REPORT

Wet Weather Flow Treatment and Disinfection Demonstration Project

Bayonne Municipal Utilities Authority
City of Bayonne, Hudson County, NJ

September 2017

This report was funded, in part, with Grants from the United States Environmental Protection Agency (USEPA) and the New Jersey Department of Environmental Protection (NJDEP). The report was developed and implemented in cooperation and in consultation with USEPA and NJDEP.

THIS PAGE INTENTIONALLY LEFT BLANK

FORWARD

The New Jersey State statute that created the grant funding to Bayonne MUA for the Wet Weather Flow Treatment and Disinfection Demonstration Project was N.J.P.L. 2008, Chapter 115,1, c. The state grant funding was "to conduct, under department and United States Environmental Protection Agency oversight, a pilot project to evaluate a variety of chemical and non-chemical disinfection technologies combined with several solids reduction technologies on combined sewer overflow discharges to provide engineering practitioners with basic design criteria for control of pathogens discharges throughout the State and nationwide." Further, pursuant to the approved Quality Assurance Project Plan, performance data shall be presented as well as estimated capital and operation and maintenance cost curves for a variety of flows for each unit based upon the findings of the project. The report shall also review and evaluate information from the manufactures on the approach and usability of the data to full scale operation and unit sizing.

ACKNOWLEDGEMENTS

The following organizations are acknowledged for their support and participation in the successful completion of the Wet Weather Flow Treatment and Disinfection Demonstration Project: Bayonne Municipal Utilities Authority; United States Environmental Protection Agency; New Jersey Department of Environmental Protection; Technical Advisory Committee – see list of committee members on page 19; Regulatory Oversight Team – see list of team members on page 19; Passaic Valley Sewerage Commission; United Water / Suez; Sampling Team - field samplers, drivers and lab team from Mott MacDonald and PVSC; Pilot Equipment Manufacturers: WWETCO - Flex Filter Compressed Media Filter by WesTech Engineering, Inc.; Hydro International- Storm King with Swirl Cleanse; Terre Kleen – TK-09; Trojan's UV30000Plus Low Pressure UV; Aquionics Inline 250+W Medium Pressure UV; PeraGreen's INJEXX, later reincorporated as Verdant Disinfection Technologies, LLC Peracetic Acid unit; Solvay Chemicals, Inc., 12% Peracetic Acid (Proxitane WW-12).

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

BMUA	Bayonne Municipal Utilities Authority
BWWDDP	Bayonne Wet Weather Flow Treatment and Disinfection Demonstration Project
$CBOD_5$	Five Day Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
CMF	Compressed Media Filtration
CoC	Chain of Custody
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
CT	Contact Time
DO	Dissolved Oxygen
EHRT	Enhanced High Rate Treatment
FSS	Fixed Suspended Solids (Inorganic TSS)
HDPE	High Density Polyethylene
HRT	Hydraulic Retention Time
HLR	Hydraulic Loading Rate
LTCP	Long Term Control Plan
LSA	Land Surface Area
MM	Mott MacDonald
NELAC	National Environmental Laboratory Accreditation Conference
NJDEP	New Jersey Department of Environmental Protection
NJPDES	New Jersey Pollution Discharge Elimination System
O&M	Operation and Maintenance
PAA	Peracetic Acid
PS	Oak Street Pumping Station
PVSC	Passaic Valley Sewerage Commission
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
ROT	Regulatory Oversight Team
SOP	Standard Operating Procedures
TAC	Technical Advisory Committee
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UVT	Ultraviolet Transmittance
VSS	Volatile Suspended Solids
VWT	Veolia Wastewater Technologies, Inc.
WERF	Water Environment Research Foundation
WPCF	Water Pollution Control Facility

WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Bayonne Wet Weather Flow Treatment and Disinfection Demonstration Project (BWWDDP) was conducted over a two-year period at the Oak Street facility in Bayonne, NJ which receives the combined sewer overflow (CSO) from Bayonne City. The project was sponsored by the Bayonne Municipal Utilities Authority (BMUA), with grants and collaboration from New Jersey Department of Environmental Protection (NJDEP) and the United States Environmental Protection Agency (USEPA). Mott MacDonald served as the project manager with review input from a team of national experts (Technical Advisory Committee) and a Regulatory Oversight Team was formed for this project. The primary focus of the BWWDDP was to select and verify the performance of selected technologies to treat CSO discharges for solids removal and disinfection under field conditions as suitable for remote satellite locations. Scientifically valid performance data was developed to evaluate the effectiveness of wet weather treatment technologies and to provide engineering practitioners with an improved understanding of their potential use (i.e., reliability, scalability, anticipated capital and operations and maintenance costs, etc.) as satellite end of the pipe wet weather CSO treatment. The BWWDDP verified the performance of the selected technologies and validated those technologies which are suitable for the treatment of combined sewer overflow discharges at remote satellite locations.

The BWWDDP treatment included high rate solids removal and disinfection where a total of six technologies were tested in eighteen treatment process combinations over nine wet weather events. (Refer to Table 5.1). The technologies included high rate solids removal (i.e., vortex and plate settler units) and enhanced high rate solids treatment (i.e., a compressed media filter). Three types of disinfection units were also included, namely chemical disinfection (i.e., Peracetic acid, PAA), and ultraviolet (UV) disinfection (low and medium pressure units).

The results of the project demonstrated that the vortex and plate settler units are effective as preliminary treatment for inorganic solids removal but are not sufficient for the lighter solids removal needed for UV disinfection. The compressed media filter is capable of high performance solids removal (90%) allowing effluent UV disinfection (medium or low pressure) as well as for PAA disinfection. Both UV technologies are capable of achieving water quality objectives of pathogens and TSS removal, but must be preceded by compressed media filtration technology or its equivalent. PAA is an effective disinfectant for wet weather flows and has advantages over chlorine including comparable or lower dosages, shorter contact time, less toxicity, and needs no neutralizing agent.

The BWWDDP has demonstrated that high-rate/high-performance satellite treatment including solids removal and disinfection is attainable and can be used in appropriate instances to protect public health and aquatic biology. The BWWDDP with the references cited herein and the input from the experts on the Technical Advisory Committee and the Regulatory Oversight Team, conclude that a combination of the technologies tested can be matched to the distribution of wet weather events, associated hydraulic and pollutant conditions, and final removal efficiency requirements.
The design of the satellite wet weather facility is ultimately a function of the level of treatment required, site constraints, and the proper combination of technologies to minimize the footprint, ease of operation, as well as capital and operations and maintenance costs. Satellite facility construction

and operating costs are typically achievable at significantly lower costs than regional solutions (transport and treatment or sewer separation). The ease and cost of operation and maintenance of the treatment units are also important considerations for remote satellite facilities. Satellite facilities can be unmanned, odor-free, easily adapted to multiple siting locations, and have minimum operations and maintenance costs relative to the capital costs of the project. The results of the BWWDDP represent a valuable addition to data from other pilot and full-scale projects, and collectively serve as the basis to select appropriate components for remote satellite treatment of combined sewer and stormwater overflows.

SECTION 1 PROJECT SUMMARY

1.1 Overview

The BMUA retained Mott MacDonald as the Project Manager to develop, coordinate, and conduct this demonstration project and to publish the data for general use within the industry. The project was undertaken jointly by the BMUA, with grants from the NJDEP and the USEPA. A Technical Advisory Committee (TAC), and a Regulatory Oversight Team were formed to review and comment on the means, methods, results, and conclusions of the project.

The goal and objective of the project was to develop scientifically valid performance data obtained under field conditions to evaluate the effectiveness of CSO treatment technologies and to gain an improved understanding of their potential use as satellite, end-of-pipe water treatment for CSO wet-weather discharges. In addition to performance evaluation, aspects such as reliability, scalability, anticipated capital and operation and maintenance (O&M) costs, efficiency, and startup procedures for each unit were included.

The primary focus of the project was to evaluate field effectiveness of selected CSO treatment units as supplied by the manufacturers at specified operating conditions. For example, hydraulic loadings rates (HLR) relate to TSS removal units and dose relates to the disinfection units. Bench-scale testing to establish operating conditions or other development work was not a part of this project.

Varying the quality and loading to the different units both above and below desired performance conditions is important to establishing design data. Hydraulic flow rates and disinfection dose were held constant for an individual test, but were varied from test to test. As expected with CSO discharges, influent quality varied considerably from the beginning to end of an event and from event to event.

No special operator attention to adjust, clean or otherwise supervise operation of the units was originally envisioned to be part of the testing, other than to provide initial start-up and sampling functions during individual Test Runs. Nevertheless, there were some equipment and support issues that are not unusual for pilot studies that the sampling crew did address. Proper design of full-scale systems should prevent most of these problems. All issues encountered are described and discussed in this report.

A solicitation for qualifications was published and various suppliers of CSO, wastewater and stormwater equipment responded offering hydrodynamic and gravimetric separators, filters, medium and low pressure ultraviolet (UV) disinfection devices and chemical disinfection units. The primary evaluation criteria for the units were: suitability for remote satellite facilities, documented performance, ease of operation, maintenance requirements, footprint or hydraulic loading rate, and cost. The technologies selected by TAC members for the demonstration project included the following existing available manufactured systems:

1. Hydro International's Storm King® with Swirl Cleanse (vortex unit)
2. Terre Kleen TK-09 (plate settler unit)

3. WWETCO's FlexFilter™ by WesTech Engineering Inc. (compressed media filter - CMF)
4. PeraGreen's (later reincorporated as Verdant Disinfection Technologies, LLC) INJEXX™ Peracetic Acid (PAA) unit; Solvay Chemicals, Inc. provided 12% Peracetic Acid (Proxitane (WW-12))
5. Trojan's UV30000Plus™ (Low Pressure UV)
6. Aquionics Inline 250+W (Medium Pressure UV)

The BMUA Oak Street Pumping Station (PS) was selected as the study location since its drainage area encompassed the entire City, the site provided adequate room, included a wet- weather CSO discharge of up to 40 mgd, and provided consistent and extended CSO overflow periods.

The project was initiated in the summer of 2014 with monitoring of four storm events (Test Runs) being completed before a winter break. Testing resumed in the Spring of 2015, but due to unusually dry weather and scheduling issues, only three additional Test Runs were successfully completed by the end of September 2015. To complete the planned total of nine sampling events, the program of "live" storm/overflow events were supplemented by two events where dry-weather BMUA sewage was diluted with groundwater to simulate the CSO discharge.

During the Test Runs, an assortment of relevant water quality parameters were monitored at 20 minute intervals, including pathogen indicators (E. coli, fecal coliforms, and Enterococci), as appropriate. For each event, the three disinfection units (medium and low pressure UV and PAA) were matched up to treat the effluent from one of the TSS treatment units (Storm King, Terre Kleen or FlexFilter). In one event PAA was used to treat the raw CSO. The FlexFilter influent came from either the vortex or the plate settler unit. Due to the lack of wet weather events the filter was not used to treat the raw CSO. The filter was operated at peak flows to provide high flow to the downstream disinfection units due to size availability.

1.1.1 TSS Removal by Storm King® and Terre Kleen:

The Storm King® and Terre Kleen units both had operating issues due to their screens clogging with materials that appeared to be primarily toilet paper, they also experienced performance issues of low TSS removals. Both units demonstrated poor TSS removal when Volatile Suspended Solids (VSS) accounted for a high percent of the influent TSS, and had removal efficiency of less than 10% in all but one Test Run. The TSS removal efficiencies improve when evaluating the inorganic component of TSS, or Fixed Suspended Solids (FSS). The FSS removal efficiencies for Terre Kleen and Storm King averaged around 17% and 22% when considering higher confidence results as described in Section 9, with the maximum removal efficiencies of 45.2% and 44.9% respectively. The low removal of VSS (or inorganic) fraction of TSS indicates that both the Storm King and Terre Kleen will be ineffective on their own with UV disinfection due to low ultraviolet light transmittance of the effluent. Grit removal and/or management will be an important component of any CSO satellite treatment, however other forms of treatment for TSS removal to meet regulatory requirements and support proper disinfection should be evaluated prior to design.

As evidenced by a study performed by EPA, the removal of solids by a vortex is contingent on the design flow and particle - settling velocities, (Manual Combined Sewer Overflow Control, USEPA, Sept. 1999). A 12- ft. diameter EPA vortex was evaluated for 11 storms and reported an averaged a mass TSS removal of 55% and VSS of 25 % at 12 gpm/ft2, (Disinfection/Treatment of CSOs, Syracuse, N.Y., USEPA, August, 1979). Proprietary vortex versions such as the Hydro-International unit and the plate settler unit tested will vary as shown by the data of this Project.

Demonstration testing in Columbus GA using a full-scale Storm King's showed that above 5 gpm/sq. ft. HLR, TSS removals would go to zero. The vortex unit was however estimated to remove 35% of the annual TSS load by capture and for smaller more frequent events at lower loading rates. The vortex units were reported to be very good at removing grit, oil and grease, and other debris. The vortex was used as a contact vessel for disinfection as it exhibits a fairly efficient plug flow regime (63%). (WERF 2002)

1.1.2 TSS Removal FlexFilter:

The influent to the FlexFilter was pumped from either the Storm King or Terre Kleen effluent. The FlexFilter pilot unit was operated at 80 inches of head loss. Operating issues with the FlexFilter were primarily related to issues with the pumps, and the time needed to backwash.

The pumps for FlexFilter, as supplied by WWETCO, experienced operational difficulties due to mechanical issues. It was noted by the manufacturer that in many cases in a staged treatment approach, the filter may be able to flow by gravity utilizing the maximum hydraulic gradient of the system while treating the smaller more frequent events, as well as the first flush portion of the larger events. Overall hydraulic and flow conditions are site specific and should be considered accordingly. Therefore, these mechanical issues with the influent and effluent pumps, if necessary, would not be realized of a properly designed satellite system.

It was originally thought that the calculation of HLR of the FlexFilter utilized the horizontal surface area of the unit, which for this pilot unit was 18 sf. Later it was learned from the manufacturer that the HLR, for the supplied unit, is based on the throat area of the media bed and that the FlexFilter pilot had an effective surface area of 8.2 sq. ft. It was built as a half of a standard filter in order to see inside the filter bed and demonstrate the porosity gradient and the associated solids penetration in the media bed. Testing of the unit was conducted at flows of 100gpm and 150gpm, which were thought to equate to a HLR of 5.5 to 8.3, but which represented an effective HLR of 12.2 and 18.3 gpm/sq. ft.

Accordingly, the testing of this unit was reported by the manufacturer to have been conducted at the higher end of the filter loading rate recommended for CSO treatment. This resulted in shorter filter run times and frequent backwashing. The manufacturer noted that for CSO applications the filter is typically operated at 4 gpm/sq. ft. HLR during the first flush portion of a CSO event and gradually increases the operating HLR as the CSO flow rate increases and solids concentration decrease. The maximum HLR of CSO treatment is typically limited to 10 gpm/sq. ft. at design peak flow.

Design of a wet weather satellite facility needs to include multiple treatment units/cells that consider backwash cycles, and redundancy to maintain continuous treatment of the design conditions with cells in backwash. Generally, for CSO treatment, 25% to 30% additional filter area is provided above that required to process the peak design flow.

The average TSS removal for the FlexFilter was very good, removing close to or over 90% of the TSS in most test runs with actual CSO flows. Removal efficiencies using the simulated wastewater for Runs 8 and 9, which may not have a comparable concentration of solids, averaged about 65%. Excluding the first event, the FlexFilter effluent concentrations for TSS and CBOD averaged 25 and 48 mg/l, respectively.

The overall TSS removal efficiency of the Storm King and Terre Kleen was very low, and as a result the FlexFilter in essence was treating raw CSO wastewater. The project testing program intended to include raw CSO feed to the FlexFilter, but the limited wet weather precluded these tests. The higher TSS removal rates for the FlexFilter improved the ultraviolet transmittance (UVT) of the effluent flow; however, UVT values were still modest. The effluent from the FlexFilter averaged approximately 25 mg/L (excluding the first run) for TSS and 40% on UVT (excluding simulated runs).

Full scale CSO treatment facilities in Springfield, OH (100MGD) using FlexFilter have been operating since March 2015. Performance of this system has reportedly resulted in over 90% TSS load reduction and 83% BOD load reduction with over 41 events tested in the first year (Fitzpatrick, 2016).

1.1.3 PAA Disinfection

PAA disinfection tests were performed with PAA dose of typically 2 to 3 mg/L, but up to 7 mg/L, targeting PAA residual in 1 to 2 mg/L range. HRT of the unit was typically 3 minutes. These conditions resulted in an average log inactivation of the pathogen indicators of 1.7, 2.0 and 2.3 for E. coli, fecal coliforms, and Enterococci, respectively. While these average reductions were modest, some important conclusions could be derived from the results obtained.

The best defined relationship derived from the study results was that between the applied dose of PAA as normalized by COD present in the wastewater and the log reduction of pathogen indicators. PAA dose of 0.01 mg/L of PAA per mg/L of COD present in wastewater resulted in 3 log reduction of fecal coliforms (on average), with slightly higher effectiveness for E. coli and slightly lower for Enterococci.

Increasing the relative dose to above 0.015 mg/L of PAA per mg/L of COD increased log reduction to 4. Further increase of the PAA dose appeared to have limited effect on further increasing reduction of the bacterial densities, although data in that range are too limited to allow for a firm conclusion.

Should the importance of PAA dose applied as normalized by COD be confirmed at other locations as the key predictive tool of disinfection effectiveness, it would be desirable to adjust the PAA application rate based on both wastewater flow and COD or organic strength. The organic strength of wastewater could potentially be measured in real time by a surrogate parameter such as Total Organic Carbon (TOC), but this would be practical only at large sites.

In the Columbus GA study, PAA dose and contact time normalized by ammonia was found to correlate very well with effluent fecal coliform (WERF 2002). These studies also found that disinfectant feed rates could be controlled by an algorithm incorporating dose/kill and historical data related to flow volume over time (WERF 2002). The Columbus facility has been operating with an algorithm to feed sodium hypochlorite in this manner for the past 15 years and has reportedly consistently demonstrated disinfection performance and maintenance of in-stream water quality.

Instrumentation of influent quality may also be used to fine tune the dose rate. Feed rate algorithms can be expressed as power equations (aX^b), wherein the "a" and "b" values can be fine-tuned with operational experience. (WERF 2002)

Salinity appears to cause rapid decomposition of the PAA and thus the potential impact on aquatic life in estuaries and ocean waters may be insignificant. Toxicity studies on PAA were conducted in San Diego in the 1980's to evaluate impact of PAA disinfected primary effluent on the bay environment. The study concluded that there was no toxicity impact (Engineering Science, 1990).

While this demonstration project and other studies referenced in this report did not experience toxicity of residual PAA, it may be an issue to consider in the selection of an appropriate disinfection strategy.

Use of PAA in satellite CSO locations could be complicated by a need for on-site storage of the chemical, which requires secondary containment and appropriate safety measures. Nevertheless, PAA also has many desired characteristics that may offset the negatives for satellite facilities such as a one-year shelf life, its effectiveness with contact times as low as three to six minutes, no toxic byproducts, and the potential elimination of other unit processes such as de-chlorination.

1.1.4 UV Disinfection

As discussed above, two UV disinfection units (Trojan based on low-pressure lamps and Aquionics based on medium-pressure lamps) were used at the flow rates within the design range specified by the manufacturers. The quality of the influent, most importantly UV transmittance (UVT), varied significantly between and within the Test Runs, with majority of the samples in the 20 to 50% UVT range. Unit manufacturers used flow and UVT values corresponding to individual sampling events within all the Test Runs. With this information, the unit's manufacturer calculated the effective irradiation dose applied based on the available validation protocol results for the tested UV units and standard industry practice as discussed in Section 11.1.

The calculated effective irradiation dose was generally below 25 mJ/cm^2 for the Trojan unit and below 45 mJ/cm^2 for the Aquionics unit. At these relatively lower effective irradiation doses, which were primarily due to the low UVT values, the log reduction for pathogen indicators averaged 1.6 to 2.4 for the Trojan unit and 1.2 to 1.7 for the Aquionics unit.

Correlation of all the individual data from the study indicated that the Trojan UV3000Plus unit using low-pressure lamps required approximately 25 mJ/cm^2 effective irradiation dose input to achieve 3-log inactivation of pathogen indicators. The Aquionics 250+W unit using medium-pressure lamps required approximately 45 mJ/cm^2 effective irradiation dose to achieve 3-log inactivation of pathogen indicators.

Design flow of UV equipment, when used in a "dirty water" application, must be significantly lowered (de-rated) compared to wastewater treatment plan (WWTP) effluent to account for poorer light transmittance of the CSO wastewater. The WWETCO filter tested provides adequate pre-treatment to reduce particle size and increase UVT. Other studies have found that effective UV disinfection is dependent upon particle size as well as light transmittance (Fitzpatrick, 2010).

UV disinfection is reportedly capable of achieving over three - log reduction at lower transmissivity by increasing UV dosages to 50 mJ/cm2 as found in other projects. (Newell St. Disinfection Demonstration, Sept, 1999, M&A; Spring Crk. CSO Disinfection Pilot Study, 1997, M&A sub consultant to CDM). Medium pressure has been applied in a U-tube arrangement that allows backwater without impacting UV operation as in Columbus, Ga. (WERF 2002). It can also be applied in open channel arrangement as in Syracuse after tertiary treatment for 120 mgd. Wastewater transmittance showed an expected, strong correlation with water quality parameters such as $CBOD_5$, COD, and TSS. (Camp Dresser & McKee and Moffa and Associates, "Spring Creek AWPCP Upgrade. CSO Disinfection Pilot Study Part II", 1999)

1.2 Guidance on Selection and Sizing of Treatment Components

Technologies that were tested under this wet weather demonstration project represent a valuable addition to data from other pilot and full-scale projects and collectively these projects can serve as the basis to select appropriate components for satellite treatment of combined sewer overflow and stormwater discharges.

It should be noted that manufacturer HLRs (typically in gpm/sq. ft.) are calculated in different ways based on the technology:

1. The Terre Kleen HLR is based on the total projected area of the slanted plates or trays within the unit. Thus, the unit as tested had 9 trays each with a projected surface area of 6.33 sq. ft. each for a total effective area of 57 sq. ft. (Recently NJDEP assigned an effective surface area of 87 sq. ft. to this unit (NJDEP 2017).
2. The Storm King HLR is based on the horizontal surface area of the circular vortex unit and thus the 2-meter diameter unit had an effective area of 33.8 sq. ft.
3. The FlexFilter HLR uses the horizontal surface area of the filter media. However, as previously noted this pilot unit was constructed with a smaller throat than typical in order to provide a window into the middle of the media bed. For scale-up purposes, this pilot had an effective surface area of 8.2 sq. ft.

To differentiate between the HLR and the land area required for each unit, the estimated land surface area (LSA) for each unit was determined based on the unit as tested. While the Storm King is circular it has a rectangular discharge channel and thus the LSA was based on the rectangular space occupied by the unit. The Storm King unit, including the discharge trough, had a LSA of approximately 88 sq. ft., (8' x 11'). The FlexFilter was a 3' x 6' tank with associated piping having an estimated LSA of 36 sq. ft. The Terre Kleen unit was a 4.5' x 7' rectangular chamber, which had a LSA of 31 sq. ft. For the Storm King the LSA (88 sq. ft.) required was about 2½ times the size of the effective area (33.8 sq. ft.). The LSA (36 sq. ft.) for the FlexFilter as tested was over 4 times the effective area (8.2 sq. ft.). However, it should be noted that the effective area of the unit as tested was about half of the effective area of a typical unit. A FlexFilter matrix layout with multiple cells has influent and effluent chambers as well as influent and effluent channels (or piping). Therefore, the LSA of a FlexFilter cell is about twice the actual filter surface area. The Terre Kleen LSA (31 sq. ft.) of the Terre Kleen, is approximately a 1/3 of the effective area of 87 sq. ft. It thus appears that when comparing LSA with effective area, the Terre Kleen has an advantage due to the sloped plates. It should be noted that the LSA relationship to effective area as noted above will most likely change for full scale facilities.

For siting purposes, the Storm King, Terre Kleen, and FlexFilter structures need to include filter area plus influent and effluent channels and chambers. In addition, to the treatment structure, appurtenant facilities also need to be provided such as coarse screening, electrical controls, blowers, backwash pumps, effluent storage, waste flow storage, and potentially effluent or influent pumping. These components will require additional footprint for siting purposes and can be integral to or separate from the treatment structure.

The actual land area used is specific to site constraints and the unit treatment considered. Screening can be accomplished within the influent channel or in a separate structure at an appropriate location. The blowers, as needed for backwash can be located on top of the treatment structure in a weather and sound enclosure or in a dedicated building depending upon size, or more likely depending upon architectural requirements and resiliency of the project. Although the treatment structure can be completely underground, electrical gear, controls and blowers need to be above ground and meet flood reliability requirements.

Backwash transfer or influent/effluent pumping can be appended to the treatment structure or located in separate structures. Depending upon site hydraulics, flood levels and tidal influence, when applicable, effluent pumping, where applied, may not be actuated for every event. Effluent pumping, depending on freedom from debris and grit, could be accomplished with axial-flow low-head pumping requiring relatively little space.

In many cases a staged treatment approach can be implemented. Historically, the majority of rainfalls events in New Jersey, and subsequent CSO events are of low volume, short duration, and relatively low flow rates. These smaller frequent events can have higher solids concentration and may contain the flush of the collection system.

Treatment at satellite facilities is typically defined in four stages. Stage 1 treatment represents when the volume of the empty satellite facility is used to capture the smallest events with no discharge. Stage 2 treatment represents high quality treatment of events up to the design capacity and will generally provide the greatest environmental return for the capital invested. Stage 3 treatment includes treatment at a higher HLR for the peak flow rates where the CSO is dilute and easier to disinfect. Stage 4 treatment may include split flows where additional disinfection treatment units may be cost effectively employed for extreme wet weather conditions.

Satellite facilities will require post-event cleanup, that is automatic and unmanned so that the facility is ready for the next event. Manned visits must also be considered and will typically include routine maintenance, collection of samples, disposal of residuals, where appropriate, and refill of consumables such as chemical oxidants (e.g., PAA) when used. The Storm King requires an underflow of 10% of design flow that would normally go to the sanitary interceptor. Similarly, the FlexFilter has backwash equal to 5% of the design flow that would go to the sanitary sewer. If capacity for these flows is not available storage facilities or a means of attenuating the waste stream must be considered. The ease and cost of O&M of the treatment units are also critical selection factors for remote satellite facilities.

The FlexFilter unit requires effluent storage or an available water source for post event backwash of those cells that did not get cleaned when the CSO hydrograph subsided. Effluent storage may also be used as the contact chamber for chemical oxidant disinfection. Effluent storage and backwash attenuation for the FlexFilter can be accommodated underneath (but separated from) the filters mirroring the filter compartments above. Nevertheless, all backwash and effluent storage will be completely drained by the end of an automatic post event cleanup.

Disinfection also requires a footprint and can be integral to, or separate from the pretreatment or solids removal treatment. UV disinfection requires a relatively small footprint compared to the solids removal footprint. Chemical disinfection requires contact time, and depending on the chemical application the possibility of chemical reduction or removal.

1.2.1 Screening and Pretreatment

Rags and wipes caused operational issues with the influent pumps as well as the operation of the Terre Kleen and Hydro International units. While a static coarse screen was used during pilot testing, separate macro screenings, i.e. ½ - ¾ inch mechanical screens, should be provided as in current full-scale operations such as ¾” screens in Columbus, GA and ½” screens in Springfield, OH. Screens are needed to minimize the potential impacts of rags/wipes on subsequent units or from redepositing these into the downstream sanitary sewer. It should be noted that New Jersey requires removal of solids/floatables greater than ½” from CSO discharges and thus ½” screening would be required if the subsequent treatment process would not remove this material. The FlexFilter top perforated plates remove 3/8” screenings and the filter removes down to a 10 *u*m particle.

Screening will need to be stored on site, or if interceptor system capacity is available diverted to the WWTP. Deflection screens keep screenings in the waste flow moving towards the WWTP. In some situations, these types of screens may not be applicable. Deflection screening depends upon the size of the outfall and potential size of debris as well as the capacity of the interceptor and WWTP to handle such screenings.

The vortex/screen unit and the plate settler units are both effective in the removal of inorganic solids but at different LSAs. The vortex unit achieved the same FSS removal as the plate settler unit but may require a larger land area. The vortex was operated at about twice the flow but has about 4-times the LSA when the trough and backwash piping projected surface area is included as compared to the Terre Kleen. The LSAs as calculated in Section 9 did not include provisions for entrance and exit channels in the case of the plate settler and piping in the case of the vortex units. Both units were ineffective in the removal of VSS (organic solids), and rags and wipes were a problem for both units.

1.2.2 TSS Removal

The compressed media filter proved to be the most consistent and effective solids removal technology sufficient to remove finer and organic suspended solids. Overall the WWETCO FlexFilter was capable of removing 90% of the TSS even at a HLR of 12 to 18 gpm/sq. ft. The unit as tested spent up to $^{1}/_{2}$ of the typical four hour run time in backwash cycle, however it was operated at 3 to 4 the recommended hydraulic loading rate in order to supply downstream disinfection with higher flows. Satellite facility design will need to consider multiple units with adequate capacity to allow for continuous treatment during both the high solids first flush period and peak design flow when other cells are in the backwash mode.

1.2.3 PAA Disinfection

Peracetic Acid (PAA) appears to be an effective disinfectant for wet weather discharges at comparable or lower dosages than chlorination and potentially with less toxicity. Furthermore, PAA contact periods as low as 3 to 6 minutes resulted in an average log inactivation of the pathogen indicators of 1.7, 2.0 and 2.3 for E. coli, fecal coliforms, and Enterococci, respectively. A significant relationship between log reduction of pathogen indicators and PAA dose applied per mg/L of COD present was documented.

PAA dosing of 0.01 mg/L of PAA per mg/L of COD present in wastewater resulted in 3 log reduction of fecal coliforms (on average), with slightly higher effectiveness for E. coli and slightly lower for Enterococci. Overall, PAA appears to be well suited for disinfection of CSO discharges for satellite locations especially those with severe area limitations. The potential PAA toxicity to aquatic life at the required dosage and special material handling and equipment requirements for PAA as experienced in other projects, e.g. City of Oneida, N.Y. Pilot Project, and Columbus, GA PAA Demonstration Projects should be considered.

1.2.4 UV Disinfection

Both UV technologies tested can achieve water quality objectives of TSS and pathogen reduction at 40% UV transmissivity or greater. Such UVTs can only be assured if preceded by compressed media filtration or equivalent. Correlation of all the individual data from the study indicated that Trojan UV3000Plus unit using low-pressure lamps required approximately 25 mJ/cm^2 irradiation energy input to achieve 3-log inactivation of pathogen indicators. Aquionics 250+W unit using medium-pressure lamps required approximately 40 mJ/cm^2 irradiation energy input to achieve 3-log inactivation of pathogen indicators. Available literature indicates that UV disinfection can achieve over 3 log inactivation of pathogens at lower transmissivity by increasing UV dosages to 50 mJ/cm^2. The selection of medium vs. low pressure UV technology should consider the applicability to open channel flow and associated impacts on facility space requirements, head loss, ease of maintenance, and total O&M costs.

1.3 Finding and Conclusions

Unscreened CSO flow was delivered by pumping to both the Storm King and Terre Kleen units followed by either pumping to the FlexFilter or by gravity flow directly to one of the 3 disinfection units. Overall findings can be summarized as follows:

1. Coarse screening (e.g. ½”) should precede any treatment scenarios.
2. The Storm King and Terre Kleen can be used as preliminary treatment for grit removal but are not sufficient for the lighter TSS removal needed for subsequent UV disinfection.
3. The FlexFilter is capable of high performance TSS removal (90%) allowing effluent UV disinfection (medium or low pressure) or PAA disinfection.
4. Both UV technologies are capable of achieving water quality objectives of TSS and pathogen reduction, but only if preceded by compressed - media filtration or equivalent.
5. Peracetic Acid is an effective disinfectant for wet weather flows.

The BWWDDP has further demonstrated that high-rate, high-performance satellite treatment including solids removal and disinfection is attainable and can be used in appropriate instances to satisfy water quality standards of pollutants of concerns, e.g. TSS, pathogenand reductions and protecting public health and aquatic biology. In general, when compared with other measures for reducing CSO loadings, satellite treatment can provide the most cost-effective means of abatement. Satellite facility construction and operating costs are typically a fraction of transport and treatment, or sewer separation costs especially in highly urbanized locations. Nevertheless, the design engineer needs to determine cost-effectiveness in conjunction with a review of available transport and treatment capacity, land availability, a collection system condition assessment, and local regional planning activities to develop a responsible and responsive long term control plan.

Satellite treatment facilities can be mostly underground, of relatively small footprint, and can serve as catalyst and integral component of projects for improving coastline, greenspace, and other community amenities, all of which are especially important in urban settings. Satellite facilities can be unmanned, odor free, and have minimal O&M cost relative to the capital costs of the project. CSO discharges are active approximately 5% of time and their O&M costs relative to the total present worth costs are generally less than 5%. In some locations satellite residuals can be minimized with nothing removed from the site, however this is highly dependent on the size and capacity of the local interceptor sewer. Larger outfalls most likely will require screenings and grit removal from the site.

The results of the BWWDDP represent a valuable addition to data from other pilot and full-scale projects, and collectively serve as the basis to select appropriate components for satellite treatment of combined sewer and stormwater overflows. In summary:

1. The compressed media filter proved to be the most consistent and effective solids - removal technology sufficient to remove additional, finer suspended solids. This technology, as pre-treatment, enhanced the effectiveness of UV disinfection by both the low and medium - pressure units. Compressed Media Filtration was included as an innovative Treatment Technology in USEPA's Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management, EPA 832-R-12-011 published in March 2013, August 2013 Addendum.

2. The selection of medium vs. low pressure UV technology needs to consider the applicability to open - channel flow. This can have a significant bearing on foot print, head loss, ease of maintenance and total O&M costs. Both UV technologies are capable of substantially reducing pathogens and achieving current receiving water quality standards at 40 % UV transmissivity or greater. Such UVTs can be assured only if preceded by compressed - media filtration or equivalent. UV disinfection equipment footprint will be proportional to flow. In a staged treatment concept, UV disinfection could be sized for the more frequent smaller events up to the knee-of-the-curve distribution of events that typically represents 90% to 95% of all events.

3. Peracetic Acid is an effective disinfectant for wet weather flows at comparable or lower dosages than chlorination, less contact time, needs no neutralizing agent, and potentially with less toxicity. It has a long shelf life and can be used to disinfect the less frequent higher CSO flow rates without pretreatment. This latter application would be appropriate for a staged treatment concept for those infrequent dilute high flows depending of the receiving water and water quality parameters of concern. PAA was included as an emerging Alternative Disinfection Technology in USEPA's Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management, EPA 832-R-12-011 published in March 2013, August 2013 Addendum.

In general, the results of the BWWDDP and the full-scale satellite operations illustrate that a combination of the technologies tested, can be matched to the distribution of wet weather events, associated hydraulic and pollutant conditions, and final removal efficiency requirements. A passive staging of treatment that includes the WWETCO FlexFilter can achieve a high level of pollutant removal, followed by UV and/or PAA disinfection. The design is ultimately a function of the level of treatment required, site constraints, and the proper combination of technologies to minimize footprint, as well as capital and O&M costs. Examples of Enhanced High Rate Treatment (EHRT) satellite facility estimated footprint, construction and O&M cost by capacity are shown in Table 3 of Appendix C. Examples of satellite treatment process flow diagrams are illustrated in Figures 1.1 and 1.2 can be found in appendix C & D. Examples of hydrodynamic separation treatment including unit size and number per design flow and treatment objectives can be found in Appendix E. These examples consider the different technologies tested and provide options for on-site removal of residuals and staged treatment concepts. Additional information as provided by the manufacturers is provided in Section 15.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 2 PROBLEM DEFINITION/BACKGROUND

2.1 Problem Definition

In 2006 Mott MacDonald (formerly Hatch Mott MacDonald) undertook the preparation of a Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) for the Bayonne Municipal Utilities Authority (BMUA) including the development of a Technical Guidance Manual to assist in the evaluation of the cost and benefit of various control technologies. A literature search conducted under that project noted there was very little independent data available on the performance of the various treatment units and that the manufacturer data had to be used in the analysis. In fact, at least one of the treatment units considered was conceptual and since that time has been discontinued. One of the main recommendations in the LTCP was to conduct pilot testing on all treatment and disinfection units under consideration, to verify data as provided by the manufacturer prior to finalization and implementation of the CSO LTCP.

The New Jersey Department of Environmental Protection (NJDEP) finalized and issued individual NJPDES Permits to Owner/Operators of combined sewer facilities in mid-2015 requiring the development of a LTCP in accordance with the US Environmental Protection Agency (USEPA) CSO Control Strategy. At the present time there is limited, verified data available on the performance of CSO treatment technologies that will need to be evaluated and possibly constructed under the permit.

2.2 Goal and Objective

The goal and objective of the project was to develop scientifically valid performance data to evaluate the effectiveness of CSO treatment technologies and to gain an improved understanding (i.e., reliability, scalability, anticipated capital and O&M costs, efficiency, and startup procedures) of their potential use as satellite end-of-pipe water quality treatment for wet-weather discharges including CSOs.

2.3 Background

The BMUA provides wastewater service to the City of Bayonne and is the owner of the combined sewer system including all existing CSO Control Facilities. The City is served by a combined (sanitary and storm) sewer system that conveys sewage, industrial wastewater, stormwater, and subsurface infiltration through the same conduit to the Authority Oak Street Pumping Station (PS). The system is currently being operated by Suez (formerly United Water) under a 40-year agreement with the BMUA. The dry weather side of the Oak Street PS has a peak pumping capacity of approximately 15 million gallons per day (mgd) and typical dry- weather flows of 7 – 9 mgd. The wet-weather side of the PS has a peak capacity of 27,000 gpm or approximately 40 mgd.

The total area of the City is approximately 3,700 acres, most of which is serviced by the combined sewer system. The only areas with separate sewers are some of the industrial areas along the Hudson River that are tributary directly to the Eastern Interceptor Sewer. All flows from the sanitary and combined sewer systems within the City are tributary to the BMUA Oak Street PS, which transports wastewater flows to the Passaic Valley Sewerage Commission (PVSC) Water Pollution Control Facility located across Newark Bay in the City of Newark. The pumping station however has limited capacity and excessive wet weather flows are discharged through a CSO outfall to upper New York Harbor. Although this is permitted under excessive flow regimes, the project will explore remedies to discharging untreated overflow directly to the receiving waters for this and other stormwater and CSO discharges across the county, state, and country.

In March 2007 BMUA completed a LTCP related analysis as required by New Jersey CSO General Permit. The LTCP analysis evaluated a variety of technologies and methodologies for addressing. Rapid (high HLR) treatment and disinfection at remote end-of-pipe facilities was included as a required element in the LTCP analysis. A variety of treatment technologies were explored including hydrodynamic separation, ballasted flocculation, and filters as well as disinfection technologies such as ultraviolet radiation and chemical disinfection. The LTCP related analysis considered CSO treatment technologies, including the Veolia Wastewater Technologies' (VWT) Hydrovex Fluid-Sep Vortex, Hydro International's Storm King^{R}, Contech's CDS SanSep^{TM} and FlocSep^{TM}, VWT's Actiflo and Suez's Densa-Deg ballasted flocculation process, and Westech Inc.'s WWETCO FlexFilter^{TM}, followed by chemical disinfection using sodium hypochlorite, Peracetic acid (PAA), and UV disinfection using Trojan's UV4000. Manufacturer's data was used as the basis for sizing conceptual facilities. At the time, there was very little independent data and accordingly independent validation of the manufacture's data under actual field condition was recommended.

The BMUA accepted the recommendation for independent verification and applied for, and subsequently received a Special Project Grant from USEPA for a CSO pilot project. This also opened discussions with the NJDEP to develop a joint wet weather demonstration project to pilot wet weather technology. The BMUA offered the Oak Street PS as a location and pursued additional funding and implementation of this project. The project is primarily being funded by the BMUA, with assistance from the USEPA Special Projects Grant and a CSO Grant made available through the NJDEP.

This is a wet weather flow demonstration project and accordingly the intent was that the sampling process would only be undertaken during wet weather events and when an actual CSO discharge is occurring at the Oak Street PS thru CSO Outfall 001/005. While overflows can occur during any season, those that are associated with snow melt are typically weaker in strength. Accordingly, sampling was only undertaken when CSO discharges were caused by rainfall events of adequate duration and volume unless otherwise noted. Due to several factors, it was necessary to conduct two events using a simulated CSO created by mixing sanitary sewage with groundwater as described in more detail later in this report.

The Oak Street PS was selected as the location for this project due to its downstream location in the BMUA combined sewer system. The pumping station collects wastewater flows from the entire City and directs them to PVSC for treatment. It provides the opportunity to sample combined sewer flow that is a homogenization of wet weather flows from the City's various land uses, provides adequate room to allow testing of several units at once, provides the ability to control flow to the units, which is typically a variable at most CSO points, and affords longer duration discharges. Dry weather average daily flow at the pumping station is approximately 8 mgd.

Typically for characterization studies, sampling is postponed and scheduled based on antecedent rainfall. Antecedent rainfall was not deemed critical for this study since the study's purpose was to review the unit's ability to deal with varying influent concentration and flows, and thus a range of influent water quality should be beneficial. Accordingly, sampling events were conducted in accordance with the following: The wet weather event must be preceded by a minimum of two dry days after a rain event of 1.0 in. or higher in volume; one dry day for rains > 0.25 in. but < 1.0 in. in volume; and no waiting period for rainfalls < 0.25 in. A dry day is defined as a 24-hour period with no (< 0.1 in.) rainfall recorded during a 24-hour period. For the samples to be valid, the storm must produce an overflow at Outfall 001/005 during the period of sampling.

The final results of this project will be available to the CSO community and has been vetted by a team of national experts and state/federal regulators. The project undertaken under this program was first identified in detail within a Quality Assurance Project Plan (QAPP) that was reviewed and subsequently approved by the NJDEP as well as Region 2 of the USEPA. This report summarizes some of the details included in the QAPP as well as the work conducted under the program.

Originally the project schedule anticipated that all pilot testing would be completed during calendar year 2014, nevertheless delays in getting approval of the QAPP (approved in May 2014), getting approvals to move forward with pilot construction, and equipment and piping issues after construction delayed the project's ability to capture wet weather events until around mid-August 2014. This was followed by an extremely dry August and September when local rainfalls totaled only around 1.5 in. per month and greatest observed rainfalls were only around 0.50 in. Four wet weather events were captured during October and early November, however temperatures dropped drastically in mid-November (The mean minimum temperature for the month was 36^0 F and the low for the month was 21^0 F). Unlike a typical treatment facility, all pilot facilities and piping were located above ground in the open and accordingly with the prediction of temperature in the low twenties and a concern for freeze damage to the equipment the decision was made to winterize the equipment and to complete the wet weather events in 2015. Difficulties with dry weather continued into 2015 and subsequently the last two events were conducted during dry weather by blending sanitary flows from the pumping station with groundwater from the decommissioned sludge tanks from the old treatment plant. While all nine sampling episodes originally anticipated within the QAPP were completed, only seven were from actual CSO events at the pumping station.

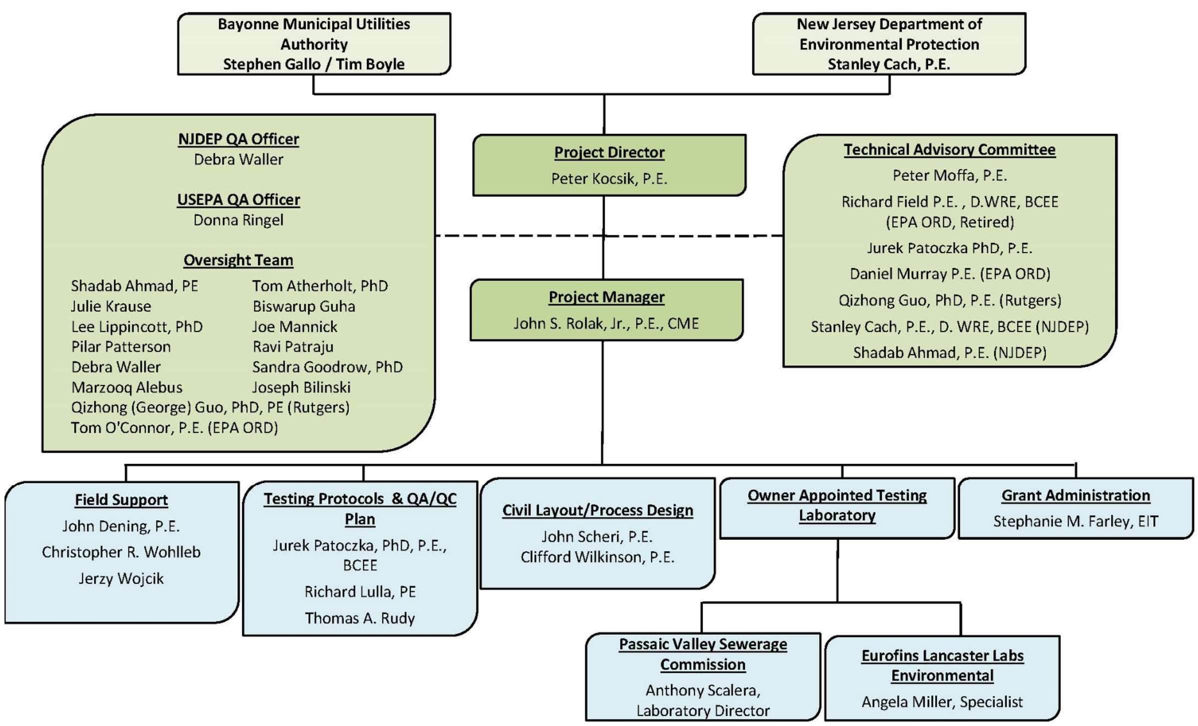
THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 3 PROJECT TEAM

3.1 Overview

The project was undertaken jointly by the BMUA, with grants from the NJDEP, and the USEPA. The project formed Technical Advisory Committee (TAC) to review and comment on the setup of the wet weather project including, but not limited to, review and recommendations on the technologies to be included, overall conceptual setup of the wet weather demonstration project, flow and sample collection frequency and locations, analytical parameters of interest, and data analysis and extrapolation. In addition, a Regulatory Oversight Team was established to review and comment on the general approach to the project, and more specifically on the QAPP for the wet weather demonstration project. The use of these two committees is intended to ensure adequate peer review and input into the design of the wet weather demonstration project by individuals with sound scientific and regulatory credentials to enhance the overall integrity and acceptance of the final project report when it is completed. The BMUA, with agreement from NJDEP and USEPA retained Mott MacDonald, Inc. as the Project Manager to develop, coordinate, and conduct this wet weather demonstration project and to report the data for general use within the industry. See Figure 3.1 for project organization chart.

Figure 3.1 Demonstration Project Organization Chart



The effort required sample collection and analysis for fecal coliform, Enterococcus, and E. Coli on both the influent and the effluent from each disinfection process. These pathogen bacteria indicator samples have only an eight hour holding time from the time of collection to when they are processed and incubated by the laboratory. Upon learning of this pilot program, the PVSC offered to provide and pay sampling and lab personnel that were interested in volunteering to pick up or to process analytical samples collected during rain events. PVSC's Water Pollution Control Facility (WPCF) is in Newark, on the other side of Newark Bay from Bayonne, and less than 30 minutes away from the Oak Street PS. PVSC's assistance was critical to the success of the project since they were willing to provide personnel any time of the day or week if their employees had no conflicts with the schedule. PVSC also conducted the analytical work for all total suspended solids (TSS) and volatile suspended solids (VSS) samples collected. Their association with the program eliminated the difficulties in finding a commercial lab that would be available during non-working hours and is greatly appreciated by the project team. In a similar matter Suez, formerly United Water Bayonne and the operator of the Oak Street PS provided an individual during each event to open the facility and to assist with pump operations. The active involvement of both organizations was invaluable to the successful completion of the project and is greatly appreciated.

SECTION 4 UNIT SELECTION PROCESS

The initial task in the project was to select the wet weather treatment and disinfection technologies to be evaluated under this project. Accordingly, the BMUA advertised for solicitation of qualification submittals for a demonstration project of wet weather treatment and disinfection to be conducted at the Oak Street (PS) (Figure 4.1)

Figure 4.1 Aerial Photograph of Site (from Google Earth)

The BMUA received qualification packages from eight manufacturers, which were subsequently evaluated by the TAC, which included wet weather experts from the NJDEP, USEPA, Rutgers University, and private companies. The primary evaluation criteria for the units were: suitability for remote satellite facilities, documented performance, ease of operation, maintenance requirements, footprint or hydraulic loading rate, and cost. Qualification packages were provided to each member together with an evaluation matrix and a request for comments. The results of individual comments and the average score for each technology was then utilized to develop the following recommendations, which were subsequently approved by the BMUA.

For the most part, the equipment provided by the manufacturers were existing trailer mounted or otherwise pilot units constructed for demonstration projects, and thus each unit had been sized and constructed independent of this project. The demonstration project was set up to test each of these units under varying flow conditions within the design parameters established by the manufacturer of each unit. The TAC members assisted in the analysis and extrapolation of data and the findings of the project, to clearly outline the sizing limitations for each unit based upon the equipment provided. It is thus anticipated that some technologies under this project may require additional testing to validate their performance under flows beyond those presently being evaluated.

The Demonstration Project included the testing of the following six pilot treatment units:

1. Terre Kleen, Terre Hill, PA

The Terre Kleen unit (Figure 4.2 and 4.3) has performed well in stormwater applications, and since stormwater pollutants are a major component of CSO it has potential to perform well in CSO applications. The Terre Kleen unit utilizes a different solids-liquid separation mechanism, plate settling as opposed to a vortex and there were concerns expressed by members of the TAC about clogging of the plates from solids found in CSOs. It was ultimately determined that a comparison of the different mechanisms could be beneficial. A concern raised by one member of the TAC was that the size of the Terre Kleen, TK-09 unit as proposed has a NJDEP certified capacity of 2.29cfs (1,000 gpm), which is much higher than most of the other units being piloted. At 1,000 gpm the unit has a HLR of approximately 25,300 gpd/sq. ft. (Information on maximum flow rates and hydraulic loading rate {i.e., gpd/sq. ft., or gpm/sq. ft.} for all equipment is provided in Table 9.1). Since removal rates vary with flow, data at lower flows, i.e., 100-250 gpm may not be extractable to higher flows. The plan as developed, anticipated testing of this unit at flows of up to 1,250 gpm, but ultimately flow restriction limited its testing to approximately half of that value.

Figure 4.2 Terre Kleen TK-09 unit delivered to site

Figure 4.3 Terre Kleen TK-09 unit interior

2. Hydro International, Portland, ME

The Storm King® with Swirl Cleanse Mobile Pilot Unit (Figure 4.4), which utilizes swirl technology has a long and proven history treating CSOs and was strongly recommended by the reviewers. The manufacturer reported maximum flow capacity for the existing pilot unit was 900 gpm (HLR of 45,800 gpd/sq. ft.). Prior to the final sampling event utilizing the Storm King® (Event 8) perforated screen (Figure 4.5) was replaced with a wedge wire screen (Figure 4.6) as discussed in the descriptions of the individual sampling events.

Figure 4.4 Storm King® unit delivered to site

Figure 4.5 Storm King® Perforated Screen

Figure 4.6 Storm King® Wedge Wire Screen

3. Westech - WWETCO, Salt Lake City, UT

The FlexFilter™ (Figure 4.7) was included in the study, and tested using the effluent of the vortex and plate separators as influent to the unit to determine if there were any advantages of operating in series with other units. The removal rates that the FlexFilter™ provided the best opportunity for the subsequent ultraviolet (UV) disinfection to be effective. The peak CSO flow for the unit being tested was reportedly 180 gpm (HLR –31,600 gpd/sq. ft.), however the influent pump provided only had a peak capacity of 150gpm (HLR – 26,300 gpd/sq. ft.) and thus limited the flow that could be tested through the unit.

Figure 4.7 Westech WWETCO FlexFilter unit delivered to site

4. Trojan Low Pressure UV, London, Ontario

The Trojan, UV3000Plus™ unit (Figure 4.8), which uses low pressure UV lamps, was included in the pilot. Trojan products have a proven record with CSO and are well known in the industry. The unit provided had a peak flow rate of 250 gpm.

Figure 4.8 Trojan UV3000 unit delivered to site

5. Aquionics, Erlanger, KY

The Aquionics, UV, 250+W unit (Figure 4.9), which uses medium pressure UV lamps will add an important additional disinfection technology to the study. The pilot unit had a capacity of 250 gpm which allowed it to fit well with the other study units

Figure 4.9 Aquionics UV 250+W Unit used in project

6. PeraGreen, Manchester, MO

The PeraGreen, INJEXX™ unit (Figure 4.10) was evaluated under this study. The PeraGreen INJEXX unit uses Peracetic acid (PAA) and was the only chemical disinfection evaluated. The PeraGreen INJEXX™ unit was selected to allow a comparison of its performance to UV disinfection. In addition, it provided an opportunity to evaluate its performance on flows with and without TSS removal. The INJEXX unit as proposed by the manufacture was to be able to accommodate flows of up to 125gpm. The performance criterion for PeraGreen had been established for a contact time as low as 5 minutes, but the TAC wanted to test a much lower contact time. As discussed later, the unit was modified by the manufacturer to reduce the contact time.

Figure 4.10 PeraGreen INJEXX™ system delivered to site

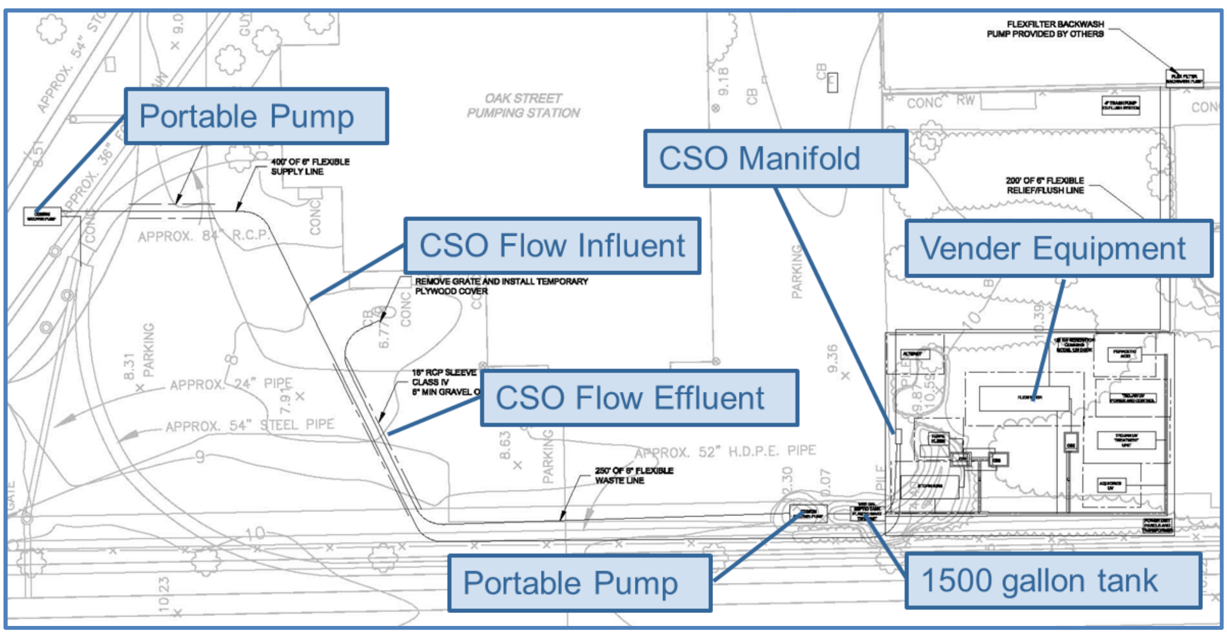
THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 5 PILOT PLANT LAYOUT AND OPERATIONS

5.1 General Description

As noted above, the units used in the study had widely varying design flows. In addition, the expectation was that varying trains of treatment were desired to provide factual data on the impact of solids removal on the various methods of disinfection. Accordingly, the pilot plant layout had to be flexible in piping configurations, but also needed to be able to achieve different flow rates at each unit. There is a diversion chamber in the front of the Oak Street Pumping Station PS. During dry weather, all flow is directed to the dry weather wet well, where flow is pumped to PVSC for treatment. Since this a combined sewer system, wet weather flows exceeding the pumping capacity to PVSC are directed by the diversion chamber to the CSO wet well where flows are lifted and directed to Outfall 001/005, which is tributary to Upper New York Harbor. Both sides of the PS have provisions for the removal of grit and/or screenings. Accordingly, to obtain wet weather flows that are representative of actual CSO outfalls, the influent flows to the wet weather demonstration project were obtained by setting up a portable suction lift pump and drawing CSO flows from the diversion chamber and upstream of the grit and screening units located in the pumping station. The NJDEP would not allow any discharges from the pilot to be discharge to the receiving waters. Accordingly, all flows passing through the wet weather demonstration project were redirected (pumped) back to the dry weather side of the PS.

Figure 5.1 Overall Pilot Layout



The general layout of the pilot facility is illustrated above in Figure 5.1. The influent to the pilot units was obtained by pumping wastewater flows from the diversion chamber of the PS to a CSO Manifold that could direct flows to the vendor equipment. It is estimated that the portable suction lift pump (influent pump) delivered approximately 1,000gpm to the wet weather facilities. The 8-in. flexible influent hose from this pump entered a pipe manifold to distribute flow to the various treatment units. Sampling ports, meters, and valves were hard piped, but connections between individual vender units was accommodated by use of quick couplings and 4 or 6 in. flexible hose to allow flexibility with the units to be tested at any one time. Wastewater flows to each vender unit was controlled by means of full port pinch valves. Excess flow not needed by individual units was redirected by a series of valves, pipes, and overflow weirs to a 1,500-gallon septic tank where flow was pumped back to the wet weather side of the PS by the portable suction lift effluent pump (effluent pump). Both the portable influent and effluent pumps were diesel powered.

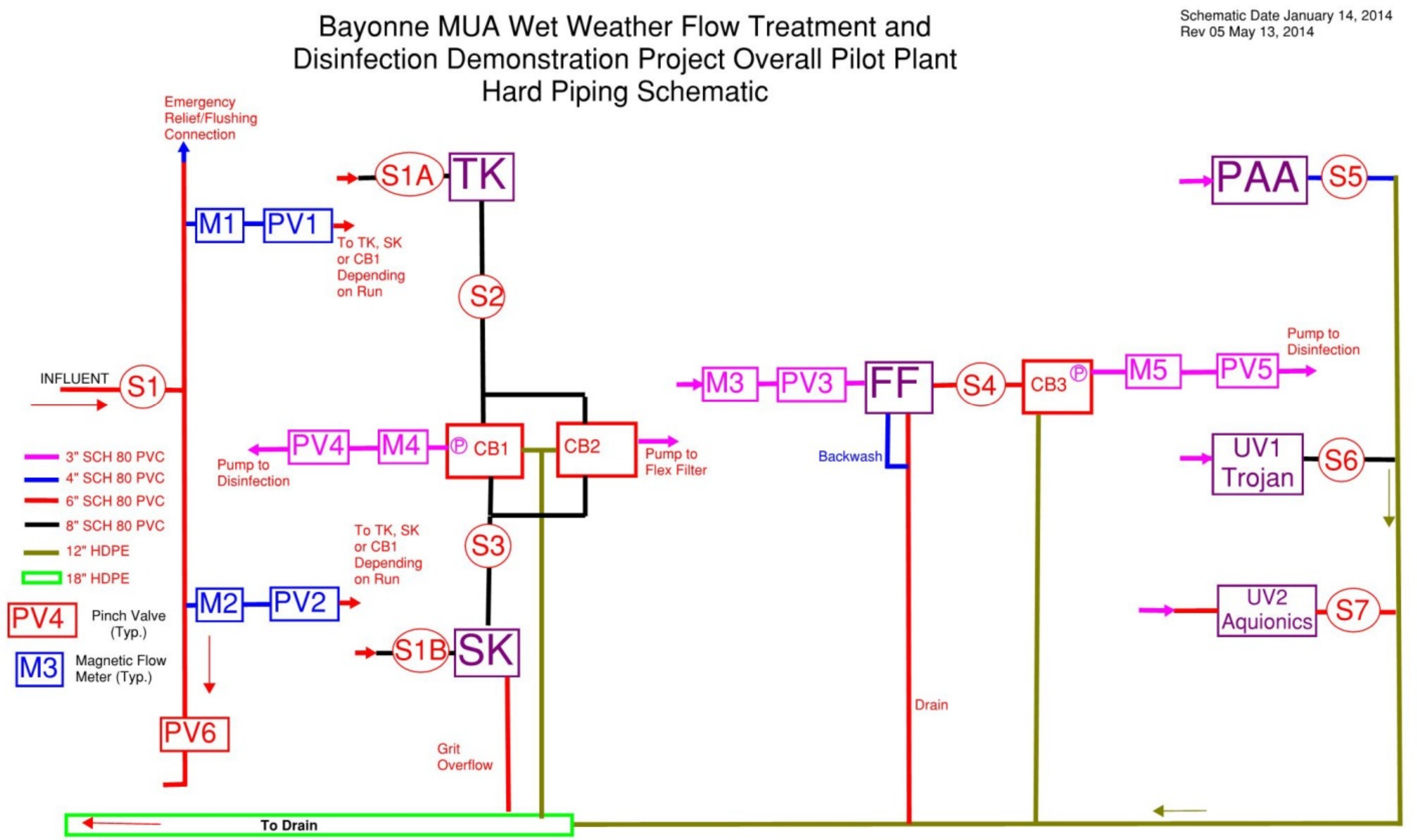
To address the flow variation between the wastewater delivered to the manifold and that going to the pilot units, the manifold included a waste pipe that directed flow to the same 1,500-gallon septic tank, as noted above. Pinch valves (PV) were installed ahead of all pilot units to control flow, while magnetic flow meters and flow recorders (M) were installed ahead of each unit to measure and document influent flows to the unit. Flows were initially set and valve positions were modified to maintain constant flow during the event. Influences such as wet well flow height and partial plugging of the pinch valves did result in some variation during each sampling event that could not be compensated for by modifying the valve settings. To offset elevation changes and headloss within the system between units, the transfer of flow from one unit to the other was accomplished using pinch valves and pumps (P), while excess flow from one unit to the next and at the end of each treatment train was handled by gravity flow to the same 1,500-gallon septic tank as previously referenced

The following is a description of the setup that was used for the wet weather testing facilities. The six (6) pilot units as noted above included the: 1) Terre Kleen (TK); 2) Storm King (SK); 3) FlexFilter (FF); 4) Peracetic Acid (PAA); 5) Trojan Low Pressure UV (UV1); and 6) Aquionics medium pressure UV (UV2).

The 1,500-gallon septic tank provided less than a minute of response time should there be a full or partial failure of the diesel effluent pump that transports flow back to the pumping station. An emergency bypass pipe was constructed between the influent header assembly and the former Sewage Treatment Plant sludge holding tanks to allow quick redirection of influent flow to the existing tanks if needed. An Emergency SOP had been developed that would allow diversion of influent flow by opening one valve and closing three valves to redirect all flow to the existing tanks in the event initiated effluent pump failure, however the system was not needed. In a like manner the bypass was also setup with an additional (third) portable pump that was used to pump groundwater from the abandoned sludge tankage through the pilot units after each sampling episode to flush out the wastewater and to prevent odor issues.

A schematic of the hard piping including meters (M), sampling ports (S), valves (V), and catch basin diversions (CB) is provided in in Figure 5.2. Additional sampling ports were incorporated into the design to provide flexibility in case difficulties are experienced during the initial wet weather event. While it was anticipated that sampling point S1 would be used to gage influent water quality there was some concern that the head available at this point may make sampling more difficult.

Figure 5.2 Pilot Plant Hard Piping Schematic



Accordingly, Sampling Ports S1A and S1B were added as possible alternate sampling locations if needed. (These sampling ports were later used as explained in Section 6). The breakdown of the various treatment train scenarios is provided in Table 5.1.

Table 5.1 Demonstration Project Treatment Scenarios

	Treatment Train	**Treatment Process**
Storm #1	**Train-1:**	Influent →Terre Kleen →Flex Filter →Trojan UV →Discharge
	Train-2:	Influent →Storm King →Aquionics UV →Discharge
Storm #2	**Train-1:**	**Storm Event**
	Train-2:	Influent →Terre Kleen → Trojan UV →Discharge
Storm #3	**Train-1:**	Influent →Terre Kleen →Flex Filter →PAA Disinfect →Discharge
	Train-2:	Influent →Storm King → Trojan UV →Discharge
Storm #4	**Train-1:**	Influent → Flex Filter →PAA Disinfect →Discharge
	Train-2:	Influent →Terre Kleen → Aquionics UV →Discharge
Storm #5	**Train-1:**	Influent → Flex Filter → Aquionics UV →Discharge
	Train-2:	Influent →Storm King → Trojan UV →Discharge
Storm #6	**Train-1:**	Influent → Flex Filter → Trojan UV →Discharge
	Train-2:	Influent →Terre Kleen → PAA Disinfect →Discharge
Storm #7	**Train-1:**	Influent →Terre Kleen → Flex Filter → Aquionics UV →Discharge
	Train-2:	Influent →Storm King → PAA Disinfect →Discharge
Storm #8	**Train-1:**	Influent →Storm King → Flex Filter →Trojan UV →Discharge
	Train-2:	Influent →Terre Kleen → PAA Disinfect →Discharge
Storm #9	**Train-1:**	Influent →Storm King →Flex Filter → PAA Disinfect →Discharge
	Train-2:	Influent →Terre Kleen → Aquionics UV →Discharge

The pilot was located on property that was normally active with vehicle traffic during normal business hours, and the above ground piping and hosing presented obstacles that could be easily become a tripping hazard. Temporary site lighting and snow fencing were used in conjunction with pipe ramps to improve overall safety, while two storage sheds were added to provide protection from the weather to speed processing of samples and field measurements. The complete pilot plant is shown in Figure 5.3.

Figure 5.3 Completed pilot plant

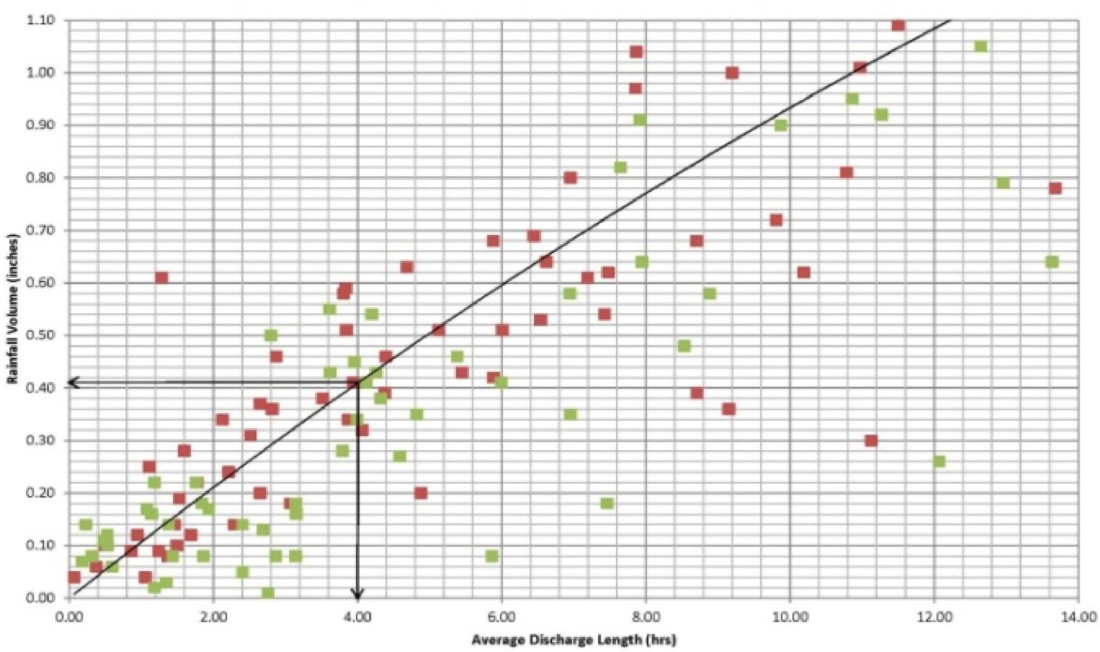
5.2 Outline of Procedures

The following outlines the procedures that were used prior to and during the wet weather event:

(1) Since there was a limit on the number of units that could be tested for each event, a preliminary list of possible testing scenarios was established at the start of the program. While efforts were made to keep to the list, modifications were made if testing could not be completed for mechanical and/or technical reasons. A decision on which individual units were to be tested at the next event was established several days prior to the event to allow adequate time to modify system piping as needed to integrate the treatment and/or disinfection trains to be evaluated.

(2) A rainfall analysis was conducted during the planning phase to determine the volume of rainfall required to provide a minimum of four hours of overflow at the Oak Street PS. Data points associated with known snow events were not used even if an overflow was recorded. Nevertheless, some of the overflow data could be skewed by snow melt that occurred during subsequent rainfall events. The analysis, as illustrated in Figure 5.4 indicated that a rainfall volume of 0.40 in. typically produced a four-hour overflow. This is consistent with previous wet weather monitoring efforts, which indicate that overflow events typically occur with rainfall volumes of around 0.5 in. Accordingly, weather predictions were monitored during the project through various websites to identify rainfall events that would produce at least 0.4 – 0.5 in. of rainfall volume within a period of 5 to 10 hours.

Figure 5.4 Oak Street Pumping Station Average Discharge Duration (hrs) vs. Rainfall Volume (2009 &11)



(3) Prior to any sampling, a training event was conducted for all personnel (MM, PVSC, and Suez) associated with the project to provide details on the project, the equipment, sampling methods and locations, instrumentation use and calibration, logging of data, and other proper QA/QC measures implemented to assure good quality data.

(4) Suez personnel monitored the station to assist Mott MacDonald with determining when an actual CSO event was occurring. Wet weather sampling was undertaken in accordance with the QAPP once an overflow was detected.

(5) Sample bottles were pre-labeled; each set of samples at each sample location was placed in a bag so that the samples could be taken efficiently. The bottles were stored at the project site and were ready to use on short notice.

(6) Mott MacDonald monitored rainfall prediction from three websites: AccuWeather, NOAA and Intellicast. When there were consistent predictions of greater than 0.5 in. of rain in a four hour period the project team was notified. The goal was to notify the team two days in advance, but due to changing weather forecasts the notification was often much shorter. It should be noted that a sampling event required direct involvement (deploying to the site or the lab) of approximately 15 people and indirect involvement from many others. The team deployed regardless of the day or time and required a great deal of flexibility and adaptability. Once the notification went out the following occurred:
   a. The private lab confirmed they were prepared to accept samples, if necessary the primary private lab's capacity was supplemented with additional labs.
   b. PVSC confirmed their lab was prepared to accept samples with a typical staff of six.
   c. PVSC confirmed a driver was available to transport samples to the PVSC lab.
   d. The sampling team confirmed their availability and the necessary tasks were assigned.
   e. BMUA confirmed the pumps were fueled and that staff was available to operate them.
   f. Twelve hours before the potential sampling event confirmation was sent to the team. Text updates were used to keep the team apprised of any last-minute changes in the forecast.
   g. The field team met at the site prior to the intensification of the rain and set up the field sampling equipment and necessary paper work prior to the overflow beginning.

(7) The wet weather sampling continued for a period of approximately four hours or until the CSO event at the PS ended, if sooner.

The performance of the various treatment units was determined using samples obtained on the influent and effluent from each of the treatment units to determine treatment efficiencies. Since treatment units in series were often used, the effluent from one unit could become the influent for the subsequent unit as illustrated in Figure 5.2. In general, samples were obtained every 20 minutes for a maximum of four hours. All samples were tested by certified laboratories. Field tests for temperature, pH, dissolved oxygen (DO), turbidity, and UV Transmittance (UVT) on the effluent of UV units was conducted by MM; pathogen indicator and TSS analyses were conducted by PVSC; and all other wet chemistry analytical work was performed by Eurofins – Lancaster Laboratories ("Lancaster Labs"). In certain circumstances, NJDEP approved the use of additional labs when insufficient lab capacity was available. All sample collection was completed in accordance with the NJDEP's Field Sampling Procedure Manual (2005) including, but not limited to; Chapter 2: Quality Assurance; Chapter 5: Sampling Equipment; Chapter 6: Sample Collection; and Chapter 10: Documentation and the Quality Assurance Project Plan as submitted and approved in the QAPP by NJDEP and USEPA.

The type (plastic, glass, clear or colored) and size of sample bottles used are a function of the sample analysis being conducted (Reference Table 6.1). Sample bottles are prepared prior to initiating sampling at each site. All sample bottles were marked with the sample parameter and preservative if any, Site Number, date of collection, and time of collection. Date and time of collection were entered during sample collection and were listed on the chain of custody (CoC). Pre-sterilized disposable bottles were purchased for pathogen indicator bacterial analyses and HDPE (High Density Polyethylene) bottles were purchased for TSS/VSS analysis. Bottles for chemical parameters were obtained and prepared by the lab.

All sampling and analysis procedures were consistent with published USEPA and NJDEP sampling and analysis procedures (40 CFR Parts 136, 260, 423, 430, and 435 "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Analysis and Sampling Procedures; Final Rule" May 18, 2012 and NJDEP "Field Sampling Procedures Manual", August 2005). Samples for field analysis were collected in plastic beakers directly from the sampling port. A separate beaker was used at each sampling location and each beaker was rinsed with wastewater from the site to prevent cross contamination of samples. Bacterial samples were collected directly into the sterile containers. Wet chemistry samples were collected directly into sample bottles. All samples were stored in wet ice at 4°C until delivered to the respective laboratory.

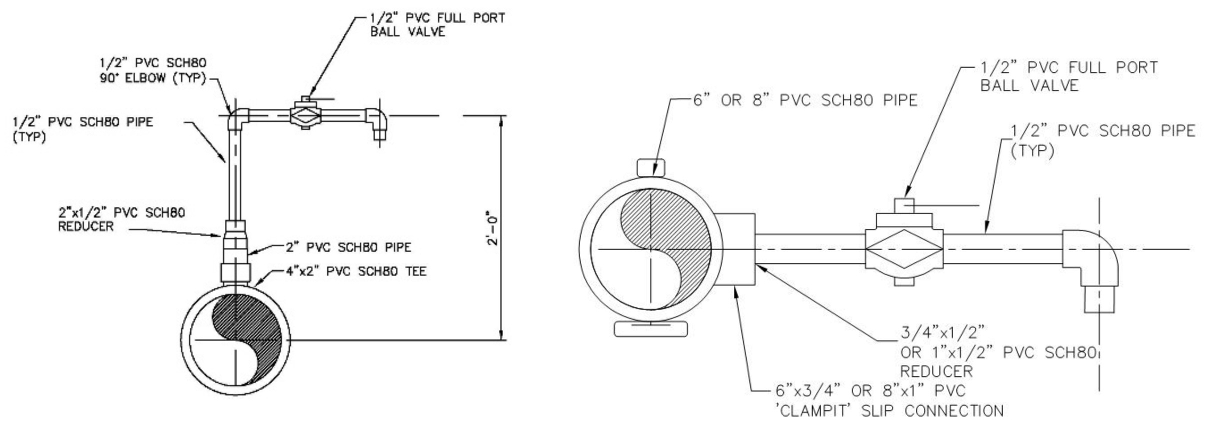
THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 6 SAMPLING AND ANALYTICAL PROGRAM

6.1 General Discussion

The location and number of samples collected were somewhat variable depending on the treatment/disinfection units in operation at the time and any operating issues associated with equipment. Sampling locations were illustrated in Section 5 (Figure 5.2). Initially the sampling ports were constructed at each station using transition piping connected at the top of the pipe; however, upon review of the initial data collected in 2014 there was a concern that TSS data may have been impacted by the inability of the sampling port to collect heavier materials that are typically located in the bottom of the pipe. Prior to the recommencing of the program in 2015, the ports used for collecting TSS samples were modified by making a direct 0.5 in. pipe connection at the side of the pipe, see Figure 6.1. Additional information on any impacts to this change is covered in Section 9.

Figure 6.1 Typical Sampling Ports Original (Left) and Revised (Right)



Bacteria sampling was conducted only before and after UV or chemical disinfection. Two disinfection units were operated during each storm and influent and effluent bacteria samples were collected to the extent possible every twenty minutes for each bacterial sample at each unit for a maximum of three hours. A maximum of eighteen individual bacteria samples were collected at each unit (9 upstream and 9 downstream) for each of the three pathogen indicator parameters of interest for a maximum total of thirty-six samples. The thirty-six samples for each pathogen indicator (108 samples total) represent the maximum number of samples that could be accommodated by PVSC during any one wet weather event.

In addition to the above, Temperature, pH, Turbidity, UVT, and DO were monitored on the influent using a grab sample and instrumentation. These parameters were in general also monitored on a twenty-minute interval basis at either: S1, S1A, or S1B for a maximum of four hours. The first sample was taken twenty minutes after the start of the overflow. Accordingly, a maximum of twelve individual samples were collected, and field measurements conducted, at each station during any one event. In addition, for one event DO measurements were monitored at S5 (PeraGreen) on a twenty-minute basis for a maximum of 3 hours to assess any impact of the PAA on the DO in the receiving waters. The results of this monitoring noted that, if anything, the PAA increased the level of DO in the effluent and thus additional monitoring of DO was deemed not necessary by the TAC and Regulatory Oversight Team

Other parameters of interest in the study include TSS, VSS, chemical oxygen demand (COD), five-day carbonaceous biochemical oxygen demand ($CBOD_5$) – Total and Soluble, and total organic carbon (TOC) as detailed in Table 6.1. Grab samples for these parameters were collected at the sampling ports located at the header assembly and the effluent to each treatment unit every twenty minutes for a maximum of four hours. The number of sampling locations for each event varied between 3 and 4 per storm. Accordingly, a total of thirty-six to forty-eight groups of samples were collected and analyzed for each storm provided that there were no operating difficulties experienced with the units. In general, the total estimated number of samples collected from each event varied due to equipment operational problems during most storms. Table 6.1 outlines the analytical data collection as originally established. Additionally, settleable TSS and VSS were measured in raw wastewater at 60 minute intervals using SM-2540F (TSS and VSS measured after a 60-minute quiescent settling).

CSO characteristics are typically highly variable during any storm and the CSO quality typical varies from one event to another depending on the rain intensity/duration, intervening dry period and other factors. Consequently, it was anticipated that the performance of each treatment process would vary during each storm event and between the different storm events. Such transient performance is not amenable to a rigorous statistical evaluation, such as could be done if the samples collected represent a subset of a normally distributed population (when the minimum number of samples could be calculated based on the desired confidence interval into the calculated mean at a prescribed confidence level). Nevertheless, while there was an attempt to minimize the number of variables within events the results obtained were highly variable.

Upon completion of the sampling for each event, Data Completeness was evaluated based on the number of samples prescribed in the sampling plan and the actual number of samples taken. Nevertheless, each sample set (influent and effluent) are independent measurements and are therefore considered valid independent of the total number of samples collected at each point.

Originally it was requested by the NJDEP that a collimated beam test be included within the project to evaluate the effectiveness of the low and medium pressure UV units. Upon additional investigations and discussions with Aquionics it was determined that the collimated beam test would not be conducted as part of this study for the following reasons:

1. The analysis is typically completed by the UV vendor. Accordingly, the holding time for bacterial samples could not be met due to the time needed to collect, deliver the sample to the vender, have them complete the necessary testing, and then send the samples out for bacterial analysis.
2. The total cost for completing one test is very high.
3. The test is site specific. It is used in the final design of the unit for a particular application.
4. The test is not applicable to any other site or location. The purpose of the study is to develop data that would be applicable to other locations.

Thus, it was determined that the collimated beam would not be a meaningful test for the wet weather demonstration project and accordingly was not conducted.

Table 6.1 Analytical Data Collection Summary

	Type of Sample / Parameter	Sampling Station	Number of Samples	Sample Container	Sampling Frequency	Sampling Period
Bacterial	E-Coli	Disinfection two Units influent two of (S1+ or S2 or S3 or S4) and effluent two of (S5 or S6 or S7)	18 18	Plastic 120ml	20 minutes	3 hours
Bacterial	Fecal Coliform		18 18	Plastic 120ml	20 minutes	3 hours
Bacterial	Enterococci		18 18	Plastic 120ml	20 minutes	3 hours
Physical	Temperature	S1, S1A or S1B	12	Plastic 250ml Beaker	20 minutes	4 hours
Physical	pH	S1, S1A or S1B	12	Plastic 250ml Beaker	20 minutes	4 hours
Physical	Turbidity	S1, S1A or S1B S2, S3, & S4	12 9 - 18	Plastic 250ml Beaker	20 minutes	4 hours 3 hours
Physical	Dissolved Oxygen (1 event)	S4 & S5	18	Plastic 250ml Beaker	20 minutes	3 hours
Physical	Collimated Beam		Eliminated as noted previously			
Physical	UVT	S1, S1A or S1B S6 and/or S7	12 9 - 18	Plastic 250ml Beaker	20 minutes	4 hours 3 hours
Physical	TSS	S1, S1A or S1B S2, S3, or S4	12 36 - 48	HDPE 500ml	20 minutes	4 hours
Physical	VSS	S1, S1A or S1B S2, S3, or S4	12 36 - 48	HDPE 500ml	20 minutes	4 hours
Physical	Settleable Solids	S1, S1A or S1B	5	HDPE 500ml	@0, 20min 1,2,4 hr.	4 hours
Chemical	COD	S1, S1A or S1B S2, S3, or S4	12 36 - 48	HDPE 250ml	20 minutes	4 hours
Chemical	$CBOD_5$ - Total	S1, S1A or S1B S2, S3, or S4	12 36 - 48	HDPE 500ml	20 minutes	4 hours
Chemical	$CBOD_5$ - Soluble	S1, S1A or S1B S2, S3, or S4	12 36 - 48	HDPE 500ml	20 minutes	4 hours
Chemical	TOC	S1, S1A or S1B S2, S3, or S4	12 36 - 48	Glass 120ml	20 minutes	4 hours

6.2 Quality Assurance Project Plan Discussion

As previously noted a QAPP was submitted and approved by the NJDEP and USEPA Region 2 prior to the start of any operations. The following outlines data collection requirements and segments of the QAPP.

6.2.1 Data Precision, Accuracy, Measurement Range

The QAPP provided specifics on the matrix, parameters, measurement range and detection levels and details on the accuracy and precision anticipated in the project. To the extent possible the program met these requirements unless otherwise noted in the results.

6.2.2 Data Representativeness

The intent of this project was that the data collected would be representative of a discharge from a CSO and thus allow the representative performance of the individual treatment/disinfection units to be evaluated; these were met to the extent possible in that the first seven storms. In an effort to maintain the representativeness of the data, collection of samples was lagged to the extent possible through the respective treatment units so that influent and effluent tested will be derived from the same general flow segment. All samples collected were grab samples and were collected directly into the sample bottle whenever possible.

6.2.3 Data Comparability

Comparability is an expression of how well one data set compares to another. Variability in data is reduced by consistency in the sampling and analytical methods being used as well as consistency in the certified lab to conduct the analysis. Analytical parameters had been separated by certified lab as follows: Mott MacDonald conducted all field collected data, i.e., pH, temperature, DO, UVT, and Turbidity; PVSC conducted all pathogen bacterial indicator analyses in addition to TSS and VSS; and for the most part Lancaster Labs conducted all remaining analyses except when the number of samples exceeded the lab capacity required the use of additional labs, which was done with NJDEP approval. The results obtained from the analysis performed in the lab was compared to the expected concentration for each sample based on other sample data collected as part of the study. Success employing the methods was assessed through QA review by the Project QA Officer, see Figure 3.1.

6.2.4 Description of Training

Prior to the start of wet weather monitoring undertaken under the program, training was conducted for all personnel associated with field sample collection and in-field testing for pollutant parameters. The training consisted of:

(1) Use and preparation of sample equipment and sample containers/bottles;
(2) Personal Protection Equipment requirements and compliance;
(3) In-field sample collection procedures and equipment;
(4) Collection of samples for pollutant parameters to be analyzed in the field;
(5) Collection of samples for pollutant parameters to be transported to a certified lab for analysis, including sample preservation and transportation requirements;
(6) In-field analysis for “Analyze-Immediately” pollutant parameters (to be analyzed within 15 minutes of sample collection);

(7) Training with instruments used for analysis of in-field pollutant parameters;

The training for infield test parameters covered analysis for: pH, temperature, UVT, DO, and turbidity. Mott MacDonald has a lab certification from the State of New Jersey for these analyzed immediate (infield) pollutant parameters, including approval of Standard Operating Procedures (SOPs) for these tests. Only individuals who attended the training could take and record field data for the project.

The bacterial pollutant parameters, TSS and VSS were analyzed in the PVSC laboratory. The remaining conventional pollutant parameters ($CBOD_5$, $CBOD_5$ soluble, COD, and TOC) were analyzed by Lancaster Labs. Both these laboratories have certification from the State of New Jersey for each test parameter. In addition, PVSC employees took part in the training program to get a better understanding of the project and to obtain additional training to the extent required by their role in the program.

In addition to training, a dry run was conducted at the site to familiarize individuals with the setup and to review and verify the procedures and schedule as previously established. Staff meetings with field personnel were conducted following the dry test run and the initial wet weather event to discuss operational and/or timing issues that occurred during the event. Steps were then undertaken as needed to alleviate problems and to improve ability to obtain reliable monitoring data for all future events. Operational problems occurred on most events and are detailed in other sections of this report.

6.2.5 Documentation and Records

Each member of the project management and sampling team was given a binder containing a copy of the QAPP and all addendums for use during the project. A unique, but consistent sampling numbering sequence was also established for each sample based on the site location, and the date and time of sample collection. Signage was also added at each sampling location noting the sampling site designation for that location (S-1 through S-7) to avoid confusion. Sampling site numbers were kept consistent throughout the study even if one or more sampling sites were not used for a particular wet weather event.

Field data sheets were generated for all field-tested parameters. The field sheets identify the sample, test methodology and any modifications or excursions from the prescribed methodology and the cause. All sample bottles were labeled with permanent marker or waterproof pen. CoC forms were used and executed by each responsible party as samples were passed onto laboratory facilities.

All information specific to this study was collected and organized in a study binder. This study binder included items such as field data sheets, records of field instrumentation calibrations, CoC forms, raw data sheets, laboratory request sheets, results of chemical analysis, and all data analysis and calculations.

The analytical report prepared by contract laboratories complied with the analytical method approved by the NJDEP, National Environmental Laboratory Accreditation Conference (NELAC) and/or USEPA, and all laboratory certification requirements. The laboratory reports included information on the sample number (station number, date, time), analysis results and date and time completed, sample analytical method, method criteria, quality control data, lab analytical chronicle and sample CoC form. In addition, any variation or exception to the sample collection procedure and sample analysis was documented in the field book or lab report. All variations and exceptions are noted in this report.

All analytical data generated was subsequently entered into Excel spreadsheets and summarized electronically. All data entries were proofed a minimum of two times to assure the accuracy of the data transfer from hard copy to electronic data. Any issues with data were properly noted in all electronic data files. Data for each event has been reviewed by the QA Officer identified in the QAPP. Summary data for all events are included as an appendix to the project report.

6.2.6 Analytical Data and Methods

The in-field tests and lab analytical tests were performed by analytical laboratories which are certified by the NJDEP for corresponding test parameters. As a part of lab certification, SOPs for tests were reviewed and approved by the NJDEP. All analytical testing followed the NJDEP, USEPA and NELAC approved analytical methods. Table 6.2 outlines the test methods used for analysis of collected samples, in addition to established analytical test holding time and the certified lab completing the analysis.

Each report provided by analytical laboratories was reviewed to assess compliance with the quality control and method criteria as approved in the USEPA/NJDEP approved method and/or the method SOP. The reports were reviewed to check information regarding proper sample transportation, CoC forms, sample lab chronicle, analytical holding time, compliance with the sample recovery and matrix, method detection level, and analytical data as outlined in the certified lab's SOP.

Table 6.2 - Test Methods Summary

	Parameter	Performed By	Test Hold Time	Test Method
Aqueous	E-Coli	PVSC Lab	8 hours	EPA Method 1603
Aqueous	Fecal Coliform	PVSC Lab	8 hours	EPA Method pg. 124 Membrane Filter
Aqueous	Enterococci	PVSC Lab	8 hours	EPA Method 1600
Aqueous	Temperature	MM Lab	15 minutes	SM-2550-B
Aqueous	pH	MM Lab	15 minutes	SM-4500-H^+ B
Aqueous	Turbidity	MM Lab	48 Hours	EPA 180.1
Aqueous	UVT	MM Lab	15 minutes	Spectrometric Test per UV Equipment Manufacturer Procedure
Aqueous	DO	MM Lab	15 minutes	SM-4500-O G
Aqueous	Collimated Beam	Eliminated		
Aqueous	TSS	PVSC Lab	7 Days	SM-2540D
Aqueous	VSS	PVSC Lab	7 Days	SM-2540E
Aqueous	Settleable Solids	PVSC Lab	7 Days	SM-2540F
Aqueous	COD	Lancaster Labs	28 Days	EPA 410.4
Aqueous	$CBOD_5$ Total	Lancaster Labs	48 Hours	SM-5210-B
Aqueous	$CBOD_5$ Soluble	Lancaster Labs	48 Hours	SM-5210-B
Aqueous	TOC	Lancaster Labs	28 Days	SM-5310-C

6.2.7 Data Review, Validation, and Verification

Throughout the process all data was reviewed for consistency. Any inconsistent data was verified to the extent possible through the analytical laboratory or from sampling personnel. Summary tables prepared for the final report were verified for accuracy internally as well as by the TAC. The following outlines the process as undertaken.

Data review is the in-house examination to ensure that the data had been recorded, transmitted, and processed correctly. Data review was performed internally by senior personnel on an on-going basis, as the operational, sampling and analytical data become available. The objective of the data review was to ascertain that operation of the treatment unit processes, unit testing procedures, and analytical sampling and testing procedures were carried out in accordance with the project plan SOPs and were properly documented. It includes confirmation and review of the following elements:

- confirmation that the designated treatment units were activated and operational or to document any issues or difficulties that occurred during the event including adequate documentation of the treatment units operating conditions;
- confirmation that analytical samples were collected and preserved properly;
- use of field QC samples and field blanks collected. The blanks were used to identify errors or contamination in sample collection and analyses and if required the laboratory was contacted to identify potential source of contamination;
- confirm that chain of custody was maintained during each event;
- note any deviations from QAPP/SOPs documented;
- review of the QA/QC information in the analytical laboratory reports for completeness, including:
  - any data entry and transcription errors,
  - proper sample storage and holding time limits,
  - QC samples analyzed,
  - deviations from QAPP/SOP documented,
  - any missing samples documented;
- verification of a correct entry of operational and analytical data into the summary tables; and
- a review of the internal consistency of the data.

Data verification is the process for evaluating the completeness, correctness, and conformance/compliance of the specific data against the method, procedural, or contractual requirements. A 100 percent verification of all data was conducted by senior staff. Data collected during the sampling events was evaluated for adherence to the SOP (for the tested treatment unit process operation) and to applicable method specification (for analytical methods). It included the following elements:

- verification that the applied hydraulic and pollutant loadings to the individual treatment units were within the ranges desired/planned for the particular tests;
- verification of the application of the correct disinfectant dose (for PAA) or light intensity (for UV disinfection);

- flow meter data are reliable based on validity of their calibration;
- field instruments, such as pH meters, thermometers, etc., were properly calibrated;
- verification of the acceptability of the field and laboratory blanks;
- checking use of, and accounting for, appropriate dilution and conversion factors; and
- verification of the use of appropriate reporting units in both analytical reports as well as in summary tables.

Verification of the data included laboratory or reviewer's qualifiers, as applicable. Any change to the result as originally reported by the laboratory has been noted in the summary tables. The verified data was accompanied by a narrative statement confirming compliance with the verification criteria and identifying any shortcomings of the data produced during the field or laboratory activities.

The primary objective of this project was to evaluate effectiveness of various high-rate solid separation technologies in treatment of CSO discharges and ability of UV and PAA disinfection technologies to inactivate pathogenic indicator organisms (enterococci and Coliform bacteria). Consequently, the objective of data reconciliation process was to:

- ascertain if the data and information collected during the individual sampling events could be used to assess performance of the individual treatment process or combination of processes in terms of removal of suspended solids, pathogen indicating bacteria and, in general, meeting the Water Quality objectives; and
- ascertain if the collected data are suitable to judge relative performance of unit processes (e.g., UV and PAA) either as tested side-by-side during the same CSO event or based on performance over a range of wet weather events.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 7 STORM-SPECIFIC TESTING PROGRAM INFORMATION

The results obtained under the pilot program must be considered relative to the individual storm event, which units were being tested, and operating or sampling difficulties that occurred during the event. Sampling was conducted at each unit at 20 minute intervals for a period of four hours unless otherwise noted. All unit manufacturers were notified for each event providing them with an opportunity to observe and correct issues, however manufacturer responses were limited in general to one or two storms. While the pilot team attempted to correct equipment, operational difficulties encountered during sampling, their primary responsibility was to collect samples and to maintain good records and thus equipment operating problems were not necessarily detected in a timely manner. The following outlines the individual events, rainfall distribution, and testing/sampling periods that occurred during this program. Equipment operating issues were reported to the manufacturers in an attempt to get issues resolved in a timely matter. A summary of the equipment setups and key issues is provided in Table 7.1 at the end of this section.

7.1 General

Safety of the sampling team was a foremost concern at the project site. Every sampling event was preceded with a safety talk noting the hazards of the site and of working with sewage. Safety took priority over sampling.

There were several items that impacted the operation of the pilot facilities on a continuing basis, these are summarized below and are not necessarily noted in every storm:

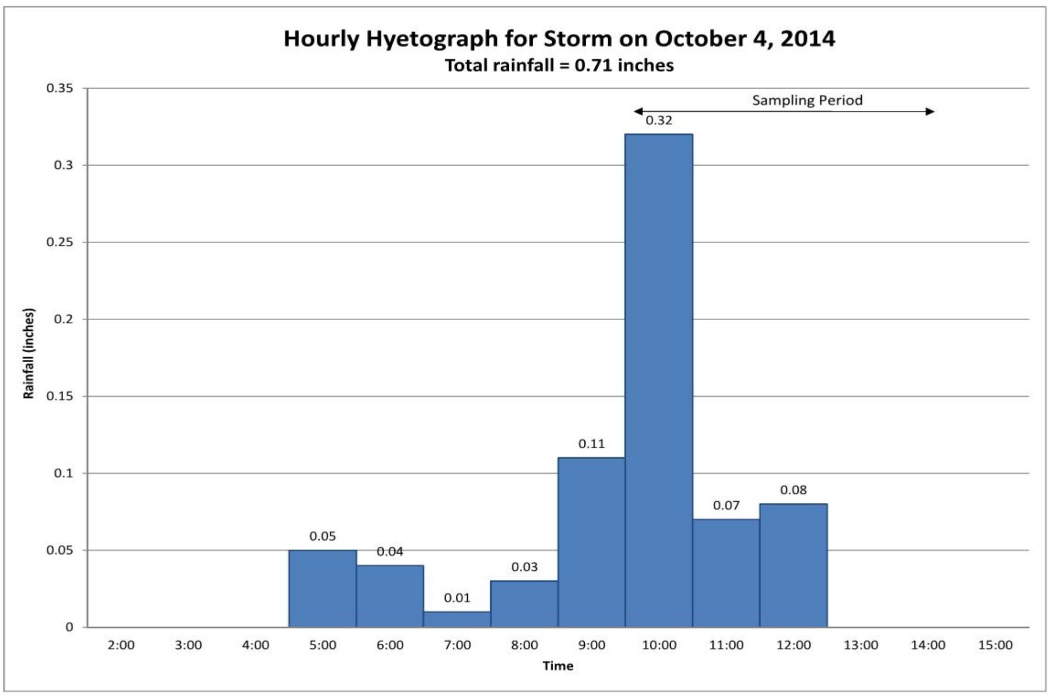
1. The influent pump screen would become progressively clogged decreasing the flow to the pilot plant.
2. At certain settings the pinch valves oscillated, to a degree that threatened the adjacent piping. When this occurred, the valve had to be adjusted reducing the degree of flow control.
3. The system's hydraulics was at times limited by kinks in hoses that could not be removed due to available space.
4. During the FlexFilter backwash, the downstream process, typically UV disinfection had to be halted as no flow was available. The FlexFilter backwash period was typically 35 minutes.
5. During the operation of the FlexFilter, Storm King and Terre Kleen, the sampling staff did not observe objectionable odors.
6. The operation of FlexFilter was automated, it switched to back-wash operation and at the completion of the backwash, the filtration operation recommenced without operator input.
7. The Storm King's Swirl Cleanse operation was occurring approximately every 25 seconds initiated by the system's incorporated hydraulic siphon actions.
8. The Terre Kleen unit was in continuous operation.

7.2 Test Run No. 1

Date of Test Run – October 4, 2014
Volume of Rainfall – 0.71 in. (Figure 7.1)
Time Rainfall Started – 05:16
The pilot equipment was started by 10:10 and the first sample was taken at 10:30

The treatment units were configured so that one flow train went from the Terre Kleen to the Aquionics, and the second train went from the Storm King to the FlexFilter to the PAA; the Trojan UV was not used. The following outlines the operating or equipment difficulties encountered during the event:

Figure 7.1 Hourly Hyetograph for Storm on October 4, 2014.



1. At some point during the sampling the screen on the Storm King floatables/solids removal screen plugged causing the majority of the flow to go down the screenings discharge. The remaining flow went over the bypass weir, the bypass flow was sufficient to supply flow to the FlexFilter, however the unit was not functioning as designed for some period during the event.

2. The Terre Kleen unit fine screen blinded very early due to sanitary sewage debris, which appeared to be primarily toilet paper and sanitary wipes. Initially the flow bypassed the fine screen, but went through the rest of the unit. Later, the water level in the upstream compartment rose above the internal weir and flow began partially bypassing the internal screen and settling plates as time progressed, the amount of flow bypassing the internal screen increased.

3. The FlexFilter alarmed when first turned on prior to sampling and would not operate. The manufacturer was contacted and after some discussion the open impeller influent pump was switched for another pump from the job box with a 0.25 in. aperture screen. Clogging of the pump screen caused the flow to the unit to drop from 150gpm to 50gpm during the course of sampling. The FlexFilter went through one backwash cycle during the sampling run.

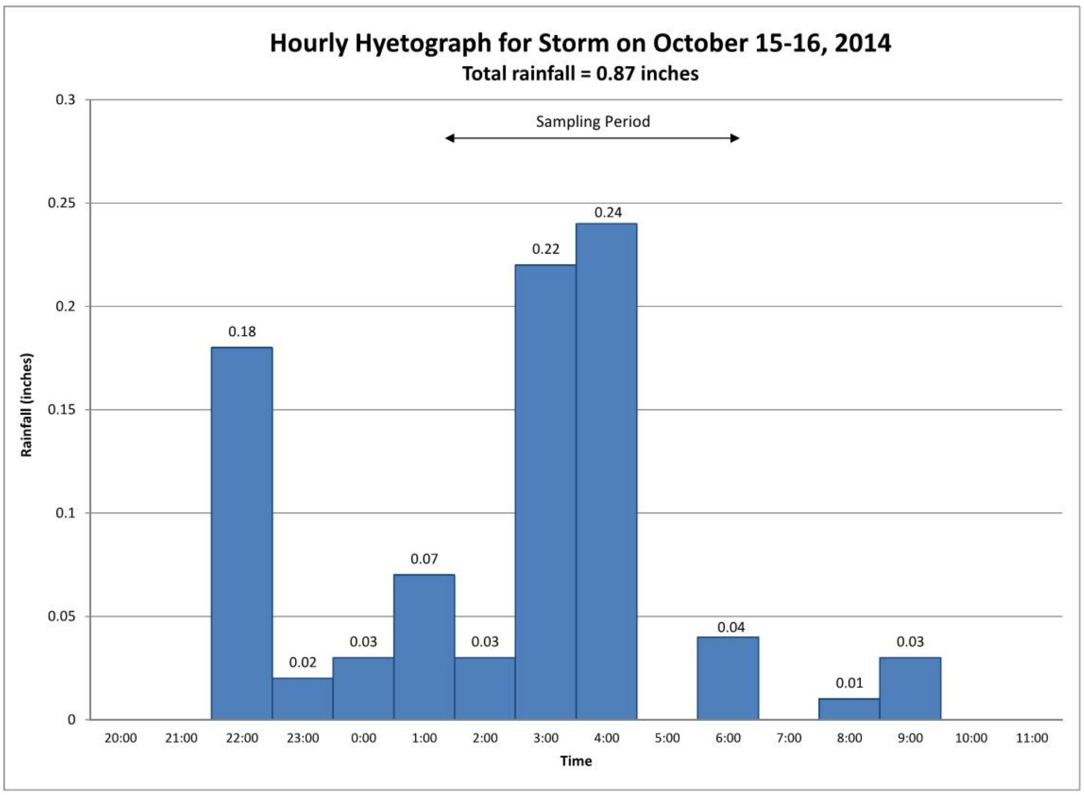
4. Initially, the PAA was not feeding into the system as intended, but was draining into a bypass tank. When this was noticed, the bypass valve was closed and the PAA began to feed through the unit. The PAA feed pump setting was adjusted in an attempt to achieve the desired PAA residual, but the feed rate was too high due to the oversized pump, and the residual did not drop below 2.35 mg/L which is the upper limit that could be measured.

5. The Aquionics unit displayed warnings but operated properly the majority of the time. The bulbs had to be reset once when a wiper error occurred and caused the unit to shut down for several minutes.

7.3 Test Run No. 2

Date of Test Run – October 16, 2014
Volume of Rainfall- 0.87 in. (Figure 7.2)
Time Rainfall Started- 22:16 (October 15, 2015)
The pilot units were all operational at 02:00 and the first sample was taken at 02:20. The treatment units were configured so that one treatment train went from the Storm King to the Trojan UV; and the second train went from the Terre Kleen to the FlexFilter to the Aquionics unit. PAA was not tested during this event. The following outlines operating or equipment difficulties encountered during the event:

Figure 7.2 Hourly Hyetograph for Storm on October 15-16, 2014



1. The Storm King floatables/solids removal screen was monitored at the start of the storm and after a short time period started to plug causing the majority of the flow to go down the screenings discharge, causing a bypass of the unit. A broom was then used to manually clean the Storm King screen when flow began bypassing the screen, this occurred at intervals of 10-30 min.

2. The fine screen was removed from the Terre Kleen unit by the manufacturer prior to the sampling event. The head loss through the Terre Kleen unit increased throughout the storm, but the unit did not enter bypass mode

3. The FlexFilter unit backwashed twice during the storm the influent pump screen required frequent cleaning with the broom to maintain the desire flow rate.

4. The Aquionics unit continued to show warnings but ran without any apparent issues. The Aquionics unit was shut down while the FlexFilter backwashed and turned back on when flow through the FlexFilter resumed.

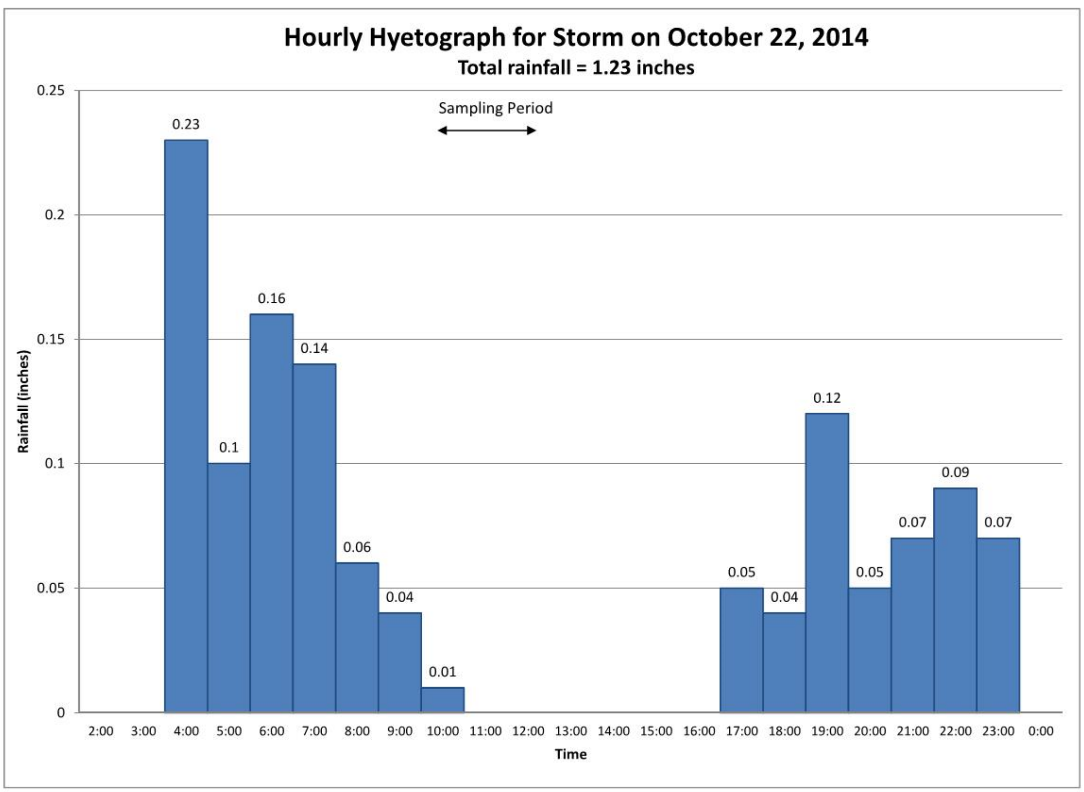
5. The Trojan unit operated without any incidents.

7.4 Test Run No. 3

Date of Test Run – October 22, 2014
Volume of Rainfall- 0.74 in. (From 04:06 until 10:51; there was a six-and-a-half-hour dry period after which an additional 0.49 in. of rain fell) (Figure 7.3)
Time Rainfall Started- 04:06

The pilot facilities were operational at 10:10 and the first sample was taken at 10:30, sampling was conducted at twenty minute intervals for 2 hours, at which point the overflow stopped. The planned configuration had to be modified in the field, because the PAA unit was initially disconnected and leakage through the weir in CB-3 would not allow adequate flow from the FlexFilter to be conveyed to the UV units. The units were configured so that one treatment train went from the Terre Kleen to the Aquionics UV; and the second train went from the Storm King to the FlexFilter to the PAA. The Trojan UV system was not used during this event. The following outlines the operating or equipment malfunction difficulties encountered during the event:

Figure 7.3 Hourly Hyetograph for Storm on October 22, 2014



1. The Terre Kleen unit functioned without incident. This was the first run with the hood over the internal screen in place.

2. There was minimal build up on the Storm King with the Swirl Cleanse (coated perforated screen) screen and no cleaning was performed.

3. The screen on the FlexFilter pump was periodically cleaned and the flow rate was maintained. The FlexFilter did not backwash during the sampling period.

4. This was the first run after the volume of the PAA contact tank was reduced from 350 gal to 150 gal to reduce contact time. The PAA unit pump wiring had been disconnected by PeraGreen before the sampling began, this was done in anticipation of a new pump arriving. When the new pump did not arrive, the old pump was reconnected by the supplier and readings were taken for the last few samples.

5. The Aquionics unit displayed warnings, but appeared to function throughout the sampling period.

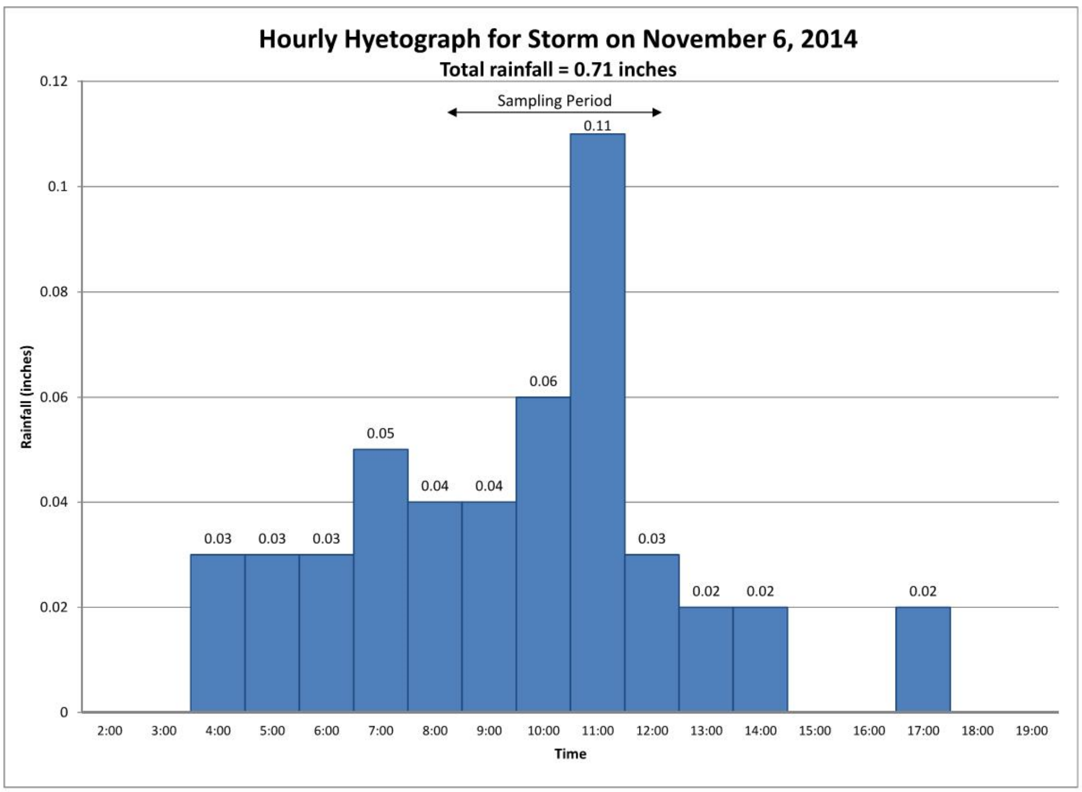
Sampling during the event was limited due to the short overflow period.

7.5 Test Run No. 4

Date of Test Run – November 6, 2014
Volume of Rainfall- 0.42 in. (From 04:08 to 12:47; an 0.06 in. was scattered throughout the rest of the day) (Figure 7.4)
Time Rainfall Started- 04:08

The pilot equipment was operational at 08:30 and the first sample was taken at 08:50. The treatment units were configured so that one treatment train went from the Terre Kleen to the PAA; and the second train went from the Storm King to the FlexFilter to the Trojan. The Aquionics was not used during this event. The following outlines the operating or equipment difficulties encountered during the event:

Figure 7.4 Hourly Hyetograph for Storm on November 6, 2014



1. The water level in the Terre Kleen increased and overtopped the internal weir around 10:20. The amount of bypassed flow increased as the sampling period progressed.

2. A representative for Hydro-International was on hand to observe the Storm King, periodically (every ten to fifteen minutes) the screen would partially blind and he would clean the screen with a broom.

3. Prior to the sampling event representatives from WWETCO replaced the FlexFilter pump which had a 0.25 in. screen with an open impeller pump that had no screen. This returned the FlexFilter to its original operation, before the first open impeller pump failed. It allowed the pump to operate without the screen clogging as had previously occurred and also allowed the full solids load carried by the CSO to be treated by the unit. The FlexFilter backwashed four times during the four hours sampling period. Each backwash cycle lasted approximately thirty-five minutes.

4. The feed pump on the PAA was the oversized pump (6 gallons per day (gpd)) that was going to be replaced by the vendor, but was not. It was difficult to control the flow of PAA with the pump set at a very low stroke and speed. Several times the flow of PAA stopped, when the drawdown column was used to measure the flow rate, it was very inconsistent.

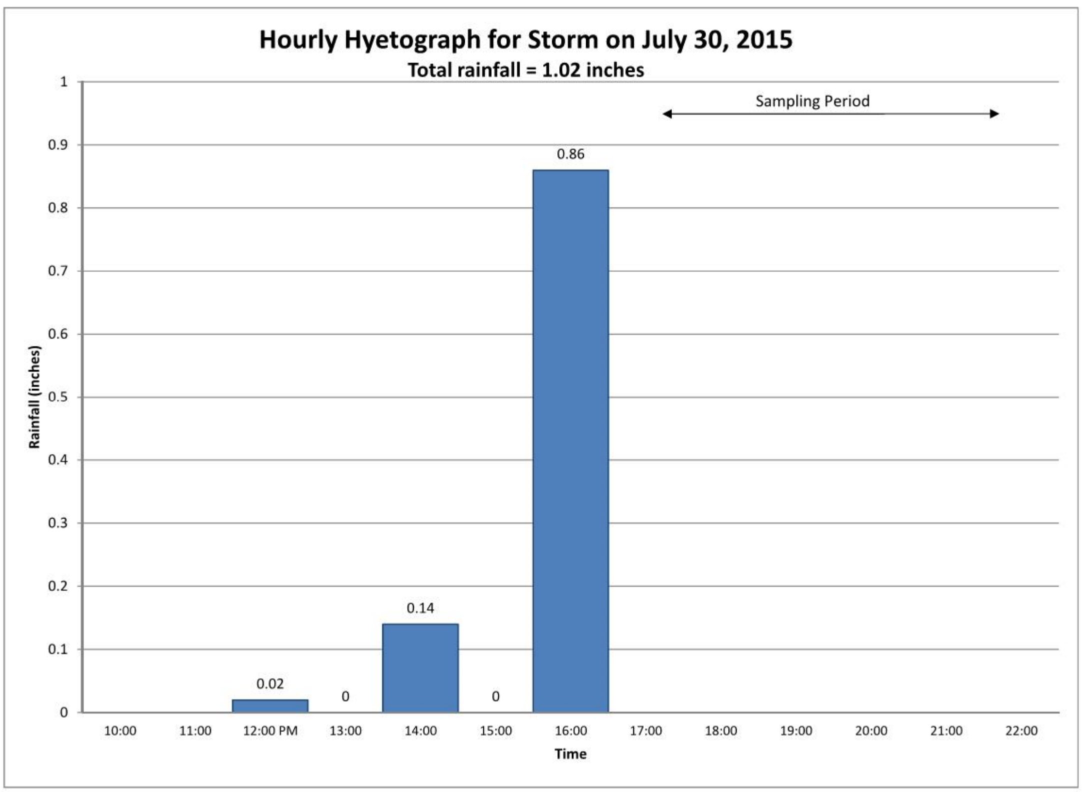
5. There were no issues with the Trojan UV unit, but it was manually turned off during the FlexFilter backwash cycle limiting the number of samples collected.

7.6 Test Run No. 5

Date of Test Run – July 30, 2015
Volume of Rainfall- 1.02 in. (Figure 7.5)
Time Rainfall Started- 12:19

The pilot equipment was operational at 17:30 and the first sample was taken at 17:50. The treatment units were configured so that one treatment train went from the Terre Kleen to the FlexFilter to the Trojan UV; and the second train went from the Storm King to PAA. The Aquionics was not used during this event. Due to the short duration of the rainfall, the pumping station outfall was check regularly throughout the sampling to ensure the overflow was still in process. The overflow continued uninterrupted throughout the sampling period. The following outlines the operating or equipment difficulties encountered during the event:

Figure 7.5 Hourly Hyetograph for Storm on July 30, 2015



1. The Storm King with the Swirl Cleanse (coated perforated) screen blinded several times and required cleaning. The screen was not cleaned until a significant portion of the flow bypassed the screen and existed in the screening discharge pipe.

2. The Terre Kleen unit water level upstream of the weir gradually built up and the unit began bypassing at approximately 18:50 or one hour and twenty minutes into the sampling period.

3. The FlexFilter unit backwashed three times. The pump for the unit also went down for roughly fifteen minutes at approximately 18:55 and was reset.

4. The PAA pump was not turned on until after the first sample was taken. This was the result of an oversight in the field.

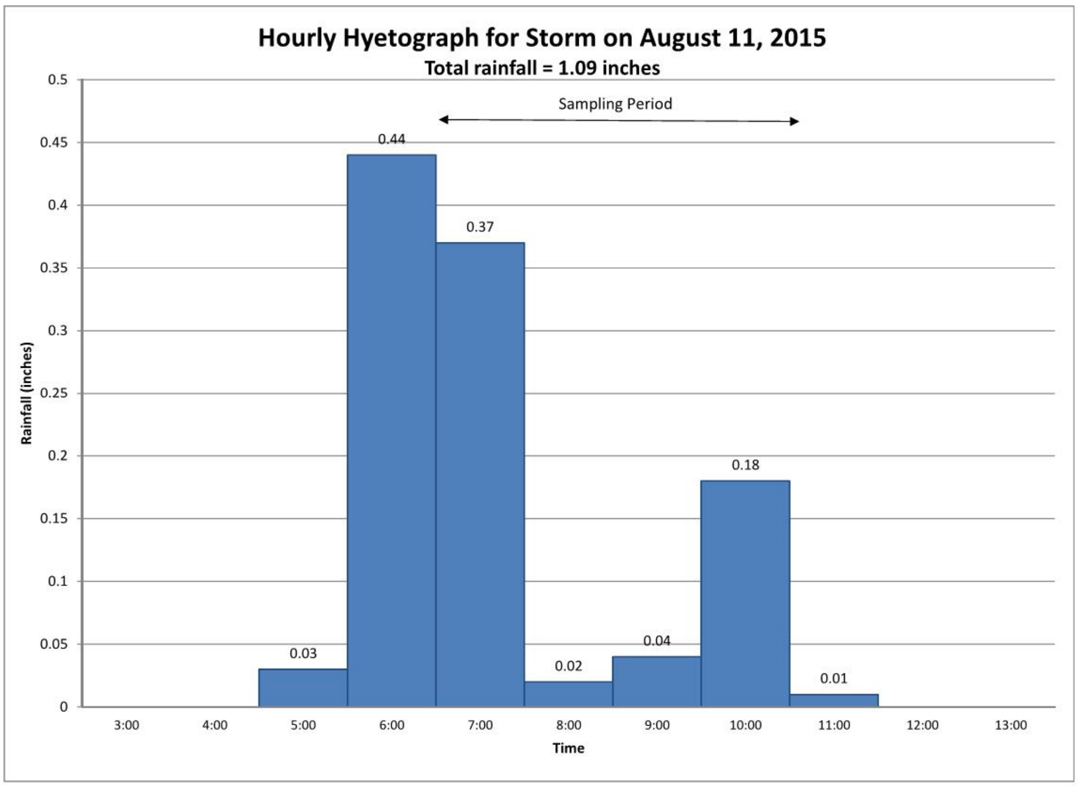
5. The Trojan UV unit operated without incident. The bulbs were turned on and off corresponding to the FlexFilter backwash cycle.

7.7 Test Run No. 6

Date of Test Run – August 11, 2015
Volume of Rainfall- 1.09 in. (Figure 7.6)
Time Rainfall Started- 05:50

The units were all operational at 07:00 and the first sample was taken at 07:20. The treatment units were configured so that one treatment train went from the Terre Kleen to PAA; and the second train went from the Storm King to the FlexFilter to the Aquionics. The Trojan UV unit was not used during this event. The following outlines the operating or equipment difficulties encountered during the event:

Figure 7.6 Hourly Hyetograph for Storm on August 11, 2015



1. The Storm King with Swirl Cleanse (coated perforated) screen blinded several times and required cleaning. The screen was not cleaned until a significant portion of the flow bypassed the screen and existed in the screening discharge pipe.

2. The Terre Kleen unit water level upstream of the weir gradually built up but the unit did not go into bypass operation.

3. The FlexFilter unit backwashed three times, with relatively short run times as noted in the results.

4. This was the first run using PAA after the tank volume of 300 gal had been restored and the unit's hydraulic flow improved by removing headloss due to pipe bends and the static mixer allowing the flow to be increased to 100 gpm to decrease the detention time to 3 minutes.

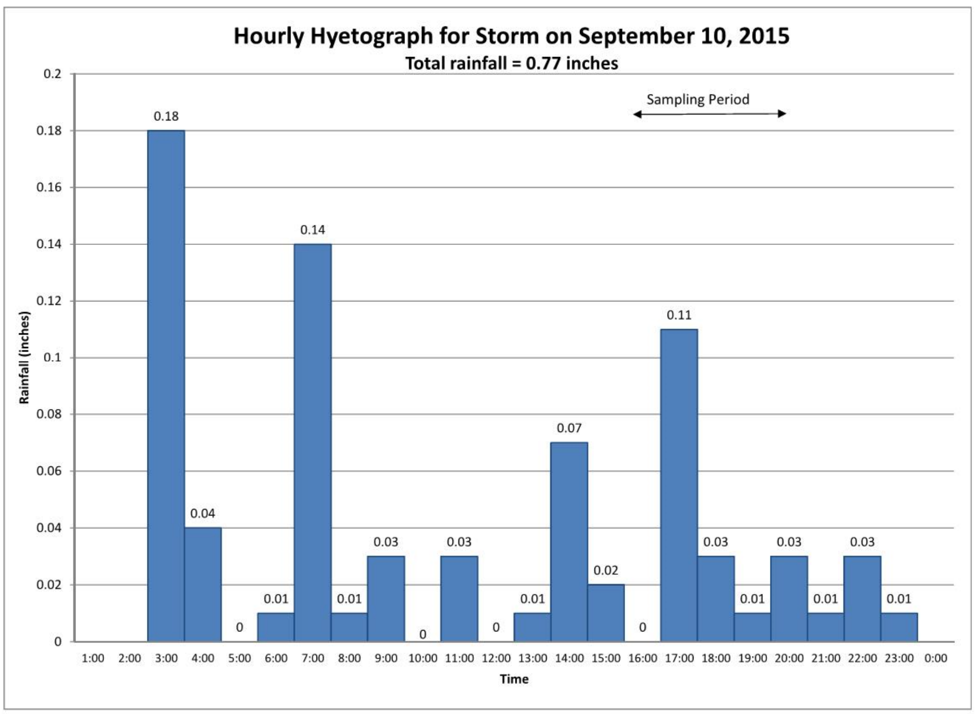
5. The Aquionics UV unit operated without incident until near the end of the sampling when a "water too hot" alarm occurred. The bulbs were turned on and off corresponding to the FlexFilter backwash cycle, which limited the number of samples collected.

7.8 Test Run No. 7

Date of Test Run – September 10, 2015
Volume of Rainfall- 0.77 in. (Figure 7.7)
Time Rainfall Started- 03:13

The units were all operational at 17:40 and the first sample was taken at 18:00. The influent pump for the FlexFilter unit could not be started so the planned treatment trains were reconfigured so that the first train had influent going only to the Terre Kleen, the second treatment train went from the Storm King to the Trojan UV, and the third train had untreated influent going directed to the PAA by directing flow through a hose to CB-3 where it was pumped to the PAA unit. The FlexFilter and Aquionics UV units were not used. The following outlines the operating or equipment malfunction difficulties encountered during the event:

Figure 7.7 Hourly Hyetograph for Storm on September 10, 2015.



1. As noted above, the pump for the FlexFilter would not start and thus the unit was taken out of the sequence for this event.

2. The Terre Kleen functioned without incident.

3. The Storm King Swirl Cleanse screen was blinded several times and required cleaning. The screen was not cleaned until a significant portion of the flow bypassed the screen and existed in the screening discharge pipe. Confusion caused by last minute field changes to the unit being tested resulted in the first several TSS/VSS samples not being collected for the Storm King.

4. Since the influent to the PAA unit did not pass a sampling port, influent samples for the PAA were obtained by dipping a bucket in CB-3 and filling the sample containers from the bucket.

5. The Trojan UV unit operated without incident.

As previously noted, the Demonstration Project was getting adequate wet weather storm events to complete the program's testing and there was a real concern that freezing weather conditions could again cause problems and damage the sensitive exposed equipment. Accordingly, discussions were held with the TAC and the NJDEP to develop a plan of action for completing the pilot testing without rainfall. It was determined that the groundwater from the existing plant's facilities underground tanks at the site would be used in conjunction with the influent raw sewage to provide a blended flow that would simulate a CSO event. The Demonstration Project's last two events were conducted using this simulated CSO discharge as noted below.

7.9 Test Run No. 8

Date of Test – October 15, 2015
Rainfall- None - Simulated CSO Discharge

The pilot units were all operational at 09:40 and the first sample was taken at 10:00. The treatment units were configured so that one treatment train went from the Storm King to the FlexFilter to the Aquionics UV, and the second train went from the Storm King to PAA. The Terre Kleen and Trojan UV units were not used. Due to the use of groundwater, only one separator was used to allow the groundwater and sewage to mix. Because of the previously noted issues of the Storm King's Swirl Cleanse coated perforated screen, the manufacturer, Hydro International, wanted to replace the existing screen with a new stainless steel wedge wire screen (Reference Figure 4.5). The design of the new screen has been used in the paper industry to prevent the clogging of stringy, fibrous material. Storm King following the testing in 2014 Storm King wanted to modify their solids/floatables screen to prevent the clogging problem. Unfortunately, the extended delays in the design, prefabrication and manufacture of the new stainless steel wedge wire screen resulted in the new screen being delivered and installed on the Storm King in October of 2015. The following outlines the operating or equipment difficulties encountered during the event:

1. This was the first and only event to make use of the wedge wire screen for the Storm King unit. The screen blinded several times and required cleaning. The screen was not cleaned until a significant portion of the flow bypassed the screen and existed in the screening discharge pipe. The influent appeared to have very little debris so the total flow going to the Storm King was increased from approximately 475 gpm to 700 gpm at 11:00.

2. This was the first event that the FlexFilter was operating with its new pump. The filter backwashed twice during the sampling period.

3. A PAA residual could not be obtained in the effluent from the PAA contact tank. The action of the pump was confirmed by observing bubbles moving through the clear solution feed clear tubing. The analysis reagent was confirmed by spiking a sample with a small amount PAA.

4. The Aquionics UV unit was operating, but had to be restarted around 12:40 due to a "water too hot" alarm. The flow was increased from 130 gpm to 150 gpm to see if the additional flow would help keep the system cooler. In addition, the unit was turned on and off corresponding to the FlexFilter backwash cycle.

7.10 Test Run No. 9

Date of Test – October 27, 2015
Volume of Rainfall- Simulated CSO Discharge

Figure 7.8 CSO solids on FlexFilter media

The pilot units were all operational at 09:00 and the first sample was taken at 09:20. The treatment units were configured so that one treatment train went from the Terre Kleen to the FlexFilter to the Trojan UV, and the second train went from the Terre Kleen to PAA. The Storm King and Aquionics UV units were not used. Due to the use of the blended groundwater with the raw sewage, only one separator was used to allow the groundwater and sewage to mix. The Technical Advisory Committee had a concern about iron in the groundwater and its impact on PAA. The groundwater was tested for iron using a home drinking water test kits. The reading was 0-0.3 ppm, which is not high value. The following outlines any operating or equipment difficulties encountered during the event:

1. The Terre Kleen unit was initially operating at 900 gpm, however to reduce splashing the flow was reduced to 850 gpm. There was some splashing of flow over the bypass weir, but not a continuous flow over the weir. There were no other operational issues with this unit.

2. The FlexFilter unit backwashed three times during the sampling period. During the operation, a heavier than typical buildup of CSO solids formed on the filter media in the upper portion of the filter bed, see Figure 7.8. The filter media appeared clean after backwashing indicating solids buildup is normal.

3. A consistent PAA residual could not be obtained in the effluent from the PAA contact tank, although several spikes were observed. The action of the chemical pump was confirmed by observing bubbles moving through the clear tubing. The analysis reagent was confirmed by spiking a sample with small amount of PAA.

4. Trojan UV unit operated without incident.

Table 7.1 Summary of the Equipment Set-up and Major Comments

Run No.	Date		Train 1			Train 2			Not Used	Comments
1	10/4/2014	Equipment	SK	FF	PAA	TK		AQ	TR	SK and TK screens plugged; FF backwashed once; influent screen plugged limiting flow to 50 gpm occasionally; PAA initially not fed, then overdosed
		Flow (gpm)	500	150	50	500		150		
2	10/16/2014	Equipment	TK	FF	AQ	SK	TR		PAA	SK screen manually cleaned; TK fed w/o screen; FF fed with a pump with a screen which was periodically manually cleaned; FF backwashed twice
		Flow (gpm)	300	150	120	300	150			
3	10/22/2014	Equipment	TK	AQ		SK	FF	PAA	Trojan	Limited sampling for PAA; TK and SK functioned w/o plugging; FF fed with a pump with a screen which was periodically manually cleaned; no backwash on FF;
		Flow (gpm)	600	160		400	100	40		
4	11/6/2014	Equipment	TK	PAA		SK	FF	TR	AQ	SK screen was plugging and was periodically manually cleaned; TK water level overtopped internal weir; FF operated with a pump w/o screen, backwashed 4 times for ~ 35 minutes; PAA dose erratic due to oversized pump
		Flow (gpm)	400	50		600	150	130		
5	7/30/2015	Equipment	TK	FF	TR	SK	PAA		AQ	SK screen was plugging and was periodically manually cleaned; TK water level overtopped internal weir; FF operated backwashed 3 times for ~ 35 minutes; PAA off for first sample.
		Flow (gpm)	550-375	150	130	450-300	100			
6	8/11/2015	Equipment	TK	PAA		SK	FF	AQ	TR	SK screen was plugging and was periodically manually cleaned; FF operated backwashed 3 times for ~ 35 minutes; PAA Tank volume restored to 300 gal; AQ "Water too hot" alarm
		Flow (gpm)	300-200	105		300-200	160-140	140-100		
7	9/10/2015	Equipment	PAA			SK	TR		FF, AQ	SK screen was plugging and was periodically manually cleaned; FF not working; PAA influent samples taken from CB-3
		Flow (gpm)	100			400-345	150			
8	10/15/2015	Equipment	SK	FF	AQ	SK	PAA		TK, TR	Wedge wire screen on SK, plugged and was periodically cleaned; FF backwashed 2 times for ~ 35 minutes; Could not achieve PAA residual
		Flow (gpm)	475-710	150	130	475-710	100			
9	10/27/2015	Equipment	TK	FF	TR	TK	PAA		SK, AQ	Unusual "sludge blanket" on FF filter media, Could not achieve PAA residual
		Flow (gpm)	900-850	145	140-100	900-850	61-105			

Legend: TK - Terre Kleen; SK - StormKing; FF - Flex Filter; PAA - INJEXX Peracetic Acid; AQ - Aquionics UV 200+W; TR - Trojan UV3000

SECTION 8 PRESENTATION OF THE RESULTS

8.1 General

Raw analytical data from all nine Test Runs are summarized in Tables presented in Appendix A. The Tables include a column for various data qualifications and comments. These comments should be read in conjunction with a more detailed description of the storm conditions, testing program, equipment status, flow conditions and other relevant circumstances presented in Section 7.

As discussed in Section 6, for each event the design flow to each pilot unit was selected prior to initiation of the sampling every effort was made to maintain that design flow throughout each sampling event. However, due to various factors relating to equipment operation, such as primary influent screen blinding, the actual measured flow frequently diverged from the design. Additionally, the single FlexFilter unit available on site was frequently backwashed, interrupting flow to the downstream disinfection units. The actual, measured flows are provided in the Tables in Appendix A.

Appendix B contains a series of chronological graphs presenting results from individual Test Runs. For each Test Run, the initial graphs present TSS and other characteristics of influent wastewater throughout the sampling event. Subsequent graphs in each series chronicle performance of different pilot units, with bacterial indicators data provided at the final group of graphs for each series.

8.2 Raw influent characteristics

Chronological raw wastewater characteristics for each individual Test Run are presented in series of Figures X-1 and X-2, where X represents number of the individual Test Run (1 through 9). These Figures (Appendix B) present conventional parameters measured in raw wastewater such as TSS, VSS, $CBOD_5$, COD (measured at 20 minute intervals) as well as fraction of settleable TSS and VSS at several points during each storm (usually measured at 1 hour intervals).

8.3 TSS Removal Efficiencies

Figures from series X- 3 and above (Appendix B) present chronological data and performance of pilot units dedicated primarily to removal of TSS and related parameters, i.e., Terra Kleen, Storm King and FlexFilter. TSS removal efficiency for each unit is based on TSS or other data from the corresponding sampling time (which includes time delay related to the hydraulic retention time of each unit).

8.4 Disinfection Efficiency

Figures from series X-10 and above (Appendix B) present chronological performance of UV and PAA disinfection units. Bacterial density measurements, log reduction outcomes as well as relevant wastewater characteristics such as UVT, TSS, soluble $CBOD_5$, COD and residual PAA, as applicable, are presented chronologically for each storm.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 9 ANALYSIS OF THE RESULTS FOR TSS

9.1 Summary for TSS Reduction Averaged over Test Runs

A summary of TSS Removal Efficiency of the Terre Kleen, Storm King and FlexFilter units for each individual Test Run is provided in Table 9.1. The average efficiency for each Test Run is calculated as average of reduction in TSS measured at each individual sampling time. The average raw (influent) wastewater TSS and VSS and settleable fraction of TSS for each Test Run is indicated as well. The settleable TSS and VSS was measured at approximately one hour intervals using gravimetric procedure SM-2540F Suspended Solid measured after a 60-minute quiescent settling.

Test Runs 1 through 4 were conducted in 2014 and Test Runs 5 through 9 in 2015. In 2014, the influent TSS was measured at S-1, which was upstream of the distribution manifold (See Figure 5.2). When the initial TSS removals for the Terre Kleen and Storm King were reviewed based on the 2014 data there was a concern that the pipe bends between the sampling port and the units may be causing turbulence that could be breaking the TSS into smaller particles. There was additional concern that the location of the sampling port at the top of the pipe and the transition from 2 in. piping to 0.5 in. piping may cause the heavier TSS material to settle out and not be included in the sample. To address these concerns the influent sampling locations were moved to S-1A and S-1B, just upstream of the respective unit and the sampling port moved to the side of the pipe and made with a 0.5 in. connection mid-pipe as previously illustrated in Figure 6.1. The new influent sampling location and ports were used throughout the 2015 sampling period.

The data presented in Table 9.1 indicates in general poor TSS removal efficiency for both the Storm King and Terre Kleen units, based on average performance for each Test Run. A review of the data indicates a general improvement in the TSS removal efficiencies between the 2014 samples (Storm Runs 1 – 4), and the 2015 samples (Storm Runs 5 – 9). Nevertheless, the Terre Kleen unit had TSS removal efficiency of less than 10% in all but one Test Run with the majority of the Test Runs actually registering an increase of the TSS through the unit. Similarly, Storm King had only one Test Run with TSS removal efficiency higher than 12% with half of the Test Runs actually registering negative efficiency.

The reasons for the poor removal rates from both the Storm King and Terre Kleen units is unknown, and not generally in agreement with other studies. The initial testing of the pilot system was conducted with the suction piping for the influent pump located on the dry weather side of the diversion chamber however the screen on the suction piping clogged in less than an hour with rags and other fibrous materials, e.g., wet wipes, which prevented the collection of any usable data. To avoid clogging of the influent pump suction piping was moved to the wet weather side of the diversion chamber during all subsequent testing (Test Runs 1 – 9). Accordingly, it is anticipated that most of the heavier solids associated with the wet weather flows may have been directed to the dry weather wet well and away from the suction piping, thus resulting in a lower TSS influent to the pilot facilities.

The above rationale is further supported by the data. One contributing factor for poor removal rates is likely the fact that VSS accounted for a high percent of the influent TSS (Table 10.1). Hydrodynamic separators such as Storm King and gravimetric separators such as Terre Kleen are typically more effective at removing heavier inorganic materials. The relatively low average inorganic component of the raw wastewater as noted can impact removal rates. In addition, another possible explanation is that between the raw wastewater sampling point and Terre Kleen and Storm King effluent sampling points some gross solids in raw wastewater were dispersed by the turbulence in the connecting piping, unit inlet structures or even units themselves. Such gross solids could escape capture by the TSS test but upon dispersion would be included into TSS sample and cause an apparent TSS increase. As noted above, following review of unfavorable performance results from the first 4 Test Runs, the sampling ports were modified to allow influent samples to be directly drawn from mid pipe for both Storm King and Terre Kleen. This somewhat improved the average performance in subsequent Test Runs, but the results were still disappointing.

FlexFilter performance in terms of TSS removal (Table 9.1) was very good, as it removed on average 90.5% of the TSS in all runs conducted on actual (i.e., not simulated) CSO except for Test Run No.1. The average removal on the CSO simulated Test Runs 8 and 9 was in the 62% to 67 % range.

9.2 Summary for FSS Reduction Averaged over Test Runs

An attempt was made to separate inorganic (non-volatile) fraction of TSS, or FSS from the total TSS by subtracting VSS from TSS. The removal efficiencies for FSS were calculated subsequently, and they are shown in Table 9.2.

The removal efficiencies of the FSS are higher than the total TSS, with the maximum removal efficiencies of 45.2% and 44.9% for Terre Kleen and Storm King respectively. However, the removal efficiency is still negative for Test Run #4 for both devices.

As indicated in Section 7 above, there were some problems due to clogging of the screens by floatables/solids causing the water bypassing the unit without treatment; specifically, the internal Terre Kleen screen and the Storm King solids/floatables screen. For Terre Kleen, the samples from Test Runs #1 and # 4 were eliminated from use for further data analysis because of the possibility that a significant amount of water (and associated solids) bypassed the settling plates via the weir without treatment. The possible significant amount of bypassed water, during storm event #4 could be an additional reason for the negative removal efficiency even for the heavy inorganic solids

Storm King experienced the screen blinding/clogging problem during all the Test Runs except #3. Among the storms causing clogging, Test Run #1 had water bypass the weir without being screened and thus the data was eliminated from use for analysis. Other Test Runs did not have water bypass the weir but instead bypassed via the central screenings return pipe. The amount of water (and associated solids) that bypassed the unit is likely insignificant. It is unknown why there is a significant negative removal of even the heavy inorganic solids for Test Run#4, and is considered as erroneous data to be excluded from further analysis.

Table 9.1 Summary of TSS Removal Efficiency of Storm King, Terre Kleen and FlexFilter

Table 9.1 Summary of TSS Removal Efficiency of Storm King, Terre Kleen and Flex Filter

Test Run #	Average Raw Waste-water TSS (mg/L)	Average Raw Waste-water VSS (mg/L)	Percent Inorganic Contents (TSS-VSS) /TSS (%)	Percent Settlable TSS, %	Terre Kleen (TK)						Storm King (SK)						Flex Filter (FF)					
					Design Flow[5] (gpm)	Hydraulic Loading Rate (HLR) (based on Effective Area of 57 sq ft) [6]		Hydraulic Loading Rate (HLR) based on LSA of 31 sq ft) [6]		Average TSS Removal Efficiency (%)	Design Flow[5] (gpm)	Hydraulic Loading Rate (HLR) (Based on Effective Area of 33.8 sq ft. [7]		Hydraulic Loading Rate (HLR) based on LSA of 88 sq ft) [7]		Average TSS Removal Efficiency (%)	Design Flow[5] (gpm)	Hydraulic Loading Rate (HLR)(based on Effective Area of 8.2 sq ft) [8]		Hydraulic Loading Rate (HLR) (based on LSA of 36 sq ft) [9]		Average TSS Removal Efficiency (%)
						gpm/sq ft	gpd/sq ft	gpm/sq ft	gpd/sq ft			gpm/sq ft	gpd/sq ft	gpm/sq ft	gpd/sq ft			gpm/sq ft	gpd/sq ft	gpm/sq ft	gpd/sq ft	
1	221	157	29%	58.1	500	8.77	12,632	16.1	23,226	7.7	500	17.7	25,442	5.7	8,182	-10.3	100	12.20	17,560	2.78	4,000	50.4
2	138	83	40%	48.3	300	5.26	7,579	9.7	13,935	-29.6	300	10.6	15,265	3.4	4,909	1.8	150	18.29	26,340	4.17	6,000	94.3
3	100	62	38%	45.9	600	10.53	15,158	19.4	27,871	-2.6	400	14.1	20,353	4.5	6,545	-50	100	12.20	17,560	2.78	4,000	91.0
4	218	172	21%	52.9	400	7.02	10,105	12.9	18,581	-9.5	600	21.2	30,530	6.8	9,818	-75.8	150	18.29	26,340	4.17	6,000	91.9
5	317/337[1]	157/159[1]	52%	72.0[2]	500	8.77	12,632	16.1	23,226	8.7	400	14.1	20,353	4.5	6,545	31.4	150	18.29	26,340	4.17	6,000	88.4
6	357/271[1]	200/165[1]	42%	62.6[2]	300	5.26	7,579	9.7	13,935	31.1	300	10.6	15,265	3.4	4,909	12	150	18.29	26,340	4.17	6,000	86.9
7	121[3]	87[3]	28%	56.2[4]	400	7.02	10,105	12.9	18,581	-1.5	500	17.7	25,442	5.7	8,182	-0.9	-					-
8	96.5[2]	78.5[2]	19%	35.8[2]	-						600	21.2	30,530	6.8	9,818	5.4	150	18.29	26,340	4.17	6,000	67.3
9	111[3]	88.5[3]	20%	35.6[3]	900	15.79	22,737	29.0	41,806	-1.3	-					-	150	18.29	26,340	4.17	6,000	62.2
		Average	32%																			

(1) - Separate Terre Kleen/Storm King Influent (Raw Wastewater not tested for TSS)
(2) - Storm King Influent
(3) - Terre Kleen Influent
(4) - Storm King Influent, where SK Influent data are available; average from Terre Kleen Influent and Peracetic Acid Influent elsewhere. Refer to the text for more detailed explanation.
(5) - The actual, measured flow varied, as detailed in Section 7
(6) - Unit has effective treatment area of 57 sq ft for all 9 trays, single tray horizontal projection area of 6.33 sq ft., and a total land surface area (LSA) of 31 sq ft including inlet and outlet chambers.
(7) - Based on 2 meter diameter (33.8 sq ft) and estimated total land surface area (LSA) of 88sq ft
(8) - Based on filter effective area of 8.2 sq ft
(9) - Based on estimated total land surface area (LSA) of 36 sq ft

Table 9.2 Summary of FSS Removal Efficiency of Storm King and Terre Kleen

Run #	Terre Kleen			Storm King		
	Influent (mg/L)	Effluent (mg/L)	Removal Efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal Efficiency (%)
1	**64**	**57**	**10.9**	**64**	**60**	**6.3**
2	55	50	9.1	*55*	*40*	*27.3*
3	38	31	18.4	38	33	13.2
4	**46**	**49**	**-6.5**	*46*	*61*	*-32.6*
5	160	124	22.5	*178*	*98*	*44.9*
6	157	86	45.2	*106*	*88*	*17.0*
7	34	34	0	--	31	--
8	--	--	--	*18*	*16.8*	*6.7*
9	22.9	21	8.3	--	--	--

* Plain font means unit operated without bypass; *italic* means excess flow went to Storm King screening discharge, use data with caution; and the **bold** font means some flow bypassed treatment process and preceded untreated to sampling point, data is questionable.

Based on the above discussions, the data from the six Test Runs (i.e., #2, #3, #5, #6, #7 and #9) for Terre Kleen and the data from the five Test Runs (i.e., #2, #3, #5, #6, and #8) for Storm King are used and analyzed below.

A correlation analysis was conducted between the influent concentrations and removal efficiencies, and significant correlations were obtained (Figure 9.1 for Terre Kleen and Figure 9.2 for Storm King). This was expected since the concentration increases as a result of heavier solids being brought into the water during the storm events, and heavier solids have higher settling velocities and higher removal efficiencies.

