AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

Wet Weather Treatment Using AquaStorm™ Cloth Media Filtration

Wet Weather Background

The US EPA is pushing states to require treatment of wet weather events through their Wet Weather Control Program. There are three types of wet weather flow events which consist of the these types of flows:

- Stormwater Runoff – Road surface rainfall runoff flow
- Sanitary Sewer Overflow (SSO) –Sanitary Sewer Flow & Inflows/Infiltration
- Combined Sewer Overflow (CSO) –Sanitary Sewer Flow & Stormwater Runoff

Wet weather events can occur in many locations with the collection network or within a treatment facility (Figure 1).

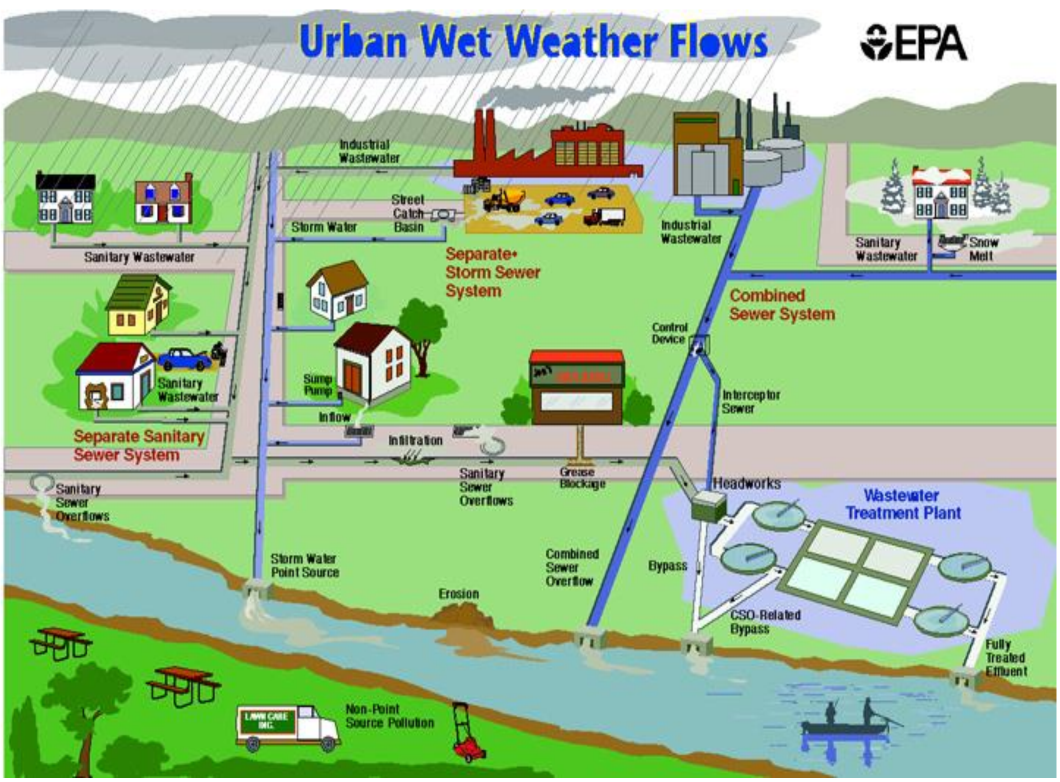

Figure 1: EPA Typical Urban Wet Weather Flows and Locations

It is important to know the following about each type of event and where they can be located:

- Stormwater – MS4
    - Only collects stormwater/rainfall runoff

  - Typically untreated or treated with green type infrastructure for infiltration of the rainfall runoff into the ground
- Combined Sewer Overflow
  - Source – Stormwater runoff and sanitary sewer flows combined in a sewer system by design
  - Discharge Point – Network surcharges, pressurized flow escapes collection system via weak points such as manholes, and designed overflow outfalls to prevent collection system from exceeding capacity in the network or at the treatment facility
  - Discharge Location – Treatment facility, rivers, streams, lakes, and other waterways
- Sanitary Sewer Overflow
  - Source - Sanitary sewer flows including infiltration and inflows
  - Discharge Point – Network surcharges, pressurized flow escapes collection system via weak points such as manholes, and designed overflow outfalls to prevent collection system from exceeding capacity in the network or at the treatment facility
  - Discharge Locations – Low points in collection system or at the treatment facility, flows over land to the waterbody or at a designed overflow

Wet Weather Management Options

While there are several ways to control wet weather flows, it typically involves managing rainfall runoff.
For stormwater only applications, flows are kept separate from sanitary sewer systems and often treated with green infrastructure and infiltration basins. Stormwater treatment devices are also used to screen out trash, settle out solids and other materials.

For SSO and CSO flows, there are generally four alternatives that are considered:

- I/I Reduction
  - Repair and replace leaking pipes
  - Repairs could take 10 to 20+ years depending on the network size
  - There is no guarantee there will not be new leaks and it will prevent I/I causing the wet weather flows
  - Cost can be very high for all the repairs and replacement
- Storage
  - Most common treatment option
  - Includes building storage basins large enough to hold the first flush event until the water can be treated after the storm passes
  - Basins require a very large footprint and can be very costly to build
  - Once the flow volume exceeds the basin's capacity, the excess flow is discharged to the receiving stream, often washing harmful pollutants into local surface waters
- Pumping and treatment at the treatment facility
  - Typically requires expansion and facility upgrades to ensure full treatment capacity
  - Often involves additional network piping and pump station(s)Facility expansion to handle wet weather flows generally leads to many processes being oversized
  - Can be very expensive
- Wet Weather Control Treatment Facility (WWCTF)
  - Can be located at the treatment facility as a side-stream treatment or remotely in the network
  - Can be sized to handle and treat peak flows for the entire duration of the storm event
  - Typically, a cost effective solution

WWCTF Treatment Locations

As mentioned, stormwater control treatment facilities can be located at the main treatment facility as a side-stream treatment, or remotely in the collection network with discharge into the receiving stream. Figure 2 below illustrates possible WWCTF locations:

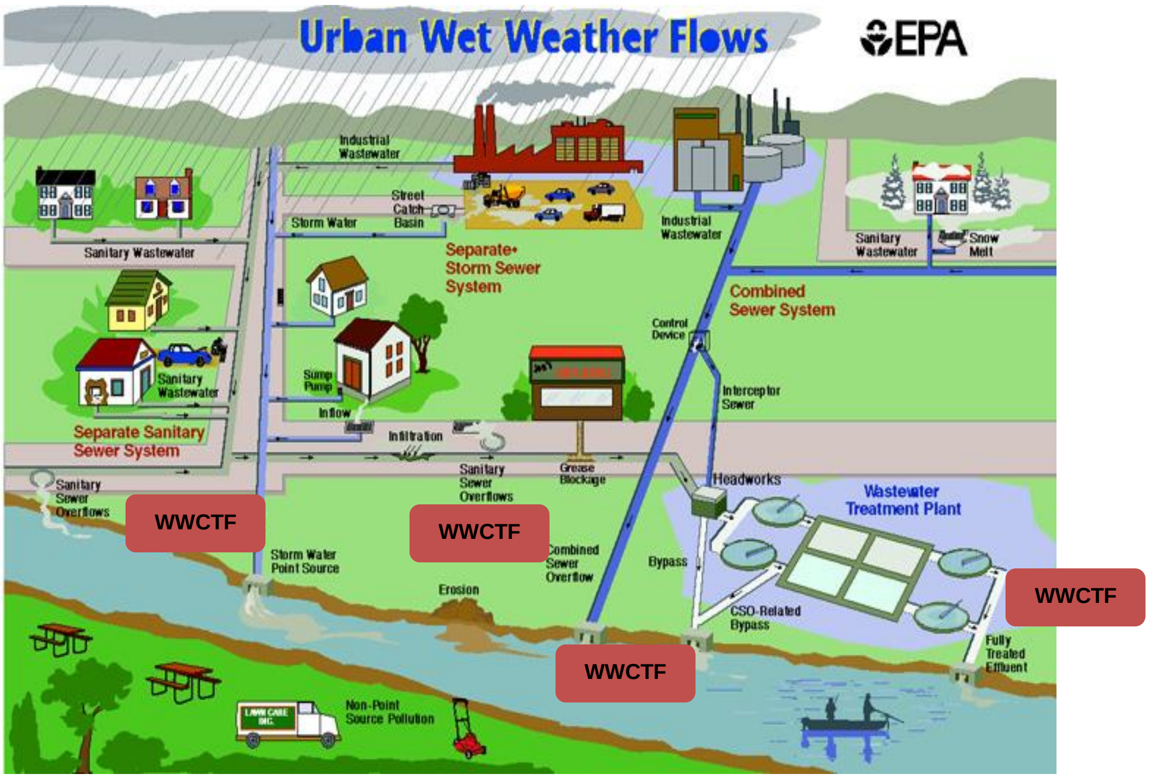

Figure 2: EPA Typical Urban Wet Weather Flows and WWCTF Locations

WWCTF Design Components

The WWCTF treatment process typically consists of the following:

- Screen & Grit Removal
- Clarification and/or Filtration
- Disinfection

WWCTF Location in Main Treatment Plant

The WWCTF treatment process can be located in several locations within the main treatment facility:

- Side-Stream to main treatment process after screen and grit removal
- After primary clarification
- Dual Application – Tertiary Treatment (Dry Weather Flows) and Wet Weather flow during events

AquaPrime® / AquaStorm™ Cloth Media Filtration System for Wet Weather Treatment

The AquaStorm system is the latest development in cloth media filtration. AquaStorm filtration is capable of be use in many application including the following:

- Primary Filtration
- Primary Effluent Filtration
- Tertiary Filtration
- Wet Weather Treatment application both in the collection network and main treatment facility

Figure 3 shows location options where an AquaStorm unit can be utilized for wet weather auxiliary side-stream treatment.

