech to see if he has a possible solution. Plant running stable otherwise and treatment objectives mostly being met.

12/01/17

- Changed pump on floc/sed unit as flow was erratic. Noted that flow conformed to setpoint of 9.0 gpm without irregularities until the acid feed was turned on. Then the previous pattern of flow irregularities returned. Changed pump back to original pump.
- Changed out static mixer as pressure on discharge of pump was at about 23 psi. Immediately dropped to about 12 psi.

12/4/17

- Plant down due to clogged floc/sed pump. Flushed discharge and inlet 3x. Turned on ozone after half hour and half hour after that filters.
- Plant operational upon leaving at 3:00 pm

12/5/17

- Plant went down about 2:30 am this morning.
  - Flushed pump of debris but pump would not get past 7gpm with 23 psi at discharge.
  - Disconnected static mixer, pipe before static mixer plugged with ferric.
  - Cleaned out pipe and replaced mixer with one cleaned yesterday.
  - Pump now runs normally and flow resumed.
- Replaced the static mixer with normal pipe to prevent further shut downs due to low flow.

12/6/17

- Noticed acid feed line near injection point was warm (40C) and discolored. We had a break in that line before but was unsure why. Now we think some raw water is getting into the line, reacting, and weakening the tube. Ordered PTFE tube and fittings (including check valve).
- Shut down all skids.

12/8/17

- Sean drained and cleaned the floc/sed basin and I installed a blade on the 2nd flocculator mixing shaft at the water surface level to keep the surface moving.
- Turned on floc/sed skid, set ferric to 200ppm without acid.

12/11/17

- 2nd flocculator still clean of surface sludge; 3rd flocculator and settling basin full of it.
- Back-flushed filters with clean water to wash out what appears to be red cyanobacteria on media surface.
- Shut down system to begin flushing raw feed line with chlorine (12:15pm).
  - Initially started feeding 150ppm chlorine into 9gpm finished water.
  - Residual not going up at discharge points so chlorine pump maxed out at 200ppm.
  - Cut feed flow to 5gpm to increase chlorine residual.
  - Eventually got 100ppm at ops spigot and 300ppm at end of line (5:00pm).

12/12/17

- Started flushing the raw water feed line with finished water (8:00am)
  - Measured 120ppm at 8:00am at end of line, 60ppm at 8:15.

- Received Teflon tubing and parts for acid line. Installed into current acid feed location. Noted that acid flow created wild fluctuations in the readings from flowmeter.
- Made decision to move acid feed to current ferric port and fabricate and install new ferric port after acid port before rapid mix

12/13/17

- Sean put a new chemical feed port where the static mixer used to be so that we could feed the acid and ferric after the flow meter.
- Drained and washed down basins (sludge had built up)
- Put system in operation
- Increased filter loading rate from 2.2 gpm/sqft to 3.48 gpm/sqft to simulate 120 MGD.

12/14/17

- Ozone leak had filled the room to about 0.1ppm concentration. Turned fan to face center of the room after shutting down ozone and left for 45 minutes while room cleared of gas.
- Turned system back on with fans on high and used ozone detector to locate leak in ozone feed line connection.
- Connection was opened, Teflon tape wrapped and connection retightened.
- Sludge noted in basins again. Skimmed after collection, but back in 3 hours when I left.

12/15/17

- Turbidity higher in effluent than influent despite ferric dose being 40 ppm higher than full scale.
- Turbidimeters are in constant need of being cleared.
- Dropped ferric to match full scale per Dr. Lei's suggestion that ferric overdose may be the reason we cannot get turbidity in flocculation skid effluent under control.

12/18/17

- Surface sludge likely caused by small bubbles attaching to floc and rising to top. After collection, turned down rapid mix speed from 1000 s^{-1} to 200 s^{-1} to see if it reduces the production of bubbles in the flocculators. Sean cleaned out entire skid.
    - Didn't make a difference.
- Sean checked all o-rings and tightened all threaded connection before the skid's raw pump.

12/21/17

- Meeting between COT, Carollo and IXOM
    - Pilot supposed to end 2/28/18 but may be pushed to 3/31/18
    - Match 140 MGD across filters
    - Check turbidity to influent of each filter
- Acid tank emptied in PM. Filled it back up.
- Floc/sed feed flow dropped below target. Had to flush pump a few times.

12/22/17

- Skimmed sludge from settling basin as it has gotten very thick and turbidity is in the mid teens. Likely sludge is getting carried over in higher concentrations as sludge blanket is thickening.
- Backwashed filters and set flow to 0.798 gpm. (simulate 140 MGD)

12/23/17

- 10:00 a.m. Remote shows filter 4 down to low flow.

- Came in to plant and cleared alarm. Filter started up. Let run for 30 minutes and excess flow still produced. Set flow on ozone to 3.6 gpm as a precaution.
- Headspace on filter 4 where none on others.
- Noted that we lost treatment at some point in floc sed. Saw no flow of ferric to floc sed. Pushed feed tube all the way down to bottom of ferric tank. Flow restarted and adjusted acid flow. Will watch remotely.

12/27/17

- Collection not taken
- Hydroxide ran out and was refilled in a.m.
- Water very dark in filter towers and in ozone columns
- Sludge blanket in settling very high and some particulate in effluent water
- Cleared up but later came back. Scooped out settling basin.
- Seems to have cleared up by 3:30

12/28/17

- Water clear in filter columns so collection taken
- Carefully scooped building sludge blanket in settling basin
- Drained effluent tank as it was very dirty and allowed refill
- Heavy buildup of sediment at bottom of ozone contactors. Sent as much to drain by flow. Allowed clear water to flow out of ozone skid before adding back to system

12/29/17

- Water condition improved from yesterday. Reddish/brown intermittent carryover into ozone skid and filter skid which was appearing yesterday no longer seems to be appearing.

1/4/18

- Conference call w/ Carollo
    - They're still figuring out gas production of raw water.
    - Carollo would like to turn on MIEX treatment
        - They believe that pH, not temperature, is currently causing surface sludge so running MIEX without pH adjustment will remedy this problem.
- Created PVC overflow to siphon off surface of Flocculator 2 and had no impact on surface sludge accumulation at a rate of 1.5 gpm.
- Closed bypass so that raw water is now passing through MIEX contactor (no resin).
- Having problems with caustic feed system
    - Caustic crystallizing in chemical tank at the tube inlet and preventing flow
        - 50% NaOH has freezing point of 58°F.

1/5/18

- Put chemical mixer in caustic tank to try to prevent freezing.
- Shut down all intuitech skids to clean basins with expectation of turning on MIEX.
    - Regen tank underdrain pump very slow; backflushed underdrain with finished water many times but not much help; hosed down underdrain after emptying tank but still no better.
        - Will remove underdrain pump tomorrow for cleaning based on Michelle's instructions.

    - Treatment screen shows very high “Air Lift Off Time (min)” and just ###### for “LR Tank Batch Time Remaining (min)”
    - Everything shut down for weekend.

1/8/18

- Sean cleaned the MIEX regen tank underdrain assembly per Michelle’s instructions.
    - Regen tank underdrain pump seemed to work fine afterwards.
    - MIEX put back into service at 200 BV for a couple cycles, then back to 600 BV.
- Floc/sed and ozone put back into service.

1/9/18

- Filters backwashed and put back into service.
- MIEX contactor mixer speed increased from 60% to 100% per Michelle.

1/10/18

- Surface sludge being removed 1-2x daily per Larry.

1/12/18

- Turned on chlorine feed to raw water.
- Changed sludge pump to constant per Larry.

1/16/18

- No change in surface sludge formation over weekend but settling sludge compacted.
    - Set sludge pump back to intermittent; compacted sludge no longer a problem.
- Ozone relief valve building up with water; need to purge daily.

1/17/18

- MIEX regen was paused
    - Happened around 1pm previous day during transfers soon after regen completed
    - Sean pushed recover (should have pressed resume)
        - Had to rinse resin in regen tank, send it all to contactor, and fill loaded resin tank with 12 gal resin.
        - Resumed regen into step 40, set a deficit, and let regen fall into place.
- **No sludge accumulation at surface of contactors since cleaning the day before**
    - No bubbles found in 2nd or 3rd basins; large bubbles in 1st basin from water weiring over.
    - There is a fluffy formation on top of settling basin plates; more noticeable now that surface sludge is gone. Easily breaks apart when disturbed so likely just floc carryover rather than any sort of biological growth.
- Sean cleaned out the settling basin and clarified water basin.

1/18/18

- **Still no new surface sludge accumulation or bubbles in basins.**

1/22/18

- Changed MIEX bed volumes from 600 to 1,000 about 5pm after regen started.
- Minimal surface sludge formation overnight.
- Floc/sed unit shutting down due to condensation inside chemical pump cabinet; chemical leak false alarms.

1/24/18

- Reduced ferric dose from 70ppm to 50ppm after sample collection. Will monitor online UV254 for a couple days before deciding to drop it any further.

1/25/18

- Lots of bubbles in basins; surface sludge coming back.

1/26/18

- Bubbles in basin gone; sludge thinned back out.
- Reduced ferric dose from 50ppm to 30ppm after sample collection.
- MIEX resin inventory a few gallons short; will create new top-off schedule with Michelle.

1/30/18

- Michelle repaired VSEP unit and began testing with water.

1/31/18

- Michelle decided that IXOM will run the VSEP unit themselves when it's time to collect samples and they will send the samples out for analysis.

2/2/18

- MIEX regen paused due to high resin bed volume. Manually transferred resin to contactor and resumed regen. Assuming this has something to do with the large volume of resin added to regen tank by Michelle to top off resin inventory.
- Began dosing polyDADMAC polymer at a dose of 1ppm (0.03 mL/min).

2/5/18

- Heavy accumulation of surface sludge in the morning. Cleaned it out.

2/6/18

- No new surface sludge accumulation in morning.
- MIEX regen paused due to high resin bed volume (about 20gal in regen tank). Manually transferred resin to contactor until ~12gal (settled) resin left in tank and resumed regen. **Need Michelle to look at program to see why this is happening.**
- Noticed polyDADMAC level in container seems to be going down faster than it should be. Should only be using 50mL per day. Sean marked line yesterday ~11am and by 8am today it was roughly 200mL lower.
- Replaced ozone destructor.

2/7/18

- Intuitech skids shut down previous day ~6pm due to chemical leak detection; chlorine barb fitting was slowly dripping.
- Chlorine wasn't flowing; seems to be plugged at end of line inside PVC; will replace section of line including check valve tomorrow (if we get new check valve by then).
- PolyDADMAC container was weighed at 2pm previous day and over 4 hr period (until shutdown) used 43g of polymer when it should have only used about 8g; dose has been over 5ppm.
    - Turned off polymer feed in morning; collection with just ferric.
    - Set up syringe pump to feed polymer to get better control at low flow (12:25pm).

2/8/18

- Repaired chlorine feed

- Decided to keep filter flow high to get quicker response time when making process control changes in upstream skids.

2/9/18

- Turned off polymer and increased ferric dose from 30ppm to 40ppm (4:00PM)

2/12/18

- Online UV254 shows no difference in treatment over the weekend between 30ppm ferric 1ppm poly compared to 40ppm ferric.

2/16/18

- Tyler helped adjust filter media levels (all filters now at 1' sand 2' GAC)
    - Backwashed all filters and put back into service (still 140MGD)
    - Dr. Lei decided to have Filters 1&2 at 80MGD and Filters 3&4 at 120MGD; changed the flow setpoints and sent all filters to backwash again.

2/19/18

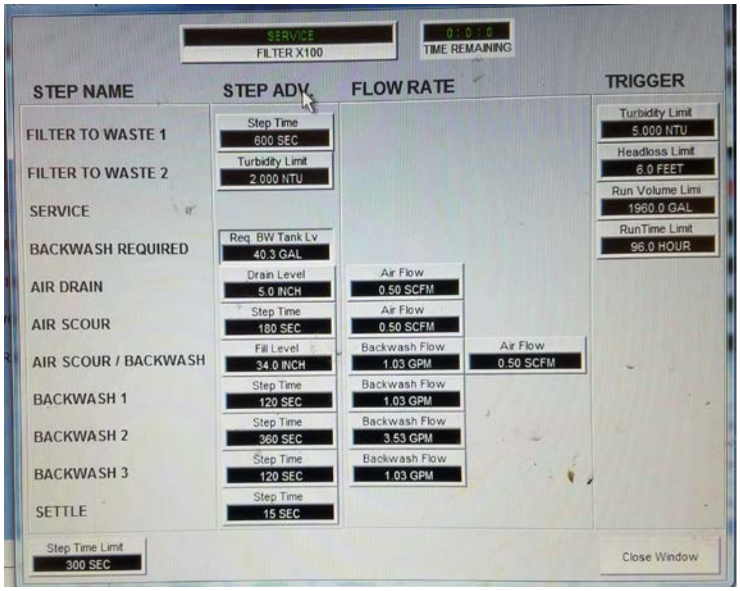
- Could smell ozone in hallway outside pilot room; shut down ozone generator.
    - Rotameter from generator to column 1 cracked and leaking.
        - Replaced it with the unused rotameter for column 2 and valved off the unused line.
- Filter skid shut down on Saturday; "Filter X100 Step Time Too Long Alarm"
    - Filter stopped during drain step. Air valve was opening not no air getting into column.
    - GAC may have plugged opening. Opened valve for all 4 filters with compressor on to force air through. Resumed backwash for all filters.
- 9:40 A little bubbling in floc/sed windows, none on miex contactor surfaces. Thin film of sludge on basin 3 and settling basin plates and surface. Scooped surfaces and blew down sludge plates. Saw turbidity out rise a little and go back down, no color change to water going into ozone or filters.

2/20/18

- Filters still stopping during drain stage of backwash.
    - Replaced air scour blower air filter to see if that helps.
        - Filter 2 went into backwash a half-hour later and stopped during drain.
    - Increased "Air Drain" air flow from 0.25 scfm to 0.50 scfm for all filters in the sequence control panel. Will see if it helps.
- Influent to all filters tested in lab for turbidity and all were the same.
- Ozone residual has been reading 0ppm at the HMI. Did a manual reading using Hach DR890 and measured 0.13ppm.
    - Need to calibrate sensor.
        - If that doesn't work, need to replace sensor tip.
- Turned off ozone generator and ran air (2 hours) through feed and off gas analyzers to zero them.
- 1:10 pm sludge on surface of basin 3 and settling basin and bubbles on Miex contactor surface. Scooped surfaces

2/22/18

- Conference call
    - Collect backwash samples from each filter at end of high rate.
        - Send Carollo backwash sequence



    - Send updated operational and WQ data
    - 2/27/18
        - Increase filters 3&4 to 140MGD
    - 3/9/18
        - Turn off MIEX, run enhanced coagulation in basins (pH adjustment, ferric and polymer)
        - Leave filters (1&2 at 80MGD, 3&4 at 140MGD)
    - 3/20/18
        - Lower filters 1&2 at 120MGD

2/23/18

- Noticed backwash pump was left in manual 50% after modifying filter media prior week; set back to auto.
- A little bubbling seen in the a.m but not in the afternoon, produced a little sludge which I scooped off about 1:00 pm
- Filters went into backwash on their own

2/26/18

- Filters still stopped again during drain stage of backwash.

2/27/18

- Found leak at top of column 1, cracked connector to off gas tube. Will replace.
- Cycled power on modems for ozone and filter skids per Rob Rider's suggestion at Intuitech and regained access to these units
- Increased off time limit on filter 1 and 2 and filters still went into alarm and stopped. Cleared alarms and they went into and finished backwash with no issues.
- Bubbling and sludge production continues as before.

2/28/18

- Very high amount of bubbling still occurring. Skimmed surfaces of floc sed basins 3 and settling after collection. Bubbling also noted on surface of Miex contactor, resin seen between very large bubbles on surface.
- Increased step time limit to 480 seconds from 300 seconds on all filters. Filter 4 went into backwash with no alarm generated after this action.
- Sludge scooped at 11:45 am. Bubbling on all surfaces continues as before.
- Increased filter flow to filters 3&4 to 140MGD and sent to backwash (1:46 pm)
- Ozone residual reading zero on grab sample; generator is maxed out.
  - Waiting to hear back from Intuitech on calibrating ozone residual sensor to get better control of ozone dose.
  - May need to increase ozone/air flow going into column (has been 4 scfh)

3/1/18

- Bubbling and sludge continues in same fashion as yesterday. Scooped sludge and surface of MIEX contactor and same concentration of surface bubbles returned within an hour
- Smell of ozone returns this afternoon of course. Cannot find source will try again tomorrow
- Sludge seems minimal given the bubble production so did not scoop surfaces
- Moved ozone residual sample line closer to injection point (SV-Z120B) to see residual on HMI for when we're ready to calibrate.

3/2/18

- Bad ozone destructor changed. Taken out at 8:00 am and ran generator for 1.5 hours at 0 power to generator with new destructor attached. Started power at 50%.
- Bubbling and sludge continues in same fashion as yesterday. Scooped sludge and surface of MIEX contactor.
- Sludge scooped out at end of the day

03/5/18

- 8:30 am Sludge in settling basin is above surface and down to the plates. Scooped/drained and scooped all other surfaces. Sludge thickness looked like about 1.5 to 2 inches in places.
- A lot of bubbling on miex contactor surface
- Afternoon scooped surfaces again, bubbling and sludge production continues as before

03/6/18

- Collection Taken
- 8:00 a.m. Sludge in basins 2,3, settling of floc/sed and bubbling, although a little less than yesterday, continues on surface of MIEX contactor and in floc/sed. Sludge about ¼" thick where it has settled, more bubbly in basin 2 thicker in basin 3 and settling. Almost none in normalization tank ahead of floc/sed skid. Scooped sludge.
- Installed makeshift splash deflector to wier between rapid mix and basin 1 on floc/sed skid.
- 13:00 scooped accumulating sludge. No real improvement of bubbling or sludge from this morning

3/7/18

- 8:30 sludge and bubbling is as it was yesterday, slightly better overall. Scooped a lot of sludge off of settling and basin 3. Basin 2 had buildup in corners.

3/8/18

- Calibrated acid feed pump ~4:40pm. Had to feed some into basins to do so.
- 9:30 No change in sludge and bubbling. Scooped sludge from all basins as yesterday.

3/9/18

- 10:00 No change to sludge and bubbling, except today there seems to be more than yesterday. Scooped sludge and cleaned basin surfaces in anticipation of starting enhanced coagulation
- Allowed MIEX last regen to complete before starting shutdown of MIEX. Shutdown completed successfully and all resin in system transferred to regen tank. Virgin salt water drawn down through resin till conductivity flowing out of tank was 10 mSiemens/cm.
- Began change to and had problems with incoming plant and insect matter.
    - Stopped system and scrubbed side of influent tank as it was caked with dirt. Got as much off the bottom of the tank as possible.
    - Influent turbidity was 25NTU but water looked normal. Took samples to lab and from the inlet of the tank it was 1.89 NTU and from the relief valve at the bottom of the tank it was 2.32 NTU while still reading 25NTU at the skid.
    - Flushed turbidometer again and flushed pump. Saw improvement to about 12NTU.
- Knowing the actual quality of water is not at fault and having flushed pump I ran turbidity from the outlet of the meter and got 2.57 NTU in the lab when skid meter read apx 12 NTU.

3/10/18

- Ran Turbidities on system before cleaning surface sludge

Location	Raw	Floc sed tank bottom valve	coag eff	O3 eff	F1	F2	F3	F4
Values(NTU)	1.64	1.8	5.9	5.04	0.107	0.116	0.128	0.112
Time	9:57	9:58	10:00	10:02	10:04	10:06	10:08	10:10

- Cleaned surfaces of floc sed. All surfaces including all basins covered with some form of sludge. The first basin is covered with what looks almost exactly like the foam found in full scale.
- Ran Turbidities today again before cleaning sludge. Results below

Location	Raw	exit tank valve	coag eff	O3 eff	F1	F2	F3	F4
Values(NTU)	1.53	1.72	4.37	4.81	0.112	0.122	0.128	0.117
Time	8:00	8:02	8:04	8:06	8:08	8:10	8:12	8:14

- Cleaned surfaces of floc sed after turbidities run.

03/12/2018

- Sludge again is covering all surfaces. Cleaned in morning after collection about 9:00 am

03/13/2018

- 9:00 am cleaned sludge. Sludge again covers all surfaces. Cleaned after collection
- As on Friday, there seems to be events where the inlet turbidity goes up. Testing it in the lab, the floc/sed normalization tank bottom drain gives a turbidity of 2.18 NTU when the turbidity is at apx 33 NTU on the skid meter. At 33 NTU flushed the meter. Water seemed fine to look at, did not look any different than normal raw water.
- 4:30pm scooped surfaces

- 5:00 pm did lab analysis of the turbidity on water at bottom of tank going into floc/sed. It was 2.18 NTU.

3/14/2018

- 9:00 Sludge as yesterday. Likely 10-15 gallons of it gets scooped every morning
- Cleaned sludge again at 1:30, it was about ¾ the volume as this morning.

3/15/2018

- 9:00 Sludge was is it was yesterday. Scooped it
- Clogging and gunking of effluent turbidometer on floc sed skid seems to require constant attention. Every time it is cleaned turbidity gets better by several NTUs.
- 1:45 Sludge cleaned again off of all surfaces.
- At 3:00 pm turbidities were sampled at the raw inlet and coagulation effluent train and results are as follws:

	Raw	Coag eff
Turbidity(NTU)	1.81	4.86
Time	3:00	3:02

3/16/2018

- 10:00 sludge same as yesterday. Scooped it out
- 2:00 cleared up accumulating sludge

3/17/2018

- 15:00 Came in and cleaned up sludge. Sludge weight has stretched the skimmer on basin 5 to where it no longer turns, so surface covered in sludge. Turbidity very high. Cleared all meters and scooped sludge.

03/19/2018

- Replaced ozone destructor, re-attached feed gas tubing to off gas sensor and zeroed out the off gas and feed gas meters
- 10:00 scooped sludge, more today than normal, but likely only because it was not cleaned on Sunday
- 1:30 pm scooped sludge

3/20/18

- Changed Filters 3&4 flow to 0.684 gpm to simulate 120 MGD
- 10:00 scooped sludge, conditions same as yesterday
- Took DO readings and sent to Tyler this evening
- 14:00 scooped sludge

3/21/2018

- 10:00 scooped sludge, conditions same as yesterday
- Took more DO readings from same location and sent to Tyler
- 14:00 scooped sludge

3/22/18

- Backwashed Filter 4 at 100% for about a minute (before putting into auto backwash) to fluidize the sand layer which hasn't been moving during the past couple backwashes. Will see if this improves runtime.

3/23/18

- Moved ozone residual sampling point from SV-Z120B back to SV-Z130E around 8AM.
- 9:00 scooped sludge, same conditions as yesterday

3/25/2018

- 13:00 Scooped sludge, flushed pH and Turbidity meters

3/26/2018

- 9:00 scooped sludge
- Ozone cannot seem to get residual, even at a power rating on the O3 generator of 98%. UV readings from inline meter are higher than when we were getting residual.
- 14:00 scooped sludge

3/27/2018

- 9:30 scooped sludge
- Still no O3 residual. Tried for 2 hours at 98% power to get residual with no luck. At 85% power mean ozone residual is about 14.5 g/Nm^3 and at 98% it is about 15.1g/Nm^3. Not wanting to constantly run the generator at its limits for only a nominal improvement in ozone concentration resulting in no improvement in residual, I put it back at 85% .

3/28/2018

- 9:30 sludge scooped
- Apx 10:00 Acid feed ran out of feedstock, refilled and brought pH back under control
- Still no O3 residual.

3/29/2018

- 9:00 sludge scooped
- Still no residual from O3

3/30/2018

- Changed Filter 2 loading rate to 3.48 gpm/sqft and Filter 4 to 2.31 gpm/sqft (essentially switched Filters 2&4 to see the response).

3/31/2018

- 5:00 pm scooped sludge
- Noticed that filter 2 stalls at restart of normal service and gives pump flow too low error message. Cleared remotely and started back up at about 6 am

04/1/2018

- 1:30 pm scooped sludge
- Noticed that filter 2 stalls at restart of normal service and gives pump flow too low error message. Cleared remotely and started back up.

4/2/2018

- Filter 2 stalled again about 5:30 am. Restarted as before.
- Plant shut down
- O3 run for about 4 hours without generator or compressor on before shutting down

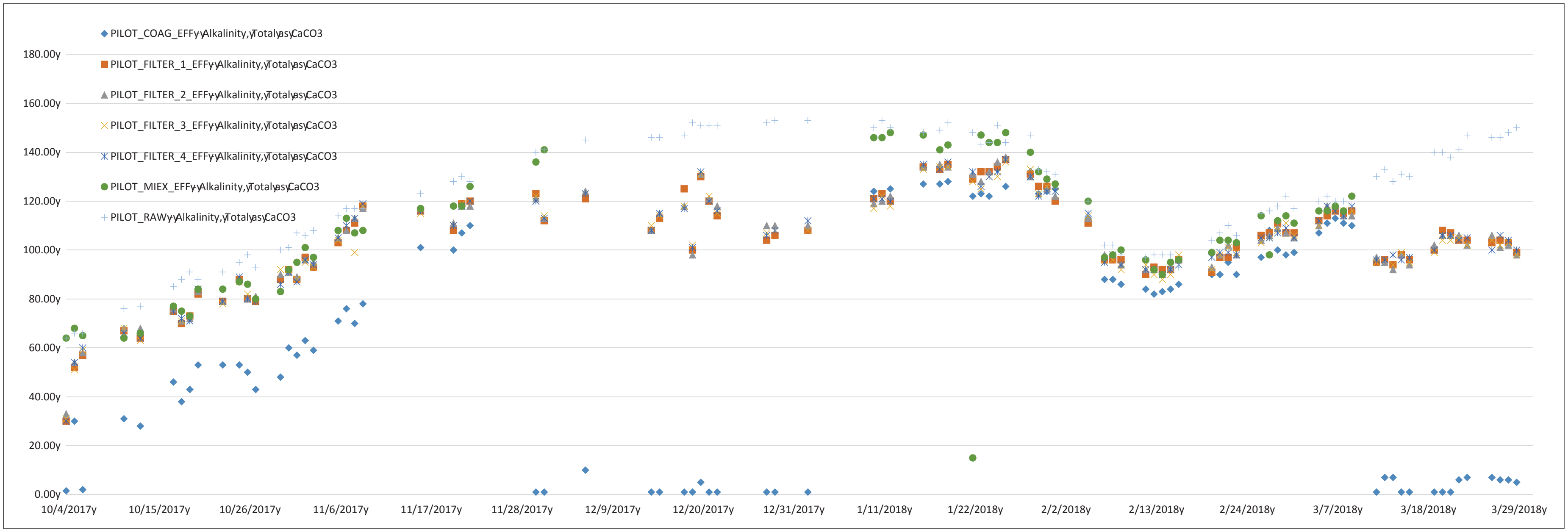
End Log

APPENDIX C – RAW WATER QUALITY DATA
(TO BE PROVIDED ELECTRONICALLY)

APPENDIX D – ANALYZED DATA

Report Name: Alkalinity
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

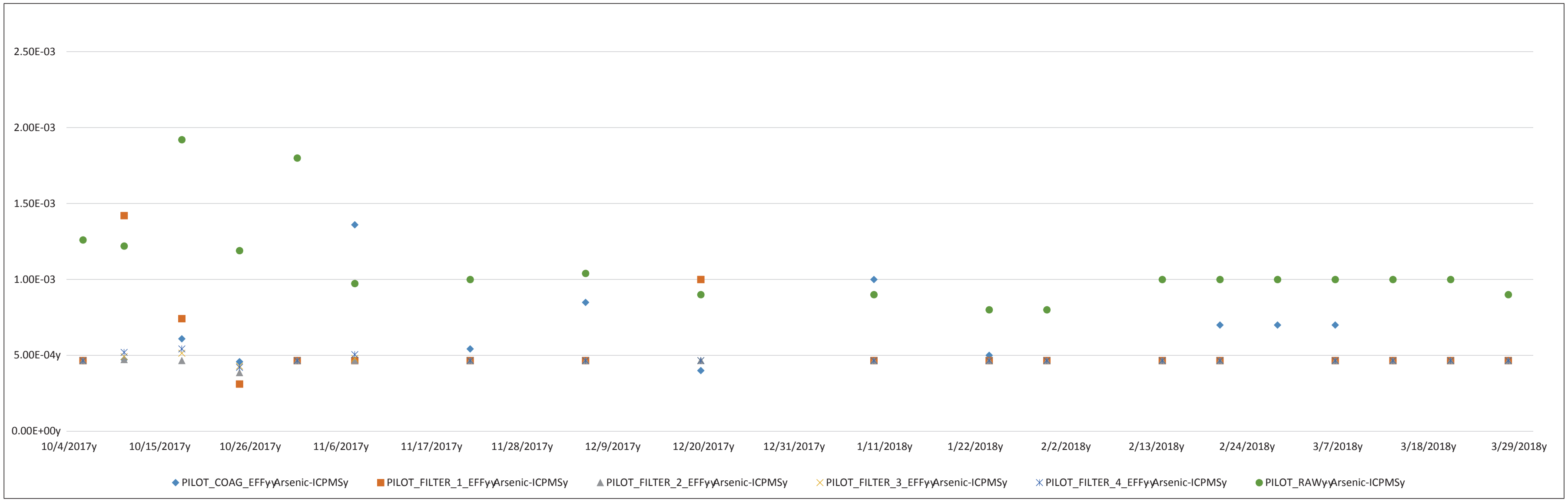
Report Date: 6/12/2018
Report Number: 1



Parameter	Location	Observations (N)	Units	Start Date	End Data	Avg Value	Max Value	Min Value	STD	Covar	Method	Analysis By	Data Source
Alkalinity, Total as CaCO3	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	62.1	133.0	1.0	47.7	0.77		City of Tampa	MP PILOT.XLSX
Alkalinity, Total as CaCO3	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	103.8	137.0	30.0	19.7	0.19		City of Tampa	MP PILOT.XLSX
Alkalinity, Total as CaCO3	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	104.1	138.0	33.0	19.3	0.19		City of Tampa	MP PILOT.XLSX
Alkalinity, Total as CaCO3	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	103.5	136.0	31.0	19.4	0.19		City of Tampa	MP PILOT.XLSX
Alkalinity, Total as CaCO3	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	104.0	137.0	30.0	19.5	0.19		City of Tampa	MP PILOT.XLSX
Alkalinity, Total as CaCO3	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	107.0	148.0	15.0	26.7	0.25		City of Tampa	MP PILOT.XLSX
Alkalinity, Total as CaCO3	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	122.5	153.0	64.0	24.0	0.20		City of Tampa	MP PILOT.XLSX

Report Name: Arsenic
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

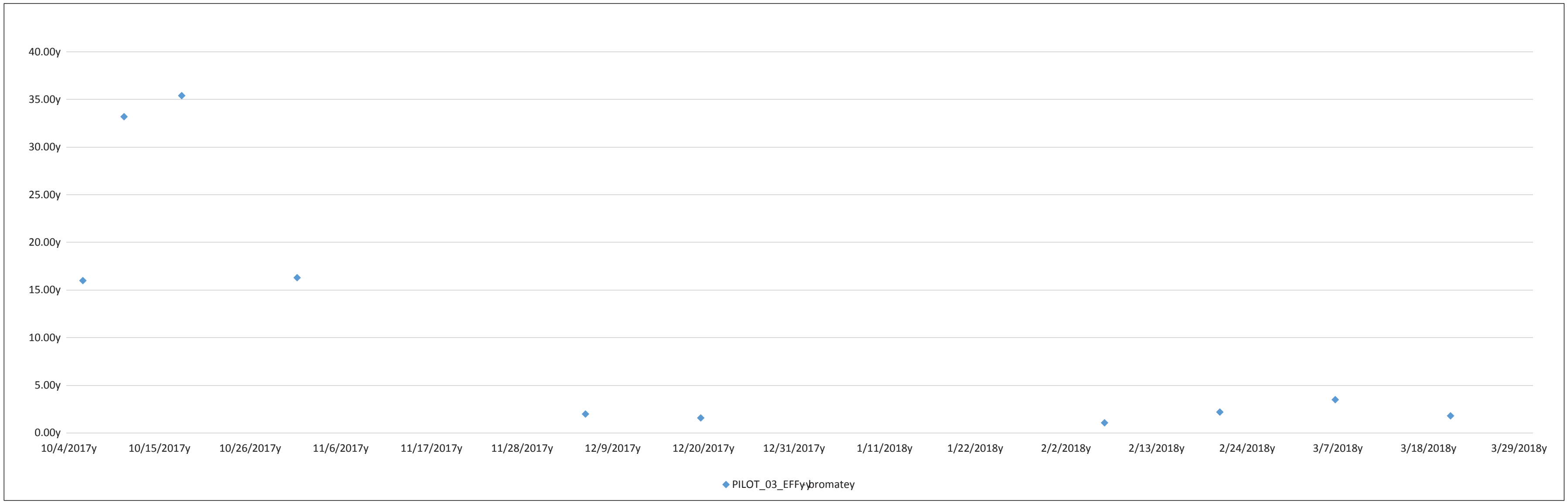
Report Date:A 6/12/2018y
Report Number:A 2y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Arsenic-ICPMS	PILOT_COAG_EFF	92	ug/L	10/4/2017	3/29/2018	6.54E-04	1.36E-03	4.00E-04	2.53E-04	0.39		City of Tampa	MP PILOT.XLSX
Arsenic-ICPMS	PILOT_FILTER_1_EFF	92	ug/L	10/4/2017	3/29/2018	5.55E-04	1.42E-03	3.11E-04	2.60E-04	0.47		City of Tampa	MP PILOT.XLSX
Arsenic-ICPMS	PILOT_FILTER_2_EFF	92	ug/L	10/4/2017	3/29/2018	4.62E-04	4.72E-04	3.86E-04	1.90E-05	0.04		City of Tampa	MP PILOT.XLSX
Arsenic-ICPMS	PILOT_FILTER_3_EFF	92	ug/L	10/4/2017	3/29/2018	4.69E-04	5.14E-04	4.29E-04	1.60E-05	0.03		City of Tampa	MP PILOT.XLSX
Arsenic-ICPMS	PILOT_FILTER_4_EFF	92	ug/L	10/4/2017	3/29/2018	4.73E-04	5.42E-04	4.21E-04	2.59E-05	0.05		City of Tampa	MP PILOT.XLSX
Arsenic-ICPMS	PILOT_RAW	92	ug/L	10/4/2017	3/29/2018	1.09E-03	1.92E-03	8.00E-04	2.98E-04	0.27		City of Tampa	MP PILOT.XLSX