9.3 Comparison with Expected TSS Removal Performance of Terre Kleen and Storm King

The Terre Kleen Hydrodynamic Separator is certified by the NJDEP to provide 50% TSS removal from separate stormwater runoff. The certification establishes a hydraulic loading rate of 6.55 gpm/ft^2 and the 9-tray unit (the unit used in the demonstration project) has an effective treatment area of 87 ft^2, which means the 9-tray unit is certified for a maximum treatment flowrate of 570 gpm (NJDEP 2017). However, as noted above, the certification is for separate stormwater runoff, and a specific particle size distribution (as well as particle density and shape) with an influent concentration of 200 mg/L of inorganic only solids to represent separate stormwater runoff was used in establishing the TSS removal efficiency and maximum treatment flow rate. Since the particles used for simulating storm wastewater did not contain any organic materials found in domestic wastewater it may not be representative of the suspended solids present in a combined sewer overflow. The influent concentrations observed during the pilot thus did not match up with the influent concentration used to establish the TSS removal efficiency and maximum treatment flow rate under the certification protocol. It is therefore reasonable to anticipate that the performance of the Terre Kleen

Hydrodynamic Separator when used to treat combined sewer overflow may vary substantially from the performance established for the treatment of separate stormwater runoff.

The results of the project confirm this. While the maximum FSS removal efficiency achieved during Test Run #6 of 45.2% approached the certified TSS removal efficiency of 50%, the average FSS removal rate of 17.25% was far lower than 50%. It should be noted that the tested treatment flow rate during Test Run #6 was 300 gpm, which is lower than the maximum treatment flowrate of 570 gpm certified by NJDEP for the 9-tray unit. In fact, only 2 of the runs had flowrates that exceeded the certified maximum treatment flowrate. Even though, for a majority of the runs the treatment flowrate was below the certified maximum treatment flowrate, the unit did not achieve the 50% FSS removal. This is most likely a result of the different particle size, density, and shape distribution for influent concentrations seen in combined sewage overflow versus those used to establish the TSS removal efficiency and maximum treatment flow rate for separate stormwater runoff, as discussed above.

Figure 9.1 Correlation between Influent Concentration and Removal Efficiencies for FSS through Terre Kleen

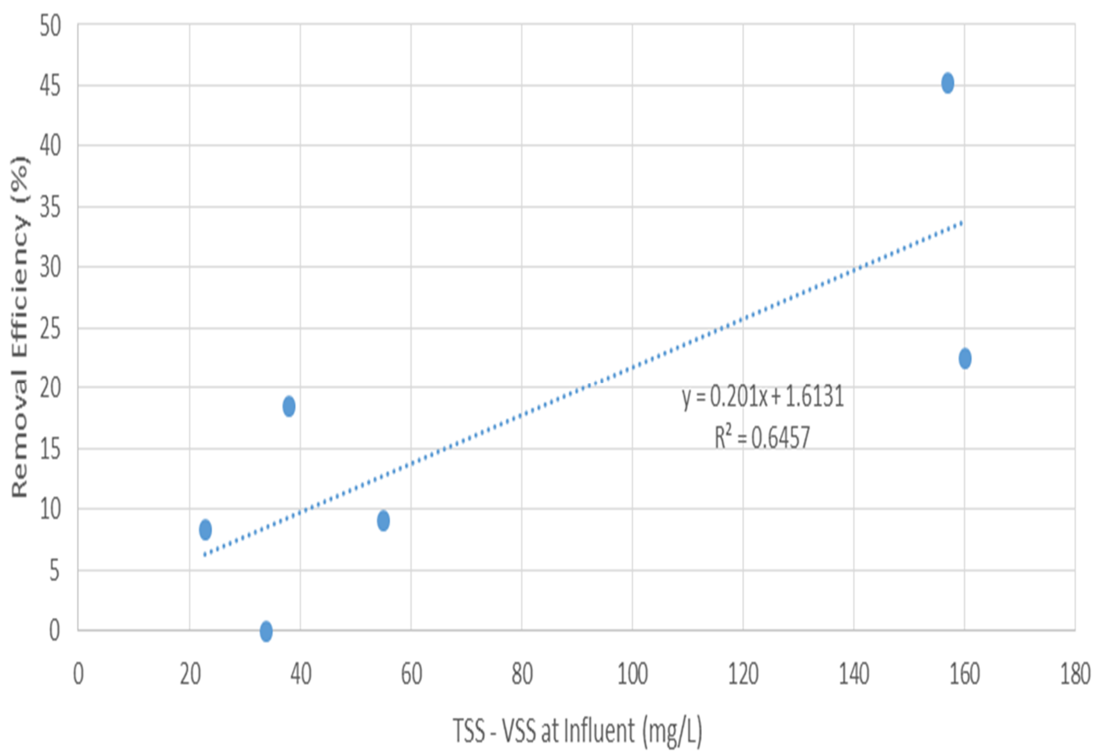
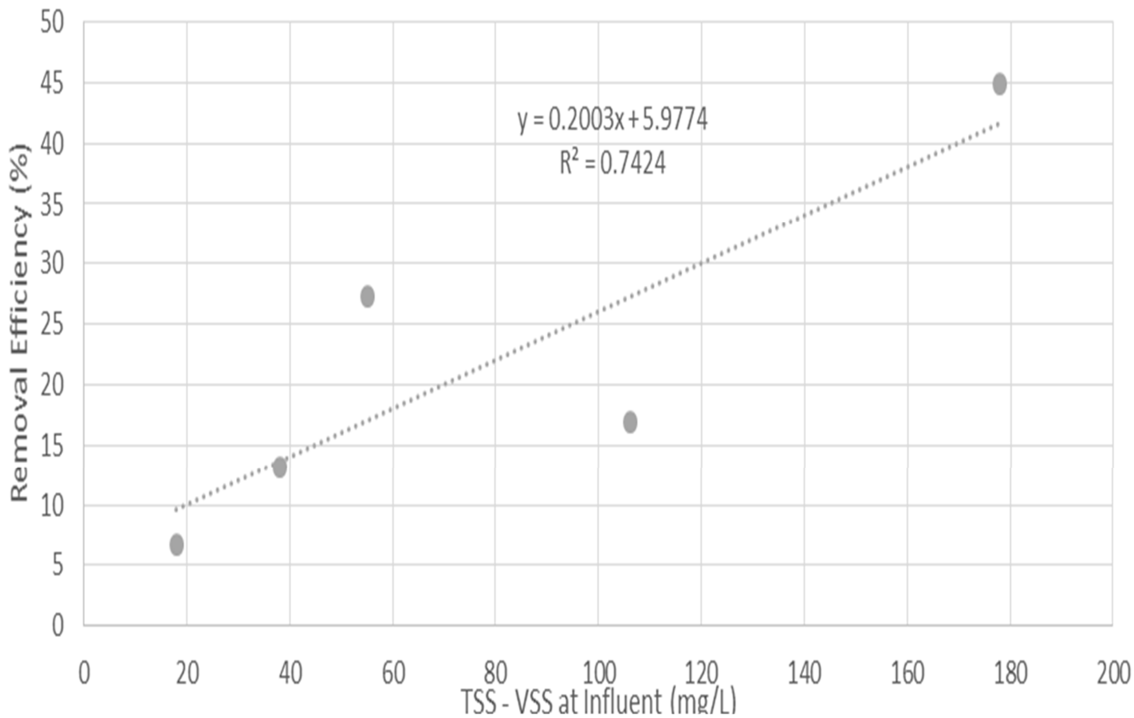


Figure 9.2 Correlation Between Influent Concentration and Removal Efficiencies for FSS through Storm King



The Storm King with the Swirl Cleanse unit is not certified by NJDEP and thus no direct comparison is possible. However, the NJDEP procedure for hydrodynamic separator type units allows for those units to be certified for 50% TSS removal. So, it can be assumed that if Storm King were to obtain certification, it would also be certified for 50% TSS removal using the same particle distribution of inorganic only solids (i.e. FSS). As with the Terre Kleen unit, the Storm King was unable to achieve the 50% TSS removal for any of the test runs. The maximum FSS removal efficiency was obtained during Test Run #5 with the event-averaged removal efficiency of 44.9%.

While neither of the units were able to achieve 50% TSS removal in any of the test runs, both were able to approach 50% FSS removal in one test run. Furthermore, Terre Kleen was able to achieve 50% inorganic TSS removal in a laboratory setting in order to obtain NJDEP certification. Thus, it is reasonable to assume that under some scenarios, these units would be capable of providing 50% inorganic TSS removal. This is demonstrated by the Saco, Maine project that measured a 55.5% TSS removal rate with a Swirl King unit. However, the solids removal efficiency would depend on the particle settling velocity (a combination of particle size, density, and shape). Since we did not measure the particle settling velocity during this demonstration project due to the time and budget constraints, it would be difficult to directly compare these results with those obtained in other projects or the NJDEP certification. Nevertheless, the solids removal efficiencies obtained in other studies were not replicated in this pilot.

9.4 Comparison with Expected TSS Removal Performance of FlexFilter

The measured TSS (both VSS and FSS fractions combined) removal efficiencies of FlexFilter in this demonstration project range from 62.2% to 94.3% (excluding the data from Test Run #1) with HLRs from 12.2 to 18.3 gpm/sq. ft.; this is comparable to what were measured at a trial in Atlanta, Georgia (McKern, et al. 2004) that showed that the FlexFilter™ is suitable for removal of TSS from raw CSO flow (75% to 94%) at lower HLRs.

Sizing of the filter matrix is a function of hydraulic and solids loading and the available head. Peak hydraulic loading rates (HLRs) range from 10 to 20 gpm/sq. ft. (USEPA 2013), with the lower end for high-strength wastewaters like CSOs and primary influent sewage. The higher HLR would apply to the more dilute solids concentrations such as for tertiary filtration or for dilute wet weather filtration.

The hydraulic loading rate of the FlexFilter in this pilot plant is the high end of the recommended rates as noted above.

9.5 Conclusions and Recommendations

1. Both Storm King and Terre Kleen had operating issues with their screens clogging with materials that appeared to be primarily toilet paper and wet wipes. It appears that a high volume of toilet paper and wet wipes in the wastewater will potentially impact the operation of these units.

2. Both Storm King and Terre Kleen demonstrated poor TSS removal when VSS accounted for a high percent of the influent TSS even when operating at flows far below their rated capacity. They both had removal efficiency of less than 10% in all, but one Test Run. This is not unexpected since hydrodynamic and gravimetric separators are typically more effective at removing heavier inorganic material.

3. The removal efficiencies of the FSS are higher for Terre Kleen and Storm King averaging around 17% and 22% respectively, based on storms used for analysis, with the maximum removal efficiencies of 45.2% and 44.9% respectively.

4. The low TSS removal for VSS indicates that both the Storm King and Terre Kleen will be ineffective on their own with UV disinfection due to low UVT of the effluent flow.

5. The design of the pilot required that the influent to the FlexFilter be pumped. Operating issues with the FlexFilter were primarily related to issues with the pumps, and the time needed to backwash. As previously noted the unit was tested at higher than normal HLRs and this was the reason for short run times. Nevertheless, it is anticipated that properly designed multiple treatment units and pump redundancy in full-scale operations will eliminate both issues.

6. The average TSS removal for the FlexFilter was very good removing on average 90.5% as described previously of the TSS in most Test Runs using actual CSO.

7. The influent to the FlexFilter represented the effluent from either the Storm King or Terre Kleen. While the overall TSS removal efficiency of the Storm King and Terre Kleen was generally low and effective in only removing inorganic solids, the ability of the FlexFilter to operate completely independent of these units was not established during this study. Nevertheless, due to the poor TSS removal rates from upstream units the FlexFilter was essentially operated as if it was receiving untreated flow. Its ability to operate independent of other solids removal units was demonstrated in Springfield, Ohio (Fitzpatrick *et al*., 2015).

8. The higher TSS removal rates for the FlexFilter improved the UVT of the effluent flow; however, UVT values were still low. Overall TSS effluent from the FlexFilter averaged approximately 27 mg/L for TSS and 40% on UVT (excluding Test Runs with synthetic CSO).

SECTION 10 ANALYSIS OF THE RESULTS FOR PERACETIC ACID

10.1 PAA Test Runs Summary

A summary of the operating conditions for all Test Runs with Peracetic Acid (PAA) is provided in Table 10.1. The Table lists information such as the pretreatment unit used, average PAA dose and measured residual, contact time (or hydraulic retention time (HRT)) and average water quality parameters, including feed (or influent) concentration of pathogen indicators. The average performance results in terms of log reduction of pathogen indicators are also provided. PAA dose was varied to be above and below design levels so that Dose/Kill relationships can be developed for a complete range of conditions. Nevertheless, due to large variability in the wastewater quality and in the PAA dose delivered within some of the Test Runs, these average performance data for individual Test Runs are listed for general information and are not further discussed or correlated. The subsequent data analysis focuses on individual data sets.

Table 10.1 Summary of the Operating Conditions for All Test Runs with Peracetic Acid (PAA)

Storm #	PAA								Geo. Mean in Feed (cfu/100 mL)			Average Log Reduction		
	Source of Influent	Design Flow, gpm	Average PAA Dose Applied, mg/L	Average PAA Residual Measured, mg/L	Design Hydra-ulic Reten-tion Time, min	Average TSS in Influent to PAA, mg/L	Average Soluble $CBOD_5$ in Influent to PAA, mg/L	Average COD in Influent to PAA, mg/L	E. Coli	Fecal coliform	Entero-cocci	E. Coli	Fecal coliform	Entero-cocci
1	FF	50	6.9	1.50	6	128	6.3	321	835,970	5,527,250	303,650	2.46	1.48	2.26
3	FF	40	0.56	1.05	4	12.1	28.3	113	688,520	3,041,255	748,488	3.78	0.73	0.91
4	TK	20	1.7	1.13	7.5	417	20.7	417	1,976,300	3,312,149	1,230,198	1.06	0.62	0.88
5	SK	50	1.7	1.82	3	225	22.1	364	1,176,657	8,318,359	370,081	1.87	2.15	1.07
6	TK	100	2.8	1.09	3	235	13.1	350	1,537,320	1,246,712	502,264	2.96	2.61	2.29
7	Raw	100	2	0.92	3	137	30.4	254	2,518,877	27,478,039	1,303,941	2.83	2.45	2.24
8	SK	100	2.8	0.00	3	90.3	53.8	312	4,339,314	2,991,547	1,327,225	0.18	0.72	-0.08
9	TK	100	2.8	0.18	3	113	48.2	342	4,428,413	1,949,520	1,375,294	0.65	0.25	-0.11

NOTE: For calculating Log Reduction for pathogen indicators, results reported as "less then" were interpreted as 1/2 of the detection level.

FF – FlexFilter; TK – Terre Kleen; SK – StormKing; PAA – Peracetic Acid

Detailed information on the operating conditions, water quality data and performance results for all valid individual sampling events are provided in Table 10.3. These data cover Test Runs 1 through 7; Test Runs 8 and 9 conducted on simulated wet weather wastewater are not included for the reasons subsequently discussed. The water quality parameters were measured in the effluent from the upstream TSS removal unit, where applicable. As mentioned above, the subsequent discussion and analysis of the results is based on sets of individual data points listed in this table.

Table 10.2 below provides a summary of pathogen indicator data from all valid individual sampling events in the Test Runs 1 through 7 indicating that the average log reduction was in the range 1.7 to 2.3 logs for all three indicators. In contrast, in the HDR (2014) study on wet weather primary effluent it was found that higher PAA and chlorine residual is required to inactivate E. coli and Enterococci to its potential regulatory limits than is required for fecal coliform. The log reductions were not identified in that study, but from the graphical presentation of the data it appears that at about 3 mg/L PAA residual and 15 min. contact time the log reduction for fecal coliform averaged 2.5 to 3, while it was approximately 2 for E. coli and Enterococci. Similarly, in the WERF (2005) study on wet weather plant influent, (corresponding to CSO) chlorine and chlorine dioxide were most effective against fecal coliform and least effective against E. coli, although the overall removal efficiencies were better than in the current study.

Table 10.2 Summary of Pathogen Indicator Data for PAA Tests

Pathogen Indicator	Initial Count Range (cfu/100 mL)	Average Log Reduction
E. coli	5.2E+05 to 4.9E+06	2.3
Fecal coliform	6.0E+05 to 5.5E+07	2.0
Enterococcus	4.0E+04 to 2.1E+06	1.7

The lower removals demonstrated during the current program are likely related to a relatively low PAA dose applied (Table 10.3), which generally was under 3 mg/L (targeting 1 to 2 mg/L residual). This compares to an order of magnitude larger dose of chlorine in the WERF (2005) study (8.5 to 28 mg/L range). More detailed discussion of the PAA effectiveness is provided in subsequent sections.

10.2 General Information on PAA Tests

A 12% solution of PAA (Proxitane WW-12) with a specific density of 1.11 g/mL was used during all runs. Those specifications, in conjunction with PAA metering pump settings and wastewater flows were utilized to calculate the applied PAA dose shown in Table 10.1.

As discussed in the methodology section (Section 6) the residual PAA concentration was measured by a chlorine residual method and the results converted to PAA residual by applying a conversion factor of 1.07. Since the upper range of the available chlorine residual kit was 2.2 mg/L, the maximum PAA residual that can be read was 2.35 mg/L.

The volume of the PAA reactor tank provided by the supplier was 300 gallons (see Figure 5.2 for set-up schematics). It was temporarily reduced to 150 gallons by internal overflow modifications for Test

Runs 3 and 4, before being restored to 300 gallons for the Test Run 5 and all subsequent Runs. The design flow rate of wastewater varied between 25 and 50 gpm for the initial Test Runs, before being

THIS PAGE INTENTIONALLY LEFT BLANK

MOTT MACDONALD

Table 10.3 Data from Peracetic Acid Test Runs

Test Run No. & Pretreat-ment	Time	Waste-water Flow (gpm)	Temp. (°C)		Turbidity (NTU)	DO (mg/L)		PAA					E. Coli (cfu/100ml)			Fecal Coliform (cfu/100ml)			Enterococci (cfu/100ml)			TSS (mg/L)	VSS (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)
			Infl	Effl	Infl	Infl	Effl	Dose (mg/L)	Residual (mg/L)	Contact Time (min)	CT (mg/L*min)	PAA Depleted (mg/L)	IN	OUT	LOG Red	IN	OUT	Log Red	IN	OUT	Log Red						
1 -FF	10/4/14 10:30	50	19.8	19.9	24.7				0.2245	6.0			1,400,000	2,400,000	-0.23	12,000,000	6,100,000	0.29	720,000	920,000	-0.11	37	31	168	41.5	5.2	17.7
1 -FF	10/4/14 10:50	50	20.0	20.1	54.7				0.0	6.0			1,280,000	1,080,000	0.07	11,000,000	12,700,000	-0.06	40,000	620,000	-1.19	232	182	551	87.9	5.6	18.4
1 -FF	10/4/14 11:10	50	20.2	20.3	33.0				0.0	6.0			1,040,000	56,000	1.27	25,000,000			1,160,000	1,300,000	-0.05	240	186	530	92.9	9.5	18.2
1 -FF	10/4/14 11:30	50	20.1	20.3	40.5			6.90	> 2.35	6.0	14.10	< 4.55	920,000	60	4.19	10,000,000	100	5.00	880,000	50	4.25	168	126	403	72.9	3.6	13.7
1 -FF	10/4/14 11:50	50	20.3	20.4	35.0			6.90	> 2.35	6.0	14.10	< 4.55	1,040,000	50	4.32		20,000		600,000	100	3.78	138	103	323	55.2	7.8	12.5
1 -FF	10/4/14 12:10	50	20.5	20.6	32.8			6.90	> 2.35	6.0	14.10	< 4.55	520,000	50	4.02	1,960,000	20,000	1.99	720,000	100	3.86	104	75	271	67.1	4.8	11.5
1 -FF	10/4/14 12:34	50	20.7	20.8	30.0			6.90	> 2.35	6.0	14.10	< 4.55	840,000	200	3.62	2,600,000	2,000,000	0.11	360,000	50	3.86	117	88	257	61.9	5.5	12.5
1 -FF	10/4/14 12:52	50	20.9	21.0	32.8			6.90	> 2.35	6.0	14.10	< 4.55	800,000			3,500,000	100,000	1.54	240,000	50	3.68	94	70	262	55.3	8.6	13.2
3-FF	10/22/14 11:50	41	15.8	15.8	11.5		7.7	0.56	1.16	3.7	4.24	-0.60	600,000	100	3.78	4,100,000	910,000	0.65	360,000	310,000	0.06	13	7	107	37	23	24
3-FF	10/22/14 12:10	41	17.1	17.1	13.2		6.74	0.56	1.02	3.7	3.73	-0.46	680,000	50	4.13	2,560,000	490,000	0.72	1,040,000	23,000	1.66	14	9	118	39	26	27
3-FF	10/22/14 12:30	42	17.8	17.8	12.0		5.77	0.56	0.98	3.6	3.50	-0.42	800,000	300	3.43	2,680,000	400,000	0.83	1,120,000	108,000	1.02	12	6	125	42	24	28
4-TK	11/6/14 8:50	29	15.1	15.4	49.6	4.85	4.24	0.77	1.97	5.2	10.18	-1.20	2,440,000	2,800,000	-0.06	3,360,000	4,900,000	-0.16	1,560,000	2,200,000	-0.15	274	222	481	179.0	17.7	28.8
4-TK	11/6/14 9:10	27	15.7	15.3	50.5	4.12	5.13	1.02	1.73	5.5	9.56	-0.71	2,680,000	280,000	0.98	1,640,000	760,000	0.33	1,640,000	2,200,000	-0.13	232	186	396	181.0	17.9	28.4
4-TK	11/6/14 9:30	25	15.3	15.6	23.0	4.64	5.00	1.10	0.15	6.0	0.89	0.95	2,760,000	92,000	1.48	2,920,000	370,000	0.90	840,000	890,000	-0.03	202	160	358	147.0	17.2	27.7
4-TK	11/6/14 9:50	24	15.4	15.4	37.7	4.29	6.02	1.14	0	6.2	0.00	1.14	1,960,000	1,800,000	0.04	3,040,000	3,300,000	-0.04	920,000	1,000,000	-0.04	208	162	403	167.0	19.7	29.2
4-TK	11/6/14 10:10	23	15.1	15.6	46.4	4.79	5.46	1.22	0	6.6	0.00	1.22	1,640,000	3,800,000	-0.36	4,700,000	5,900,000	-0.10	1,960,000	790,000	0.39	226	184	405	102.0	20.0	28.4
4-TK	11/6/14 10:30	21	14.5	14.6	62.0	8.02	8.80	3.23	1.79	7.3	13.00	1.44	1,840,000	8,000	2.36	5,200,000	70,000	1.87	1,320,000	200	3.82	328	266	587	201.0	23.0	27.7
4-TK	11/6/14 10:50	18	14.6	14.8	36.0	7.10	8.33	2.71	2.35	8.1	19.15	0.36	2,040,000	12,000	2.23	4,400,000	30,000	2.17	1,280,000	100,000	1.11	326	268	405	228.0	28.1	31.5
4-TK	11/6/14 11:10	18	14.5	15.0	41.0	6.71	7.58	2.38	1.36	8.6	11.65	1.02	1,760,000			4,000,000	1,100,000	0.56	880,000	1,800	2.69	212	170	375	146.0	22.8	27.7
4-TK	11/6/14 11:30	16	14.0	14.3	37.7	7.22	7.25	2.64	0	9.5	0.00	2.64	1,200,000	20,000	1.78	2,280,000	2,200,000	0.02	1,120,000	660,000	0.23	224	154	358	66.7	17.8	23.6
5-SK	7/30/15 18:10	99	24.1		24.8			2.81	1.69	3.0	5.14	1.12	720,000	3,100	2.37	2,400,000	1,400	3.23	320,000	300	3.03	278	156	301	91.8	13.7	
5-SK	7/30/15 18:30	99	24.1		20.8			2.81	1.77	3.0	5.36	1.04	1,760,000	5,000	2.55	6,000,000	30,000	2.30	480,000	300	3.20	240	134	382	136.0	14.1	
5-SK	7/30/15 18:50	97	24.1		16.9			1.43	2.05	3.1	6.33	-0.62	1,000,000	6,000	2.22	4,200,000	20,000	2.32	280,000	52,000	0.73	302	170	451	66.6	8.2	
5-SK	7/30/15 19:10	98	24.1		29.6			1.42	1.51	3.1	4.65	-0.09	1,000,000	20,000	1.70	8,000,000	470,000	1.23	280,000	53,000	0.72	260	150	317	97.4	19.1	
5-SK	7/30/15 19:30	98	24.1		32.5			1.41	1.51	3.1	4.62	-0.10	2,240,000	500	3.65	14,000,000	60,000	2.37	320,000	20,000	1.20	212	114	278	96.9	18.6	
5-SK	7/30/15 19:50	98	24.1		24.7			1.42	1.92	3.1	5.89	-0.50	1,600,000	70,000	1.36	34,000,000	320,000	2.03	600,000	460,000	0.12	256	158	409	148.0	25.4	
5-SK	7/30/15 20:10	98	24.1		27.4			1.42	> 2.35	3.1	7.20	-0.93	2,500,000	460,000	0.74	23,000,000	2,100,000	1.04	640,000	650,000	-0.01	280	172	697	241.0	44.7	
5-SK	7/30/15 20:30	98	24.1		22.9			1.42	1.74	3.1	5.33	-0.32	560,000	230,000	0.39	25,000,000	52,000	2.68	200,000	570,000	-0.45	208	114	386	122.0	29.8	
6-TK	8/11/15 7:20	102	22.8					1.36	0.00	2.9	0.00	1.36	4,900,000	8,700,000	-0.25	1,320,000	4,800,000	-0.56	680,000	440,000	0.19	486	340	701	314.0	38.4	
6-TK	8/11/15 7:40	104	22.8					2.66	0.00	2.9	0.00	2.66	3,080,000	46,000	1.83	3,100,000	113,000	1.44	1,600,000	450,000	0.55	454	312	788	296.0	29.8	
6-TK	8/11/15 8:00	105	22.8					2.65	0.34	2.9	0.98	2.31	2,560,000	3,200	2.90	2,100,000	7,200	2.46	560,000	39,000	1.16	294	180	451	196.0	13.5	
6-TK	8/11/15 8:20	106	22.8		52.0			2.62	0.45	2.8	1.27	2.17	1,400,000	200	3.85	1,400,000	1,400	3.00	760,000	1,800	2.63	250	152	359	152.0	11.0	
6-TK	8/11/15 8:40	106	22.8		45.4			2.61	1.19	2.8	3.35	1.42	880,000	200	3.64	800,000	2,100	2.58	440,000	900	2.69	174	100	310	80.7	6.6	
6-TK	8/11/15 9:00	106	22.8		46.5			2.62	1.80	2.8	5.09	0.82	1,160,000	50	4.37	1,000,000	200	3.70	240,000	200	3.08	136	78	207	75.6	6.9	
6-TK	8/11/15 9:20	106	22.8		36.9			2.61	2.09	2.8	5.88	0.52	1,040,000	2,000	2.72	600,000	50	4.08	520,000	50	4.02	175	99	219	77.2	6.1	
6-TK	8/11/15 9:40	106	22.8		37.4			2.61	1.77	2.8	4.98	0.85	720,000	50	4.16	2,100,000	200	4.02	200,000	50	3.60	171	94	198	62.7	6.0	
6-TK	8/11/15 10:00	106	22.8		37.0			2.61	2.19	2.8	6.18	0.41	1,160,000	50	4.37	600,000	500	3.08	400,000	200	3.30	183	111	230	72.9	7.3	
7-Raw	9/10/15 18:00	110	24.5		55.9			2.52	0.83	2.7	2.27	1.68	3,600,000	10,000	2.56	55,000,000	240,000	2.36	2,080,000	1,100	3.28	187	146	335			
7-Raw	9/10/15 18:20	99	24.5		46			2.80	1.68	3.0	5.08	1.12	4,300,000	700	3.79	33,000,000	2,000	4.22	1,800,000	100	4.26	109	80	230			
7-Raw	9/10/15 18:40	100	24.5		46.5			1.39	0.14	3.0	0.42	1.25	4,700,000	50,000	1.97	41,000,000	1,900,000	1.33	1,840,000	420,000	0.64	151	113	265			
7-Raw	9/10/15 19:00	99	24.5		48.9			2.79	1.67	3.0	5.04	1.12	1,200,000	700	3.23	16,000,000	27,000	2.77	1,320,000	200	3.82	271	226	293			
7-Raw	9/10/15 19:20	98	24.5		51.8			1.41	0.64	3.1	1.96	0.77	4,100,000	1,100	3.57	12,000,000	190,000	1.80	1,600,000	2,000	2.90	114	88	239			
7-Raw	9/10/15 19:40	99	24.5		45.2			1.41	0.33	3.0	1.01	1.08	4,000,000	1,700	3.37	23,000,000	260,000	1.95	1,720,000	270,000	0.80	113	89	311			
7-Raw	9/10/15 20:00	97	24.5		38.3			1.43	0.65	3.1	2.02	0.78	1,280,000	900	3.15		180,000		480,000	33,000	1.16	84	70	200			
7-Raw	9/10/15 20:20	98	24.5		38.9			1.41	0.03	3.1	0.10	1.38	1,920,000	1,800,000	0.03	43,000,000	2,900,000	1.17	1,080,000	1,500,000	-0.14	100	75	218			
7-Raw	9/10/15 20:40	98	24.5		35.1			2.82	2.34	3.0	7.14	0.48	1,160,000	200	3.76	23,000,000	2,500	3.96	840,000	300	3.45	106	83	195			
	Average							2.06	1.18	4.0	4.46	0.88	2,071,176	527,989	2.32	12,236,364	806,163	2.01	918,824	311,956	1.71	222	152	361	142.6	18.6	28.0
	Max												4.9E+06			5.5E+07			2.1E+06								
	Min												5.2E+05			6.0E+05			4.0E+04								
	Count	46	46	20	43	9	12	43	46	46	43		46	44	44	44	45	43	46	46	46	46	46	46	37	37	20

FF - Flex Filter; TK - Terre Kleen; SK - Storm King

Error in PAA analysis or problems with PAA feed - data not used for graphs and correlations

Bacterial counts reported as less then the detection level. Value equal to 1/2 of the detection level is shown in the table and used for correlations

THIS PAGE INTENTIONALLY LEFT BLANK

set at 100 gpm for Run 5 and all subsequent Runs. The resulting contact time (HRT) for all sampling events is provided in Table 10.2 and it varied from 3 to 6 minutes, with HRT standardized at 3 minutes after the Run 4. The wastewater flow rate to the PAA unit fluctuated to some degree during each Test Run in response to hydraulic head and other factors. Wastewater flow monitoring measurements corresponding to each individual sampling event, where available, are indicated in Table 10. 2.

During initial Test Runs dissolved oxygen (DO) concentration of the influent and effluent to the PAA reactor was measured, with a complete set of DO data available for Test Run 4 (Appendix A). These data indicate that DO concentration increased in the PAA reactor by 7%, on average. Since the data did not warrant any additional measurements DO concentration was not measured in subsequent Test Runs.

PAA solution was initially pumped into the PAA reactor system by a dosing pump with 6 gpd flow rate. The initial results indicated that the resulting dose was too high and that it was difficult to adjust the pump dosing rate to a smaller flow rate with a stable output. Consequently, starting with the Test Run 5 a smaller 3 gpd dosing pump was utilized. During the Test Runs the dosing pump settings (stroke and speed) were adjusted in a response to the current results of the PAA residual measurement. The objective was to maintain the PAA residual in the range 1 to 2 mg/L, but this was difficult to accomplish in real time, with limited ability to conduct frequent grab sampling and measurements for adjustments. Additionally, in several instances the metering pump was observed, such as during Run No. 4 to stall and not provide the desired dosing. When on several occasions the drawdown column was used to verify the actual PAA flow rate, the results were sometimes inconsistent.

Table 10.3 provides the applied PAA dose based on the record of the metering pump stroke and speed settings which were used to calculate PAA flow rate based on the pump calibration curves (which basically showed a linear correlation between stroke and speed and the pump output). Comparison between the calculated PAA applied dose and the measured residual presented in Table 10.3 indicate that in some instances the residual exceeded the applied dose (a negative PAA depleted concentration). This is likely attributable to the unstable PAA pumping rate, as discussed above. For these reasons the information on the applied PAA dose is subject to some uncertainty. However, the information on the measured PAA residual dose, as presented in Table 10.3, is considered reliable.

10.3 Results Overview

10.3.1 Statistical Significance

In the subsequent analysis of the observed data a linear correlation between various parameters was sometimes derived as a first approach. The goodness of fit of correlation is typically assessed by the R2 value of the fit. The statistical significance of the R2 for any particular correlation is a function of both sample size (number of independent data pairs) and the desired confidence level as illustrated in Table 10.3.

For example, the correlation coefficient (R2) of 0.39 for 8 data points indicates a 90% statistical confidence level for the correlation (i.e., there is only 10% chance that there is no linear correlation between the fitted parameters).

Table 10.4 Statistical Significance of Linear Correlation Coefficient R2 as a Function of Sample Size

Sample Size	Statistical Significance Level		
	10%	5%	1%
4	0.810	0.903	0.980
5	0.65	0.77	0.92
6	0.53	0.66	0.84
7	0.45	0.57	0.77
8	0.39	0.50	0.70
9	0.34	0.44	0.64
10	0.30	0.40	0.59
12	0.25	0.33	0.50
15	0.19	0.26	0.41
20	0.14	0.20	0.31
25	0.11	0.16	0.26
30	0.09	0.13	0.22
40	0.07	0.10	0.16
50	0.05	0.08	0.13
100	0.03	0.04	0.07

After Berthouex and Brown (1994)

10.3.2 Results Highlights

The effect of PAA residual on disinfection effectiveness could be tracked in chronological graphs provided for each Test Run in Appendix B. As a general observation, in many cases PAA appears to be effective (i.e., at least 1 log reduction) in reduction of pathogen indicators whenever the measured residual exceeded 1 to 2 mg/L. This could be seen from data in Table 10.2 or by inspecting chronological performance plots presented in Appendix B (particularly for Test Runs 4, 6 and 7, the last of which treated CSO without any TSS pretreatment step). The effect of elevated levels of COD (and related parameters, such as TSS, VSS and total and soluble CBOD5) on disinfection reduction and PAA residual is also evident, (see Run 6 discussed in Section 10.4.6 below).

Table 10.2 provides data from all individual sampling events for all 6 Test Runs in which PAA's addition was evaluated, and meaningful results obtained. This Table excludes individual results from the simulated Test Runs 8 and 9, as discussed in more detail below. However, Appendices A and B provide all available data, including for Test Runs 8 and 9.

Figures 10.1 through 10.3 provide graphical representation of the relationship between the measured PAA residual and log reduction of pathogen indicators for all individual sampling events in all 6 Test

Runs where a measurable residual PAA concentration was obtained in at least some samples. The data are sorted according to the Test Run.

Figure 10.1 PAA Residual vs Log Reduction of E. Coli

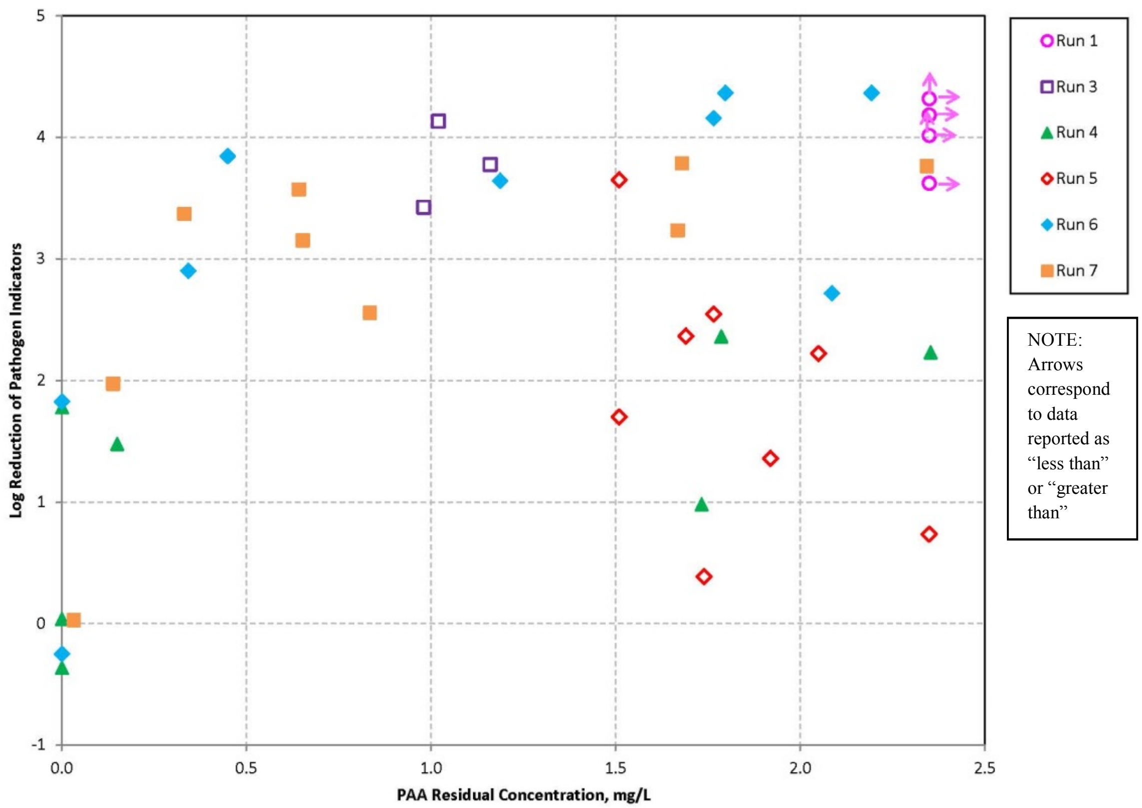


Figure 10.2 PAA Residual vs Log Reduction of Fecal Coliform

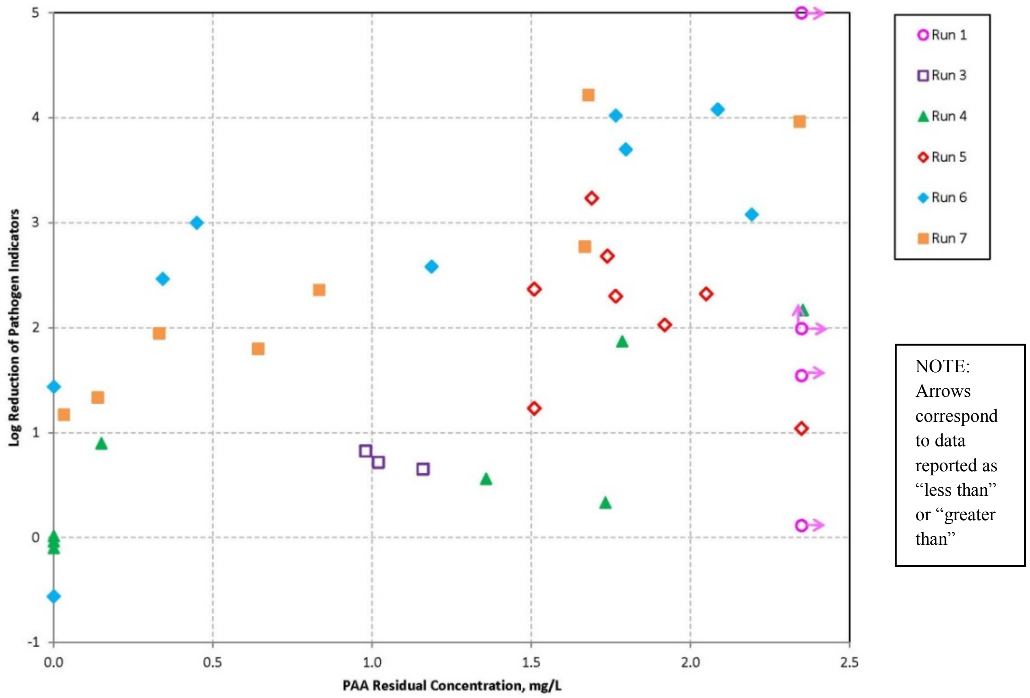
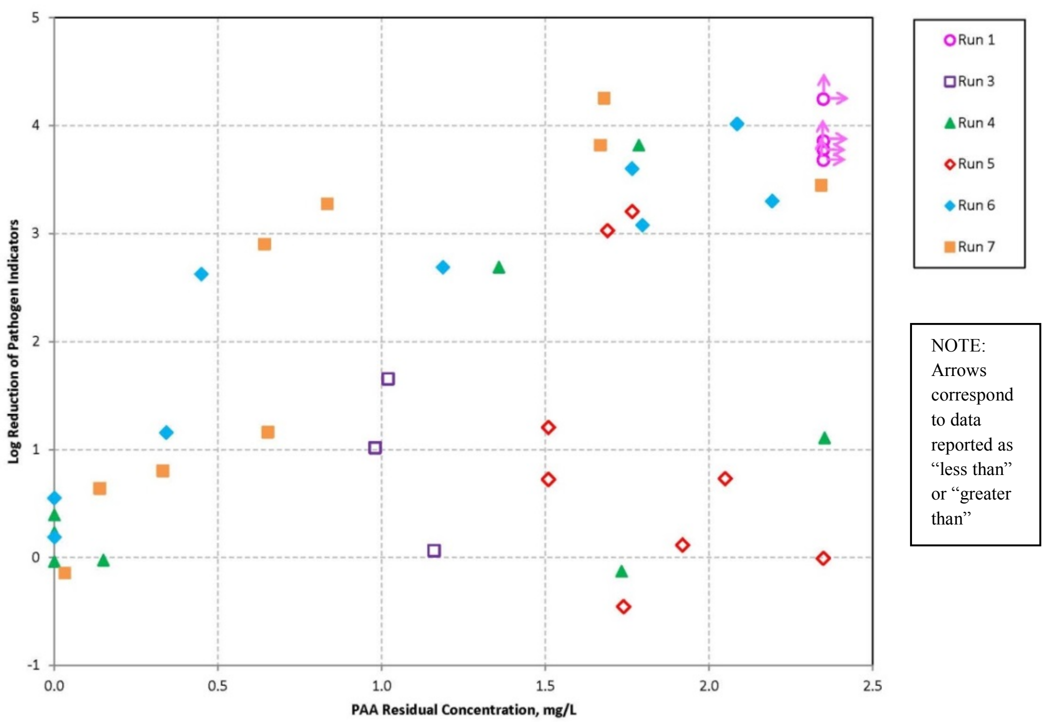


Figure 10.3 PAA Residual vs Log Reduction of Enterococci



Figures 10.4 through 10.6 provide the same data consolidated without distinction (or sorting) according to Test Runs to allow derivation of a correlation for all individual, valid data points. The linear correlations shown on these Figures indicate relatively low values of the R2. Although the linear correlations shown are statistically significant at 95% confidence level due to the relatively large number of data points (see Section 10.3), it was judged that no reasonable relationship between the residual PAA concentration and log reduction could be derived from the data obtained.

Figure 10.4 Correlation Between PAA and Log Reduction of E. Coli. All Valid Individual Data Point from All Runs

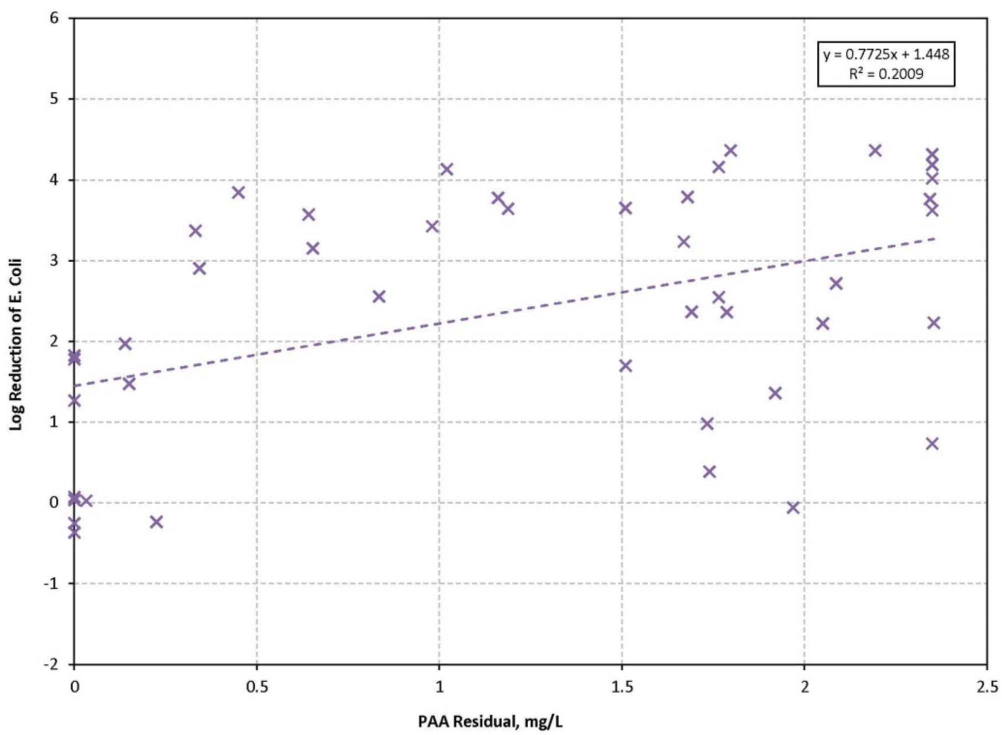


Figure 10.5 Correlation Between PAA and Log Reduction of Fecal Coliforms. All Valid Data Points from All Runs

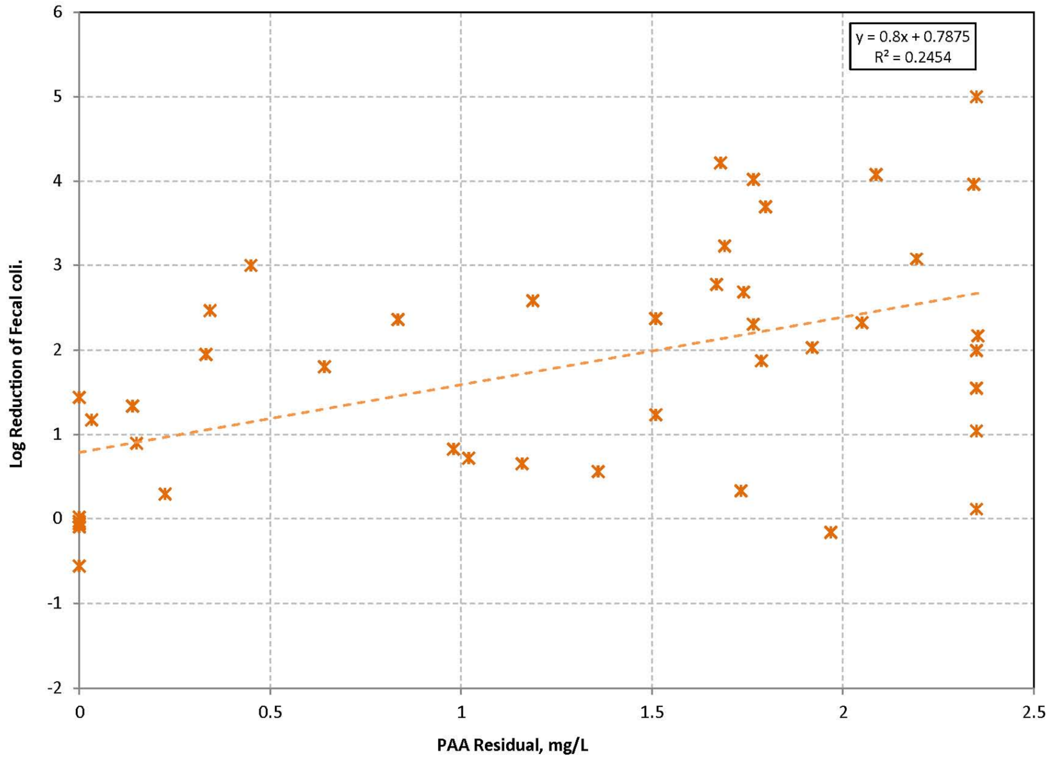
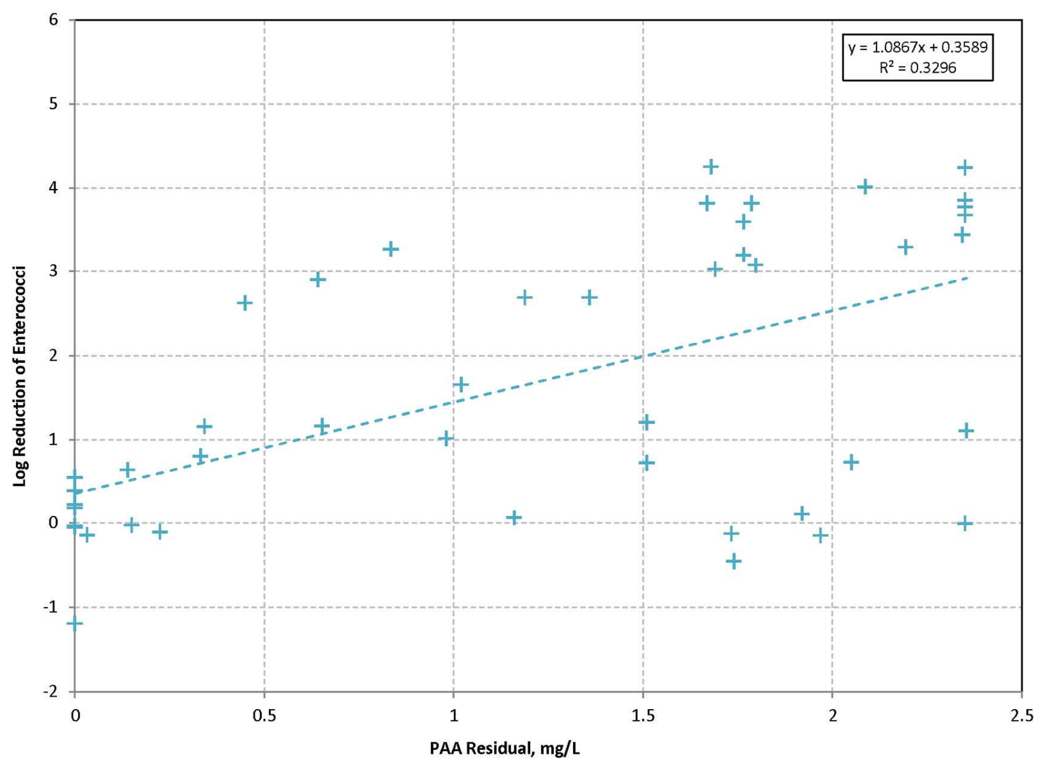


Figure 10.6 Correlation Between PAA and Log Reduction of Enterococci. All Valid Individual Data Points from All Runs



Figures 10.7 through 10.9 show similar data with the PAA contact time factored in, i.e. present the relationship between the log reductions and HRT in the reactor tank multiplied by the measured residual PAA (i.e., equivalent to the contact time (CT) factor in chlorine disinfection). The use of the CT term did not appear to improve the overall correlations. This is consistent with findings in WERF (2003) study, which indicated that contact time for some disinfecting chemicals is not as important as the initial oxidant demand. Additionally, it is noted that following the nominal contact time (HRT) in the PAA reactor, the PAA in the wastewater or in bacteriological samples collected was not neutralized. Consequently, any residual PAA in the samples continued to be available to provide additional disinfection action. This may provide explanation why the initial PAA dose (as normalized by COD) appears to be more important than the residual modified by the contact time.

The HRT in all the Test Runs was practically constant, and was close to 3 minutes in all Test Runs except 1 (6 minutes) and 4 (5 to 8 minutes). Thus, the analysis of relationships within the individual Runs presented below is focused on PAA dose and residual (as opposed to CT factor).

Figure 10.7 Correlation Between CT (PAA Residual x Contact Time) and Log Reduction of E. Coli. All Valid Individual Data Points from All Test Runs

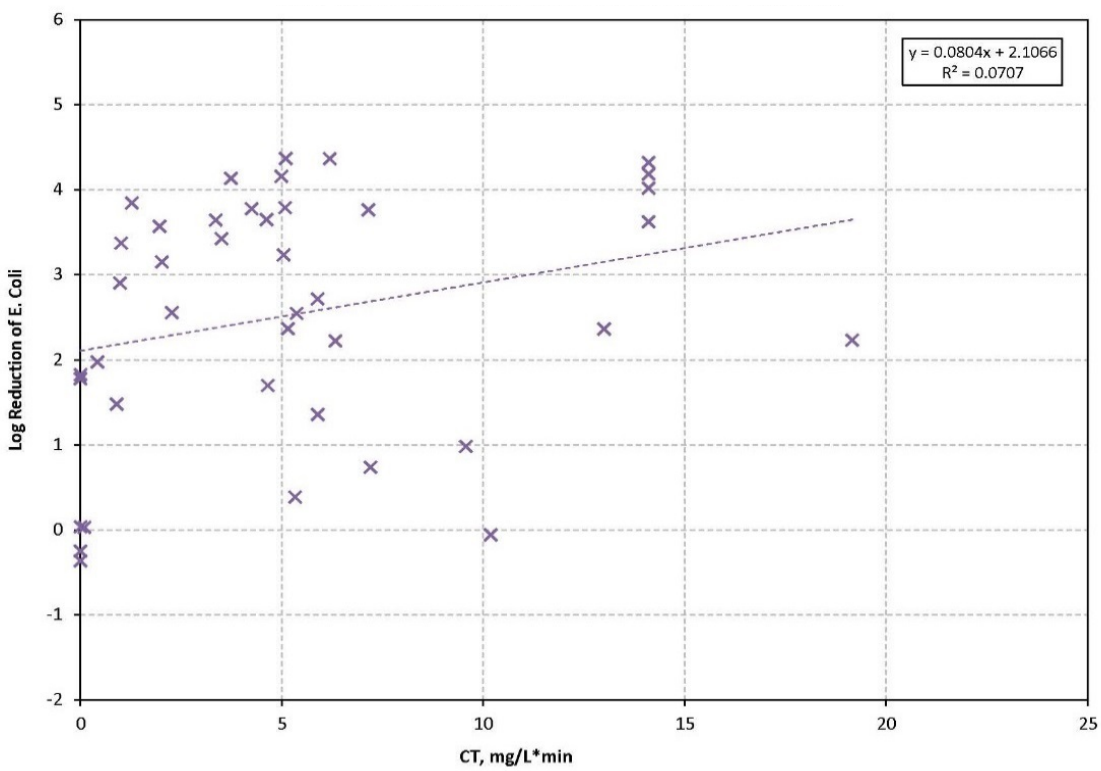


Figure 10.8 Correlation Between CT (PAA Residual x Contact Time and Log Reduction of Fecal Coli. All Valid Data Points from All Test Runs

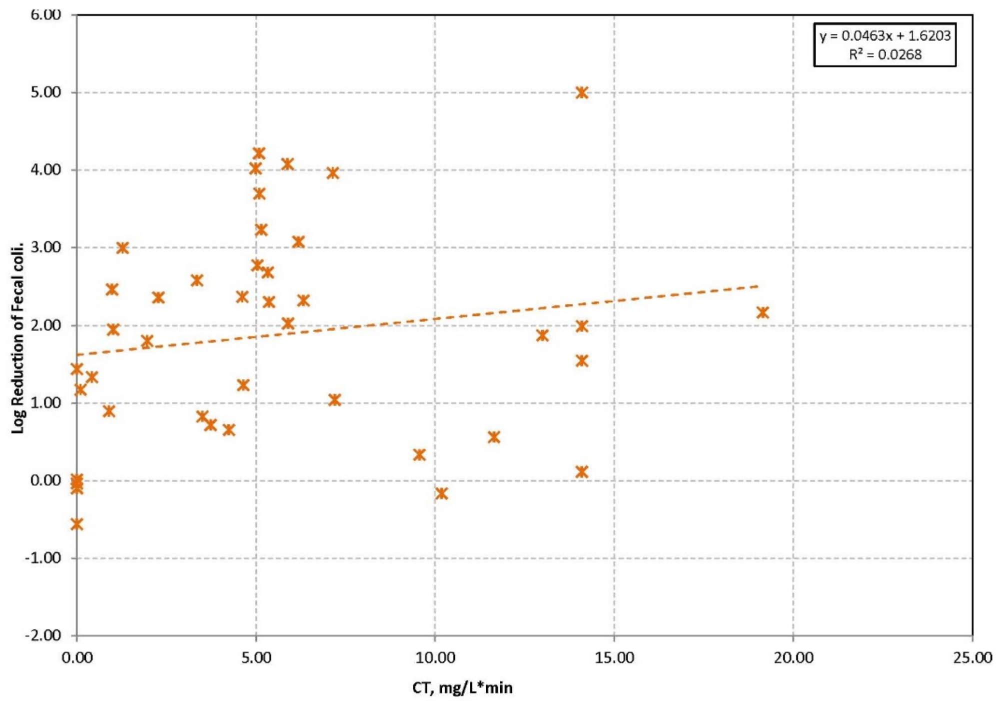
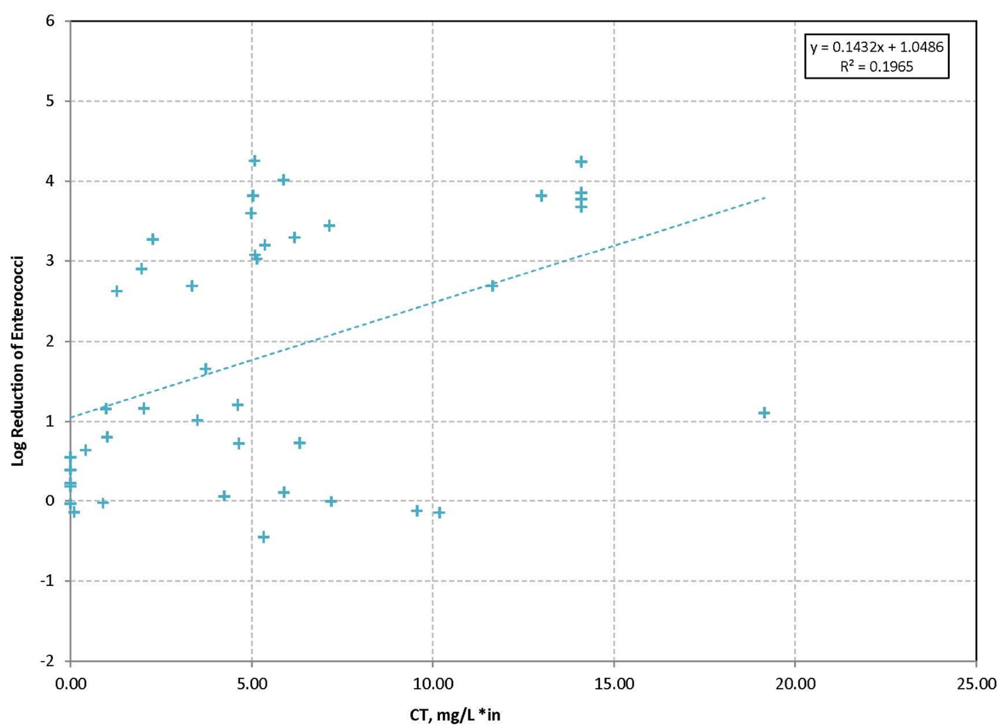


Figure 10.9 Correlation Between CT (PAA Residual x Contact Time) and Log Reduction of Enterococci. All Valid Individual Data Points from All Test Runs



Figures 10.10 through 10.12 present the relationship between the applied PAA dose and log reduction of bacterial indicators. The data are grouped vertically, reflecting relatively constant PAA dose applied within each individual Test Runs (with some exceptions).

Figure 10.10 PAA Dose Applied vs Log Reduction of E. Coli

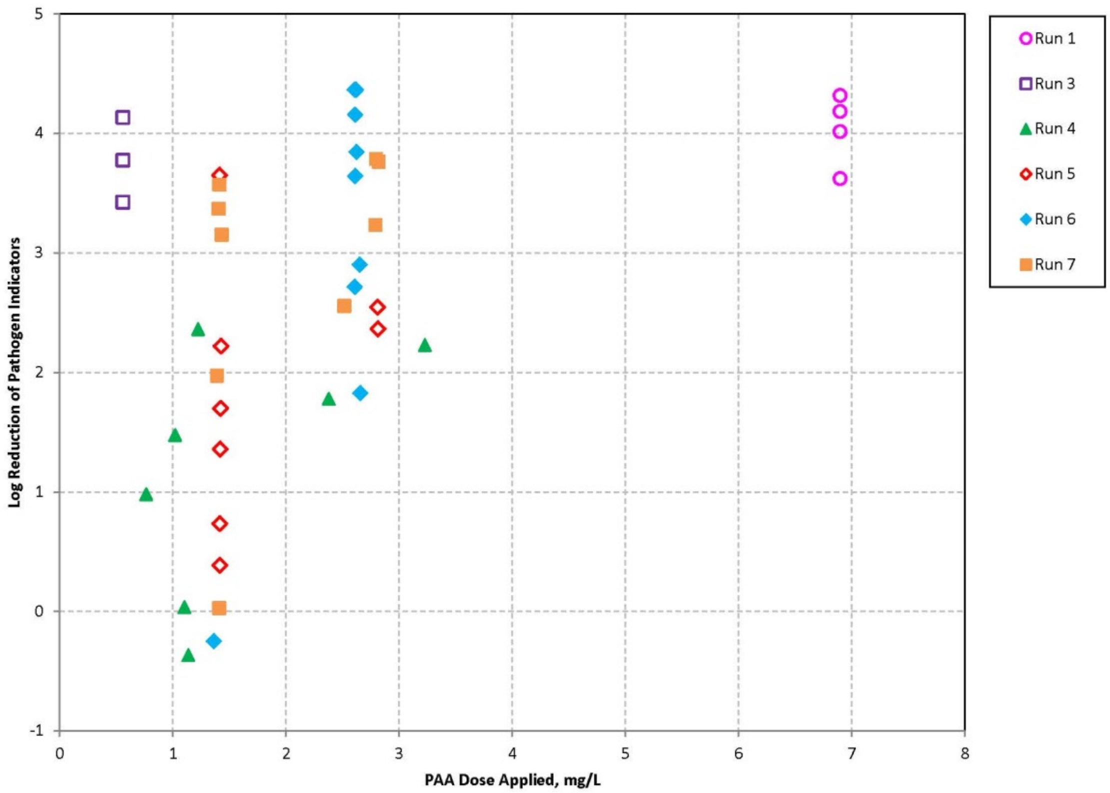


Figure 10.11 PAA Dose Applied vs Log Reduction of Fecal Coliforms

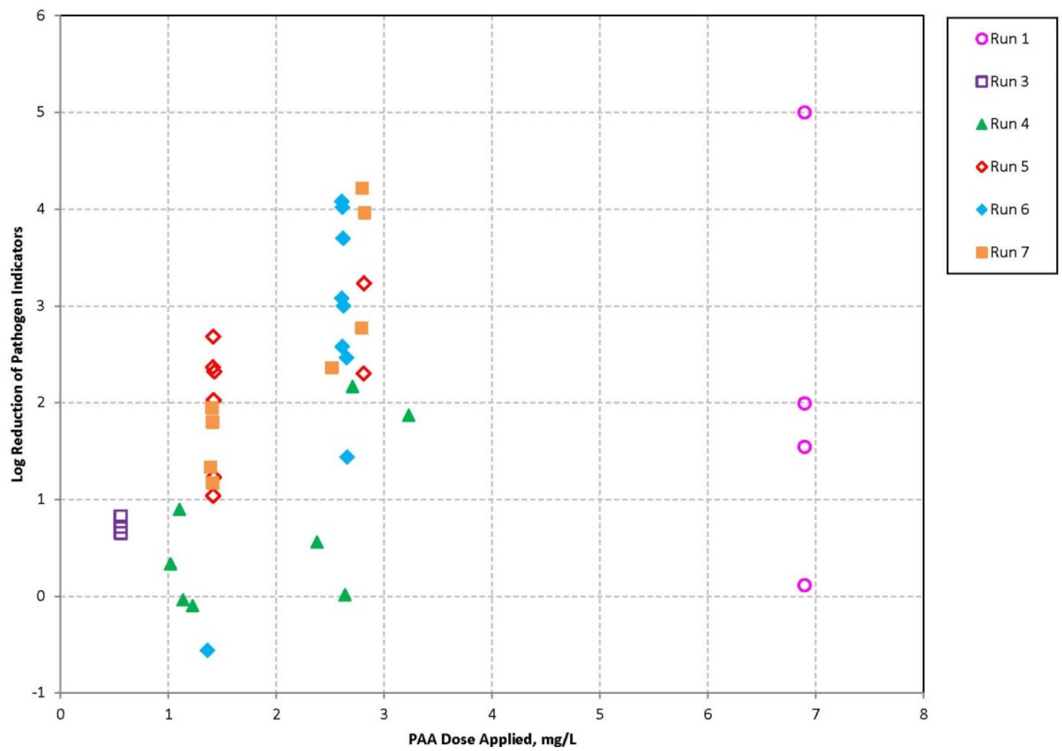
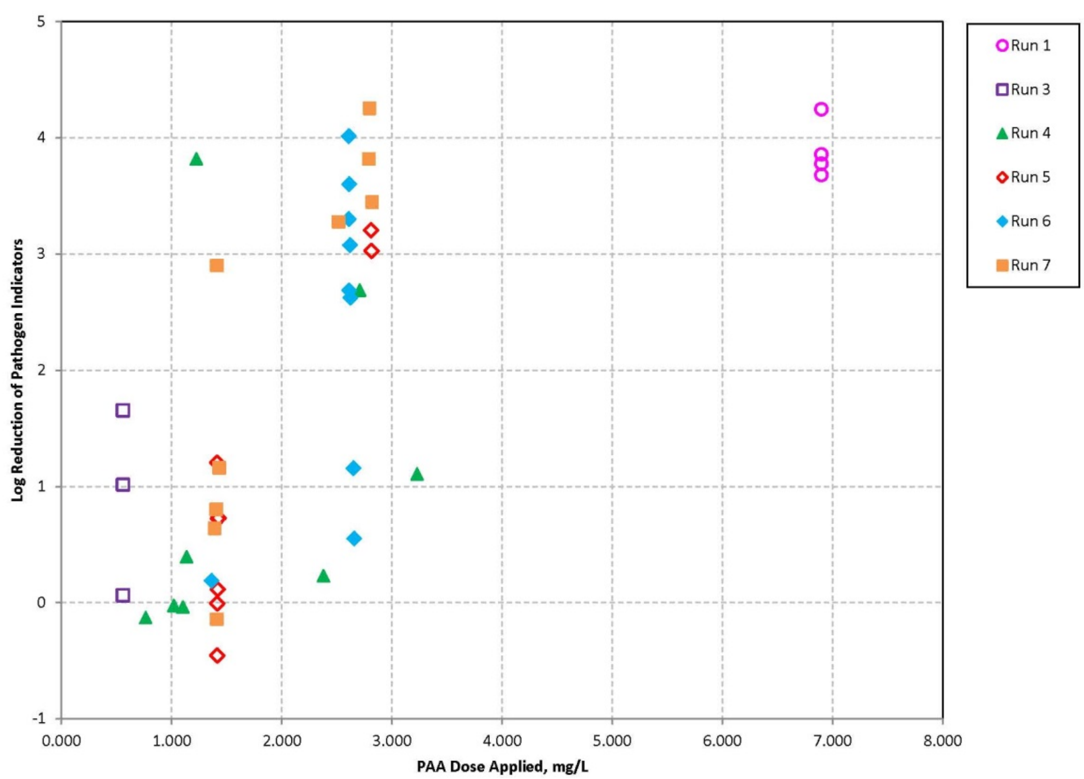


Figure 10.12 PAA Dose Applied vs Log Reduction of Enterococci



Subsequently, the applied PAA dose was normalized with the measured COD by dividing the dose by COD measured in the corresponding wastewater sample. The normalized dose correlates very well with the log reduction of pathogen indicator for all three indicators (Figures 10.13 through 10.15). The only outliers are 3 data points for fecal coliforms for the Test Run 1, where a few interferences and out of range results were reported by the laboratory.

Figure 10.13 PAA Dose per COD vs Log Reduction of E. Coli

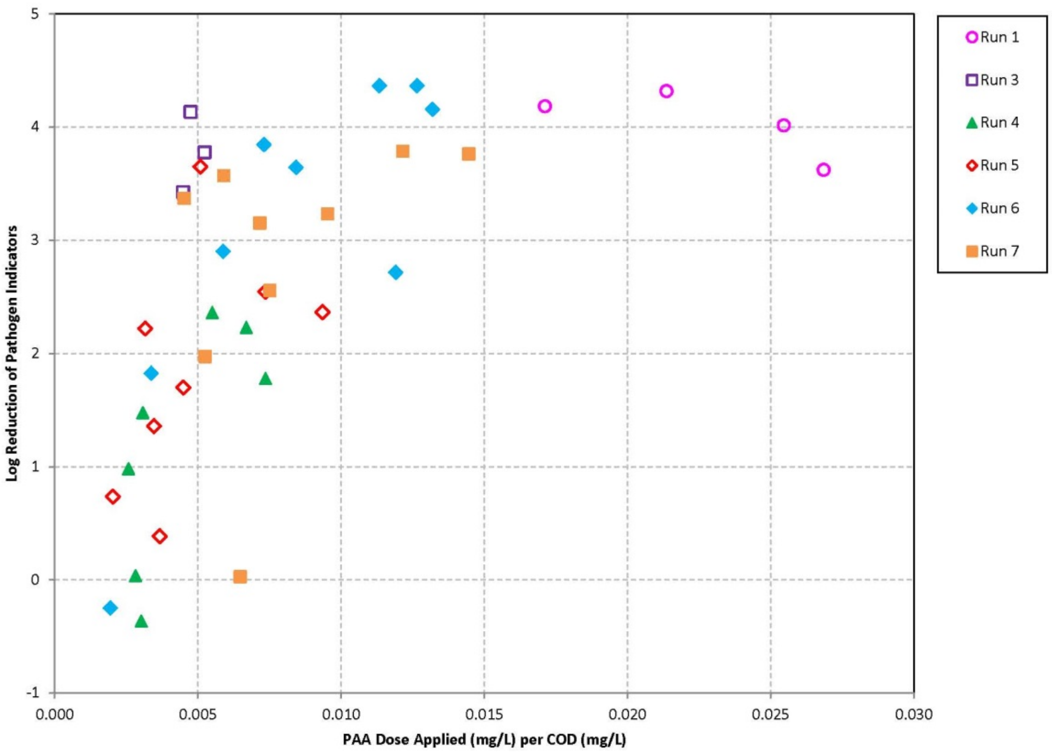


Figure 10.14 PAA Dose per COD vs Log Reduction of Fecal Coliforms

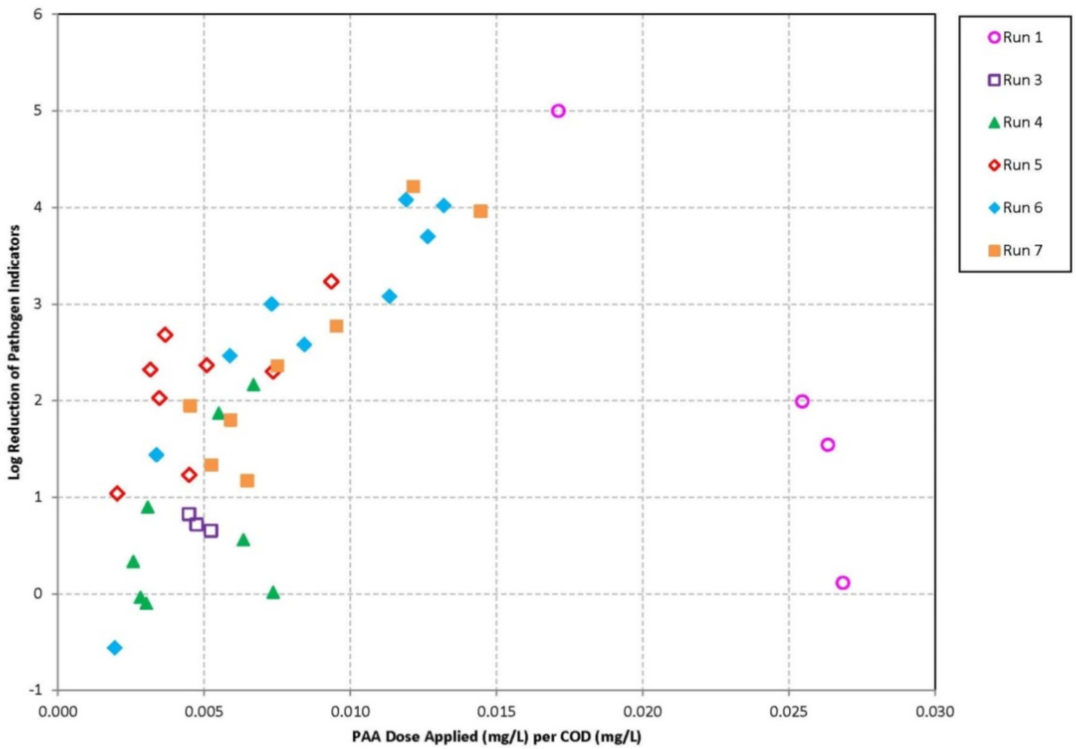


Figure 10.15 PAA Dose per COD vs Log Reduction of Enterococci

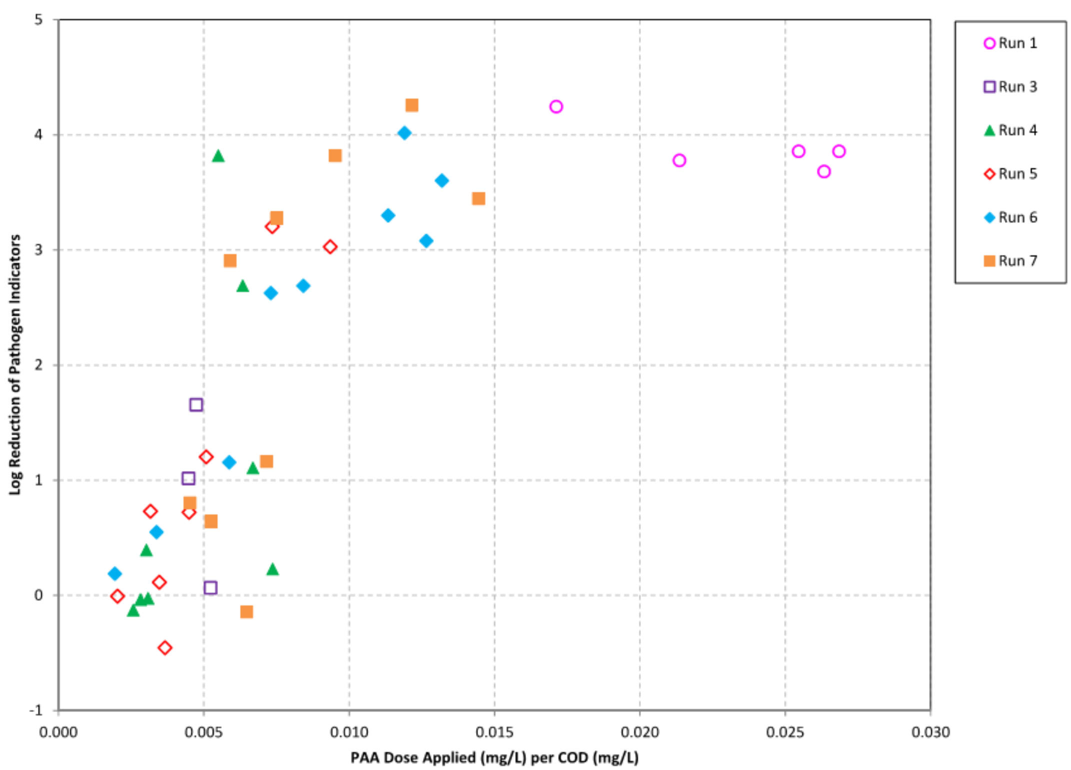


Figure 10.16 provides data from all Test Runs consolidated for each of the 3 pathogen indicators, except for the 3 outlying data points for fecal coliforms. Best fit logarithmic regressions lines shown on this graph indicate a very good fit, with better than 99% confidence level. Figure 10.17 visualizes the same information on a logarithmic scale.

From Figure 10.17 it could be inferred that PAA dose of 0.01 mg/L of PAA per mg/L of COD typically results in 3 log reduction of fecal coliforms, with slightly higher effectiveness for E. coli and slightly lower for Enterococci. Increasing the relative dose to above 0.015 mg/L of PAA per mg/L of COD increased log reduction to 4. Further increase of the PAA dose appeared to have limited effect on further increasing reduction of the bacterial densities, although data in that range are too limited to allow for a firm conclusion.

Figure 10.16 PAA Dose per COD vs Log Reduction of Pathogen Indicators

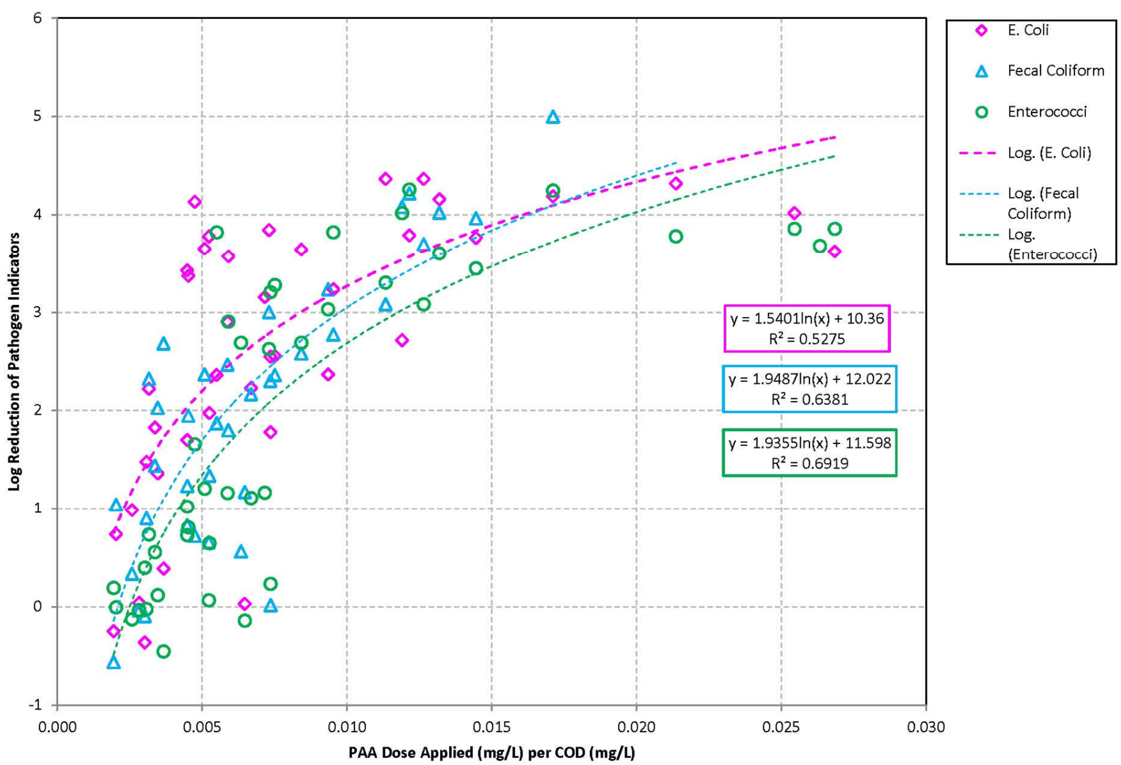
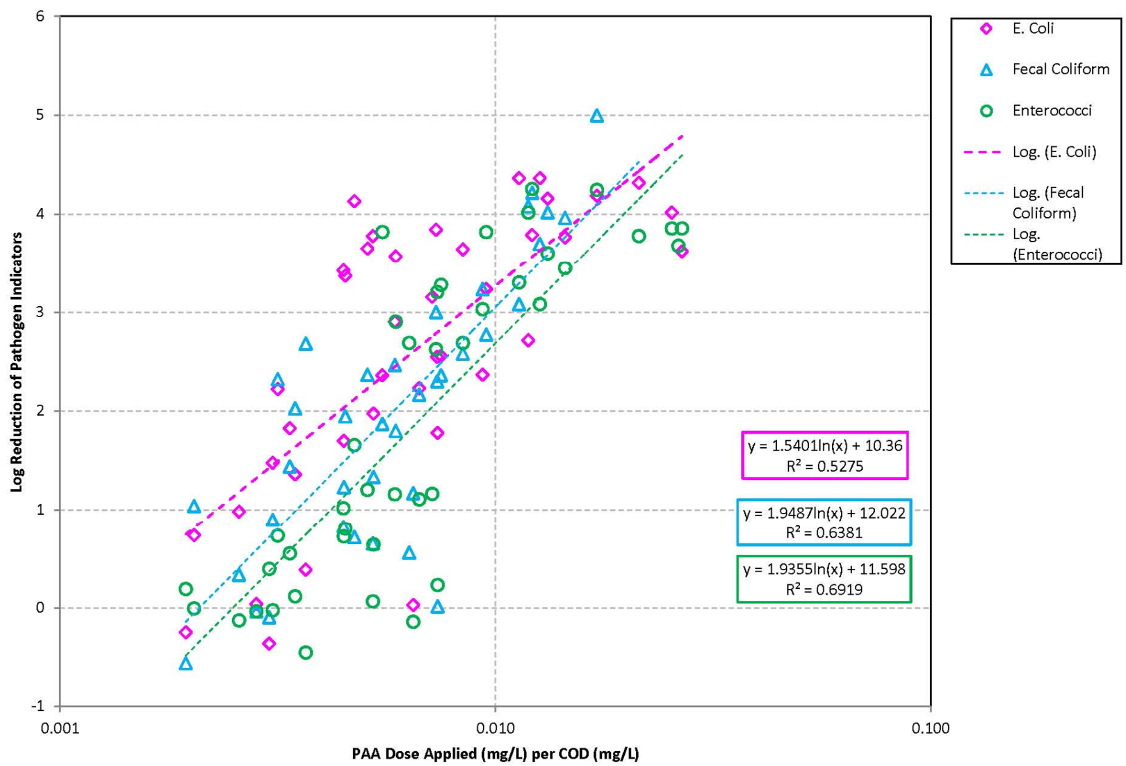


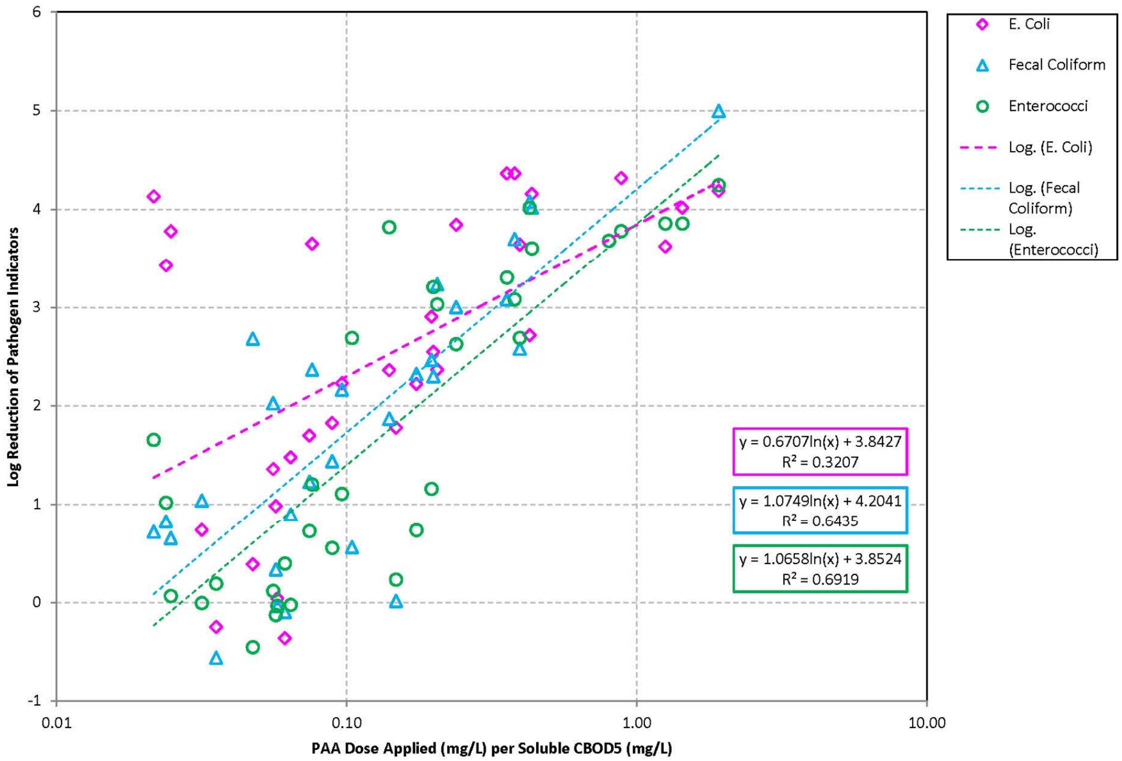
Figure 10.17 PAA Dose per COD vs Log Reduction of Pathogen Indicators



Several literature sources quoted by Kitis (2004), report that a PAA CT factor of 200 (i.e., dose of 20 mg/L with contact time of 10 minutes) was optimal for log reduction of fecal coliforms of 3.5 to 4 in primary effluent, with little improvement observed at even higher CT factors. The strength (COD) of the tested wastewater was not provided. While the primary effluent is expected to be richer in COD than CSO discharge, the results obtained in the current study indicate PAA performance at least as good as reported elsewhere.

Figure 10.18 provides similar correlation utilizing PAA dose normalized to soluble $CBOD_5$ concentration, with the resulting correlations also indicating good fit. Only data for E. coli show some outliers.

Figure 10.18 PAA Dose per Soluble CBOD5 vs Log Reduction of Pathogen Indicators



10.4 Results from Individual Test Runs (PAA)

10.4.1 Test Run 1

During the Test Run 1, the PAA pump initially did not feed properly and during the first 3 sampling events little, if any, PAA was being delivered. Data from these 3 initial sampling events were not used for graphs and correlations. During the remainder of the Test Run 1, the 6 gpd PAA pump was delivering too much PAA, with the PAA residual exceeding the maximum measurable concentration (i.e., 2.35 mg/L), despite the adjustments made to lower the pump output. The PAA residual and disinfection performance in Test Run 1 is provided in Table 10.2 and illustrated on Figures 10.1 through 10.3. The recorded log reductions for E. Coli and Enterococci were quite consistent at a respectable level of approximately 4 for all data points. Data for fecal coliform are more variable, with some interferences and out-of-range results reported. Since the PAA residual for all valid samples was non-quantifiable (at >2.35 mg/L) and log reduction for pathogen indicators was at the same level (except for fecal coliforms), no further correlation of the PAA data from Run 1 was possible.

10.4.2 Test Run 2

Test Run 2 did not include PAA testing.

10.4.3 Test Run 3

During the Test Run 3, the PAA metering pump was not functioning until late into the Run and only 3 sets of samples were collected. With the PAA residual measured at close to 1 mg/L value for all 3 samples, the E. Coli log removals were closely clustered in 3.5 to 4.2 range as previously illustrated in Figure 10.1. Surprisingly, the corresponding fecal coliform data showed equally consistent results but at very low log removal range of below 1 (Figure 10.2). In turn, Enterococci removal data were widely scattered for the same 3 sampling events (Figure 10.3).

10.4.4 Test Run 4

In this run the problems with the oversized pump were observed, as it was difficult to maintain a stable PAA flow at a low pump stroke and speed settings. Flow of PAA was observed to stop completely on several occasions. PAA flow rate measurements taken with drawdown column were inconsistent with that expected from the corresponding pump settings. Consequently, the PAA residual measurements taken throughout the run varied considerably, as illustrated on Figure 10.19. Figure 10.20 shows marginal correlations between that residual and log reduction of bacterial indicators (except for a relatively strong correlation for fecal coliforms).

Figure 10.19 Test Run 4 (11/06/2014). PAA Performance (Following Terre Kleen)

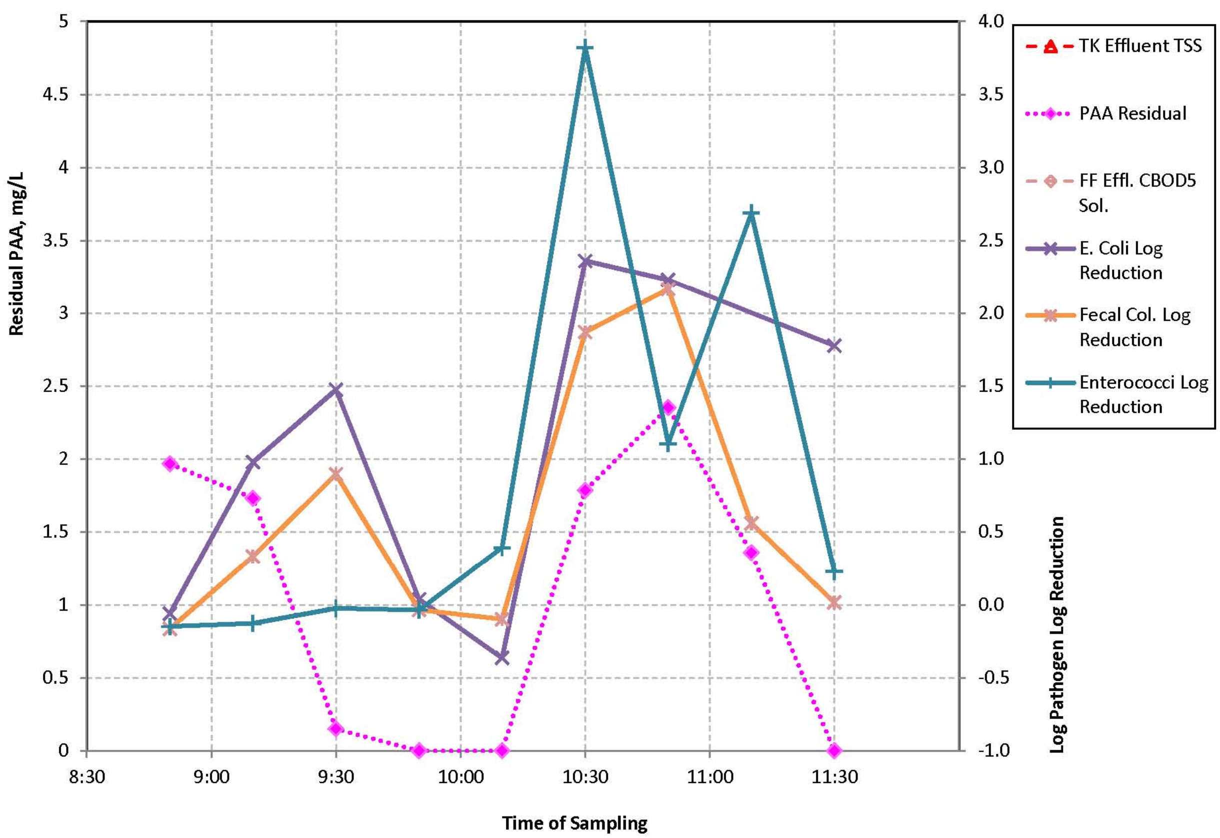
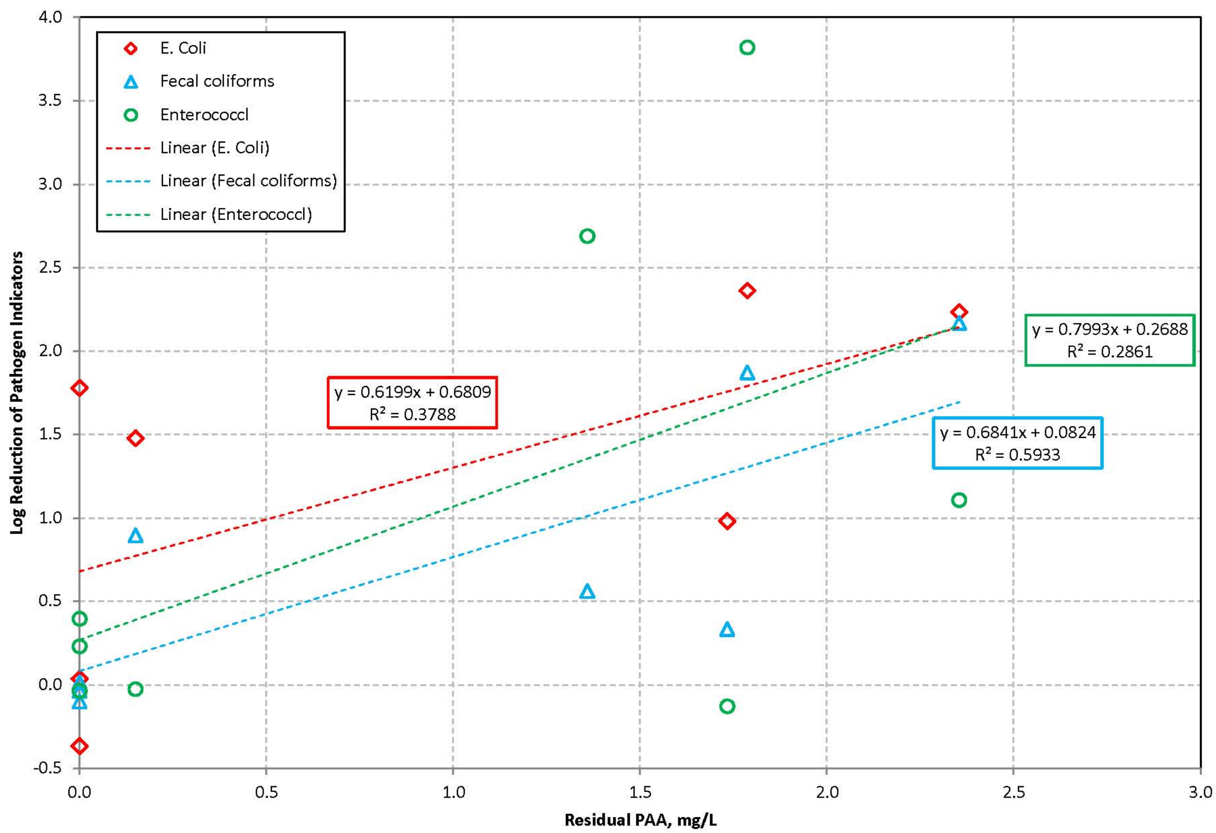


Figure 10.20 Residual PAA vs Log Reduction of Pathogen Indicators Test Run 4



10.4.5 Test Run 5

This was the first run with a smaller PAA pump installed and the oxidant flow rate was more consistent and easier to control with the residual PAA remaining mostly in a relatively narrow range between 1.5 and 2 mg/L. However, the applied dose, as calculated from the pump settings, was for most of the data points smaller than the measured residual (Table 10.2). Figures 10.21 through 10.23 show the resulting pathogen indicator log reductions in the context of the results from other storms.

10.4.6 Test Run 6

This Test Run was characterized by a very high concentration of TSS and other parameters at the beginning of the Run, with a gradual tailing-off as the storm progressed. This is illustrated on Figure 10.21, with additional chronological plots available in Appendix B. The PAA dose applied was kept constant during the Run, except for the first sampling event. Consequently, the **residual PAA concentrations and ratio of PAA dose to COD gradually increased during the test Run and with it the efficiency of removal of the pathogen indicators (Figures 10.21 and 10.22).**

Figure 10.21 Test Run 6 (8/11/2015). PAA Performance (Following Terre Kleen)

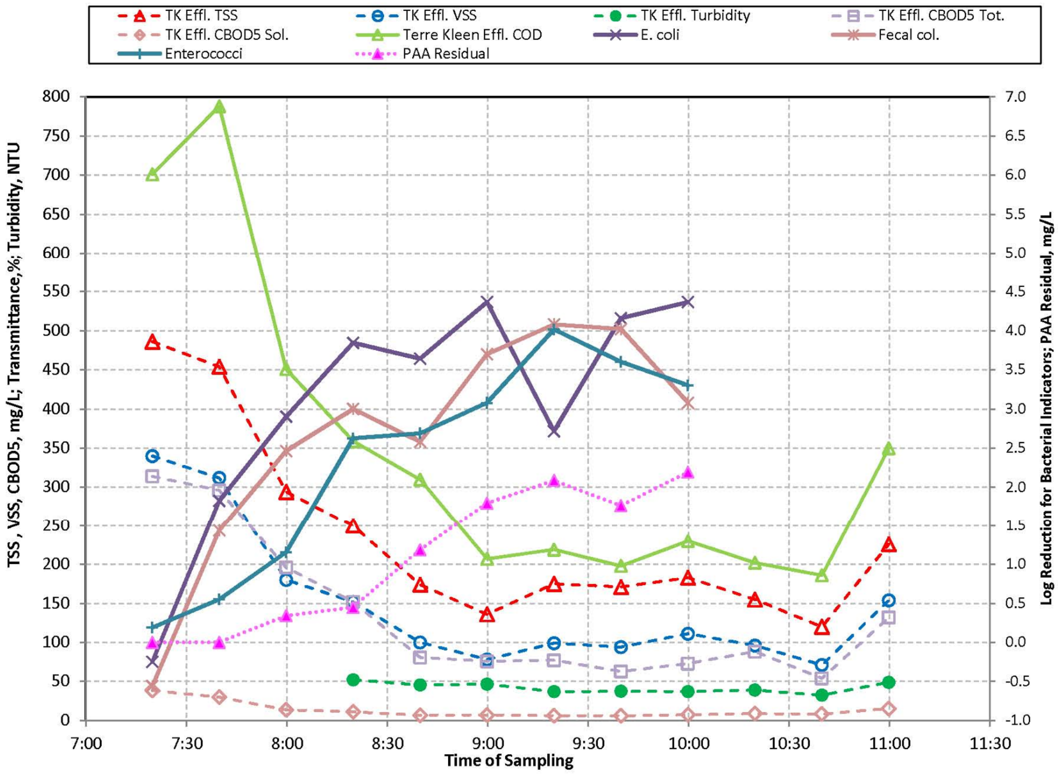


Figure 10.22 Test Run 6 (8/11/2015). PAA Performance (Following Terre Kleen)

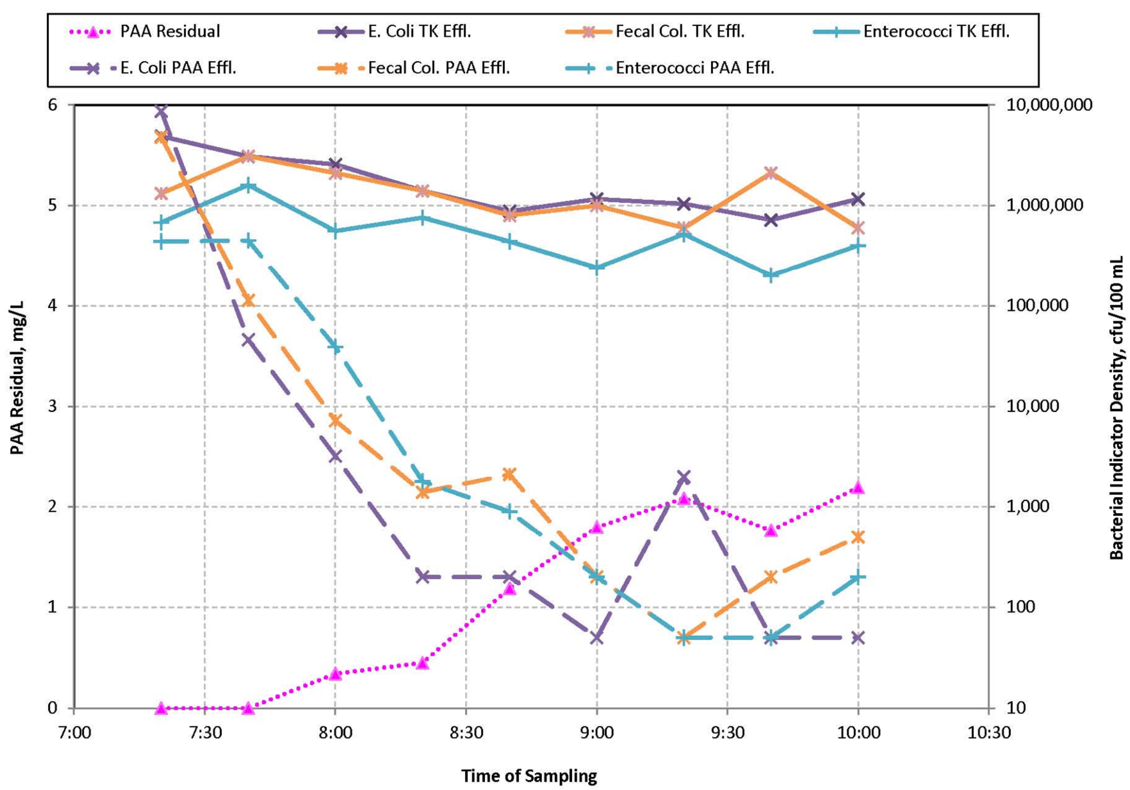


Figure 10.23 indicates a strong correlation between the residual PAA and log reduction for pathogen indicators, at a confidence level exceeding 95% for all indicators. A similarly strong correlation is observed between the wastewater COD and log reduction (Figure 10.24) and even stronger for soluble $CBOD_5$ (Figure 10.25). These correlations are the expected result of the fact that PAA applied dose was constant during the test run and the previously discussed effect of the ratio of the applied PAA to COD (and soluble $CBOD_5$).

Figure 10.23 Residual PAA vs Log Reduction of Pathogen Indicators Test Run 6

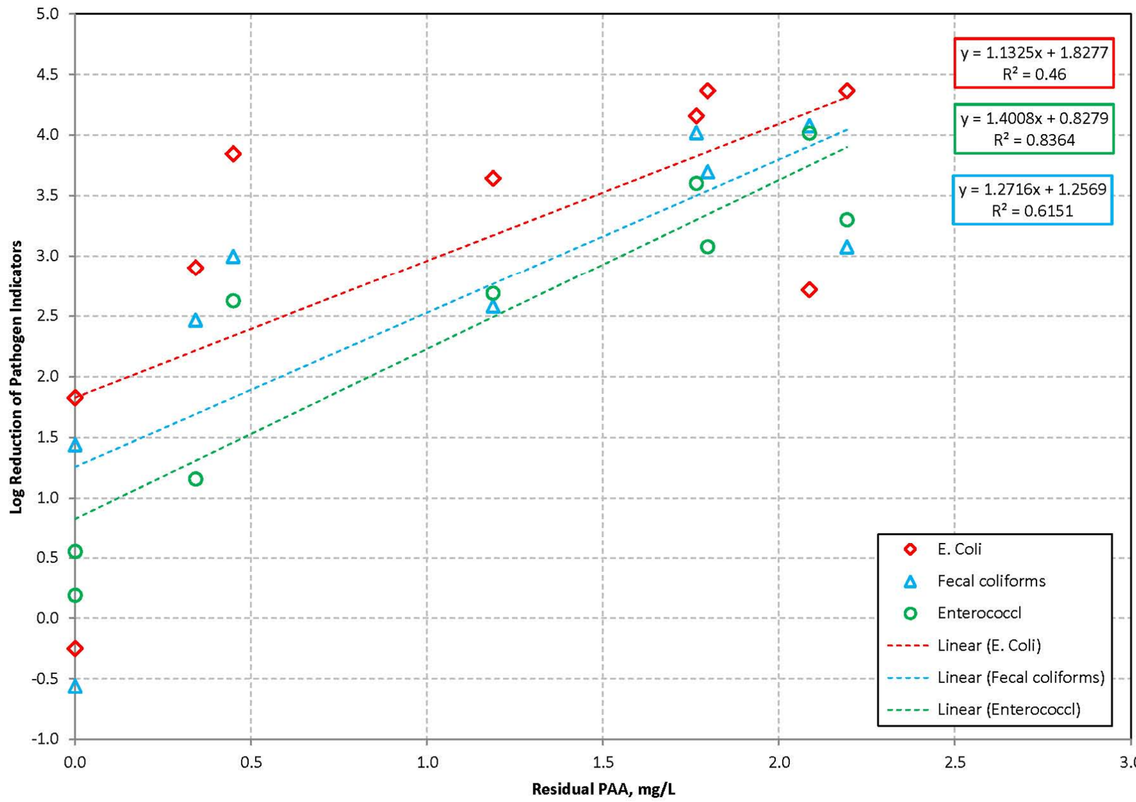


Figure 10.24 COD vs Log Reduction of Pathogen Indicators Test Run 6

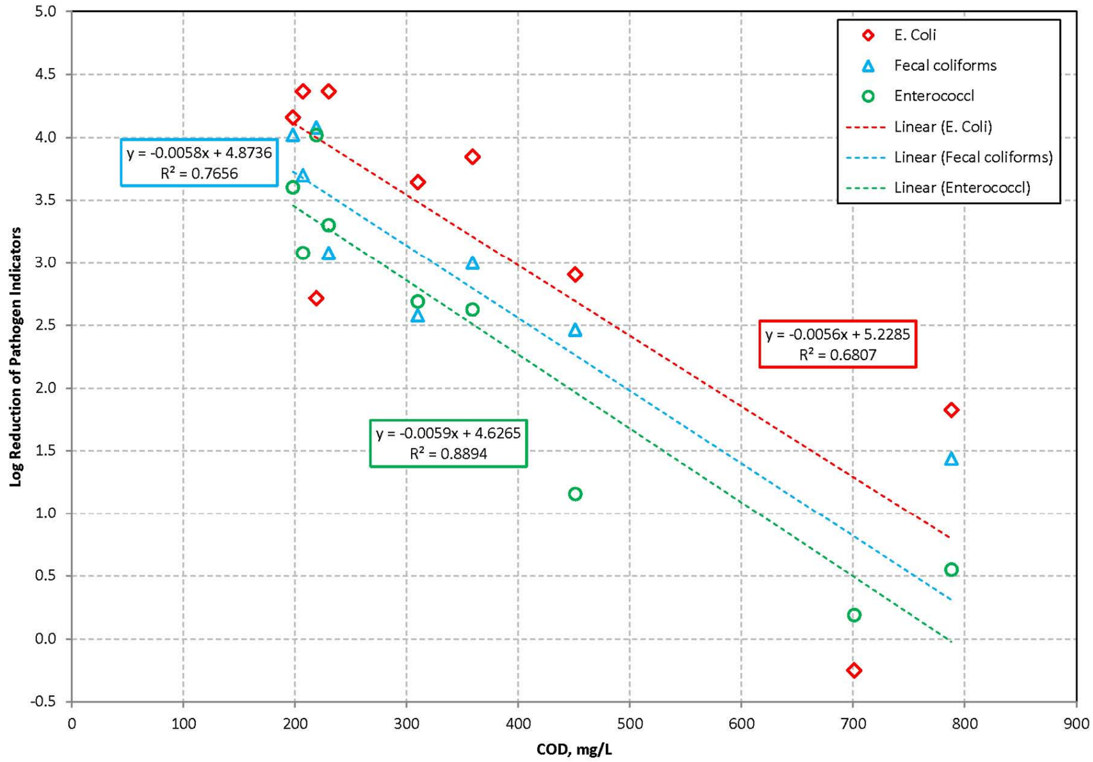


Figure 10.25 Soluble CBOD5 vs Log Reduction of Pathogen Indicators Test Run 6

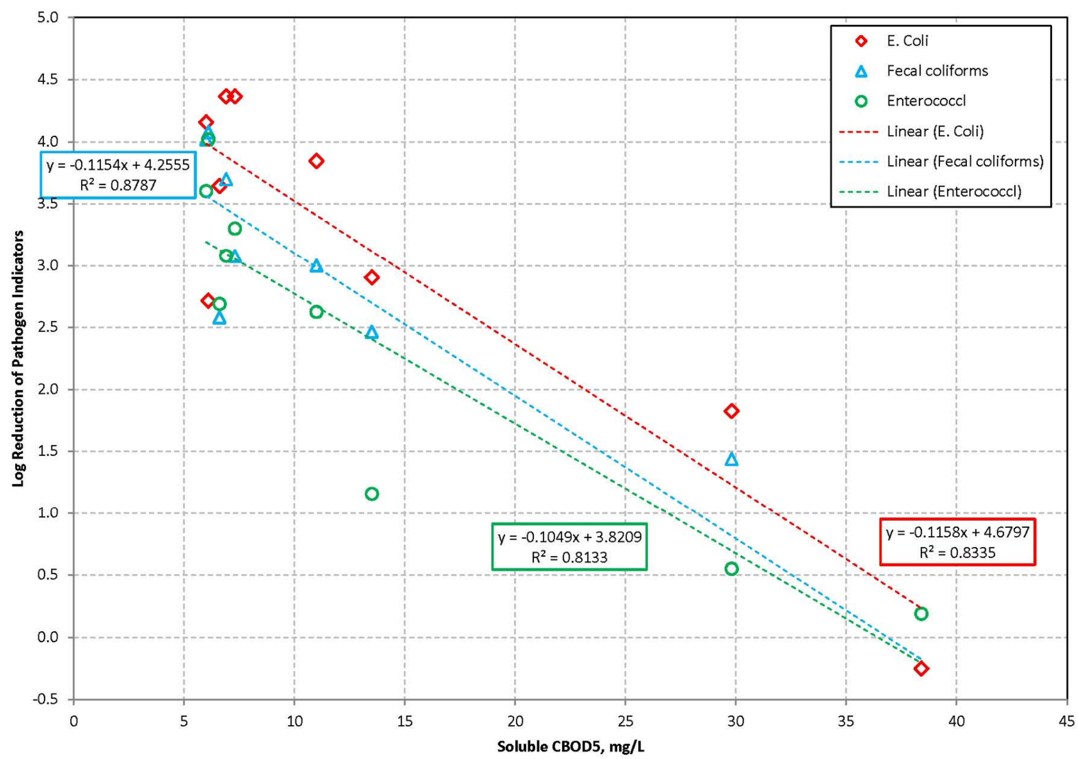
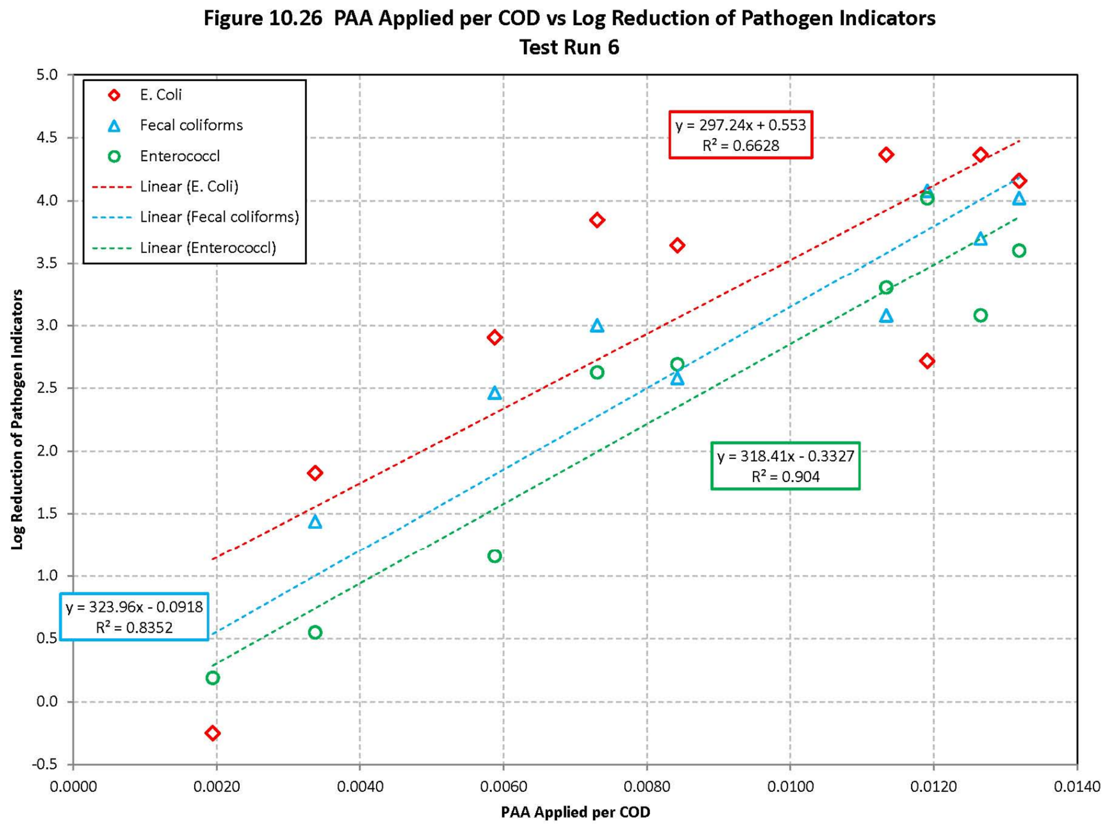


Figure 10.26 illustrates a very strong correlation between the ratio of the (calculated) applied PAA dose to COD of the wastewater and log reductions for all pathogen indicators.

Figure 10.26 PAA Applied per COD vs Log Reduction of Pathogen Indicators Test Run 6



10.4.7 Test Run 7

Due to the malfunction of the FlexFilter, the PAA reactor was fed in this Test Run with raw wastewater. The delivered dose of the PAA was adjusted several times during the Run resulting in fluctuations in the residual PAA concentration (Figure 10.27).

Figure 10.28 indicates a strong correlation between the residual PAA and log reduction for pathogen indicators, at confidence level exceeding 99% for Fecal coliforms and Enterococci and just below 95% for E. coli. Similarly, strong relationship exists between the ratio of the (calculated) applied PAA dose to COD and log reductions, except for E. Coli (Figure 10.29).

Figure 10.27 Test Run 7 (9/10/2015). PAA Performance (No Pre-Treatment)

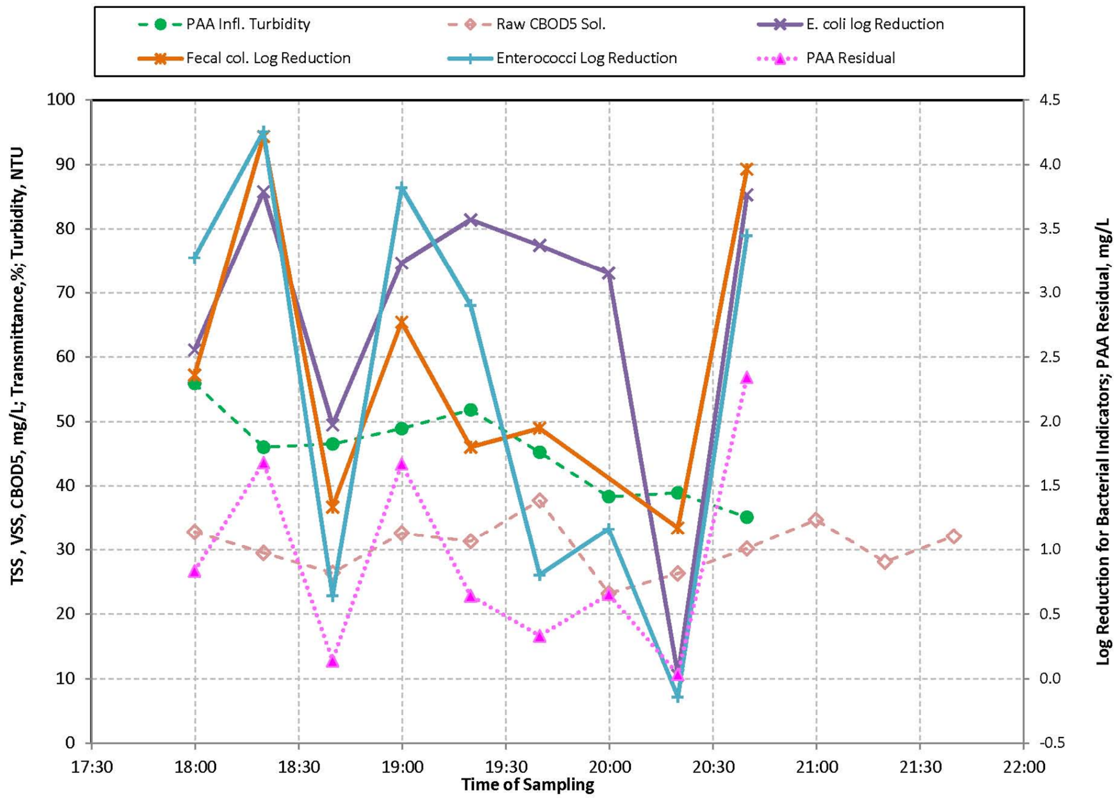


Figure 10.28 Residual PAA vs Log Reduction of Pathogen Indicators Test Run 7

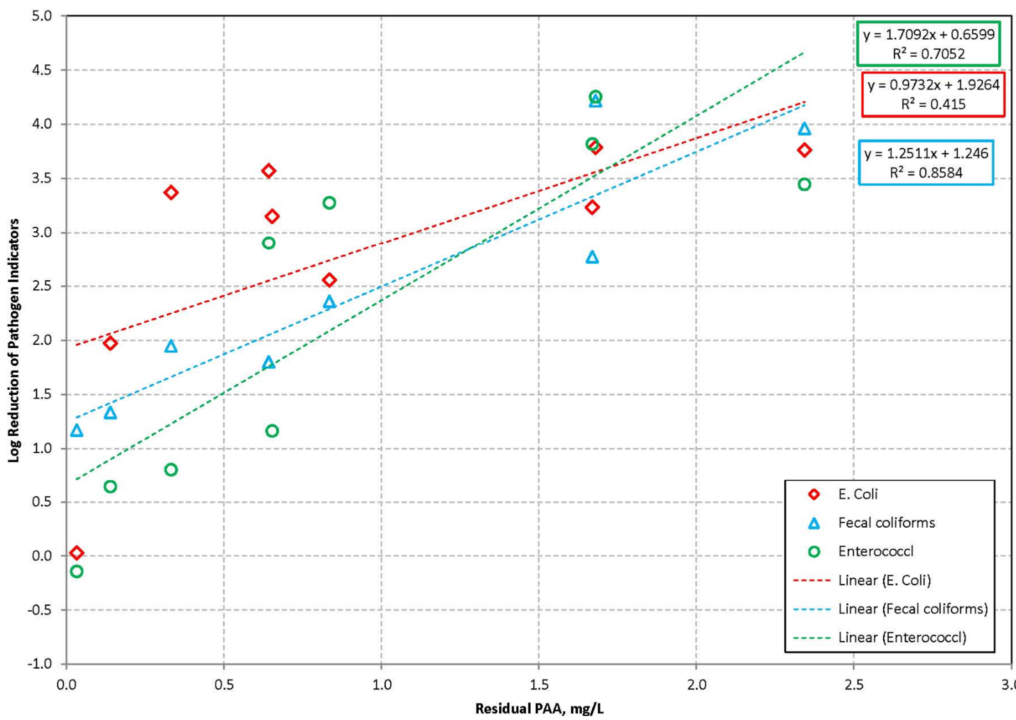
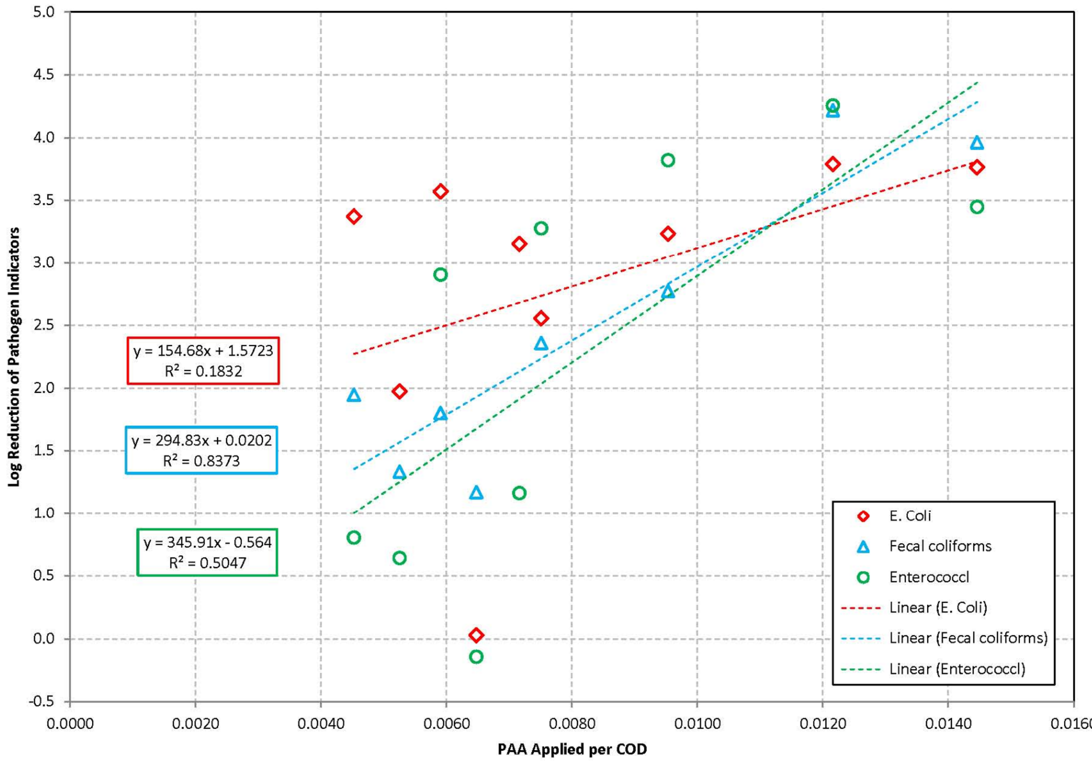


Figure 10.29 PAA Applied per COD vs Log Reduction of Pathogen Indicators Test Run 7



10.4.8 Test Runs 8 and 9

As discussed in Section 7, it was decided to run the two last tests on simulated wastewater. The simulated wastewater was generated by mixing groundwater from the underground tankage at the site (former primary clarifiers) with raw wastewater at an approximate ratio of 1:1.

The simulated wastewater at PAA unit influent (as pretreated in Storm King and Terre Kleen for Test Runs 8 and 9, respectively) had the average COD commensurable with the previously tested CSO wastewater (Table 10.1). However, the soluble $CBOD_5$ was higher than in the previous Test Runs. In turn, the TSS concentrations were lower than typically measured in the initial Test Runs, likely the result of the lack of contribution from heavier TSS scoured from the sewer system during the real CSO events.

Unfortunately, during the both Tests Runs 8 and 9 no measurable PAA residual was achieved, even though the PAA feed pump was operating at full capacity. Accordingly, little or no reduction in density of the bacteria during these Runs was observed across the PAA unit (Table 10.1).
A possible explanation of this lack of PAA residual is an accelerated degradation of PAA caused by high salinity. Such effects were reported by Liu *et al.* (2014), where 1% and 3% sea water solutions were found to significantly accelerate degradation of PAA solutions, although at half-life times of 30 to 60 minutes. In tests on undiluted seawater Howarth (2003), found half-life of PAA to be 12 to 30 minutes, depending on the initial PAA concentration. Since the pilot test site is adjacent to coastline (approximately 650 feet), groundwater in the underground tanks could be impacted by saltwater

intrusion. During the Run 9 conductivity of the simulated wastewater was measured at 4.2 uS/cm, which is consistent with about 10% contribution of seawater. Subsequent test of the groundwater from the underground tanks confirmed that contamination, with the TDS measured there at 4,630 mg/L. Even though the contact time in the Test Runs 8 and 9 was only 3 minutes, the high salinity in our simulated wastewater was likely contributing to the accelerated decay of the PAA and the lack of residual.

The relatively high soluble $CBOD_5$ in the simulated wastewater (Table 10.1) could have been another factor in the lack of a measured PAA residual.

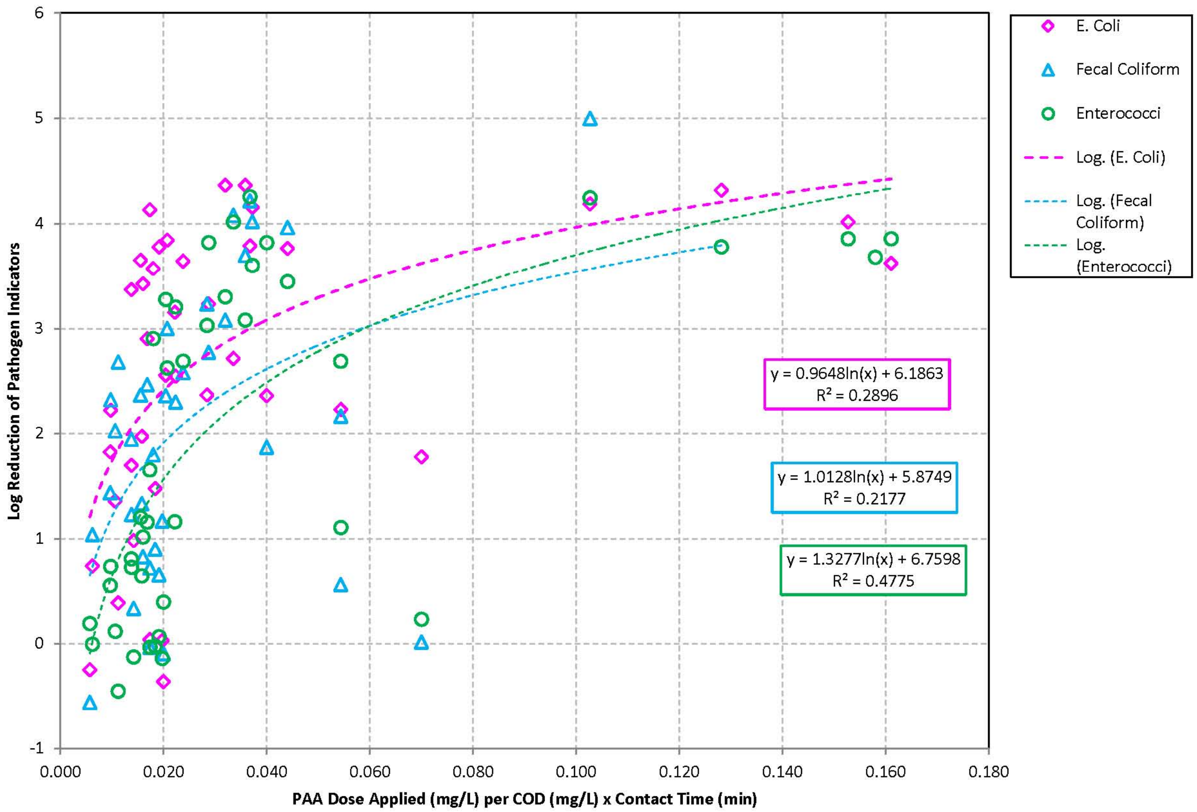
In any case, due to the lack of PAA residual and meaningful log removal, the results of PAA disinfection tests for the Test Runs 8 and 9 are not discussed further.

10.5 Additional Analysis of the Results

10.5.1 Effect of Contact Time

The effect of the contact time (through the CT factor) was previously discussed in Section 10.3. In order to further inspect the impact of the contact time, the previously developed critical relationship between the applied PAA dose normalized to COD with log reduction was further modified by multiplying the ratio by the contact time. Figure 10.30 provides the resulting correlation and comparison with Figure 10.16 shows that the resulting fit is weaker. This indicates that test results developed in this pilot program do not demonstrate a significant impact of the PAA contact time on log reduction under the conditions tested.

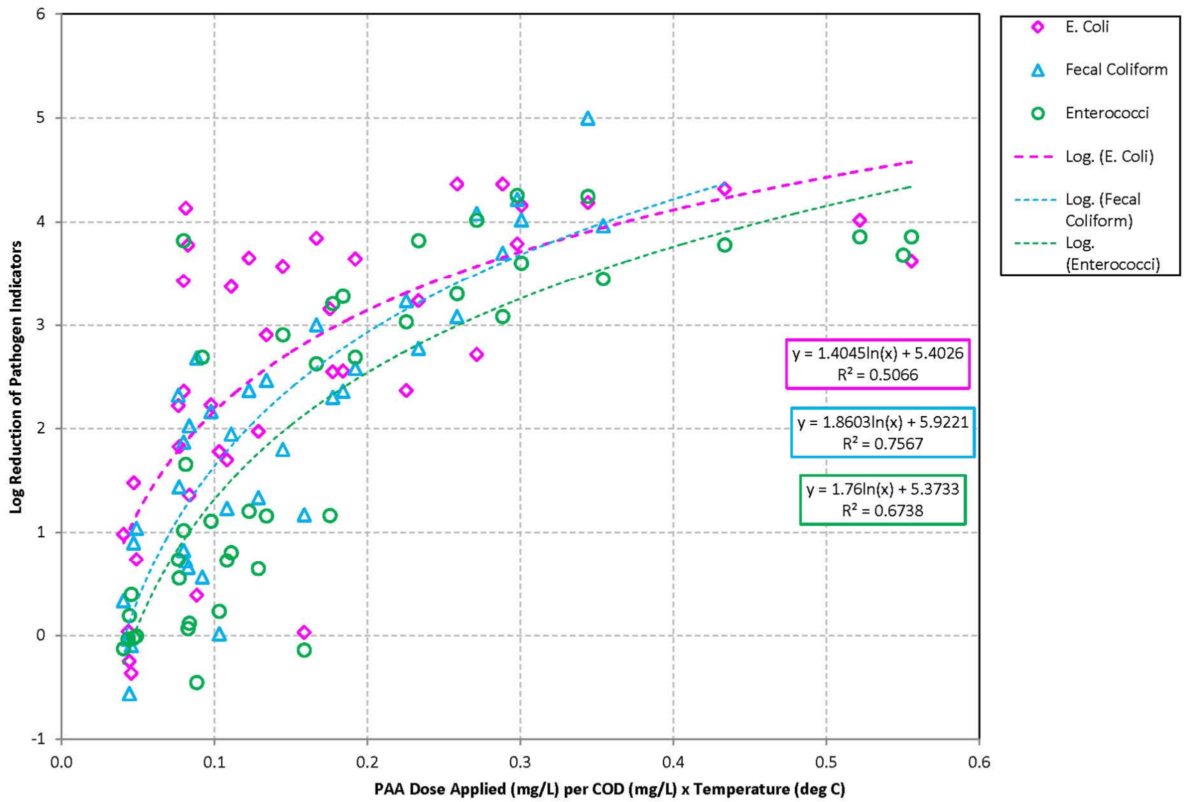
Figure 10.30 PAA Dose per COD x Contact Time vs Log Reduction of Pathogen Indicators



10.5.2 Effects of Temperature and pH

Temperature during the Test Runs varied from 15° to 24° C (Table 10.3). In order to further inspect impact of the temperature, the previously developed critical relationship between the applied PAA dose normalized to COD with log reduction was further modified by multiplying the ratio by the wastewater temperature. Figure 10.31 provides the resulting correlation and comparison with Figure 10.16 shows no significant effect. While such effect would be expected based on literature data for other chemical oxidants (WERF 2005), the data developed during this study are too limited in this respect to allow drawing of a conclusion.

Figure 10.31 PAA Dose per COD x Temperature vs Log Reduction of Pathogen Indicators



Chhetri *et al.*, (2014) found that PAA degradation in simulated CSO wastewater is unaffected by pH in the range from 4.16 to 8.0. During all of the Test Runs the pH of wastewater remained in the relatively narrow neutral range of pH from 6.5 to 7.5. Considering the large variability in the other water quality parameters and test conditions, no observable impact of the minor variations in pH were discernible.

10.5.3 Correlation between Individual Pathogen Indicators

Table 10.3 shows that the most numerous pathogen indicators in the PAA reactor influent were fecal coliforms, as expected, followed by E. coli and Enterococci. This is consistent with the CSO testing reported in WERF (2005) study, with similar range of the densities reported. Figures 10.32 through 10.34 illustrate correlation between densities of various pathogen indicators in the influent to the PAA reactor, sorted according to the Test Run. Figures 10.35 through 10.37 provide the same data consolidated without distinction (or sorting) according to Test Runs. Regression equations shown on Figures 10.35 through 10.37 indicate that correlation between E. coli and Enterococci is stronger than between fecal coliforms and E. coli. This is unexpected, as E. coli is a subset of fecal coliforms and as such a better correlation was expected.

Figure 10.32 Influent E. Coli vs Enterococci

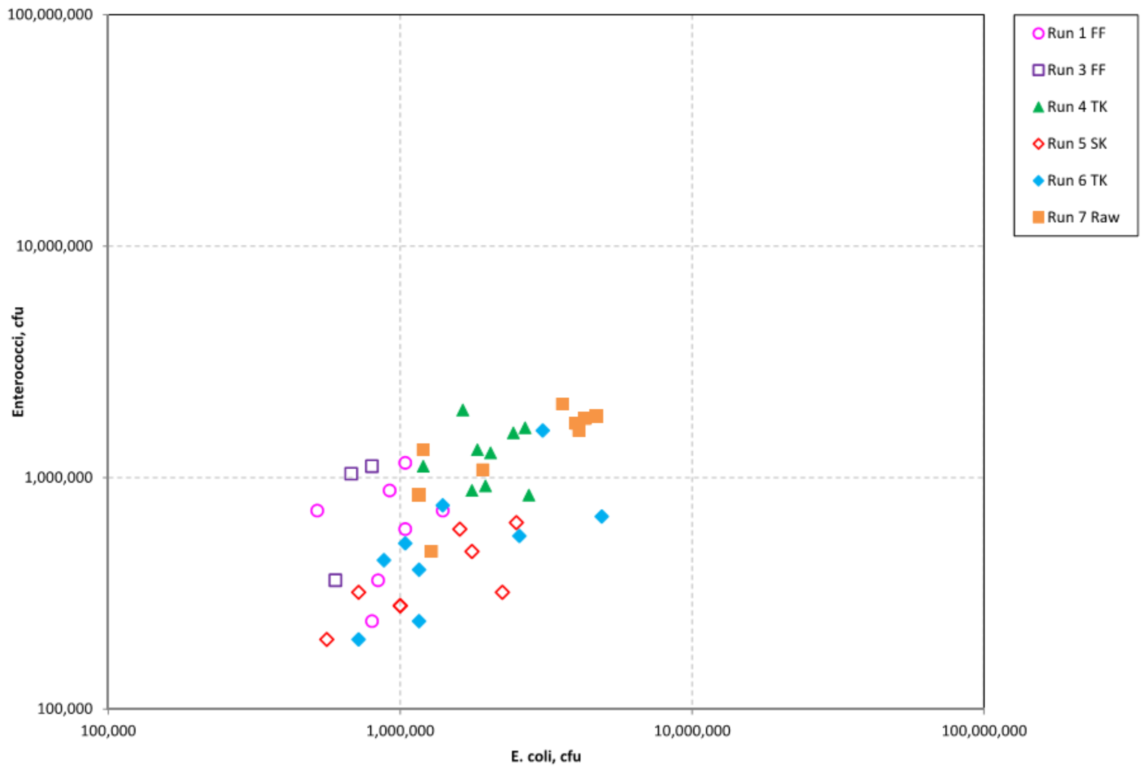


Figure 10.33 Influent Fecal Coliform vs Enterococci

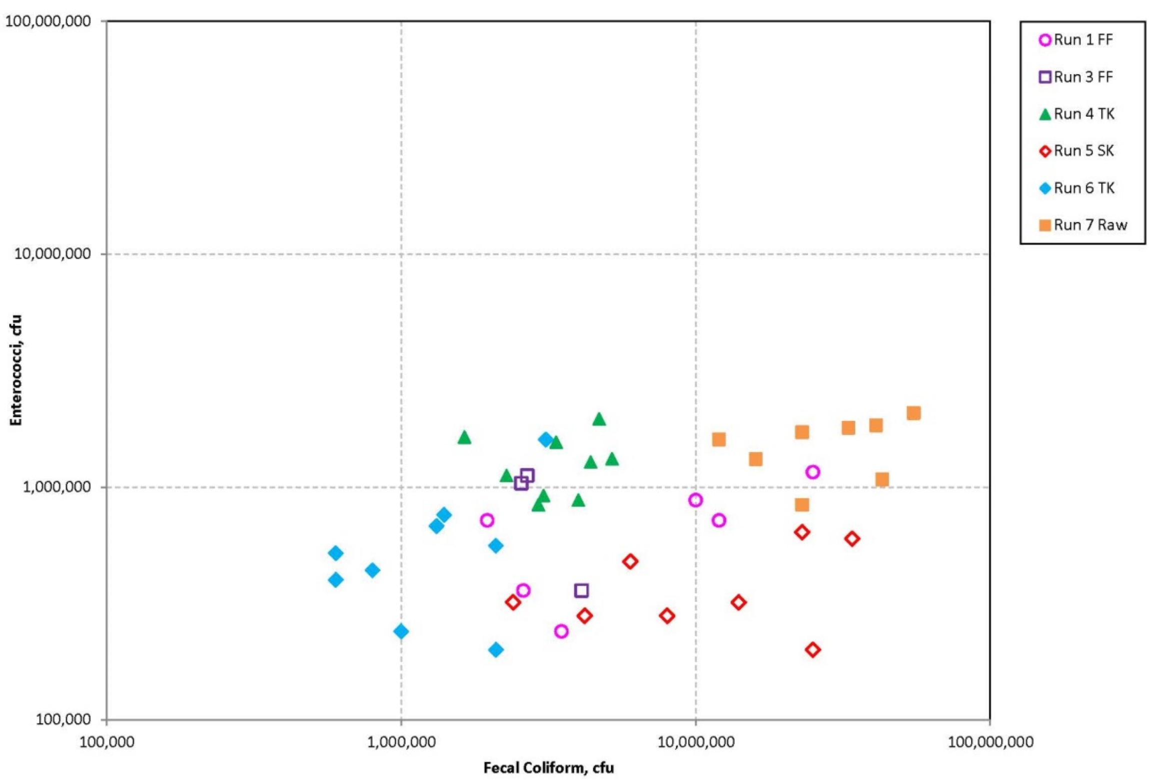


Figure 10.34 Influent Fecal Coliform vs E. Coli

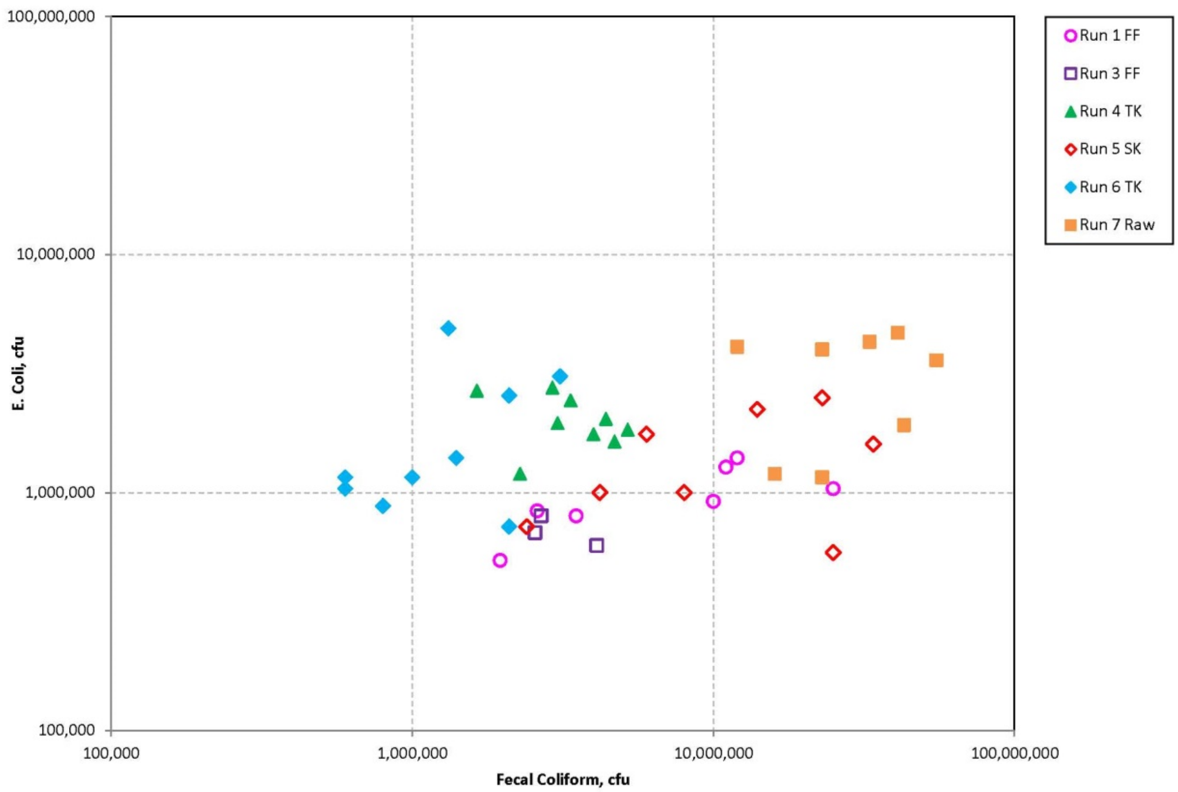


Figure 10.35 Influent E. Coli vs Enterococci

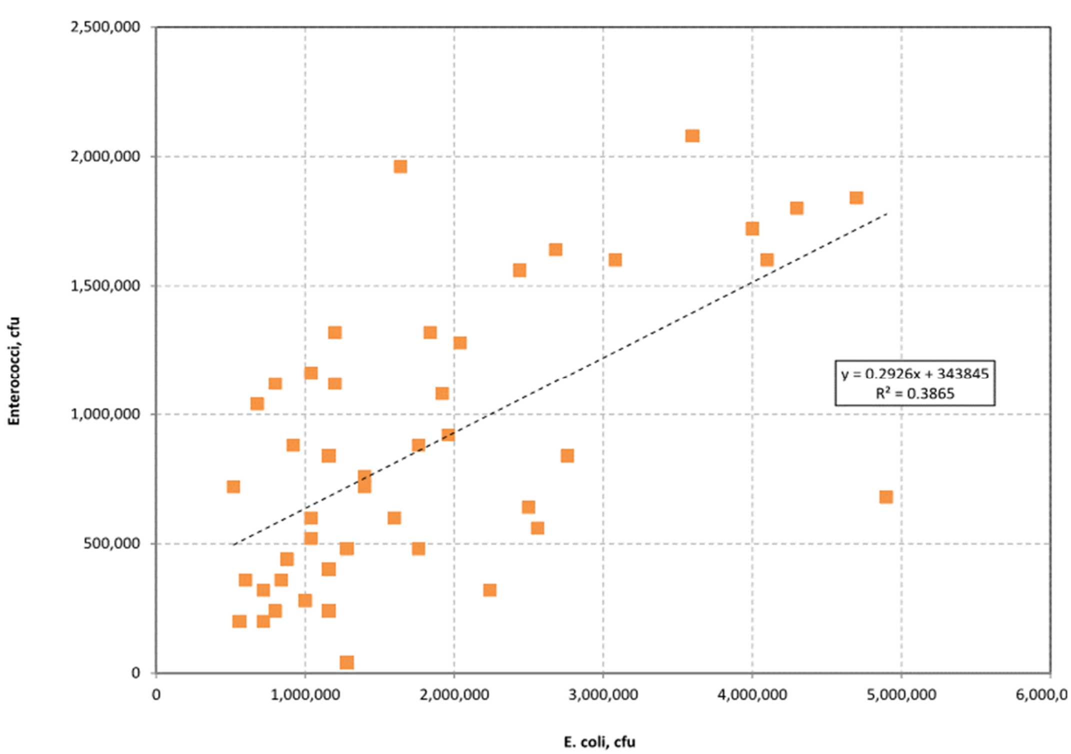


Figure 10.36 Influent Fecal Coliform vs Enterococci

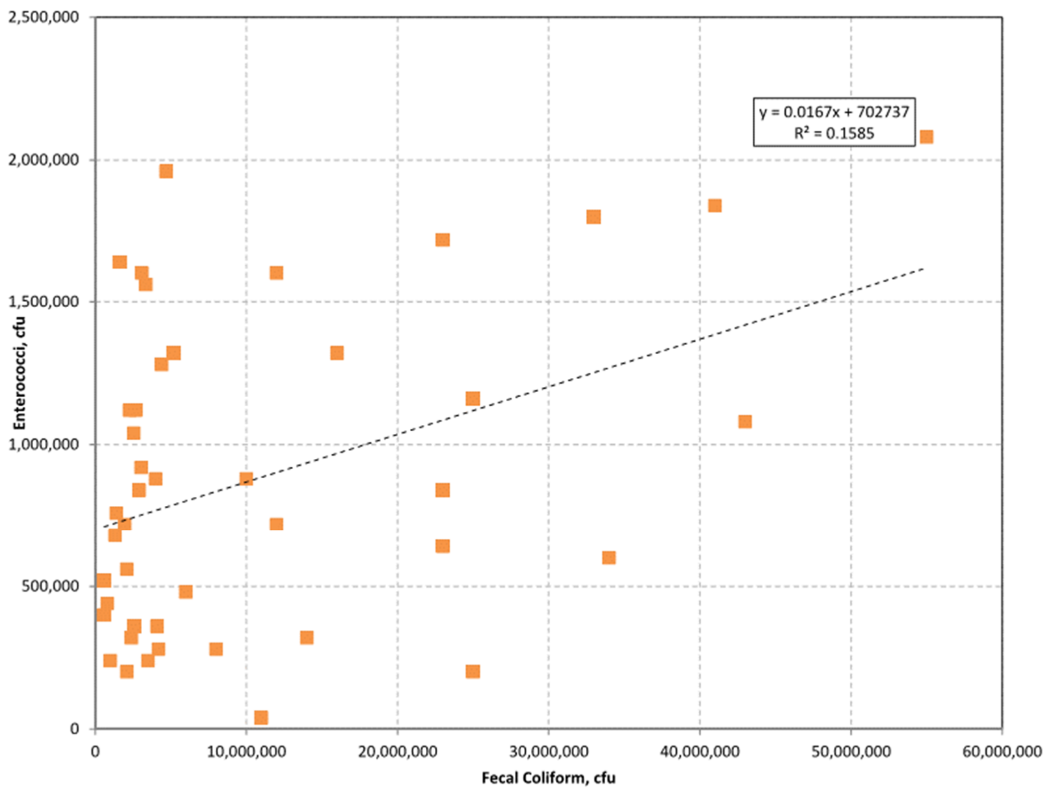


Figure 10.37 Influent Fecal Coliform vs E. Coli

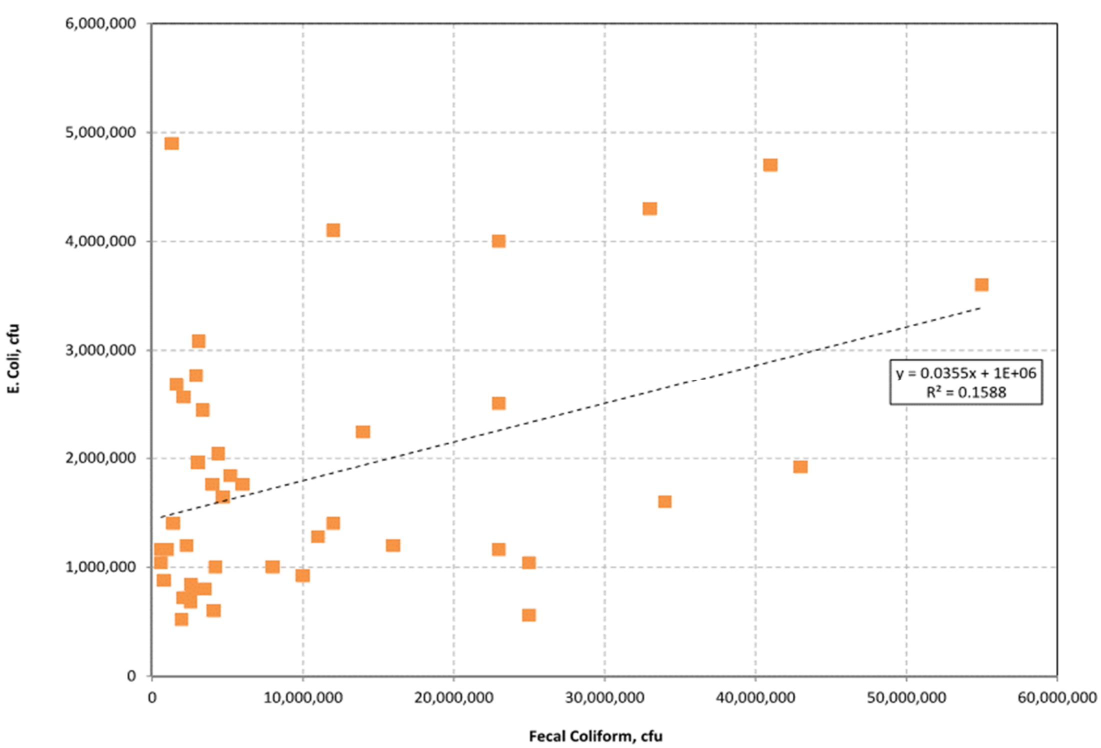
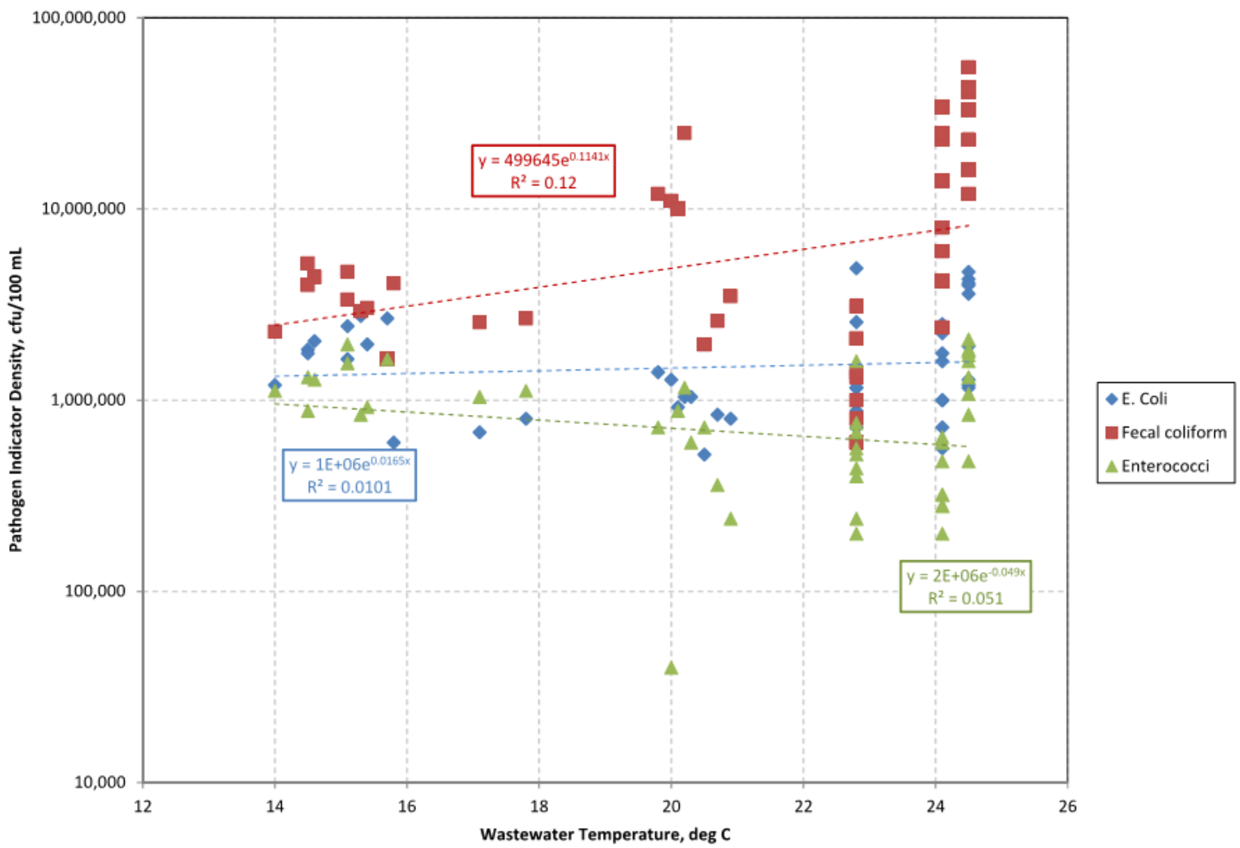


Figure 10.38 illustrate the effect of wastewater temperature on density of the pathogen indicators. Fecal coliforms appear to be significantly more numerous at higher temperatures, which is consistent with expectations. Other pathogen indicators do not show such trend in the available data.