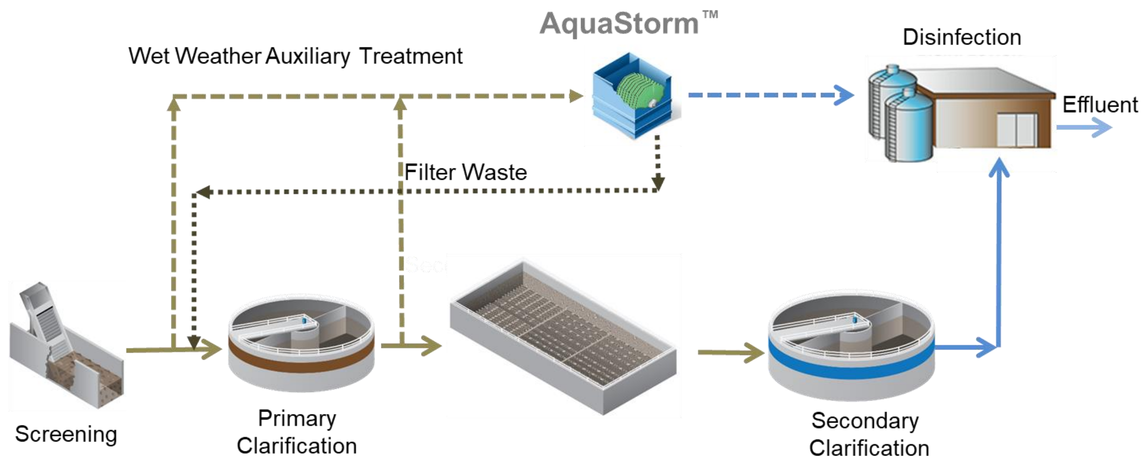

Figure 3: Primary & Side-Stream Wet Weather Treatment

Figure 4 shows a location option of the AquaStorm system to be used for dual treatment consisting of tertiary filtration during dry weather conditions and combined treatment during wet weather events.

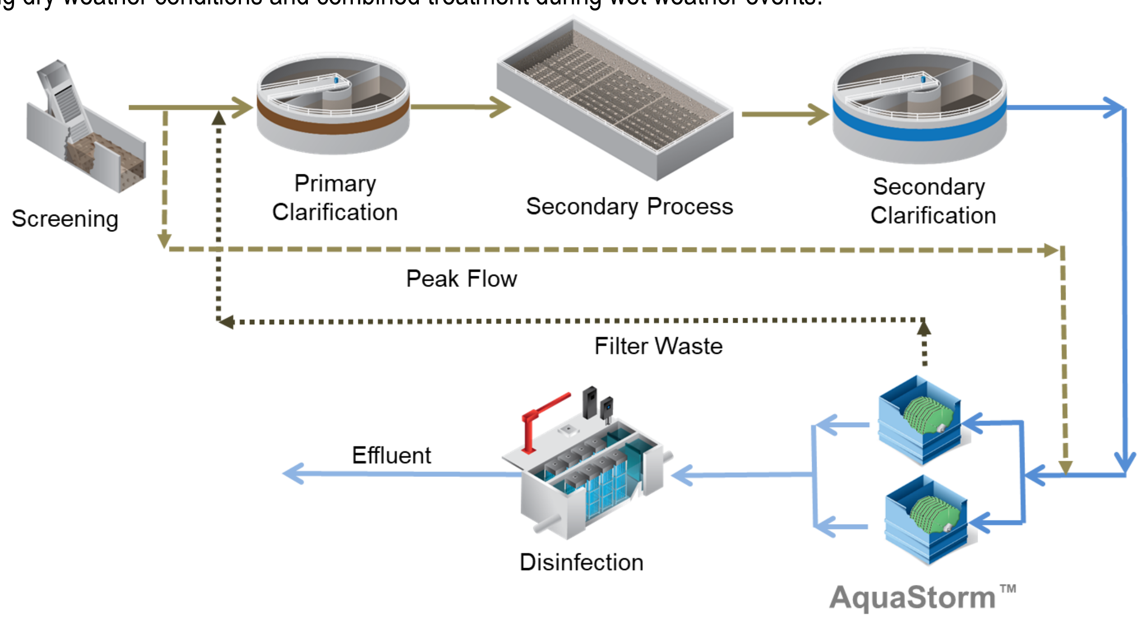

Figure 4: Dual Treatment (Tertiary and Wet Weather)

Figure 5 shows a location option of the AquaStorm system to be used for wet weather treatment at remote SSO/ CSO sites.

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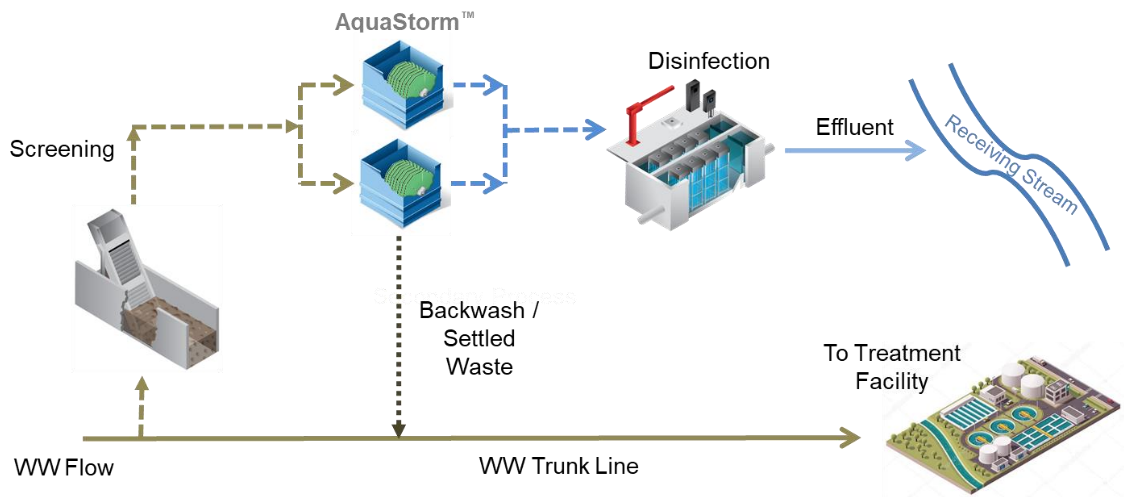


Figure 5: Remote SSO/CSO Site Treatment

The configuration and use of AquaPrime / AquaStorm can be customized to project specifics. The system can be configured to be using in the following additional configurations:

- Primary Filtration in Dry Weather Conditions and Dual Primary and Wet Weather Treatment during wet weather flows due to the high quality effluent
- Tri-Mode of Wet Weather Treatment Based on Wet Weather Flow Conditions – Operate in all three modes below:
    - Dry Weather – Tertiary Filtration
    - Wet Weather - Dual Treatment – Tertiary Filtration and Wet Weather Filtration (Figure 4)
    - Auxiliary Side-Stream Treatment – Wet Weather (Figure 3)

AquaStorm™ Unit Design

Cloth media filtration has been used in tertiary applications for over 20 years. Its proven performance and operational advantages models a viable solution for primary filtration or wet weather treatment applications.

The outside-in flow path in cloth media filters allows for three zones of solids removal. These three zones become even more critical in wet weather applications due to the high solids environment in primary filtration and wet weather treatment applications. These zones are shown in Figure 6.