Report Name: Bromate
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

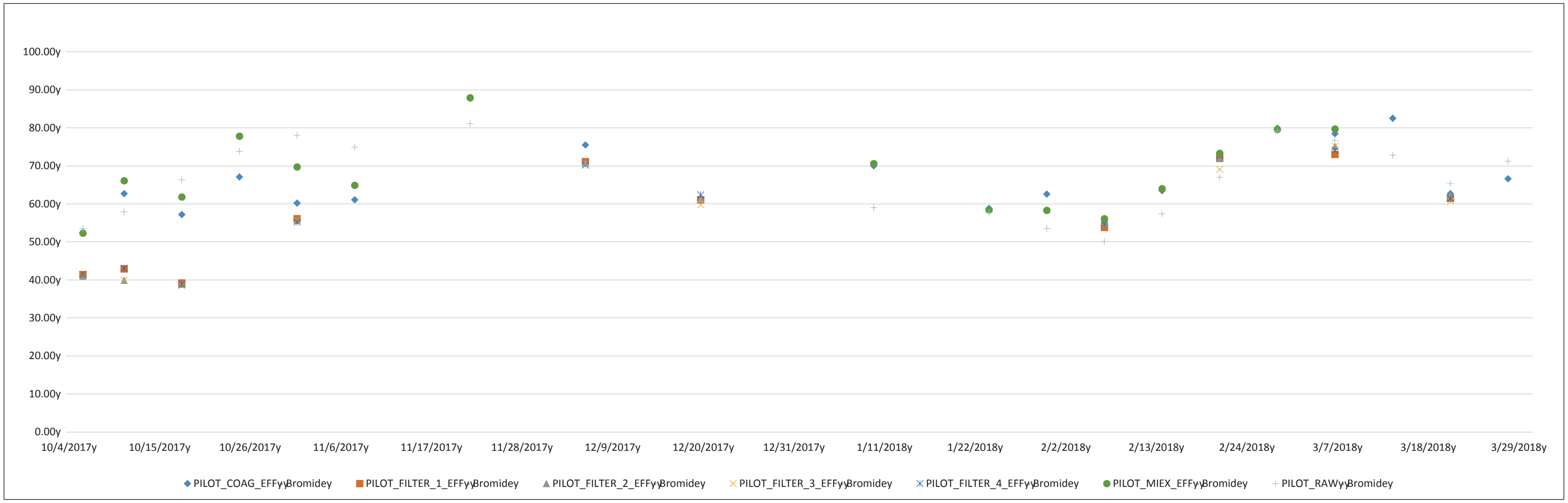
Report Date:A 6/12/2018y
Report Number:A 3



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
bromate	PILOT_03_EFF	92	ug/L	10/4/2017	3/29/2018	11.31	35.40	1.07	13.44	1.19		City of Tampa	MP PILOT.XLSX

Report Name: Bromide
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

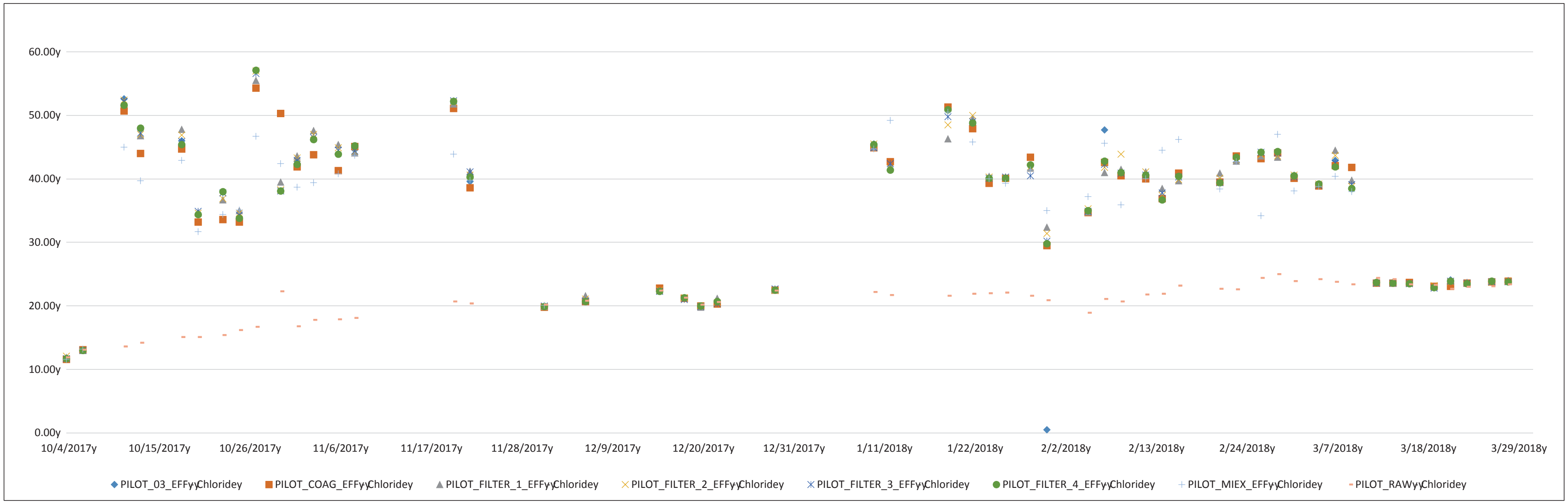
Report Date: 6/12/2018
Report Number: 4



Parameter	Location	Observations (N)	Units	Start Date	End Data	Avg Value	Max Value	Min Value	STD	Covar	Method	Analysis By	Data Source
Bromide	PILOT_COAG_EFF	92	ug/L	10/4/2017	3/29/2018	66.89	87.80	52.50	9.70	0.15		City of Tampa	MP PILOT.XLSX
Bromide	PILOT_FILTER_1_EFF	92	ug/L	10/4/2017	3/29/2018	57.21	73.00	39.20	12.85	0.22		City of Tampa	MP PILOT.XLSX
Bromide	PILOT_FILTER_2_EFF	92	ug/L	10/4/2017	3/29/2018	57.18	75.10	38.90	13.63	0.24		City of Tampa	MP PILOT.XLSX
Bromide	PILOT_FILTER_3_EFF	92	ug/L	10/4/2017	3/29/2018	56.48	75.20	38.50	13.19	0.23		City of Tampa	MP PILOT.XLSX
Bromide	PILOT_FILTER_4_EFF	92	ug/L	10/4/2017	3/29/2018	57.40	74.10	38.80	13.08	0.23		City of Tampa	MP PILOT.XLSX
Bromide	PILOT_MIEX_EFF	92	ug/L	10/4/2017	3/29/2018	68.03	87.90	52.30	10.15	0.15		City of Tampa	MP PILOT.XLSX
Bromide	PILOT_RAW	92	ug/L	10/4/2017	3/29/2018	66.32	81.10	50.10	9.58	0.14		City of Tampa	MP PILOT.XLSX

Report Name: Chloride
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

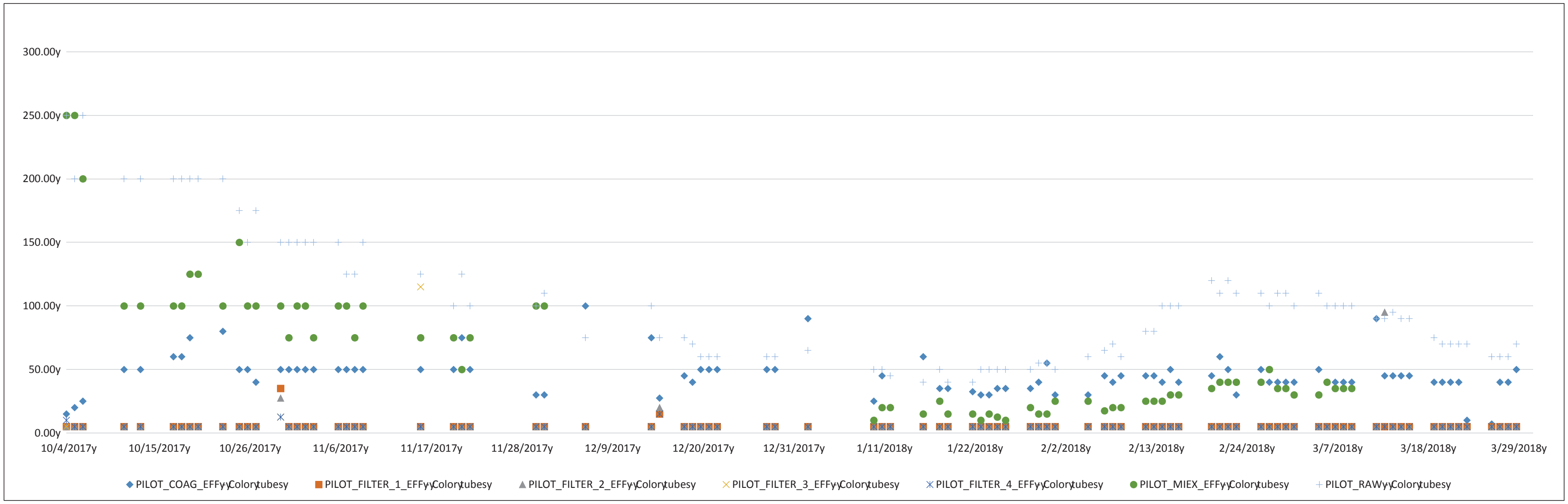
Report Date:A 6/12/2018y
Report Number:A 5y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Chloride	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	34.1	52.6	0.5	13.6	0.40		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	35.4	54.3	11.6	11.0	0.31		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	35.7	55.5	11.9	11.0	0.31		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	35.7	57.0	12.1	11.1	0.31		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	35.6	56.6	11.7	11.1	0.31		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	35.5	57.1	11.7	11.1	0.31		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	39.0	50.5	11.6	8.3	0.21		City of Tampa	MP PILOT.XLSX
Chloride	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	20.6	25.0	11.9	3.3	0.16		City of Tampa	MP PILOT.XLSX

Report Name: Color
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

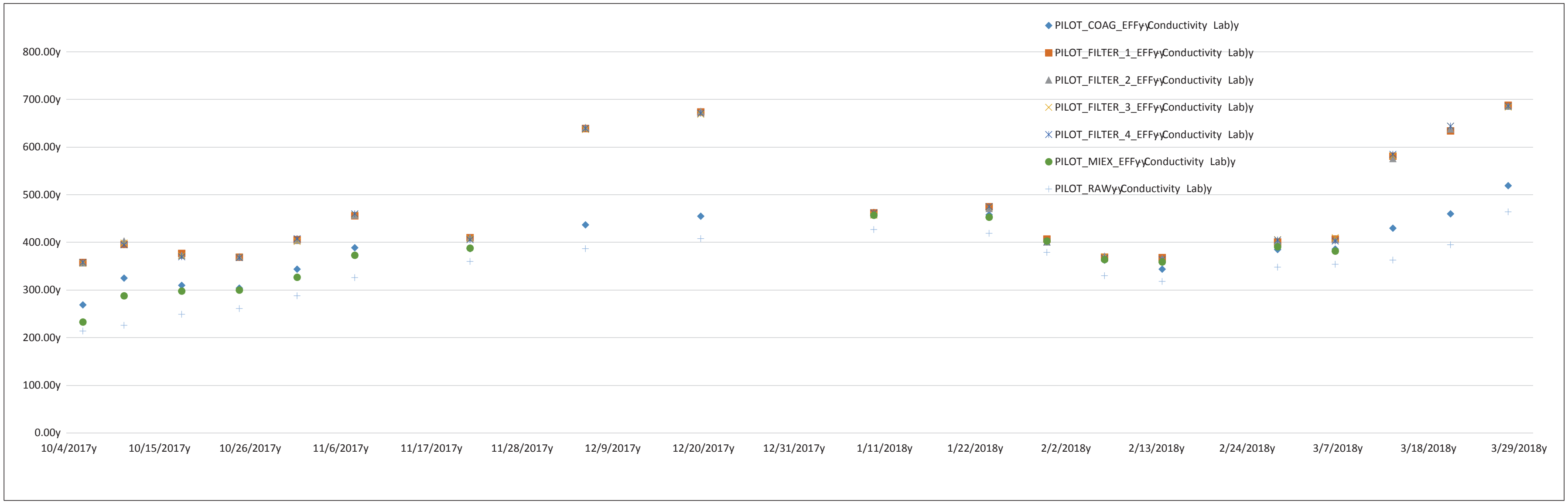
Report Date:A 6/12/2018y
Report Number:A 6y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Color tubes	PILOT_COAG_EFF	92	PCU	10/4/2017	3/29/2018	45.8	125.0	7.0	17.5	0.38		City of Tampa	MP PILOT.XLSX
Color tubes	PILOT_FILTER_1_EFF	92	PCU	10/4/2017	3/29/2018	5.4	35.0	5.0	3.3	0.61		City of Tampa	MP PILOT.XLSX
Color tubes	PILOT_FILTER_2_EFF	92	PCU	10/4/2017	3/29/2018	6.4	95.0	5.0	9.8	1.53		City of Tampa	MP PILOT.XLSX
Color tubes	PILOT_FILTER_3_EFF	92	PCU	10/4/2017	3/29/2018	6.4	115.0	5.0	11.6	1.81		City of Tampa	MP PILOT.XLSX
Color tubes	PILOT_FILTER_4_EFF	92	PCU	10/4/2017	3/29/2018	5.2	15.0	5.0	1.4	0.27		City of Tampa	MP PILOT.XLSX
Color tubes	PILOT_MIEX_EFF	92	PCU	10/4/2017	3/29/2018	61.8	250.0	10.0	52.9	0.86		City of Tampa	MP PILOT.XLSX
Color tubes	PILOT_RAW	92	PCU	10/4/2017	3/29/2018	102.4	250.0	40.0	50.4	0.49		City of Tampa	MP PILOT.XLSX

Report Name: Conductivity
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

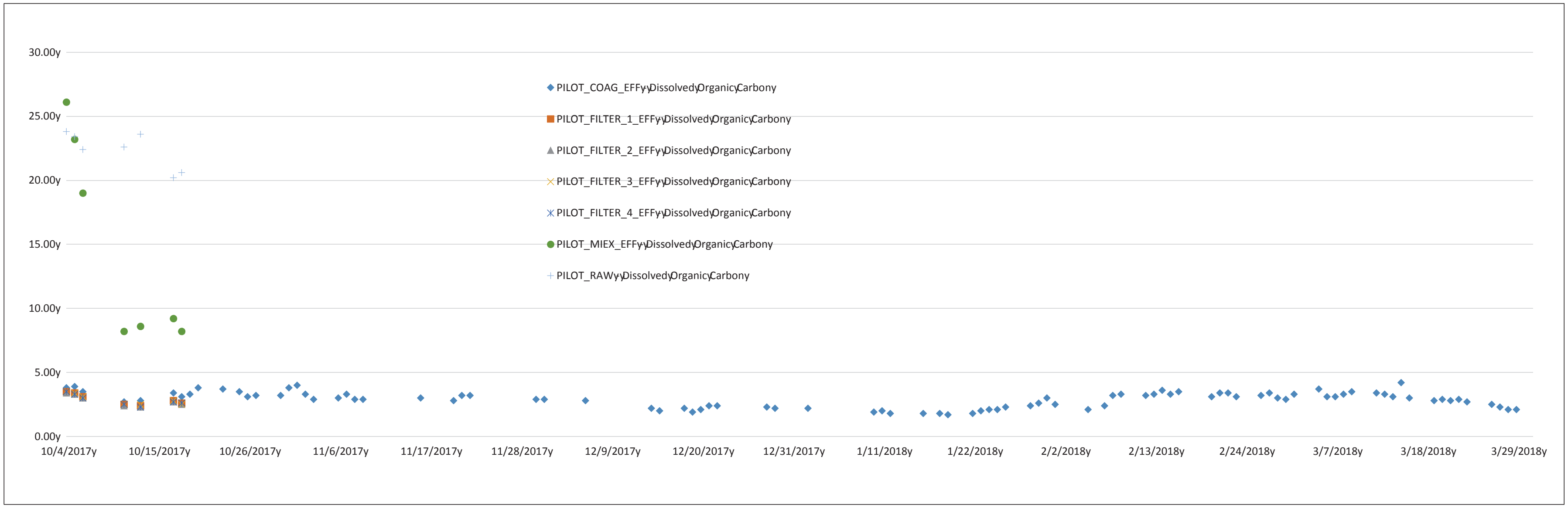
Report Date:A 6/12/2018y
Report Number:A 7y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Conductivity (Lab)	PILOT_COAG_EFF	92	umhos/cm	10/4/2017	3/29/2018	391.1	519.0	269.0	65.5	0.17		City of Tampa	MP PILOT.XLSX
Conductivity (Lab)	PILOT_FILTER_1_EFF	92	umhos/cm	10/4/2017	3/29/2018	467.2	688.0	358.0	114.2	0.24		City of Tampa	MP PILOT.XLSX
Conductivity (Lab)	PILOT_FILTER_2_EFF	92	umhos/cm	10/4/2017	3/29/2018	466.7	686.0	357.0	114.5	0.25		City of Tampa	MP PILOT.XLSX
Conductivity (Lab)	PILOT_FILTER_3_EFF	92	umhos/cm	10/4/2017	3/29/2018	466.5	684.0	356.0	114.5	0.25		City of Tampa	MP PILOT.XLSX
Conductivity (Lab)	PILOT_FILTER_4_EFF	92	umhos/cm	10/4/2017	3/29/2018	466.7	686.0	358.0	115.7	0.25		City of Tampa	MP PILOT.XLSX
Conductivity (Lab)	PILOT_MIEX_EFF	92	umhos/cm	10/4/2017	3/29/2018	358.3	457.0	233.0	63.3	0.18		City of Tampa	MP PILOT.XLSX
Conductivity (Lab)	PILOT_RAW	92	umhos/cm	10/4/2017	3/29/2018	342.9	464.0	214.0	70.1	0.20		City of Tampa	MP PILOT.XLSX

Report Name: Dissolved Organic Carbon
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

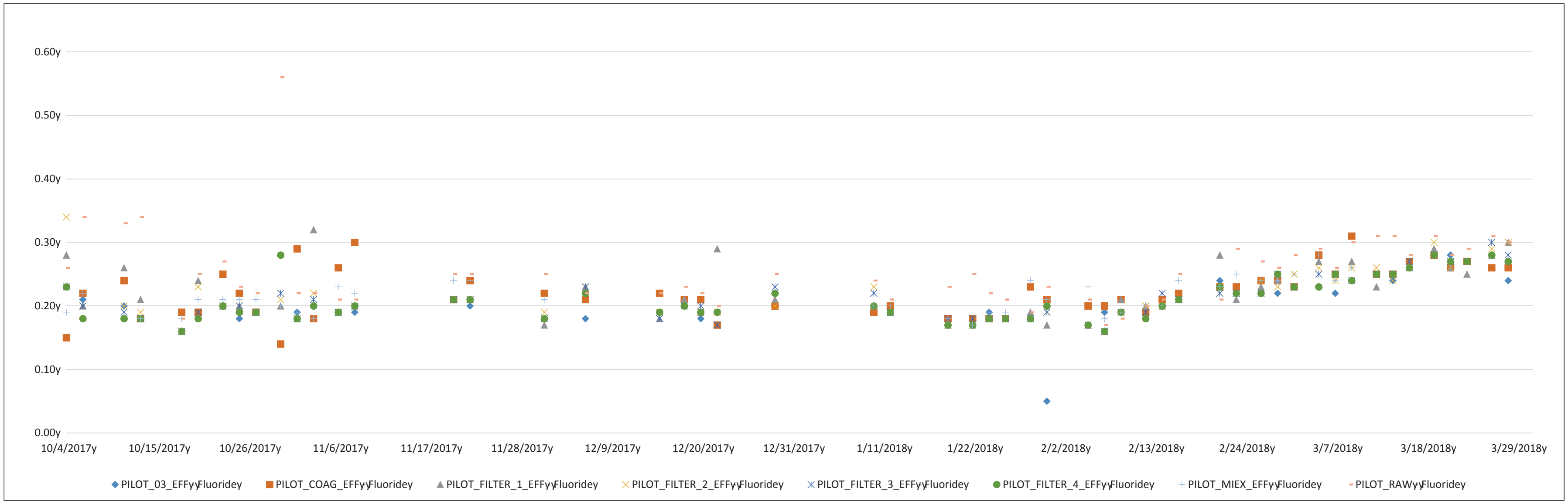
Report Date:A 6/12/2018y
Report Number:A 8y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Dissolved Organic Carbon	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	2.87	4.20	1.70	0.60	0.21		City of Tampa	MP PILOT.XLSX
Dissolved Organic Carbon	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	2.90	3.50	2.40	0.44	0.15		City of Tampa	MP PILOT.XLSX
Dissolved Organic Carbon	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	2.80	3.40	2.30	0.44	0.16		City of Tampa	MP PILOT.XLSX
Dissolved Organic Carbon	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	2.90	3.50	2.50	0.44	0.15		City of Tampa	MP PILOT.XLSX
Dissolved Organic Carbon	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	2.84	3.50	2.30	0.44	0.15		City of Tampa	MP PILOT.XLSX
Dissolved Organic Carbon	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	14.64	26.10	8.20	7.88	0.54		City of Tampa	MP PILOT.XLSX
Dissolved Organic Carbon	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	22.37	23.80	20.20	1.44	0.06		City of Tampa	MP PILOT.XLSX

Report Name: Fluoride
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

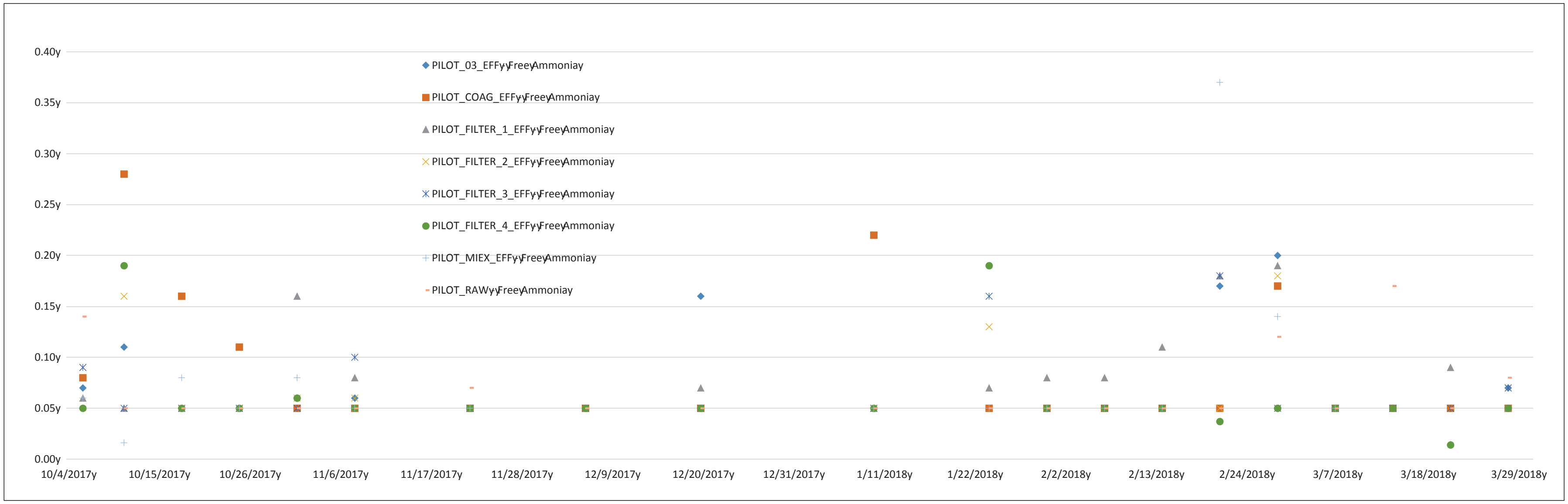
Report Date:A 6/12/2018y
Report Number:A 9y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Fluoride	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.1	0.0	0.23		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.1	0.0	0.17		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.2	0.0	0.18		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.2	0.0	0.18		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.2	0.0	0.16		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.2	0.0	0.16		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.2	0.3	0.2	0.0	0.12		City of Tampa	MP PILOT.XLSX
Fluoride	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.3	0.6	0.2	0.1	0.24		City of Tampa	MP PILOT.XLSX

Report Name: Free Ammonia
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

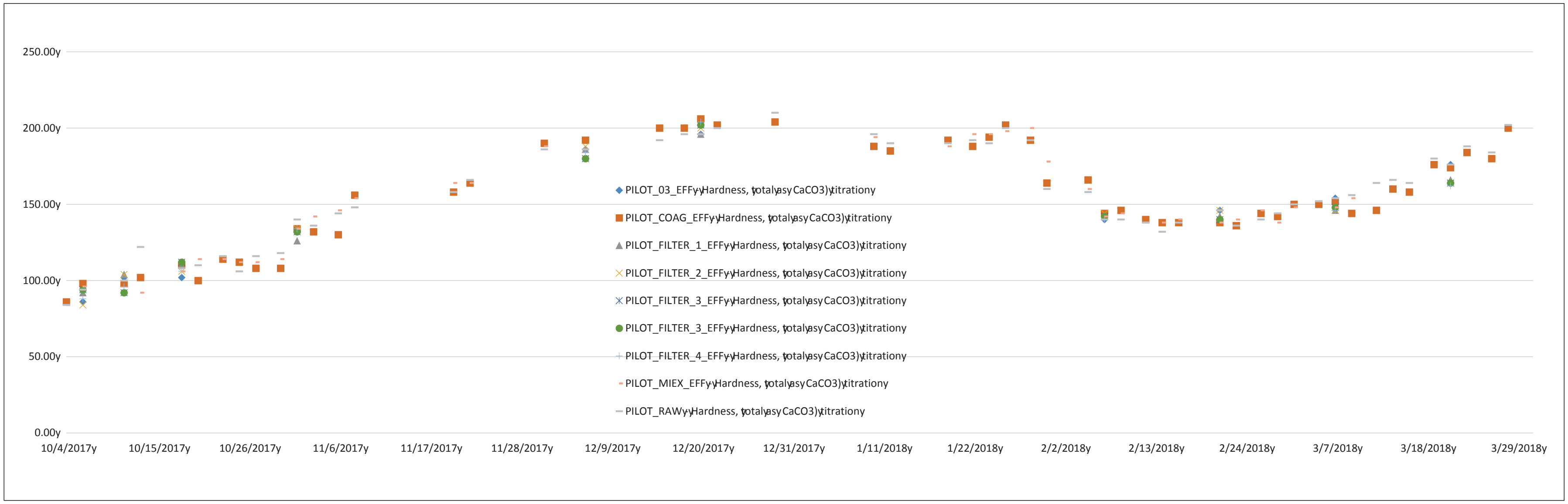
Report Date:A 6/12/2018y
Report Number:A 10y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Free Ammonia	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.2	0.1	0.0	0.62		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.3	0.1	0.1	0.79		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.2	0.1	0.0	0.55		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.2	0.1	0.0	0.56		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.2	0.1	0.0	0.56		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.2	0.0	0.0	0.72		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.4	0.0	0.1	1.06		City of Tampa	MP PILOT.XLSX
Free Ammonia	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.1	0.2	0.1	0.0	0.53		City of Tampa	MP PILOT.XLSX

Report Name: Hardness
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

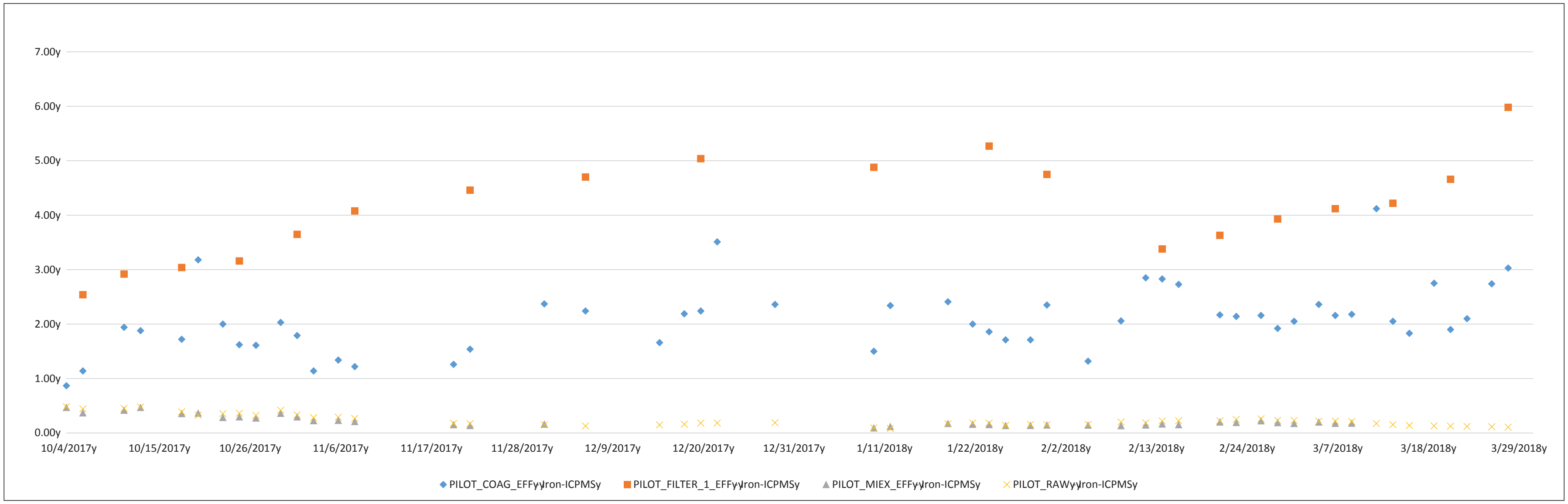
Report Date:A 6/12/2018y
Report Number:A 11y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Hardness, total as (CaCO3) titra	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	142.0	196.0	86.0	37.4	0.26		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	155.0	206.0	86.0	33.7	0.22		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	141.0	196.0	92.0	34.4	0.24		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	141.6	200.0	84.0	36.8	0.26		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	140.6	202.0	92.0	35.5	0.25		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	140.6	202.0	92.0	35.5	0.25		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	140.6	204.0	88.0	37.1	0.26		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	146.2	200.0	84.0	32.2	0.22		City of Tampa	MP PILOT.XLSX
Hardness, total as (CaCO3) titra	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	156.4	210.0	84.0	32.4	0.21		City of Tampa	MP PILOT.XLSX

Report Name: Iron
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

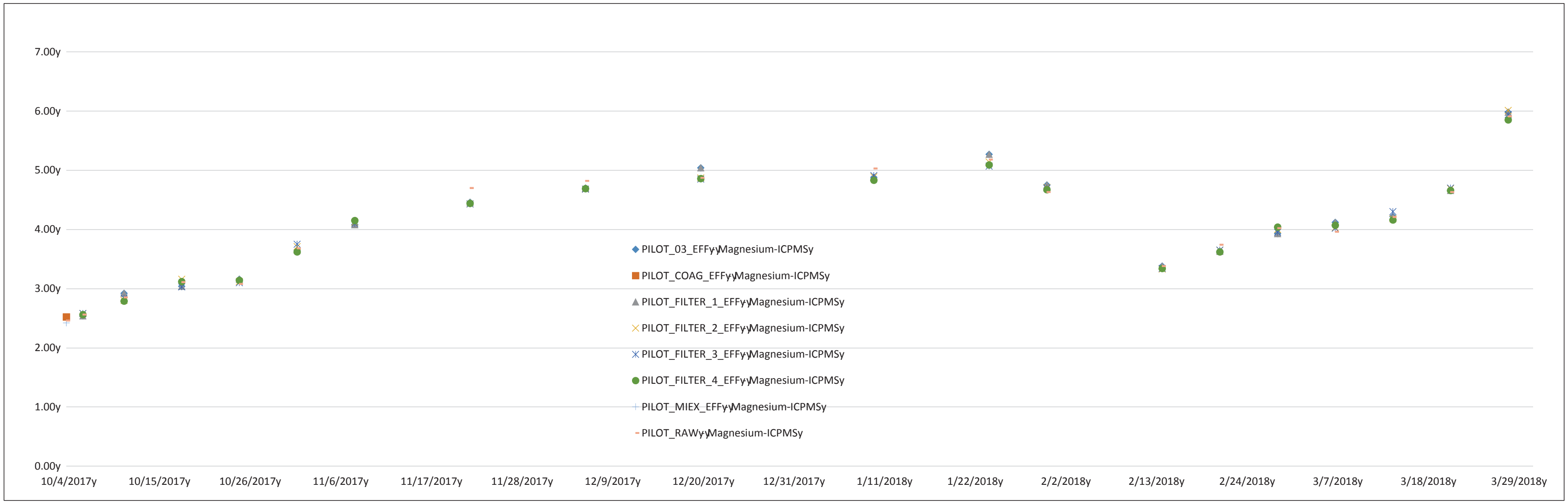
Report Date: 6/12/2018
Report Number: 12



Parameter	Location	Observations (N)	Units	Start Date	End Data	Avg Value	Max Value	Min Value	STD	Covar	Method	Analysis By	Data Source
Iron-ICPMS	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	2.08	4.12	0.87	0.61	0.29		City of Tampa	MP PILOT.XLSX
Iron-ICPMS	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	4.13	5.98	2.54	0.90	0.22		City of Tampa	MP PILOT.XLSX
Iron-ICPMS	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.22	0.47	0.09	0.10	0.45		City of Tampa	MP PILOT.XLSX
Iron-ICPMS	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.23	0.48	0.08	0.10	0.46		City of Tampa	MP PILOT.XLSX