Figure 10.38 Effect of the Temperature on PAA Influent Pathogen Indicator Density



Conclusions and Recommendations

1. The most important finding from the PAA pilot study was definition of a predictive relationship between the applied dose of PAA per mg/L of COD present in the CSO and the log reduction of pathogen indicators as illustrated in Figure 10.16. PAA dose of 0.01 mg/L of PAA per mg/L of COD predicted a 3-log reduction of fecal coliforms, with slightly higher effectiveness of around 3.2 log reduction for E. coli and slightly lower of 2.6 log reduction for Enterococci.

2. Increasing the relative dose to above 0.015 mg/L of PAA per mg/L of COD increased log reduction to 4. Further increase of the PAA dose appeared to have limited effect on further increasing reduction of the bacterial densities, although data in that range are too limited to allow for a firm conclusion.

3. The PAA contact time and dose applied in most of the Test Runs were relatively low (typically 3 minutes); nevertheless 99% (or two log) reduction of the pathogen indicator organisms was documented, on average, as noted in Table 10.2. Higher applied dose, as modified by COD concentration, may be needed to satisfy the disinfection requirements and guidelines of many States and the Federal government.

4. Should applicability of the relationships discussed under items 1 and 2 above be confirmed at other locations, it would be desirable to adjust the PAA application rate based on both wastewater flow and organic strength. The organic strength could potentially be measured in real time by a surrogate parameter such as TOC, but this could be practical only at large sites. Alternatively, a typical COD profile of CSO discharge could be developed based on historical data and PAA dose adjusted based on that profile and instantaneous flow. Lacking this, the only available strategy to accomplish significant disinfection would be to apply a pre-set PAA dose effective at the high end of the possible COD concentrations. This, however, will result in potentially significant residual PAA concentration, which could be toxic to the aquatic life.

5. While this demonstration project did not experience toxicity residual of PAA, it may be an issue to consider in the selection of an appropriate disinfection strategy.

6. Use of PAA in satellite CSO locations could be complicated by a need for on-site storage of large volumes of the chemical, which requires secondary containment and appropriate safety measures.

7. PAA can be employed in a staged treatment system for less frequent high volume flows.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 11 ANALYSIS OF THE RESULTS FOR UV DISINFECTION

11.1 UV Test Runs Summary

Two UV disinfection units were tested during the demonstration project: a low-pressure, high-intensity Trojan UV3000Plus model, and a medium-pressure, high-intensity Aquionics UV 250+W model. Section 4 provides details of the equipment design and parameters. However, it is noted that the units supplied by the manufacturer were rated as follows:

- Trojan – maximum hydraulic capacity of 250 gpm (no further specifications, such as acceptable UVT range, were provided). (Maximum flow rate during test runs was 130 gpm.)

- Aquionics – flow range 100 - 300 gpm at 45 to 65% UVT. (Maximum flow rate during test runs was 130 gpm.)

In the case of the Aquionics unit the specified flow range was designed to provide a minimum UV dose of 30 mJ/cm^2 under the above listed conditions. The 65% is a typical minimum value of UVT found in secondary effluents and is a standard design value for UV disinfections systems aimed at three to four log reduction of pathogen indicators (HydroQual, 2006)). The unit's flow rating decreased to 100 gpm at UVT values of 45% in order to achieve the same UV dose.

A summary of the operating conditions for all Test Runs utilizing either of the UV disinfection units is provided in Table 11.1. The Table lists information such as the pretreatment unit used, average water quality parameters' concentrations, including average count of pathogen indicators in the influent. The average performance results in terms of log reduction of pathogen indicators are also provided. Due to large variability in the wastewater quality during the individual the Test Runs, these average performance data are listed for general information only and are not further discussed or correlated.

All detailed information on the operating conditions, water quality data and performance results for all valid individual sampling events within each Test Run are provided in Table 11.2 for the Trojan UV unit and in Table 11.3 for the Aquionics UV unit. The water quality parameters were measured in the effluent from the upstream TSS removal unit. The subsequent discussion and analysis of the results is based on sets of individual data points listed in Table 11.2 and 11.3.

Tables 11.2 and 11.3 also provide the value of the applied UV dose calculated by the UV units' suppliers based on the UVT value measured at the time of the individual sampling event and the corresponding wastewater flow to the UV unit. For several sampling events with particularly low transmittance, the calculated dose is an approximation by the manufacturer, as the parameters were outside of the validated range.

Table 11.1 UV Disinfection Summary

Storm #	UV Disinfection											
	Source of Influent	UV Unit Type (Trojan or Aqu-ionics)	Design Flow, gpm	Trans-mittance %	Average TSS in Influent to UV, mg/L	Average Soluble $CBOD_5$ in Influent to UV, mg/L	Geo. Mean in Feed (cfu/100 mL)			Average Log Reduction		
							E. Coli	Fecal coliform	Entero-cocci	E. Coli	Fecal coliform	Entero-cocci
1	TK	A	200	16.8	199	9.9	784,244	7,316,329	636,498	1.25	1.35	1.15
2	SK	T	150	44.8	196	6.9	493,504	1,934,295	364,299	2.31	2.87	1.91
	FF	A	120	40.1	9.9	5.1	300,370	726,924	235,048	2.27	2.48	1.91
3	TK	A	160	27.0	97	31	889,599	5,664,802	886,950	1.51	1.83	1.14
4	FF	T	130	27.1	31	16.2	1,281,190	1,602,734	742,545	2.29	2.30	1.76
5	FF	T	130	39.6	29.2	21.9	522,495	3,944,017	287,200	2.27	3.40	1.98
6	FF	A	130	40.1	27.8	13.4	1,150,762	907,888	342,454	1.89	1.52	1.07
7	SK	T	150	23.8	118	28.4	2,468,098	21,815,203	1,262,797	1.42	1.98	1.27
8	FF	A	130	25.9	28	41.3	3,393,289	1,455,492	1,019,468	0.94	1.38	0.73
9	FF	T	130	27.0	37.9	39	3,425,122	2,288,616	1,349,306	1.23	1.53	1.27

NOTE: For calculating Log Reduction for pathogen indicators, results reported as "less then" were interpreted as 1/2 of the detection level.

TK- Terre Kleen: SK – Storm King: FF – FlexFilter: A: Aquionics: T - Trojan

MOTT MACDONALD

Table 11.2 Summary of Data from Individual Sampling Events for Trojan UV Disinfection

Rest Run	Time	Flow to UV (gpm)	Turbidity (NTU)	UV T, %	Power Input mJ/cm2	E-Coli (cfu/100 mL)			Fecal Coliform (cfu/100 mL)			Enterococci (cfu/100 mL)			TSS (mg/L)	VSS (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)
						In	Out	Log Red.	In	Out	Log Red.	In	Out	Log Red.						
2-T	10/16/14 2:12	150	30.4	25.8	9.8	520,000	2,000	2.41	8,000,000			480,000	18,000	1.43	140	102	285	58.4	7.5	13
2-T	10/16/14 2:32	150	21.3	27.1	10.4	480,000	5,000	1.98	1,600,000			480,000	6,000	1.90	106	78	168	52.4	5.6	10.9
2-T	10/16/14 2:50	150	49	10.9	3.4	1,080,000	24,000	1.65	4,200,000	40,000	2.02	600,000	43,000	1.14	210	160	354	154	8.4	13.3
2-T	10/16/14 3:12	150	33.6	15.2	5.2	1,040,000	12,000	1.94	7,000,000	18,000	2.59	560,000	13,000	1.63	208	168	455	110	6.6	12.3
2-T	10/16/14 3:32	150	31.7	30.2	11.9	560,000	2,000	2.45	1,320,000	5,000	2.42	440,000	6,000	1.87	161	121	299	50.1	5.2	11.5
2-T	10/16/14 3:52	150	62	31.7	12.7	600,000	500	3.08	1,200,000	500	3.38	360,000	2,000	2.26	170	90	219	51.3	5.5	6.8
2-T	10/16/14 4:12	150	48	46.8	20.3	320,000	500	2.81	960,000	500	3.28	160,000	2,000	1.90	110	71	203	35.3	3.7	8.1
2-T	10/16/14 4:32	150	22.7	43.6	18.7	480,000	2,000	2.38	920,000	500	3.26	360,000	500	2.86	86	56	205	29.2	4.5	8.2
2-T	10/16/14 4:52	150	31.9	45.3	19.6	120,000	1,000	2.08	720,000	500	3.16	160,000	1,000	2.20	104	75	142	28.3	N.D.	6.6
4 - T	11/6/14 9:30	140	16.9	27.6	11.2	1,760,000	36,000	1.69	1,520,000	27,000	1.75	1,160,000	35,000	1.52	30	26	158	48.3	18.3	26.5
4 - T		0		21.0			26,000			20,000			36,000							
4 - T	11/6/14 10:30	135	22.1	20.2	7.8	2,080,000	14,000	2.17	2,280,000	35,000	1.81	600,000	24,000	1.40	37	32	168	53.4	14.1	26.1
4 - T	11/6/14 11:30	132	20	32.7	14.0	920,000	2,800	2.52	1,360,000	3,100	2.64	840,000	6,900	2.09	30	26	144	43.1	12.6	21
4 - T	11/6/14 12:30	132	19.8	33.9	14.7	800,000	1,300	2.79	1,400,000	1,400	3.00	520,000	4,800	2.03	26	23	137	43.2	19.8	22.5
5 - T	7/30/15 17:50	128	17.1	49.7	24.2	600,000	400	3.18	1,000,000	50	4.30	240,000	800	2.48	21	13		15	2	
5 - T	7/30/15 17:54	39		50.1			100			200			100							
5 - T	7/30/15 18:38	118	24.8	39.5	19.3	280,000	2,300	2.09		2,100		280,000	3,500	1.90	35	25		28	6	
5 - T	7/30/15 18:50	108	20.8	44.1	23.3	280,000	200	3.15	2,080,000	200	4.02	320,000	800	2.60	23	15		24	8	
5 - T	7/30/15 19:10		16.9	44.2		520,000	400	3.11	4,800,000	100	4.68	120,000	1,100	2.04	26	17		40	14	
5 - T	7/30/15 19:50	136	29.6	32.7	14.0	440,000	12,000	1.56	8,000,000	6,600	3.08	280,000	7,800	1.56	45	33		73	27	
5 - T	7/30/15 20:10	114	32.5	28.0	12.9	480,000	240,000	0.30	6,400,000	34,000	2.27	520,000	15,000	1.54	37	29		89	48	
5 - T	7/30/15 21:00	132	24.7	33.7	14.8	960,000	3,700	2.41	6,600,000	9,000	2.87	280,000	5,200	1.73	25	19		73	32	
5 - T	7/30/15 21:10	131	27.4	34.5	15.2	1,120,000	5,000	2.35	4,400,000	12,000	2.56	440,000			27	22		69	34	
7 - T	9/10/15 18:00	85	50.6	20.1	10.4	4,600,000	180,000	1.41	39,000,000	100,000	2.59	1,440,000	90,000	1.20	170	121		150	33.6	
7 - T	9/10/15 18:20	151	52.3	21.1	7.7	2,600,000	100,000	1.41	20,000,000	520,000	1.59	1,560,000	64,000	1.39	153	114		167	43.4	
7 - T	9/10/15 18:40	150	42.9	23.2	8.6	2,880,000	150,000	1.28	17,000,000	280,000	1.78	1,720,000	77,000	1.35	128	93		110	25.6	
7 - T	9/10/15 19:00	150	46.9	21.0	7.6	2,440,000	170,000	1.16	39,000,000	470,000	1.92	1,920,000	100,000	1.28	149	105		118	28.2	
7 - T	9/10/15 19:20	150	75.8	22.3	8.2	2,920,000	130,000	1.35	14,000,000	500,000	1.45	1,520,000	150,000	1.01	135	94		170	26.5	
7 - T	9/10/15 19:40	150	42.5	24.1	9.0	1,800,000	110,000	1.21	30,000,000	540,000	1.74	1,040,000	60,000	1.24	111	85		125	35.1	
7 - T	9/10/15 20:00	150	44.3	24.1	9.0	1,320,000	56,000	1.37	14,000,000	420,000	1.52	800,000	65,000	1.09	120	89		99.4	19.7	
7 - T	9/10/15 20:20	151	39.6	25.3	9.6	3,100,000	46,000	1.83	16,000,000	30,000	2.73	640,000	41,000	1.19	113	81		89.1	19.6	
7 - T	9/10/15 20:40	151	40.2	26.4	10.1	1,880,000	34,000	1.74	23,000,000	80,000	2.46	1,360,000	27,000	1.70	92	72		115	29.5	
7 - T	9/10/15 21:00	151	34.7	30.2	11.9										86	66		87.6	26.9	
9 - T	10/27/15 9:20	136	20.5	22.4	8.8	3,500,000	350,000	1.00	700,000	74,000	0.98	680,000	58,000	1.07	37	31		57.5	28.3	
9 - T	10/27/15 9:40	115	20.5	28.6	13.2	4,100,000	230,000	1.25	500,000	57,000	0.94	880,000	56,000	1.20	43	32		57.5	31.6	
9 - T	10/27/15 9:57	118	19.9	29.3	13.4	2,600,000	240,000	1.03	4,000,000	21,000	2.28	1,760,000	50,000	1.55	36	29		58.4	34.2	
9 - T	10/27/15 10:40	133	22.3	27.8	11.6	4,400,000	250,000	1.25	5,400,000	74,000	1.86	2,080,000	92,000	1.35	38	30		73	50.5	
9 - T	10/27/15 11:00	115	21.9	27.1	12.4	4,400,000	340,000	1.11	2,900,000	88,000	1.52	1,760,000	124,000	1.15	45	35		76	57.7	
9 - T	10/27/15 12:00	119	21.9	26.8	11.9	2,900,000	88,000	1.52	3,000,000	118,000	1.41	1,600,000	82,000	1.29	31	24		69.3	40	
9 - T	10/27/15 12:55	102	23.6	26.9	13.2	2,640,000	100,000	1.42	5,000,000	100,000	1.70	1,320,000	66,000	1.30	35	28		65.9	30.6	

THIS PAGE INTENTIONALLY LEFT BLANK

Table 11.3 Summary of Data from Individual Sampling Events for Aquionics UV Disinfection

Rest Run	Time	Flow to UV (gpm)	Turbidity (NTU)	UV T, %	Power Input mJ/cm2	E-Coli (cfu/100 mL)			Fecal Coliform (cfu/100 mL)			Enterococci (cfu/100 mL)			TSS (mg/L)	VSS (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)
						In	Out	Log Red.	In	Out	Log Red.	In	Out	Log Red.						
1 - A	10/4/14 10:30	150		5.8	17.5	1,720,000	460,000	0.57				600,000	300,000	0.30	297	195	549	203	18.7	21.0
1 - A	10/4/14 10:50	150		6.9	17.5	1,960,000	880,000	0.35	22,000,000	8,400,000	0.42	600,000	590,000	0.01	424	314	765	280	17.4	21.3
1 - A	10/4/14 11:10	150		7.1	17.5	280,000	1,070,000	-0.58	28,000,000	8,500,000	0.52	1,200,000	510,000	0.37	336	248	650	212	25.2	20.2
1 - A	10/4/14 11:30	150		13.3	18.0	560,000	1,360	2.61		210,000		720,000	100,000	0.86	185	135	471	88.1	2.7	15.8
1 - A	10/4/14 11:50	150	39.2			880,000	51,000	1.24	10,000,000	370,000	1.43	880,000	48,000	1.26	196	137	450	4.5	8.2	13.7
1 - A	10/4/14 12:10	45	37.8			800,000	42,000	1.28	10,000,000	110,000	1.96	640,000	48,000	1.12	185	129	457	63.9	5	13.8
1 - A	10/4/14 12:30	150	34.4	18.6	18.0		2,100,000			6,700,000			550,000		179	126	342	43.8	5.6	15.1
1 - A	10/4/14 12:50	150	35.1	22.8	18.0	520,000	23,000	1.35	8,000,000	570,000	1.15	520,000	6,800	1.88	185	125	779	96.2	7.7	12.6
1 - A	10/4/14 13:10	150	38.2	28.7	19.0	760,000	5,800	2.12	3,500,000	16,000	2.34	520,000	6,400	1.91	114	77	259	56.3	3.8	12.7
1 - A	10/4/14 13:30	150	27.7	31.1	19.0	880,000	4,000	2.34	1,700,000	39,000	1.64	360,000	900	2.60	98	69	259	61.1	8	14.9
1 - A	10/4/14 13:50		28.5			680,000			2,800,000			640,000			92	69	234	61.6	6.4	15.6
1 - A	10/4/14 14:10		30.6			1,520,000			3,900,000			400,000			100	76	274	68.3	9.5	18.7
2 - A	10/16/14 2:20	120	10.26	45.0	30.0	680,000	8,000	1.93	1,040,000	9,000	2.06	400,000	120,000	0.52	13	11	92.4	21.2	7.9	14.6
2 - A	10/16/14 2:40	120	8.61	46.5	31.0	440,000	500	2.94	760,000	500	3.18	240,000	2,000	2.08	9	9	73.6	18.2	6.8	12.6
2 - A	10/16/14 3:40	120	9.74	39.6	27.0	600,000	47,000	1.11	1,160,000	43,000	1.43	560,000	19,000	1.47	19	14	80.6	17.7	7	13.3
2 - A	10/16/14 4:00	120	29.2	50.6	35.0	400,000	500	2.90	640,000	3,000	2.33	480,000	500	2.98	6	5	57.1	12.2	4.7	9.4
2 - A	10/16/14 4:20	120	7.44	57.0	43.0	320,000	500	2.81	680,000	500	3.13	80,000	500	2.20	7	6	40.6	9.6	3.9	6.8
2 - A	10/16/14 4:40	120	5.94	55.9	41.0	80,000	1,000	1.90	560,000	1,000	2.75	80,000	500	2.20	7	6	43	9.7	4.1	6.8
3 - A	10/22/14 10:30	100	22.7			840,000	4,300	2.29	2,240,000	3,900	2.76	800,000	22,000	1.56	83	64	170	58.5	19	19.8
3 - A	10/22/14 10:50	100	21.3	30.3	28.0	1,200,000	33,000	1.56	2,920,000	43,000	1.83	1,160,000	37,000	1.50	110	87	191	69.8	23.6	24.3
3 - A	10/22/14 11:10	100	26.5	26.1	27.0	680,000	57,000	1.08	7,400,000	490,000	1.18	920,000	102,000	0.96	105	66	248	111	58.6	38.2
3 - A	10/22/14 11:30	100	23.3	27.1	27.5	920,000	23,000	1.60	13,000,000	120,000	2.03	560,000	58,000	0.98	124	80	215	76.9	27.1	25.7
3 - A	10/22/14 11:50	100	26.1	27.3	27.5	1,000,000	51,000	1.29	7,000,000	300,000	1.37	840,000	46,000	1.26	117	65	224	78.4	28.2	26
3 - A	10/22/14 12:10	100	26.8	26.5	27.5	760,000	33,000	1.36	5,000,000	102,000	1.69	1,120,000	91,000	1.09	78	53	208	79.8	27.5	29.3
3 - A	10/22/14 12:30	100	26.4	24.6	27.0	920,000	41,000	1.35	8,500,000	98,000	1.94	960,000	210,000	0.66	65	46	208	79.6	30.4	30.2
6 - A	8/11/15 7:20	140	30	22.9	19.0	2,640,000	124,000	1.33	2,500,000	57,000	1.64	320,000	100,000	0.51	40	34		75.4	30.6	
6 - A	8/11/15 8:00	98	26.9	38.8	32.0	1,800,000	27,000	1.82	440,000	25,000	1.25	760,000	37,000	1.31	40	31		40	14.6	
6 - A	8/11/15 8:09	140	22.3	42.7	24.5	1,760,000	4,300	2.61	2,400,000	9,000	2.43	64,000	16,000	0.60	29	24		34.8	16.6	
6 - A	8/11/15 8:44	139	17.7	43.2	24.5	880,000	2,300	2.58	1,300,000	3,300	2.60	480,000	7,000	1.84	41	24		29.6	14.5	
6 - A	8/11/15 8:54		17			800,000			520,000			280,000			22	17		31.6	2	
6 - A	8/11/15 9:01	135	16.6	47.4	29.0	880,000	450,000	0.29	520,000	3,400,000	-0.82	240,000	480,000	-0.30	23	18		2	2	
6 - A	8/11/15 10:00	104	17.4	42.5	33.0	1,160,000	8,100	2.16	160,000	73,000	0.34	480,000	8,800	1.74	22	17				
6 - A	8/11/15 10:10		15.0												18	14				
6 - A	8/11/15 10:25	104	14.4	43.1	33.0	920,000	3,200	2.46	1,960,000	1,300	3.18	480,000	7,800	1.79						
6 - A	8/11/15 10:30		14.5			640,000			1,440,000			560,000			15	12				
8 - A	10/15/15 10:00	134	16.8	27.8	21.0	3,000,000	280,000	1.03	1,680,000	12,000	2.15	800,000	120,000	0.82	27	22		47.4	22.1	
8 - A	10/15/15 10:20	128	17.7	30.3	22.0	5,100,000	240,000	1.33	800,000	4,000	2.30	960,000	54,000	1.25	24	20		48.4	28.7	
8 - A	10/15/15 10:40	132	17.9	29.6	21.0	5,300,000	240,000	1.34	3,000,000	5,500	2.74	1,120,000	102,000	1.04	25	21		60.6	33.6	
8 - A	10/15/15 11:00	135	21.1	27.9	20.5	2,600,000	154,000	1.23	11,000,000	44,000	2.40	1,000,000	94,000	1.03	34	28		71.1	41.1	
8 - A	10/15/15 12:00	118	29	22.3	23.0	3,500,000	240,000	1.16	400,000	112,000	0.55	1,680,000	300,000	0.75	28	23		75	46.6	
8 - A	10/15/15 12:20	138	26.3	20.4	19.0	3,900,000	3,500,000	0.05	120,000	6,200,000	-1.71	1,320,000	2,400,000	-0.26	33	26		94.3	45.7	
8 - A	10/15/15 12:40	152	25.7	23.2	18.0	1,800,000	610,000	0.47	6,500,000	400,000	1.21	600,000	210,000	0.46	27	23		95.6	58.4	

THIS PAGE INTENTIONALLY LEFT BLANK

The Aquionics UV unit occasionally displayed warnings, probably due to the low UVT values, particularly in Runs 1 and 3. Otherwise both UV disinfection units performed without major problems, as detailed in Section 7.

Table 11.4 below provides a summary of pathogen indicator data from all valid individual UV sampling events. From these data, it is apparent that UV was most effective in inactivation of fecal coliforms, while least effective in inactivation of Enterococci, although the differences were small

Table 11.4 Summary of Pathogen Indicator Data for UV Tests

Pathogen Indicator	UV Unit	Initial Count Range (cfu/100 mL)	Average Log Reduction
E. coli	Trojan	1.2E+05 to 4.6E+06	1.9
	Aquionics	8.0E+04 to 5.3E+06	1.5
Fecal coliform	Trojan	5.0E+05 to 3.9E+07	2.4
	Aquionics	1.2E+05 to 2.8E+07	1.7
Enterococcus	Trojan	1.2E+05 to 2.1E+06	1.6
	Aquionics	6.4E+04 to 1.7E+06	1.2

11.2 Results

Figure 11.1 illustrates log reduction of E. coli recorded from all Test Runs with Trojan UV unit as a function of the calculated UV dose, grouped by the individual Runs. Figure 11.2 provides similar data for the Aquionics unit. Figure 11.3 groups and correlates all E. coli data for Trojan UV Runs and, separately for Aquionics UV. Figures 11.4 through 11.6 provide the same information for fecal coliforms, while Figures 11.7 through 11.9 are for Enterococci.

Inspection of Figures 11.3, 11.6 and 11.9 indicate an expected trend of increasing log reduction of pathogen indicators as UV dose increases. Despite the ostensibly low values of correlation coefficients (R2) shown on these figures, the correlations (forced through the origin) are statistically significant at 99% confidence level for 4 out of 6 data sets, with the remaining 2 being at 95% level. This is due to the relatively large number of data points available for these correlations, as discussed in Section 10.3.

Figure 11.1 Trojan UV Dose vs Log Reduction of E. Coli

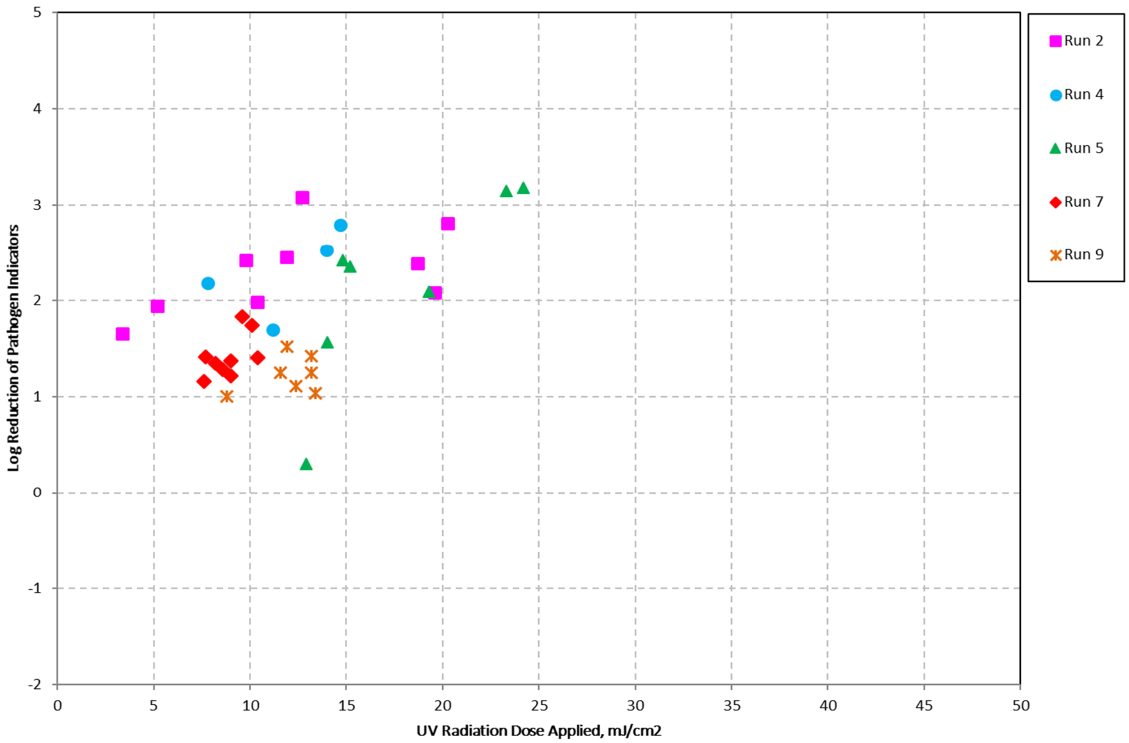


Figure 11.2 Aquionics UV Dose vs Log Reduction of E. Coli

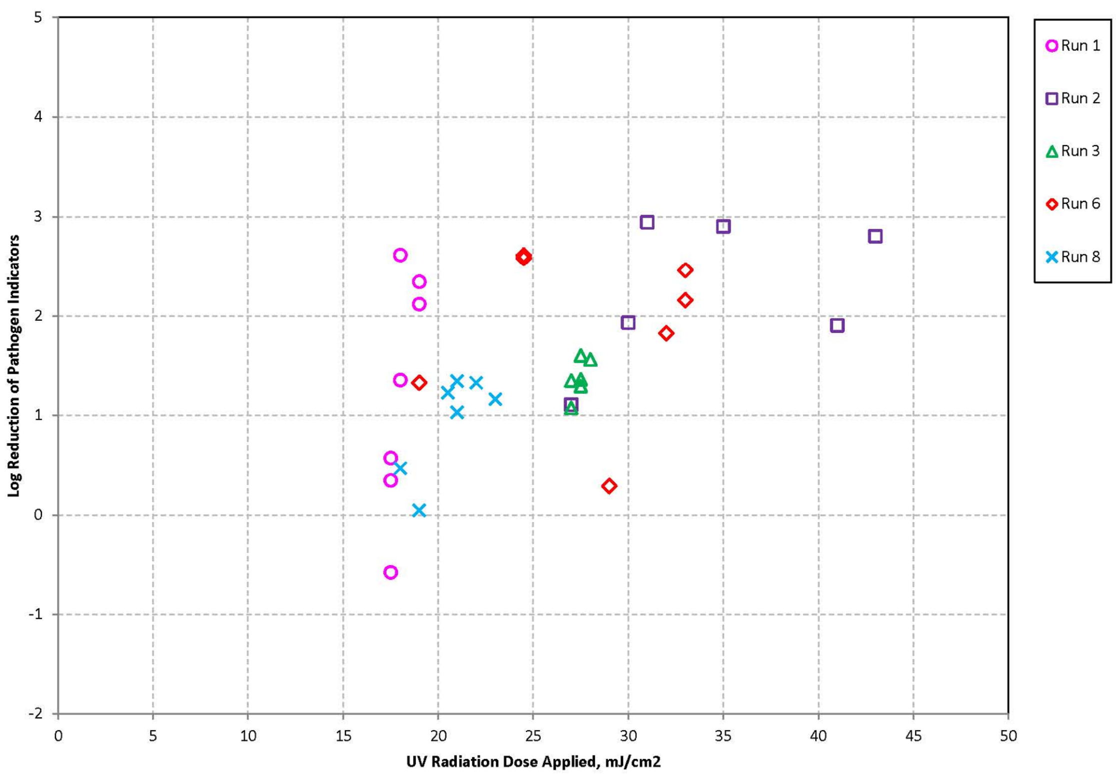


Figure 11.3 UV Dose vs Log Reduction of E. Coli

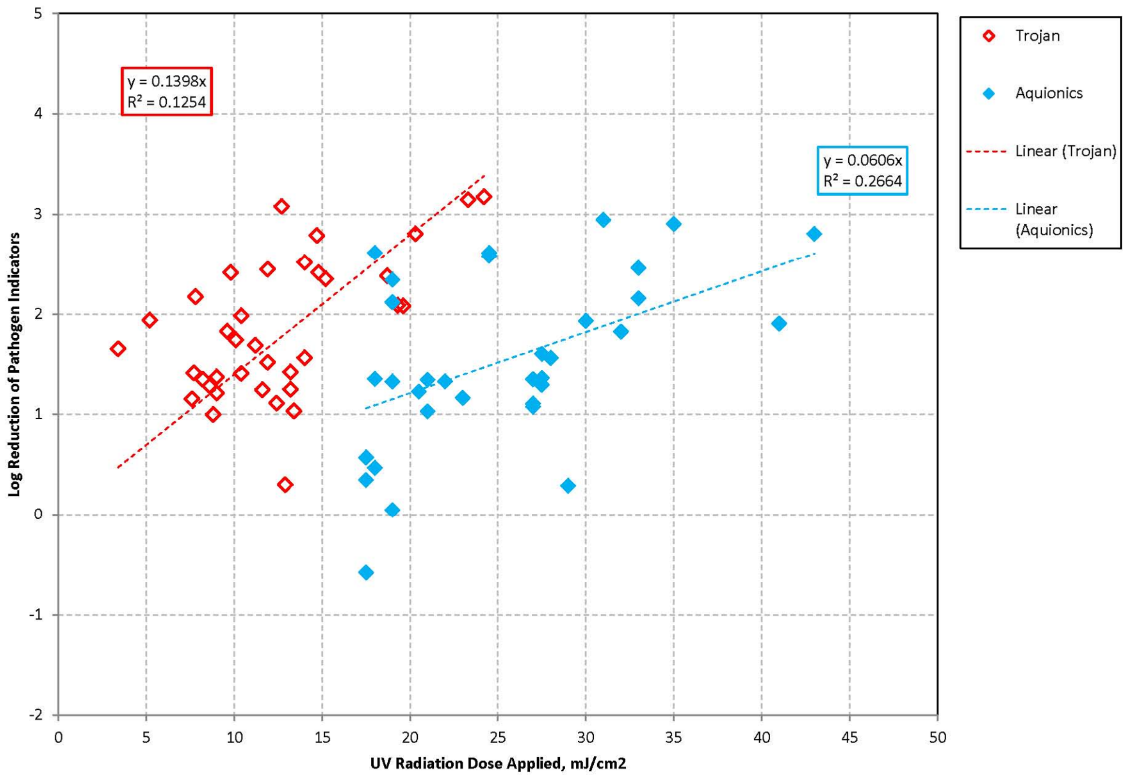


Figure 11.4 Trojan UV Dose vs Log Reduction of Fecal Coliform

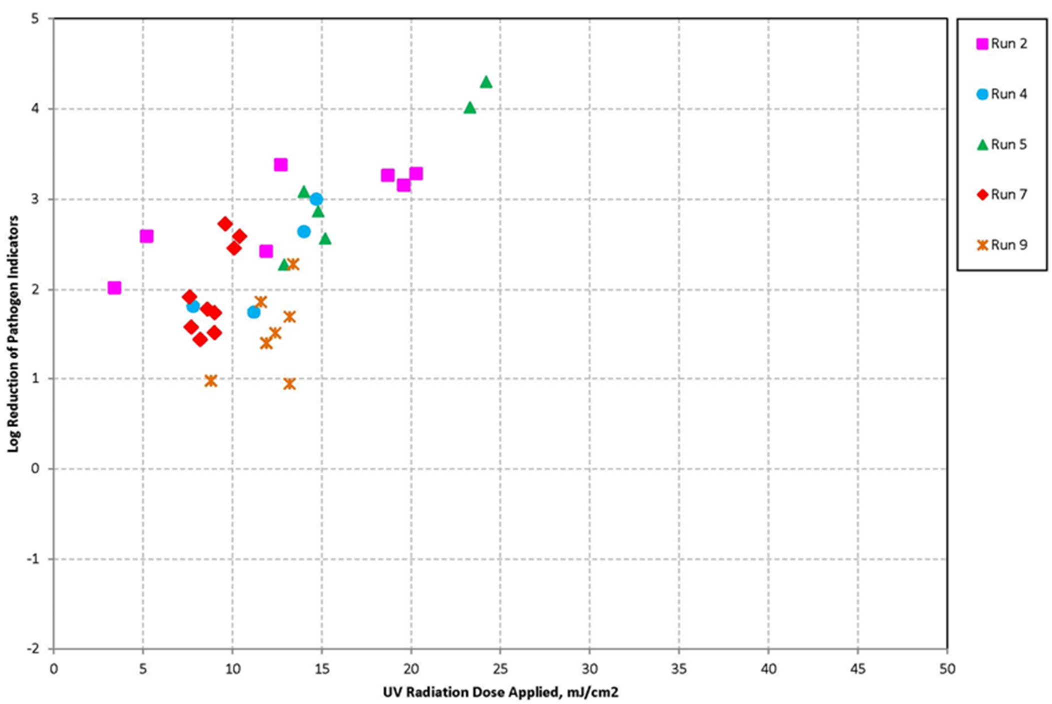


Figure 11.5 Aquionics UV Dose vs Log Reduction of Fecal Coliforms

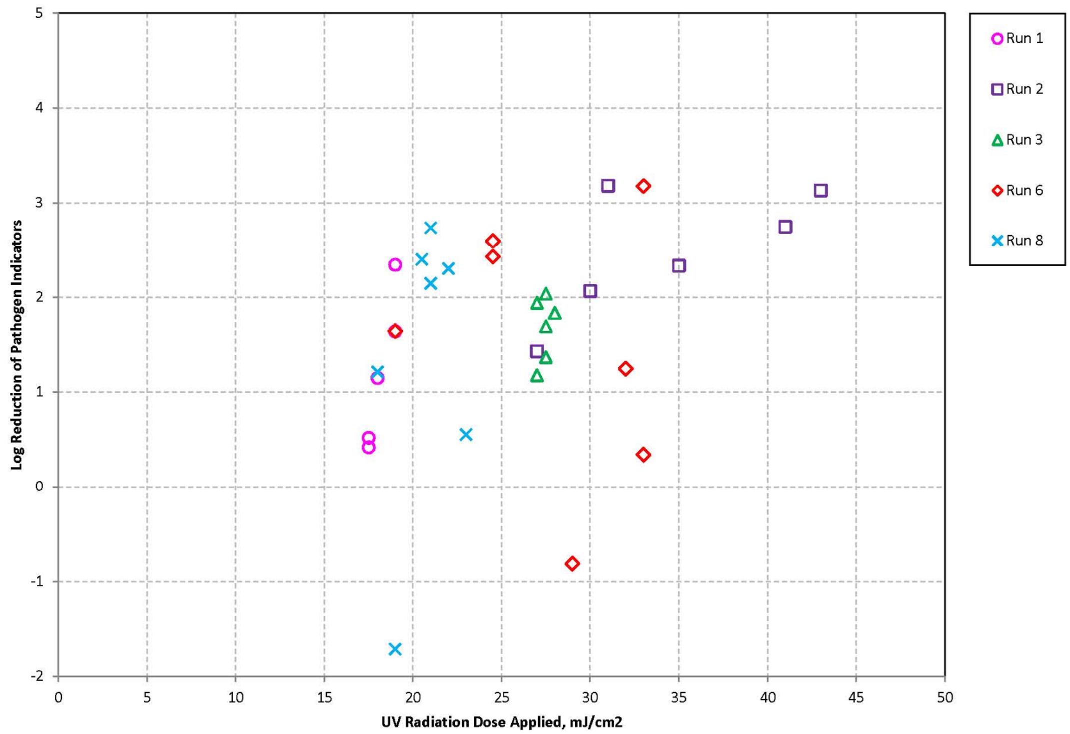


Figure 11.6 UV Dose vs Log Reduction of Fecal Coliforms

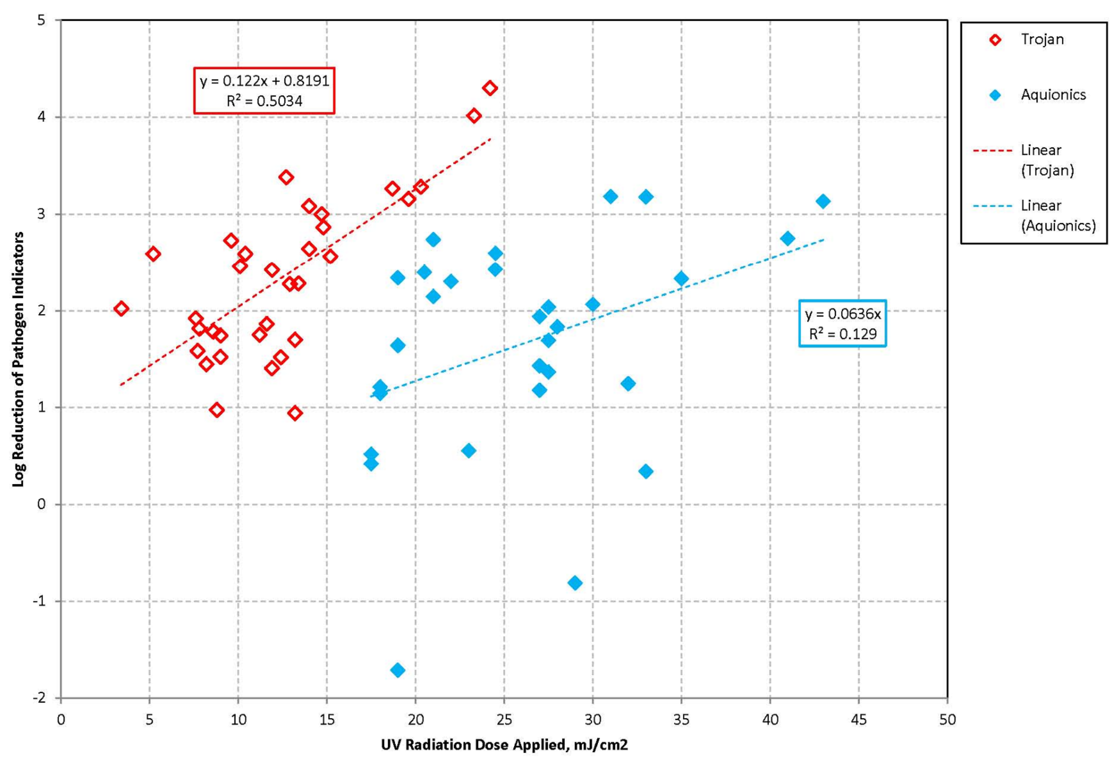


Figure 11.7 Trojan UV Dose vs Log Reduction of Enterococci

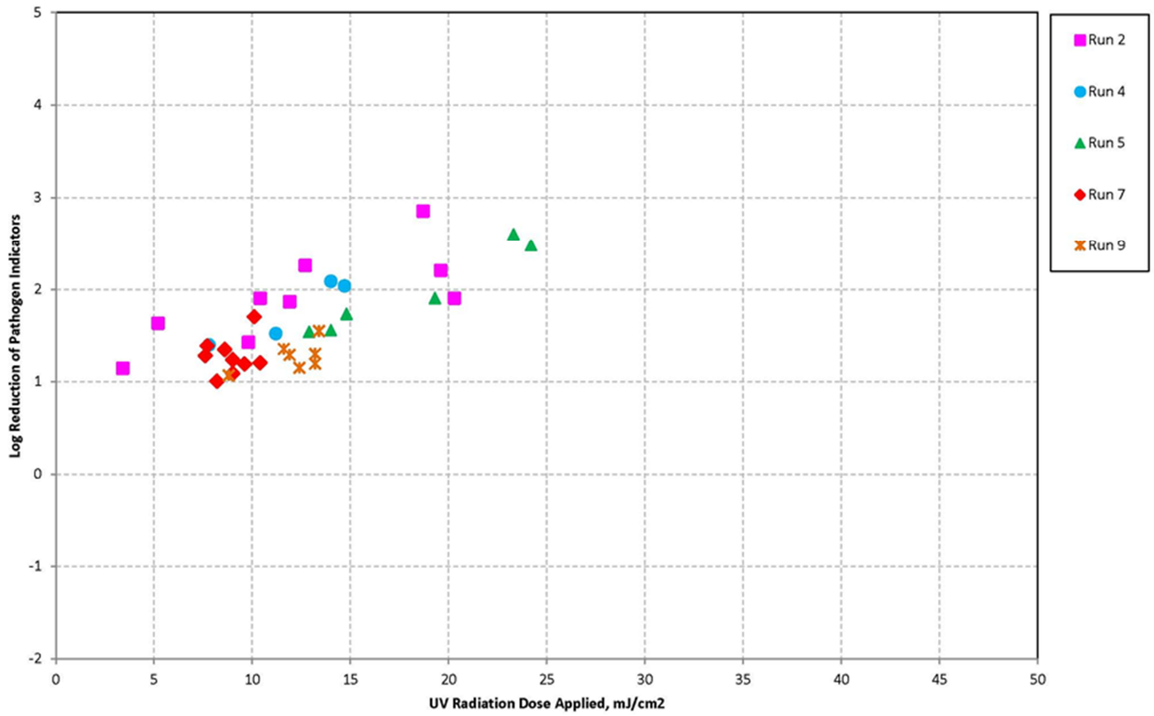


Figure 11.8 Aquionics UV Dose vs Log Reduction of Enterococci

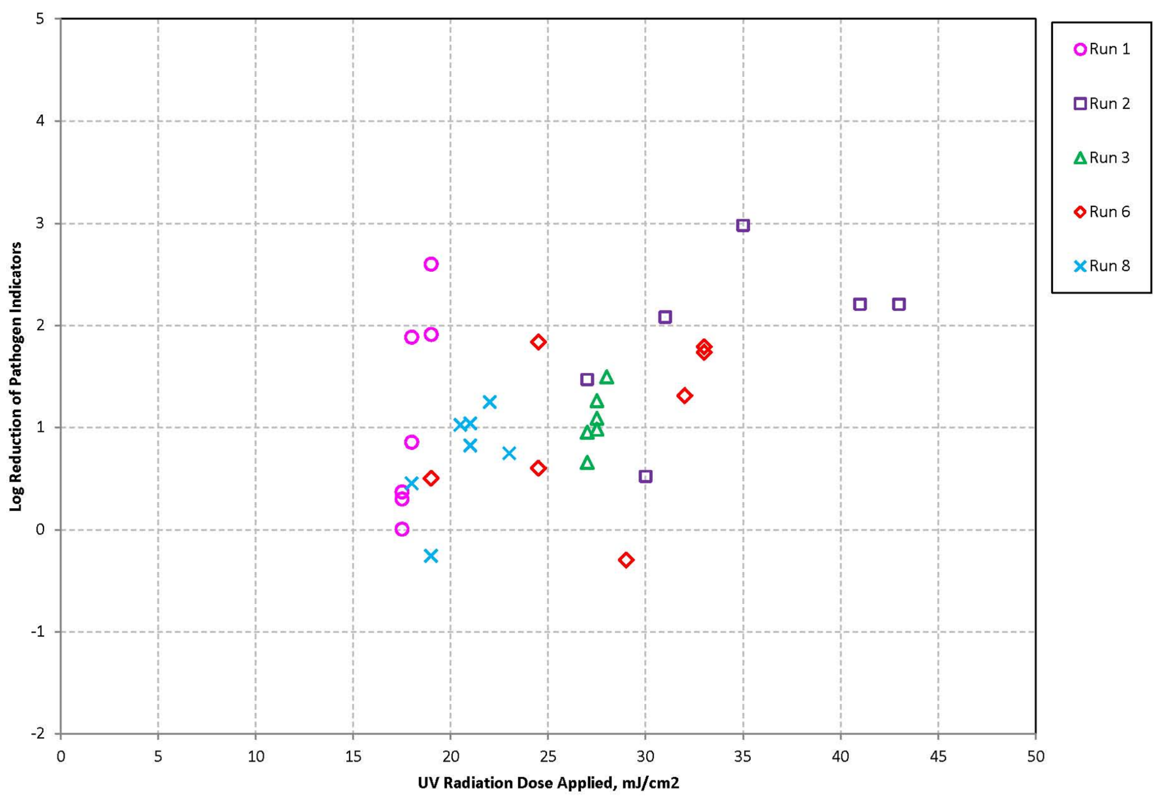
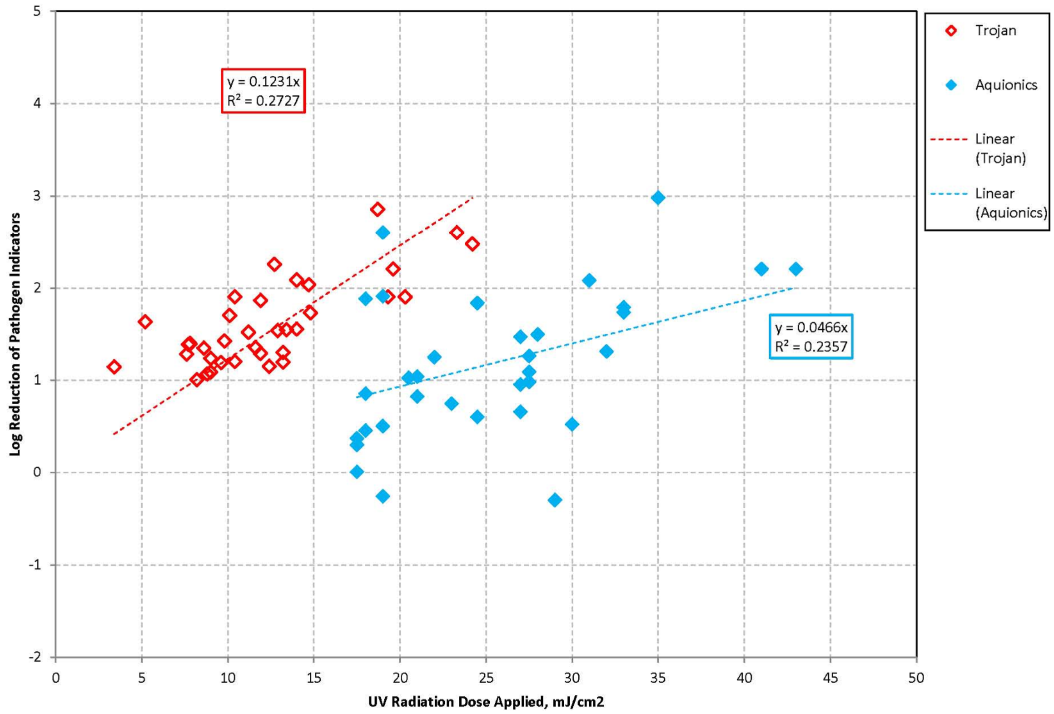


Figure 11.9 UV Dose vs Log Reduction of Enterococci



Attempts to further improve the resulting correlations by normalizing the UV dose by COD were not successful. It is assumed that this is because the organic strength of the wastewater, as measured by COD, is already factored into the UV dose calculation by independent measurement of the transmittance (and transmittance's relationship to COD).

Inspection of Figures 11.3, 11.6 and 11.9 reveals also that the Trojan UV unit performed better than the Aquionics UV unit at the same calculated UV dose. It is not clear if the disparity in performance is a result of systemic difference in the validation procedure and effective dose calculation, or if it is also related to the lower efficiency in generation of UV in the germicidal range by the polychromatic medium pressure lamps as compared to the relatively monochromatic low pressure lamps.

The following reservations regarding the UV effective dose calculated by the manufacturers were expressed by them, and they could, at least partially, explain differences in performance between the two units:

- For Trojan - for some sampling data sets either the flow to the unit or UVT was out of validated range thus the predicted dose is burdened with some uncertainty. The calculations were based on Trojan's UV3000Plus 3 MS2 validation.

- For Aquionics – effective dose information for UVT of below 20% (and particularly below10%) are burdened with uncertainty.

However, the most obvious observation is that the relatively low log reduction of bacterial densities achieved by the UV units is the inadequate UV dose caused by frequently very low transmittance of the CSO. This is shown in the data Tables 10.1, 10.2 and 10.3, but can be most readily inspected on Figure 11.10, where the expected, strong relationship between the CSO TSS and transmittance is evident. Figure 11.11 presents the same data grouped by the Test Run. The transmittance ranged from single digits to 60%, with majority clustered in the 20 to 50% range. These low transmittance values are consistent with expectations. For example, transmittance of primary effluent is quoted to be in 20 to 50% range by Metcalf & Eddy/AECOM (2014). The HDR (2014) study on wet weather primary effluent found the UVT values to be somewhat higher, in the range from 40 to 60%.

Figure 11.10 Effect of TSS on UV Transmittance

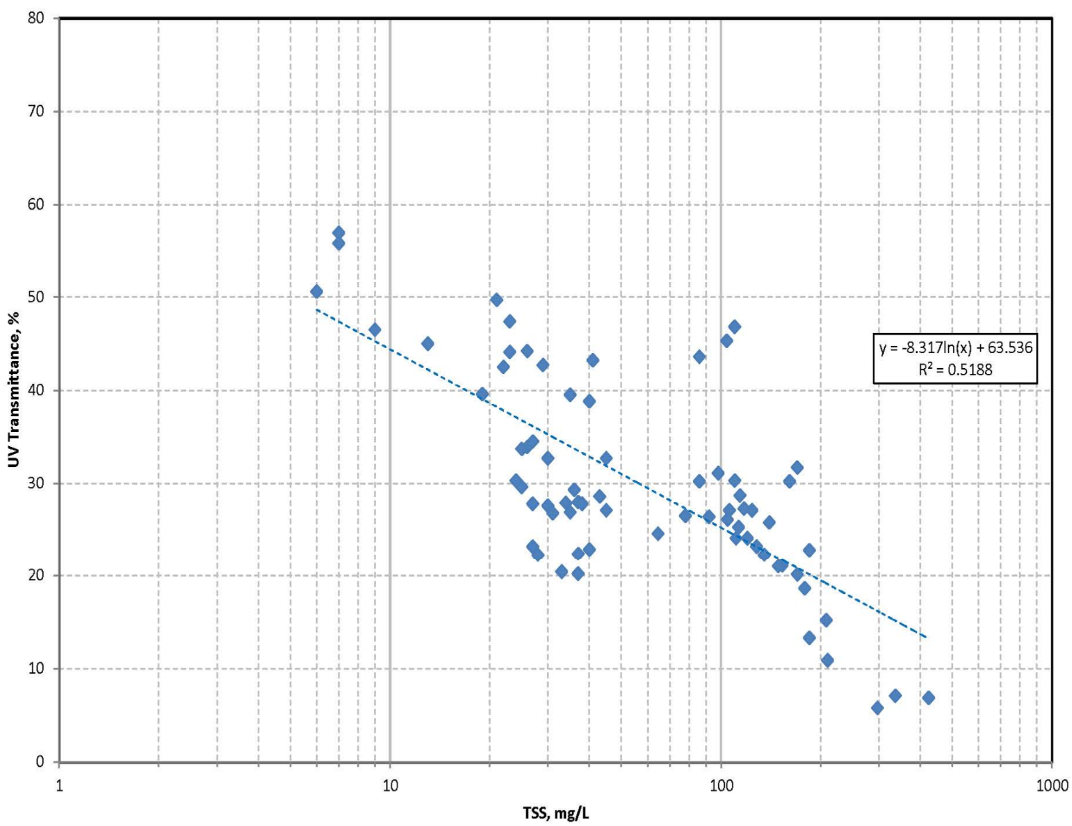
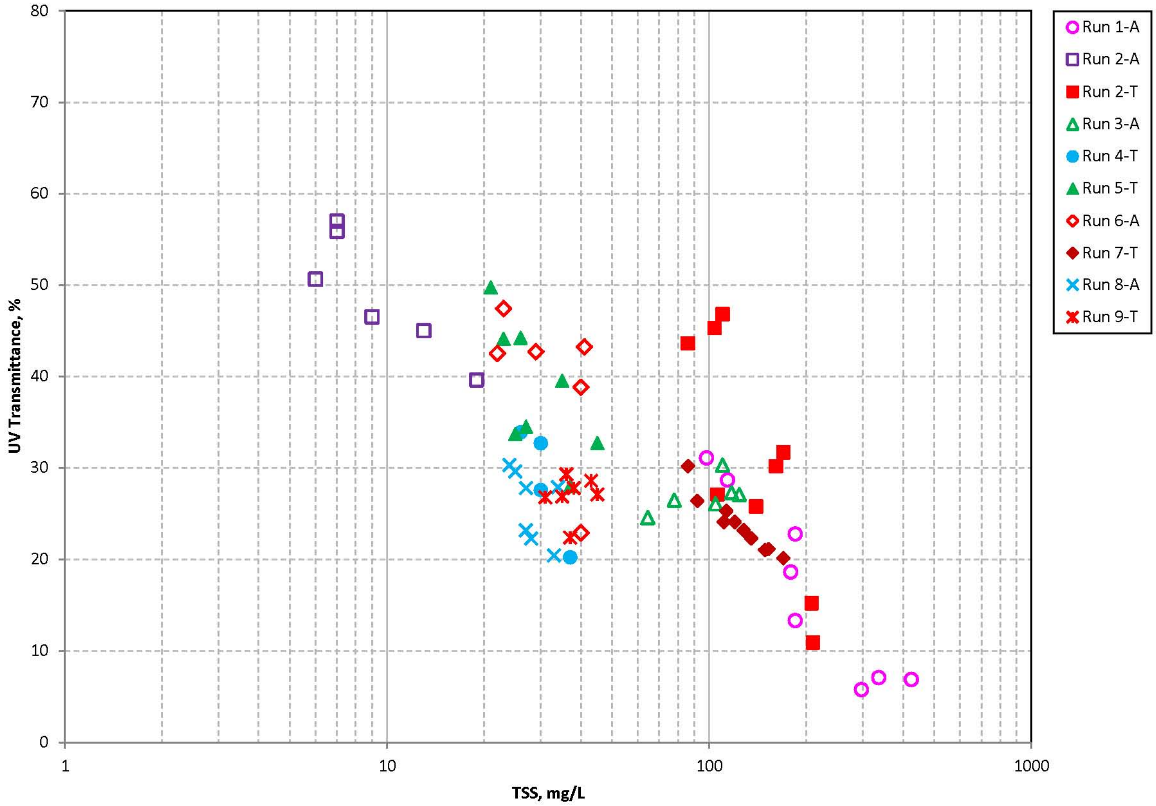


Figure 11.11 Effect of TSS on UV Transmittance. Individual Test Runs



It is clear that the flow rating of the supplied UV units was suitable for a typical, secondary effluent application, without taking into account the expected, significantly worse quality of the CSO effluent. As a result, the applied dose for the Trojan UV unit never exceeded 25 mJ/cm^2 and was below 45 mJ/cm^2 for the Aquionics unit. This is contrasted with much higher effective UV dose applied during the wet weather tests reported by WERF (2005), when it ranged from 65 to 220 mJ/cm^2.

Figure 11.10 shows the expected effect of TSS on the transmittance. Even better fit is observed with total $CBOD_5$ values (Figure 11.12) and COD (Figure 11.13), attesting to the contribution of soluble organics to the UV absorbance.

Figure 11.12 Effect of Total CBOD5 on UV Transmittance

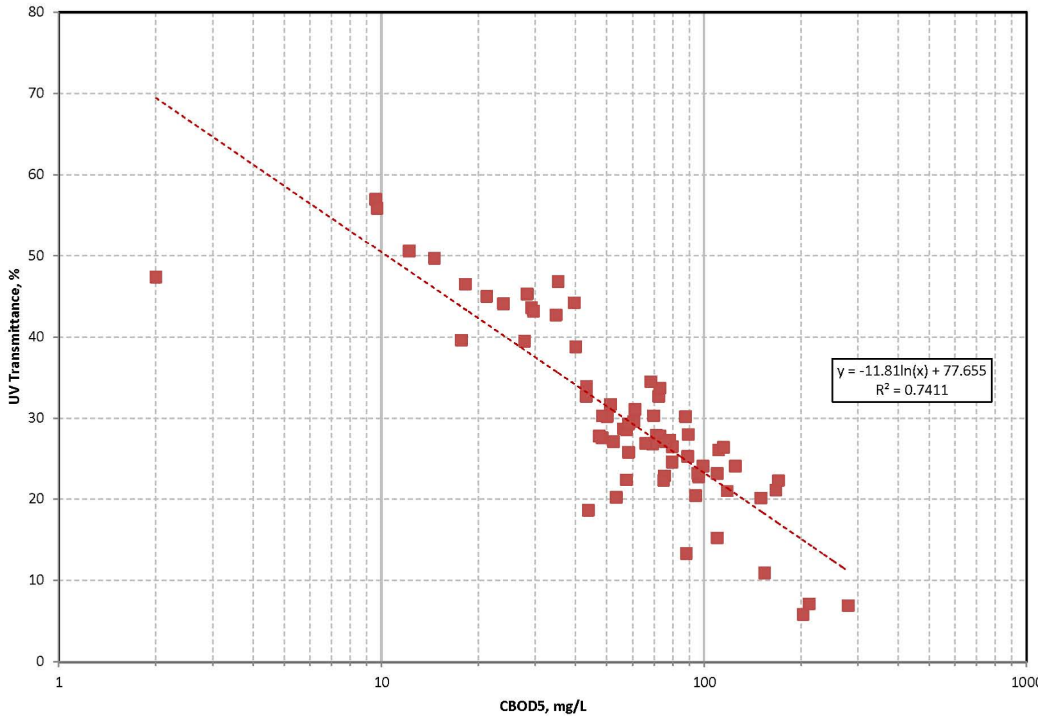
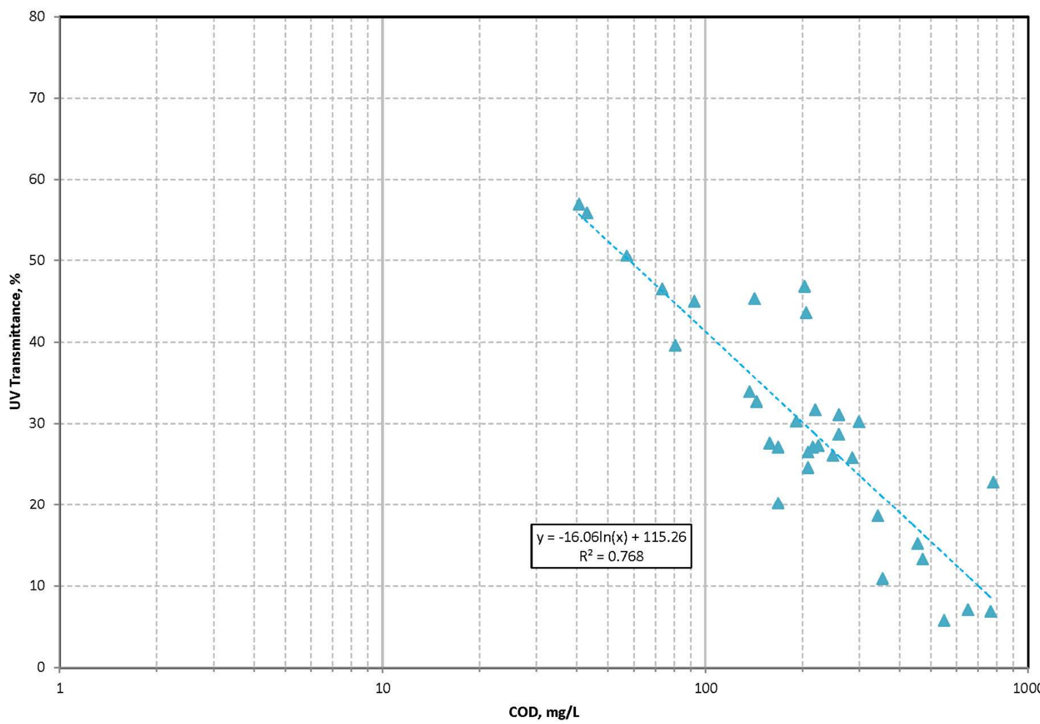


Figure 11.13 Effect of COD on UV Transmittance



11.3 Conclusions and Recommendations

1. The UV units tested exhibited the expected effectiveness commensurable with the modest UV dose applied. The UV dose was frequently limited by very low UV transmittance of the CSO.

2. The pathogen inactivation increased as the applied UV irradiation dose increased, as expected.

3. The Trojan UV3000Plus unit using low-pressure lamps required approximately 25 mJ/cm^2 irradiation energy input to achieve 3 log inactivation of pathogen indicators, on average (with respect to the 3 different pathogen bacteria indicators).

4. The Aquionics 250+W unit using medium-pressure lamps required more than 45 mJ/cm^2 irradiation energy input to achieve a 3-log inactivation of pathogen indicators, on average (with respect to the 3 different pathogen bacteria indicators).

5. In the absence of adequate pre-treatment to increase UVT the design flows for UV equipment, must be significantly lowered (de-rated) to account for poor UVT of the CSO discharge.

6. As expected, wastewater transmittance showed a strong correlation with the water quality parameters concentrations for TSS, $CBOD_5$, and COD. As these parameter concentrations increased, UVT decreased.

Information on other projects and pilot studies is available from the various manufacturers.

SECTION 12 COSTS

To enhance the applicability of this study for developing end-of- pipe CSO control concepts, costing information was requested from the manufacturers. To normalize the costs, the manufacturers were given the following guidelines and provide a basis for comparison:

1. Assume the unit operates 40 times annually
2. Provide data on four maximum peak flow rates 5, 25, 100 and 250 MGD; i.e., four different sizes of outfall.
3. Assume the average peak flow rate is 25% of the maximum
4. Assume the average flow is 10% of the maximum peak flow rate.
5. Assume electricity cost of $0.15/kWh
6. Assume UVTs of 25% and 40% (UV units only)
7. Size based on 3 log pathogen reduction per study data.
8. Assume an influent TSS of 100 mg/L (FlexFilter only)
9. Maintain a PAA residual of 0.8-1.0 mg/l (PAA only)
10. Provide annual maintenance costs

The above guidelines were considered typical for CSOs in NJ and fit well with the 2006 LTCP data for Bayonne. They provide a uniform basis for the costing so that a relative comparison between the various technologies can be made. The individual characteristics of each outfall will obviously need to be considered when evaluating effectiveness and costs of a full-scale system.

The costs provided include only the cost of equipment delivered to the site and are in current dollars. The cost of a contact tank providing three minutes of hydraulic retention time was included for the PAA. These costs have not been verified. Site preparation costs, modification to the existing sewers and real estate costs were considered too site specific and would render the result non-transferrable. Likewise, some units may require pumping to create the hydraulic conditions necessary to force flow through the units, however, this would be a function of the site topography and the capacity of the upstream sewer. The information provided has been summarized into the following graphs shown in Figures 12.1 through 12.16 for equipment capital costs and annual O&M costs.

Figure 12.1 Terre Kleen Equipment Cost

Figure 12.2 Terre Kleen Annual Operation & Maintenance Cost

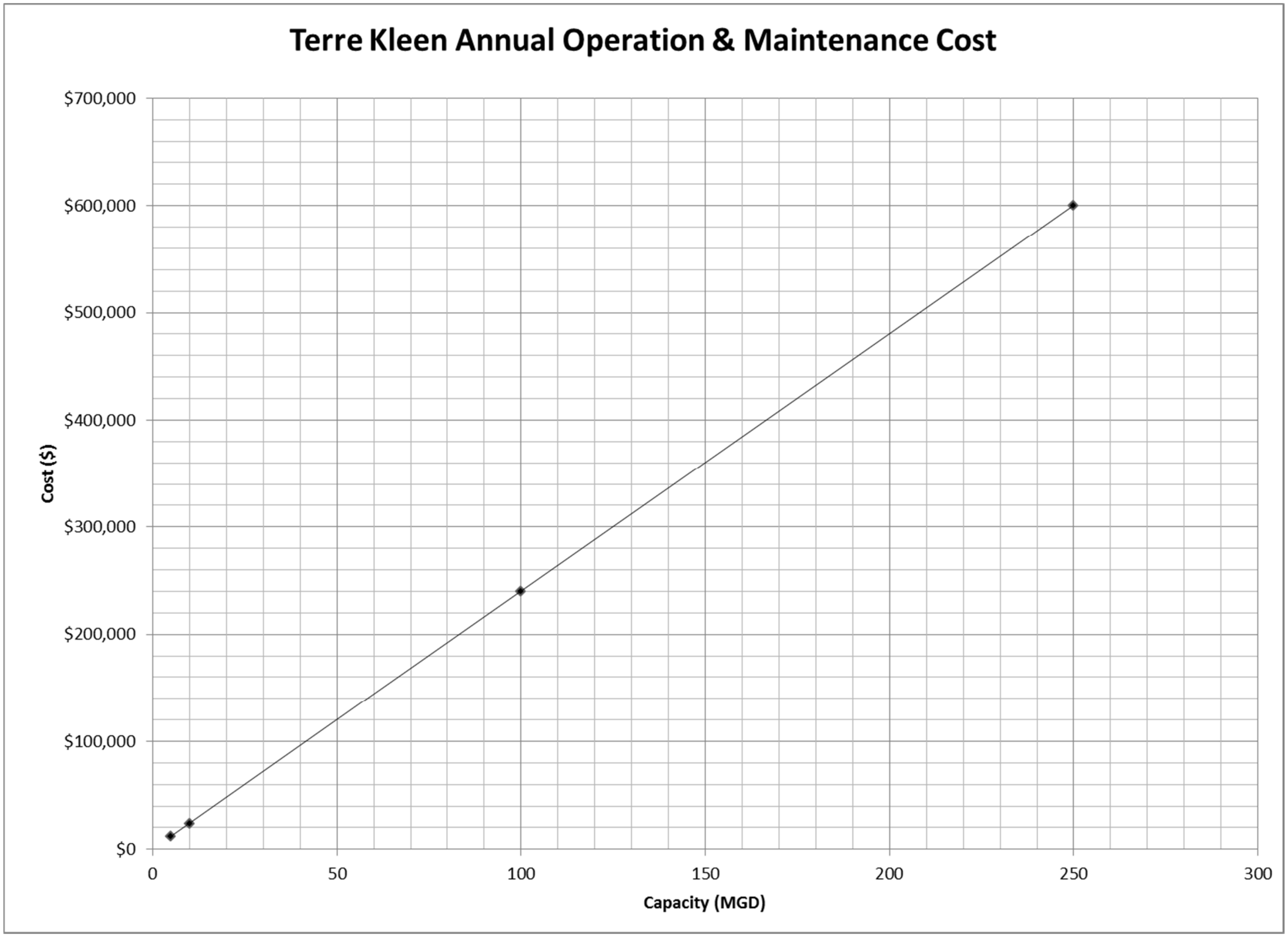


Figure 12.3 Storm King Equipment Cost

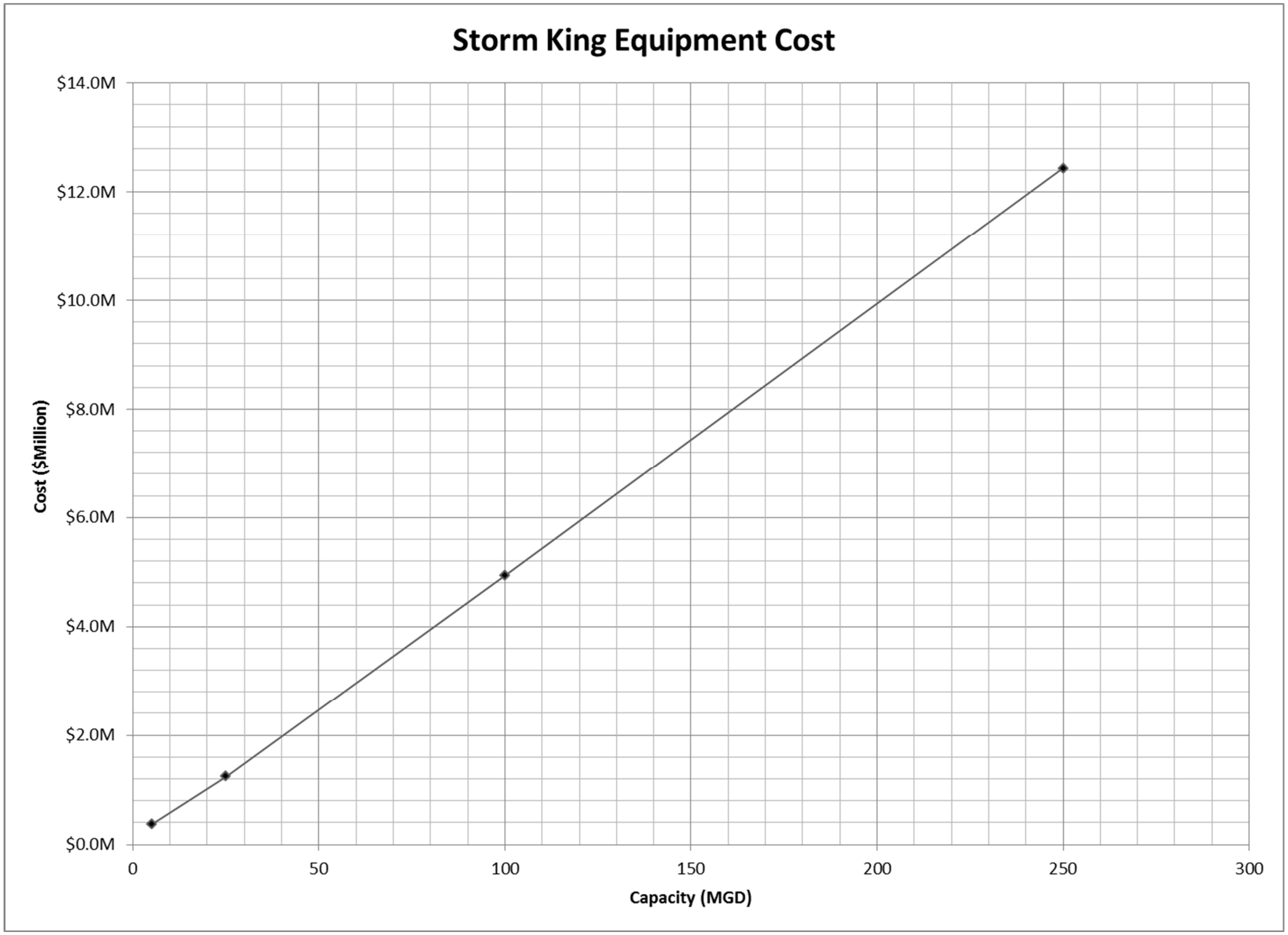


Figure 12.4 Storm King Annual Operation & Maintenance Cost

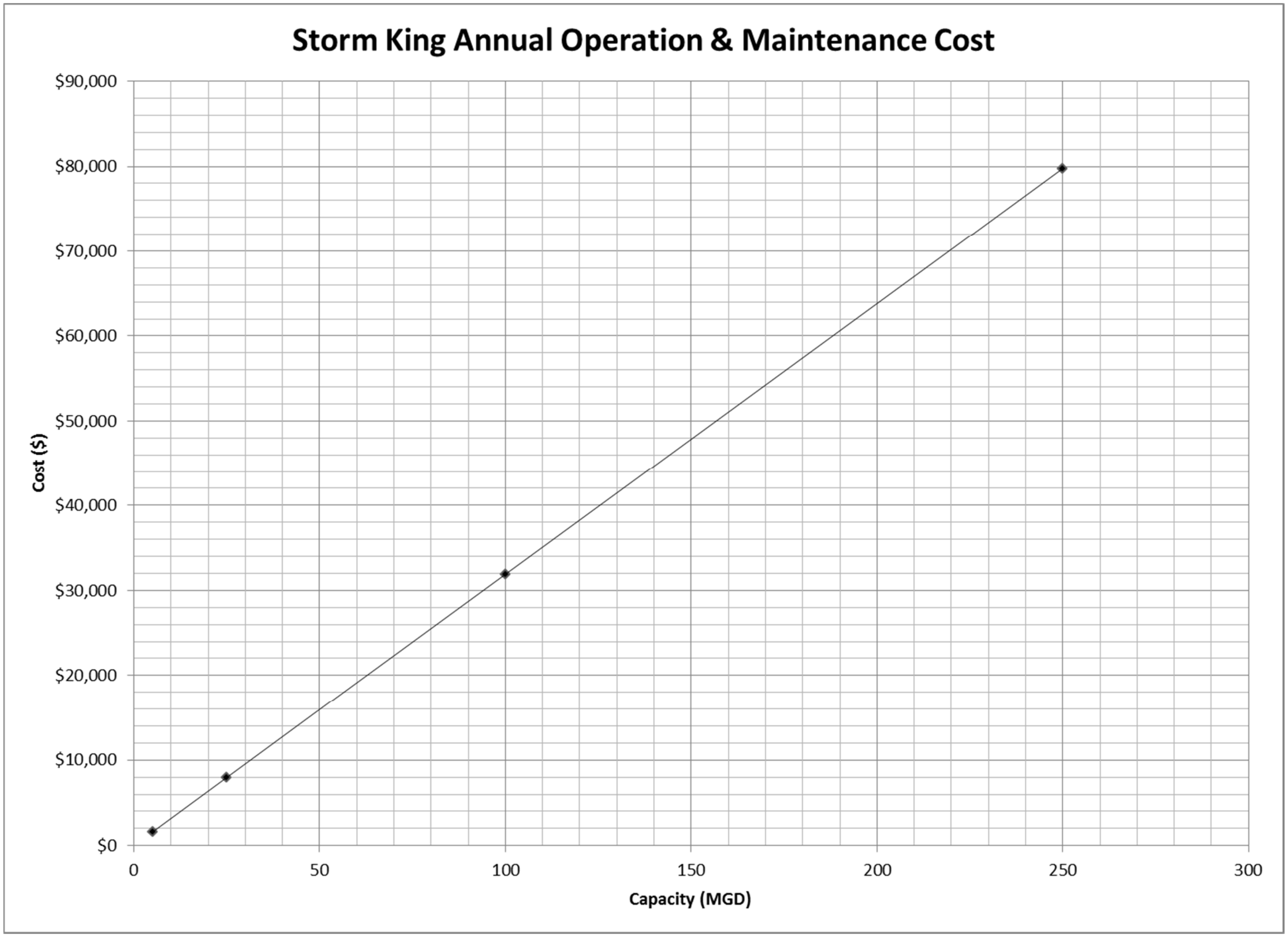


Figure 12.5 Flex Filter Equipment Cost

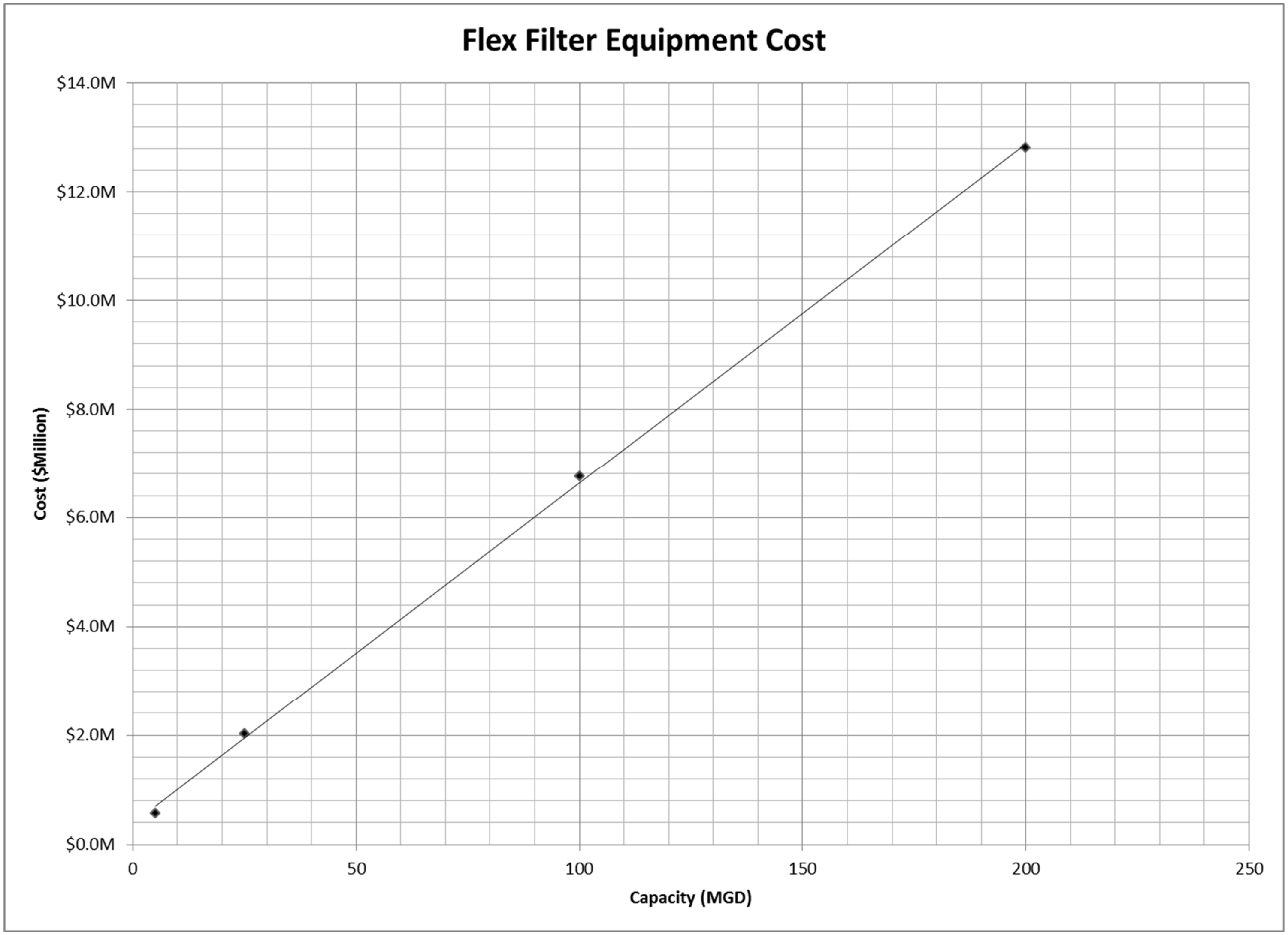


Figure 12.6 Flex Filter Annual Operation & Maintenance Cost

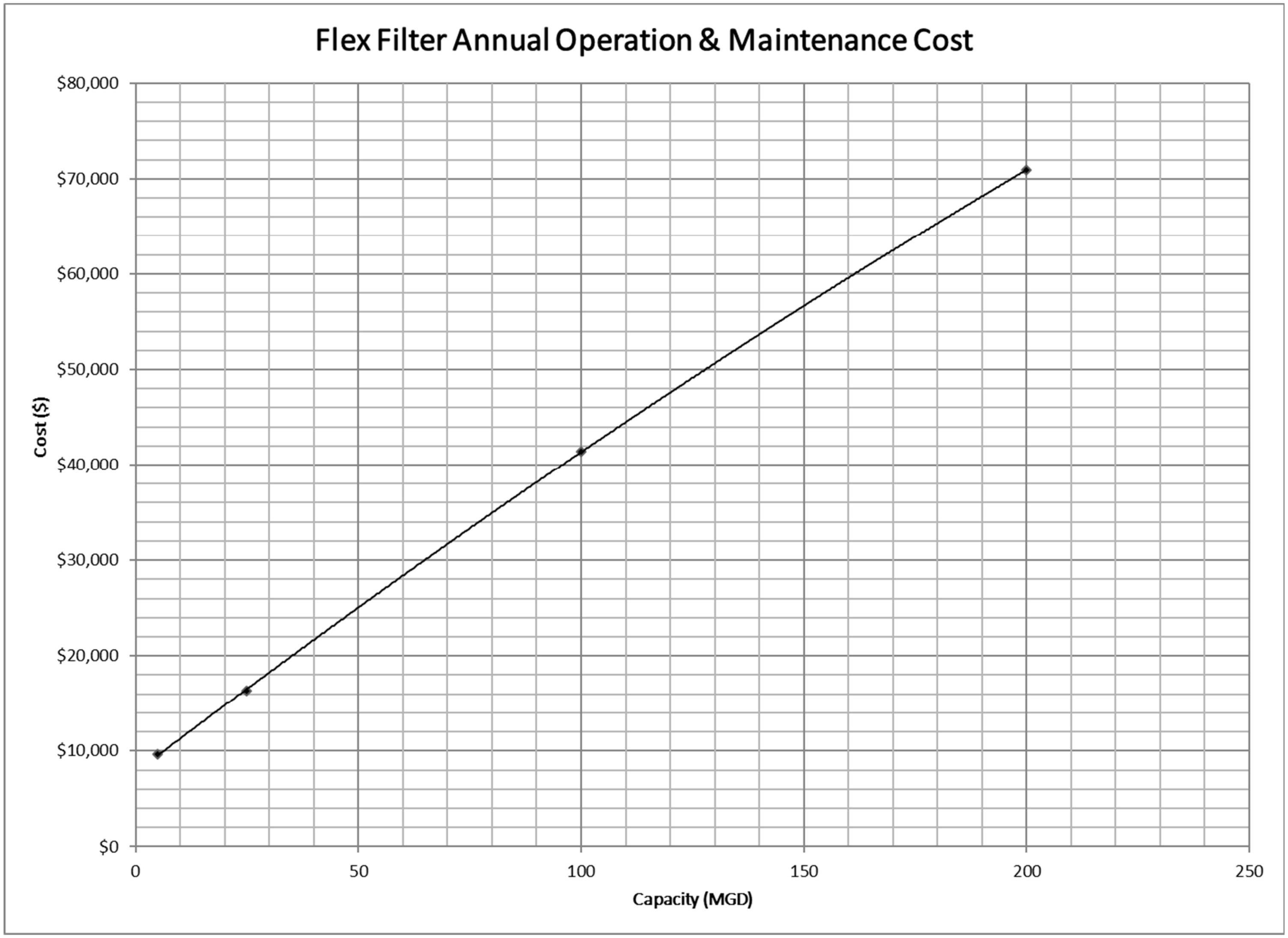


Figure 12.7 Trojan UV (25 % Transmittance) Equipment Cost Curve

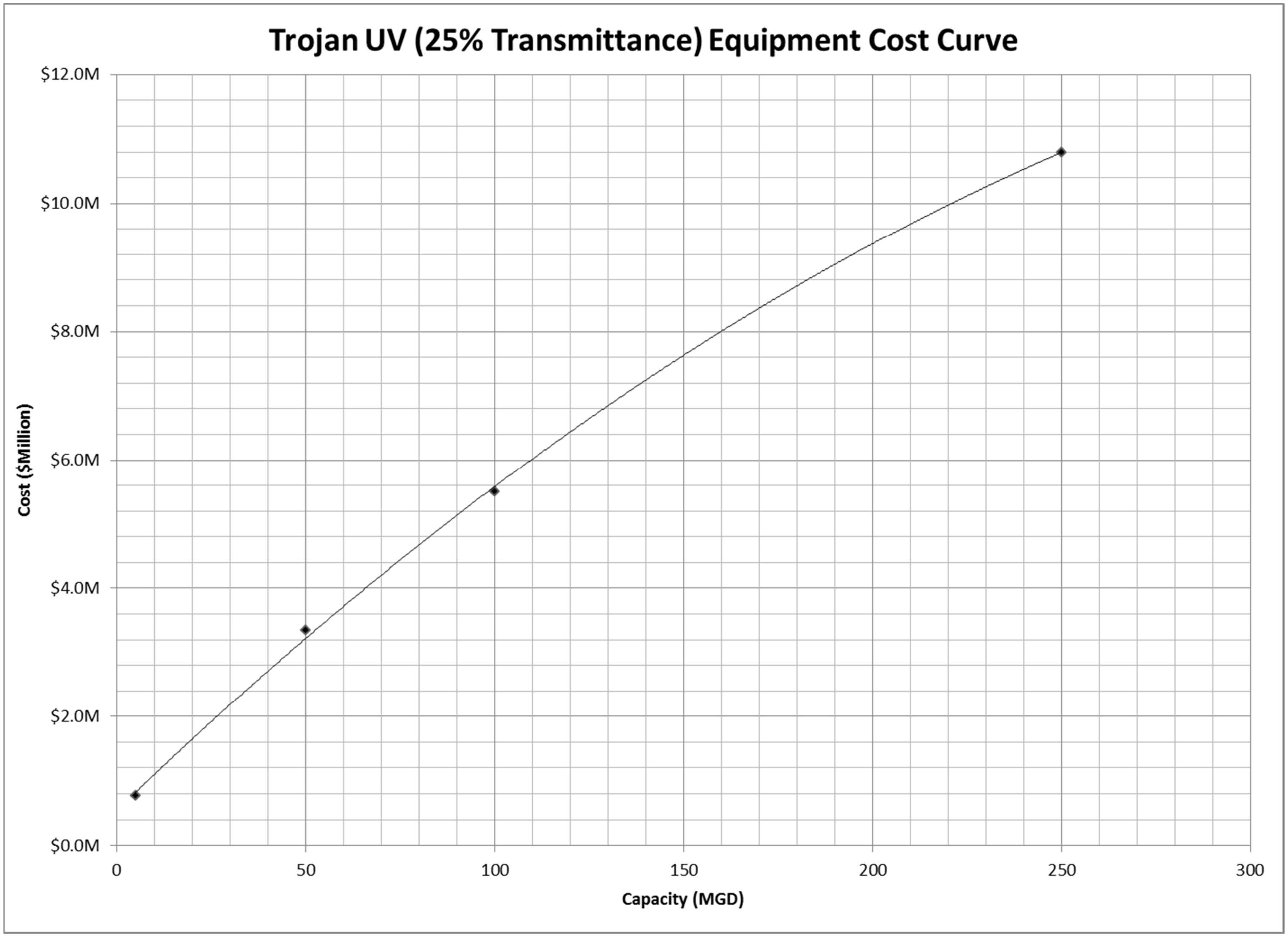


Figure 12.8 Trojan UV (25 % Transmittance) Annual O&M Cost

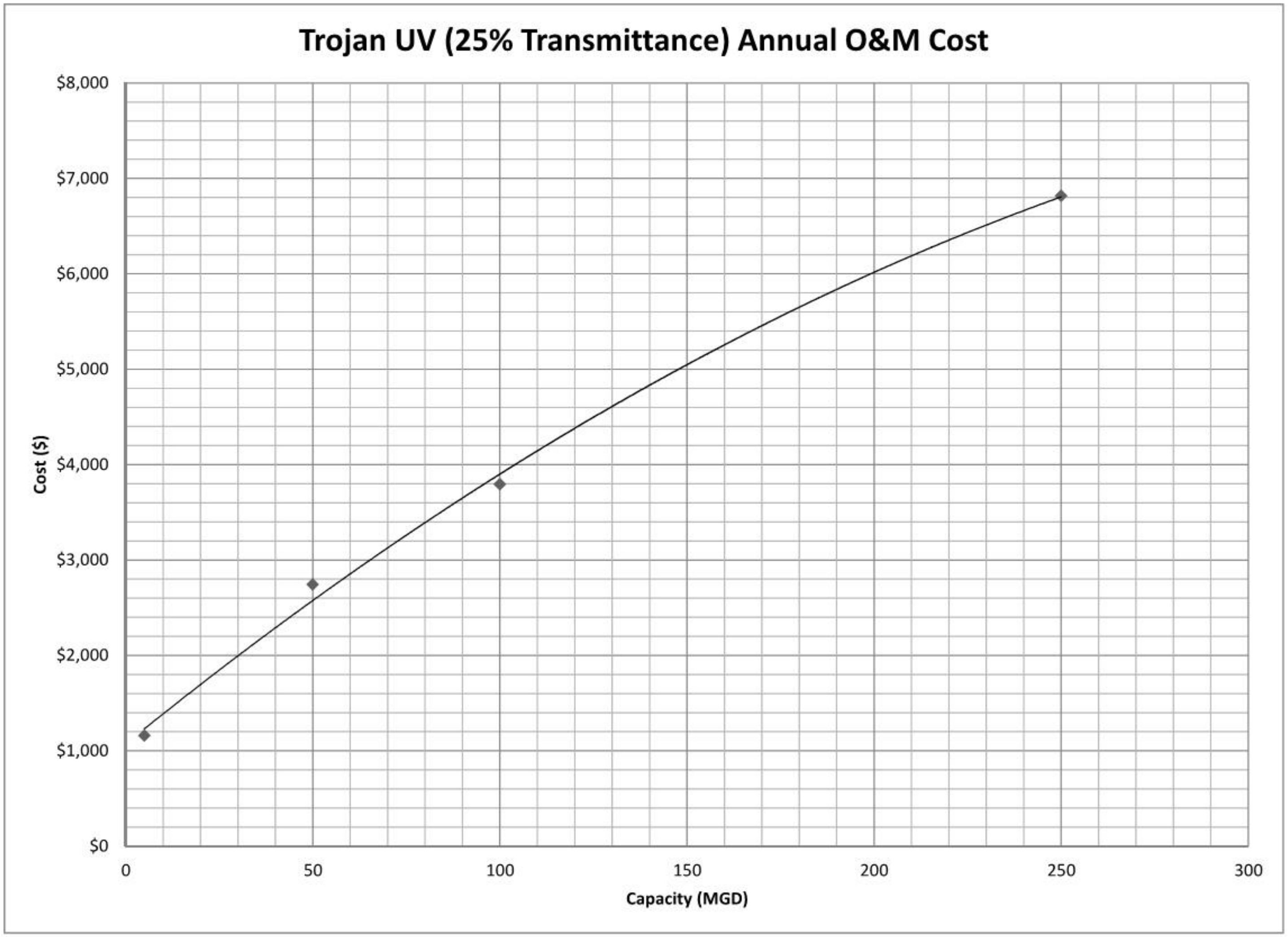


Figure 12.9 Trojan UV (40% Transmittance) Equipment Cost Curve

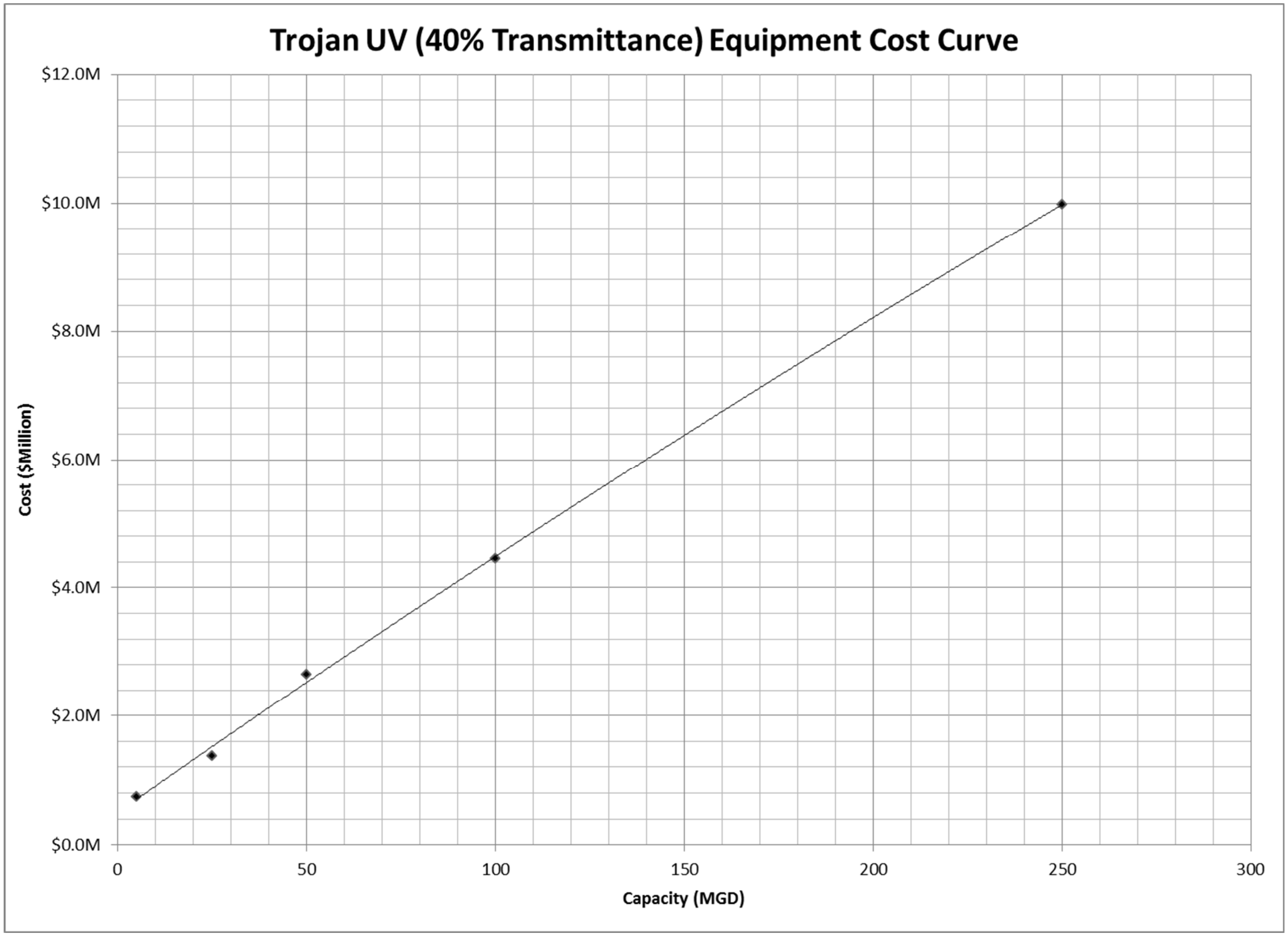


Figure 12.10 Trojan UV (40% Transmittance) Annual O&M Cost

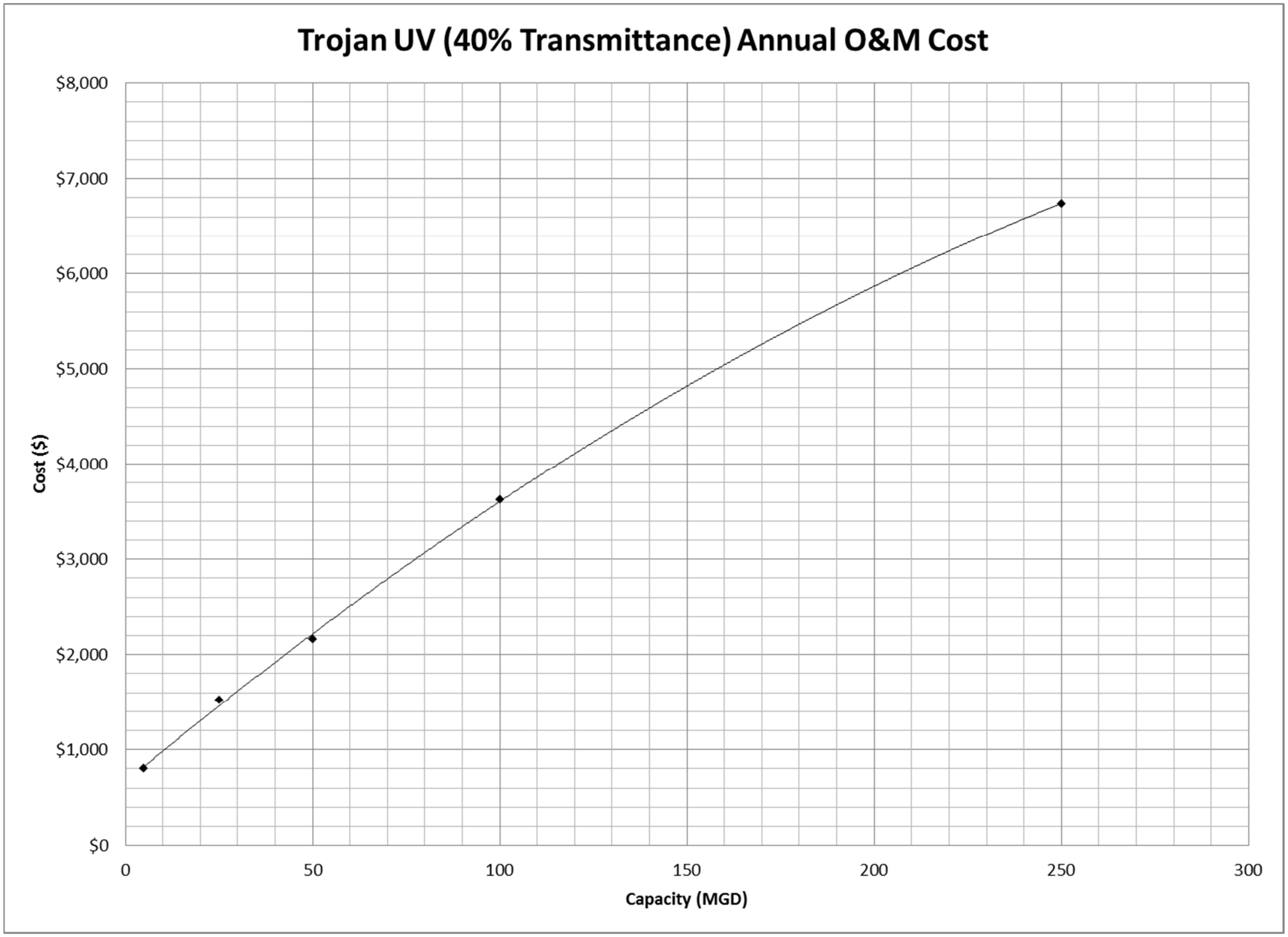


Figure 12.11 Aquionics UV (25% Transmittance) Equipment Cost Curve

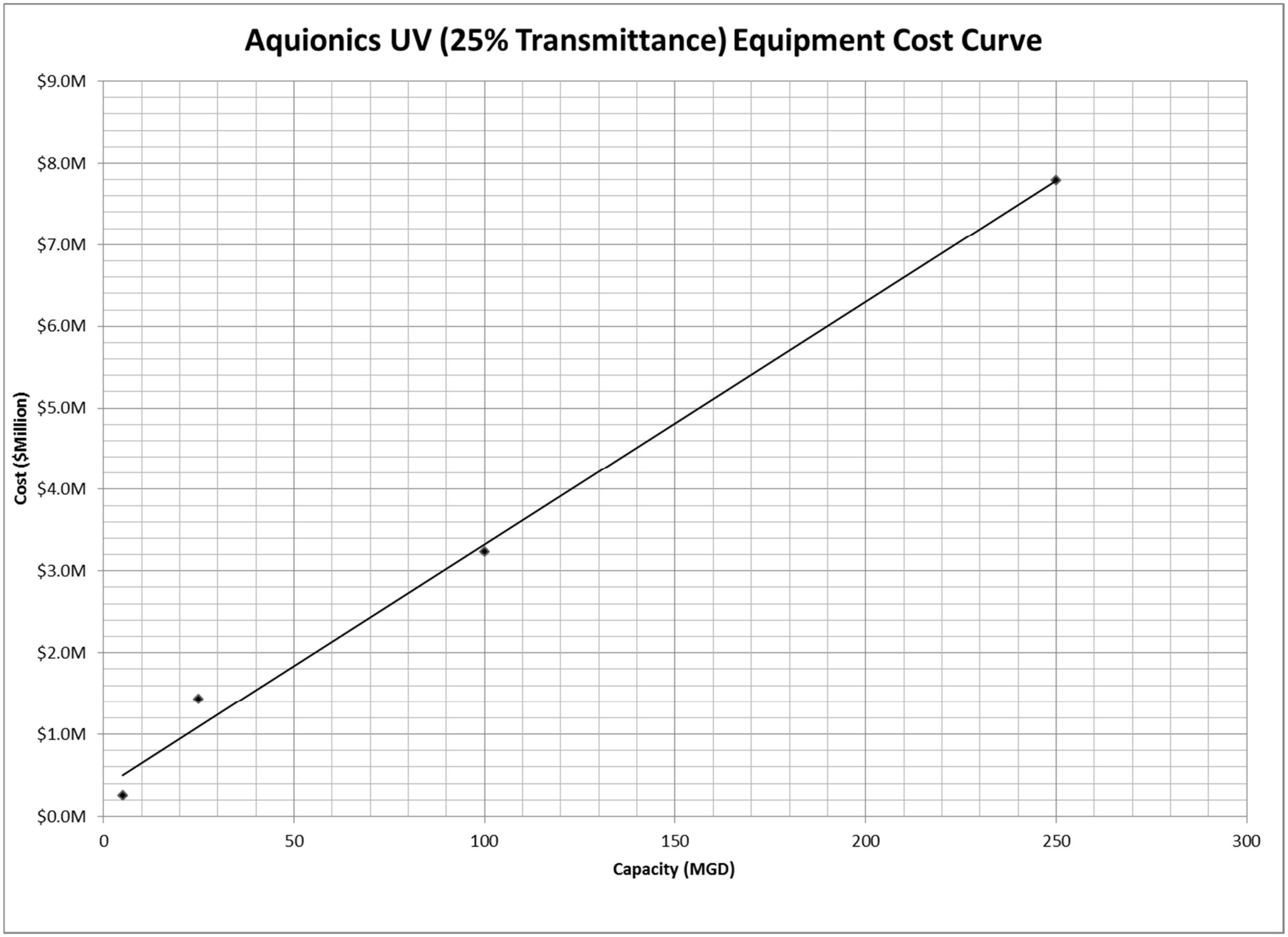


Figure 12.12 Aquionics UV (25% Transmittance) Annual O&M Cost

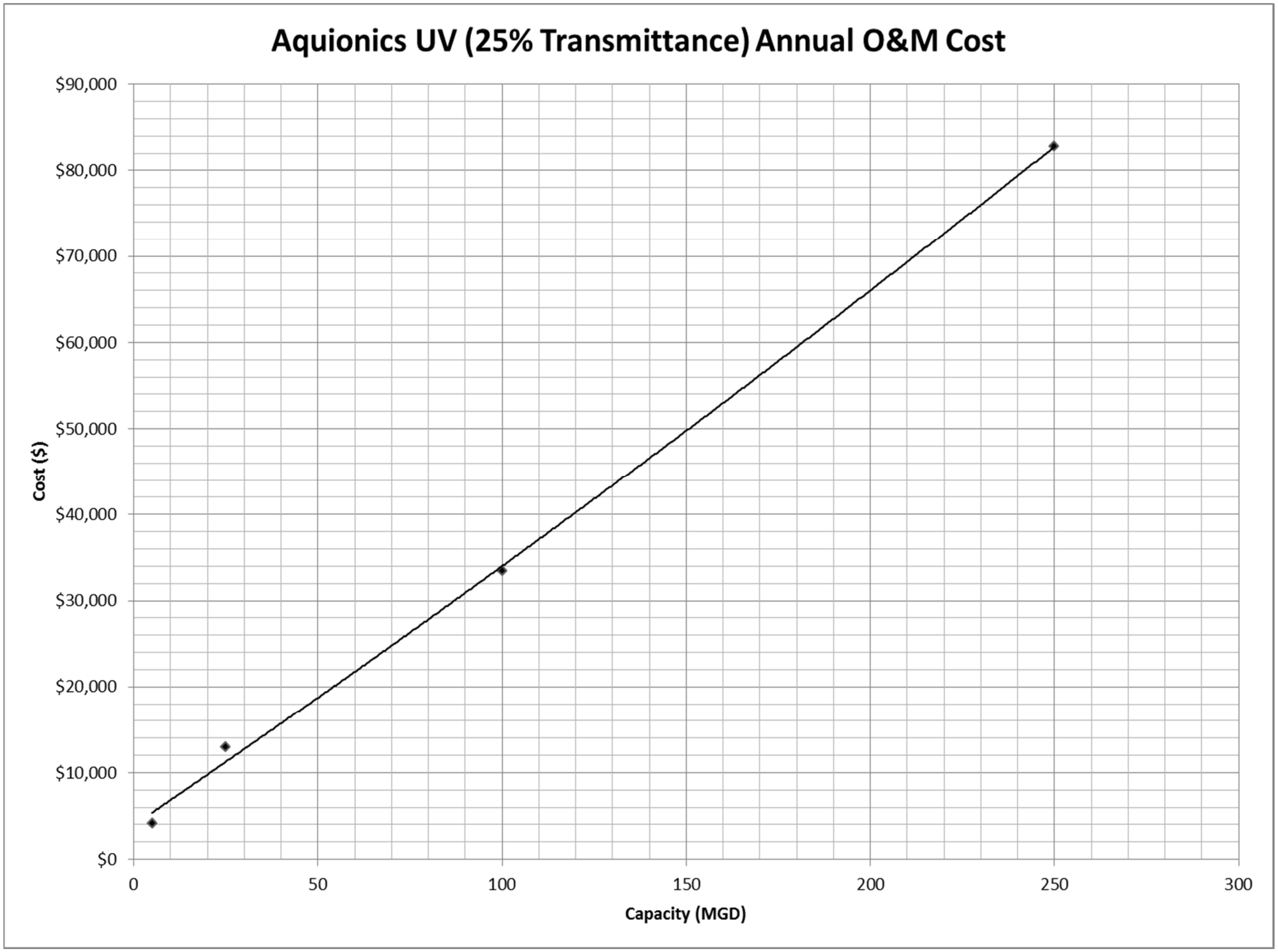


Figure 12.13 Aquionics UV (40% Transmittance) Equipment Cost Curve

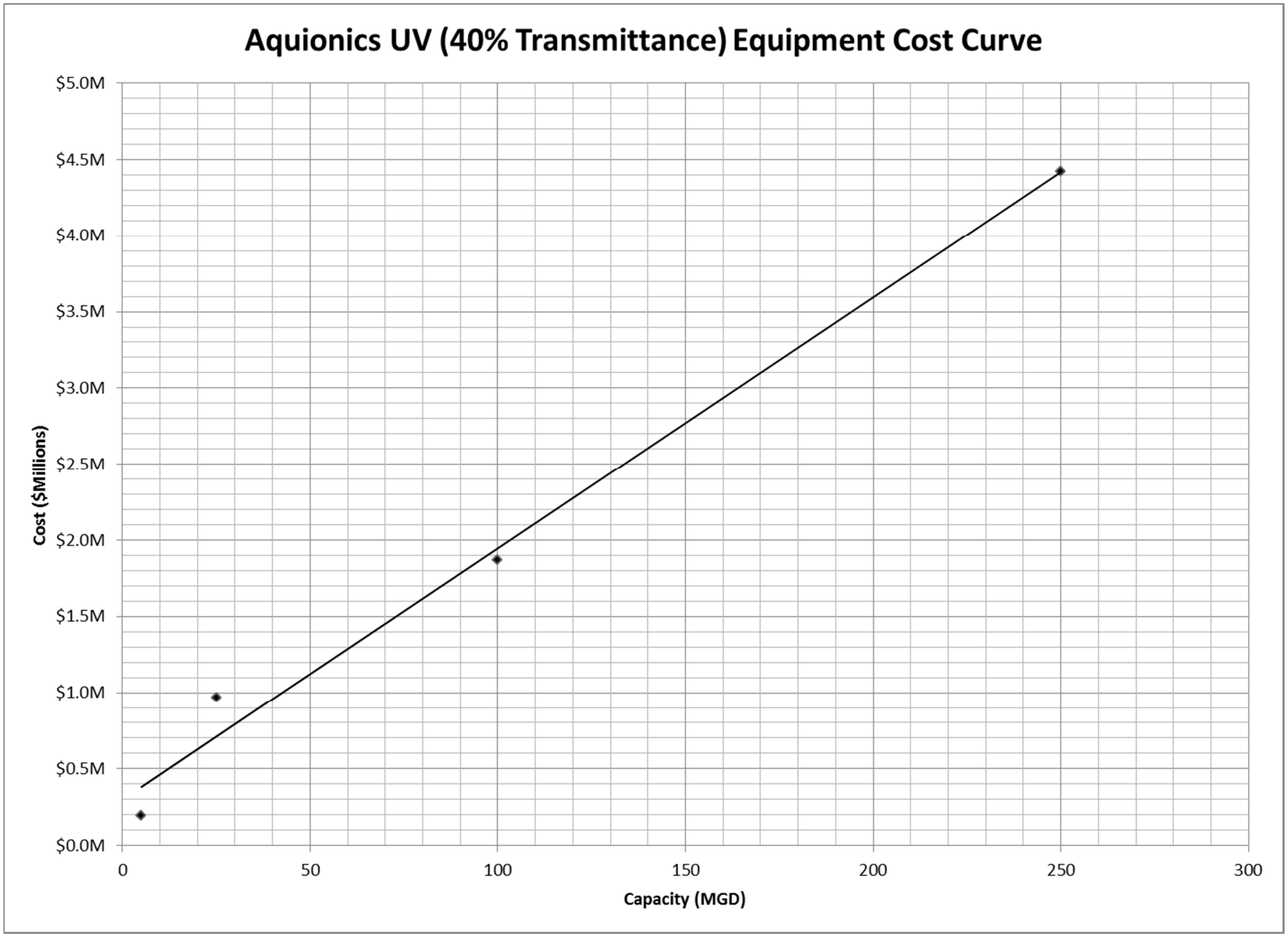


Figure 12.14 Aquionics UV (40% Transmittance) Annual O&M Cost

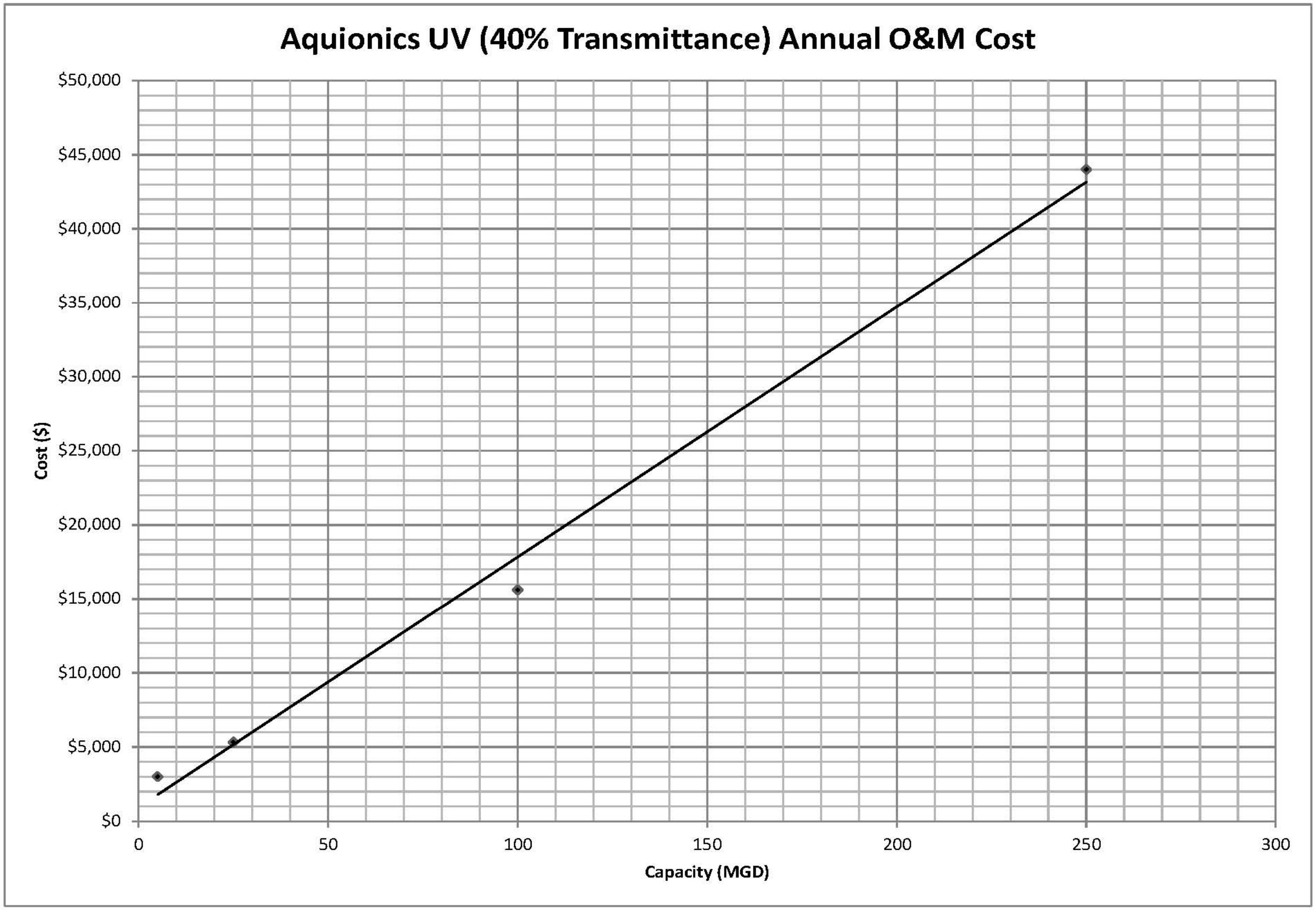


Figure 12.15 Peracetic Equipment Cost

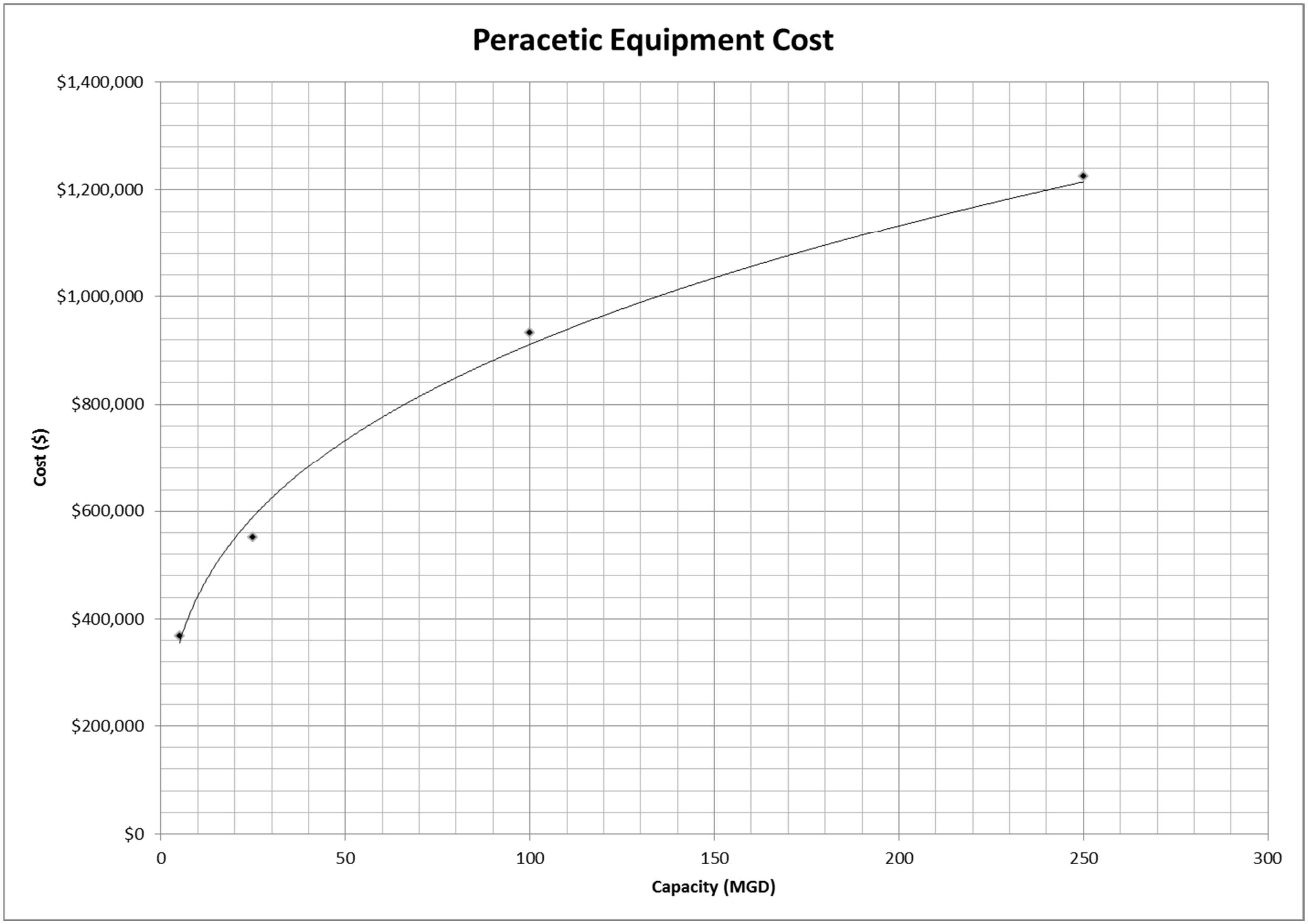
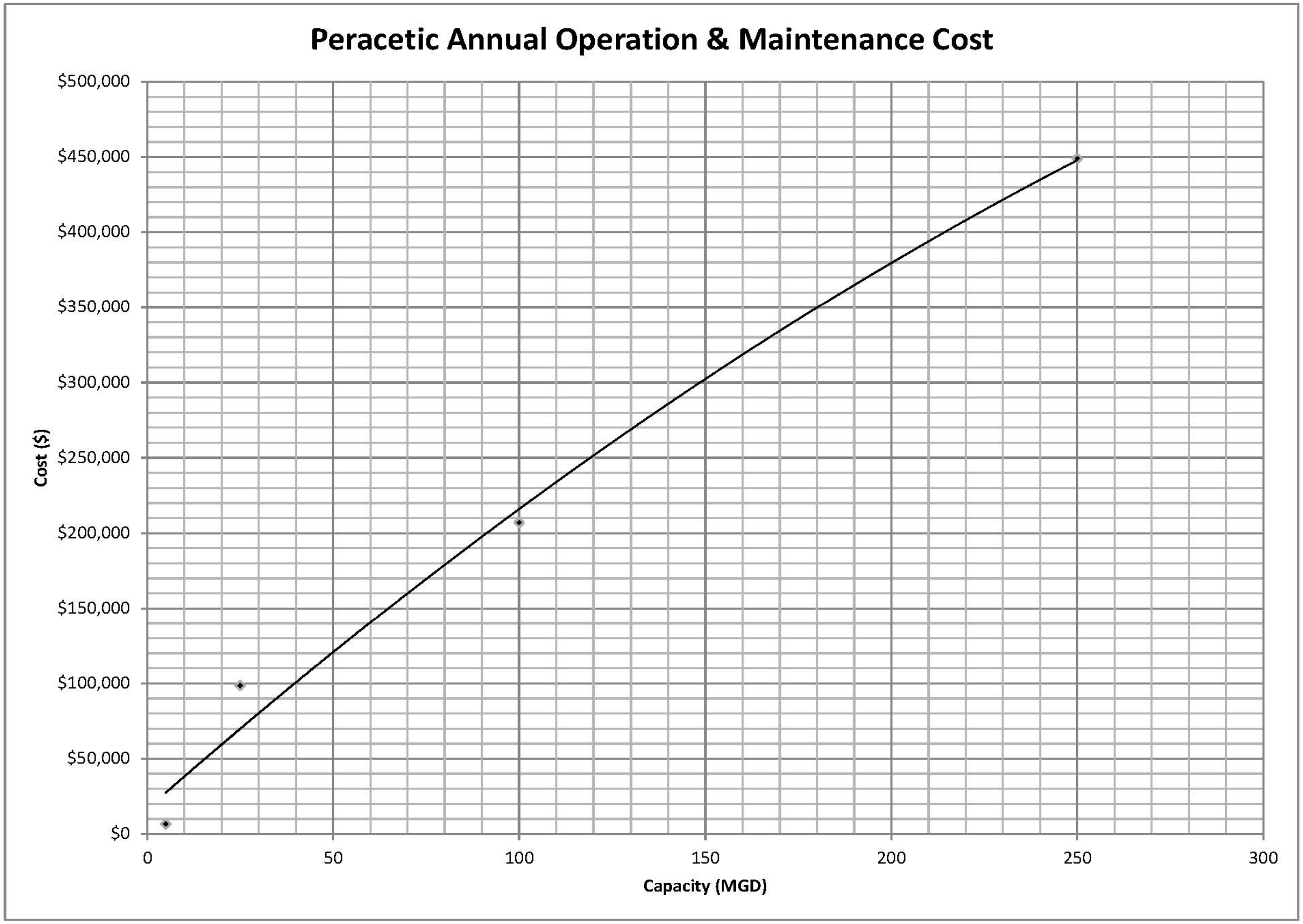


Figure 12.16 Peracetic Annual Operation & Maintenance Cost



THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 13 REFERENCES

Berthouex, P. M. and L.C. Brown, "Statistics for Environmental Engineers," by CRC Pres, Inc., 1994

Engineering Science, Inc. 1990 Tijuana Oceanographic Engineering Study Phase IV. South Bay Outfall Preliminary Planning Study. Prepared for the City of San Diego. March 30, 1990.

Fitzpatrick, J., J. Champion, J. Hutchins, S. McCreary, C. R. O'Bryan, T. Weaver, W. Young, J. Ussher (2015) Taking an Emerging Enhanced High-Rate Treatment Technology from Concept to 100-mgd Reality, WEFTEC 2015.

Fitzpatrick, J.; Gilpin, D.; Kadava, A.; Kliewer, A.; Pekarek, S.; Schlaman, J.; Tarallo, S. (2010) Wet-Weather Pilot Studies Demonstrate Effectiveness of High-Rate Filtration Technologies, Proceedings of the 83rd Annual Water Environment Federation Technical Exhibition and Conference, New Orleans, LA

HDR (2014), *ALCOSAN Disinfection Assessment, Part II: Pilot Disinfection Study of ALCOSAN Primary Effluent,* (unpublished report).

Howarth, J. (2003) Decay Kinetics of Peroxyacetic Acid (PAA) and Hydrogen Peroxide in a Variety of Water Matrices (unpublished report by Enviro Tech Chemical Services), Modesto, California.

HydroQual (2006) *Technical Memorandum: Evaluation of UV Disinfection Process for City of Elizabeth, NJ Combined Sewer Overflow Long Term Plan*, (unpublished report).

Kitis M (2004) Disinfection of wastewater with peracetic acid: a review. *Environment International*; **30**, (47-55).

Liu, D., Steinberg C.E.W., Straus, D. L., Pedersen L. F., Meinelt, T., (2014) Salinity, dissolved organic carbon and water hardness affect peracetic acid (PAA) degradation in aqueous solutions, *Aquacultural Engineering*, **60** (35-40).

McKern, R; Days, P., Matthews, S., White, C., Andoh, R., Boner, M. (2004). Atlanta CSO Pilot Plant Performance Results. *Proceedings of the Water Environment Federation, WEFTEC 2004*. Session 31 through Session 40, pp. 537-555(19). Water Environment Federation

Meinert, Bill, Elizabeth Maio (2016). Shining the Light on Chemistry – Ultra-low TRC Limit Leads to PAA Piloting and Design in Oneida, NYWEA Annual Meeting, February 8th, 2016.

Metcalf & Eddy/AECOM (2014) *Wastewater Engineering; Treatment and Resource Recovery*, McGraw-Hill Education, New York, New York.

Moffa and Associates, "Final Disinfection Technology Pilot Demonstration Report" done for Onondaga, County, Newell Street, September 1999.

Mott MacDonald (2014) Approved *Wet Weather Flow Treatment and Disinfection Demonstration Project Quality Assurance Project Plan*

NJDEP (New Jersey Department of Environmental Protection) (2011) *MTD Laboratory Test Certification for the TerreKleen Stormwater Device by Terre Hill Stormwater Systems, TSS Removal Rate: 50%*, August 31.

NJDEP (New Jersey Department of Environmental Protection) (2017) *MTD Lab Certification, Terre KleenTM Hydrodynamic Separator by Terre Hill Stormwater Systems, Online Installation, TSS Removal Rate 50%,* February 17.

NJDEP (New Jersey Department of Environmental Protection) (2015) *Revised MTD Laboratory Test Certification for the Downstream Defender Stormwater Treatment Device by Hydro International, TSS Removal Rate: 50%*, August 18.

Camp Dresser & McKee and subcontractor Moffa and Associates for the NYCDEP and the USEPA, 1997 "Spring Creek AWPCP Upgrade, CSO Disinfection Pilot Study – Part I" – Final Report

Camp Dresser & McKee and subcontractor Moffa and Associates for the NYCDEP and the USEPA, 1999 "Spring Creek AWPCP Upgrade, CSO Disinfection Pilot Study – Part II" – Final Report

USEPA (2013). Addendum - USEPA Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management, Office of Wastewater Management, U.S. Environmental Protection Agency, Washington, D.C., EPA 832-R-12-011, August 2013.

USEPA, Disinfection/Treatment of Combined Sewer Overflows, Syracuse, N.Y., EPA-600/2-79-134, August,1979 By Frank J. Drehwing, Arthus J. Oliver, Dwight A. MacArthur.

USEPA, Manual Combined Sewer Overflow Control, Sept. 1999

WERF (Water Environment Research Foundation) (2005) *Identifying Technologies and Communicating the benefits and Risks of Disinfecting Wet Weather Flows*; Alexandria, Virginia

WERF (Water Environment Research Foundation) (2002) Peer Review: Wet Weather Demonstration Project in Columbus, GA; WERF Alexandria, Virginia & IWA Publishing London, UK 2002.

SECTION 14 ADDITIONAL LITERATURE ON CSO TREATMENT AND RELATED TOPICS

Block, David, Patrick Fisher, Katherine Evans, Nanette Bradbury, and Jonathan Howarth Block Environmental Services, Inc., Enviro-Tech Chemical Services, "Ecotoxicity of Peracetic Acid to Freshwater Fish, Macroinvertebrate, and Plant Species, WEF Disinfection 2009.

Biswal, Basanta Kumar, Ramzi Khairallah, Kareem Bibi, Alberto Mazza, Ronald Gehr, Luke Masson, Dominic Frigona (2014). "Impact of UV and Peracetic Acid Disinfection on the Prevalence of Virulence and Antimicrobial Resistance Genes in Uropathogenic Escherichia coli in Wastewater Effluents." Applied and Environmental Microbiology, p. 3656–3666 June 2014 Volume 80 Number 12.

CB&I Federal Services LLC., Muddy Creek CSO HRT Disinfection Study, Prepared for Terta Tech Inc., April 29, 2016

Chhetri K, Thornberg D, Berner J, Gramstad R, Ojstedt U, Sharma A, Anderson H, "Chemical disinfection of combined sewer overflow waters using performic acid or peracetic acids." Science of the Total Environment 2014; 490 (1065-1072)

Chhetri K, Thornberg D, Berner J, Gramstad R, Ojstedt U, Sharma A, Anderson H (2014). "Chemical disinfection of combined sewer overflow waters using performic acid or peracetic acids." Science of the Total Environment, 490 (1065-1072)

Chhetri, Ravi Kumar, Rasmus Flagstad, Ebbe Sonne Munch, Claus Hørning, Jesper Berner, Annette Kolte-Olsen, Dines Thornberg, Henrik Rasmus Andersen (2015). "Full scale evaluation of combined sewer overflows disinfection using performic acid in a sea-outfall pipe." Chemical Engineering Journal, 270 (133-139).

de Souza, Jeanette Beber, Fernanda Queiroz Valdez, Rhuan Felipe Jeranoski,, Carlos Magno de Sousa Vidal, and Grasiele Soares Cavallini (2015). "Water and Wastewater Disinfection with Peracetic Acid and UV Radiation and Using Advanced Oxidative Process PAA/UV, Hindawi Publishing Corporation," International Journal of Photoenergy, Volume 2015, Article ID 860845, 7 pages, http://dx.doi.org/10.1155/2015/860845

Drehwing, Frank J., Arthur J. Oliver, Dwight A. MacArthur, Peter E. Moffa (1979). Disinfection/Treatment of Combined Sewer Overflows, Syracuse, New York, United States Environmental Protection Agency, Municipal Environmental Research Laboratory, EPA-600/2-79-134, August 1979, Cincinnati, OH 45268.

Elligson, James C., J. Bradley Mikula, Shirley E. Clark, Christopher D. Roenning, Julia M. Hafera, and Kelly A. Franklin (2006). INCLINED PLATE SETTLERS TO TREAT STORMWATER SOLIDS, WEFTEC 06.

Field, Richard, Daniel Sullivan and Anthony N. Tafuri, Editors (2004). Management of Combined Sewer Overflows, CRC Press, ISBN: 0-56670-636-X, ISBN13: 9781566706360; Chapter 2, Richard Field, Chi-Yuan Fan, Mary Stinson, and Anthony N. Tafuri "Source Management and Control Technologies, pp 49-104"; Chapter 3, Chi-Yuan Fan and Richard Field "Treatment and Solids Management, pp105-156; Chapter 4, Izabela Wojtenko, Mary K. Stinson and Richard Field "Disinfection, 157-188"; Chapter 5, Thomas O'Connor and Richard Field "Effective Control Systems, 189-228".

Field, R., D. Averill, T. P. O'Connor, and P. Steel (1997). "Vortex Separation Technology." Water Quality Research Journal of Canada, Vol. 32, No. 1, pp. 185-214, January, 1997. (Issue link: http://digital.library.mcgill.ca/wqrj/search/issue.php?issue=WQRJ_Vol_32_No_1; Direct link: http://digital.library.mcgill.ca/wqrj/pdfs/WQRJ_Vol_32_No_1_Art_12.pdf).

Field, R, and T. P. O'Connor (1996). Assessment of Vortex Solids Separators for the Control-Treatment of Wet Weather Flow. U.S. Environmental Protection Agency, Municipal Technology Branch, Office of Wastewater Management, Office of Water, Washington, DC. EPA 832-B-96-006, October, 1996 (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=200042GF.txt)

Field, R., and T. P. O'Connor (1996). "Swirl Technology: Enhancement of Design, Evaluation and Application." Journal of Environmental Engineering. American Society of Civil Engineering, Vol. 122, No. 8, pp. 741-748, August 1996. (http://dx.doi.org/10.1061/(ASCE)0733-9372(1996)122:8(741))

Fujita, Gary, James Sherrill (2007). The Importance of Operations and Maintenance Staffing and Non-Staffing Needs for SSO/CSO Control Facilities, WEFTEC 07.

Force, Jim, (2015). "How to Solve the Flushable Wipes Problem at Your Plant," Treatment Plant Operator, Online Exclusives, March 3, 2015.

LaCross, Thomas D., Brent Avery (2007). Retention Treatment Basin Operation, Maintenance, and Budgeting Requirements, WEFTEC 07.

Liu, Dibo, Christian E.W. Steinbergc, David L. Strausd, Lars-Flemming Pedersene, Thomas Meineltba, Salinity (2014). "Dissolved organic carbon and water hardness affect peracetic acid (PAA) degradation in aqueous solutions," Aquacultural Engineering, 60 (35-40).

Maziuk, John, Robert T. Freeborn, and Chuck Murphy (2013). Peracetic Acid: Proves Effective as Alternative Disinfection Method, http://www.waterworld.com/articles/print/volume-29/issue-9/departments/case-studies/peracetic-acid.html[10/16/2013 10:04:13 PM]

Moffa, Peter, Editor (1990). Control and Treatment of Combined Sewer Overflows, Van Nostrand Reinhold, ISBN 0-442-26491-7; Chapter 4, Richard Field "Combined Sewer Overflows: Control and Treatment, pp 119-190."

Moffa, Peter, John LaGorga and Chris Somerlot, Daniel Davis (2004). Technical Memorandum on StormKingR Swirl CleanseTM Data Testing at Onondaga County METRO, Brown and Caldwell, December 20, 2004.

Moffa, Peter E., Clayton McCormack, Terrance Moore, Sr. (2007). OPERATIONS AND MAINTENANCE REQUIREMENT OF VORTEX WITH DISINFECTION AND SCREENING WITH DISINFECTION CSO FACILITIES, WEFTEC 07.

Moffa, Peter E. (2008). CSO Treatment Technologies from Floatables Control to Disinfection, EPA 1-Day CSO Workshop, June 19, 2008, Double Tree Hotel, Syracuse, NY.

Murphy, Sean P., Terrance Moore, Sr. (2007). Operations and Maintenance Requirements for Storage Tunnels and In-System Storage Facilities, WEFTEC 07.

MWRD (2012). Evaluation of Disinfection Technologies for the Calumet and North Side Water Reclamation Plants, Technical Memorandum 2, Metropolitan Water Reclamation District of Greater Chicago, December 21, 2011.

NJCAT (2010). NJCAT TECHNOLOGY VERIFICATION: Terre Kleen™ TK18 Separator, Terre Hill Stormwater Systems, January 2010 (April 2011 Addendum to this report starts on page 44).

NJDEP (2017). Revised MTD Lab Certification, Downstream Defender Stormwater Treatment Device by Hydro International, TSS Removal Rate 50% , March 2017.

PAA Pilot Demonstration to Determine PAA, Efficacy as an Alternative Disinfectant to Chlorine and Sodium Bisulfite Technology for Wastewater, City of Steubenville WWTP “PAA” Demonstration, WEFTEC, October 7, 2013.

Prevo, Dennis B., S. Piddington, B. Avery, A. Coleman, F. Fath-Azam, T. Moore, R. Facione (2007). BEST MANAGEMENT PRACTICES FOR STAFFING OF WET WEATHER CONTROL FACILITIES, WEFTEC 07.

Proxitane® WW-12 Microbiocide, ACTIVE INGREDIENT.
Peracetic Acid (CAS No. 79-21-0) and its Equilibrium Solutions, JACC No. 40, ISSN-0733-6339-40, Brussels, January 2001.

Scheible, Karl (2002). Continuous Deflection Separation, Fuzzy Filter, and UV Treatment of SSO-Type Wastewaters: Pilot Study Results. USEPA Cooperative Agreement, No. X-82435210, EPA/600/R-02/100, December 2002. (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1001P0Y.txt)

Sherrill, James, Gary Fujita (2007). Budget Development for Operations/Maintenance Requirements for CSO/SSO Control Facilities, WEFTEC 07.

USEPA (2012). Alternative Disinfection Methods Fact Sheet: Peracetic Acid, United States Environmental Protection Agency, September 2012.

USEPA (2013). USEPA Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management, Office of Wastewater Management, U.S. Environmental Protection Agency, Washington, D.C., EPA 832-R-12-011, March 2013.

Vancouver, City of (2013). FIELD TEST OF COMPATABILITY OF NON-WOVEN PERSONAL WIPE MATERIALS, PROJECT REPORT, City of Vancouver, WA, July 17, 2013.