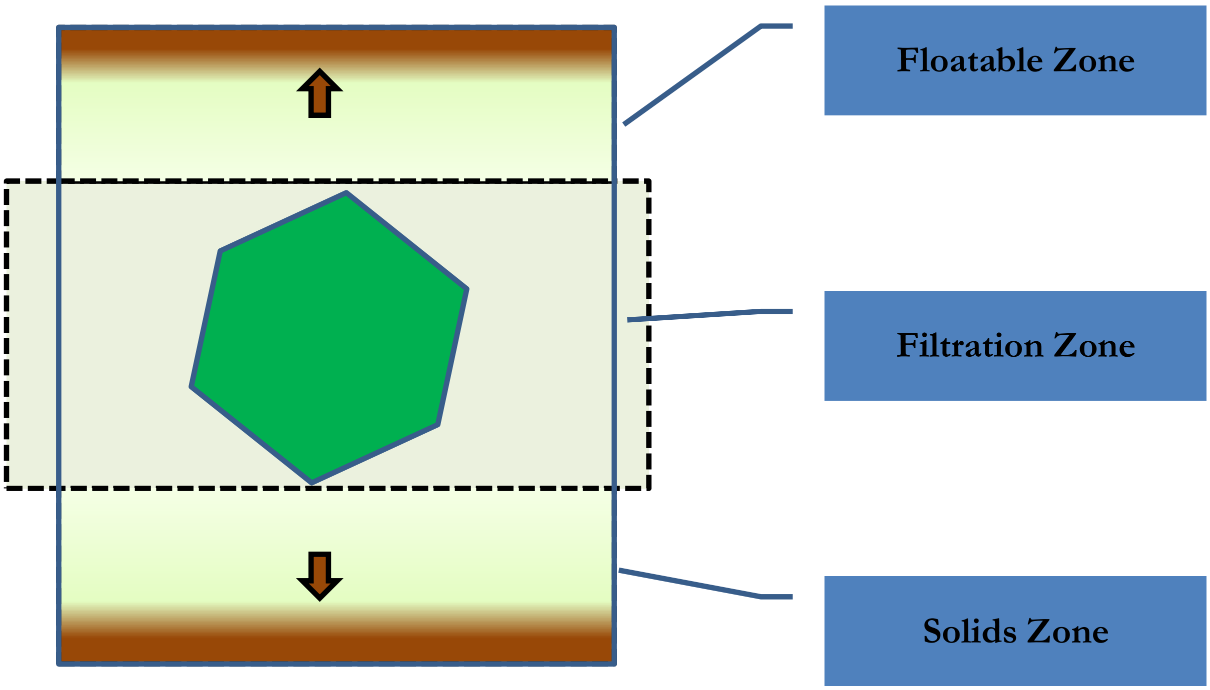


Figure 6: Three Zones for Solids Removal in a Cloth Media Filter

Floatable Zone

The top zone is the "floatable zone" where floatable scum is allowed to collect on the water surface. As the water level increases, the scum is removed by flowing over the scum removal weir. It is then directed to the plant's waste handling facilities. The floatable scum is removed typically 1 to 3 times per day by opening a floatable valve.

Filtration Zone

The middle zone is the "filtration zone" where the majority of solids are removed through filtration. Here, solids deposit on the outside of the cloth media forming a mat as filtrate flows through the media. Once a predetermined liquid level or time is met, the backwash shoe contacts the media directly and solids are removed by vacuum pressure using the backwash pump. During backwash, fibers fluidize to provide an efficient release of stored solids deep within the fiber (Figure 7).

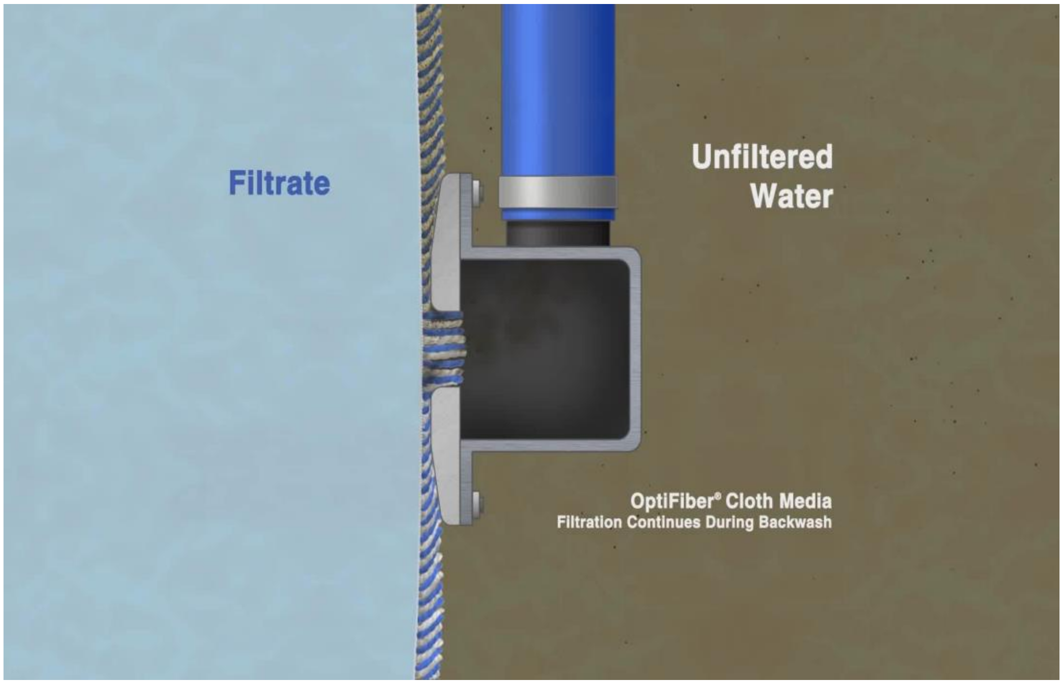


Figure 7: Backwashing of the cloth media.

Solids Zone

The bottom zone is the “solids zone” when heavier solids collected on the bottom of the tank are removed on an intermittent basis. The solids are removed from the hopper with collection laterals and the solids or backwash pump.

AquaStorm™ Cloth Media Filter Arrangement

With knowledge of the three zones, Aqua-Aerobic Systems looked for ways to further improve solids removal. A floatable baffle and valve were added to remove floatable scum that accumulates in the floatable zone of the tank. The solids zone was enhanced by improving the hopper bottom design and adding an improved solids collection manifold. Other enhancements include elevating the tank height, moving the influent baffle, and raising the centertube to accommodate the hopper design.

The AquaStorm system is available in both concrete and steel package tank configuration. Figure 8 and 9 show the 3-D model in concrete and steel package.

