Water Treatment Plant Final Report

Plainfield GAC Pilot Project, GAC2018

Prepared for

Plainfield Charter Township

December 31, 2019

2180036

Contents

Tables

Figures

Appendices

ACKNOWLEDGEMENTS

Special credit and thanks are given to the following individuals for their foresight, planning and implementation of this Pilot Study, for countless hours spent collecting, analyzing and summarizing data, and for producing this report, all of which have improved the water system in Plainfield Charter Township and can be used to benefit communities throughout Michigan.

Plainfield Charter Township

Rick Solle, P.E., Director of Public Services
Don Petrovich, Water Plant Superintendent
Mike Slomski, Water Plant Assistant Superintendent
Water Plant Operators:

- Tim Clement
- Bill Martin
- Randy Peck
- Roger Vandervoord
- Brian VanDyken

Prein & Newhof, Civil Engineering Consultants

Mark Prein, P.E., Team Leader
Kevin Gritters, P.E., Project Manager
Tom Newhof, P.E., Senior Advisor

1 INTRODUCTION

Plainfield Charter Township (Plainfield) operates three well fields (West, East and Versluis) as source water for a lime softening water treatment plant that supplies water for over 40,000 people in Plainfield and adjacent communities.

Plainfield conducted monitoring of its water supply between June 2013 and March 2014 as part of the third unregulated contaminants monitoring rule (UCMR3). The water supply met all regulatory requirements, and Plainfield continued to operate Versluis Well Field to supply peak water system demand during summer months. After operating for the summer of 2015, the Versluis Well Field was closed for the season in October 2015. In March 2106, the Township again tested the raw water at Versluis and found elevated levels of per- and polyfluoroalkyl substances (PFAS). At that time, Plainfield made the decision to keep the Versluis wells shut down for the summer of 2016. From March 2016 through early 2018, Plainfield tested the treated water as it left the Water Treatment Plant (WTP) a total of eleven times. The combined concentrations of PFOA and PFOS in that time period ranged from 4.9 ng/L (commonly known as parts per trillion, or ppt) to 10.3 ppt, with an average of 8.1 ppt. The results were well below the EPA's Health Advisory level of 70 ppt for PFOA and PFOS.

In 2016, the Township began the process of searching for a new well field to replace the capacity lost when the Versluis Well Field was closed. In 2017, the Township appropriated funds for Township engineers to investigate suitable groundwater sources and help locate property that could be used for that purpose. From 2017 until the present time, the Township has worked to identify several areas that may be geologically suitable for a municipal water supply. However, the ongoing discovery of PFAS in residential wells, groundwater monitoring wells and various surface waters within the Township has significantly slowed the process. A plan has been developed to sample for water quality, and the Township anticipates drilling soil borings and/or monitoring wells in late 2019 or early 2020.

Prior to early 2018, Plainfield's water treatment process was not designed to remove PFAS compounds. WTP operators worked with the engineers to research alternative methods available to remove PFAS. Factors considered when evaluating a treatment system included performance of the treatment method, effectiveness of treatment method for a wide range of contaminants, acceptability to the MDEQ (now and hereafter referred to as the Department of Environment, Great Lakes and

Energy, or "EGLE") for permit purposes, initial capital cost to construct and incorporate the treatment system, and ongoing cost to maintain the treatment system.

On March 13, 2018, the State Administrative Board approved a grant to Plainfield to conduct a pilot project for treating PFAS in the public water supply. The Township received this grant for the following reasons:

- It showed initiative to immediately retrofit its existing rapid sand filters to provide for PFAS removal, and it proposed a pilot study along with their efforts.
- The Township's water plant is designed similarly to other municipal filtration plants and had adequate space to conduct a study.
- The Township had been collecting PFAS data on its system for more than four years and already had a good baseline. The concentrations were high enough to gather quality pilot test data but were well below the Part 201 cleanup criteria and EPA Health Advisory Level for PFOA and PFOS.
- Plainfield's water system was one of the first in Michigan to experience significant demand for filtration and removal of PFAS to non-detect levels. Lessons learned in Plainfield were and are likely to be beneficial to other water supplies.

The State grant supported accelerated column testing prior to implementation of the full-scale pilot project, modifications to the WTP filters, installation of flow meters, installation of new filter media, substantial water and media sampling and laboratory analytics, and consulting engineering services. This report presents the design, implementation and data collection components of the WTP pilot project, and it summarizes the results of the data collected.

2 PILOT STUDY DESIGN

The Plainfield WTP is a lime softening plant whose source water is classified as groundwater under the influence of surface water. The plant's dual media (rapid sand and anthracite) filtration capacity is 16 million gallons per day (mgd), while the average day demand is about 3.8 mgd and the all-time maximum day demand is 11.82 mgd. The filtration capacity is provided by eight (8) 1-mgd filters (Filters 1-8) and four (4) 2-mgd filters (Filters 9-12).

2.1 Design Intent

The objective of the pilot study was to determine the effectiveness of retrofitting the existing dual media filters with granular activated carbon (GAC) to maintain existing water treatment standards and add the ability to remove PFAS. The pilot study was designed in three phases, each progressively building on and contingent on the success of the previous phase, while evaluating two types of GAC and available empty bed contact times (EBCT).

The intent of Phase 1 was to demonstrate pathogen removal in a dual-media – sand and GAC – filter using a type of GAC that would function like anthracite and also provide a level of PFAS removal. Calgon F-820 GAC closely matched the physical characteristics of the previous anthracite. The GAC depth was maximized to allow 30% bed expansion below the bottom of the overflow troughs during backwash, which provided 8.2 minutes of EBCT.

The intent of Phase 2 was to evaluate pathogen and PFAS removal in a mono-media (GAC only) filter using a type of GAC that is optimal for PFAS removal. Calgon F-400 GAC was chosen for that purpose, and the depth was maximized to allow 30% bed expansion below the bottom of the overflow troughs during backwash, which provided 8.3 minutes of EBCT.

The intent of Phase 3 was to demonstrate pathogen and PFAS removal in a mono-media filter, again using the Calgon F-400 GAC, and a 20% longer EBCT. The GAC depth was maximized to keep 30% bed expansion below the bottom of the overflow troughs during backwash, which provided 10.1 minutes of EBCT.

2.2 Quality Assurance Project Plan

An extensive Quality Assurance Project Plan (QAPP) was prepared as part of the grant application process and was reviewed and approved by EGLE prior to commencement of the pilot study.

The QAPP outlined the pilot project sampling and analysis procedures for field and analytical work pertaining to the analyses for PFAS and other substances, both pre- and post-filtration. It identified water samples that would be collected during the project, how the samples would be analyzed, and how the results would be evaluated. The QAPP established quality assurance and quality control (QA/QC) measures for the project and detailed the overall sampling schedule for the duration of the pilot study.

The QAPP was then executed to ensure the data obtained were of the type and quality needed to meet the pilot study objectives. All samples were collected and tested in accordance with USEPA and/or other approved drinking water methods.

2.3 EGLE Permitting

Plainfield submitted an Act 399 Permit Application for Water Supply Systems in January 2018 to construct the proposed WTP filter modifications. After working with EGLE on objectives, standards and subsequent design revisions, an updated permit application was submitted in March 2018. The final application outlined the proposed plant modifications and explained how compliance with all water treatment standards would be demonstrated for each phase before proceeding to subsequent phase. An Act 399 permit was issued by EGLE in April 2018.

2.4 Accelerated Column Test

Early in the pilot study process, several 55-gallon drums of Plainfield's clarified water were shipped to Calgon Carbon Corporation to undergo accelerated column testing (ACT). The intent of the two ACTs conducted was to compare the performance of two types of GAC for the removal of PFAS from Plainfield's own source water and to predict a bed life for the GAC.

Since Plainfield's raw water PFAS concentrations were so low, Calgon needed to spike the feed drums with additional PFOA and PFOS to ensure breakthrough would be achieved during the test. The ACT was conducted over a two-month period. Many assumptions regarding raw water quality and consistency, and GAC treatment configurations, were made. The ACT simulated and projected several years of filter operation prior to PFAS breakthrough. The ACT report is included in Appendix A.

2.5 WTP Modifications

Plainfield contracted with several suppliers and contractors to complete the water treatment plant modifications necessary for the pilot study. A mechanical contractor raised the existing stainless-steel surface wash piping and supports so that the rotating wash arms were just above the proposed GAC surface. An instrumentation contractor installed flow meters on the filtered water piping. The mechanical contractor and WTP staff installed water sampling ports at many locations throughout the plant to facilitate the extensive water sampling regimen. Since the testing was for such low concentrations of PFAS, special care was taken not to use Teflon tape or

any other materials in the sampling ports that could give false readings. Finally, Calgon Carbon Corporation (CCC) removed the existing filter media and installed the new GAC. Following are more details pertaining to each phase of the pilot study.

2.5.1 Phase 1 – Filters 9 & 10

In Filters 9 and 10, which have a combined filtration capacity of 4 mgd and do not have the capability of filtering to waste, the existing anthracite and about one-third of the existing sand layer were removed. Twelve (12) inches of sand were preserved as the base filter media layer (over Leopold Superblock II with IMS Cap underdrain system), and about 42 inches of Calgon F-820 GAC were added over the sand. The F-820 GAC closely matched the physical characteristics of the previous anthracite, and the GAC depth was maximized to provide 30% bed expansion during backwash while keeping the expanded bed below the bottom of the overflow troughs. Maximum available EBCT was about 8.2 minutes when maintaining the standard filtration rate of about 2.9 gpm/s.f.

2.5.2 Phase 2 – Filter 1

In Filter 1, which has a filtration capacity of 1 mgd and the capability of filtering to waste, all the existing anthracite and sand were removed. The existing Wheeler bottom with Roberts Retroliner and Plastic Wheeler Inserts (PWI) was overlain with 3 inches of silica gravel and about 52 inches of Calgon F-400 GAC. The GAC depth was maximized to provide 30% bed expansion during backwash while keeping the expanded bed below the bottom of the overflow troughs. Maximum available EBCT was about 8.3 minutes when maintaining the standard filtration rate of about 4 gpm/sf.

2.5.3 Phase 3 – Filters 11 & 12

The existing anthracite and sand layers were removed from Filters 11 and 12, which have a combined filtration capacity of 4 mgd and do not have the capability of filtering to waste. The Leopold Superblock II with IMS Cap underdrain system, which could support the new GAC directly, was overlain with about 47 inches of Calgon F-400 GAC. The GAC depth was maximized to provide 10.1 minutes of EBCT while keeping 30% bed expansion below the bottom of the overflow troughs during backwash. The standard filtration rate in these filters was maintained at about 2.9 gpm/s.f

2.6 Operational Protocols

As part of the QAPP and pilot study design, operational protocols and contingency plans were developed to address potential disruptions in the treatment process. For example, protocols were established to address potential problems such as a spike in the heterotrophic plate count (HPC), repeatedly shorter filter run times, excessive media loss, PFAS in backwash water, low chlorine contact time and PFAS breakthrough. In addition, sand and anthracite media suppliers were on call for the unlikely event that the new GAC needed to be removed and the filters restored to pre-pilot conditions.

3 IMPLEMENTATION

3.1 Phase 1 – Filters 9 & 10

Upon receipt of the EGLE permit for construction in the WTP, contractors commenced work to retrofit the Phase 1 filters. Modifications were completed and on June 7, 2018, Filters 9 & 10 came online with Calgon F-820 GAC. Since the new GAC closely matched the previous anthracite, the filtration and backwash rates were not adjusted. WTP staff monitored the filter operation closely to ensure proper operation, particularly during backwashing. Extensive testing in the following weeks demonstrated that turbidity and pathogen removal were maintained, and initial PFAS testing showed that at least PFOA and PFOS were removed by the F-820 GAC.

3.2 Phase 2 – Filter 1

With the proven success of Phase 1, work in Phase 2 (Filter 1) commenced, and on July 16, 2018, Filter 1 came online with Calgon F-400 GAC. Filter 1 was operated to waste until testing showed that turbidity, pathogen and PFAS removal were being achieved.

Due to the finer particle size of the F-400 GAC, the backwash rate was reduced to minimize the potential for washing media out of the filter bed. Subsequent backwashes were monitored closely, and the backwash rate was optimized to provide maximum cleaning.

3.3 Phase 3 – Filters 11 & 12

Phase 2 was shown to be successful in the middle of Summer 2018 during peak water demand in the water system. Since Plainfield could not afford to lose 4 mgd of filtration capacity during the retrofitting of Filters 11 and 12, the Township decided to wait until water demands returned to

average-day levels in the fall. As such, modifications to Filters 11 and 12 commenced in September, and on October 11, 2018, Filters 11 and 12 came online with Calgon F-400 GAC. As with the previous phases, initial testing demonstrated achievement of all water treatment goals, and operators proceeded to optimize filtration and backwash procedures and rates.

4 DATA COLLECTION

Extensive water sampling, laboratory testing and data analyses were conducted for the duration of the pilot study. The parameters tested during the pilot study included bacteria, heterotrophic plate counts (HPC), total organic carbon (TOC), PFAS, trihalomethanes (THM), halo-acetic acids (HAA5), volatile organic compounds (VOC), metals, chromium, hexavalent chromium, 1,4-dioxane, strontium, molybdenum and vanadium.

4.1 EPA Method 537

PFAS concentrations were tested using EPA Method 537, which tests for the following twelve (12) analytes:

CAS #	Name
375-73-5	Perfluorobutanesulfonic acid (PFBS)
335-76-2	Perfluorodeconoic acid (PFDA)
375-85-9	Perfluoroheptanoic acid (PFHpA)
355-46-4	Perfluorohexanesulfonic acid (PFHxS)
307-24-4	Perfluorohexanoic acid (PFHxA)
307-55-1	Perfluorododecanoic acid (PFDoA)
376-06-7	Perfluorotetradecanoic acid (PFTeDA)
375-95-1	Perfluorononanoic acid (PFNA)
1763-23-1	Perfluorooctanesulfonic acid (PFOS)
335-67-1	Perfluorooctanoic acid (PFOA)
72629-94-8	Perfluorotridecanoic acid (PFTrDA)
2058-94-8	Perfluoroundecanoic acid (PFUnA)

Of these twelve analytes, only PFBS, PFHpA, PFHxS, PFHxA, PFOS and PFOA were detected at any time or location during the pilot study.

4.2 Eurofins Method L402

Many samples were collected for duplicate analysis with Eurofins Method L402, which tests for thirty-nine (39) total analytes, including HFPO-DA (commonly known as Gen-X). Rather than listing all analytes tested for with this method, following is a list of only those analytes that were detected at any time or location during the pilot study:

CAS #	Name
27619-97-2	6:2 Fluorotelomer sulfonic acid (6:2 FTS)
375-73-5	Perfluorobutanesulfonic acid (PFBS)
375-22-4	Perfluorobutanoic acid (PFBA)
375-85-9	Perfluoroheptanoic acid (PFHpA)
355-46-4	Perfluorohexanesulfonic acid (PFHxS)
307-24-4	Perfluorohexanoic acid (PFHxA)
NA	Perfluorododecanesulfonic acid (PFDoS)
2706-90-3	Perfluoropentanoic acid (PFPeA)
2706-91-4	Perfluoropentanesulfonic acid (PFPeS)
151772-58-6	Perfluoro-2-methoxyethoxyacetic acid
67905-19-5	Perfluorohexadecanoic acid (PFHxDA)
31506-32-8	N-methylperfluorooctane sulfonamide (NMeFOSA)

Testing for non-PFAS parameters was included in the pilot study to verify the ability of dual- and mono-media GAC filters to maintain and enhance the WTP's existing treatment capabilities. The frequency of testing varied by parameter but generally involved more aggressive testing initially, followed by scaled-back testing when results confirmed the processes were successful.

Other data collected within the plant were standard operational parameters for the filters such as headloss, turbidity, chlorine residuals, flow rates, duration and volume of filtration and backwash, and all other normal measurements, including which wells were in operation for each test.

5 SUMMARY AND ANALYSIS OF RESULTS

This section contains a summary of the overall results of the pilot study, including an assessment of the pilot study's performance relative to the following seven expected outcomes identified in the Pilot Study Work Plan:

1) assess the ability of rapid sand filters with a cap of GAC to remove PFAS

2) assess the ability of mono-media GAC gravity filters to maintain existing treatment capabilities while also removing PFAS
3) determine if filters with different EBCT can achieve removal of PFAS to non-detect
4) verify if the affinity of PFAS to GAC is strong enough to withstand backwash energy
5) assess the increased maintenance costs attributable to the addition of GAC
6) verify the filters' ability to remove pathogens is not compromised
7) verify the filters' ability to remove TOC and PFAS, particularly as GAC media ages.

These seven expected outcomes were assessed for both the dual-media and mono-media filters, and while the seven outcomes are not each addressed individually, the results are consolidated in the following sections.

5.1 Dual Media Filters

The Phase 1 filters – Filters 9 & 10 – were the dual-media filters consisting of 12 inches of sand and about 42 inches of F-820 GAC.

5.1.1 Turbidity Removal

As described previously, the design intent of implementing a dual-media filter with sand base and GAC cap was first to confirm the ability of the filter to maintain the primary treatment objective of turbidity and pathogen removal. Verification of pathogen removal was done by assessing turbidity removal which is a surrogate for the presence of pathogens. Turbidity was measured continuously at each filter, and operators watched for any peaks in turbidity as well as turbidity at the start and end of each filter run.

During normal operations, turbidity in the filter effluent typically was less than 0.05 NTU but had occasional readings between 0.05 and 0.10 NTU as shown in Figure 1a. This was consistent with turbidity levels in the pre-GAC filters.

It was observed in the turbidimeters, which monitor every minute, that within 4 – 5 minutes after filter startup, turbidity levels increased to 0.12 – 0.16 NTU before returning to normal levels. The increase typically lasted 10 – 20 minutes. Turbidity levels during a representative filter start-up are shown in Figure 1b. While this turbidity increase is greater in magnitude and duration than before the changeout to GAC, the peak turbidity was well within minimum compliance levels. The increase was reviewed with the GAC manufacturer and it is likely

due to microbial sloughing from the filter bed after being stagnant overnight. Additional testing, such as a Silt Density Index (SDI) test, is being conducted for confirmation.

Heterotrophic plate count (HPC) tests were conducted throughout the treatment process. With the addition of GAC, the filters became biologically active as shown by the HPC levels in Figure 2. However, the microbial population generally stayed harbored within the filter bed. A low dosage of chlorine applied prior to the filters along with standard post-filtration disinfection maintained non-detect levels for HPC at the Plant Confluence, which is the point at which the two halves of the WTP join and pump to the on-site ground storage tanks. See Figure 3. With these results, the design intent of Phase 1 of the pilot study was confirmed.

5.1.2 TOC Removal

The presence of total organic carbon (TOC) in water that is applied to a GAC filter can affect the ability of the filter to remove PFAS as the media ages. Since GAC operates via adsorption and the adsorption sites are limited in number, it was suspected that the GAC may be preferential to one parameter or the other. Therefore, both TOC and PFAS removal efficiencies were monitored closely.

The level of TOC applied to Filters 9 and 10 was measured in the West (New) Plant clarified water. As shown in Figure 4, the TOC applied to Filters 9 and 10 generally was between 1.0 and 1.5 mg/L with an average of about 1.3 mg/L. Upon start-up of Filters 9 and 10, TOC at the filter effluent was measured at about 0.3 mg/L, which was about 80% removal initially. However, within about one month of operation, TOC at the filter effluent was up to about 1.0 mg/L – only about 20% removal – and that level of removal efficiency remained for the balance of the pilot study. See Figure 5.

Along with TOC removal, there was the additional benefit of reduction in total trihalomethanes (THM). Figure 6 shows this reduction in THM from the Clarified Water (West Plant) sample to the Plant Confluence sample when Filters 9 and 10 came on-line. In addition, Figure 7 shows negligible THM in the Filters 9 and 10 effluent sample. However, in the same way that TOC removal decreased with time, so did the THM removal.

5.1.3 PFAS Removal

While the ability of Filters 9 and 10 to remove TOC was very good initially but dropped shortly after start-up, their ability to remove various PFAS compounds varied throughout the pilot study.

EPA Method 537

The concentration of total PFAS entering Filters 9 and 10 (Clarified Water West Plant) ranged from 7 ng/L to 46 ng/L as shown in Figure 8. PFOA and PFOS (both eight carbon, or C8, compounds) were the primary compounds of concern during the pilot study as they were the only two analytes with an EPA Health Advisory level (70 ng/L combined). Figure 9 shows that PFOA and PFOS were consistently removed by the F-820 GAC to non-detect levels through nearly nine (9) months of operation. Later in the pilot study, PFOA and/or PFOS were detected in the filtered water during each sampling event at 6.0 ng/L or less, combined. During this time, the filters maintained about 50% removal of PFOA and PFOS.

Other PFAS compounds detected with this method in the water applied to Filters 9 and 10 were PFHxS (C6), PFHxA (C6), PFHpA (C7) and PFBS (C4). The F-820 GAC consistently removed PFHxS to non-detect levels for the duration of the pilot study. PFHxA was detected in the filtered water after about one (1) month of operation, PFHpA after about two (2) months, and PFBS after about three (3) months. Figures 10 and 11 show that Filters 9 and 10 achieved 100% removal of PFAS for about one month of operation, but removal gradually decreased to about 40% (60% breakthrough) at the end of the pilot study.

Eurofins Method L402

The total concentration of PFAS detected at all locations using laboratory Method L402 is shown in Figure 12.

Tested concentrations of PFOS and PFOA were substantially similar between Method 537 and Method L402 as can be seen in Figure 9.

Other PFAS compounds detected with this method in the water applied to Filters 9 and 10 were 6:2 FTS, PFBA (C4), PFPeA (C5), and PFPeS (C7). The 6:2 FTS and PFPeS were not detected in Filters 9 and 10 treated water, but PFBA and PFPeA were detected regularly during the pilot study as shown in Figures 10 and 11.

Volume of Water Treated

Filters 9 and 10 treated 266 million gallons and 238 million gallons of water, respectively, before seeing breakthrough of PFOA or PFOS. There was breakthrough of other PFAS compounds after treating about 40 million gallons. Figures 10 and 11 show the individual PFAS compound concentrations in the Filter 9 and 10 water as a function of time with references to volume treated over the duration of the pilot study.

Iodine Number Test

Notably, after about fifteen (15) months of operation, the F-820 GAC in Filters 9 and 10 had an iodine number of 714 and 729, respectively. Compared to virgin F-820 (iodine number of 900) and with Calgon's recommendation that the GAC be replaced when the iodine number drops below 500, Calgon's iodine number test indicated that Filters 9 and 10 should have about 50% adsorption capacity remaining. However, due to the slower kinetics of the F-820 and the less than recommended empty bed contact time, it is clear that the F-820 is no longer removing PFAS effectively.

5.1.4 Empty Bed Contact Time

With the current water plant configuration and operation, Filters 9 and 10 provided an EBCT of just over 8 minutes. This was less than the 10 minutes recommended by Calgon, but it was the maximum available without making more significant changes to the water plant. It is expected that using F-820 GAC with a longer EBCT would provide a greater potential for PFAS removal, but this was not able to be tested with the current pilot study.

5.2 Mono Media Filters

The Phase 2 and Phase 3 filters were the mono-media filters with about 52 inches (Filter 1) or 47 inches (Filters 11 and 12) of F-400 GAC.