WERF (2003) "Peer Review: Wet Weather Demonstration Project in Columbus, Georgia

SECTION 15 ADDITIONAL REFERENCE MATERIALS PROVIDED BY MANUFACTURERS

Hydro International Provided:

(1) Saco, ME, Wet Weather Case Study - Storm King® Dynamic Separator Project Profile
(2) Storm King® Operational Data, 2007-2014, City of Saco, WWTP, 68 Front Street, Saco, ME 04072, Tel: 207-282-3564

WWETCO Provided:

(1) Narrative on FlexFilter "Enhanced High Rate Treatment (EHRT) for CSO, SSO, Stormwater Treatment & WWTP Effluent Polishing"

PeraGreen provided:

(1) PeraGreen Solutions, LLC, PERACETIC ACID, Field Demonstrations and "Lessons Learned", NJDEP, April 7, 2014.
(2) Kansas City WWTP – PAA Uptake Test and Dilution Tests (spreadsheet)
(3) Lemay WWTP - PAA Uptake Test and Dilution Tests (Spreadsheet)
(4) PROXITANE® WW-12 Microbiocide, SAFETY DATA SHEET, North American Version
(5) CU101_41740_INSTALL_TRIMMED_Layout
(6) PeraGreen Solutions, LLC, OVERVIEW, New Jersey Wet Weather Flow Treatment and Disinfection Demonstration Project, 11/20/13.
(7) CITY OF STEUBENVILLE, OHIO WASTEWATER TREATMENT FACILITY, PAA Pilot Demonstration to determine PAA, Efficacy as an alternative disinfectant to Chlorine and Sodium Bisulfite technology for wastewater

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

Tables with Individual Data from All Test Runs

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.1

Data Entered By: AML, RJL Date: 11/01/14
Checked By: SM Date: 11/11/14
QA Review By: Date:

Indicates data is anomalous see notes column for qualifications regarding the data
Calculated Value
No data collected for this parameter at this location.
Unable to Collect Sample
Not Detected at or above the Method Detection Limit (MDL)

Configuration Plan
Train 1: Terre Kleen (500 gpm)-->Aquionics UV (200 gpm)
Train 2: Storm King (500 gpm)-->Flex Filter (100 gpm)-->PAA (50 gpm)

Upon completion of data entry sheet shall be protected DO **NOT PASSWORD PROTECT**

								Field Analysis						Laboratory Analysis														
														PVSC							LL	Accutest / Test America (2,3)				LL		
Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm) (4)	Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (%) (6)	PAA Residual (mg/L) (5)	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS (1) (mg/L)	VSS (mg/L)	Non Settleable VSS (1) (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	Q	$CBOD_5$ Soluble (mg/L)	Q	TOC (mg/L)	Notes	
10/4/2014	**S-1**	Influent	0:00	10:30	10:30		N/A	20.4	7.15	5.00							352	119	218	92	652	212		31.6		23.5	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-1**		0:00	10:50	10:50		N/A	20.3	6.93	12.0							446		328		859	327		28.3		21.5	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-1**		0:00	11:10	11:10		N/A	20.4	6.96	-1.00							374		284		578	218		43.6		18.9	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-1**		0:00	11:30	11:30		N/A	20.4	6.93	-6.00							270	103	196	82	802	148		13.5		16.5	CBOD from Accutest; Turbidity meter appeared to have malfunctioned; Meter recalibrated @ 11:41	
10/4/2014	**S-1**		0:00	11:50	11:50		N/A	20.4	7.08	41.6							248		180		690	143	H	4.6	JH	14.7	CBOD from TA	
10/4/2014	**S-1**		0:00	12:10	12:10		N/A	20.6	7.06	33.9							186		134		427	49.8	JH	4.9	J	13.3	CBOD from TA	
10/4/2014	**S-1**		0:00	12:30	12:30		N/A	20.7	7.12	39.3							171	79	119	59	562	76.4		4.6	JH	13.4	CBOD from TA	
10/4/2014	**S-1**		0:00	12:50	12:50		N/A	20.9	7.00	37.8							179		121		313	64.8	H	5.9	J	15.0	CBOD from TA	
10/4/2014	**S-1**		0:00	13:10	13:10		N/A	20.9	6.95	28.4							126		87		247	54	JH	5.2	J	14.6	CBOD from TA	
10/4/2014	**S-1**		0:00	13:30	13:30		N/A	21.1	7.00	29.3							105	52	74	40	313	63.8		5.6	J	16.4	CBOD from TA	
10/4/2014	**S-1**		0:00	13:50	13:50		N/A	21.2	7.07	27.0							91		67		256	59.8		8.6		18.4	CBOD from TA	
10/4/2014	**S-1**		0:00	14:10	14:10		N/A	21.3	7.03	27.5							102		78		247	65.3		9.8		20.2	CBOD from TA; "Uncomplete date on LL COC"	
10/4/2014	**S-2**	Terre Kleen (Effluent)	0:03	10:33	10:30	M1-Avg	505			1.00				1,720,000	INTERFERENCE	600,000	297		195		549	203		18.7		21.0	CBOD from Accutest; Extra container to LL; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-2**		0:03	10:53	10:50	M1-Avg	524			16.0				1,960,000	22,000,000	600,000	424		314		765	280		17.4		21.3	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-2**		0:03	11:13	11:10	M1-Avg	507			4.00				280,000	28,000,000	1,200,000	336		248		650	212		25.2		20.2	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-2**		0:03	11:33	11:30	M1-Avg	493			-7.00				560,000	INTERFERENCE	720,000	185		135		471	88.1	H	2.7	JH	15.8	CBOD from TA; Turbidity meter appeared to have malfunctioned; Meter recalibrated @ 11:41	
10/4/2014	**S-2**		0:03	11:53	11:50	M1-Avg	492			39.2				880,000	10,000,000	880,000	196		137		450	4.5	JH	8.2		13.7	CBOD from TA; Insufficient sample volume was provided to Test America	
10/4/2014	**S-2**		0:03	12:13	12:10	M1-Avg	480			37.8				800,000	10,000,000	640,000	185		129		457	63.9	H	5	J	13.8	CBOD from TA	
10/4/2014	**S-2**		0:03	12:33	12:30	M1-Avg	476			34.4				NS??	NS?	NS?	179		126		342	43.8	JH	5.6	J	15.1	CBOD from TA; Only one container was received by LL when 4 containers were written on the COC	
10/4/2014	**S-2**		0:03	12:53	12:50	M1-Avg	460			35.1				520,000	8,000,000	520,000	185		125		779	96.2	H	7.7		12.6	CBOD from TA	
10/4/2014	**S-2**		0:03	13:13	13:10	M1-Avg	468			38.2				760,000	3,500,000	520,000	114		77		259	56.3		3.8	J	12.7	CBOD from TA; Only one container was received by LL when 3 containers were written on the COC	
10/4/2014	**S-2**		0:03	13:33	13:30	M1-Avg	471			27.7				880,000	1,700,000	360,000	98		69		259	61.1		8		14.9	CBOD from TA	
10/4/2014	**S-2**		0:03	13:53	13:50	M1-Avg	459			28.5				680,000	2,800,000	640,000	92		69		234	61.6		6.4		15.6	CBOD from TA	
10/4/2014	**S-2**		0:03	14:13	14:10	M1-Avg	452			30.6				1,520,000	3,900,000	400,000	100		76		274	68.3		9.5		18.7	CBOD from TA	
10/4/2014	**S-3**	Storm King (Effluent)	0:02	10:32	10:30	M2-Avg	509			14.0							347		226		690	249		35.9		23.3	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-3**		0:02	10:52	10:50	M2-Avg	530			15.0							526		416		824	299		46.9		20.3	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-3**		0:02	11:12	11:10	M2-Avg	503			9.00							342		258		707	312		27.3		20.1	CBOD from Accutest; Turbidity meter appeared to have malfunctioned	
10/4/2014	**S-3**		0:02	11:32	11:30	M2-Avg	481			1.00							428		342		575	117	H	6.3	H	15.0	CBOD from TA; Sample was labeled as S-3 on LL COC but was labeled as S-1 on label, TOC & COD; Turbidity meter appeared to have malfunctioned; Meter recalibrated @ 11:41	
10/4/2014	**S-3**		0:02	11:52	11:50	M2-Avg	477			43.3							244		184		412	71.1	H	9.5		13.1	CBOD from TA	
10/4/2014	**S-3**		0:02	12:12	12:10	M2-Avg	473			108							154		110		321	75	H	5.9	J	12.5	CBOD from TA; Time on COC was incorrect (12:12 vs 12:13)	
10/4/2014	**S-3**		0:02	12:32	12:30	M2-Avg	459			43.7							150		107		419	55.8	JH	5.8	J	13.9	CBOD from TA	
10/4/2014	**S-3**		0:02	12:52	12:50	M2-Avg	446			47.2							155		112		361	75.8	H	8.9		13.8	CBOD from TA	
10/4/2014	**S-3**		0:02	13:12	13:10	M2-Avg	455			33.3							127		95		292	60.5		5.2	J	12.7	CBOD from TA	
10/4/2014	**S-3**		0:02	13:32	13:30	M2-Avg	460			30.4							221		170		384	51.9	JH	6.5		14.7	CBOD from TA	
10/4/2014	**S-3**		0:02	13:52	13:50	M2-Avg	446			32.2							91		66		238	8.6	H	8.6		15.6	CBOD from TA	
10/4/2014	**S-3**		0:02	14:12	14:10	M2-Avg	440			27.4							93		71		427	8.9	H	8.9		17.1	CBOD from TA	
10/4/2014	**S-4**	Flex Filter (Effluent)	0:11	10:41	10:30		N/A	19.8		24.7	75.6	0.11		1,400,000	12,000,000	720,000	37		31		168	41.5		5.2	JH	17.7	CBOD from TA	
10/4/2014	**S-4**		0:11	11:01	10:50		N/A	20.0		54.7	64.1	0.064		1,280,000	11,000,000	40,000	232		182		551	87.9	H	5.6	JH	18.4	CBOD from TA	
10/4/2014	**S-4**		0:11	11:21	11:10		N/A	20.2		33.0	59.1	0.043		1,040,000	25,000,000	1,160,000	240		186		530	92.9	H	9.5	H	18.2	CBOD from TA	
10/4/2014	**S-4**		0:11	11:41	11:30		N/A	20.1		40.5	74.0	0.0		920,000	10,000,000	880,000	168		126		403	72.9	H	3.6	JH	13.7	CBOD from TA	
10/4/2014	**S-4**		0:11	12:01	11:50		N/A	20.3		35.0	65.4	0.214		1,040,000	INTERFERENCE	600,000	138		103		323	55.2		7.8		12.5	CBOD from TA, ta mislabed this sample as S-5 12:01 in their report, COC shows S-4 12:01	
10/4/2014	**S-4**		0:11	12:21	12:10		N/A	20.5		32.8	66.5	0.0		520,000	1,960,000	720,000	104		75		271	67.1		4.8	J	11.5	CBOD from TA	
10/4/2014	**S-4**		0:11	12:45	12:34		N/A	20.7		30.0	63.6	0.0		840,000	2,600,000	360,000	117		88		257	61.9		5.5	J	12.5	CBOD from TA	
10/4/2014	**S-4**		0:11	13:03	12:52		N/A	20.9		32.8	66.2	0.0		800,000	3,500,000	240,000	94		70		262	55.3		8.6		13.2	CBOD from TA; Due to flow drop, sample taken from CB-3 not S-4	13:05?
10/4/2014	**S-4**		0:11	13:21	13:10		N/A	NS		NS	NS			NS	NS	NS	NS		NS		NS	NS		NS		NS		
10/4/2014	**S-4**		0:11	13:41	13:30		N/A	NS		NS	NS			NS	NS	NS	NS		NS		NS	NS		NS		NS		
10/4/2014	**S-4**		0:11	14:05	13:54		N/A	21.0		14.2	81.0	0.00		320,000	1,480,000	20,000	18		15		128	21.5		6		14.9	CBOD from TA	
10/4/2014	**S-4**		0:11	NS	NS		N/A	NS		NS	NS			NS	NS	NS	NS		NS		NS	NS		NS		NS		
10/4/2014	**S-5**	PAA (Effluent)	0:22	10:52	10:30		N/A	19.9			78.5	0.2245		2,400,000	6,100,000	920,000											PAA not feeding properly	
10/4/2014	**S-5**		0:22	11:12	10:50		N/A	20.1			68.9	0.0		1,080,000	12,700,000	620,000											PAA not feeding properly	
10/4/2014	**S-5**		0:22	11:32	11:10		N/A	20.3			63.5	0.0		56,000	INTERFERENCE	1,300,000											PAA not feeding properly	
10/4/2014	**S-5**		0:22	11:52	11:30		N/A	20.3			86.7	2.35		60	100	<100												
10/4/2014	**S-5**		0:22	12:12	11:50		N/A	20.4			88.5	2.35		<100	<40,000	100												
10/4/2014	**S-5**		0:22	12:32	12:10		N/A	20.6			84.9	2.35		<100	<40,000	100												
10/4/2014	**S-5**		0:22	12:55	12:33		N/A	20.8			80.6	2.35		200	2,000,000	<100												
10/4/2014	**S-5**		0:22	13:15	12:53		N/A	21.0			86.4	2.35		NS??	100,000	<100												
	S-5						N/A	NS			NS			NS	NS	NS												
	S-5						N/A	NS			NS			NS	NS	NS												
	S-5						N/A	NS			NS			NS	NS	NS												
	S-5						N/A	NS			NS			NS	NS	NS												
	S-6	Trojan UV (Effluent)	Location Not Sampled				N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
	S-6						N/A																					
10/4/2014	**S-7**	Aquionics UV (Effluent)	0:06	10:36	10:30		N/A						5.8	460,000	INTERFERENCE	300,000												
10/4/2014	**S-7**		0:06	10:56	10:50		N/A						6.9	880,000	8,400,000	590,000												
10/4/2014	**S-7**		0:06	11:16	11:10		N/A						7.1	1,070,000	8,500,000	510,000												
10/4/2014	**S-7**		0:06	11:36	11:30		N/A						13.3	1,360	210,000	100,000												
10/4/2014	**S-7**		0:06	11:56	11:50		N/A						0.3	51,000	370,000	48,000											Suspected malfunction of UVT meter	
10/4/2014	**S-7**		0:06	12:16	12:10		N/A						0.3	42,000	110,000	48,000											Flow drop 45 gpm; Valve altered to restore flow	
10/4/2014	**S-7**		0:06	12:36	12:30		N/A						18.6	2,100,000	6,700,000	550,000											UV wiper timeout error- bulb off	
10/4/2014	**S-7**		0:06	13:00	12:54		N/A						22.8	23,000	570,000	6,800												
10/4/2014	**S-7**		0:06	13:25	13:19		N/A						28.7	5,800	16,000	6,400												
10/4/2014	**S-7**		0:06	13:45	13:39		N/A						31.1	4,000	39,000	900												

General Notes:
PVSC = Passaic Valley Sewerage Commission
LL = Lancaster Laboratories
ACU = Accutest Laboratories
TA = Test America Laboratories
J: Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value
H: Sample was prepped or analyzed beyond the specified holding time
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. Test America did not receive #28 FB
3. Page 2 of 3 of the Test America COC had no tests checked
4. Flow not continuously monitored
5. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.
6. Dissolve Oxygen inadvertenly measured in % saturation rather tham mg/L

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.2

Data Entered By: AML / RJL   Date: 11/01/14
Checked By: SM   Date: 11/11/14
QA Review By: Date:

Legend:
- (yellow) Indicates data is suspect see notes column for qualifications regarding the data
- (light green) Calculated Value
- (blue) No data collected for this parameter at this location.
- (magenta) Unable to Collect Sample
- (green) Not Detected at or above the Method Detection Limit (MDL)

Configuration Plan
Train 1: Storm King (300 gpm) --> Trojan UV (150 gpm)
Train 2: Terre Kleen (300 gpm) --> Flex Filter (150 gpm) -->Aquionics UV (120 gpm)

Upon completion of data entry sheet shall be protected **DO NOT PASSWORD PROTECT**

								Field Analysis						Laboratory Analysis											
														PVSC							Lancaster Laboratories				
Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L)	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS [1] (mg/L)	VSS (mg/L)	Non Settleable VSS [1] (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)	Notes
10/16/2014	S-1	Influent	0:00	2:20	10/16/14 2:20		N/A	21.3	7.09	28.6							170		104		236	77.7	6.8	13	
10/16/2014	S-1		0:00	2:40	10/16/14 2:40		N/A	21.3	7.10	21.1							128	117	80	71	215	49.9	6.4	10.1	
10/16/2014	S-1		0:00	3:00	10/16/14 3:00		N/A	21.3	7.03	43.5							218		156		372	128	11.9	15.7	
10/16/2014	S-1		0:00	3:20	10/16/14 3:20		N/A	21.2	7.00	31.5							208	76	142	60	311	80.6	6.3	12.3	
10/16/2014	S-1		0:00	3:40	10/16/14 3:40		N/A	21.2	7.13	22.0							140		86		219	42.1	5.4	10.5	
10/16/2014	S-1		0:00	4:00	10/16/14 4:00		N/A	20.9	7.23	27.7							196	63	102	47	177	57.9	4.1	8.1	
10/16/2014	S-1		0:00	4:20	10/16/14 4:20		N/A	21.0	7.08	17.5							110		58		114	23.7	3.9	5.8	
10/16/2014	S-1		0:00	4:40	10/16/14 4:40		N/A	21.0	7.12	19.4							81		43		128	32.7	3.5	6.4	
10/16/2014	S-1		0:00	5:00	10/16/14 5:00		N/A	20.9	7.02	20.1							93	56	54	38	111	37.6	4.1	4.5	
10/16/2014	S-1		0:00	5:20	10/16/14 5:20		N/A	20.9	7.03	18.2							102		64		116	38.5	3.9	4.5	
10/16/2014	S-1		0:00	5:40	10/16/14 5:40		N/A	20.9	7.02	17.8							102		60		135	35.4	4.2	5.2	
10/16/2014	S-1		0:00	6:00	10/16/14 6:00		N/A	20.8	7.05	19.8							105	40	52	24	231	29.0	4.7	5.2	
10/16/2014	S-2	Terre Kleen (Effluent)	0:03	2:33	10/16/14 2:30	M1-Avg	294	21.2	7.08	29.9							134		90		210	64.4	7.0	13.9	
10/16/2014	S-2		0:03	2:53	10/16/14 2:50	M1-Avg	282	21.2	7.10	44.5							168		128		462	103	10.2	14.8	
10/16/2014	S-2		0:03	3:05	10/16/14 3:02	M1-Avg	282	21.3	7.05	66.0							456		376		695	189	9.8	19.9	
10/16/2014	S-2		0:03	3:30	10/16/14 3:27	M1-Avg	287	21.2	7.14	50.7							266		220		382	125	6.5	13.0	
10/16/2014	S-2		0:03	3:50	10/16/14 3:47	M1-Avg	282	21.2	7.17	39.9							179		127		408	56.2	6.2	12.5	
10/16/2014	S-2		0:03	4:10	10/16/14 4:07	M1-Avg	290	21.0	7.18	48.6							192		116		259	63.6	4.9	8.3	
10/16/2014	S-2		0:03	4:30	10/16/14 4:27	M1-Avg	293	21.0	7.09	23.4							98		63		123	37.7	4.0	6.7	
10/16/2014	S-2		0:03	4:50	10/16/14 4:47	M1-Avg	302	20.9	7.09	23.1							104		65		132	54.0	5.4	5.7	
10/16/2014	S-2		0:03	5:10	10/16/14 5:07	M1-Avg	324	20.9	7.01	16.8							72		43		102	30.2	4.6	5.6	
10/16/2014	S-2		0:03	5:30	10/16/14 5:27	M1-Avg	259	20.9	7.05	54.0							214		166		337	133	8.8	9.3	
10/16/2014	S-2		0:03	5:50	10/16/14 5:47	M1-Avg	278	20.8	7.06	50.0							240		188		245	119	8.0	7.3	
10/16/2014	S-2		0:03	6:10	10/16/14 6:07	M1-Avg	256	20.8	7.06	42.0							224		168		269	137	7.6	7.1	
10/16/2014	S-3	Storm King[3] (Effluent)	0:13	2:25	10/16/14 2:12	M2-Avg	306	21.3	7.15	30.4				520,000	8,000,000	480,000	140		102		285	58.4	7.5	13.0	
10/16/2014	S-3		0:13	2:45	10/16/14 2:32	M2-Avg	294	21.2	7.11	21.3				480,000	1,600,000	480,000	106		78		168	52.4	5.6	10.9	
10/16/2014	S-3		0:13	3:03	10/16/14 2:50	M2-Avg	278	21.3	7.05	49.0				1,080,000	4,200,000	600,000	210		160		354	154	8.4	13.3	
10/16/2014	S-3		0:13	3:25	10/16/14 3:12	M2-Avg	307	21.2	7.15	33.6				1,040,000	7,000,000	560,000	208		168		455	110	6.6	12.3	See Note 4
10/16/2014	S-3		0:13	3:45	10/16/14 3:32	M2-Avg	298	21.1	7.2	31.7				560,000	1,320,000	440,000	161		121		299	50.1	5.2	11.5	See Note 4 no sample for 05:45 however there is an extra sample for 03:45
10/16/2014	S-3		0:13	4:05	10/16/14 3:52	M2-Avg	407	21.0	7.24	62.0				600,000	1,200,000	360,000	170		90		219	51.3	5.5	6.8	See Note 4
10/16/2014	S-3		0:13	4:25	10/16/14 4:12	M2-Avg	302	21.0	7.14	48.0				320,000	960,000	160,000	110		71		203	35.3	3.7	8.1	See Note 4
10/16/2014	S-3		0:13	4:45	10/16/14 4:32	M2-Avg	281	20.9	7.18	22.7				480,000	920,000	360,000	86		56		205	29.2	4.5	8.2	See Note 4
10/16/2014	S-3		0:13	5:05	10/16/14 4:52	M2-Avg	313	20.9	7.09	31.9				120,000	720,000	160,000	104		75		142	28.3	N.D.	6.6	
10/16/2014	S-3		0:13	5:25	10/16/14 5:12	M2-Avg	259	20.9	7.10	24.7				NS	NS	NS	80		58		165	43.1	N.D.	5.8	
10/16/2014	S-3		0:13	5:45	10/16/14 5:32	M2-Avg	292	20.9	7.09	26.6				NS	NS	NS	112		74		163	45.0	N.D.	6.4	No sample for 05:45 however there is an extra sample for 03:45
10/16/2014	S-3		0:13	6:05	10/16/14 5:52	M2-Avg	265	20.8	7.14	24.5				NS	NS	NS	115		76		375	26.3	N.D.	7.1	
10/16/2014	S-4	Flex Filter[2] (Effluent)	0:12	2:32	10/16/14 2:20		N/A			10.26				680,000.00	1,040,000.00	400,000.00	13		11		92.4	21.2	7.9	14.6	See Note 4
10/16/2014	S-4		0:12	2:52	10/16/14 2:40		N/A			8.61				440,000.00	760,000.00	240,000.00	9		9		73.6	18.2	6.8	12.6	See Note 4
10/16/2014	S-4		0:12	NS			N/A			NS				NS	NS	NS	ns		ns		NS	NS	NS	NS	Flex Filter Backwash, No Sample (RJL)
10/16/2014	S-4		0:12	NS			N/A			NS				NS	NS	NS	ns		ns		NS	NS	NS	NS	Flex Filter Backwash, No Sample (RJL)
10/16/2014	S-4		0:12	3:52	10/16/14 3:40		N/A			9.74				600,000.00	1,160,000.00	560,000.00	19		14		80.6	17.7	7.0	13.3	See Note 4
10/16/2014	S-4		0:12	4:12	10/16/14 4:00		N/A			29.2				400,000.00	640,000.00	480,000.00	6		5		57.1	12.2	4.7	9.4	See Note 4
10/16/2014	S-4		0:12	4:32	10/16/14 4:20		N/A			7.44				320,000.00	680,000.00	80,000.00	7		6		40.6	9.6	3.9	6.8	See Note 4
10/16/2014	S-4		0:12	4:52	10/16/14 4:40		N/A			5.94				80,000.00	560,000.00	80,000.00	7		6		43.0	9.7	4.1	6.8	
10/16/2014	S-4		0:12	NS			N/A			NS				NS	NS	NS	ns		ns		NS	NS	NS	NS	Flex Filter Backwash, No Sample (RJL)
10/16/2014	S-4		0:12	5:32	10/16/14 5:20		N/A			7.32				120,000.00	480,000.00	240,000.00	13		8		43.0	12.9	3.2	5.4	
10/16/2014	S-4		0:12	5:52	10/16/14 5:40		N/A			7.24				NS	NS	NS	9		7		40.6	9.3	N.D.	5.6	
10/16/2014	S-4		0:12	6:12	10/16/14 6:00		N/A			7.22				NS	NS	NS	6		6		40.6	8.8	3.4	5.9	
	S-5	PAA (Effluent)	Location Not Sampled				N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
	S-5						N/A																		
10/16/2014	S-6	Trojan UV (Effluent)	0:05	2:25	10/16/14 2:20		N/A						25.8	2,000	INTERFERENCE	18,000									
10/16/2014	S-6		0:05	2:45	10/16/14 2:40		N/A						27.1	5,000	INTERFERENCE	6,000									
10/16/2014	S-6		0:05	3:05	10/16/14 3:00		N/A						10.9	24,000	40,000	43,000									
10/16/2014	S-6		0:05	3:25	10/16/14 3:20		N/A						15.2	12,000	18,000	13,000									
10/16/2014	S-6		0:05	3:45	10/16/14 3:40		N/A						30.2	2,000	5,000	6,000									
10/16/2014	S-6		0:05	4:05	10/16/14 4:00		N/A						31.7	<1000	<10,000	2,000									
10/16/2014	S-6		0:05	4:25	10/16/14 4:20		N/A						46.8	<1000	<10,000	2,000									
10/16/2014	S-6		0:05	4:45	10/16/14 4:40		N/A						43.6	2,000	<10,000	<1000									
10/16/2014	S-6		0:05	5:05	10/16/14 5:00		N/A						45.3	1,000	<10,000	1,000									
10/16/2014	S-6		0:05	5:25	10/16/14 5:20		N/A						88.0	NS	NS	NS									
10/16/2014	S-6		0:05	5:45	10/16/14 5:40		N/A						74.0	NS	NS	NS									
10/16/2014	S-6		0:05	6:05	10/16/14 6:00		N/A						99.3	NS	NS	NS									
10/16/2014	S-7	Aquionics UV (Effluent)	0:15	2:35	10/16/14 2:20		N/A						45.0	8,000	9,000	120,000									
10/16/2014	S-7		0:15	2:55	10/16/14 2:40		N/A						46.5	<1000	<10,000	2,000									
10/16/2014	S-7		0:15	NS			N/A						NS	NS	NS	NS									Flex Filter Backwash, No Sample (RJL)
10/16/2014	S-7		0:15	NS			N/A						NS	NS	NS	NS									Flex Filter Backwash, No Sample (RJL)
10/16/2014	S-7		0:15	3:55	10/16/14 3:40		N/A						39.6	47,000	43,000	19,000									
10/16/2014	S-7		0:15	4:15	10/16/14 4:00		N/A						50.6	<1000	3,000	<1000									
10/16/2014	S-7		0:15	4:35	10/16/14 4:20		N/A						57.0	<1000	<10,000	<1000									
10/16/2014	S-7		0:15	4:55	10/16/14 4:40		N/A						55.9	1,000	1,000	<1000									
10/16/2014	S-7		0:15	NS			N/A						NS	NS	NS	NS									Flex Filter Backwash, No Sample (RJL)
10/16/2014	S-7		0:15	5:35	10/16/14 5:20		N/A						98.3	NS	NS	NS									
10/16/2014	S-7		0:15	5:55	10/16/14 5:40		N/A						98.2	NS	NS	NS									
10/16/2014	S-7		0:15	6:15	10/16/14 6:00		N/A						74.3	NS	NS	NS									

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. Flex Filter operating with 1/4" screen on pump. Flow varied from 140-160 gpm as screen was periodically brushed to maintain flow at 150 gpm. Following backwash cycle flex filter flow would briefly rise to 170 gpm.
3. Due to accumulation of material, the Storm King screen was brushed when flow began bypassing screen to the screenings discharge approximately every 20-30 minutes.
^: The result is equal to or greater than Maximum Range of the PAA test.
4. This batch's seed controls were inadvertently spiked with GGA solution meant for the Laboratory Control Sample (LCS) bottles. Thus the batch has no LCS recovery and the seed controls are not indicative of the seed's dissolved oxygen (DO) uptake which is subtracted from each bottle's DO depletion. Because three other CBOD batches were analyzed this day, all using the same Polyseed lot, we averaged the Seed Correction Factors (SCF) from these, namely, 0.90, 0.90 and 1.02, to yield a SCF of 0.94. This average SCF was applied to each sample bottle on this batch to produce reasonable CBOD data.

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.3

Data Entered By: AML, RJL Date: 11/01/14
Checked By: SM Date: 11/11/14
QA Review By: Date:

Key (cell shading):
- Yellow: Indicates data is suspect see notes column for qualifications regarding the data
- Green-grey: Calculated Value
- Blue: No data collected for this parameter at this location.
- Magenta: Unable to Collect Sample
- Green: Not Detected at or above the Method Detection Limit (MDL)

Configuration Plan
Train 1: Terre Kleen (xxgpm) --> Aquionics UV (xxgpm)
Train 2: Storm King (xxgpm)--> Flex Filter (xxgpm) --> PAA (xxgpm)
Overflow ceased at 12:30, samples taken through the system

Upon completion of data entry sheet shall be protected **DO NOT PASSWORD PROTECT**

Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Field Analysis: Temp. (°C)	Field Analysis: pH (SU)	Field Analysis: Turbidity (NTU)	Field Analysis: DO (mg/L)	Field Analysis: PAA Residual (mg/L)	Field Analysis: UV Trans. (%)	Laboratory Analysis, PVSC: E-Coli (cfu)	PVSC: Fecal Coliform (cfu)	PVSC: Enterococci (cfu)	PVSC: TSS (mg/L)	PVSC: Non Settleable TSS [1] (mg/L)	PVSC: VSS (mg/L)	PVSC: Non Settleable VSS [1] (mg/L)	Lancaster Laboratories: COD (mg/L)	Lancaster Laboratories: CBOD$_5$ Total (mg/L)	Lancaster Laboratories: CBOD$_5$ Soluble (mg/L)	Lancaster Laboratories: TOC (mg/L)	Notes
10/22/2014	S-1	Influent	0:00	10:30	10/22/14 10:30		N/A	16.8	7.03	21.8							83	39	62	29	187	58.0	19.5	20.0	
10/22/2014	S-1		0:00	10:50	10/22/14 10:50		N/A	16.9	7.20	17.0							73		53		172	59.4	15.7	18.9	
10/22/2014	S-1		0:00	11:10	10/22/14 11:10		N/A	16.9	7.1	21.7							97	48	61	34	248	92.1	63.3	39.1	
10/22/2014	S-1		0:00	11:30	10/22/14 11:30		N/A	17.1	7.16	25.8							140		76		222	77.4	28.5	27.3	
10/22/2014	S-1		0:00	11:50	10/22/14 11:50		N/A	17.7	7.15	24.5							163		86		201	87.4	26.6	26.9	
10/22/2014	S-1		0:00	12:10	10/22/14 12:10		N/A	17.6	7.19	20.2							79	53	55	35	196	83.7	25.9	29.5	
10/22/2014	S-1		0:00	12:30	10/22/14 12:30		N/A	17.7	7.16	24.1							64		41		203	68.7	24.2	30.0	
10/22/2014	S-2	Terre Kleen (Effluent)	0:03	10:33	10/22/14 10:30	M1-Avg	597	16.4		22.7	6.53			840,000	2,240,000	800,000	83		64		170	58.5	19.0	19.8	
10/22/2014	S-2		0:03	10:53	10/22/14 10:50	M1-Avg	588	16.4		21.3	6.63			1,200,000	2,920,000	1,160,000	110		87		191	69.8	23.6	24.3	
10/22/2014	S-2		0:03	11:13	10/22/14 11:10	M1-Avg	575	16.4		26.5	5.91			680,000	7,400,000	920,000	105		66		248	111	58.6	38.2	
10/22/2014	S-2		0:03	11:33	10/22/14 11:30	M1-Avg	567	16.2		23.3	5.73			920,000	13,000,000	560,000	124		80		215	76.9	27.1	25.7	
10/22/2014	S-2		0:03	11:53	10/22/14 11:50	M1-Avg	476	16.7		26.1	7.18			1,000,000	7,000,000	840,000	117		65		224	78.4	28.2	26.0	
10/22/2014	S-2		0:03	12:13	10/22/14 12:10	M1-Avg	510	17.1		26.8	6.48			760,000	5,000,000	1,120,000	78		53		208	79.8	27.5	29.3	
10/22/2014	S-2		0:03	12:33	10/22/14 12:30	M1-Avg	497	16.7		26.4	4.88			920,000	8,500,000	960,000	65		46		208	79.6	30.4	30.2	
10/22/2014	S-3	Storm King (Effluent)	0:02	10:32	10/22/14 10:30	M2-Avg	406			24.5							143		116		349	88.6	11.9	21.4	
10/22/2014	S-3		0:02	10:52	10/22/14 10:50	M2-Avg	402			34.0							131		106		299	80.5	9.5	21.2	
10/22/2014	S-3		0:02	11:12	10/22/14 11:10	M2-Avg	396			4.00							114		86		584	122	52.7	37.9	
10/22/2014	S-3		0:02	11:32	10/22/14 11:30	M2-Avg	391			3.24							193		142		537	191	33.6	30.0	
10/22/2014	S-3		0:02	11:52	10/22/14 11:50	M2-Avg	321			37.6							167		124		342	137	28.7	27.8	
10/22/2014	S-3		0:02	12:12	10/22/14 12:10	M2-Avg	371			45.2							111		83		405	113	28.7	28.8	
10/22/2014	S-3		0:02	12:32	10/22/14 12:30	M2-Avg	361			39.2							129		101		358	128	28.5	30.5	
10/22/2014	S-4	Flex Filter (Effluent)	0:08	10:38	10/22/14 10:30		N/A			13.3				NS	NS	NS	13		10		87.7	28.6	17.9	19.4	No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-4		0:08	10:58	10/22/14 10:50		N/A			11.8				NS	NS	NS	11		8		83.0	30.8	17.1	18.2	No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-4		0:08	11:18	10/22/14 11:10		N/A			12.9				NS	NS	NS	14		11		156	67.1	62.7	35.2	No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-4		0:08	11:38	10/22/14 11:30		N/A			12.5				NS	NS	NS	9		5		116	39.0	28.6	26.8	No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-4		0:08	11:58	10/22/14 11:50		N/A			11.5				600,000	4,100,000	360,000	13		7		107	36.5	22.6	24.1	
10/22/2014	S-4		0:08	12:18	10/22/14 12:10		N/A			13.2				680,000	2,560,000	1,040,000	14		9		118	39.0	25.9	26.7	
10/22/2014	S-4		0:08	12:38	10/22/14 12:30		N/A			12.0				800,000	2,680,000	1,120,000	12		6		125	41.6	23.5	28.2	
10/22/2014	S-5	PAA [2] (Effluent)	0:19	-			N/A							NS	NS	NS									No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-5		0:19	-			N/A							NS	NS	NS									No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-5		0:19	-			N/A							NS	NS	NS									No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-5		0:19	-			N/A							NS	NS	NS									No Pathogens Taken because PAA unit was not Functioning
10/22/2014	S-5		0:19	12:09	10/22/14 11:50		N/A	15.8			7.7	1.16		100	910,000	310,000									
10/22/2014	S-5		0:19	12:29	10/22/14 12:10		N/A	17.1			6.74	1.02		<100	490,000	23,000									
10/22/2014	S-5		0:19	12:49	10/22/14 12:30		N/A	17.8			5.77	0.98		300	400,000	108,000									
	S-6	Trojan UV (Effluent)	Location Not Sampled				N/A																		
	S-6						N/A																		
	S-6						N/A																		
	S-6						N/A																		
	S-6						N/A																		
	S-6						N/A																		
	S-6						N/A																		
10/22/2014	S-7	Aquionics UV (Effluent)	0:03	10:33	10/22/14 10:30		N/A						0.60	4,300	3,900	22,000									Suspected malfunction of UVT meter
10/22/2014	S-7		0:03	10:53	10/22/14 10:50		N/A						30.3	33,000	43,000	37,000									
10/22/2014	S-7		0:03	11:13	10/22/14 11:10		N/A						26.1	57,000	490,000	102,000									
10/22/2014	S-7		0:03	11:33	10/22/14 11:30		N/A						27.1	23,000	120,000	58,000									
10/22/2014	S-7		0:03	11:53	10/22/14 11:50		N/A						27.3	51,000	300,000	46,000									
10/22/2014	S-7		0:03	12:13	10/22/14 12:10		N/A						26.5	33,000	102,000	91,000									
10/22/2014	S-7		0:03	12:33	10/22/14 12:30		N/A						24.6	41,000	98,000	210,000									Last Sample, No more Overflow

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. PAA Tank reduced from 350 gallons to 150 gallons

Flows rates (GPM) based on periodic observation of meter display					
Time	S2	S3	S4	S5	S7
10:50	585	400	103		161
11:15	575	397	110		162
11:55	485	338	100	41	164
12:10	511	371	92	41	163
12:25	505	367	110	42	165

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.4

Data Entered By: RJL Date: 12/11/14
Checked By: SM Date: 12/17/14
QA Review By: Date:

- (yellow) Indicates data is suspect see notes column for qualifications regarding the data
- (light green) Calculated Value
- (blue) No data collected for this parameter at this location.
- (magenta) Unable to Collect Sample
- (green) Not Detected at or above the Method Detection Limit (MDL)

Configuration Plan
Train 1: Storm King (600gpm) --> Flex Filter (150gpm) -->Trojan (130 gpm)
Train 2: TerreKleen (400 gpm)--> PAA (50 gpm)

								Field Analysis							Laboratory Analysis											
															PVSC							Lancaster Laboratories				
Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L) (2)	PAA pump/Stroke	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS (1) (mg/L)	VSS (mg/L)	Non Settleable VSS (1) (mg/L)	COD (mg/L)	CBOD$_5$ Total (mg/L)	CBOD$_5$ Soluble (mg/L)	TOC (mg/L)	Notes
11/6/2014	**S-1 SS**		0:00	11:30	11/6/14 11:30		N/A																			
11/6/2014	**S-1 SS**		0:00	12:10	11/6/14 12:10		N/A																			
11/6/2014	**S-1 SS**		0:00	13:10	11/6/14 13:10		N/A																			
11/6/2014	**S-1**		0:00	8:50	11/6/14 8:50		N/A	15.4	7.17	42.8								262	134	208	110	504	194	19.3	28.3	
11/6/2014	**S-1**		0:00	9:10	11/6/14 9:10		N/A	15.8	7.29	44.5								222		176		438	163	20.5	28.9	
11/6/2014	**S-1**		0:00	9:30	11/6/14 9:30		N/A	15.9	7.26	45.7								190	108	152	88	377	133	19.9	29.2	
11/6/2014	**S-1**		0:00	9:50	11/6/14 9:50		N/A	15.7	7.31	43.5								258		206		408	156	18.1	29.7	
11/6/2014	**S-1**		0:00	10:10	11/6/14 10:10		N/A	15.4	7.29	44.8								206		162		405	155	20.7	29.8	
11/6/2014	**S-1**	Influent	0:00	10:30	11/6/14 10:30		N/A	15.0	7.18	11.0								266	116	208	90	511	155	22.5	28.6	Anamolous turbidity reading, recalibrated Turbidity Unit at 10:54
11/6/2014	**S-1**		0:00	10:50	11/6/14 10:50		N/A	14.9	7.11	43.1								280		214		422	115	27.1	31.1	
11/6/2014	**S-1**		0:00	11:10	11/6/14 11:10		N/A	14.7	7.20	42.3								202		156		427	110	22.9	28.6	
11/6/2014	**S-1**		0:00	11:30	11/6/14 11:30		N/A	14.4	7.20	41.3								214	85	168	66	330	117	17.4	22.9	
11/6/2014	**S-1**		0:00	11:50	11/6/14 11:50		N/A	14.4	7.17	40.3								168		132		349	159	18.3	23.6	
11/6/2014	**S-1**		0:00	12:10	11/6/14 12:10		N/A	14.4	7.15	37.5								180		144		281	109	17.0	23.1	
11/6/2014	**S-1**		0:00	12:30	11/6/14 12:30		N/A	14.4	7.04	41.7								170	75	134	59	307	97.9	20.4	25.6	
11/6/2014	**S-2**		0:04	8:54	11/6/14 8:50	M1-Avg	390	15.1		49.6	4.85	2.0437	20/20		2,440,000	3,360,000	1,560,000	274		222		481	179	17.7	28.8	Error in PAA analysis
11/6/2014	**S-2**		0:04	9:14	11/6/14 9:10	M1-Avg	391	15.7		50.5	4.12	1.8725	25/20		2,680,000	1,640,000	1,640,000	232		186		396	181	17.9	28.4	Error in PAA analysis
11/6/2014	**S-2**		0:04	9:34	11/6/14 9:30	M1-Avg	382	15.3		23.0	4.64	0	25/20		2,760,000	2,920,000	840,000	202		160		358	147	17.2	27.7	
11/6/2014	**S-2**		0:04	9:54	11/6/14 9:50	M1-Avg	279	15.4		37.7	4.29	0.0214	25/20		1,960,000	3,040,000	920,000	208		162		403	167	19.7	29.2	
11/6/2014	**S-2**		0:04	10:14	11/6/14 10:10	M1-Avg	245	15.1		46.4	4.79	0	25/20		1,640,000	4,700,000	1,960,000	226		184		405	102	20.0	28.4	
11/6/2014	**S-2**	Terre Kleen (Effluent)	0:04	10:34	11/6/14 10:30	M1-Avg	383	14.5		62.0	8.02	0	40/40		1,840,000	5,200,000	1,320,000	328		266		587	201	23.0	27.7	
11/6/2014	**S-2**		0:04	10:54	11/6/14 10:50	M1-Avg	372	14.6		36.0	7.10	0	30/30		2,040,000	4,400,000	1,280,000	326		268		405	228	28.1	31.5	
11/6/2014	**S-2**		0:04	11:14	11/6/14 11:10	M1-Avg	372	14.5		41.0	6.71	0	25/30		1,760,000	4,000,000	880,000	212		170		375	146	22.8	27.7	
11/6/2014	**S-2**		0:04	11:34	11/6/14 11:30	M1-Avg	369	14.0		37.7	7.22	0	25/30		1,200,000	2,280,000	1,120,000	224		154		358	66.7	17.8	23.6	
11/6/2014	**S-2**		0:04	11:54	11/6/14 11:50	M1-Avg	350	13.8		43.6	8.36	0	50/10					176		138		330	109	21.9	24.3	
11/6/2014	**S-2**		0:04	12:14	11/6/14 12:10	M1-Avg	339	13.8		39.8	8.65	0.0214	50/10					198		152		382	129	17.8	22.9	
11/6/2014	**S-2**		0:04	12:30	11/6/14 12:26	M1-Avg	319	14.1		47.5	9.03	0	50/10					246		210		518	166	24.2	25.6	
11/6/2014	**S-3**		0:02	8:52	11/6/14 8:50	M2-Avg	500			64.0								490		410		678	470	19.9	27.2	
11/6/2014	**S-3**		0:02	9:12	11/6/14 9:10	M2-Avg	491			52.5								368		312		1,090	282	21.5	33.7	
11/6/2014	**S-3**		0:02	9:32	11/6/14 9:30	M2-Avg	475			35.0								406		348		619	307	22.2	31.1	
11/6/2014	**S-3**		0:02	9:52	11/6/14 9:50	M2-Avg	538			22.0								316		264		643	265	25.3	32.3	
11/6/2014	**S-3**		0:02	10:12	11/6/14 10:10	M2-Avg	529			18.0								334		278		702	177	22.6	31.0	Anamolous turbidity reading, recalibrated Turbidity Unit at 10:54
11/6/2014	**S-3**	Storm King (Effluent)	0:02	10:32	11/6/14 10:30	M2-Avg	407			15.0								536		456		1,010	295	27.3	32.5	Anamolous turbidity reading, recalibrated Turbidity Unit at 10:54
11/6/2014	**S-3**		0:02	10:52	11/6/14 10:50	M2-Avg	395			3.0								428		352		549	185	25.7	33.1	Anamolous turbidity reading, recalibrated Turbidity Unit at 10:54
11/6/2014	**S-3**		0:02	11:12	11/6/14 11:10	M2-Avg	400			29.0								468		402		448	285	21.0	29.2	
11/6/2014	**S-3**		0:02	11:32	11/6/14 11:30	M2-Avg	393			38.0								536		462		944	321	17.8	27.5	
11/6/2014	**S-3**		0:02	11:52	11/6/14 11:50	M2-Avg	374			40.9								340		284		389	192	18.1	26.6	Anamolous turbidity reading, recalibrated Turbidity Unit at 10:54
11/6/2014	**S-3**		0:02	12:12	11/6/14 12:10	M2-Avg	358			59.0								190		152		318	146	16.0	23.2	
11/6/2014	**S-3**		0:02	12:32	11/6/14 12:30	M2-Avg	338			45.3								194		158		452	85.0	19.8	24.2	
11/6/2014	**S-4**		0:08	8:58	11/6/14 8:50	M3-Avg	0																			
11/6/2014	**S-4**		0:08	9:18	11/6/14 9:10	M3-Avg	0																			
11/6/2014	**S-4**		0:08	9:38	11/6/14 9:30	M3-Avg	161			16.9					1,760,000	1,520,000	1,160,000	30		26		158	48.3	18.3	26.5	
11/6/2014	**S-4**		0:08	9:58	11/6/14 9:50	M3-Avg	0																			
11/6/2014	**S-4**		0:08	10:18	11/6/14 10:10	M3-Avg	0																			
11/6/2014	**S-4**	Flex Filter (Effluent)	0:08	10:38	11/6/14 10:30	M3-Avg	160			22.1					2,080,000	2,280,000	600,000	37		32		168	53.4	14.1	26.1	
11/6/2014	**S-4**		0:08	10:58	11/6/14 10:50	M3-Avg	0																			
11/6/2014	**S-4**		0:08	11:18	11/6/14 11:10	M3-Avg	50																			
11/6/2014	**S-4**		0:08	11:38	11/6/14 11:30	M3-Avg	160			20.0					920,000	1,360,000	840,000	30		26		144	43.1	12.6	21.0	
11/6/2014	**S-4**		0:08	11:58	11/6/14 11:50	M3-Avg	0																			
11/6/2014	**S-4**		0:08	12:18	11/6/14 12:10	M3-Avg	42																			
11/6/2014	**S-4**		0:08	12:38	11/6/14 12:30	M3-Avg	160			19.8					800,000	1,400,000	520,000	26		23		137	43.2	19.8	22.5	
11/6/2014	**S-5**		0:09	8:59	11/6/14 8:50	M4-Avg	29	15.4			4.24	1.97	20/20		2,800,000	4,900,000	2,200,000									Error in PAA analysis
11/6/2014	**S-5**		0:09	9:19	11/6/14 9:10	M4-Avg	27	15.3			5.13	1.73	25/20		280,000	760,000	2,200,000									
11/6/2014	**S-5**		0:09	9:39	11/6/14 9:30	M4-Avg	25	15.6			5.00	0.15	25/20		92,000	370,000	890,000									
11/6/2014	**S-5**		0:09	9:59	11/6/14 9:50	M4-Avg	24	15.4			6.02	0	25/20		1,800,000	3,300,000	1,000,000									
11/6/2014	**S-5**		0:09	10:19	11/6/14 10:10	M4-Avg	23	15.6			5.46	0	25/20		3,800,000	5,900,000	790,000									
11/6/2014	**S-5**	PAA (Effluent)	0:09	10:39	11/6/14 10:30	M4-Avg	21	14.6			8.80	1.79	40/30		8,000	70,000	200									
11/6/2014	**S-5**		0:09	10:59	11/6/14 10:50	M4-Avg	18	14.8			8.33	2.35	30/30		12,000	30,000	100,000									
11/6/2014	**S-5**		0:09	11:19	11/6/14 11:10	M4-Avg	18	15.0			7.58	1.36	25/30		INTERFERENCE	1,100,000	1,800									
11/6/2014	**S-5**		0:09	11:39	11/6/14 11:30	M4-Avg	16	14.3			7.25	0	25/30		20,000	2,200,000	660,000									PAA feed pimp shut off
11/6/2014	**S-5**		0:09	11:59	11/6/14 11:50	M4-Avg	14	14.4			7.83	0.91	50/10		5,000	10,000	1,100									
11/6/2014	**S-5**		0:09	12:19	11/6/14 12:10	M4-Avg	12	14.1			8.78	1.04	50/10		2,000	6,000	700									
11/6/2014	**S-5**		0:09	12:34	11/6/14 12:25	M4-Avg	12	14.6			8.57	2.20	50/10		7,000	<100	<100									
11/6/2014	**S-6**		0:10	9:00	11/6/14 8:50	M5-Avg	0																			
11/6/2014	**S-6**		0:10	9:20	11/6/14 9:10	M5-Avg	0																			
11/6/2014	**S-6**		0:10	9:40	11/6/14 9:30	M5-Avg	140							27.6	36,000	27,000	35,000									
11/6/2014	**S-6**		0:10	10:00	11/6/14 9:50	M5-Avg	0							21.0	26,000	20,000	36,000									
11/6/2014	**S-6**		0:10	10:20	11/6/14 10:10	M5-Avg	0																			
11/6/2014	**S-6**	Trojan UV (Effluent)	0:10	10:40	11/6/14 10:30	M5-Avg	135							20.2	14,000	35,000	24,000									
11/6/2014	**S-6**		0:10	11:00	11/6/14 10:50	M5-Avg	0																			
11/6/2014	**S-6**		0:10	11:20	11/6/14 11:10	M5-Avg	75																			
11/6/2014	**S-6**		0:10	11:40	11/6/14 11:30	M5-Avg	132							32.7	2,800	3,100	6,900									
11/6/2014	**S-6**		0:10	12:00	11/6/14 11:50	M5-Avg	0																			
11/6/2014	**S-6**		0:10	12:20	11/6/14 12:10	M5-Avg	35																			
11/6/2014	**S-6**		0:10	12:40	11/6/14 12:30	M5-Avg	132							33.9	1,300	1,400	4,800									
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**	Aquionics UV (Effluent)	x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			
11/6/2014	**S-7**		x	x	x		N/A																			

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatant into sample collection bottle
2. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.5

Data Entered By: SM Date: 08/12/15
Checked By: NS Date: 09/24/15
QA Review By: Date:

Legend:
- Yellow: Indicates data is suspect see notes column for qualifications regarding the data
- Light green: Calculated Value
- Blue: No data collected for this parameter at this location.
- Magenta: Unable to Collect Sample
- Green: Not Detected at or above the Method Detection Limit (MDL

Configuration Plan
Train 1: TerreKleen (500 gpm) --> Flex Filter (150 gpm) --> Trojan (130 gpm)
Train 2: Storm King (400 gpm) --> PAA (50 gpm)

Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Field Analysis: Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L) [2]	PAA Speed/Stroke	UV Trans. (%)	Laboratory Analysis – PVSC: E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS [1] (mg/L)	VSS (mg/L)	Non Settleable VSS [1] (mg/L)	Lancaster Laboratories: COD (mg/L)	CBOD$_5$ Total (mg/L)	CBOD$_5$ Soluble (mg/L)	TOC (mg/L)	Notes
7/30/2015	**S-1**	Influent	0:00	17:50	7/30/15 17:50		N/A	24	6.31	58.4													197	11.1		
7/30/2015	**S-1**		0:00	18:10	7/30/15 18:10		N/A	23.9	6.34	60.7													139	17.2		
7/30/2015	**S-1**		0:00	18:30	7/30/15 18:30		N/A	24.1	6.28	59.5													153	18.9		
7/30/2015	**S-1**		0:00	18:50	7/30/15 18:50		N/A	24.6	6.39	69.1													174	10.8		
7/30/2015	**S-1**		0:00	19:10	7/30/15 19:10		N/A	24.5	6.33	71.5													136	23.3		
7/30/2015	**S-1**		0:00	19:30	7/30/15 19:30		N/A	24.4	6.4	57.5													156	24.6		
7/30/2015	**S-1**		0:00	19:50	7/30/15 19:50		N/A	24.2	6.44	64.5													208	43.4		
7/30/2015	**S-1**		0:00	20:10	7/30/15 20:10		N/A	24.2	6.63	34.0													287	72.3		
7/30/2015	**S-1**		0:00	20:30	7/30/15 20:30		N/A	24	6.53	55.7													145	31		
7/30/2015	**S-1**		0:00	20:50	7/30/15 20:50		N/A	23.9	6.6	56.4													245	27.3		
7/30/2015	**S-1**		0:00	21:10	7/30/15 21:10		N/A	23.9	6.56	44.6													182	30.6		
7/30/2015	**S-1**		0:00	21:30	7/30/15 21:30		N/A	23.8	6.63	56.5													127	41.3		
7/30/2015	**S-1A**	Terre Kleen (Influent)	0:00	17:50	7/30/15 17:50	M1-Avg	541											179		85						
7/30/2015	**S-1A**		0:00	18:10	7/30/15 18:10	M1-Avg	540											352		166						
7/30/2015	**S-1A**		0:00	18:30	7/30/15 18:30	M1-Avg	535											350		194						
7/30/2015	**S-1A**		0:00	18:50	7/30/15 18:50	M1-Avg	524											498		246						
7/30/2015	**S-1A**		0:00	19:10	7/30/15 19:10	M1-Avg	499											308		146						
7/30/2015	**S-1A**		0:00	19:30	7/30/15 19:30	M1-Avg	473											256		116						
7/30/2015	**S-1A**		0:00	19:50	7/30/15 19:50	M1-Avg	417											364		200						
7/30/2015	**S-1A**		0:00	20:10	7/30/15 20:10	M1-Avg	381											394		210						
7/30/2015	**S-1A**		0:00	20:30	7/30/15 20:30	M1-Avg	379											210		96						
7/30/2015	**S-1A**		0:00	20:50	7/30/15 20:50	M1-Avg	370											240		112						
7/30/2015	**S-1A**		0:00	21:10	7/30/15 21:10	M1-Avg	379											314		144						
7/30/2015	**S-1A**		0:00	21:30	7/30/15 21:30	M1-Avg	368											340		174						
7/30/2015	**S-1B**	Storm King (Influent)	0:00	17:50	7/30/15 17:50	M2-Avg	434											177	53	85	31					
7/30/2015	**S-1B**		0:00	18:10	7/30/15 18:10	M2-Avg	440											542		222						
7/30/2015	**S-1B**		0:00	18:30	7/30/15 18:30	M2-Avg	437											374		194						
7/30/2015	**S-1B**		0:00	18:50	7/30/15 18:50	M2-Avg	432											430	90	224	64					
7/30/2015	**S-1B**		0:00	19:10	7/30/15 19:10	M2-Avg	412											312	63	136	42					
7/30/2015	**S-1B**		0:00	19:30	7/30/15 19:30	M2-Avg	388											304		142						
7/30/2015	**S-1B**		0:00	19:50	7/30/15 19:50	M2-Avg	328											342	124	188	86					
7/30/2015	**S-1B**		0:00	20:10	7/30/15 20:10	M2-Avg	308											348	114	168	74					
7/30/2015	**S-1B**		0:00	20:30	7/30/15 20:30	M2-Avg	308											268		142						
7/30/2015	**S-1B**		0:00	20:50	7/30/15 20:50	M2-Avg	304											282		128						
7/30/2015	**S-1B**		0:00	21:10	7/30/15 21:10	M2-Avg	307											298		110						
7/30/2015	**S-1B**		0:00	21:30	7/30/15 21:30	M2-Avg	297											362		170						
7/30/2015	**S-2**	Terre Kleen (Effluent)	0:03	17:53	7/30/15 17:50	M1-Avg	541			49.2								234		91			66.9	9.1		
7/30/2015	**S-2**		0:03	18:13	7/30/15 18:10	M1-Avg	540			58.9								300		156			117	15.5		
7/30/2015	**S-2**		0:03	18:33	7/30/15 18:30	M1-Avg	535			63.6								324		186			142	20.2		
7/30/2015	**S-2**		0:03	18:53	7/30/15 18:50	M1-Avg	524			68.7								402		240			154	11.8		
7/30/2015	**S-2**		0:03	19:13	7/30/15 19:10	M1-Avg	499			62.4								266		146			146	25.3		
7/30/2015	**S-2**		0:03	19:33	7/30/15 19:30	M1-Avg	473			67.9								312		180			153	23.7		
7/30/2015	**S-2**		0:03	19:53	7/30/15 19:50	M1-Avg	417			66.3								254		138			196	37.7		
7/30/2015	**S-2**		0:03	20:13	7/30/15 20:10	M1-Avg	381			26.0								274		156			239	52.1		
7/30/2015	**S-2**		0:03	20:33	7/30/15 20:30	M1-Avg	379			62.7								320		204			155	19.7		
7/30/2015	**S-2**		0:03	20:53	7/30/15 20:50	M1-Avg	370			54.6								176		102			101	29.3		
7/30/2015	**S-2**		0:03	21:13	7/30/15 21:10	M1-Avg	379			45.1								242		102			114	21.9		
7/30/2015	**S-2**		0:03	21:33	7/30/15 21:30	M1-Avg	368			43.5								190		110			120	27.1		
7/30/2015	**S-3**	Storm King (Effluent)	0:02	17:52	7/30/15 17:50	M2-Avg	434			51.6					680,000	1,440,000	440,000	163		77		198	67.3	9.8		
7/30/2015	**S-3**		0:02	18:12	7/30/15 18:10	M2-Avg	440			60.7					720,000	2,400,000	320,000	278		156		301	91.8	13.7		
7/30/2015	**S-3**		0:02	18:32	7/30/15 18:30	M2-Avg	437			59.8					1,760,000	6,000,000	480,000	240		134		382	136	14.1		
7/30/2015	**S-3**		0:02	18:52	7/30/15 18:50	M2-Avg	432			63.7					1,000,000	4,200,000	280,000	302		170		451	66.6	8.2		
7/30/2015	**S-3**		0:02	19:12	7/30/15 19:10	M2-Avg	412			47.0					1,000,000	8,000,000	280,000	260		150		317	97.4	19.1		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-3**		0:02	19:32	7/30/15 19:30	M2-Avg	388			52.9					2,240,000	14,000,000	320,000	212		114		278	96.9	18.6		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-3**		0:02	19:52	7/30/15 19:50	M2-Avg	328			57.2					1,600,000	34,000,000	600,000	256		158		409	148	25.4		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-3**		0:02	20:12	7/30/15 20:10	M2-Avg	308			77.7					2,500,000	23,000,000	640,000	280		172		697	241	44.7		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-3**		0:02	20:32	7/30/15 20:30	M2-Avg	308			62.7					560,000	25,000,000	200,000	208		114		386	122	29.8		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-3**		0:02	20:52	7/30/15 20:50	M2-Avg	304			47.4								152		86		308	90	24.2		
7/30/2015	**S-3**		0:02	21:12	7/30/15 21:10	M2-Avg	307			42.6								168		94		297	92.4	26.3		
7/30/2015	**S-3**		0:02	21:32	7/30/15 21:30	M2-Avg	297			48.9								176		102		345	120	31.8		
7/30/2015	**S-4**	Flex Filter (Effluent)	0:09	17:59	7/30/15 17:50	M3-Avg	150			17.1					600,000	1,000,000	240,000	21		13			14.6	N.D.		
7/30/2015	**S-4**		0:09	18:47	7/30/15 18:38	M3-Avg	149			24.8					280,000		280,000	35		25			27.8	6.3		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-4**		0:09	18:59	7/30/15 18:50	M3-Avg	147			20.8					280,000	2,080,000	320,000	23		15			23.9	7.8		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-4**		0:09	19:19	7/30/15 19:10	M3-Avg	151			16.9					520,000	4,800,000	120,000	26		17			39.6	14		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-4**		0:09	19:59	7/30/15 19:50	M3-Avg	154			29.6					440,000	8,000,000	280,000	45		33			72.5	26.9		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-4**		0:09	20:19	7/30/15 20:10	M3-Avg	150			32.5					480,000	6,400,000	520,000	37		29			89.3	47.6		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-4**		0:09	21:09	7/30/15 21:00	M3-Avg	151			24.7					960,000	6,600,000	280,000	25		19			73	31.8		Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-4**		0:09	21:19	7/30/15 21:10	M3-Avg	151			27.4					1,120,000	4,400,000	440,000	27		22			68.5	33.6		Fecal coliform, E.coli and Enterocci sampled at 21:29, Incubation time for E.Coli was onl
7/30/2015	**S-4**		0:09	21:39	7/30/15 21:30	M3-Avg	129			22.9								24		20			67.6	26.7		
7/30/2015	**S-5**	PAA (Effluent)	0:06	17:56	7/30/15 17:50	M4-Avg	99								620,000	2,000,000	350,000									PAA pump was not turned on
7/30/2015	**S-5**		0:06	18:16	7/30/15 18:10	M4-Avg	99					1.69	100/100		3,100	1,400	300									
7/30/2015	**S-5**		0:06	18:36	7/30/15 18:30	M4-Avg	99					1.77	100/100		<10,000	30,000	300									
7/30/2015	**S-5**		0:06	18:56	7/30/15 18:50	M4-Avg	97					2.05	100/50		6,000	20,000	52,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-5**		0:06	19:16	7/30/15 19:10	M4-Avg	98					1.51	100/50		20,000	470,000	53,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-5**		0:06	19:36	7/30/15 19:30	M4-Avg	98					1.51	100/50		<1000	60,000	20,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-5**		0:06	19:56	7/30/15 19:50	M4-Avg	98					1.92	100/50		70,000	320,000	460,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-5**		0:06	20:16	7/30/15 20:10	M4-Avg	98					2.35	100/50		460,000	2,100,000	650,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-5**		0:06	20:36	7/30/15 20:30	M4-Avg	98					1.74	100/50		230,000	52,000	570,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**	Trojan UV (Effluent)	0:12	18:02	7/30/15 17:50	M5-Avg	128							49.70	400	<100	800									
7/30/2015	**S-6**		0:12	18:06	7/30/15 17:54	M5-Avg	39							50.10	100	200	100									
7/30/2015	**S-6**		0:12	18:50	7/30/15 18:38	M5-Avg	118							39.5	2,300	2,100	3,500									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**		0:12	18:59	7/30/15 18:47	M5-Avg	108							44.1	200	200	800									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**		0:12	19:20	7/30/15 19:08	M5-Avg	7							44.2	400	100	1,100									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**		0:12	20:02	7/30/15 19:50	M5-Avg	136							32.7	12,000	6,600	7,800									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**		0:12	20:22	7/30/15 20:10	M5-Avg	114							28.0	240,000	34,000	15,000									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**		0:12	21:15	7/30/15 21:03	M5-Avg	132							33.7	3,700	9,000	5,200									Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-6**		0:12	21:32	7/30/15 21:20	M5-Avg	131							34.5	5,000	12,000										Incubation time for E.Coli was only 14 hrs instead of 24 +/-2 hrs.
7/30/2015	**S-7**	Aquionics UV (Effluent)	x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			
7/30/2015	**S-7**		x	x	x		N/A																			

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.
3. Storm King Screen cleaned approximately once an hour.

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.6

Data Entered By: SM Date: 08/17/15
Checked By: NS Date: 09/25/15
QA Review By: Date:

Indicates data is suspect see notes column for qualifications regarding the data
Calculated Value
No data collected for this parameter at this location.
Unable to Collect Sample
Not Detected at or above the Method Detection Limit (MDL

Configuration Plan
Train 1: TerreKleen (300 gpm) --> PAA (100 gpm)
Train 2: Storm King (300 gpm) --> Flex Filter (150 gpm) --> Aquionics (130 gpm)

								Field Analysis							Laboratory Analysis											
															PVSC							Lancaster Laboratories				
Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L) (2)	PAA Speed/Stroke	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS (1) (mg/L)	VSS (mg/L)	Non Settleable VSS (1) (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)	Notes
8/11/2015	**S-1**	Influent	0:00	7:20	8/11/15 7:20		N/A	22.8	6.35	*err													285	30.6		Turbid, likely out of range. 100 blank measures 99.9. See Note 5 regardin
8/11/2015	**S-1**		0:00	7:40	8/11/15 7:40		N/A	22.8	6.68	14 (1400?)													320	29.6		Turbid, likely out of range. 100 blank measures 99.9. See Note 5 regardin
8/11/2015	**S-1**		0:00	8:00	8/11/15 8:00		N/A	22.8	6.67	1 (1000?)													193	16.7		Turbid, likely out of range. 100 blank measures 99.9. See Note 5 regardin
8/11/2015	**S-1**		0:00	8:20	8/11/15 8:20		N/A	22.7	6.74	51.7													182	9.4		
8/11/2015	**S-1**		0:00	8:40	8/11/15 8:40		N/A	22.6	6.73	45.5													90.8	6.9		
8/11/2015	**S-1**		0:00	9:00	8/11/15 9:00		N/A	22.7	6.75	47.5													85	13.3		
8/11/2015	**S-1**		0:00	9:20	8/11/15 9:20		N/A	22.7	6.84	39.5													121	7.6		
8/11/2015	**S-1**		0:00	9:40	8/11/15 9:40		N/A	22.7	6.99	45.7																Confilct in reported CBOD data
8/11/2015	**S-1**		0:00	10:00	8/11/15 10:00		N/A	22.7	6.86	36.5													112	10		
8/11/2015	**S-1**		0:00	10:20	8/11/15 10:20		N/A	22.9	6.76	40.3													107	13.4		
8/11/2015	**S-1**		0:00	10:40	8/11/15 10:40		N/A	22.9	6.87	37.9													92.7	7.6		
8/11/2015	**S-1**		0:00	11:00	8/11/15 11:00		N/A	23.1	6.83	-9 (900?)													179	16.9		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-1A**	Terre Kleen (Influent)	0:00	7:20	8/11/15 7:20	M1-Avg	307											988		506						
8/11/2015	**S-1A**		0:00	7:40	8/11/15 7:40	M1-Avg	301											458		302						
8/11/2015	**S-1A**		0:00	8:00	8/11/15 8:00	M1-Avg	322											462		264						
8/11/2015	**S-1A**		0:00	8:20	8/11/15 8:20	M1-Avg	329											374		192						
8/11/2015	**S-1A**		0:00	8:40	8/11/15 8:40	M1-Avg	310											328		164						
8/11/2015	**S-1A**		0:00	9:00	8/11/15 9:00	M1-Avg	297											278		138						
8/11/2015	**S-1A**		0:00	9:20	8/11/15 9:20	M1-Avg	280											198		130						
8/11/2015	**S-1A**		0:00	9:40	8/11/15 9:40	M1-Avg	259											222		120						
8/11/2015	**S-1A**		0:00	10:00	8/11/15 10:00	M1-Avg	216											267		140						
8/11/2015	**S-1A**		0:00	10:20	8/11/15 10:20	M1-Avg	219											217		133						
8/11/2015	**S-1A**		0:00	10:40	8/11/15 10:40	M1-Avg	243											164		95						
8/11/2015	**S-1A**		0:00	11:00	8/11/15 11:00	M1-Avg	219											332		212						
8/11/2015	**S-1B**	Storm King (Influent)	0:00	7:20	8/11/15 7:20	M2-Avg	297											504	266	328	216					
8/11/2015	**S-1B**		0:00	7:40	8/11/15 7:40	M2-Avg	293											426		296						
8/11/2015	**S-1B**		0:00	8:00	8/11/15 8:00	M2-Avg	315											348	96	214	72					
8/11/2015	**S-1B**		0:00	8:20	8/11/15 8:20	M2-Avg	317											292		160						
8/11/2015	**S-1B**		0:00	8:40	8/11/15 8:40	M2-Avg	298											236		120						
8/11/2015	**S-1B**		0:00	9:00	8/11/15 9:00	M2-Avg	234											170	74	96	53					
8/11/2015	**S-1B**		0:00	9:20	8/11/15 9:20	M2-Avg	216											195		113						
8/11/2015	**S-1B**		0:00	9:40	8/11/15 9:40	M2-Avg	195											224		130						
8/11/2015	**S-1B**		0:00	10:00	8/11/15 10:00	M2-Avg	199											201	62	119	53					
8/11/2015	**S-1B**		0:00	10:20	8/11/15 10:20	M2-Avg	207											205		120						
8/11/2015	**S-1B**		0:00	10:40	8/11/15 10:40	M2-Avg	234											180		108						
8/11/2015	**S-1B**		0:00	11:00	8/11/15 11:00	M2-Avg	203											274	88	172	65					
8/11/2015	**S-2**	Terre Kleen (Effluent)	0:03	7:23	8/11/15 7:20	M1-Avg	307			*err					4,900,000	1,320,000	680,000	486		340		701	314	38.4		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-2**		0:03	7:43	8/11/15 7:40	M1-Avg	301			17 (1700?)					3,080,000	3,100,000	1,600,000	454		312		788	296	29.8		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-2**		0:03	8:03	8/11/15 8:00	M1-Avg	322			0.0					2,560,000	2,100,000	560,000	294		180		451	196	13.5		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-2**		0:03	8:23	8/11/15 8:20	M1-Avg	329			52.0					1,400,000	1,400,000	760,000	250		152		359	152	11		
8/11/2015	**S-2**		0:03	8:43	8/11/15 8:40	M1-Avg	310			45.4					880,000	800,000	440,000	174		100		310	80.7	6.6		
8/11/2015	**S-2**		0:03	9:03	8/11/15 9:00	M1-Avg	297			46.5					1,160,000	1,000,000	240,000	136		78		207	75.6	6.9		
8/11/2015	**S-2**		0:03	9:23	8/11/15 9:20	M1-Avg	280			36.9					1,040,000	600,000	520,000	175		99		219	77.2	6.1		See Note 6 regarding CBOD
8/11/2015	**S-2**		0:03	9:43	8/11/15 9:40	M1-Avg	259			37.4					720,000	2,100,000	200,000	171		94		198	62.7	6.0		See Note 6 regarding CBOD
8/11/2015	**S-2**		0:03	10:03	8/11/15 10:00	M1-Avg	216			37.0					1,160,000	600,000	400,000	183		111		230	72.9	7.3		
8/11/2015	**S-2**		0:03	10:23	8/11/15 10:20	M1-Avg	219			38.9								155		96		202	88.2	8.8		
8/11/2015	**S-2**		0:03	10:43	8/11/15 10:40	M1-Avg	243			32.3								120		71		186	53.9	8.2		
8/11/2015	**S-2**		0:03	11:03	8/11/15 11:00	M1-Avg	219			48.8								226		154		350	132	15.1		
8/11/2015	**S-3**	Storm King (Effluent)	0:02	7:22	8/11/15 7:20	M2-Avg	297			*err								420		292			232	31		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-3**		0:02	7:42	8/11/15 7:40	M2-Avg	293			20 (2000?)								558		406			248	26		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-3**		0:02	8:02	8/11/15 8:00	M2-Avg	315			1.0								312		192			131	16		Turbidity meter likely out of range or malfunctionng
8/11/2015	**S-3**		0:02	8:22	8/11/15 8:20	M2-Avg	317			53.5								236		150			109	17.1		
8/11/2015	**S-3**		0:02	8:42	8/11/15 8:40	M2-Avg	298			44.3								192		114			90.1	16.8		
8/11/2015	**S-3**		0:02	9:02	8/11/15 9:00	M2-Avg	234			36.6								154		92			69.5	ND		
8/11/2015	**S-3**		0:02	9:22	8/11/15 9:20	M2-Avg	216			37.6								192		99			63	ND		
8/11/2015	**S-3**		0:02	9:42	8/11/15 9:40	M2-Avg	195			34.7								152		97			65.2	ND		
8/11/2015	**S-3**		0:02	10:02	8/11/15 10:00	M2-Avg	199			36.4								195		117			82.3	ND		
8/11/2015	**S-3**		0:02	10:22	8/11/15 10:20	M2-Avg	207			34.6								159		95						Confilct in CBOD reported data
8/11/2015	**S-3**		0:02	10:42	8/11/15 10:40	M2-Avg	234			29.8								129		69						Confilct in CBOD reported data
8/11/2015	**S-3**		0:02	11:02	8/11/15 11:00	M2-Avg	203			44.5								238		158						
8/11/2015	**S-4**	Flex Filter (Effluent)	0:07	7:27	8/11/15 7:20	M3-Avg	0			30					2,640,000	2,500,000	320,000	40		34			75.4	30.6		
8/11/2015	**S-4**		0:07	8:07	8/11/15 8:00	M3-Avg	158			26.9					1,800,000	440,000	760,000	40		31			40	14.6		
8/11/2015	**S-4**		0:07	8:16	8/11/15 8:09	M3-Avg	46			22.3					1,760,000	2,400,000	64,000	29		24			34.8	16.6		
8/11/2015	**S-4**		0:07	8:51	8/11/15 8:44	M3-Avg	160			17.7					880,000	1,300,000	480,000	41		24			29.6	14.5		
8/11/2015	**S-4**		0:07	9:01	8/11/15 8:54	M3-Avg	157			17					800,000	520,000	280,000	22		17			31.6	ND		
8/11/2015	**S-4**		0:07	9:08	8/11/15 9:01	M3-Avg	156			16.6					880,000	520,000	240,000	23		18			ND	ND		
8/11/2015	**S-4**		0:07	10:07	8/11/15 10:00	M3-Avg	137			17.4					1,160,000	160,000	480,000	22		17						Confilct in CBOD reported data
8/11/2015	**S-4**		0:07	10:17	8/11/15 10:10	M3-Avg	137			15.0								18		14						Confilct in CBOD reported data
8/11/2015	**S-4**		0:07	10:32	8/11/15 10:25	M3-Avg	137			14.4					920,000	1,960,000	480,000									
8/11/2015	**S-4**		0:07	10:37	8/11/15 10:30	M3-Avg	111			14.5					640,000	1,440,000	560,000	15		12						
8/11/2015	**S-5**	PAA (Effluent)	0:06	7:26	8/11/15 7:20	M4-Avg	102					0.00	100/50		8,700,000	4,800,000	440,000									
8/11/2015	**S-5**		0:06	7:46	8/11/15 7:40	M4-Avg	104					0.00	100/100		46,000	113,000	450,000									
8/11/2015	**S-5**		0:06	8:06	8/11/15 8:00	M4-Avg	105					0.34	100/100		3,200	7,200	39,000									
8/11/2015	**S-5**		0:06	8:26	8/11/15 8:20	M4-Avg	106					0.45	100/100		200	1,400	1,800									
8/11/2015	**S-5**		0:06	8:46	8/11/15 8:40	M4-Avg	106					1.19	100/100		200	2,100	900									
8/11/2015	**S-5**		0:06	9:06	8/11/15 9:00	M4-Avg	106					1.80	100/100		<100	200	200									
8/11/2015	**S-5**		0:06	9:26	8/11/15 9:20	M4-Avg	106					2.09	100/100		2,000	<100	<100									
8/11/2015	**S-5**		0:06	9:46	8/11/15 9:40	M4-Avg	106					1.77	100/100		<100	200	<100									
8/11/2015	**S-5**		0:06	10:06	8/11/15 10:00	M4-Avg	106					2.19	100/100		<100	500	200									
8/11/2015	**S-6**	Trojan UV (Effluent)	0:10	9:00	8/11/15 8:50		N/A																			
8/11/2015	**S-6**		0:10	9:20	8/11/15 9:10		N/A																			
8/11/2015	**S-6**		0:10	9:40	8/11/15 9:30		N/A																			
8/11/2015	**S-6**		0:10	10:00	8/11/15 9:50		N/A																			
8/11/2015	**S-6**		0:10	10:20	8/11/15 10:10		N/A																			
8/11/2015	**S-6**		0:10	10:40	8/11/15 10:30		N/A																			
8/11/2015	**S-6**		0:10	11:00	8/11/15 10:50		N/A																			
8/11/2015	**S-6**		0:10	11:20	8/11/15 11:10		N/A																			
8/11/2015	**S-6**		0:10	11:40	8/11/15 11:30		N/A																			
8/11/2015	**S-6**		0:10	12:00	8/11/15 11:50		N/A																			
8/11/2015	**S-6**		0:10	12:20	8/11/15 12:10		N/A																			
8/11/2015	**S-6**		0:10	12:40	8/11/15 12:30		N/A																			
8/11/2015	**S-7**	Aquionics UV (Effluent)	0:50	8:10	8/11/15 7:20	M5-Avg	140							22.90	124,000	57,000	100,000									
8/11/2015	**S-7**		0:50	8:54	8/11/15 8:04	M5-Avg	98							38.80	27,000	25,000	37,000									
8/11/2015	**S-7**		0:50	9:04	8/11/15 8:14	M5-Avg	140							42.70	4,300	9,000	16,000									
8/11/2015	**S-7**		0:50	9:11	8/11/15 8:21	M5-Avg	139							43.20	2,300	3,300	7,000									
8/11/2015	**S-7**		0:50	10:10	8/11/15 9:20	M5-Avg	135							47.40	450,000	3,400,000	480,000									
8/11/2015	**S-7**		0:50	10:35	8/11/15 9:45	M5-Avg	104							42.50	8,100	73,000	8,800									
8/11/2015	**S-7**		0:50	10:38	8/11/15 9:48	M5-Avg	104							43.1	3,200	1,300	7,800									

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.
3. Storm King Screen cleaned at the beginning of sampling

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.7

Data Entered By:	SM	Date:	09/18/15	Indicates data is suspect see notes column for qualifications regarding the data
Checked By:	NS	Date:	09/25/15	Calculated Value
QA Review By:		Date:		No data collected for this parameter at this location.
				Unable to Collect Sample
				Not Detected at or above the Method Detection Limit (MDL)

Configuration Plan
Train 1: TerreKleen (400 gpm)
Train 2: Storm King (500 gpm) --> Trojan (150 gpm)
Train 3: Raw Influent-->PAA(100gpm)

								Field Analysis							Laboratory Analysis											
															PVSC							Lancaster Laboratories				
Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L) (2)	PAA Speed/Stroke	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS (1) (mg/L)	VSS (mg/L)	Non Settleable VSS (1) (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)	Notes
9/10/2015	**S-1**	Influent	0:00	18:00	9/10/15 18:00		N/A	24.6	6.74	73.6													305	32.8		
9/10/2015	**S-1**		0:00	18:20	9/10/15 18:20		N/A	24.8	6.79	47.8													140	29.5		
9/10/2015	**S-1**		0:00	18:40	9/10/15 18:40		N/A	24.7	6.82	47.2													106	26.4		
9/10/2015	**S-1**		0:00	19:00	9/10/15 19:00		N/A	24.8	6.86	52.1													134	32.6		
9/10/2015	**S-1**		0:00	19:20	9/10/15 19:20		N/A	24.6	6.9	104.6													114	31.3		
9/10/2015	**S-1**		0:00	19:40	9/10/15 19:40		N/A	24.5	6.83	44.8													138	37.7		
9/10/2015	**S-1**		0:00	20:00	9/10/15 20:00		N/A	24.3	6.81	42.4													94.1	23.2		
9/10/2015	**S-1**		0:00	20:20	9/10/15 20:20		N/A	24.4	6.88	39.9													102	26.3		
9/10/2015	**S-1**		0:00	20:40	9/10/15 20:40		N/A	24.3	6.87	36.0													96.8	30.2		See Note 4 regarding CBOD
9/10/2015	**S-1**		0:00	21:00	9/10/15 21:00		N/A	24.4	6.88	35.4													94.9	34.7		See Note 4 regarding CBOD
9/10/2015	**S-1**		0:00	21:20	9/10/15 21:20		N/A	24.3	6.89	31.3													84.8	28.1		See Note 4 regarding CBOD
9/10/2015	**S-1**		0:00	21:40	9/10/15 21:40		N/A	24.3	6.88	27.8													89.8	32.1		See Note 4 regarding CBOD
9/10/2015	**S-1A**	Terre Kleen (Influent)	0:04	18:04	9/10/15 18:00	M1-Avg	409											171		121						
9/10/2015	**S-1A**		0:04	18:24	9/10/15 18:20	M1-Avg	376											130		92						
9/10/2015	**S-1A**		0:04	18:44	9/10/15 18:40	M1-Avg	380											127		91						
9/10/2015	**S-1A**		0:04	19:04	9/10/15 19:00	M1-Avg	373											179		131						
9/10/2015	**S-1A**		0:04	19:24	9/10/15 19:20	M1-Avg	368											134		92						
9/10/2015	**S-1A**		0:04	19:44	9/10/15 19:40	M1-Avg	366											126		94						
9/10/2015	**S-1A**		0:04	20:04	9/10/15 20:00	M1-Avg	360											119		86						
9/10/2015	**S-1A**		0:04	20:24	9/10/15 20:20	M1-Avg	360											115		77						
9/10/2015	**S-1A**		0:04	20:44	9/10/15 20:40	M1-Avg	368											93		75						
9/10/2015	**S-1A**		0:04	21:04	9/10/15 21:00	M1-Avg	355											92		69						
9/10/2015	**S-1A**		0:04	21:24	9/10/15 21:20	M1-Avg	353											79		56						
9/10/2015	**S-1A**		0:04	21:44	9/10/15 21:40	M1-Avg	351											87		64						
9/10/2015	**S-1B**	Storm King (Influent)	0:04	18:04	9/10/15 18:00	M2-Avg	400												68		52					TSS Sample not taken
9/10/2015	**S-1B**		0:04	18:24	9/10/15 18:20	M2-Avg	378																			TSS Sample not taken
9/10/2015	**S-1B**		0:04	18:44	9/10/15 18:40	M2-Avg	384																			TSS Sample not taken
9/10/2015	**S-1B**		0:04	19:04	9/10/15 19:00	M2-Avg	371												66		50					TSS Sample not taken
9/10/2015	**S-1B**		0:04	19:24	9/10/15 19:20	M2-Avg	368																			TSS Sample not taken
9/10/2015	**S-1B**		0:04	19:44	9/10/15 19:40	M2-Avg	367																			TSS Sample not taken
9/10/2015	**S-1B**		0:04	20:04	9/10/15 20:00	M2-Avg	356												53		45					TSS Sample not taken
9/10/2015	**S-1B**		0:04	20:24	9/10/15 20:20	M2-Avg	355																			TSS Sample not taken
9/10/2015	**S-1B**		0:04	20:44	9/10/15 20:40	M2-Avg	363											82		63						
9/10/2015	**S-1B**		0:04	21:04	9/10/15 21:00	M2-Avg	355											88	49	69	45					
9/10/2015	**S-1B**		0:04	21:24	9/10/15 21:20	M2-Avg	353											84		61						
9/10/2015	**S-1B**		0:04	21:44	9/10/15 21:40	M2-Avg	344																			
9/10/2015	**S-1B**		0:04	22:04	9/10/15 22:00	M2-Avg	0																			
9/10/2015	**S-2**	Terre Kleen (Effluent)	0:04	18:04	9/10/15 18:00	M1-Avg	409			82.0								185		129			134	31.3		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	18:24	9/10/15 18:20	M1-Avg	376			47.0								127		88			117	31.6		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	18:44	9/10/15 18:40	M1-Avg	380			45.6								162		112			121	29.2		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	19:04	9/10/15 19:00	M1-Avg	373			50.1								159		113			161	24.7		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	19:24	9/10/15 19:20	M1-Avg	368			86.8								149		109			125	31.5		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	19:44	9/10/15 19:40	M1-Avg	366			46.7								114		86			129	35.1		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	20:04	9/10/15 20:00	M1-Avg	360			41.1								109		81			134	22.9		See Note 4 regarding CBOD
9/10/2015	**S-2**		0:04	20:24	9/10/15 20:20	M1-Avg	360			40.3								113		81			97	27.2		
9/10/2015	**S-2**		0:04	20:44	9/10/15 20:40	M1-Avg	368			36.0								94		71			105	29.3		
9/10/2015	**S-2**		0:04	21:04	9/10/15 21:00	M1-Avg	355			34.3								95		69			108	31.4		
9/10/2015	**S-2**		0:04	21:24	9/10/15 21:20	M1-Avg	353			32.1								83		65			92.4	28.9		
9/10/2015	**S-2**		0:04	21:44	9/10/15 21:40	M1-Avg	351			30.1								82		62			88.8	33.7		
9/10/2015	**S-3**	Storm King (Effluent)	0:02	18:02	9/10/15 18:00	M2-Avg	400			50.6					4,600,000	39,000,000	1,440,000	170		121			150	33.6		
9/10/2015	**S-3**		0:02	18:22	9/10/15 18:20	M2-Avg	378			52.3					2,600,000	20,000,000	1,560,000	153		114			167	43.4		
9/10/2015	**S-3**		0:02	18:42	9/10/15 18:40	M2-Avg	384			42.9					2,880,000	17,000,000	1,720,000	128		93			110	25.6		
9/10/2015	**S-3**		0:02	19:02	9/10/15 19:00	M2-Avg	371			46.9					2,440,000	39,000,000	1,920,000	149		105			118	28.2		
9/10/2015	**S-3**		0:02	19:22	9/10/15 19:20	M2-Avg	368			75.8					2,920,000	14,000,000	1,520,000	135		94			170	26.5		
9/10/2015	**S-3**		0:02	19:42	9/10/15 19:40	M2-Avg	367			42.5					1,800,000	30,000,000	1,040,000	111		85			125	35.1		
9/10/2015	**S-3**		0:02	20:02	9/10/15 20:00	M2-Avg	356			44.3					1,320,000	14,000,000	800,000	120		89			99.4	19.7		
9/10/2015	**S-3**		0:02	20:22	9/10/15 20:20	M2-Avg	355			39.6					3,100,000	16,000,000	640,000	113		81			89.1	19.6		
9/10/2015	**S-3**		0:02	20:42	9/10/15 20:40	M2-Avg	363			40.2					1,880,000	23,000,000	1,360,000	92		72			115	29.5		
9/10/2015	**S-3**		0:02	21:02	9/10/15 21:00	M2-Avg	355			34.7								86		66			87.6	26.9		
9/10/2015	**S-3**		0:02	21:22	9/10/15 21:20	M2-Avg	353			32.3								78		61			87.2	23.8		
9/10/2015	**S-3**		0:02	21:42	9/10/15 21:40	M2-Avg	344			29.4								79		64			92.1	29.3		
9/10/2015	**S-4**	Influent directly to PAA, see Note 3	0:12	18:12	9/10/15 18:00		N/A			55.9					3,600,000	55,000,000	2,080,000	187		146		335				
9/10/2015	**S-4**		0:12	18:32	9/10/15 18:20		N/A			46					4,300,000	33,000,000	1,800,000	109		80		230				
9/10/2015	**S-4**		0:12	18:52	9/10/15 18:40		N/A			46.5					4,700,000	41,000,000	1,840,000	151		113		265				
9/10/2015	**S-4**		0:12	19:12	9/10/15 19:00		N/A			48.9					1,200,000	16,000,000	1,320,000	271		226		293				
9/10/2015	**S-4**		0:12	19:32	9/10/15 19:20		N/A			51.8					4,100,000	12,000,000	1,600,000	114		88		239				
9/10/2015	**S-4**		0:12	19:52	9/10/15 19:40		N/A			45.2					4,000,000	23,000,000	1,720,000	113		89		311				
9/10/2015	**S-4**		0:12	20:12	9/10/15 20:00		N/A			38.3					1,280,000	Interference	480,000	84		70		200				
9/10/2015	**S-4**		0:12	20:32	9/10/15 20:20		N/A			38.9					1,920,000	43,000,000	1,080,000	100		75		218				
9/10/2015	**S-4**		0:12	20:52	9/10/15 20:40		N/A			35.1					1,160,000	23,000,000	840,000	106		83		195				
9/10/2015	**S-5**	PAA (Effluent)	0:15	18:15	9/10/15 18:00	M5-Avg	110					0.83	100/100		10,000	240,000	1,100									
9/10/2015	**S-5**		0:15	18:35	9/10/15 18:20	M5-Avg	99					1.68	100/100		700	2,000	100									
9/10/2015	**S-5**		0:15	18:55	9/10/15 18:40	M5-Avg	100					0.14	100/50		50,000	1,900,000	420,000									
9/10/2015	**S-5**		0:15	19:15	9/10/15 19:00	M5-Avg	99					1.67	100/100		700	27,000	200									
9/10/2015	**S-5**		0:15	19:35	9/10/15 19:20	M5-Avg	98					0.64	100/50		1,100	190,000	2,000									
9/10/2015	**S-5**		0:15	19:55	9/10/15 19:40	M5-Avg	99					0.33	100/50		1,700	260,000	270,000									
9/10/2015	**S-5**		0:15	20:15	9/10/15 20:00	M5-Avg	97					0.65	100/50		900	180,000	33,000									
9/10/2015	**S-5**		0:15	20:35	9/10/15 20:20	M5-Avg	98					0.03	100/50		1,800,000	2,900,000	1,500,000									
9/10/2015	**S-5**		0:15	20:55	9/10/15 20:40	M5-Avg	98					2.34	100/100		200	2,500	300									
9/10/2015	**S-6**	Trojan UV (Effluent)	0:03	18:03	9/10/15 18:00	M4-Avg	85							20.1	180,000	100,000	90,000									
9/10/2015	**S-6**		0:03	18:23	9/10/15 18:20	M4-Avg	151							21.1	100,000	520,000	64,000									
9/10/2015	**S-6**		0:03	18:43	9/10/15 18:40	M4-Avg	150							23.2	150,000	280,000	77,000									
9/10/2015	**S-6**		0:03	19:03	9/10/15 19:00	M4-Avg	150							21.0	170,000	470,000	100,000									
9/10/2015	**S-6**		0:03	19:23	9/10/15 19:20	M4-Avg	150							22.3	130,000	500,000	150,000									
9/10/2015	**S-6**		0:03	19:43	9/10/15 19:40	M4-Avg	150							24.1	110,000	540,000	60,000									
9/10/2015	**S-6**		0:03	20:03	9/10/15 20:00	M4-Avg	150							24.1	56,000	420,000	65,000									
9/10/2015	**S-6**		0:03	20:23	9/10/15 20:20	M4-Avg	151							25.3	46,000	30,000	41,000									
9/10/2015	**S-6**		0:03	20:43	9/10/15 20:40	M4-Avg	151							26.4	34,000	80,000	27,000									
9/10/2015	**S-6**		0:03	21:03	9/10/15 21:00	M4-Avg	151							30.2												
9/10/2015	**S-7**	Aquionics UV (Effluent)	0:50	8:10	9/10/15 7:20		N/A																			
9/10/2015	**S-7**		0:50	8:54	9/10/15 8:04		N/A																			
9/10/2015	**S-7**		0:50	9:04	9/10/15 8:14		N/A																			
9/10/2015	**S-7**		0:50	9:11	9/10/15 8:21		N/A																			
9/10/2015	**S-7**		0:50	10:10	9/10/15 9:20		N/A																			
9/10/2015	**S-7**		0:50	10:35	9/10/15 9:45		N/A																			
9/10/2015	**S-7**		0:50	10:38	9/10/15 9:48		N/A																			

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.
3. Flex Filter was not working, raw influent was directed to CB-3 where it was pumped to the PAA system. Sample were taken by filling a bucket from CB-3.

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.8

Data Entered By: NET Date: 11/10/15
Checked By: RC Date: 11/16/15
QA Review By: Date:

Indicates data is suspect see notes column for qualifications regarding the data
Calculated Value
No data collected for this parameter at this location.
Unable to Collect Sample
Not Detected at or above the Method Detection Limit (MDL)

Configuration Plan
Train 1: Storm King (600 gpm) --> PAA (100gpm)
Train 2: Storm King (600 gpm) --> FlexFilter (150 gpm) --> Aquionics (130 gpm)

								Field Analysis								Laboratory Analysis											
																PVSC							Lancaster Laboratories				
Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L) (2)		PAA Speed/Stroke	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS (1) (mg/L)	VSS (mg/L)	Non Settleable VSS (1) (mg/L)	COD (mg/L)	CBOD$_5$ Total (mg/L)	CBOD$_5$ Soluble (mg/L)	TOC (mg/L)	Notes
10/15/2015	S-1	Influent					N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1						N/A																				
10/15/2015	S-1A	Terre Kleen (Influent)					N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1A						N/A																				
10/15/2015	S-1B	Storm King (Influent)	0:00	10:00	10/15/15 10:00	M2-Avg	477	19.3	7.43	28.7									75	45	62	38		127	41.2		See footnote 3
10/15/2015	S-1B		0:00	10:20	10/15/15 10:20	M2-Avg	478	19.5	7.45	27.2									78		65			102	37.6		See footnote 3
10/15/2015	S-1B		0:00	10:40	10/15/15 10:40	M2-Avg	476	20.1	7.37	33.8									79	61	66	50		140	63.7		See footnote 3
10/15/2015	S-1B		0:00	11:00	10/15/15 11:00	M2-Avg	469	19.5	7.43	32.7									196		163			129	46.3		See footnote 3
10/15/2015	S-1B		0:00	11:20	10/15/15 11:20	M2-Avg	692	20.5	7.29	39.1									96		78			165	60.9		See footnote 3
10/15/2015	S-1B		0:00	11:40	10/15/15 11:40	M2-Avg	693	20.7	7.29	42.6									105	61	86	49		161	61.3		See footnote 3
10/15/2015	S-1B		0:00	12:00	10/15/15 12:00	M2-Avg	692	20.8	7.25	40.2									85		69			147	58.8		See footnote 3
10/15/2015	S-1B		0:00	12:20	10/15/15 12:20	M2-Avg	699	20.8	7.25	44.9									97		77			148	59.8		See footnote 3
10/15/2015	S-1B		0:00	12:40	10/15/15 12:40	M2-Avg	701	21.1	7.22	45.3									101	62	76	48		150	63.6		See footnote 3
10/15/2015	S-1B		0:00	13:00	10/15/15 13:00	M2-Avg	708	21	7.12	51									101		82			176	69.1		See footnote 3
10/15/2015	S-1B		0:00	13:20	10/15/15 13:20	M2-Avg	702	21.1	7.21	40									91		73			149	70.6		See footnote 3
10/15/2015	S-1B		0:00	13:40	10/15/15 13:40	M2-Avg	701	21.4	7.21	45.3									96		77			154	66.7		See footnote 3
10/15/2015	S-1B		0:00	14:40	10/15/15 14:40	M2-Avg	0												55		46						
10/15/2015	S-2	Terre Kleen (Effluent)					N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-2						N/A																				
10/15/2015	S-3	Storm King (Effluent)	0:02	10:02	10/15/15 10:00	M2-Avg	477			27.3						3,800,000	13,000,000	1,120,000	61		51		231	89.3	41.8		See footnote 3
10/15/2015	S-3		0:02	10:22	10/15/15 10:20	M2-Avg	478			28.9						4,200,000	6,000,000	1,080,000	81		68		258	103	47.2		See footnote 3
10/15/2015	S-3		0:02	10:42	10/15/15 10:40	M2-Avg	476			30.4						4,400,000	100,000	1,040,000	75		62		258	111	49.9		See footnote 3
10/15/2015	S-3		0:02	11:02	10/15/15 11:00	M2-Avg	469			34.0						4,700,000	1,300,000	1,160,000	86		71		279	119	39.8		See footnote 3
10/15/2015	S-3		0:02	11:22	10/15/15 11:20	M2-Avg	692			38.2						4,400,000	1,840,000	1,880,000	98		79		359	130	50		See footnote 3
10/15/2015	S-3		0:02	11:42	10/15/15 11:40	M2-Avg	693			41.5						3,700,000	6,200,000	1,160,000	103		84		325	137	58.4		See footnote 3
10/15/2015	S-3		0:02	12:02	10/15/15 12:00	M2-Avg	692			39.7						4,700,000	6,400,000	1,240,000	100		80		332	140	55.9		See footnote 3
10/15/2015	S-3		0:02	12:22	10/15/15 12:20	M2-Avg	699			37.4						4,500,000	7,200,000	1,760,000	99		78		336	135	65.2		See footnote 3
10/15/2015	S-3		0:02	12:42	10/15/15 12:40	M2-Avg	701			40.2						4,800,000	3,600,000	1,840,000	107		82		329	151	57.6		See footnote 3
10/15/2015	S-3		0:02	13:02	10/15/15 13:00	M2-Avg	708			43									93		76		343	147	52.9		
10/15/2015	S-3		0:02	13:22	10/15/15 13:20	M2-Avg	702			43.5									91		72		348	134	66.3		
10/15/2015	S-3		0:02	13:42	10/15/15 13:40	M2-Avg	701			44.4									89		75		341	138	60.7		
10/15/2015	S-4	Flex Filter (Effluent)	0:12	10:12	10/15/15 10:00	M3-Avg	150			16.8						3,000,000	1,680,000	800,000	27		22			47.4	22.1		
10/15/2015	S-4		0:12	10:32	10/15/15 10:20	M3-Avg	149			17.7						5,100,000	800,000	960,000	24		20			48.4	28.7		
10/15/2015	S-4		0:12	10:52	10/15/15 10:40	M3-Avg	148			17.9						5,300,000	3,000,000	1,120,000	25		21			60.6	33.6		
10/15/2015	S-4		0:12	11:12	10/15/15 11:00	M3-Avg	150			21.1						2,600,000	11,000,000	1,000,000	34		28			71.1	41.1		
10/15/2015	S-4		0:12	12:12	10/15/15 12:00	M3-Avg	150			29						3,500,000	400,000	1,680,000	28		23			75	46.6		
10/15/2015	S-4		0:12	12:32	10/15/15 12:20	M3-Avg	151			26.3						3,900,000	120,000	1,320,000	33		26			94.3	45.7		
10/15/2015	S-4		0:12	12:52	10/15/15 12:40	M3-Avg	155			25.7						1,800,000	6,500,000	600,000	27		23			95.6	58.4		
10/15/2015	S-4		0:12	13:04	10/15/15 12:52	M3-Avg	155			25.7									26		22			104	53.8		
10/15/2015	S-4						N/A																				
10/15/2015	S-5	PAA (Effluent)	0:06	10:06	10/15/15 10:00	M4-Avg	106					0	0	100/100		2,800,000	350,000	900,000									
10/15/2015	S-5		0:06	10:26	10/15/15 10:20	M4-Avg	106					0	0	100/100		1,000,000	660,000	1,300,000									
10/15/2015	S-5		0:06	10:46	10/15/15 10:40	M4-Avg	103					0	0	100/100		2,000,000	1,800,000	1,500,000									
10/15/2015	S-5		0:06	11:06	10/15/15 11:00	M4-Avg	103					0	0	100/100		2,800,000	110,000	1,060,000									
10/15/2015	S-5		0:06	11:26	10/15/15 11:20	M4-Avg	104					0	0	100/100		3,300,000	100,000	1,400,000									
10/15/2015	S-5		0:06	11:46	10/15/15 11:40	M4-Avg	101					0	0	100/100		4,100,000	1,600,000	2,000,000									
10/15/2015	S-5		0:06	12:06	10/15/15 12:00	M4-Avg	101					0	0	100/100		3,900,000	550,000	1,600,000									
10/15/2015	S-5		0:06	12:26	10/15/15 12:20	M4-Avg	101					0	0	100/100		1,900,000	450,000	2,600,000									
10/15/2015	S-5		0:06	12:46	10/15/15 12:40	M4-Avg	100					0	0	100/100		8,700,000	3,200,000	2,900,000									
10/15/2015	S-6	Trojan UV (Effluent)					N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-6						N/A																				
10/15/2015	S-7	Aquionics UV (Effluent)	0:14	10:14	10/15/15 10:00	M5-Avg	134								27.80	280,000	12,000	120,000									
10/15/2015	S-7		0:14	10:34	10/15/15 10:20	M5-Avg	128								30.30	240,000	4,000	54,000									
10/15/2015	S-7		0:14	10:54	10/15/15 10:40	M5-Avg	132								29.60	240,000	5,500	102,000									
10/15/2015	S-7		0:14	11:14	10/15/15 11:00	M5-Avg	135								27.90	154,000	44,000	94,000									
10/15/2015	S-7		0:14	12:14	10/15/15 12:00	M5-Avg	118								22.30	240,000	112,000	300,000									
10/15/2015	S-7		0:14	12:34	10/15/15 12:20	M5-Avg	138								20.40	3,500,000	6,200,000	2,400,000									
10/15/2015	S-7		0:14	12:54	10/15/15 12:40	M5-Avg	152								23.2	610,000	400,000	210,000									

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatent into sample collection bottle
2. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.

THIS PAGE INTENTIONALLY LEFT BLANK

Table A.9

Data Entered By: NET Date: 11/10/15
Checked By: RC Date: 11/16/15
QA Review By: Date:

- Indicates data is suspect see notes column for qualifications regarding the data
- Calculated Value
- No data collected for this parameter at this location.
- Unable to Collect Sample
- Not Detected at or above the Method Detection Limit (MDL

Configuration Plan
Train 1: Terre Kleen (900 gpm) --> PAA (100gpm)
Train 2: Terre Kleen (900 gpm) --> FlexFilter (150 gpm) --> Trojan (130 gpm)

Date	Location	Process Name	System Delay Time	Sample Time	System Time	Meter	Unit Flow (gpm)	Field Analysis									Laboratory Analysis											Notes
																	PVSC							Lancaster Laboratories				
								Temp. (°C)	pH (SU)	Turbidity (NTU)	DO (mg/L)	PAA Residual (mg/L) (2)		PAA Speed/Stroke	Conductivity (uS/cm)	UV Trans. (%)	E-Coli (cfu)	Fecal Coliform (cfu)	Enterococci (cfu)	TSS (mg/L)	Non Settleable TSS (1) (mg/L)	VSS (mg/L)	Non Settleable VSS (1) (mg/L)	COD (mg/L)	$CBOD_5$ Total (mg/L)	$CBOD_5$ Soluble (mg/L)	TOC (mg/L)	
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1	Influent					N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1						N/A																					
10/27/2015	S-1A		0:00	9:20	10/27/15 9:20	M1-Avg	902	15.7	7.58	38.3										93	63	77	51		101	36.5		
10/27/2015	S-1A		0:00	9:40	10/27/15 9:40	M1-Avg	861	17.6	7.56	45.8										111		93			116	31.6		
10/27/2015	S-1A		0:00	10:00	10/27/15 10:00	M1-Avg	867	17.9	7.59	39.4										107	62	90	51		91	40		
10/27/2015	S-1A		0:00	10:20	10/27/15 10:20	M1-Avg	861	18.1	7.56	41.5										112		97			104	40.4		
10/27/2015	S-1A		0:00	10:40	10/27/15 10:40	M1-Avg	859	18.3	7.53	43.1										113		93			126	50.8		
10/27/2015	S-1A	Terre Kleen (Influent)	0:00	11:00	10/27/15 11:00	M1-Avg	861	18.4	7.47	39.3										99	74	81	60		160	72.4		
10/27/2015	S-1A		0:00	11:20	10/27/15 11:20	M1-Avg	866	18.9	7.37	48.2										136		108			153	72.2		
10/27/2015	S-1A		0:00	11:40	10/27/15 11:40	M1-Avg	860	18.9	7.38	37.7										98		74			127	56.8		
10/27/2015	S-1A		0:00	12:00	10/27/15 12:00	M1-Avg	858	19.1	7.38	41.2										98	56	76	43		132	60.2		
10/27/2015	S-1A		0:00	12:20	10/27/15 12:20	M1-Avg	861	19.1	7.33	50.9										127		101			142	59.9		
10/27/2015	S-1A		0:00	12:40	10/27/15 12:40	M1-Avg	851	19.2	7.31	43.9										123		97			127	50		
10/27/2015	S-1A		0:00	13:00	10/27/15 13:00	M1-Avg	851	19.0	7.32	49.4										120		75			146	49.7		
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B	Storm King (Influent)					N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-1B						N/A																					
10/27/2015	S-2		0:02	9:22	10/27/15 9:20	M1-Avg	902			32.7							5,700,000	3,000,000	720,000	69		56		270	87.2	44.6		
10/27/2015	S-2		0:02	9:42	10/27/15 9:40	M1-Avg	861			36.6							4,200,000	4,000,000	1,760,000	85		70		316	93.5	35.9		
10/27/2015	S-2		0:02	10:02	10/27/15 10:00	M1-Avg	867			43.0							6,300,000	100,000	1,120,000	138		115		329	99.2	35		
10/27/2015	S-2		0:02	10:22	10/27/15 10:20	M1-Avg	861			45.0							3,700,000	1,300,000	840,000	132		114		339	141	43.3		
10/27/2015	S-2		0:02	10:42	10/27/15 10:40	M1-Avg	859			39.9							5,500,000	1,200,000	1,680,000	117		101		385	136	51.2		
10/27/2015	S-2	Terre Kleen (Effluent)	0:02	11:02	10/27/15 11:00	M1-Avg	861			42.6							5,000,000	1,000,000	1,880,000	97		80		346	135	61.1		
10/27/2015	S-2		0:02	11:22	10/27/15 11:20	M1-Avg	866			44.0							5,200,000	7,300,000	1,560,000	139		109		380	157	54.8		
10/27/2015	S-2		0:02	11:42	10/27/15 11:40	M1-Avg	860			35.6							4,600,000	1,720,000	1,640,000	95		74		318	122	59.5		
10/27/2015	S-2		0:02	12:02	10/27/15 12:00	M1-Avg	858			39.1							4,000,000	1,700,000	2,000,000	112		89		323	100	35.6		
10/27/2015	S-2		0:02	12:22	10/27/15 12:20	M1-Avg	861			49.3							2,700,000	7,300,000	1,080,000	121		96		366	130	57.9		Pathogens Collected at 12:24 (2 min late)
10/27/2015	S-2		0:02	12:42	10/27/15 12:40	M1-Avg	851			43.1							3,240,000	5,300,000	1,600,000	126		100		368	130	52.2		
10/27/2015	S-2		0:02	13:02	10/27/15 13:00	M1-Avg	851			53.2										126		101		359	124	47.4		
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3	Storm King (Effluent)					N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-3						N/A																					
10/27/2015	S-4		0:09	9:29	10/27/15 9:20	M3-Avg	146			20.5					4.18		3,500,000	700,000	680,000	37		31			57.5	28.3		
10/27/2015	S-4		0:09	9:49	10/27/15 9:40	M3-Avg	145			20.5					4.13		4,100,000	500,000	880,000	43		32			57.5	31.6		
10/27/2015	S-4		0:09	10:06	10/27/15 9:57	M3-Avg	143			19.9					4.10		2,600,000	4,000,000	1,760,000	36		29			58.4	34.2		
10/27/2015	S-4		0:09	10:49	10/27/15 10:40	M3-Avg	145			22.3					4.22		4,400,000	5,400,000	2,080,000	38		30			73	50.5		
10/27/2015	S-4	Flex Filter (Effluent)	0:09	11:09	10/27/15 11:00	M3-Avg	143			21.9					4.29		4,400,000	2,900,000	1,760,000	45		35			76	57.7		
10/27/2015	S-4		0:09	12:09	10/27/15 12:00	M3-Avg	151			21.9					4.20		2,900,000	3,000,000	1,600,000	31		24			69.3	40		
10/27/2015	S-4		0:09	13:04	10/27/15 12:55	M3-Avg	148			23.6					4.14		2,640,000	5,000,000	1,320,000	35		28			65.9	30.6		
10/27/2015	S-4						N/A																					
10/27/2015	S-4						N/A																					
10/27/2015	S-5		0:06	9:26	10/27/15 9:20	M4-Avg	62					0.02	0.02	100/100			510,000	600,000	1,500,000									
10/27/2015	S-5		0:06	9:46	10/27/15 9:40	M4-Avg	61					0	0.00	100/100			1,000,000	520,000	1,100,000									
10/27/2015	S-5		0:06	10:06	10/27/15 10:00	M4-Avg	61					0.09	0.10	100/100			460,000	700,000	1,000,000									
10/27/2015	S-5		0:06	10:26	10/27/15 10:20	M4-Avg	61					0	0.00	100/100			112,000	470,000	1,400,000									
10/27/2015	S-5		0:06	10:46	10/27/15 10:40	M4-Avg	61					0.19	0.20	100/100			600,000	610,000	1,800,000									
10/27/2015	S-5	PAA (Effluent)	0:06	11:06	10/27/15 11:00	M4-Avg	63					0	0.00	100/100			1,400,000	200,000	2,200,000									
10/27/2015	S-5		0:06	11:26	10/27/15 11:20	M4-Avg	63					0	0.00	100/100			1,600,000	2,000,000	2,200,000									
10/27/2015	S-5		0:06	11:46	10/27/15 11:40	M4-Avg	104					1.19	1.27	100/100			1,400,000	1,700,000	2,000,000									
10/27/2015	S-5		0:06	12:06	10/27/15 12:00	M4-Avg	104					0	0.00	100/100			2,700,000	3,300,000	2,100,000									
10/27/2015	S-5		0:06	12:26	10/27/15 12:20	M4-Avg	105										2,600,000	4,200,000	2,500,000									
10/27/2015	S-5		0:06	12:46	10/27/15 12:40	M4-Avg	105										2,500,000	4,700,000	2,700,000									
10/27/2015	S-6		0:12	9:32	10/27/15 9:20	M5-Avg	136									22.4	350,000	74,000	58,000									
10/27/2015	S-6		0:12	9:52	10/27/15 9:40	M5-Avg	115									28.6	230,000	57,000	56,000									
10/27/2015	S-6		0:12	10:08	10/27/15 9:56	M5-Avg	118									29.3	240,000	21,000	50,000									
10/27/2015	S-6		0:12	10:52	10/27/15 10:40	M5-Avg	133									27.8	250,000	74,000	92,000									
10/27/2015	S-6	Trojan UV (Effluent)	0:12	11:09	10/27/15 10:57	M5-Avg	115									27.1	340,000	88,000	124,000									
10/27/2015	S-6		0:12	12:12	10/27/15 12:00	M5-Avg	119									26.8	88,000	118,000	82,000									
10/27/2015	S-6		0:12	13:05	10/27/15 12:53	M5-Avg	102									26.9	100,000	100,000	66,000									
10/27/2015	S-6						N/A																					
10/27/2015	S-6						N/A																					
10/27/2015	S-6						N/A																					
10/27/2015	S-7						N/A																					
10/27/2015	S-7						N/A																					
10/27/2015	S-7						N/A																					
10/27/2015	S-7	Aquionics UV (Effluent)					N/A																					
10/27/2015	S-7						N/A																					
10/27/2015	S-7						N/A																					
10/27/2015	S-7						N/A																					

General Notes:
1. Non Settleable samples were allowed to settle for 1 hour before drawing off supernatant into sample collection bottle
2. 2.20*1.07>: The result is equal to or greater than Maximum Range of the PAA test.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B

Graphs with Chronological Performance for Major Parameters for All Test Runs

Appendix B contains a series of chronological graphs presenting results from individual Test Runs. For each Test Run, the initial graphs present TSS and other characteristics of influent wastewater throughout the sampling event. Subsequent graphs in each series chronicle performance of different pilot units, with bacterial indicators data provided at the final group of graphs for each series.

Chronological raw wastewater characteristics for each individual Test Run are presented in series of Figures X-1 and X-2, where X represents number of the individual Test Run (1 through 9). These Figures present conventional parameters measured in raw wastewater such as TSS, VSS, CBOD5, COD as well as fraction of settleable TSS and VSS at several points during each storm (usually measured at 1 hour intervals).

Figures from series X- 3 and above present chronological data and performance of pilot units dedicated primarily to removal of TSS and related parameters, i.e., Terra Kleen, Storm King and Flex Filter. TSS removal efficiency for each unit is based on TSS or other data from the corresponding sampling time (which includes time delay related to the hydraulic retention time of each unit).

Figures from series X-10 and above present chronological performance of UV and PAA disinfection units. Bacterial density measurements, log reduction outcomes as well as relevant wastewater characteristics such as UVT, TSS, soluble CBOD5, COD and residual PAA, as applicable, are presented chronologically for each storm.

The above outlined convention of numbering of Figures separates Figures pertaining to conventional parameters (Figures 1 through 4 and above, depending on the Test Run) from group of Figures with numbers 10 and above which present data pertaining to disinfection. **Consequently, some Figures with single digit numbers preceding number 10 are not present.**

THIS PAGE INTENTIONALLY LEFT BLANK

Figure 1-1. Storm 1 (10/4/2014). Raw TSS Characteristics

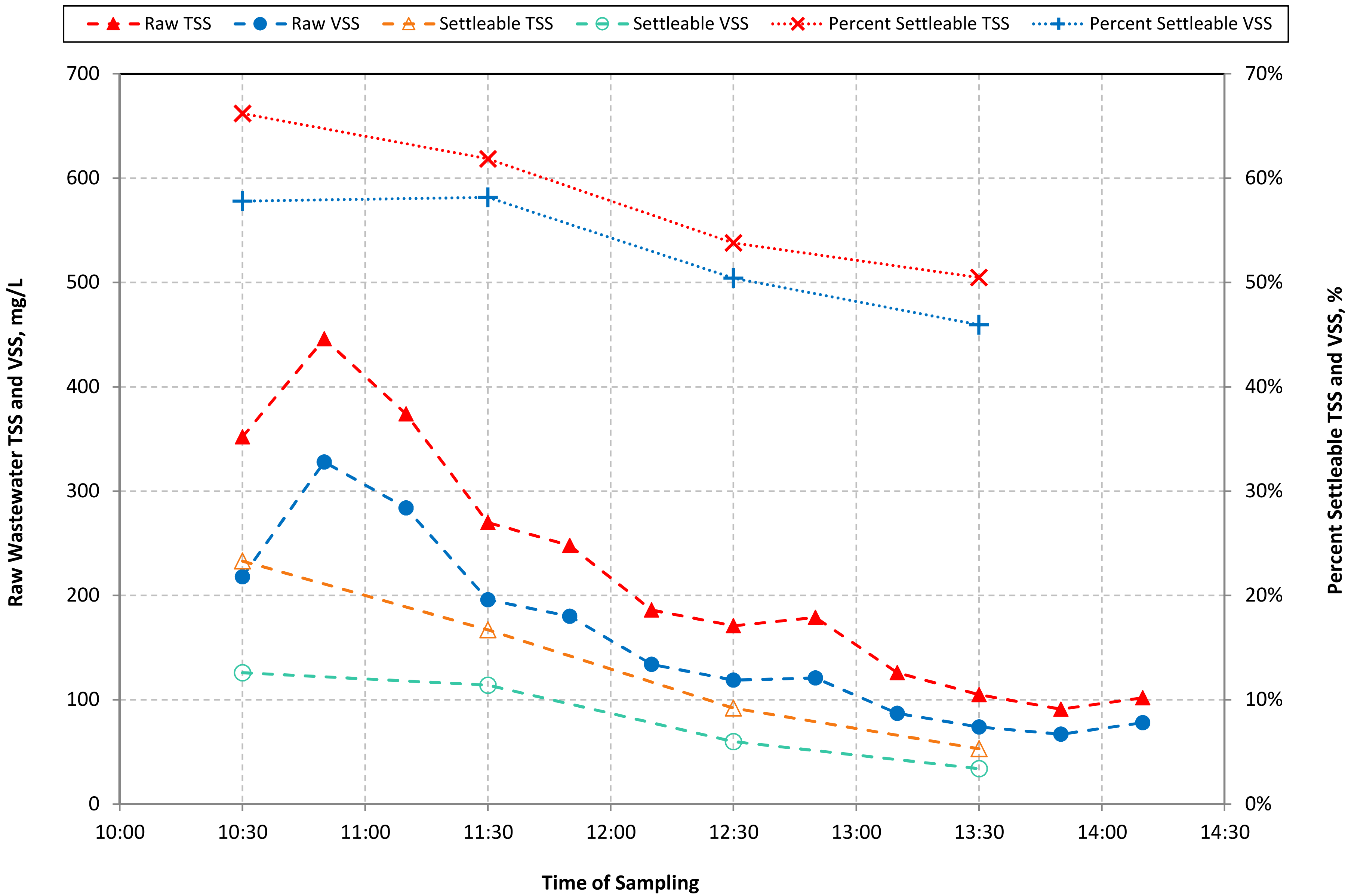


Figure 1-2. Storm 1 (10/4/2014). Raw Wastewater Characteristics

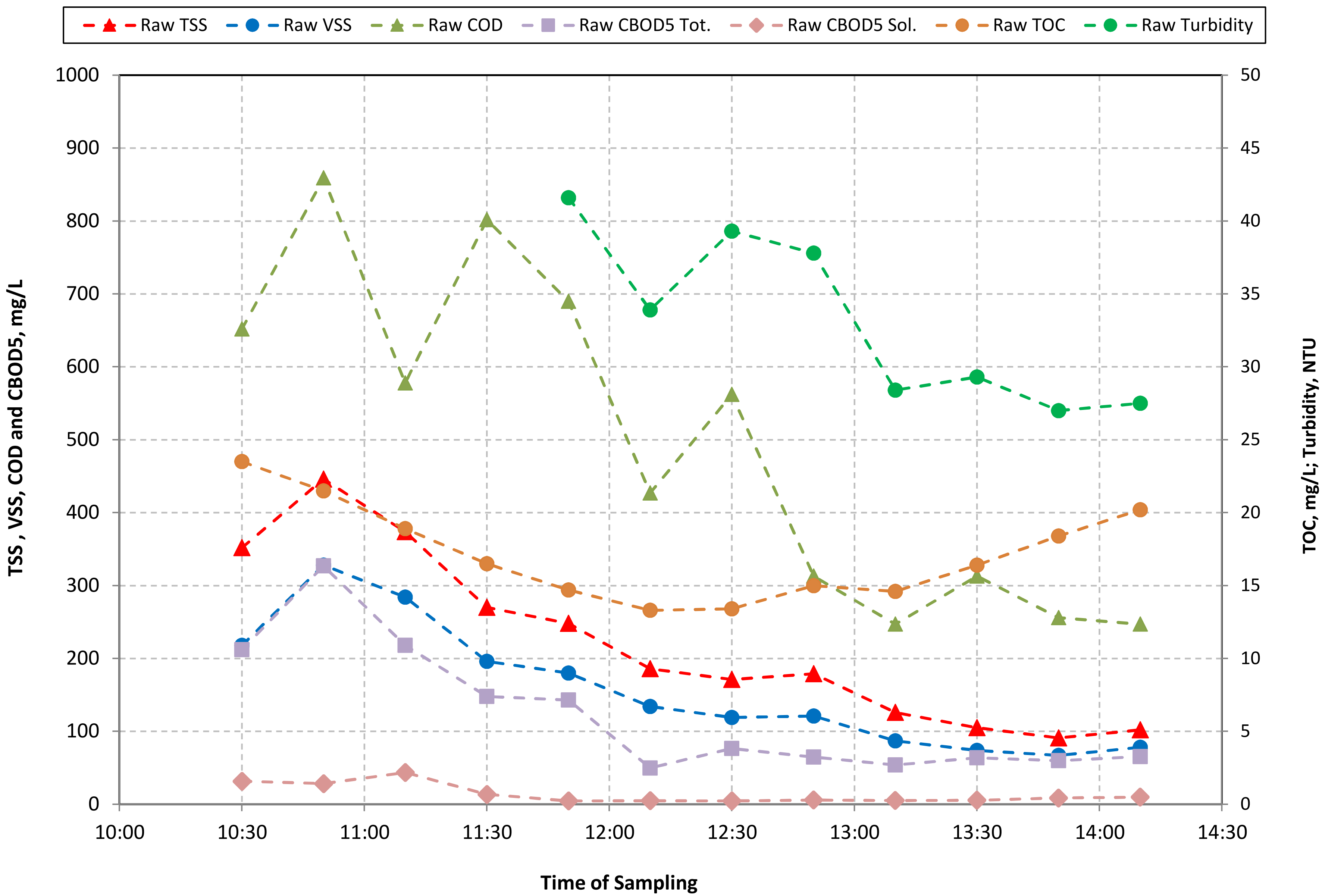


Figure 1-3. Storm 1 (10/4/2014). Terre Kleen Performance

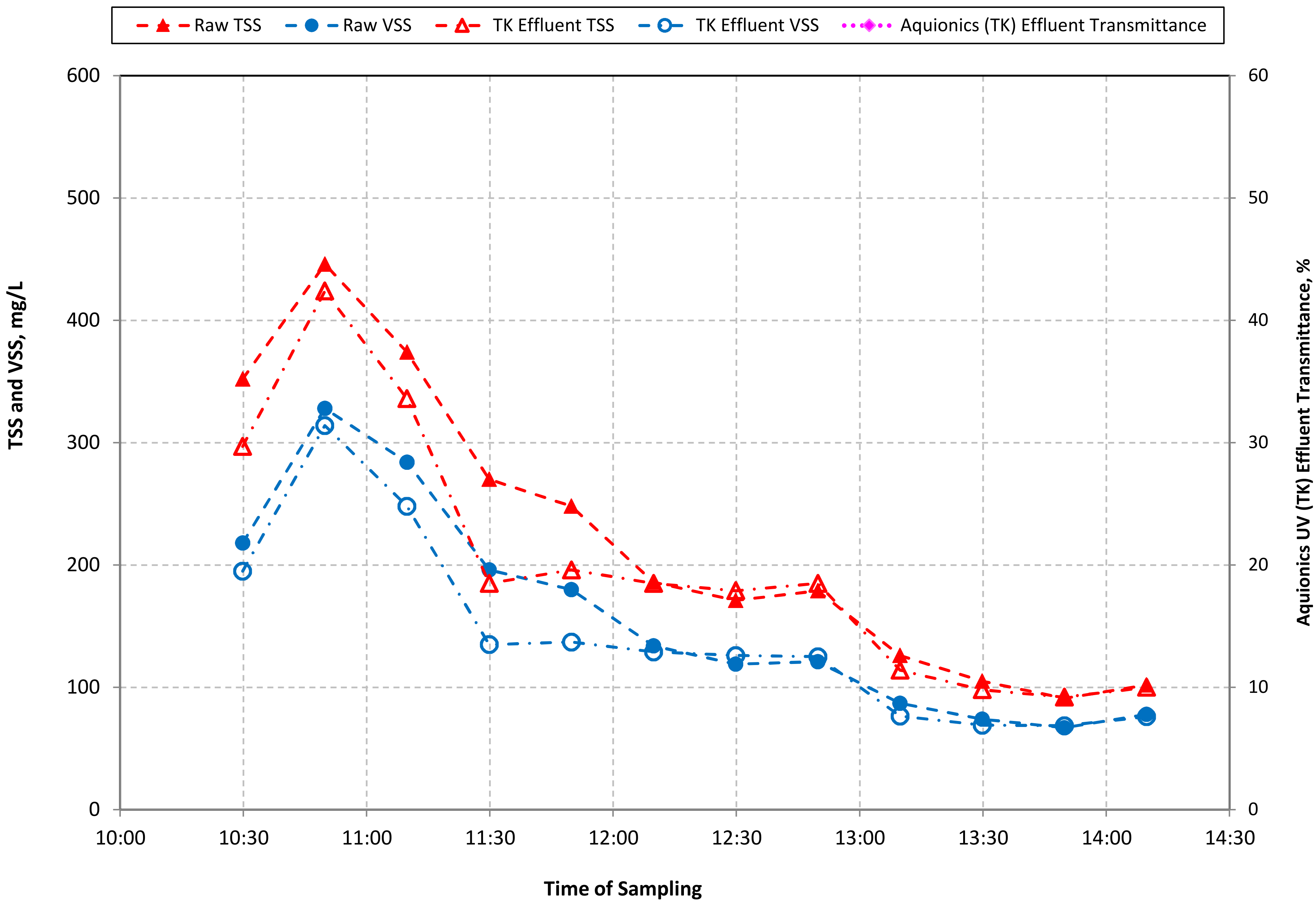


Figure 1-4. Storm 1 (10/4/2014). Storm King Performance

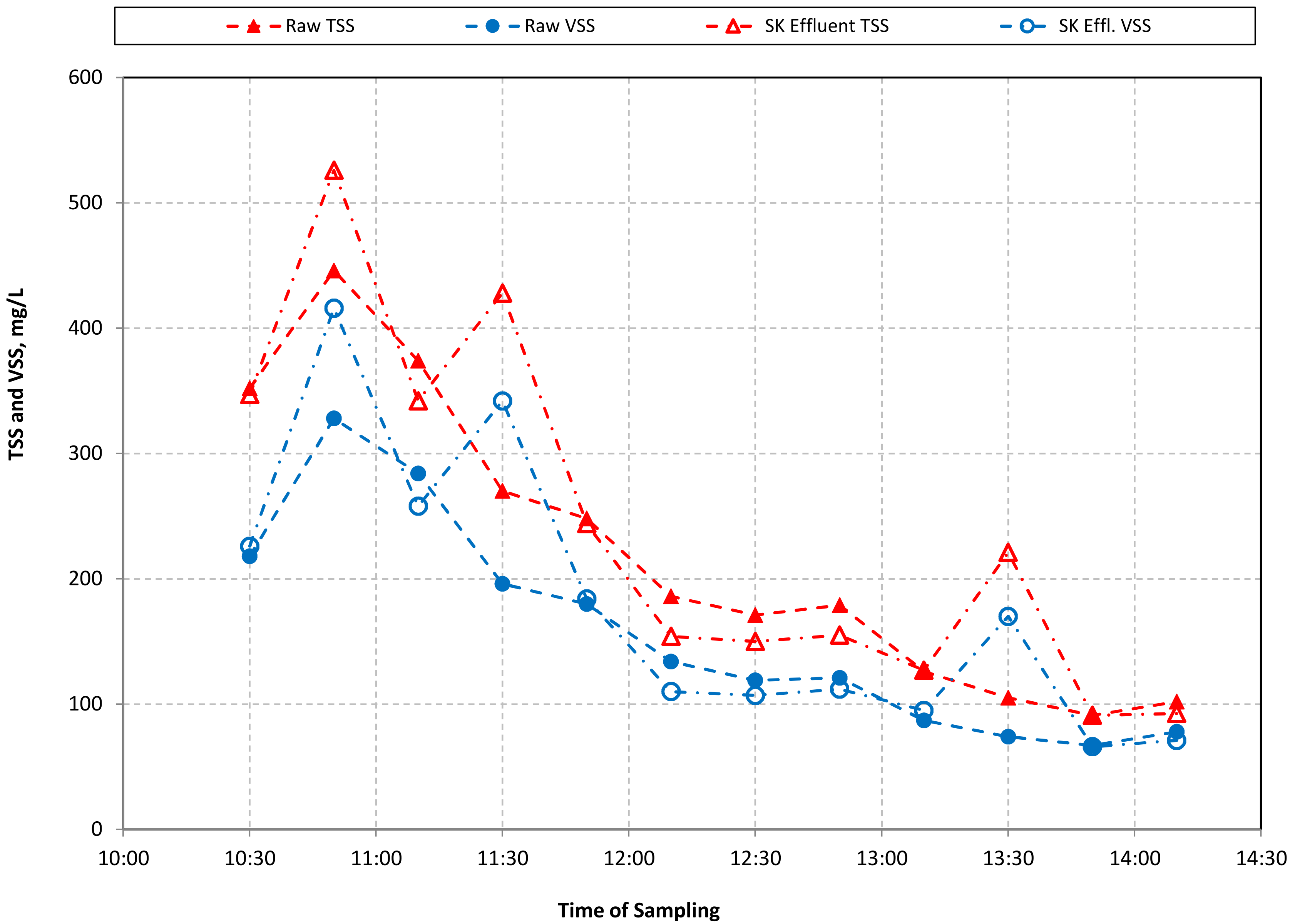


Figure 1-5. Storm 1 (10/4/2014). Flex Filter Performance

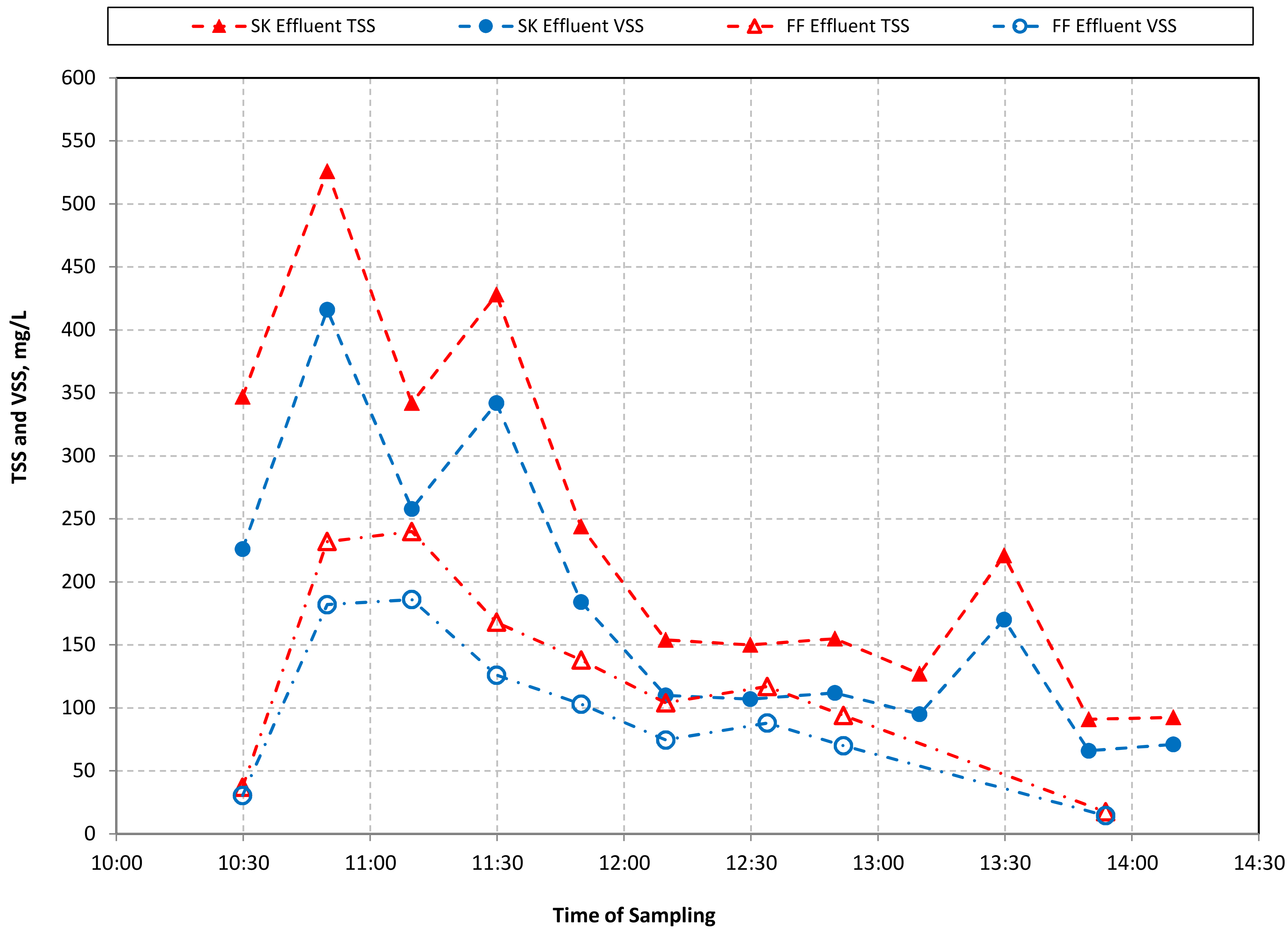


Figure 1-6. Storm 1 (10/4/2014) . Terre Kleen COD and TOC Performance

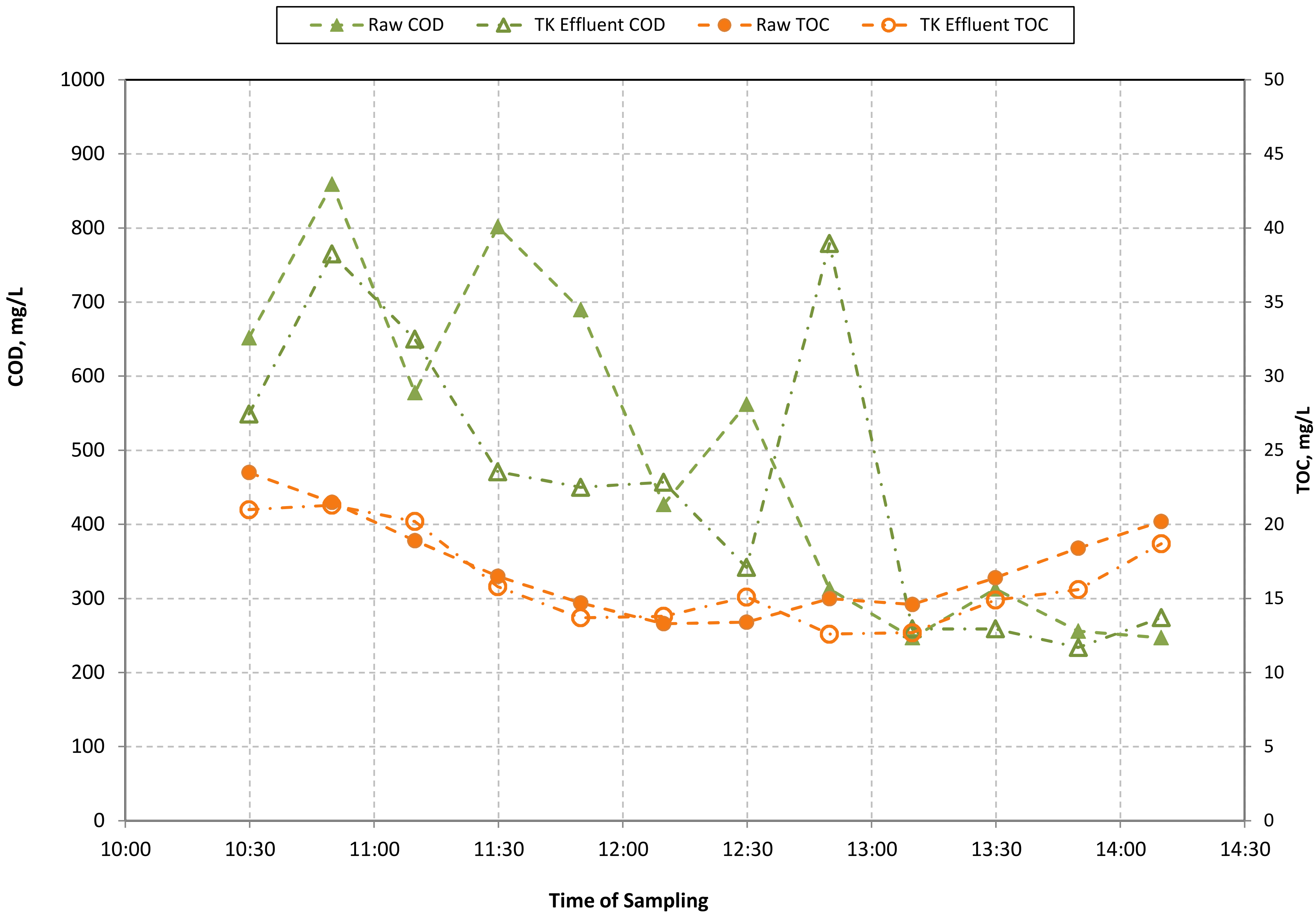


Figure 1-7. Storm 1 (10/4/2014) . Flex Filter COD and TOC Performance

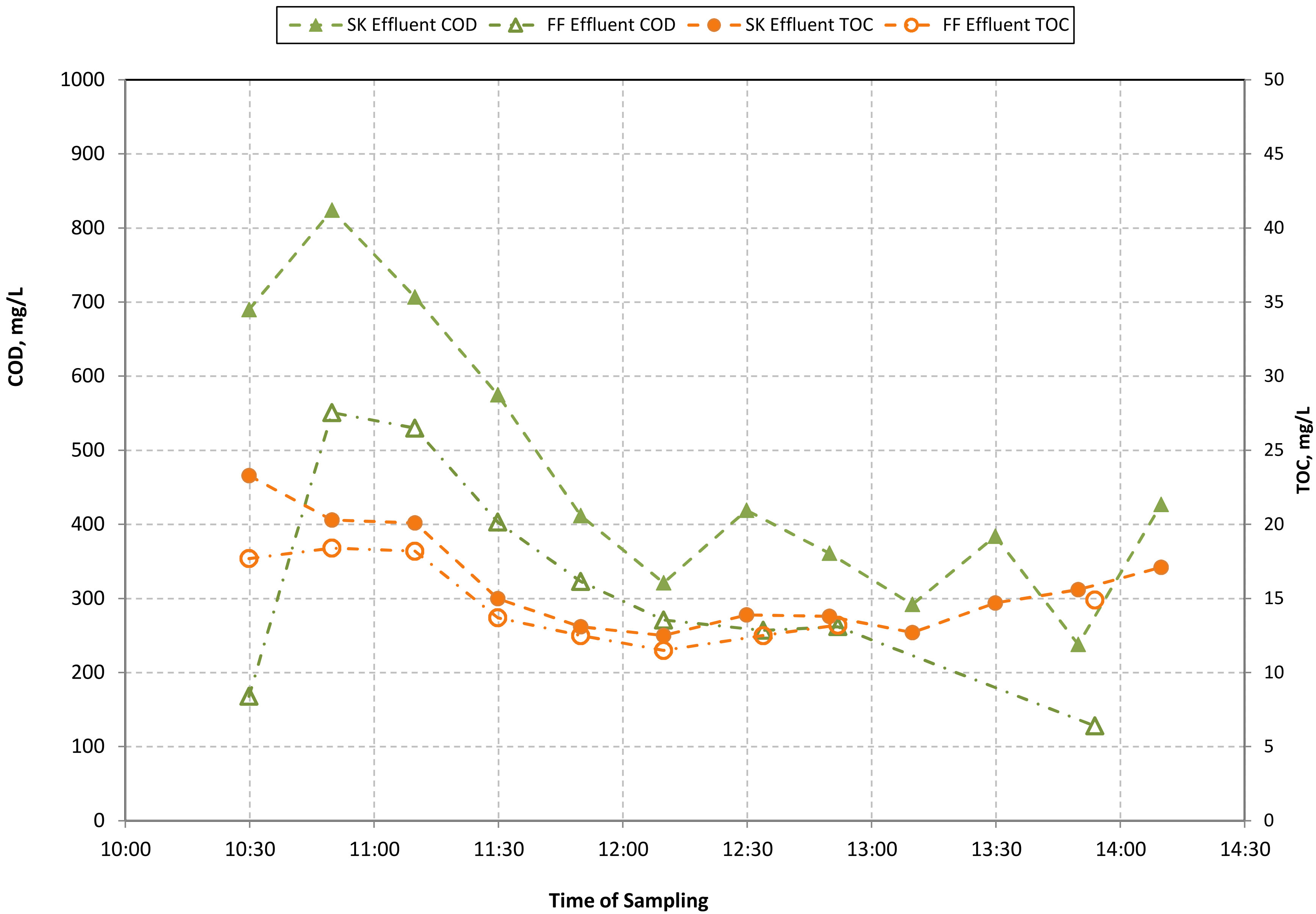


Figure 1-10. Storm 1 (10/4/2014). UV performance

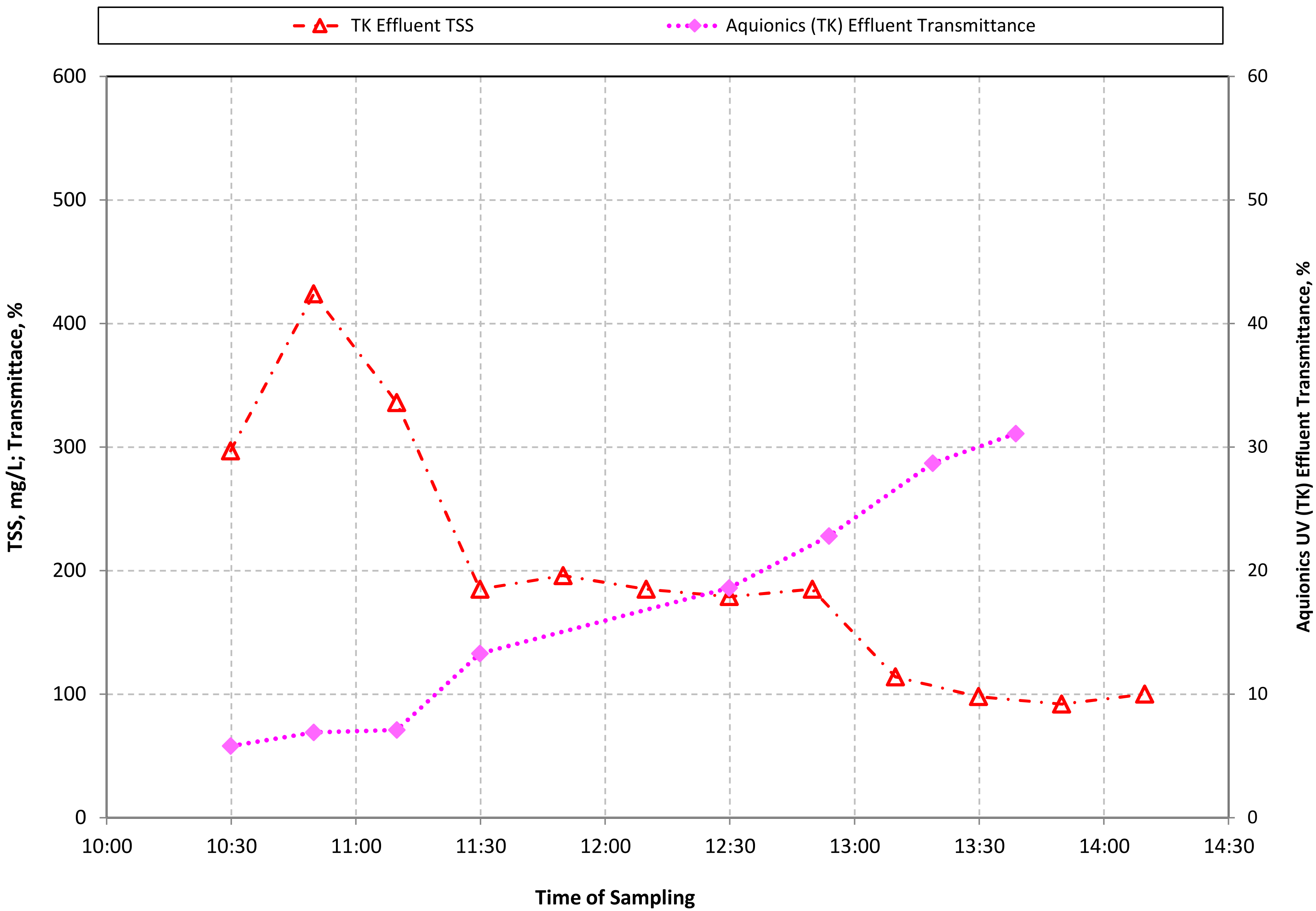


Figure 1-11. Storm 1 (10/4/2014). Aquionics UV Performance (Following Terre Kleen)