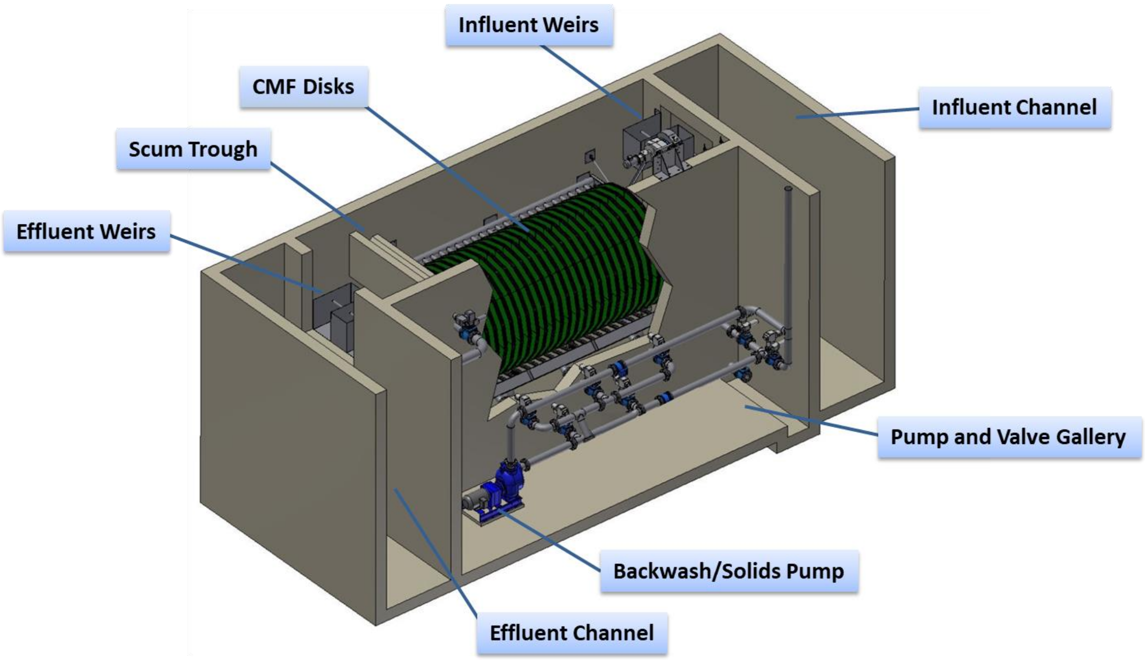


Figure 8: AquaStorm-™ Concrete Unit – 108 ft² Disks

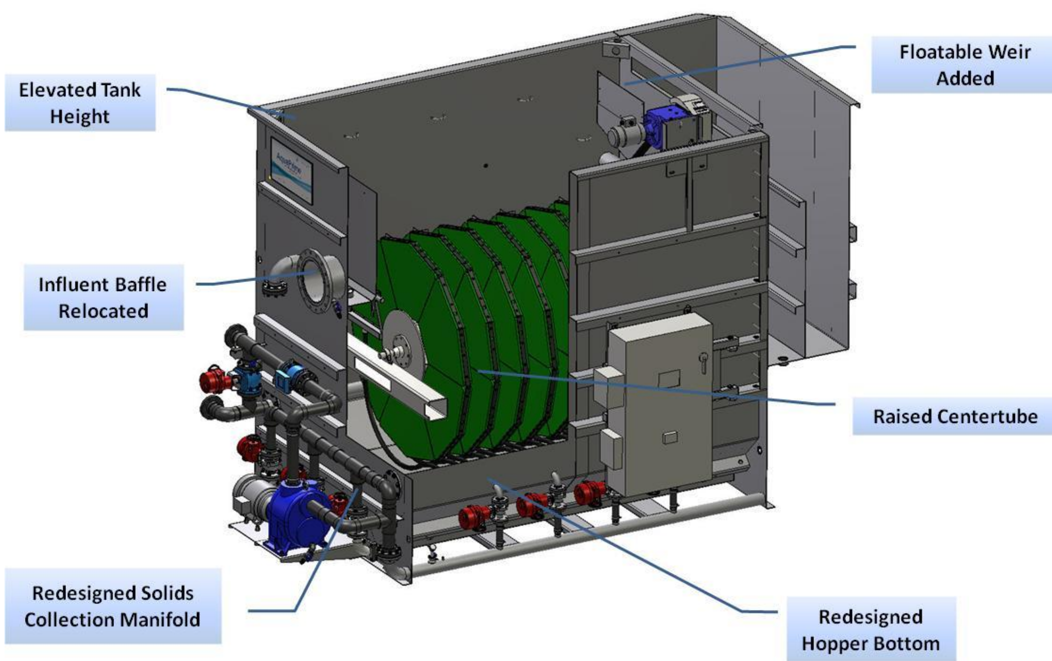


Figure 9: AquaStorm-™ Package Unit – 54 ft² Disks

Pilot Testing

Aqua-Aerobic Systems has now built a pilot trailer and three stand alone units specifically designed for primary filtration and wet weather filtration application (Figure 10). The filter features the modifications described above. The unit is currently traveling the country and collecting data at various plants.

Figure 10: Primary Filtration and Wet Weather Pilot System

AquaStorm™ Filtration Side Stream Wet Weather Treatment Arrangement

Plants are now considering cloth media filtration to treat the excess flow during CSO events as an alternative to building large holding basins or expanding the entire plant. The cloth media filter is used as a side stream treatment process and is typically followed by disinfection. Alternatively, the filters can be used as a tertiary treatment step under normal operation and directly filter the excess flow during a CSO event.

A typical dual / side stream treatment schematic is shown as Figure 11. The example shows a conventional plant that can handle up to 4 MGD with a SSO/CSO flow of 12 MGD. It is important to consider filter backwash for this application. SSO/CSO applications will typically see a first flush event with high solids, which leads to a higher backwash than what is typical in a tertiary application. Most plants will send the filter backwash back to the secondary process. The example in Figure 11 shows how to account for this backwash. The filter is designed to handle the flow in excess of the capacity of the conventional plant plus the filter backwash.

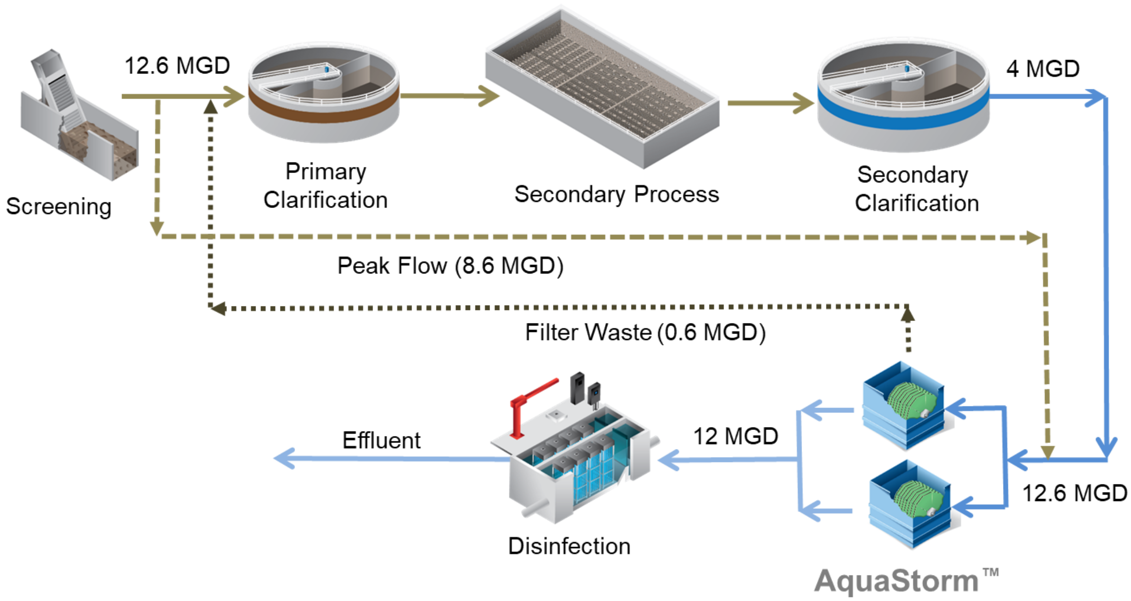


Figure 11: Typical Dual Tertiary / SSO/CSO Treatment Schematic

Key Benefits & Advantages

- High quality effluent
- Simple to operation and maintain
- No chemical usage or ballast material required
- Instant startup and shutdown
- Continued treatment throughout the entire storm event
- Automatic start up and shut down with no advanced preparation
- Flexibility to use cloth media filters for tertiary treatment under normal dry weather conditions
- Small footprint and reduced construction costs compared to other solutions

AquaStorm™ Wet Weather Treatment Case Studies

Rock River Water Reclamation District, IL

Aqua Aerobic Systems, Inc.'s Research and Technology Center is located inside the Rock River Water Reclamation District facility (RRWRD) in Rockford, IL. The plant has a design flow of 40 MGD with a peak flow capability of 80 MGD through secondary treatment. RRWRD is a SSO facility and can experience flows as high as 130 MGD during extreme storm events. In the development of the AquaStorm™ Cloth Media Filter, a cloth media filter pilot unit was placed beside the existing rectangular primary clarifier for a primary filtration study.

Several wet weather events occurred during the primary filtration study, which allowed for testing of the capabilities of the AquaStorm filter for Wet Weather application. Below is the TSS removal data for several wet weather events:

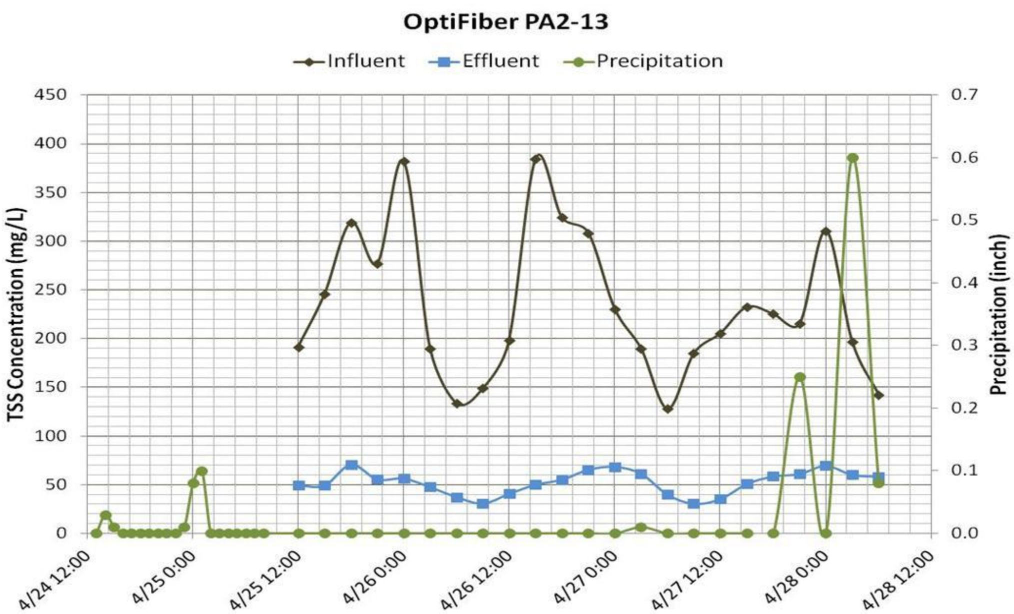


Figure 12: Wet Weather Event w/ PA2-13 Cloth

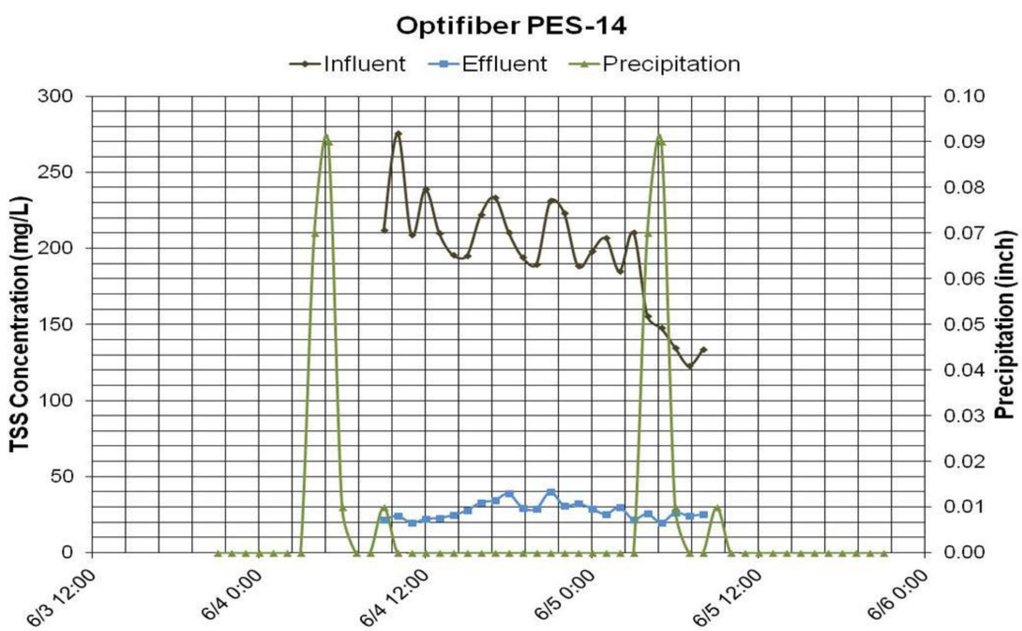


Figure 13: Wet Weather Event w/ PES-14 Cloth

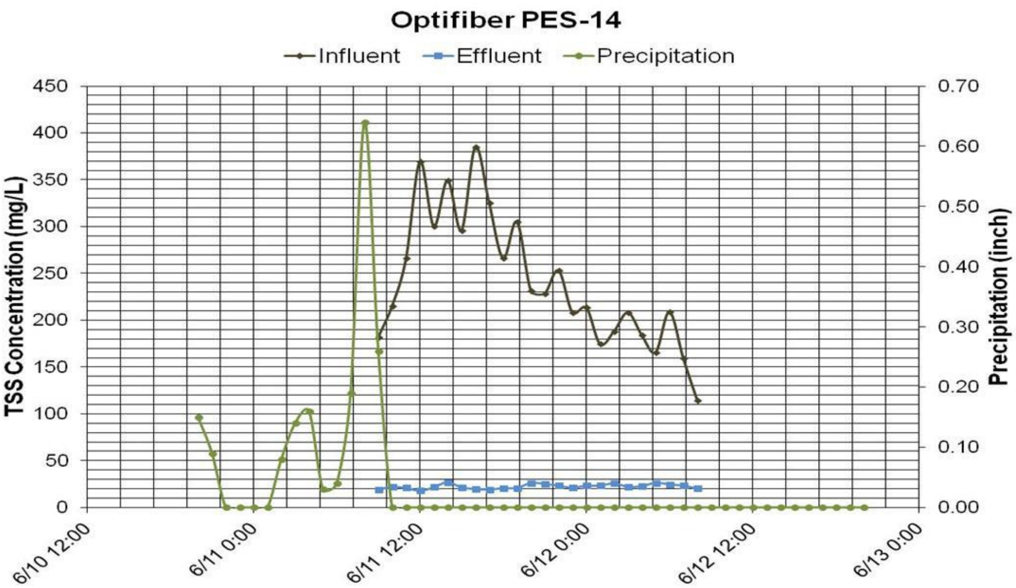


Figure 14: Wet Weather Event w/ PES-14 Cloth

The pilot work demonstrated the AquaStorm Cloth Media Filter's capability to handle the first flush conditions which were as high at 400 mg/L.

Rushville, IN Project – Pilot Testing

The town of Rushville, IN has one active CSO outfall located at the city's wastewater treatment plant. This outfall is used on average 11 times each year through the opening of a bypass gate when the plant's influent flow exceeds plant capacity. The plant's long term control plan required the construction of a holding basin that would eliminate all untreated discharges from the 1-year, 1-hour storm event. As an alternative, the plant personnel agreed to participate in a pilot study with Aqua-Aerobic Systems to asseses side stream CSO treatment using cloth media filtration. This study was conducted over the summer of 2015.

Due to the sporadic nature of CSO/SSO events, automatic startup is an important aspect of treatment systems. In the full-scale installation, the pilot unit needed to start up automatically. The equipment for this automatic startup is shown in Figure 15. An influent pump, level switch, and TSS probe were placed in the CSO bypass channel. When the float switch began to float, the influent pump would activate, sending water to the unit. When chemical was added, this pump would also activate the chemical feed pumps.

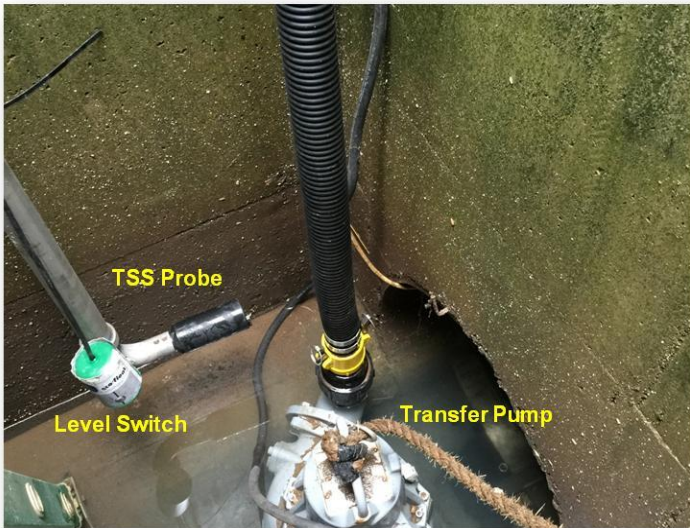


Figure 15: Influent pump, level switch, and TSS probe in CSO bypass Channel at Rushville, IN

Figure 16 shows the pilot unit setup in Rushville, IN.

TABLES AND FIGURES

Table 1. Summary of TSS removal. Alum dosed during CSO events 1-2.

CSO Event	Date	ALL DATA			PEAK VALUES	
		Average Influent	Average Effluent	Average Removal (%)	Influent	Effluent
1	May 16, 2015	141	5.2	96	350	10
2	June 30, 2015	114	4.8	96	340	17

3	July 7, 2015	136	4.9	96	268	14
4	July 12, 2015	74	3.8	95	356	25
5	July 13, 2015	24	2.0	92	58	6

Table 2. Summary of BOD5 removal. Alum dosed during CSO events 1-2.

CSO Event	Date	ALL DATA			PEAK VALUES	
		Average Influent	Average Effluent	Average Removal (%)	Influent	Effluent
1	May 16, 2015	87	3.5	96	381	11
2	June 30, 2015	37	4.3	88	101	9
3	July 7, 2015	55	18.2	67	224	25
4	July 12, 2015	60	14.5	76	69	24
5	July 13, 2015	73	18.1	75	81	20

Table 3. Summary of hydraulic and solids loading rates. Alum dosed during CSO events 1-2.