Report Name: Magnesium
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

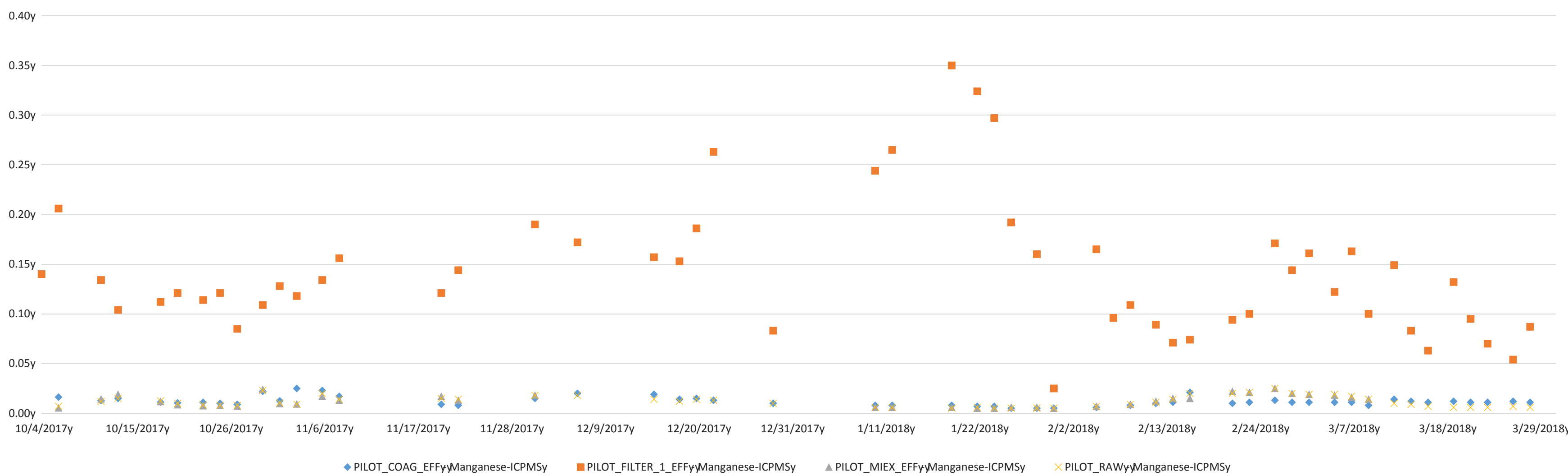
Report Date:A 6/12/2018y
Report Number:A 13



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Magnesium-ICPMS	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	4.1	6.0	2.5	0.9	0.22		City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	2.5	2.5	2.5				City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	4.1	6.0	2.5	0.9	0.22		City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	4.1	6.0	2.6	0.9	0.21		City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	4.1	5.9	2.6	0.9	0.21		City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	4.1	5.9	2.6	0.9	0.21		City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	2.4	2.4	2.4				City of Tampa	MP PILOT.XLSX
Magnesium-ICPMS	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	4.0	5.9	2.5	1.0	0.24		City of Tampa	MP PILOT.XLSX

Report Name: Manganese
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

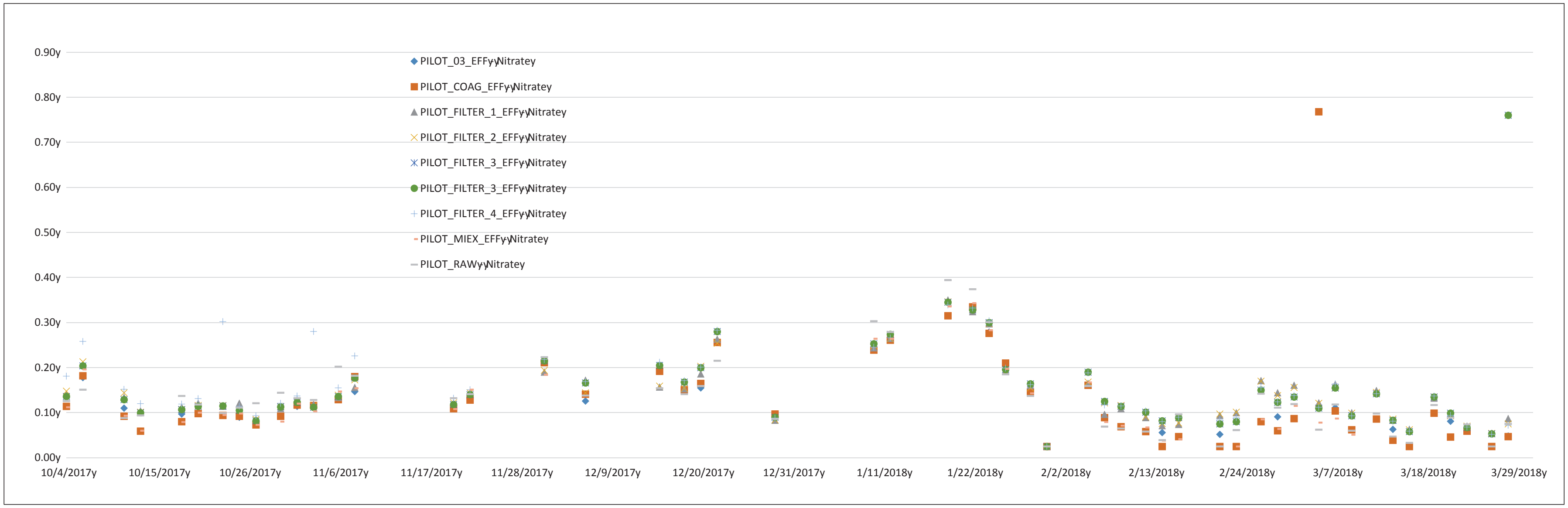
Report Date:A 6/12/2018y
Report Number:A 14y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Manganese-ICPMS	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.03	0.01	0.00	0.38		City of Tampa	MP PILOT.XLSX
Manganese-ICPMS	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	0.14	0.35	0.03	0.07	0.47		City of Tampa	MP PILOT.XLSX
Manganese-ICPMS	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.03	0.01	0.01	0.48		City of Tampa	MP PILOT.XLSX
Manganese-ICPMS	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.01	0.03	0.01	0.01	0.47		City of Tampa	MP PILOT.XLSX

Report Name: Nitrate
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

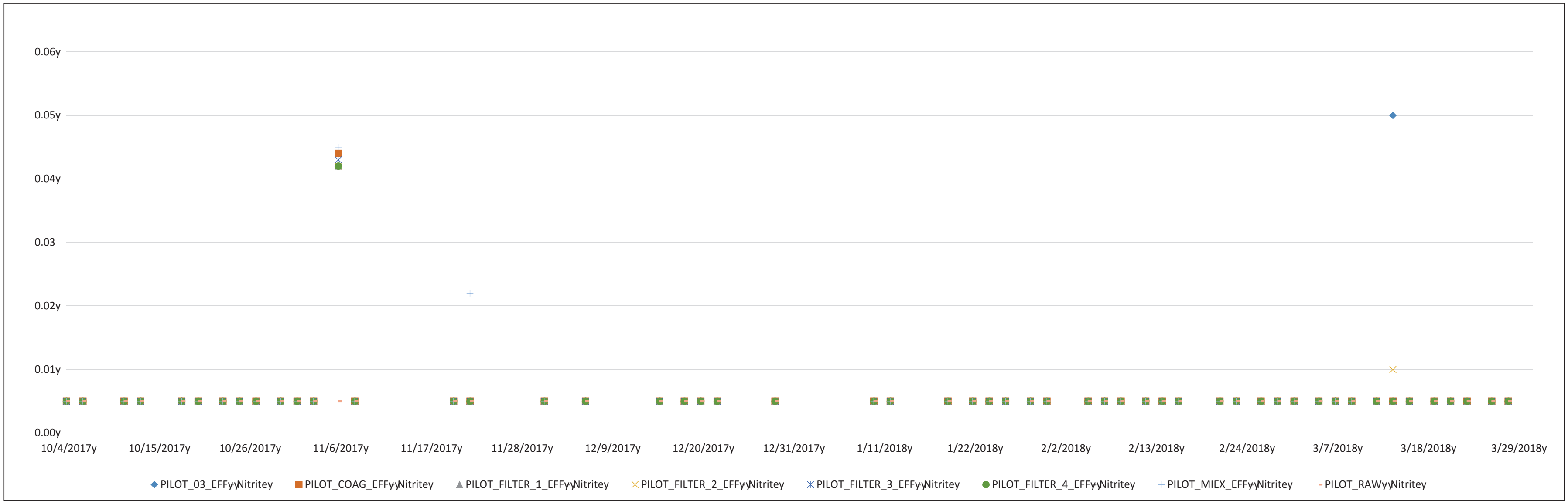
Report Date:A 6/12/2018y
Report Number:A 15y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Nitrate	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	0.11	0.28	0.03	0.06	0.55		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	0.13	0.77	0.03	0.12	0.91		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	0.14	0.35	0.03	0.07	0.47		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	0.14	0.35	0.03	0.07	0.47		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	0.16	0.76	0.03	0.11	0.70		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	0.16	0.76	0.03	0.11	0.70		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	0.16	0.34	0.03	0.08	0.49		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.12	0.34	0.03	0.08	0.67		City of Tampa	MP PILOT.XLSX
Nitrate	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.13	0.39	0.03	0.08	0.62		City of Tampa	MP PILOT.XLSX

Report Name: Nitrite
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

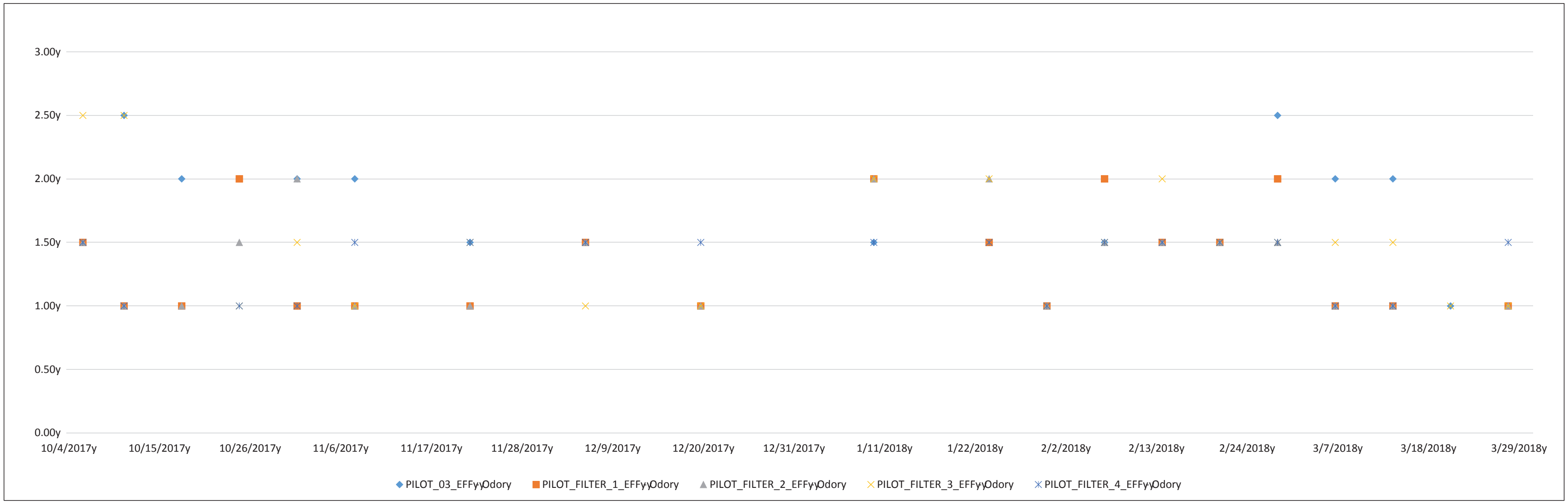
Report Date:A 6/12/2018y
Report Number:A 16y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Nitrite	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.05	0.01	0.01	1.39		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.04	0.01	0.01	0.93		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.04	0.01	0.01	0.89		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.04	0.01	0.01	0.88		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.04	0.01	0.01	0.91		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.04	0.01	0.01	0.89		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.01	0.05	0.01	0.01	1.07		City of Tampa	MP PILOT.XLSX
Nitrite	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.01	0.01	0.01	0.00	0.00		City of Tampa	MP PILOT.XLSX

Report Name: Odor
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

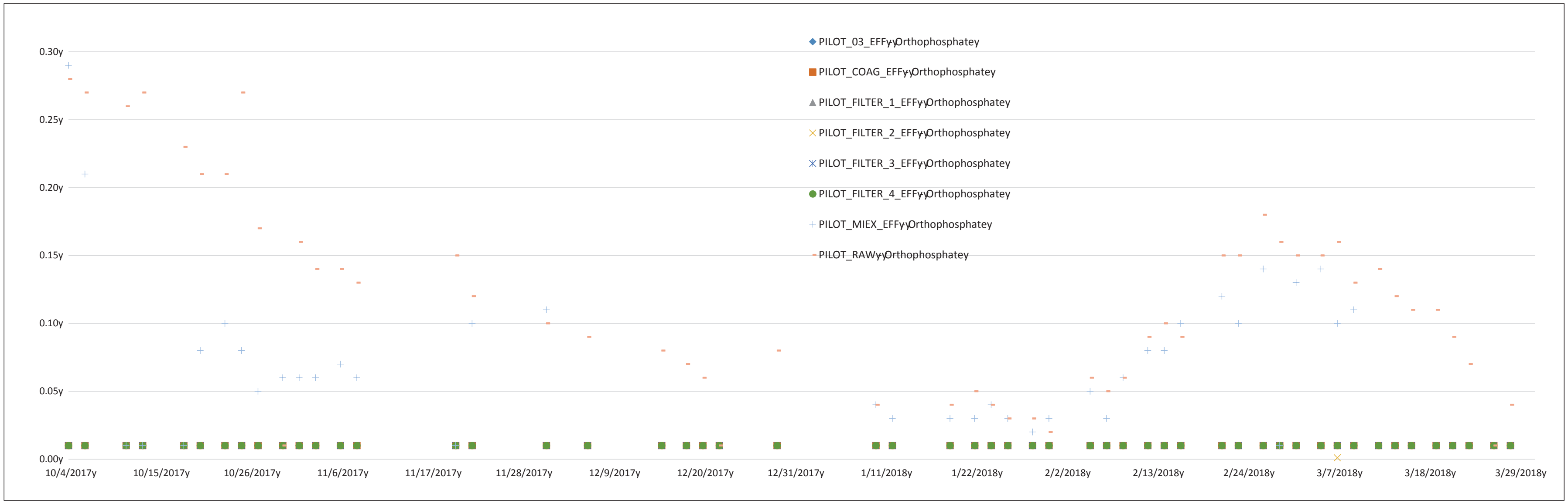
Report Date:A 6/12/2018y
Report Number:A 17y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Odor	PILOT_03_EFF	92	TON	10/4/2017	3/29/2018	1.7	2.5	1.0	0.5	0.28		City of Tampa	MP PILOT.XLSX
Odor	PILOT_FILTER_1_EFF	92	TON	10/4/2017	3/29/2018	1.3	2.0	1.0	0.4	0.31		City of Tampa	MP PILOT.XLSX
Odor	PILOT_FILTER_2_EFF	92	TON	10/4/2017	3/29/2018	1.3	2.0	1.0	0.4	0.28		City of Tampa	MP PILOT.XLSX
Odor	PILOT_FILTER_3_EFF	92	TON	10/4/2017	3/29/2018	1.5	2.5	1.0	0.5	0.33		City of Tampa	MP PILOT.XLSX
Odor	PILOT_FILTER_4_EFF	92	TON	10/4/2017	3/29/2018	1.3	1.5	1.0	0.2	0.18		City of Tampa	MP PILOT.XLSX

Report Name: Orthophosphate
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

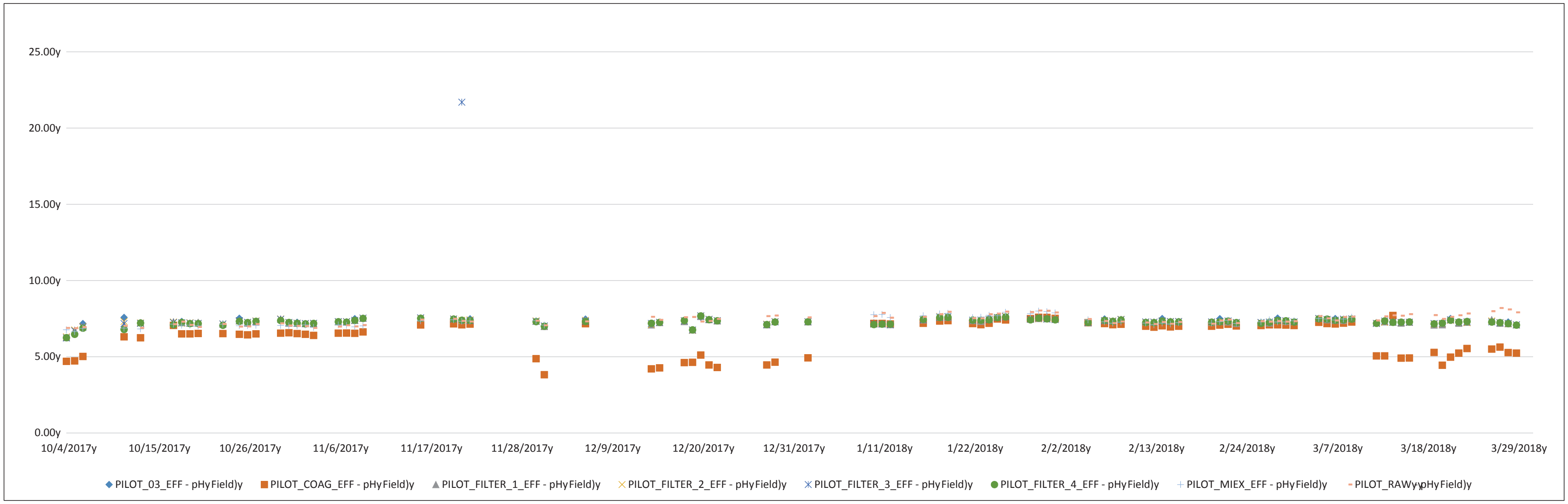
Report Date:A 6/12/2018y
Report Number:A 18y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Orthophosphate	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	0.0	0.0	0.0	0.0	0.00		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	0.0	0.0	0.0	0.0	0.00		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	0.0	0.0	0.0	0.0	0.00		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	2.8	146.4	0.0	20.1	7.25		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	0.0	0.0	0.0	0.0	0.00		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	0.0	0.0	0.0	0.0	0.00		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	0.1	0.3	0.0	0.1	0.78		City of Tampa	MP PILOT.XLSX
Orthophosphate	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	0.6	23.6	0.0	3.2	5.75		City of Tampa	MP PILOT.XLSX

Report Name: pH (grab)
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

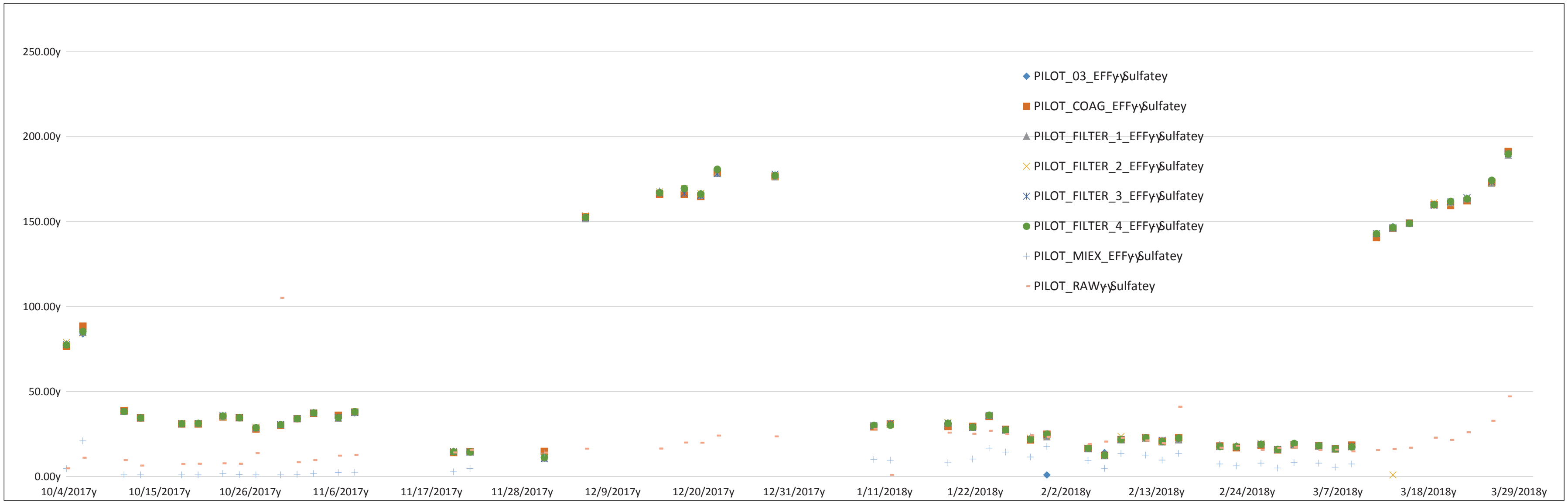
Report Date:A 6/12/2018y
Report Number:A 19y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
pH (Field)	PILOT_03_EFF	92	SU	10/4/2017	3/29/2018	7.45	7.63	7.18	0.13	0.02		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_COAG_EFF	92	SU	10/4/2017	3/29/2018	6.34	7.71	3.82	1.06	0.17		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_FILTER_1_EFF	92	SU	10/4/2017	3/29/2018	7.29	7.65	6.26	0.20	0.03		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_FILTER_2_EFF	92	SU	10/4/2017	3/29/2018	7.30	7.68	6.31	0.19	0.03		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_FILTER_3_EFF	92	SU	10/4/2017	3/29/2018	7.46	21.70	6.24	1.52	0.20		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_FILTER_4_EFF	92	SU	10/4/2017	3/29/2018	7.28	7.68	6.26	0.21	0.03		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_MIEX_EFF	92	SU	10/4/2017	3/29/2018	7.31	7.99	6.65	0.32	0.04		City of Tampa	MP PILOT.XLSX
pH (Field)	PILOT_RAW	92	SU	10/4/2017	3/29/2018	7.43	8.19	6.87	0.33	0.04		City of Tampa	MP PILOT.XLSX

Report Name: Sulfate
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

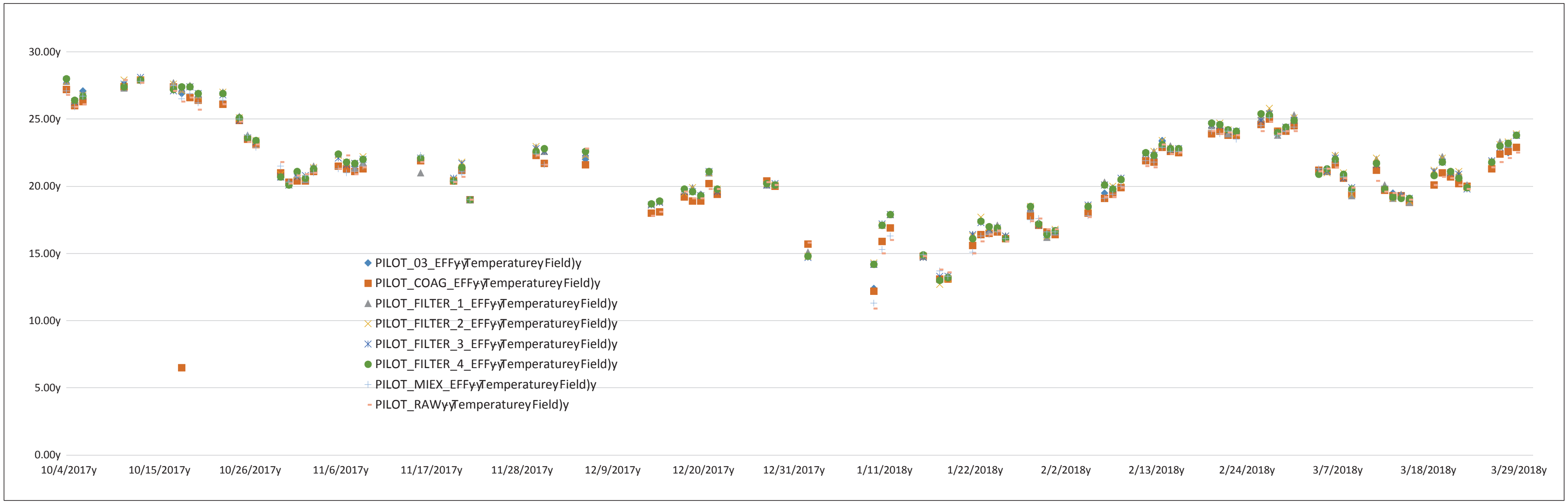
Report Date:A 6/12/2018y
Report Number:A 20y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Sulfate	PILOT_03_EFF	92	mg/L	10/4/2017	3/29/2018	62.2	191.4	1.0	62.6	1.01		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	64.0	191.4	12.5	61.9	0.97		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	64.1	189.2	10.9	62.1	0.97		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	61.5	190.2	1.0	61.7	1.00		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	64.1	190.0	10.5	62.1	0.97		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	64.3	189.9	11.3	62.3	0.97		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	7.2	21.0	1.0	5.4	0.75		City of Tampa	MP PILOT.XLSX
Sulfate	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	19.7	105.2	1.0	14.7	0.74		City of Tampa	MP PILOT.XLSX

Report Name: Temperature (grab)
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

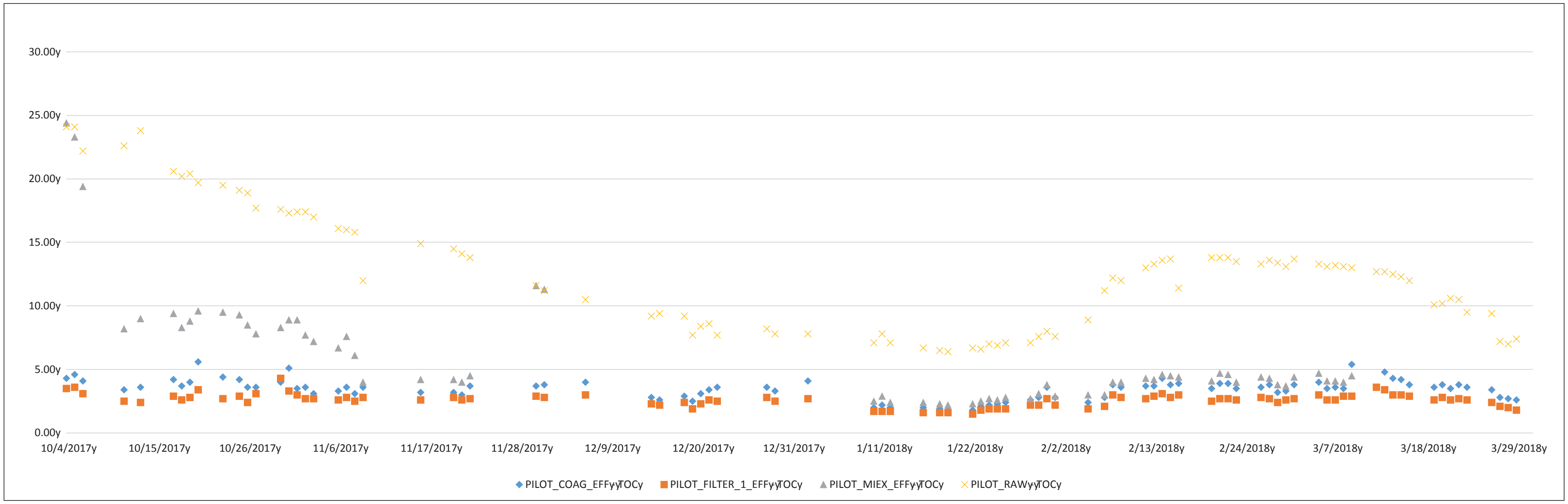
Report Date:A 6/12/2018y
Report Number:A 21y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Temperature (Field)	PILOT_03_EFF	92	°C	10/4/2017	3/29/2018	21.53	27.60	12.40	3.84	0.18		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_COAG_EFF	92	°C	10/4/2017	3/29/2018	20.65	27.90	6.50	3.67	0.18		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_FILTER_1_EFF	92	°C	10/4/2017	3/29/2018	21.30	27.90	13.10	3.41	0.16		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_FILTER_2_EFF	92	°C	10/4/2017	3/29/2018	21.30	27.90	12.70	3.45	0.16		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_FILTER_3_EFF	92	°C	10/4/2017	3/29/2018	21.25	28.10	13.30	3.40	0.16		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_FILTER_4_EFF	92	°C	10/4/2017	3/29/2018	21.27	28.00	13.00	3.42	0.16		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_MIEX_EFF	92	°C	10/4/2017	3/29/2018	21.21	27.80	11.30	3.90	0.18		City of Tampa	MP PILOT.XLSX
Temperature (Field)	PILOT_RAW	92	°C	10/4/2017	3/29/2018	20.81	27.90	10.90	3.41	0.16		City of Tampa	MP PILOT.XLSX

Report Name: TOC
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

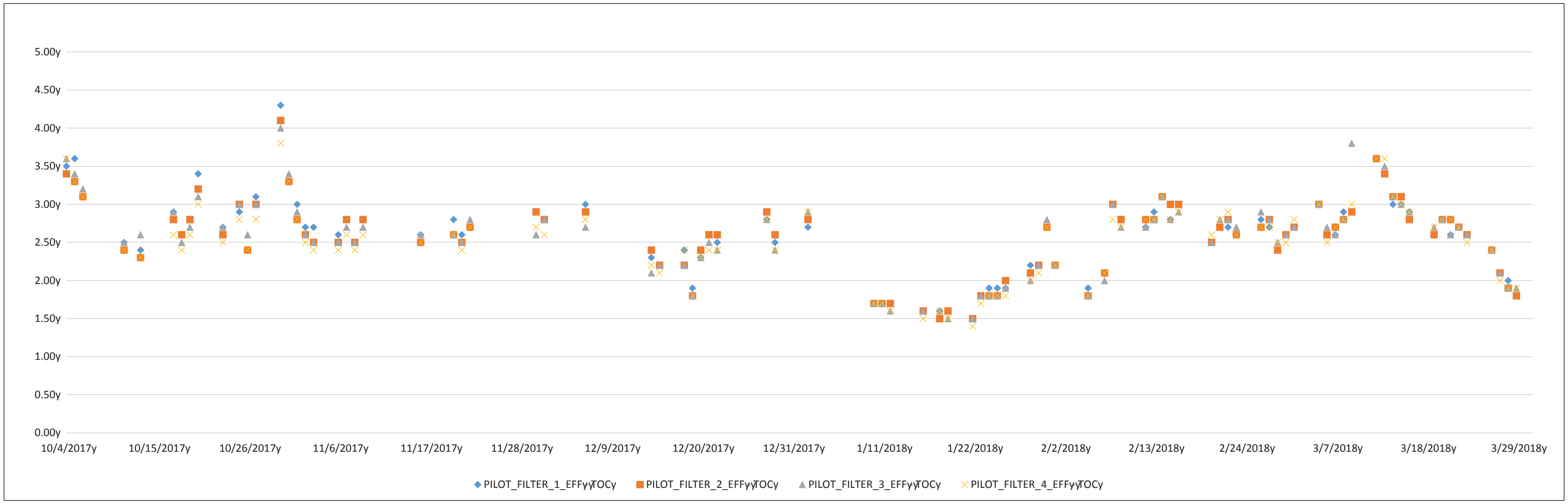
Report Date:A 6/12/2018y
Report Number:A 22y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
TOC	PILOT_COAG_EFF	92	mg/L	10/4/2017	3/29/2018	3.43	5.60	1.80	0.77	0.22		City of Tampa	MP PILOT.XLSX
TOC	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	2.59	4.30	1.50	0.50	0.19		City of Tampa	MP PILOT.XLSX
TOC	PILOT_MIEX_EFF	92	mg/L	10/4/2017	3/29/2018	6.00	24.40	2.20	4.40	0.73		City of Tampa	MP PILOT.XLSX
TOC	PILOT_RAW	92	mg/L	10/4/2017	3/29/2018	12.54	24.10	6.40	4.64	0.37		City of Tampa	MP PILOT.XLSX

Report Name: TOC - Filters
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

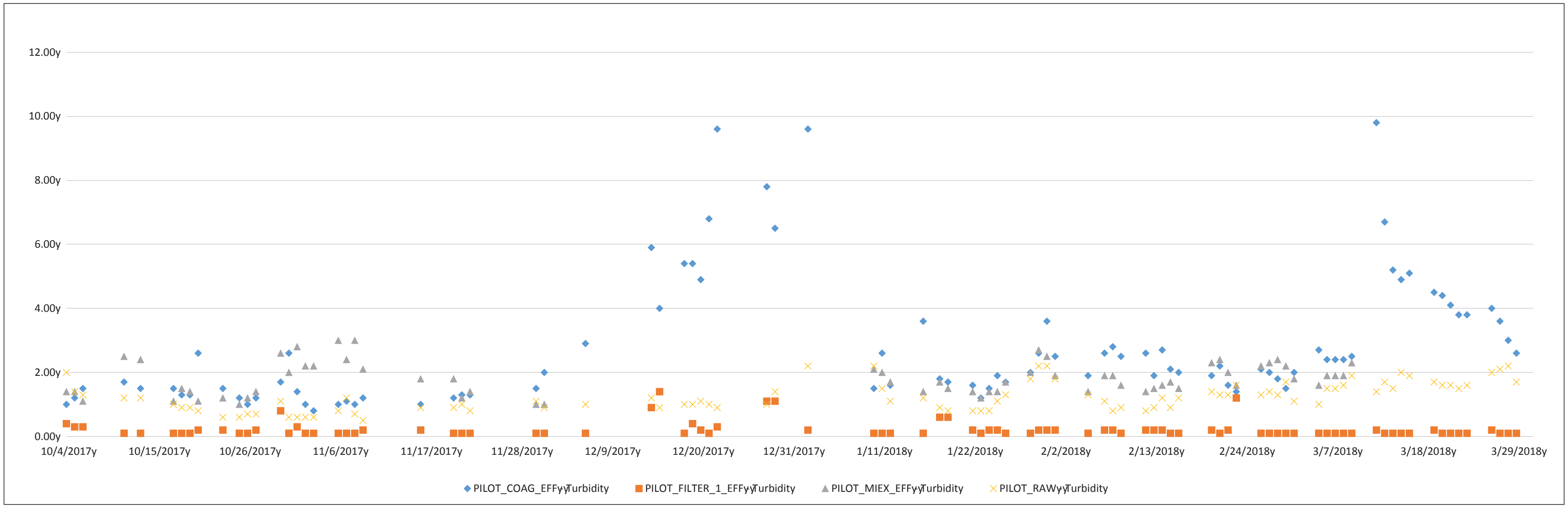
Report Date:A 6/12/2018y
Report Number:A 23