5.2.1 Turbidity Removal

Verification of pathogen removal also was a requirement in the mono-media filters. As with the dual-media filters, this was done by assessing turbidity removal which is a surrogate for the presence of pathogens. Turbidity was measured continuously at each filter, and operators watched for any peaks in turbidity as well as the start and end of each filter run.

In Filter 1, the applied turbidity – measured as the average effluent concentration from Clarifiers 1-4 – ranged from 1 to 6 NTU. Turbidity in the Filter 1 effluent typically was less than 0.05 NTU. Shortly after filter start-up, there were occasional increases to about 0.4 NTU NTU as shown in Figure 13.

Turbidity in the Filter 11 and 12 effluent typically was less than 0.05 NTU but had occasional readings between 0.05 and 0.10 NTU as shown in Figure 14. Overall, this level of turbidity removal was better than pre-GAC operation, so with these results, the pathogen removal goal of Phases 2 and 3 of the pilot study was confirmed.

It was observed in the Filter 11-12 turbidimeters that within 4 – 5 minutes after filter startup, turbidity levels increased to 0.10 – 0.15 NTU before returning to normal levels. The increase typically lasted 10 – 20 minutes. Turbidity levels during a representative filter start-up are shown in Figure 14b. While this turbidity increase is slightly larger in magnitude and duration than before the changeout to GAC, the peak turbidity was well within minimum compliance levels. The increase was reviewed with the GAC manufacturer and it is likely due to microbial sloughing from the filter bed after being stagnant overnight. Additional testing, such as a Silt Density Index (SDI) test, is being conducted for confirmation.

Heterotrophic plate count (HPC) tests again were conducted throughout the treatment process. With the addition of GAC, the filters became biologically active as shown by the HPC levels in Figure 2. However, disinfection as described in Phase 1 maintained non-detect levels for HPC at the Plant Confluence. See Figure 3.

5.2.2 TOC Removal

As in Phase 1, TOC removal efficiencies were monitored closely in Phases 2 and 3. The level of TOC applied to Filter 1 was measured in the East (Old) Plant clarified water. As shown in Figure 4, the TOC applied to Filter 1 generally was between 1.0 and 1.75 mg/L with an average of about 1.4 mg/L. At start-up, TOC was measured at about 0.2 mg/L at the filter effluent, which represented nearly 90% removal initially. Over the next year, the TOC removal efficiency in Filter 1 gradually decreased to about 50% as shown in Figure 5.

The level of TOC applied to Filters 11 and 12 was measured in the West Plant clarified water and generally was between 1.0 and 1.5 mg/L with an average of about 1.3 mg/L. Upon start-up, Filters 11 and 12 provided better than 80% TOC removal initially. Over the next eleven

months, the TOC in the filter effluent gradually increased, representing a gradual decrease in removal efficiency to about 30-40% as shown in Figures 2 and 3.

Again, along with the TOC removal provided by GAC came the additional benefit of reduction in total trihalomethanes (THM), as shown in Figures 6 and 7. This was evident particularly in Filters 11 and 12 which had THM testing both before and after the media conversion. However, in the same way TOC removal decreased with time, so did the THM removal, although the F-400 maintained THM removal longer than the F-820.

5.2.3 PFAS Removal

5.2.3.1 Filter 1

Similar to Filter 1's ability to remove TOC was its efficiency at removing PFAS. Again, PFOA and PFOS were the primary compounds of concern during the pilot study. As shown in Figure 9, PFOA and PFOS (both C8) were removed by the F-400 GAC to non-detect levels for the duration of the pilot study.

EPA Method 537

The concentration of total PFAS entering Filter 1 (Clarified Water East Plant) ranged from 21 ng/L to 50 ng/L as shown in Figure 8.

As shown in Figure 15, all PFAS compounds detected with this method in the East Plant clarified water – PFBS (C4), PFHpA (C7), PFHxS (C6) and PFHxA (C6) – were removed by the F-400 GAC to non-detect levels for the duration of the pilot study.

Eurofins Method L402

The total concentration of PFAS detected at all locations using laboratory Method L402 is shown in Figure 12.

Tested concentrations of PFOS and PFOA were substantially similar between Method 537 and Method L402 as noted previously.

Other PFAS compounds detected with this method in the water applied to Filter 1 were 6:2 FTS, PFBA (C4), PFPeA (C5), PFPeS (C7), PFHxDA (C16), and NMeFOSA (C9). The F-400 GAC in Filter 1 removed all these compounds except for two detects of PFBA

at <7 ppt after about one year of operation as shown in Figure 15. There was also one detect of PF-2-methoxyethoxyacetic acid at 5 ppt, but this was the only detect of this compound at any location during the pilot study.

Iodine Number Test

After about fourteen (14) months of operation, the F-400 GAC in Filter 1 had an iodine number of 889. Compared to virgin F-400 (iodine number of 1,000) and with Calgon's recommendation that the GAC be replaced when the iodine number drops below 500, this test indicated that Filter 1 should have about 80% adsorption capacity remaining.

Volume of Water Treated

These results need to be considered in the context of volume of water treated. During the pilot study, Filter 1 treated about 37 million gallons, which is less than 10% of the volume treated by Filter 9 or 10. Figure 15 shows the individual PFAS compound concentrations in the Filter 1 water as a function of time with references to volume treated over the duration of the pilot study.

5.2.3.2 Filters 11 and 12

Similar to Filter 11's and 12's ability to remove TOC was their efficiency at removing PFAS. As shown in Figure 9, PFOA and PFOS (both C8) were removed by the F-400 GAC to non-detect levels for the duration of the pilot study.

EPA Method 537

The concentration of total PFAS entering Filters 11 and 12 (Clarified Water West Plant) ranged from 7 ng/L to 46 ng/L.

As shown in Figures 16 and 17, all other PFAS compounds detected in the West Plant clarified water – PFBS (C4), PFHpA (C7), PFHxS (C6) and PFHxA (C6) – were removed by the F-400 GAC to non-detect levels through eight (8) months of operation.

PFHxA was detected first at 2.2 ng/L in Filter 12 effluent after about eight (8) months and was detected regularly at < 3.0 ng/L thereafter. PFBS was the only other compound detected in Filter 12 effluent at < 3.0 ng/L beginning at about 10 months after start-up.

PFBS was detected first at 2.4 ng/L in Filter 11 effluent after about eleven (11) months. No other PFAS compounds were detected in Filter 11 using this method.

Eurofins Method L402

The total concentration of PFAS detected at all locations using laboratory Method L402 is shown in Figure 12.

Tested concentrations of PFOS and PFOA were substantially similar between Method 537 and Method L402 as noted previously.

Other PFAS compounds detected in the water applied to Filters 11 and 12 were 6:2 FTS, PFBA (C4), PFPeA (C5), and PFPeS (C7). The F-400 GAC removed all of these compounds except for infrequent, low detects of 6:2 FTS (one detect, one week after startup in Filter 11), PFPeA and PFBA as shown in Figures 16 and 17. Detects increased after about eight months of operation but total levels remained below.

Volume of Water Treated

Although they did not begin operating until October 2018, Filters 11 and 12 were utilized heavily and treated 290 and 301 million gallons of water, respectively, without seeing breakthrough of PFOA or PFOS. Breakthrough of any PFAS compound tested occurred in Filters 11 and 12 after each treated about 100 million gallons. Figures 16 and 17 show the individual PFAS compound concentrations in the Filter 11 and 12 water as a function of time with references to volume treated for the duration of the pilot study.

Iodine Number Test

After about eleven (11) months of operation, the F-400 GAC in Filters 11 and 12 had an iodine number of 794 and 793, respectively. Compared to virgin F-400 (iodine number of 1,000) and with Calgon's recommendation that the GAC be replaced when the iodine number drops below 500, this test indicated that Filters 11 and 12 should have about 60% adsorption capacity remaining.

5.2.4 Empty Bed Contact Time

With the current water plant configuration and operation, Filter 1 provided an EBCT of just over 8 minutes. This was less than the 10 minutes recommended by Calgon, but it was the

maximum available without making significant changes to the water plant. For the duration of the pilot study, the F-400 removed all PFAS even with the lower EBCT.

Filters 11 and 12 were reconfigured in such a way that an EBCT of just over 10 minutes was provided. Since Filters 11 and 12 treated almost ten times more water than Filter 1 and because Filter 1 did not see any breakthrough of PFAS during the pilot study, a direct comparison between the 8-minute and 10-minute EBCT was not possible. However, given the results of the iodine test, which indicate remaining life in the GAC, it is anticipated that maximizing the EBCT – even in excess of 10 minutes – would be beneficial.

5.3 Other Observations

5.3.1 F-820 GAC

As expected, Calgon's F-820 GAC was more effective at removing long-chain PFAS compounds than short-chain compounds. Its physical characteristics are similar to anthracite which allowed the WTP to operate as it did prior to GAC, demonstrate the effectiveness of GAC for pathogen removal, and provide some additional benefit of PFAS removal.

5.3.2 F-400 GAC

Calgon's F-400 GAC, which had been proven by Calgon to be optimal for PFAS removal prior to Plainfield's pilot study, was found to be effective at removing long-chain and some short-chain PFAS compounds. Figures 18 and 19 show individual PFAS concentrations, as tested using Method's 537 and L402, respectively, of the WTP's final treated water that was pumped into the distribution system. Due to the breakthrough of PFHxA and PFBS initially in Filters 9 and 10 (F-820 GAC) and later in Filters 11 and 12, these compounds were detected below 5 ppt in the Plant Tap between 4 and 5 months after Filters 11 and 12 came online with F-400 GAC. There were also detects of PFBA below 6 ppt starting about 5 months after Filters 11 and 12 came online. Finally, PFPeA was reduced significantly but was never completely removed from the Plant Tap water.

Operationally, the F-400 required lower backwash rates due to the finer particle size. The F-400 proved itself to be highly effective at removing TOC initially, but its effectiveness reduced over time as the adsorption sites became populated. Results appear to indicate that the F-400 may be preferential to removing PFAS over TOC.

5.3.3 GAC Fines in Backwash Water

The Calgon F-400 GAC produced gray-colored backwash water when the surface wash system was operating, which was believed to be powder or extremely fine particles from the carbon. It was expected that the backwash water would clear up over time, but the color of backwash water was fairly consistent for the duration of the pilot study. The physical condition of the GAC (sieve analysis) was tested quarterly, and the depth of GAC was measured quarterly. The sieve analysis results showed slight variations in effective size and gradation over time, and the bed depth measurements indicated minimal change (variations of less than +/- ¾" in any of the filters. The reason for the gray backwash water is unknown and will continue to be monitored.

5.3.4 Filter Run-Times

Filter run-time trends varied slightly with seasonal changes in demand, particularly as operators needed to stagger backwashes to maintain treatment capacity. See Figure 20. Generally, Filters 9 and 10 (Phase 1) runtimes averaged 120 – 170 hours, which was about double compared to pre-GAC operation (average 74 hours in 2017-18). The Phase 2 filter (Filter 1) initially had runtimes of 24 – 48 hours. With increased water demands through the spring and summer, Filter 1 runtimes normalized in the 48-hour range, which was about 30% higher than pre-GAC operation (average 36 hours in 2017-18) in Filter 1. The Phase 3 (Filters 11 and 12) runtimes held fairly steady between 60 – 100 hours, which was similar to the pre-GAC average runtimes of 78 hours for Filter 11 and 74 hours for Filter 12 in 2017-18. Runtimes trended upward during the pilot study as operators optimized procedures.

Composite filter runtimes also were evaluated for comparison between pre-GAC and post-GAC operation. For all filters in operation from May 2017 through May 2018 (pre-GAC), the average filter runtime was 61 hours. From June 2018 through September 2019 (partial or full GAC filtration), the average filter runtime increased about 30% to 80 hours.

Overall, F-400 GAC backwashes required a greater amount of time to backwash due to the slower backwash rate but the volume of water used was similar to the pre-GAC filters. The F-820 GAC backwashes, on average, used more water than the pre-GAC filters. Visually clean water typically signaled the end of the backwash cycle.

5.3.5 Backwash Energy

Another aspect of the pilot study was to verify if the affinity of PFAS to GAC was strong enough to withstand backwash energy. This was done by sampling the backwash water for PFAS. Throughout the study, there was no indication that PFAS was released from the GAC during backwash. In fact, several tests appeared to show that the GAC may be providing incremental additional removal of PFAS during the backwash operation. See Table 1.

5.3.6 Operation and Maintenance Changes

Upon completion of the pilot study, changes in water plant operation and maintenance (O&M) were evaluated to estimate any increased costs attributable to the addition of GAC. Changes in O&M were as follows:

5.3.6.1 Filter Runtime and Backwash

As noted previously, the composite average filter runtime increased by about 30% after conversion to GAC. This resulted in fewer backwashes during the year-long pilot study. However, each backwash took longer to perform because the backwash rate was lower, and operators needed to monitor the backwashes more closely to prevent loss of media and to optimize flow rates.

Average backwash volumes before and after the change-out to GAC are summarized in the following table.

	Avg. Backwash Volume Pre-GAC	Avg. Backwash Volume Post-GAC	Percentage Change
Filter 1 (F-400)	46,000	48,000	+ 6%
Filter 9 (F-820)	134,000	164,000	+ 23%
Filter 10 (F-820)	134,000	167,000	+ 25%
Filter 11 (F-400)	144,000	123,000	- 15 %
Filter 12 (F-400)	139,000	123,000	- 11%

These data should not be interpreted as definitive results that one can expect to see upon converting a rapid sand filter to GAC. Backwash scheduling and duration is an operator decision and can vary significantly based on plant operations. For example, for Filter 12 prior to GAC, while the average volume used was 139,000 gallons, the range in volume used was from 95,000 gallons up to 174,000 gallons. Therefore, a change in volume of +/- 25% does not represent a substantial variation from normal operations.

Since the WTP is configured to use finished water from ground storage reservoirs to complete the backwashes, such changes in backwash volume represent negligible cost increases or savings.

5.3.6.2 Personnel Time

The pilot study itself was labor intensive for WTP managers and operators. Extra time was required to learn how to operate the GAC filters and to monitor them closely to ensure all requirements were met. Process optimization also took extra time until operators became comfortable with the filters. However, now that the filters are operating in predictable ways, the amount of time required by managers and operators is very similar to the old rapid sand filters.

5.3.6.3 Laboratory Analysis

Extra laboratory analysis is required with the GAC filters, particularly because they are biologically active filters. HPCs and turbidity are tested more frequently, and chlorine residuals are monitored very closely. Most of this testing is done in the water plant's laboratory so there is no additional cost. Going forward, there will be extra analytical costs for monitoring PFAS to gauge the life expectancy of the GAC and predicting media change-out schedules.

6 CONCLUSIONS

The GAC Pilot Study was a success for Plainfield Charter Township. In a span of about ten months, the Township conceived a plan to address PFAS contamination, designed the necessary WTP improvements, worked through the State permitting process for a pilot study, obtained a grant from the State of Michigan, constructed the necessary improvements to provide 9 mgd of GAC filtration capacity, and optimized the plant to achieve the treatment objectives. All this was completed while continuing to operate a fully functional water treatment plant producing 4 mgd on average and about 10 mgd maximum of safe, clean drinking water.

6.1 Rapid Sand Filter Retrofit

On a short-term basis, it was feasible and effective for Plainfield Charter Township to address its PFAS contamination by retrofitting its existing rapid sand filters. While retrofitting an existing plant may not work for every water utility, the main reasons it succeeded for Plainfield were the

following: 1) elected officials and managers, water system management and operators were willing to go above and beyond any State or Federal requirement to address an emerging contaminant; 2) the WTP had an adequate number of filters that enabled a full-scale pilot study while the plant was in operation; 3) there was adequate operational flexibility in the WTP for filter selection and adjusting backwash rates; 4) there was 8 – 10 minutes of available empty bed contact time for removal of PFOA and PFOS and at least partial removal of many other PFAS compounds.

Access to the filter gallery and high-pressure water source are required for media change-out. During media change-outs, hoses are strung through doors, hallways and corridors, semi-trucks are mobilized on site, and the process is noisy and intrusive. This is less than ideal for WTP operations especially since this process will occur more regularly with GAC filters.

6.2 TOC and PFAS Removal

Calgon F-820 GAC's ability to remove TOC dropped substantially after only one month. Although F-820 removed PFOA and PFOS for nearly nine months, other PFAS compounds were detected after only one month of operation. Continued removal of some PFAS with minimal removal of TOC over time may indicate the F-820 is preferential to PFAS. Breakthrough of PFAS does not necessarily mean the GAC life is expended, as shown in Calgon's iodine number test. It is expected that increasing and maximizing the available empty bed contact time, if possible, could increase the removal efficiency.

Calgon F-400 GAC's ability to remove TOC dropped after about three months of operation in Filters 11 and 12, which were the F-400 filters primarily used. The long duration of the F-400's good TOC removal efficiency in Filter 1 is somewhat misleading because Filter 1 treated much less water than Filters 11 and 12 during the pilot study.

With the approximately 8-minute EBCT in Filter 1 and the 10-minute EBCT in Filters 11 and 12, the F-400 GAC was effective at removing PFOA, PFOS and other PFAS compounds for the duration of the pilot. While the WTP saw some breakthrough of PFAS compounds, the F-400 was determined to be the GAC of choice for TOC and PFAS removal. Again, breakthrough of PFAS does not necessarily mean the GAC life is expended, as shown in Calgon's iodine number test, and it is expected that increasing and maximizing the available empty bed contact time, if possible, could increase the removal efficiency.

Removal efficiencies for both types of carbon are highly dependent on source water quality and contaminant concentrations. While initial projections estimate the GAC will have a shorter life expectancy than was predicted by Calgon's accelerated column testing, continued sampling will reveal the actual life expectancy of the GAC and will guide future decision-making.

It should be noted that EBCT and raw water TOC are critical factors in the success of GAC in rapid sand filter beds. While 8 – 10 minutes of EBCT worked for removal of PFOA and PFOS and several other PFAS during the pilot study, this EBCT is not sufficient for removal of other short-chain PFAS compounds. Longer EBCT likely is needed for complete removal of all PFAS; additional study is needed in this area.

With GAC media in the rapid sand filter beds, the GAC is responsible for removal of both TOC and any lime softening residuals, both of which can compromise a GAC filter's long-term ability to remove PFAS. While GAC can accomplish many removal goals for a relatively short time, the life of a GAC filter could be extended if the GAC is dedicated to PFAS removal.

6.3 O&M Cost Increases

Changes to backwash procedures do not represent a significant increase in or decrease to plant operation costs.

Additional personnel time and laboratory analytical expenses will be required to monitor the GAC. The required personnel time does not represent a substantial cost increase compared with the capital costs for plant modifications and GAC installation. However, significant laboratory analytical expenses will continue as the water plant monitors TOC and PFAS levels to gauge the life expectancy of the GAC. Going forward, the water plant will reduce the high frequency of sampling but will continue at least quarterly sampling for PFAS at select locations. During the pilot study, the lab fee for one sample was $200 using EPA Method 537 (including blanks) and it was $433 per sample (including blanks) using the L402 method. With more laboratories now offering PFAS testing, it is expected that these rates will decrease.

Tables

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge	
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
June 7, 2018	**Filters 9 & 10 Online with Calgon F-820 GAC**				
June 25, 2018	*Method: EPA 537*				
	PFOS (ng/L)	2.3		<2	
	PFOA (ng/L)	<2		<2	
	PFOS+PFOA (ng/L)	***2.3***		**<2**	
	Other Detects	none tested		none tested	
	PFBS (ng/L)				
	PFHpA (ng/L)				
	PFHxS (ng/L)				
	PFHxA (ng/L)				
	Total PFAS (ng/L)	**2.3**		***<2***	
July 16, 2018	**Filter 1 Online with Calgon F-400 GAC**				
July 29, 2018	*Method: EPA 537*	Plant Tap data from 7/30/18			
	PFOS (ng/L)	4.4	<2	2.4	
	PFOA (ng/L)	2.5	<2	<2	
	PFOS+PFOA (ng/L)	***6.9***	***<2***	***2.4***	
	Other Detects				
	PFBS (ng/L)	2.8	<2	2.2	
	PFHpA (ng/L)	9.7	<2	7.0	
	PFHxS (ng/L)	<2	<2	<2	
	PFHxA (ng/L)	10	<2	8.5	
	Total PFAS (ng/L)	**29.4**	**<2**	**20.1**	
July 29, 2018	*Method: L402*				
	PFOS (ng/L)	5.0	<2	3.0	
	PFOA (ng/L)	2.7	<2	<2	
	PFOS+PFOA (ng/L)	***7.7***	***<2***	***3.0***	
	Other Detects				
	6:2 FTS (ng/L)	2.5	<2	<2	
	PFBS (ng/L)	3	<2	2.4	
	PFBA (ng/L)	12	<5	12	
	PFHpA (ng/L)	10	<2	7.9	
	PFHxS (ng/L)	<2	<2	<2	
	PFHxA (ng/L)	11	<2	9.4	
	PFPeA (ng/L)	33	<2	30	
	Total PFAS (ng/L)	**79.2**	**<2 / <5**	**64.7**	

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
September 9, 2018	*Method: EPA 537*	Plant Tap data from 9/10/18			
	PFOS (ng/L)	3.9	<2	2.3	
	PFOA (ng/L)	<2	<2	<2	
	PFOS+PFOA (ng/L)	***3.9***	***<2***	***2.3***	
	Other Detects				
	PFBS (ng/L)	3.1	<2	2.5	
	PFHpA (ng/L)	5.8	<2	4.4	
	PFHxS (ng/L)	<2	<2	<2	
	PFHxA (ng/L)	7.0	<2	5.9	
	Total PFAS (ng/L)	**19.8**	**<2**	**15.1**	
September 9, 2018	*Method: L402*				
	PFOS (ng/L)	4.4	<2	2.9	
	PFOA (ng/L)	2.2	<2	<2	
	PFOS+PFOA (ng/L)	***6.6***	***<2***	***2.9***	
	Other Detects				
	6:2 FTS (ng/L)	3.8	<2	2.5	
	PFBS (ng/L)	3.5	<2	2.8	
	PFBA (ng/L)	9.8	6.9	10	
	PFHpA (ng/L)	6.5	<2	5.3	
	PFHxS (ng/L)	<2	<2	<2	
	PFHxA (ng/L)	8.0	<2	7.2	
	PFDoS (ng/L)	<2	<2	<2	
	PFPeA (ng/L)	24	8.5	23	
	PFPeS (ng/L)	<2	<2	<2	
	Total PFAS (ng/L)	**62.2**	**15.4**	**53.7**	
October 11, 2018	**Filters 11 & 12 Online with Calgon F-400 GAC**				
October 22, 2018	*Method: EPA 537*	Plant Tap data from 10/22/18			
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	PFBS (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	Total PFAS (ng/L)	**<2**			**<2**