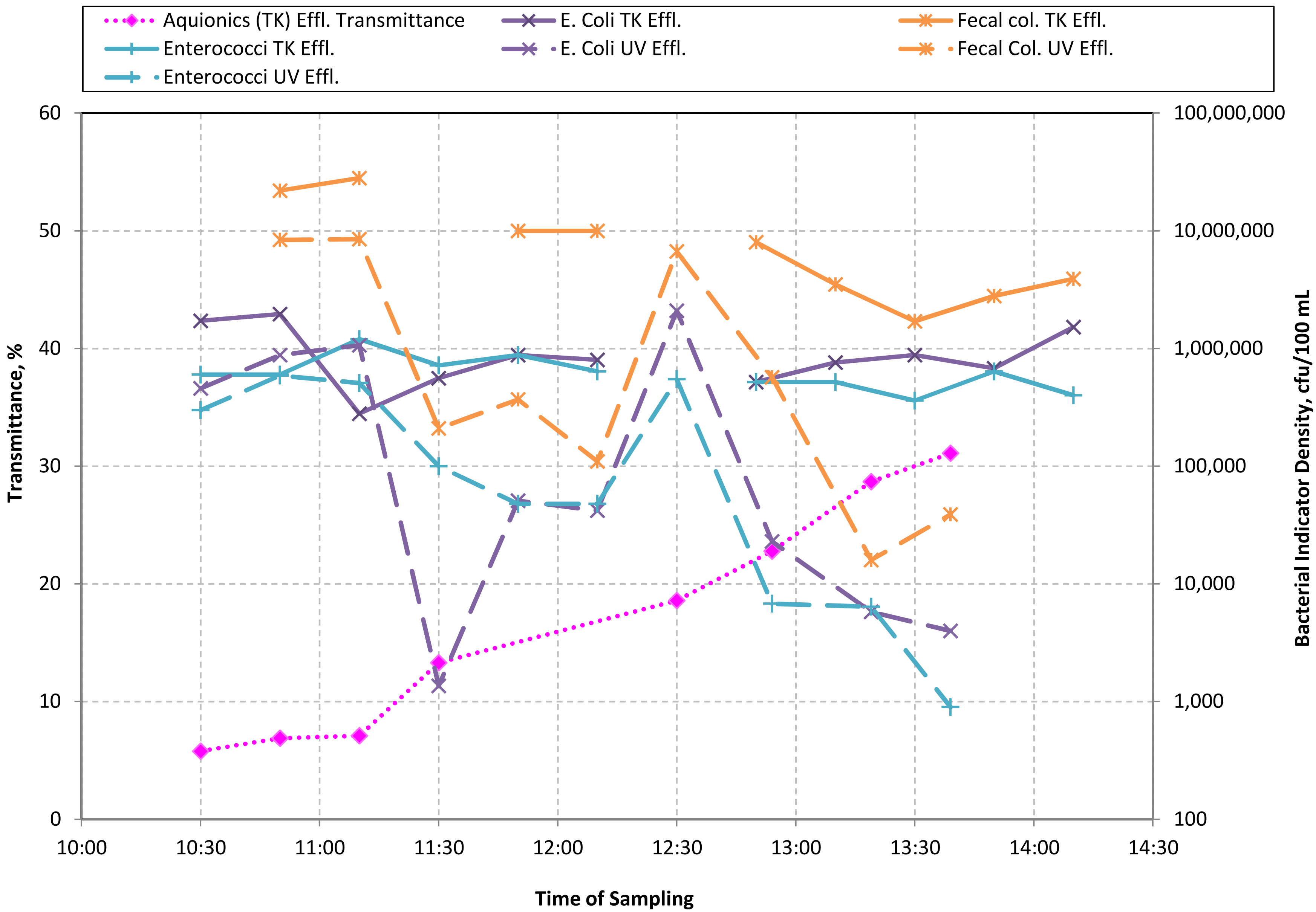


Figure 1-12. Storm 1 (10/4/2015). Aquionics UV Performance (Following Terre Kleen)

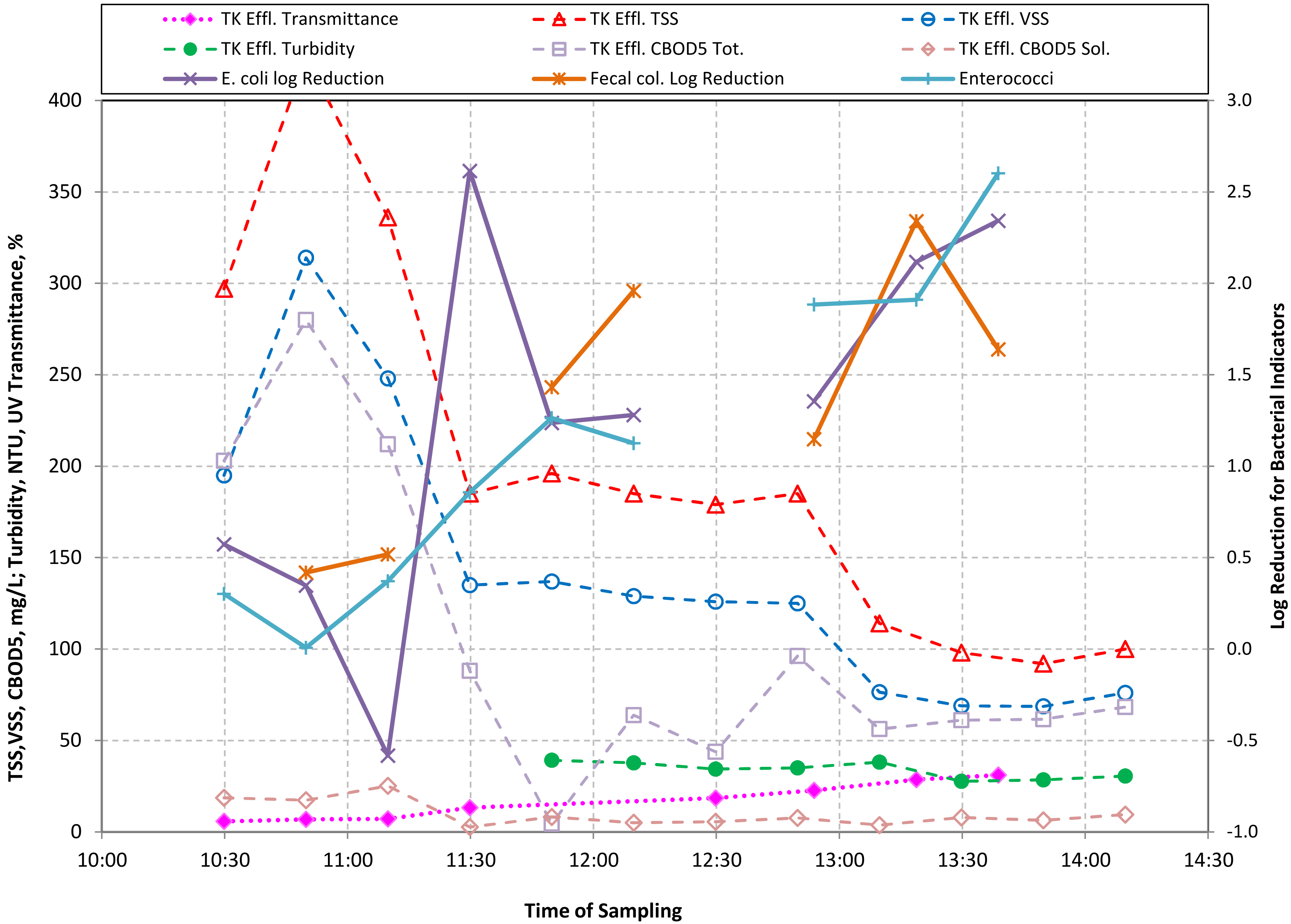


Figure 1-13. Storm 1 (10/4/2015). Aquionics UV Performance (Following Terre Kleen)

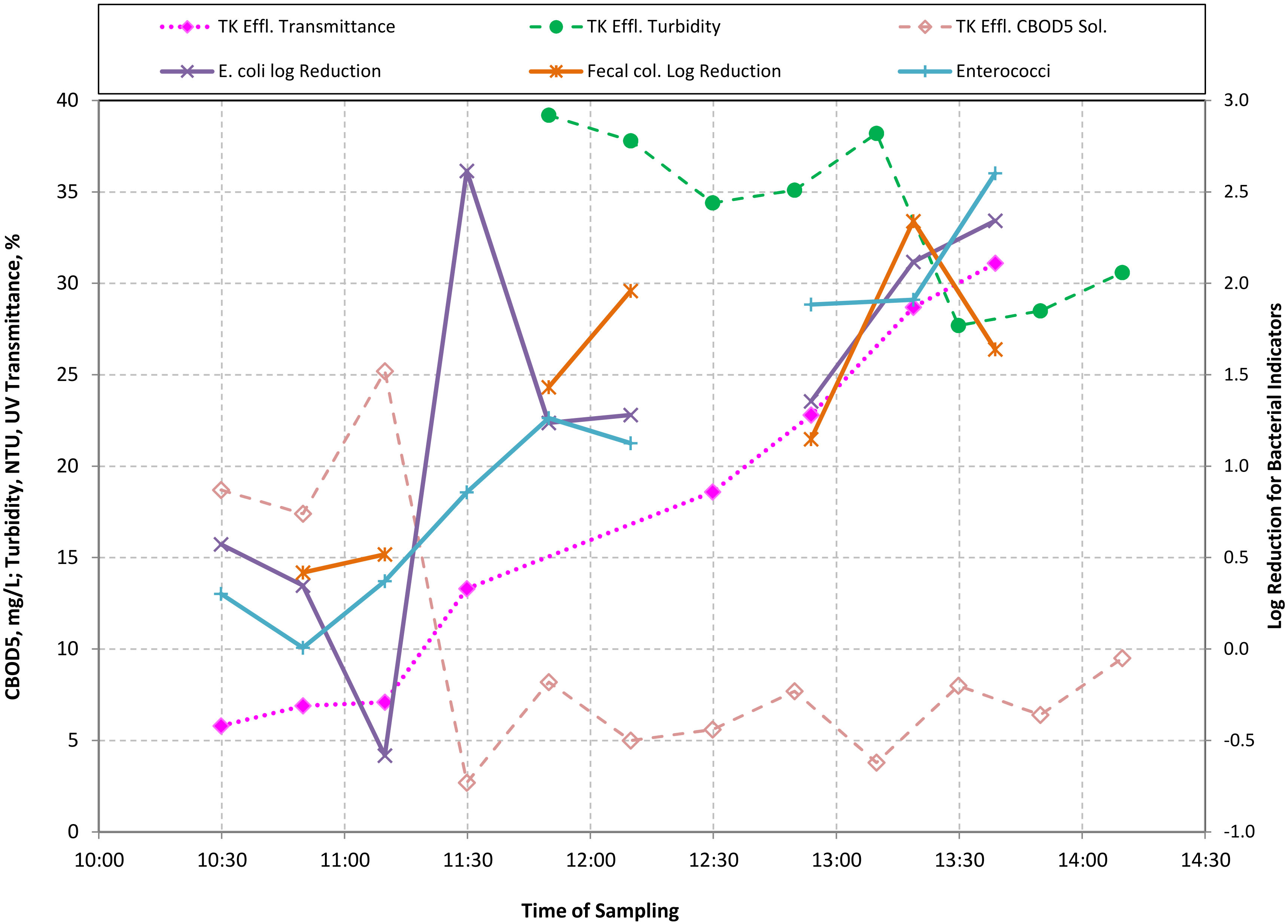
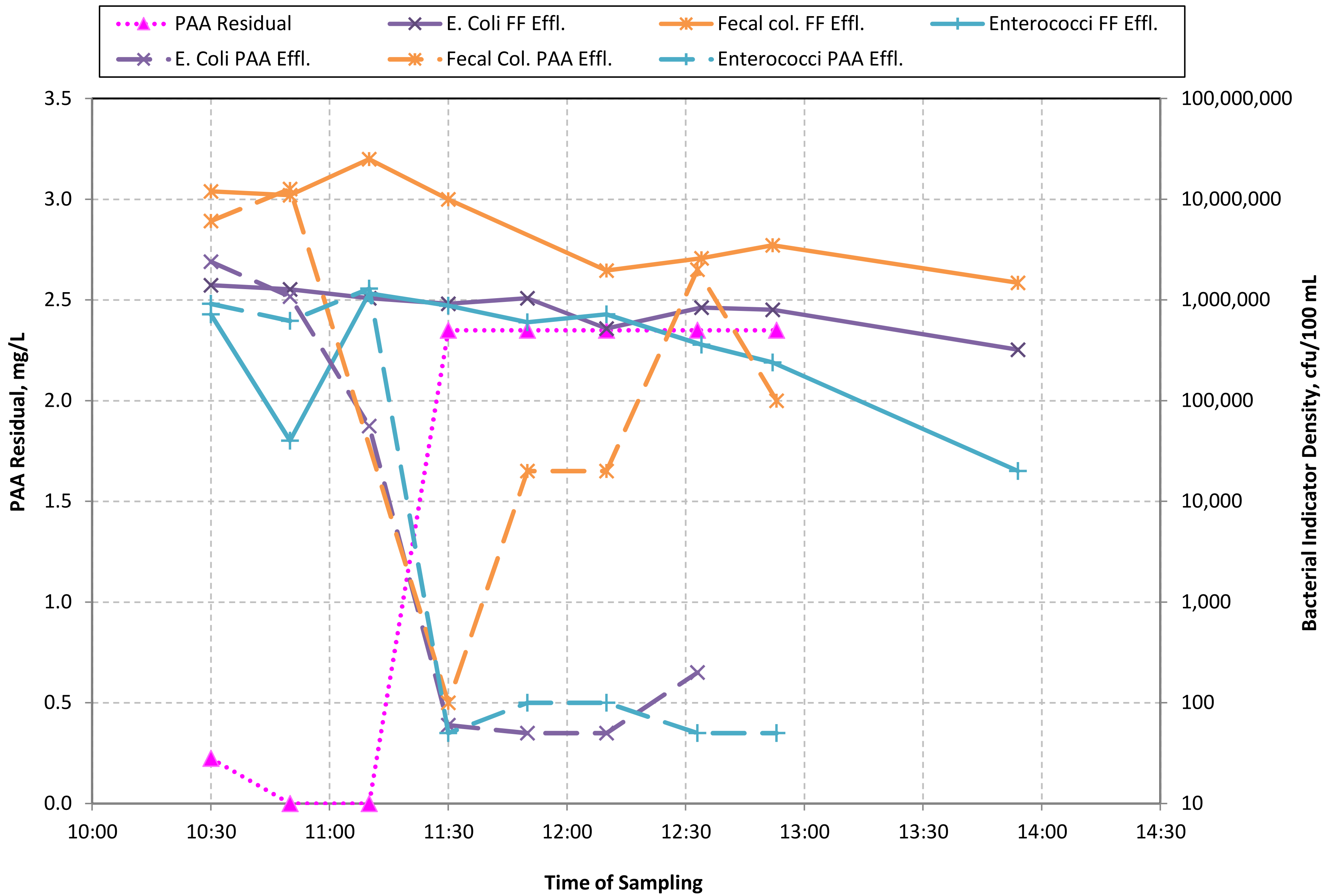


Figure 1-14. Storm 1 (10/4/2014). PAA Performance (Following Flex Filter)



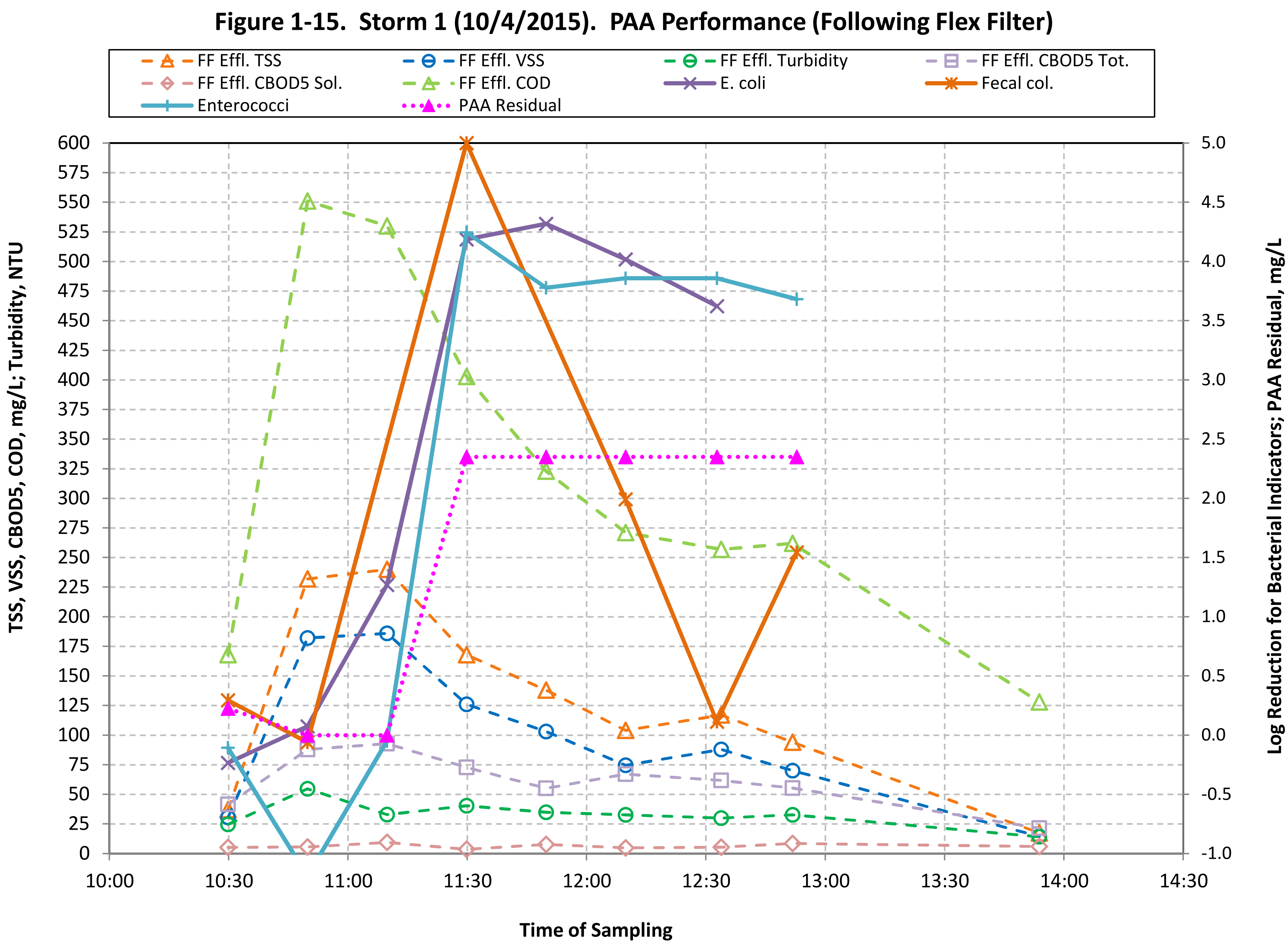


Figure 1-15. Storm 1 (10/4/2015). PAA Performance (Following Flex Filter)
FF Effl. TSS
FF Effl. VSS
FF Effl. Turbidity
FF Effl. CBOD5 Tot.
FF Effl. CBOD5 Sol.
FF Effl. COD
E. coli
Fecal col.
Enterococci
PAA Residual
TSS, VSS, CBOD5, COD, mg/L; Turbidity, NTU
Log Reduction for Bacterial Indicators; PAA Residual, mg/L
Time of Sampling
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30

Figure 1-16. Storm 1 (10/4/2015). PAA Performance (Following Flex Filter)

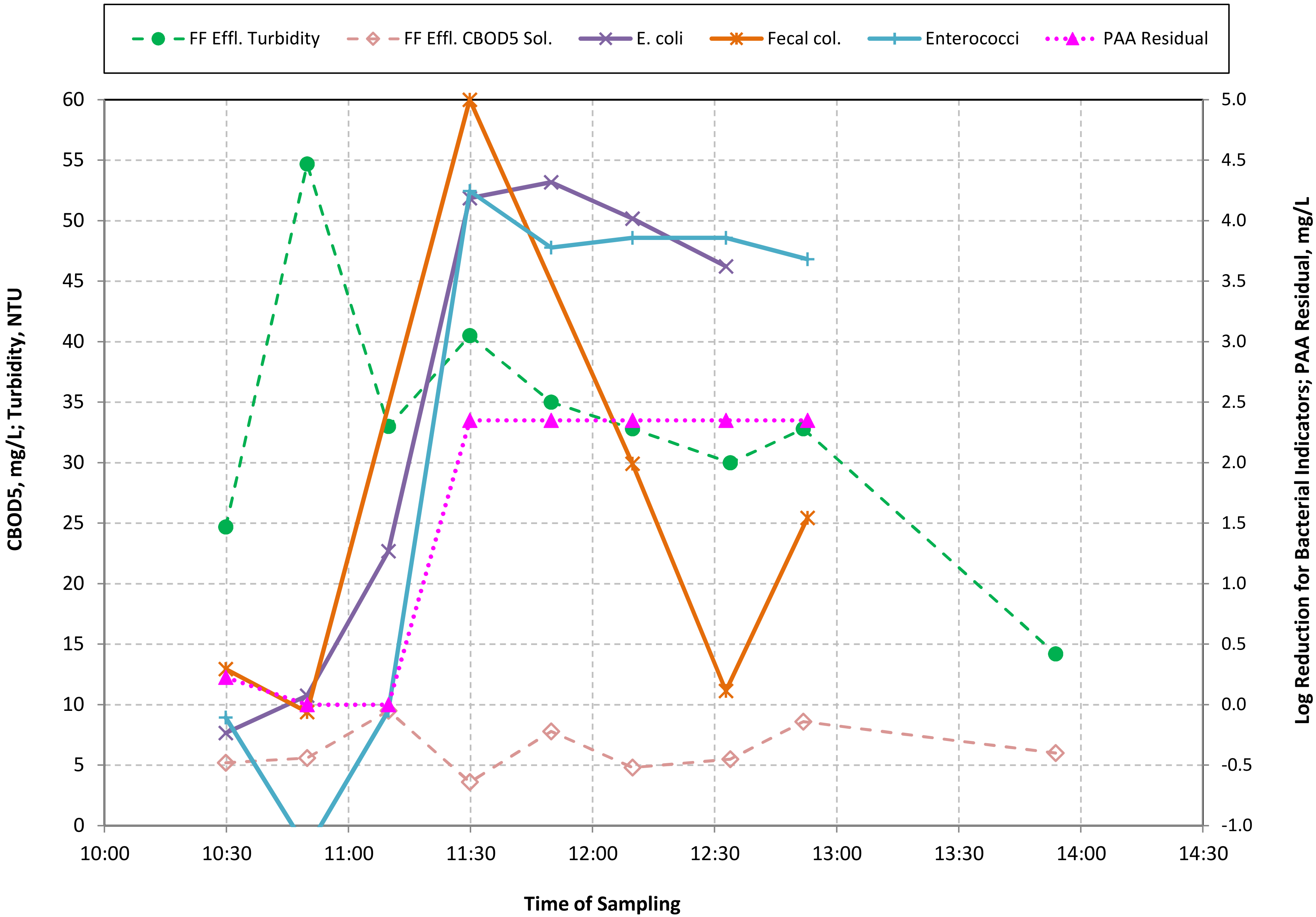


Figure 1-17. Storm 1 (10/4/2015). PAA Residual

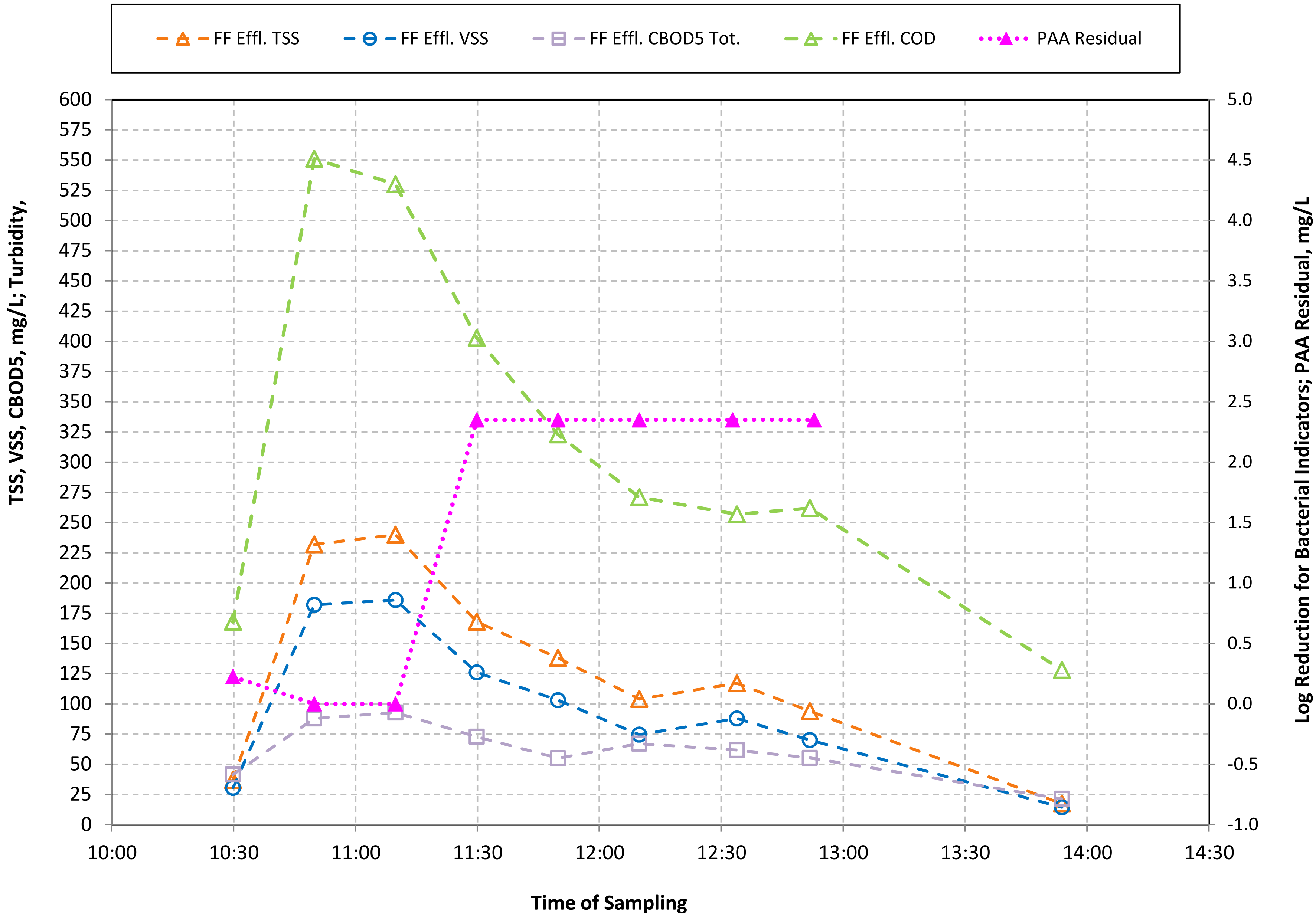


Figure 2-1. Storm 2 (10/16/2014). Raw TSS Characteristics

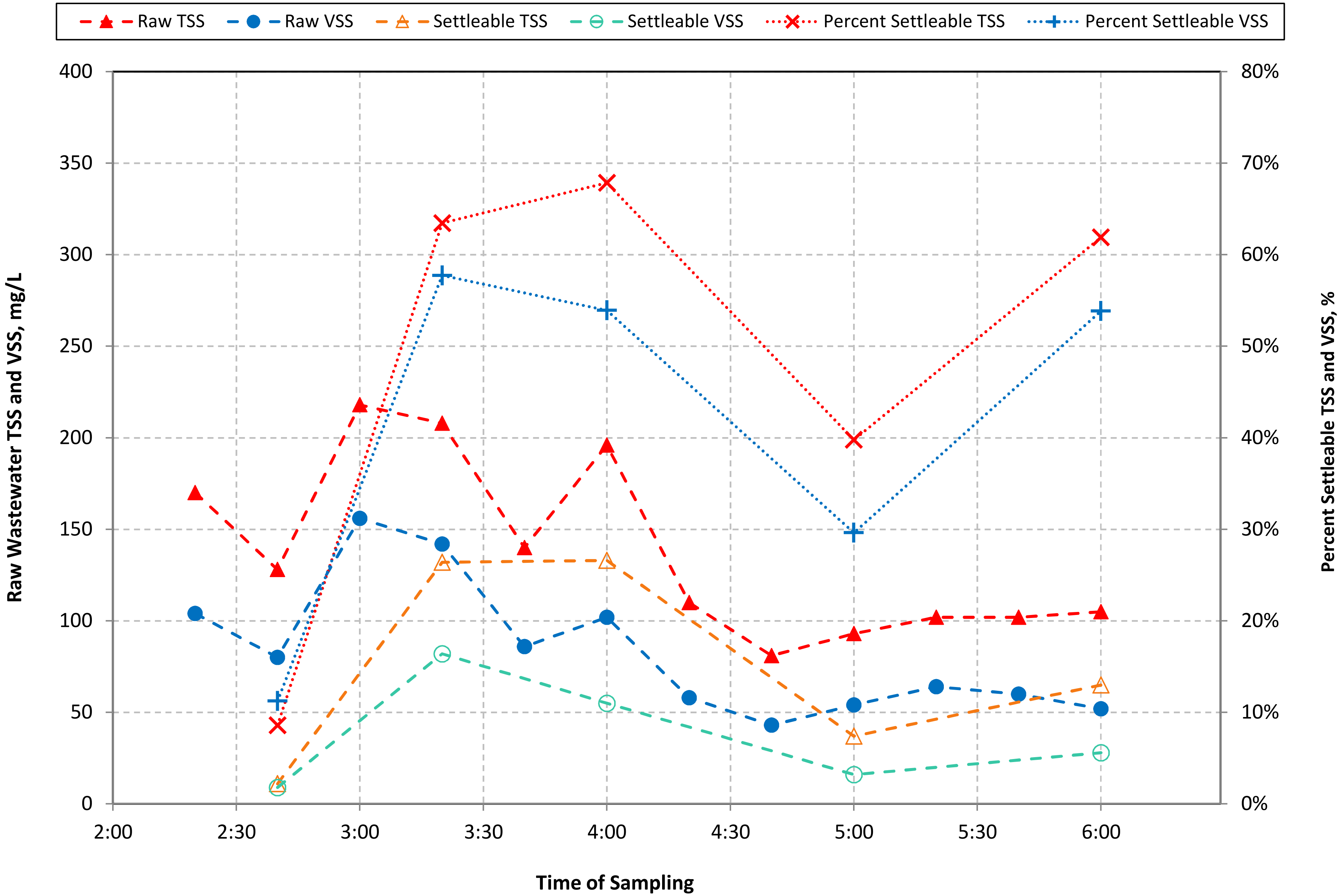


Figure 2-2. Storm 2 (10/16/2014). Raw Wastewater Characteristics

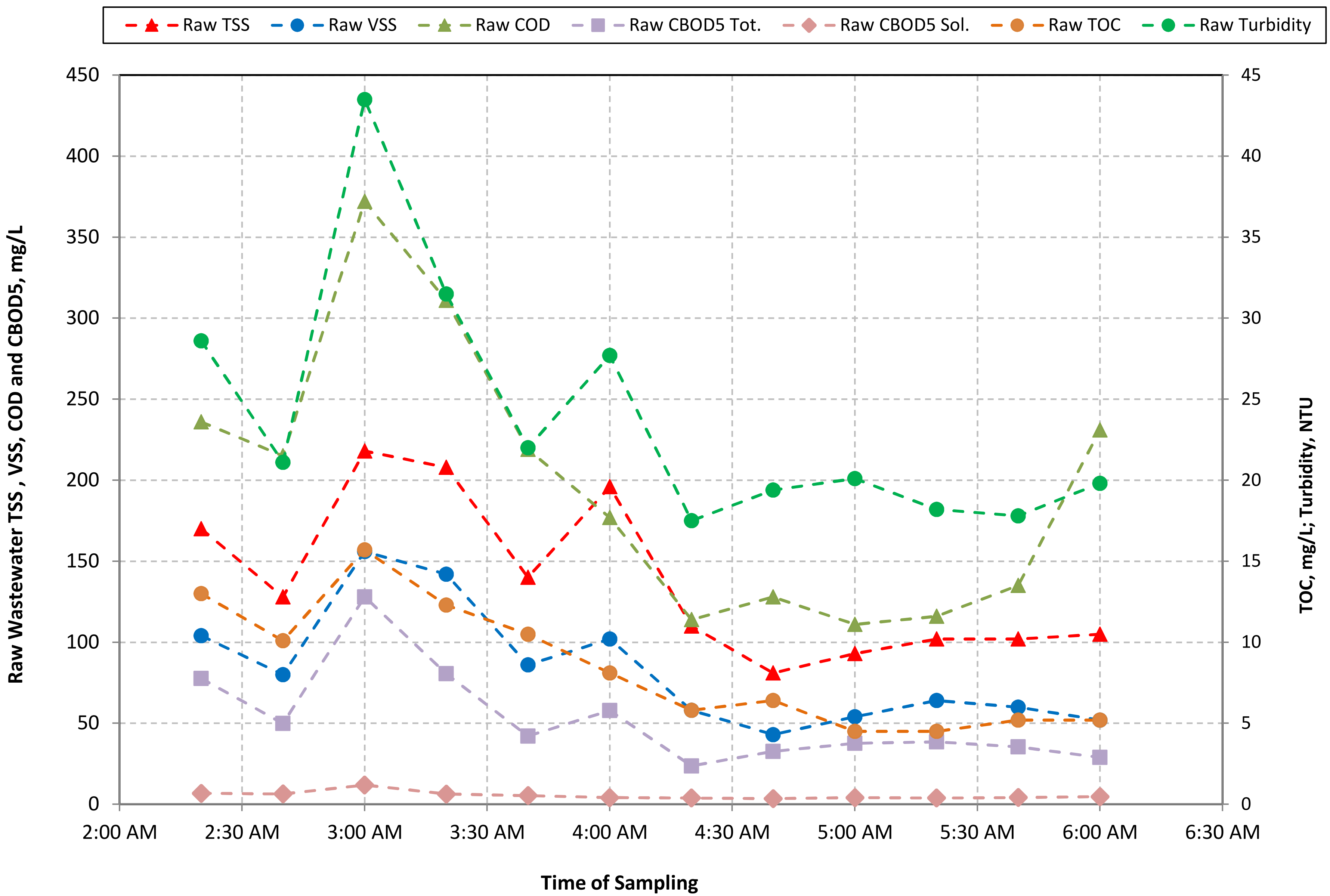


Figure 2-3. Storm 2 (10/16/2014). Terre Kleen Performance

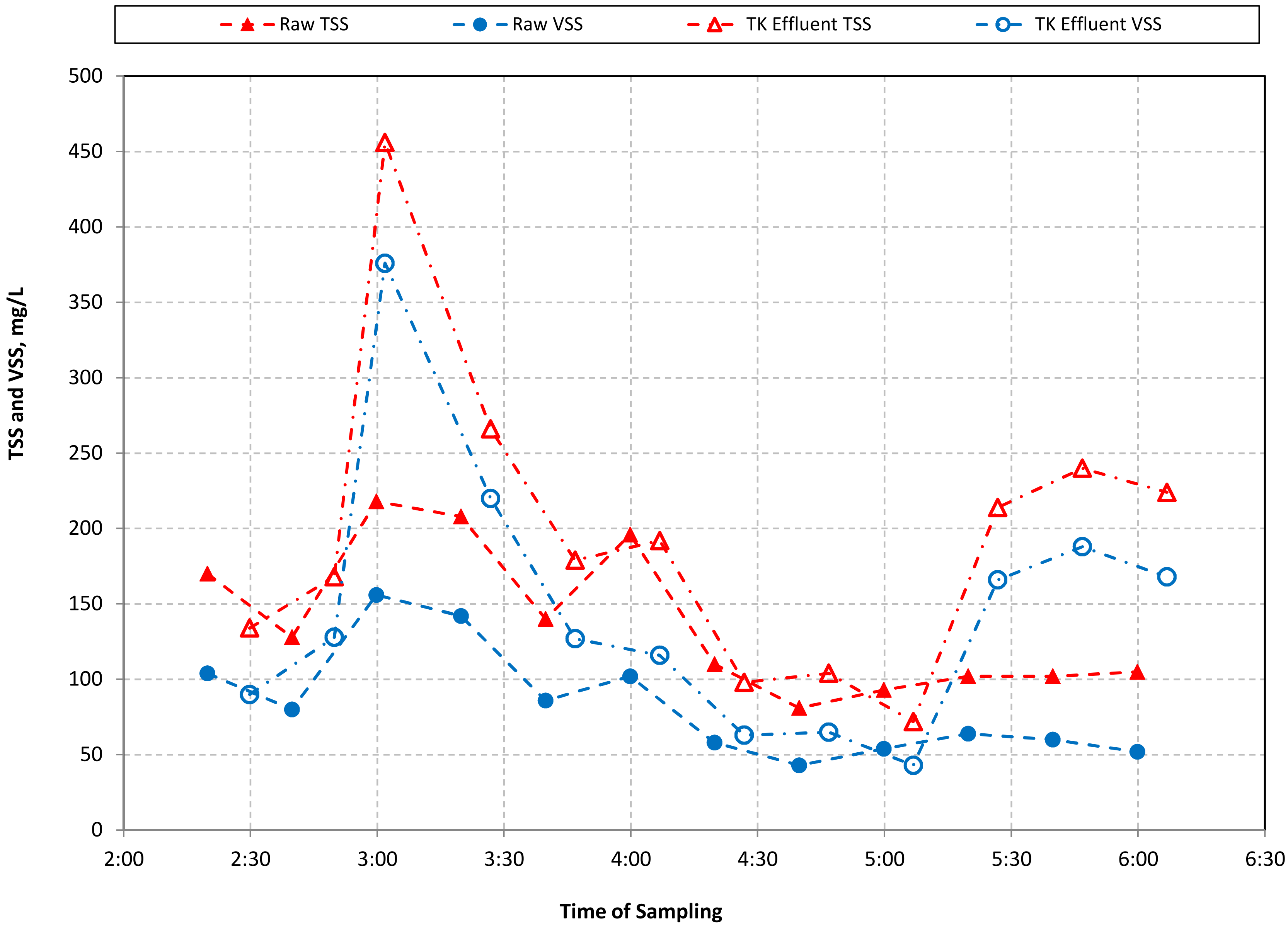


Figure 2-4. Storm 2 (10/16/2014). Storm King Performance

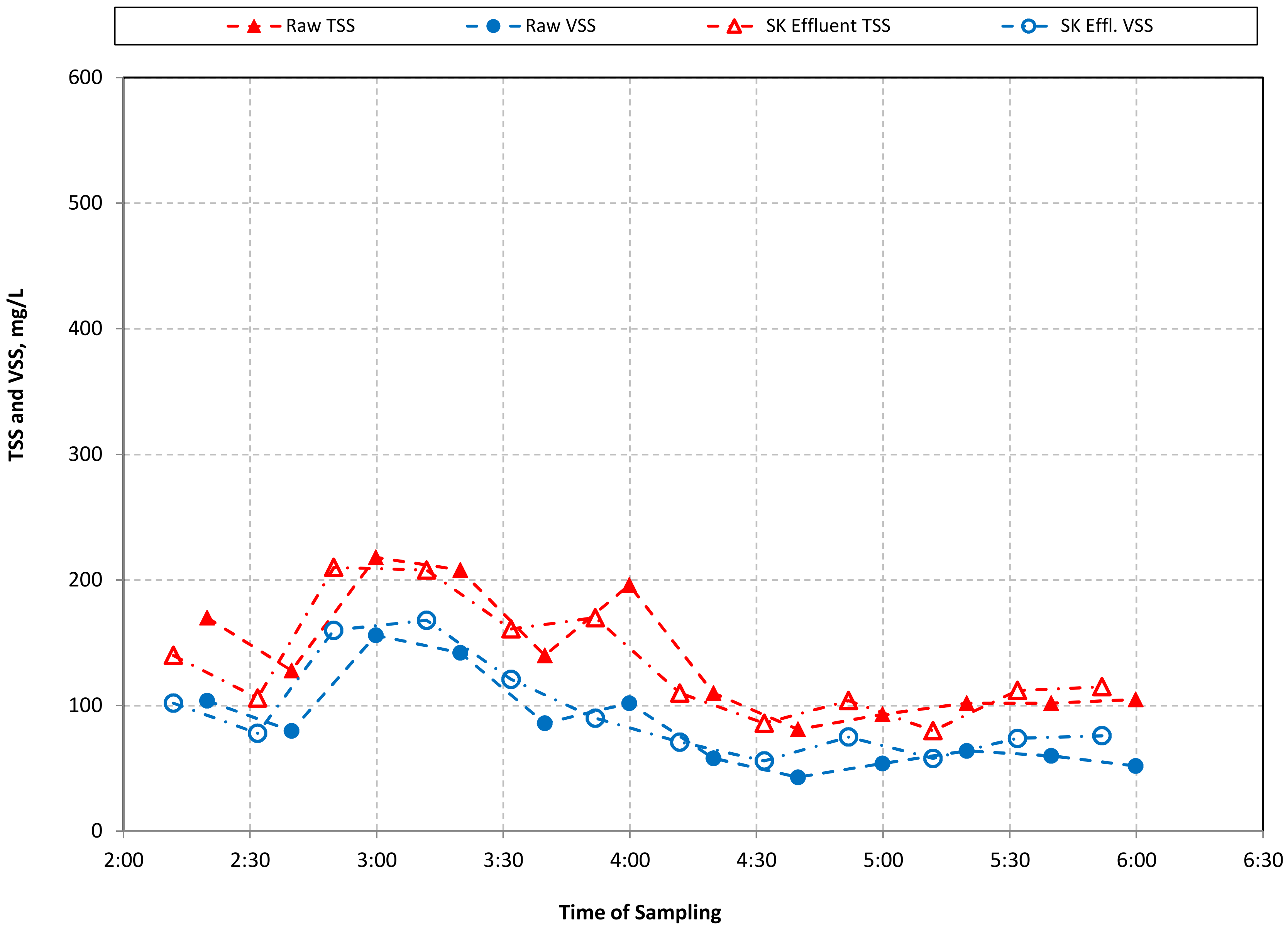


Figure 2-5. Storm 2 (10/16/2014). Flex Filter Performance

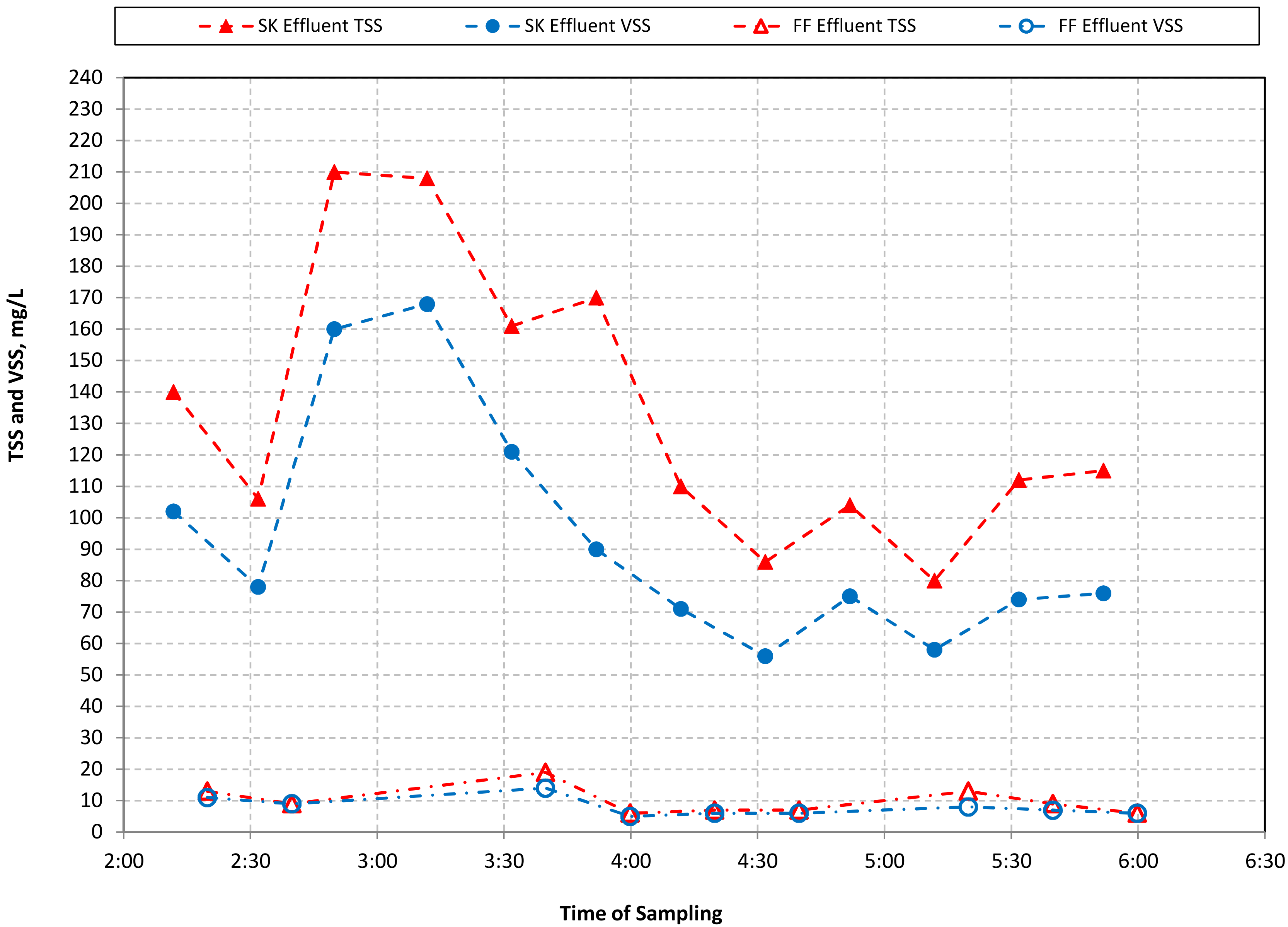


Figure 2-6. Storm 2 (10/16/2014). TK COD and TOC Performance

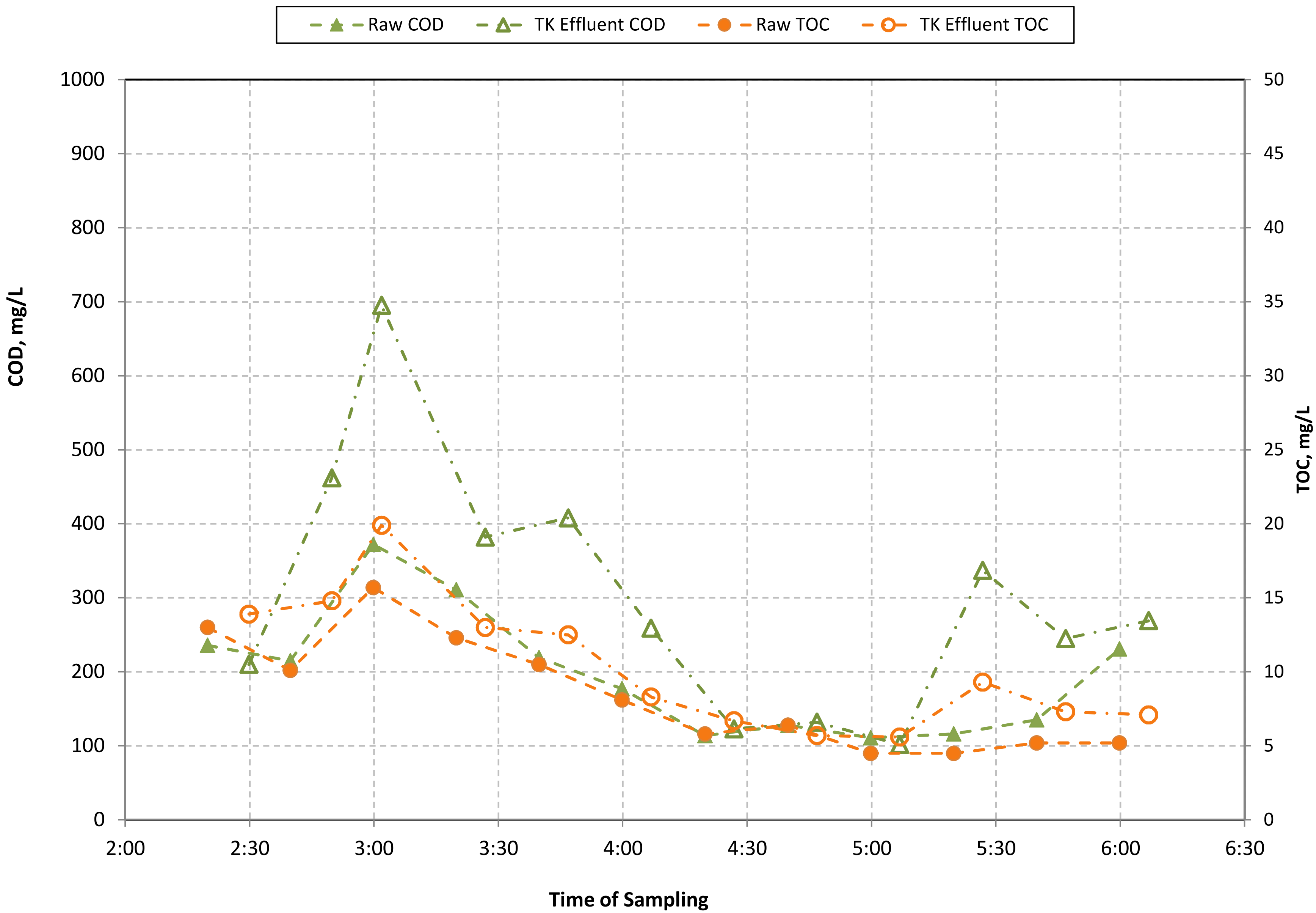


Figure 2-7. Storm 2 (10/16/2014). FF COD and TOC Performance

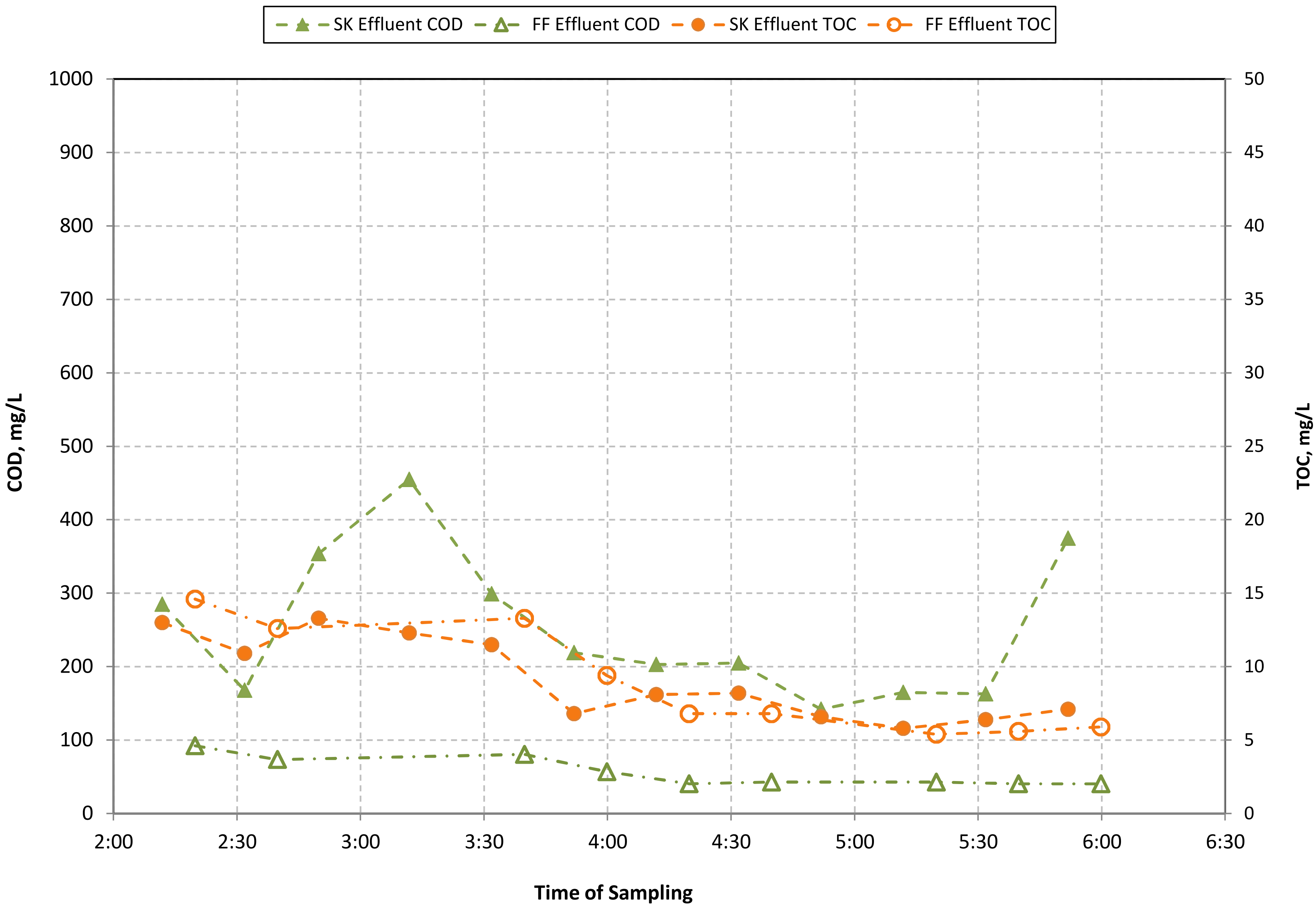


Figure 2-10. Storm 2 (10/16/2014). Aquionics UV Performance (Following Flex Filter)

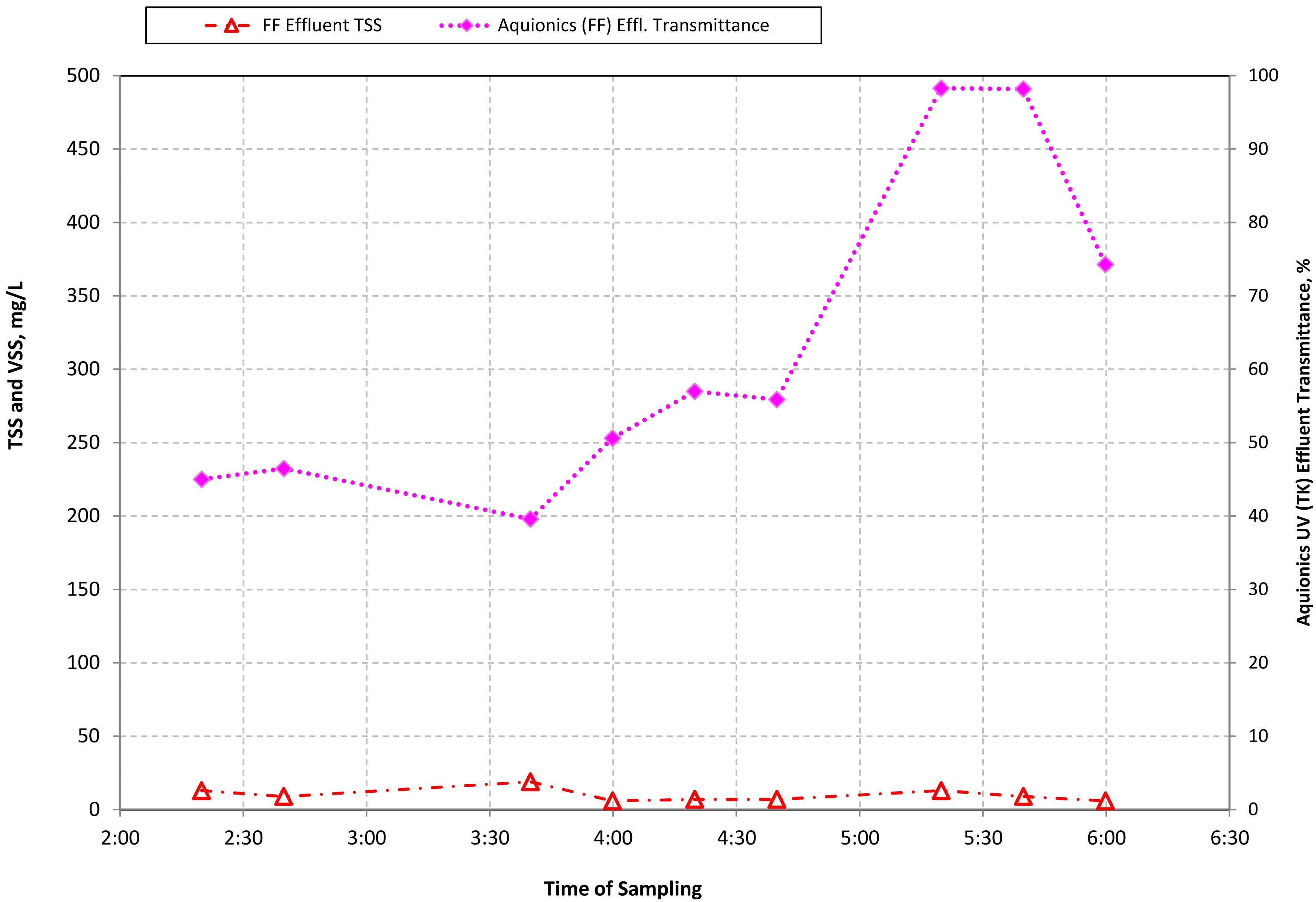


Figure 2-11. Storm 2 (10/4/2014). Aquionics UV Performance (Following Flex Filter)

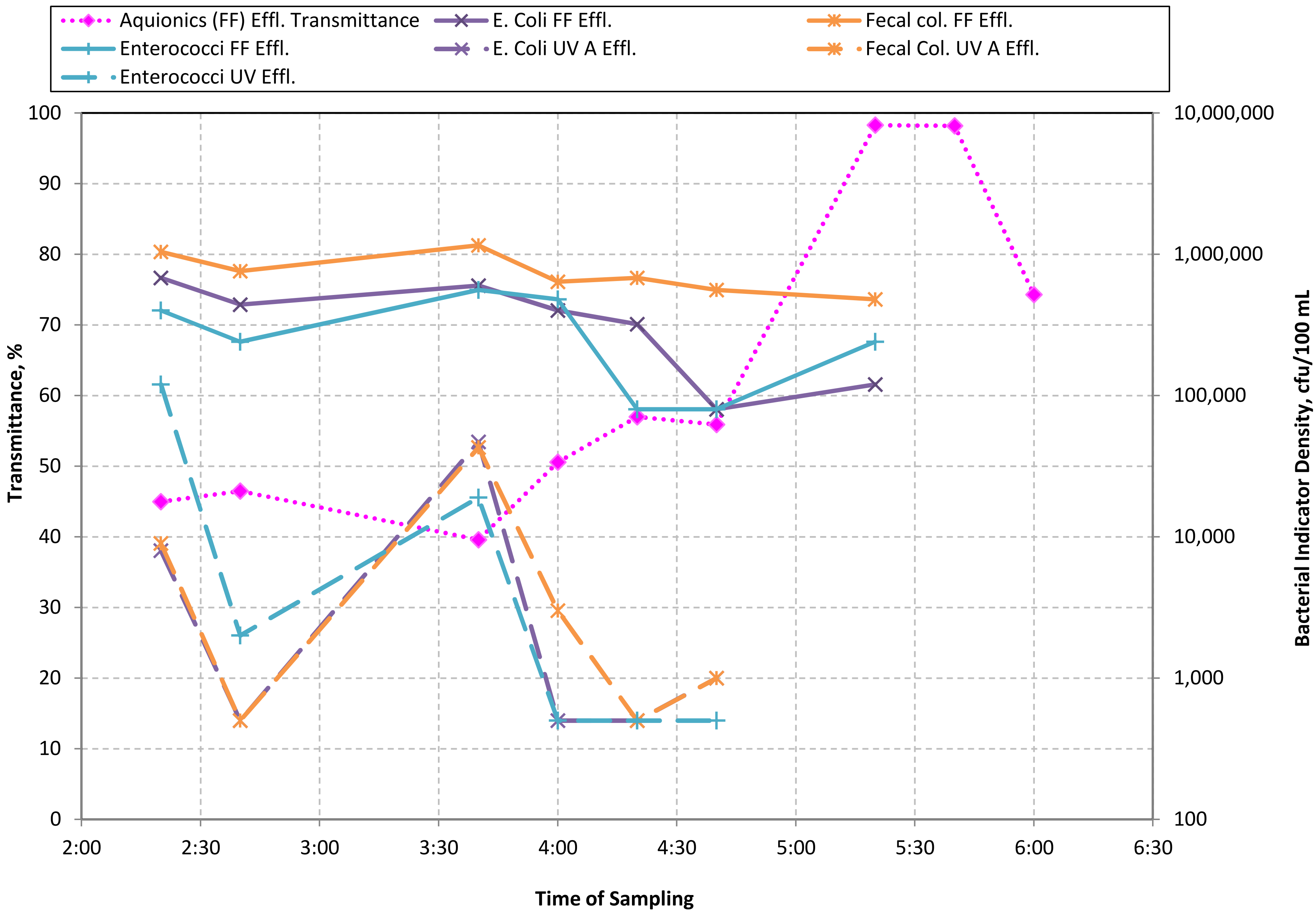


Figure 2-12. Storm 2 (10/16/2015). Aquionics UV Performance (Following Flex Filter)

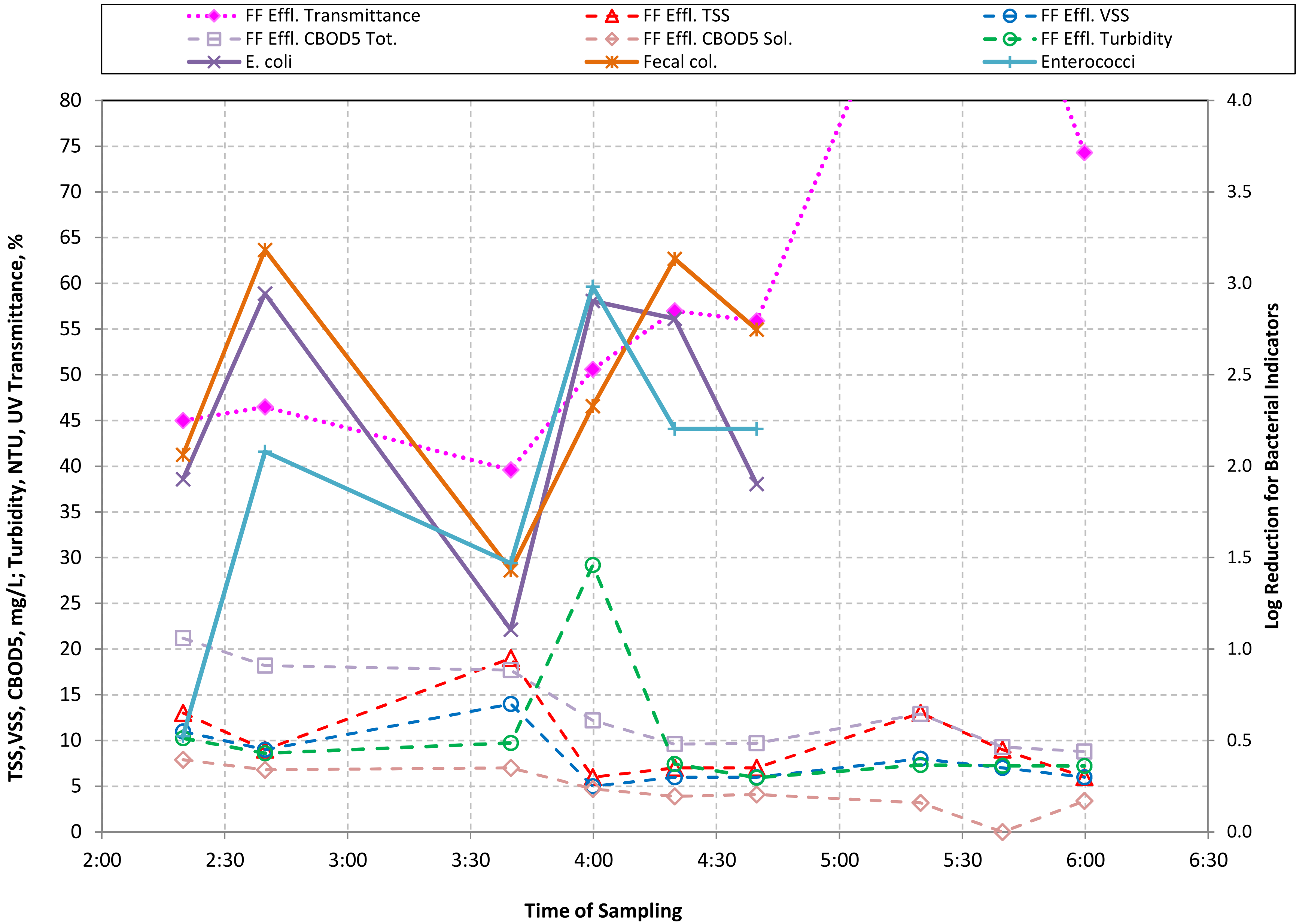


Figure 2-13. Storm 2 (10/16/2015). Aquionics UV Performance (Following Flex Filter)

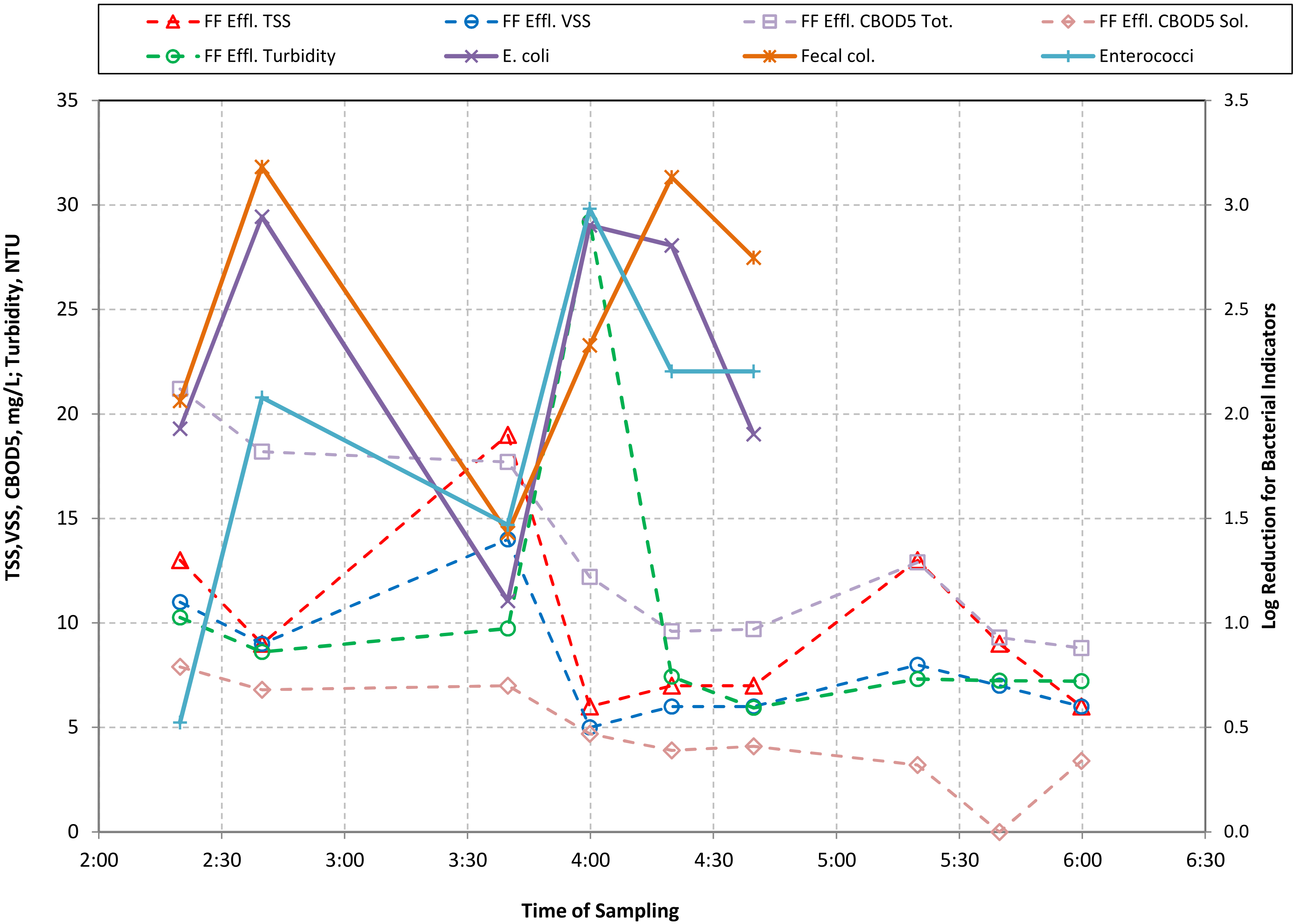


Figure 2-14. Storm 2 (10/4/2014). Trojan UV Performance (Following Storm King)

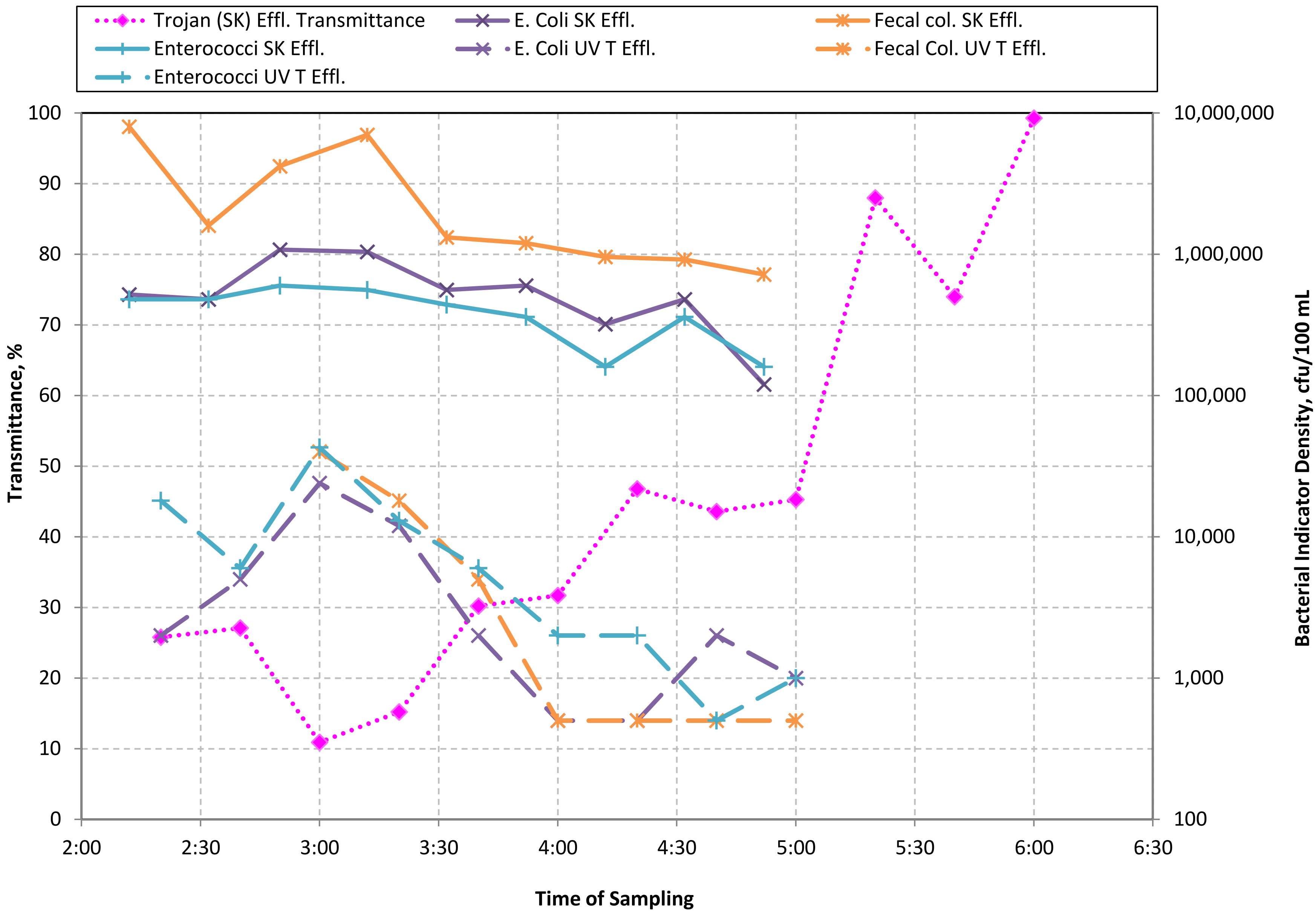


Figure 2-15. Storm 2 (10/16/2015). Trojan UV Performance (Following Storm King)

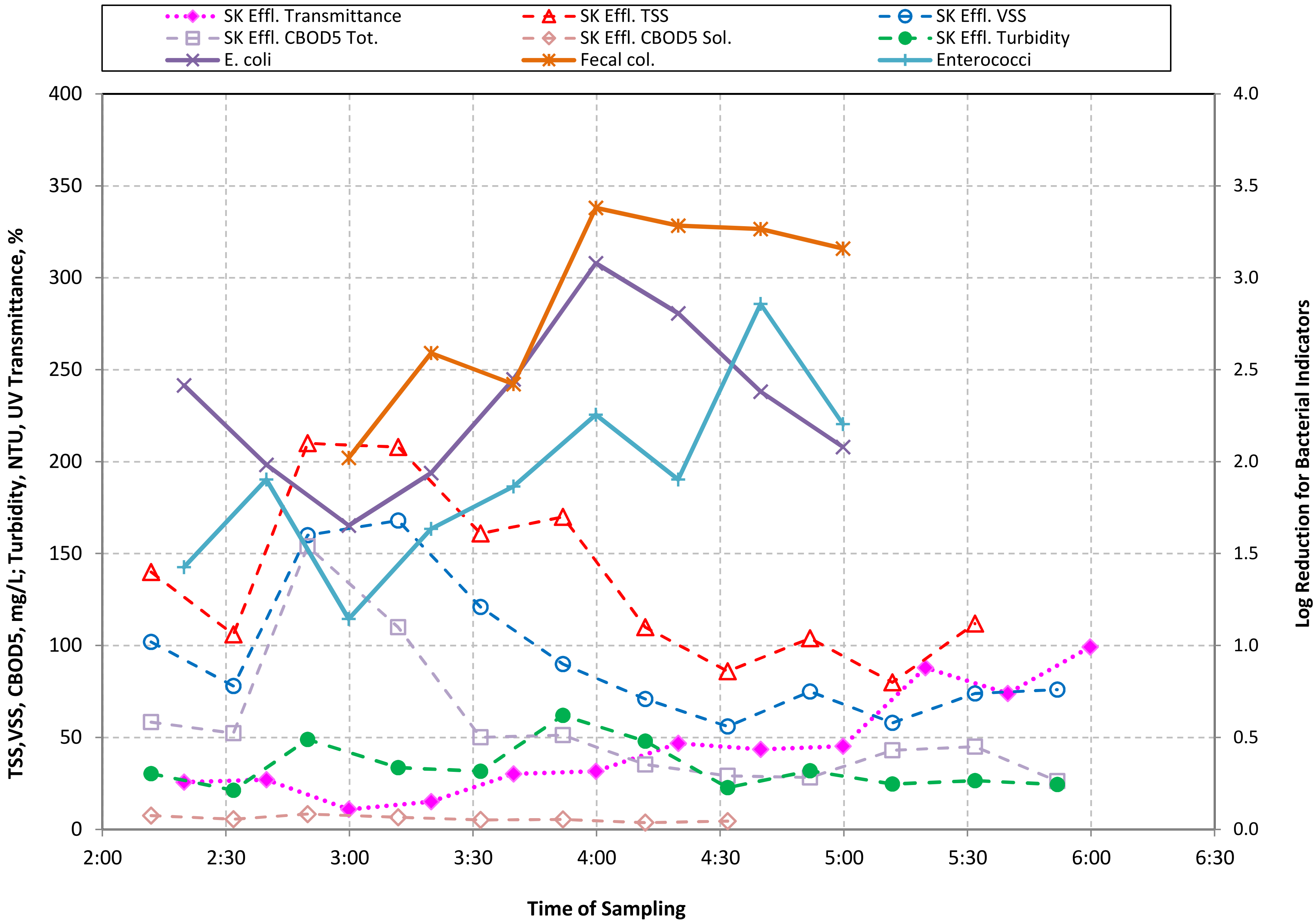


Figure 2-16. Storm 2 (10/16/2015). Trojan UV Performance (Following Storm King)

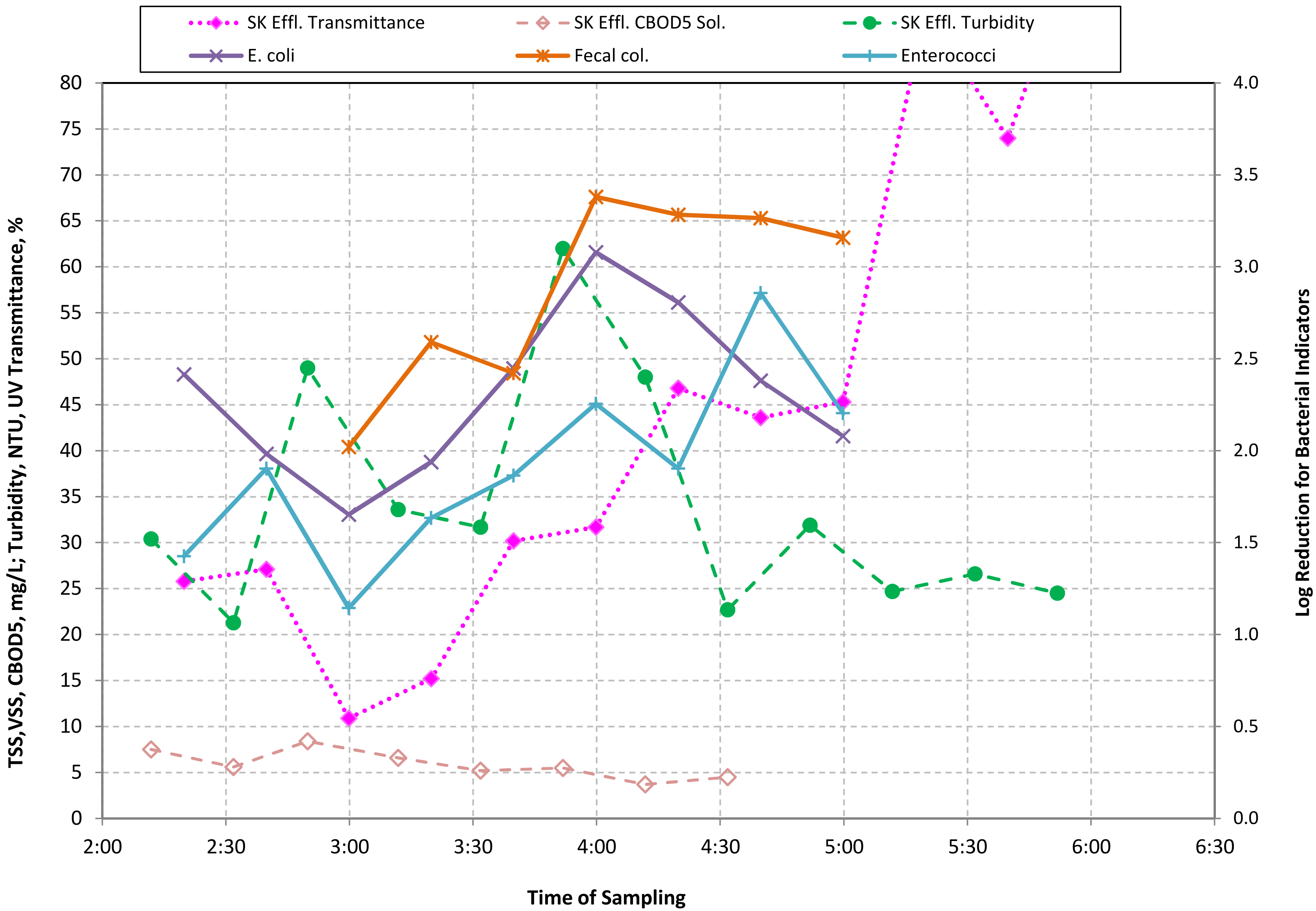


Figure 3-1. Storm 3 (10/22/2014). Raw TSS Characteristics

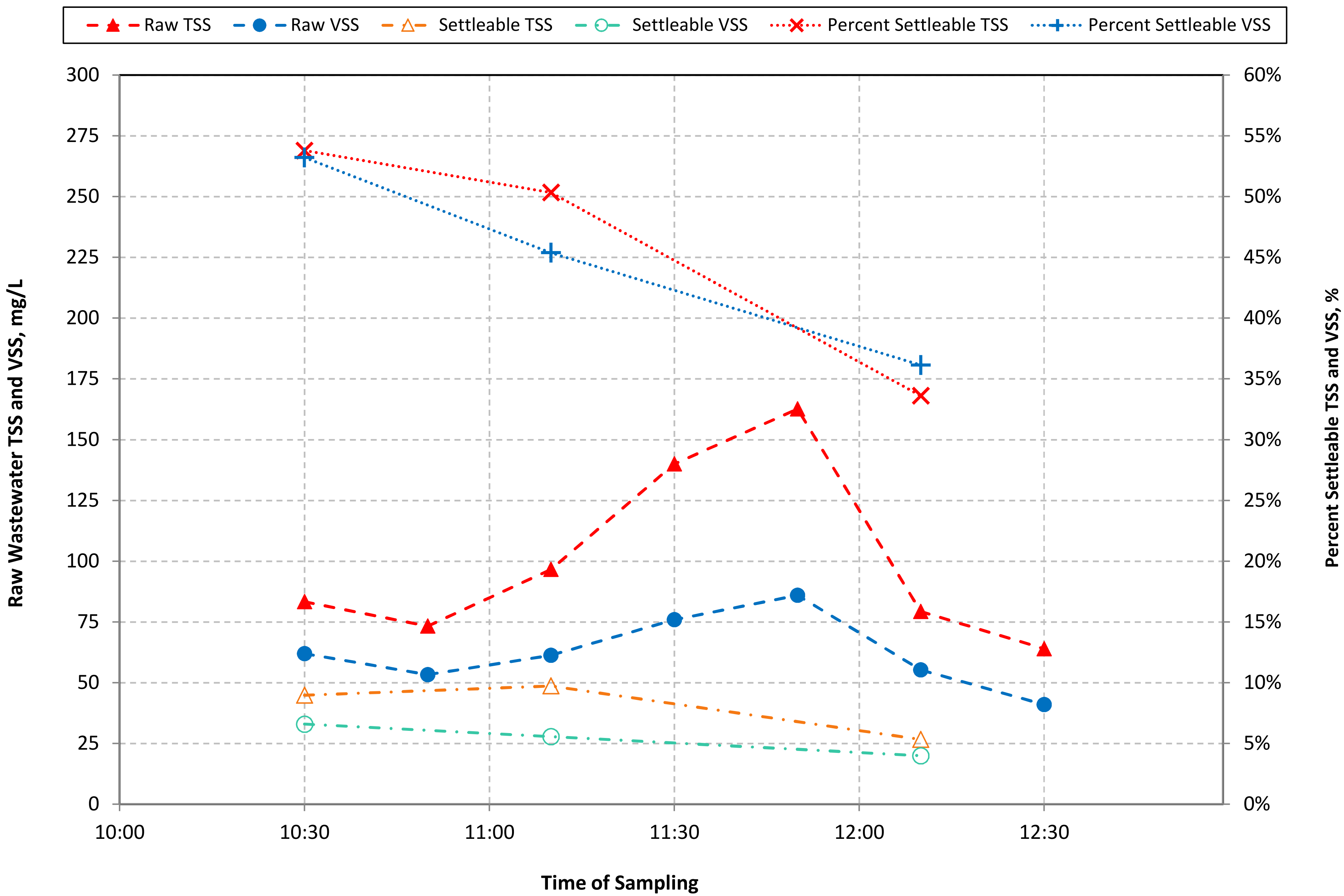


Figure 3-2. Storm 3 (10/22/2014). Raw Influent Characteristics

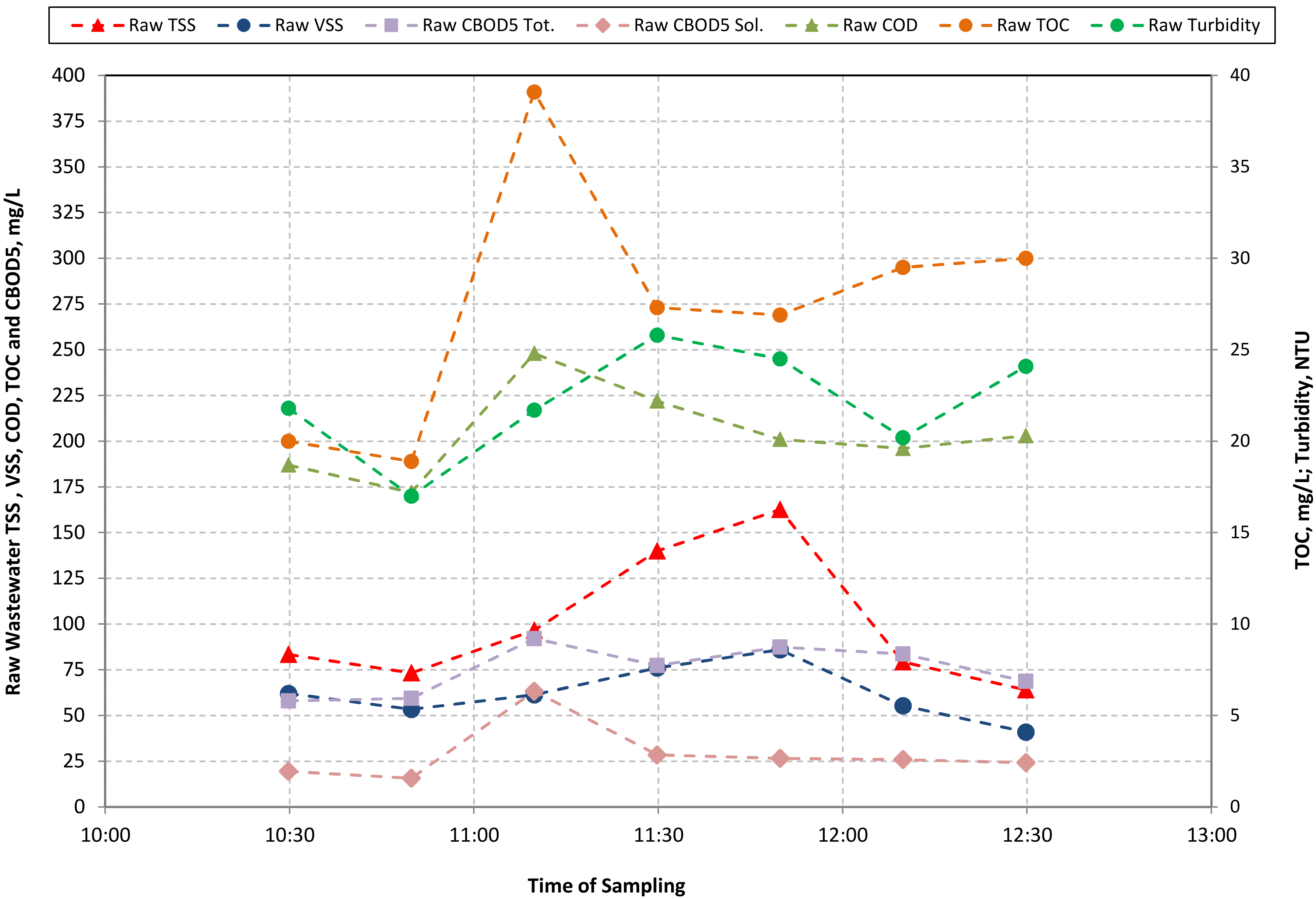


Figure 3-3. Storm 3 (10/22/2014). Terre Kleen Performance

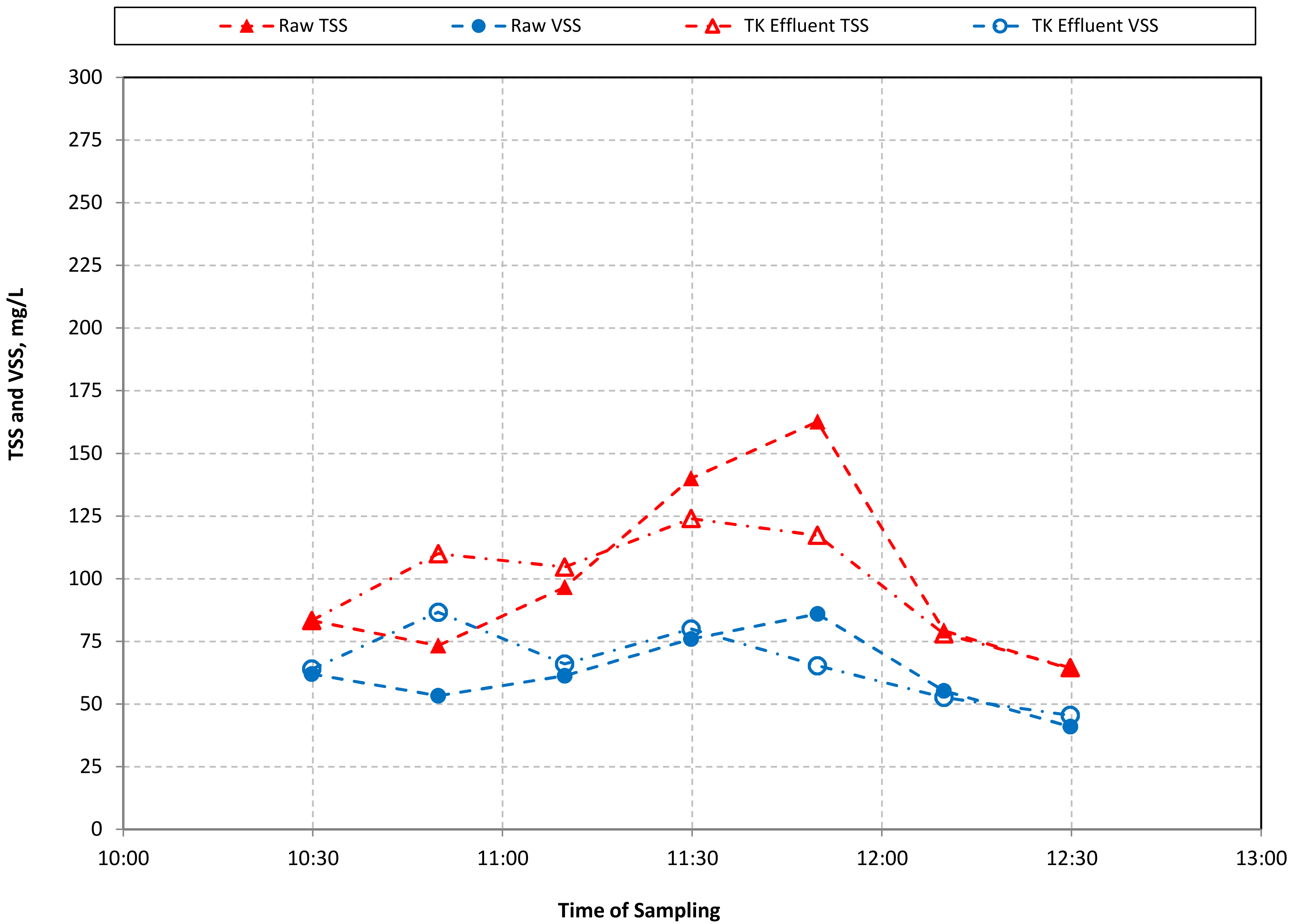


Figure 3-4. Storm 3 (10/22/2014). Storm King Performance

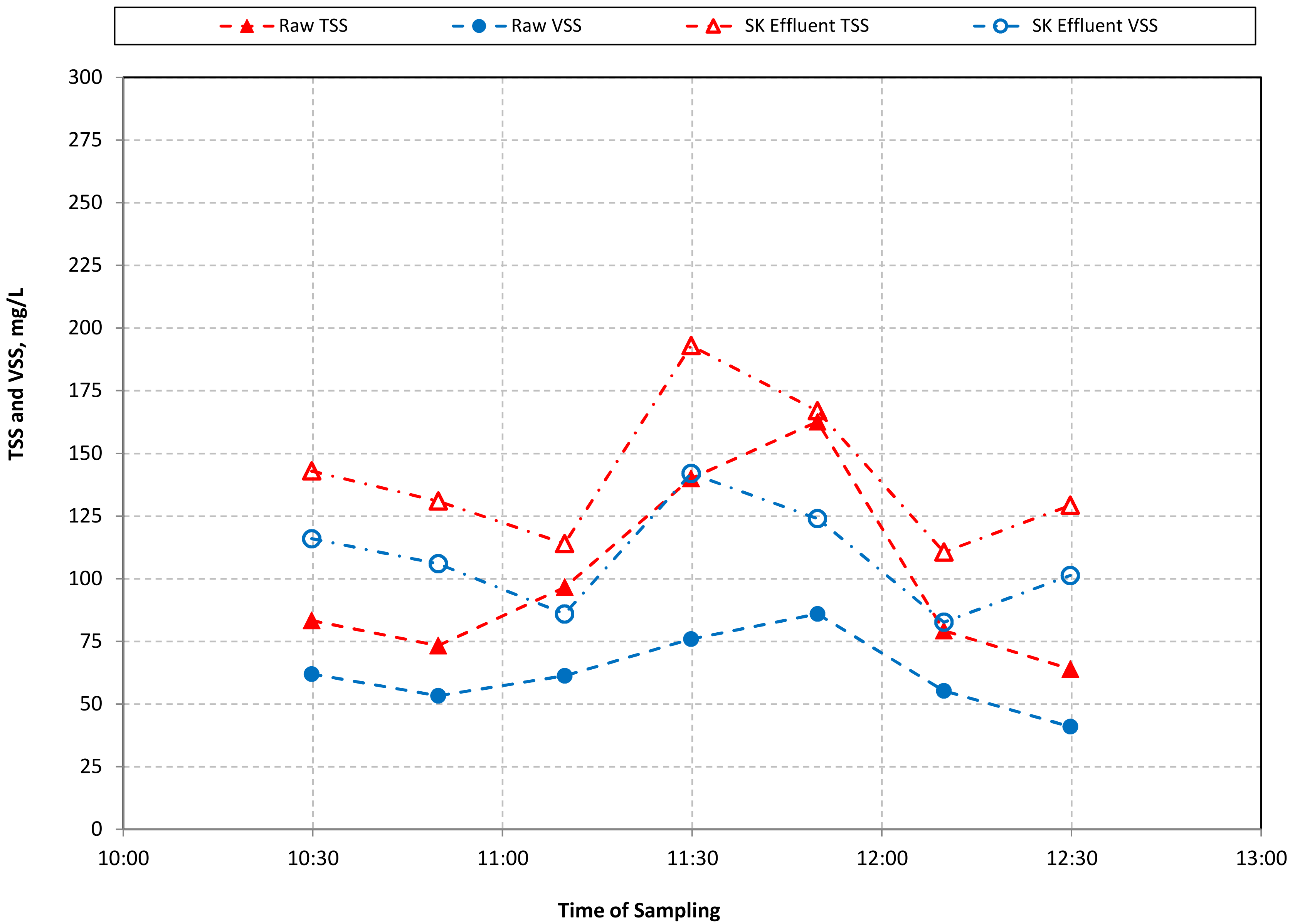


Figure 3-5. Storm 3 (10/22/2014). Flex Filter Performance

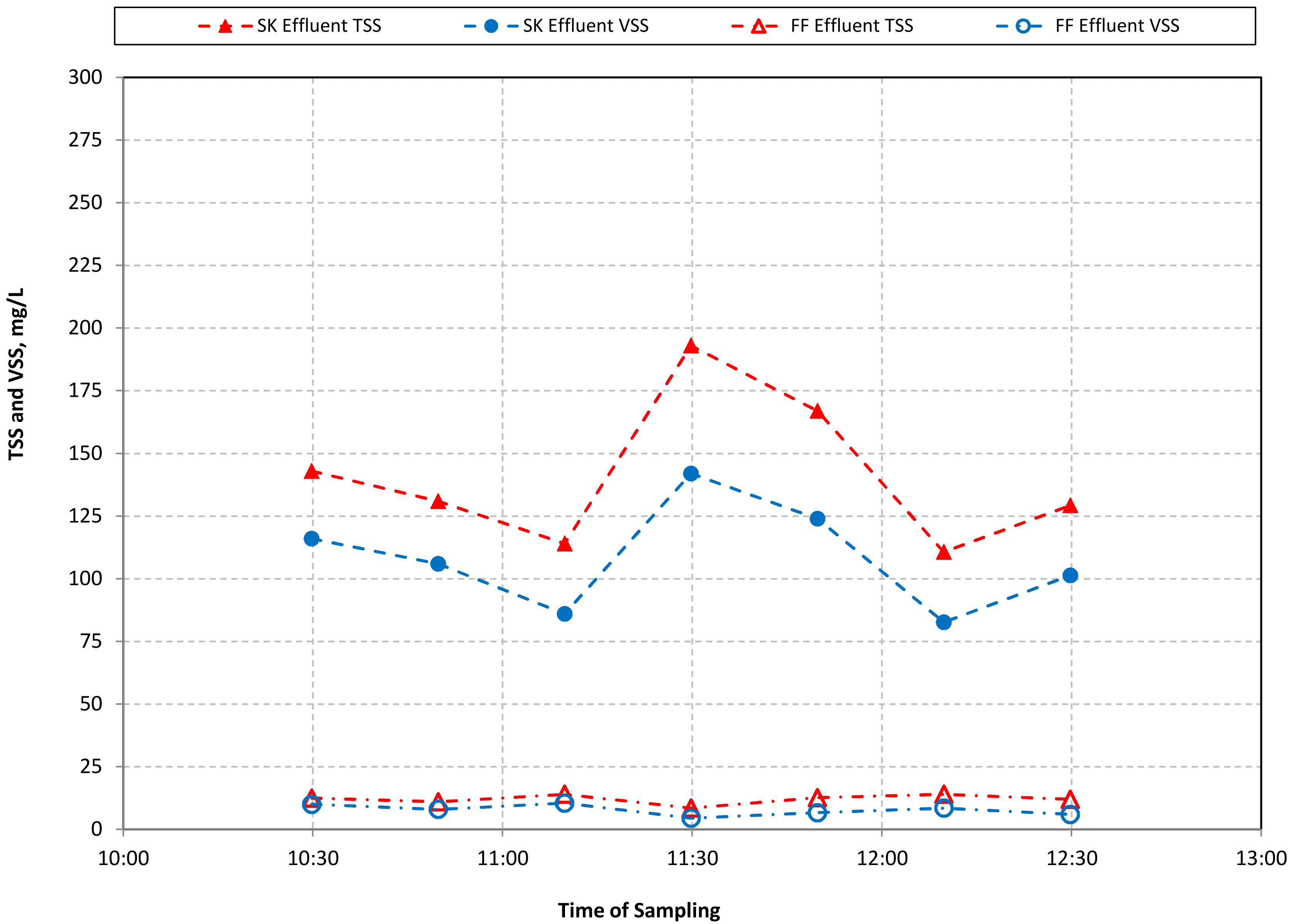


Figure 3-6. Storm 3 (10/22/2014). Terre Kleen (TK) COD and TOC Performance

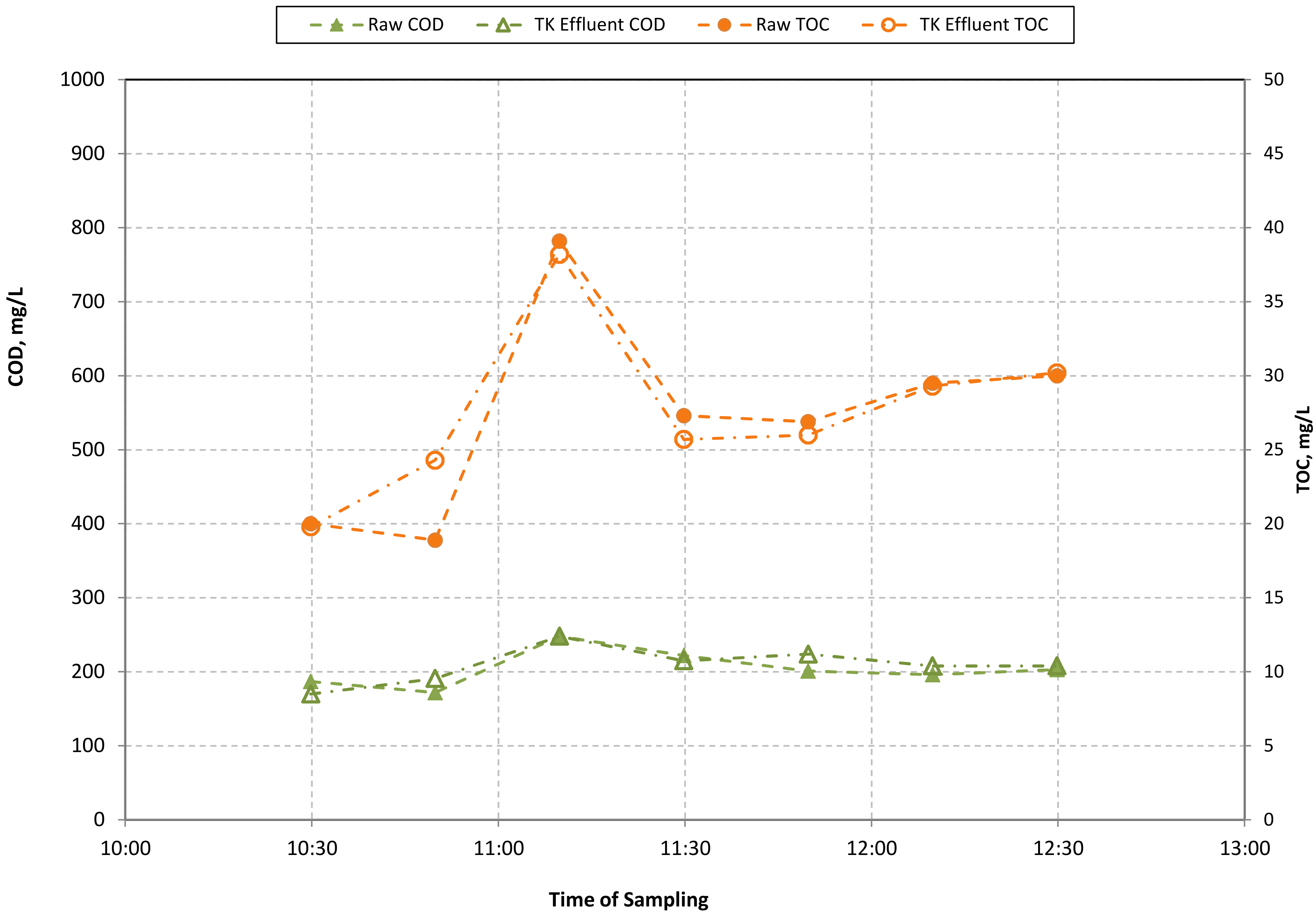


Figure 3-7. Storm 3 (10/22/2014). Flex Filter COD and TOC Performance

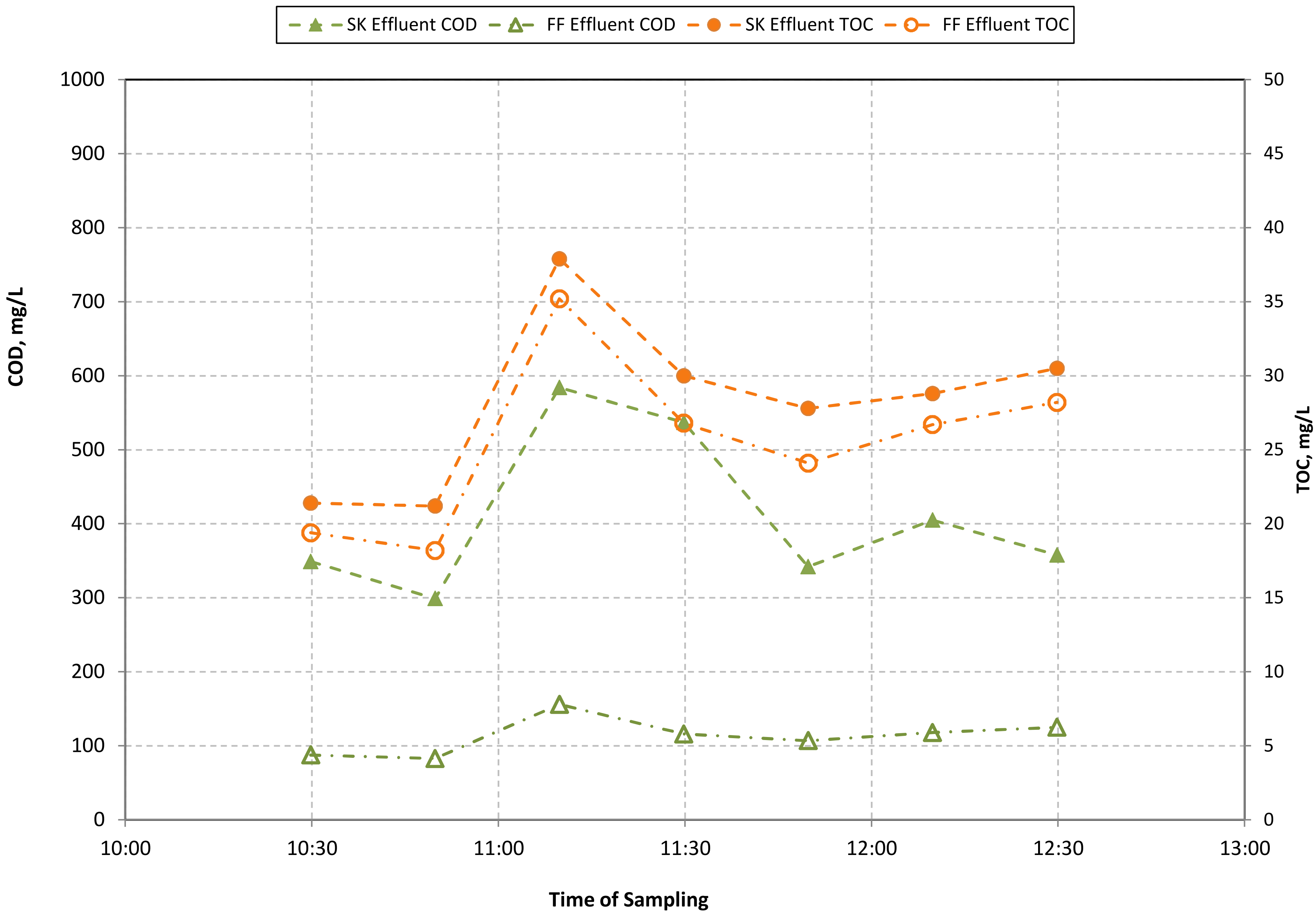


Figure 3-10. Storm 3 (10/22/2014). Aquionisc UV Performance

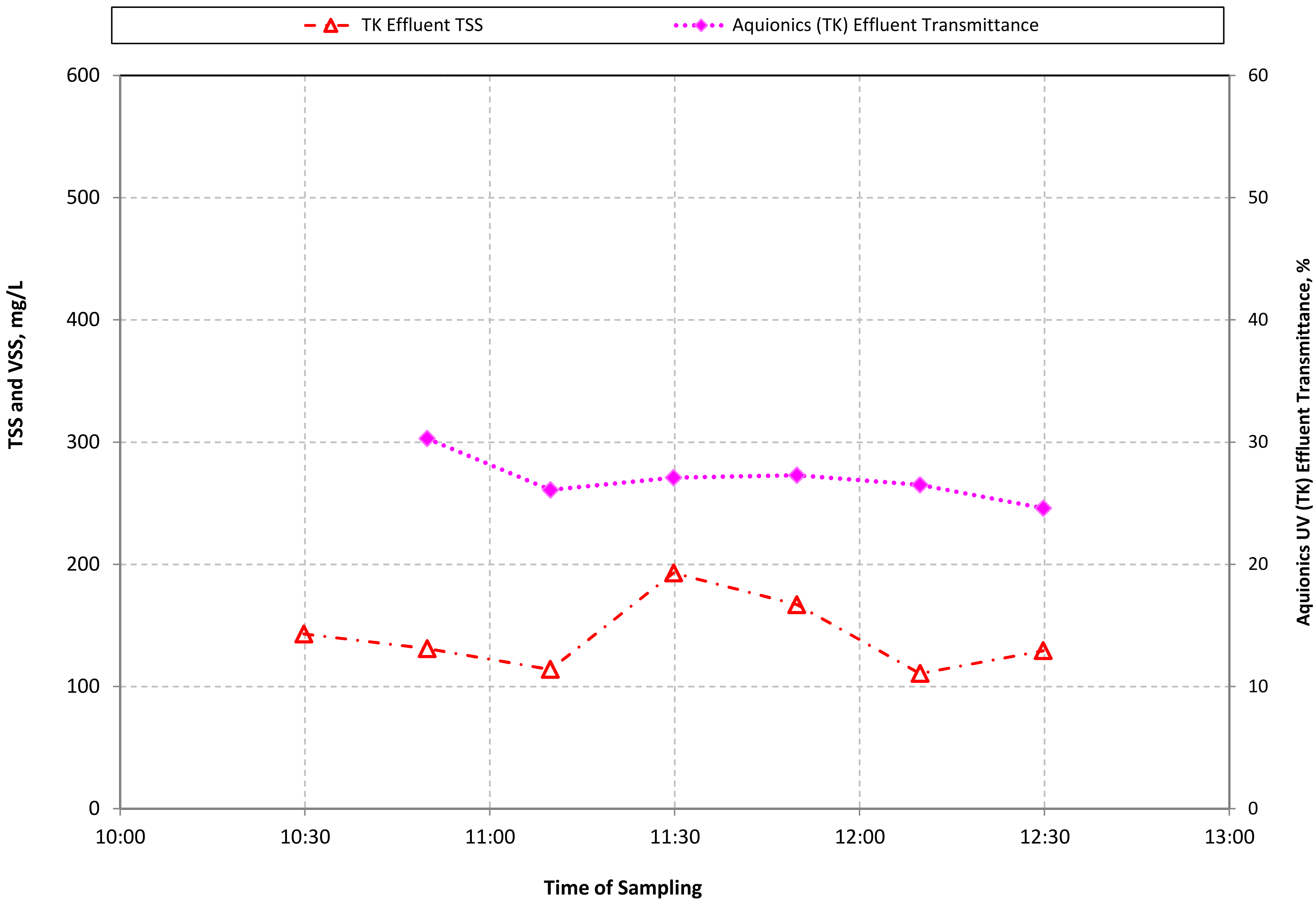


Figure 3-11. Storm 3 (10/22/2014). Aquionics UV Performance (Following Terre Kleen)

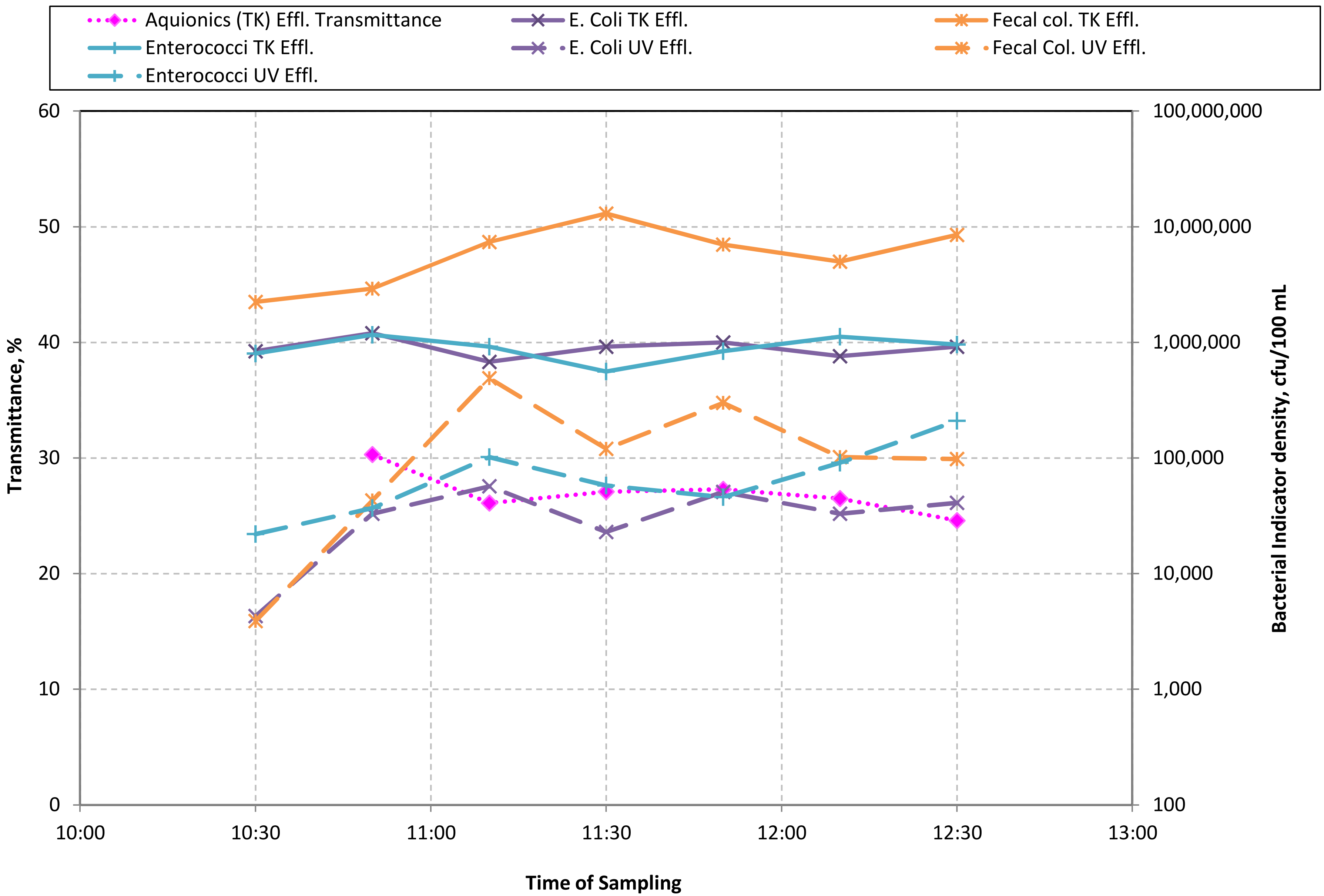


Figure 3-12. Storm 3 (10/22/2014). Aquionics UV Performance (Following Terre Kleen)

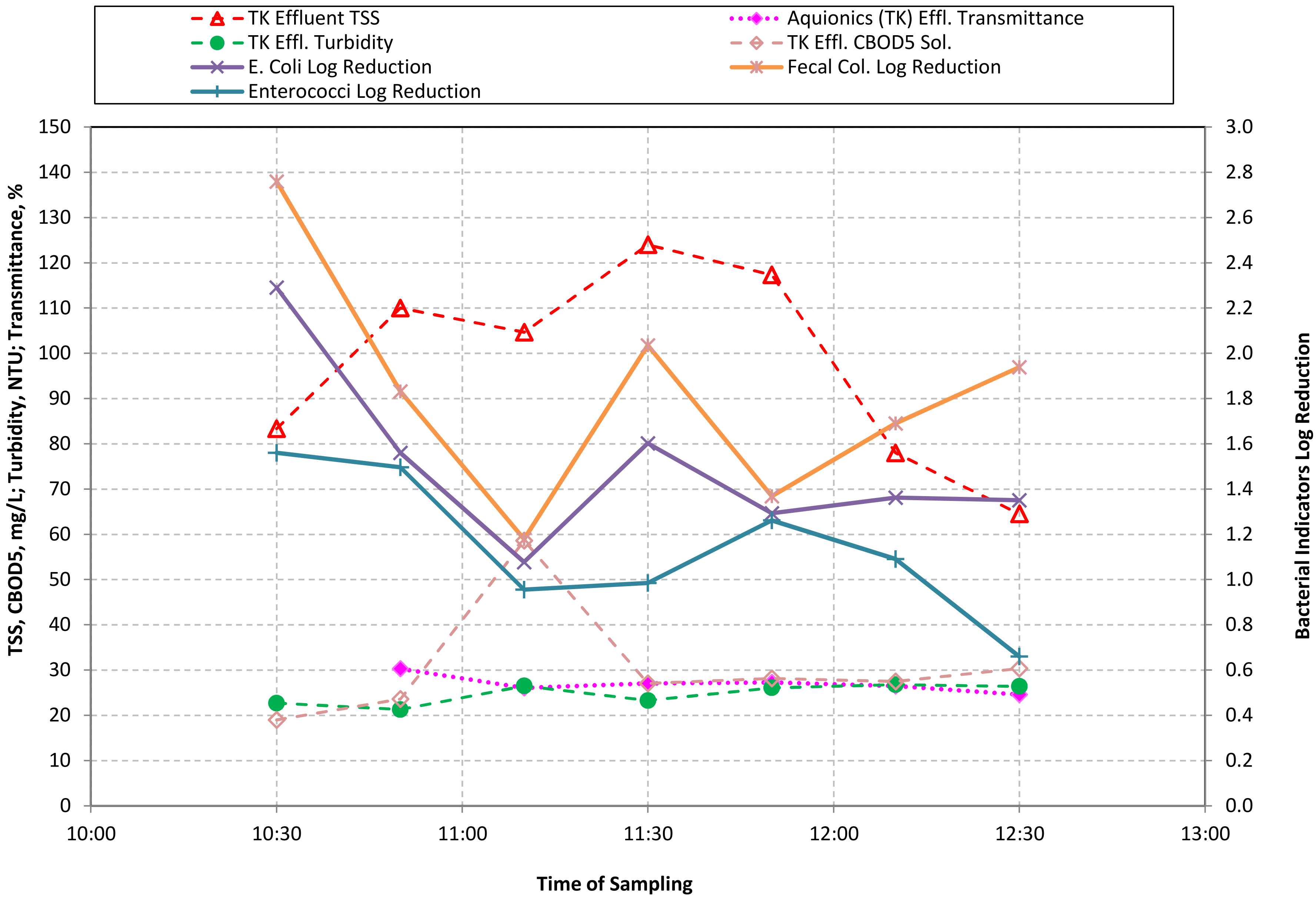


Figure 3-13. Storm 3 (10/22/2014). Aquionics UV Performance (Following Terre Kleen)

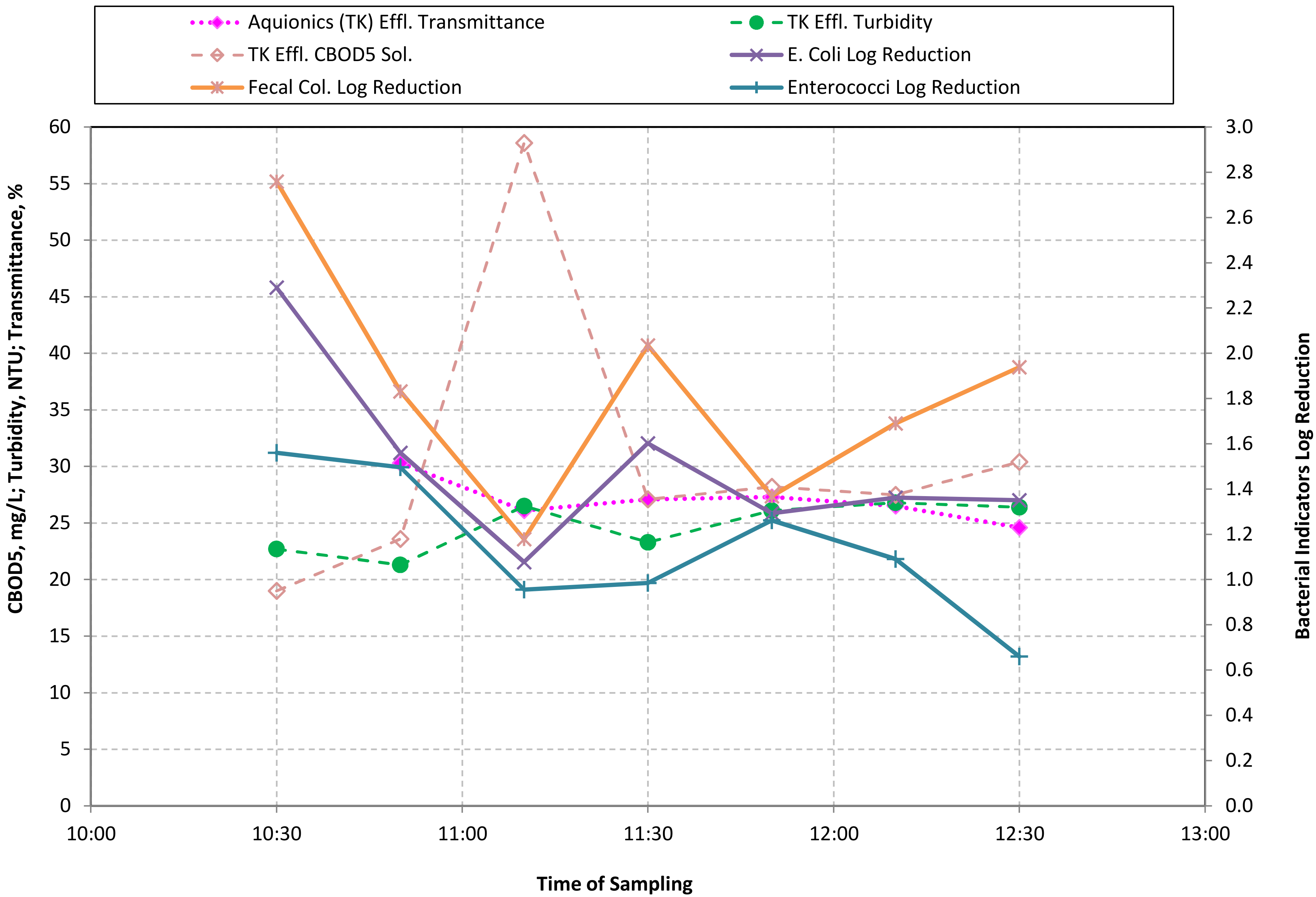


Figure 3-14. Storm 3 (10/22/2014). PAA Performance

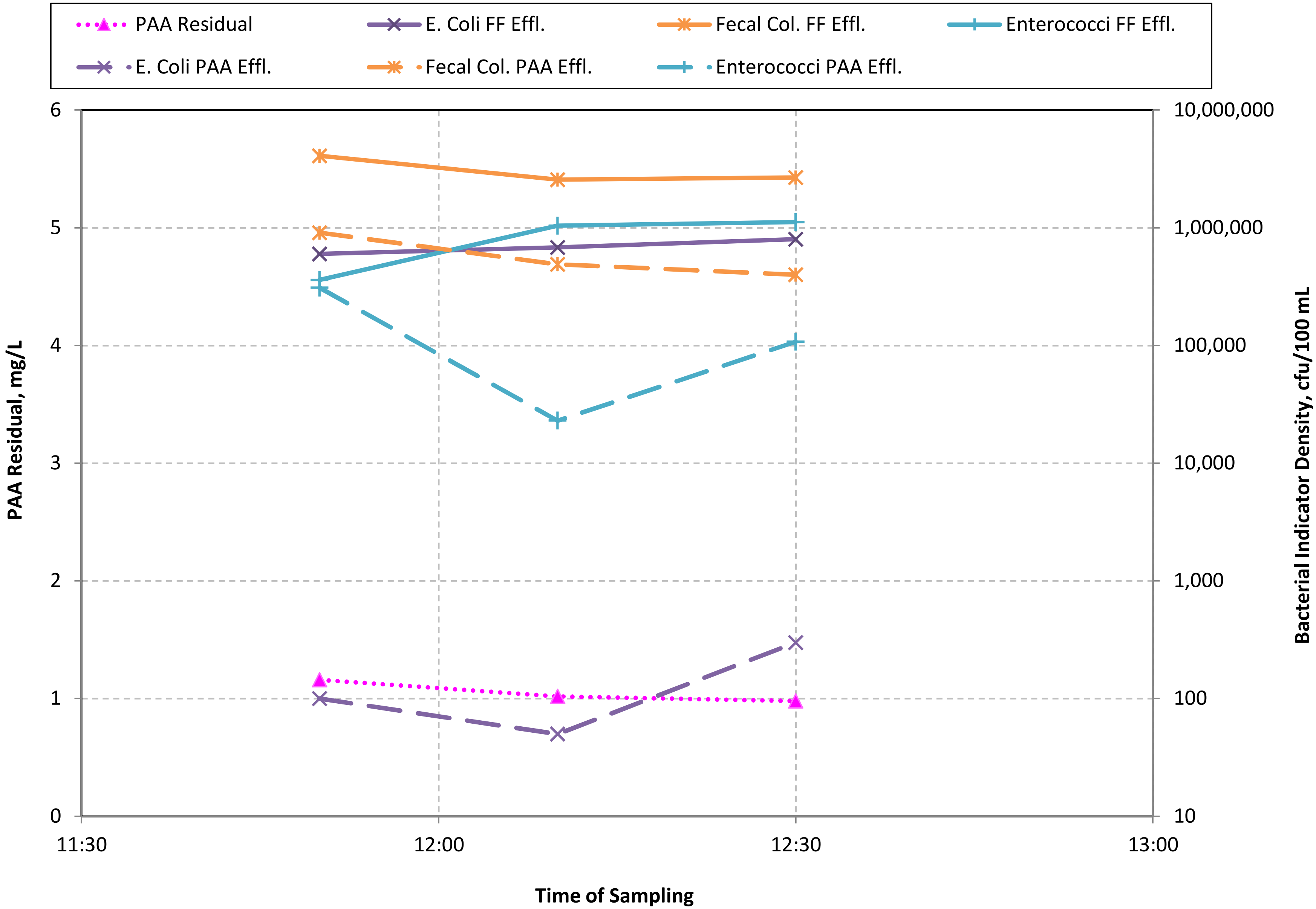


Figure 3-15. Storm 3 (10/22/2014). PAA Performance

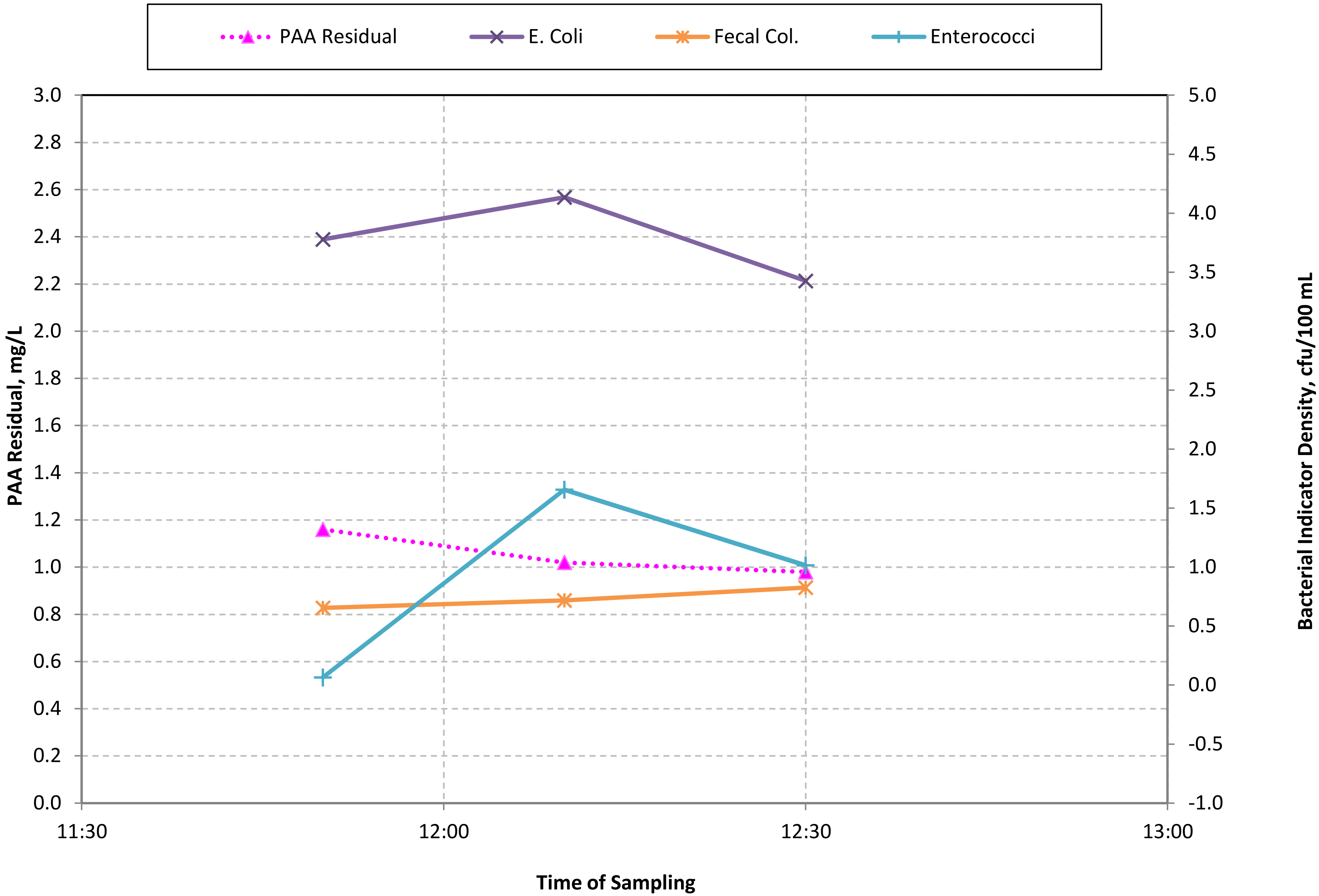


Figure 4-1. Storm 4 (11/06/2014). Raw TSS Characteristics

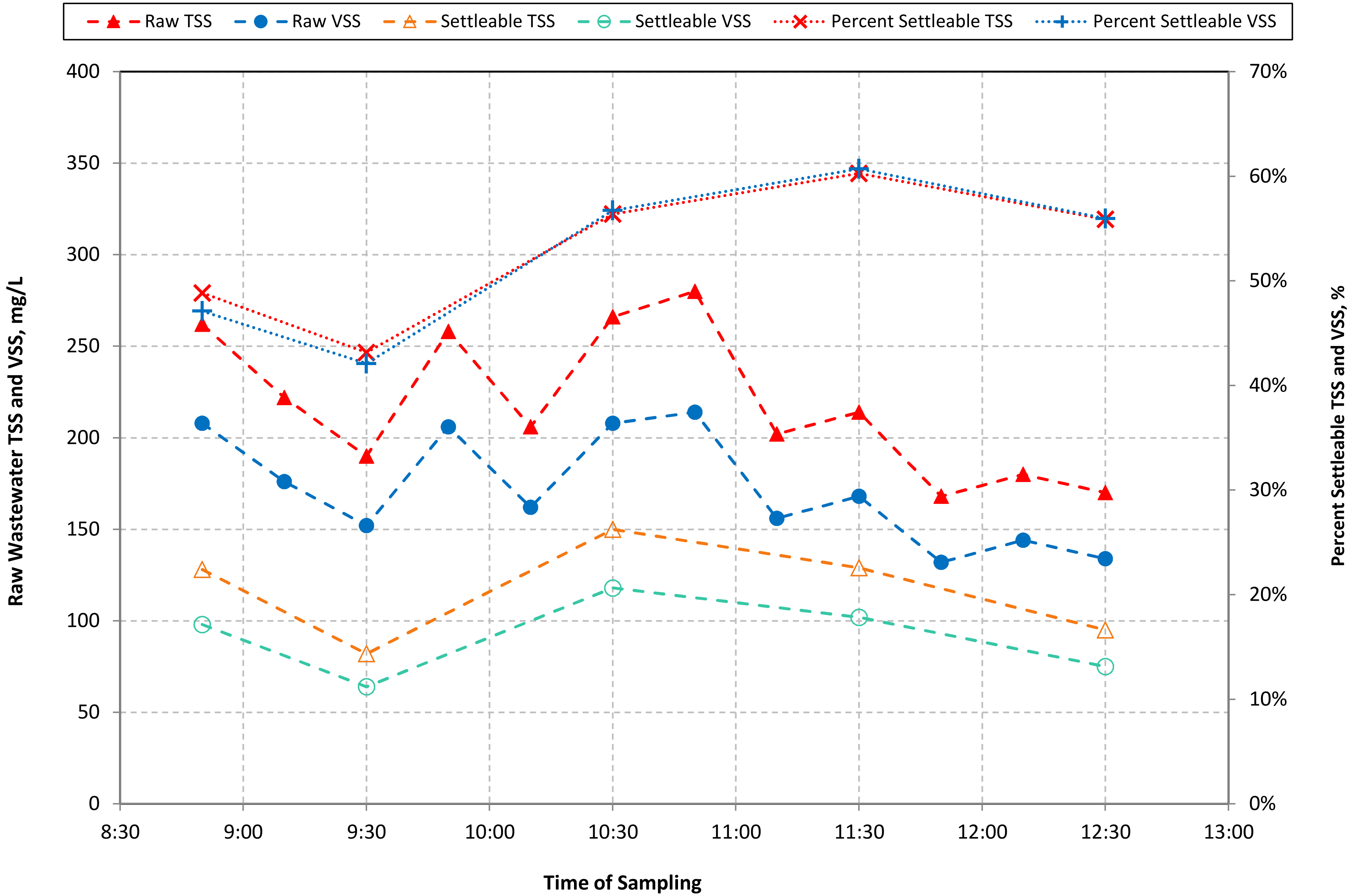


Figure 4-2. Storm 4 (11/06/2014). Raw Characteristics

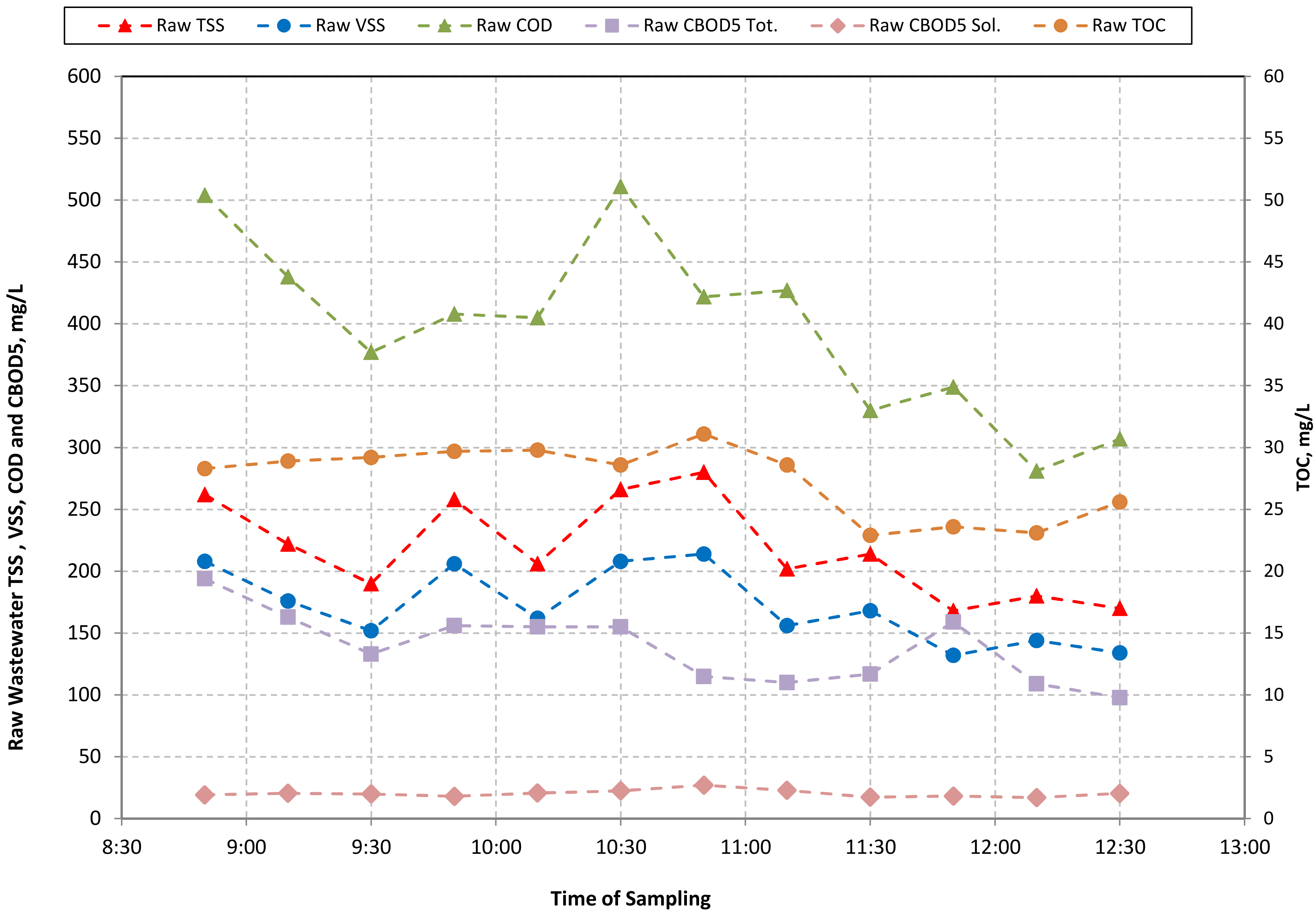


Figure 4-3. Storm 4 (11/06/2014). Terre Kleen Performance

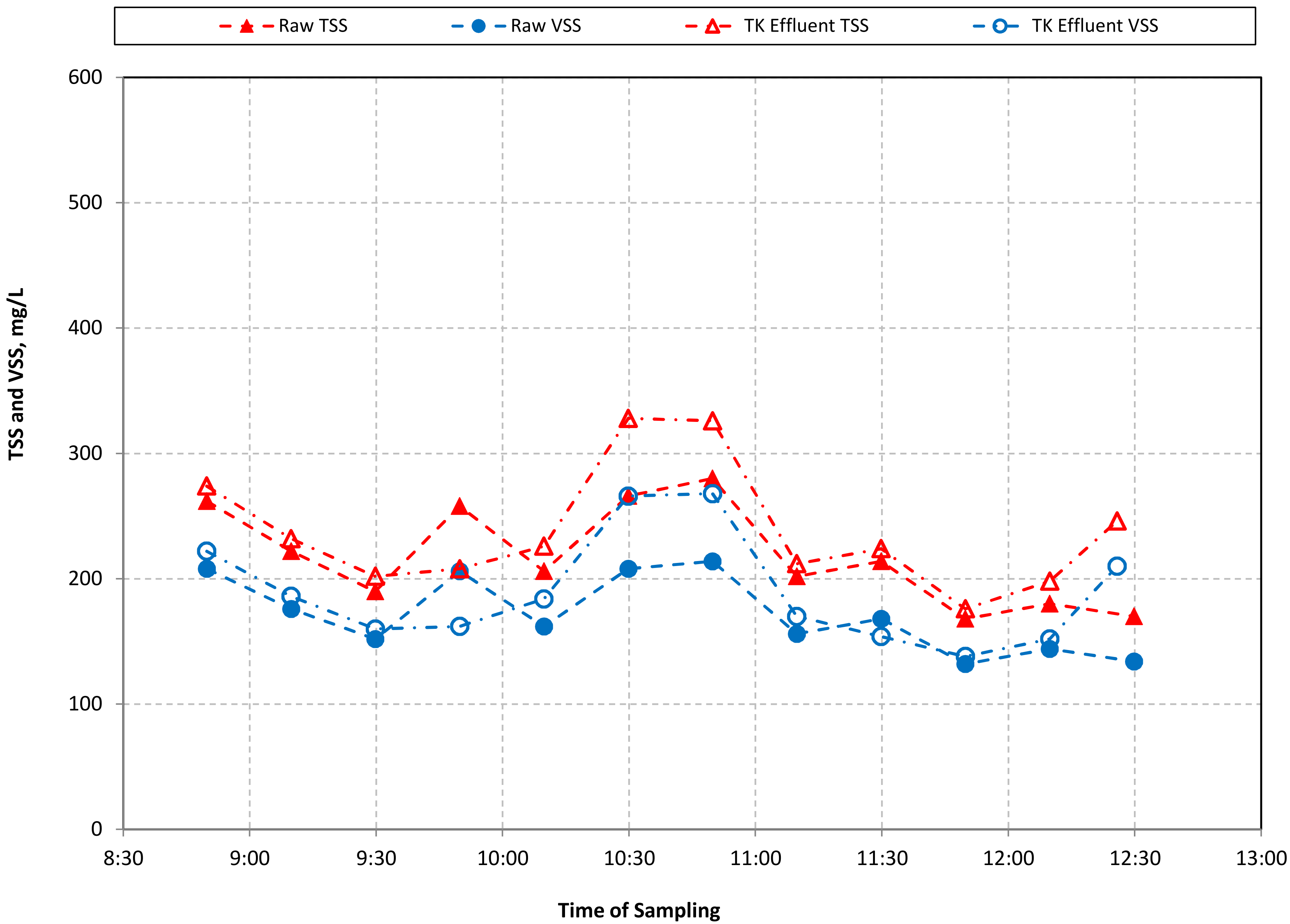


Figure 4-4. Storm 4 (11/06/2014). Storm King Performance

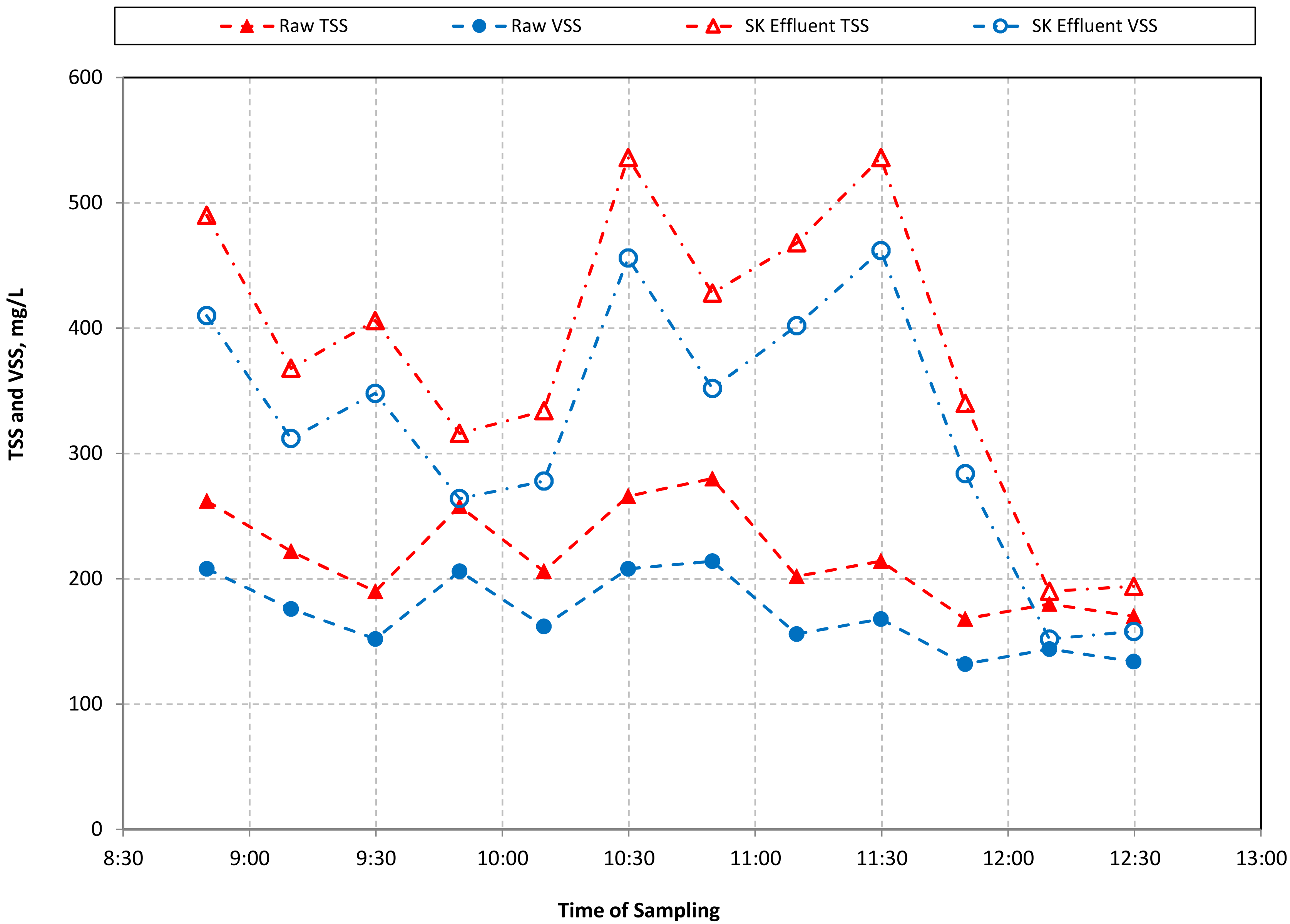


Figure 4-5. Storm 4 (11/06/2014). Flex Filter Performance

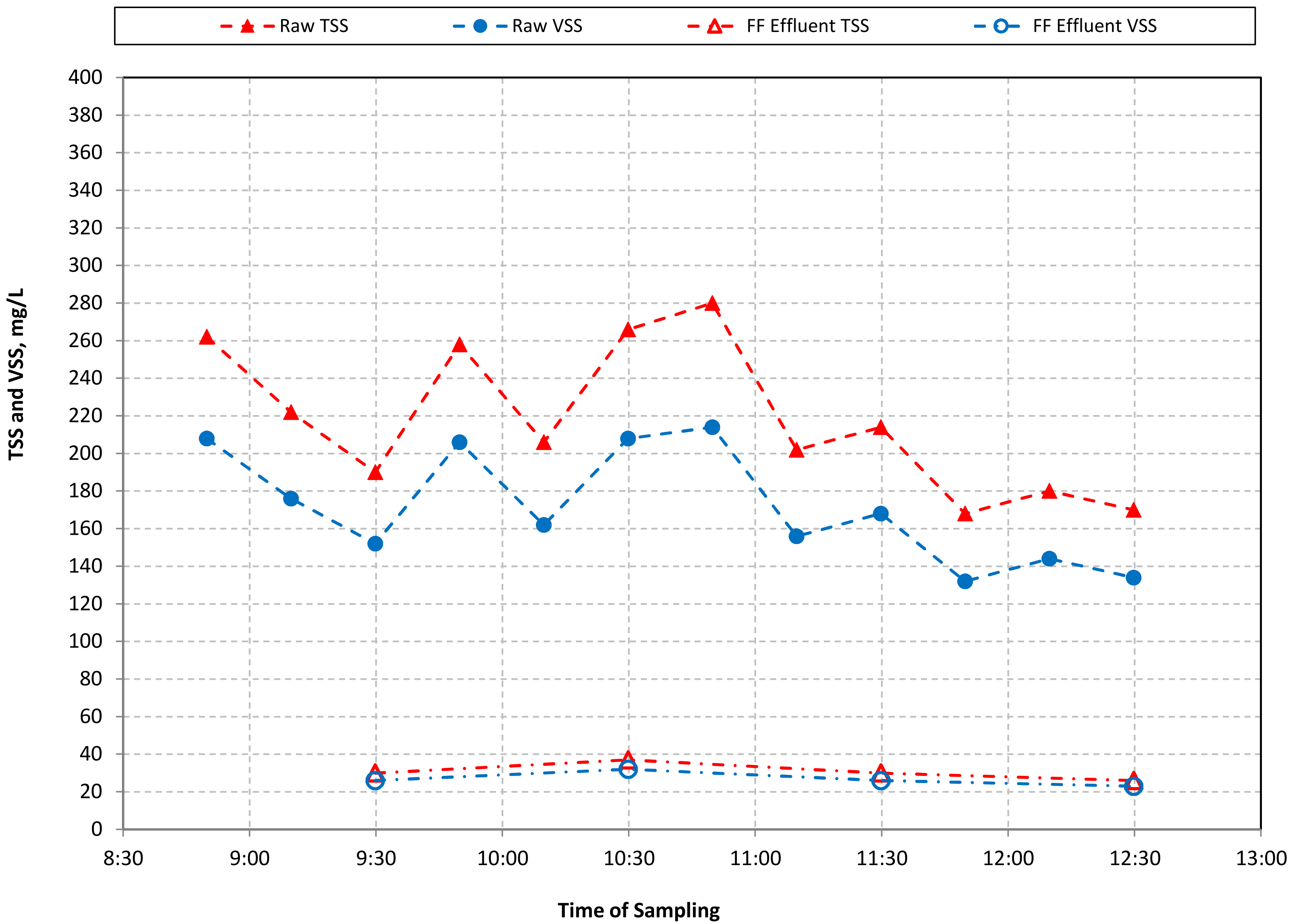


Figure 4-6. Storm 4 (11/06/2014). Terre Kleen COD and TOC Performance

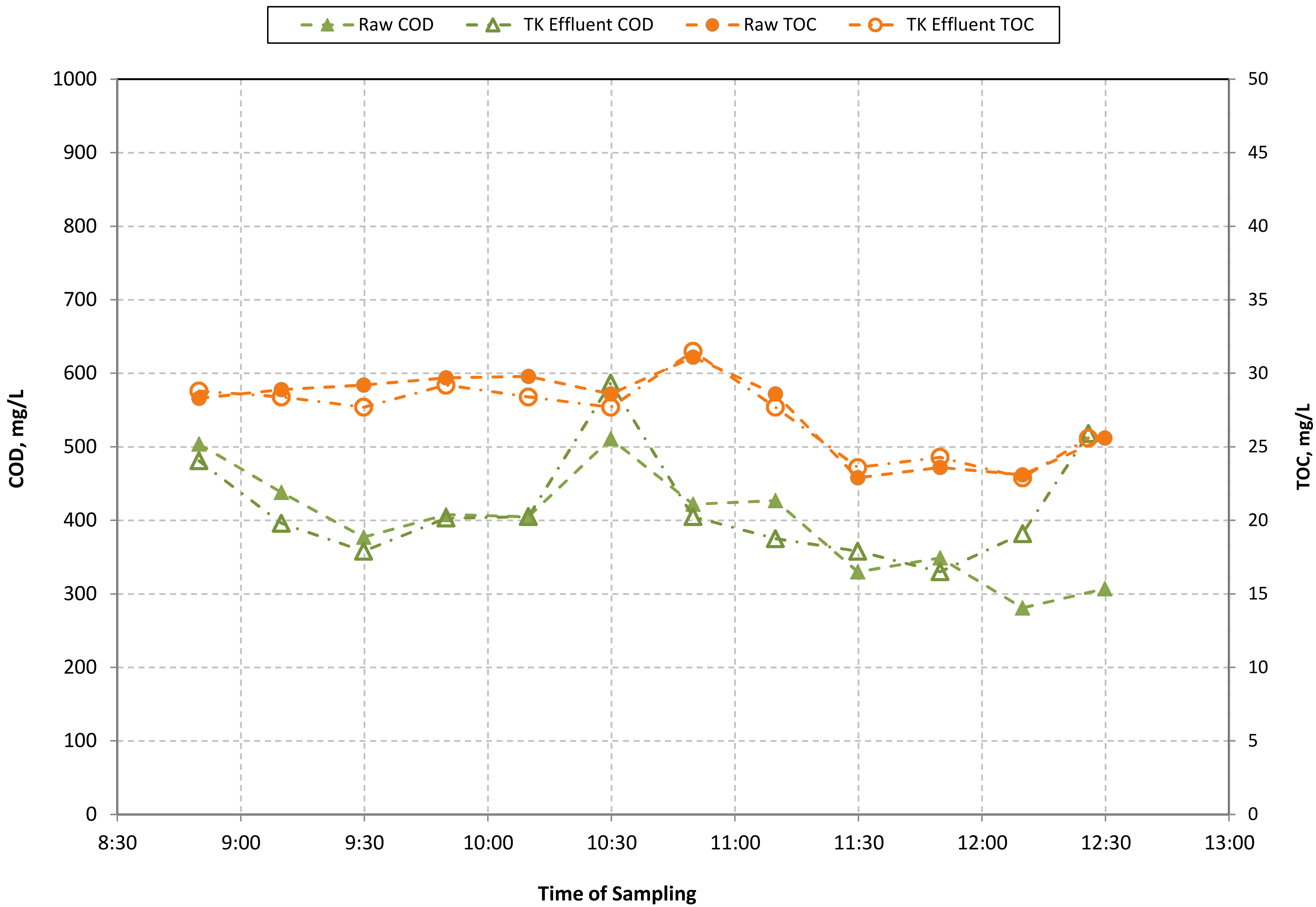


Figure 4-7. Storm 4 (11/06/2014). Flex Filter COD and TOC Performance

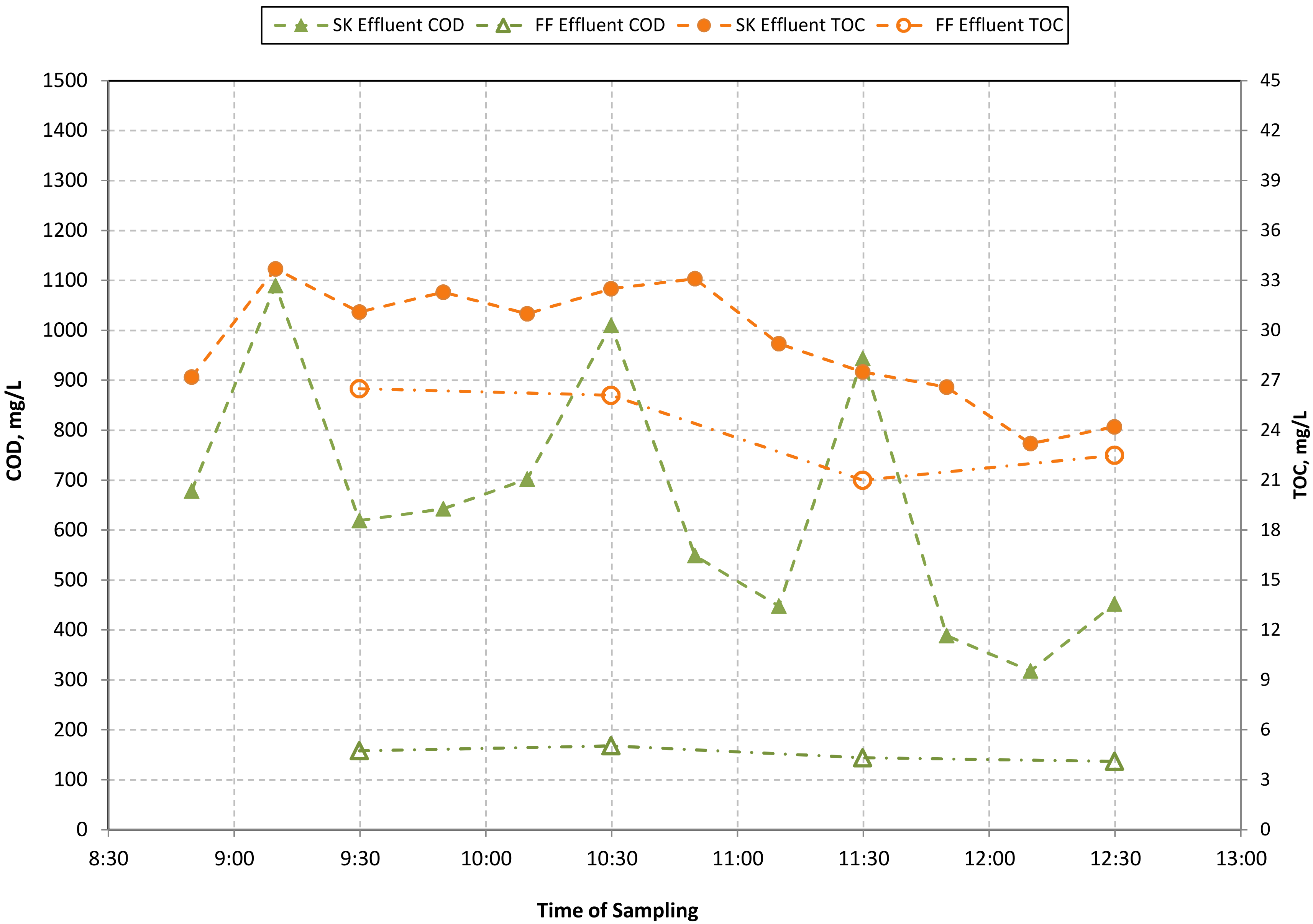


Figure 4-10. Storm 4 (11/06/2014). Effect of Different Parameters on Transmittance