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
TOC	PILOT_FILTER_1_EFF	92	mg/L	10/4/2017	3/29/2018	2.59	4.30	1.50	0.50	0.19		City of Tampa	MP PILOT.XLSX
TOC	PILOT_FILTER_2_EFF	92	mg/L	10/4/2017	3/29/2018	2.57	4.10	1.50	0.50	0.19		City of Tampa	MP PILOT.XLSX
TOC	PILOT_FILTER_3_EFF	92	mg/L	10/4/2017	3/29/2018	2.56	4.00	1.50	0.51	0.20		City of Tampa	MP PILOT.XLSX
TOC	PILOT_FILTER_4_EFF	92	mg/L	10/4/2017	3/29/2018	2.52	3.80	1.40	0.50	0.20		City of Tampa	MP PILOT.XLSX

Report Name: Turbidity
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

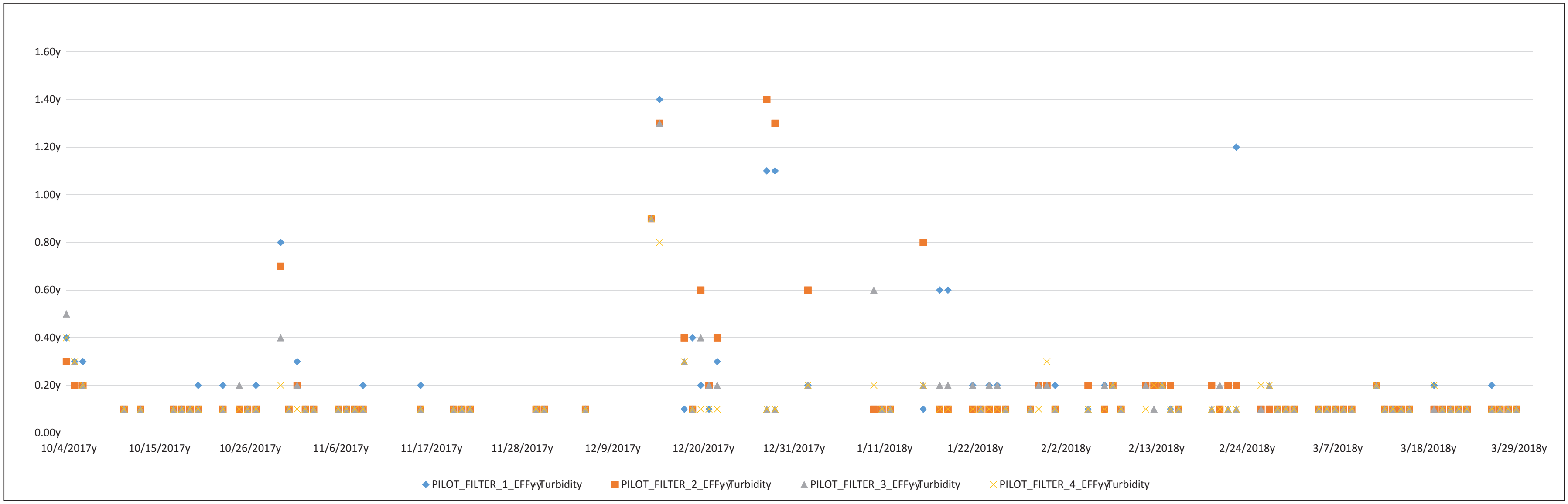
Report Date:A 6/12/2018y
Report Number:A 24y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Turbidity	PILOT_COAG_EFF	92	NTU	10/4/2017	3/29/2018	2.79	9.80	0.80	1.99	0.71		City of Tampa	MP PILOT.XLSX
Turbidity	PILOT_FILTER_1_EFF	92	NTU	10/4/2017	3/29/2018	0.22	1.40	0.10	0.26	1.18		City of Tampa	MP PILOT.XLSX
Turbidity	PILOT_MIEX_EFF	92	NTU	10/4/2017	3/29/2018	1.80	3.00	1.00	0.51	0.28		City of Tampa	MP PILOT.XLSX
Turbidity	PILOT_RAW	92	NTU	10/4/2017	3/29/2018	1.23	2.20	0.50	0.45	0.36		City of Tampa	MP PILOT.XLSX

Report Name: Turbidity - Filters
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

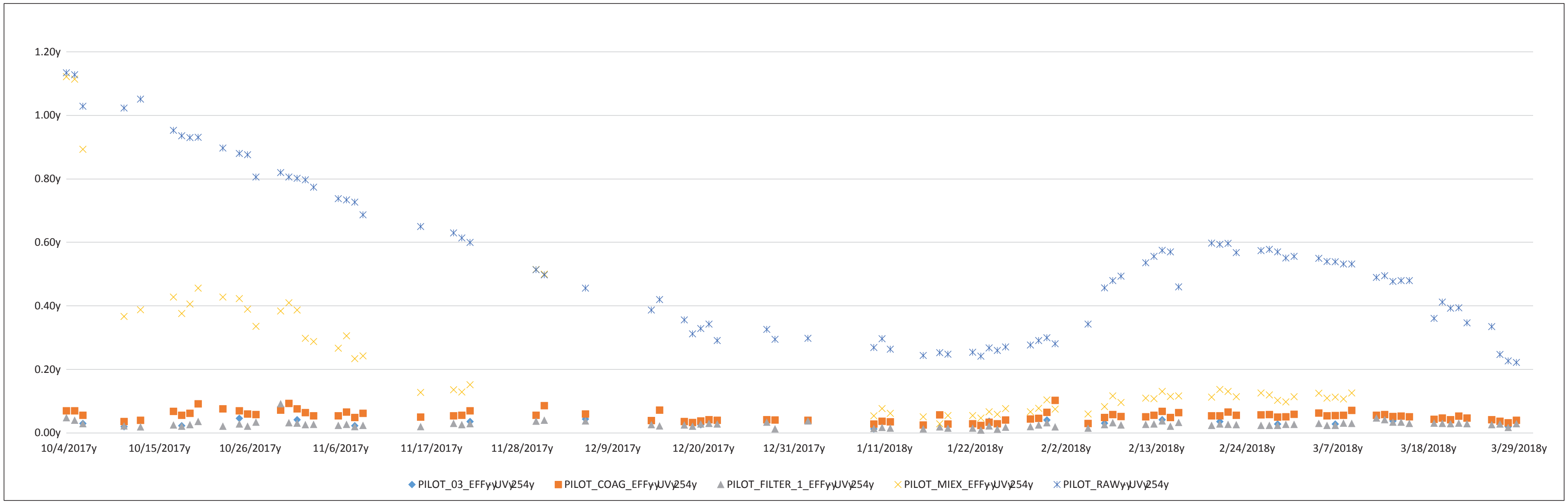
Report Date:A 6/12/2018y
Report Number:A 25y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Turbidity	PILOT_FILTER_1_EFF	92	NTU	10/4/2017	3/29/2018	0.22	1.40	0.10	0.26	1.18		City of Tampa	MP PILOT.XLSX
Turbidity	PILOT_FILTER_2_EFF	92	NTU	10/4/2017	3/29/2018	0.20	1.40	0.10	0.26	1.28		City of Tampa	MP PILOT.XLSX
Turbidity	PILOT_FILTER_3_EFF	92	NTU	10/4/2017	3/29/2018	0.17	1.30	0.10	0.17	1.02		City of Tampa	MP PILOT.XLSX
Turbidity	PILOT_FILTER_4_EFF	92	NTU	10/4/2017	3/29/2018	0.14	0.90	0.10	0.12	0.87		City of Tampa	MP PILOT.XLSX

Report Name: UV254
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

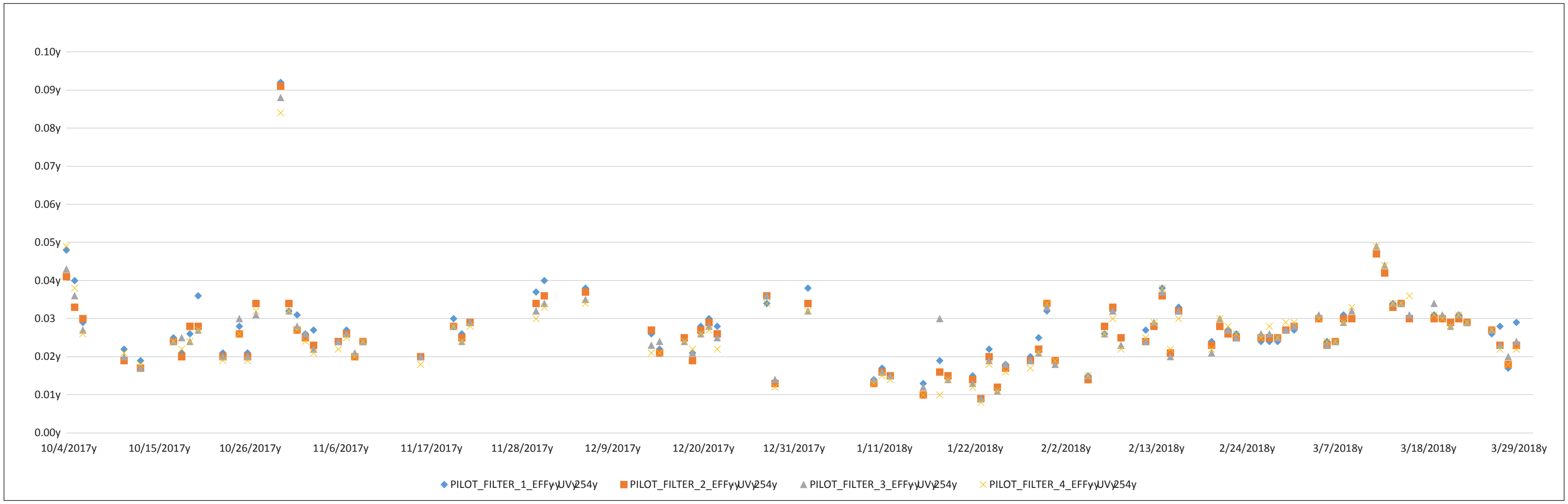
Report Date:A 6/12/2018y
Report Number:A 26y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
UV 254	PILOT_03_EFF	92	cm-1	10/4/2017	3/29/2018	0.032	0.046	0.013	0.009	0.29		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_COAG_EFF	92	cm-1	10/4/2017	3/29/2018	0.053	0.103	0.024	0.015	0.29		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_FILTER_1_EFF	92	cm-1	10/4/2017	3/29/2018	0.027	0.092	0.009	0.010	0.37		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_MIEX_EFF	92	cm-1	10/4/2017	3/29/2018	0.228	1.122	0.029	0.227	1.00		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_RAW	92	cm-1	10/4/2017	3/29/2018	0.533	1.134	0.222	0.238	0.45		City of Tampa	MP PILOT.XLSX

Report Name: UV254 Filters
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

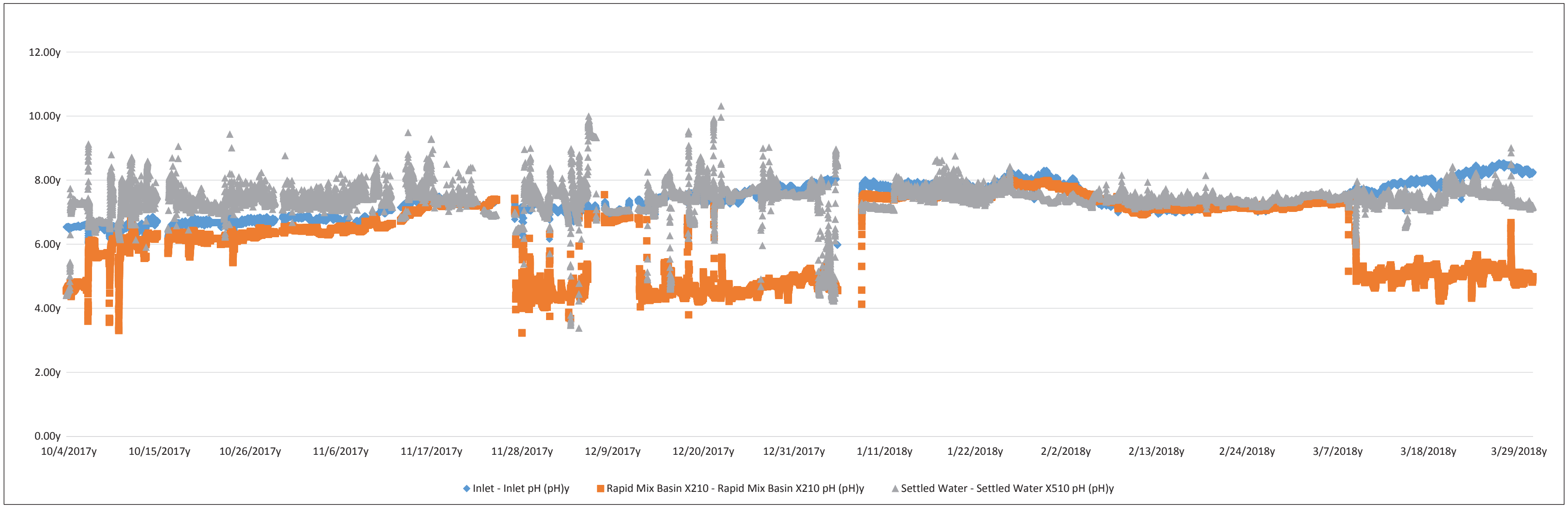
Report Date:A 6/12/2018y
Report Number:A 27y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
UV 254	PILOT_FILTER_1_EFF	92	cm-1	10/4/2017	3/29/2018	0.027	0.092	0.009	0.010	0.37		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_FILTER_2_EFF	92	cm-1	10/4/2017	3/29/2018	0.026	0.091	0.009	0.010	0.38		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_FILTER_3_EFF	92	cm-1	10/4/2017	3/29/2018	0.026	0.088	0.009	0.010	0.37		City of Tampa	MP PILOT.XLSX
UV 254	PILOT_FILTER_4_EFF	92	cm-1	10/4/2017	3/29/2018	0.026	0.084	0.008	0.010	0.39		City of Tampa	MP PILOT.XLSX

Report Name: pH (online) FLOC/SED UNIT
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

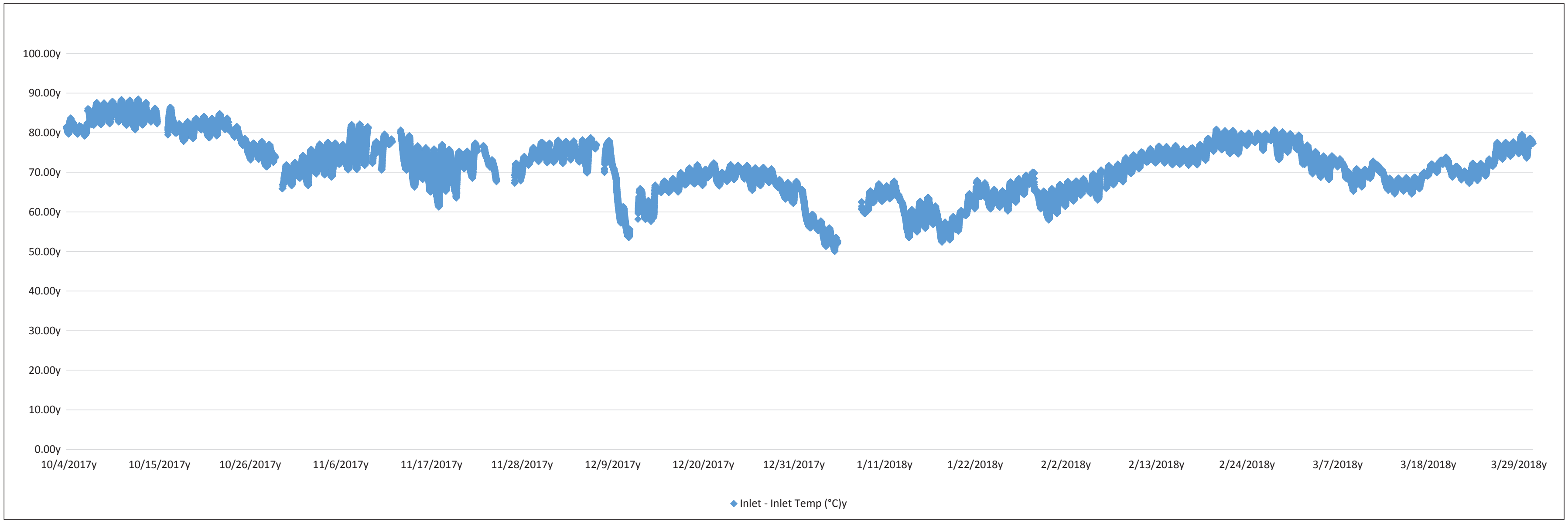
Report Date:A 6/12/2018y
Report Number:A 28y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Inlet pH (pH)	Inlet	51375	SU	9/14/2017	4/2/2018	7.30	8.54	4.03	0.57	0.08		City of Tampa	Compiled Pilot Floc Sed Data.xlsx
Rapid Mix Basin X210 pH (pH)	Rapid Mix Basin X210	51375	SU	9/14/2017	4/2/2018	6.20	8.04	3.23	1.13	0.18		City of Tampa	Compiled Pilot Floc Sed Data.xlsx
Settled Water X510 pH (pH)	Settled Water	51375	SU	9/14/2017	4/2/2018	7.24	10.32	0.00	0.74	0.10		City of Tampa	Compiled Pilot Floc Sed Data.xlsx

Report Name: Temperature (online) FLOC/SED UNIT
Client: City of Tampa
Project: DLTWTF MASTER PLAN - PILOT PLANT STUDY
Carollo Project Number: 10194A00

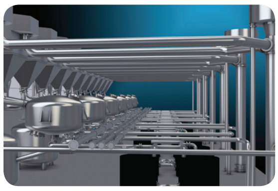
Report Date:A 6/12/2018y
Report Number:A 29y



ParameterA	LocationA	Observations (N)A	UnitsA	Start DateA	End Data	Avg ValueA	Max ValueA	Min ValueA	STD A	CovarA	Method	Analysis ByA	Data SourceA
Inlet Temp (°C)	Inlet	51375	mg/L	9/14/2017	4/2/2018	72.24	88.80	50.10	7.79	0.11		City of Tampa	Compiled Pilot Floc Sed Data.xlsx

APPENDIX E – SIX RESIN TREATMENT INFORMATION



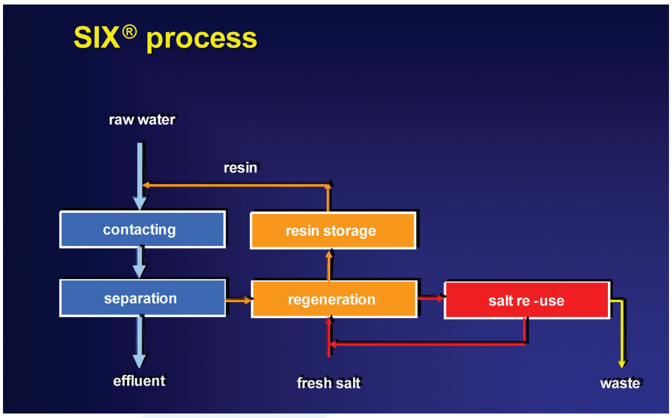


Innovative designs for sustainable, advanced water treatment

SIX

Resin treatment technology for drinking water

PWN Technologies is a leading company when it comes to developing innovative drinking water technology. We translate our know-how into sustainable solutions for water supply. Our latest solution is called SIX: a new resin treatment technology for drinking water, which has many advantages compared to other ion exchange processes.



In the past three years PWN Technologies has developed a new ion exchange process for the direct treatment of water containing high amounts of suspended matter and organics, such as surface waters. SIX is a suspended ion exchange process, suitable for purifying untreated surface waters. It involves not just an ion exchange process, but also resin separation and dosing of regenerated resin. In addition SIX includes techniques for reducing the level of salt regeneration. The process design is based on a fully validated model and can be adapted to all commercially available resins.

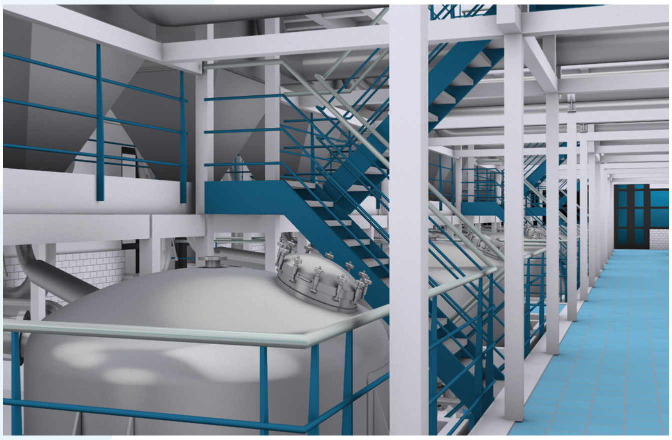
Only a limited amount of test data is needed to design a pilot or a full size plant. The process can achieve a very high rate of organics removal. Compared to other ion exchange processes for treating water containing suspended matter and organics, the single pass ion exchange process (SIX) distinguishes itself by compactness, a low resin concentration and inventory, low salt usage, high effluent quality and full control of the adsorption process without blinding the resin or producing biomass. The adsorption of the SIX process has been modeled to such a degree of accuracy that it is possible to design a reliable installation for any commercially available resin based on only a few jar tests. As the resins used have optimal adsorption capacities and rates, the overall performance is unsurpassed.

Additional advantages:

- No pumps are used to displace the resin, resulting in low attrition rates
- New sensors are used to control resin concentration and water quality
- Additional technologies have been developed to reduce salt usage

Benefits

- Unit is very compact with a small footprint
- Model is fully validated
- Reduced resin inventory
- Full control
- 100% regeneration of dosed resin
- No risk of resin blinding
- Short resin contact times; no risk of biofouling
- Low resin attrition; minimal resin loss
- Can be used with all commercially available resins



PWN Technologies: innovation engine

PWN Technologies, a subsidiary of water supply company PWN in the Netherlands, was established to make the utility's innovations in water treatment available to other water companies around the globe. The revenues of PWN Technologies are invested in R&D programmes to strengthen PWN's position as an innovative water supply company. PWN Technologies has developed advanced and sustainable solutions in water treatment, based on suspended ion exchange, ceramic membrane applications and advanced oxidation. In addition PWN Technologies also delivers innovative solutions like the Perfector Series for drinking water production in emerging countries. PWN Technologies is located in the Netherlands (Velserbroek and Andijk) and Singapore.

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NOM-removal at SWTP Andijk (Netherlands) with a New Anion Exchange Process, called SIX®

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Abstract: The new developed ion exchange process SIX presents an advanced solution for a world-wide challenge: How to remove NOM/DOC as a first step in surface water treatment to improve efficiency of downstream processes and to improve water quality. Besides the possibility to treat water containing suspended matter another advantage is the fact that the process has advanced to an economical and technical feasible process, guaranteeing a stable water quality, resulting in a large tolerance for flow fluctuations and relatively low contact times and small resin inventory. Most important advancement however is that almost every commercially available resin can be used creating the desired flexibility in suppliers for water supply companies. This paper describes the process and generates advantages and disadvantages compared to conventional technologies leading to the world first full-scale application with a capacity of 5500 m3/h.

Keywords: NOM-removal, DOC-removal, ion exchange, regeneration

Introduction

Ion exchange (IX) is considered to be both an adsorption process and a sorption process (Wachinski, 2006). The term ion exchange describes the unit process of IX, which is widely used in water treatment to remove unwanted contaminants. The most common application of IX is softening, but there are many kinds of resin, and anion IX resins can be used for the removal of anions like nitrate, DOC, and arsenate. IX has been introduced by the WHO as a nitrate removal technology and approved as the Best Available Technology (BAT) for nitrate removal by US EPA. Cation ion-exchange refers to the removal of cations, such as calcium and magnesium.

Wachinski and others argue that the role of IX in water treatment is changing. This is because of the proposed brine discharge legislation in California, Montana, and Texas and also because of advanced membrane technologies, AOP and the need for many utilities to lower DBP formation potential. Ion exchange processes generate a waste stream which is usually referred to as a brine, because salt is most commonly used to regenerate the IX resin. This waste water contains high concentrations of the contaminant ions and high concentrations of regenerant solution, usually sodium chloride. Management and disposal of these brines present a formidable challenge to engineers, just as is the case for NF/RO membrane concentrates. Engineers must not only select the proper pre-treatment and IX process but also the proper brine recovery or brine disposal option. Conventional alternatives like coagulation or nanofiltration, which are alternatives for DOC removal, also generate waste. In some situations, these waste streams are more difficult to discharge or dispose of than the brine of an anion IX process. This problem is very site specific and depends on local legislation and the water characteristics.

Anion IX however offers a very good opportunity for enhanced removal of organic matter for source waters that contain medium to high concentrations of NOM because the majority of compounds which make up NOM are negatively charged.

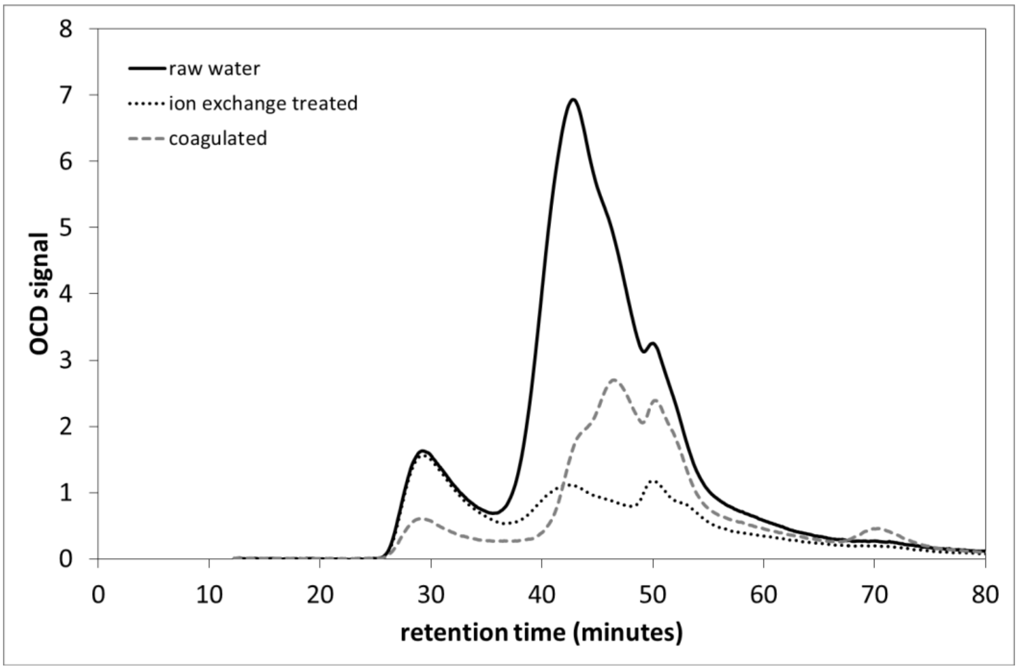


Figure 1, SEC-OCD chromatogram of ion exchanged and in-line coagulated IJssel Lake water

The size exclusion chromatography-liquid chromatography-organic carbon detection (SEC-LC-OCD) method is a powerful analytical tool to characterize organic matter and to observe relative differences in DOC. The SEC broadly groups the organics into five fractions: biopolymers (MW>>20,000 g/mol), humics (MW~1,000 g/mol), building blocks (MW 300-500 g/mol), LMW acids and LMW neutrals (MW < 350 g/mol) (in the order of retention time). Two detectors, organic carbon detector (OCD) and ultraviolent detector (UVD) detect the organics. The OCD spectrum is used to determine the total mass of organic carbon, whereas the UVD spectrum detects only the UV adsorbing species (i.e., double bond carbon), the so-called chromophoric DOM. Figure 1 shows an example of an OCD signal where the same surface water is treated with enhanced coagulation and anion IX. It is clear that enhanced coagulation removes a part of the biopolymer fraction (around 30 minutes retention time) and a small portion of humics (around 40 minutes retention time). The IX removed most of the humics with the highest UVT254nm molar absorption coefficients and LMW fractions (around 40 and 50 minutes retention time) but it has almost no impact on biopolymer removal. As a result, the UVT 254nm for enhanced coagulation was 82 percent while anion IX achieved a treated water UVT of 94 percent.

Problem description

Some waters can have elevated concentrations of DOC, especially sources like surface waters that are under the influence of secondary effluent, recreation, heavy population, farming and industry. In places like in the United Kingdom and Scandinavia DOC levels are inclining due to climate change. For these types of water, IX as a pre-treatment is of interest because the removal of colour and DOC by IX will increase the efficiency of all downstream processes, including coagulation, membrane filtration, AOP and GAC. With these waters, there is also suspended and colloidal matter and this makes it nearly impossible to use standard state-of-the-art, fixed bed IX columns. This is because these beds will foul quickly (i.e., head loss build-up) with the suspended matter. When this happens, the ion exchange bed starts to function as a filtration bed rather than as an adsorption media.

Available technologies to treat such heavy polluted waters are based on fluidized bed reactors or on totally-mixed reactors with very high concentrations of resin (>400 mL/L), like in the MIEX® process, (an acronym for Magnetic Ion Exchange, manufactured and commercialized by Orica) or in fluidised bed reactors to prevent entrapment of suspended matter. In the fluidised bed and the MIEX®-process the bed volumes treated until regeneration are designed to be as high as possible with the goal to remove as much of the pollutants as possible before regeneration, thus lowering the salt consumption needed for regeneration [Slunski, 1999]. This approach can have a few disadvantages depending on the treated water that makes it less attractive to use (i.e., more expensive), but more importantly, for some waters, the anion ion exchange resin of the MIEX® process which is used to remove dissolved organic carbon (DOC) from raw surface waters is sometimes not feasible. This is because these waters often contain phosphates, which will be adsorbed, and with the large detention times (used to minimize the number of regenerations) and porous resin beads, the perfect environment for bacteria to grow in is created because the resin is now a source of carbon and phosphorous. The biofilm that forms on the resin, blinds the active groups of the resin, and this is referred to as “resin blinding”. Resin blinding occurs slowly but can lead to serious problems. Besides losing adsorption capacity [Wachinski, 2006], this leads to the need to operate with a higher resin concentration or longer contact time [Verdickt, 2011; Cornelissen 2009], thus increasing operational costs and/or lowering plant capacity, and after time, the biofilm itself starts to release organic matter or adenosine triphosphate (ATP) that can be detrimental to downstream processes [Cornelissen, 2010], especially membranes.

To overcome resin blinding, fixed bed or fluidised reactor systems are flushed with a high pH solution on a periodic basis to kill and dissolve the biofilm as much as possible. These fixed beds, however, like mentioned before, cannot treat waters with suspended matter. For the MIEX® processes, which use a hydrophobic resin, it is not possible to use high pH (hydroxide ions) to control biofilm development because the resin is not resistant to hydroxide, and with exposure would begin to fall apart over time, thus shortening the lifetime of this relatively expensive resin.

These issues have led to the development of a new ion exchange process [Galjaard, 2009] by PWNT. Compared to the other described ion exchange processes treating waters containing suspended matter, the ‘single pass’ or ‘suspended’ ion exchange process (SIX®) achieves full control of the adsorption process without (serious) ‘blinding’ the resin or producing biomass (www.pwntechnologies.com) and, hence, optimum sorption kinetics and reduced contact times. This can be done with any resin that is commercially available, and the resins used to date can be treated with hydroxide for biofilm control, if necessary.

The SIX®-process

Basic principle

In the SIX® process, resin is dosed from a dosing tank into the raw water at a low concentration of 4 to 20 mL resin/L, depending on the raw water quality, desired treated water quality, and resin type. This mixture then flows through plug flow contactors. In these contactors, the resin has the same residence time as the treated water, because the resin travels together with the water through these contactors. Unlike packed bed systems, in which the resin is retained in the contactors, all resin particles are exposed to equal conditions, leading to homogeneous distribution of the adsorbed matter over these particles. This, in turn, gives rise to a more stable and superior process performance, as well as more efficient use of the counter anion (Cl-) during regeneration.

The number, shape, and design of the contactors play an important role in the adsorption kinetics of this process. The aim of design is to approach the ideal contactor system of a plug-flow reactor [Ramaswamy, 1995], leading to shorter residence times of the resin, and therefore shorter contact times. After the contact time in the contactors, the resin is separated from the treated water using a customized lamella settler. The resin collects in the hopper, and is then immediately regenerated and returned to the dosing tank (figure 2).

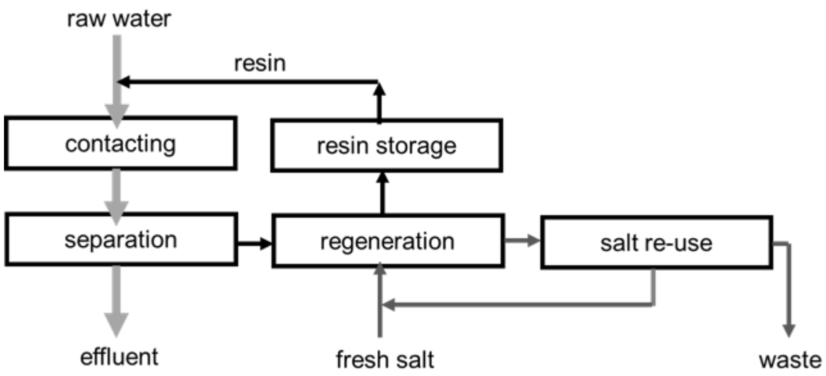


Figure 2, Schematic of the SIX® process of PWN Technologies

Kinetics

Knowing the exact residence time of the resin makes it possible to regenerate all of the resin equally, leading to an equally low number of regenerations for all of the resin. The relatively short contact time (e.g., 10 min < t < 30 min) of the treated water with the resin before the regeneration procedure makes it difficult and almost impossible for bacteria to grow on the resin particles surface. This overcomes the problem of resin blinding and ensures that the resin continues to operate at stable adsorption kinetics. This is shown with the help of a pseudo first-order reaction according to Lagergren, for which reaction constants can be determined using jar tests (Koreman 2013). According to this pseudo-first order reaction non equilibrium adsorption is controlled by an adsorption rate constant k (min^{-1}) and the difference between actual and equilibrium concentration. Since k is proportional with resin concentration, normalization with concentration results in a constant value, the normalized rate constant K (L/min.mL resin)

First, the resin in this case the standard MIEX resin, has been loaded with the estimated amount of BV with the same raw water (in this case, raw IJssel Lake water). After that, a certain amount of this resin (i.e., 2,4, 8, 12 and 30 ml/L) of this resin were added to jars and regularly sampled to determine UV254nm Transmission (UVT) at various time intervals, ranging from 2 to 30 minutes. From the reactions, k values as a function of the resin concentration where determined. Table 15.1 gives the overall inventory of the different processes.