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
October 22, 2018	*Method: L402*				
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	6:2 FTS (ng/L)	<2			<2
	PFBS (ng/L)	<5			<5
	PFBA (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	PFDoS (ng/L)	<2			<2
	PFPeA (ng/L)	5.6			<2
	PFPeS (ng/L)	<2			<2
	Total PFAS (ng/L)	**5.6**			**<2**
November 5, 2018	*Method: EPA 537*	Plant Tap data from 11/5/18			
	PFOS (ng/L)	<2	<2		<2
	PFOA (ng/L)	<2	<2		<2
	PFOS+PFOA (ng/L)	***<2***	***<2***		***<2***
	Other Detects				
	PFBS (ng/L)	<2	<2		<2
	PFHpA (ng/L)	<2	<2		<2
	PFHxS (ng/L)	<2	<2		<2
	PFHxA (ng/L)	<2	<2		<2
	Total PFAS (ng/L)	**<2**	**<2**		**<2**
November 5, 2018	*Method: L402*				
	PFOS (ng/L)	<2	<2		<2
	PFOA (ng/L)	<2	<2		<2
	PFOS+PFOA (ng/L)	***<2***	***<2***		***<2***
	Other Detects				
	6:2 FTS (ng/L)	<2	<2		<2
	PFBS (ng/L)	<5	<5		<5
	PFBA (ng/L)	<2	<2		<2
	PFHpA (ng/L)	<2	<2		<2
	PFHxS (ng/L)	<2	<2		<2
	PFHxA (ng/L)	<2	<2		<2
	PFDoS (ng/L)	<2	<2		<2
	PFPeA (ng/L)	4.8	<2		<2
	PFPeS (ng/L)	<2	<2		<2
	Total PFAS (ng/L)	**4.8**	**<2**		**<2**

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
November 26, 2018	*Method: EPA 537*	Plant Tap data from 11/26/18			
	PFOS (ng/L)	<2		<2	<2
	PFOA (ng/L)	<2		<2	<2
	PFOS+PFOA (ng/L)	***<2***		***<2***	***<2***
	Other Detects				
	PFBS (ng/L)	<2		<2	<2
	PFHpA (ng/L)	<2		<2	<2
	PFHxS (ng/L)	<2		<2	<2
	PFHxA (ng/L)	<2		<2	<2
	Total PFAS (ng/L)	**<2**		**<2**	**<2**
November 26, 2018	*Method: L402*	Plant Tap sample on 11/26/18 not analyzed using Method L402			
	PFOS (ng/L)			<2	<2
	PFOA (ng/L)			<2	<2
	PFOS+PFOA (ng/L)			***<2***	***<2***
	Other Detects				
	6:2 FTS (ng/L)			<2	<2
	PFBS (ng/L)			<5	<5
	PFBA (ng/L)			<2	<2
	PFHpA (ng/L)			<2	<2
	PFHxS (ng/L)			<2	<2
	PFHxA (ng/L)			<2	<2
	PFDoS (ng/L)			<2	<2
	PFPeA (ng/L)			4.7	<2
	PFPeS (ng/L)			<2	<2
	Total PFAS (ng/L)			**4.7**	**<2**

*Filter 9 Backwash Samples taken on 11/25/2018

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
December 12, 2018	*Method: EPA 537*	Plant Tap data from 11/17/18			
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	PFBS (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	Total PFAS (ng/L)	**<2**			**<2**
December 12, 2018	*Method: L402*				
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	6:2 FTS (ng/L)	<2			<2
	PFBS (ng/L)	<5			<5
	PFBA (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	PFDoS (ng/L)	<2			<2
	PFPeA (ng/L)	3.5			<2
	PFPeS (ng/L)	<2			<2
	Total PFAS (ng/L)	**3.5**			**<2**

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
January 11, 2019	*Method: EPA 537*	Plant Tap data from 01/14/2019			
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	PFBS (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	Total PFAS (ng/L)	**<2**			**<2**
February 8, 2019	*Method: EPA 537*	Plant Tap data from 2/11/19			
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	PFBS (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	Total PFAS (ng/L)	**<2**			**<2**
February 8, 2019	*Method: L402*				
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	6:2 FTS (ng/L)	<2			<2
	PFBS (ng/L)	<5			<5
	PFBA (ng/L)	<2			<2
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	<2			<2
	PFDoS (ng/L)	<2			<2
	PFPeA (ng/L)	4.0			2.5
	PFPeS (ng/L)	<2			<2
	Total PFAS (ng/L)	**4.0**			**2.5**

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
March 8, 2019	*Method: EPA 537*	Plant Tap data from 3/12/19			Filter 12 3/11/2019
	PFOS (ng/L)	<2		<2	<2
	PFOA (ng/L)	<2		<2	<2
	PFOS+PFOA (ng/L)	***<2***		***<2***	***<2***
	Other Detects				
	PFBS (ng/L)	2.0		<2	<2
	PFHpA (ng/L)	<2		<2	<2
	PFHxS (ng/L)	<2		<2	<2
	PFHxA (ng/L)	2.3		2.4	<2
	Total PFAS (ng/L)	**4.3**		**2.4**	**<2**
March 8, 2019	*Method: L402*				
	PFOS (ng/L)	<2		<2	<2
	PFOA (ng/L)	<2		<2	<2
	PFOS+PFOA (ng/L)	***<2***		***<2***	***<2***
	Other Detects				
	6:2 FTS (ng/L)	<2		<2	<2
	PFBS (ng/L)	<2		<5	<5
	PFBA (ng/L)	5.5		6.0	5.7
	PFHpA (ng/L)	<2		<2	<2
	PFHxS (ng/L)	<2		<2	<2
	PFHxA (ng/L)	2.4		2.5	<2
	PFDoS (ng/L)	<2		<2	<2
	PFPeA (ng/L)	6.0		6.4	5.1
	PFPeS (ng/L)	<2		<2	<2
	Total PFAS (ng/L)	**13.9**		**14.9**	**10.8**
April 18, 2019	*Method: EPA 537*	Plant Tap data from 4/24/19			
	PFOS (ng/L)	<2		<2	
	PFOA (ng/L)	<2		<2	
	PFOS+PFOA (ng/L)	***<2***		***<2***	
	Other Detects				
	PFBS (ng/L)	2.2		<2	
	PFHpA (ng/L)	<2		<2	
	PFHxS (ng/L)	<2		<2	
	PFHxA (ng/L)	2.2		2.1	
	Total PFAS (ng/L)	**4.4**		**2.1**	

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
May 20, 2019	*Method: EPA 537*				
	PFOS (ng/L)	<2	<2		
	PFOA (ng/L)	<2	<2		
	PFOS+PFOA (ng/L)	***<2***	***<2***		
	Other Detects				
	PFBS (ng/L)	2.6	<2		
	PFHpA (ng/L)	<2	<2		
	PFHxS (ng/L)	<2	<2		
	PFHxA (ng/L)	2.7	<2		
	Total PFAS (ng/L)	**5.3**	**<2**		
June 1, 2019	*Method: EPA 537*	Plant Tap data from 6/3/19			
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	PFBS (ng/L)	2.7			2.1
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	3.2			2.6
	Total PFAS (ng/L)	**5.9**			**4.7**
June 1, 2019	*Method: L402*				
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	6:2 FTS (ng/L)	<2			<2
	PFBS (ng/L)	2.9			2.3
	PFBA (ng/L)	6.0			6.3
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	3.2			2.7
	PFDoS (ng/L)	<2			<2
	PFPeA (ng/L)	7.6			6.8
	PFPeS (ng/L)	<2			<2
	PF-2-methoxyethoxyacetic acid	<5			<5
	PFHxDA	<2			<2
	Total PFAS (ng/L)	**19.7**			**18.1**

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

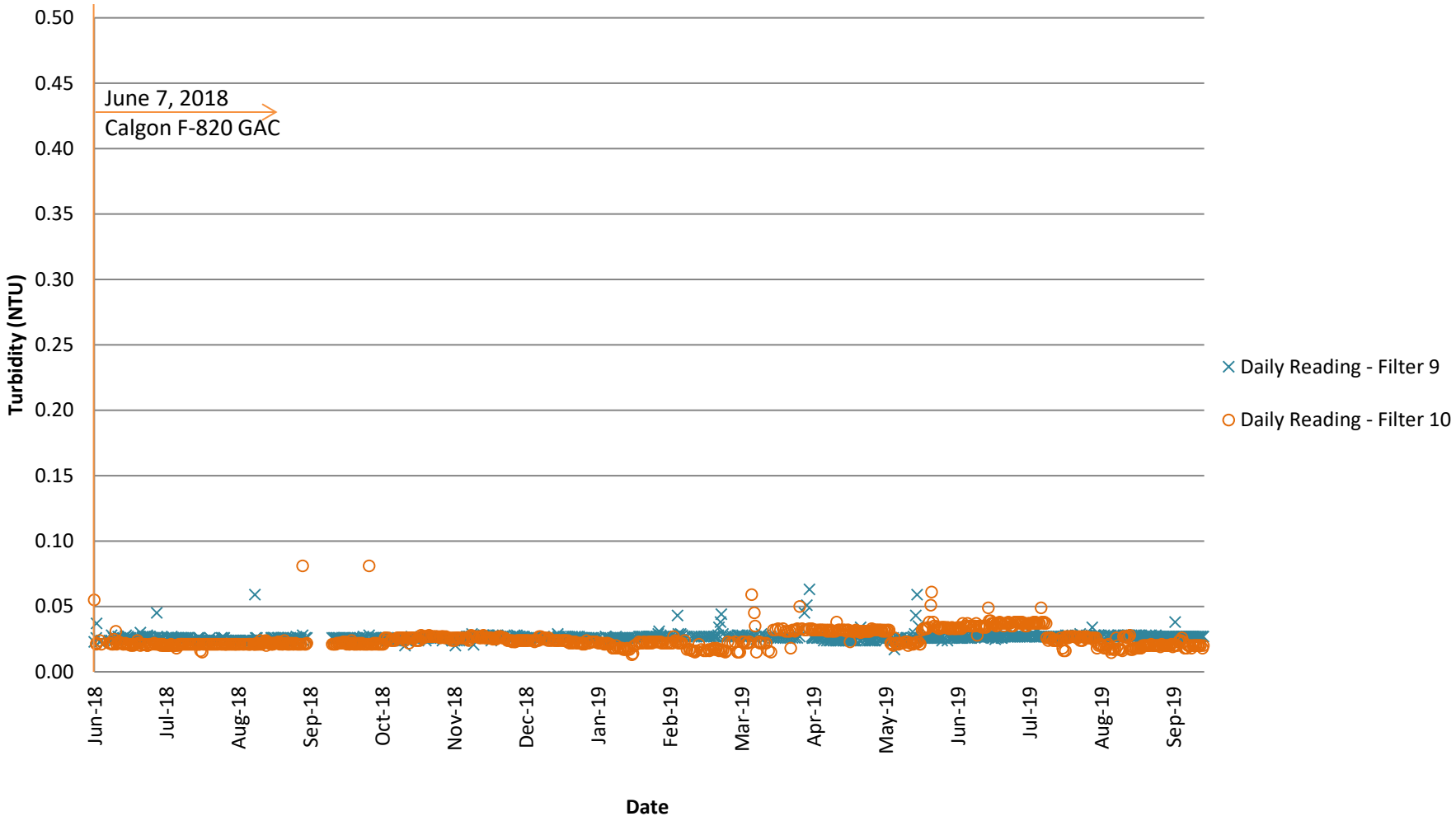
			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
June 28, 2019	*Method: EPA 537*	Plant Tap data from 7/1/19			
	PFOS (ng/L)	<2			<2
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***<2***
	Other Detects				
	PFBS (ng/L)	2.4			2.3
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	2.9			3.0
	Total PFAS (ng/L)	**5.3**			**5.3**
June 28, 2019	*Method: L402*				
	PFOS (ng/L)	<2			2.0
	PFOA (ng/L)	<2			<2
	PFOS+PFOA (ng/L)	***<2***			***2.0***
	Other Detects				
	6:2 FTS (ng/L)	<2			<2
	PFBS (ng/L)	2.7			2.4
	PFBA (ng/L)	5.3			6.4
	PFHpA (ng/L)	<2			<2
	PFHxS (ng/L)	<2			<2
	PFHxA (ng/L)	3.2			3.2
	PFDoS (ng/L)	<2			<2
	PFPeA (ng/L)	7.8			8.5
	PFPeS (ng/L)	<2			<2
	PF-2-methoxyethoxyacetic acid	<5			<5
	PFHxDA	<2			<2
	Total PFAS (ng/L)	**19.0**			**20.5**

Plainfield Charter Township
Water Treatment Plant Filter GAC Pilot Study
TABLE 1 - Backwash Chemical Data Collection

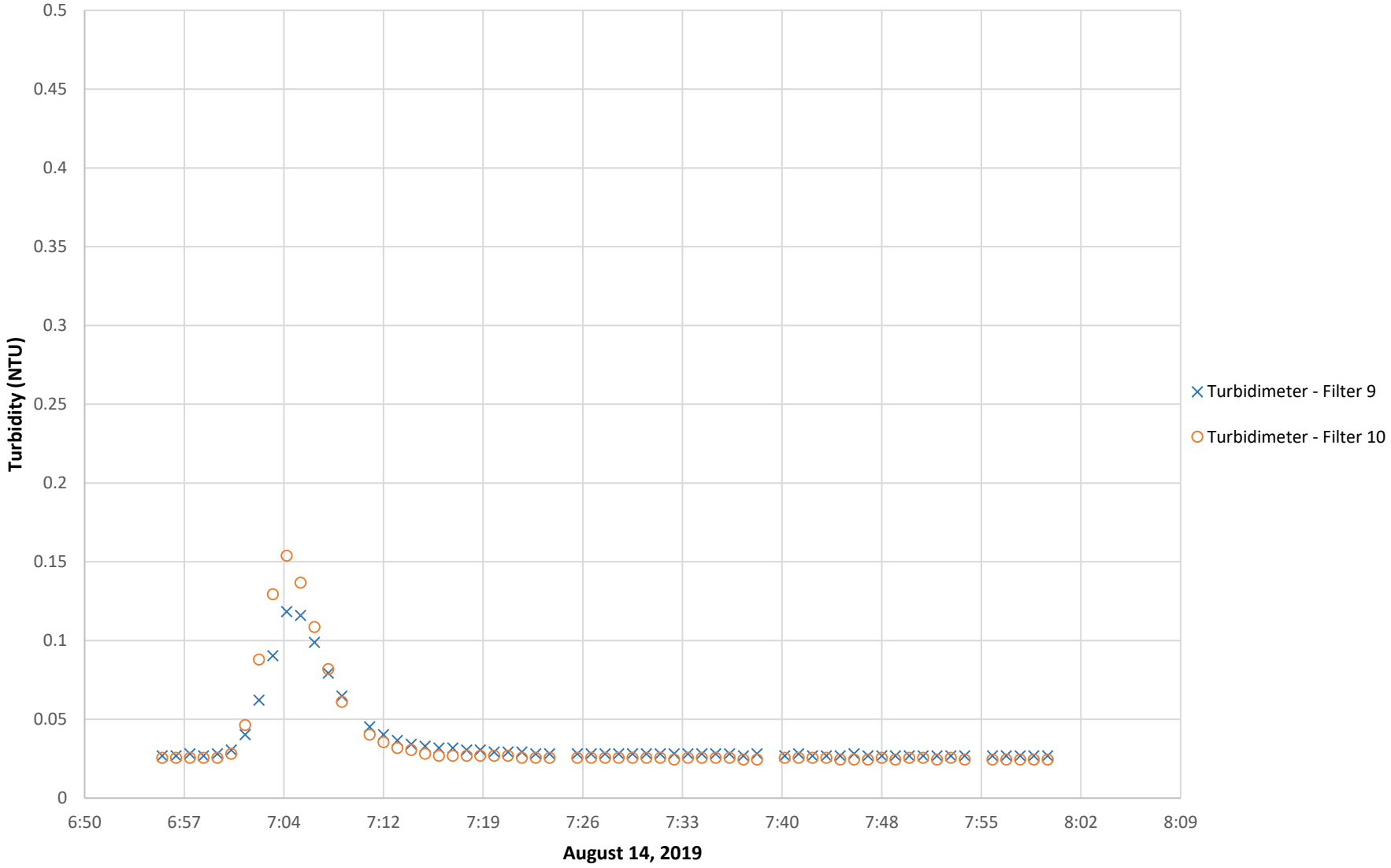
			Backwash Discharge		
Sample Location		Plant Tap (copy from "PFAS Removal Eff")	Filter 1 (East Plant)	Filter 9&10 (West Plant)	Filter 11&12 (West Plant)
Parameter: PFAS					
Collection Date					
Note: "Plant Tap" water is used to backwash filters in both halves of the WTP					
July 26, 2019	*Method: EPA 537*	Plant Tap data from 7/29/19			
	PFOS (ng/L)	<2	<2		
	PFOA (ng/L)	<2	<2		
	PFOS+PFOA (ng/L)	***<2***	***<2***		
	Other Detects				
	PFBS (ng/L)	2.9	<2		
	PFHpA (ng/L)	<2	<2		
	PFHxS (ng/L)	<2	<2		
	PFHxA (ng/L)	2.5	<2		
	Total PFAS (ng/L)	**5.4**	**<2**		
July 26, 2019	*Method: L402*				
	PFOS (ng/L)	<2	<2		
	PFOA (ng/L)	<2	<2		
	PFOS+PFOA (ng/L)	***<2***	***<2***		
	Other Detects				
	6:2 FTS (ng/L)	<2	<2		
	PFBS (ng/L)	2.9	<2		
	PFBA (ng/L)	5.2	<2		
	PFHpA (ng/L)	<2	<2		
	PFHxS (ng/L)	<2	<2		
	PFHxA (ng/L)	2.6	<2		
	PFDoS (ng/L)	<2	<2		
	PFPeA (ng/L)	5.6	3.1		
	PFPeS (ng/L)	<2	<2		
	PF-2-methoxyethoxyacetic acid	<5	<5		
	PFHxDA	<2	<2		
	Total PFAS (ng/L)	**16.3**	3.1		

Figures

Plainfield WTP
FIGURE 1a - Filters 9 & 10 Turbidity

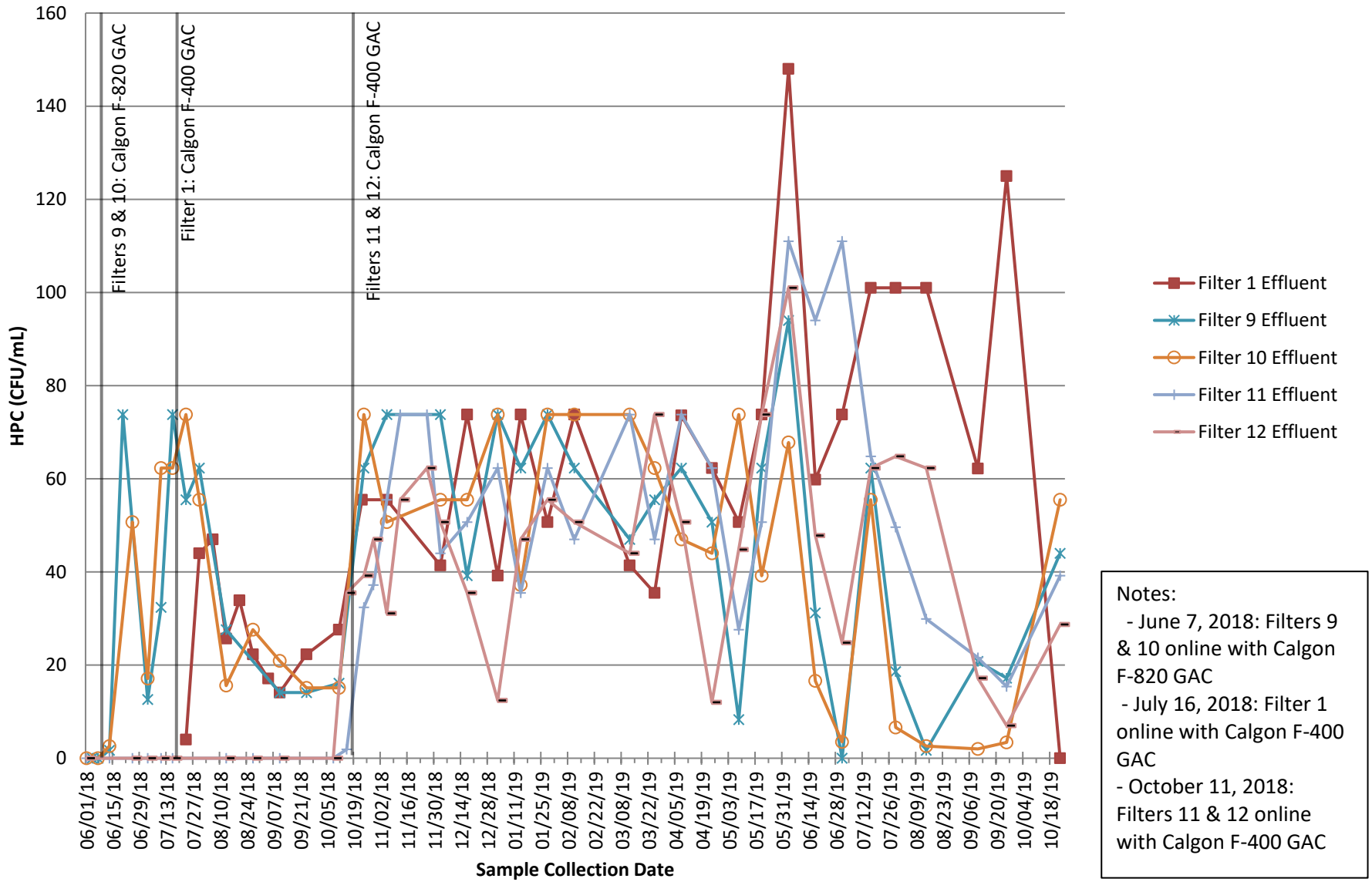


Plainfield WTP
FIGURE 1b - Filters 9 & 10 Turbidity at Start-up



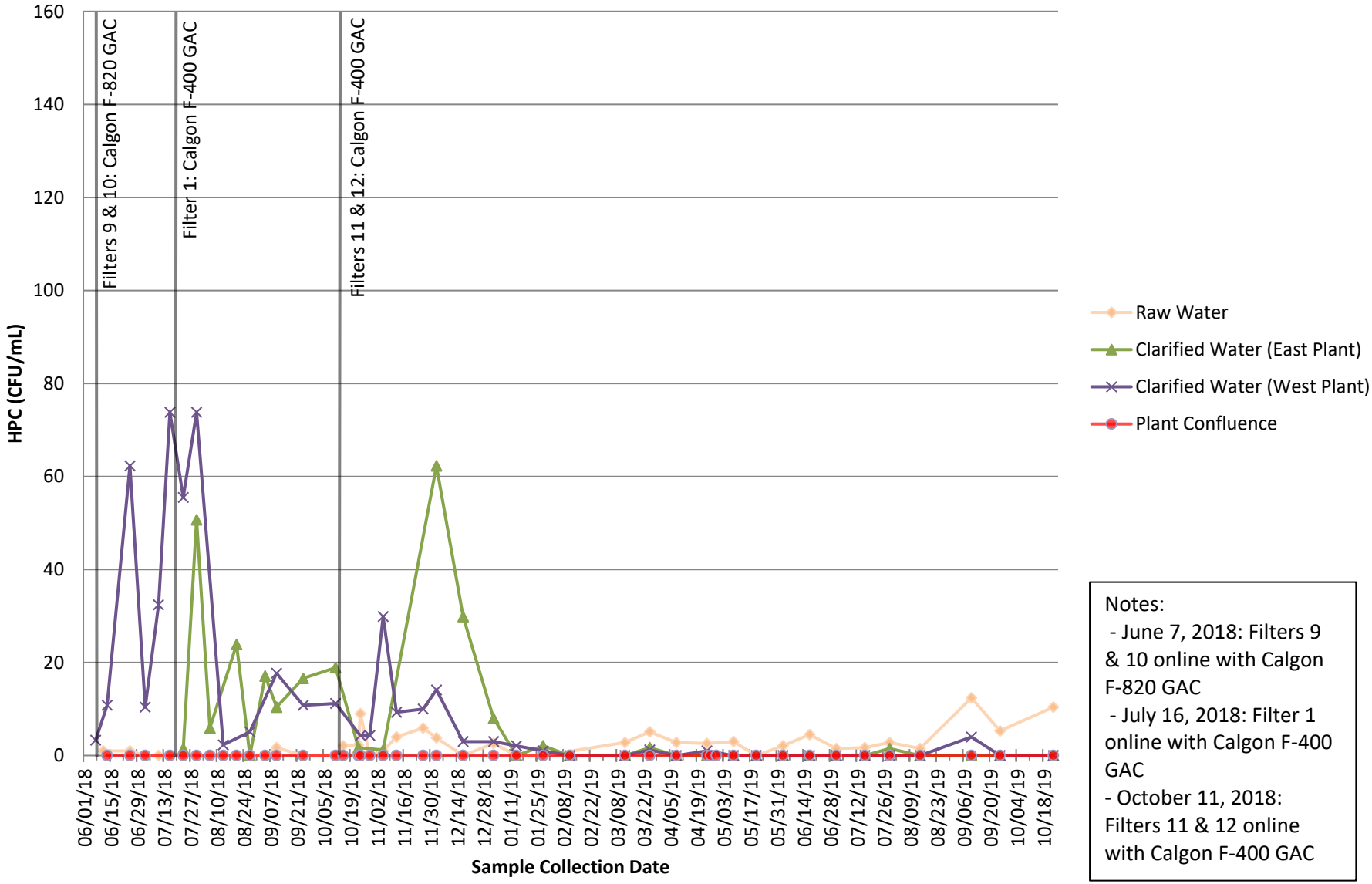
S:\2018\2180036 Plainfield Charter Township\DNC\Filter Improvements Data\Filter Turbidity Data\2019-12-20_Pilot Study Report Figures\FR F1b Filter 9-10 Turb Startup