CSO Event	HLR (gpm/ft^2)	Event Duration (hours)	Ave. SLR ($lbs/ft^2/day$)	Peak SLR ($lbs/ft^2/day$)
1	3.7	2.8	6.3	15.6
2	6.5	12.0	8.9	26.6
3	6.5	4.0	10.6	20.9
4	6.5	5.5	5.8	27.8
5	6.5	7.0	1.9	4.5

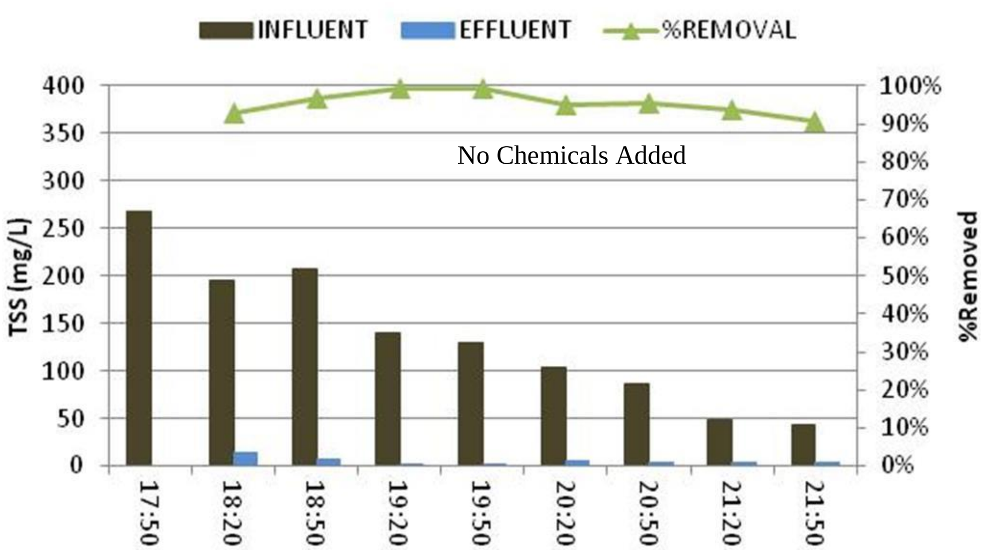


Figure 17. TSS removal in CSO event 3 (July 7, 2015)

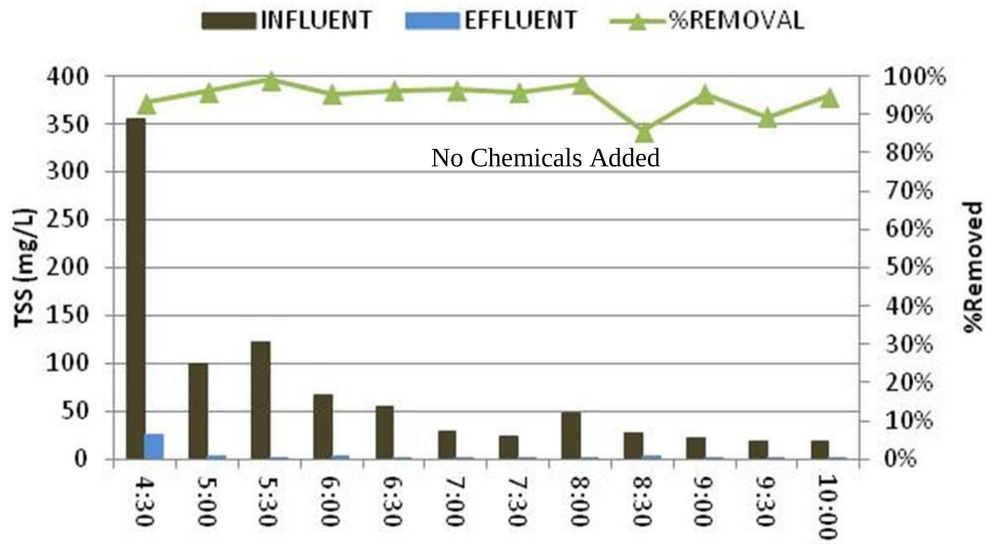


Figure 18. TSS removal in CSO event 4 (July 12, 2015)

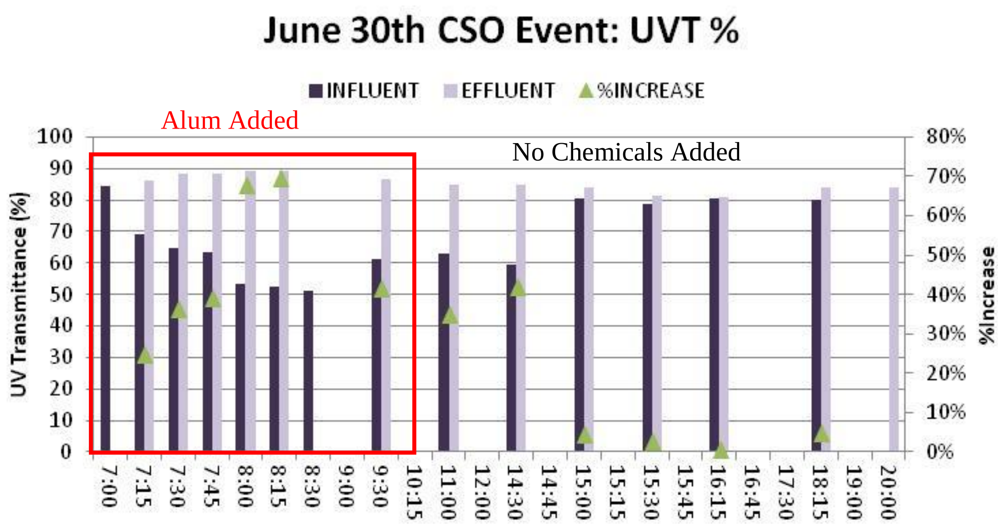


Figure 19. UVT improvement in CSO event 2 (June 30, 2015)

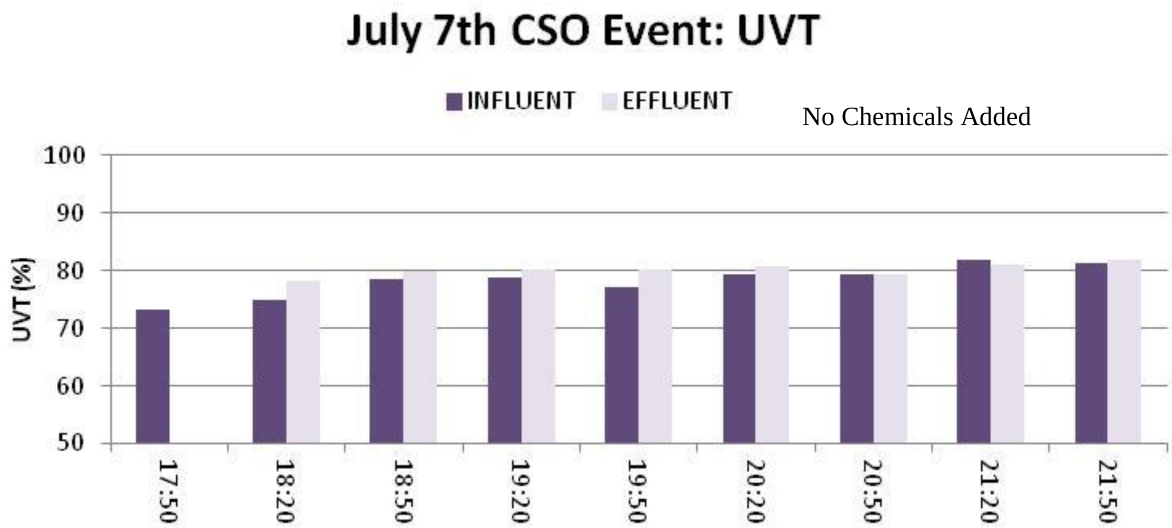


Figure 20. UVT in CSO event 3 (July 7, 2015)

As a result of the successful pilot study, Rushville, IN has designed and started construction of two (2) AquaStorm units to be utilized for tertiary filtration and wet weather treatment. The units will operate in tertiary mode during dry weather conditions and switch to wet weather treatment for major rainfall events. One reason for the dual application mode is the reduced loads to the receiving stream not only during wet weather events, but yearlong due to the treatment. The table below outlines the impact of solids removal on the receiving stream due to the dual modes of operation:

Conditions	Rainfall (in.)	Eff WW Flow (MG)	TSS Load (lbs)
2015 Annual Avg Daily WWTP Dischg		1.54	70.4
2015 Total Annual WWTP Dischg	51.21	562	25,696
Avg. Annual CSO in LTCP		38.2	30,584
2015 Annual WWTP & Avg Annual CSO Dischg		**600**	**56,280**
Annual CMF Filter Trt of CSO Flow		38.2	1,274
2015 Total Annual WWTP Eff with Tertiary Filter Trt		562	7,709
2015 Annual WWTP Filtered Eff + CSO Filter Eff		**600**	**8,983**
CMF Filtering of all Flow Reduction over 2015 Existing Trt Fac			**73%**

Table 4. Solids Removal of Treatment on Receiving Stream

Little Rock, AR – Adams Field WWTP Project

The plant has a design peak flow of 36 MGD through secondary treatment and can see flows as high as 90 MGD during extreme storm events. The existing primary clarifier is sized to hydraulically pass the full storm flow. Due to the capability of the primary clarifier to pass the max flow, the AquaStorm™ was piloted on primary clarifier effluent to handle wet weather flows over 36 MGD. Below are the pilot results:

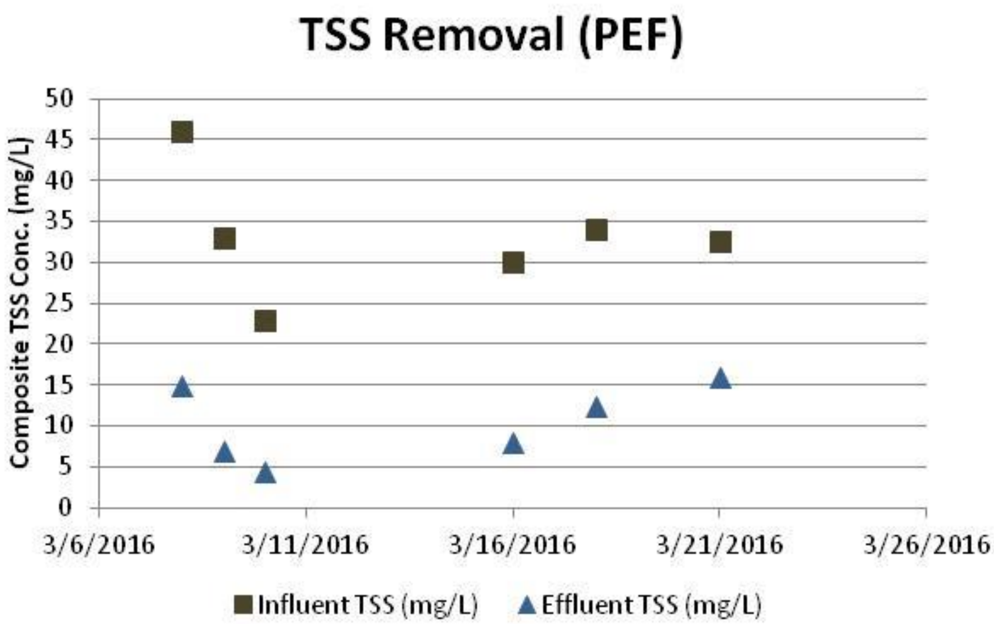


Figure 21. Primary Effluent TSS Removal

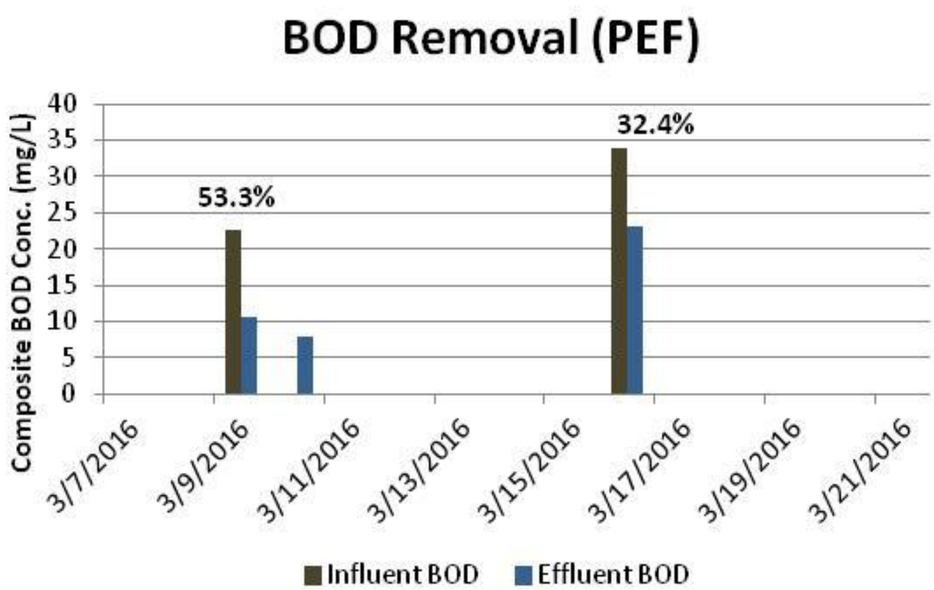
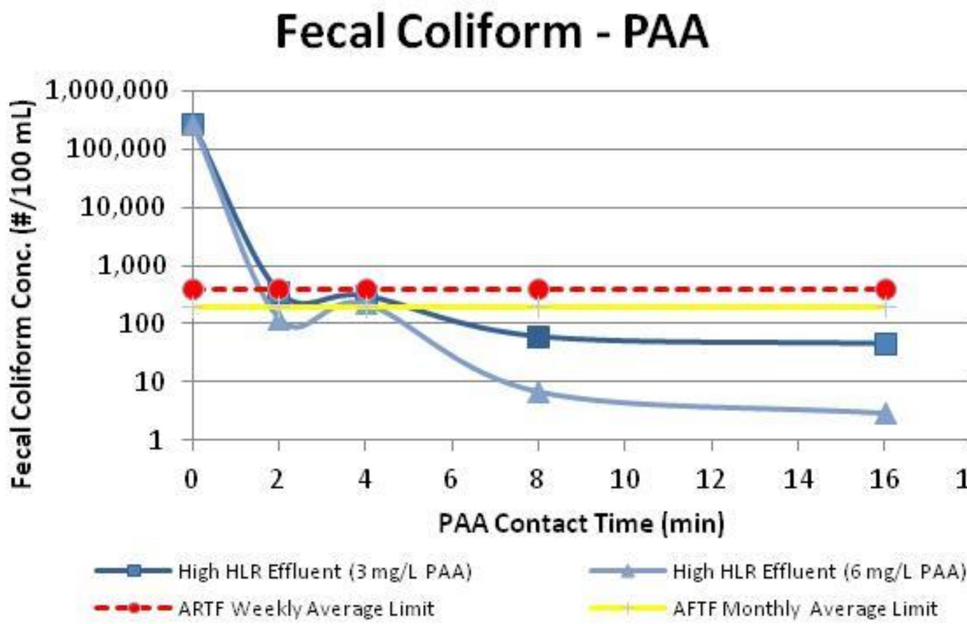


Figure 22. Primary Effluent BOD Removal



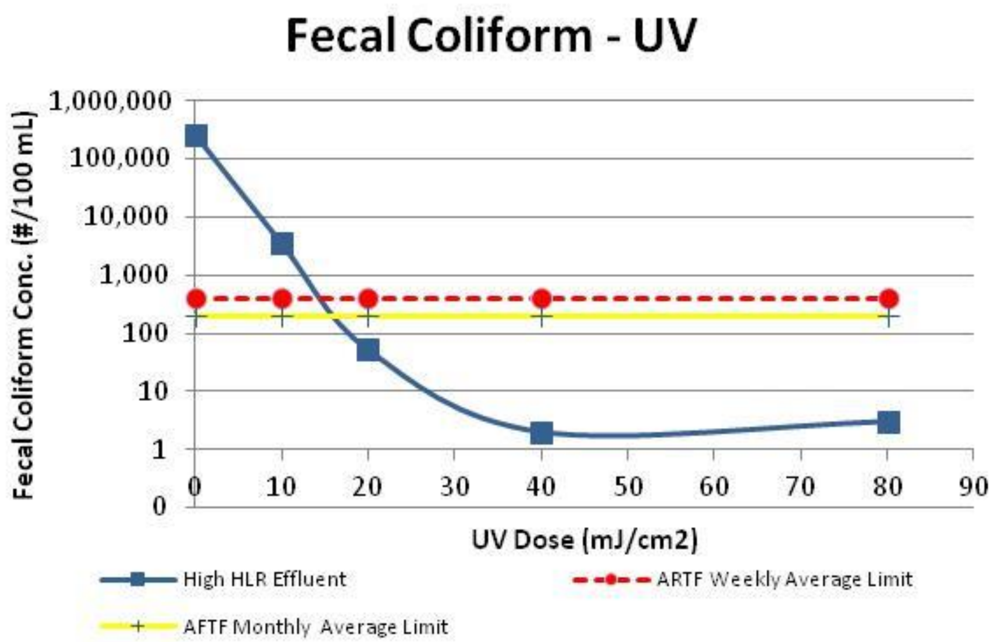


Figure 23 & 24. Primary Effluent –Disinfection Results

The table 5 below shows the impact of solids removal on the receiving stream during tertiary and wet weather treatment.

Total Facility Flow (MGD)	Split (MGD)	Number of WW Events	Type	Influent TSS (mg/L)	Treatment Type	Effluent TSS (mg/L)	Daily / Event Discharge Saving (lbs TSS)	TSS Reduction Per year (lbs TSS)	Est. Effluent (mg/L)
15	15	0	Secondary	10	Tertiary	5	625	226,078	**5**
30	30	0	Secondary	15	Tertiary	5	2,498	904,312	**5**
36	36	0	Secondary	20	Tertiary	5	4,497	1,627,762	**5**
50	36	0	Secondary	20	Tertiary	5	4,497	1,627,762	**9.2**
	14	5	Overflow	85	SSO	20	7,578	37,888	
72	36		Secondary	20	Tertiary	5	4,497	1,627,762	**12.5**
	36	5	Overflow	85	SSO	20	19,485	97,426	
94	36		Secondary	20	Tertiary	20	0	0	**20**
	58	3	Overflow	85	SSO	20	31,393	94,178	

Table 5. Solids Removal of Treatment on Receiving Stream

MSD Greater Cincinnati – Remote Site Pilot Study

An AquaStorm ™Cloth Media Filter was piloted for 3.5 months at the MSDGC Muddy Creek Remote CSO site. The pilot's feed pump and float system was installed directly into the CSO channel. During wet weather events, the channel's rising water level initiates the feed pump, prompting automatic operation of the filter. When the flows subsided, the float switch stopped the feed pump and placed the filter in an idle mode. Influent and effluent automatic composite samplers were used to draw samples at intervals in conjunction with grab samples. During the study, analysis was primarily conducted for TSS and BOD, but other parameters were analyzed such as particle and UVT. The sampling consisted of both composite and grab samples.