Table 1, Parameters and K-values of different processes for MIEX® resin

	SIX	**MIEX classic**	**MIEX high-rate**	**FIX**	**Column**
BV					
Min	50	200	2000	60000	12000
Max	250	1000	5000	120000	
Residence time resin					
Min (min)	10	300	>3000	>4000	>20000
Max (min)	30	600			
Average K-value	0.0419	0.0252	<0.0041	n calc	n calc

n calc = not calculated

The lower K-value of the classic MIEX® process compared to SIX® at almost the same BV of treated water immediately confirms that resin blinding not only with biomass but also with non-desorbed anions lowering equilibrium values as well as rate constants, occurs in the MIEX® process on this resin, with this feed water, at longer resin residence times. Using this K-factor to model UVT development in time for a certain resin concentration and initial UVT (UVT of the raw water) results in figure 2 , showing even more clearly the advantage of a single pass, leading to lower contact times or lower resin concentrations to reach a certain target UVT . Extending the BV and residence time further leads to a significant loss of adsorption capacity (i.e., lower k value and UVTeq), due to resin exhaustion and inadequate regeneration. With longer residence times and higher BVs of water treated before regeneration, it is easy to see that fluidized bed systems (FIX), and fixed bed columns are technically not feasible for treating this type of water. Resin blinding (biomass, residual adsorbed anions) undoubtedly occurs, and performance deteriorates. Finally, resin exhaustion gives rise to higher initial salt levels in the regenerant liquid, needed to maintain enough desorption efficiency and to prevent further deterioration of the adsorption capacity on the long term.

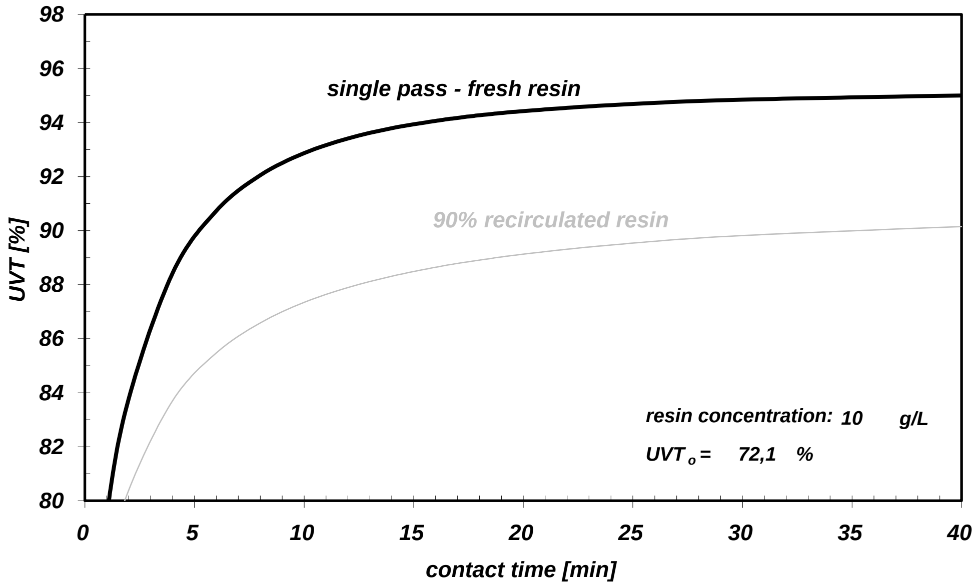


Figure 2, Modelling UVT development in time based on pseudo first-order reaction

Resin choice

The MIEX-resin itself has very high kinetics based on the same K-factor when fresh resin is used compared to other commercially available resins comparing them in ml/L (figure 3) . This is partly caused by the macro-porous properties and strong basic groups but mainly by its fine particle distribution creating a very large surface area compared to other macro-porous resins. Figure 3 shows that the adsorption kinetics differ from one resin to the other as was investigated by lab scale batch experiments. If resin choice would only be determined by these results, it would be difficult to explain why finally Lewatit VPOC 1017 was finally selected as the most preferred resin for Andijk III. The reason for this is that - next to adsorption kinetics - desorption kinetics, capital costs, resin debris and sedimentation properties are very important criteria too. With respect to the latter, Lewatit VPOC performs better than the other resins that were investigated. VPOC – a strongly basic acrylic gelular anion resin - has superior sedimentation properties and thus lamella separator footprint is relatively small, whilst the resin beads are less sensitive for abrasive (mechanical) forces and as a consequence fine particles “carry over” is very low. Further, its pore structure tends to be more of a macroporous type, rather than a microporous. As a consequence it contains less functional groups per unit surface area compared to the other resins that were investigated. This implies that relatively higher resin dosages need to be applied to achieve target UVT (DOC) levels, but on the other hand less salt and shorter desorption times are required during resin regeneration. Together with relatively low resin cost per unit mass, last mentioned benefit is of major importance for total cost reduction.

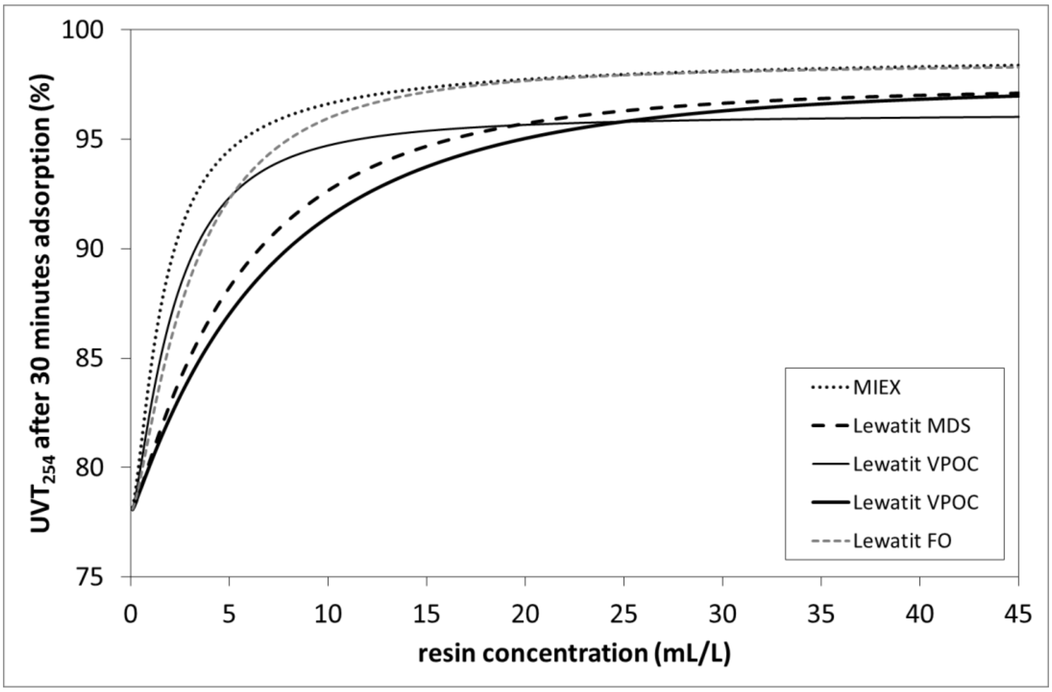


Figure 3. UVT254nm for various anion exchange resins after 30 minutes adsorption as a function of resin concentration (raw water source: IJssel Lake)

Another advantage of this process is that because the resin is not fully loaded prior to a regeneration, the regeneration (equilibrium reaction) requires less salt and lower contact times for the regeneration procedure.

Case study WTP Andijk (PWN)

In 1920, when NV PWN Water Supply Company North Holland (PWN) was founded, the demand for drinking water was satisfied by ground water extraction. However, with the growing drinking water demand PWN was compelled to utilize surface water as an additional source. Therefore in 1968 Water Treatment Plant Andijk (WTP Andijk) was constructed for the direct production of drinking water from IJssel Lake (River Rhine). Originally the plant consisted of micro-straining, breakpoint chlorination, coagulation, sedimentation, rapid filtration and post disinfection (Figure 4). In 1978 the plant was upgraded with pseudo moving bed GAC filtration. In the beginning of the 90's a minor improvement in water quality was made by softening in the raw water reservoir by dosing NaOH in the intake from the IJssel Lake to the reservoir followed by a pH adjustment right before the micro-strainers with CO2. After almost 40 years of operation, WTP Andijk still complied with all Dutch drinking water standards.

Nevertheless a second large upgrade was desired to install a universal barrier against pathogenic micro-organisms such as protozoa and organic micro pollutants such as pesticides [Kruithof, 2000]. This retrofit included the world's first large scale application of advanced oxidation with UV/H2O2 which became operational in 2004 [Kruithof, 2005]. This advanced oxidation is placed between the existing pre-treatment and GAC filtration (Figure 4). The GAC treatment provides removal of residual H2O2 and easily assimilable organic carbon (AOC). Since the advanced oxidation with UV/H2O2 requires a higher UV dose, superior disinfection is provided and breakpoint chlorination can be abandoned.

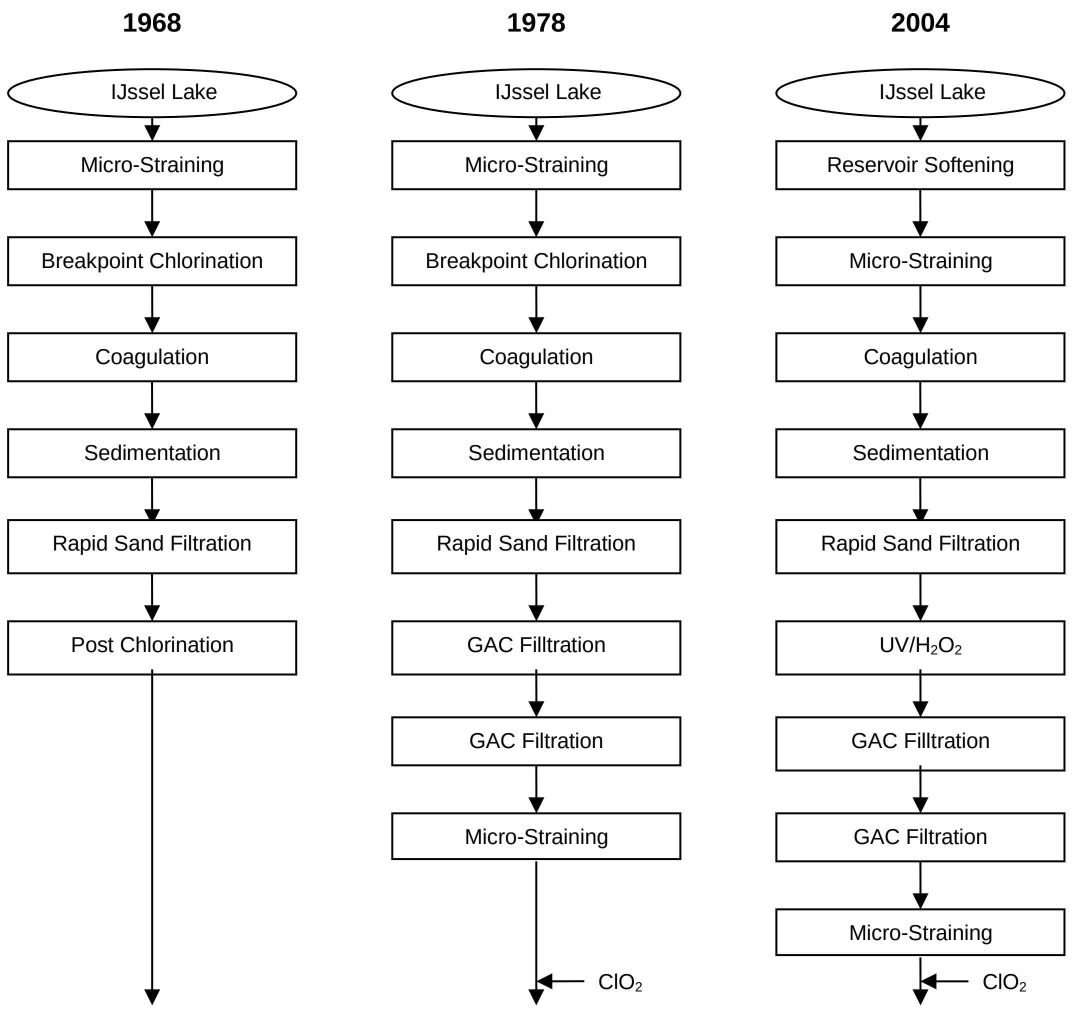


Figure 4: Technologic progression of WTP Andijk from 1968-2004

In a third phase the existing pre-treatment which still dates from 1968 will be renewed. The desire to retrofit the pre-treatment is based on a few challenges:

- increase the UV-transmission (UVT) to improve the efficiency of the advanced oxidation process (AOP);
- increase the removal of dissolved organic carbon (DOC) to improve the efficiency of the AOP and to lower the formation of AOC;
- remove nitrate to improve the efficiency of the AOP and to lower the formation of nitrite;
- total removal of suspended and colloidal matter independent of the feed water quality;
- increase overall capacity from 3000 to 5000 m^3/h.

The wish to remove all suspended matter led quickly to the idea of using micro- or ultrafiltration (MF/UF). A former PWN study [Galjaard, 2005] indicated that the direct treatment of IJssel Lake water with MF/UF was only possible after the removal of the low molecular weight (LMW) DOC fractions with an anion resin (at that time MIEX®), which

resulted in a high gross flux rate with almost no fouling. The use of an anion resin like the also increased UVT considerably and removed a large amount of nitrate and DOC.
The pre-treatment of ion exchange followed by MF/UF looked promising to fulfil the needs for the post-treatment and resulted in the first large scale SIX plant in operation since 2014.

Figure 5 represents seasonal fluctuations in raw water UV transmittance at 245 nm (UVT_{245}) and SIX effluent from the Andijk SIX pilot plant. During this period the pilot was operated at “regular” conditions, i.e. resin concentrations ranging between 13 and 15 mL/L and contact times between 25 and 30 minutes. These conditions were first selected as being the most appropriate for the Andijk situation by means of laboratory batch tests.

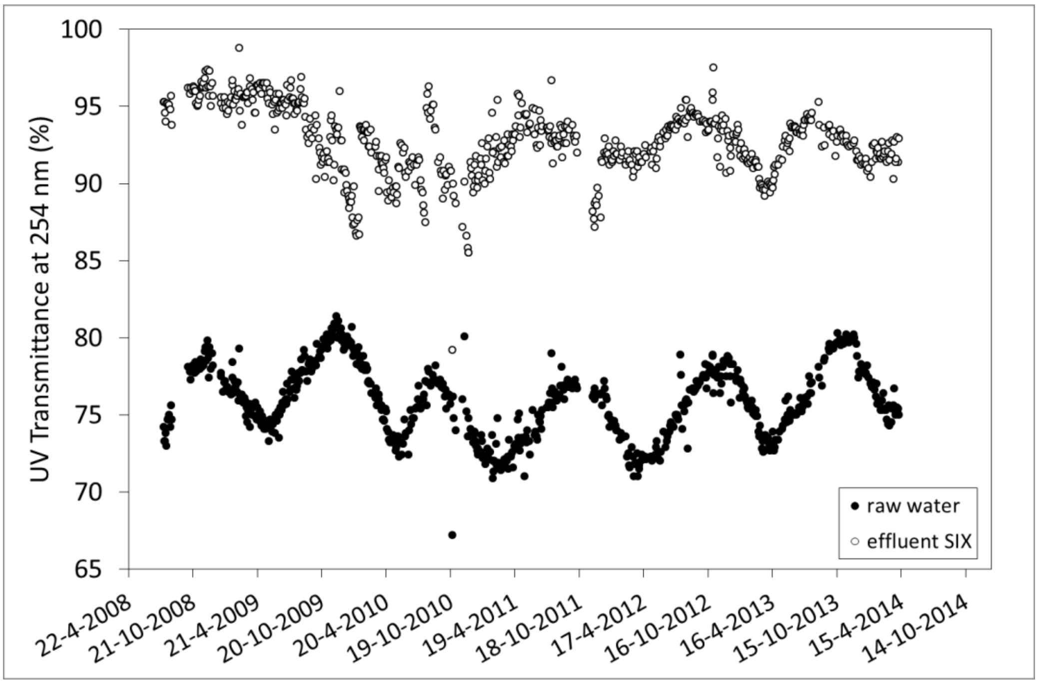


Figure 5. seasonal fluctuations in UVT_{254} for raw IJssel Lake water and Andijk SIX pilot effluent

One can see that raw water UVT_{254} has maximum values in late summer/early autumn. The opposite is true for the spring season. This has to do with fluctuations of the ratio between humic substances and biopolymers. This so-called HS/biopolymer ratio has a maximum value in the spring and a minimum value in late summer/early autumn. Since HS strongly adsorbs UV_{254}, whereas biopolymers do not (see figure 6). As as consequence, raw water UVT_{254} has the lowest values in spring, whereas DOC raw water levels do not fluctuate significantly over the whole season.
The difference between maximum and minimum UVT_{254} is quenched by SIX treatment. This is illustrated by figure 7 where we can see that the UVT increase is the highest in spring and summer and the lowest in the autumn and winter period. This can be explained by the fact that anion exchange in particular removes humics and (almost) no biopolymers, as has already been discussed. It also explains why we have have better NOM removal kinetics in spring and summer since non equilibrium or rate limited adsorption is proportional with the difference between equilibrium UVT and initial UVT, as well as adsorption rate constant, that are both higher in spring and summer. Further quenching, if desired, can be obtained using higher resin concentrations during this period.

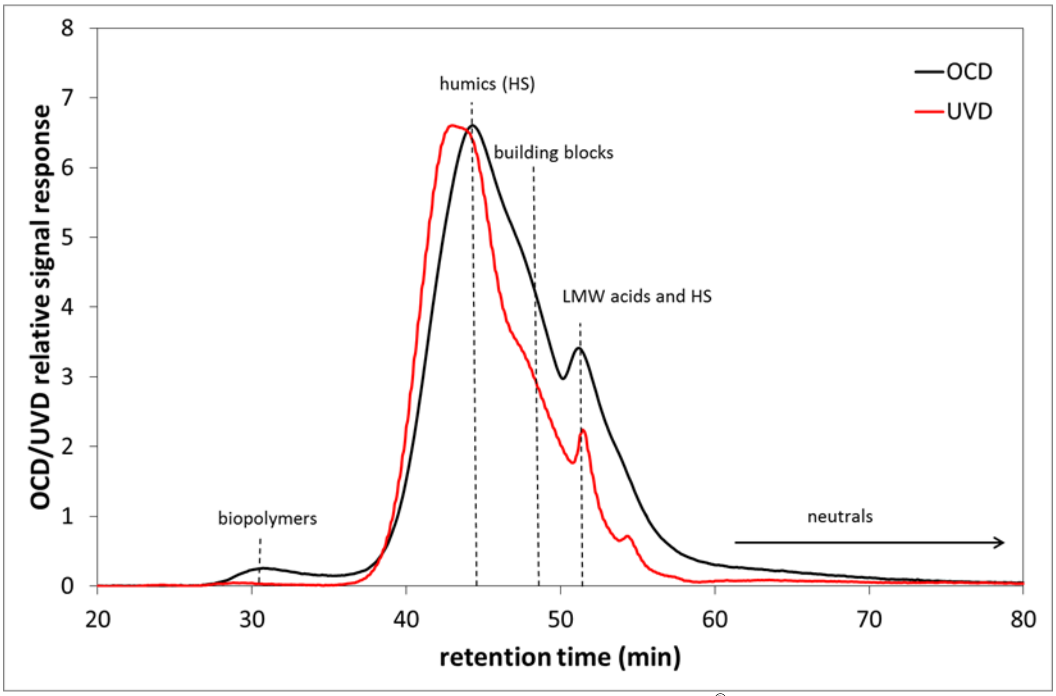


Figure 6. SEC-OCD/UVD spent regenerant chromatogram of SIX® treated IJssel Lake water

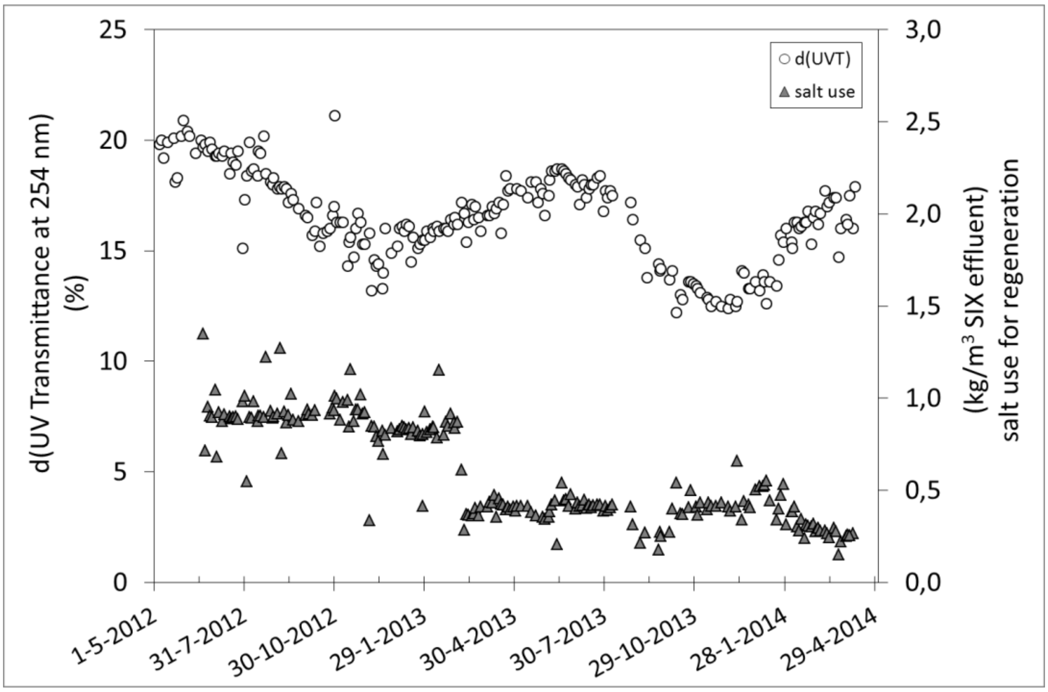
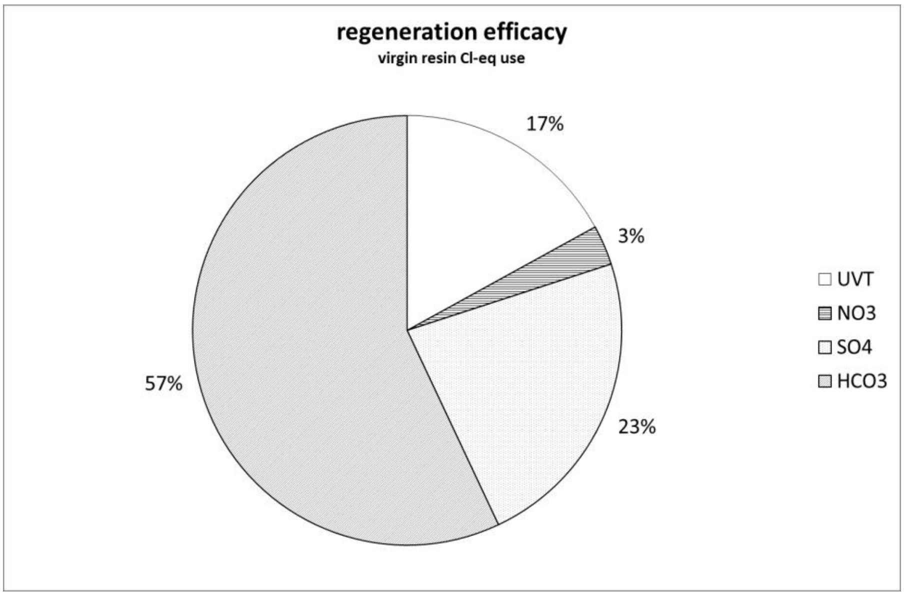


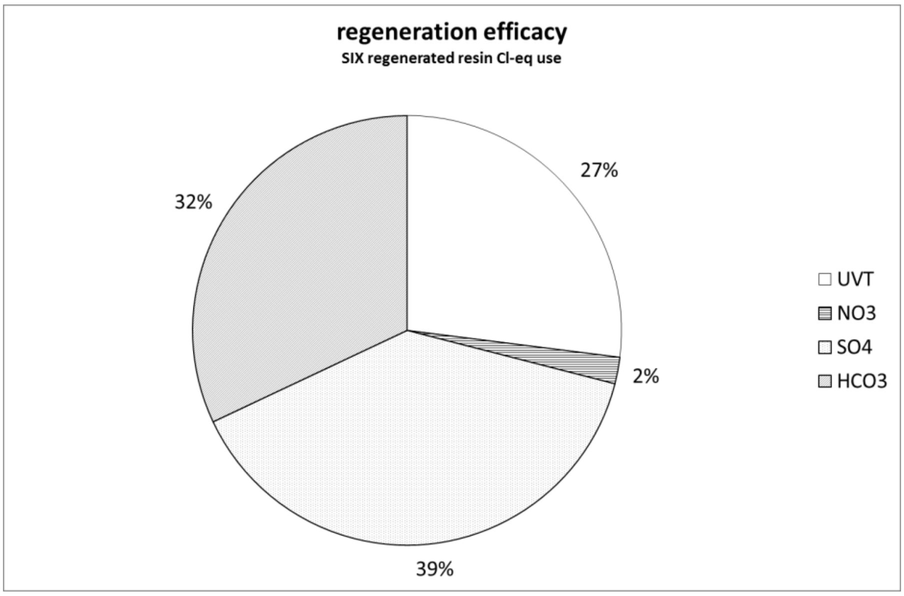
Figure 7. absolute UVT_{254} improvement for Andijk SIX pilot treatment and salt use during regeneration

With respect to resin regeneration we may further state that a drastic reduction of the salt use had only little effect on UVT improvement, that seems to have been dropped with 1,0 to 1,5 %, after salt use was reduced with more than 65%. Figure 8 demonstrates why effluent-

UVT_{254} - and thus NOM/DOC removal - is only slightly affected by this substantial reduction. Apparently, using (much) smaller amounts of chloride counter anions during regeneration predominantly results in blinding of adsorption sites for anions different from DOC. Since UVT_{254} is an accurate surrogate parameter for DOC – for the Lake IJssel water matrix both are linear related with each other – comparison of both figures 8 a and b makes clear that reduction of the chloride use during regeneration has resulted in a higher chloride efficiency for UVT/DOC, i.e. the amount of chloride that is being exchanged wit DOC during adsorption has increased with about 10% for the SIX regenerated resin compared with the virgin resin, mainly due to reduced HCO_3^- adsorption. The latter anion however is not a target anion, but rather a 'chloride scavenger'.



(a)



(b)

Figure 8. comparison of virgin (a) and fresh (b) meq-chloride use efficiencies during anion exchange at 16 mL resin/L and 30 minutes contact time

Conclusions

Overall, the SIX-process functions really well and seems to be a solution for further removal of DOC. The higher removal of DOC but also other negatively charged ions impacts water quality and efficiency of all the downstream processes dramatically as was also demonstrated in Andijk and other locations among which Crownhill (South West Water) (Shorney-Darby, 2014). The advantages of SIX compared to existing ion exchange processes and enhanced coagulation/sand filtration systems (ECSF) are:

- no (significant) resin 'blinding';
- capable of using any available commercial resin;
- low resin concentration and inventory;
- high effluent quality;
- costs comparable or lower to ECSF.

With respect to regeneration we may conclude that:

- substantial reduction of chloride during regeneration of the loaded resins does not result in a noticeable deterioration of DOC removal per se. In Andijk it is first the bicarbonate anion adsorption that is being delayed, most likely because of its relative low position in the anion selectivity order. On the other hand DOC adsorption is only slightly retarded;
- Since chloride demand is being determined by total anion equivalents, SIX treatment becomes more attractive as the anion content – especially sulphate – is relative low.

With respect to the spent regenerant or brine we may further state that:

- The biggest risk for this process is brine discharge or treatment (0.2 – 0.4%), but this is a similar problem for a NF solution. The average salt usage for regeneration with no re-use is 0.05 – 0.2 kg/m^3 treated based on the Andijk and Crownhill studies.

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APPENDIX F – MIEX® POTABLE REUSE PAPER

Evaluation of Magnetic Ion-Exchange (MIEX) Resins in Potable Water Reuse

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1. Introduction

With burgeoning population, water scarcity has increasingly become severe and caused increased pressure around the world to secure reliable and dependable drinking water resources. Potable water reuse can be a viable option to alleviate such water stress. To this end, various physical and chemical water treatment processes have been employed to remove chemical and biological contaminants. The primary model for indirect potable reuse (IPR) is the Orange County Groundwater Replenishment System (GWRS) in California, which uses ultrafiltration (UF), reverse osmosis (RO), and UV-advanced oxidation (UV-AOP). Other systems in California, and around the world, have used the GWRS model with little variation. One of the reasons for such advanced treatment is to achieve the Title 22 of California Code of Regulation requirement of total organic carbon (TOC) concentrations no greater than 0.5 mg/L in the final water. Even though this treatment scheme—often called full advanced treatment (FAT)—can remove total organic carbon (TOC) effectively, its widespread implementation is hindered mainly by high costs of capital, operations and maintenance of RO process (Gerrity et al. 2013). In addition, some FAT systems in California have greatly underperformed due to membrane fouling issues. The West Basin IPR system in El Segundo, Calfornia, installed ozone ahead of the UF membranes to reduce fouling. Unfortunately, the implementation of ozone created smaller organic molecules capable of passing through the RO membrane causing and exceedance of the regulatory TOC limit and caused many of the membranes to physically fail (presumably because of low ozone residuals reaching the polymeric membrane surface). While FAT can be successful, there remain challenges. In addition, many water agencies do not wish to lose approximately 20% of their water resources to the RO brine stream and/or have no mechanism to dispose of such large wastestreams. Thus, more cost-effective and brine reducing alternative treatment technologies are currently being explored and in high demand.

Ozone followed by biological activated carbon (BAC) process (O_3-BAC) has been shown more cost effective than FAT (Gerrity et al. 2014) and provide . In addition, substantial reduction of various trace organic contaminants (TOrCs) such as pharmaceutical, personal care products, industrial compounds and steroid hormones can be achieved by O_3-BAC. However, this treatment is often not sufficient to meet regulatory requirement of TOC removal. The removal of DOC by O_3-BAC processes ranges from 15% to 50% depending on empty bed contact time (EBCT) (Reungoat et al. 2012), which would not sufficient to achieve TOC concentration less than 0.5 mg/L in the final water since typical TOC range of secondary wastewater effluent falls between 4 mg/L and 20 mg/L (Lee et al. 2013). Therefore, evaluation of cost-effective alternative technologies is crucial to successful implementation of potable water reuse. In addition, pre-treatment technologies to lower membrane fouling and reduce TOC burden in FAT (membrane based) systems is highly desirable to potable reuse facilities.

In general, physical processes are more efficacious for DOC removal than chemical processes. The main mechanism of DOC removal by chemical processes (mainly oxidation processes) is mineralization of organic carbons, but a generally unrealistic amount of energy is required for mineralization, which makes it impractical for DOC reduction. Even advanced oxidation processes (AOPs) remove only a small portion of the DOC and will inherently result in production of transformation products, sometimes with greater toxicological effects than precursor compounds. A viable alternative is a physical treatment process for DOC removal using anion exchange resins (AERs). DOC is mainly composed of organic matter with acidic functional groups and can be effectively removed by AERs (Reiller et al. 2006). One of the main challenges for the applications of AERs in water treatment is its separation from aqueous phase when it is exhausted and needs to be regenerated. As a means of searching for solution for efficient AER separation, Magnetic Ion Exchange (MIEX®) resin, which is an anion exchange resin impregnated with a magnetic component. This feature enables faster agglomeration that facilitates a separation stage such as clarification. MIEX® resin has strong base functionality, hence capable of exchanging weak organic acid ions at neutral pH and thus has been successfully applied in water treatment (Slunjski et al. 2000).

We will conduct routine bench-scale testing of MIEX® in potable water reuse, where removal of dissolved organic carbon (DOC) is of primary concern to secure water quality and to reduce membrane fouling potential. MIEX has been widely studied to remove organic carbon. Apell and Boyer demonstrated DOC removal greater than 70 % in a groundwater with DOC of 5.6 mg/L (Apell and Boyer 2010). In addition, MIEX was shown to be efficacious for DOC removal in wastewater effluent. For instance, Zhang et al. achieved 30–80 % DOC removal depending on resin dose (corresponding to 20 mL/L to 150 mL/L) for a synthetic wastewater containing 10 mg/L of DOC (Zhang et al. 2008). In addition to DOC removal, MIEX® resin can also reduce the concentrations of some trace organic chemicals (TOrCs) in water. TOrCs ubiquitously occur in the wastewater effluent and can pose a risk to human health. MIEX® resin was reported to attenuate TOrCs by ion exchange and hydrophobic attraction mechanisms (Neale et al. 2010). Snyder's group also demonstrated the removal of recalcitrant perfluorinated alkylsubstances, such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), in a groundwater by MIEX® resin as illustrated in Figure 1.

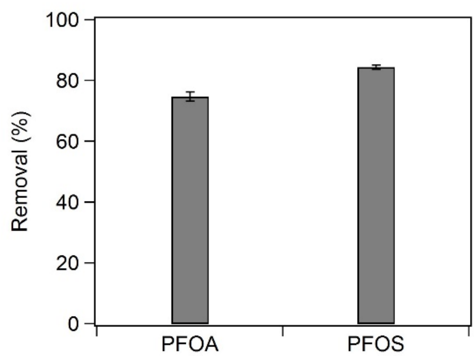

Figure 1. Percent removal of PFOA and PFOS in a surface water by MIEX® DOC resin

Additional benefit of MIEX® in water reuse application is its capability of removal of toxic inorganic compounds. Ozone is cost-effective treatment and widely implemented in water reuse. However, ozone converts bromide to bromate that is carcinogenic and has greater toxicological effects than bromide. Hence, MIEX® can be applied as a barrier for such harmful anions produced by ozone oxidation in water reuse.