Plainfield WTP
FIGURE 2 - HPC Filter Effluent



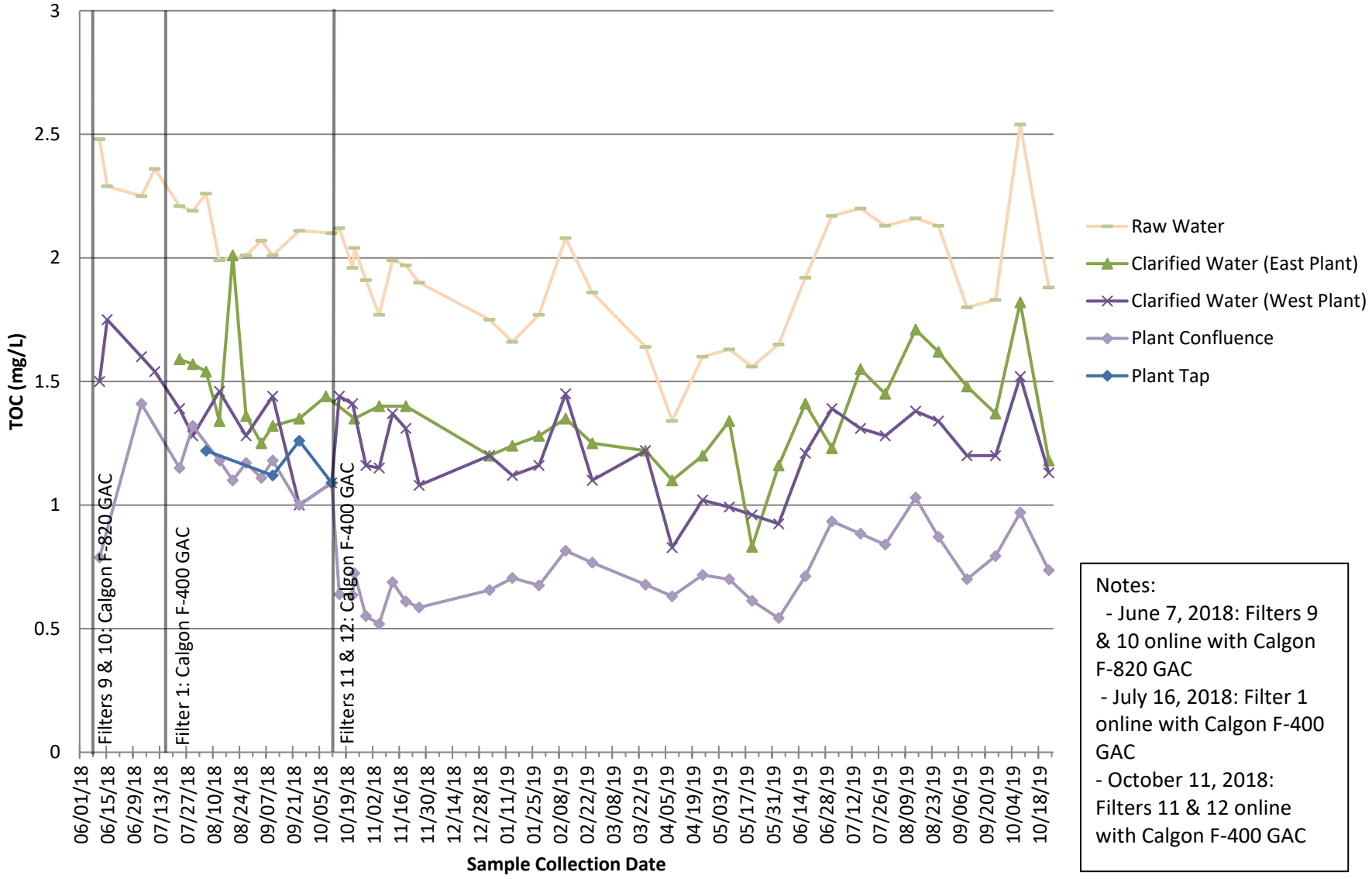
Notes:
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 3 - HPC General Locations



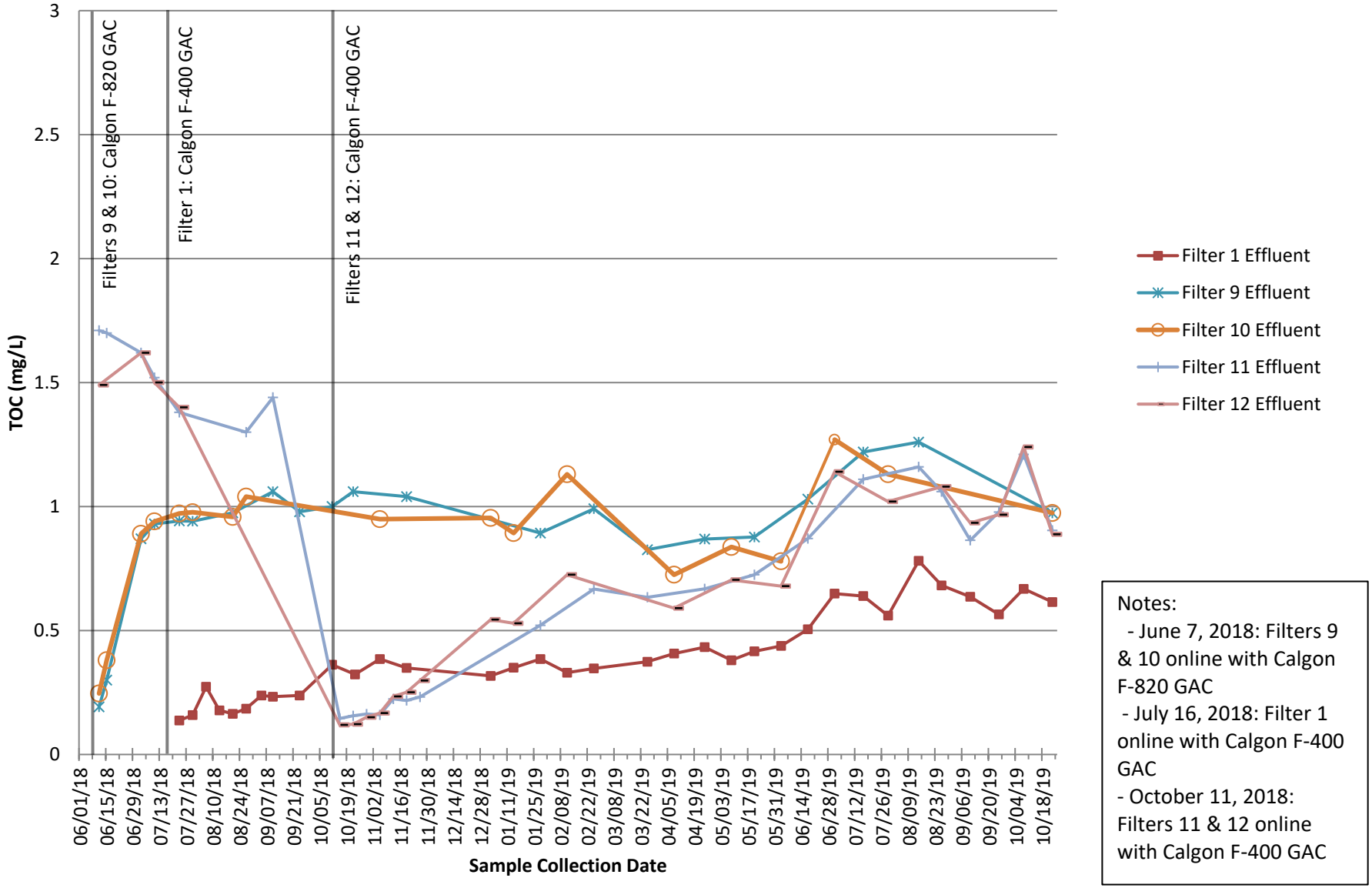
Notes:
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 4 - TOC General Locations



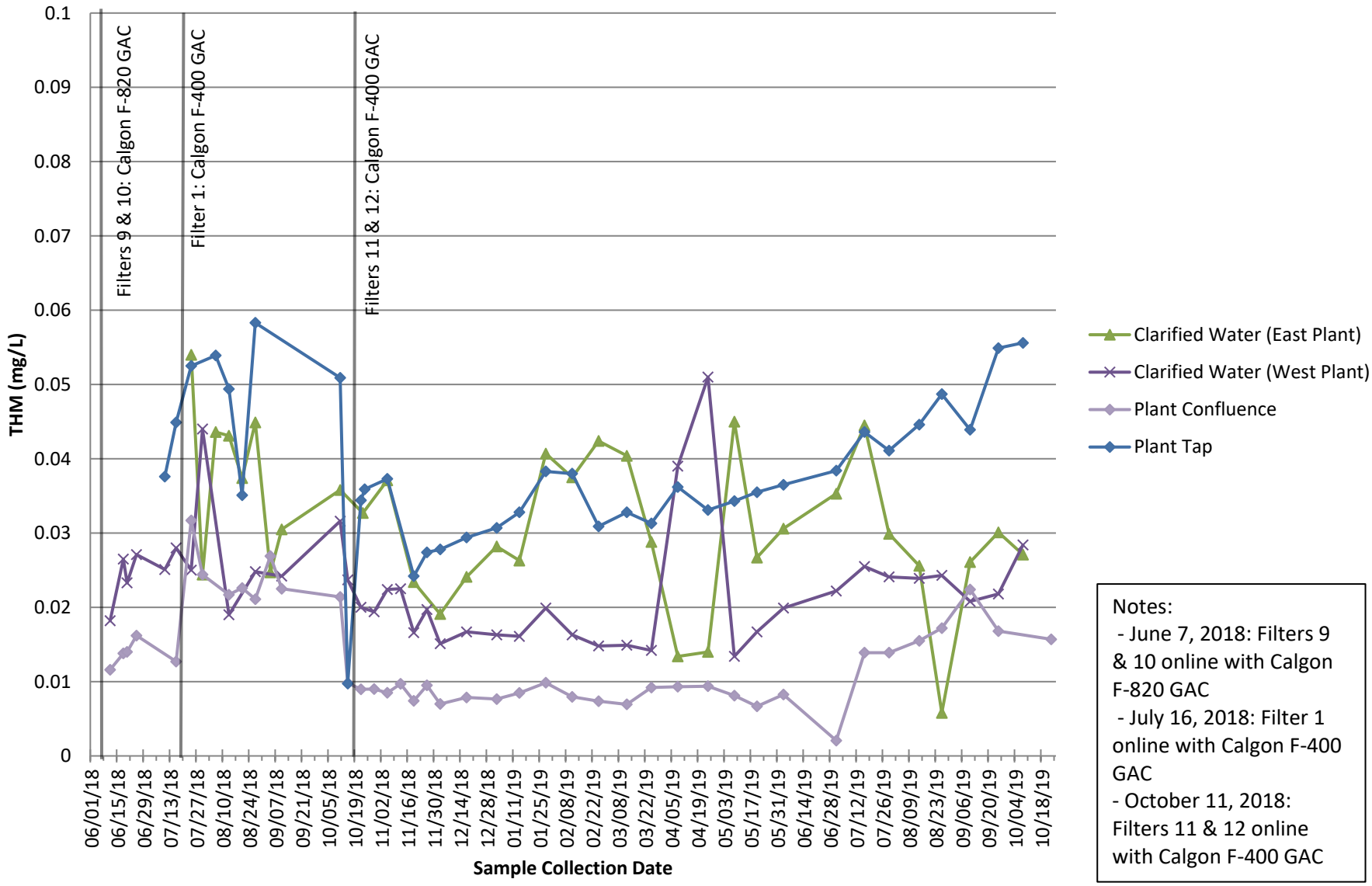
Notes:
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 5 - TOC Filter Effluent



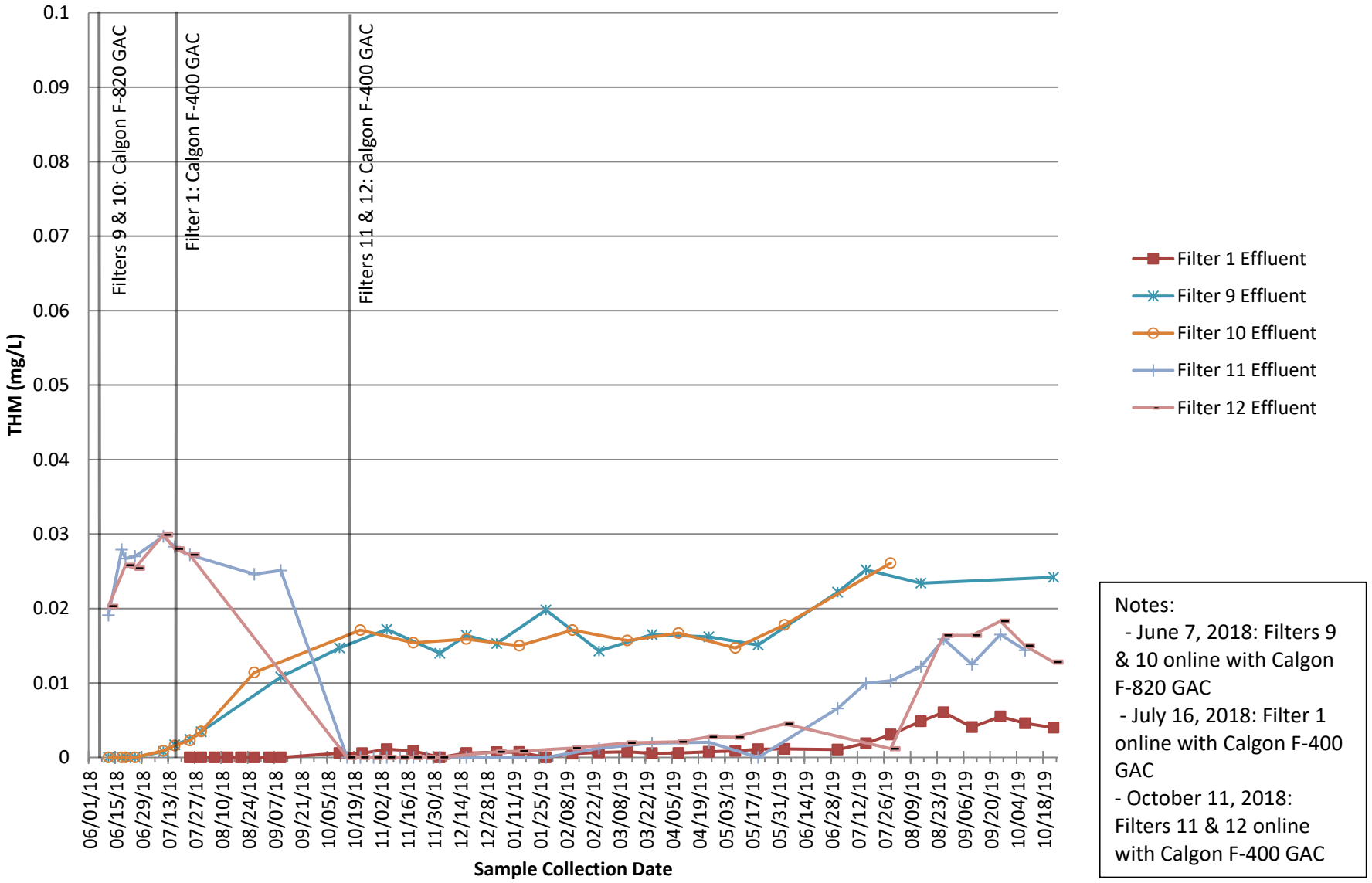
Notes:
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 6 - THM General Locations



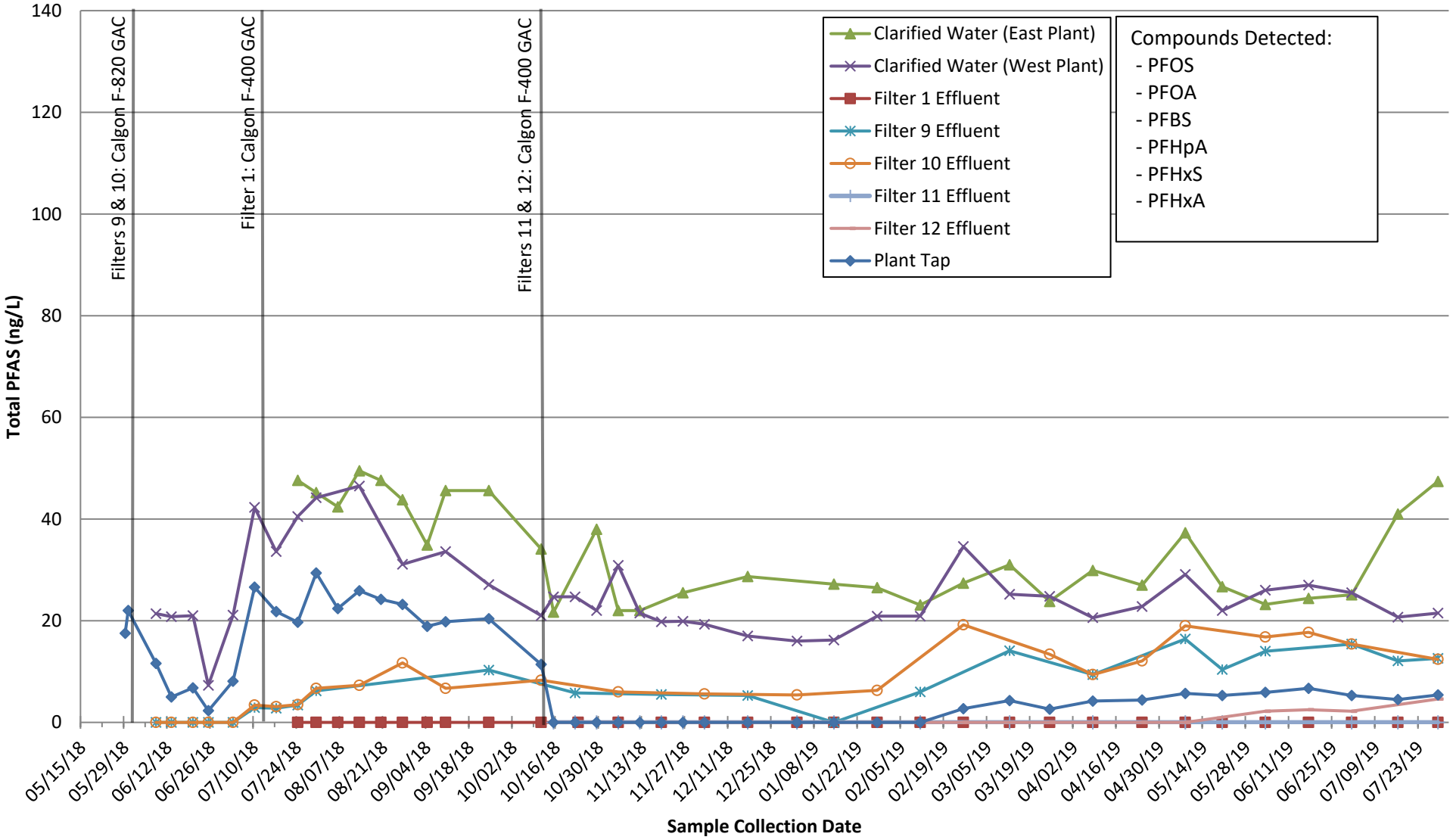
Notes:
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 7 - THM Filter Effluent

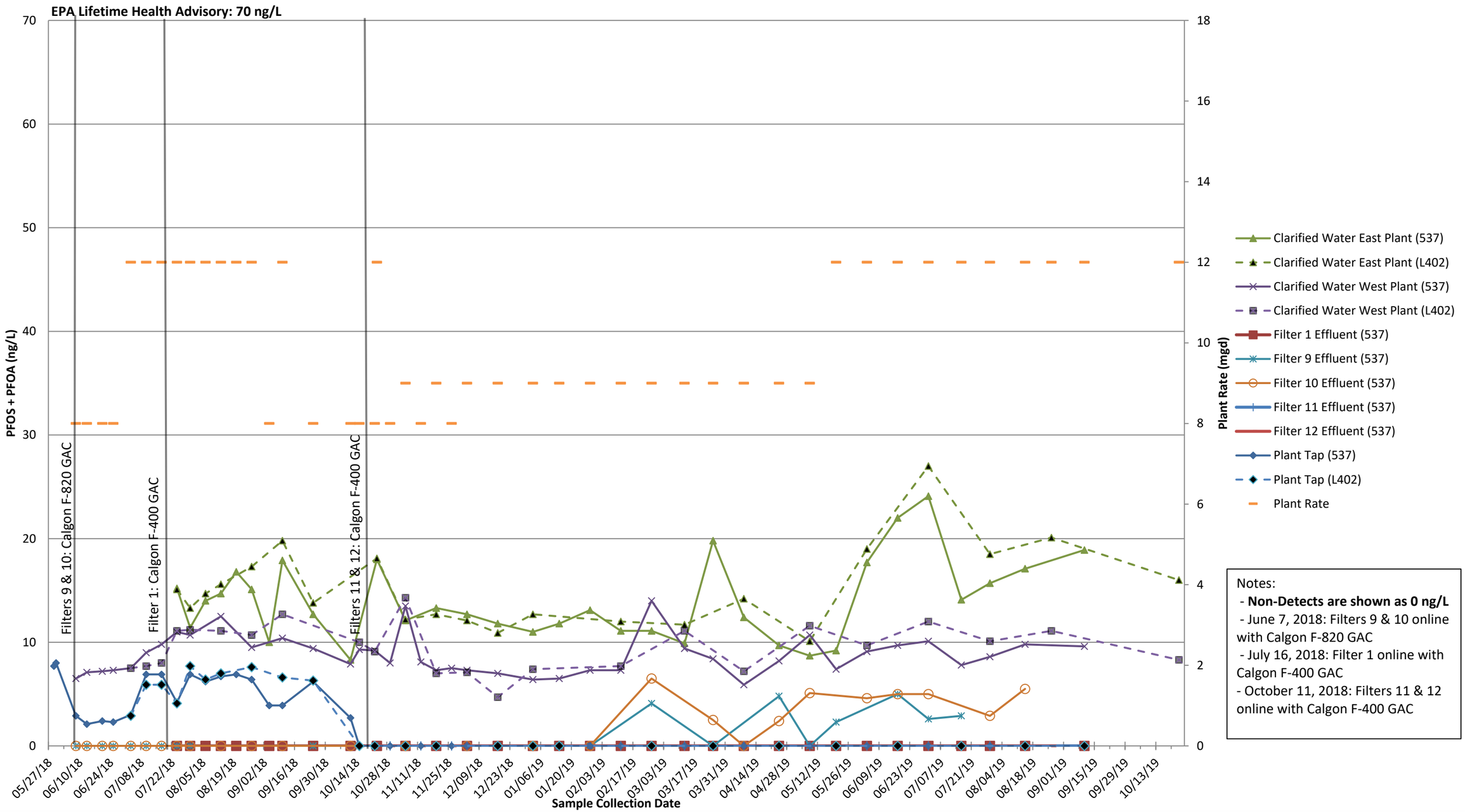


Notes:
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 8 - Total PFAS, EPA Method 537