Four major events were captured with the AquaStorm™ pilot unit. Table 6 presents the summary of the influent flow conditions and waste volumes during each event. A nominal hydraulic loading rate of 6.5 gpm/ft^2 was used for the first three events to match the standard design hydraulic loading rate for AquaStorm™ filters. A hydraulic loading rate of 7.0 gpm/ft^2 was used in the fourth event to push the filter beyond typical design values. The total waste flow was made up of backwash, solids waste, and scum waste. Scum waste represented a negligible fraction of the total waste volume. The total was volume was less than 5% of the forward flow through the filter in all cases. At a remote CSO site, it is assumed the waste flow with the solids removed would be returned to the sewer for treatment at the downstream treatment facility.

Event Start Date	Avg HLR (gpm/sf)	Backwash (%)	Solids Waste (%)	Total Waste Volume (%)
9/26/2016	6.5	3.3%	1.1%	4.3%
9/28/2016	6.5	2.9%	1.2%	4.1%
10/19/2016	6.5	2.1%	0.9%	3.0%
12/6/2016	7.0	2.7%	1.3%	4.0%

Table 6: Hydraulic Loading Rates and Waste Volumes for Four CSO Events

Figure 25 demonstrate the TSS removal results from the four major events. The influent TSS varies significantly throughout a CSO event and is typically high at the beginning of an event and dramatically decreases after the first flush. Indexing auto-samplers were used to take samples at 15 minute intervals throughout each event. Filter effluent TSS ranged from 5 mg/L to 59 mg/L. The filter removed between 50% and 93% of the influent TSS. The TSS removal percentage increased as the influent TSS increased. All of the pilot work was done without the addition of coagulant, which would likely improve TSS reduction.

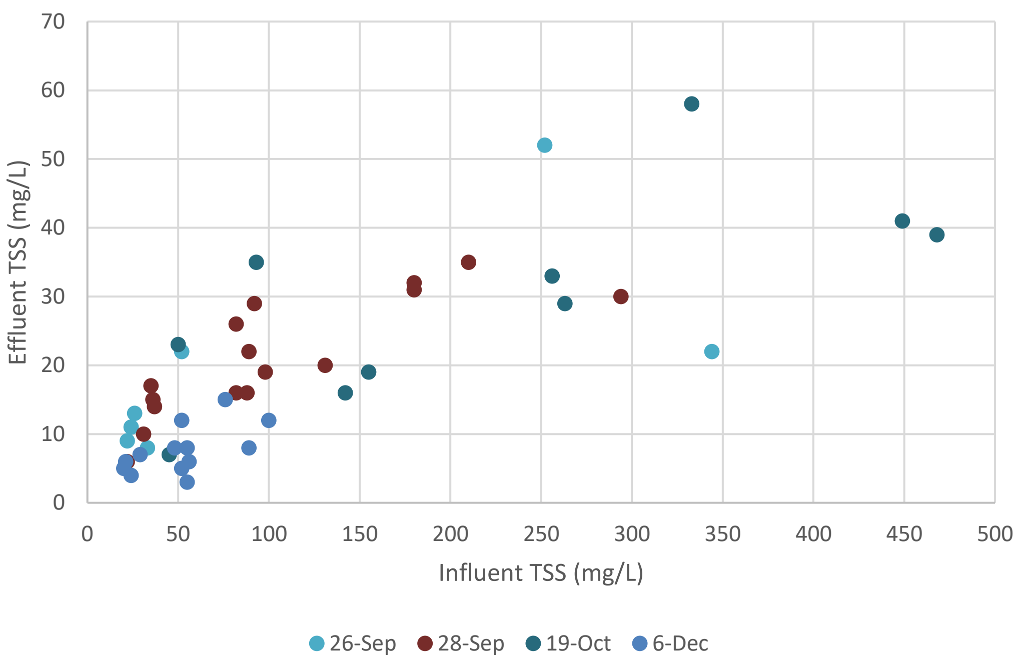


Figure 24: Effluent TSS vs. Influent TSS.

Figure 25 demonstrates the typical BOD removal seen during major events. During the study the cBOD removal can be as high as 70%. BOD removal varies greatly due to wide range of influent conditions. Cloth media filtration will only remove particulate BOD and at the end of the events there is very little BOD remaining in the influent and is mostly soluble.

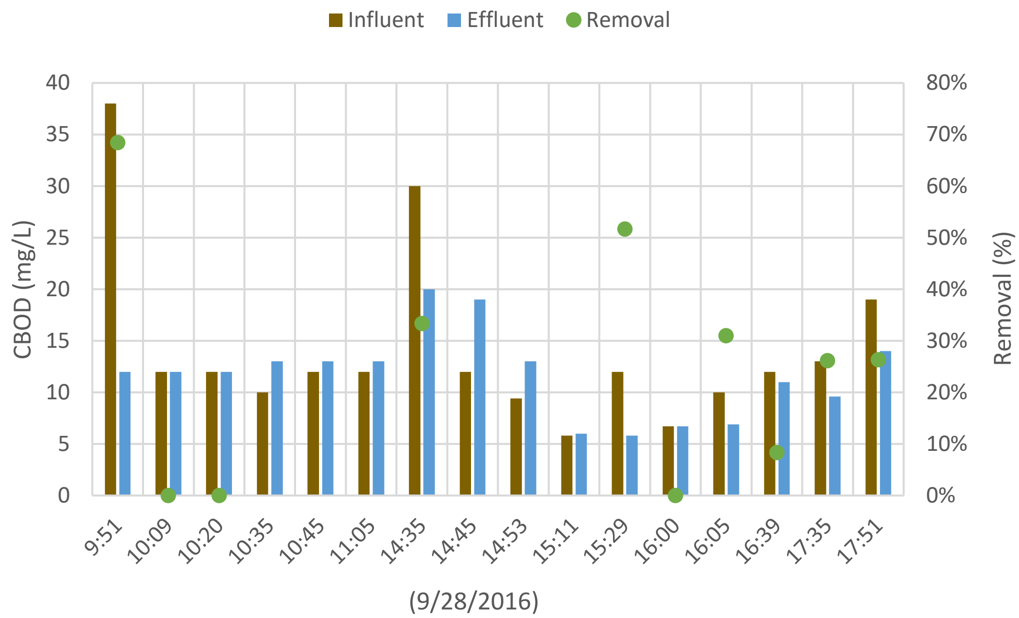


Figure 26: BOD Removal from Sept 28th event.

Figure 26 demonstrates the improvement in UVT with filtration.

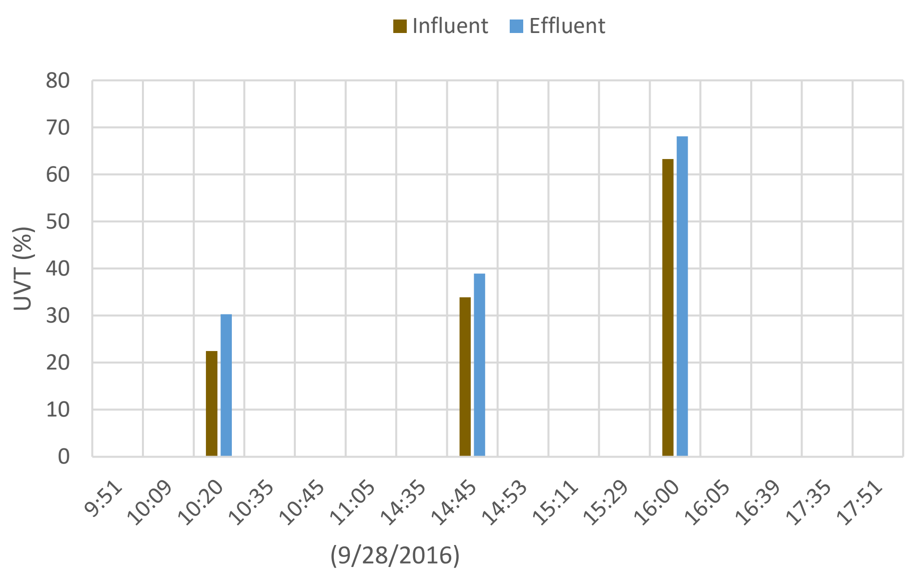


Figure 27: UVT improvement.

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Thomas W. Amidon, James F. Cosgrove Jr. & Ronald S. Anastasio (2016), *A Novel Solution to Sanitary Sewer Overflows,* WE&T, July 2016.

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