Due to the aforementioned treatment capabilities of MIEX®, ***this proposal provides a plan for a scoping study to demonstrate various applications of MIEX® resin in potable water reuse.***

2. Study plan

A critical component of the proposed research will be to demonstrate MIEX® in various potable water reuse scenarios. This demonstration includes five treatment schemes to be tested as shown in Figure 2. Scheme 1 is the case of standalone application of MIEX® to remove TOC and other contaminants. Since MIEX® is known to be efficacious to remove TOC, optimal MIEX® dose will be determined and consequent water quality change at the optimal dose will be evaluated as Scheme 1. Scheme 2 adds MF filtration followed by MIEX®. MIEX® was reported to effectively remove humic acids, building blocks and low molecular weight acids, but macromolecules such as biopolymers was not amenable to MIEX® (Koreman and Galjaard). Hence, Scheme 2—MIEX® followed by MF—is proposed since not only MIEX® can simultaneously remove small molecules and reduce fouling propensity of the subsequent MF, but also MF can complement relatively lower removal of macromolecules by MIEX®. Scheme 3–5 includes nanofiltration membrane (NF) for TOC removal. NF is less costly than RO while maintaining good rejection of TOC as well as TOrCs. In general, NF membrane can reject TOC greater than 80% (Bellona et al. 2012). However, organic fouling is a major challenge to sustainably operate NF systems in potable water reuse. Hence, the application of MIEX® will be demonstrated to alleviate NF membrane fouling (Scheme 2). Ozone can be a viable option to reduce NF membrane fouling (Park et al. 2017b) and is known to be more cost-efficient compared to other oxidation processes such as UV/H_2O_2 (Plumlee et al. 2014). In addition, ozone is also efficacious for inactivation of pathogens such as virus. However, formation of toxic disinfection by-products (DBPs) such as bromate is of primary concern. Even though NF membrane can be applied following ozone as a barrier of bromate, NF was reported to exhibit poor rejection of bromate (<20%) (Listiarini et al. 2010), therefore the introduction of additional barrier would be crucial. MIEX® can not only effectively remove bromate, but also attenuate its precursor (i.e., bromide) (Johnson and Singer 2004). Therefore, Scheme 3 and 4 are proposed to investigate the implementation of MIEX® following and followed by ozone oxidation process, respectively as a means of DBP control. The feasibility of the proposed scheme will be evaluated by chemical analysis and bioassay based on a tier structure as depicted in Figure 3.

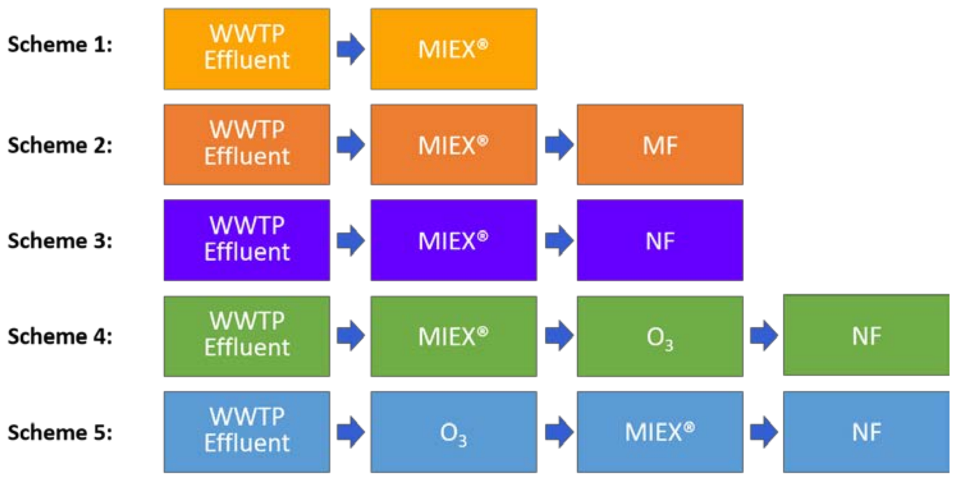

Figure 2. Treatment schemes to be tested.

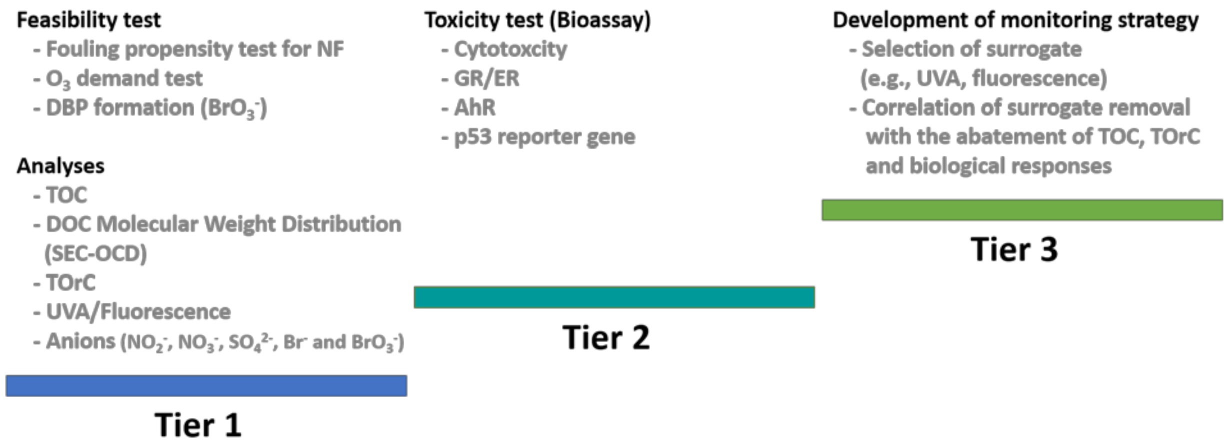

Figure 3. Tier structure for the water quality assessment of the proposed treatment schemes.

2.1. Tier 1: Demonstrate MIEX® to attenuate TOC, membrane fouling of MF and NF, and control DBPs

Figure 3 shows the tier structure of water quality test to assess the feasibility of the proposed schemes in potable water reuse. Tier 1 focuses on the feasibility test for the proposed schemes based upon regulatory perspectives. To be specific, 0.5 mg/L of TOC is set as a criterion for removal of total organic matter. In addition, the schemes including ozone oxidation (i.e., Scheme 4 and 5) will be evaluated based on 10 µg/L bromate concentration as regulatory standpoint. Bulk water quality parameters and other contaminants of concerns such as TOrCs will be monitored along the treatment processes in Tier 1. In order to evaluate membrane fouling propensity, flux decline with respect to time will be evaluated. The impacts of MIEX® on fouling propensity will be assessed by scrutinizing molecular weight distribution of organic matter using size-exclusion chromatography (SEC) hyphenated with organic carbon detector (DOC).

2.2.Tier 2: Toxicity test

While chemical monitoring provides quantitative assessment of contaminants in a water sample, effect-based monitoring can complement chemical analysis that does not reflect non-target and/or unknown compounds and mixture effects. Hence, demonstration of *in vitro* bioassays with relevant endpoints is proposed as follows to secure water quality of the final waters from each treatment scheme (Figure 4).

- Cytotoxicity: Measures the reduction in cell growth compared to an untreated control. Cytotoxicity captures the widest array of toxic modes of action.
- Specific (Receptor -mediated) Toxicit
  Receptor (ER): Estrogens and glucocorticoids have been reported to occur widely in WWTP effluents. This bioassay measures responses to chemicals mimicking estrogens and glucocorticoids.
- Xenobiotic Metabolism: Aryl Hydrocarbon Receptor (AhR): Measures cellular response to chemicals similar to dioxins and PCBs.
- p53 reporter gene: The p53 protein is known for its major role in the prevention of cancer. It acts as a tumor suppressant, recognizing damaged DNA and triggering DNA repair. This bioassay provides a sensitive measure of damage to the genome (genotoxicity). This mode of action is particularly relevant to DBPs.

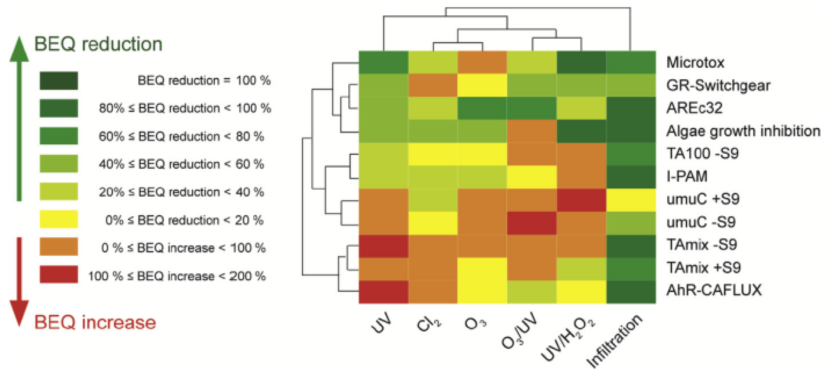

Figure 4. Hierarchical clustering of 11 primary bioassays for various physico-chemical treatment processes implemented in potable water reuse (Jia et al. 2015).

2.3. Tier 3: Development of monitoring strategy using surrogate correlation model

Surrogates can be a quantifiable water quality parameter that represents removal characteristics of parameters of interest. In potable water reuse, UV absorbance (UVA) and fluorescence have been widely implemented as surrogates for the prediction of TOrC attenuation (Ziska et al. 2016). For example, the increase in ozone dose attenuates UVA and fluorescence along with TOrC (Figure 5). This characteristic allows UVA and fluorescence to indirectly monitor TOrC abatement (Figure 6). Since MIEX® reduces chromophoric organic matter as well as TOrCs, UVA and fluorescence would be good candidates as surrogates for MIEX® efficacy. Currently, the State of California requires continuous monitoring of at least one surrogate to ensure oxidation treatment efficacy for recycled water. Therefore, development of surrogate correlation is essential to provide monitoring strategy to ensure treatability of MIEX® in a real-time manner.

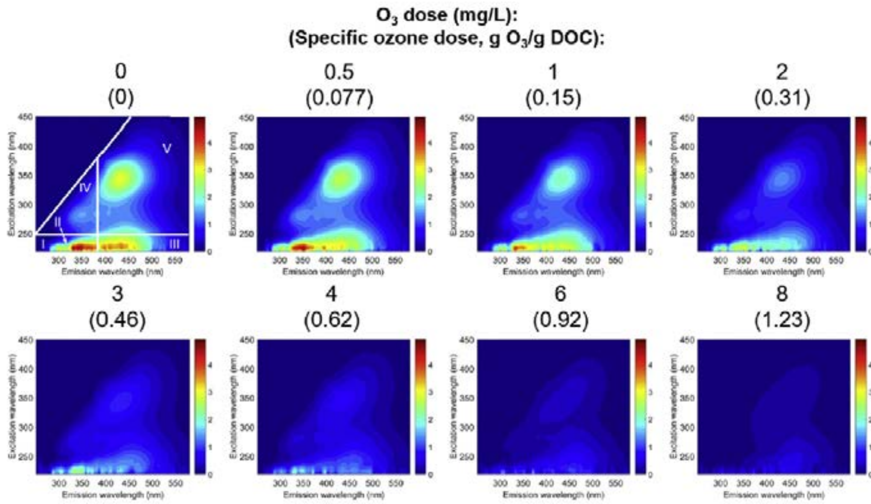

Figure 5. Excitation-emission matrix (EEM) change with respect to ozone dose

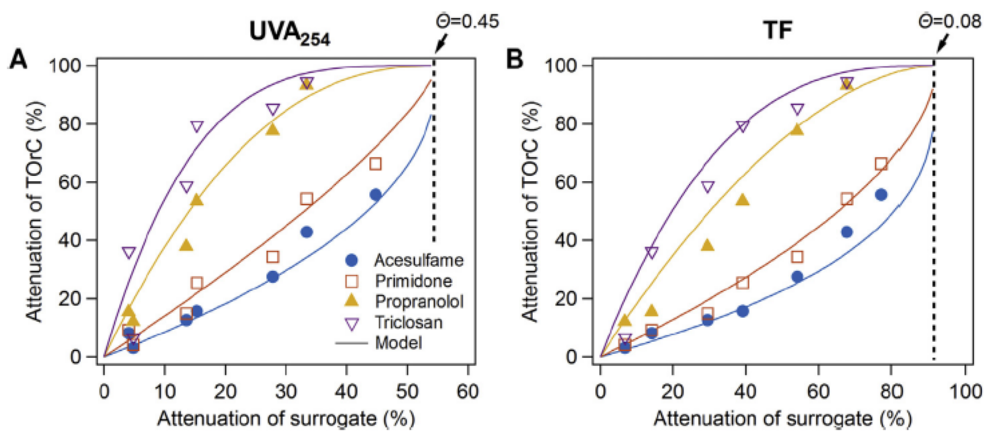

Figure 6. Surrogate model prediction of TOrC attenuation in ozone oxidation of secondary wastewater effluent (Park et al. 2017a).

3. Management, communication, and quality assurance plans

Project management is a dynamic process that involves communication, planning, monitoring, QA/QC, and cost and schedule management in order to meet project objectives. The PIs for the prosed work are Dr. Minkyu Park and Professor Shane Snyder, both of which have many years of water research experience to successfully achieve the research and technical goals. In addition, each team member will have accountability and responsibility for specific tasks, deliverables with clearly assigned milestone dates, and a consultation role through their ongoing involvement in the project.

For quality assurance, sampling protocols for chemical analysis and bioassay will follow previously published work (Anumol et al. 2013, Anumol and Snyder 2015, Jia et al. 2015, Merel et al. 2015). In addition, our team has developed a new large-volume direct injection (LVI) method (Anumol et al. 2015). We propose to use only on-line SPE (OSPE) and LVI for the suite of TOrCs shown in Table 1. These methods save time and resources by relying only on a few mL of water and avoid the labor intensive and error-prone conventional SPE and necessary sample preparation manipulations. To complement ion suppression, isotope-dilution methodology will be implemented for the analytes. In addition, we recommend one set of true triplicate samples from each sampling event along with two field blanks.

Table 1 List of TOrCs to be monitored

Analyte	Class*	Online solid phase extraction MDL (ng/L)	Large volume injection MDL (ng/L)
Acesulfame	HC	-	4
Atenolol	Pharm	2.5	-
Atrazine	Pest	0.3	37
Benzophenone	PCP	11.3	-
Benzotriazole	I/CC	10.8	-

Analyte	Class*	Online solid phase extraction MDL (ng/L)	Large volume injection MDL (ng/L)
Bisphenol A	HC/I/CC	13.1	-
Caffeine	HC	0.5	8
Carbamazepine	Pharm	0.1	3
Clofibric acid	Pharm	0.7	-
DEET	PCP	0.3	34
Diclofenac	Pharm	2.8	14
Diphenhydramine	Pharm	0.9	7
Ditiazem	Pharm	0.2	-
Fluoxetine	Pharm	3	-
Gemfibrozil	Pharm	0.5	23
Hydracortisone	Pharm	9.3	-
Hydrochlorothiazide	Pharm	0.4	15
Iohexol	I/CC	-	13
Iopromide	I/CC	-	39
Ibuprofen	Pharm	1.9	-
Meprobamate	Pharm	0.4	8
Naproxen	Pharm	2.5	-
Norgestrel	S/H	11.6	-
PFHxA	PFC	3.6	-
PFOA	PFC	3	-
PFOS	PFC	6.1	-
Primidone	Pharm	2	9
Propranolol	Pharm	1.2	-
Propylparaben	PCP	1.4	-
Simazine	Pest	0.4	-
Sucralose	HC	-	302
Sulfamethoxazole	Pharm	0.5	5
TCEP	PCP/HC	2.1	20
TCPP	PCP/HC	9	22
Testosterone	S/H	4.4	-
Triclocarban	PCP	1.1	14
Triclosan	PCP	2.6	15
Trimethoprim	Pharm	0.1	11

* HC: Household chemical; I/CC: Industrial/commercial chemical; PCP: Personal-care product; Pest.: Pesticide; PFC: Perfluorinated compound; Phar.: Pharmaceutical; S/H: Steroid/Hormone

OPTIONAL STUDIES:

Based on recent joint discussions between IXOM and Singapore PUB, a desire to investigate phosphate and virus removal were discussed. If desired by IXOM, phosphate removal and virus removal studies can be added either at bench or pilot scale if resources allow.

4. Schedule and deliverables

Our proposed project schedule is summarized in Figure 7. While the total project will be completed within 12 months, the first 3 months will focus on experimental planning and setup of treatment processes. Once the treatment systems are setup, their evaluation, chemical analysis and bioassay will be proceeded to demonstrate the feasibility of the proposed treatment schemes (Tier 1) and toxicological evaluation of the treated waters (Tier 2). Subsequently, the development of surrogate model will be studied for the following two months (Tier 3). As deliverables, a progress report will be drafted and delivered for the first 6-month progress and final report will be delivered at the end of the project.

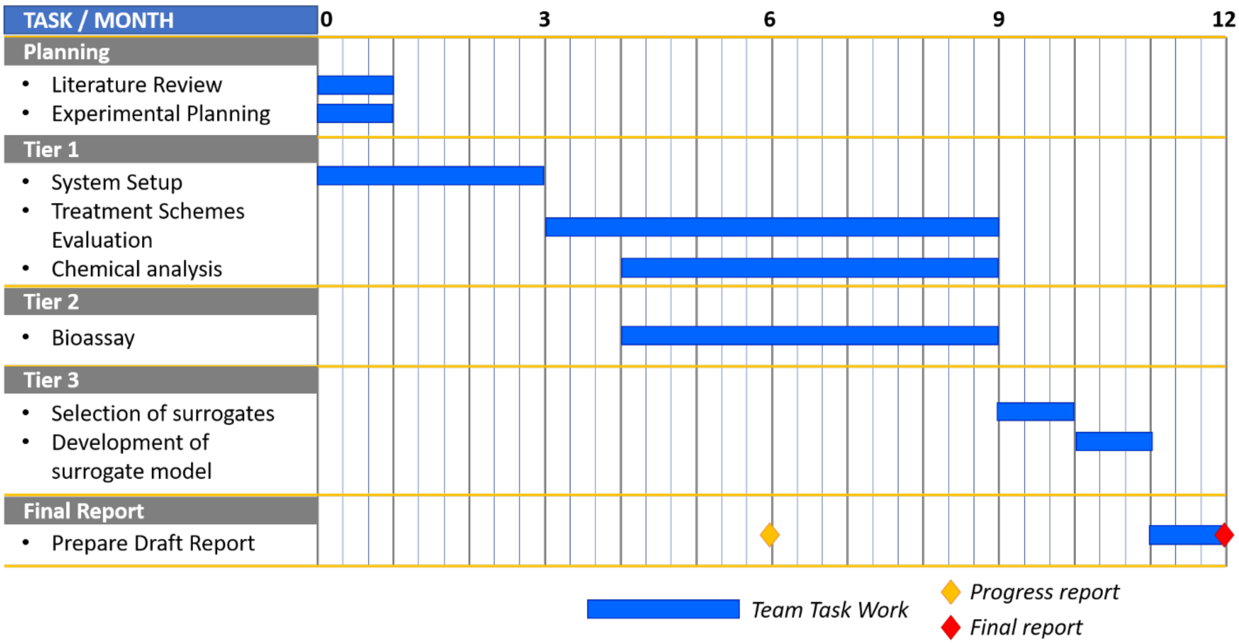

Figure 7. Proposed timeline

5. Budget narrative

5.1. Senior Personnel

The Principal Investigator (Professor Shane Snyder) holds a 9-month academic appointment in the Department of Chemical and Environmental Engineering at The University of Arizona (UA). Professor Snyder will oversee the UA portion of the proposed research and be ultimately responsible for all report and manuscript writing for the proposed project. The Co-Principal Investigator (Dr. Minkyu Park) is a Post-Doctoral Research Fellow at the WEST Center and will direct the day to day operations and data analyses.

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APPENDIX G – VSEP RUN DATA

IXOM WATERCARE

DL Tippin Water Treatment Plant

Waste Brine VSEP Pilot Plant Operation Log Sheet

Date	Time	Operation	Vibration Amplitude	Feed Target Pressure	Initial Feed Vol	Curr Feed Vol	Total Recovery	Feed Flow	Feed Pressure	Permeate Flow Volume	Permeate Flow Time	Permeate Flow Flow	Permeate Flux	Concentrate Flow	Concentrate Flow	Concentrate Pressure
			(inch)	(psig)	(gal)	(gal)	(%)	(mL/min)	(psig)	(mL)	(sec)	(mL/min)	(GFD)	(gpm)	(mL/min)	(psig)
1/31/2018	10:21	Start Up	1/2	350	205	205	0.0%	11355	346					3.0	11355	330
	10:28	Perm Flow Check/Sample						13535	348	2180	60	2180	16.59	3.0	11355	
	10:40	Increase amplitude	3/4											3.0	11355	
	10:46	Perm Flow Check												3.0	11355	
	11:05	~10% Recovery Check	3/4			180.0	12.2%	13535	348	2180	60	2180	16.59	3.0	11355	330
	11:13	Paused to retorque						11355						3.0	11355	
	11:25	Increased pressure	3/4	400				11355	406					3.0	11355	390
	11:35	Perm Flow Check	3/4					14036	410	2681	60	2681	20.40	3.0	11355	
	11:47	~20% Recover Check	3/4			160.0	22.0%	14095	408	2740	60	2740	20.85	3.0	11355	390
	12:15	~30% Recovery Check	3/4			140.0	31.7%	14036	410	2681	60	2681	20.40	3.0	11355	390
	12:44	~40% Recovery Check	3/4			120.0	41.5%	14080	416	2725	60	2725	20.73	3.0	11355	400
	13:13	~50% Recovery Check	3/4			100.0	51.2%	14090	418	2735	60	2735	20.81	3.0	11355	300
4/9/2018	14:37	Start Up	1/2	400	230	230	0%	11355	400					3.0	11355	
	14:44	Perm Flow Check				220.0	4%	15075	400	1240	20	3720	28.31	3.0	11355	
	14:57	Perm Flow Check				210.0	9%	15075	400	1240	20	3720	28.31	3.0	11355	
		~10% Recovery Check	1/2			200.0	13%		400					3.0	11355	
	15:07	Paused to retorque														
	15:18	Restart														
	15:30	Perm Flow Check	1/2					14910	400	1185	20	3555	27.05	3.0	11355	
	15:38	~20% Recover Check				180.0	22%									
		~30% Recovery Check	1/2			155.0	33%	14805	400	1150	20	3450	26.25	3.0	11355	
		~40% Recovery Check	1/2			130.0	43%	14613	400	1629	30	3258	24.79	3.0	11355	
		~50% Recovery Check	1/2			115.0	50%									

IXOM WATERCARE

DL Tippin Water Treatment Plant

Waste Brine VSEP Sample Results

Date	Sample	% Recovery	DOC mg/L	Chloride mg/L	Sodium mg/L	Conductivity mS/cm	TDS mg/L
1/31/2018	Feed	--	2,581	35,450	20,833	85.30	67,896
	Permeate	12%	120	26,942	13,350	68.59	44,189
	Permeate	20%	85	26,588	13,400	66.61	44,975
	Permeate	30%	136	28,360	14,900	71.52	46,250
	Permeate	40%	126	30,487	14,500	75.17	49,123
	Permeate	50%	146	31,905	14,600	78.00	52,292
	Concentrate	12%	3,518	31,905	21,000	83.91	75,334
	Concentrate	20%	3,815	33,678	21,800	85.12	118,136
	Concentrate	30%	4,253	34,032	21,950	93.49	86,354
	Concentrate	40%	4,900	34,741	24,200	95.13	89,114
	Concentrate	50%	5,845	34,741	23,350	99.08	96,734
4/9/2018	Feed	--	5,150	37,223	24,140	74.84	69,264
	Permeate	10%	213	28,360	18,392	66.58	41,642
	Permeate	20%	304	26,942	17,472	67.75	59,062
	Permeate	30%	262	28,360	18,392	69.38	45,200
	Permeate	40%	286	26,942	17,472	71.55	45,876
	Permeate	50%	220	29,778	19,312	73.25	59,948
	Concentrate	10%	9,750	37,223	24,140	81.62	114,326
	Concentrate	20%	12,125	31,905	20,691	82.89	87,446
	Concentrate	30%	13,375	31,905	20,691	84.96	89,866
	Concentrate	40%	13,450	31,905	20,691	85.31	99,004
	Concentrate	50%	17,850	35,450	22,990	74.51	106,860

APPENDIX H – IXOM PROPOSAL

PRELIMINARY INFORMATION DOCUMENT FOR

CITY OF TAMPA
100 AND 140 MGD MIEX® SYSTEMS

DATE: 19th April 2017

DOCUMENT No: MR-2017-001

Revision: 2

Rev History

Rev	Status	Date	Prepared	Checked	Approved
0	Issued	10-Feb-2017	S. Mitchell	E Gaby	S Mitchell
1	Revised. Waste Brine Treatment	3-Mar-2017	S. Mitchell	E Gaby	S Mitchell
2	Revised, Updated operating costs	17-April-2018	M. Larson	S. Mitchell	S. Mitchell

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SECTION 1: OVERVIEW

Carollo Engineers has been engaged by the City of Tampa to investigate the feasibility of a 108 or 140 million gallon per day (MGD) MIEX® Treatment Systems at the David L. Tippin Water Treatment Plant (WTP), Tampa, FL.

As part of this investigation study, Carollo has requested Ixom provided some preliminary information relating to the MIEX Systems, namely the following items:

1. Overall preliminary MIEX system potential layout:
    - Option 1 – 108 MGD average daily flow, 140 MGD maximum daily flow
    - Option 2 – 77 MGD average daily flow, 100 MGD maximum daily flow
2. Equipment and Initial Resin Inventory budget for the two plant sizes
3. Waste brine rates for average and max conditions
4. Waste brine composition
5. Pilots available (see Attachments)
6. Examples of resin supply agreements (See Attachments)
7. Example of Parent Company Support for building U.S. Resin Manufacturing
8. Statements regarding IP position for MIEX® DOC and Gold resins
9. Technical Note on Exposure to Oxidants (see Attachments)
10. Technical Note on Salt for MIEX resin
11. Information on Third Party Reuse / Treatment of Waste Brine

SECTION 2: BACKGROUND

2.1 General

The purpose of this document is to present Carollo Engineers with general system information in conjunction with budget equipment costs for a 108 and 140 MGD MIEX® Treatment Systems. The MIEX® High Rate system is designed to pre-treat City of Tampa's current coagulation / filtration plant in order to reduce chemical demand, reduce residual sludge, and to decrease treated water organics and bromide. The plant design (max) flows evaluated in this document are 100 and 140 MGD plant capacities. The contents of this preliminary proposal cover:

- Assumed MIEX® system design basis (i.e. operating parameters).
- Some design parameters are based on results from the MIEX® feasibility testing conducted by Ixom/Carollo
- General process information.
- MIEX® process equipment details and operational costs.
- Budget estimate of MIEX® plant equipment.
- Preliminary plant layout drawings

2.2 MIEX® Resin

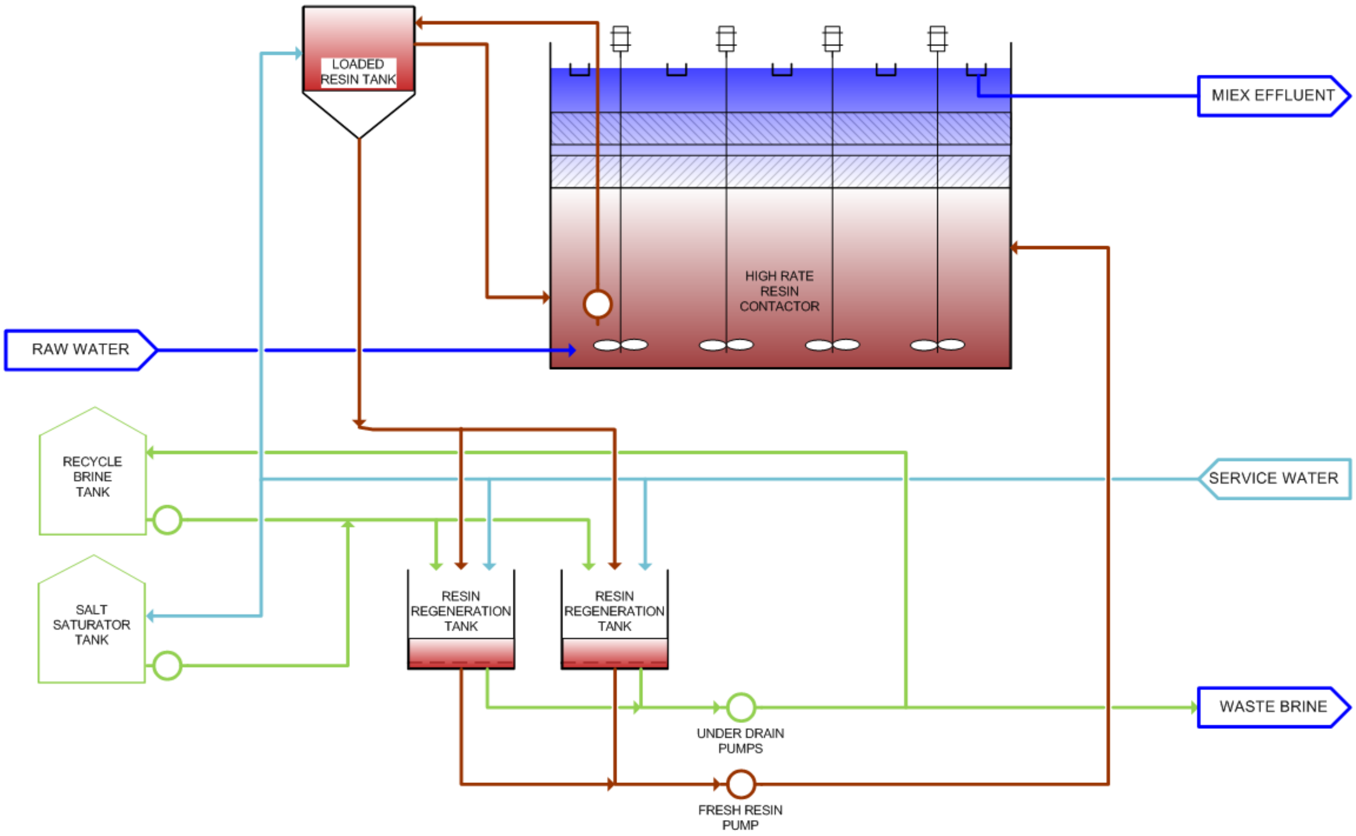
The name "MIEX®" comes from **M**agnetic **I**on **EX**change, because the ion exchange resin beads contain a magnetized component within their structure that allows the beads to act as weak individual magnets. The very small resin bead size of around 180-200µm provides a high surface area allowing rapid Dissolved Organic Content (DOC) attachment.

MIEX Resin has been specifically designed for the removal of DOC from drinking water sources. Negatively charged DOC ions are removed by exchanging with a chloride ion on the resin surface. This results in a reduction in the DOC level and a small increase in the treated water chloride level. In the regeneration process, resin loaded with DOC undergoes a reversed ion exchange reaction, where the resin substitutes chloride ions for DOC, which is released from the resin into a concentrated salt/brine (NaCl) solution. A general flow schematic of the MIEX Treatment process is given below.

MIEX Resin is certified by the NSF for use in drinking water systems under the provisions of the ANSI/NSF Standard 61: Drinking Water System Components - Health Effects. In addition, all MIEX Resin is produced in ISO 9001 registered manufacturing facilities

Ixom Watercare manufactures several products used specifically for fluidized ion exchange processes. MIEX® DOC and MIEX® Gold are two Strong Base Anion Exchange resins, both with methacrylate, macroporous matrices. Both products display excellent resistance to organic fouling, but with separate affinities to varying molecular weight fractions. Both resins have good resistance to oxidants (see Tech Note on Exposure to Oxidants).

Figure 1: MIEX Process Schematic



SECTION 3: TECHNICAL PROPOSAL

3.1 Treatment Plant Capacity Requirements

Preliminary design parameters for this system are based on results from the MIEX pilot study conducted from August 2017 to March 2018.

Table 1 – MIEX System Capacities

Parameter	Units	Design 1 (100 MGD)	Design 2 (140 MGD)
Maximum Daily Flow Capacity	MGD	100.0	140.0
Average Daily Flow Capacity	MGD	77.0	108.0
Regeneration Rate: High TOC Period	BV	600	600
Regeneration Rate: Low TOC Period	BV	1000	1000

3.2 Resin Contactor Basins

3.2.1 Basin Size and Configuration

NOTE: The proposed configuration summarized in this document is based on a standard high rate MIEX System configuration. There is also potential for an 'Integra' option (not detailed in this document), which would involve retro-fitting out an existing coagulation/sedimentation basin.

The proposed number of contactor basins required for treating up to the maximum design flow rates are detailed below. Overall basin area is designed based around an effective upflow rate of ~±8.0gpm/ft². The maximum size of an individual basin recommended (based on current designs) is ~30ft x 30ft which equates to 10MGD capacity per basin.

Table 2 – Contactor Basins (High Rate Configuration)

Parameter	Units	Design 1 (100 MGD)	Design 2 (140 MGD)
Number of Contactor Basins	Qty	10	14
Contactor Basin Area	ft x ft	30 x 30	30 x 30
Contactor Internal Depth [1]	ft	22.0	22.0
MIEX Resin Concentration	mL/L	200	200
Overall Hydraulic Head Loss [2]	ft	2.5 – 3.0	2.5 – 3.0
Plate Settler Loading Rate	gpm/ft²	0.8 - 1.0	0.8 - 1.0

Notes:

1. Site hydraulic requirements will often factor in determining the overall basin height. Basin internal dimensions.

2. Vessel hydraulic head loss figure for internal equipment only. Other allowances for influent flow weir / gates, effluent channel losses etc will need to be accounted for.

During times of low flow, each contactor can be operated as low as 30% capacity for treatment, or alternatively some basins could be taken offline for longer durations of lower capacity (will save on power costs). It will be necessary to continually rotate the use of contactor vessels, to prevent water and resin in offline basins from becoming stagnated and/or fouled. Alternatively, lay up procedures will be provided.