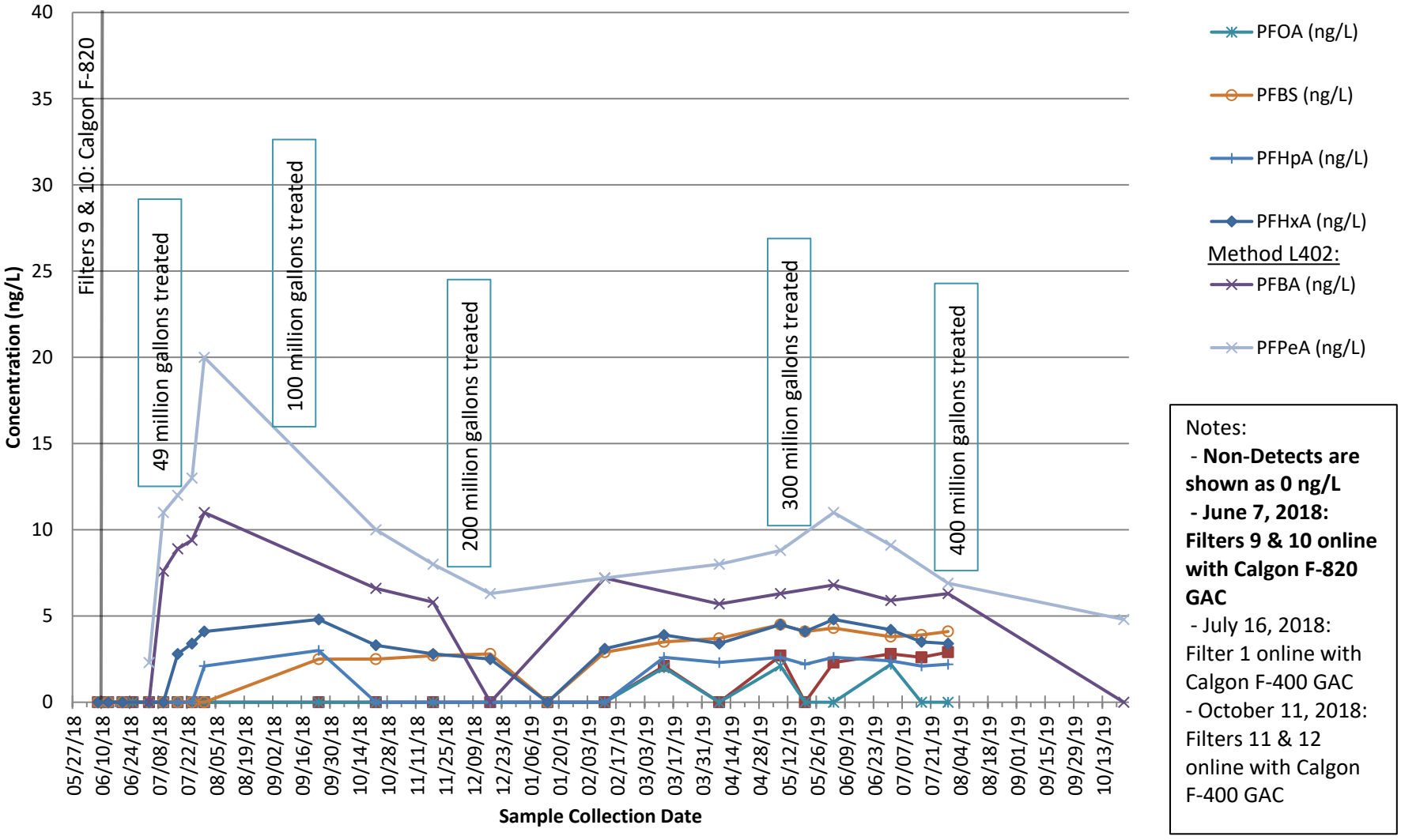


Plainfield WTP
FIGURE 9 - PFOS + PFOA, EPA Method 537 vs L402



Plainfield WTP

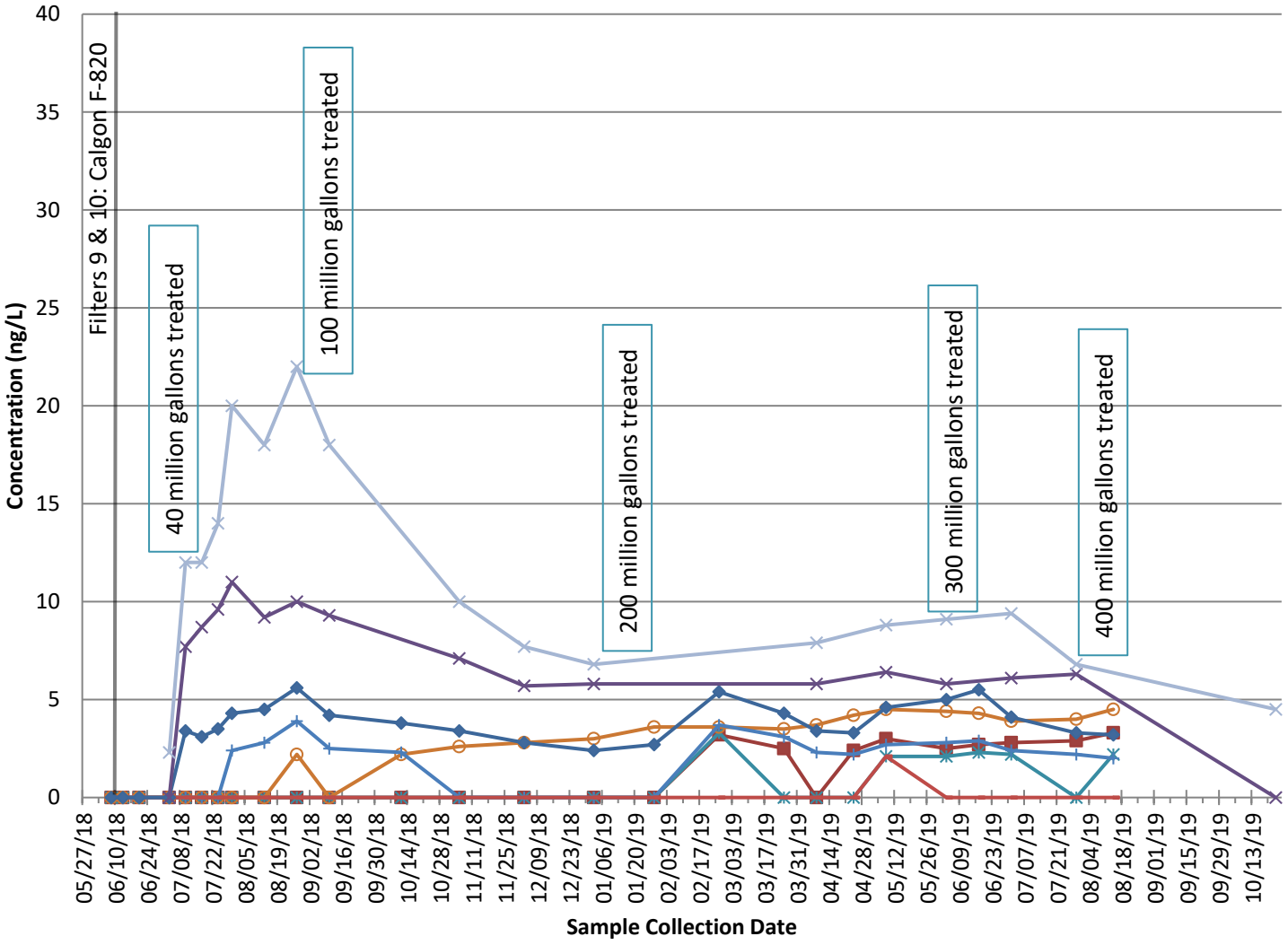
FIGURE 10 - Individual PFAS Detected, Method 537 and L402 - FILTER 9



Notes:
- **Non-Detects are shown as 0 ng/L**
- **June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC**
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP

FIGURE 11 - Individual PFAS Detected, Method 537 and L402 - FILTER 10

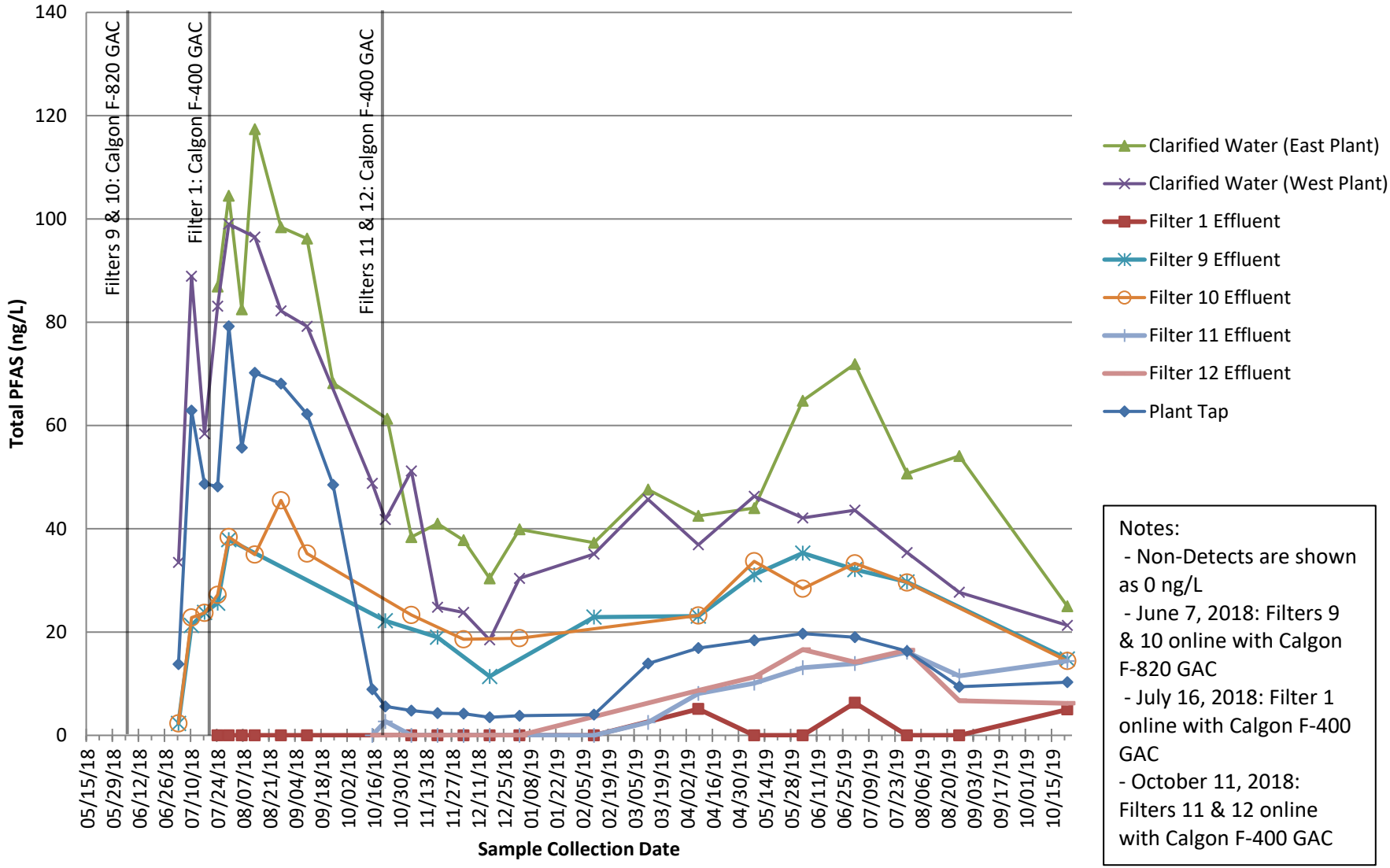


Method 537:
- PFOS (ng/L)
- PFOA (ng/L)
- PFBS (ng/L)
- PFHpA (ng/L)
- PFHxS (ng/L)
- PFHxA (ng/L)

Method L402:
- PFBA (ng/L)
- PFPeA (ng/L)

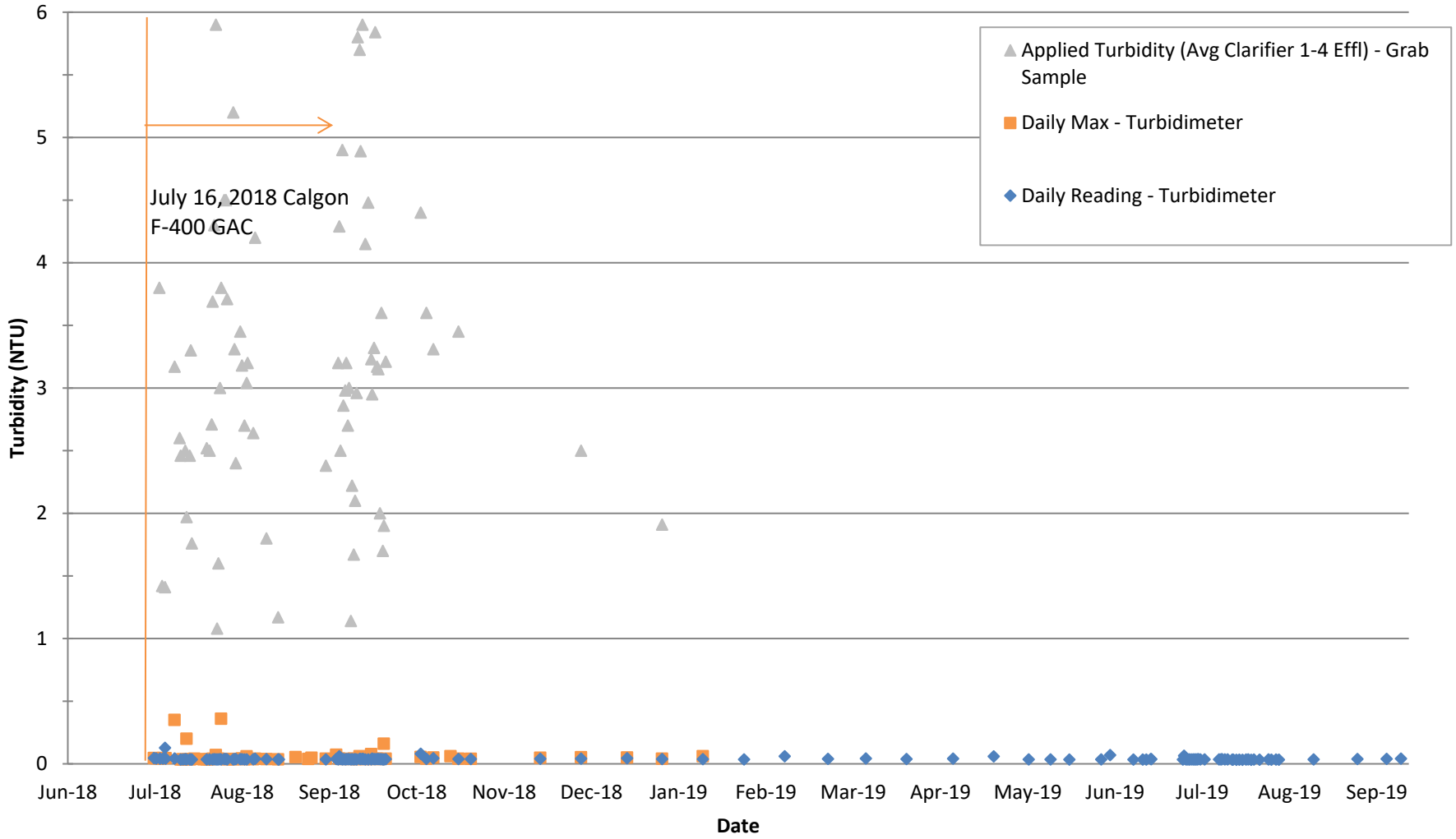
Notes:
- **Non-Detects are shown as 0 ng/L**
- **June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC**
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 12 - Total PFAS, Method L402

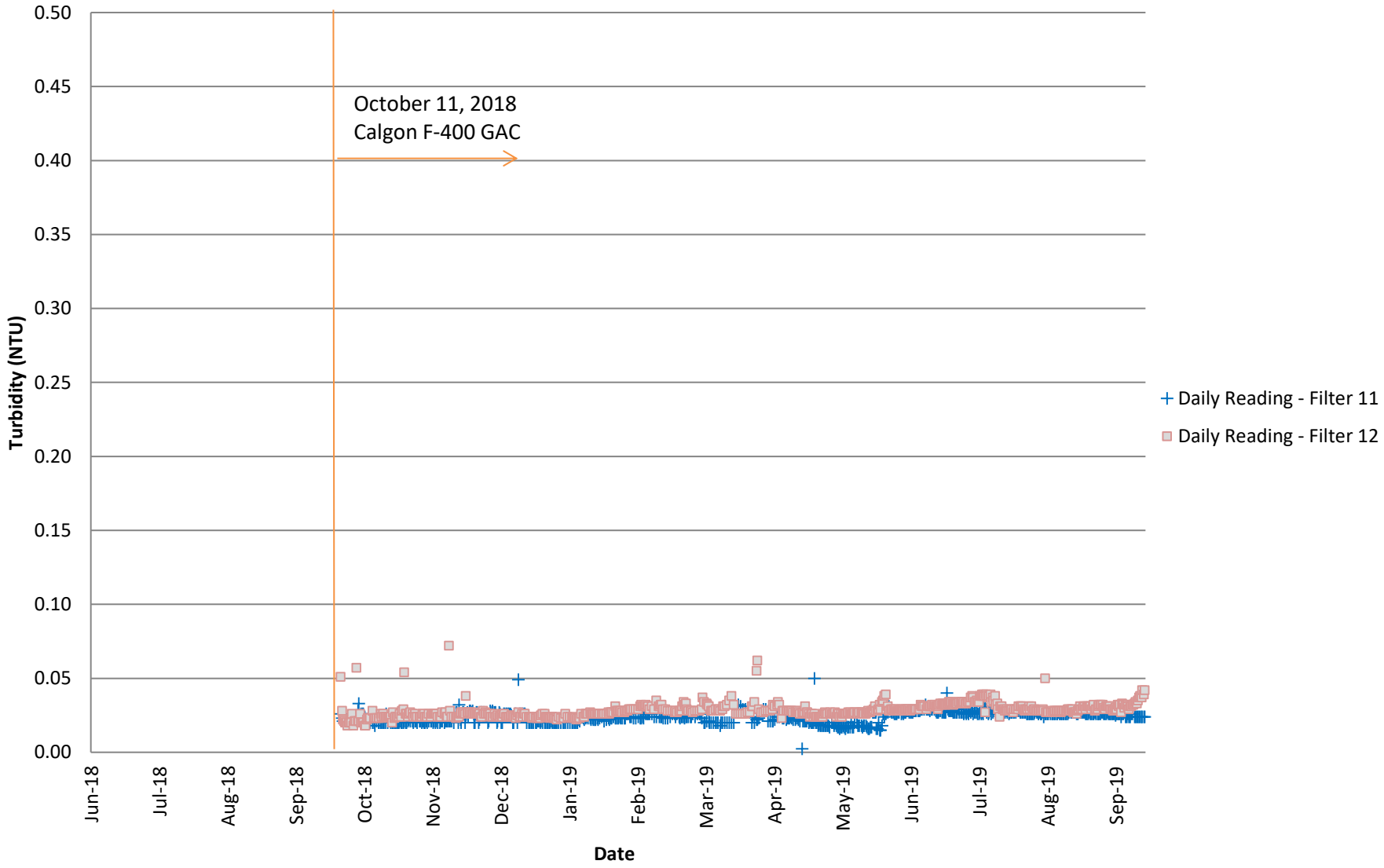


Notes:
- Non-Detects are shown as 0 ng/L
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

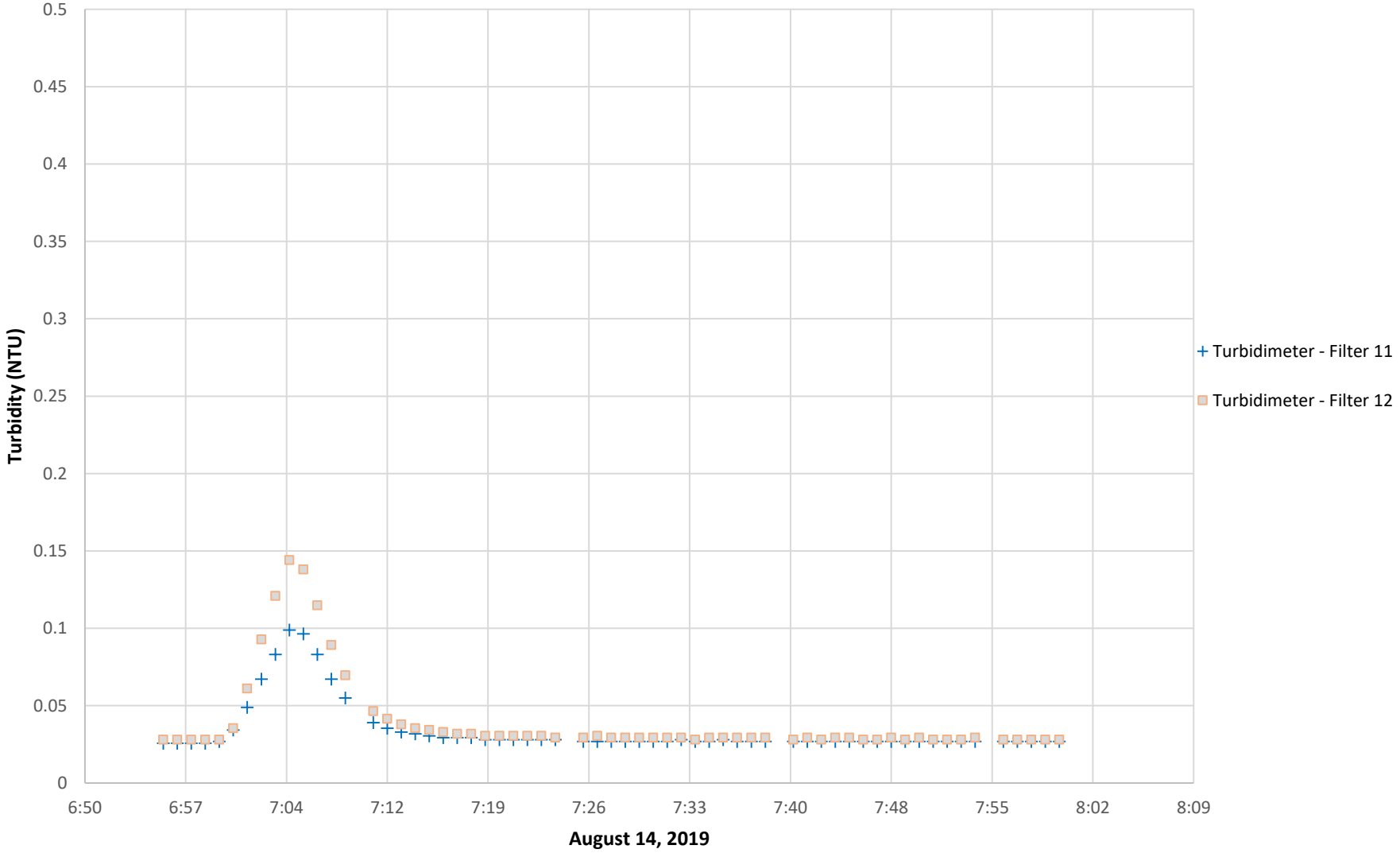
Plainfield WTP
FIGURE 13 - Filter 1 Turbidity