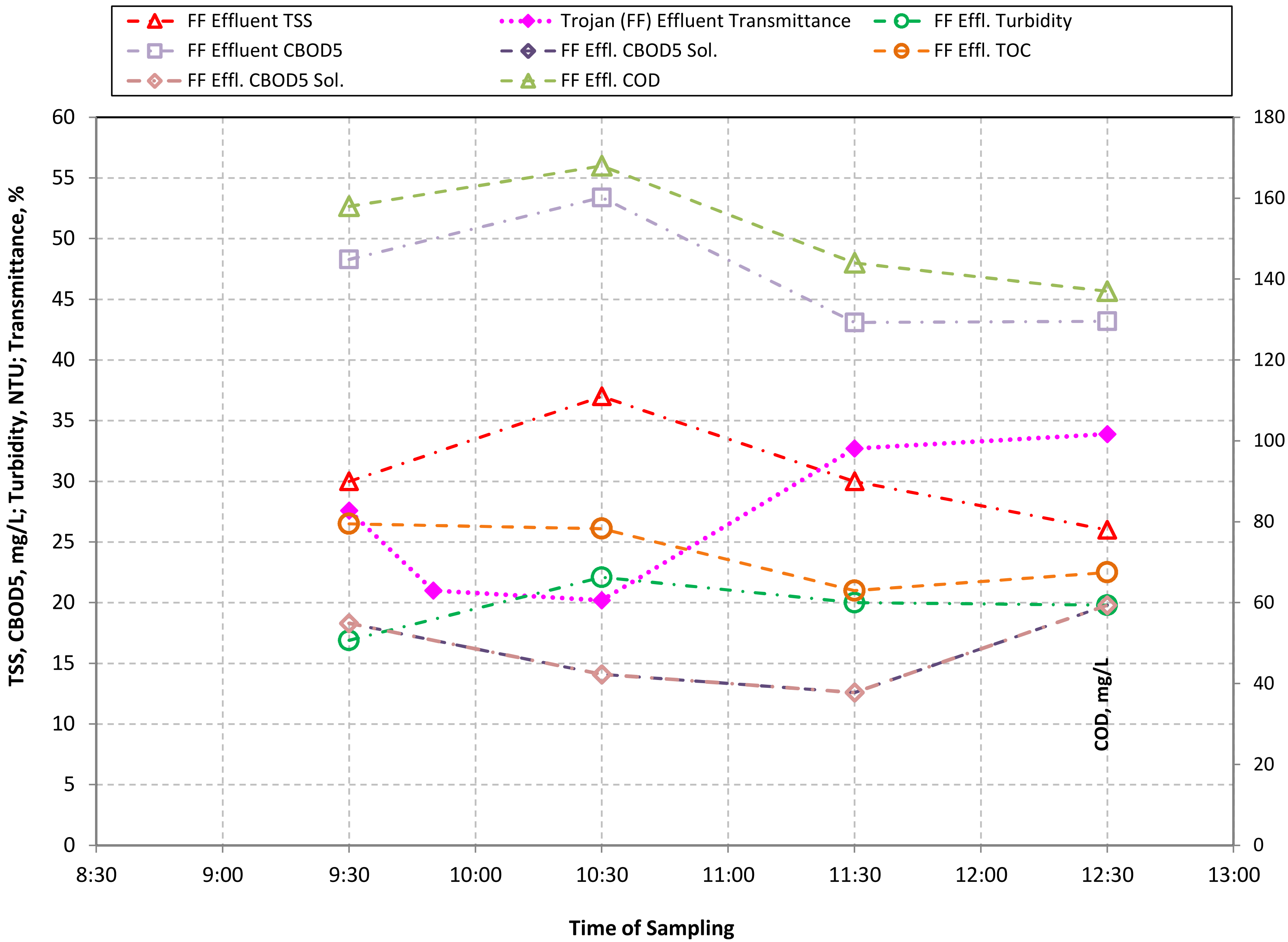


Figure 4-11. Storm 4 (11/06/2014). Trojan UV Performance (Following Flex Filter)

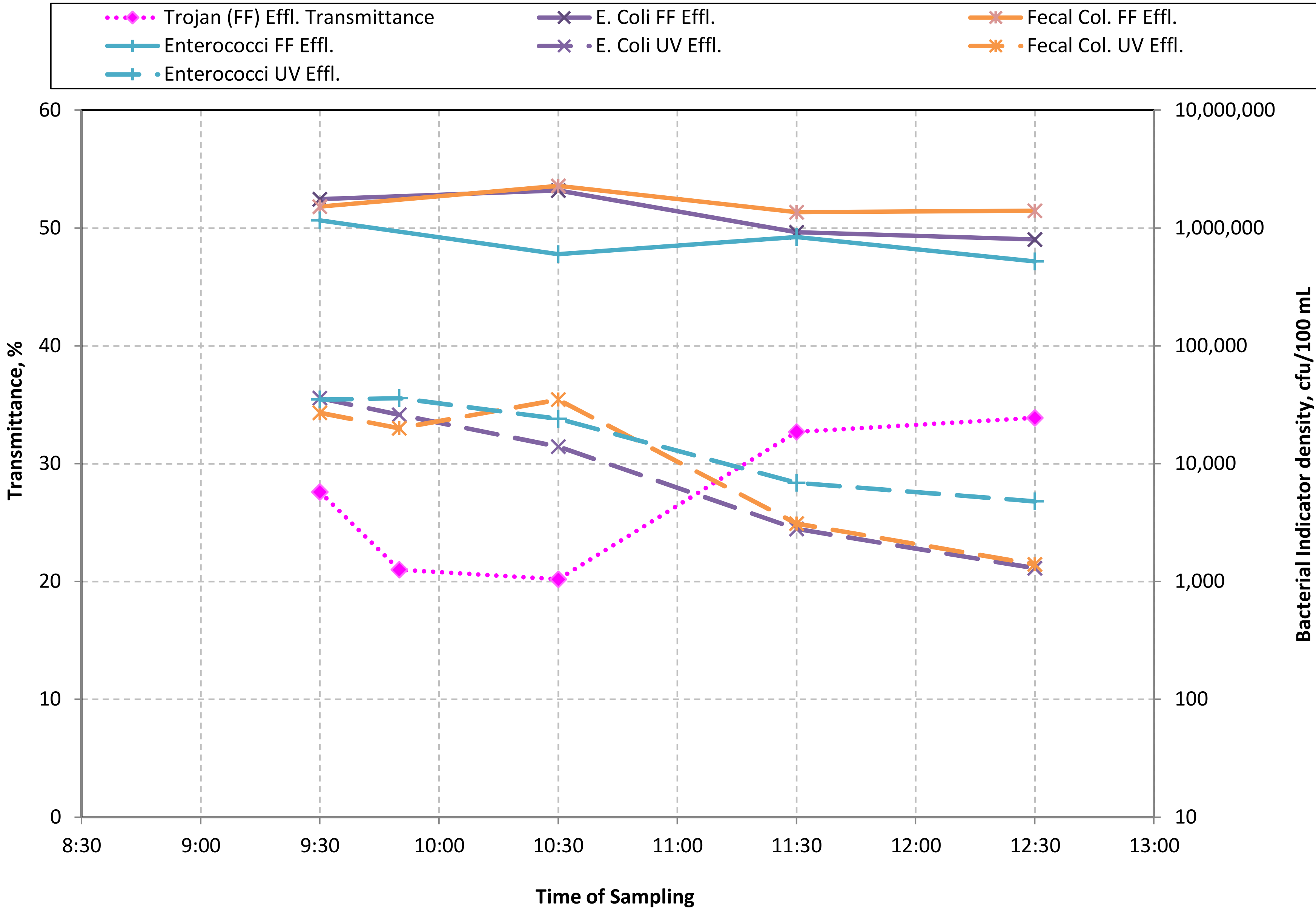


Figure 4-12. Storm 4 (11/06/2014). Trojan UV Performance (Following Flex Filter)

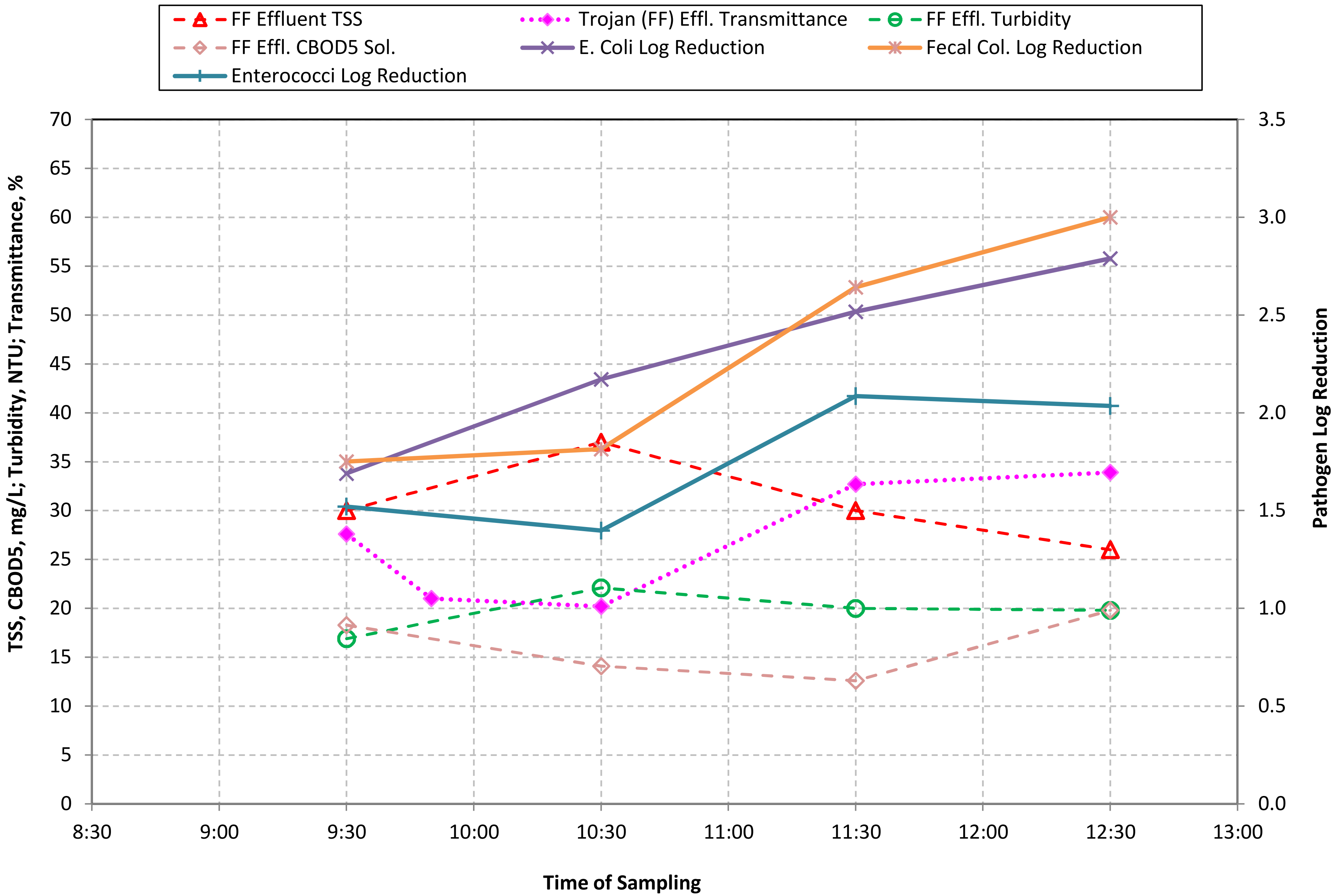
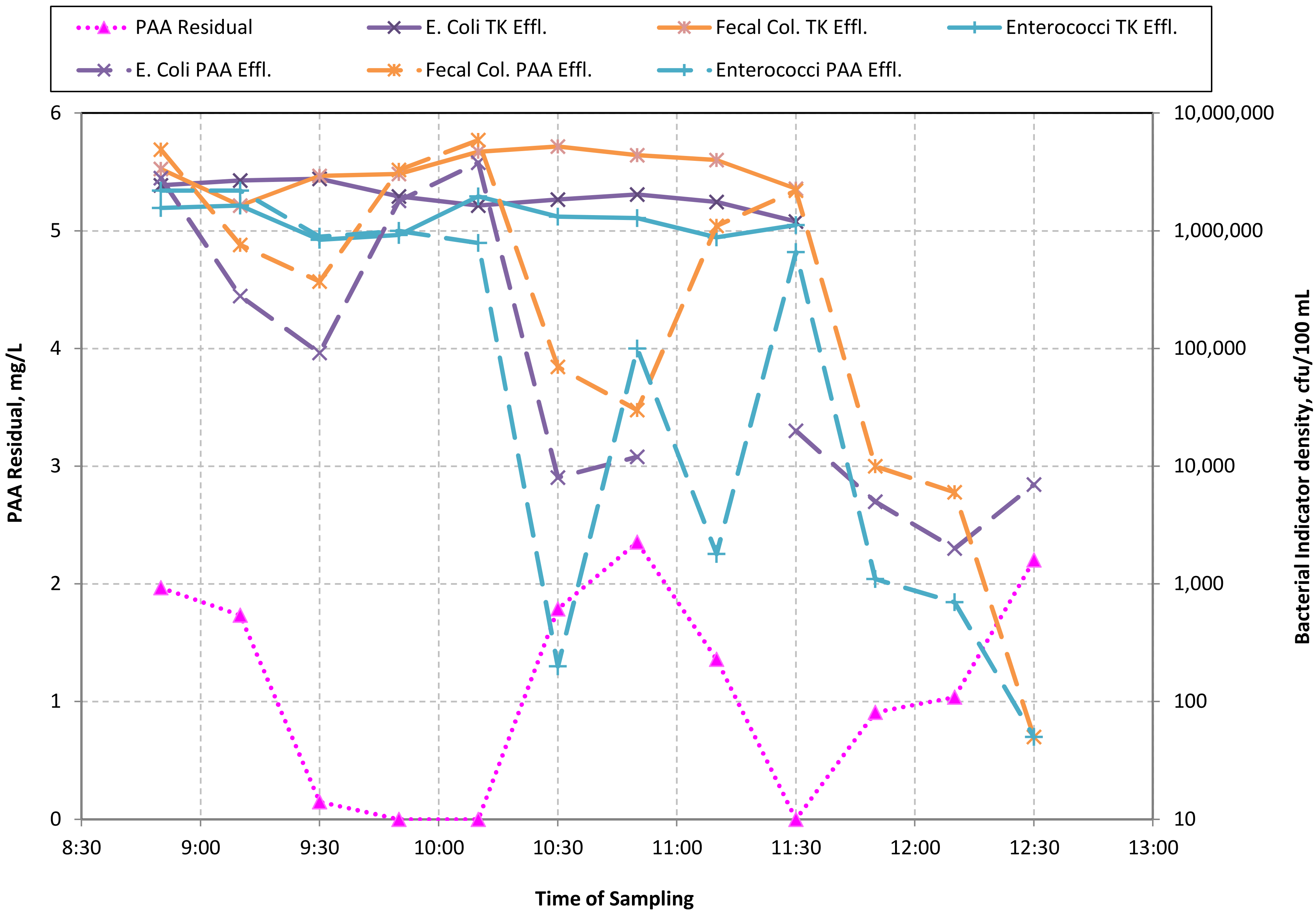


Figure 4-13. Storm 4 (11/06/2014). PAA Performance (Following Terre Kleen)



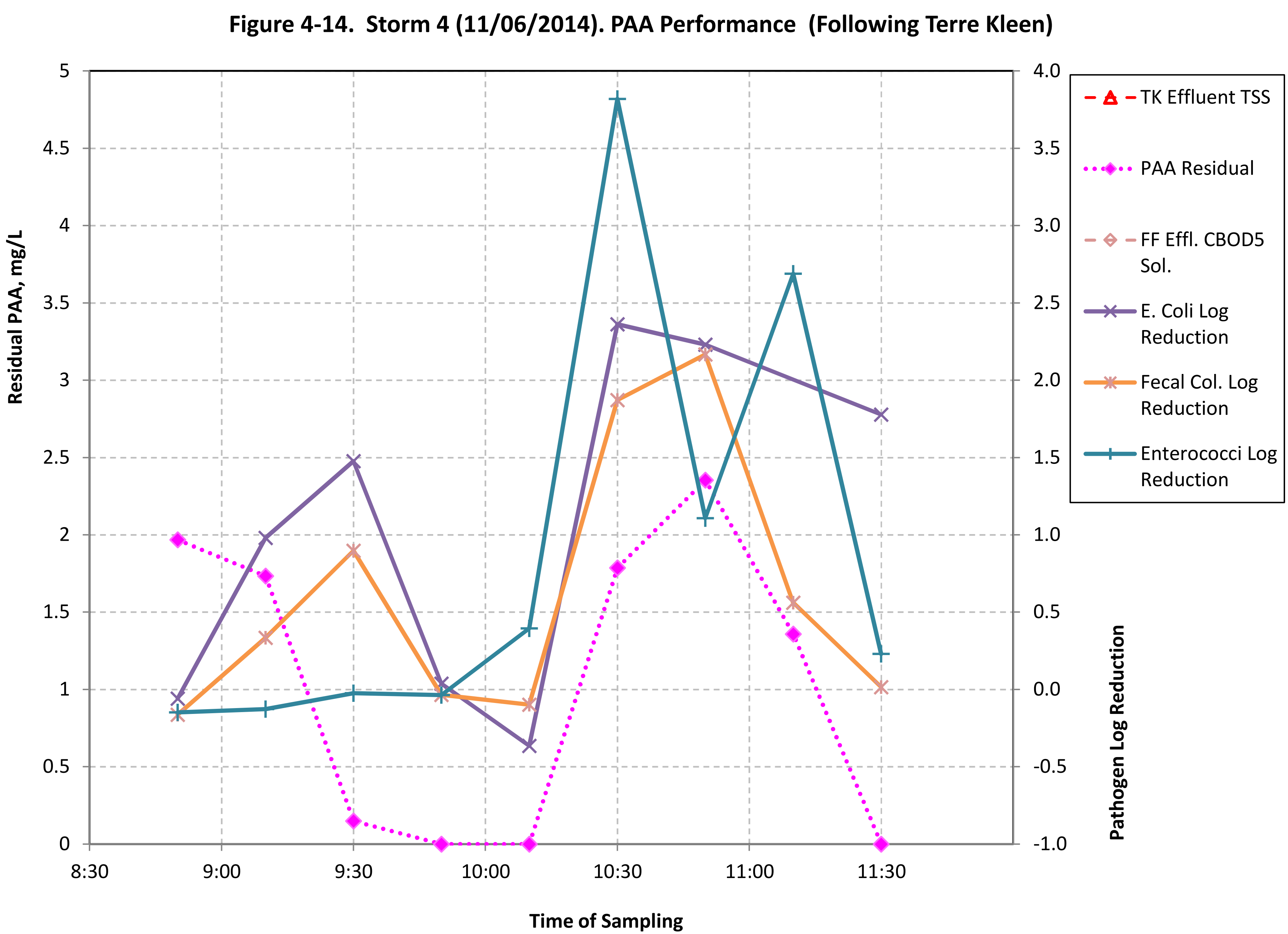


Figure 4-14. Storm 4 (11/06/2014). PAA Performance (Following Terre Kleen)
Residual PAA, mg/L
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Pathogen Log Reduction
8:30
9:00
9:30
10:00
10:30
11:00
11:30
Time of Sampling
TK Effluent TSS
PAA Residual
FF Effl. CBOD5 Sol.
E. Coli Log Reduction
Fecal Col. Log Reduction
Enterococci Log Reduction

Figure 5-1. Storm 5 (7/30/2015). Raw TSS Characteristics

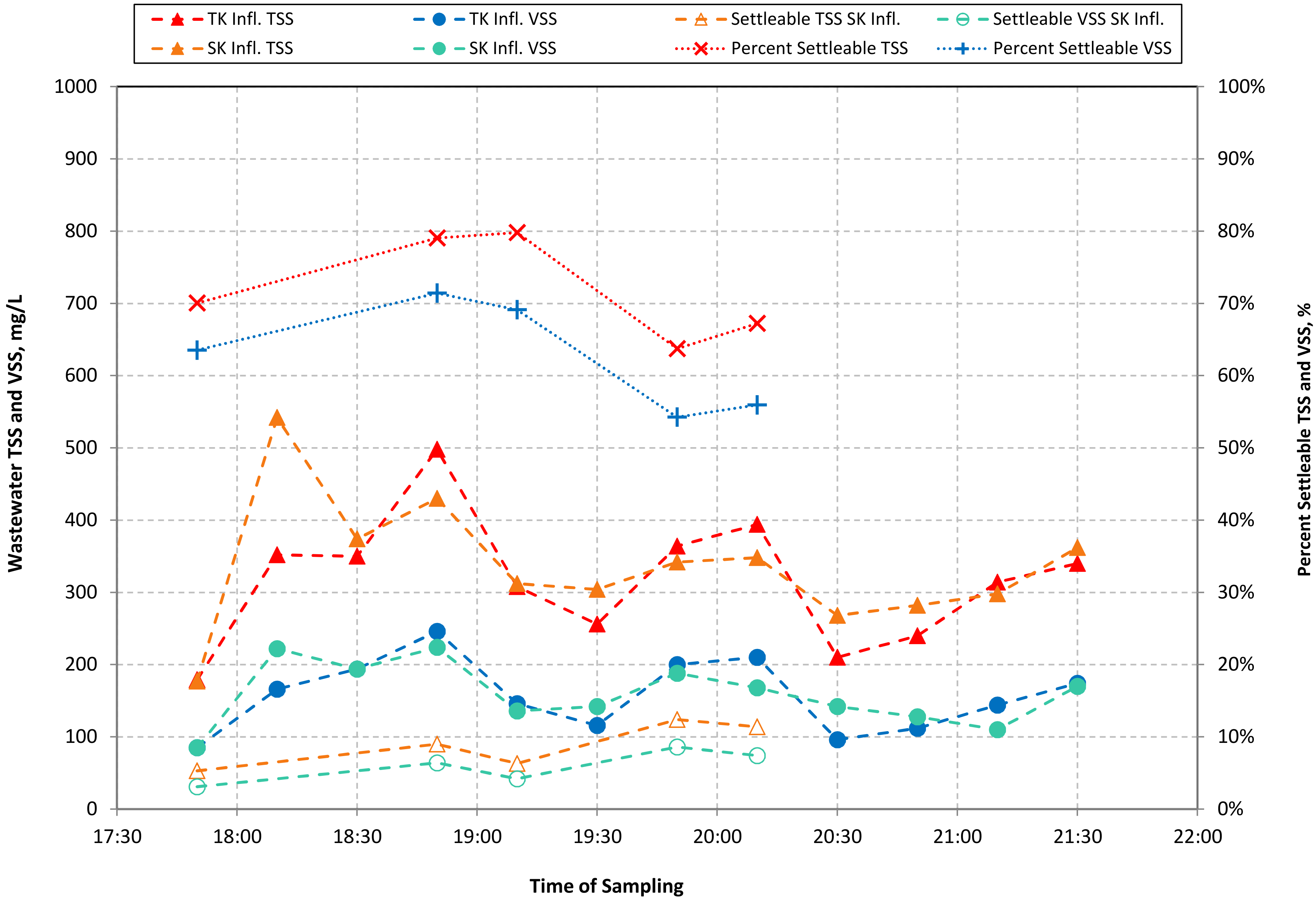
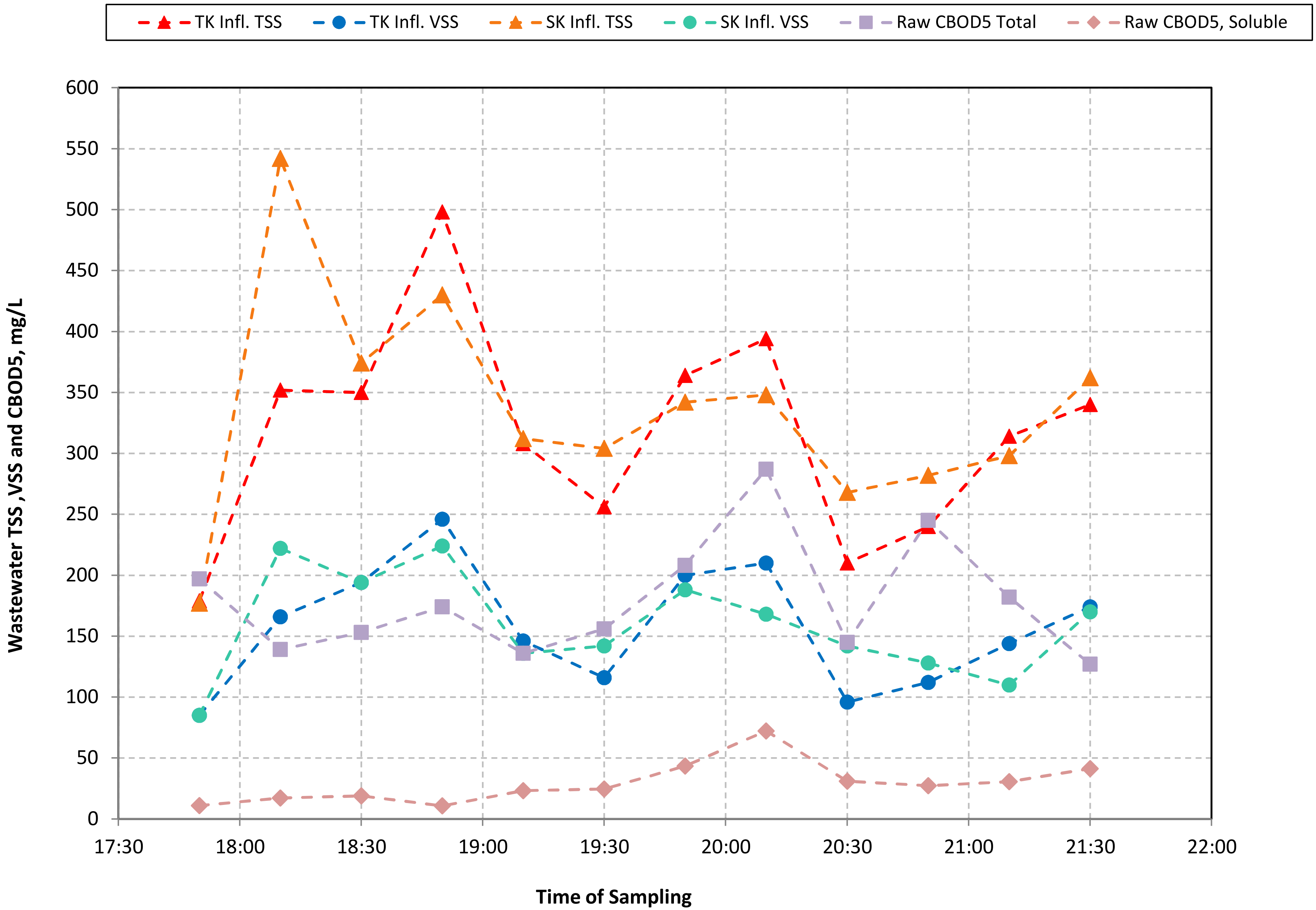


Figure 5-2. Storm 5 (7/30/2015). Raw TSS Characteristics



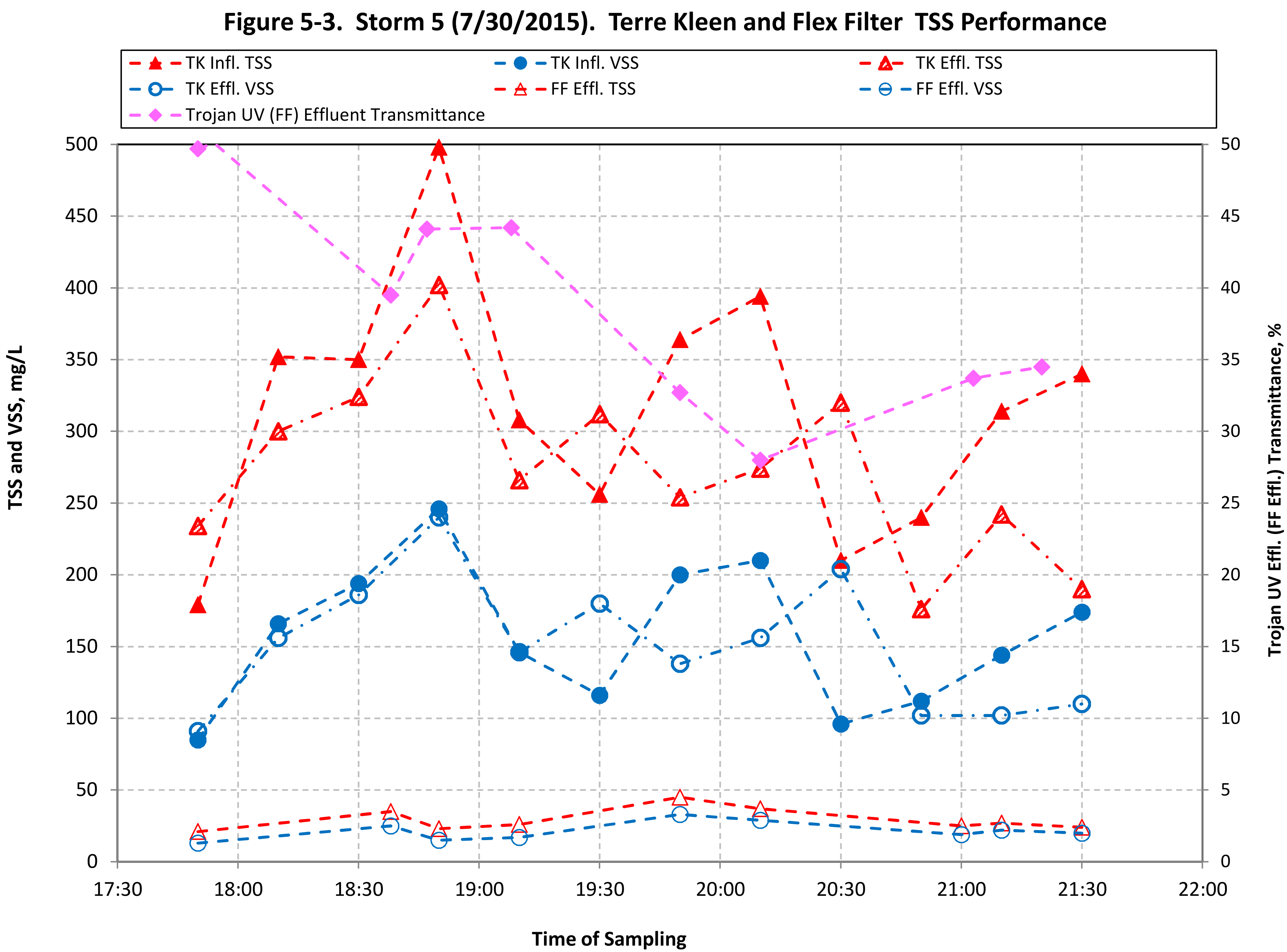


Figure 5-3. Storm 5 (7/30/2015). Terre Kleen and Flex Filter TSS Performance
TK Infl. TSS
TK Infl. VSS
TK Effl. TSS
TK Effl. VSS
FF Effl. TSS
FF Effl. VSS
Trojan UV (FF) Effluent Transmittance
TSS and VSS, mg/L
Trojan UV Effl. (FF Effl.) Transmittance, %
Time of Sampling
0
50
100
150
200
250
300
350
400
450
500
0
5
10
15
20
25
30
35
40
45
50
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00

Figure 5-4. Storm 5 (7/30/2015). Terre Kleen and Flex Filter CBOD5 Performance

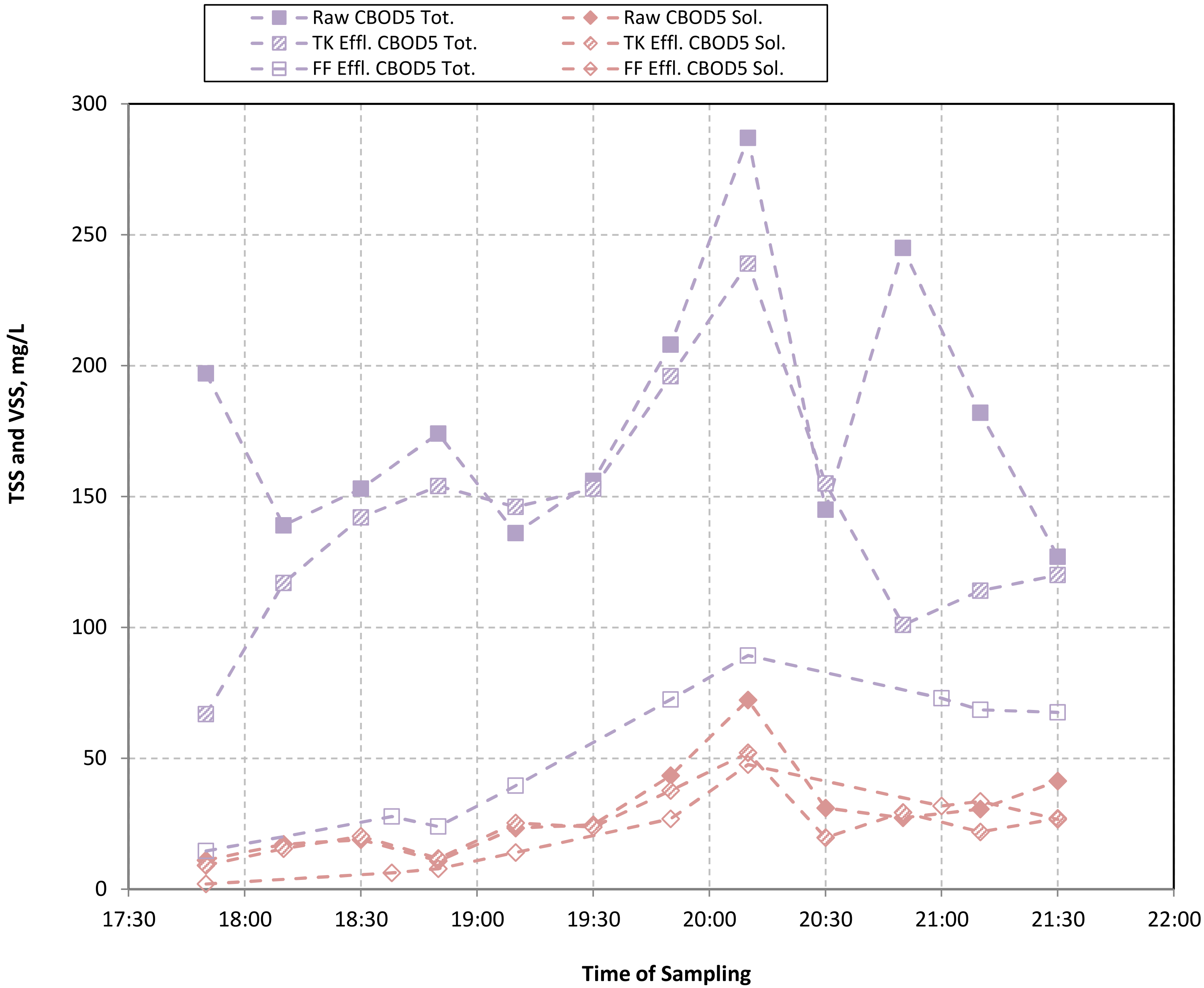


Figure 5-5. Storm 5 (7/30/2015). Storm King TSS Performance

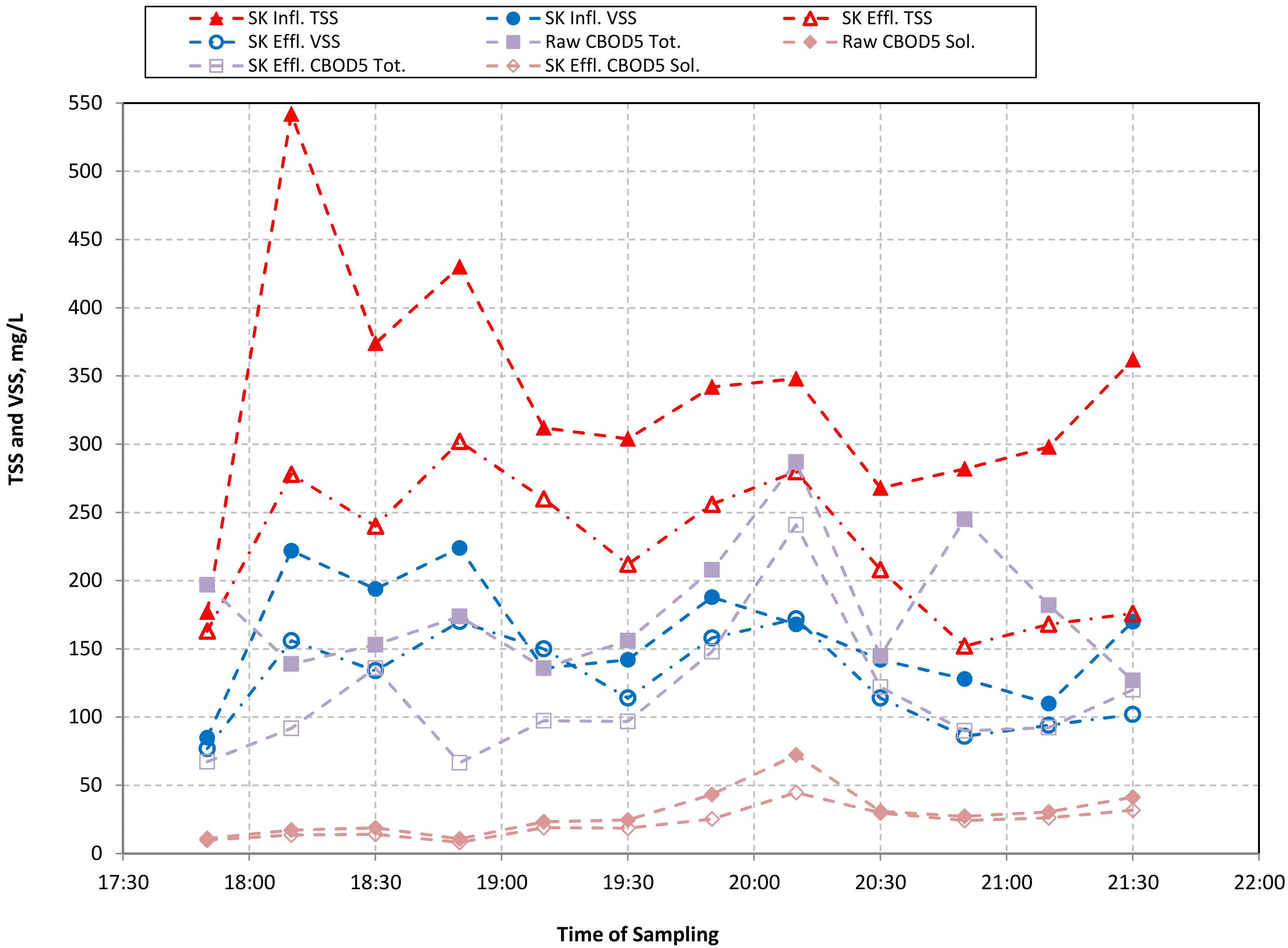


Figure 5-10. Storm 5 (7/30/2015). Trojan UV Performance (Following Flex Filter)

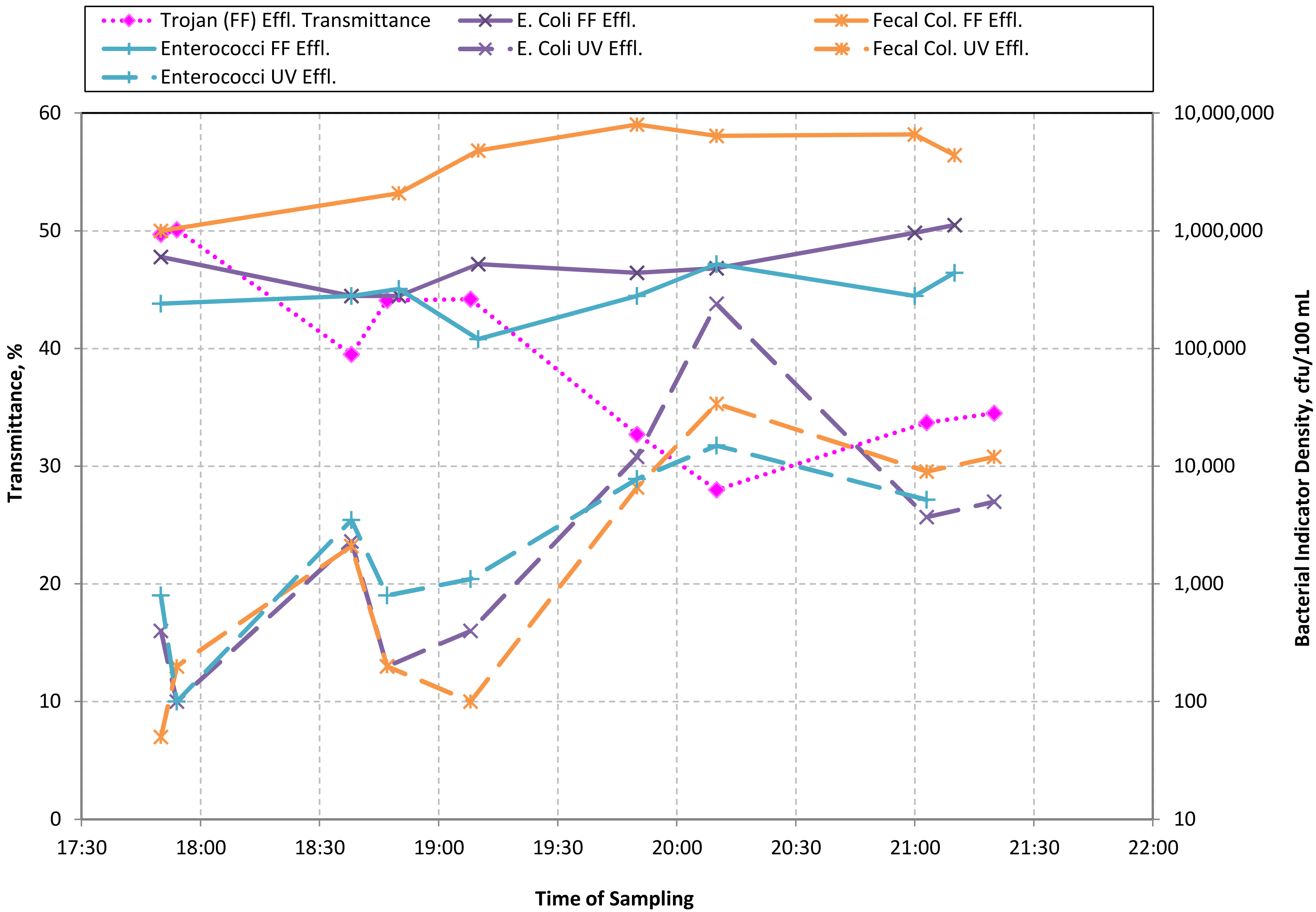


Figure 5-11. Storm 5 (7/30/2015). Trojan UV Performance (Following Flex Filter)

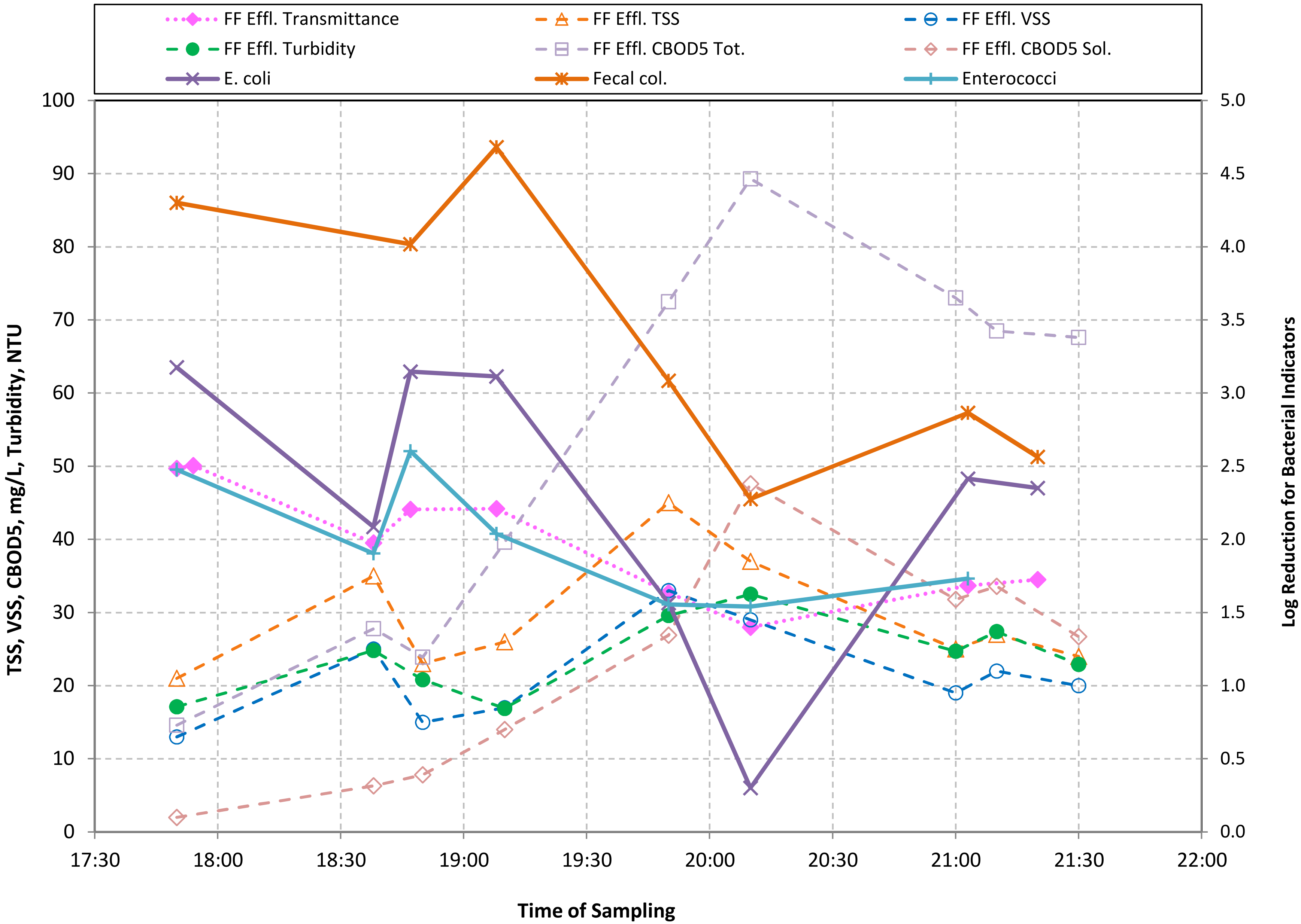


Figure 5-12. Storm 5 (7/30/2015). Trojan UV Performance (Following Flex Filter)

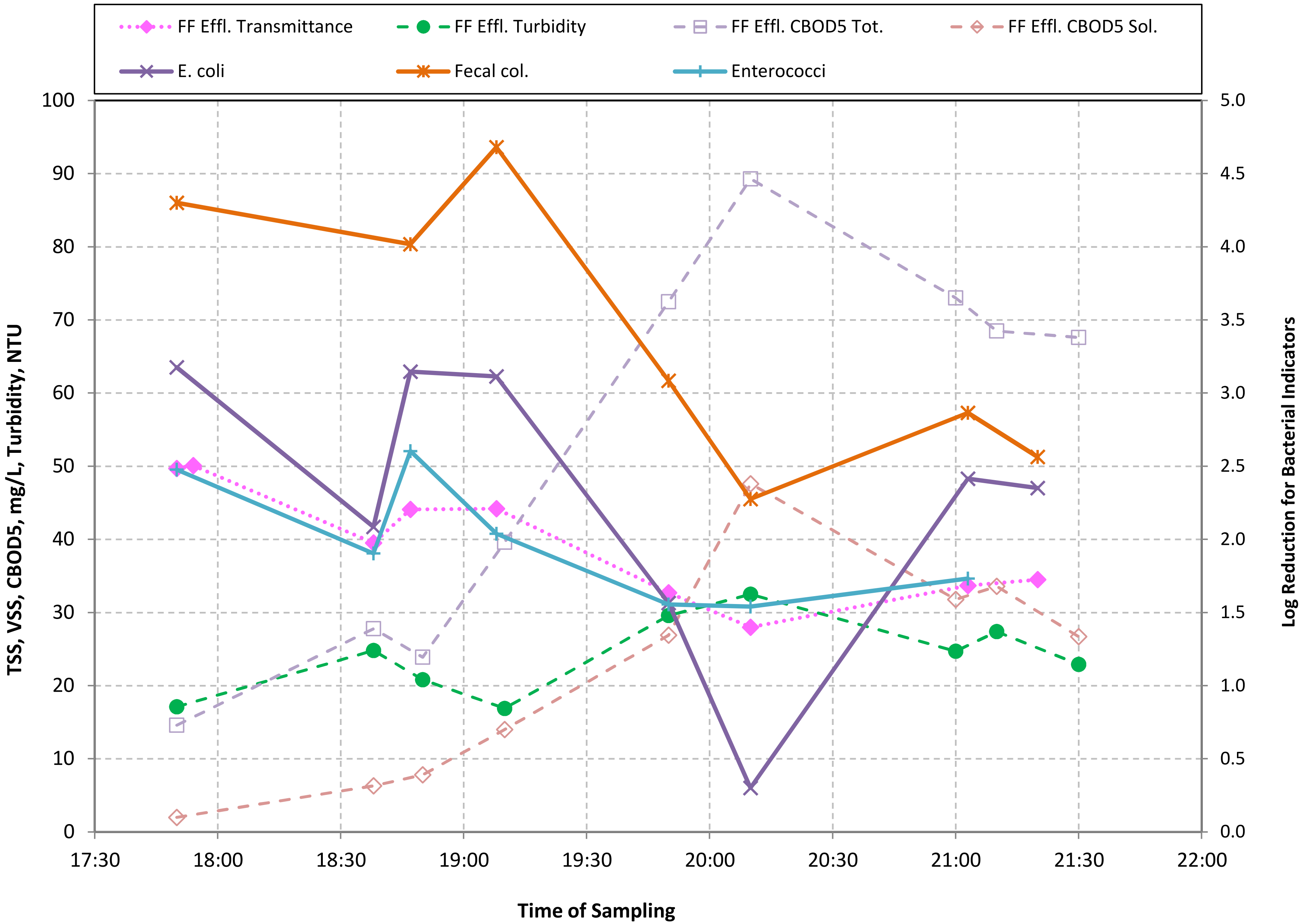


Figure 5-13. Storm 5 (7/30/2015). PAA Performance (Following Storm King)

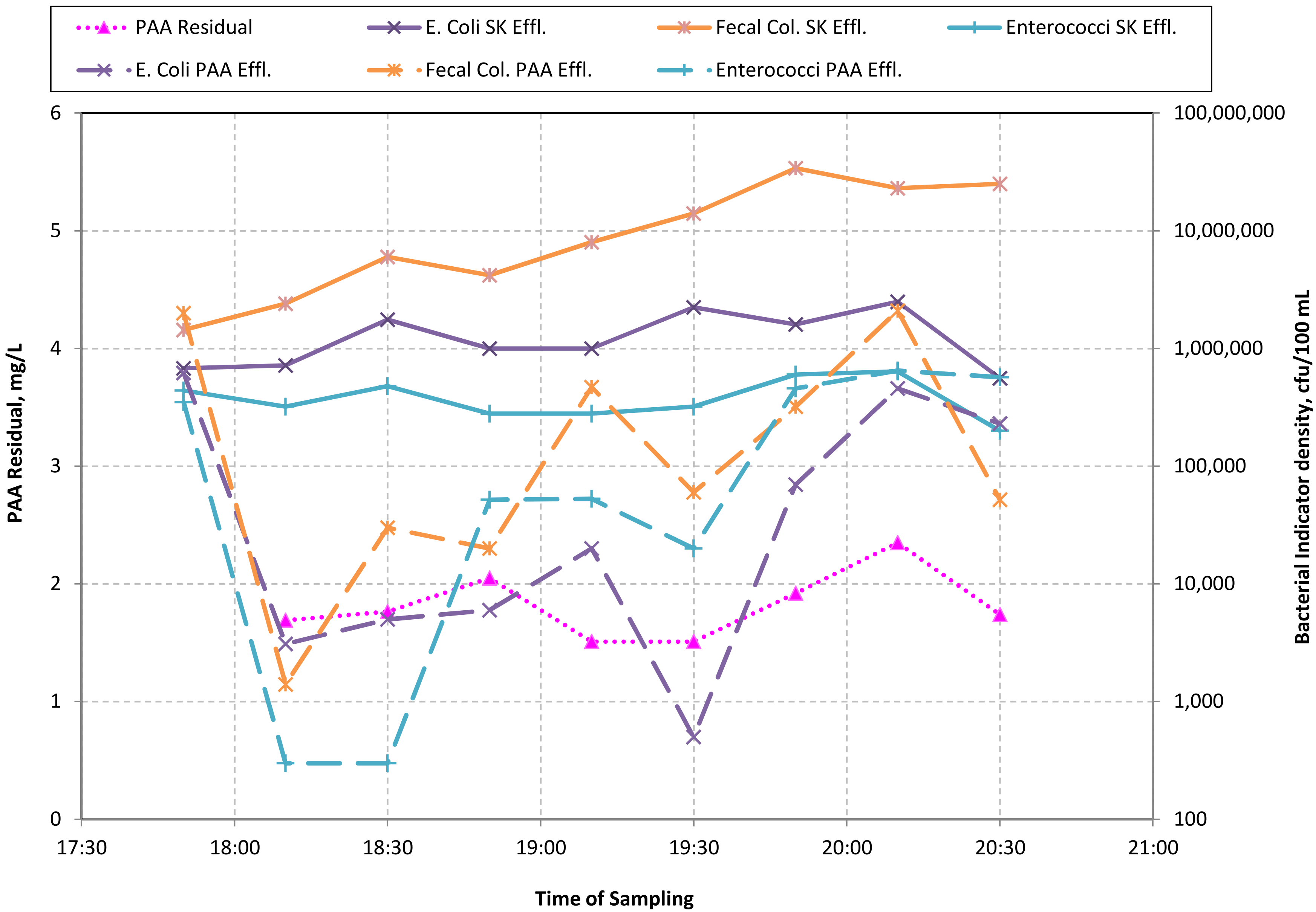
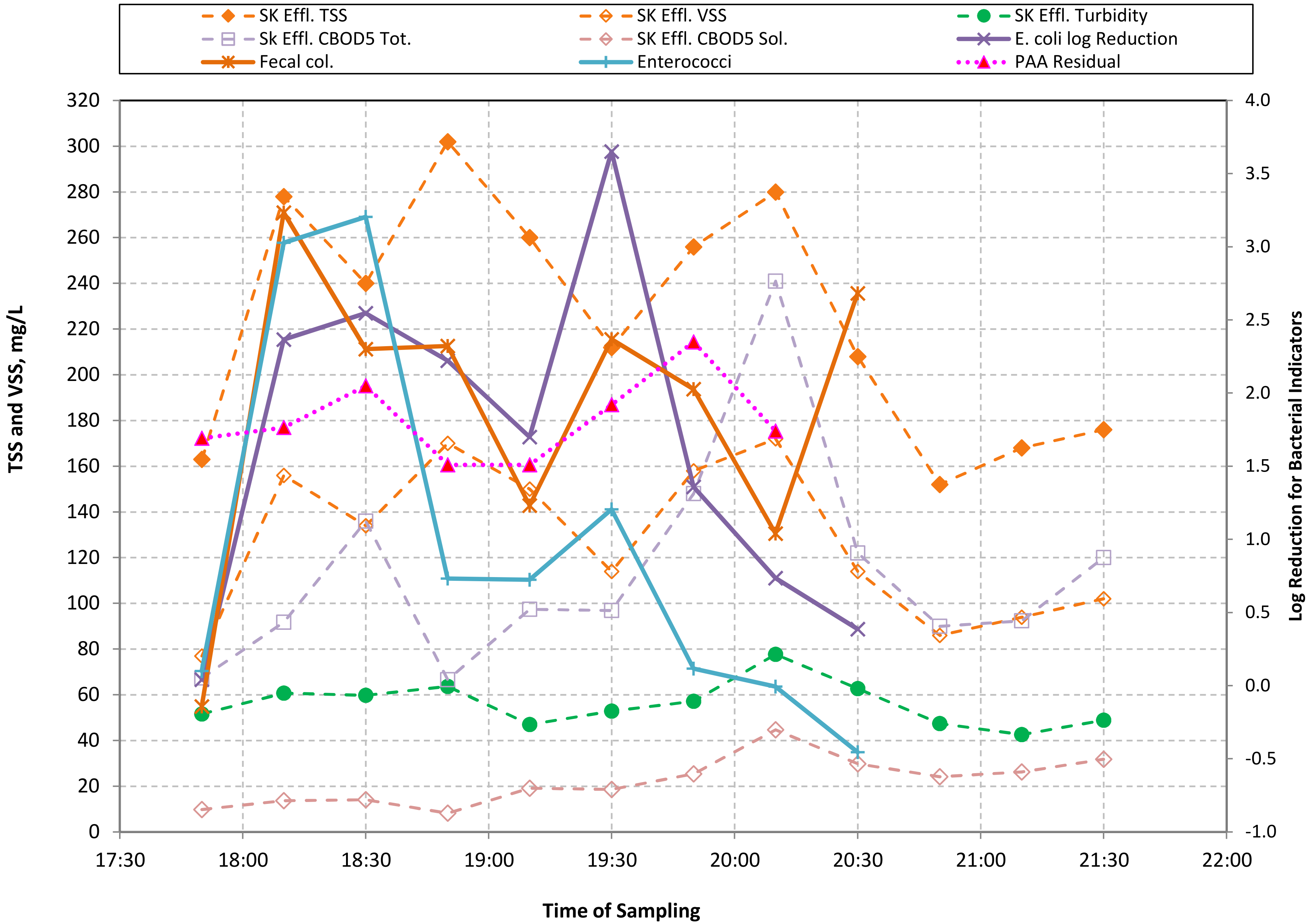


Figure 5-14. Storm 5 (7/30/2015). Peracetic Acid Performance (Following Storm King)



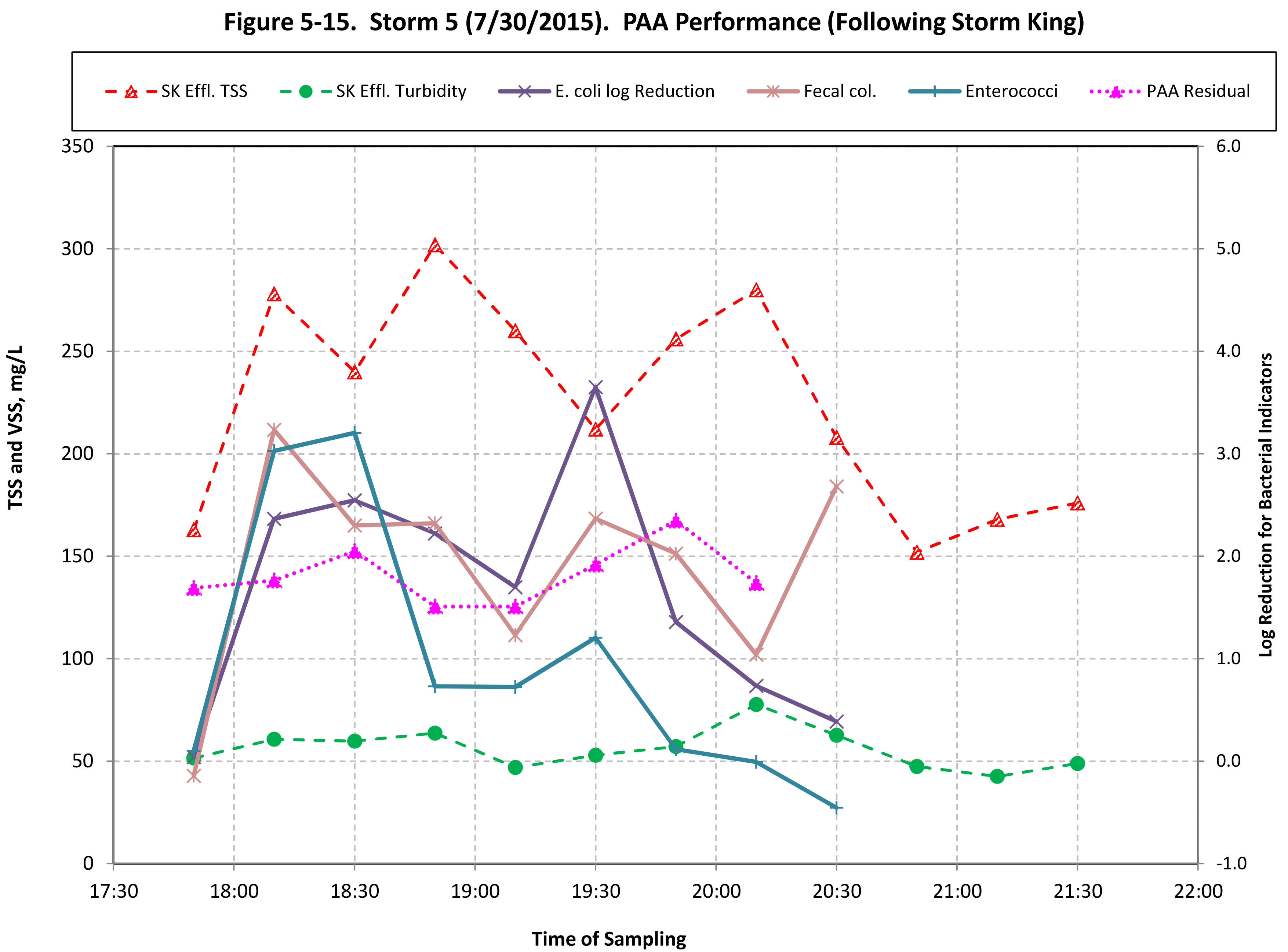


Figure 5-15. Storm 5 (7/30/2015). PAA Performance (Following Storm King)
SK Effl. TSS
SK Effl. Turbidity
E. coli log Reduction
Fecal col.
Enterococci
PAA Residual
TSS and VSS, mg/L
Log Reduction for Bacterial Indicators
Time of Sampling
350
300
250
200
150
100
50
0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00

Figure 6-1. Storm 6 (8/11/2015). Raw TSS Characteristics

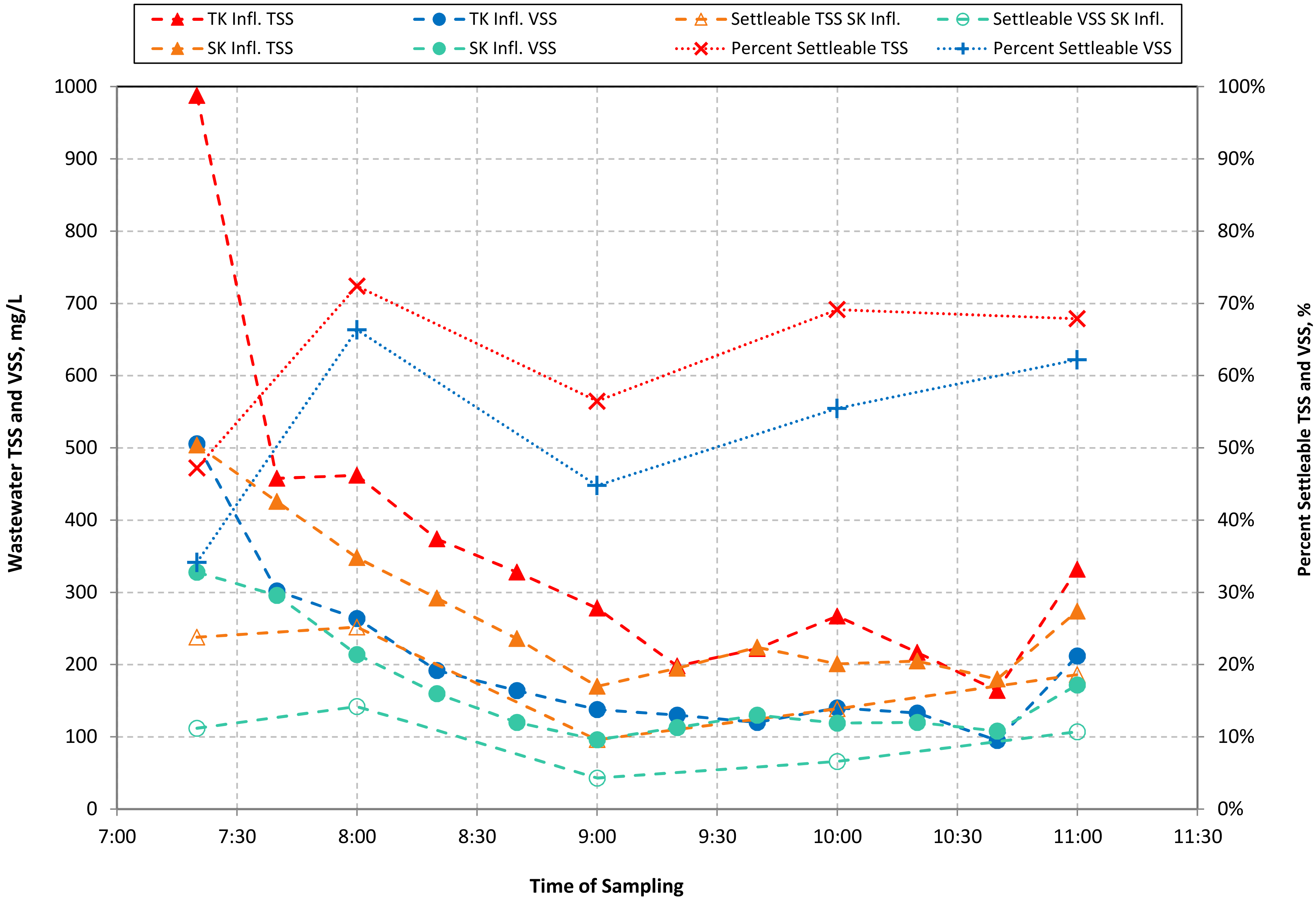
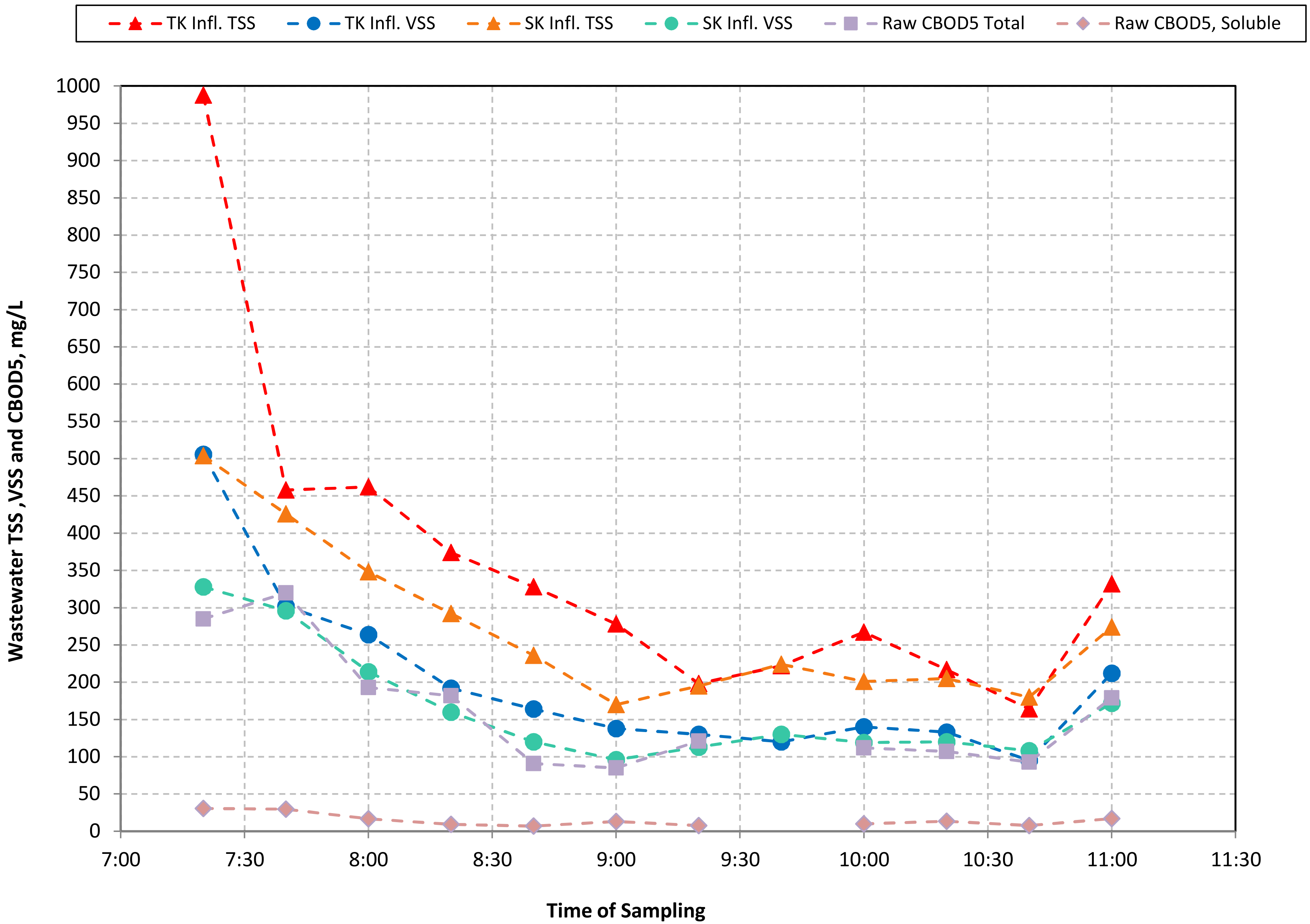


Figure 6-2. Storm 6 (8/11/2015). Raw Wastewater Characteristics



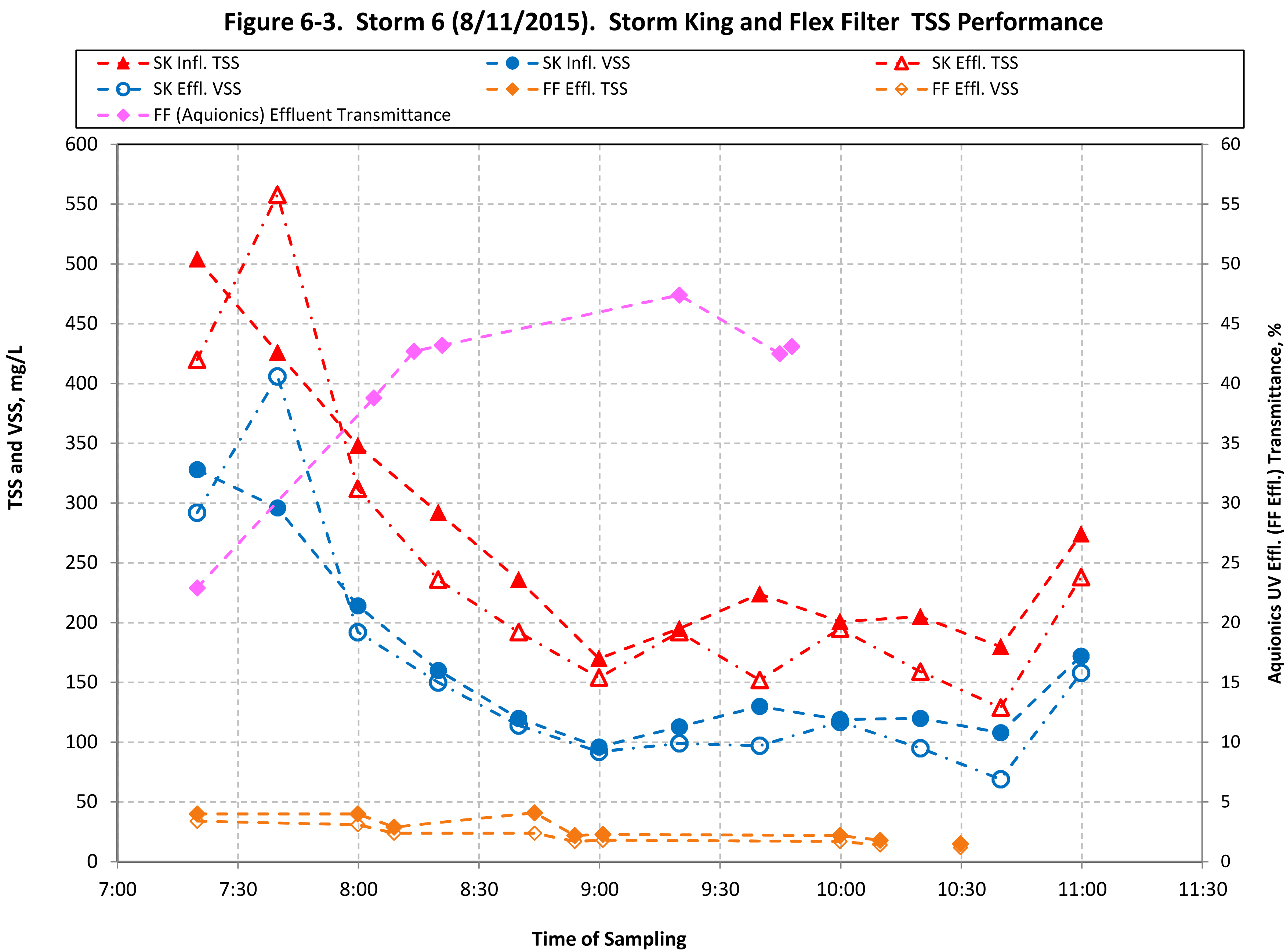


Figure 6-3. Storm 6 (8/11/2015). Storm King and Flex Filter TSS Performance
SK Infl. TSS
SK Infl. VSS
SK Effl. TSS
SK Effl. VSS
FF Effl. TSS
FF Effl. VSS
FF (Aquionics) Effluent Transmittance
TSS and VSS, mg/L
Aquionics UV Effl. (FF Effl.) Transmittance, %
Time of Sampling
0
50
100
150
200
250
300
350
400
450
500
550
600
0
5
10
15
20
25
30
35
40
45
50
55
60
7:00
7:30
8:00
8:30
9:00
9:30
10:00
10:30
11:00
11:30

Figure 6-4. Storm 6 (8/11/2015). Storm King and Flex Filter CBOD5 Performance

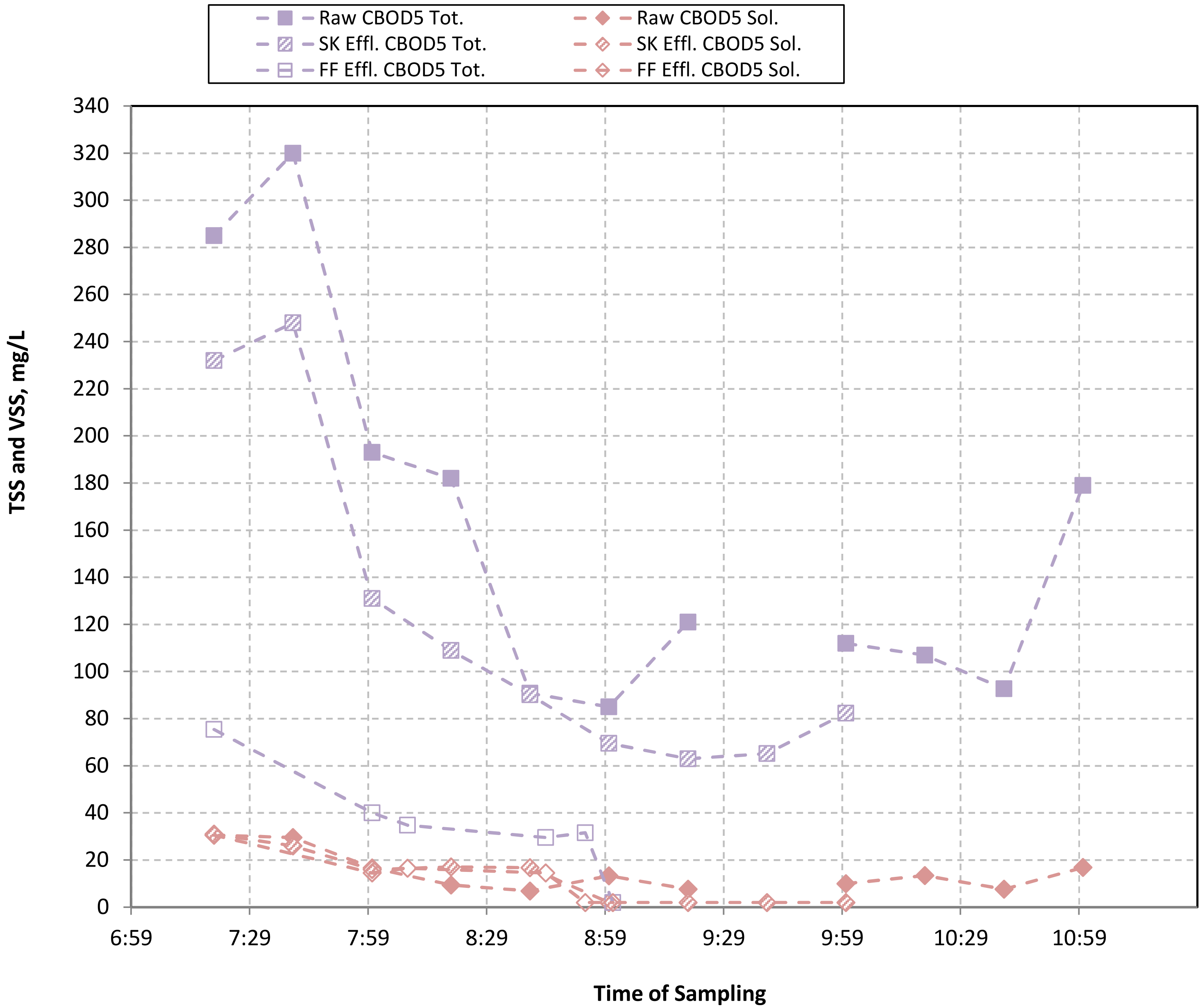


Figure 6-5. Storm 6 (8/11/2015). Terre Kleen Performance

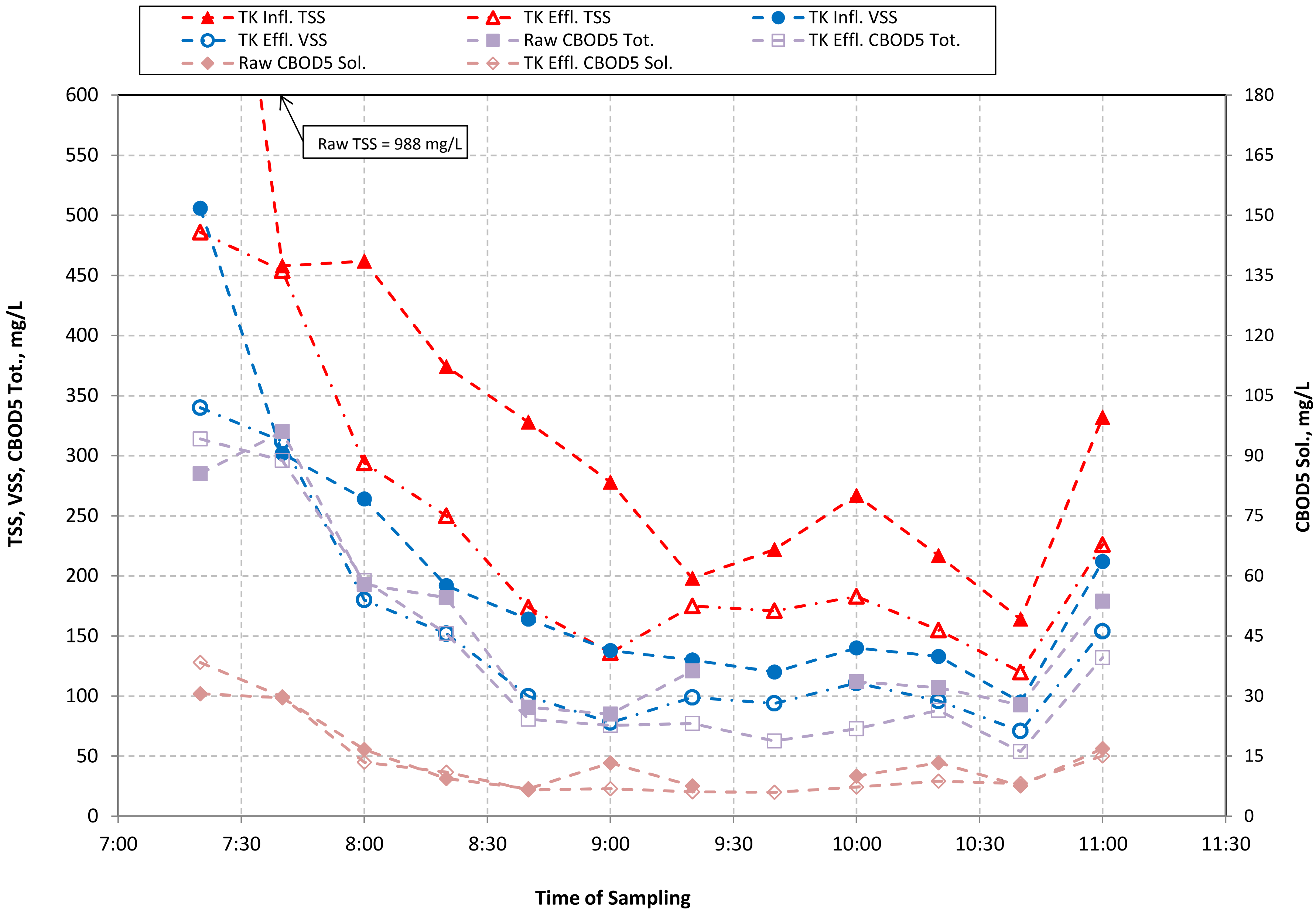


Figure 6-7. Storm 6 (8/11/2015). Effect of Various Parameters on Transmittance

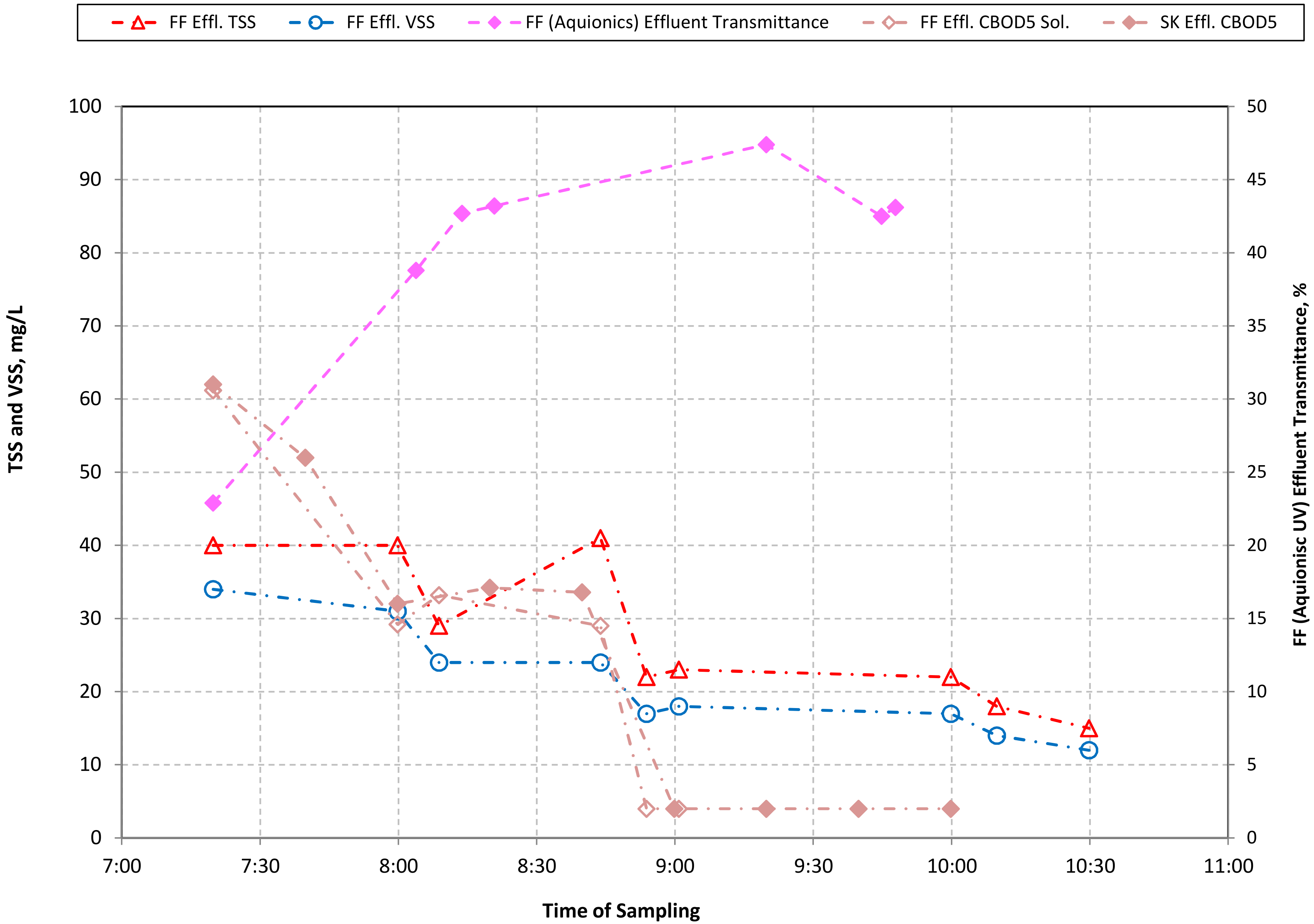


Figure 6-10. Storm 6 (8/11/2015). Aquionics UV Performance (Following Flex Filter)

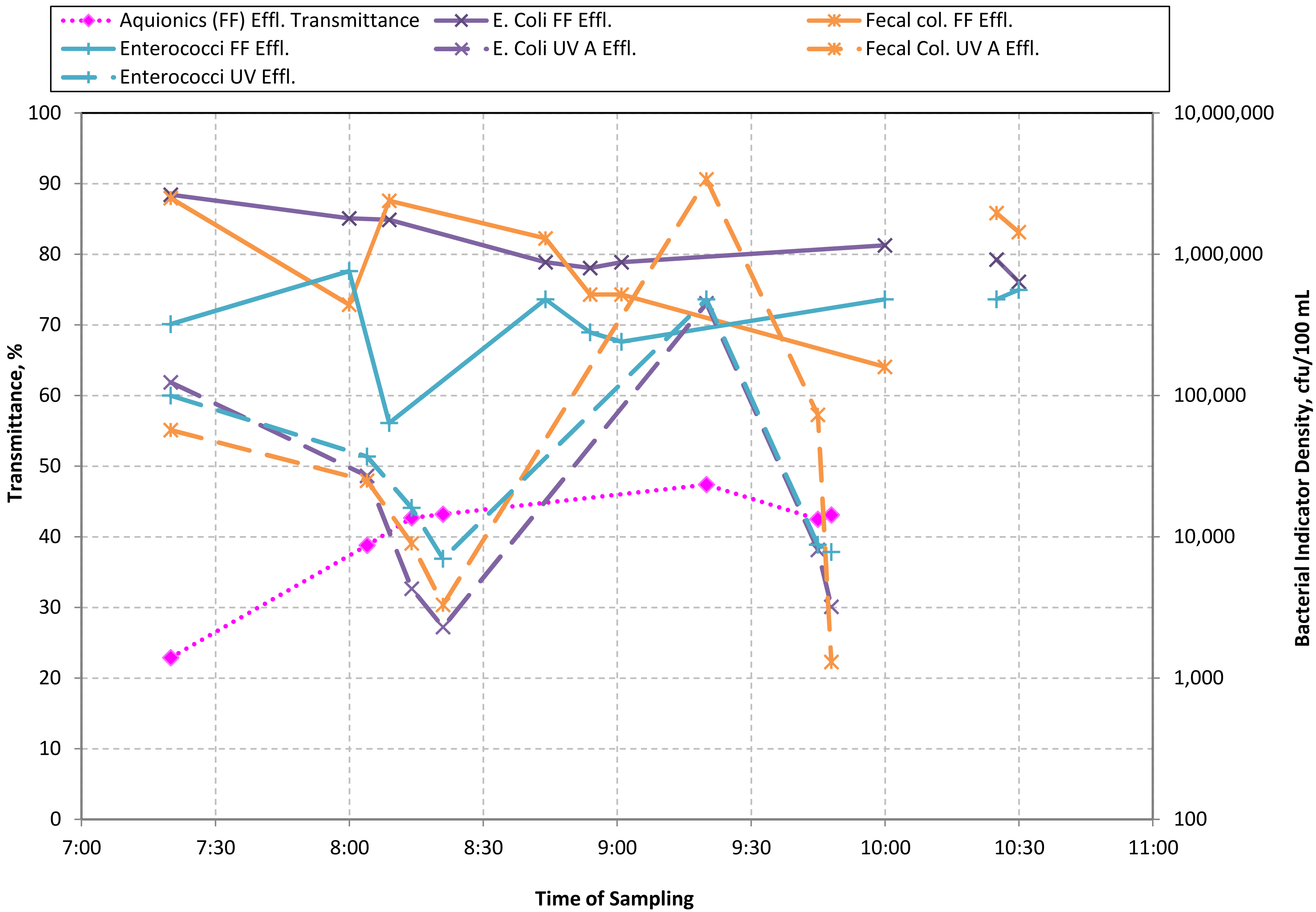


Figure 6-11. Storm 6 (8/11/2015). Aquionisc UV Performance (Following Flex Filter)

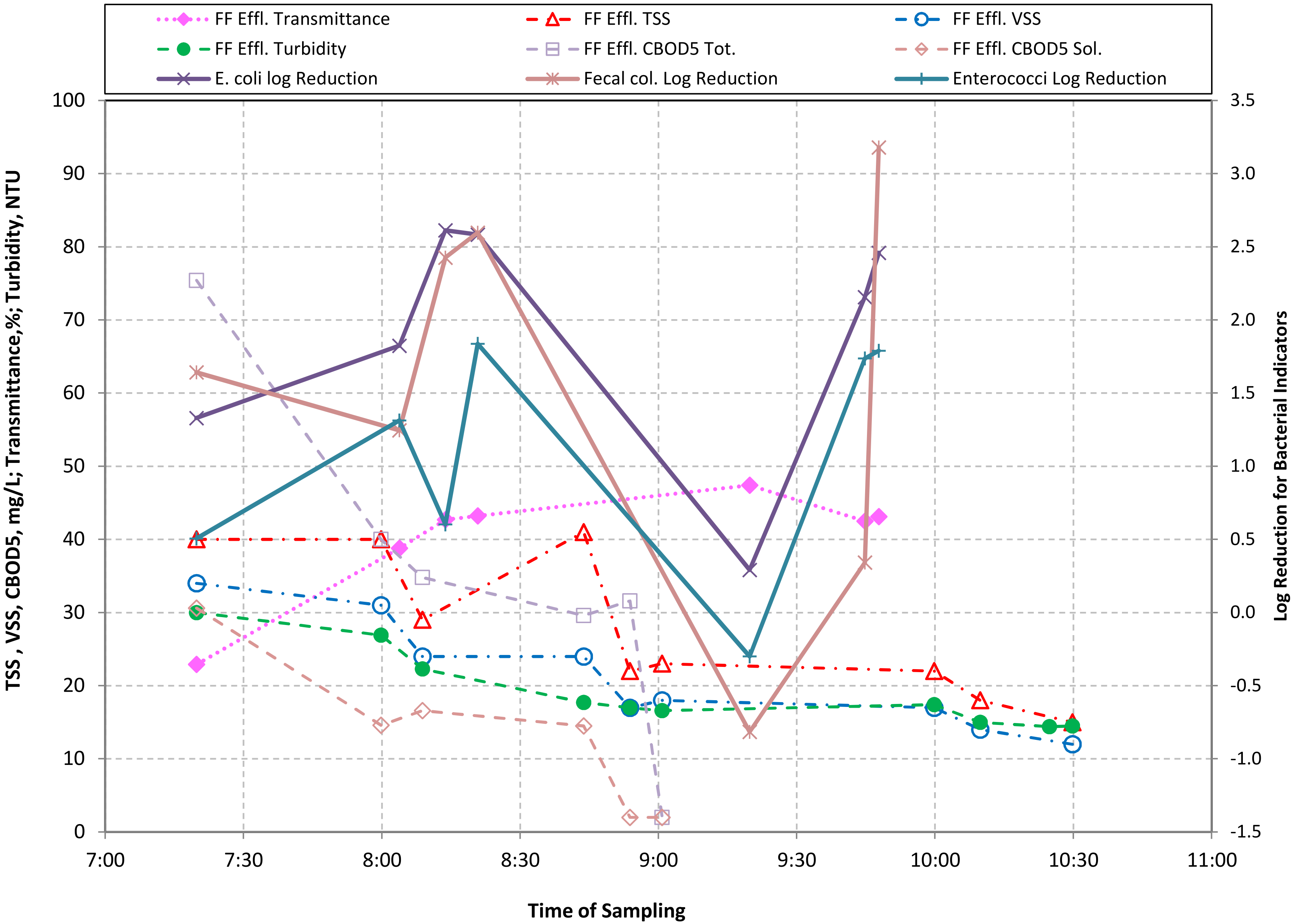


Figure 6-12. Storm 06 (8/11/2015). PAA Performance (Following Terre Kleen)

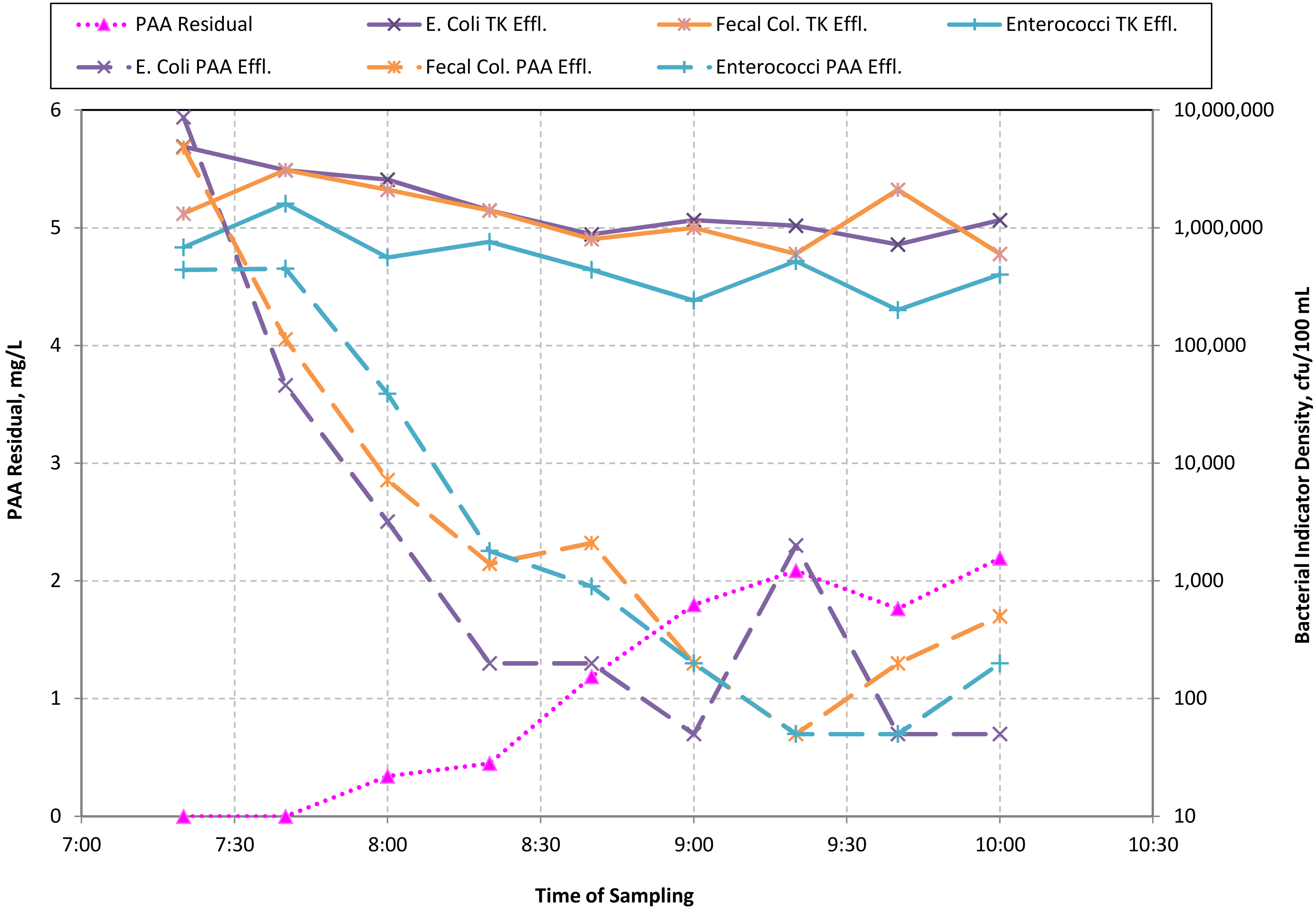


Figure 6-13. Storm 6 (8/11/2015). PAA Performance (Following Terre Kleen)

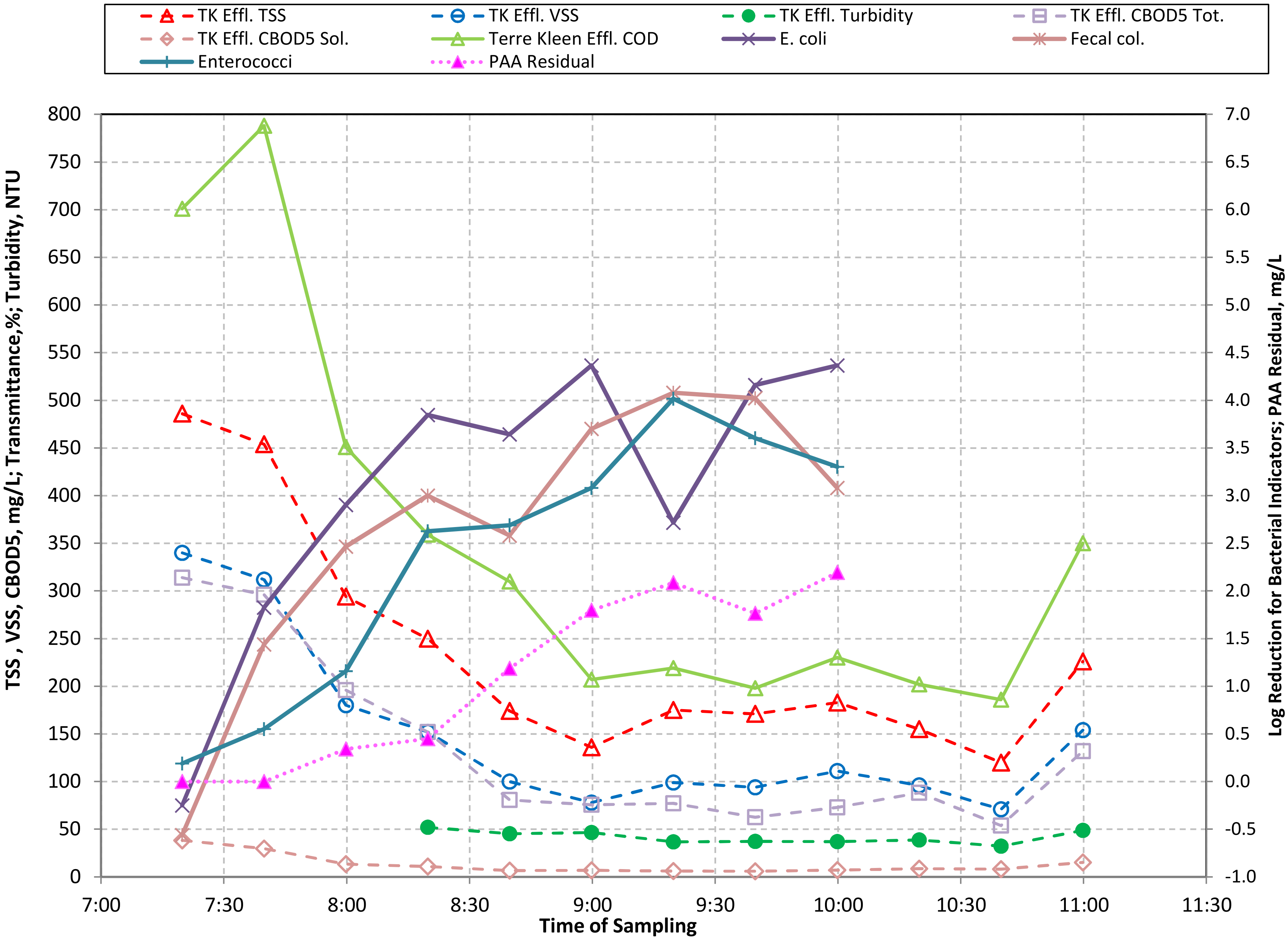


Figure 6-14. Storm 6 (8/11/2015). PAA Performance (Following Terre Kleen)

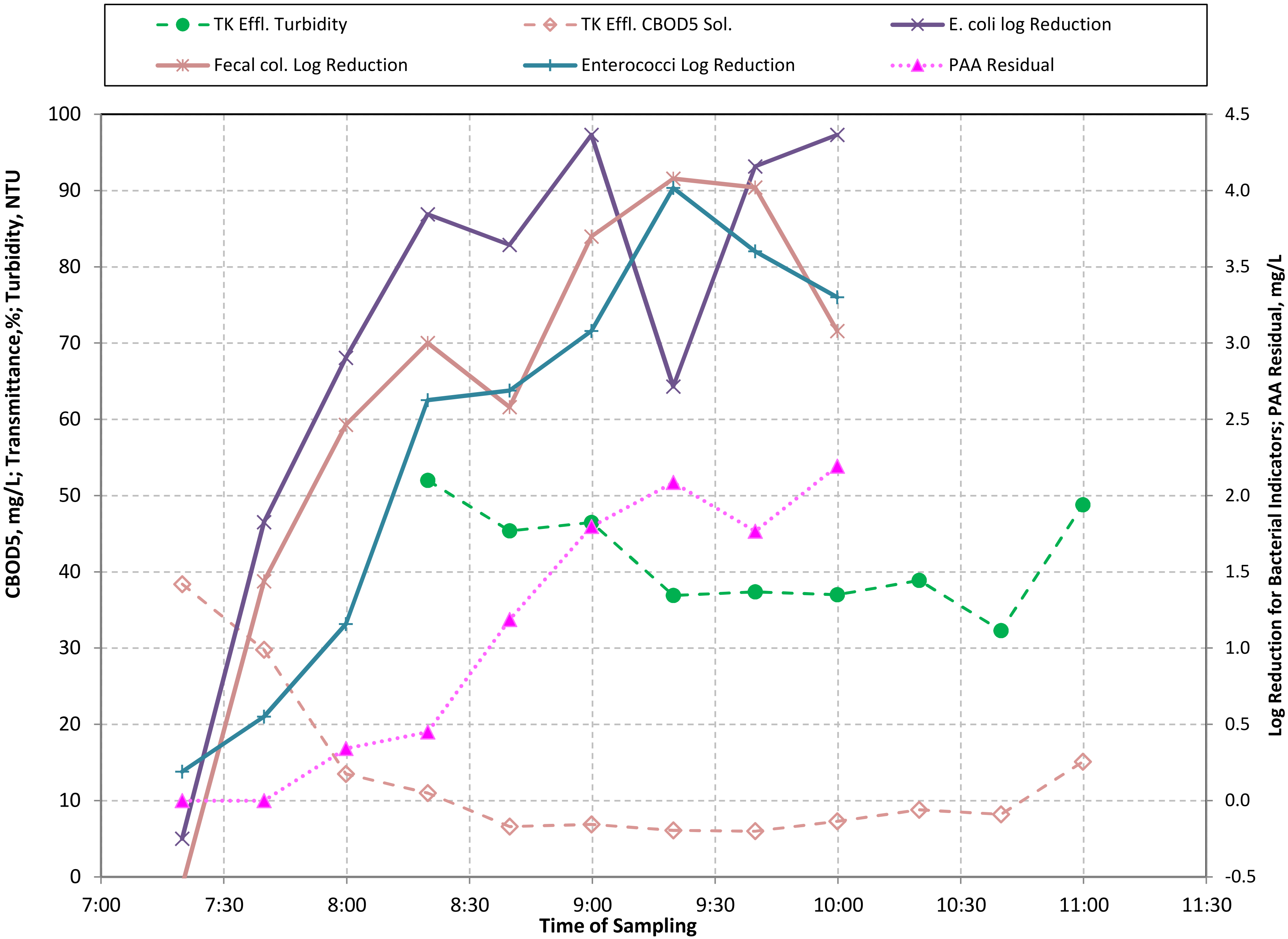


Figure 7-1. Storm 7 (9/10/2015). Raw TSS Characteristics

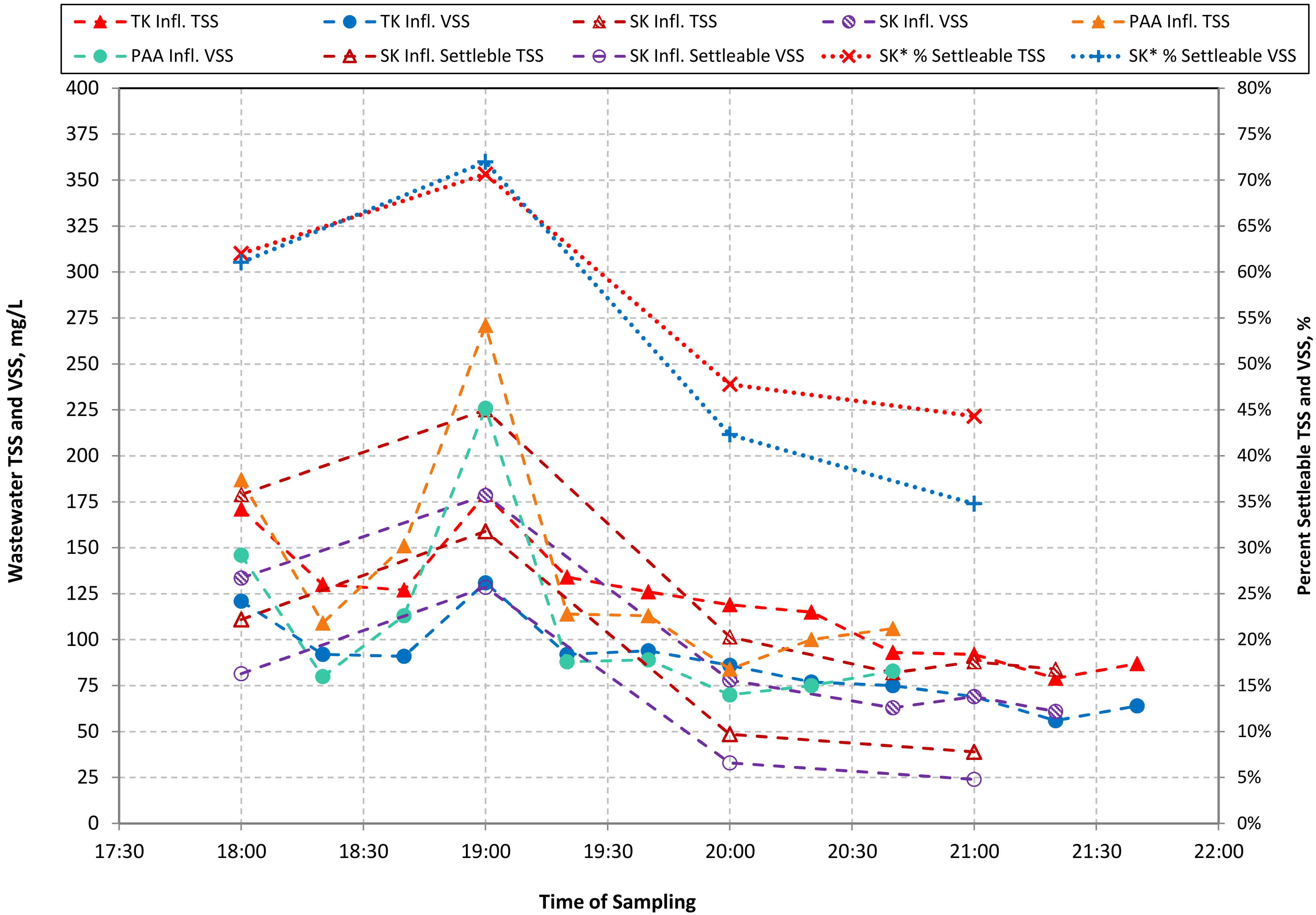
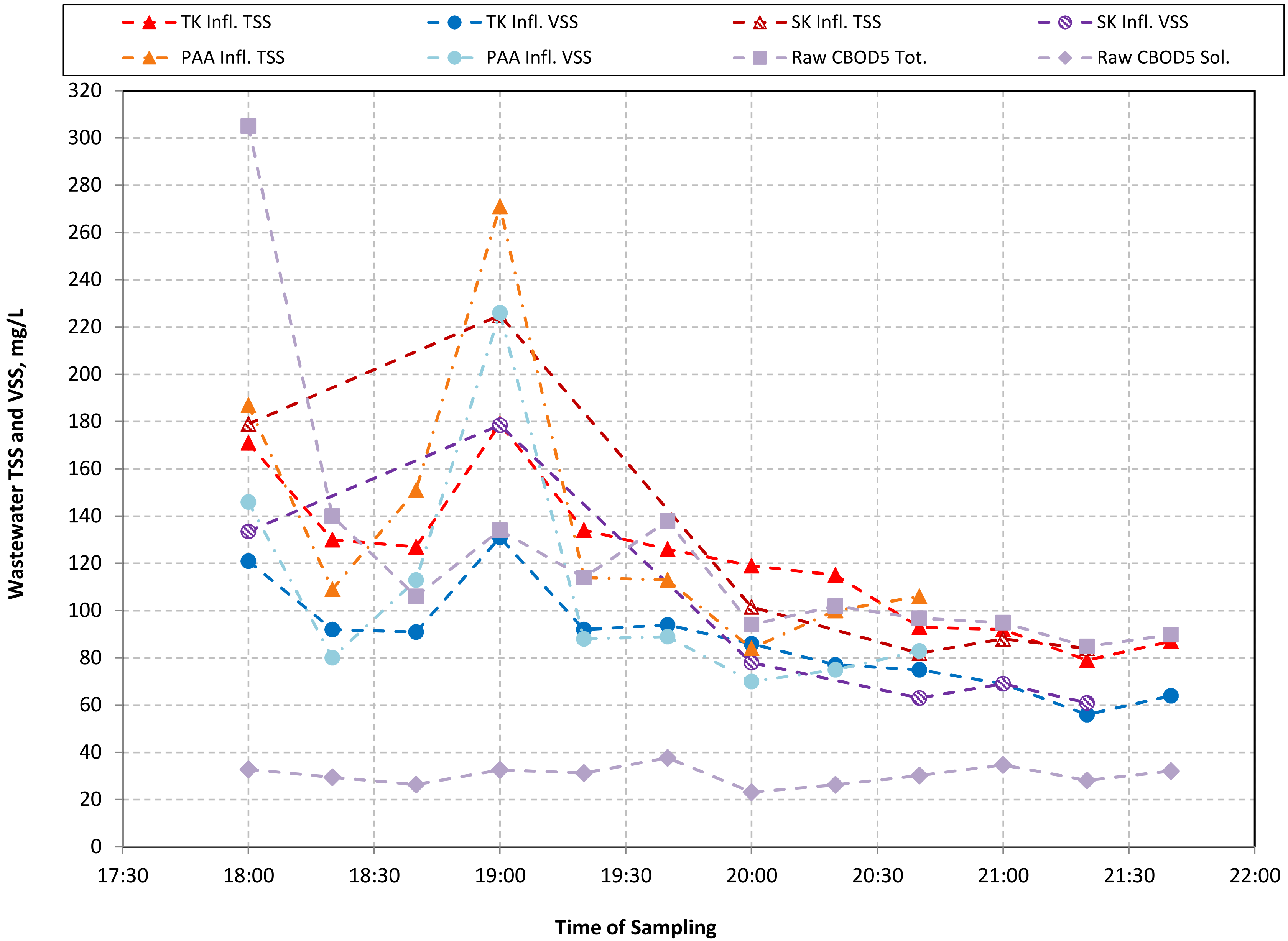


Figure 7-2. Storm 7 (9/10/2015). Raw Wastewater Characteristics



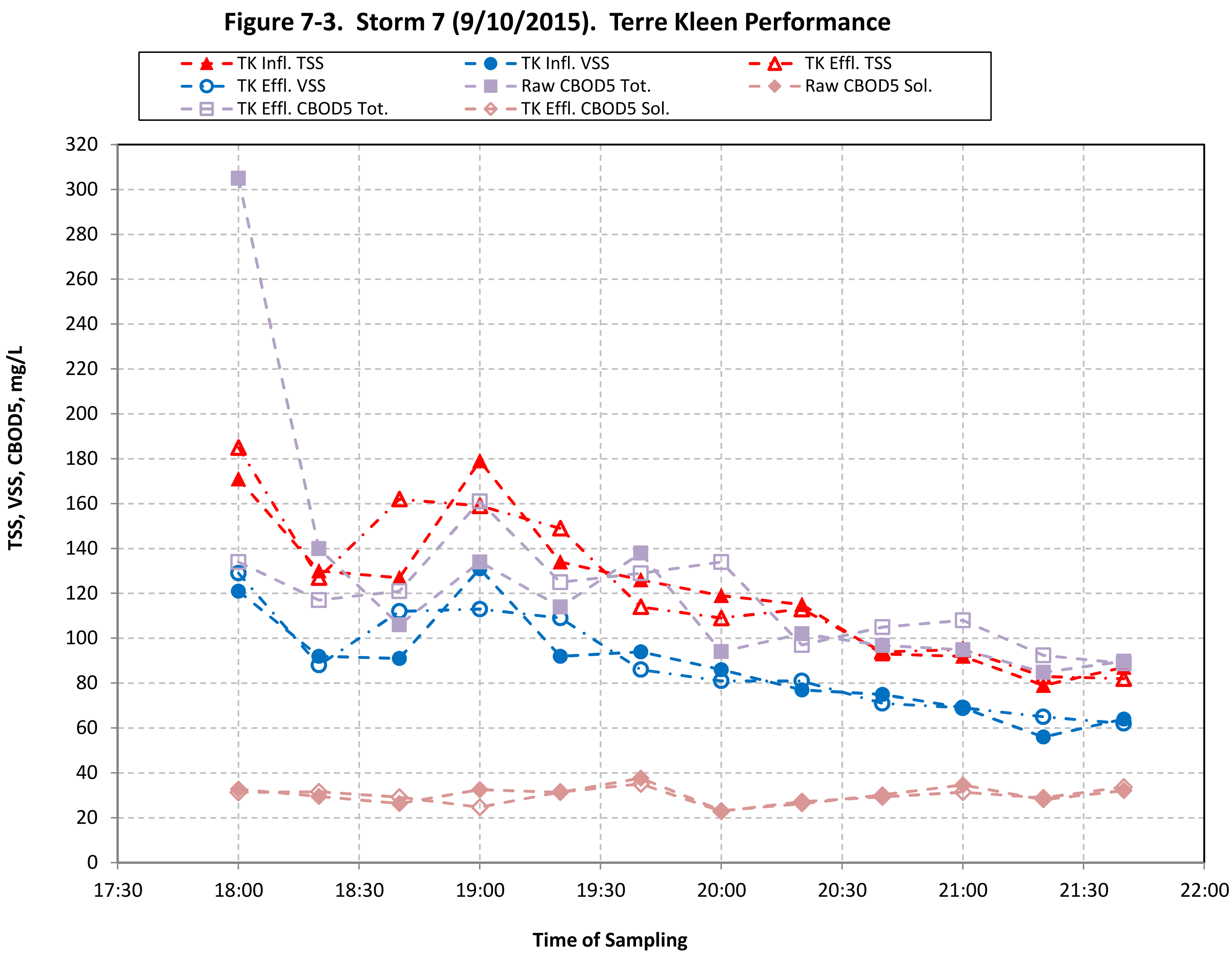
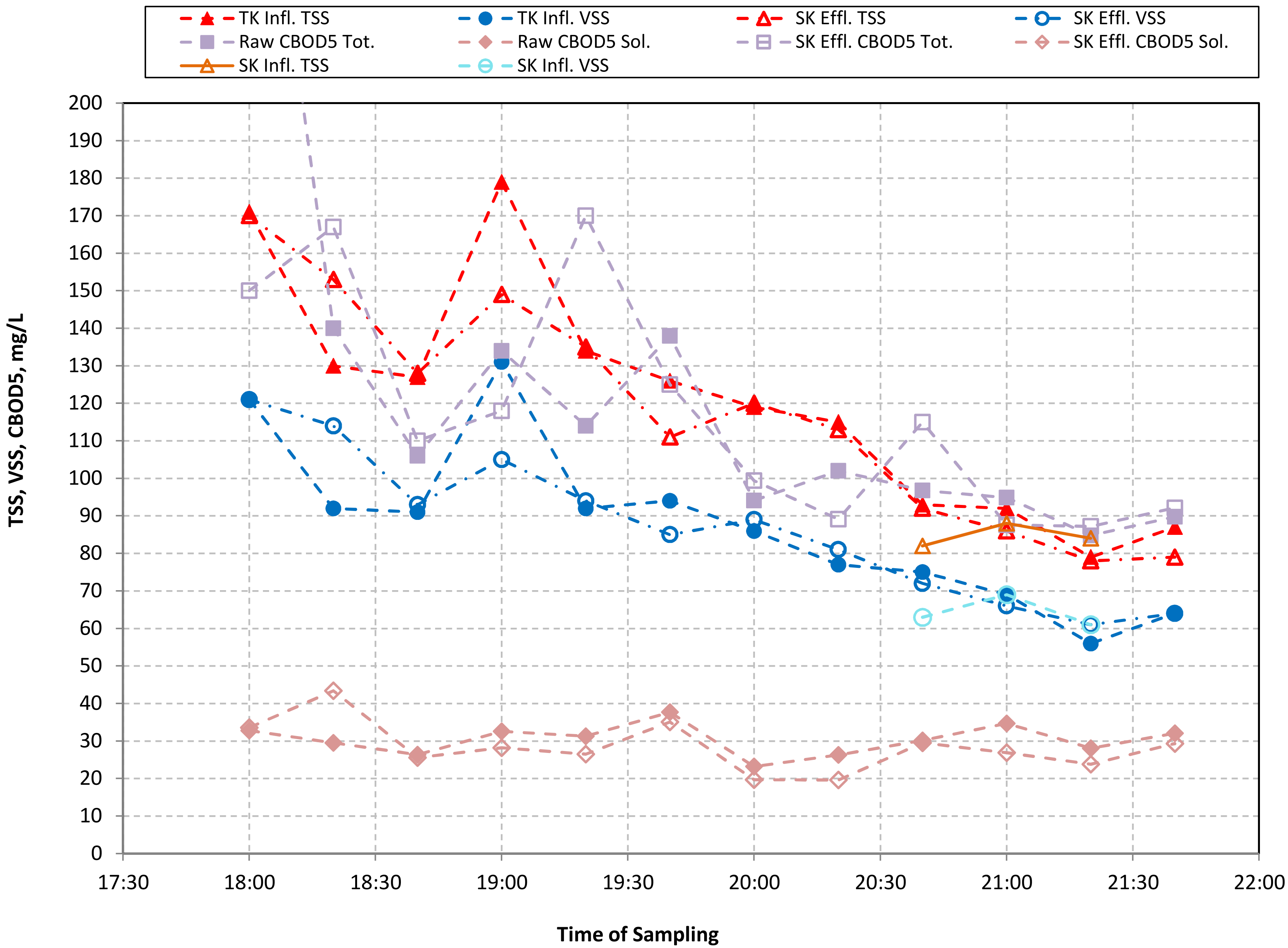


Figure 7-3. Storm 7 (9/10/2015). Terre Kleen Performance
TK Infl. TSS
TK Infl. VSS
TK Effl. TSS
TK Effl. VSS
Raw CBOD5 Tot.
Raw CBOD5 Sol.
TK Effl. CBOD5 Tot.
TK Effl. CBOD5 Sol.
TSS, VSS, CBOD5, mg/L
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00
Time of Sampling

Figure 7-4. Storm 7 (9/10/2015). Storm King Performance



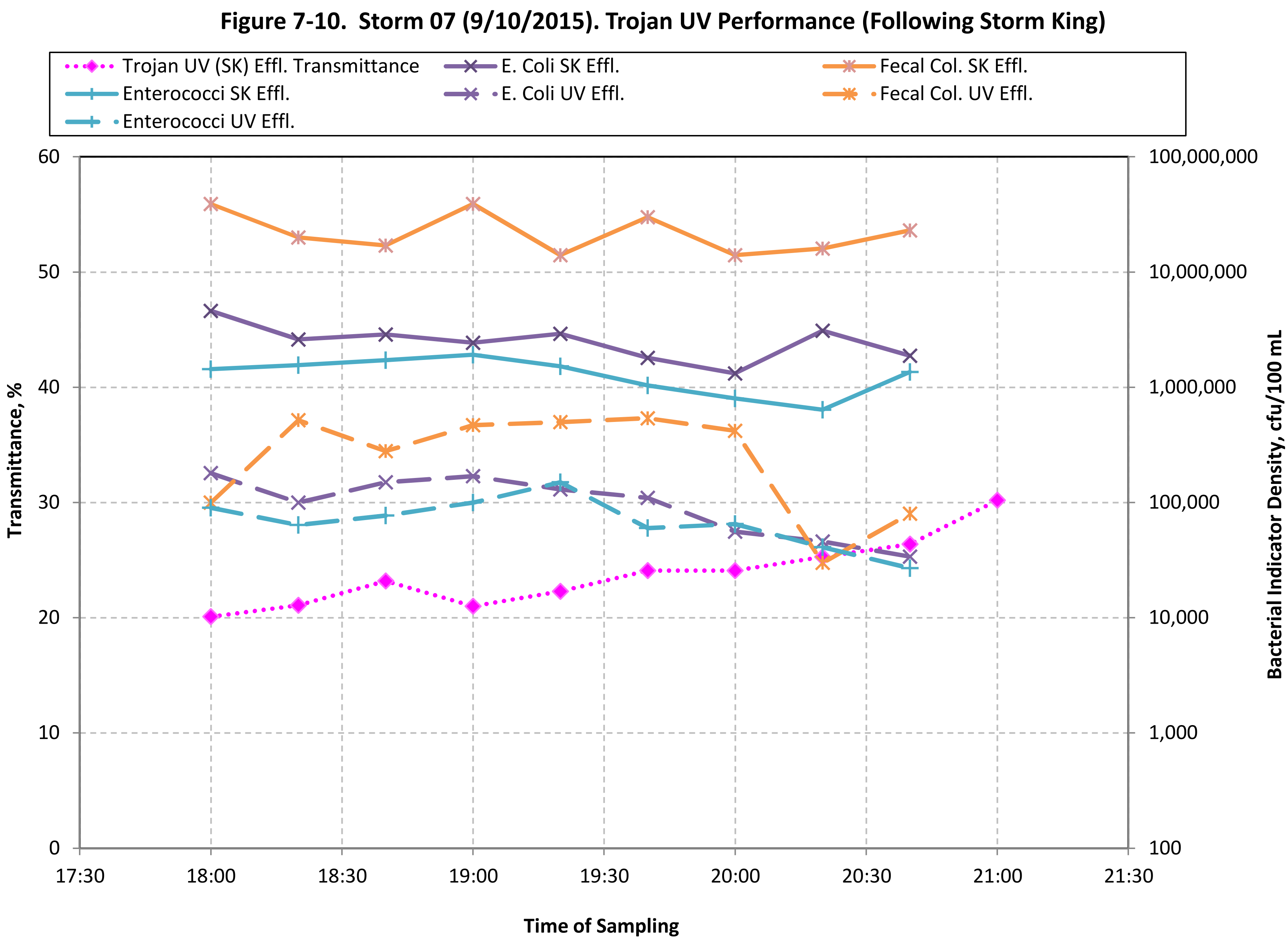


Figure 7-10. Storm 07 (9/10/2015). Trojan UV Performance (Following Storm King)
Trojan UV (SK) Effl. Transmittance
E. Coli SK Effl.
Fecal Col. SK Effl.
Enterococci SK Effl.
E. Coli UV Effl.
Fecal Col. UV Effl.
Enterococci UV Effl.
Transmittance, %
Bacterial Indicator Density, cfu/100 mL
Time of Sampling
0
10
20
30
40
50
60
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30

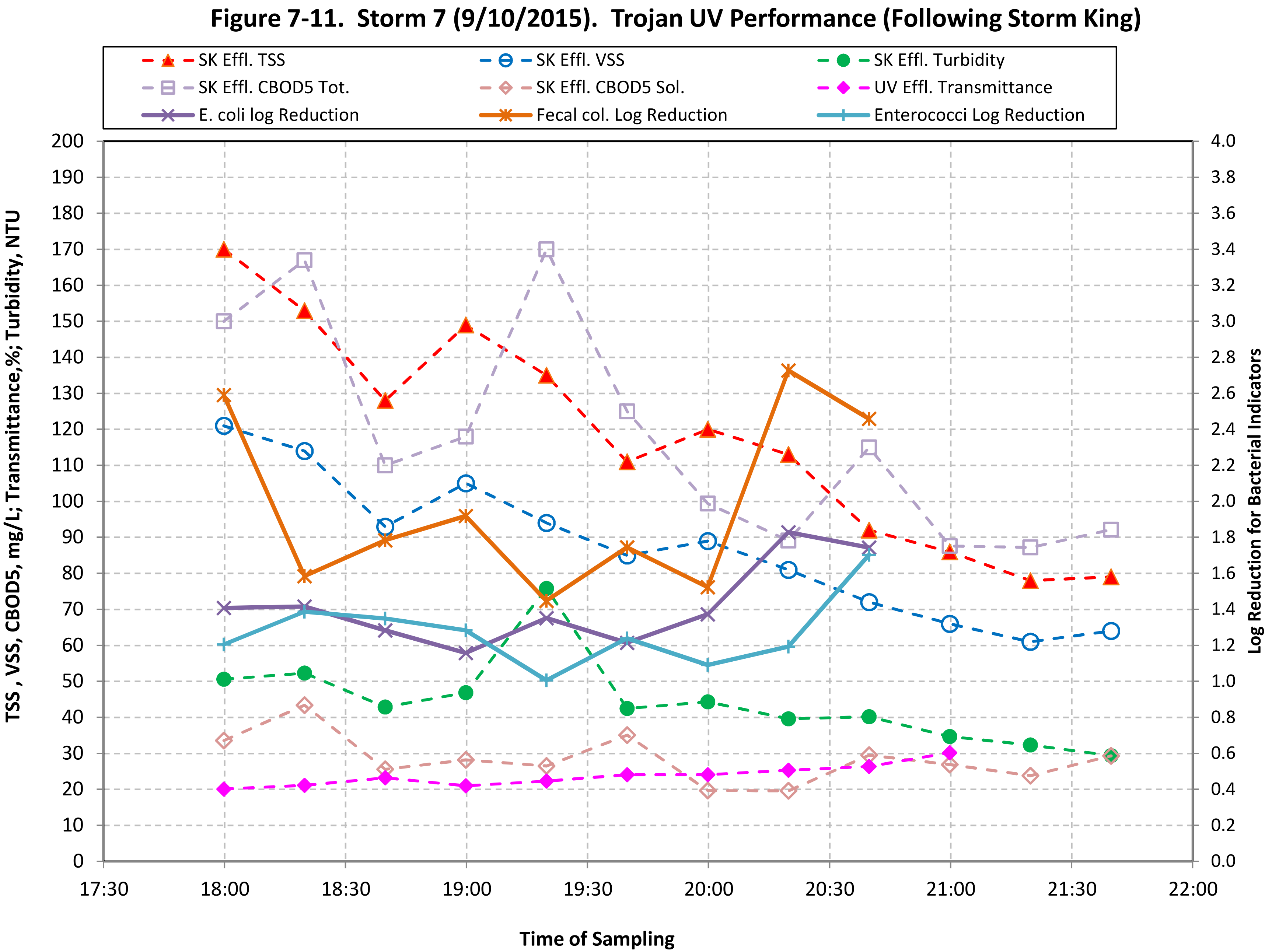


Figure 7-11. Storm 7 (9/10/2015). Trojan UV Performance (Following Storm King)
SK Effl. TSS
SK Effl. VSS
SK Effl. Turbidity
SK Effl. CBOD5 Tot.
SK Effl. CBOD5 Sol.
UV Effl. Transmittance
E. coli log Reduction
Fecal col. Log Reduction
Enterococci Log Reduction
TSS , VSS, CBOD5, mg/L; Transmittance,%; Turbidity, NTU
Log Reduction for Bacterial Indicators
Time of Sampling
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00

Figure 7-12. Storm 7 (9/10/2015). Trojan UV Performance (Following Storm King)

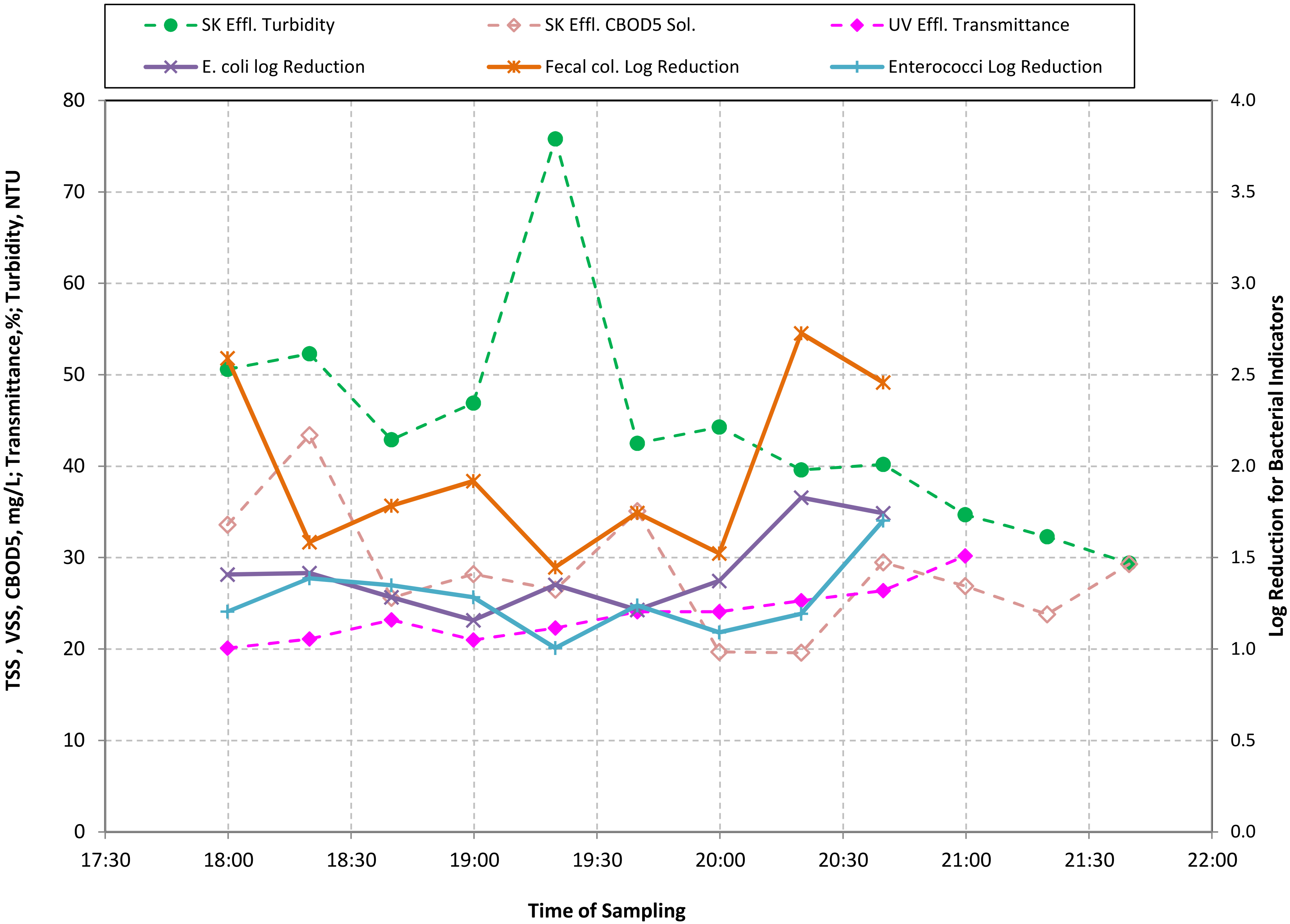


Figure 7-13. Storm 07 (9/10/2015). PAA Performance (No Pretreatment)