3.2.2 Internal Equipment

Each contactor vessel (square concrete basin construction) is fitted with the following main internal components:

1. Influent Distributor Pipes: Installed in the base of the basin/tank; their main function is to evenly distribute water across the area of the vessel so that the MIEX Resin is evenly fluidized (i.e. creating an up-flow) and water does not short circuit.
2. Inclined Plate Settler Modules: Inclined plate settler modules are used to capture (and settle) resin particles that escape the fluidized resin bed. Resin captured settles on the plates, and drops back into the resin bed below (same principal where tubes/plates or tubes are used in sedimentation basins for conventional treatment plants).
3. Effluent Troughs: Effluent troughs are used to collect effluent and discharge into a common effluent outlet.
4. Agitators: Mixers / Agitators are used to help with flow and resin distribution and to keep the resin fully suspended in times of lower flow. Agitators are VFD controlled so their speed can be adjusted based on raw water flow.
5. Loaded Resin Tank Air-lift Pump: Each basin is fitted with a loaded resin air-lift pump to supply the Loaded Resin Tank, which is used as a feed supply for the regeneration system.
6. Sampling System: A sampling system is used to take resin concentration samples from each vessel by an operator.
7. Basin Access Ladder: Allows access to basin for general inspections (NOTE: A basin wall side access hatch is helpful - especially during construction).

3.2.3 Other Considerations and Items

A. Raw Water Distribution to Basins: Raw water could be distributed to each basin via a common piping header, with smaller branch pipe to each basin. Each basin would likely require an on/off actuated valve for flow control, and potentially a flowmeter.

B. Effluent Collection from Basins: Treated effluent from all the basins could be directed into a common effluent channel, which directs water to downstream treatment. This effluent channel would be part of the large overall basin concrete structure.

C. Contactor Basin Covers: It's likely that the basin will require cover(s). A super structure will be required to span the basin to support such covers, and also could be used for mounting the agitator units.

D. Access to Top: Access (i.e. stairs) to top of the basins will be required, handrailing etc.

E. General: Wash down hoses (1.5-2.0in size) to reach all basin area from up top; area lighting; safety shower/eyewash.

3.3 Regeneration System

3.3.1 Equipment Components

The regeneration system is designed to remove DOC from the resin by exchanging it with chloride ions utilizing a salt brine solution (NaCl). The majority of the regeneration equipment ideally would be installed inside a process building. Some associated tanks are suitable for an outdoor location adjacent to the building. The main regeneration components are:

A. Regeneration Tanks: Resin is loaded into the tank, and the overall regeneration process takes place. At the end of the cycle, the regenerated or fresh resin is then transferred out of the tank back to the contactor vessel(s). All of the tanks act independently of each other, and at any one time all tanks could be in use. The tanks are typically a circular fiberglass construction.

B. Regeneration Equipment Skid Modules: Each tank has an equipment skid module that has various control valves, piping, pumps, instruments and electrical panel. The skid modules are fully shop fabricated and are stacked end on end based on the number required to achieve the required treatment rate.

C. Recycle Brine Tank, Instruments, Pumps: Brine (salt) is used as the regenerant to remove DOC off of the resin. Brine is pumped from storage to the regeneration tanks during the process. A portion of the brine is wasted (with a DOC purge), and the remaining brine can be recycled back to the tank.

D. Salt Saturator Tanks, Instrument, Pumps: Saturated salt is used as make-up for the brine solution that is rejected with the DOC stream purge. Solid salt (i.e. solar grade) is delivered into the saturator tanks, where water is added to dissolve salt forming a saturated solution. As part of the regeneration cycle, liquid saturated salt in transferred to the regeneration tanks. The tank is typically a circular fiberglass construction; solid salt in blown into the tank and several tanks would be required. See attachment for Technical Note on Salt.

3.4 Configuration and Capacity

The regeneration system would be sized to treat the below daily quantities of resin. The daily quantities are based on the maximum regeneration rate of 600 BV. Based on the daily (maximum) demand, a required number of regeneration tanks are needed to treat the necessary total daily volume.

Given the overall number of regeneration tanks required, it would be best to group them into groups of four (4) tank sets that operate together, and are independent of all the other regeneration tanks / sets.

Table 3 – Regeneration System Equipment

Parameter	Units	Design 1 (100 MGD)	Design 2 (140 MGD)
Regeneration Rate (max)	BV	600	600
Resin Volume Regenerated	gal/day	167,000	233,800
No. of Regeneration Vessels	Qty	12	16
No. of 4 x Regen Tank Sets	Qty	3	4
Regeneration Vessel Size	ft x ft	13.0 (ID) x 10.0 (H)	13.0 (ID) x 10.0 (H)
Recycle Brine Tanks	Qty	2	3
Recycle Brine Tanks - Capacity	gal (ea)	20,000	20,000
Salt Saturator Tanks	Qty	4	6
Salt Saturator Tanks - Capacity	Tons (ea)	80	80

3.5 Consumables

A MIEX Treatment system has three (3) main consumables:

- Make-up MIEX Resin replacement
- Salt for resin regenerations
- Power

3.5.1 MIEX Resin

Small amounts of resin that have broken down / attrited as part of the process are carried over in the treated effluent. It's expected that this carry over rate of resin will be in the range of 1.0 to 1.5 liters resin per 1 million liters treated (1.0 – 1.5 gal/MG) based on current plant designs and resin in use.

For a plant of this capacity, and assuming a carry-over rate of 1.2 gal/MG at the maximum daily rate, plant staff / PLC would add an entire resin tote (238gal resin) per addition:

- 100 MGD Plant: Every 2.0 days
- 140 MGD Plant: Every 1.4 days

3.5.2 Salt

Based on the MIEX System Design Parameters outlined above and the addition of a waste brine recovery process (~30% salt savings), the expected net salt consumption is ~260 lb/MG treated at 1000 BV treatment rate and ~440 lb/MG treated at 600BV treatment rate. This equates to a daily usage of (at design capacities):

- 100 MGD Plant:
  - High TOC Period: ~21.9 tons/day
  - Low TOC Period: ~13.1 tons/day
- 140 MGD Plant:

- o High TOC Period: ~30.6 tons/day
- o Low TOC Period: ~18.4 tons/day

Currently for all large MIEX Systems in the USA, salt it delivered via tanker loads (~25 tons), and solid dry salt is air blown into storage vessels. Assuming a site storage capacity of ~15 days (with waste brine treatment & salt recovery), would require the following number of bulk salt tanks:

- 100 MGD Plant: 4 x 80 Ton tanks (at full plant capacity)
- 140 MGD Plant: 6 x 80 Ton tanks (at full plant capacity)

With this many tanks, there will be variation in the levels of salt that need to be monitored, and tanks in use rotated accordingly. The use of an intermediate common liquid saturated salt would likely be required, which the regeneration tanks would draw from, rather than all from the bulk tanks.

3.5.3 Power

The majority of the power consumption come from motor drives. The expected drive sizes (HP), and percentage utilizations of drives (i.e. how much used over 24 hrs) are summarized below, with a total estimated power usage (kW.hr).

Table 4 – Raw Water Envelope for MIEX Design

Parameter	Units	Design 1 (100 MGD)	Design 2 (140 MGD)
Contactor Agitators (9 per basin)	HP	90 x 1.0 HP	126 x 1.0 HP
Regeneration Tank Agitators	HP	12 x 2 HP	16 x 2 HP
Fresh Resin Pumps	HP	3 x 10 HP	4 x 10 HP
Recycle Brine Pumps	HP	3 x 7.5 HP	4 x 7.5 HP
Saturated Salt Pumps	HP	3 x 2.0 HP	4 x 3.0 HP
Compressed Air (High Pressure)	HP	3 x 75 HP	4 x 75 HP
Virgin Resin Booster Pump	HP	1 x 2 HP	1 x 2 HP
Total Connected Power [1, 2]	**HP**	**~403**	**~542**
Estimated Avg Usage (MDF) [2]	**kW.hr**	**~185**	**~267**

NOTE:

1. Power loads do not include the like of low voltage (120V) for likes of control for SCADA, PLC's, I/O etc. Power considerations for like of new building(s), HVAC, area lighting etc. required.
2. At design maximum daily flow.

3.6 Services

3.6.1 Process Water

Process (or potable water) is used as part of the MIEX Process for make-up water, rinse water etc. for the regeneration process at various times. Overall <1% of plant overall capacity is used. The majority of process water used is not lost, as it gets re-processed through the MIEX Regeneration System.

3.6.2 Compressed Air

The MIEX Process uses compressed air for:

- Loaded resin air lift pumps (low pressure).
- Contactor sample pumps (low pressure).
- Regeneration tank underdrain pumps (high pressure)
- Air actuated valves (high pressure).

For the lower pressure applications, rather than use high pressure air (i.e. compressors) and have to then throttle down pressure and waste energy, overall it is likely more economical to use blower(s) for this application. As outlined in the table above, the use of multiple smaller units to achieve the required demands rather than single larger units which would be less efficient to operate when plant capacity is turned down.

3.7 Waste Brine

3.7.1 Volumes

As part of the regeneration systems, a waste brine stream (non-hazardous) with concentrated DOC and salt requires disposal of. Most common methods of disposal is discharge to a suitable sewer connection, deep well injection, or 3rd party reuse. A treatment and off-site disposal options are further outlined below.

Based on the MIEX System Design Parameters outlined above, the expected waste brine generation is 400-450 gal per 1 MG water treated (at 1000 BV) and 667-750 gal per 1MG water treated (at 600BV). Daily expected waste brine volume are given below (volumes are proportional to flow):

- 100 MGD Plant:
  - High TOC Period: 66,700 – 75,000 gal/day (600BV)
  - Low TOC Period: 40,000 – 45,000 gal/day (1000 BV)
- 140 MGD Plant:
  - High TOC Period: 93,000 – 105,000 gal/day (600BV)
  - Low TOC Period: 56,000 – 63,000 gal/day (1000 BV)

3.7.2 Composition

Waste brine will consist mainly of salt and concentrated DOC, plus some other contaminants that are slightly removed by the resin and concentrated in the waste stream.

Table 5 – Waste Brine Composition

Parameter	Units	Range
Salt	mg/L	40,000 – 90,000
pH		6.5 – 8.5
DOC	mg/L	5,000 – 15,000

3.7.3 Waste Brine Treatment and Salt Recovery

For the waste brine regenerated, it is proposed that it would all be treated with an industrial nano-filtration (NF) system. An NF system will allow the majority of monovalent ions (i.e. chloride ions) to pass through the membrane and separate them from larger ions (i.e. dissolved organics). This will produce a mostly clean permeate stream concentrated with chlorides and a waste concentrate stream concentrated with organics and other larger ions.

The clean permeate stream can be reused again in the MIEX system i.e. added back to the salt saturator vessels in lieu of make-up water, which saves on overall salt consumption, and a reduced volume of waste is disposed. Overall testing has previously shown that operating an EcoRegen system will result in around 30-32% net salt savings.

The NF concentrate waste, will all be tankered off-site to a disposal facility (by BORAC) that can extract the organics materials and into a usable solid for fertilizer application. Overall volumes summarized below at an assumed overall plant average treatment rate of 800BV.

Table 6 – Waste Brine Volumes & Treatment

Parameter	BVTR	Total Waste NF Treated (gal/day)	NF Permeate (Recovered Salt) (gal/day	NF Concentrate (Waste DOC/Brine) (gal/day
100 MGD	600	75,000	30,000	45,000
	1000	45,000	18,000	27,000
140 MGD	6000	105,000	42,000	63,000
	1000	63,000	25,200	37,800

SECTION 4: IXOM SCOPE OF SUPPLY

4.1 Process and Equipment Design Documentation

As part of the MIEX System process design, the following types of standard design documentation will be provided in Ixom standard supply formats:

Specification Documents:

- Specification – Process Description, Design Basis and Scope
- Specification – Responsibilities Matrix
- Specification – Control System Functional Description & Sample HMI Screens
- Specification – Performance Verification
- Specification – Start-up / Process Commissioning Plan
- Equipment Data sheets (Ixom forms)

Schedule Documents:

- Schedule – Ixom Equipment Summary
- Schedule – Ixom Valve Summary
- Schedule – Ixom Instrument Summary
- Schedule – Ixom Drive Load Summary
- Schedule – Ixom I/O List

Drawings:

- Process Flowsheet Mass Balance
- Process & Instrumentation Drawings (w/ scope breaks)
- Hydraulic Profile Schematic (Line Type)
- Vessel drawings and arrangements views
- Equipment skids arrangement views
- Overall Site Layout and Arrangement Views
- Overall Site Interconnecting Piping (Schematic Lines)
- Electrical panels layout and wiring

4.2 High Rate Resin Contactor Vessel

Supply of internal equipment for concrete Contactor Basins (constructed by others). Each basin supplied with the following internal equipment (all site installed equipment by others):

1. Set of Influent distributor pipes and supports. Constructed from stainless steel piping and fittings.
2. Set of set of plastic tube settlers or incline plate settler modules, and necessary internal support structure for mounting. Constructed from all stainless steel; 5 to 6 modules per basin.

3. Set of top mounted agitators (with standard TEFC motor, gearbox, 316 stainless steel shaft and impeller). Total of nine (9) agitator units per basin.
4. Contactor loaded resin air-lift pump components. One (1) per basin.
5. Contactor sample air-lift pump components. One (1) per basin.
6. Basin access ladder constructed from FRP. One (1) per basin
7. Basin high level switch. One (1) per basin

4.3 Loaded Resin Tanks

Loaded resin tanks are part of the overall contactor basin construction (BY OTHERS). Supply of some associated components fitted with concrete tanks:

1. Tank high level switch. One (1) per basin.
2. Air Actuated Process Valves: A set of air operated actuated valves for each resin vessel; valves constructed from PVC / EPDM.
3. Manual Process Valves: A set of manual operated valves; valves constructed from PVC / EPDM

4.4 Resin Regeneration System

4.4.1 General

The following equipment will be part of the packaged regeneration systems supplied by Ixom. Site setting and installation of skid modules BY OTHERS.

4.4.2 Tank Module Sets

Depending on the system capacity, three (3) or four (4) tank sets are required; with each set consisting of four (4) individual tanks that are connected as a system. Each individual regeneration tanks consists of the following:

1. Resin Regeneration Vessel: One (1) regeneration vessels of approximate dimensions 13.0.ft (ID) x 10.0ft (H) constructed from FRP.
2. Vessel Agitator: One (1) regeneration vessel agitator units (with standard TEFC motor, gearbox, 316 stainless steel shaft and impeller).
3. Underdrain Pump: One (1) air-operated, non-metallic diaphragm underdrain pump used for separating resin / liquid, constructed from plastic.
4. Level Transmitter: One (1) vessel radar level transmitter.
5. Conductivity Probe: One (1) conductivity probes and transmitters for the vessel underdrain system.
6. Air Actuated Process Valves: A set of air operated actuated valves for each resin vessel; valves constructed from PVC / EPDM.
7. Manual Process Valves: A set of manual operated valves; valves constructed from PVC / EPDM.
8. Skid Frame: One (1) aluminum constructed skid frame for mounting vessels, mixers, instruments, valves, pumps, associated piping and controls. Regeneration skid may be fitted with access stairs and platform with handrails, kick plates, etc. for viewing into regeneration tanks.

9. Resin Process Piping: One (1) set of piping for resin duties on the regeneration skid to distribute resin to and from the regeneration vessels. Piping and fittings constructed from Sch 80 PVC.
10. Brine Process Piping: One (1) set of piping for brine duties on the regeneration skid to distribute brine to and from the regeneration vessels. Piping and fittings constructed from Sch 80 PVC.
11. Service Water Piping: One (1) set of piping for service water duties on the regeneration skid to distribute service water to and from the regeneration vessels. (NOTE: Service water connection supplied BY OTHERS).
12. Service Air Piping: One (1) set of piping/tubing for service air duties on the regeneration skid to distribute compressed air to applicable skid/vessel services. Pipe/tube and fittings constructed from stainless steel and poly tubing

4.4.3 Fresh Resin Pump Skids

With each set of four (4) tanks, systems are supplied with one (1) fresh resin pump skid consisting of:

1. Fresh Resin Pump: One (1) low shear pump skid for transferring fresh resin from the regeneration vessels to the contractor inlet (NOTE: This is a common pump skid for all tanks).
2. Pump Pressure: One (1) common pump discharge pressure transmitter.
3. Discharge Conductivity: One (1) common pump discharge conductivity probe and transmitter.
4. Air Actuated Process Valves: A set of air operated actuated valves for each resin vessel; valves constructed from PVC / EPDM.
5. Manual Process Valves: A set of manual operated valves; valves constructed from PVC / EPDM.
6. Skid Frame: One (1) aluminum constructed skid frame for mounting pump, valves, instrument and associated piping.

4.4.4 Access and Walkway Platform

With each set of four (4) tank sets, system are supplied with one (1) common access stairs and walkway platform:

1. One (1) fabricated set of access stairs constructed from structural aluminum members, aluminum handrail components and GRP grid stair treads.
2. One (1) common tank walkway / access platform constructed from structural aluminum members, aluminum handrail components and GRP grid walkway grating.

4.5 Recycle Brine Tanks and Components

Depending on the system capacity, two (2) or three (3) sets of equipment for brine tanks and transfer pump(s) are supplied. Tanks to be installed on concrete foundation BY OTHERS. Transfer pump(s) and associated piping/valves will be supplied loose for site installation BY OTHERS. Each brine tank system will consist of:

1. One (1) ~20,000 gal recycle brine tank with all required nozzles constructed from FRP or HDPE.
2. One (1) brine tank ultrasonic or pressure level transmitter.
3. One (1) brine tank high level switch.
4. One (1) magnetic drive centrifugal pumps for transferring recycle brine to the resin regeneration module.
5. One (1) recycle brine tank/piping conductivity sensor and transmitter.
6. One (1) set of air operated actuated valves with position feedback for associated recycle brine tank piping; valves constructed from PVC / EPDM.
7. One (1) set of manual valves for associated brine tank piping; valves constructed from PVC / EPDM

4.6 Salt Saturator Tank and Components

Depending on the system capacity, four (4) or six (6) sets of saturated salt tanks and transfer pump(s) are supplied. Tanks to be installed on concrete foundation BY OTHERS. Transfer pump(s) and associated piping/valves will be supplied loose for site installation BY OTHERS. Each saturator tank system will consist of:

1. One (1) 80 Ton salt saturator vessel with all required nozzles constructed from FRP. Vessel of flat bottom and domed top design; with access ladder; necessary internal components; translucent strip; anchor chairs or tie downs; lifting lugs; dust collection bag.
2. One (1) magnetic drive centrifugal pumps (duty / standby) for transferring saturated brine to the resin regeneration module and Reuse Brine Tank.
3. One (1) pressure level transmitter for controlling water flow to saturator.
4. One (1) vessel high level switch.
5. One (1) set of air operated actuated valves with position feedback for the brine vessel skid; valves constructed from PVC / EPDM.
6. One (1) set of manual valves for the brine vessel skid; valves constructed from PVC / EPDM.

4.7 Waste Brine Treatment Equipment

One (1) set of equipment for treating waste brine from MIEX Process:

1. One (1) NF membrane package system for treatment waste brine from MIEX(r) System.
2. Necessary storage / holding tanks for waste brine, permeate (recovered brine), and concentrated waste DOC/brine reject.
3. Storage tank transfer pumps, level instruments and valves (for site installation)

4.8 MIEX Resin Addition Skid

One (1) MIEX resin handling system. MIEX resin pump and associated piping/valves will be supplied on an aluminum or stainless steel support frame:

4. One (1) resin container interface device with slurry attachment.
5. One (1) virgin resin educator for transferring from the tank to the resin regeneration module.
6. One (1) set of manual valves; valves constructed from PVC / EPDM.

4.9 Package Air Compressors

Package air compressors units (duty / stand-by type operation).

- Duty (100-MGD system): Three (3) of; approx. 75 HP each
- Duty (140-MGD system): Four (4) of; approx. 75 HP each

All supplied as lose items for site installation (by a general contractor). Each compressor unit will be comprised of:

1. One (1) package rotary screw air compressor and air receiver tank.
2. One (1) low sound enclosure.
3. One (1) coalescing pre-filter unit (prior to drying).
4. One (1) refrigerated air drier.
5. One (1) pressure transmitter to monitor supplied air pressure (common for all).
6. Other features; safety relief valve; high temperature shutdown, motor starter
7. One (1) set of manual piping and manual valves for compressor equipment. Valves constructed from stainless steel / EPDM.
8. Air compressors are supplied with internal motor starter and controls (only require a power feeds).

NOTE: The air compressor units are sized to provide compressed air demand for ONLY process components that are supplied by Ixom

4.10 Package Air Blowers

Package air blowers units:

- Duty (100-MGD system): Two (2) of; approx. 30 HP each
- Duty (140-MGD system): Two (2) of; approx. 25 HP each

All supplied as lose items for site installation (by a general contractor). Each blower unit will be comprised of:

1. One (1) package air blower.
2. One (1) low sound enclosure, with inlet and discharge silencers.
3. One (1) inlet pre-filter unit, and differential pressure indicator.
4. One (1) discharge pressure and temperature sensors.
5. One (1) pressure transmitter to monitor supplied air pressure (common for all).
6. Other features; safety relief valve; high temperature shutdown, motor starter
7. One (1) set of manual piping and manual valves for compressor skid equipment, installed on the skid frame. Valves constructed from stainless steel / EPDM. Valves will be three-piece ball with threaded ends.

4.11 Electrical Panels

4.11.1 Motor Control Panel

Motor controls center (MCC) for supplied drives are included in scope of supply by Ixom. Preliminary required motor control loads are listed above in previous section. These would be free-standing type MCC panels (not bucket type), with access door (3 to 4) per MCC panel. Panels supplied with:

- Motor drives, VFD's and controls as needed.
- Panel from VFD keypads with HOA type features.

4.11.2 Programmable Logic Control Panel

Supply of one (1) stand-alone Programmable Logic Controller (PLC) control panel which will house necessary PLC controls for the MIEX System alone. Supplied with:

- Power (120 VAC) supply / circuits.
- One (1) PLC processor, power supply and necessary communication cards.
- Necessary relays, terminals and other wiring devices.
- Ethernet switch for communications to motors/drives

Panel supplied as a loose items (not skid installed) for site setting BY OTHERS. Wiring and communications to remote I/O panels, drive VSD, and other plant connections all BY OTHERS.

4.11.3 Remote I/O Panels

Supply of necessary remote I/O panels for regeneration tank skids, recycle brine and salt saturator equipment, and resin contactor equipment. Panels contain:

- Power (120V VAC) supply / circuits for associated field equipment devices.
- I/O cards (analog, discrete) for necessary field equipment devices control signals.
- Necessary relays, terminals and other wiring devices.
- Pneumatic controls for field air actuated valves.
- Ethernet switch for communications.

The regeneration I/O panels are skid mounted with shop installed skid wiring. Other I/O panels are supplied a loose items for site installation and all field wiring to devices in BY OTHERS.

4.12 Initial MIEX Resin Inventory

Total MIEX Resin initial inventory requirements (for full plant capacities). MIEX Resin is supplied for the initial resin inventory sufficient for system start-up / commissioning, and currently in 1,000L totes (with 900L resin each).

1. Additional ongoing operating make-up resin is NOT INCLUDED.
2. Site unloading, storage and handling of resin BY OTHERS

4.13 Regeneration Salt

Salt for resin regeneration is NOT INCLUDED. Any and all initial / ongoing salt supply is BY OTHERS.

4.14 Equipment Spares

Currently no equipment spares are included in scope of supply and preliminary pricing provided. Ultimately, some shelf spares would be recommended.

4.15 Professional Design and Field Services

Included with equipment costs is engineering and field services for the overall project, for the likes of:

- System planning, design and review meetings with Engineer and City
- Full equipment design, drawings, detailing and submittal packages.
- Management of equipment procurement, fabrication and delivery to site
- Site presence for overviews / reviews of equipment installation (no actual installation of equipment included)
- Site presence for system start-up, testing and commissioning, operator training
- Full documentation, as built, OM manuals etc

4.16 General Equipment Comments / Clarifications

Skid/Frame Structure: Equipment skids are constructed from Aluminum unless otherwise specified. Some equipment and pipe supports on equipment skids may be constructed from 304 stainless steel.

Process Piping: Process piping and fittings that is pre-fabricated on equipment skids shall be constructed from:

- Sch 80 PVC for MIEX resin duties.
- Sch 80 PVC for brine duties.
- Sch 80 PVC for service water duties.
- Stainless steel 304 sch 10 pipe/fittings for compressed air (for main header line); and nylon or PP tubing for individual lines to equipment items (e.g. from electric solenoid valve to underdrain pump).

Coatings: Scope of supply is based on standard coatings/finishes provided by equipment suppliers (pumps, motors, instruments, etc.).

Anchors: All equipment skids and tanks are designed with footing pads and hold-down features. ALL anchors/hold down bolts, washers, nuts and grout for leveling equipment shall be BY OTHERS unless otherwise noted.

Electrical Assembly of Equipment Skids: Any equipment skids will be pre-wired in the shop as much as practical. Field wiring to equipment skids will be terminated in junction boxes / panels installed on the equipment skids.

SECTION 5: EXCLUSIONS AND SCOPE OF WORKS PROVIDED BY OTHERS

5.1 General

All the items listed in this Section and other Sections where scope has been identified as BY OTHERS or BY BUYER/CONTACTOR are equipment, items, scope, works etc. that are fully carried out by others in terms of supply necessary equipment, materials, consumables and labor to perform the required tasks.

5.2 Ixom Equipment Unloading / Site Setting

The following items or works have NOT BEEN INCLUDED:

1. The unloading, storage and handling of process equipment and resin items supplied by Ixom shall be BY OTHERS.
2. All labor, materials, consumables, construction facilities, site setting and installation of process equipment items supplied by Ixom shall be BY OTHERS.

5.3 Contactor Basins

The following items or works have NOT BEEN INCLUDED:

1. The design and construction of any concrete tanks/basins and foundations or other services required shall be BY OTHERS.
2. Installation of all Ixom supplied internal components shall be BY OTHERS
3. The design and construction of any buildings or structures to house the equipment supplied by Ixom shall be BY OTHERS.
4. The design, supply and installation of any covers, unless specifically noted shall be BY OTHERS.
5. The design, supply and installation of any equipment/component supports, unless specifically noted shall be BY OTHERS.
6. The supply and installation of any general equipment for general power outlets, visual lighting, electrical ground wiring and lightning conductors, etc. around the equipment and access stairs / walkways shall be BY OTHERS.
7. The supply and installation of any protective coatings on concrete foundation/structures that are installed by others shall be BY OTHERS.
8. Dissolved / entrained gas in the raw water feed shall be removed prior to entry into the MIEX System. Provision for gas removal (if required) shall be BY OTHERS.
9. Provisions for raw water grit or other foreign solid material removal (if required) shall be BY OTHERS.

5.4 Raw Water and MIEX Treatment Effluent

The following items or works have NOT BEEN INCLUDED:

1. The supply and installation of any piping, fittings and controls to and from the MIEX Plant boundary; or to and from any upstream or downstream process equipment shall be BY OTHERS.
2. The supply and installation of any transfer pumps, flow measuring devices, automated controls, instruments, electrical equipment, civil structures, buildings, etc. shall be BY OTHERS.
3. The supply of any standalone or online water quality instruments or devices (such as to measure but not limited to TOC, DOC, UVA, Color, Turbidity) shall be BY OTHERS.

5.5 Loaded Resin Tank Equipment

The following items or works have NOT BEEN INCLUDED:

1. The design and construction of concrete foundations or structures for the tank shall be BY OTHERS.
2. Site setting of supplied equipment associated with the tank.
3. Supplying and installation of loaded resin piping from tank outlet to regeneration system shall be BY OTHERS.

5.6 Resin Regeneration Equipment

The following items or works have NOT BEEN INCLUDED:

1. The design and construction of concrete foundations or structures shall be BY OTHERS.
2. The design and construction of any buildings or structures to house regeneration equipment supplied by Ixom shall be BY OTHERS.
3. The supply and installation of any protective coatings on concrete structures shall be BY OTHERS.
4. Supply and installation of resin transfer piping for inter connecting between Ixom supplied equipment items/skids shall be BY OTHERS.
5. Supply and installation of brine transfer piping for inter connecting between Ixom supplied equipment items/skids shall be BY OTHERS.
6. Supply and installation of service water piping for inter connecting between Ixom supplied equipment items/skids shall be BY OTHERS.
7. Supply and installation of compressed air piping for inter connecting between Ixom supplied equipment items/skids shall be BY OTHERS.
   Supply and installation of a service water supply and controls for the MIEX Treatment System shall be BY OTHERS.
8. Supply and installation of waste brine piping from the resin regeneration module to a waste storage tank or other location shall be BY OTHERS.
9. Supply provisions for and application of all piping labeling BY OTHERS
10. The supply and installation of a fork lift, pallet jack, crane or other lifting/handling device for handling MIEX Resin bulk containers shall be BY OTHERS.

5.7 Electrical and Instrumentation

The following items or works have NOT BEEN INCLUDED:

1. The supply and installation of Motor Control Center for Ixom supplied pump and agitators. Motor controls and communications shall be BY OTHERS.
2. The supply and installation of power supply cabling / equipment to the MIEX Plant location shall be BY OTHERS.
3. The supply and installation of any additional equipment required for a Motor Control Center (MCC) room; building or structures shall be BY OTHERS.
4. Field installation, conduit, cable trays, wiring terminations, etc. of Ixom supplied electrical equipment (e.g. motors, disconnects, instruments, electrical panels, etc.) and associated interconnections shall be BY OTHERS.
5. Any components, wiring, software required for integrating an existing PLC / SCADA control system with the MIEX control system shall be BY OTHERS.

5.8 SCADA / HMI Control System

It is assumed that water treatment plant has an existing SCADA control and operator interface system. This MIEX system and related components, software and programming is assumed to be integrated into the existing customer SCADA system BY OTHERS. Ixom would provide an overall specification document which outlines recommended SCADA/HMI features required for a MIEX System. The SCADA/HMI system integrator will use this to develop the necessary MIEX system sections.

5.9 General Items

The following items or works have NOT BEEN INCLUDED:

1. Necessary permits and/or governmental agency approval shall be BY OTHERS.
2. The supply and installation of a potable water supply, valves and controls to the MIEX Plant location shall be BY OTHERS. Potable (service) water max pressure: 3-4 bar.
3. The supply and installation of a services (compressed air, water) piping, and other valves shall be BY OTHERS.
4. The supply and installation of floor drains, any storm water or other underground drainage shall be BY OTHERS.
5. The supply and installation of any general operator amenities, office equipment, laboratory equipment, etc. shall be BY OTHERS.

SECTION 6: PROJECT DELIVERY

6.1 Ixom Project Team

Design, manufacture and delivery of equipment will be managed by a dedicated in-house team specializing in the use of water treatment applications. Currently overall there is combined experience of over 40+ years of total experience related to the design and implementation of MIEX Systems. Where required, a network of specialized supporting design engineers / contractors are used.

Scott Mitchell	Engineering Director (BE Chem.)
Sasa Golubovic	Principal Process Engineer (M.S Che.E)
David Gorlow	Project Manager (BE Mech.)
Michelle Larson	Project Engineer (BE Chem.)
Clint Bottorff	Controls and Instrumentation Specialist
Scott Padias	Mechanical Designer

6.2 Key Suppliers

Equipment procurement and fabrication will be provided through long-term pre contracted Ixom suppliers. Ixom has selected these suppliers based on their ability to deliver high quality cost efficient products on time and to Ixom's requirements and standards.

6.3 Design Process, Project Management & Quality Assurance

The packages will be delivered through Ixom's Project Management System. The project management system covers all aspects of the project, including project management, design, procurement and construction. System procedures have been specifically designed for water treatment projects.

6.4 Equipment Procurement and Manufacture

Manufacture of equipment items shall be conducted in accordance with all applicable engineering requirements and safe work methods. In order to ensure these standards are met, the following tools are used where required:

Job Safety and Environmental Risk Analysis (JSERA)
Work method procedures
Shop inspection and test plans

6.5 Factory Acceptance Testing (FAT)

For fabricated equipment skids, where possible these are shop inspected and tested as much as practically possible to ensure less time onsite for testing and quicker implementation. Types of work and testing performed:

- Inspections and verifications with design documents
- Piping hydrostatic testing
- Water testing and operation (close to as normal conditions)
- Electrical: Power up and point to point testing of panels / wiring
- Instruments: Power up and check instruments, perform initial set-up/calibration
- Document FAT on standard forms to be included in overall OM Manual

A client representative is welcome to witness final inspections (at their own expense), perform any further inspections or tests.

6.6 Installation

Ixom's proposal excludes as site works related to equipment setting, mechanical and electrical installation.

6.7 Commissioning

Process commissioning of the MIEX System will be performed by Ixom (with Contactor involvement). Prior, and overall Commissioning plan can be submitted for review and approval. Overall commissioning propose for MIEX System has the main following activity groups:

1. Equipment Installation Inspections: Final visual inspection of equipment and installation (by Ixom and Contractor). Only Ixom supplied items reviewed.
2. Electrical Panel Inspections, Power-up: Inspection of electrical panels installed and wiring inspected (by Ixom and Contractor). Panels powered up and general checks carried out
3. Load SCADA / PLC Programs: SCADA application (if by Ixom) loaded. PLC application loaded to controller. Communication checks with instrument/devices (other site PLC's).
4. Equipment and Instrument Calibrations: With the panels powered up, HMI and PLC applications loaded, various equipment items can be calibrated, i.e. flowmeters, level instruments. Check signals back to PLC / SCADA screen.
5. Equipment Functional (Dry and Wet) Testing: Initial function (dry) testing of pumps, agitators, valves, instruments. Checking control system and signals. Introduction of water to regeneration /brine systems. Contactor hydraulic test.
6. Loading Initial Resin Inventory: Loading initial MIEX Resin inventory into the process. By Ixom and Contractor.
7. Plant Demonstration / Performance Testing: Operational testing of plant systems and controls. Documented checkouts. Proceed into 'Performance / Demonstration Test' period. Plant monitoring, water quality checks, reporting.
8. Plant Handover and Acceptance: Completion of performance test. Handover and acceptance checks. Plant documentation.