Plainfield WTP
FIGURE 14a - Filters 11 and 12 Turbidity

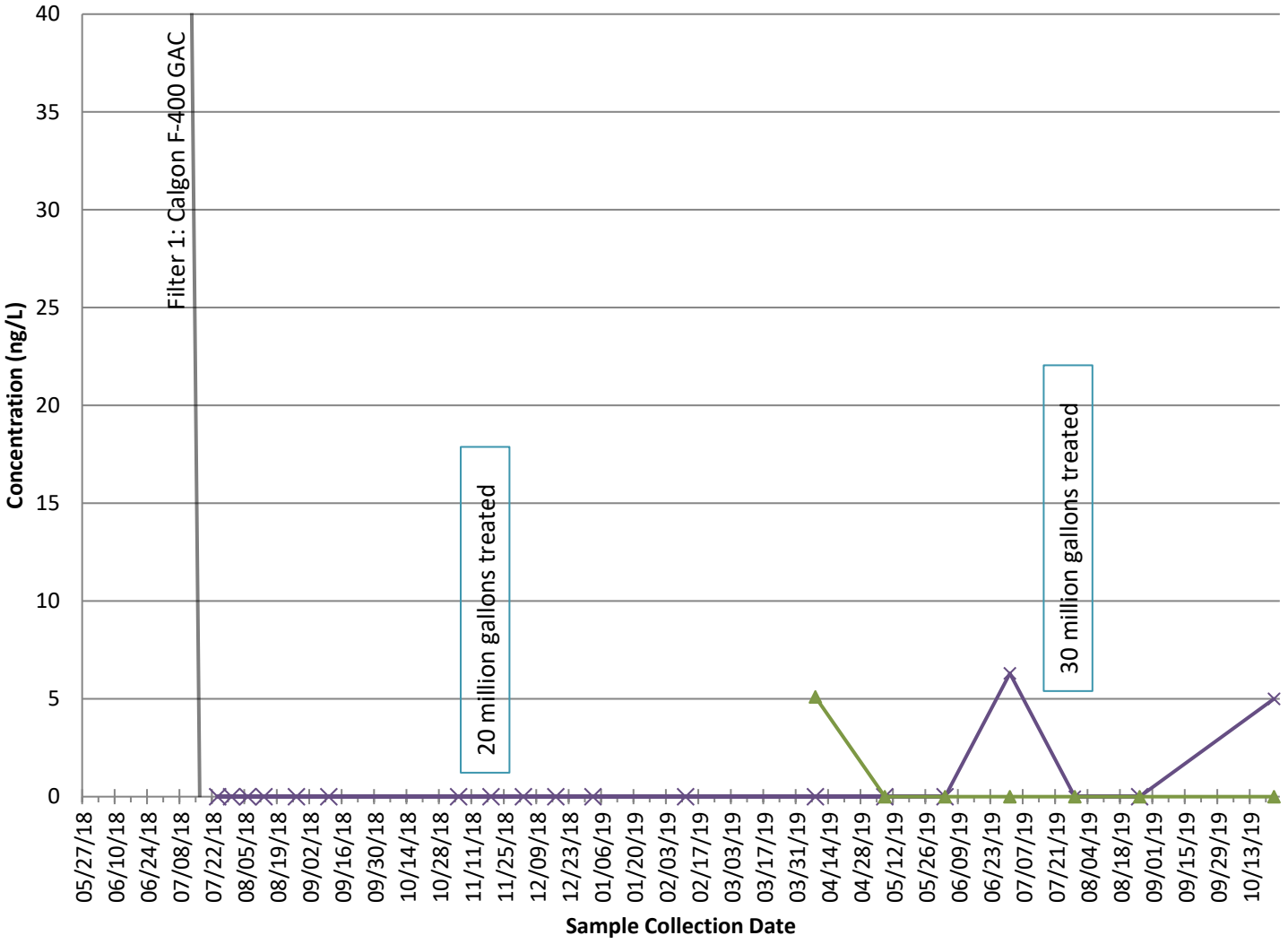


Plainfield WTP
FIGURE 14b - Filters 11 & 12 Turbidity at Start-up



Plainfield WTP

FIGURE 15 - Individual PFAS Detected, Method 537 and L402 - FILTER 1



Method 537:
None

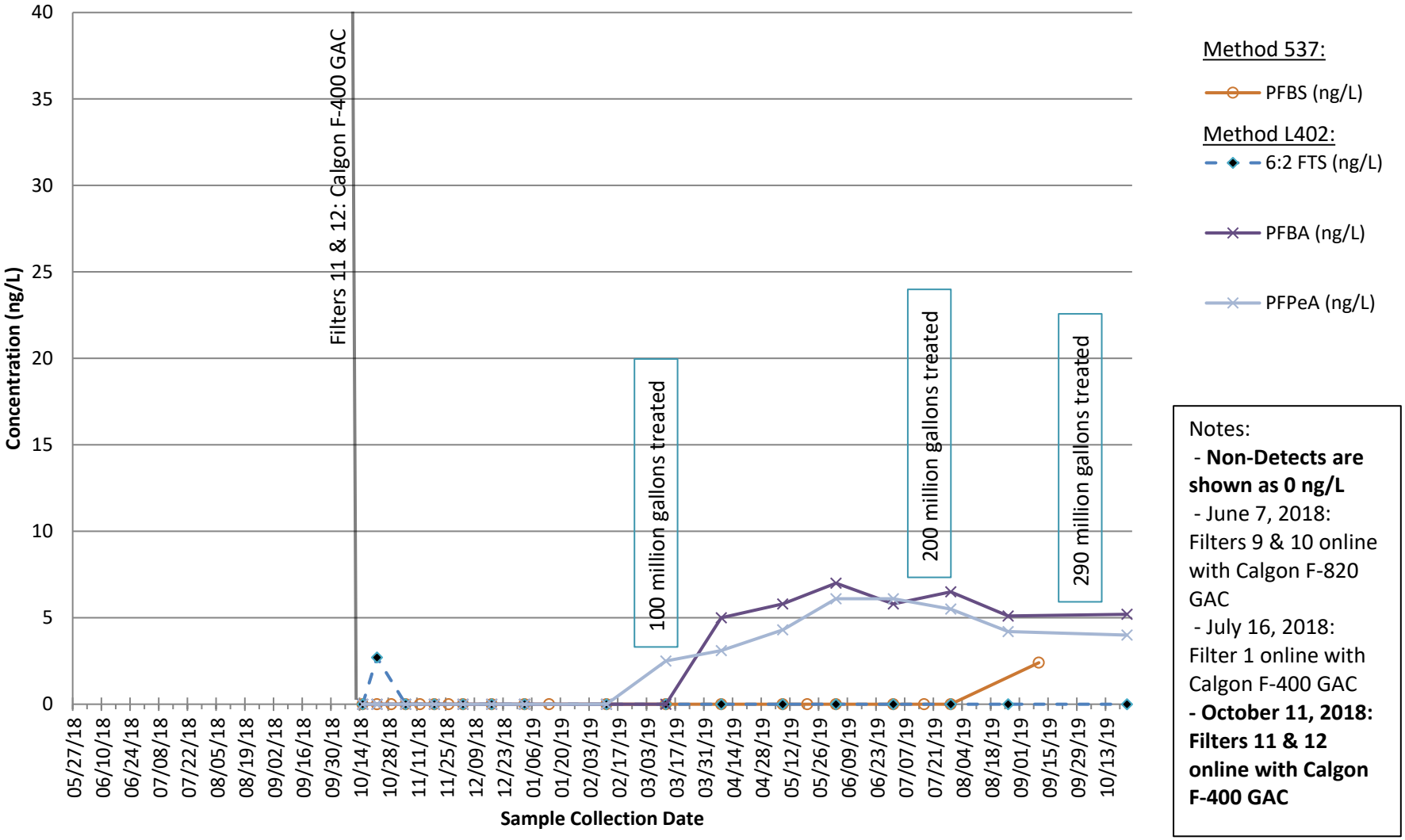
Method L402:
PFBA (ng/L)

PF-2-methoxyethoxyacetic acid (ng/L)

Notes:
- **Non-Detects are shown as 0 ng/L**
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- **July 16, 2018: Filter 1 online with Calgon F-400 GAC**
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP

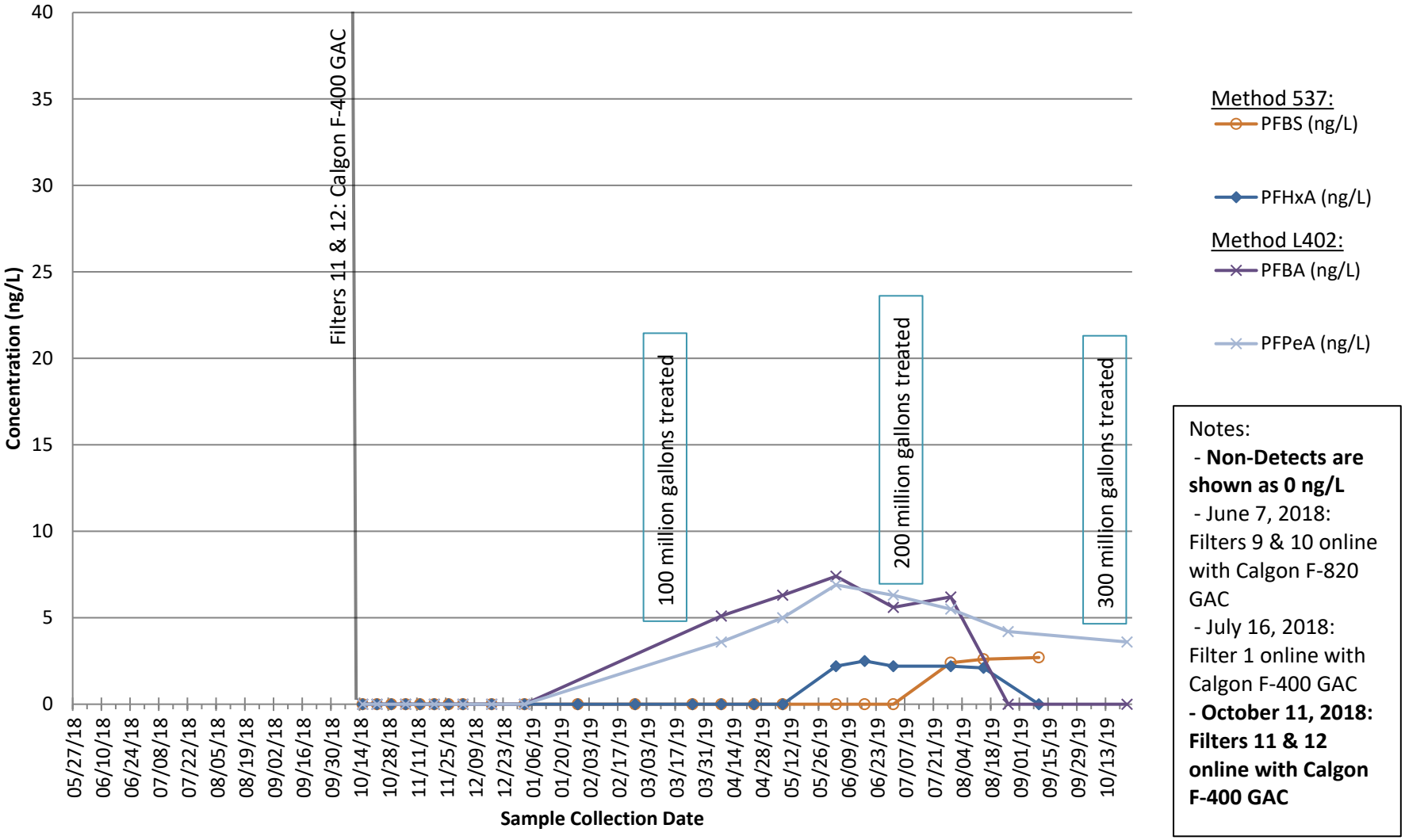
FIGURE 16 - Individual PFAS Detected, Method 537 and L402 - FILTER 11



Notes:
- **Non-Detects are shown as 0 ng/L**
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- **October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC**

Plainfield WTP

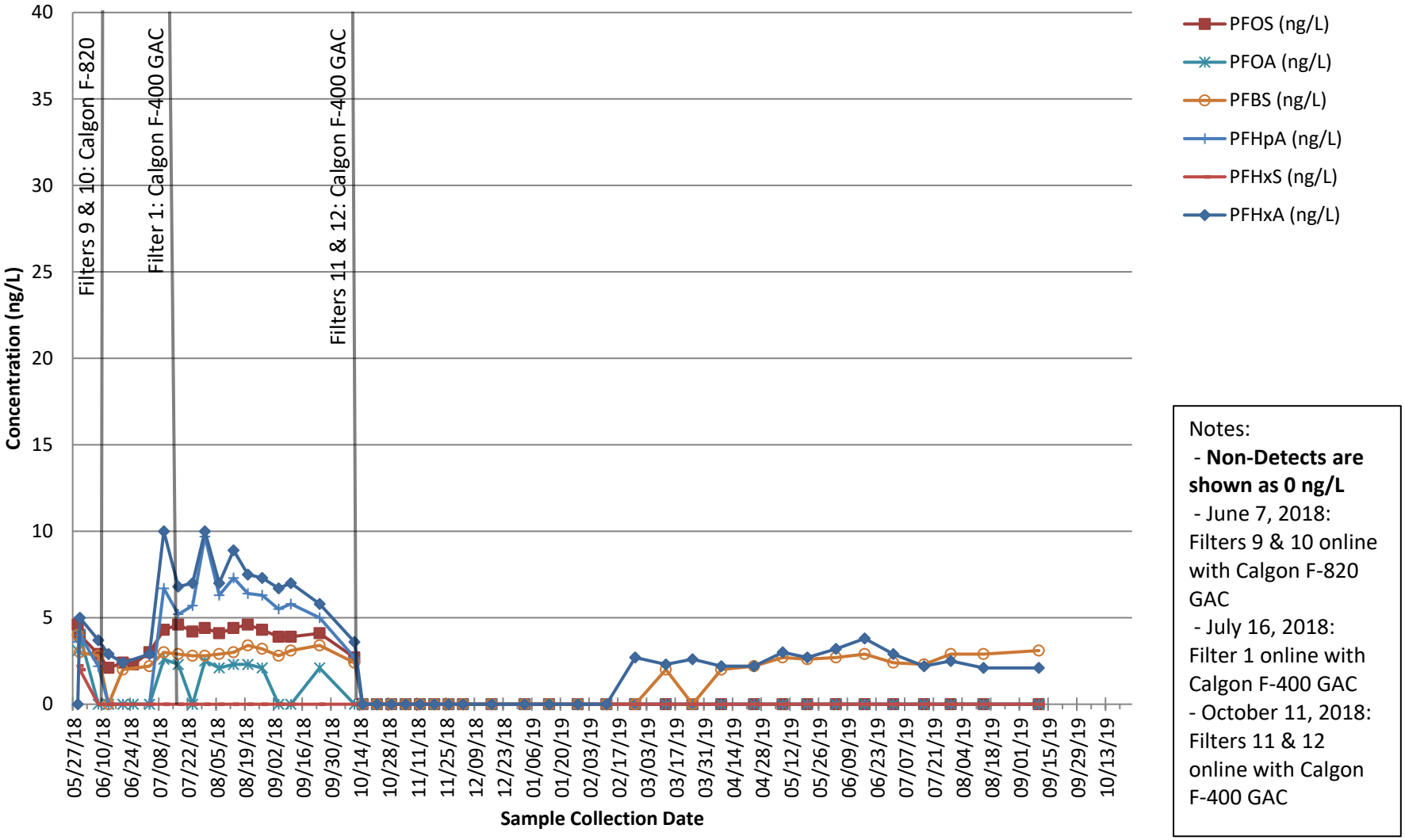
FIGURE 17 - Individual PFAS Detected, Method 537 and L402 - FILTER 12



Notes:
- **Non-Detects are shown as 0 ng/L**
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- **October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC**

Plainfield WTP

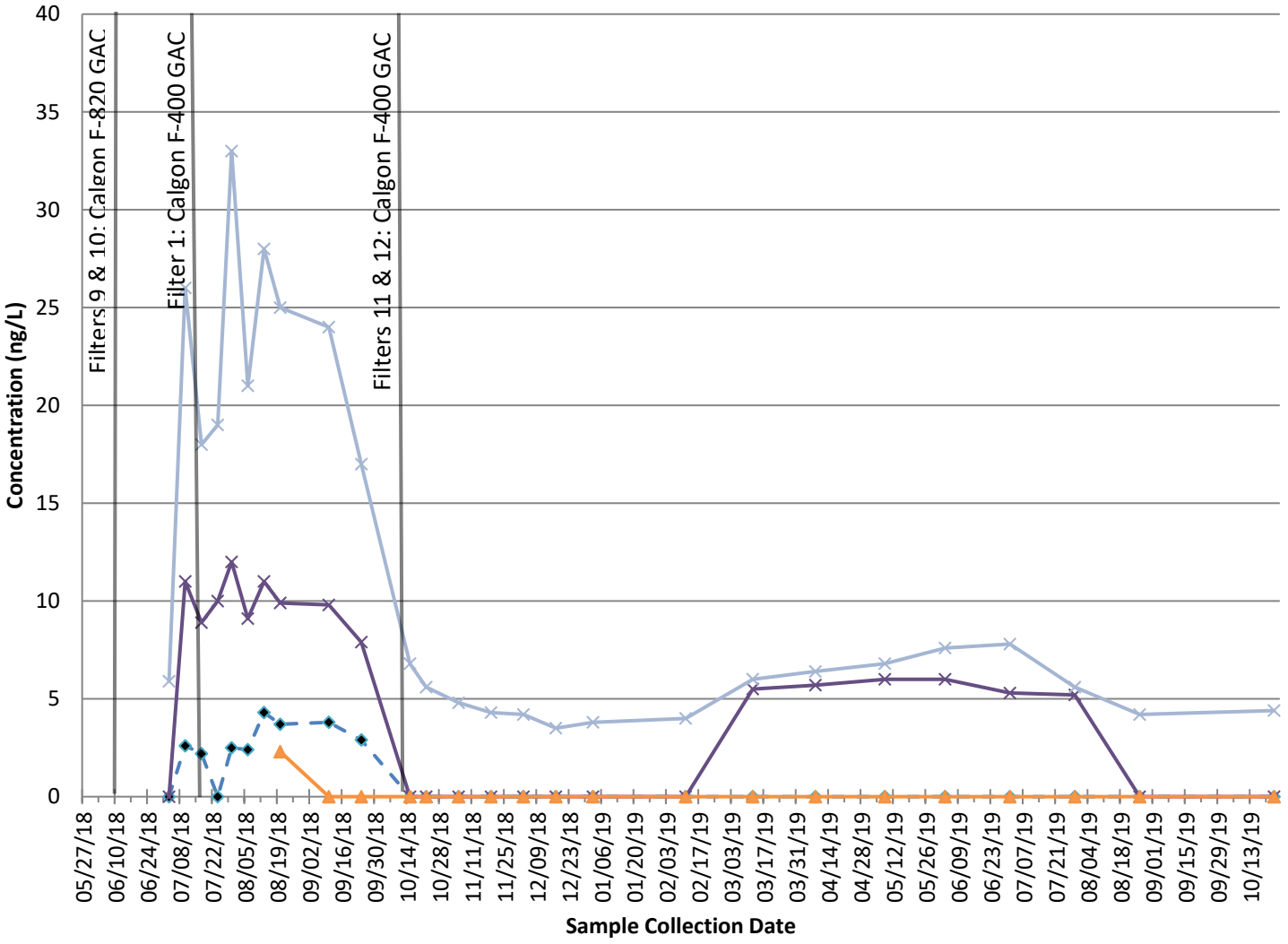
FIGURE 18 - Individual PFAS Detected, EPA Method 537 - PLANT TAP



Notes:
- **Non-Detects are shown as 0 ng/L**
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