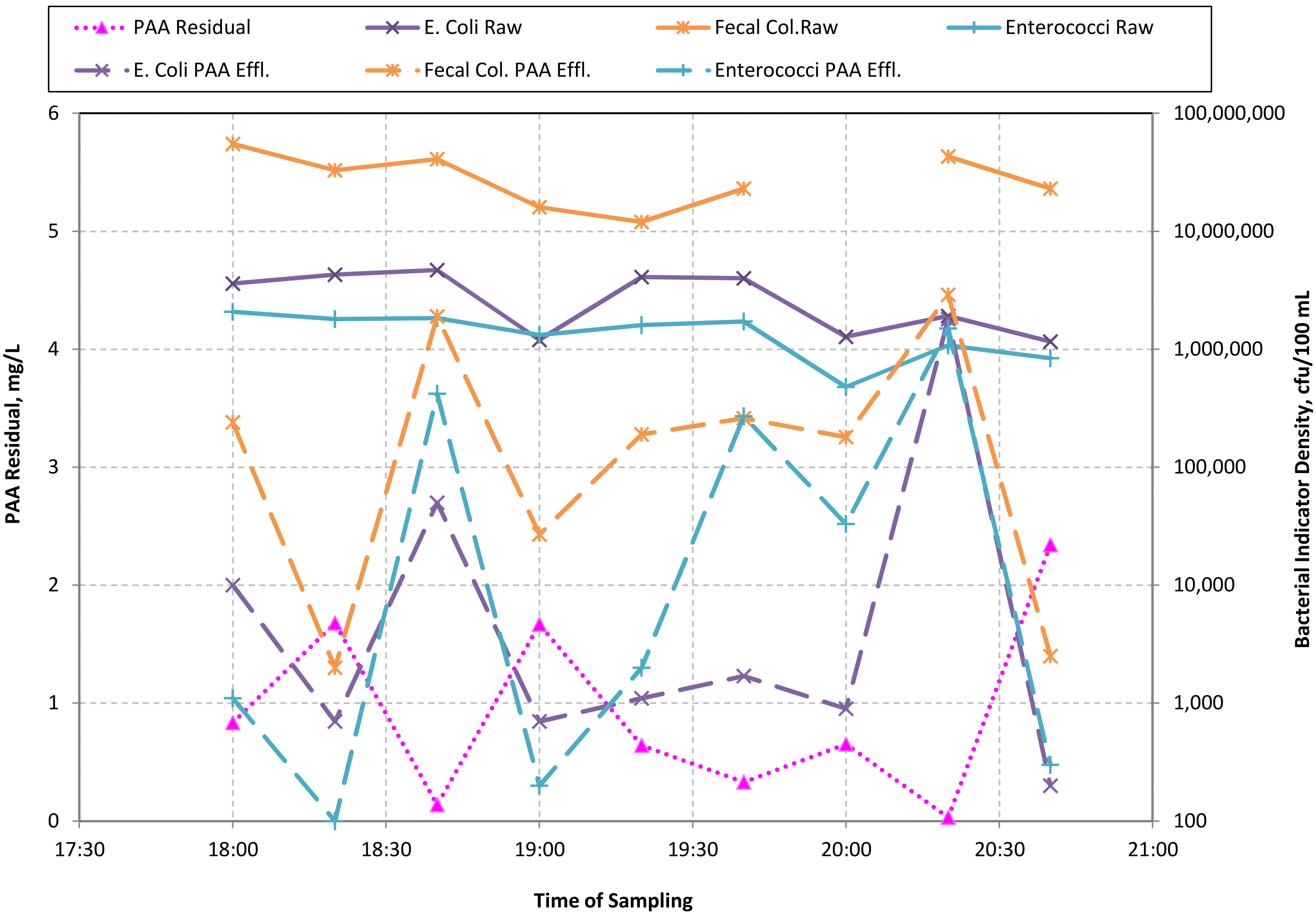


Figure 7-14. Storm 7 (9/10/2015). PAA Performance (No Pre-treatment)

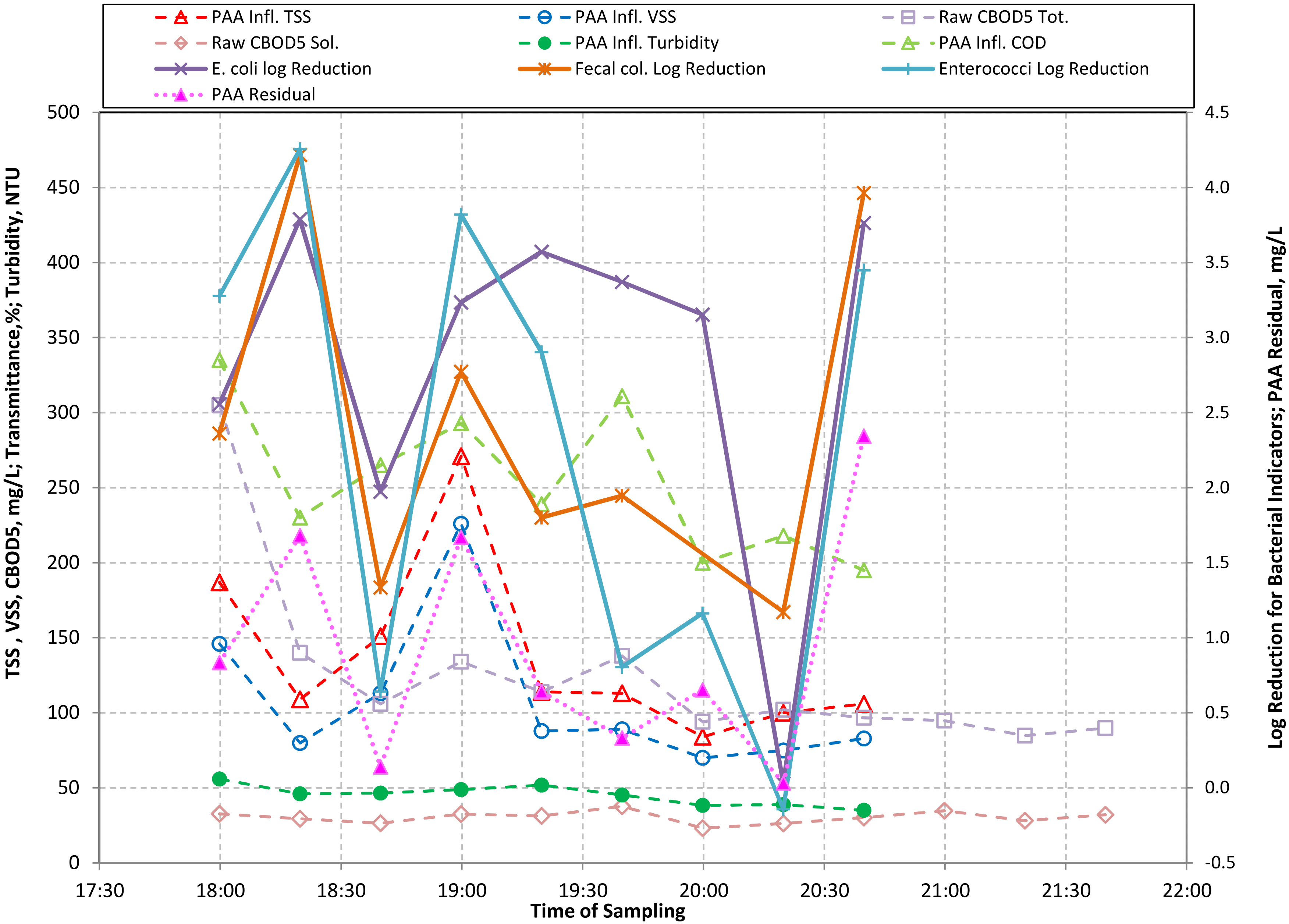


Figure 7-15. Storm 7 (9/10/2015). PAA Performance (No Pre-treatment)

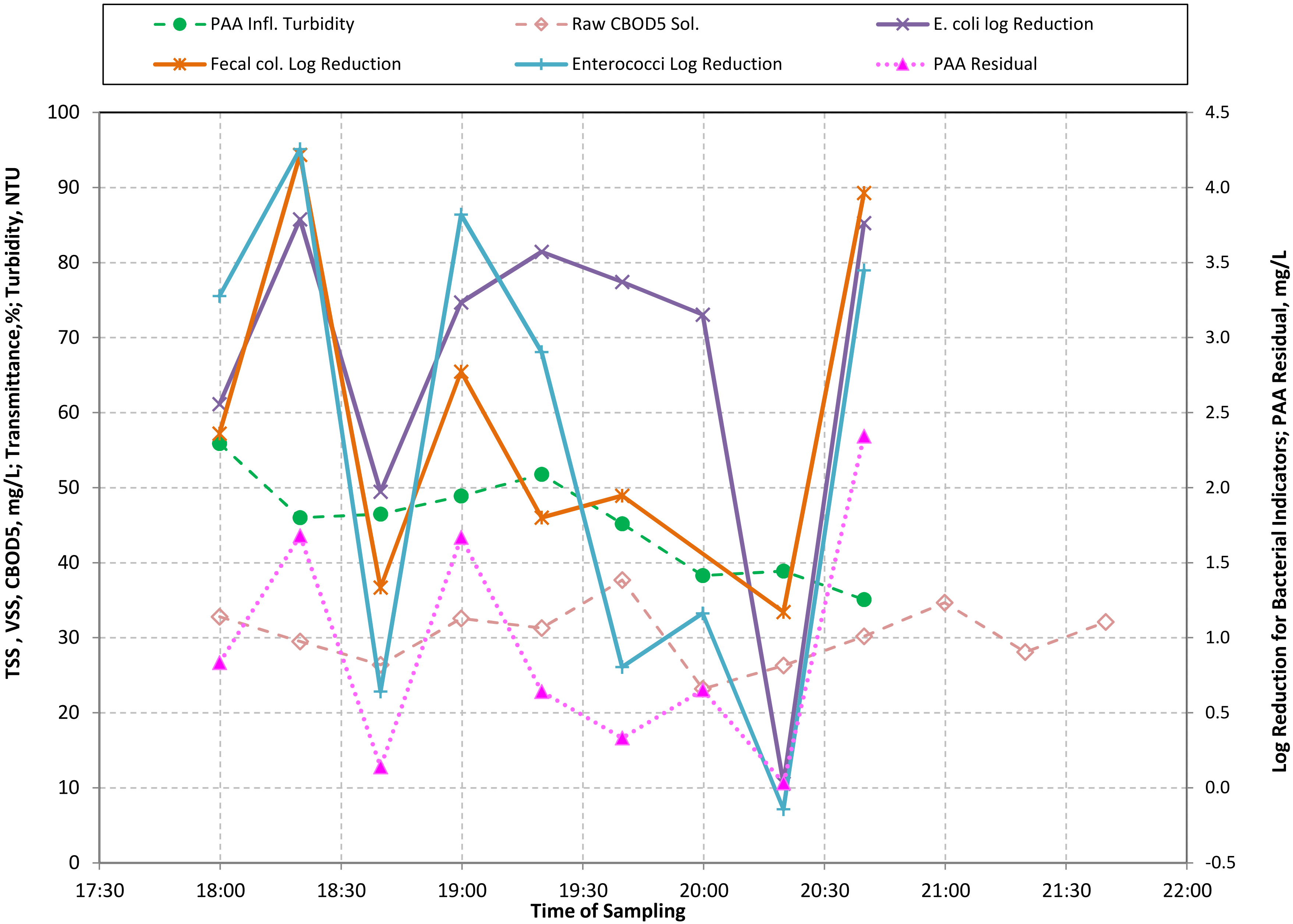


Figure 8-1. Storm 8 (10/15/2015). Raw TSS Characteristics

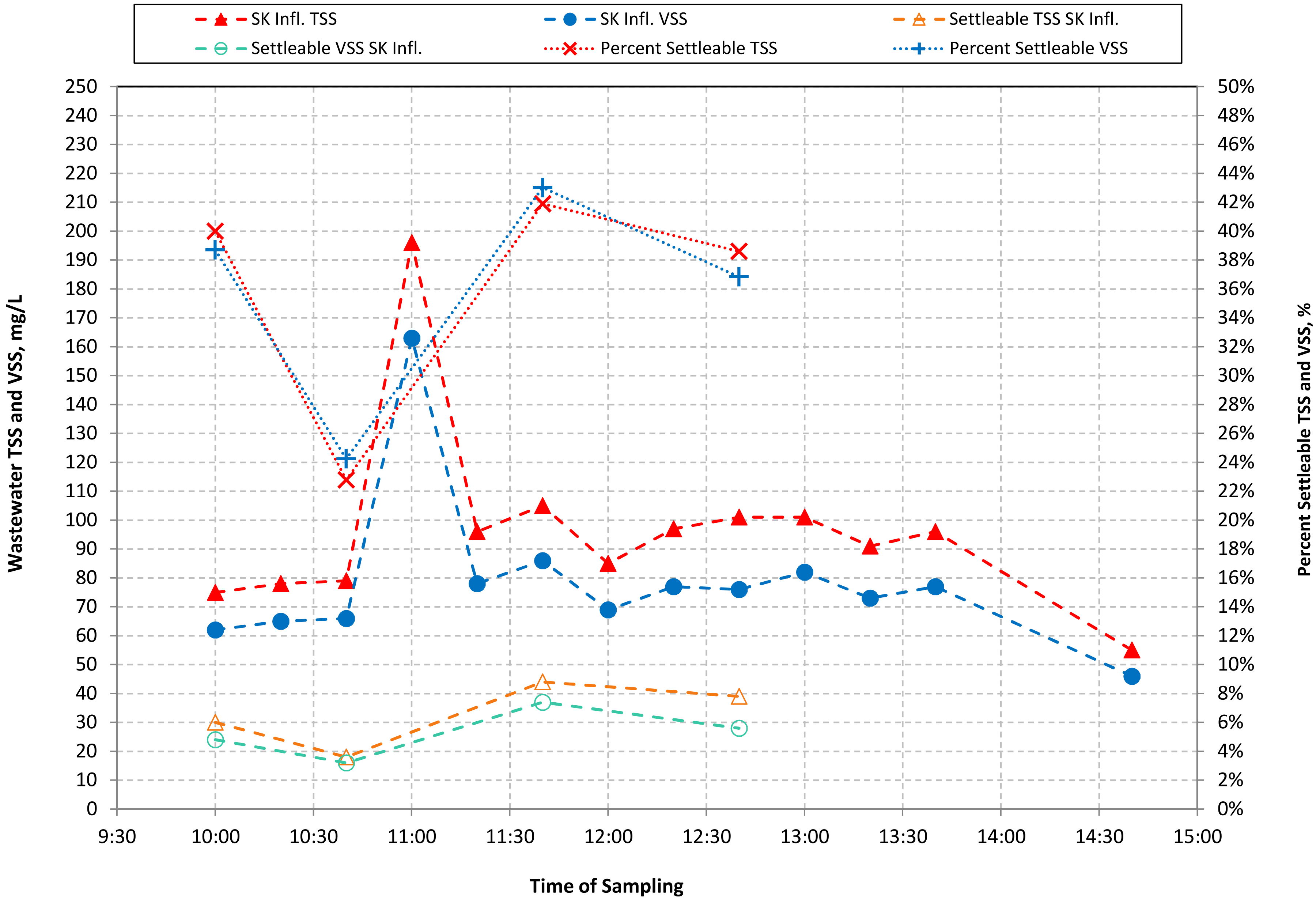


Figure 8-2. Storm 8 (10/15/2015). Raw TSS Characteristics

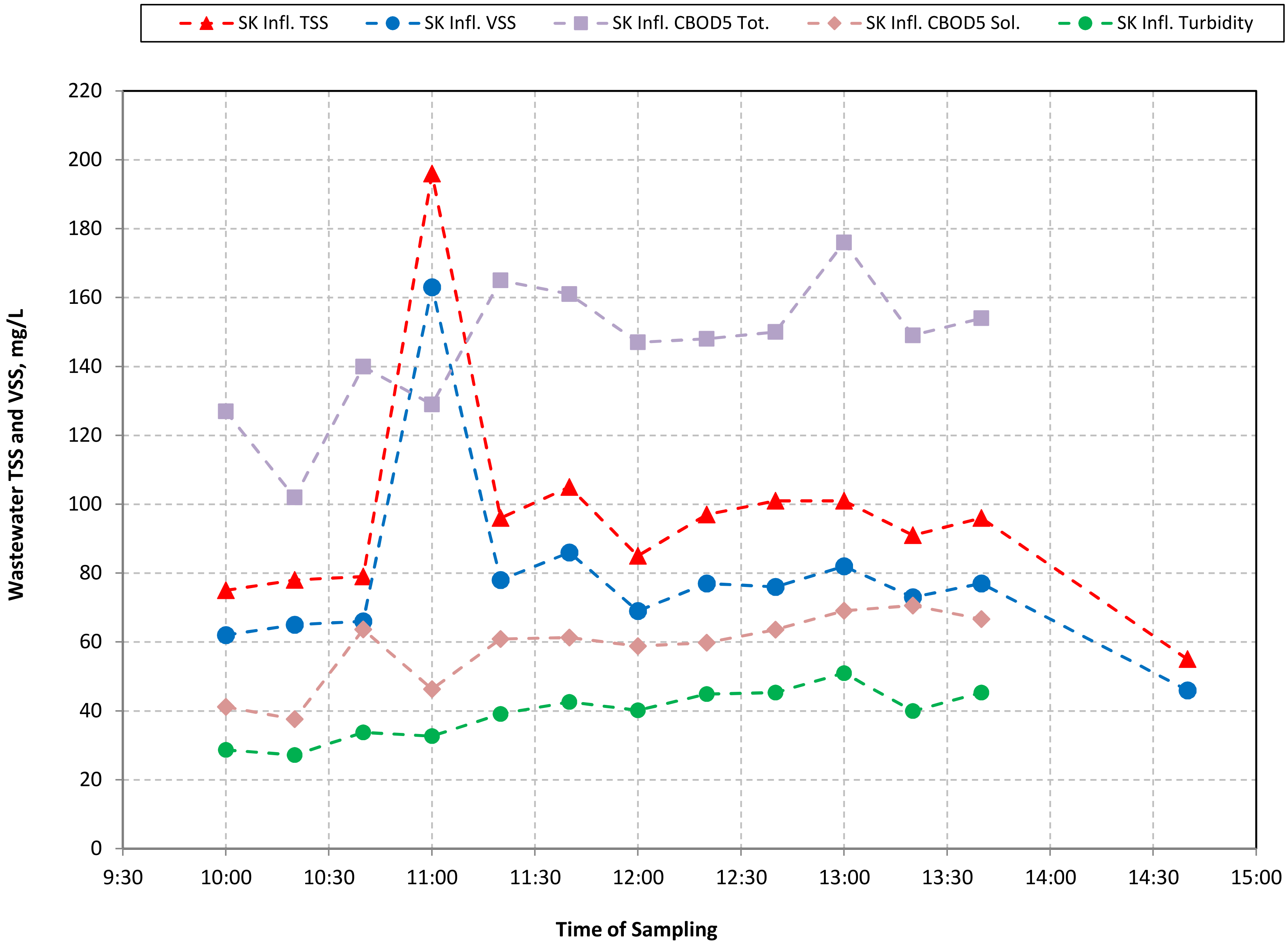
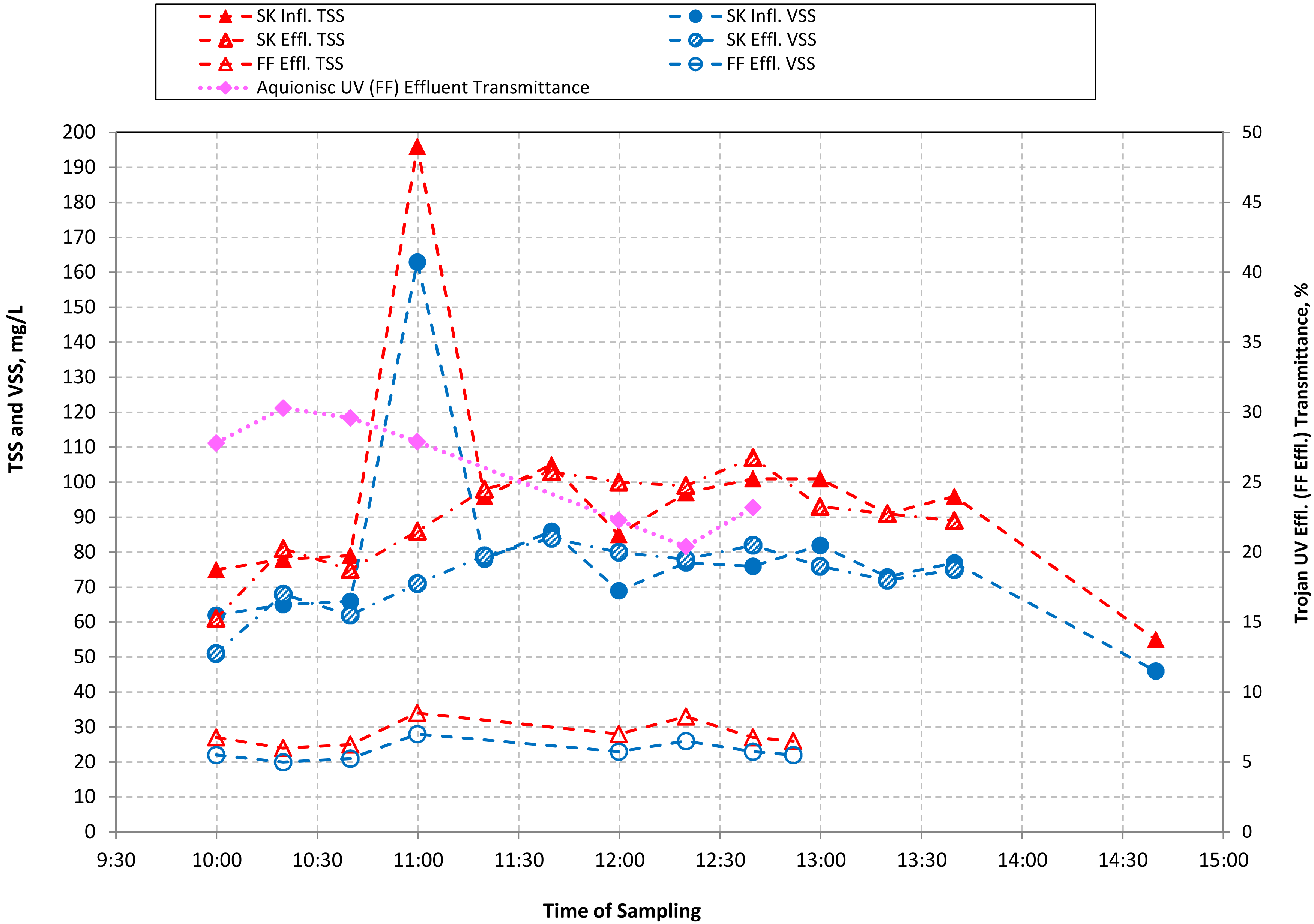


Figure 8-3. Storm 8 (10/15/2015). Storm King and Flex Filter TSS Performance



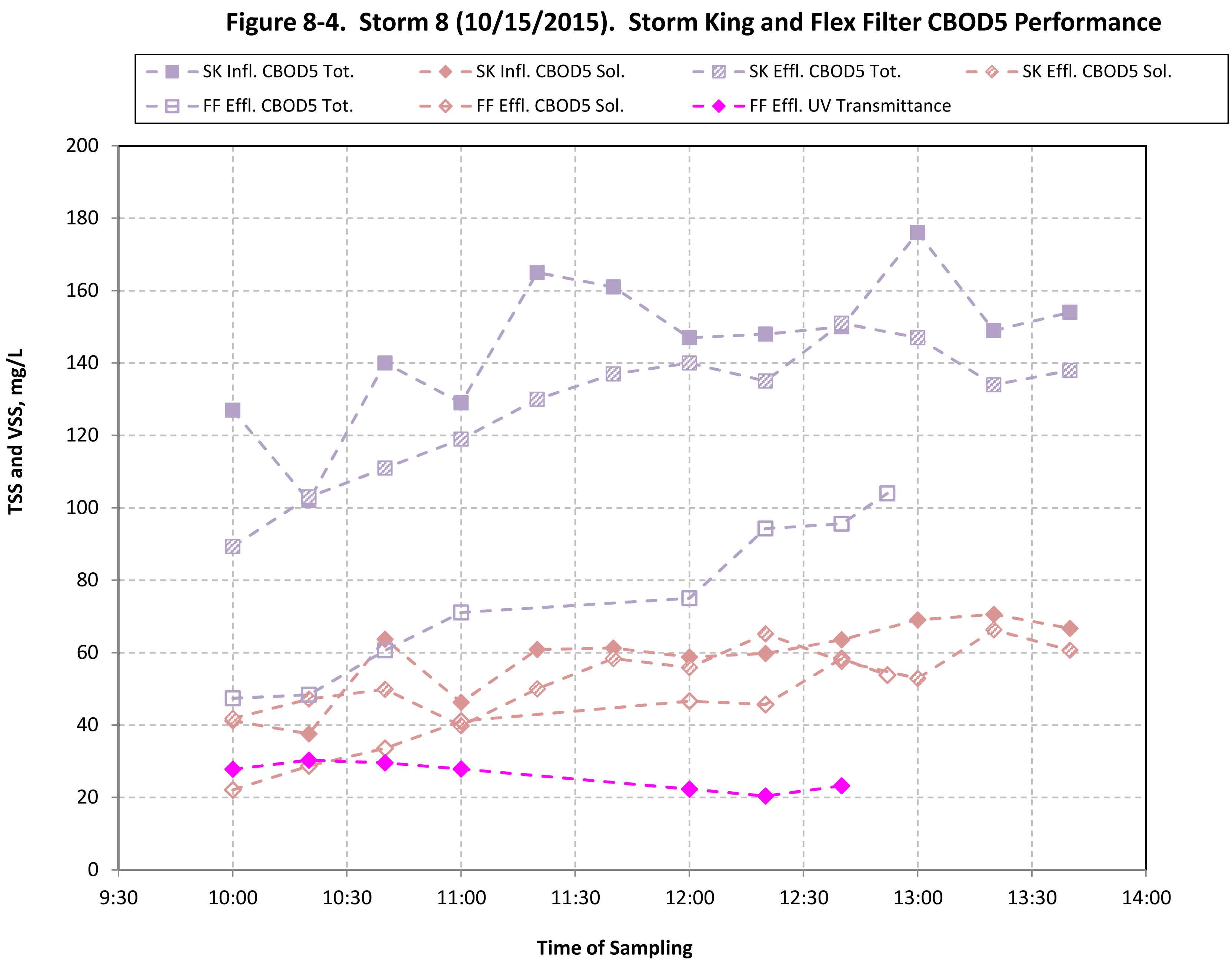


Figure 8-4. Storm 8 (10/15/2015). Storm King and Flex Filter CBOD5 Performance
SK Infl. CBOD5 Tot.
SK Infl. CBOD5 Sol.
SK Effl. CBOD5 Tot.
SK Effl. CBOD5 Sol.
FF Effl. CBOD5 Tot.
FF Effl. CBOD5 Sol.
FF Effl. UV Transmittance
TSS and VSS, mg/L
0
20
40
60
80
100
120
140
160
180
200
9:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
Time of Sampling

Figure 8-10. Storm 8 (10/15/2015). Aquionisc UV Performance (Following Flex Filter)

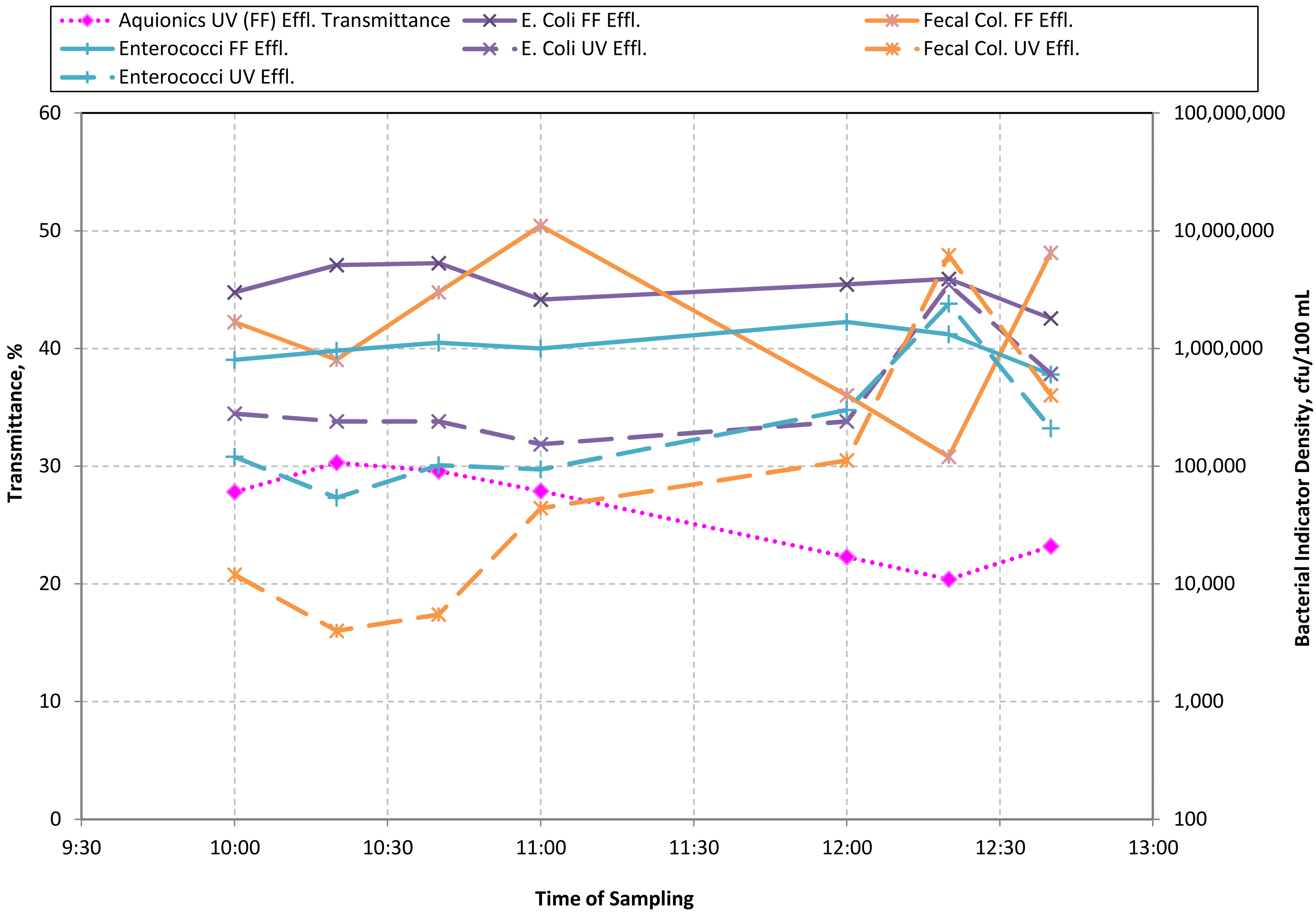
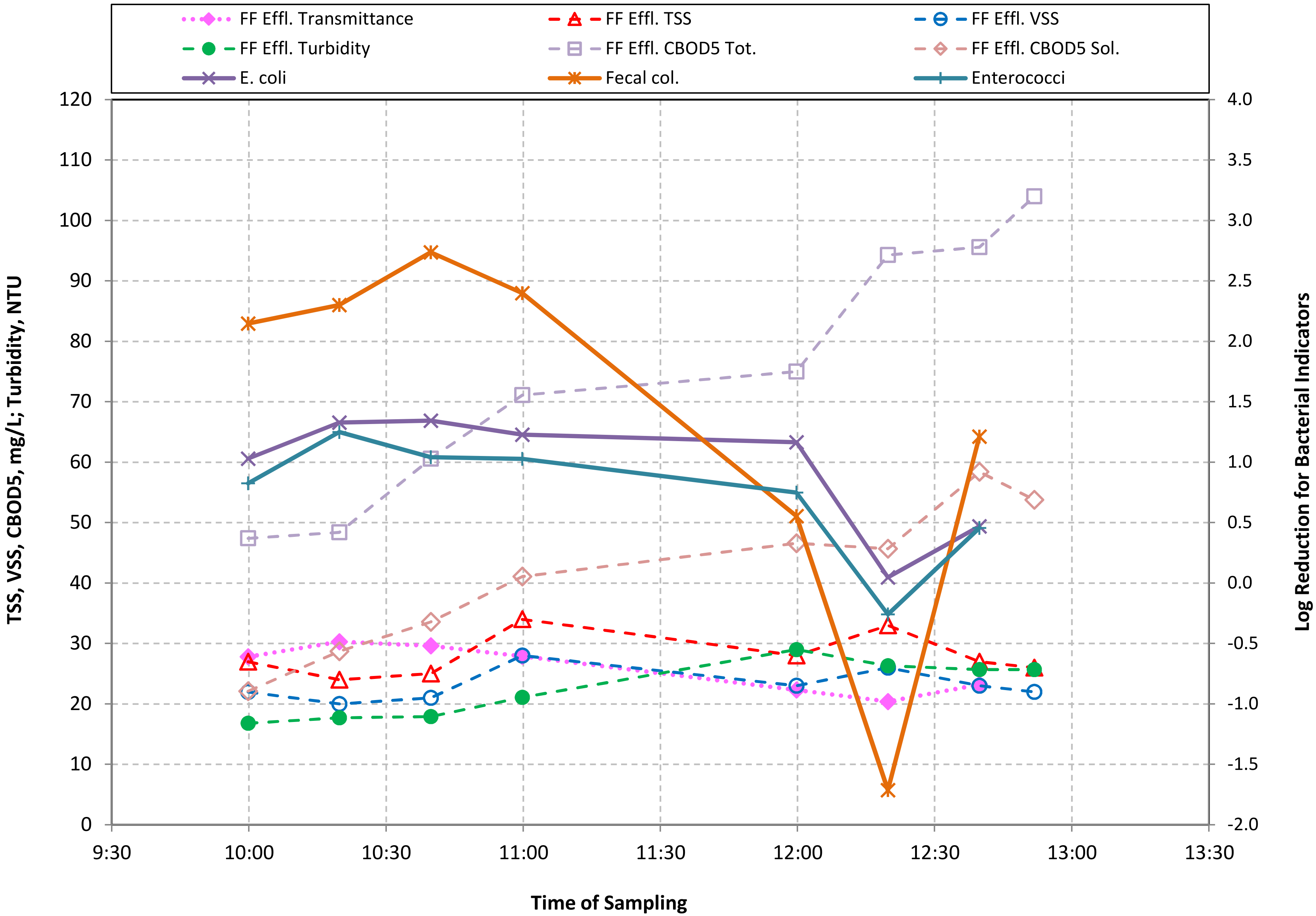


Figure 8-11. Storm 8 (10/15/2015). Aquionics UV Performance (Following Flex Filter)



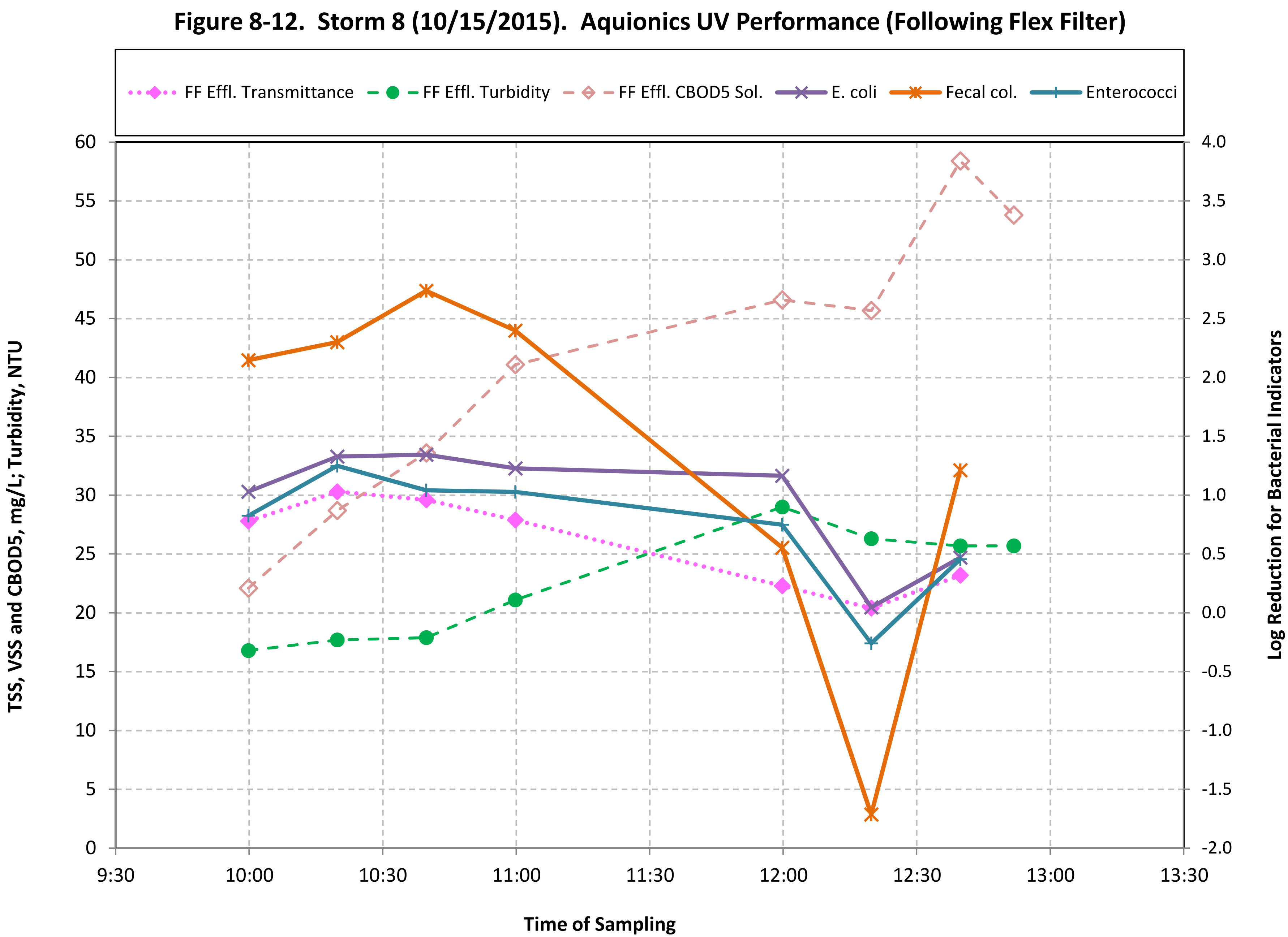
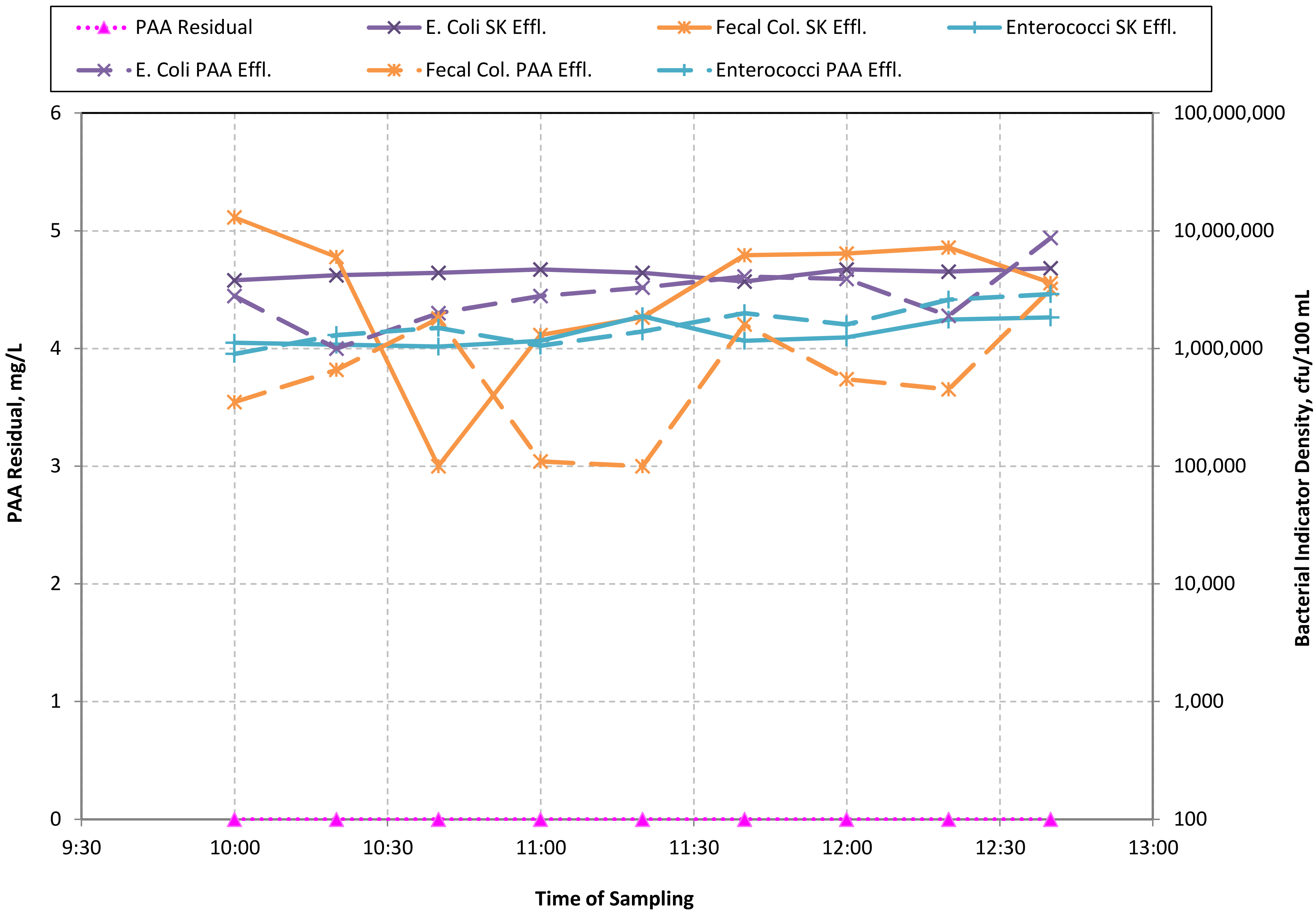


Figure 8-12. Storm 8 (10/15/2015). Aquionics UV Performance (Following Flex Filter)
FF Effl. Transmittance
FF Effl. Turbidity
FF Effl. CBOD5 Sol.
E. coli
Fecal col.
Enterococci
TSS, VSS and CBOD5, mg/L; Turbidity, NTU
Log Reduction for Bacterial Indicators
Time of Sampling
60
55
50
45
40
35
30
25
20
15
10
5
0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
9:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30

Figure 8-13. Storm 8 (10/15/2015). PAA Performance (Following Storm King)



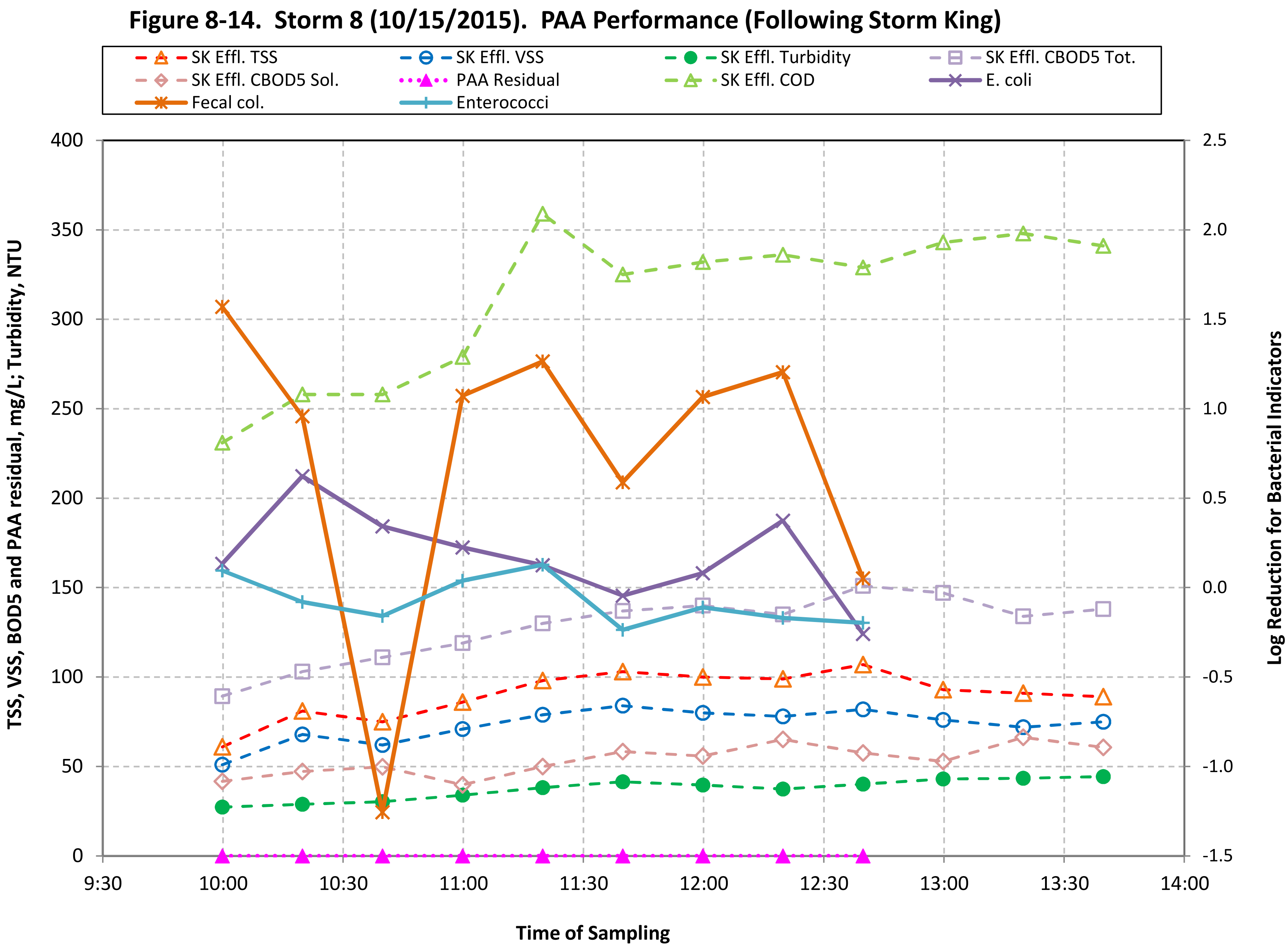


Figure 8-14. Storm 8 (10/15/2015). PAA Performance (Following Storm King)
SK Effl. TSS
SK Effl. VSS
SK Effl. Turbidity
SK Effl. CBOD5 Tot.
SK Effl. CBOD5 Sol.
PAA Residual
SK Effl. COD
E. coli
Fecal col.
Enterococci
TSS, VSS, BOD5 and PAA residual, mg/L; Turbidity, NTU
Log Reduction for Bacterial Indicators
Time of Sampling
0
50
100
150
200
250
300
350
400
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
9:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00

Figure 8-15. Storm 8 (10/15/2015). PAA Performance

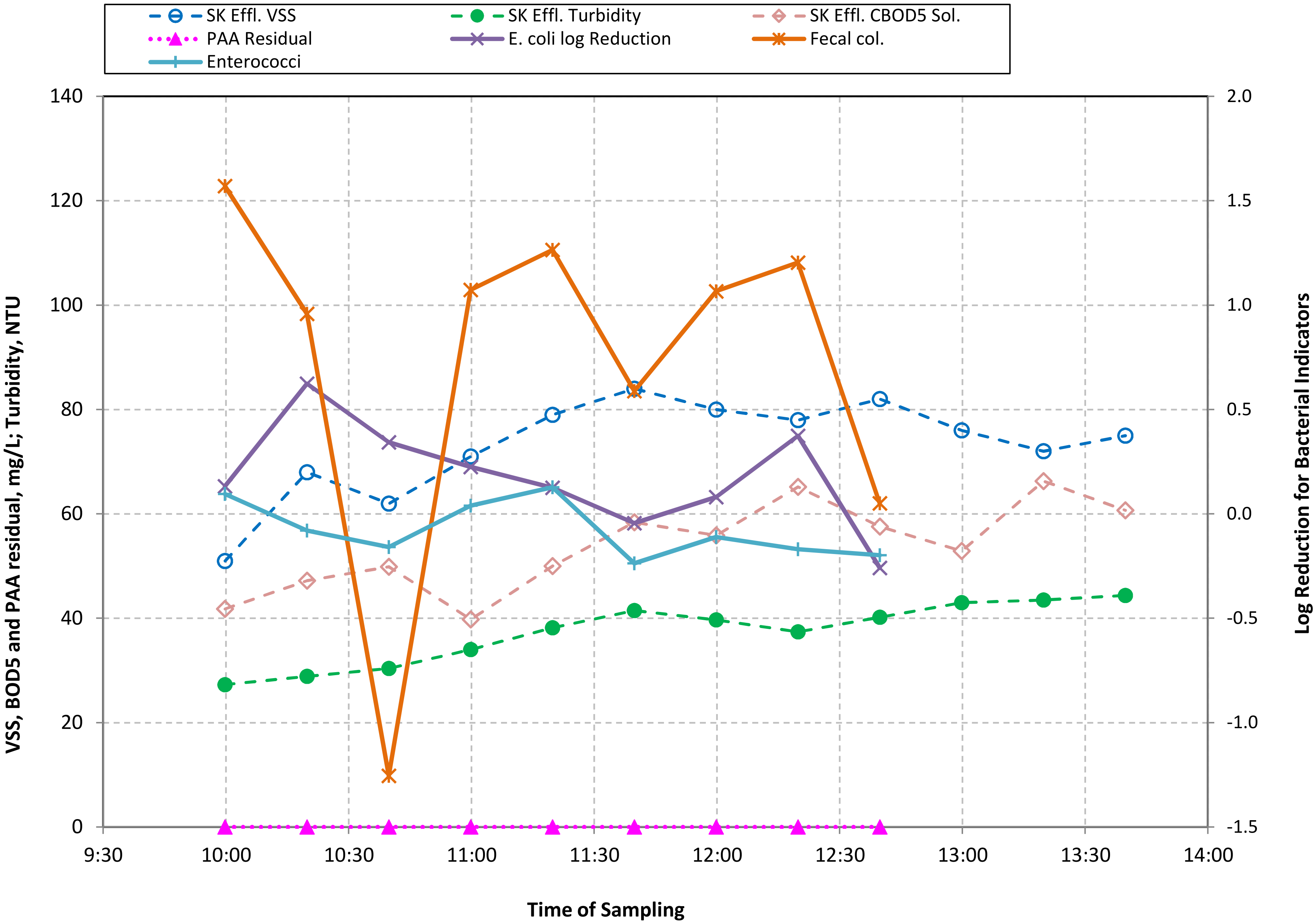


Figure 9-1. Storm 9 (10/27/2015). Raw (Terre Kleen Influent) TSS Characteristics

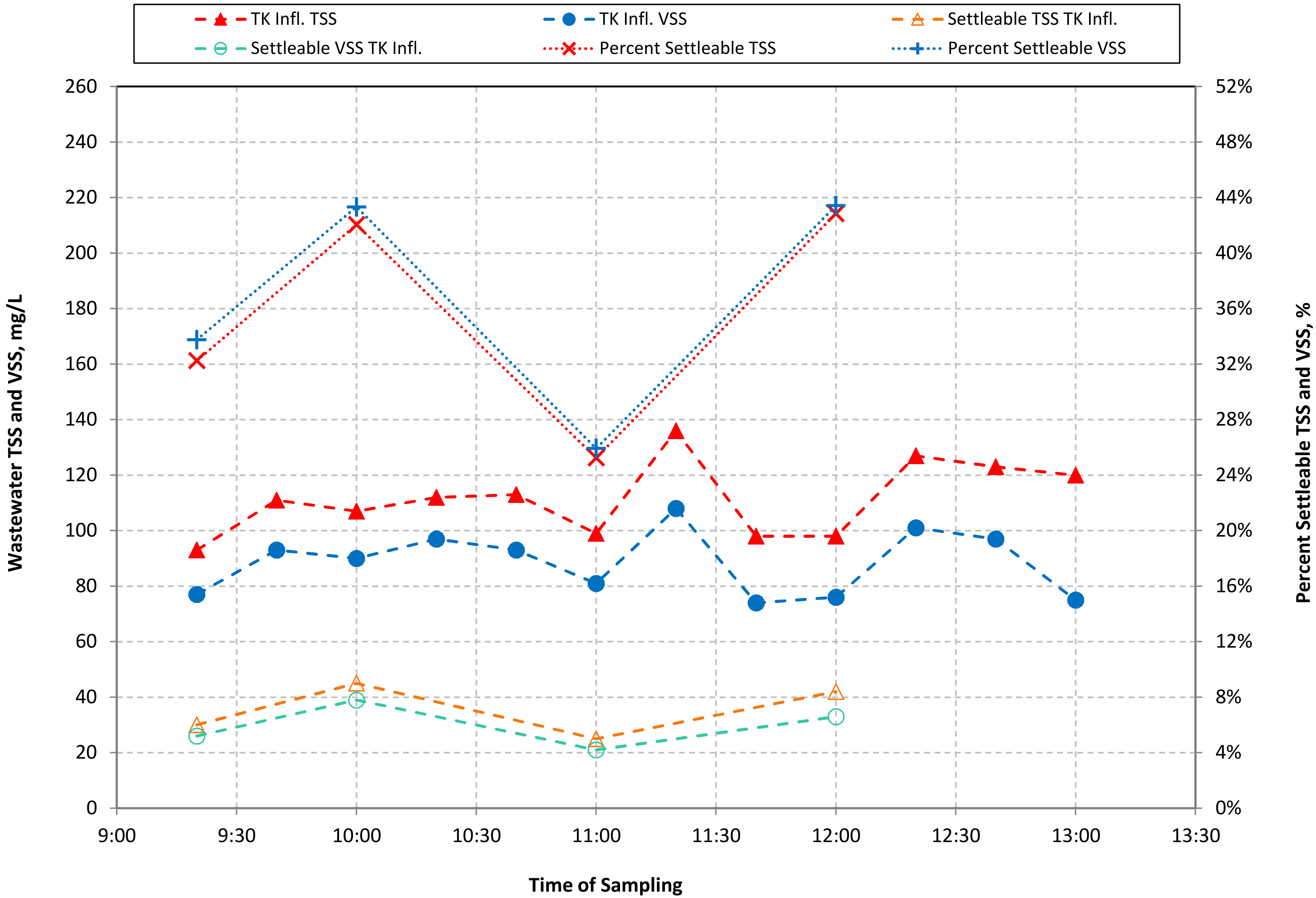


Figure 9-2. Storm 9 (10/27/2015). Raw (Terre Kleen Influent)TSS Characteristics

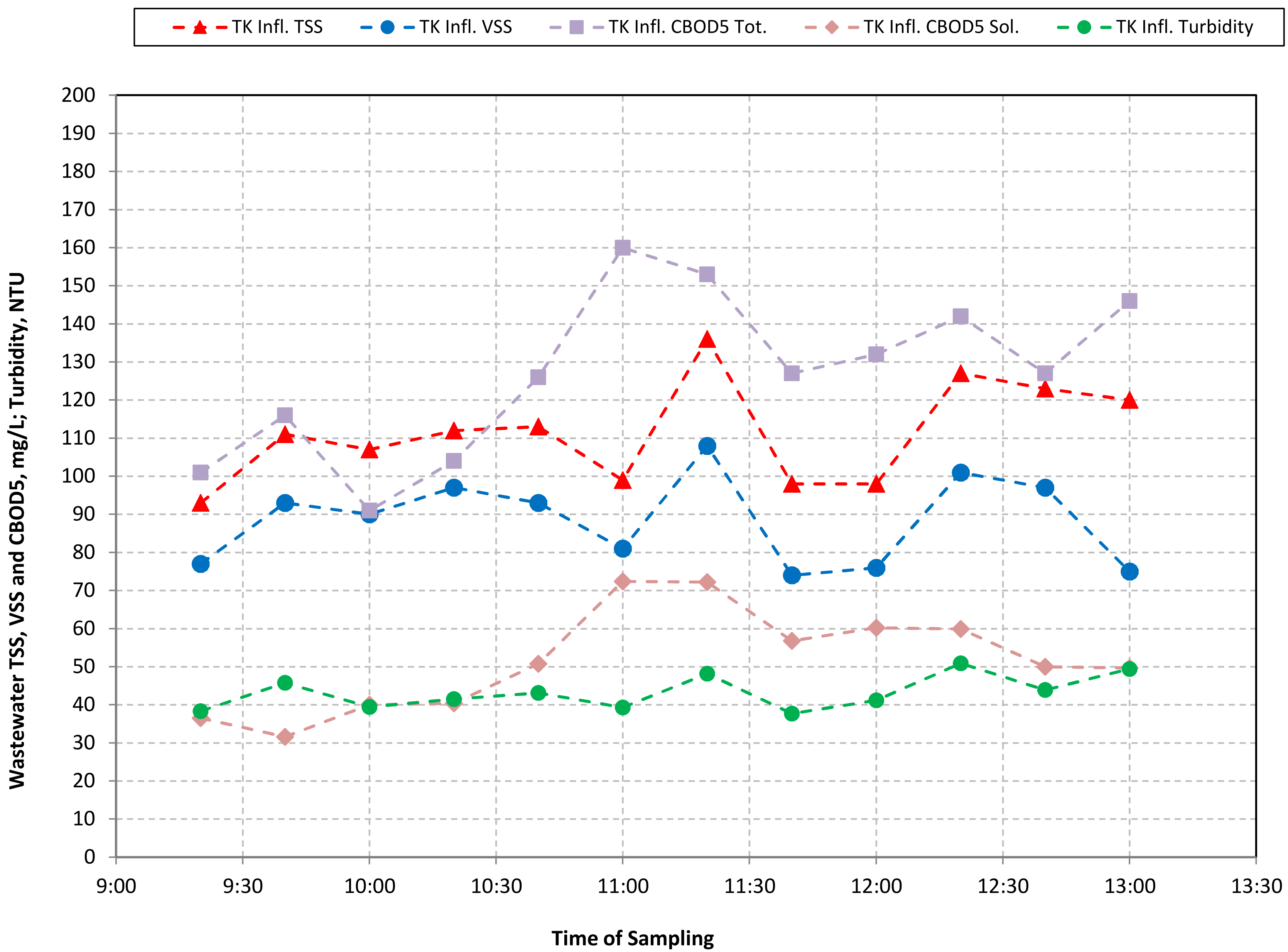


Figure 9-3. Storm 9 (10/27/2015). Terre Kleen and Flex Filter TSS Performance

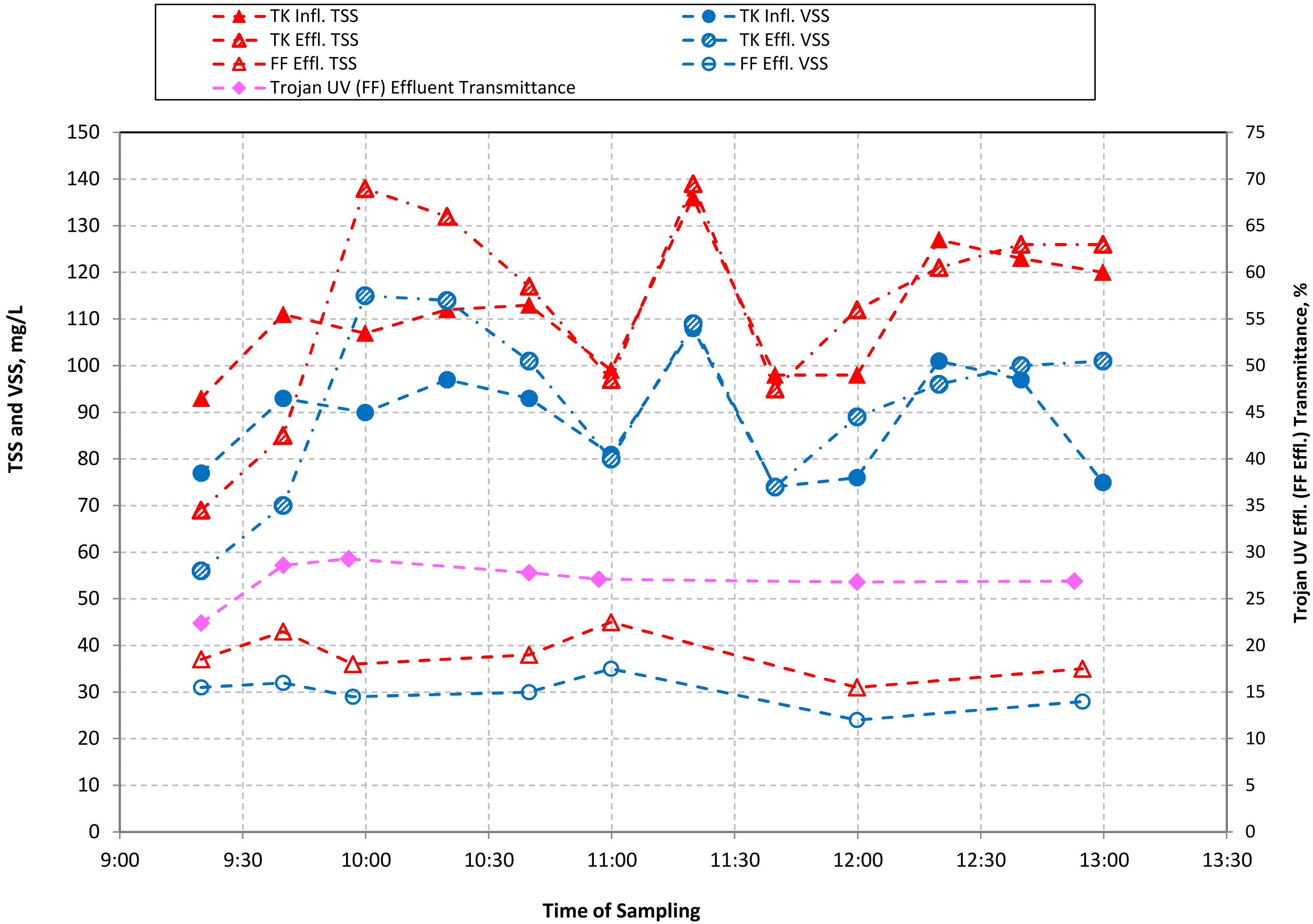


Figure 9-4. Storm 9 (10/27/2015). Terre Kleen and Flex Filter CBOD5 Performance

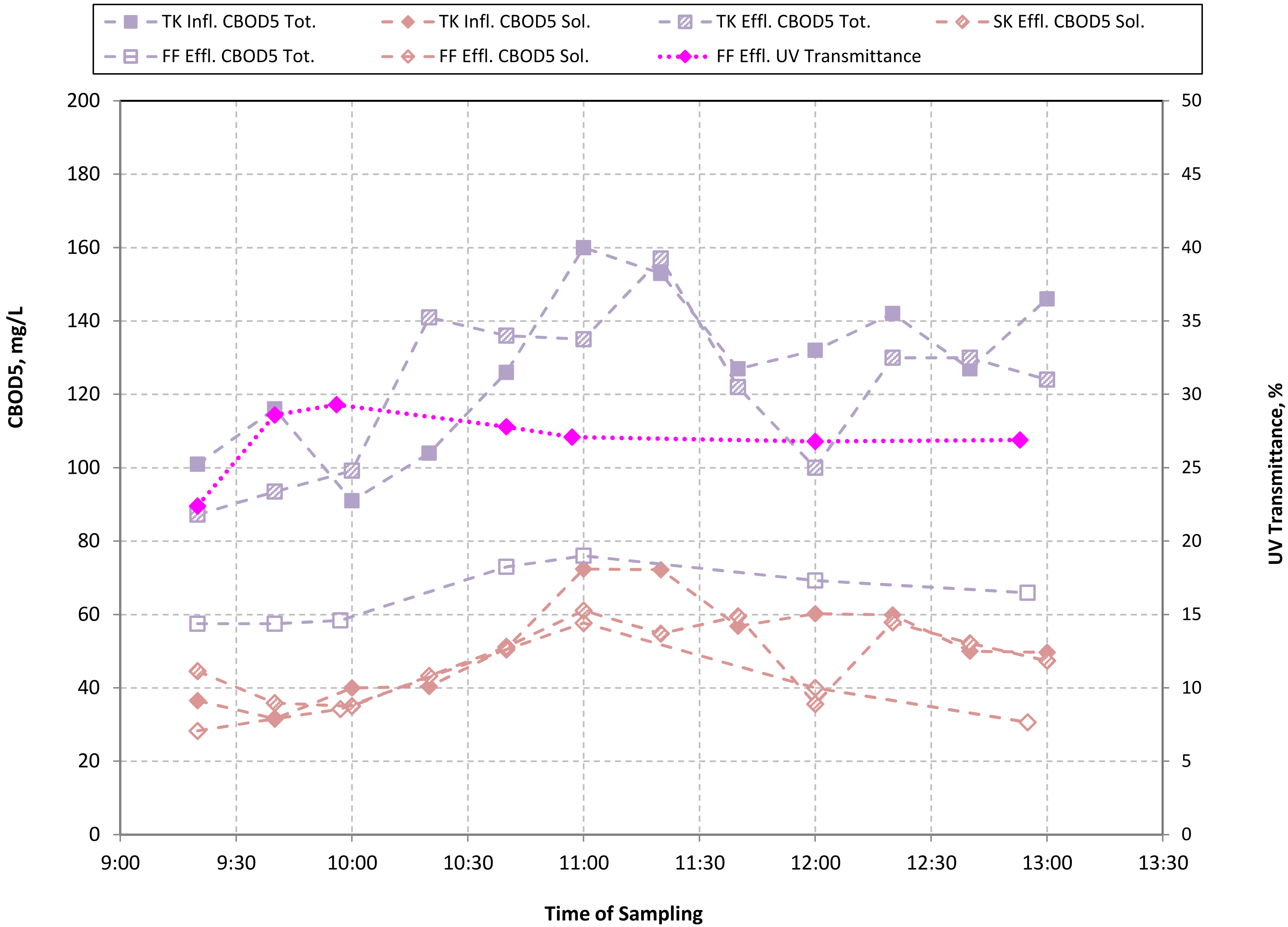


Figure 9-10. Storm 9 (10/27/2015). Trojan UV Performance (Following Flex Filter)

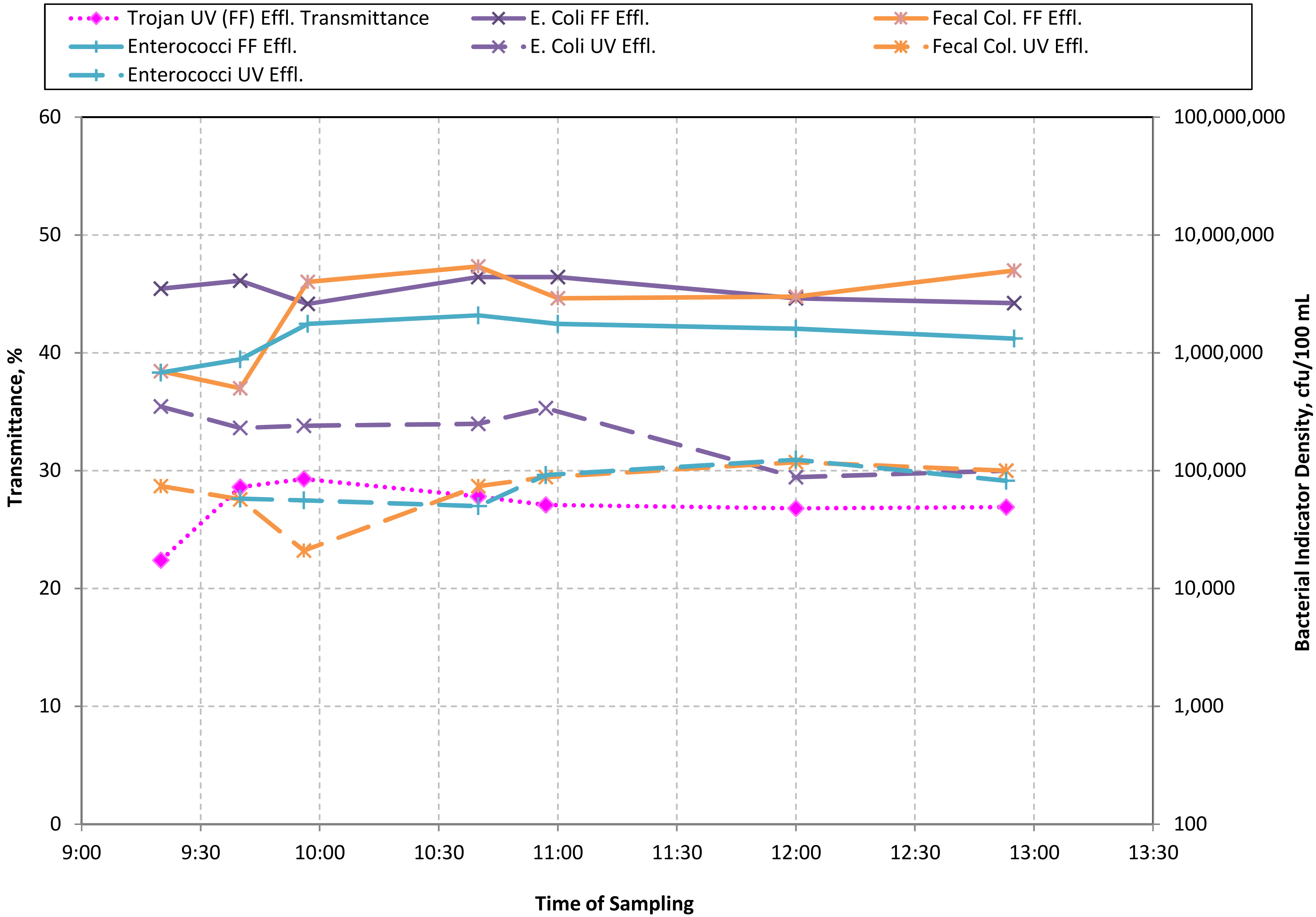


Figure 9-11. Storm 9 (10/27/2015). Trojan UV Performance (Following Flex Filter)

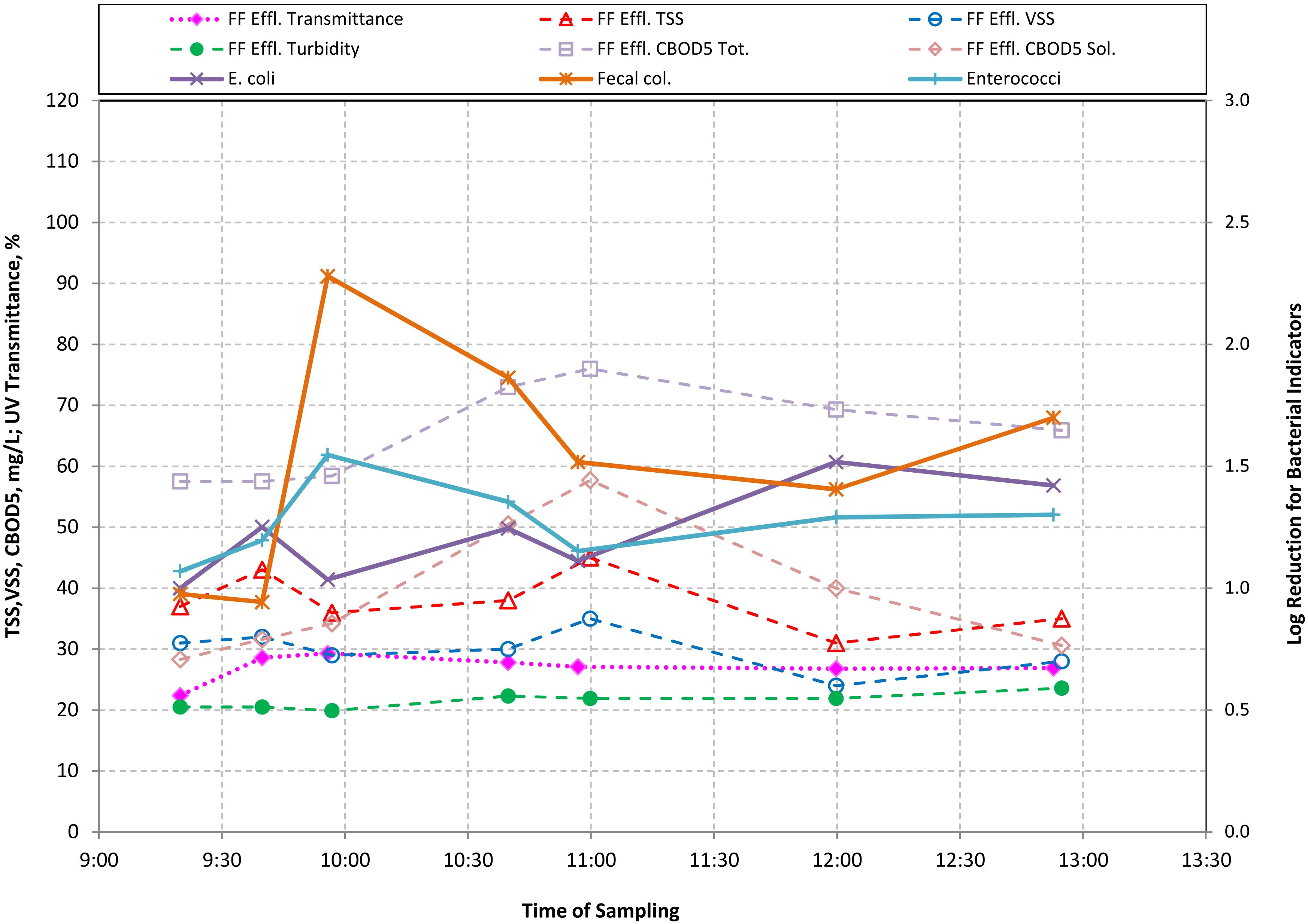


Figure 9-12. Storm 9 (10/27/2015). Trojan UV Performance (Following Flex Filter)

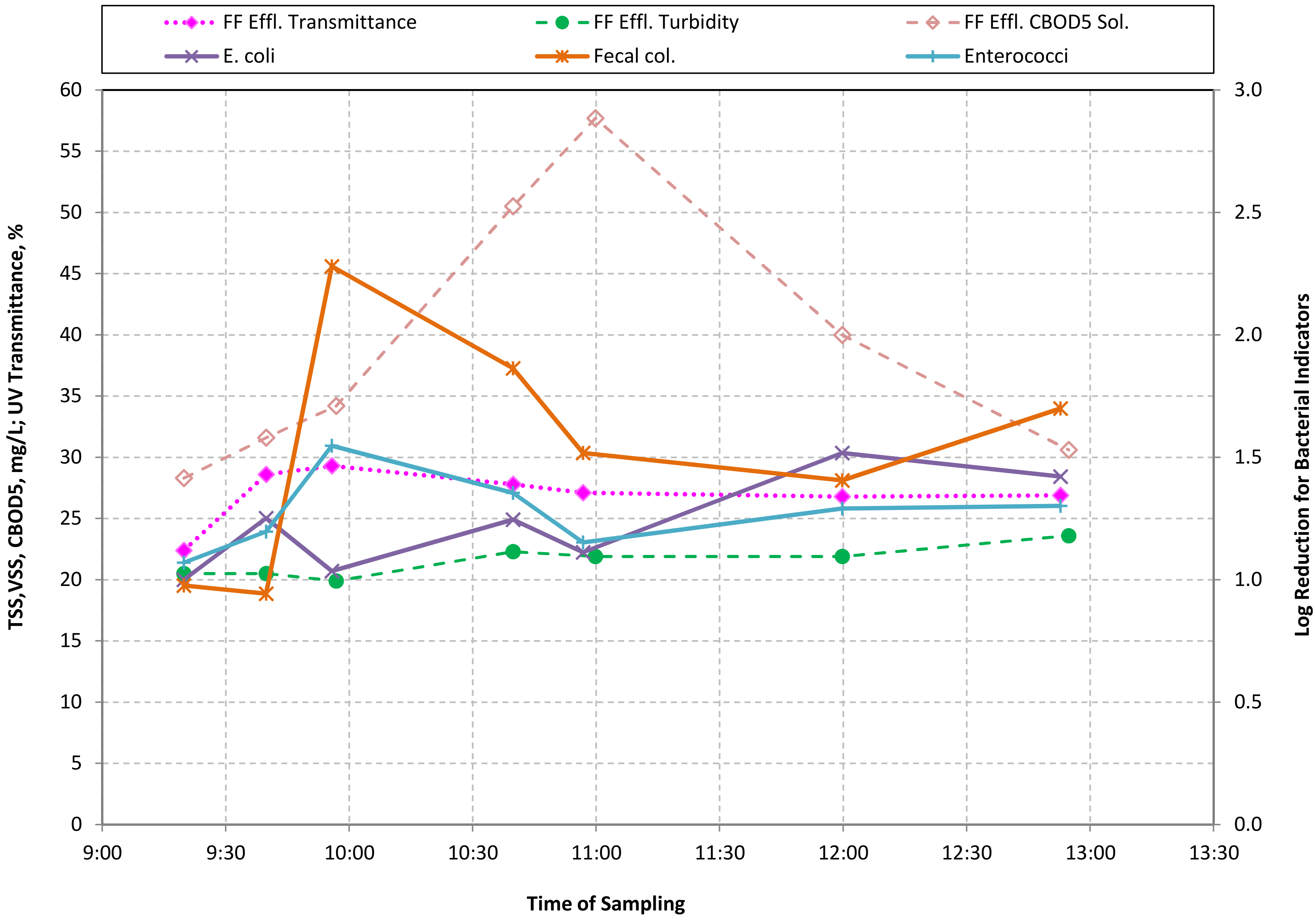
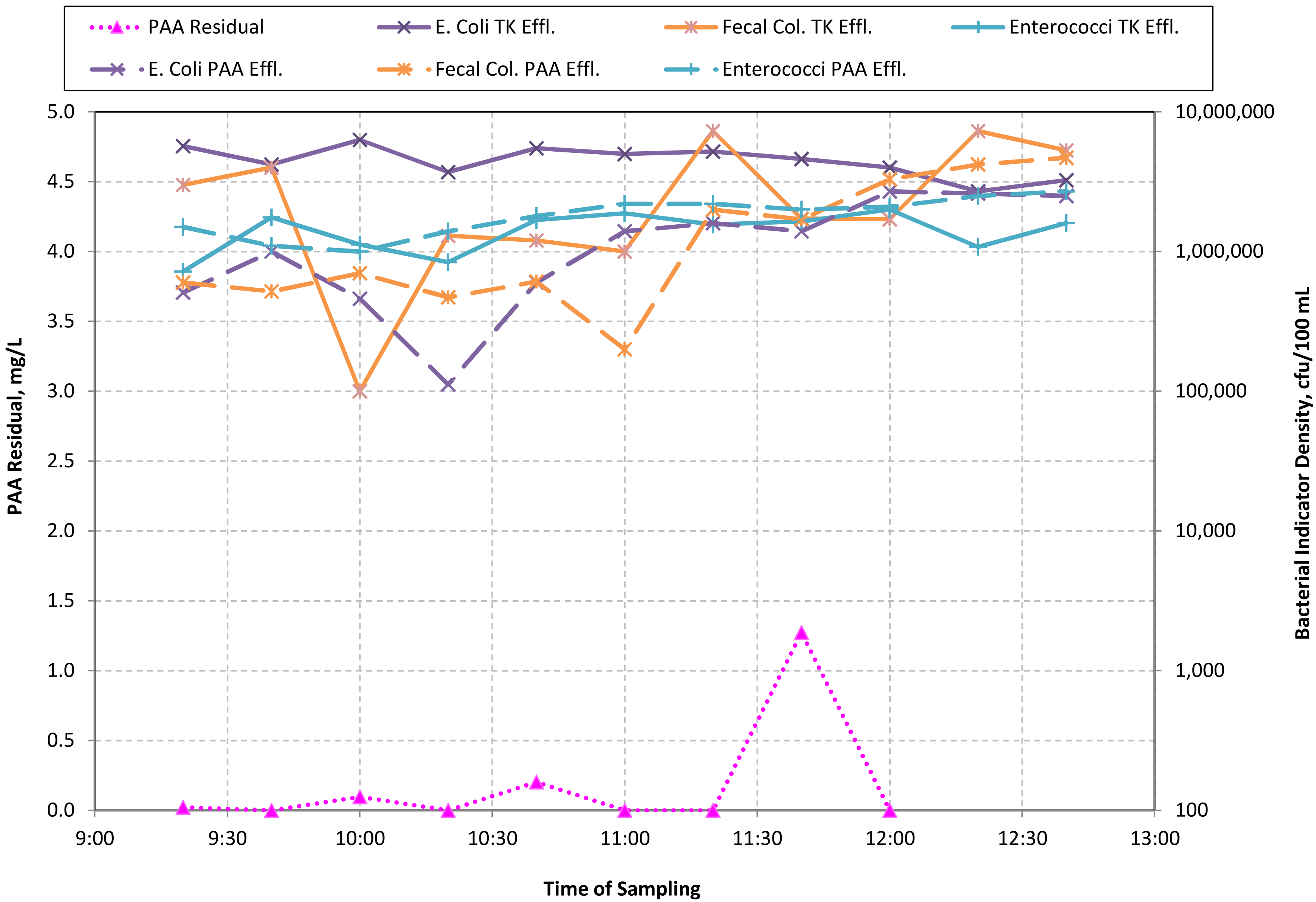


Figure 9-13. Storm 9 (9/27/2015). PAA Performance (Following Terre Kleen)



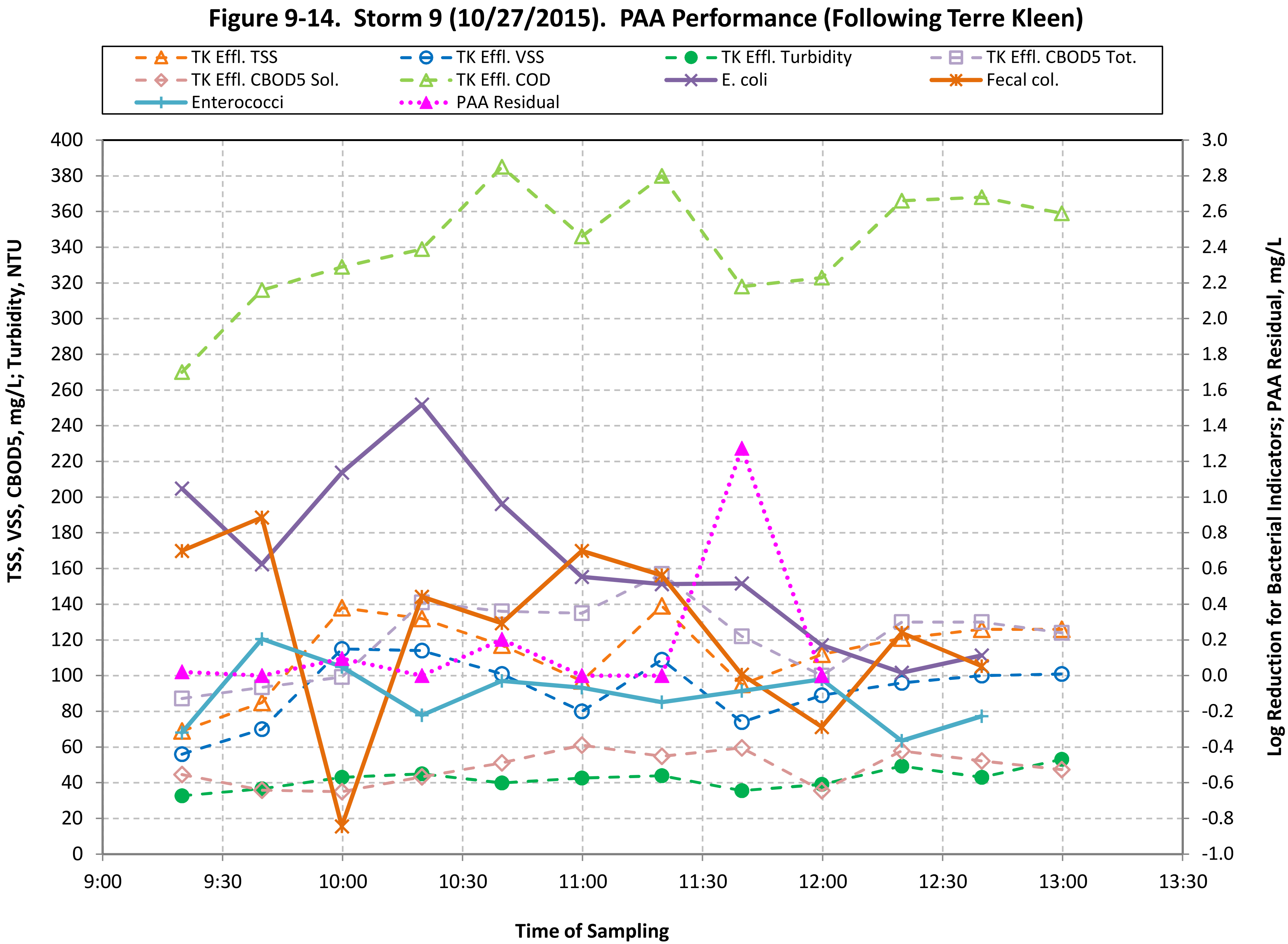
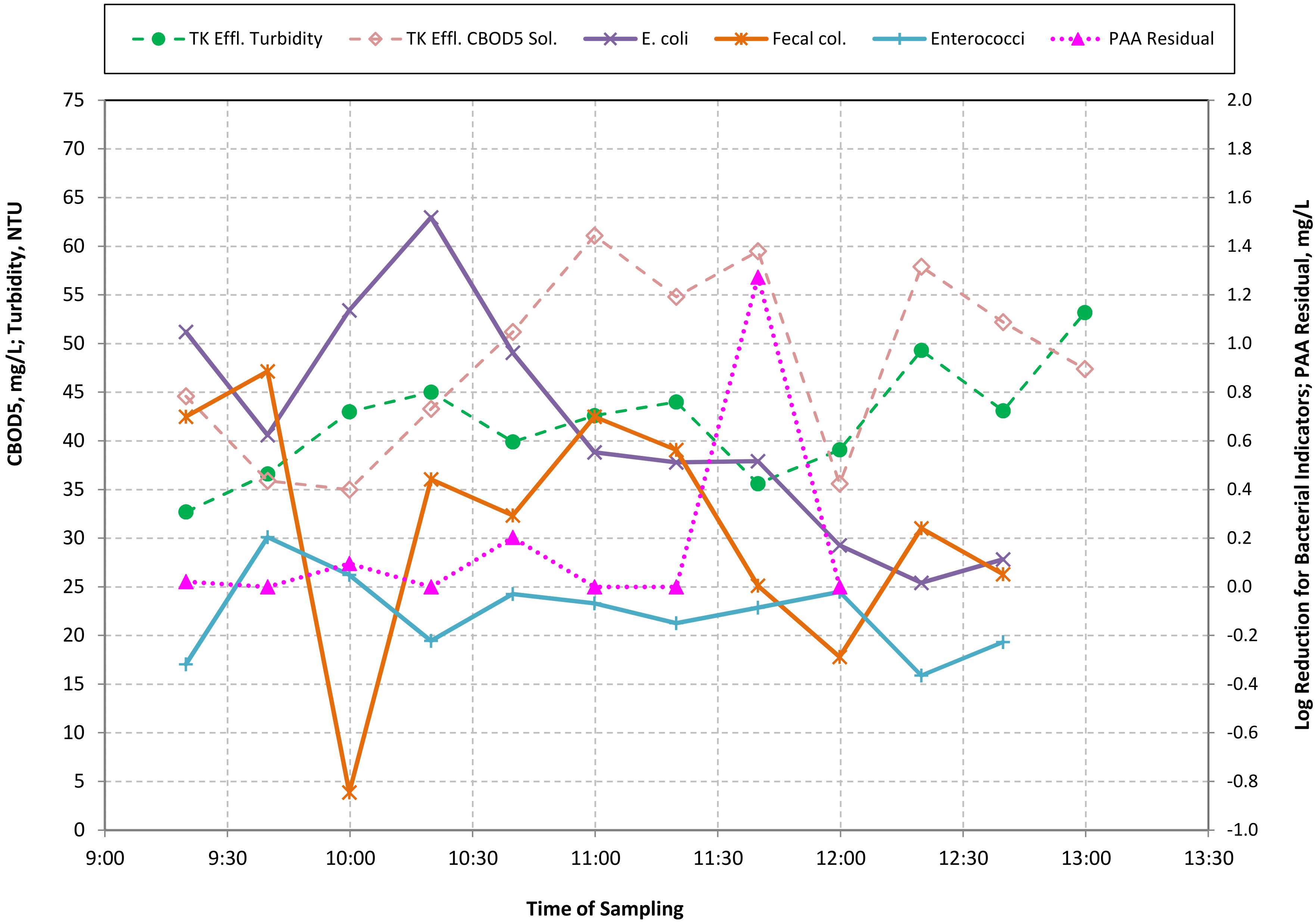


Figure 9-14. Storm 9 (10/27/2015). PAA Performance (Following Terre Kleen)
TK Effl. TSS
TK Effl. VSS
TK Effl. Turbidity
TK Effl. CBOD5 Tot.
TK Effl. CBOD5 Sol.
TK Effl. COD
E. coli
Fecal col.
Enterococci
PAA Residual
TSS, VSS, CBOD5, mg/L; Turbidity, NTU
Log Reduction for Bacterial Indicators; PAA Residual, mg/L
Time of Sampling
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
9:00
9:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30

Figure 9-15. Storm 9 (10/27/2015). PAA Performance (Following Terre Kleen)



APPENDIX C

Enhanced High Rate Treatment Data from WWETCO

Please note, the information contained in this appendix is provided as supplied by the manufacturer. The information presented herein is independent of the Wet Weather Flow Treatment and Disinfection Demonstration Project and may or may not be reflective of the demonstration project results and conclusions.

THIS PAGE INTENTIONALLY LEFT BLANK

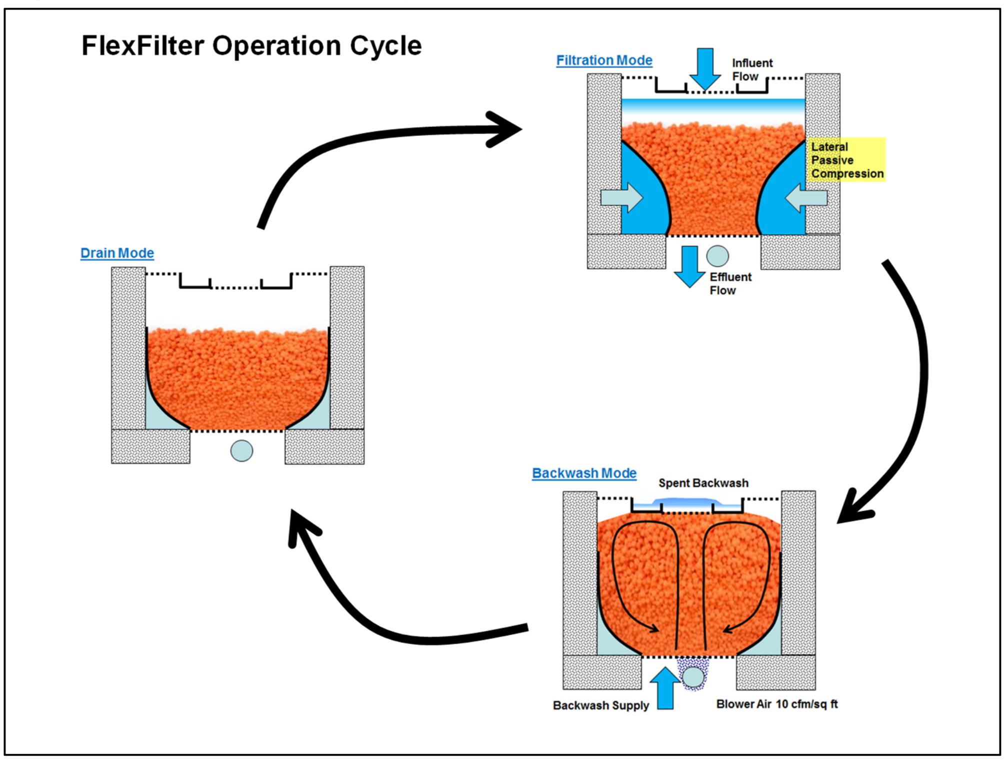
Enhanced High Rate Treatment (EHRT) for CSO, SSO, Stormwater Treatment & WWTP Effluent Polishing WWETCO a subsidiary of WesTech Engineering, Inc.

WWETCO FlexFilter™ Technology

The FlexFilter is a compressible media filtration technology. It was developed specifically for treatment of wet weather sewer overflow problems and was borne from a $20 million decade-long project including a 5-year full-scale applied research operation and testing program in Columbus, GA. The experience gained from this program has been incorporated into the development of the FlexFilter technology and its design for satellite treatment. This national demonstration project was peer reviewed by a team of experts under the auspices of by the Water Environment Research Foundation (WERF) with Quality Assurance Project Planning (QAPP) oversight by the US EPA Office of Research and Development (ORD).

The FlexFilter technology uses passive lateral forces of the incoming water against an engineered fabric (bladder) producing a cone-shaped media bed. This creates a high porosity gradient from large to very small pores in the direction of the flow. Large and small particles are removed in a stratified fashion as the flow passes through the media bed. The filter bed operation is shown in Figure 1.

Figure 1 – Filter Operation Cycle

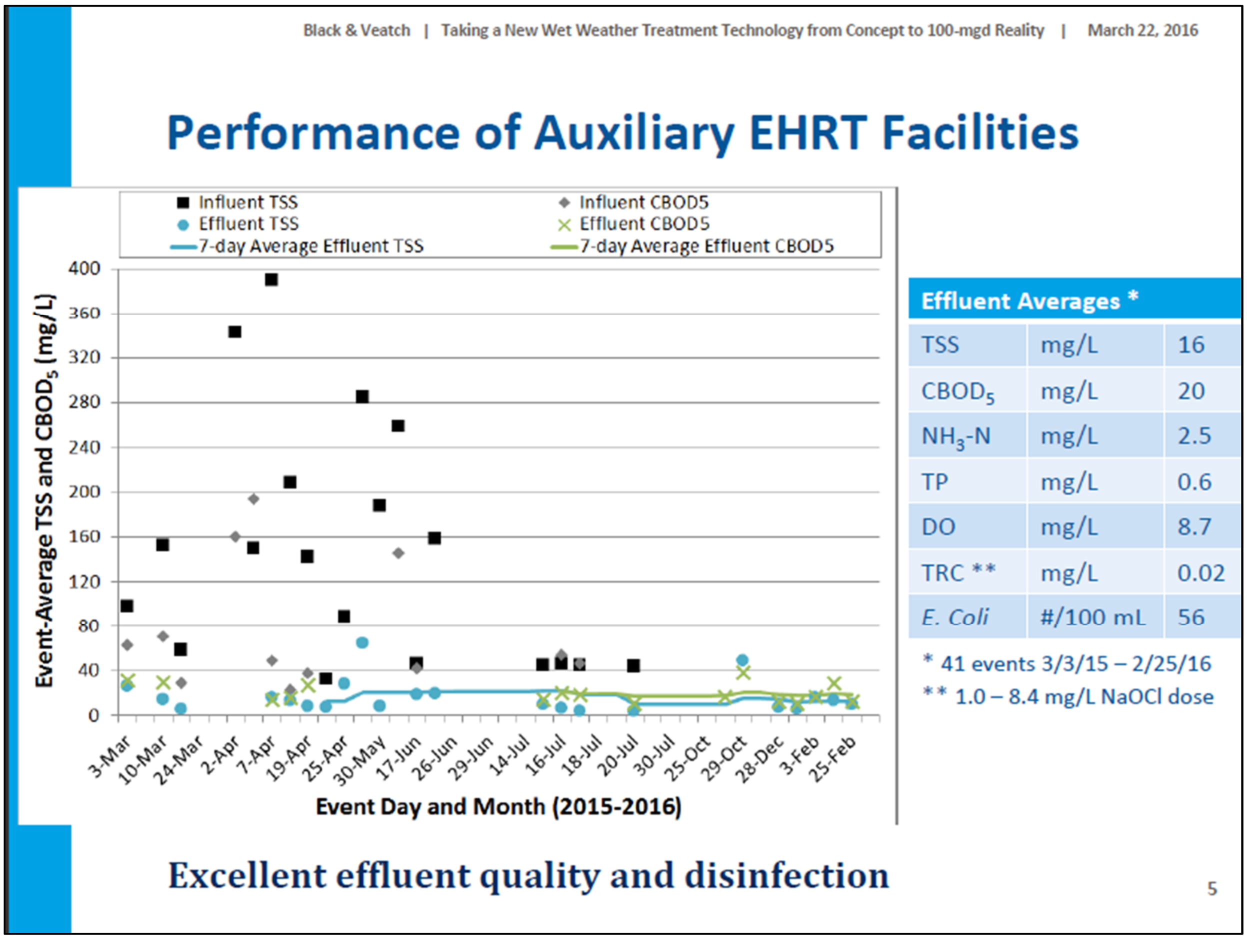


Performance Experience

When treating CSOs, the FlexFilter can be hydraulically loaded at high solids concentrations and produce an effluent of only small particle size with low TSS concentration. Chemicals such as metal salt flocculants are not required for solids removal. The solids removed from the physical straining process are returned as food to the biological process or to the downstream sanitary sewer interceptor in the case of satellite treatment. A summary of testing by the engineering community is displayed in Table 1.

First year operation results from the Springfield Ohio 100 MGD EHRT for CSO treatment is displayed in Figure 2. This facility is producing secondary standard effluent quality with an average TSS of 16 mg/l and an average BOD of 20 mg/l. Influent TSS and BOD to the EHRT facility have been as high as 400 mg/l and 200 mg/l event averages, respectively.

Figure 2 – Springfield, OH First Years Results



Because the effluent contains only small particles, the FlexFilter is amenable to UV as well as chemical disinfection. It has been found to require less than one-half the UV light intensity to meet E. coli effluent criteria compared to chemical EHRT treatment systems, as shown in Figure 3 for primary influent CSO treatment.

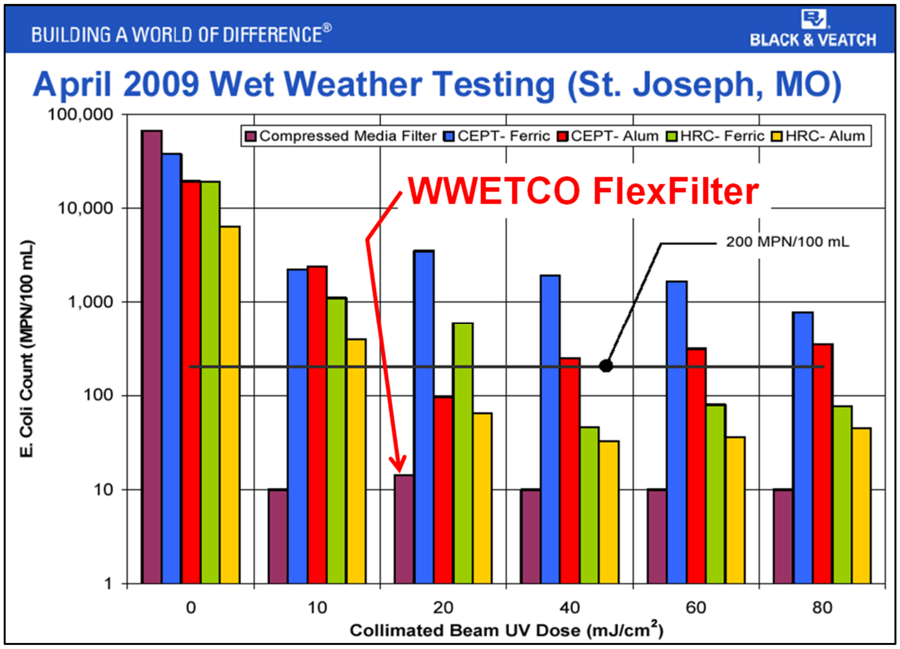
Table 1 - Summary of WWETCO Filter Performance by Wastewater Category

Pilot Study / Installation	Application	Parameter	Influent Avg. (Range) (mg/L)	% Removal Avg. (Range) (%)	Effluent Avg. (Range) (mg/L)
CSO, SSO or Primary Filtered Wastewaters					
Chesterfield, VA	*Primary Influent*	*TSS*	*177 (102-276)*	*89% (82-93%)*	*19 (11-35)*
Chesterfield, VA	Primary Effluent	TSS	60 (33-87)	70% (29-88%)	17 (6-29)
Johnson Co KS[1]	Primary Influent Dry Weather	TSS	218 (186-235)	87% (85-90%)	29 (19-36)
Johnson Co KS[1]	Primary Influent Wet Weather	TSS	114 (105-132)	83% (75-88%)	19 (14-26)
Johnson Co KS[1]	Primary Effluent Dry Weather	TSS	69 (58-80)	76% (70-86%)	16 (10-24)
Johnson Co KS[1]	Primary Effluent Wet Weather	TSS	56 (35-94)	62% (25-83%)	20 (7-36)
St. Joseph, MO[2]	CSO	TSS	106	94%	6
St. Joseph, MO[2]	CSO	CBOD	35	66%	12
Springfield, OH[3]	CSO	TSS	124 (26-524)	84% (73-94%)	16 (5-63)
Springfield, OH[3]	CSO	CBOD	47 (12-198)	53% (16-69%)	22 (4-81)
Springfield, OH[4]	Primary Influent Dry Weather	TSS	163 (74-660)	84% (69-92%)	27 (7-50)
Springfield, OH[5]	Primary Influent	CBOD	77 (62-188)	65% (41-96%)	26 (4-62)
	Continuous	SBOD	40 (15-83)	38% (8-65%)	25 (3-54)
Charleroi, PA	CSO	TSS	200 (104-340)	87% (74-95%)	24 (12-59)
		CBOD	84 (47-120)	70% (51-80%)	25 (11-40)
Springfield, OH	CSO	TSS	101 (54 – 152)	85% (73-91%)	15 (6-26)
Full-Scale HRT		CBOD	50 (17-70)	59% (57-62%)	21 (7-30)
Stormwater Filtration					
Weracoba Creek 10 MGD BMP	Stormwater	TSS	78 (6-224)	69% (46-80%)	25 (10-64)
Vehicle Yard BMPs	Stormwater	TSS	52 (17-89)	52% (44-56%)	25 (8-44)
High Rate Biological Solids Filtration					
Columbus GA	High Rate Bio	TSS	41 (20-58)	99% (97-99.9%)	0.3 (0.2-0.6)
Columbus GA	High Rate Bio	BOD	16 (14-21)	76% (69-96%)	4 (2-6)
Columbus GA	High Rate Bio	TP	1.4 (0.9-1.6)	55% (34-73%)	0.6 (0.4-0.9)
Chesterfield, VA	High Rate Bio	TSS	17 (3.5-32)	98% (94-99.9%)	0.3 (0-0.8)
Tertiary Filtration with Chemical Addition Directly To Filter [6]					
Columbus, GA	Tertiary Chem	TSS	24 (4-49)	71% (33-95%)	3.1 (2-5.2)
Columbus GA	Tertiary Alum	TP	1.5 (1.3-1.6)	74% (47-93%)	0.4 (0.1-0.8)
Chesterfield, VA	Tertiary Ferric	TP	1.2 (0.9-1.6)	70% (58-79%)	0.4 (0.3-0.7)
Springfield, OH	Tertiary+Alum	TP	2.0 (1.6-3.0)	55% (10-88%	1.0 (0.2-1.8)
Milwaukee, WI	Tertiary Ferric	TP	0.4 (0.38-0.45)	75% (64-84%)	0.1 (0.06-0.16)
Tertiary Filtration (no chemical)					
Akron, OH	Tertiary No Chem	TSS	4.2 (4.0-4.4)	78% (55-90%)	1.0 (0.4-2.0)
Akron, OH	Tertiary No Chem	TP	0.7(0.5-1.2)	17%(12-26%)	0.6(0.4-1.0)
Columbus GA	Tertiary No Chem	TSS	5 (5-6)	79% (73-82%)	1.1 (1-1.4)
Columbus GA	Tertiary No Chem	TP	1.6 (1.4-1.7)	16% (13-17%)	1.3 (1.3-1.4)
Chesterfield, VA	Tertiary No Chem	TSS	2.9 (1-5)	89% (50-99.9%)	0.2 (0-0.5)
Springfield, OH	Tertiary No Chem	TSS	6.4 (3-12.2)	78% (50-98%)	1.2 (0.1-2.0)

1. *Average (range) for effluent TSS for all Johnson Co KS Testing is 21(7-36) mg/L TSS.*

2. *Composite sample over actual CSO event.*
3. *19 separate filter run tests over 5 wet weather events*
4. *24 separate filter run tests, half of which were impacted by septage discharges*
5. *111 separate filter run tests operating continuously from March through September 2011*
6. *Metal salt addition to filter influent was variable to establish dose to TP reduction relationship.*

Figure 3 – Comparative UV Testing of FlexFilter (CMF) and other Technology Effluents



Springfield Ohio 100 MGD EHRT for CSO Treatment

The Springfield facility includes coarse screening (1/2" openings), gravity flow to an 11-cell FlexFilter matrix, chlorination in a 10-minute serpentine contact basin (at peak flow), dechlorination and effluent pumping. The Springfield facility is illustrated in Figures 4, 5 and 6.

Figure 4 – Springfield, OH - FlexFilter EHRT Facilities

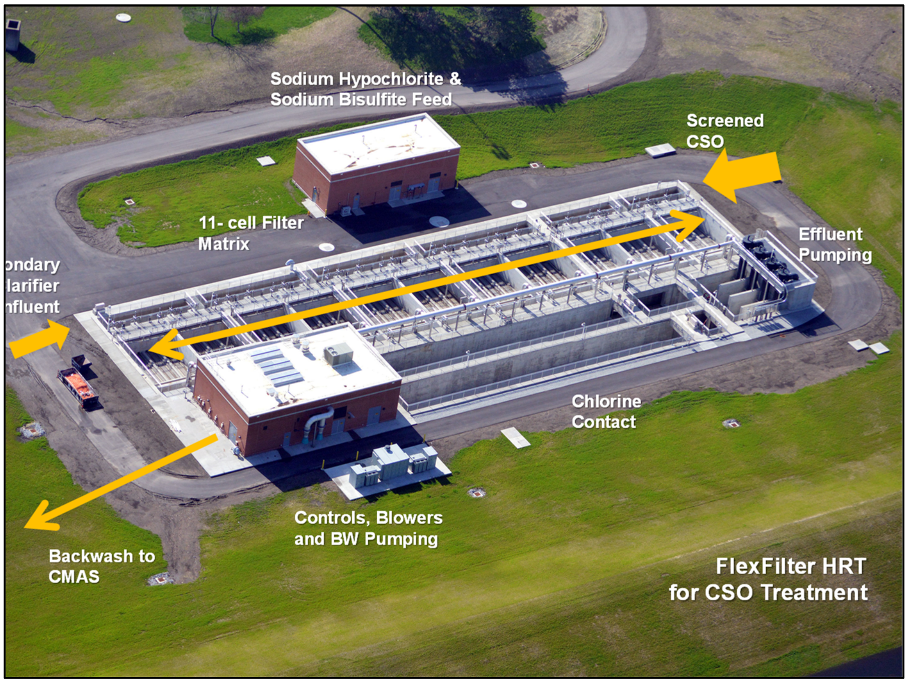


Figure 5 – FlexFilter Cell in Springfield, OH – Longitudinal Section

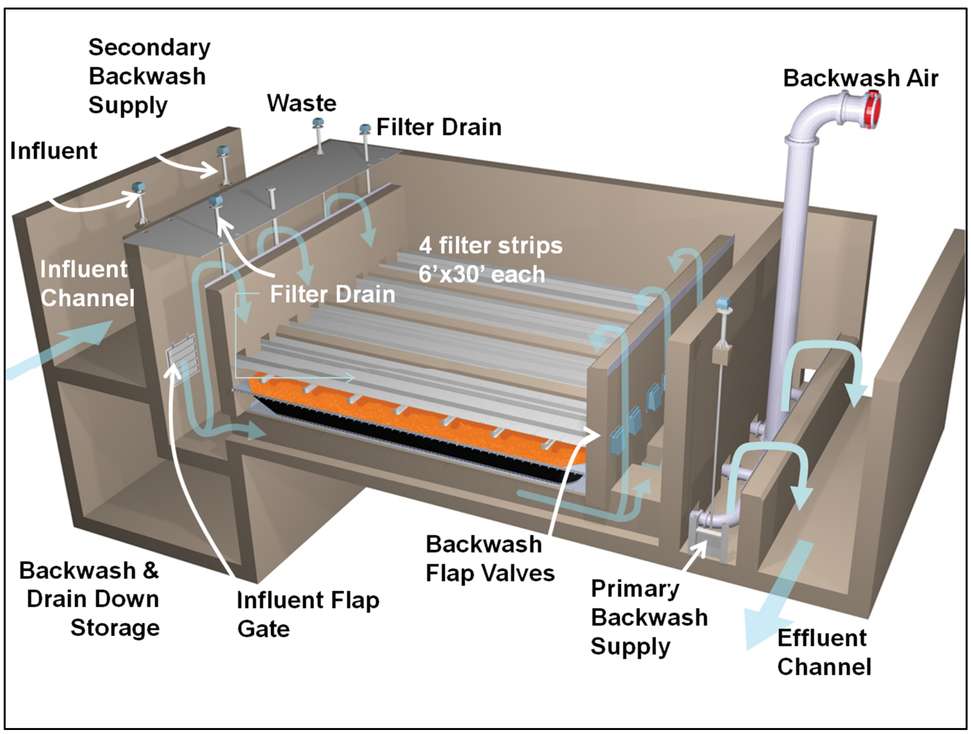
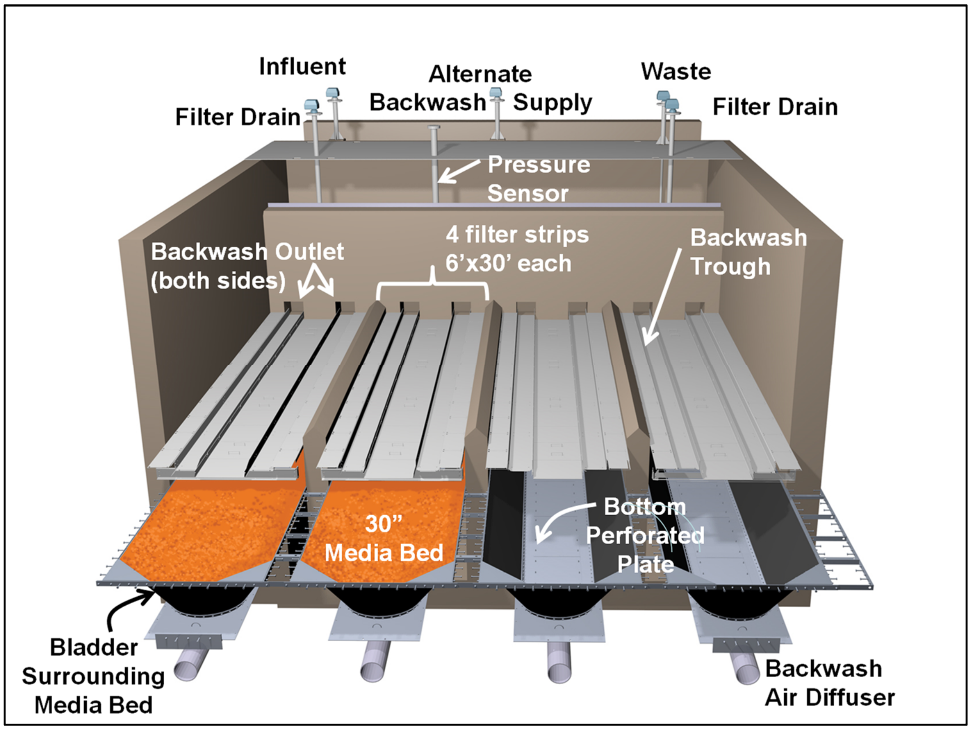


Figure 6 - FlexFilter Cell in Springfield, OH – Cross-Section



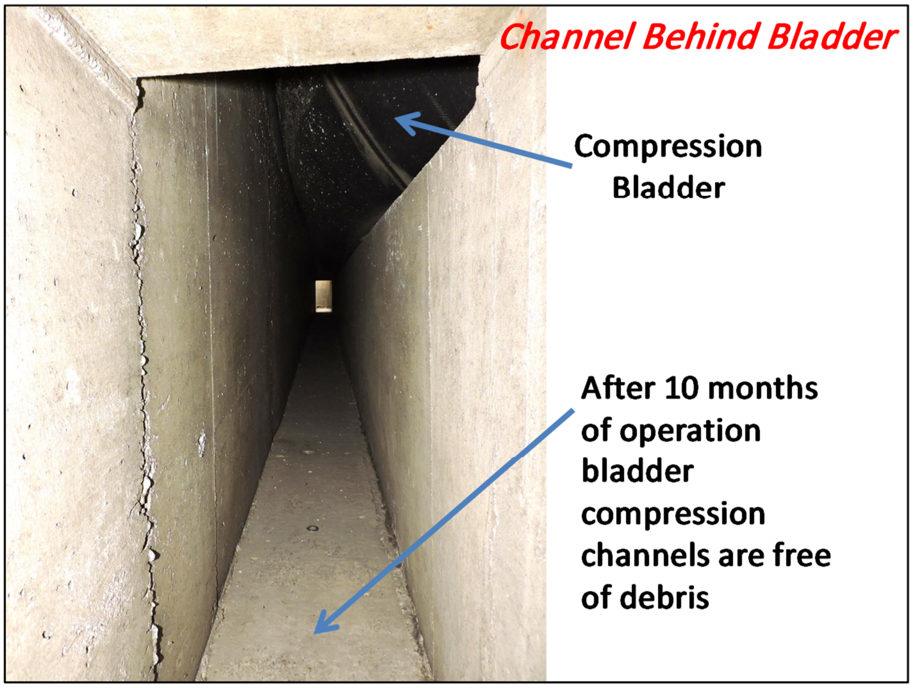
Wet Weather Operation

The FlexFilter operation in Springfield is fully automated from the on-set of a storm event through the post event final cleaning operation. Filter cells are brought on line as flow increases and are sent to standby as the hydrograph descends. Standby cells may re-open if the CSO flow resumes. The cell matrix ultimately goes into a post event cleanup when normal plant or interceptor level conditions return. The automated operations include failsafe protections and can be switched back and forth to a semi-manual control in a bump-less transfer. Semi-manual control by an operator occurs by watching flows and levels, placing cells on line and sending cells into backwash.

Cells go into backwash as the level over the filter rises. Multiple level setpoints are used to stagger cleaning and initiate backup cell operation. The top perforated plate with 3/8" diameter openings serves as a fine screen before compressed media filtration. Screenings are completely removed with the backwashing process. Backwash is sent to the completely mixed activated sludge process, thereby keeping the biomass from starving during long wet weather periods.

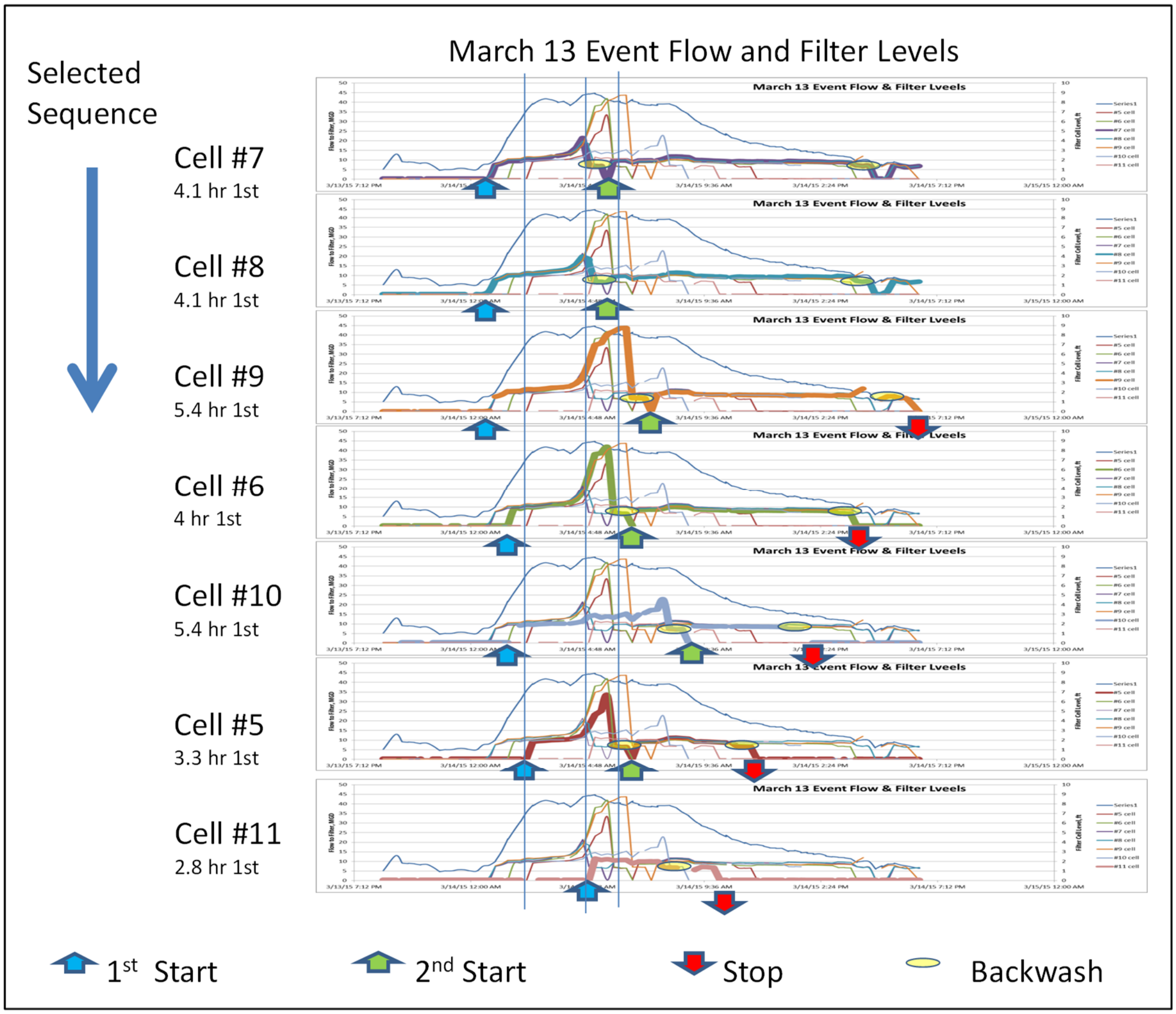
The Hydraulic design of the EHRT will accommodate large and small events of varying quality and quantity. This facility has the ability to effectively handle CSO flush conditions with grit and screenings. Neither has impacted the FlexFilter performance, operation or cleanup. Hydraulic design of the FlexFilter EHRT results in high velocity scouring of all channels in the structure. Each filter cycle leaves the channels clean of debris and virtually free of solids. A picture of the channel behind the bladder, typical of all the channels in the structure, is shown as Figure 7.

Figure 7 – Bladder Channel after 10-months of EHRT Operation



Filter cell run-times have averaged 2 to 5 hours during the beginning of the CSO hydrograph, with much longer durations during the dilute portion of the event. Typical event operation is illustrated in Figure 8. The automated operation brings cells on line at the beginning of an event at lower hydraulic loading rates (HLRs) and increases the HLR as the wet weather flow increases. This logic optimizes filter bed solids removal during flush conditions and together with multiple levels for initiating backwash staggers the cleaning process. Cells operate at higher HLRs at peak CSO flow when lower TSS concentrations are predominant.

Figure 8 – Filter Cell Operation during a Wet Weather CSO Event



Dry Weather Operations

The FlexFilter operating program includes non-wet weather sub-routines. Gates and valves are automatically exercised on scheduled periods or on demand and if an issue exists an alarm alerts the operator to the particular gate. A backwashing program can be initiated by the operator to clean any or all selected units. A backwashing sub-routine is used to flood and surcharge the entire top perforated plate which lifts screenings that may be lingering from the storm event or trapped in the corners. This subroutine is automatic in the post event cleanup program. An underdrain flood and flushing routine can be initiated if icing conditions are present. An oxidant can be added during cleanup programs to freshen the facilities, if desired. Odor issues have not been detected at the Springfield facility since its first event in March of 2015. Other than testing the system, chlorine has not been added to the cleanup operations.

O&M Requirements

Labor and power requirements are minimal. The operation is automatic, self-cleaning and there are dry weather automated programs for valve exercise and freshening of any or all cells. Other than scheduled maintenance on the blower, pumps, and gates the facility requires very little attention. Power consumption is limited to the blower, backwash pumps and effluent pumps. Some installations with sufficient head may not require pumping.

Backwash pumps, if needed, represent smaller power consumption because they are transferring less than 10% of the CSO volume. Effluent pumps, if needed, may only operate 50% of the time as the structure itself will completely or partially capture the more frequent smaller events. Blowers and pumps only operate for part of an event and events only occur for a fraction of the year. Therefore operating costs represent a relatively small percentage of life cycle costs.

Over 50% of the historical CSO volume in Springfield is now being completely captured. Volume capture occurs through three mechanisms: 1) filter, disinfection and backwash storage chamber volumes, 2) backwash return during an event, and 3) bottleneck improvements through the plant. The filters operate passively from zero to full flow representing 100% turn-down.

Multi-Use Technology at the WWTP

When applied at the WWTP, the FlexFilter can serve also serve as a tertiary filter to control phosphorous. In fact in Springfield OH it has been estimated that in addition to reducing CSO solids loading to the river by 90%, if used as a tertiary filter, an equivalent solids load reduction can be achieved by operating the filter during both dry and wet weather periods. Similar to solids reduction, CBOD loads would also be reduced but in a somewhat smaller proportion.

Phosphorous load reductions by operating the filter matrix during dry weather can achieve very low concentration levels. The effluent phosphorous can be controlled by metal salt addition to upstream clarifiers or directly to the filter influent. No flocculation chamber is required as the media is an excellent flocculation filter.

The Springfield staff used the EHRT facility to treat the entire plant flow for one work week while a repair to the influent splitter box was made. During this period, the discharge from the EHRT averaged 6 mg/l TSS and 16 mg/l BOD. The FlexFilter matrix serves as a safety net protecting plant performance and receiving water quality.

During a 6-month pilot testing period in Springfield OH the FlexFilter was operated continuously treating primary influent at a loading rate of 5 gpm/sq ft. Performance results from over 90 tests show that the filter was achieving a consistent 38% soluble CBOD removal as well as particulate CBOD removal (approximately 70% total removal). The testing also found that in order to maintain a sufficient throughput (70% to 80%) a chlorine feed of 3 to 5 mg/l had to be added to the backwash. Additional testing of this process is projected to significantly reduce energy consumption through carbon diversion, reducing downstream biological activated sludge energy and increased gas production in the anaerobic digestion process.

Hydraulic Loading Rates

The conical shape of the FlexFilter when compressed produces a loose upper layer in the media bed and a throat near the bottom with highly compacted media. The upper bed removes the bulk of the larger particle sizes and the throat minimizes the passage of smaller particles and protects the media bed from breakthrough.

In CSO treatment, the FlexFilter has produced solids removals up to 2 pounds per hour per square foot (PPH/sq ft) of surface area. This removal rate is achieved due to the high porosity in the upper zone of the bed and particle size (larger particle sizes are predominant during the CSO flush period). During the flush period cells are opened to maintain a low HLR. This maximizes the solids removal rate and allows longer filter runs.

The Springfield EHRT has been operated with secondary clarifier water at HLR rates up to 22 gpm/ft^2, and still had head available for solids removal. Likewise, during dilute portions of wet weather events, the filter matrix is operated at higher HLRs.

The solids in SSO wastewater (diluted sewage) are generally very low compared to CSO flows (during the flush period) and the corresponding filter run times are very long. Run times for filter cells during a CSO event are shown in Figure 8.

The design of the Springfield EHRT was based upon 6 hours of TSS at 526 mg/l. The maximum HLR was set at 10 gpm/ft^2. During the flush period of the storm the cells start at 4 gpm/ft^2 and gradually increase to the 10 HLR as the flow nears the peak design flow of 100 MGD.

From testing experience with various dry and wet weather sources, the recommended FlexFilter HLRs at peak flow are defined for the following applications:

1. CSO (500 mg/l TSS during flush and 200 mg/l at peak flow) 10 HLR
2. SSO (100 mg/l at peak flow) 15 HLR
3. Tertiary Filtration (30 mg/l TSS at peak flow) 20 HLR
4. Chemical Floc Filtration (metal salts added to filter influent) 5 to 10 HLR
5. Bio-Filtration (primary influent wastewater) 5 HLR

FlexFilter Basis of Design

Criteria representing the Basis of Design and Operating Conditions are delineated in Table 2 for a range of peak design flows for CSO treatment.

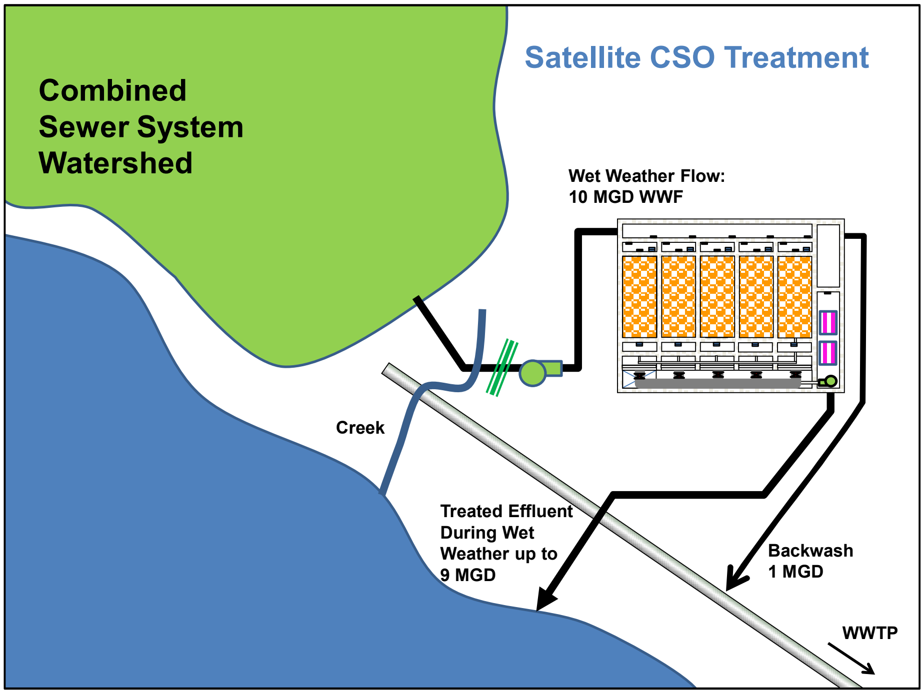
Table 2 – Basis of Design for Range of CSO EHRT Facilities

Criteria	Units					
Hydraulic Capacity	MGD	5	10	25	100	200
Number of Cells	#	5	5	5	10	18
Strips per cell	#	1	1	2	4	4
Nominal strip dimensions	ft x ft	6x12	6x24	6x30	6x30	6x30
Cell Area	ft^2	72	144	360	720	720
Operating Head	inches	90	90	90	90	90
HLR with cell(s) in backwash	gpm/ft^2	12.1	12.1	12.1	12.1	13.8
Number of Cells in Backwash	#	1	1	1	2	4
Flush TSS Concentration	mg/l	500	500	500	500	500
Average TSS Concentration	mg/l	100	100	100	100	100
Average Effluent TSS	mg/l	<20	<20	<20	<20	<20
Average TSS Removal	%	85%	85%	85%	85%	85%
Blower Air Loading Rate	SCFM/sq ft	10	10	10	10	10
Blower Size	SCFM @ 4 psi	720	1440	3600	7200	7200
Duty/Standby Blowers	#/#	1/1	1/1	1/1	2/1	4/1
Blower Power Consumption	KWHr/MG Treated	47	47	48	48	53
Backwash HLR	gpm/sq ft	5	5	5	5	5
Backwash Time	min	25	25	25	25	25
Backwash Rate	MGD	0.65	1.04	2.78	10.1	22.7
Backwash Volume	% of Influent	13%	12%	11%	10%	11%
Backwash Concentration	mg/l	1500	1500	1500	1500	1500
Backwash Transfer Pumps	Duty/Standby	1/1	1/1	2/1	4/1	8/1
Backwash Pump Power	kWHr/MG treated	18	18	18	18	18
Drain Down Pumps	Duty/Standby	1/1	1/1	2/1	4/1	8/1
Drain Down Pump Power	kWHr/MG treated	13	13	13	13	13
Media Addition	% per year	1%	1%	1%	1%	1%
EHRT Structure Footprint	sq ft	1080	1656	3800	19200	35000
EHRT Concrete Volume	cu yds	224	476	830	3108	5507

10 MGD EHRT Satellite for CSO Treatment

A concept for a satellite system is shown in Figure 9. Different from a CSO EHRT at the WWTP, a satellite facility will normally return its backwash flow and screening residuals to the downstream sanitary sewer interceptor. The wet weather flow entering the sanitary interceptor is typically regulated. If the resultant CSO flow is defined as 9 MGD for example, the backwash return flow of approximately 1 MGD would require the CSO EHRT to be sized at 10 MGD.

Figure 9 – Satellite EHRT Concepts



An example footprint for a satellite treatment system using the above design criteria for a 10 MGD EHRT facility is shown in Figures 10 through 13. The two plan views illustrate the upper and lower structures representing the filter cells and contact/storage chambers, respectively. Cells above and chambers below offer economical construction and minimizes footprint for a complete system. The treatment structure does not require a building and can be open to the weather or completely underground providing a useable green space on the surface. A small building is required for electrical equipment but may also be used to enclose coarse screening, backwash blowers, backwash pumps, and oxidant storage/feed equipment or UV, as appropriate. The building enclosure can be configured on top of the filter structure.

The structure footprint can be elongated to other rectangular shapes by making more cells of smaller length and/or by separating the cells into multiple trains. This makes it more amenable to tight locations possibly limited by existing right-of-ways. Storage below the cells can be used for attenuation of backwash return and for disinfection contact (if used) and/or effluent storage for a post event cleanup. Effluent storage for cleanup should allow the backwash of two cells. Storage for backwash should allow for a complete drain down of one filter cell at its high water level. Backwash pumping should be sized for one cell in backwash at 5 gpm/sq ft. A sub-divided lower structure depth of 5 feet will generally provide sufficient storage for drain down and backwash attenuation; for 5-minute oxidant contact and for post event cleanup water.

Section views in Figures 12 and 13 show hydraulic profile for a cell in filtration and a cell in backwash mode, respectively. The side-water-depth for the upper filter structure is 15 feet. The total inside depth of the structure is approximately 21 feet including the storage defined above. Eight foot headloss across the filter structure is optimum although lower head can be accommodated with a larger filter footprint.

Figure 10 – Upper Plan View – 10 MGD Satellite EHRT for CSOs

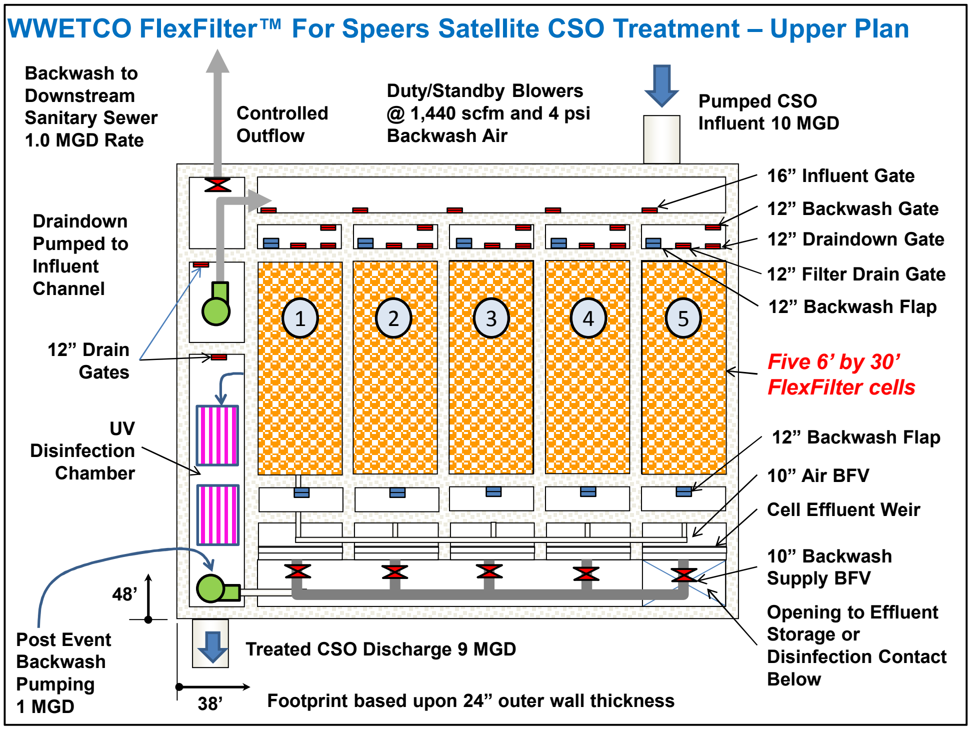


Figure 11 – Lower Plan View – 10 MGD Satellite EHRT for CSOs

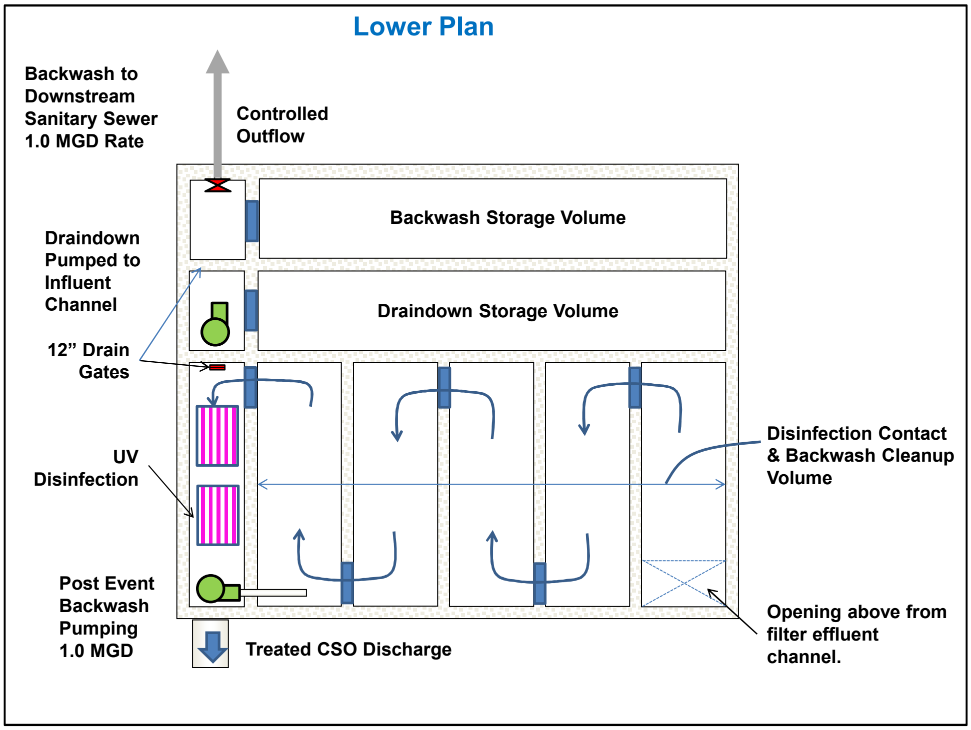


Figure 12 – Section View Showing Filtration Mode – 10 MGD Satellite EHRT for CSOs

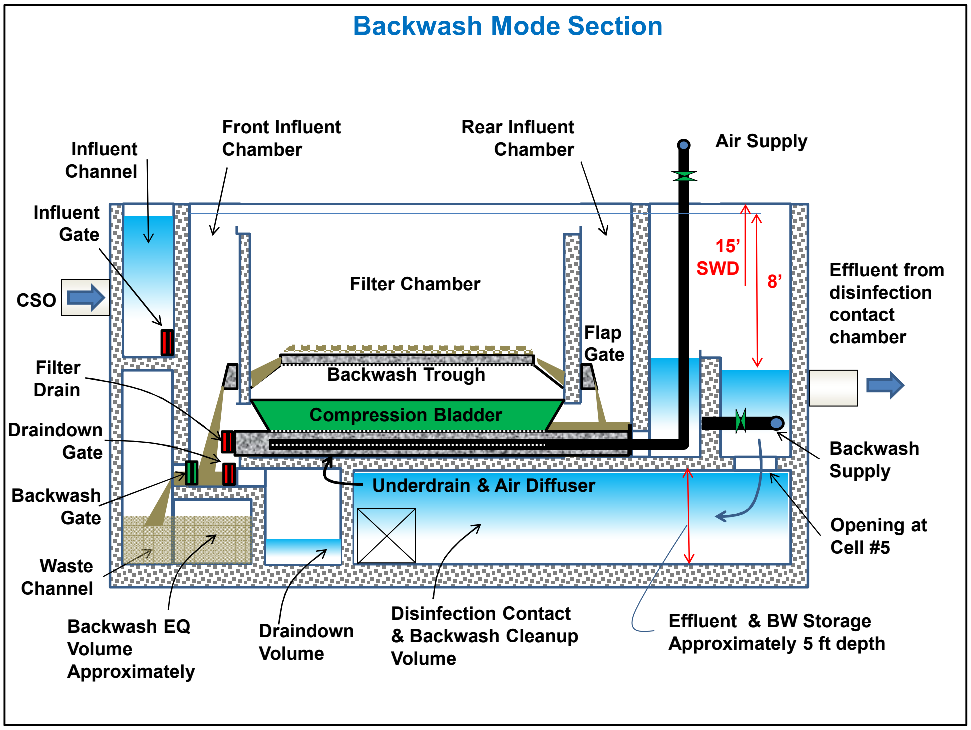


Figure 13 – Section View Showing Backwash Mode – 10 MGD Satellite EHRT for CSOs

Satellite Operation

The flow to each filter cell is controlled passively. When filter influent gates are opened, the influent flow is evenly split between all operating cells. The opening and closing of filters is controlled by either measured flow or measured level in the influent channel. As level or flow rises, cells are brought on line; as they decrease, cells go into standby. If the CSO flow resumes, cells come back on line from standby and continue to filter.

As the hydrograph declines and influent flow returns to normal operating conditions, cells go into a post event cleanup using captured water to accomplish the cleaning. The structure is completely emptied after each event and remains in the ready position for the next event.

During the storm event, the water level directly over the operating cell will rise as solids are removed. When the water level reaches a set point, it goes into a queue and if a blower is available, it goes into cleaning. When in queue, the cell remains in filtration until the backwash is initiated or the cell reaches a maximum level. Backup cells come on line when another goes into cleaning.

During backwash, the blower air is scrubbing and lifting spent backwash water and solids from the filter media bed into backwash troughs, flowing behind the compression bladder, down the backwash drain and into the backwash channel. The backwash channel is located under the filter influent chambers and serves as the wet well for backwash transfer pumps if needed.

Two blowers (duty and lag for redundancy) sized at 1440 SCFM and 4 psi can be located in a sound and weather enclosure or in a building adjacent to or on top of the filter structure. UV disinfection if provided can be located in the last pass of an effluent storage chamber.

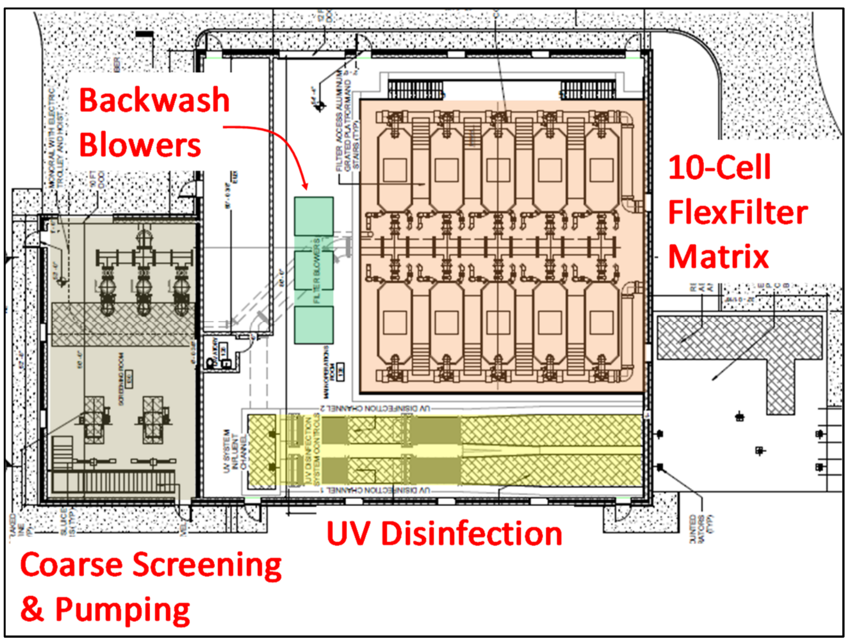
15 MGD Steel Tank EHRT for CSO Treatment

Another example of a satellite treatment facility is an indoor EHRT as shown in Figure 14 for a 15 MGD EHRT for SSO treatment. The filters in this facility are made of stainless steel at 6’x15’x15’ high. The building has a footprint of 100’x80’ that houses filters, UV disinfection, blowers, electrical and controls (excludes the influent pumping facility).

Planning Level Cost Estimates

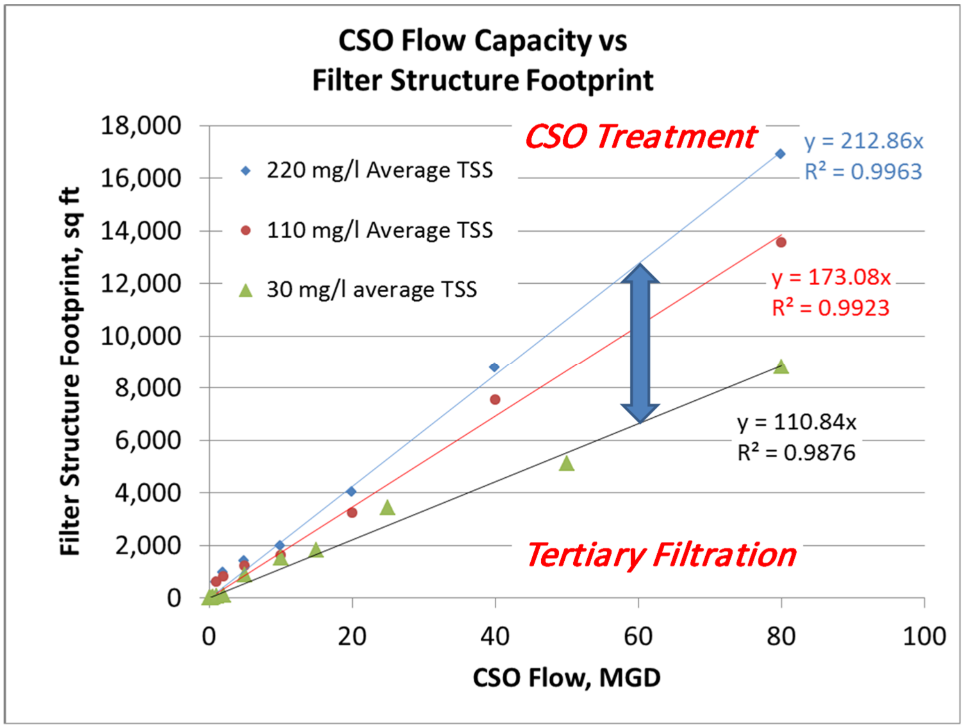
The EHRT filter matrix can generally be sized as a typical CSO knowing the peak flow, average solids concentration and available head. The optimum head is 8 ft across the filter structure with 7 ft used across the media bed. If lower heads are available and pumping is not desired, a somewhat larger filter footprint may be required to process the same flow conditions. Additional pertinent data would be a design flow hydrograph and temporal solids concentrations. Generally, average solids at peak flow and 500 TSS at ½ peak flow would normally be used to size the CSO facility.