6.8 Training

Ixom employees will perform the required training for operation and maintenance of the MIEX System. Prior to performing, training information can be submitted for review and approval. Training involves both class room type sessions and hands on operation. Ixom's standard training follows the below format:

Part 1- MIEX Introduction: This is a power point presentation / group discussion which covers:

What is Ion Exchange, what is MIEX, the ion exchange process
Target containments, DOC removal
Overall explanation of the MIEX Process
How the MIEX Process works, plant monitoring, testing

Part 2 – Plant Walk around / Explanation:

- Plant walk around and introduction / explanation of equipment functions and features
- Where equipment is monitored and checked

Part 3 – MIEX System Operation:

- Actual plant operation (hands on)
- Pre-start up inspections and checks
- Start-up / shutdown sequences of processes (water treatment and regeneration)
- Normal day to day monitoring, water quality checks
- Process alarms, actions to take

Part 3 – MIEX System Maintenance:

- Explanation of equipment maintenance requirements (demonstrations not performed)
- Overview of OM Manual information, where to find manuals, part numbers etc.

6.9 MIEX System Documentation

Complete plant documentation are provided by Ixom which the likes include:

- MIEX System Installation guidelines (supplied prior to equipment shipments).
- Operation and maintenance manual - incorporating technical specifications, principles of operation, operating instructions, maintenance, repair and overhaul, equipment schedules, equipment manuals, and emergency management
- Detailed "as-built" drawings of various equipment items supplied, which include: P&ID's, equipment arrangement drawings, skid drawings
- Mechanical and electrical equipment summary schedules
- Site testing and commissioning documents / copies.

6.10 Project Schedules

As required by projects, Ixom will develop overall schedules related for direct scope of works that can be used by the Engineer, Contractors etc. to incorporate details into bigger overall entire plant project schedules.

SECTION 7: PRELIMINARY BUDGET COSTS

7.1 Equipment and Initial Resin Inventory

100 MGD MIEX System The Total Lump Sum Costs for Supply of MIEX System Design, Equipment Supply, Waste Brine Treatment Equipment, Site Services and Initial Resin Inventory As Detailed Within This Preliminary Information Document:	**Budget Cost (USD)** **$ 28,154,000**
140 MGD MIEX System The Total Lump Sum Costs for Supply of MIEX System Design, Equipment Supply, Waste Brine Treatment Equipment, Site Services and Initial Resin Inventory As Detailed Within This Preliminary Information Document:	**Budget Cost (USD)** **$ 34,120,000**

These costs are preliminary budget numbers only and are not a firm or fixed quote price. Costs are estimated based on current pricing of equipment and components. Depending on the timing of the overall project, the user of these numbers in budget planning should allow for standard types of time related increases like inflation.

Prices quoted do NOT include any state taxes, sales, use, excise, privilege, or other taxes or assessments imposed on or concerning the products sold hereunder. All taxes other than those specifically listed shall be the responsibility of the buyer.

Budget costs provided are FOB destination with freight allowed to a staging location near or at the jobsite. All equipment off-loading and setting is BY OTHERS.

7.2 Ongoing Resin Supply

Based on current pricing, an on-going preliminary resin price offered is $12.66 per Liter of resin. On average the price has historically increased in the 2-4% range (tied to consumer indexes) over the last several years. An example of a long term resin pricing agreement is attached.

7.3 System Operating Costs

The MIEX System main operating costs (excluding personnel) are resin, salt and power. Expected usages and unit rates are summarized below and total per MG and daily costs at expected treatment rates per TOC period.

Table 7 – MIEX Unit Operating Costs During TOC Periods

Parameter	Usage	Unit Rate	Unit Costs ($/MG) High TOC (600 BV)	Unit Costs ($/MG) Low TOC (1000 BV)
MIEX Resin	1.2 gal/MG	$43.11/gal [1]	$51.73	
Salt	260 - 440 lb/MG [2]	$120/ton	$26.25	$15.75
Power	2.0 kW.hr/MG	$0.070 kW.hr	$0.14	
Waste Brine Treatment	450 - 750 gal/MG [4]	$8.5/1000gal	$6.38	$3.38
		TOTAL ($/MG)	**$84.50**	**$71.00**

NOTES:

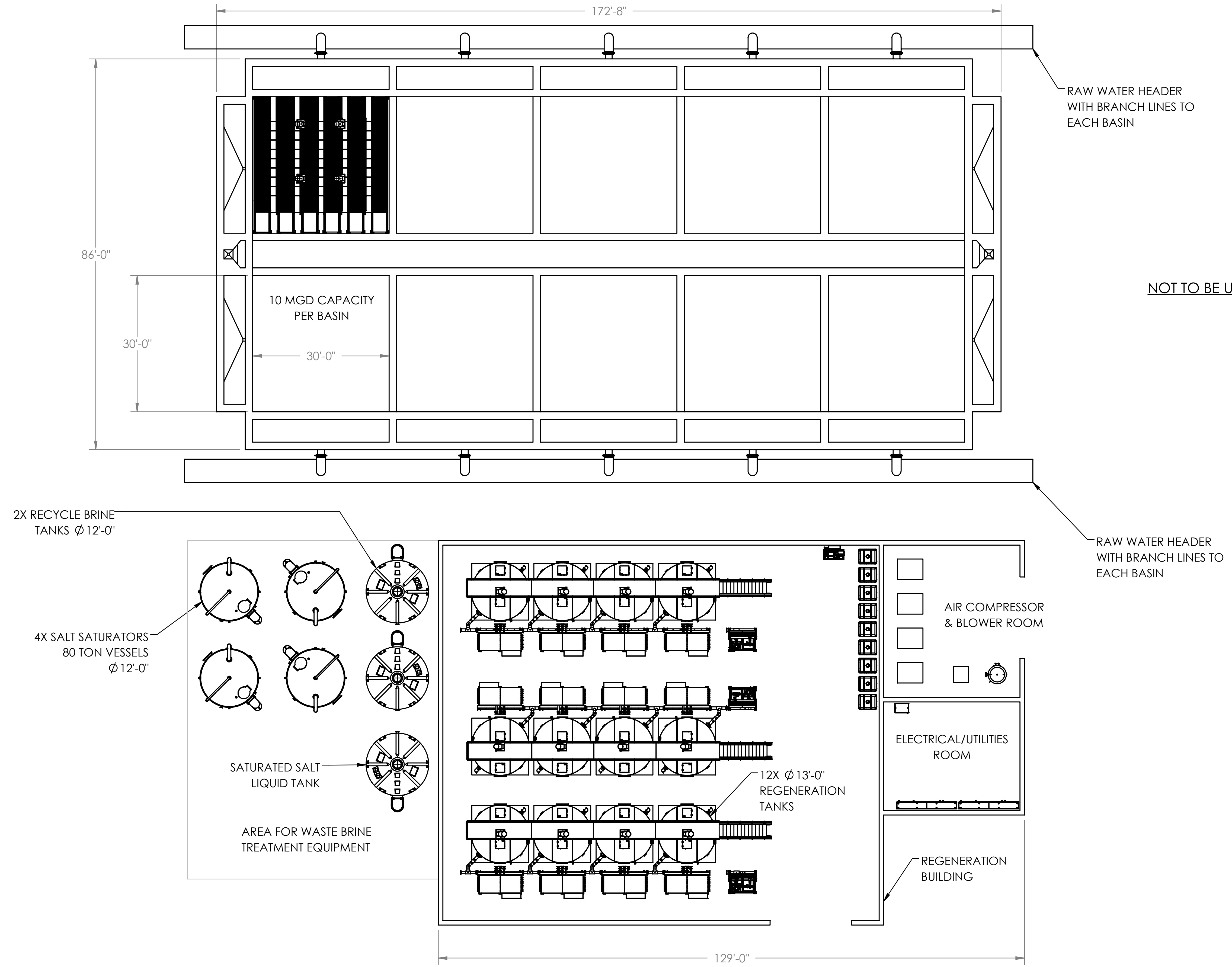
1. Resin costs based on $11.39/L
2. Net salt usage at 600 – 1000 BV treatment for (with recovery from waste brine treatment)
3. Salt cost based on $120/US (short) ton
4. Waste brine generation based on volumes at 600 – 1000 BV treatment rate

Table 8 –MIEX Daily Operating Costs By Plant Flow Rate and TOC Period

MIEX Operating Costs	100 MGD System High TOC (600 BV)	100 MGD System Low TOC (1000 BV)	140 MGD System High TOC (600 BV)	140 MGD System Low TOC (1000 BV)
Total Operating Costs ($/day)	$8,770	$7,465	$12,280	$10,450
Total Operating Costs ($/year)	$ 2,923,865		$ 4,093,410	

SECTION 8: ATTACHMENTS

1. 100MGD MIEX System Layout
2. 140MGD MIEX System Layout
3. Ixom Equipment Warranty Terms
4. Ixom Standard Terms and Conditions of Sale



PRELIMINARY

NOT TO BE USED FOR BUILDING DESIGN OR SCOPE DETERMINATION

NOTES:

1. ALL DIMENSIONS APPROXIMATE.
2. EQUIPMENT LOCATIONS SUBJECT TO SITE CONSIDERATION AND NOT GIVEN FOR ANY PARTICULAR ARRANGEMENT.

REV.	DESCRIPTION	DATE	CHANGED BY	CHECKED BY	ENGINEER

REVISIONS

STAMP

TOLERANCE

FRACTION	± 1/8
DECIMAL: .XX	± 0.03
DECIMAL: .XXX	± 0.010
ANGULAR	± 1°

FINISH 125

	SIGNATURE	DATE
DRAWN BY	S. PADIAS	02/08/17
CHECKED BY	S. MITCHELL	02/08/17
ENGINEER	S. MITCHELL	01/03/17
DISCIPLINE ENGR		
CLIENT		
PROJECT NO.		
PROJECT MGR	S. MITCHELL	
FILENAME	NAXXXX-05-00-002	

IXOM

(FORMERLY ORICA WATERCARE INC.)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

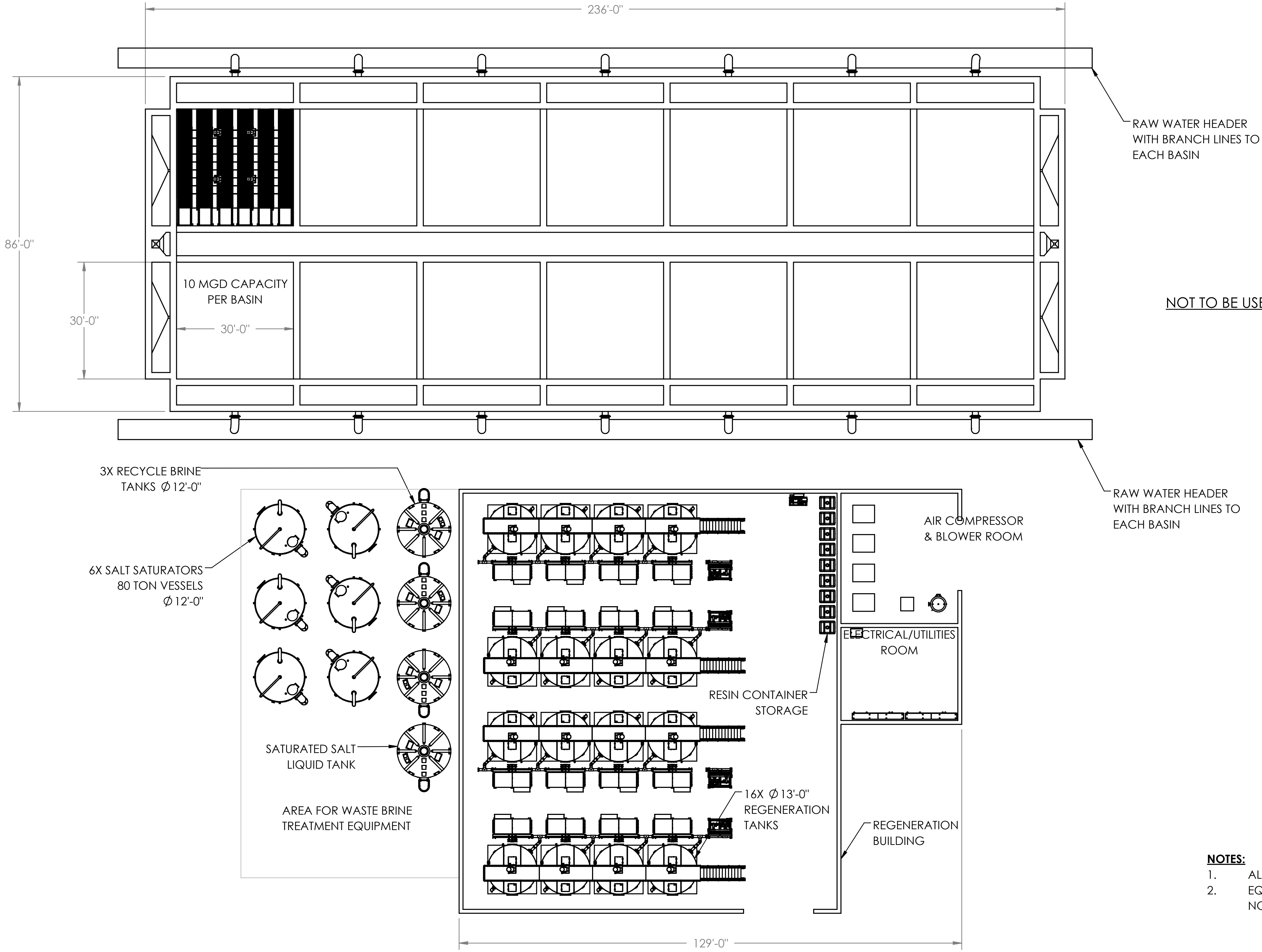
PROJECT: CITY OF TAMPA

SERVICE: MIEX® PRE-TREATMENT

TITLE: **MIEX® SYSTEM PRELIMINARY SITE LAYOUT 100 MGD CAPACITY**

SIZE: B | DWG NO.: **NAXXXX-05-00-002** | REV: **A**

SCALE: 1:275 | SHEET: 1 OF 1



PRELIMINARY

NOT TO BE USED FOR BUILDING DESIGN OR SCOPE DETERMINATION

NOTES:

1. ALL DIMENSIONS APPROXIMATE.
2. EQUIPMENT LOCATIONS SUBJECT TO SITE CONSIDERATION AND NOT GIVEN FOR ANY PARTICULAR ARRANGEMENT.

REVISIONS

REV.	DESCRIPTION	DATE	CHANGED BY	CHECKED BY	ENGINEER

STAMP

TOLERANCE

FRACTION ± 1/8
DECIMAL: .XX ± 0.03
DECIMAL: .XXX ± 0.010
ANGULAR ± 1°

FINISH 125

	SIGNATURE	DATE
DRAWN BY	S. PADIAS	02/08/17
CHECKED BY	S. MITCHELL	02/08/17
ENGINEER	S. MITCHELL	01/03/17
DISCIPLINE ENGR		
CLIENT		
PROJECT NO.		
PROJECT MGR		
FILENAME	NAXXXX-05-00-001	

IXOM

(FORMERLY ORICA WATERCARE INC.)

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

PROJECT: CITY OF TAMPA

SERVICE: MIEX® PRE-TREATMENT

TITLE: **MIEX® SYSTEM PRELIMINARY SITE LAYOUT 140 MGD CAPACITY**

SIZE: B

DWG NO.: **NAXXXX-05-00-001**

REV: **A**

SCALE: 1:320

SHEET: 1 OF 1

IXOM WATERCARE INC LIMITED WARRANTY

Ixom Watercare Inc. (IXOM) warrants all new equipment manufactured by IXOM against defects in material and workmanship, and will repair or replace at IXOM's expense, F.O.B. shipping point, any part(s) returned to IXOM which upon IXOM's examination are shown to have failed under normal use and service within twelve (12) months from date of equipment start-up, or eighteen (18) months from shipment to the purchaser, whichever occurs first. The warranty for repaired or replacement equipment shall continue for the remainder of the original warranty period, or for a period of six (6) months, whichever is longer. IXOM shall not be responsible for providing working access to the defective equipment, including disassembly and reassembly of the equipment, or for providing transportation to and from the repair facility, all of which shall be at purchaser's expense.

When the nature of the warranty item is such that it is appropriate in the judgment of IXOM to make such repairs or modifications at the site of operation, purchaser agrees to provide site access to IXOM or its sub-contractors, during normal working hours 8:00 a.m. to 5:00 p.m., Monday through Friday, exclusive of holidays. Labor performed at other times at the request of purchaser will be billed at the applicable rate then prevailing for services provided.

THE FOREGOING WARRANTY SHALL CONSTITUTE THE SOLE AND EXCLUSIVE REMEDY OF PURCHASER AND IS IN LIEU OF ALL OTHER WARRANTIES, REPRESENTATIONS, CONDITIONS, RIGHTS AND REMEDIES WITH RESPECT TO THE QUALITY, CONDITION OR PERFORMANCE OF THE EQUIPMENT, WHETHER EXPRESS OR IMPLIED, STATUTORY OR OTHERWISE AND WHETHER WRITTEN OR ORAL. ALL OTHER WARRANTIES, REPRESENTATIONS, CONDITIONS, RIGHTS AND REMEDIES, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF MERCHANTABILITY, DURABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE HEREBY EXPRESSLY DISCLAIMED AND EXCLUDED TO THE FULLEST EXTENT PERMITTED BY LAW. IXOM SHALL NOT BE LIABLE FOR ANY CONTINGENT, SPECIAL, INCIDENTAL, INDIRECT OR CONSEQUENTIAL DAMAGE OR LOSS OF ANY KIND, INCLUDING BUT NOT LIMITED TO, LOSS OF PROFITS, DUE TO PARITAL OR COMPLETE INOPERABILITY OF IXOM'S EQUIPMENT FOR ANY REASON WHATSOEVER.

IXOM only warrants equipment that has been paid for in full and which was put into service for its intended purpose. The warranty contained herein shall not apply to normal wear and tear, defects in materials provided by purchaser, or those items such as media, resin, and the like that are normally replaced or consumed as part of routine operation or maintenance of the equipment.

The warranty contained herein shall terminate if the equipment failure giving rise to a claim under warranty results from (a) unauthorized modification, repair or alteration, (b) improper or abnormal operation, application, maintenance or installation, (c) damage during shipment, or (d) operation, handling or other dealings with the equipment in a negligent manner.

GENERAL TERMS AND CONDITIONS OF SALE

These terms and conditions (collectively, "Terms and Conditions") govern all sales of products, equipment and services (collectively, "Goods") agreed to be supplied by IXOM Watercare Inc ("Seller") to any person to whom any quotation is made or who is offering to contract with the Seller ("Buyer"). The Terms and Conditions are incorporated into any order, offer, arrangement or understanding between the Seller and the Buyer (including pursuant to a quotation or letter of offer accepted by the Buyer) as well as any quotation or invoice or any other document to which they are attached (individually and collectively "Order"). All purchases by Buyer are expressly limited and conditioned upon acceptance of the Terms and Conditions and without limiting any other mode of acceptance, Buyer's acceptance of the Goods manifests Buyer's assent to the Terms and Conditions and the credit terms offered by Seller. Seller objects to and rejects any provision additional to or different from the Terms and Conditions that may appear in Buyer's purchase order, acknowledgement, confirmation, writing or in any prior or later communication from Buyer to Seller, unless Seller expressly agrees to such provision in a written amendment signed by Seller. An Order together with these Terms and Conditions are herein referred to as "Contract".

1. PRICES; TAXES; PAYMENT TERMS; DEFAULT.

(a) Prices for Goods and any adjustments to such prices shall be determined in accordance with Seller's final pricing letter or offer forming part of the Contract which has been accepted by Buyer ("Price").

(b) Prices do not include any sales, use, excise, privilege, or other taxes or assessments imposed on the Goods sold hereunder and unless Buyer provides proof of exemption satisfactory to Seller, such may be added to the price of the Goods.

(c) Subject to Section 1(e) and unless otherwise agreed in writing, payment terms are net 30 days from date of invoice. Payments not received when due shall incur service charges at the rate of 1½% per month (18% per annum) until paid, compounded on a daily basis.

(d) If any of the events set out in this Section 1(d)(i) through (v) below occur, Seller reserves the right, among other remedies, to delay or suspend further shipments or require full or partial cash payment in advance until all sums due have been paid. Buyer shall be liable for all costs and expenses incurred by Seller in collecting any overdue amounts, including without limitation reasonable attorneys' fees..

- (i) Buyer defaults in any payments or is unable or states that it is unable to pay its debts as and when they fall due.
- (ii) Buyer commits an act of bankruptcy, files a voluntary petition in bankruptcy or has filed against it an involuntary petition in bankruptcy or has a trustee, receiver, liquidator, custodian, conservator, manager, controller or voluntary administrator appointed in respect of Buyer's estate or any part of Buyer's property or assets.
- (iii) Buyer passes a resolution for its winding up or enters into liquidation or has an application for winding up filed against it.
- (iv) Buyer makes an assignment for the benefit of its creditors.
- (v) Buyer experiences any analogous event having substantially similar effect to any of the events listed above.

(e) Notwithstanding Section 1(a), Seller may at any time in its sole and unfettered discretion and without being under any duty or obligation to assign reasons, review, alter or terminate Buyer's credit limit or payment terms without notice. Without limiting the generality of the foregoing, the decision of Seller shall be final and Seller accepts no liability or responsibility for any loss, howsoever arising, incurred by Buyer due to the operation of this condition.

2. SHIPMENT; DELIVERY AND RESPONSIBILITY TO PURCHASE.

(a) Unless agreed otherwise in writing, all shipments are F.C.A. Seller's or its sub-contractor's warehouse. Shipping dates are estimates only and are subject to Seller's lead time policy. Seller shall make all reasonable efforts to have Goods delivered to Buyer on or about the date or within the time frame of the Order but Seller shall not be liable for any failure or delay in delivery for any reason. Buyer is responsible for disposing of all non-returnable containers and shipping materials

(b) Purchase orders issued by Buyer and placed with Seller are irrevocable and Buyer is contractually obliged to take delivery and pay for all Goods ordered and supplied or made available by Seller pursuant to such purchase order. If Seller does not receive forwarding instructions sufficient to enable it to dispatch Goods within fourteen (14) days after notice to Buyer that such Goods are ready, Buyer shall be deemed to have taken delivery from such date and shall be obliged to pay reasonable storage charges payable on demand. Unless otherwise agreed upon by the parties in writing, if Buyer does not accept delivery or collect Goods from Seller when made available at the agreed delivery point in accordance with the Contract, Buyer also will pay Seller for storage costs and reimburse Seller for any demurrage, transport or futile delivery costs incurred by Seller.

3. TITLE; RISK OF LOSS OR DAMAGE.

Title to and risk of loss of the Goods shall pass to Buyer upon delivery to the carrier at point of shipment.

4. INSPECTION; ACCEPTANCE.

Buyer shall promptly examine the Goods for any damage or shortage or failure of the Goods to comply with the Seller's standard sales specifications or the specifications contained in or referenced in the Contract. All claims for damage or shortage of Goods shall be deemed waived unless made in writing and received by Seller within 30 days of delivery of the Goods. If Buyer finds that any of the Goods do not comply with the specifications, Buyer may, at its option, reject that portion of the Goods that fail to comply by providing Seller with a notice made in writing and received by the Seller within 30 days of delivery of the Goods. Failure to timely deliver written notice of any such claim or rejection of the Goods within the warranty period specified in this clause 4 shall be deemed an absolute and unconditional waiver of such claim for damage or shortage or a right to reject such Goods and all claims related thereto and shall constitute an unqualified acceptance of such Goods, irrespective of whether the facts giving rise to such claim shall have then been discovered or of whether use or application of the Goods shall have then taken place.

5. **RETURNS.**

Returned Goods shall not be accepted unless Buyer obtains prior written approval and transportation instructions from Seller. All Goods returned to Seller must be in full containers or cases, unopened and in the same condition as when delivered. If a return is approved by Seller, Goods may be returned for exchange or credit only. Seller shall give no cash refunds for returned Goods. Approved returned Goods are subject to a restocking charge of 15% of the invoiced value of such Goods and Buyer shall pay all transportation charges.

6. LIMITED WARRANTY.

(a) Subject to Section 6(e) and Section 7 below, Seller warrants title and that the Goods shall conform to Seller's standard sales specifications in effect at the time of manufacture or the specifications agreed by the parties in writing and contained or referenced in the Order. Equipment components not manufactured by Seller which are incorporated in the Goods may, if specified elsewhere in the Contract, be subject only to warranties of Seller's vendors and Seller hereby assigns to Buyer all such rights in such vendor's warranties and will provide reasonable assistance in enforcing such rights.

(b) Buyer is solely responsible for determining that the Goods and their specification and scope are appropriate for Buyer's intended use. Any advice or recommendations by Seller with respect to the Goods or the use of the Goods are provided in good faith based on tests or experience believed to be reliable but such advice or recommendations are not warranted. Buyer agrees that it is responsible for ensuring that Goods that comply with the warranties in Section 6(a) are fit and suitable for its purposes, requirements, processes, plant and equipment.

(c) To the maximum extent permitted by law, Seller makes no other representation or warranty of any kind, and hereby expressly disclaims all other representations or warranties, express, implied, statutory or arising from a course of dealing, usage of the trade or otherwise, including without limitation any representation or warranty as to merchantability, fitness for a particular purpose, or any other matter with respect to the goods, whether used alone or in combination with any other goods, substances processes or materials or services.

(d) In the event the exclusion of some or all of such warranties under section 6(c) for certain goods subject to this contract would be illegal, any additional warranty would be limited to the warranty required by applicable law and to the extent permitted by such law, would be subject to section 6(e) and section 7, and is conditioned upon use in accordance with label directions under normal conditions reasonably foreseeable to seller with buyer assuming the risk of any use contrary to label directions, under abnormal conditions or under conditions not reasonably foreseeable to seller.

(e) Seller's sole liability and Buyer's sole remedy for breach of warranty are specifically limited to the repair of the goods (or re-performance of services when applicable) or the cost thereof where Seller fails to perform such repair necessitate by a breach of warranty, and such liability and remedy re exclusive of all other liabilities and remedies. Should these remedies be found inadequate or to have failed of their essential purpose for any reason whatsoever, Buyer agrees that the return of the amount paid by buyer to seller for the purchase of the goods which fail to conform with the warranties set forth in section 7 shall be considered a fair and adequate remedy and prevent the remedies from failing of their essential purpose.

7. LIMITATION OF LIABILITY.

(a) The liability of Seller and its affiliates to Buyer under and in connection with the Contract is limited to the price allocable to the Goods giving rise to the claim and in no event shall the cumulative liability of Seller howsoever arising, whether under warranty, contract, tort, negligence, strict liability, indemnification, defense or any other cause or combination of causes whatsoever, exceed the total payments received from Buyer under the Contract in connection with the Goods.

(b) To the extent permitted by law and not withstanding any provision to the contrary in the contract, Seller shall not be liable for special, indirect, incidental or consequential damages, including without limitation, and loss of profits. Loss of business revenues, loss of capital, failure to realize expected profits or savings, overhead costs, loss by reason of service interruption or increased expense of operation, loss of goodwill, loss of reputation, loss of value in any intellectual property, damages or liquidated sums payable pursuant to other agreements or to other third parties, other economic losses, whether arising under warranty, contract; negligence (including negligent misrepresentation) or other tort, strict liability, breach of statute, indemnification, or any other cause or combination of causes, including any theories of concurrent liability arising from a duty of care by operation of law or otherwise.

8. **SAFE STORAGE HANDLING AND USE; ASSUMPTION OF RISK; INDEMNIFICATION**.

Buyer acknowledges that it is familiar with the risks associated with the storage, handling and use of Goods and any waste resulting therefrom. Accordingly and notwithstanding anything to the contrary set forth in the Contract, Buyer covenants and warrants and shall ensure that (i) that it and its employees, agents, carriers and customers are familiar with and adhere to all necessary and appropriate precautions and safety measures to safely store, handle or use the Goods; (ii) it and its employees, agents, carriers and customers shall comply with all applicable Laws, including without limitation, environmental laws and regulations pertaining to the storage, handling and use of Goods; (iiI) shall obtain and comply with all required permits and licenses. Seller takes no responsibility for, and Buyer assumes all risks associated with waste characterization, regulatory status and chemical composition of any product, process, material, waste or substance into which the Goods are incorporated or applied. Without limiting the foregoing, Buyer shall further ensure that all storage tanks, vessels, and pipes, hoses and valves and other components used by Buyer or its employees, agents, carriers and customers to store, handle and transfer Goods which are bulk chemicals are properly installed and maintained to prevent injury, death or loss of containment during storage, handling and transfer of such Goods. If Buyer resells or distributes Goods to third parties, Buyer assumes responsibility for ensuring that it provides detailed instructions to such third parties regarding safe storage, handling and use of those Goods and any Storage Items or packaging in which such Goods are stored. To the maximum extent allowed by law, Buyer assumes all risks and liability whatsoever for all injuries, losses and damages to persons or property or otherwise and shall indemnify, defend and hold harmless Seller and Seller's employees and agents against all claims, damages, losses, costs, liabilities, and other expenses (including investigation and attorneys' fees) that Seller incurs or may be obligated to pay as a result of (i) Buyer's, its employees', agents', carriers' or customers' handling, possession, further processing, storage, use treatment, transportation, disposal, sale or other use or disposition of the Goods, whether used alone or in combination with other products, materials, substances or wastes, (ii) Buyer's, its employees', agents', carriers' or customers' violation or alleged violation of any Law, or (iii) Buyer's breach of any of its obligations set forth herein.

9. FORCE MAJEURE. Shipments or deliveries may be totally or partially suspended or delayed by Seller during any period in which the Seller may be prevented or hindered from manufacture, delivery or supply through any circumstances outside Seller's reasonable control or where such manufacture, delivery or supply is rendered materially more expensive by such circumstances. Circumstances beyond Seller's reasonable control shall include, without limitation, strikes, lockouts or other labor difficulty; acts of carriers; acts of God; acts of civil or military authorities; acts or omissions of Buyer; war; riot; fire; explosion; acts of terrorism; flood; any inability to obtain or lack of any necessary or adequate materials, inputs, fuel, power, labor, equipment, containers, facilities or services on usual terms; power or water shortage; accidents or breakdowns or failures of plant or machinery or apparatus; delays, congestions or blockages at sea ports or transport depots or software, hardware or communication network; changes in applicable Laws; or any other event, whether or not enumerated herein, beyond the reasonable control of Seller that makes impractical the manufacture, transportation or shipment of the Goods or of a material or other resource upon which the manufacture, transportation or shipment of the Goods depends. Seller shall not incur any liability to Buyer in respect of such suspension.

10. **INTELLECTUAL PROPERTY**.

Seller is the sole and exclusive owner of the Intellectual Property in the Goods and processes incorporated in such Goods, and the rights attached to that Intellectual Property. Nothing herein grants to Buyer any right, title or interest in or to any of the Intellectual Property in the Goods. Buyer shall not claim to have acquired any right, title or interest to the Intellectual Property in the Goods by virtue of purchasing Goods sold hereunder. Buyer shall not deconstruct, reverse compile or reverse engineer the Goods in any way for the purpose of deciphering or replicating the chemical composition of the Goods. As used herein, "Intellectual Property" means any intellectual or industrial property right anywhere in the world including, without limitation, any patent, patent application, utility model, copyright (including copyright in manuals, databases, and promotional materials), registered design and other design rights, unpatented secrets and innovations, confidential information, and any other rights that may subsist anywhere in the world in improvements, inventions and other manufacturing processes or technical and other information of Seller. Buyer shall not resell, distribute or supply the Goods to any third party for any reason without Seller's prior written consent

11. CONFIDENTIALITY; ENTIRE AGREEMENT; AMENDMENTS; CHANGES TO TERMS AND CONDITIONS.

(a) All information that Buyer acquires from Seller hereunder, directly or indirectly, and all information that arises out of the sale of the Goods hereunder, concerning such Goods and/or proprietary processes involved, including information concerning Seller's current and future business plans, information relating to Seller's operations, know-how, and other

Seller-furnished information shall be deemed Seller's "Proprietary Information". Buyer shall (a) hold Seller's Proprietary Information in strictest confidence, (b) not disclose it to others, (c) use it solely for purposes of this Agreement and (d) upon Seller's request, either promptly deliver to Seller all such Proprietary Information that is in written, electronic or other form, including copies and summaries, or, at Seller's option, destroy such Proprietary Information and provide Buyer certification of such destruction. The obligations under this Section shall survive the expiration or termination of the Contract.

(b) The Contract constitutes the entire agreement of the parties with respect to the purchase and sale of Goods and supersedes and excludes all prior and other discussions, representations (contractual or otherwise) and arrangements relating to the supply of Goods, including but not limited to, those relating to the performance of Goods or results that ought to be expected from using the Goods. Nothing in the Terms and Conditions is

12. **GOVERNING LAW**.

The rights and duties of the parties and any dispute regarding the sale of Goods covered hereby shall be resolved according to the laws of the state of Colorado, without regard to its conflicts of law provisions. Buyer hereby agrees to submit to the non-exclusive jurisdiction of the courts in the state of Colorado. Any controversy or claim arising out of or relating to the sale of Goods or the dealings between the parties shall be settled exclusively by arbitration in Denver, Colorado by a single arbitrator pursuant to the American Arbitration Association's Commercial Arbitration rules then in effect, and judgment upon the award shall be entered in any court having jurisdiction thereof. The prevailing party in any arbitration proceeding shall be entitled to recover its reasonable attorneys' fees and costs, in addition to any other relief obtained.

13. WAIVER.

No failure to exercise nor any delay or omission in exercising any right, power or remedy by Seller operates as or constitutes a waiver. A single or partial exercise by Seller of any right, power or remedy does not preclude any other or further exercise by it of that or any other right, power or remedy. A waiver is not valid or binding on Seller unless made in writing. No failure by Seller to exercise, nor any delay or omission by Seller in exercising any right, power or remedy nor any representation made or conduct carried out by Seller under the Contract or in connection with the supply of Goods or any of them shall constitute or provide grounds for a common law or equitable estoppel.

14. SEVERANCE.

If any provision of the Terms and Conditions or its application to any person or circumstances is or becomes invalid, illegal or unenforceable, the provision shall so far as possible be read down to such extent as may be necessary to ensure that it is not invalid, illegal or unenforceable. If any provision or part of it cannot be so read down, the provision or part of it shall be deemed void and severable and the remaining provisions of the Terms and Conditions shall not in any way be affected or impaired.