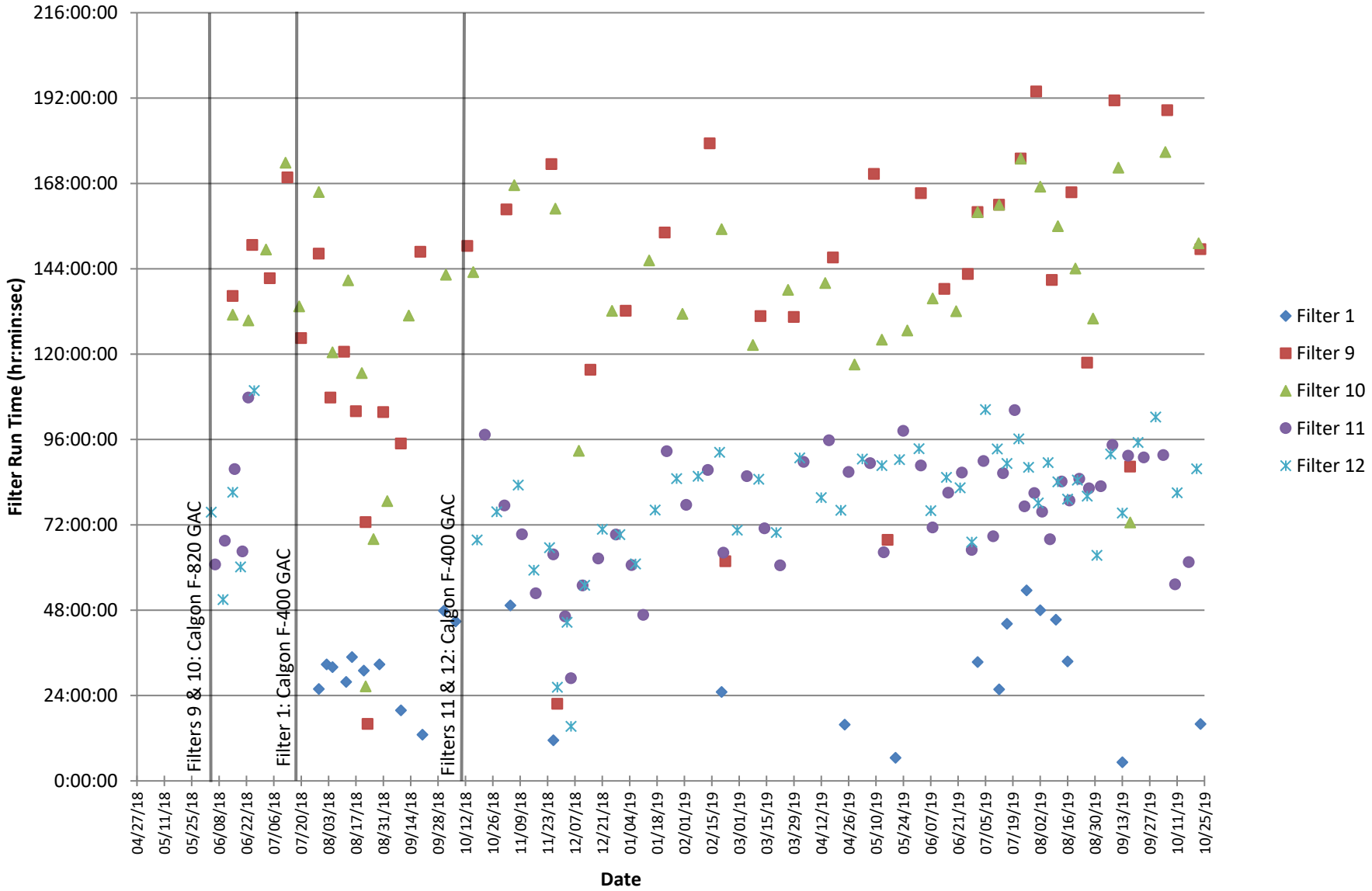
Plainfield WTP

FIGURE 19 - Additional PFAS Detected, Eurofins L402 - PLANT TAP



Notes:
- **Non-Detects are shown as 0 ng/L**
- June 7, 2018: Filters 9 & 10 online with Calgon F-820 GAC
- July 16, 2018: Filter 1 online with Calgon F-400 GAC
- October 11, 2018: Filters 11 & 12 online with Calgon F-400 GAC

Plainfield WTP
FIGURE 20 - Filter Run Times



Appendix A

Calgon Accelerated Column Test Report, September 25, 2018

CONFIDENTIAL

Calgon Carbon Corporation
Pittsburgh, PA

Technical Service Report No. 20180607

ACT Study: Comparison of Filtrasorb 400 and Filtrasorb 820 Granular Activated Carbon for the Removal of Per-and Polyfluoroalkyl Substances from Drinking Water

Prepared For:

Plainfield Charter Township Water Plant

Author: _____
Rebecca DiStefano x6316

Date: September 25, 2018

cc: A. Lynn
K. Ryan
J. Gray
A. Redding
L. Zappa
R. Klingbeil
S. Briczinski

INTRODUCTION

Calgon Carbon Corporation, hereinafter CCC, conducted two accelerated column tests (ACTs) at the request of Plainfield Charter Township Water Plant to compare the performance of Filtrasorb 400 (F400) and Filtrasorb 820 (F820) granular activated carbon (GAC) for the removal of Per-and Polyfluoroalkyl Substances (PFAS) from drinking water sourced from the treatment plant. The ACTs simulated a Model 12-40 system with a flow rate of 750 gpm operating for 2 years.

Both F400 and F820 are commonly used in municipal water applications. Differences between the two include mesh size and iodine number. F400 is a 12x40 mesh carbon with 1000 iodine number, F820 is an 8x20 mesh carbon with a 900 iodine number. Both carbons are made from select grades of bituminous coal through CCC's reagglomeration process.

Due to their useful properties, such as oil and water repellency, PFAS have been used in a variety of manufacturing processes since the mid-20th century. Some PFAS are problematic because of their stability and persistence in the environment, mobility, and bioaccumulative nature. In the United States, the EPA Health Advisory Exposure Limit for combined perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) is 70 ng/L (ppt) in treated water. Pefluoroalkyl substances, where every carbon atom in the chain is saturated with fluorine atoms, are generally separated into two main categories: perfluoroalkyl sulfonic acid and perfluoroalkyl carboxylic acid, of which PFOS and PFOA are respective examples.

SUMMARY and CONCLUSIONS

The two ACTs were conducted using either virgin F400 or virgin F820 activated carbon to determine bed life for removal of PFOA and PFOS detected in the water. The column tests simulated the lead bed of a lead-lag Model 12-40 system containing 40,000 lb of GAC operating at 750 gallons per minute and providing ~11.5 minutes of Empty Bed Contact Time (EBCT) based on apparent density (AD) packing; ~14.3 minutes after back-washing and bed expansion. Complete simulation details are shown in Table 1. At completion, the columns simulated 740 and 785 days of operation for F400 and F820 respectively and ~800 million and ~850 million gallons of water treated. For the complete set of data collected, consult Appendices B and C.

Initial PFAS analyses of the as-received water shows PFOA and PFOS concentrations of 2.5 ppt and 3.4 ppt respectively, both below the EPA Health Advisory Limit of 70 ppt. The feed drums were spiked, as requested, with additional PFOA and PFOS to target 20 ppt in the influent to ensure breakthrough would be achieved during the study.

F400:

PFAS compounds were successfully removed by F400 GAC. Initial breakthrough of PFOA, where values are consistently above the reporting limit, occurred at ~ 541 simulated days of operation (~584 million simulated gallons). PFOS breakthrough occurred at ~650 simulated days of operation (~752 million simulated gallons). Charts of PFOA and PFOS breakthrough curves are shown in Figures 1 and 2 respectively. Other PFAS compounds were adsorbed to lesser degrees relative to PFOA and PFOS. These include PFBA, PFPeA, PFHxA, PFHpA and PFBS which are plotted in Figure 4. Breakthrough occurred at 38, 97, 215, 505, and 299 simulated days of operation for PFBA, PFPeA, PFHxA, PFHpA and PFBS respectively.

F820:

PFAS compounds were successfully removed by F820 carbon, though to a slightly lesser degree than F400. Initial breakthrough of PFOA, where values are consistently above the reporting limit, occurred at ~ 385 simulated days of operation (~415 million simulated gallons). PFOS breakthrough occurred at ~525 simulated days of operation (~567 million simulated gallons). Charts of PFOA and PFOS breakthrough curves relative to F400 are shown in Figures 1 and 2. Other PFAS compounds were adsorbed to lesser degrees relative to PFOA and PFOS. These include PFBA, PFPeA, PFHxA, PFHpA and PFBS which are plotted in Figure 5. Breakthrough occurred at 32, 32, 114, 385, and 197 simulated days of operation for PFBA, PFPeA, PFHxA, PFHpA and PFBS respectively.

TOC:

The influent contained an average of 1.55 ppm TOC and was consistent over the course of the ACTs. TOC breakthrough was seen at the first sampling point of each column at 38 and 32 simulated days of operation for F400 and F820 respectively. The effluent TOC levels steadily increased over the course of the ACTs with F400 showing slightly better performance than F820. The TOC breakthrough curves for both columns are shown in Figure 3.

MODELING:

- Breakthrough of PFOA occurred prior to PFOS on both the F400 and F820 columns. Therefore, all modeling calculations are based on PFOA. As Figure 1 shows, F400 performed better than F820 for removal of PFOA. F820 achieved 50% breakthrough over the course of the study at 588 simulated days of operation. F400 did not achieve 50% PFOA breakthrough, requiring the effluent data be extrapolated to model lead-lag operation. A linear extrapolation, which provides the most conservative estimate, was used for F400 calculations.

- The mass transfer zone (MTZ) for PFOA occupies 82% and 53% of the carbon bed for F400 and F820 carbons respectively. The difference in MTZ

demonstrates the differences in adsorptive properties of the carbon. Both carbons contain the MTZ for PFOA, however given the high percentages of the bed occupied by the MTZ, lead/lag operation is recommended. In general, lead/lag operation allows for optimum carbon use rate and is typically recommended for very low level treatment objectives.

- Tables 3 and 4 include the service life and Carbon Usage Rate (CUR) for each carbon for either single vessel or lead/lab operation. To consistently achieve non-detect values in the effluent as a treatment objective and to optimize CUR, single vessel operation is not recommended, values are shown for comparison

- Carbon Usage Rate and service life were calculated based on the average feed PFOA concentration of 20.3 ppt. The initial fill of carbon will provide ~990 and ~588 days of operation for F400 or F820 respectively. At subsequent changeouts (steady-state operation) where the lag bed is moved into the lead position, the carbon will provide ~763 and ~525 days of operation for F400 or F820 respectively. Steady-state operation will result in CURs of ~0.48 and ~0.71 lb/1,000 gal for F400 and F820 respectively. Differences in feed concentration may alter these numbers. The as-received feed concentration of PFOA was 2.5 ppt, approximately 8x lower than the spiked feed value. The resulting calculations would indicate an unreasonably long service and low carbon use rate. Given the potential for the MTZ to spread with a lower concentration and the desire for a non-detect treatment objective, a three year (1095 day) service life and 0.034 lb/1,000 gal CUR is estimated for feed levels of ~2.5 ppt.

EXPERIMENTAL

ACT Design

The two ACTs each simulated a Model 12 adsorber containing 40,000 lbs of either F400 12x40 or F820 8x20 granular activated carbon, operating at 750 gpm, and providing 11.5 minutes of EBCT (14.4 minutes EBCT after backwash and drain). See Table 1 for details of the full-scale adsorber simulation. The F400 and F820 ACTs at completion simulated ~740 and ~785 days of operation respectively and ~800,000,000 and 850,000,000 gallons of water treated respectively.

A description of the ACT is shown in Appendix A.

ACT Carbon Preparation

Current production samples of virgin F400 12x40 and F820 8x20 GAC were systematically re-sized to 100x325 mesh for use in the ACT. The test carbon was oven dried at 105 °C for 16 hours then allowed to cool in a desiccator. Prior to the introduction of the challenge water, the column was pre-wetted with deionized water for approximately 16 hours.

ACT Feed Preparation

Calgon Carbon Corporation received four 55-gallon plastic drums on June 7, 2018. One drum was sampled for PFAS analyses, results are shown in Table 2. The water from each drum used in the ACT was spiked with additional PFOA and PFOS to target 20 ng/L (ppt) final concentration of each. Table 2 lists the TOC and PFAS concentration of as-received raw water and spiked samples. The individual PFAS concentrations are very consistent. An unusually high PFOS values was reported on the Drum 2 spiked sample although the PFOA value was as expected. The high PFOS is likely due to sample contamination and is not representative of the actual value of the feed.

ACT Sampling

PFAS effluent samples were collected once daily into trace clean 500 mL amber glass bottles via an automated sample collector and transferred into 250 mL HDPE bottles. TOC effluent samples were manually collected from the 500 mL bottles into 250 mL amber glass bottles.

The flow rates of the ACTs were closely monitored throughout the study. Composite samples of each ACT effluent, minus discrete samples for analysis, were collected and measured three times a week. From this data, average flow rates were calculated and the flow rate was adjusted as necessary.

Analytical

All PFAS samples were submitted to Test America (Monrovia, CA) and analyzed via:

Modified EPA Method 537 – Fluorinated Alkyl Substances

All TOC samples were analyzed in CCC's analytical laboratory according to:

SM 5310B - Total Organic Carbon, High Temperature Combustion Method

Table 1: ACT Simulation Details

Carbon Name	**F400**	**F820**
Adsorber Flow Rate (gpm)	**750**	**750**
Carbon A.D. (g/cc)	**0.561**	**0.555**
Carbon Mesh Size	**12x40**	**8x20**
ACT Scale Factor	**14.67**	**20.29**
ACT Column I.D. (cm)	**0.46**	**0.46**
Adsorber I.D. (ft)	**12**	**12**
Weight of Carbon in Adsorber (lbs)	**40000**	**40000**

Table 2: Influent Data

Analyte		Units	Feed As-received 6/12/2018 11:00	Feed Drum 2 - spiked 7/31/2018 11:00	Feed Drum 3 - spiked 8/16/2018 11:00	Feed Drum 3 - spiked 8/23/2018 9:00
Total Organic Carbon	TOC	mg/L	---	1.53	1.56	---
Perfluorobutanoic acid	PFBA*	ng/L	4.9	7.5	5.2	5.7
Perflurorpentanoic acid	PFPeA*	ng/L	9.4	12	11	11
Perflurorhexanoic acid	PFHxA*	ng/L	5.4	6.9	7.3	7.3
Perfluoroheptanoic acid	PFHpA*	ng/L	3.5	4.1	3.6	4.1
Perfluorooctanoic acid	PFOA*	ng/L	2.5	24	18	19
Perfluorononanoic acid	PFNA	ng/L	0.29J	ND	ND	0.25J
Perfluorodecanoic acid	PFDA	ng/L	ND	ND	ND	ND
Perfluoroundecanoic acid	PFUnA	ng/L	ND	ND	ND	ND
Perfluorododecanoic acid	PFDoA	ng/L	ND	ND	ND	ND
Perfluorotridecanoic acid	PFTriA	ng/L	ND	ND	ND	ND
Perflurortetradecanoic acid	PFTeA	ng/L	ND	0.41J	ND	ND
Perfluorobutanesulfonic acid	PFBS*	ng/L	4.1	5.1	5	4.9
Perfluorohexanesulfonic acid	PFHxS	ng/L	1.8J	4	2.7	3
Perfluoroheptanesulfonic acid	PFHpS	ng/L	ND	0.75J	0.31J	0.3J
Perfluoroocatnesulfonic acid	PFOS*	ng/L	3.4	89**	18	16
Perfluorodecanesulfonic acid	PFDS	ng/L	ND	0.8J	ND	ND
Perfluoroocatne Sulfonamide	FOSA	ng/L	ND	0.63J	ND	ND

J indicates result is less than reporting limit but greater than or equal to the minimum detection limit and the concentration is an approximation. J-values are not plotted on charts.

*Analyte included in effluent analyses

**Spike confirmed to be to target 20ppt, the reported value of 89 is likely due to sample contamination.

Table 3: Single Vessel Design Estimates based on PFOA Breakthrough Curve

Calculations based on Initial Breakthrough Assuming Treatment Objective is Non-Detect PFOA				
	F400		**F820**	
Influent Concentration used in calculation	Spiked: 20 ppt	As-received: 2.5 ppt	Spiked: 20 ppt	As-received: 2.5 ppt
Service Life (days)	541	>1095	385	>1095
Bed Volumes Treated	68,416	>138,000	48,090	>138,000
Gallons Treated	584,000,000	>1,182,600,000	415,000,000	>1,182,600,000
Carbon Use Rate (lb / 1,000 gal)	0.068	<0.034	0.097	<0.034

Table 4: Dual Vessel Lead-Lab Design Estimates PFOA Breakthrough Curve

Calculations based on 50% PFOA Loading on the Lead Bed in a Lead/Lag System				
	F400		**F820**	
Influent Concentration used in calculation	Spiked: 20 ppt	As-received: 2.5 ppt	Spiked: 20 ppt	As-received: 2.5 ppt
Service Life (initial fill) (days)	990	>1095	588	>1095
Service Life (subsequent change-outs) (days)	763	>1095	525	>1095
Bed Volumes Treated (subsequent change-outs)	96,457	>138,000	65,630	>138,000
Gallons Treated (subsequent change-outs)	824,000,000	>1,182,600,000	567,000,000	>1,182,600,000
Carbon Use Rate (lb / 1,000 gal) (subsequent change-outs)	0.048	<0.034	0.071	<0.034

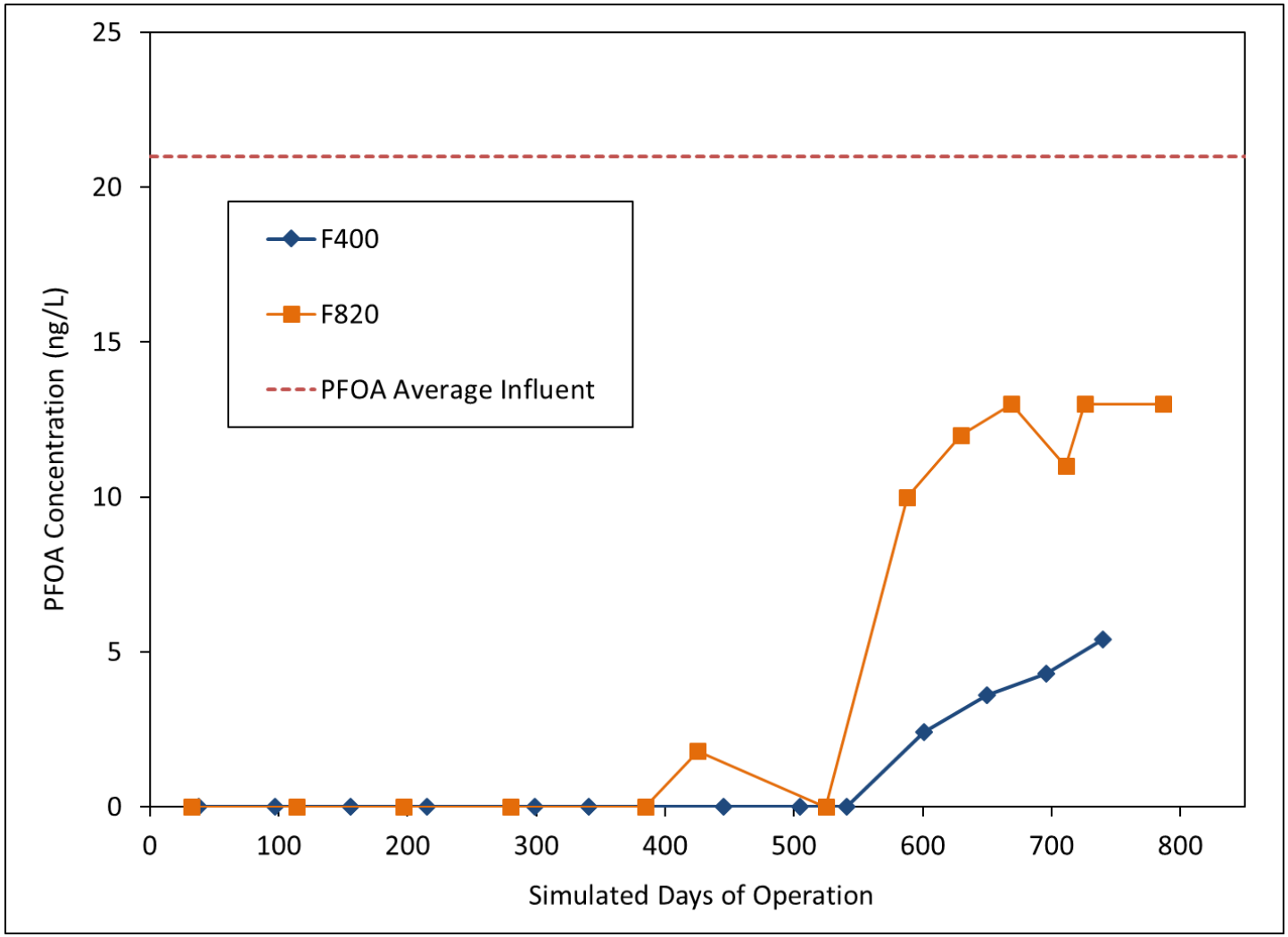


Figure 1: Plainview, MI ACT – F400 and F820 Effluent PFOA Concentration vs. Simulated Days of Operation w/Average Influent Concentration

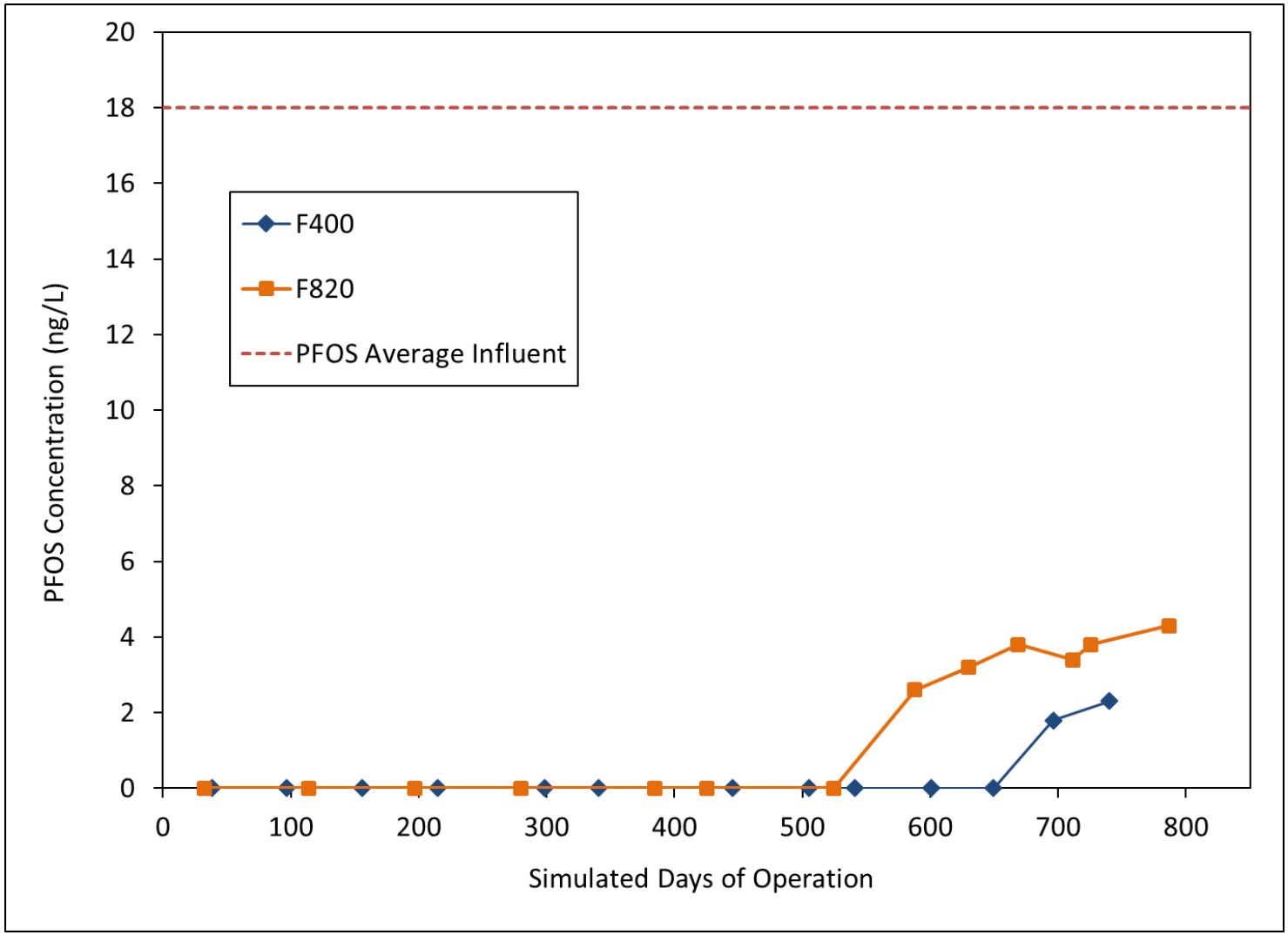


Figure 2: Plainview, MI ACT – F400 and F820 Effluent PFOS Concentration vs. Simulated Days of Operation w/Average Influent Concentration