Figure 14 – Plan View of 10 MGD Satellite EHRT for SSOs – Steel Tank Design



Example structure foot prints for a range of design flow and average TSS concentration is illustrated in Figure 15. As an example, a CSO HRT with an average 220 mg/l influent TSS would be about twice the footprint for the same flow of a tertiary filter with an average influent of 30 mg/l TSS.

Figure 15 – Flow versus Structure Footprint for Range of Influent TSS

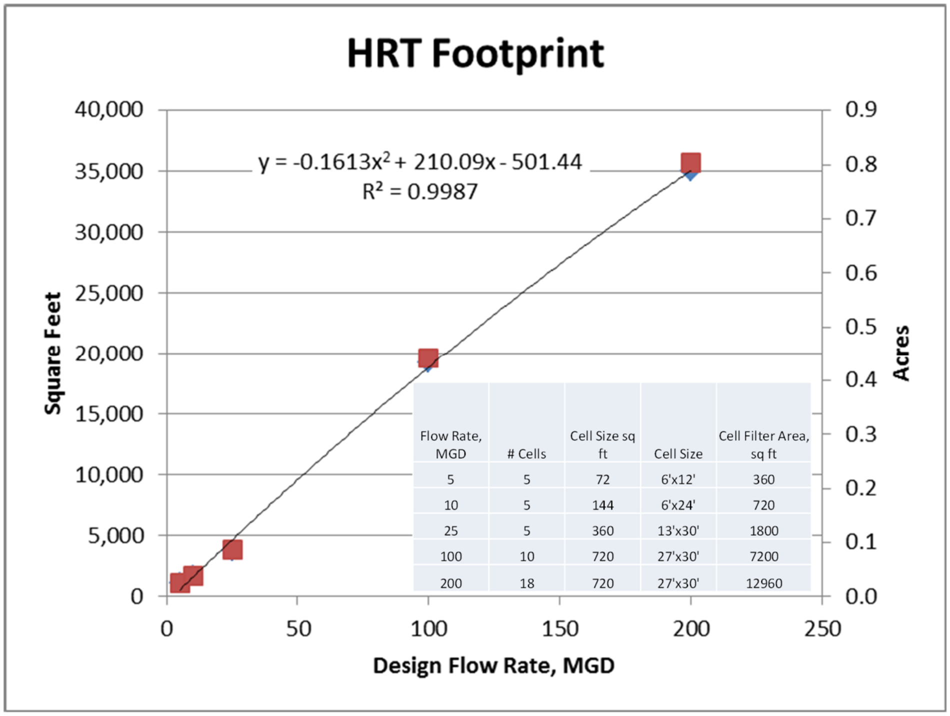


The same data is shown in Figure 16, providing the EHRT footprint for different CSO flows at an average TSS concentration of 110 mg/l. This graph shows design flows up to 200 MGD. Cell sizes for each data point and total filter media area is also shown in the embedded table.

The Springfield OH 100 MGD EHRT was built for $33.5 million. It included: 1) an overflow screening structure, 2) 84" influent and effluent conduits to and from the filter structure, 3) an 11-cell filter matrix with each cell at 720 sq ft media surface, 4) a 10-minute serpentine chlorine contact tank at the 100 MGD peak flow with sodium bi-sulfite dechlorination at the effluent, 5) 100 MGD effluent pumping, 6) 2-duty/1-standby blowers at 7,200 SCFM each, 7) 9 MGD backwash pumping and 8) chlorine and bi-sulfite chemical storage and feed equipment. FlexFilter components including blowers, gates, valves and controls represented about 20% of the EHRT construction costs. EHRT construction costs for other size facilities were calculated based upon their footprint proportion to the Springfield filter matrix. This is represented as the upper range construction cost as shown in Figure 17. The lower range was calculated using engineering cost estimates for reduced components. These include the footprint and concrete savings by locating the contact tank under the filter, combining overflow screening with the influent channel and eliminating effluent pumping that may not be required.

The lower range EHRT construction cost is displayed next to equipment and structural concrete cost components for a range of design flows, illustrated in Figure 18. The FlexFilter equipment cost in this graph represents about 33% of the EHRT construction cost. Cast-in-place concrete is based upon 12" walls and a 2 ft base slab at an installation cost of $1,000 per cubic yard.

Figure 16 – CSO Flow Rate versus Structure Footprint for 110 mg/l Average TSS by Design Capacity



Flow Rate, MGD	# Cells	Cell Size sq ft	Cell Size	Cell Filter Area, sq ft
5	5	72	6'x12'	360
10	5	144	6'x24'	720
25	5	360	13'x30'	1800
100	10	720	27'x30'	7200
200	18	720	27'x30'	12960

Figure 16 - **CSO Flow Rate versus Structure Footprint for 110 mg/l Average TSS by Design Capacity**

Figure 17 – Potential Construction Cost Range by Design Capacity

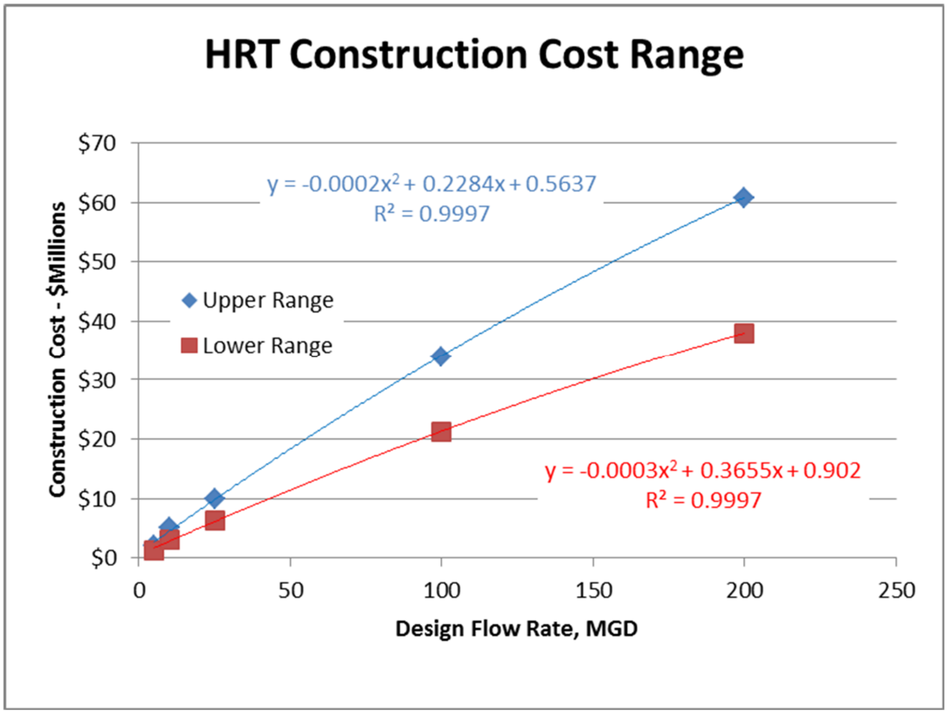
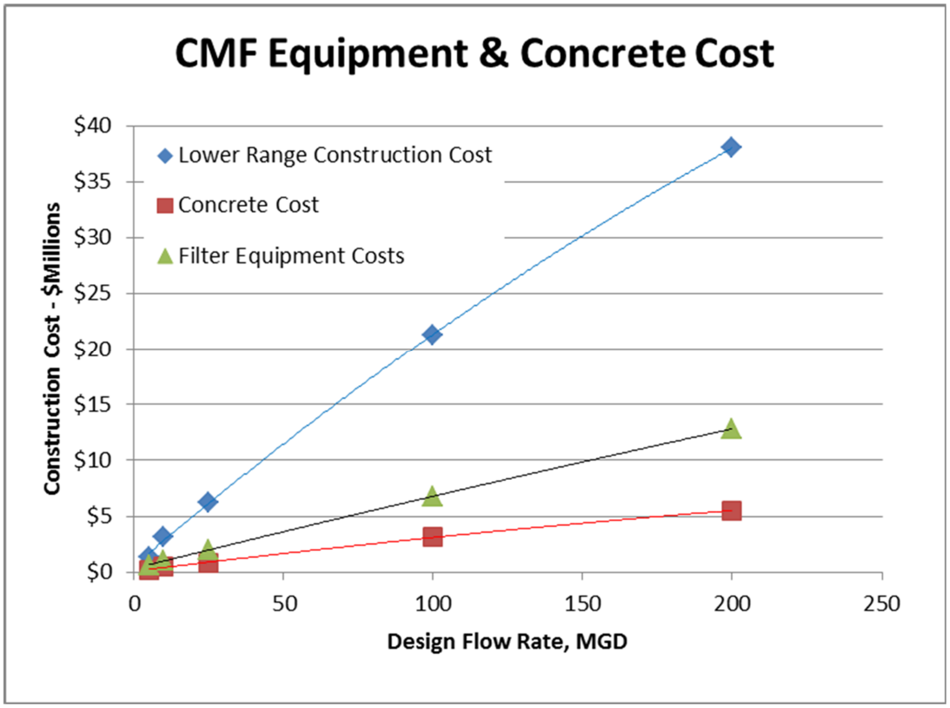


Figure 18 – Lower Range Construction, Filter Equipment and Concrete Cost by Design Capacity



Footprint and Construction and O&M Costs by Design Capacity

Satellite facility footprint, construction and O&M costs are shown in Table 3 for a range of design capacities. Notes at the bottom of this table describes general design parameters, footprint considerations, construction cost components and O&M considerations.

Construction costs are based upon a complete EHRT facility similar to the Springfield OH facility and proportioned to other size systems based upon the footprint for the specific design flow. Additional costs have been added for UV disinfection and escalation ($38 million for 100 MGD). This allows a two-tier disinfection operation where filtration and UV is used for 95% of events and PAA is used for the rest of the annual distribution of events.

Similar to the Springfield facility, the satellite EHRT's are unmanned and are automatically cleaned and drained after an event. For the most part, residuals are sent back to the sanitary sewer interceptor. O&M costs are relatively low and primarily include power, preventative maintenance and chemicals for the larger less frequent events (PAA).

In general, CSOs may occur 40 to 80 times a year, however, each overflow point is different. The temporal nature of CSOs may range from 15 minutes to days of overflow. In general, the average CSO duration may be around 3 to 5 hours. This generally means that CSO events last less than 5% of the time. O&M costs are therefore a small portion of capital costs when evaluated on a life cycle basis.

Table 3 - EHRT Satellite CSO Treatment Facility – Estimated Footprint, Construction and O&M Costs by Design Capacity

Design Flow (MGD)	Filter Matrix Cell (width x length)[1]	Matrix Foot Print[2] Square Feet	-Acres	Construction Cost [3] ($M)	Annual O/M Cost[4] ($)
5	5(6x12)	1,700	0.04	3.1	17,200
10	5(6x24)	2,200	0.05	4.0	23,400
25	5(13x30)	5,400	0.11	9.8	36,600
30	5(20X30)	7,000	0.18	12.7	41,800
100	10(27x30)	21,000	0.48	38.0	104,800
167	17(27x30)	34,000	0.78	61.5	160,400
200	20(27x30)	40,000	0.92	72.4	187,000
250	24(27x30)	50,000	1.15	90.5	226,000

Notes:
1. Filter Matrix design is based upon a flush loading of 500 mg/l TSS at ½ Design Flow & 100 mg/l TSS at Design Flow.
2. The Matrix footprint is a rectangular to square concrete structure that includes influent and effluent channels, filter cells, effluent storage (for disinfection contact and/or post event cleanup), concentrated backwash solids attenuation, and backwash recycle attenuation. Storage and attenuation chambers are located under the filter structure. The filter structure has a depth of 15 ft whereas the chambers underneath the filter structure would be about 6 ft for a total structure depth of 22 ft down to the bottom slab elevation. Influent screening can be located in the influent channel. UV equipment can be located in the effluent channel. Blowers, pumps, disinfectant chemicals (if used), electrical gear and controls can be housed above the filter matrix. Housing for chemicals if used is generally about 6% of the filter matrix structure. Housing for other equipment and electrical control is generally about 9% of the footprint. The structure can be below or above grade. The below grade process can typically accommodate gravity flow. Where required axial flow low head effluent pumping may be used (or influent sewage pumping). A total head requirement of 8 ft across the structure is ideal. Larger footprints may be required for a smaller hydraulic head. The head between the maximum hydraulic gradient and the design storm gradient can generally be used for gravity flow (with effluent pumping if and when required).
3. Estimated construction costs are based upon $38 million for an all inclusive 100 MGD EHRT facility similar to the Springfield OH facility but includes UV disinfection for the majority of events and PAA disinfection for the larger events. The Springfield OH 100-MGD EHRT facility (2013 to 2015 construction) included overflow screening and conduits, filter matrix, effluent disinfection & contact, backwash storage and pumping, chlorination/dechlorination chemical feed facilities, effluent pumping, and electrical/controls building. The Springfield CSO EHRT construction cost was $33.5 million (33.5¢ per gallon design capacity). Construction costs for other facility sizes are proportional to the matrix footprint.
4. Estimated annual O&M is based upon power consumption (blowers, pumps and UV), chemicals (PAA), labor for post event attendance, preventative maintenance, and replacement costs. O&M costs for filtration, UV disinfection and PAA disinfection are from charts in this this document. UV disinfection costs are for the more frequent smaller events (85% of the annual volume). PAA costs are for the larger events (15% of the annual volume).

Table 3 – EHRT Satellite CSO Treatment Facility – Estimated Footprint, Construction and O&M Costs by Design Capacity

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX D

Enhanced High Rate Treatment Suggested Figures from WWETCO

Please note, the information contained in this appendix is provided as supplied by the manufacturer. The information presented herein is independent of the Wet Weather Flow Treatment and Disinfection Demonstration Project and may or may not be reflective of the demonstration project results and conclusions.

THIS PAGE INTENTIONALLY LEFT BLANK

	Design Flow					Option 2		Option 3		Option 4	
	MGD	Capital	Annual O&M	PW O&M	Total PW	Capital	PW $	Capital	PW $	Capital	PW $
Screening	10			$0	$0	$0	$0	$0	$0	$0	$0
	100			$0	$0	$0	$0	$0	$0	$0	$0
Storm King	10	$600,000	$3,000	$34,500	$634,500			$600,000	$634,500		
	100	$5,000,000	$32,000	$368,000	$5,368,000			$5,000,000	$5,368,000		
FlexFilter	10	$1,000,000	$2,400	$27,600	$1,027,600	$1,000,000	$1,027,600			$1,000,000	$1,027,600
	100	$6,800,000	$27,000	$310,500	$7,110,500	$6,800,000	$7,110,500			$6,800,000	$7,110,500
Medium Pressure UV	10	$500,000	$7,000	$80,500	$580,500	$500,000	$580,500				
	100	$3,300,000	$34,000	$391,000	$3,691,000	$3,300,000	$3,691,000				
Low Pressure UV	10	$1,200,000	$1,200	$13,800	$1,213,800						
	100	$5,600,000	$3,800	$43,700	$5,643,700						
PAA	10	$440,000	$43,000	$494,500	$934,500	$440,000	$934,500	$440,000	$934,500	$440,000	$934,500
	100	$940,000	$120,000	$1,380,000	$2,320,000	$940,000	$2,320,000	$940,000	$2,320,000	$940,000	$2,320,000
Grit King	10	$200,000	$1,000	$11,500	$211,500	$200,000	$211,500				
	100	$600,000	$3,000	$34,500	$634,500	$600,000	$634,500				
Filter Concrete	10	$480,000	$0	$0	$480,000	$480,000	$480,000			$480,000	$480,000
	100	$3,110,000	$0	$0	$3,110,000	$3,110,000	$3,110,000			$3,110,000	$3,110,000
Vortex Concrete	10	$75,000	$0	$0	$75,000			$75,000	$75,000		
	100	$1,065,000	$0	0	$1,065,000			$1,065,000	$1,065,000		
Superstructure	10			$0	$0	$0	$0	$0	$0	0	$0
	100			$0	$0	$0	$0	$0	$0	0	$0
Pumping	10			$0	$0						
	100			$0	$0						
Civil Works	10			$0	$0	$0	$0	$0	$0	0	$0
	100			$0	$0	$0	$0	$0	$0	0	$0
Installation	10			$0	$0	$0	$0	$0	$0	0	$0
	100			$0	$0	$0	$0	$0	$0	0	$0
				Subtotals	10 MGD	$2,620,000	$3,234,100	$1,115,000	$1,644,000	$1,920,000	$2,442,100
					100 MGD	$14,750,000	$16,866,000	$7,005,000	$8,753,000	$10,850,000	$12,540,500
				Equip Total	10 MGD	$2,140,000		$1,040,000		$1,440,000	
					100 MGD	$11,640,000		$520,000		$720,000	
				50%	10 MGD	$1,070,000		$520,000		$720,000	
				Installation	100 MGD	$5,820,000		$260,000		$360,000	
					Construction Estimate	Option 1	$/gal capacity	Option 2	$/gal capacity	Option 3	$/gal capacity
					10 MGD	$3,690,000	$0.37	$1,635,000	$0.16	$2,640,000	$0.26
					100 MGD	$20,570,000	$0.21	$7,265,000	$0.07	$11,210,000	$0.11

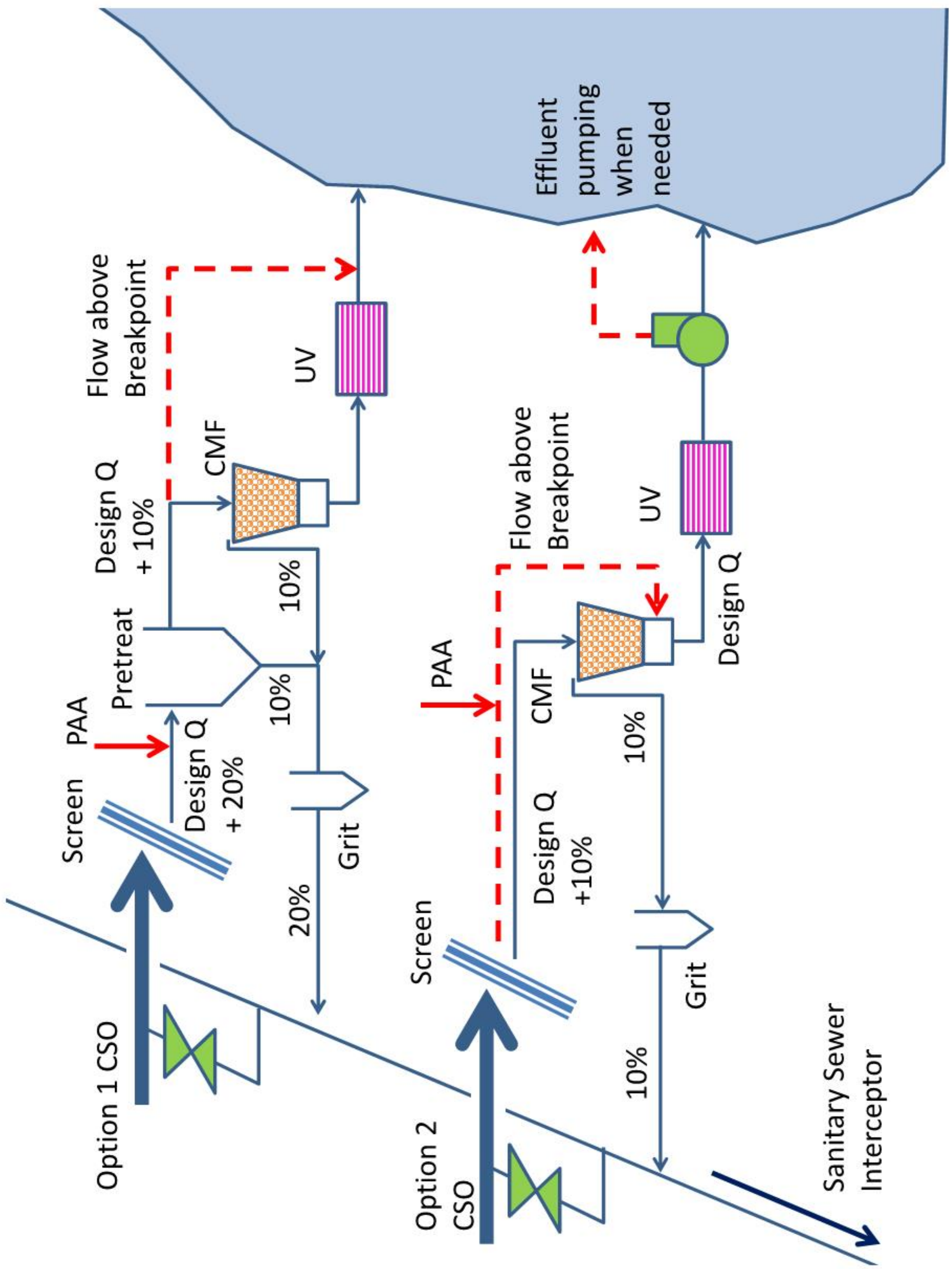

Effluent pumping when needed
Flow above Breakpoint
UV
CMF
Design Q + 10%
10%
Pretreat
10%
PAA
Screen
Design Q + 20%
Grit
20%
Option 1 CSO
Flow above Breakpoint
UV
Design Q
PAA
CMF
10%
Design Q +10%
Screen
Grit
10%
Option 2 CSO
Sanitary Sewer Interceptor

Figure 1.1

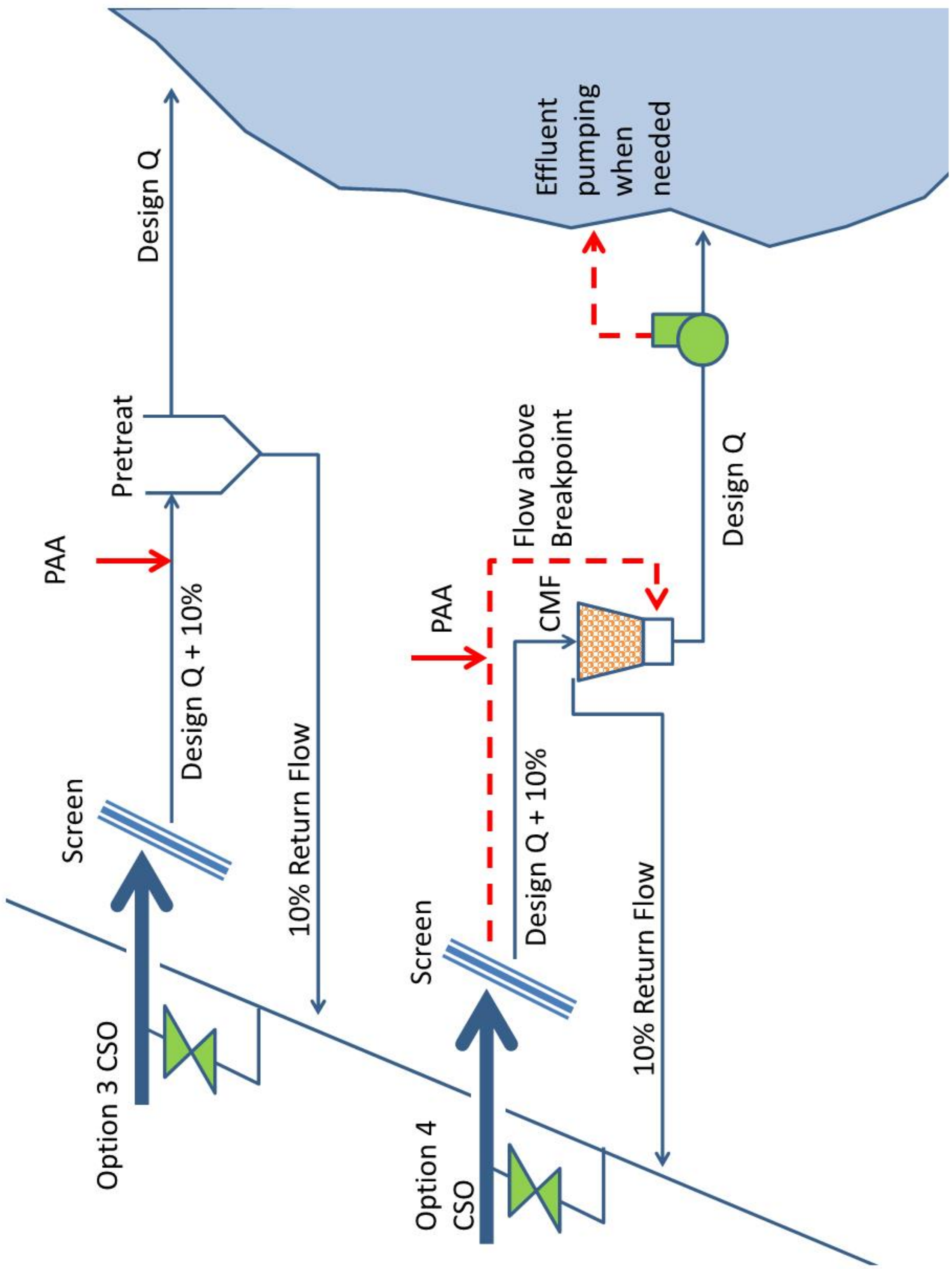

Design Q
Pretreat
PAA
Design Q + 10%
Screen
10% Return Flow
Option 3 CSO
Effluent pumping when needed
Flow above Breakpoint
Design Q
CMF
PAA
Design Q + 10%
Screen
10% Return Flow
Option 4 CSO

Figure 1.2

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX E

Wet Weather Case Study – Storm King® Dynamic Separator, Hydro-International Saco and Bucksport, ME

Technical Bulletin- Storm King as a Contact Vessel for Disinfection

Table – Storm King Unit Size and Number per Design Flow and Treatment Objectives.

Wet Weather Technical Brochure

Please note, the information contained in this appendix is provided as supplied by the manufacturer. The information presented herein is independent of the Wet Weather Flow Treatment and Disinfection Demonstration Project and may or may not be reflective of the demonstration project results and conclusions.

THIS PAGE INTENTIONALLY LEFT BLANK

Saco, ME

Wet Weather Case Study - Storm King® Dynamic Separator

Project Profile

Objective

Untreated sewage was overflowing into the Saco River during intense storm events. The city had separated 7 of 8 combined sewers, but needed an alternative solution for the 8th sewer due to its downtown location.

Solution

A 22-ft diameter Storm King® was smaller, more economical and more efficient than conventional clarifier tanks.

Project Highlights

- Storm King® unit combines screening, sedimentation and disinfection
- Storm King® System achieves primary treatment equivalency
- The system showed up to 83% BOD removal and 72% TSS removal during an intense 4-day spring storm

The Storm King® system treats flow prior to discharge into the Saco River (pictured in the background).

Like many other urban communities in the Northeast, the city of Saco, Maine, has been working hard in recent years to correct problems caused by combined sewer overflows. The city's storm sewers were built to collect wastewater and stormwater runoff, and during particularly heavy rains untreated sewage has overflowed pipes and spilled into the Saco River.

The city opted for a hybrid solution to the problem: Eliminating seven of the eight CSO outfall sites by separating the stormwater and wastewater sewers, and pursuing an alternative solution for the eighth. The eighth site served the downtown area. City officials decided against separating the sewers in the downtown area to avoid the high costs of land acquisitions and the ensuing traffic disruptions that would be caused by the digging up of large sections of downtown streets.

> *"It has exceeded our expectations."*
>
> - Chris Osterrider, Senior Engineer
> DeLuca-Hoffman Associates Inc.

The eighth CSO site would require a mechanism at the overflow site to treat the effluent before it reached the river. The question was whether to use a "conventional" primary clarification system or to try a system that employed an alternative technology promising a higher degree of treatment.

Conventional primary clarification systems, typically contact chambers and settling basins, can be prone to "short circuiting", and require prolonged contact times with disinfectants to ensure proper treatment. To avoid this short circuiting, many municipalities simply utilize much larger tanks to lengthen the amount of time that water is residing within the tank and exposed to coagulants and disinfectants. However, larger tanks require a considerably larger capital investment and far greater maintenance costs. For the effluent to meet the water quality standard required by the Maine

www.hydro-int.com | Tel: (866) 615 8130

Two Hydro-Brake® Vortex Valve flow controls are used at the Saco CSO Treatment Facility

The efficiency of the Storm King® unit is derived from the unique configuration of its internal components

The low maintenance Swirl-Cleanse screen is self-cleansing with no power requirement

Department of Environmental Protection, the city would have had to more than double the size of the tank.

The challenge was two fold: First, how to treat excess storm water, and second, how to control the flow of water to ensure proper treatment and avoid polluting runoff. To gauge the storm system needs, the city analyzed precipitation in the Saco River catchment from the 1980s and '90s, as well as a recent five-year period. Based on the findings, city officials felt confident they had a good gauge on estimating future storm events.

"Treating storm water isn't a finite process" explained Christopher J. Osterrieder, senior engineer with DeLuca-Hoffman Associates of Portland, Maine, the engineering firm that worked on the Saco sewer project. "We had to be careful to only send enough water so that we can perform within the vortex separator's rated range."

The city implemented a new conveyance line at the treatment plant. To control the flow, the city installed two Hydro-Brake® Vortex Valve flow controls from Hydro International Inc. To avoid the cost and performance challenges of conventional tankage systems, the city chose to deploy this alternative system to treat the excess flow to the same standard.

The first vortex valve restricts the flow to the treatment plant and the second valve splits the flow, allowing the design peak volume to go through the normal wastewater treatment process and the balance goes to the city's new CSO treatment system based on Hydro International's Storm King® Advanced Hydrodynamic Vortex Separator. When that capacity is exceeded, the overflow is treated by the 22-ft diameter Storm King® prior to discharge.

In the new CSO treatment system, sedimentation, screening and disinfection are all accomplished in the Storm King®. The disinfectant, sodium hypochlorite (NaClO), is injected into the flow of the vessel. The disinfectant and combined sewage then mix in the Storm King®, where the sewer solids are removed by gravitational and rotational forces. These forces increase the time it takes for water to flow through the tank, thereby increasing its contact time for disinfection. This increased contact time provides a more efficient "kill rate" for pollutants in the water. Because of the improved efficiency of the Storm King®, a smaller tank could be used to achieve the required level of treatment, vastly reducing the up-front capital investment and ongoing maintenance costs.

As settleable solids collect in the base of the vessel, the flows are directed upward through the central area of the vortex chamber and then down through the Swirl-Cleanse screen which captures all floatables and neutrally buoyant material greater than 4mm in diameter. The screened and disinfected effluent is discharged from the system through an air-regulated siphon, which also provides an effective self-activating backwash mechanism to prevent the screen from blinding. After screening, the treated sewer flows are directed through a de-chlorination process prior to being discharged into the Saco River. The collected screenings and settleable solids are then pumped a short distance back to the wastewater treatment plant for processing.

The system went online in November 2006. "We've had some very large storms beyond set design criteria and the system still performed very well," Osterrieder said. "Prior to the project, storm overflow caused discharge of untreated sewage right into the river. Today, we have influent and sampling rates so we know what we're getting for removals. With previous storm events we might see TSS levels of 300 mg/L. Now we see removal rates going down to 60mg, and in most instances we've done better than that."

Maintenance upkeep for this type of CSO treatment is minimal. After storm events all solids are pumped back into the treatment system and disposed of. The maintenance crew simply performs a quick washdown of the tank to prepare for the next storm. "Low maintenance is a big thing for municipalities like Saco," Osterrieder said. "Alternative systems would have been far more mechanical in nature. With more conventional filtration solutions we would have needed to do a more intensive washdown as well as a drawdown with more manual effort after each storm event."

During the Patriot's Day Storm that lasted from April 15 to April 19, 2007, the Storm King® unit treated sustained flows between 0.26 – 3.9 mgd. During that time, samples drawn from the system showed that the Storm King® removed up to 83%[1] BOD and 72% TSS.

Saco can now capture and treat far greater volumes of water. "We're getting consistent results from varying degrees of storms," Osterrieder said. "It's exceeded our expectations."

[1] additional BOD removal attributed to effects of the self-cleansing fine mesh screen

Hydro International. 2925 NW Aloclek Suite 140. Hillsboro, OR 97124. Tel: (866) 615 8130
Email: **wet-weather@hydro-int.com** Web: **www.hydro-int.com**

Storm King® - Saco, ME - Case Study - V15.2

Wet Weather Solutions
Turning Water Around...®

City of Saco, WWTP
68 Front Street
Saco, ME 04072
Tel: 207-282-3564

Storm King® Operational Data

Storm Date	Precipitation (inches)	Treated Flow (million gallons)	Duration (hrs)	Influent BOD (mg/L)	Effluent BOD (mg/L)	BOD Percent Removal	Influent TSS (mg/L)	Effluent TSS (mg/L)	TSS Percent Removal	Fecal* (cfu/100 mL)	Cl_2 Residual
1/8/2007	1.0	0.100	1.9	110.0	26.0	76.4%	118.0	16.0	86.4%	146	0.09
3/3/2007	1.8	0.140	2.4	83.0	18.3	78.0%	234.0	30.0	87.2%	NSR	NSR
4/15/2007	1.1	0.266	4.0	138.0	24.0	82.6%	183.0	53.0	71.0%	NSR	NSR
4/16/2007	3.2	3.889	24.0	83.0	18.0	78.3%	110.0	49.0	55.5%	NSR	NSR
4/17/2007	0.2	3.134	24.0	66.0	16.0	75.8%	91.0	55.0	39.6%	173	0.59
4/18/2007	0.0	2.930	24.0	52.0	17.0	67.3%	78.0	27.0	65.4%	TNTC	0.58
4/19/2007	0.0	1.031	21.0	70.0	31.0	55.7%	93.0	35.0	62.4%	12	0.69
7/15/2007	1.6	0.082	1.5	73.0	31.0	57.5%	45.0	30.0	33.3%	NSR	NSR
8/6/2007	1.4	0.090	1.0	148.0	58.0	60.8%	301.0	92.0	69.4%	NSR	NSR
9/11/2007	1.6	0.200	2.0	50.0	22.0	56.0%	88.0	57.0	35.2%	NSR	NSR
10/12/2007	2.8	0.204	2.7	75.0	30.0	60.0%	83.0	64.0	22.9%	NSR	NSR
11/3/2007	1.2	0.100	1.5	88.0	61.0	30.7%	139.0	78.0	43.9%	NSR	NSR
1/11/2008	1.0	0.750	6.5	227.0	35.0	84.6%	195.0	17.0	91.3%	NSR	NSR
1/18/2008	0.7	0.070	1.3	67.0	47.0	29.9%	191.0	81.0	57.6%	5	0.01
2/2/2008	0.3	0.100	2.0	64.0	9.0	85.9%	107.0	7.0	93.5%	NSR	NSR
2/13/2008	1.7	0.480	8.0	74.0	37.0	50.0%	132.0	53.0	59.8%	NSR	NSR
2/18/2008	1.3	0.463	11.3	37.0	19.0	48.6%	93.0	26.0	72.0%	NSR	NSR
3/5/2008	1.2	0.103	2.3	105.0	48.0	54.3%	118.0	75.0	36.4%	68	0.01
3/9/2008	1.7	0.946	14.1	73.0	24.0	67.1%	53.0	10.0	81.1%	NSR	NSR
3/20/2008	0.6	0.043	0.1	59.0	34.0	42.4%	62.0	11.0	82.3%	20	0.01
4/29/2008	1.7	1.490	2.1	78.0	22.0	71.8%	70.0	41.0	41.4%	75	0.01
7/24/2008	2.1	0.124	2.4	59.0	32.0	45.8%	112.0	22.0	80.4%	NSR	NSR
7/31/2008	0.4	0.267	4.5	78.0	44.0	43.6%	173.0	48.0	72.3%	NSR	NSR
8/6/2008	0.7	0.436	5.0	110.0	41.0	62.7%	265.0	58.0	78.1%	78	0.01
8/8/2008	1.1	0.768	11.0	92.0	27.0	70.7%	97.0	28.0	71.1%	90	0.01
9/6/2008	2.6	0.229	2.0	151.0	20.0	86.8%	90.0	41.0	54.4%	NSR	NSR
9/7/2008	2.8	1.290	11.3	145.0	27.0	81.4%	101.0	40.0	60.4%	NSR	NSR
9/27/2008	2.5	0.507	4.1	114.0	33.0	71.1%	78.0	48.0	38.5%	NSR	NSR
9/28/2008	1.6	0.713	10.6	81.0	21.0	74.1%	89.0	20.0	77.5%	NSR	NSR
9/29/2008	0.9	0.556	14.9	41.0	38.0	7.3%	36.0	11.0	69.4%	NSR	NSR
10/27/2008	1.6	0.205	2.5	55.0	31.0	43.6%	153.0	52.0	66.0%	NSR	NSR
11/25/2008	1.4	0.371	5.9	41.0	26.0	36.6%	64.0	22.0	65.6%	NSR	NSR
12/12/2008	0.7	0.534	5.6	24.0	17.0	29.2%	35.0	20.0	42.9%	18	0.10
2/19/2009	0.9	0.082	2.1	78.0	64.0	17.9%	243.0	159.0	34.6%	10	0.00
3/11/2009	0.3	0.156	3.0	70.8	52.3	26.1%	ERR	ERR	ERR	165	0.05
4/6/2009	1.7	0.958	6.5	41.4	34.7	16.2%	85.0	70.0	17.6%	NSR	NSR
4/7/2009	0.0	0.625	14.0	55.5	36.9	33.5%	24.0	12.0	50.0%	238	0.01
4/21/2009	1.6	0.243	3.6	55.9	39.5	29.3%	98.0	48.0	51.0%	NSR	NSR
6/12/2009	1.8	0.170	3.8	59.6	30.3	49.2%	161.0	33.0	79.5%	1	0.01
6/19/2009	3.0	1.940	16.4	34.7	32.3	6.9%	79.0	61.0	22.8%	115	0.01
6/29/2009	0.9	0.029	1.1	47.0	34.4	26.8%	59.0	57.0	3.4%	NSR	NSR
7/2/2009	1.9	1.034	13.0	29.4	17.3	41.2%	35.0	11.0	68.6%	400	0.02
7/8/2009	1.1	0.451	8.9	70.9	26.1	63.2%	112.0	16.0	85.7%	49	0.00
7/24/2009	3.0	1.200	11.2	40.8	21.6	47.1%	54.0	18.0	66.7%	123	0.07
8/29/2009	2.6	0.192	3.4	43.3	35.2	18.7%	61.0	19.0	68.9%	NSR	NSR
11/14/2009	5.1	1.380	9.1	ERR	ERR	ERR	29.0	4.0	86.2%	NSR	NSR
11/15/2009	0.3	1.414	14.9	47.2	16.6	64.8%	123.0	47.0	61.8%	NSR	NSR
11/27/2009	1.4	0.495	7.6	61.8	36.8	40.5%	90.0	29.0	67.8%	NSR	NSR
12/3/2009	1.4	0.633	6.9	25.2	21.2	15.9%	25.0	18.0	28.0%	63	0.07
12/9/2009	1.4	0.548	7.0	72.4	37.0	48.9%	139.0	54.0	61.2%	NSR	NSR
12/27/2009	1.1	0.498	6.7	65.6	59.8	8.8%	149.0	82.5	44.6%	NSR	NSR
1/25/2010	0.8	1.011	8.9	64.0	23.1	63.9%	174.0	46.0	73.6%	NSR	NSR
2/24/2010	1.4	0.520	4.8	102.0	33.1	67.5%	215.0	21.0	90.2%	75	0.04
2/26/2010	0.5	2.471	23.1	37.0	17.2	53.5%	46.0	18.0	60.9%	NSR	NSR
3/1/2010	0.1	0.047	2.5	47.0	29.5	37.2%	36.0	20.0	44.4%	38	0.03
3/15/2010	1.1	3.212	22.3	26.1	19.6	24.9%	30.0	10.0	66.7%	43	0.66
3/23/2010	2.7	2.534	16.4	32.2	22.3	30.7%	56.0	48.0	14.3%	108	0.03
3/24/2010	0.5	2.886	23.5	29.1	25.2	13.4%	20.0	19.0	5.0%	140	0.32
3/25/2010	0.0	0.160	7.4	78.4	28.8	63.3%	54.0	9.0	83.3%	8	0.02
3/29/2010	1.1	1.296	14.3	72.4	49.7	31.4%	87.0	46.0	47.1%	18	0.03
3/30/2010	3.1	3.077	23.6	ERR	ERR	ERR	88.0	40.0	54.5%	230	0.23
3/31/2010	0.3	3.971	23.6	ERR	ERR	ERR	23.0	18.0	21.7%	25	0.17
4/1/2010	0.0	1.974	23.3	ERR	ERR	ERR	ERR	ERR	ERR	38	0.03
4/2/2010	0.0	0.258	12.2	32.4	19.5	39.8%	87.0	21.0	75.9%	3	0.01
7/14/2010	2.9	0.040	3.3	74.6	54.5	26.9%	120.0	76.0	36.7%	NSR	NSR
8/25/2010	3.4	0.039	3.2	73.8	27.6	62.6%	100.0	35.0	65.0%	175	0.00
10/6/2010	1.7	0.019	1.6	108.0	49.4	54.3%	163.0	88.0	46.0%	NSR	NSR
10/15/2010	3.4	0.080	8.3	55.0	30.3	44.9%	103.0	101.0	1.9%	145	0.00
11/4/2010	1.5	0.021	4.3	67.4	49.6	26.4%	98.0	52.0	46.9%	NSR	NSR
11/17/2010	1.6	0.048	7.5	95.1	28.4	70.1%	229.0	47.0	79.5%	138	0.17
12/12/2010	2.0	0.050	7.0	80.8	13.1	83.8%	107.0	41.0	61.7%	NSR	NSR
3/7/2011	2.1	0.249	21.9	79.9	13.1	83.6%	145.0	27.0	81.4%	48	0.03
3/11/2011	1.0	0.185	20.1	25.6	20.4	20.3%	50.0	20.0	60.0%	120	0.03
3/12/2011	0.0	0.004	2.2	42.0	20.5	51.2%	ERR	ERR	ERR	NSR	NSR
3/16/2011	0.6	0.020	4.7	59.0	30.9	47.6%	87.0	77.0	11.5%	NSR	NSR
4/13/2011	1.5	0.107	11.6	71.3	46.4	34.9%	125.0	93.0	25.6%	70	0.02
4/17/2011	1.7	0.155	18.7	32.7	13.0	60.2%	75.0	54.0	28.0%	NSR	NSR
7/30/2011	0.9	0.009	0.8	177.0	68.0	61.6%	290.0	146.0	49.7%	NSR	NSR
8/2/2011	0.7	0.003	0.3	208.0	145.0	30.3%	388.0	273.0	29.6%	NSR	NSR
8/15/2011	1.6	0.011	1.6	70.8	20.6	70.9%	106.0	55.0	48.1%	NSR	NSR
8/28/2011	1.4	0.007	1.1	77.8	15.6	79.9%	146.0	66.0	54.8%	NSR	NSR
10/2/2011	1.4	0.006	1.5	54.0	22.6	58.1%	83	56	32.5%	NSR	NSR
12/8/2011	1.7	0.046	5.6	63.2	19.2	69.6%	88.0	50.0	43.2%	15	0.01
1/27/2012	1.34	1.456	16.7	57.8	69.4	0.0%	80	147	0.0%	308	0.09
4/23/2012	4.5	2.6519	14.9	20.4	35.7	0.0%	57	128	0.0%	106	0.02
5/10/2012	0.98	0.4914	4.4	43.9	52.8	0.0%	92	74	19.6%	113	0.02
6/2/2012	3.63	1.108	6.1	18.8	23.4	0.0%	47	54	0.0%	NSR	NSR
6/3/2012	2.37	5.638	23.9	23.8	24.4	0.0%	22	41	0.0%	NSR	NSR
6/4/2012	0.97	3.8654	23.8	25.3	23.1	8.7%	21	20	4.8%	21	0.15
6/5/2012	0.03	0.221	4.9	40.3	28.1	30.3%	45	10	77.8%	1	0.19
6/8/2012	0.74	0.0256	0.5	54.7	40	26.9%	113	109	3.5%	NSR	NSR
7/27/2012	0.23	0.0662	0.8	27.4	24.9	9.1%	137	91	33.6%	NSR	NSR
12/18/2012	3.42	4.259	18.1	26	24.5	5.8%	70	63	10.0%	816	0.11
12/19/2012	0.17	1.395	14.9	54.1	41.5	23.3%	41	34	17.1%	146	0.08
12/21/2012	0.78	0.8785	9.5	41.8	30.6	26.8%	51	53	0.0%	NSR	NSR
1/31/2013	0.56	0.2904	4.4	17.1	50.0	0.0%	115	103	10.4%	178.5	0.00
2/28/2013	1.35	0.1386	2.6	24.5	23.2	5.3%	38	41	0.0%	NSR	NSR
3/13/2013	0.53	0.8177	6.7	33.8	33.6	0.6%	48	25	47.9%	NSR	NSR
6/25/2013	0.9	0.0479	0.6	56.5	46.3	18.1%	250	181	27.6%	NSR	NSR
7/1/2013	1.82	0.5172	4.2	28.2	21.5	23.8%	115	114	0.9%	NSR	NSR
3/12/2014	0.9	0.0182	0.4	50.6	33.5	33.8%	42	17	59.5%	NSR	NSR
4/8/2014	0.91	0.4571	4.7	35.8	31.3	12.6%	47	46	2.1%	214	0.05
8/13/2014	5.12	2.18	12.2	21.9	19.3	11.9%	81	36	55.6%	NSR	NSR
8/31/2014	1.85	0.3461	1.7	62.6	40.4	35.5%	no data	no data	no data	NSR	NSR
10/23/2014	1.34	0.15	1.9	38.2	36.8	3.7%	62	46	25.8%	NSR	NSR
			Averages	**69.3**	**32.6**	**46.6%**	**106.1**	**49.0**	**51.2%**	**91.27**	**0.11**

Definitions	
NSR	No Sample Required
ERR	Sampling Error
TNTC	To numerous to count
*	Permit limit is 200 cfu/100mL

Note, fecal sampling is only required when discharge durations surpass 60 minutes continuously or 120 minutes collectively over a 24-hour period, during normal working hours.

Town of Bucksport, CSO Facility
Drawer X
Bucksport, ME 04410
Tel: 207-469-0021

Hydro International

Storm King® Operational Data											
Storm Date	Precipitation (inches)	Treated Flow (million gallons)	Duration (hrs)	Influent BOD (mg/L)	Effluent BOD (mg/L)	BOD Percent Removal	Influent TSS (mg/L)	Effluent TSS (mg/L)	TSS Percent Removal	Fecal* (cfu/100 mL)	Cl_2 Residual
4/29/2008	4.0	0.62	7.3	56.0	46.0	17.9%	92.0	64.0	30.4%	NSR	NSR
4/30/2008	N/A	0.15	3.0	27.0	23.0	14.8%	15.0	11.5	23.3%	NSR	NSR
9/7/2008	3.89	0.16	5.6	ERR	ERR	ERR	ERR	ERR	ERR	1	0.03
9/28/2008	2.8	0.50	19.7	54.0	47.0	13.0%	59.0	47.0	20.3%	1	0
9/29/2008	0.7	0.14	6.3	ERR	ERR	ERR	63.0	51.0	19.0%	1	0
10/2/2008	1.56	0.09	3.8	69.0	58.0	15.9%	64.0	50.0	21.9%	NSR	NSR
11/16/2008	1.7	0.13	5.6	61.0	23.0	62.3%	88.0	19.0	78.4%	NSR	NSR
11/26/2008	2.8	0.42	14.4	23.0	18.0	21.7%	50.0	35.0	30.0%	NSR	NSR
12/12/2008	1.45	0.39	12.3	57.0	45.0	21.1%	104.0	61.0	41.3%	NSR	NSR
4/7/2009	1.67	0.28	8.5	71.0	33.0	53.5%	ERR	ERR	ERR	NSR	NSR
4/21/2009	2.77	0.11	9.5	56.0	14.0	75.0%	76.0	7.0	90.8%	NSR	NSR
4/22/2009	0.33	0.20	14.2	68.0	56.0	17.6%	49.0	12.0	75.5%	NSR	NSR
6/20/2009	4.28	1.05	23.8	49.0	32.0	34.7%	34.0	15.0	55.9%	1	0.16
6/21/2009	0.1	0.61	7.5	52.0	41.0	21.2%	30.0	17.0	43.3%	1	0
7/3/2009	1.11	0.05	1.7	ERR	ERR	ERR	ERR	ERR	ERR	12	0
7/13/2009	0.82	0.03	3.6	ERR	ERR	ERR	ERR	ERR	ERR	1	0.03
9/1/2009	**	0.16	17.5	177.0	133.0	24.9%	115.0	28.0	75.7%	1	0.02
11/14/2009	2.42	0.31	20.9	60.0	34.0	43.3%	36.0	19.0	47.2%	NSR	NSR
12/3/2009	0.16	0.26	13.4	46.0	16.0	65.2%	79.0	21.0	73.4%	NSR	NSR
1/25/2010	1.33	0.71	16.4	74.0	42.0	43.2%	105.0	55.0	47.6%	NSR	NSR
2/26/2010	0.26	0.07	13.2	ERR	ERR	ERR	14.0	10.0	28.6%	NSR	NSR
3/24/2010	0.01	0.19	23.9	73.0	53.0	27.4%	79.0	35.0	55.7%	NSR	NSR
3/30/2010	0.97	0.51	24	46.0	23.0	50.0%	61.0	26.0	57.4%	NSR	NSR
3/31/2010	0.08	0.36	24	47.0	22.0	53.2%	37.0	6.0	83.8%	NSR	NSR
11/7/2010	2.01	0.45	15.8	36.0	24.0	33.3%	54.0	29.0	46.3%	NSR	NSR
12/13/2010	1.01	1.1	25.4	44.0	36.0	18.2%	65.0	18.0	72.3%	NSR	NSR
3/7/2011	0.62	1.53	20.2	56.0	19.0	66.1%	47.0	22.0	53.2%	NSR	NSR
3/8/2011	**	0.22	8.4	14.0	11.0	21.4%	25.0	4.0	84.0%	NSR	NSR
3/12/2011	**	0.7	17.2	46.0	22.0	52.2%	47.0	27.0	42.6%	NSR	NSR
4/16/2011	0.84	0.13	5.8	73.0	59.0	19.2%	64.0	44.0	31.3%	NSR	NSR
			Averages	**57.4**	**37.2**	**35.5%**	**59.7**	**28.2**	**51.1%**	**2**	**0.03**

Definitions	
NSR	No Sample Required
ERR	Sampling Error
*	Permit limit is 200 cfu/100mL
**	Dry Weather Event

Note, fecal sampling is only required when discharge durations surpass 60 minutes continuously or 120 minutes collectively over a 24-hour period, during normal working hours and between and including the months of May to October.

Storm King®
Dynamic Wet Weather Separator

Hydro International®

Bucksport, ME

Storm King® Halts the Impact of CSO Related Flooding

Wet Weather Case Study - Project Profile

Objective

The Town of Bucksport, ME required a solution to the CSO related flooding from the nearby Penobscot river that wouldn't disrupt their community at an affordable price.

Solution

An 18' (5.5 m) diameter Storm King® system used as satellite treatment was smaller, more economical, and more efficient than conventional solutions that were considered.

Project Highlights

- Untreated combined sewerage discharged to the Penobscot River during intense storm events
- Grant funding meant that the entire project cost local taxpayers nothing
- Aesthetically pleasing building has become a focal point for the community
- Significantly reduced the amount of fecal bacteria, total suspended and biological solids to the Penobscot River

Hundreds of municipalities across the country have combined sewer systems in place – the result of turn of the 20th century (or earlier) urban development where both sanitary sewerage and stormwater runoff flow downstream through the same pipes. Today, these communities serve roughly 40 million people in older cities and towns throughout the Northeast and Midwest.

During periods of heavy rain, these sewers will fill beyond capacity causing a combined sewer overflow, or CSO. Historically, CSOs were handled by discharging the sewage at designated outfall points into nearby bodies of water. However, the National Pollutant Discharge Elimination System (NPDES) portion of the Clean Water Act has mandated that communities with CSOs take action and handle their overflow in a more environmentally conscious manner.

While everyone wants to protect the environment, cash-strapped cities and towns across the country are struggling to fund CSO mitigation projects in the midst of the current recession. Improvement projects often cost millions of dollars that local taxpayers cannot afford to pay, leaving cities stuck between expensive government mandates and unhappy constituents.

One town in Maine faced this problem in 2007. But with an alternative treatment method and some old-fashioned Yankee ingenuity, the town turned an eyesore into a local landmark, without costing the town's taxpayers a single dollar.

Bucksport is a working-class community on the Maine coast, located at the mouth of the Penobscot River, on the main thoroughfare to Acadia National Park. Each summer, thousands of tourists drive up Route 1, many stopping in Bucksport before the last hour of their drive southeast to Bar Harbor.

> ***"It is exactly what we wanted and more."***
>
> **Roger Raymond, Bucksport Town Manager**

However, Bucksport's two CSO outfalls were located within eyesight of Route 1, defacing an important part of the town's downtown district. "It was an eyesore," said Town Manager Roger Raymond about the CSO at the heart of four dilapidated buildings.

In 2000, Raymond formed a Sewer Committee, comprised of wastewater treatment operators, citizens and town council members to investigate the town's CSO abatement alternatives.

Bucksport, like many New England cities, faced several options to address their CSO issues. It could add a significant amount of capacity to the WWTP located downstream of the overflows or it could split stormwater and wastewater flows by constructing a 'separate' collection system. Either option would be a costly and disruptive proposition. Land would be required for the project, downtown traffic would be significantly impacted, and extensive work would be required to stabilize sediment in areas with unstable native soil. Bucksport's third option was satellite treatment within the collection system – provided by Hydro International.

Satellite treatment involves treating wet weather flows further upstream, before such flows reach the treatment plant. Solids break down as they travel through the collection system. Capturing both floatable and settleable solids (and their associated pollutants) early in the system provides the greatest opportunity for removing high levels of solids and associated pollutants without more complex treatment processes.

Interior Storm King® Facility

Bucksport Ribbon Cutting Ceremony

www.hydro-int.com Tel: (866) 615 8130

Satellite treatment proved to be the most cost-effective alternative for the town. However, local leaders still had to fund the $3.1 million project. Instead of having taxpayers shoulder the bill, they came up with a novel idea. With the outfall located next to several neglected buildings, they used this as a community betterment initiative.

This transformed a neglected downtown block into a community focal point. With the help of several rural development, community development, public infrastructure and enterprise grants, Bucksport had the funding it needed. In May 2007, the project was underway.

Bucksport contracted Wright Pierce, an engineering firm headquartered in Topsham, Maine to design the new downtown treatment center. Given that the Town's main pump station could transport only 1.0 Mgal/d (44 L/s) to the treatment plant, the objective was to route excess wet weather flows via a new diversion structure and pump station to an advanced hydrodynamic vortex separator for treatment, the Storm King® provided by Hydro International.

Flow is introduced into the Storm King® via a tangentially positioned inlet causing a rotational flow path around the dip plate. As the flow spirals down the wall of the chamber, solids settle out by gravitational and rotational forces. Settleable solids collect in the base as the center cone directs flow up and around the center of the shaft into the inside of the dip plate cylinder. The upward flow rotates at a slower velocity than the outer downward flow. The resulting 'shear' zone scrubs out the finer particles.

The collected settleable solids are gravity fed from the base of the unit to the sewage treatment plant. The system also doubles as a chlorine contact and mixing chamber for the reduction of fecal coliforms being discharged into the Penobscot River. The unit was designed to incorporate a Swirl-Cleanse screening component in the future. This component would capture all floatables and neutrally buoyant material greater than 4 mm in diameter. An air regulated siphon would backwash the screen to prevent it from blinding.

When the project broke ground in the fall of 2007, it was greeted by locals with skepticism. A wastewater treatment facility is not generally regarded as a community beautification initiative. "We were questioned regularly when we chose that location," said Raymond.

When the project finished in the fall of 2008, the Storm King® was effectively taking the pressure off of the plant and treating all wet weather events that would have been discharged without treatment in the past. Since the Storm King® was commissioned in 2008, all rain events the system has handled have been treated in accordance with regulatory requirements.

"It gives an unbelievable view of the fort and the new bridge."

Roger Raymond, Bucksport Town Manager

To the residents of Bucksport, initial skepticism has changed to resounding approval. Two years after the project, the site is now the most publicly used area in the community. In addition to the CSO facility, the site contains a cupola, fishing pier, fountain, Veteran's memorial, water wheel and pond. In front of the site stretches a mile-long waterfront walkway and picnic tables where the public can enjoy the view of Penobscot Bay, the Penobscot Narrows Bridge and the 19th century Fort Knox located on the other side of the river. "It gives an unbelievable view of the fort and the new bridge," said Town Manager Roger Raymond. "We built a building that people think is a restaurant or museum. No one would think that it's a CSO treatment facility."

When visitors drive up Route 1 to Acadia, they have the option of turning right, continuing their trip or turning left, into downtown Bucksport. Due to some creative funding and alternative technology, Bucksport is a town that's turning heads in the left direction. "It's exactly what we wanted and more," said Raymond. "People can be proud of the fact their waste is treated."

Bucksport CSO Facility From Fishing Pier

Exterior View of CSO Facility and Fort Knox (Across the River)

Hydro International. 2925 NW Aloclek Suite 140. Hillsboro, OR 97124. Tel: (866) 615 8130
Email: questions@hydro-int.com Web: www.hydro-int.com

Wet Weather Solutions

Turning Water Around...®

Storm King® as a contact vessel for disinfection

Technical Bulletin

Wet Weather Solutions

Turning Water Around…®

Introduction

Storm King® has long been used as a vessel for preventing solids, grit, and screenings from being discharged at combined sewer overflows (CSOs). If disinfection of the discharge is also required, the norm has been to provide separate tanks for disinfection. Trials conducted at Columbus and Saco have shown that because of the flow characteristics of the Storm King®, both solids removal and disinfection can be achieved in the same vessel. This bulletin outlines the theory of how this is achieved; along with practical examples from active full-scale sites, and cites where independent studies have been undertaken on this application, together with what was observed.

Disinfection Theory

The elimination of harmful bacteria by disinfection has been practiced for decades. The rate of die-off of micro-organisms can be described as an empirical first order kinetic equation commonly referred to as "Chick's Law" (USEPA 1986).

$$\frac{-dN}{dt} = kN$$

Where N is the number of surviving organisms per unit volume at any given time, and k is the organism die-off constant. (Chick 1908)

It is recognised that many factors can cause deviations from the model such as changes in disinfectant concentration over time, and varying resistances of individual micro-organisms. This work was then built on experimentally by Watson to show "a clear definite logarithmic relationship between concentration of disinfectant and mean reaction velocity" (Watson 1908).

Disinfection performance is often measured through changes in concentration of indicator micro-organisms such as total and faecal coliforms over time. The Collins model predicts the reduction in bacterial concentrations as a function of chlorine residual concentrations and system contact time (USEPA 1999).

The Collins Model

The Collins model of disinfection is built on the work by Chick-Watson (USPEA 1986) on reduction in bacteria concentration as a function of chlorine residual concentrations and system contact time in accordance with the following equation:

$$Y_t = Y_0\ (1+0.23CT)^{-3}$$

Y_t = Bacterial concentration after time T (MPN/100ml)

Y_0 = Original bacterial concentration (MPN/100ml)

C = Chlorine residual concentration after time T (mg/l)

T = Contact time (min)

The Collins model is widely quoted and accepted in many texts such as Metcalf and Eddy (Metcalf and Eddy 2004) and USEPA (USEPA 1999) as a reasonable model of the effectiveness of the disinfection, with the proviso that initial mixing intensity, CSO water quality, flow characteristic, and disinfectant effectiveness are also considered.

Reactor Theory

Disinfection ideally occurs in a Plug Flow Reactor (PFR), whereby all of the flow entering the reactor leaves the reactor after the same period of time. This allows the disinfectant the longest possible contact time with the flow. This ideal reactor does not exist, the closest real world approximation of this are serpentine tank type reactors often used for municipal water and wastewater disinfection. The opposite extreme is the Complete Stirred Tank Reactor (CSTR), whereby the flow entering the tank is immediately distributed evenly throughout the reactor; a real world example to this would be a flash mixing tank or "race track" activated sludge plant. In this case some of the flow entering the reactor leaves immediately, whilst some stays in the reactor forever.

A number of CSTR tanks in series can approximate a plug flow reactor, the higher the number of CSTR the closer the approximation, (Perry 1997).

Using the equation

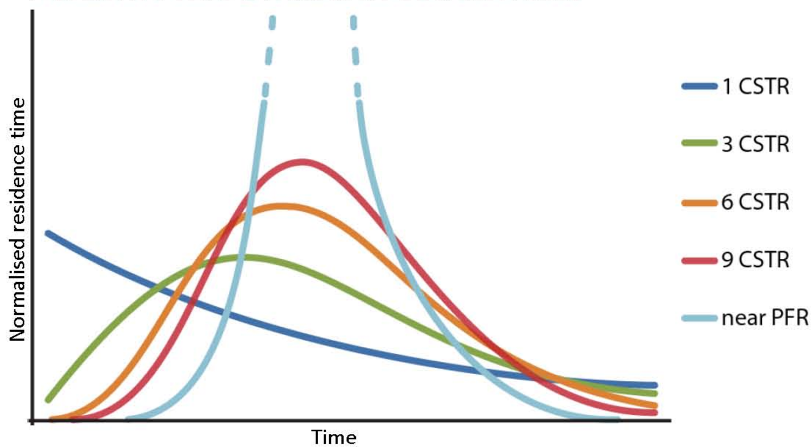
$$E(t_r) = \frac{n^n}{(n-1)!} t_r^{n-1} \exp(-nt_r)$$

$E(t_r)$ is the Normalised residence time distribution

n is the number of ideal mixed tanks in series

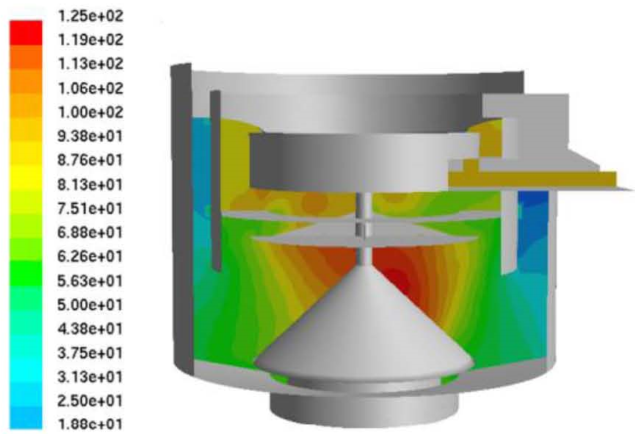
t_r is the time divided by the mean residence time

Residence Time Distribution Characteristics



Storm King® Reactor Kinetics

Hydro International have undertaken a number of studies of the Residence Time Distribution (RTD) characteristics of the Storm King® using CFD modelling, and have also engaged independent experts in the field to estimate the RTD characteristic of the Storm King® both mathematically and experimentally. (Egarr 2005)



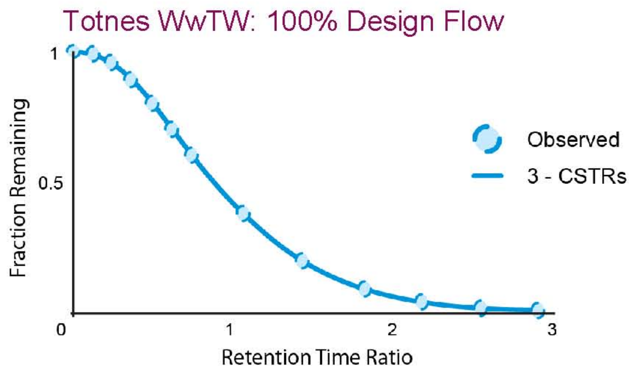
Contours of mean residence time

The Storm King® can be approximated to 3 CSTR tank reactors in series. Using the equation below, the fractional flow leaving in discrete periods of retention time (as a ratio to the mean hydraulic retention time) can be calculated.

Fractional Time as a percentage of the mean hydraulic residence time	Fraction flow leaving the system during time period
10%	1.00%
20%	2.96%
30%	4.94%
40%	6.51%
50%	7.53%
60%	8.03%
70%	8.10%
80%	7.84%
90%	7.35%
100%	6.72%
110%	6.02%
120%	5.31%
130%	4.62%
140%	3.97%
150%	3.37%
160%	2.84%
170%	2.38%
180%	1.98%
190%	1.63%
200%	1.34%

Based on $E(t_r) = \frac{9}{4} t_r^2 \exp(-3t_r)$ (Perry 1997)

This relationship was also confirmed experimentally at the Totnes Wastewater Treatment Plant in the south west region of the UK, where the dye tracer test results showed remarkable correlation.



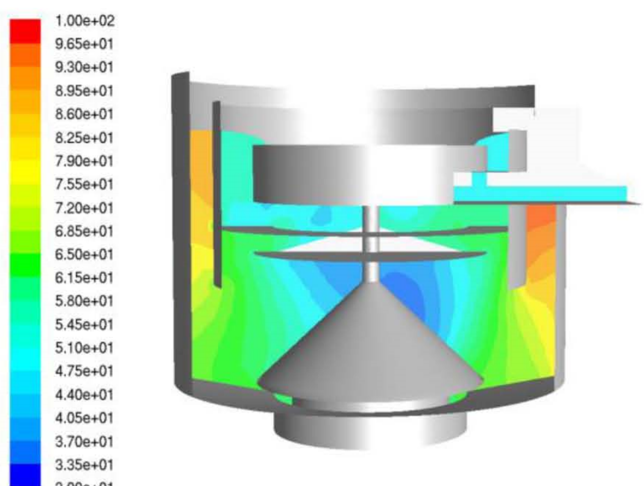
By combining these models it is possible to develop a disinfection model for the Storm King®. The residence time distribution model is divided into 20 identical time segments spanning up to twice the mean hydraulic detention time. The Collins model is then applied to the fractional microbial load in that time segment, with the resultant bacterial level from each segment summated to produce an overall survival level.

$$Y_t = Y_{0.1}(1+0.23CT_{0.1})^{-3} + Y_{0.2}(1+0.23CT_{0.2})^{-3} + Y_{0.3}(1+0.23CT_{0.3})^{-3} + Y_{0.4}(1+0.23CT_{0.4})^{-3} + Y_{0.5}(1+0.23CT_{0.5})^{-3} + Y_{0.6}(1+0.23CT_{0.6})^{-3} + Y_{0.7}(1+0.23CT_{0.7})^{-3} + Y_{0.8}(1+0.23CT_{0.8})^{-3} + Y_{0.9}(1+0.23CT_{0.9})^{-3} + Y_{1.0}(1+0.23CT_{1.0})^{-3} + Y_{1.1}(1+0.23CT_{1.1})^{-3} + Y_{1.2}(1+0.23CT_{1.2})^{-3} + Y_{1.3}(1+0.23CT_{1.3})^{-3} + Y_{1.4}(1+0.23CT_{1.4})^{-3} + Y_{1.5}(1+0.23CT_{1.5})^{-3} + Y_{1.6}(1+0.23CT_{1.6})^{-3} + Y_{1.7}(1+0.23CT_{1.7})^{-3} + Y_{1.8}(1+0.23CT_{1.8})^{-3} + Y_{1.9}(1+0.23CT_{1.9})^{-3} + Y_{2.0}(1+0.23CT_{2.0})^{-3}$$

Where $Y_0 = Y_{0.1} + Y_{0.2} + Y_{0.3} + Y_{0.4} + Y_{0.5} + Y_{0.6} + Y_{0.7} + Y_{0.8} + Y_{0.9} + Y_{1.0} + Y_{1.1} + Y_{1.2} + Y_{1.3} + Y_{1.4} + Y_{1.5} + Y_{1.6} + Y_{1.7} + Y_{1.8} + Y_{1.9} + Y_{2.0}$

Results above twice the mean hydraulic residence time are ignored as it represents a small fraction of the load, and also has the highest kill rate.

CFD modelling has shown that even in very short retention time significant microbial kill occurs (Egarr 2005)

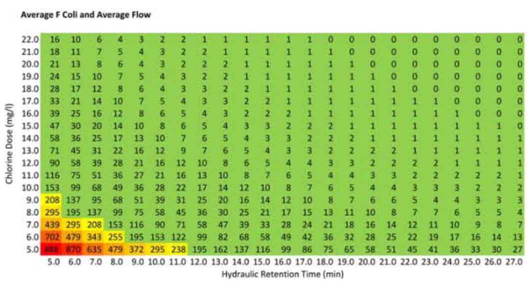


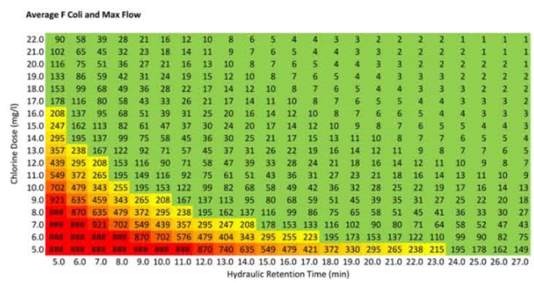
Contours of micro-organism survival, %

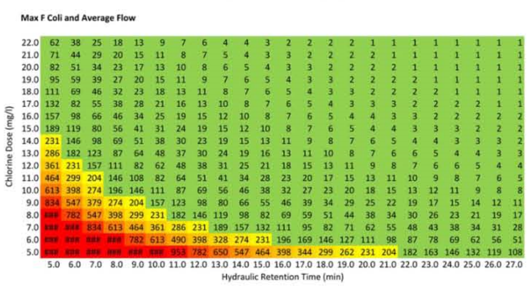
Averages vs. Peaks

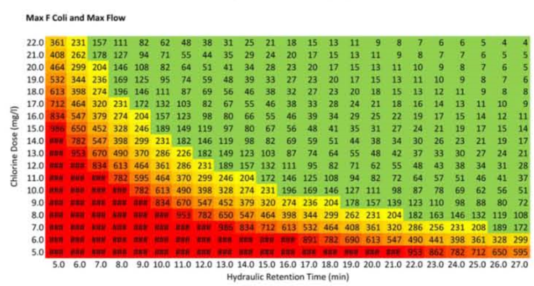
Both flow and microbial load vary, therefore designing for an absolute level of microbial survival at all flows and load situations will lead to overdesign of the system. Typically the CSO device will be designed on the basis of peak flows resulting from a 1 in 5, 1 in 30, to 1 in 100 year storm event, therefore in a normal situation the flow experienced by the unit is significantly less than the design flow. This leads to longer contact time being experienced in most storm events than those designed for peak flow conditions.

Equally the microbial load on the system will vary with higher loads experienced infrequently, with high flows unlikely to coincide with high loads due to dilution. The Storm King® model therefore allows designers to understand the risks associated with the retention time and dose selected, allowing the proper balance between capital (unit size) and operating (disinfectant dosing) costs to be appreciated.





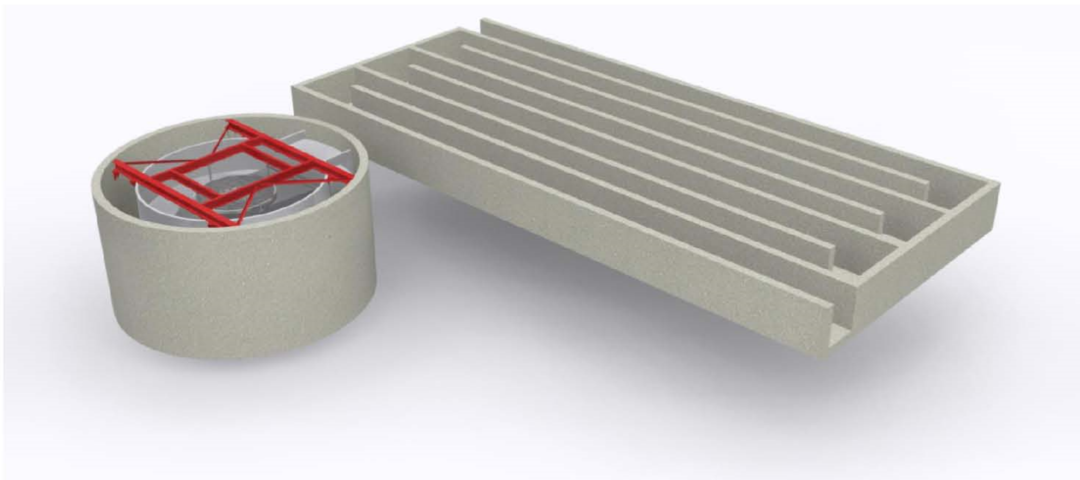




It is also possible to monitor flow data and adjust the disinfectant dosing accordingly.

Space Saving

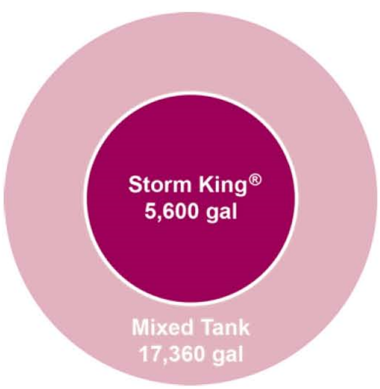
The Storm King® represents a huge saving in land requirements, with the same volume of contact vessel taking a quarter of the space required for a conventional tank, along with using just 30 to 35% of the concrete volume for construction. A typical serpentine tank arrangement is shown below; it has a width to depth to length ration of 1:1:140 (USEPA 1986). Hydro International's Storm King® is shown alongside to give a comparison.

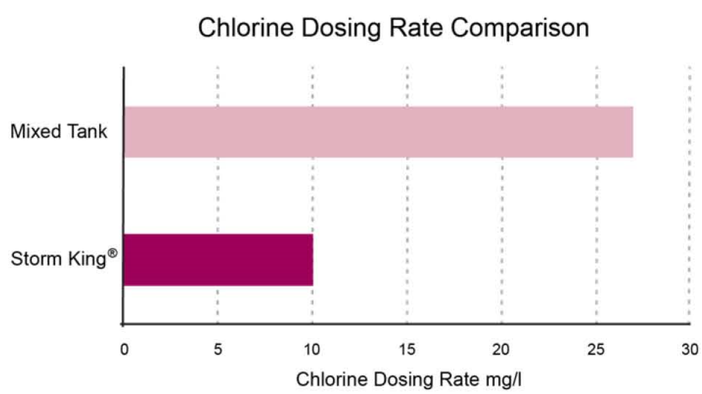


25.5' (7.75m) diameter tank. Water depth = 11.5' (3.5m), allow 10" (250mm) freeboard, and 10" (250mm) base slab. All walls 10" (250mm)

67.25' (20.5m) x 29.5' (9.0m) tank. Water depth = 3.25' (1.0m), allow 10" (250mm) freeboard, and 10" (250mm) base slab. All walls 10" (250mm)

Due to the Storm King® unit's superior residence time distribution characteristic and its solids removal and associated microbial properties, the Storm King® provides exceptional savings in both disinfectant dosing and reactor volume. To achieve the same disinfection performance as the Storm King® a conventional tank would have to be either three times as large, or have its dosing rate increase by 170%.



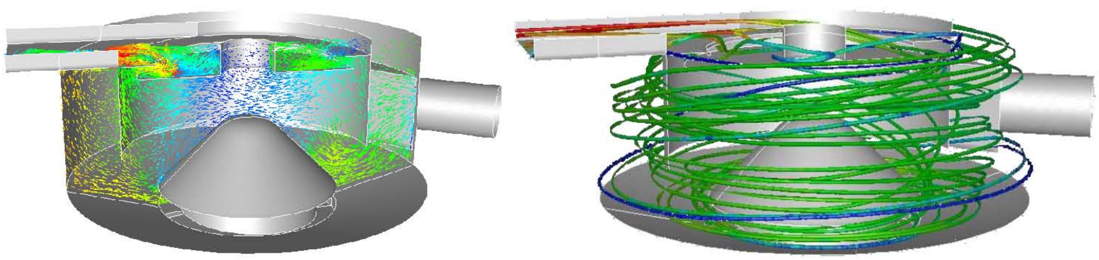


This represents a large saving in concrete costs and time on site, and allows the use of precast concrete segments, again saving time and money.

Grit and Solids Removal

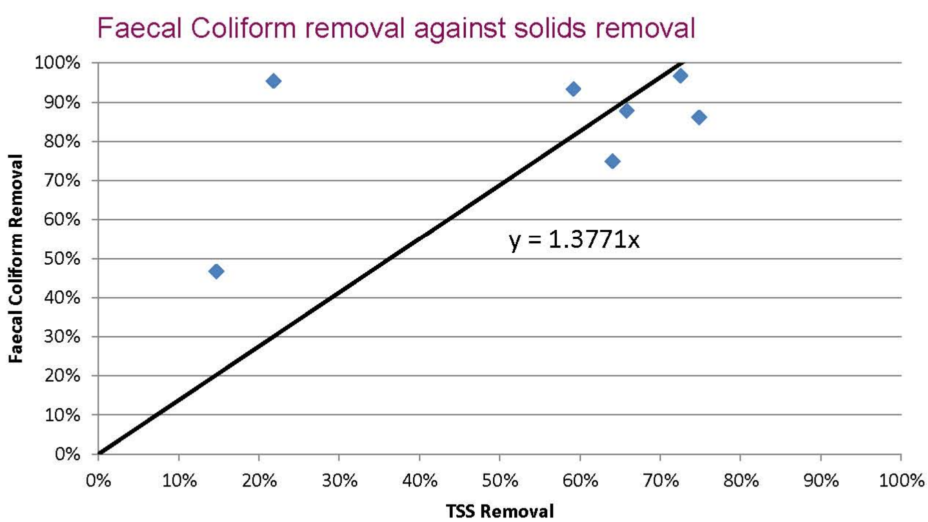
Because the Storm King®, has a controlled flow regime and resulting elongated flow path which encourages grit and solids to settle whilst disinfecting the flow, this allows the unit to combine its disinfection duties with total suspended solids and grit removal. It also eliminates the build-up of grit and solids in the contact tank meaning that no prior separate removal stage is required such as a micro-strainer or other pre-treatment devices.

The Storm King® offers 50% or more cost savings over micro-strainers (USEPA 1979) treating the same flow and eliminates the need for a separate disinfectant contact tank.



Microbial reduction through solids removal

Based on the results generated from 5 years monitoring of the full scale Storm King® installation at Columbus, GA site, a strong link has been observed between total suspended solids removal (TSS), and removal of coliform bacteria. Typically 1.4% of coliforms are removed for every 1% of TSS removed. This shows a very high affinity for the solid material to harbour the bacteria, and thus removal of the solid material dramatically reduces the microbial load on the disinfected flow. Solids removal is typically in the range of 60 to 75%, and the associated microbial reduction was found to be in the range 75 to 97%. Lower removals of solids are typically seen at higher flow rates when the settling and retention times are lower and the influent flows are more dilute.



This removal can be factored into the model to allow for a reduction of the initial load. We would suggest that this is set at 75% as standard, representing a 0.6 log kill due to solids separation.

Mixing

It is vitally important that sufficient initial rapid mixing occurs of the disinfectant with the wastewater (USEPA 1973) with the "G" value often used to assess this aspect of the process which is known as the velocity gradient.

$G = \sqrt{(P / \mu V)}$ (Metcalf and Eddy 2004)

Where:

G is the average velocity gradient (s^{-1})

μ is the dynamic viscosity (Ns/m^2)

P is the power input (W)

V is the volume (m^3)

Water viscosity changes with temperature, and therefore has an impact on the velocity gradient. (Perry 1997)

For practical purposes it has been found that injecting the chemical disinfectant in a well-mixed region upstream of the Storm King® (eg. Diversion Chamber) is sufficient to provide the initial rapid mixing. The Storm King® has a tapering velocity gradient field which has been found to be good for effective contacting. Mechanical or static mixers could also be used but could suffer from problems associated with screenings in the flow.

It has been shown that "G" values of $500s^{-1}$ or more, offer sufficient mixing with no additional advantage offered at higher velocity gradients (Lee 2002).

References

USEPA (1999) Combined Sewer Overflow Technology Fact Sheet Chlorine Disinfection, USEPA, EPA 832-F-99-034

USEPA (1986) Design Manual Municipal Wastewater Disinfection, USEPA, EPA/625/1-86/021

USEPA (1979) Disinfection/Treatment of Combined Sewer Overflows - Syracuse, New York, USEPA, EPA-600/2-79-134

USEPA (1973) Microstraining and Disinfection of Combined Sewer Overflows – Phase II, USEPA, EPA-R2-73-124

Metcalf and Eddy (2004) Wastewater Engineering Treatment and Reuse, 4th ed., McGraw Hill

Chick, H. (1908) An Investigation of the Laws of Disinfection, J. Hyg., 8, 92, 1908.

Watson, H.E. (1908) A Note of the Variation of the Rate of Disinfection with Changes in the Concentration of the Disinfectant. J. Hyg., 8, 536, 1908.

Egarr, D.A. (2005) Studies of fluidic systems for environmental applications. Cardiff School of Engineering, University of Wales, Cardiff.

Perry, R. H., Green, D.W (1997) Perry's Chemical Engineers' Handbook, 7th ed. McGraw-Hill, London

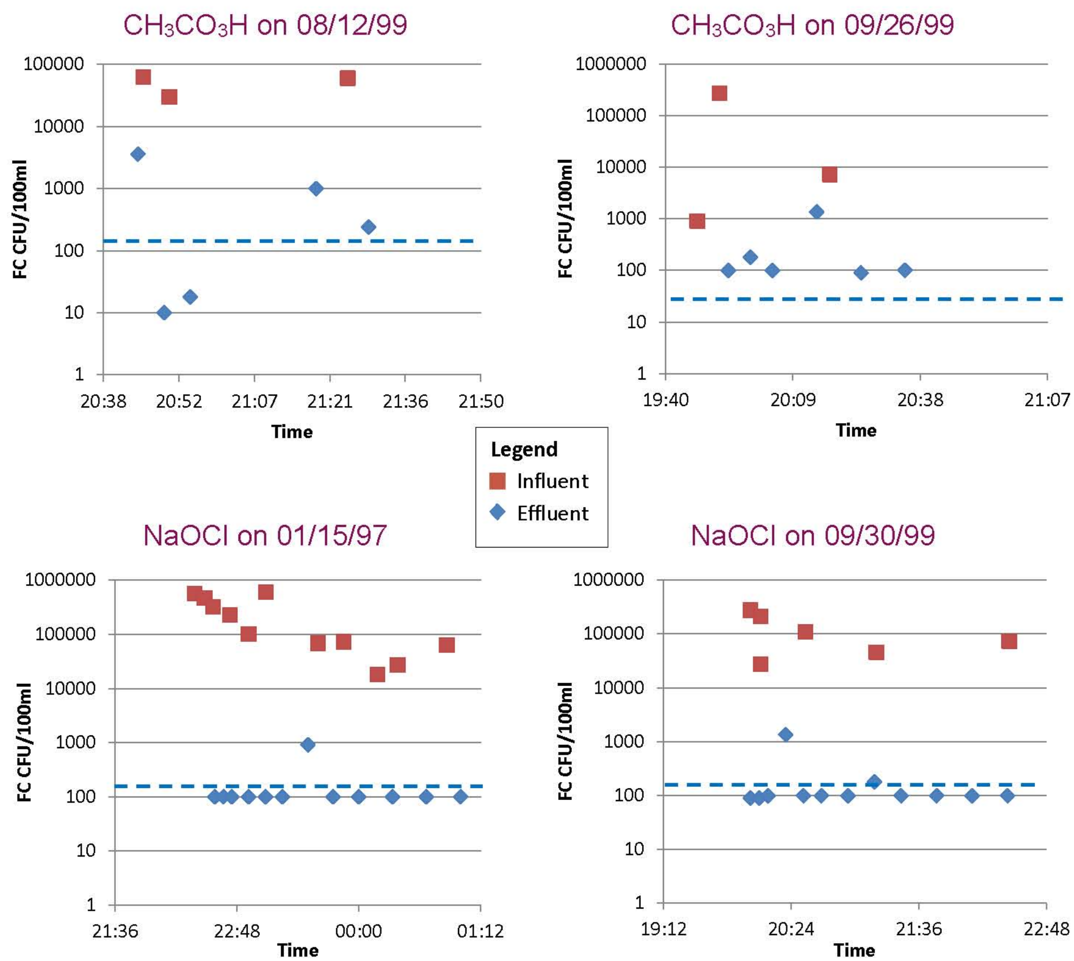
Lee, Y., Nam, S. (2002) Reflection on Kinetic Models to the Chlorine Disinfection for Drinking Water Purification, J. Microbiology, June 2002, p.119-p124.

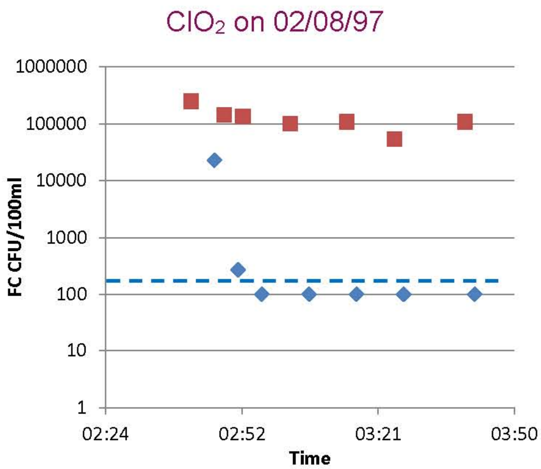
Case Studies

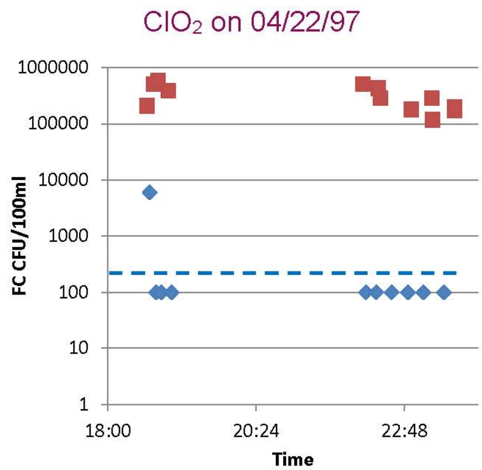
Columbus, GA

Columbus Advanced Demonstration Facility (ADF) featured a number of identical Storm King® units operating with different disinfectants; these were Sodium Hypochlorite (NaOCl), Chlorine Dioxide (ClO_2), and Peracetic Acid (CH_3CO_3H).

The study showed that the required effluent standard could be met with any of the disinfectants. Typical dosing values were in the range of 7 to 15 mg/l. The facility was designed to handle 48 mgd, but has a hydraulic capacity of 144 mgd; 15.8 minutes to 5.3 minutes hydraulic retention time respectively.





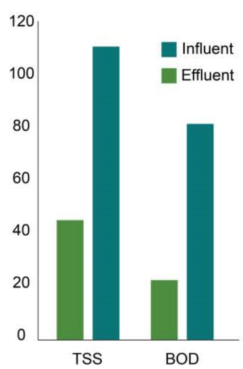


The full report on the Columbus ADF was published by WERF in 2003.

Saco, ME

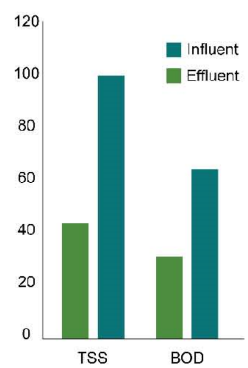
The Saco, Maine CSO treatment facility, which consist of a 22 foot diameter Storm King® was commissioned in 2006. It was designed for a maximum flow of 5.63 mgd, and has been dosed with sodium hypochlorite for disinfection.

The design hydraulic retention time was 8 minutes.



	Influent (mg/l)	Effluent (mg/l)	% Removal
TSS	111	43.8	61
BOD	81.8	21.2	74

Note that this chart is the 2007 Nor'easter where the system ran for 5 days continuously.



	Influent (mg/l)	Effluent (mg/l)	% Removal
TSS	100	42.1	58
BOD	65.6	29.1	56

Note that this chart is the average of all storm events to date.

The annual data summaries for post construction monitoring over a period of more than four years, shows fairly consistent average effluent concentrations for both BOD and TSS with the observed relatively high BOD removals repeated in successive years. The figure above (which shows the observed overall average TSS and BOD removals over the period January 2007 to March 2011) and the table below clearly highlight that even for the periods when the influent BOD concentrations have been low; removals have been above the norm of 50% TSS and 20% BOD. It is surmised that the observed high BOD removals may be a function of the additional effects of the integral self-cleaning fine screen mesh within the Storm King® unit.

Data summaries for January 2007 to March 2011

Year	Number of CSO Events	Avg. Influent BOD (mg/l)	Avg. Effluent BOD (mg/l)	BOD Removals (%)	Avg. Influent TSS (mg/l)	Avg. Effluent TSS (mg/l)	TSS Removals (%)	Avg. Faecal Count (cfu/100ml)
2007	19	86.3	29.4	66	130.3	48.8	63	110
2008	21	84.5	30.1	64	110.2	34.8	68	51
2009	18	51.0	34.2	33	93.2	47.5	49	129
2010	22	54.5	30.8	44	87.7	38.6	56	90
2011*	4	51.6	21.2	59	78.8	40.8	48	84

*Note: 2011 is not a full year's worth of data

The observed average annual faecal counts are also below the consent requirements of 200 colony forming units (cfu) per 100ml for the site; confirming the effectiveness of the Storm King® as a contact chamber for high-rate disinfection of CSO and other wet-weather flows.

What is HX?

HX is Hydro Experience, it is the essence of Hydro. It's interwoven into every strand of Hydro's story, from our products to our people, our engineering pedigree to our approach to business and problem-solving.

HX is a stamp of quality and a mark of our commitment to optimum process performance. A Hydro solution is tried, tested and proven.

There is no equivalent to Hydro HX.

Wet Weather Solutions

2925 NW Aloclek Drive, Suite 140
Hillsboro OR 97124

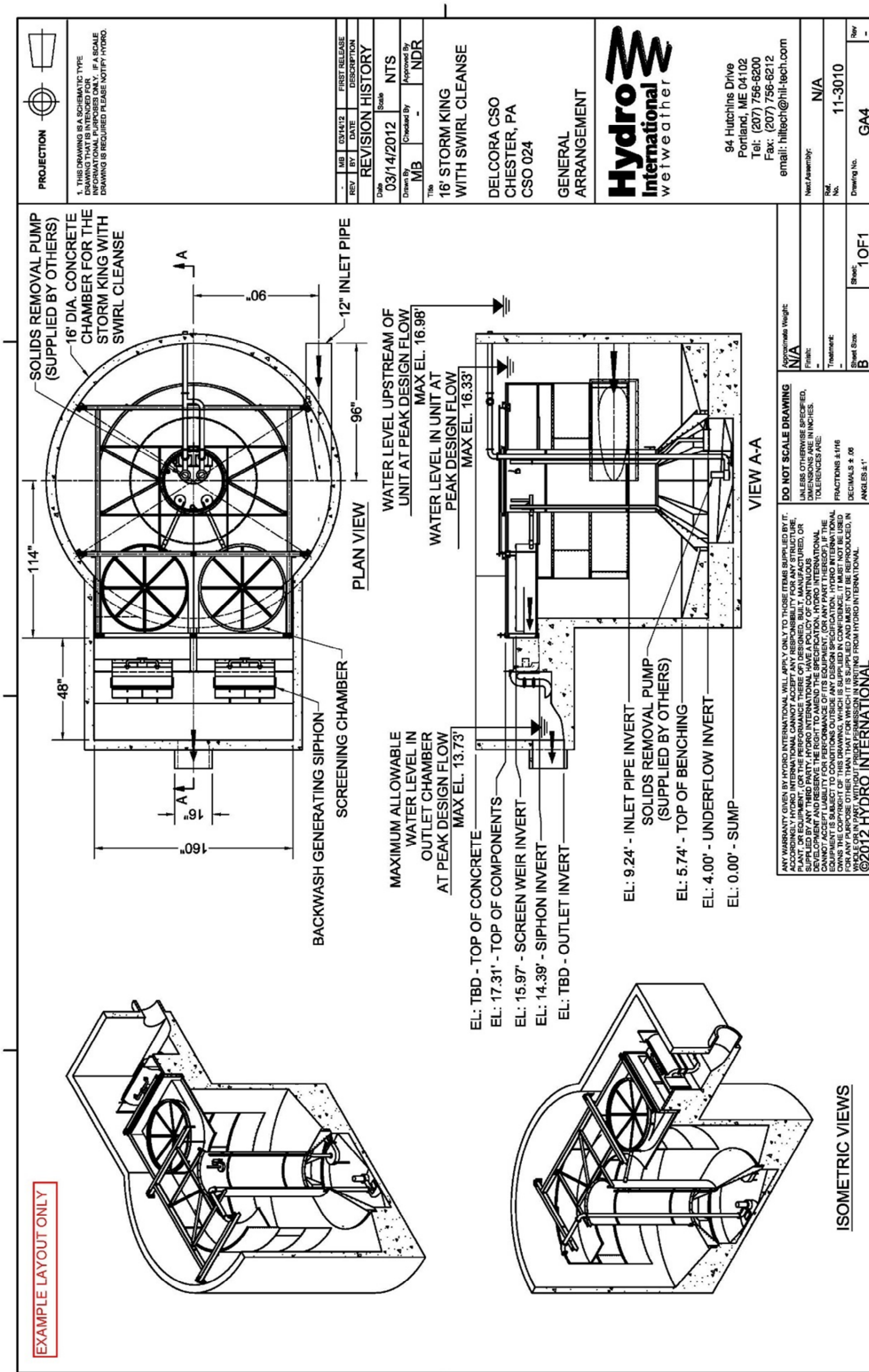
Tel: (503) 615-8130
Fax: (503) 615 2906

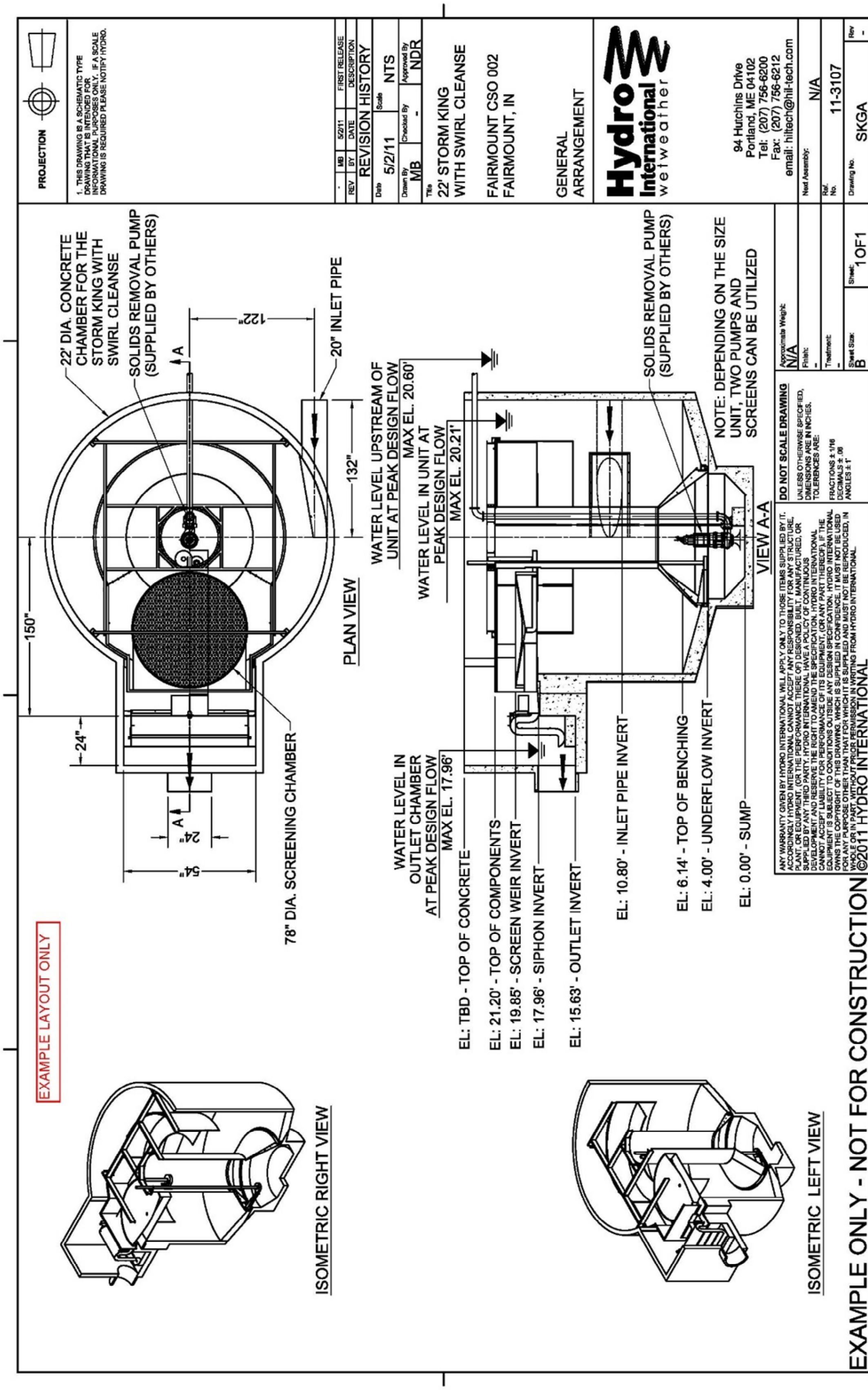
www.hydro-int.com

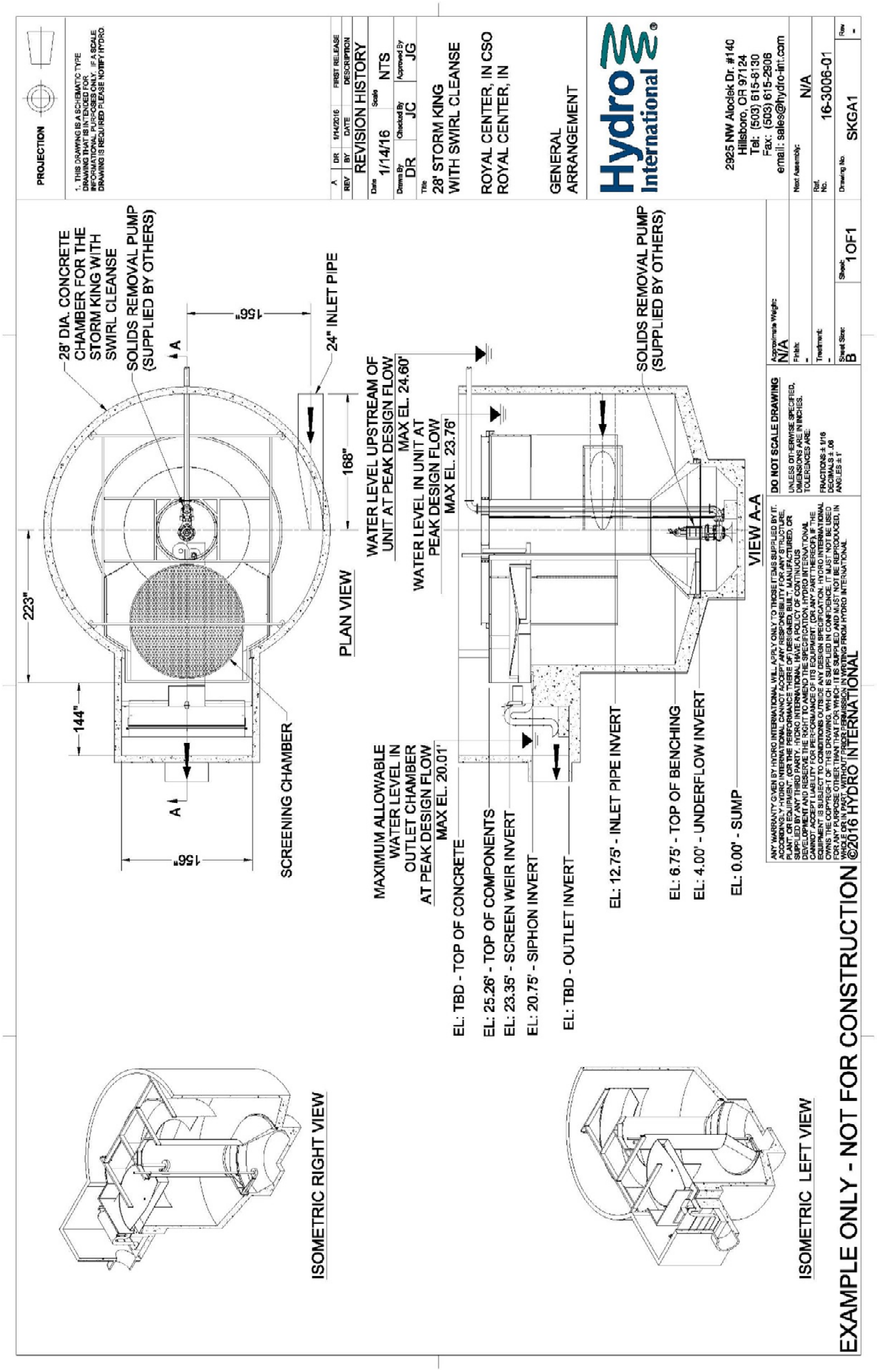
Turning Water Around...®

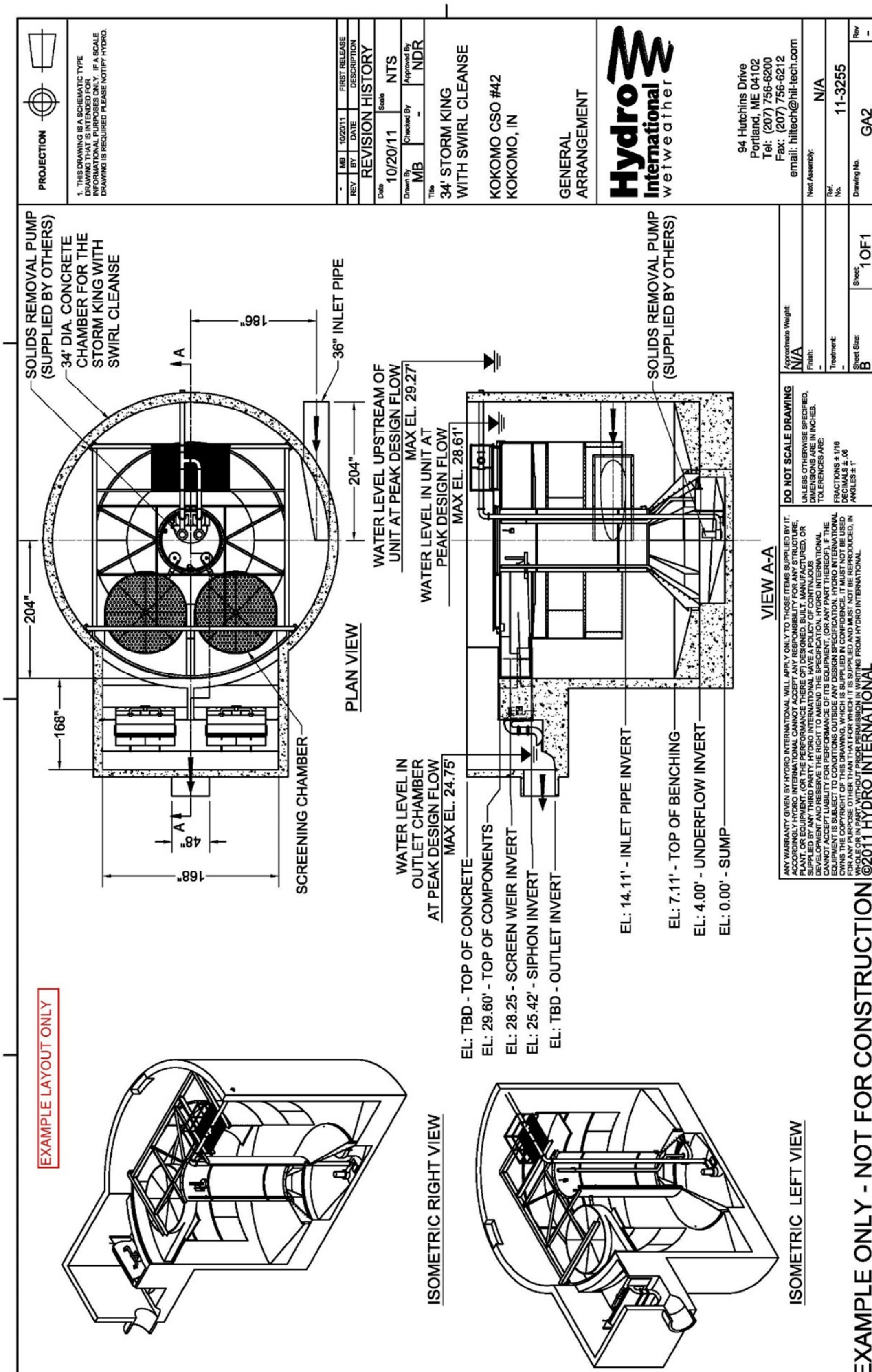
Table - Storm King Unit Size and Number per Design Flow & Treatment Objectives

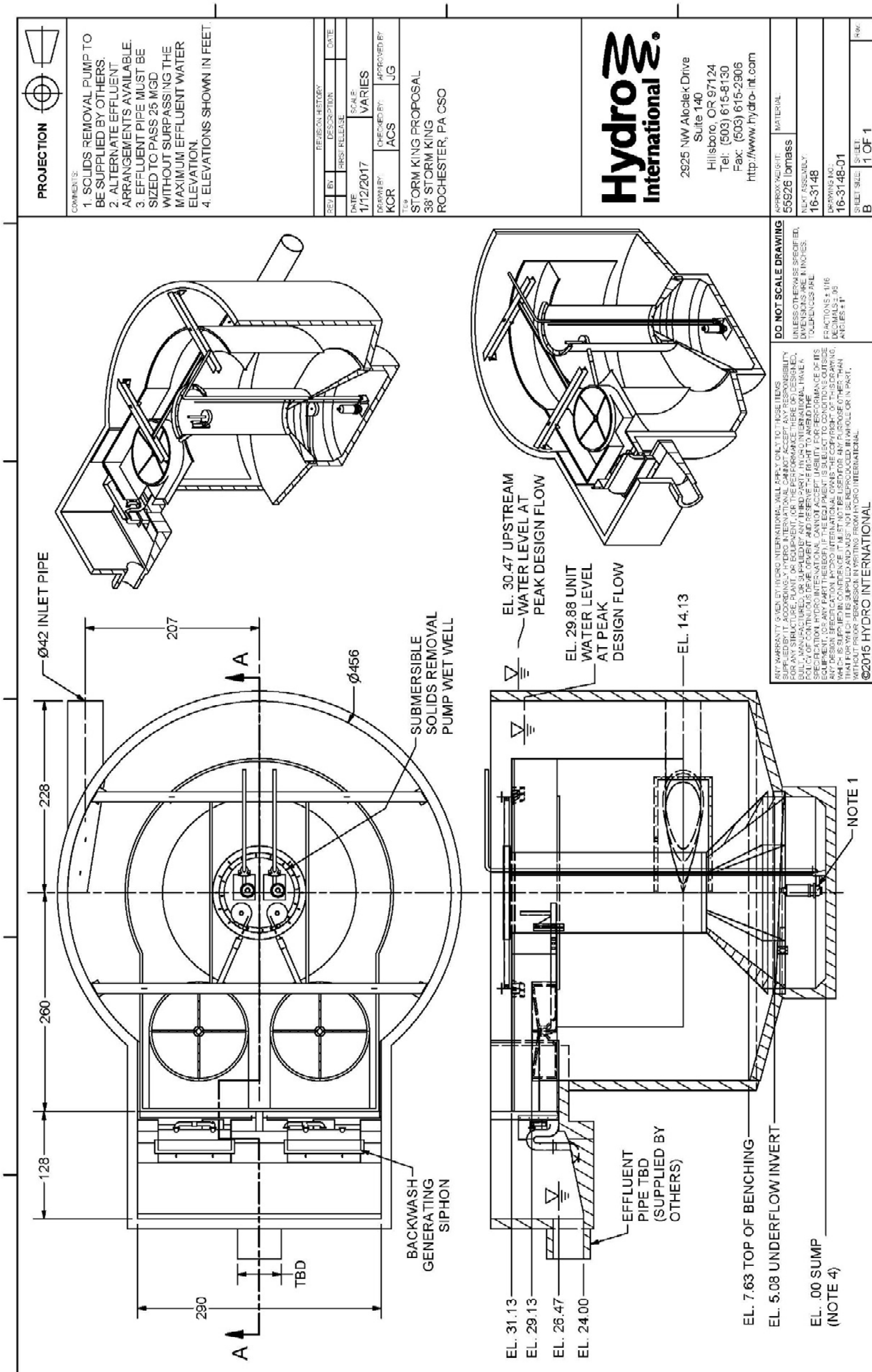
Flow (mgd)	Treatment Objective	Quantity	Unit Diameter (ft)	Treatment Objective	Quantity	Unit Diameter (ft)
5	TSS Removal	1	16	TSS Removal & Disinfection	1	22
10	TSS Removal	1	22	TSS Removal & Disinfection	1	28
25	TSS Removal	1	34	TSS Removal & Disinfection	1	38
100	TSS Removal	2	44	TSS Removal & Disinfection	3	40
200	TSS Removal	4	44	TSS Removal & Disinfection	5	44
250	TSS Removal	5	44	TSS Removal & Disinfection	6	44

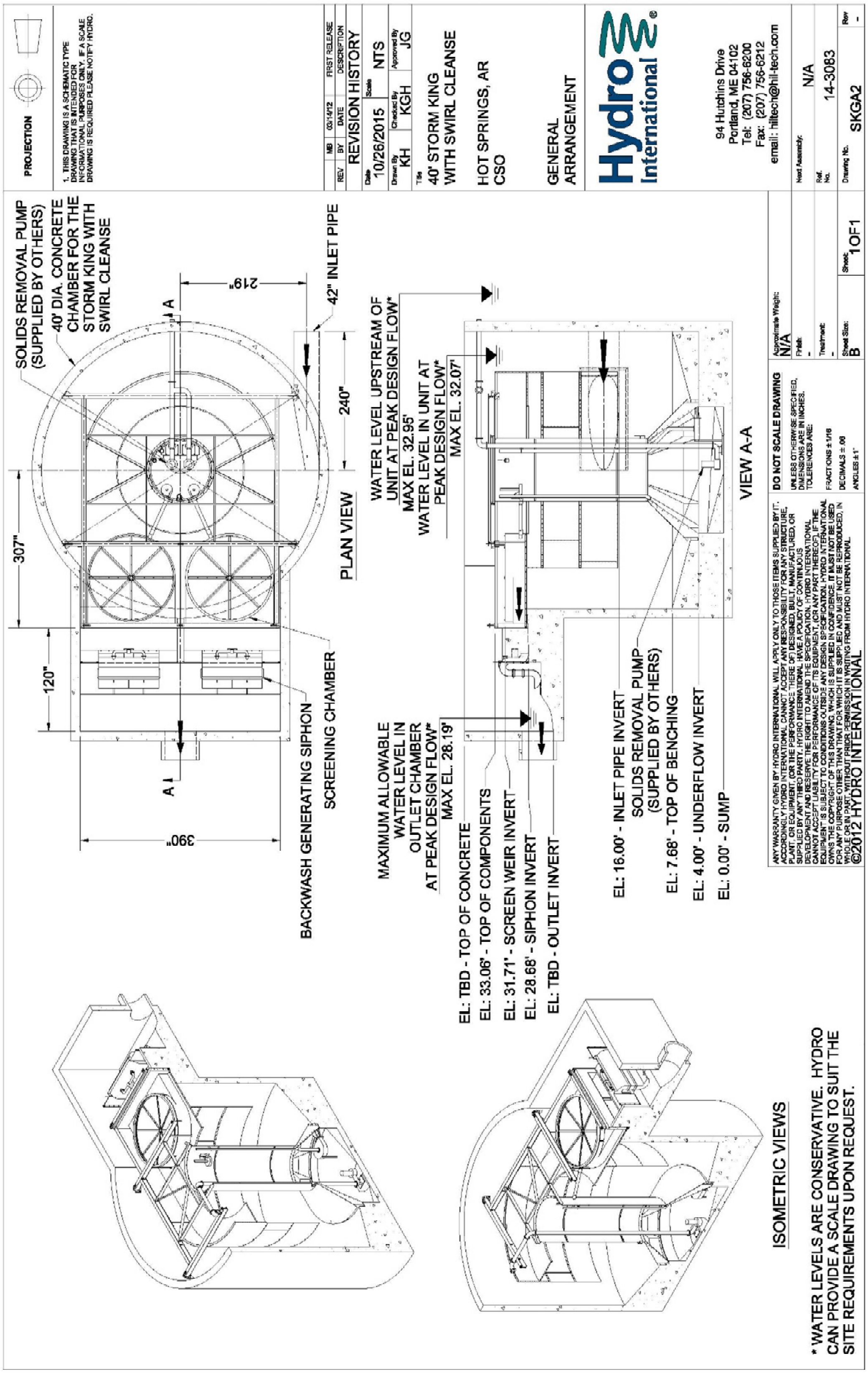

PROJECTION
1. THIS DRAWING IS A SCHEMATIC TYPE DRAWING THAT IS INTENDED FOR INFORMATIONAL PURPOSES ONLY. IF A SCALE DRAWING IS REQUIRED PLEASE NOTIFY HYDRO.
- MB 03/14/12 FIRST RELEASE
REV BY DATE DESCRIPTION
REVISION HISTORY
Date 03/14/2012
Scale NTS
Drawn By MB
Checked By -
Approved By NDR
Title
16' STORM KING WITH SWIRL CLEANSE
DELCORA CSO
CHESTER, PA
CSO 024
GENERAL ARRANGEMENT
Hydro International
wetweather
94 Hutchins Drive
Portland, ME 04102
Tel: (207) 756-6200
Fax: (207) 756-6212
email: hiltech@hil-tech.com
Next Assembly:
Ref. No. N/A
11-3010
Drawing No. GA4
Rev -
Sheet: 1OF1
Sheet Size: B
Approximate Weight: N/A
Finish: -
Treatment: -
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
16' DIA. CONCRETE CHAMBER FOR THE STORM KING WITH SWIRL CLEANSE
12" INLET PIPE
90"
96"
114"
48"
16"
160"
A
PLAN VIEW
BACKWASH GENERATING SIPHON
SCREENING CHAMBER
WATER LEVEL UPSTREAM OF UNIT AT PEAK DESIGN FLOW MAX EL. 16.98'
WATER LEVEL IN UNIT AT PEAK DESIGN FLOW MAX EL. 16.33'
MAXIMUM ALLOWABLE WATER LEVEL IN OUTLET CHAMBER AT PEAK DESIGN FLOW MAX EL. 13.73'
EL: TBD - TOP OF CONCRETE
EL: 17.31' - TOP OF COMPONENTS
EL: 15.97' - SCREEN WEIR INVERT
EL: 14.39' - SIPHON INVERT
EL: TBD - OUTLET INVERT
EL: 9.24' - INLET PIPE INVERT
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
EL: 5.74' - TOP OF BENCHING
EL: 4.00' - UNDERFLOW INVERT
EL: 0.00' - SUMP
VIEW A-A
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERENCES ARE:
FRACTIONS ± 1/16
DECIMALS ± .06
ANGLES ± 1°
©2012 HYDRO INTERNATIONAL
ISOMETRIC VIEWS
EXAMPLE LAYOUT ONLY


PROJECTION
1. THIS DRAWING IS A SCHEMATIC TYPE DRAWING THAT IS INTENDED FOR INFORMATIONAL PURPOSES ONLY. IF A SCALE DRAWING IS REQUIRED PLEASE NOTIFY HYDRO.
REVISION HISTORY
Date 5/2/11
Scale NTS
Drawn By MB
Checked By -
Approved By NDR
Title 22' STORM KING WITH SWIRL CLEANSE
FAIRMOUNT CSO 002
FAIRMOUNT, IN
GENERAL ARRANGEMENT
Hydro International wetweather
94 Hutchins Drive
Portland, ME 04102
Tel: (207) 756-6200
Fax: (207) 756-6212
email: hiltech@hil-tech.com
Next Assembly: N/A
Ref. No. 11-3107
Drawing No. SKGA
Rev -
Sheet: 1OF1
Sheet Size: B
Approximate Weight: N/A
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERENCES ARE:
FRACTIONS ± 1/16
DECIMALS ± .06
ANGLES ± 1°
22' DIA. CONCRETE CHAMBER FOR THE STORM KING WITH SWIRL CLEANSE
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
20" INLET PIPE
122"
132"
150"
24"
54"
78" DIA. SCREENING CHAMBER
PLAN VIEW
WATER LEVEL UPSTREAM OF UNIT AT PEAK DESIGN FLOW MAX EL. 20.60'
WATER LEVEL IN UNIT AT PEAK DESIGN FLOW MAX EL. 20.21'
WATER LEVEL IN OUTLET CHAMBER AT PEAK DESIGN FLOW MAX EL. 17.96'
NOTE: DEPENDING ON THE SIZE UNIT, TWO PUMPS AND SCREENS CAN BE UTILIZED
VIEW A-A
EL: TBD - TOP OF CONCRETE
EL: 21.20' - TOP OF COMPONENTS
EL: 19.85' - SCREEN WEIR INVERT
EL: 17.96' - SIPHON INVERT
EL: 15.63' - OUTLET INVERT
EL: 10.80' - INLET PIPE INVERT
EL: 6.14' - TOP OF BENCHING
EL: 4.00' - UNDERFLOW INVERT
EL: 0.00' - SUMP
EXAMPLE LAYOUT ONLY
ISOMETRIC RIGHT VIEW
ISOMETRIC LEFT VIEW
©2011 HYDRO INTERNATIONAL
EXAMPLE ONLY - NOT FOR CONSTRUCTION

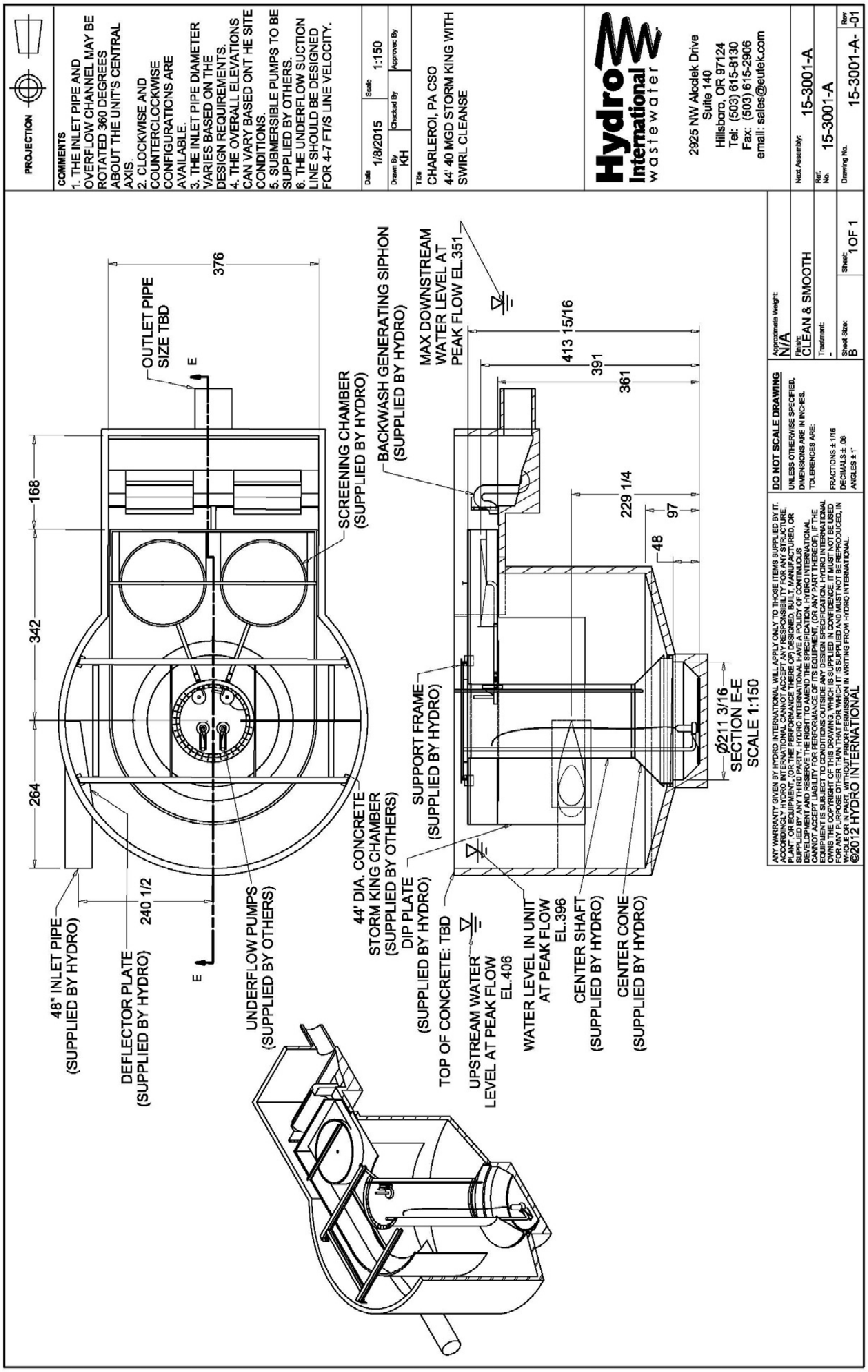

PROJECTION
1. THIS DRAWING IS A SCHEMATIC TYPE DRAWING THAT IS INTENDED FOR INFORMATIONAL PURPOSES ONLY. IF A SCALE DRAWING IS REQUIRED PLEASE NOTIFY HYDRO.
REVISION HISTORY
1/14/16
NTS
DR
JC
JG
28' STORM KING WITH SWIRL CLEANSE
ROYAL CENTER, IN CSO ROYAL CENTER, IN
GENERAL ARRANGEMENT
Hydro International
2925 NW Aloclek Dr. #140
Hillsboro, OR 97124
Tel: (503) 615-8130
Fax: (503) 615-2906
email: sales@hydro-int.com
N/A
16-3006-01
SKGA1
1OF1
28' DIA. CONCRETE CHAMBER FOR THE STORM KING WITH SWIRL CLEANSE
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
24" INLET PIPE
156"
168"
223"
144"
156"
SCREENING CHAMBER
PLAN VIEW
WATER LEVEL UPSTREAM OF UNIT AT PEAK DESIGN FLOW MAX EL. 24.60'
WATER LEVEL IN UNIT AT PEAK DESIGN FLOW MAX EL. 23.76'
MAXIMUM ALLOWABLE WATER LEVEL IN OUTLET CHAMBER AT PEAK DESIGN FLOW MAX EL. 20.01'
EL: TBD - TOP OF CONCRETE
EL: 25.26' - TOP OF COMPONENTS
EL: 23.35' - SCREEN WEIR INVERT
EL: 20.75' - SIPHON INVERT
EL: TBD - OUTLET INVERT
EL: 12.75' - INLET PIPE INVERT
EL: 6.75' - TOP OF BENCHING
EL: 4.00' - UNDERFLOW INVERT
EL: 0.00' - SUMP
VIEW A-A
DO NOT SCALE DRAWING
©2016 HYDRO INTERNATIONAL
ISOMETRIC RIGHT VIEW
ISOMETRIC LEFT VIEW
EXAMPLE ONLY - NOT FOR CONSTRUCTION


EXAMPLE LAYOUT ONLY
ISOMETRIC RIGHT VIEW
ISOMETRIC LEFT VIEW
PLAN VIEW
VIEW A-A
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
34' DIA. CONCRETE CHAMBER FOR THE STORM KING WITH SWIRL CLEANSE
36" INLET PIPE
SCREENING CHAMBER
204"
168"
186"
48"
WATER LEVEL UPSTREAM OF UNIT AT PEAK DESIGN FLOW MAX EL. 29.27'
WATER LEVEL IN UNIT AT PEAK DESIGN FLOW MAX EL. 28.61'
WATER LEVEL IN OUTLET CHAMBER AT PEAK DESIGN FLOW MAX EL. 24.75'
EL: TBD - TOP OF CONCRETE
EL: 29.60' - TOP OF COMPONENTS
EL: 28.25 - SCREEN WEIR INVERT
EL: 25.42' - SIPHON INVERT
EL: TBD - OUTLET INVERT
EL: 14.11' - INLET PIPE INVERT
EL: 7.11' - TOP OF BENCHING
EL: 4.00' - UNDERFLOW INVERT
EL: 0.00' - SUMP
PROJECTION
1. THIS DRAWING IS A SCHEMATIC TYPE DRAWING THAT IS INTENDED FOR INFORMATIONAL PURPOSES ONLY. IF A SCALE DRAWING IS REQUIRED PLEASE NOTIFY HYDRO.
REVISION HISTORY
Date 10/20/11
Scale NTS
Drawn By MB
Approved By NDR
34' STORM KING WITH SWIRL CLEANSE
KOKOMO CSO #42
KOKOMO, IN
GENERAL ARRANGEMENT
Hydro International wetweather
94 Hutchins Drive
Portland, ME 04102
Tel: (207) 756-6200
Fax: (207) 756-6212
email: hiltech@hil-tech.com
N/A
11-3255
GA2
Sheet Size: B
Sheet: 1OF1
DO NOT SCALE DRAWING
©2011 HYDRO INTERNATIONAL
EXAMPLE ONLY - NOT FOR CONSTRUCTION


PROJECTION
COMMENTS:
1. SOLIDS REMOVAL PUMP TO BE SUPPLIED BY OTHERS.
2. ALTERNATE EFFLUENT ARRANGEMENTS AVAILABLE.
3. EFFLUENT PIPE MUST BE SIZED TO PASS 25 MGD WITHOUT SURPASSING THE MAXIMUM EFFLUENT WATER ELEVATION.
4. ELEVATIONS SHOWN IN FEET.
REVISION HISTORY
REV
BY
DESCRIPTION
DATE
FIRST RELEASE
DATE:
1/12/2017
SCALE:
VARIES
DRAWN BY:
KCR
CHECKED BY:
ACS
APPROVED BY:
JG
STORM KING PROPOSAL
38' STORM KING
ROCHESTER, PA CSO
Hydro International
2925 NW Aloclek Drive
Suite 140
Hillsboro, OR 97124
Tel: (503) 615-8130
Fax: (503) 615-2906
http://www.hydro-int.com
APPROX WEIGHT:
55926 lbmass
MATERIAL:
NEXT ASSEMBLY:
16-3148
DRAWING NO:
16-3148-01
SHEET SIZE:
B
SHEET:
1 OF 1
REV:
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
FRACTIONS ± 1/16
DECIMALS ± .06
ANGLES ± 1°
©2015 HYDRO INTERNATIONAL
Ø42 INLET PIPE
207
A
Ø456
SUBMERSIBLE SOLIDS REMOVAL PUMP WET WELL
228
260
128
290
TBD
BACKWASH GENERATING SIPHON
EL. 30.47 UPSTREAM WATER LEVEL AT PEAK DESIGN FLOW
EL. 29.88 UNIT WATER LEVEL AT PEAK DESIGN FLOW
EL. 14.13
NOTE 1
EFFLUENT PIPE TBD (SUPPLIED BY OTHERS)
EL. 31.13
EL. 29.13
EL. 26.47
EL. 24.00
EL. 7.63 TOP OF BENCHING
EL. 5.08 UNDERFLOW INVERT
EL. .00 SUMP (NOTE 4)


PROJECTION
1. THIS DRAWING IS A SCHEMATIC TYPE DRAWING THAT IS INTENDED FOR INFORMATIONAL PURPOSES ONLY. IF A SCALE DRAWING IS REQUIRED PLEASE NOTIFY HYDRO.
REVISION HISTORY
FIRST RELEASE
10/26/2015
NTS
KH
KGH
JG
40' STORM KING WITH SWIRL CLEANSE
HOT SPRINGS, AR CSO
GENERAL ARRANGEMENT
Hydro International
94 Hutchins Drive
Portland, ME 04102
Tel: (207) 756-6200
Fax: (207) 756-6212
email: hiltech@hil-tech.com
N/A
14-3083
SKGA2
1OF1
B
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
40' DIA. CONCRETE CHAMBER FOR THE STORM KING WITH SWIRL CLEANSE
42" INLET PIPE
219"
240"
307"
120"
390"
A
PLAN VIEW
BACKWASH GENERATING SIPHON
SCREENING CHAMBER
WATER LEVEL UPSTREAM OF UNIT AT PEAK DESIGN FLOW*
MAX EL. 32.95'
WATER LEVEL IN UNIT AT PEAK DESIGN FLOW*
MAX EL. 32.07'
MAXIMUM ALLOWABLE WATER LEVEL IN OUTLET CHAMBER AT PEAK DESIGN FLOW*
MAX EL. 28.19'
EL: TBD - TOP OF CONCRETE
EL: 33.06' - TOP OF COMPONENTS
EL: 31.71' - SCREEN WEIR INVERT
EL: 28.68' - SIPHON INVERT
EL: TBD - OUTLET INVERT
EL: 16.00' - INLET PIPE INVERT
SOLIDS REMOVAL PUMP (SUPPLIED BY OTHERS)
EL: 7.68' - TOP OF BENCHING
EL: 4.00' - UNDERFLOW INVERT
EL: 0.00' - SUMP
VIEW A-A
DO NOT SCALE DRAWING
©2012 HYDRO INTERNATIONAL
ISOMETRIC VIEWS
* WATER LEVELS ARE CONSERVATIVE. HYDRO CAN PROVIDE A SCALE DRAWING TO SUIT THE SITE REQUIREMENTS UPON REQUEST.

N


PROJECTION
COMMENTS
1. THE INLET PIPE AND OVERFLOW CHANNEL MAY BE ROTATED 360 DEGREES ABOUT THE UNIT'S CENTRAL AXIS.
2. CLOCKWISE AND COUNTERCLOCKWISE CONFIGURATIONS ARE AVAILABLE.
3. THE INLET PIPE DIAMETER VARIES BASED ON THE DESIGN REQUIREMENTS.
4. THE OVERALL ELEVATIONS CAN VARY BASED ONT HE SITE CONDITIONS.
5. SUBMERSIBLE PUMPS TO BE SUPPLIED BY OTHERS.
6. THE UNDERFLOW SUCTION LINE SHOULD BE DESIGNED FOR 4-7 FT/S LINE VELOCITY.
Date 1/8/2015
Scale 1:150
Drawn By KH
CHARLEROI, PA CSO
44' 40 MGD STORM KING WITH SWIRL CLEANSE
Hydro International wastewater
2925 NW Aloclek Drive
Suite 140
Hillsboro, OR 97124
Tel: (503) 615-8130
Fax: (503) 615-2906
email: sales@eutek.com
Next Assembly: 15-3001-A
Ref. No. 15-3001-A
Drawing No. 15-3001-A-
Rev -01
Approximate Weight: N/A
Finish: CLEAN & SMOOTH
Treatment: -
Sheet Size: B
Sheet: 1 OF 1
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.
FRACTIONS ± 1/16
ANGLES ± 1°
©2012 HYDRO INTERNATIONAL
376
OUTLET PIPE SIZE TBD
168
342
264
240 1/2
48" INLET PIPE (SUPPLIED BY HYDRO)
DEFLECTOR PLATE (SUPPLIED BY HYDRO)
UNDERFLOW PUMPS (SUPPLIED BY OTHERS)
SCREENING CHAMBER (SUPPLIED BY HYDRO)
BACKWASH GENERATING SIPHON (SUPPLIED BY HYDRO)
MAX DOWNSTREAM WATER LEVEL AT PEAK FLOW EL.351
413 15/16
391
361
229 1/4
97
48
44' DIA. CONCRETE STORM KING CHAMBER (SUPPLIED BY OTHERS)
DIP PLATE (SUPPLIED BY HYDRO)
SUPPORT FRAME (SUPPLIED BY HYDRO)
TOP OF CONCRETE: TBD
UPSTREAM WATER LEVEL AT PEAK FLOW EL.406
WATER LEVEL IN UNIT AT PEAK FLOW EL.396
CENTER SHAFT (SUPPLIED BY HYDRO)
CENTER CONE (SUPPLIED BY HYDRO)
Ø211 3/16
SECTION E-E
SCALE 1:150

Storm King®

Sedimentation, Screening, & Disinfection in One Device

Hydro International®

Primary treatment equivalency, floatables control, & in-vessel disinfection.

Wet Weather Technical Brochure - Product Profile

The Storm King® is an advanced hydrodynamic vortex separator that incorporates an optional self-cleansing, non-powered Swirl Cleanse screening system to provide screening to 4mm in diameter. The Storm King® is a proven technology which combines grit removal, primary treatment equivalency (TSS and BOD removal), floatables control and in-vessel disinfection within a single unit process. The system is ideal for satellite or centralized treatment at overflow sites because it is self-activating, has no moving parts and requires no power to separate solids.

Applications

- Floatables control, primary treatment equivalency and disinfection of combined sewer overflows (CSOs) and wet weather induced flows
- Remote or unmanned treatment facilities
- Treatment of excess wet weather flows at centralized facilities or POTWs
- Retrofit or new wet weather treatment facilities
- Preliminary treatment prior to storage or equalization

Advantages

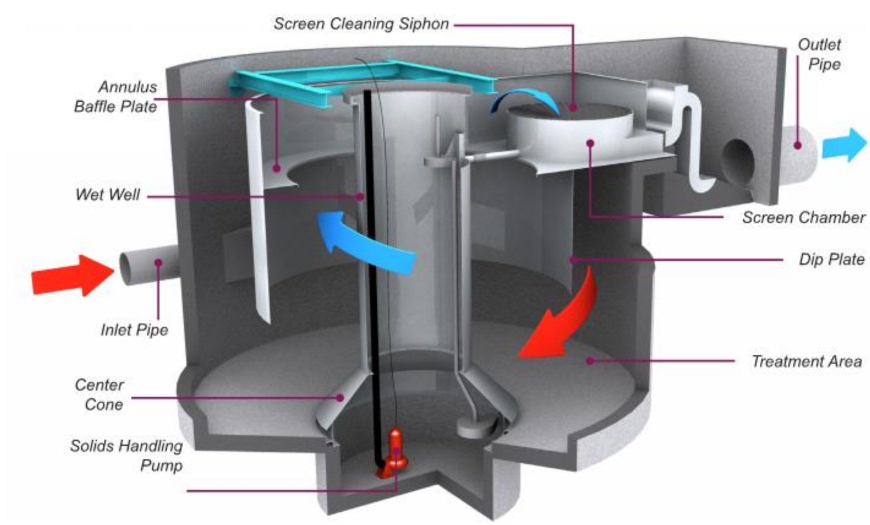
- No power and no moving parts
- Self-activating with a small footprint
- Fine grit removal and primary treatment equivalency
- Combines three unit processes in a single device
- Higher effluent standards can be achieved with the addition of coagulants and flocculants
- Captured material returned to sanitary flow thereby eliminating the need for residuals handling capabilities at remote sites

How it Works

Flow is introduced tangentially into the side of the Storm King® barrel causing the contents to rotate slowly about the vertical axis. The flow spirals down the perimeter allowing solids to settle out by gravity. This process is aided by rotary forces, shear forces and drag forces at the boundary layer on the wall and base of the vessel.

The internal components direct the main flow away from the perimeter and back up the middle of the vessel as a broad spiraling column, rotating at a slower velocity than the outer downward flow. A dip plate locates the shear zone, the interface between the outer downward circulation and the inner upward circulation, where a marked difference in velocity encourages further solids separation. Settled solids are directed to the helical channel located under the center cone and are conveyed out of the main chamber through the underflow outlet.

The flow passes down through the Swirl Cleanse screen which captures all floatables and neutrally buoyant material greater than 4mm in diameter. The air regulated siphon provides an effective backwash mechanism to prevent the screen from blinding. Screened effluent is discharged into a receiving watercourse, a storage facility, or continues on to receive further treatment. (light blue arrow).



The collected screenings and settled solids from the underflow are pumped or gravity fed from the base of the unit and returned to the sanitary flow to continue on to the wastewater treatment facility.

Bacteria reduction is achieved within the Storm King® by introducing chemicals such as Sodium Hypochlorite, Peracetic Acid, or Chlorine Dioxide into the upstream diversion structure or into the inlet pipe of the vessel. The spiraling action integral to the system combined with the predictable flow path of the separator allows the unit to combine its solids and grit removal duties with disinfection. Dechlorination (if applicable) is performed at the discharge of the siphon.

www.hydro-int.com Tel: (866) 615 8130

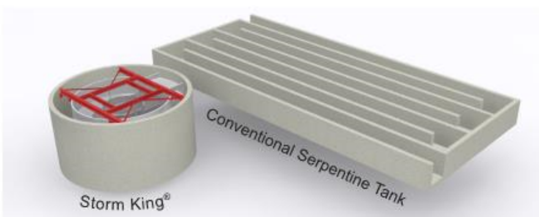
Performance

- Screening to 4 mm in diameter
- Proven high rate disinfection in less than 8 minutes

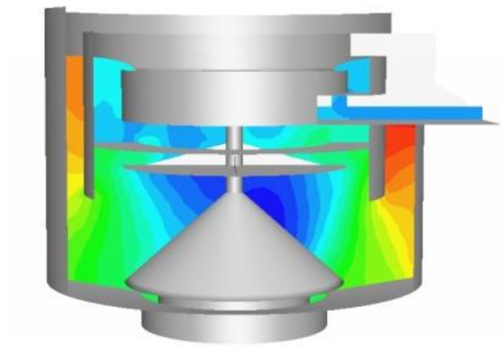
Disinfection

The Storm King® has a long history of providing protection to watercourses. However, it is not widely known that the Storm King® can provide solids removal and disinfection in the same vessel. Taking advantage of the separator's complex flow paths created by the unique internal components, the Storm King® can provide excellent efficiencies while occupying less than 30% of the area required for conventional disinfection solutions.

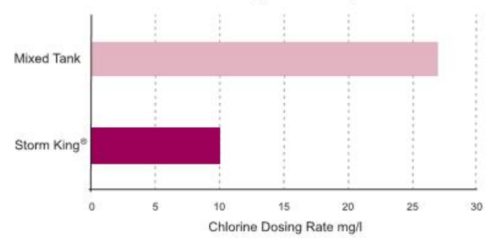
The Storm King® is able to achieve 3 to 4 log kills of total or fecal coliform bacteria within an 8 minute hydraulic retention time and handle commonly available disinfectants such as Sodium Hypochlorite, Peracetic Acid, or Chlorine Dioxide.



Comparisons of Disinfection Area Required for Storm King® and Conventional Disinfection Tanks



CFD simulation showing predicted fecal coliform kills in Storm King® (survival color code: Red is alive and blue is dead).



Maintenance

The Storm King® with Swirl Cleanse has no moving parts and typically requires no higher maintenance commitment than the sewer system in which it is placed.

The maintenance requirement is dependent upon the influent characteristics, which in turn are dependent upon the nature of the contributing system.

Once the device has been brought on-line, the Storm King® and Swirl Cleanse screen should be visually inspected after the first two spill events. After the initial inspections, visual inspection of the equipment should be carried out twice per year, or as deemed appropriate for the location.

Hydro International - Wet Weather / CSO Solutions · 2925 NW Aloclek #140 · Hillsboro, OR 97124 · (866) 615 8130 · V16.1

APPENDIX F

Project Endorsements

THIS PAGE INTENTIONALLY LEFT BLANK

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
WATER SUPPLY AND WATER RESOURCES DIVISION
2890 WOODBRIDGE AVENUE, BUILDING 10, MS-104
EDISON, NJ 08837

February 8, 2007

OFFICE OF
RESEARCH AND DEVELOPMENT

Stanley V.Cach, Assistant Director
State of New Jersey
Department of Environmental Protection
Division of Water Quality
Municipal Finance & Construction Element
401 East State Street
Trenton, NJ 08625-0425

Re: CSO High-Rate Disinfection Demonstration Project Proposal

Dear Mr. Cach,

We here in the Edison EPA National Urban Wet-Weather Flow (WWF) Research Program are excited to learn that the New Jersey Department of Environmental Protection (NJDEP) proposed combined sewer overflow (CSO) disinfection research demonstration project is progressing towards fruition. We admire your ability to bring together governments, CSO communities, technology vendors, consultants and researchers, and other concerned stakeholders for the purposes of gathering interest in the project and leveraging their resources. We are also happy to hear that New Jersey CSO communities, including the city of Bayonne Municipal Utilities Authority(BMUA), communicated their willingness to support such a project.

The reason for our strong support for this venture, outside of our research interest of course, is that the project will not only result in local municipal and state benefits but will make a significant beneficial national impact as well. This is because it will be an evaluation of new and improved high-rate disinfection technologies, required to satisfy the intent of National and State CSO Control Policies and mandates. Further, high-rate disinfection will be of lower cost and greater effectiveness than conventional disinfection. The proposed project stands to save the State and the Nation hundreds of millions of dollars while reducing risks to human health.

BMUA' s willingness to be involved with this project, is welcomed at this juncture because EPA's research budget is low. We are aware that a full-scale demonstration of this nature is estimated to cost a few million dollars and the BMUA is offering their abandoned primary wastewater treatment plant to conduct the demonstration. Such a facility is hard to find elsewhere. Equally impressive is the willingness of new technology manufacturers and vendors (i.e., per-acetic acid, bromine, UV and fuzzy-filter) to contribute resources to this project. All the above contributions will add to the NJDEP's resources to make this project become a reality.

Our WWF Research Program will seek to have some funding available for this project and an in-kind contribution in the analytical area. However, our main contribution to this project will be our expertise in disinfection technology. Mary Stinson and I, conducted many pilot and prototype disinfection projects and we will gladly share our experience with you on this project.

Sincerely,

Richard Field, P.E., D.WRE
Senior Environmental Engineer
Leader, Wet-Weather Flow Management Program
Urban Watershed Management Branch

cc: Anthony Tafuri, UWMB
James Olander, Region 2
Mary K. Stinson, UWMB

-13-

NY/NJ Baykeeper • Hackensack Riverkeeper

May 23, 2007

Senator Frank R. Lautenberg
Hart Senate Office Building
Suite 324
Washington, DC 20510

Newark Office
One Gateway Center
Twenty-Third Floor
Newark, NJ 07102

Re: City of Bayonne's CSO High Rate Disinfection Pilot Project

Dear Senator Lautenberg,

Please accept the following comments on the above referenced pilot project on behalf of New York/New Jersey Baykeeper and Hackensack Riverkeeper (collectively the "Keepers"). The Keepers have been working regularly with the City of Bayonne on CSO abatement issues, and recently attended a presentation of the proposed disinfection pilot project. We believe the pilot would make good use of a pre-existing city owned facility, while addressing the increasing needs for disinfection.

This disinfection pilot project, coupled with the city's interest in a potential low impact development pilot project, makes Bayonne on the cutting edge of source control. We hope your office can assist the city in locating funding for this pilot.

Sincerely,

Betsy McDonald

Betsy McDonald, J.D.
Policy Associate
NY/NJ Baykeeper

Capt Bill Sheehan

Captain Bill Sheehan
Riverkeeper & Executive Director
Hackensack Riverkeeper

Andrew Willner
Baykeeper & Executive Director
NY/NJ Baykeeper

-11-

THIS PAGE INTENTIONALLY LEFT BLANK