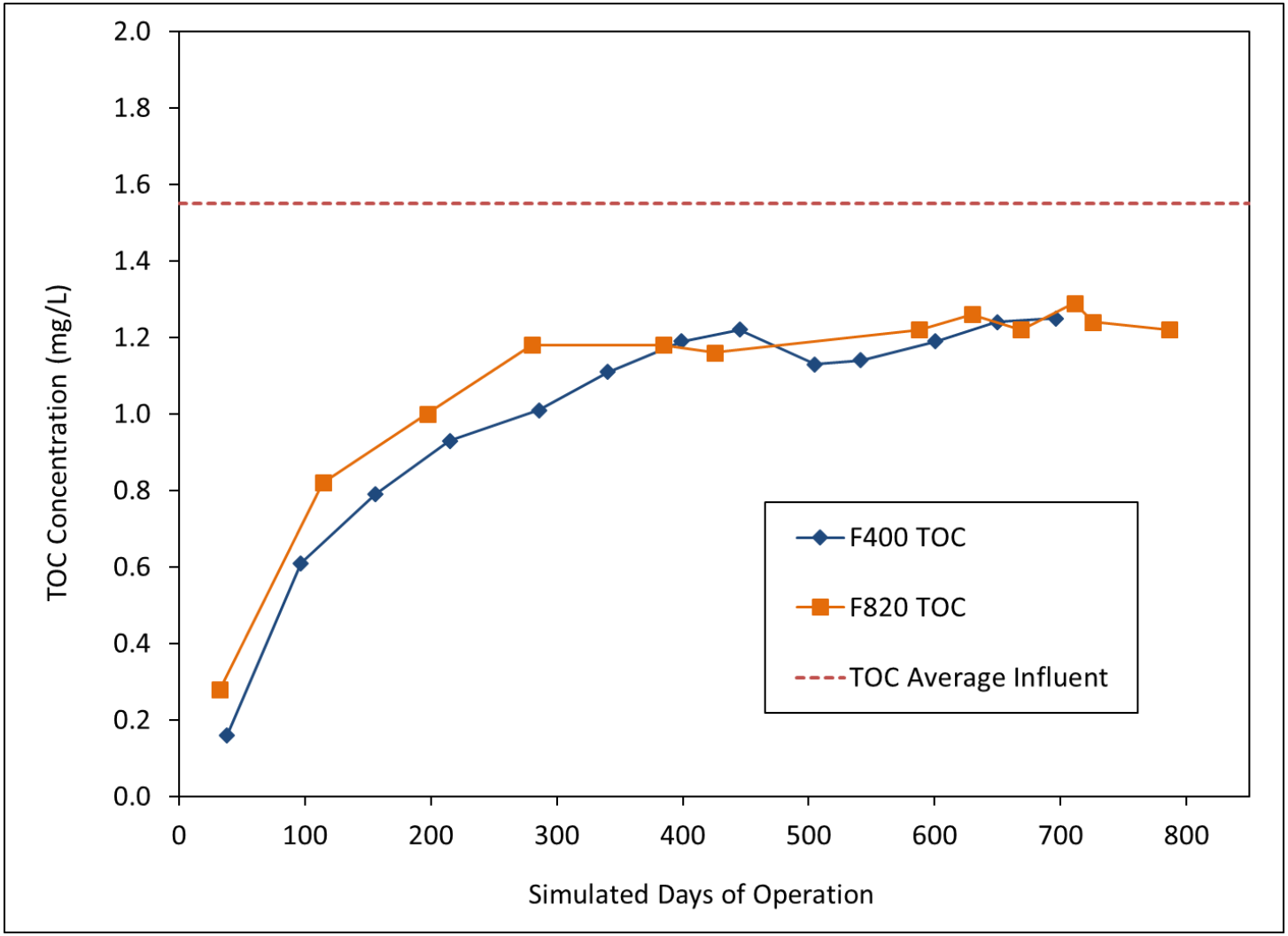


Figure 3: Plainview, MI ACT – F400 and F820 Effluent TOC Concentration vs. Simulated Days of Operation w/Average Influent Concentration

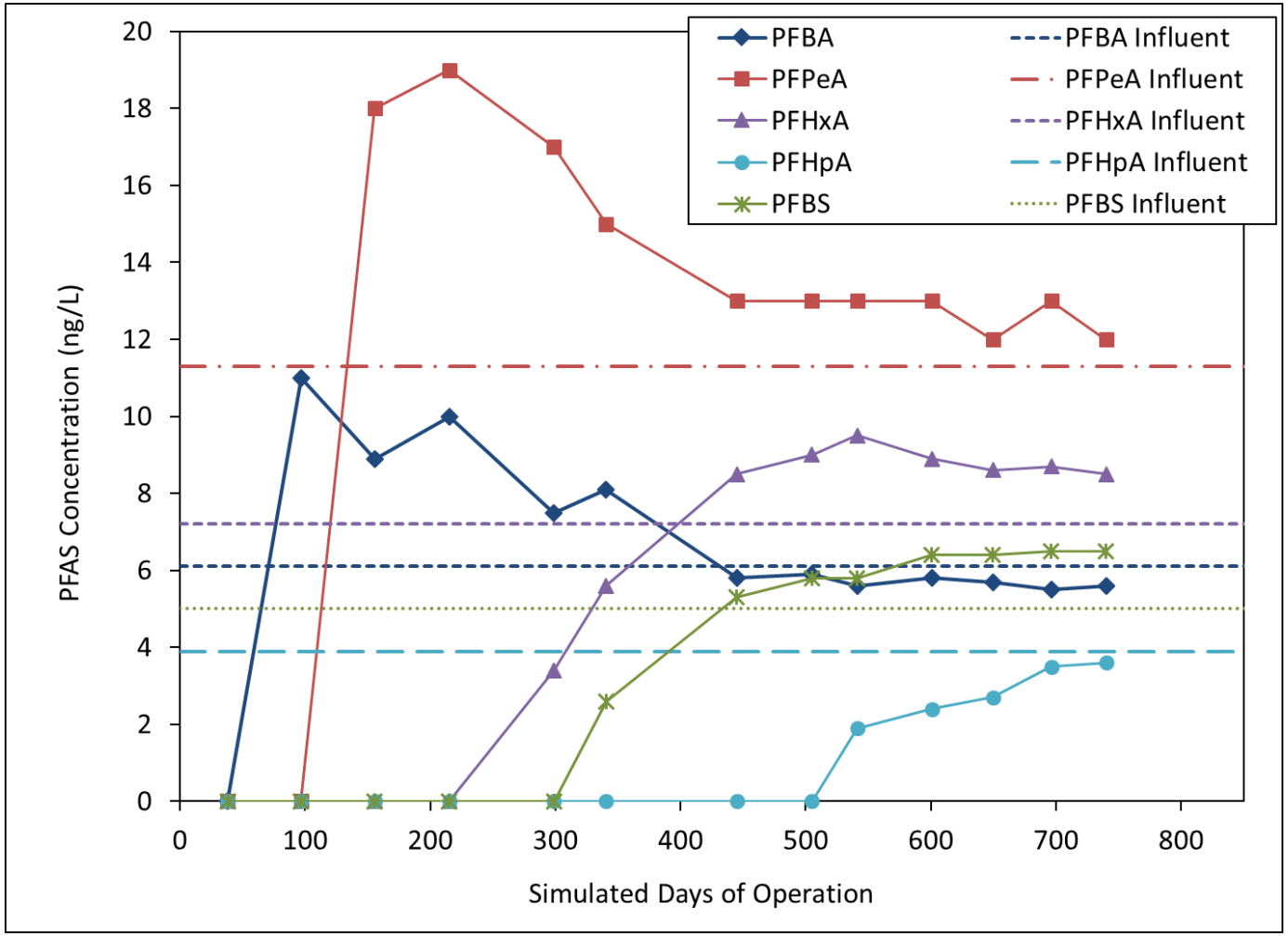


Figure 4: Plainview, MI ACT – F400 Effluent PFBA, PFPeA, PFHxA, PFHpA, and PFBS Concentration vs. Simulated Days of Operation w/Average Influent Concentrations

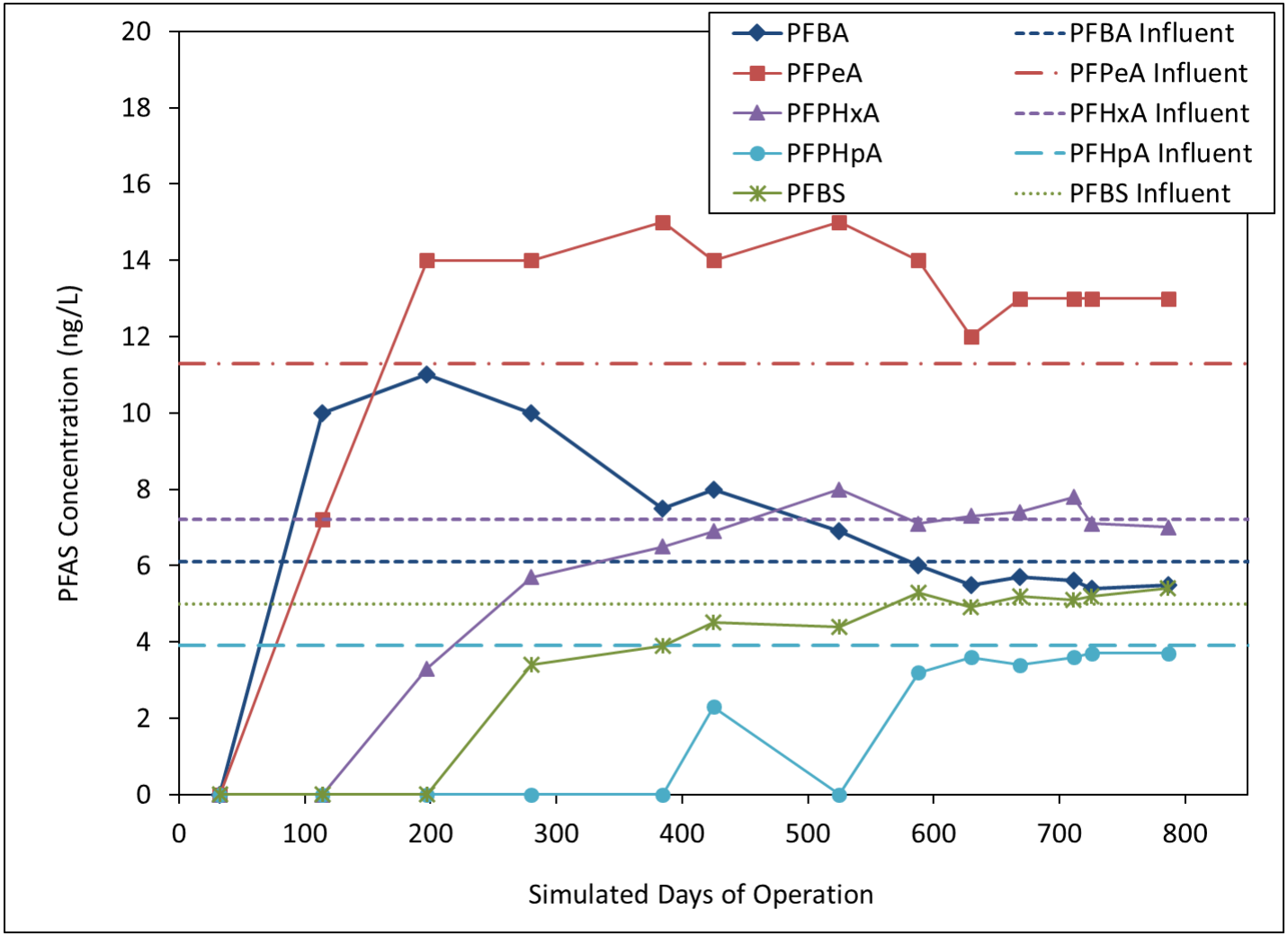


Figure 5: Plainview, MI ACT – F820 Effluent PFBA, PFPeA, PFHxA, PFHpA, and PFBS Concentration vs. Simulated Days of Operation w/Average Influent Concentrations

Appendix A:
ACCELERATED COLUMN TEST PROTOCOL

The Accelerated Column Test (ACT) procedure uses a miniature carbon-filled column to rapidly simulate the adsorption breakthrough curve that would be obtained by treating an aqueous stream in a large adsorption system. This technique, developed by Calgon Carbon Research and Development, has been shown to accurately simulate the carbon treatment of a wide range of waters and wastewaters under various conditions.

The principle advantage of the ACT procedure compared to the one-inch diameter column adsorption test is its increased speed. Typically, an ACT can be completed in 1/20th to 1/10th of the time required for a one-inch diameter study. The basic description of the ACT system is defined in the article, "High Pressure Technique for Rapid Screening of Activated Carbons for Use in Potable Water." [1]

Scale factors for sizing the full-scale adsorbers from the ACT data are developed by a proprietary method based on the chemistry of adsorption on activated carbon. To predict the volume breakthrough curve for the full-scale adsorber, the ACT results must be multiplied by the volume scale factor determined for each carbon type. The time breakthrough curve for the full-scale adsorber can be calculated by either of two methods. First, one can divide the predicted volumes calculated above by the flow rate of the full-scale system. Second, one can multiply the run time by the scale factor determined for each carbon type.

[1] Rosene, M.R., R. T. Deithorn, J. R. Lutchko, and N.J. Wagner, "High Pressure Technique for Rapid Screening of Activated Carbon for Use in Potable Water," Activated Carbon Adsorption of Organics from the Aqueous Phase, Vol. 1. I. H. Suffet and M. J. McGuire, editors, Ann Arbor Science, Ann Arbor, MI Chapter 15 (1980)

Appendix B: F400 ACT Effluent Raw Data

Date/Time	Simulated Days of Operation	Simulated Gallons Treated (x1000)	Bed Volumes Treated (BV)	Total Organic Carbon	Perfluorobutanoic acid	Perflurorpentanoic acid	Perflurorhexanoic acid	Perfluoroheptanoic acid	Perfluorooctanoic acid	Perfluorobutanesulfonic acid	Perfluorohexanesulfonic acid	Perfluoroocatnesulfonic acid
				TOC	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFBS	PFHxS	PFOS
				mg/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
7/3/18 16:00	START											
7/6/18 9:00	38	41102	4811	0.16	1.3J	1.5J	ND	0.39J	ND	ND	0.29J	ND
7/10/18 9:00	97	104624	12244	0.61	11	1.3J	ND	ND	ND	ND	0.23J	ND
7/14/18 9:00	156	168197	19688	0.79	8.9	18	ND	ND	ND	ND	0.29J	ND
7/18/18 9:00	215	232325	27194	0.93	10	19	1.1J	ND	ND	0.27J	0.26J	ND
7/23/18 10:00	286	308684	36132	0.94	---	---	---	---	---	---	---	---
7/24/18 9:00	299	322712	37774	---	7.5	17	3.4	ND	ND	1.3J	0.27J	ND
7/27/18 9:00	341	367762	43047	1.01	8.1	15	5.6	ND	ND	2.6	0.28J	ND
7/31/18 9:00	400	431039	50454	1.11	---	---	---	---	---	---	---	---
8/3/18 9:00	445	480690	56266	1.19	5.8	13	9	0.71J	ND	5.3	0.32J	ND
8/7/18 9:00	505	545188	63815	1.22	5.9	13	9.0	1.5J	1.0J	5.8	0.37J	ND
8/10/18 9:00	541	584491	68416	1.13	5.6	13	9.5	1.9	1.4J	5.8	0.42J	ND
8/14/18 9:00	601	648861	75950	1.14	5.8	13	8.9	2.4	2.4	6.4	0.53J	0.78J
8/17/18 9:00	650	701517	82114	1.19	5.7	12	8.6	2.7	3.6	6.4	0.69J	1.1J
8/20/18 9:00	696	751923	88014	1.24	5.5	13	8.7	3.5	4.3	6.5	0.81J	1.8
8/23/18 9:00	740	799433	93575	1.25	5.6	12	8.5	3.6	5.4	6.5	0.9J	2.3

J: Indicates result is less than reporting limit but greater than or equal to the minimum detection limit and the concentration is an approximation. J-values are not plotted on charts.

Appendix C: F820 ACT Effluent Raw Data

Date/Time	Simulated Days of Operation	Simulated Gallons Treated (x1000)	Bed Volumes Treated (BV)	Total Organic Carbon	Perfluorobutanoic acid	Perflurorpentanoic acid	Perflurorhexanoic acid	Perfluoroheptanoic acid	Perfluorooctanoic acid	Perfluorobutanesulfonic acid	Perfluorohexanesulfonic acid	Perfluoroocatnesulfonic acid
				TOC	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFBS	PFHxS	PFOS
				mg/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
7/3/18 16:00	START											
7/5/18 9:00	33	35131	4068	0.28	0.74J	0.73J	ND	ND	ND	ND	0.33J	ND
7/9/18 9:00	114	123303	14279	0.82	10	7.2	ND	ND	ND	ND	0.3J	ND
7/13/18 9:00	197	212800	24642	1.00	11	14	3.3	0.32J	ND	1.4J	0.36J	ND
7/17/18 9:00	280	302358	35013	1.18	10	14	5.7	1.1J	1.3J	3.4	0.44J	ND
7/24/18 9:00	385	415291	48091	1.18	7.5	15	6.5	1.5J	1.4J	3.9	0.47J	ND
7/26/18 9:00	425	459177	53172	1.16	8.0	14	6.9	2.3	1.8	4.5	0.63J	0.75J
7/31/18 9:00	525	566742	65629	---	6.9	15	8.0	0.36J	ND	4.4	0.26J	ND
8/3/18 9:00	589	634798	73509	1.22	6.0	14	7.1	3.2	10	5.3	1.4J	2.6
8/5/18 9:00	630	680033	78748	1.26	5.5	12	7.3	3.6	12	4.9	1.5J	3.2
8/7/18 9:00	669	722222	83633	1.22	5.7	13	7.4	3.4	13	5.2	1.8	3.8
8/9/18 16:00	711	768145	88951	1.29	5.6	13	7.8	3.6	11	5.1	1.6J	3.4
8/10/18 9:00	726	783664	90748	1.24	5.4	13	7.1	3.7	13	5.2	1.7J	3.8
8/13/18 9:00	787	849393	98360	1.22	5.5	13	7.0	3.7	13	5.4	1.8	4.3

J: Indicates result is less than reporting limit but greater than or equal to the minimum detection limit and the concentration is an approximation. J-values are not plotted on charts.

Appendix D: Filtrasorb 400 Sales Specifications Sheet

FILTRASORB 400

Granular Activated Carbon

Test	Specification		Calgon Carbon Test Method
	Min	Max	
IODINE NUMBER, mg/g	1000	-	TM-4,ASTM D4607
MOISTURE (AS PACKAGED), wt%	-	2	TM-1,ASTM D2867
ABRASION NUMBER	75	-	TM-9,AWWA B604
EFFECTIVE SIZE, mm	0.55	0.75	TM-47,ASTM D2862
UNIFORMITY COEFFICIENT	-	1.9	TM-47,ASTM D2862
12 US MESH [1.70 mm], wt%	-	5	TM-8,ASTM D2862
< 40 US MESH [0.425 mm] (PAN), wt%	-	4	TM-8,ASTM D2862

Typical Properties:

This product complies with ANSI/AWWA B604 (2005) – Granular Activated Carbon.

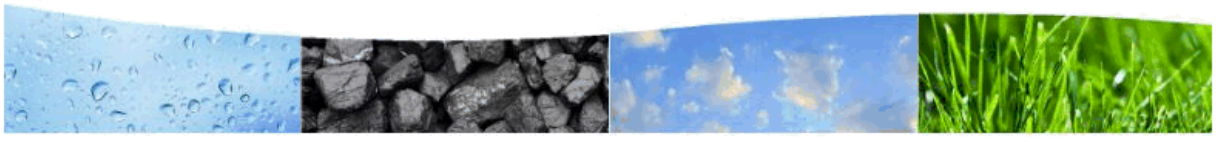
This product complies with the requirements for activated carbon as defined by the Food Chemicals Codex (FCC) (8th Edition) published by the U.S. Pharmacopeia.

This product is produced under supervision of the Islamic Food and Nutrition Council of America (IFANCA).

This product is prepared under the supervision of the Kashruth Division of the Orthodox Union and is Kosher.

Only products bearing the NSF Mark are Certified to NSF/ANSI 61 - Drinking Water System Components - Health Effects standard. Certified Products will bear the NSF Mark on packing or documentation shipped with the product.

Calgon Carbon Corporation's activated carbon products are continuously being improved and changes may have taken place since this publication went to press. 2030-08/29/2013



+1 800 422 7266 calgoncarbon.com

CalgonCarbon
A Kuraray Company

Appendix E: Filtrasorb 820 Sales Specification Sheet

FILTRASORB 820

Granular Activated Carbon

Test	Specification		Calgon Carbon Test Method
	Min	Max	
IODINE NUMBER, mg/g	900	-	TM-4,ASTM D4607
MOISTURE (AS PACKAGED), wt%	-	2.0	TM-1,ASTM D2867
ABRASION NUMBER	75	-	TM-9,AWWA B604
DENSITY (APPARENT), g/cc	0.50	-	TM-7,ASTM D2854
EFFECTIVE SIZE, mm	1.0	1.2	TM-47,ASTM D2862
UNIFORMITY COEFFICIENT	-	1.5	TM-47,ASTM D2862
TRACE CAPACITY NUMBER (TCN), mg/cc	9	-	TM-79,TM-85 (converted to TCN)
8 US MESH [2.36 mm], wt%	-	5.0	TM-8,ASTM D2862
< 20 US MESH [0.850 mm] (PAN), wt%	-	4.0	TM-8,ASTM D2862

Typical Properties:

This product complies with ANSI/AWWA B604 (2005) – Granular Activated Carbon.

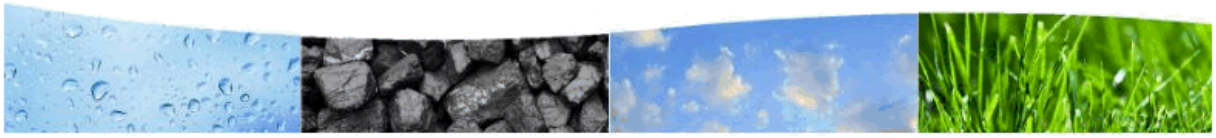
This product complies with the requirements for activated carbon as defined by the Food Chemicals Codex (FCC) (8th Edition) published by the U.S. Pharmacopeia.

This product is produced under supervision of the Islamic Food and Nutrition Council of America (IFANCA).

This product is prepared under the supervision of the Kashruth Division of the Orthodox Union and is Kosher.

Only products bearing the NSF Mark are Certified to NSF/ANSI 61 - Drinking Water System Components - Health Effects standard. Certified Products will bear the NSF Mark on packing or documentation shipped with the product.

Calgon Carbon Corporation's activated carbon products are continuously being improved and changes may have taken place since this publication went to press. 2135-08/13/2013



+1 800 422 7266 calgoncarbon.com

CalgonCarbon
A Kuraray Company