

Wet-Weather Piloting Toward the Largest Compressible Media Filter on the Planet

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ABSTRACT

Onsite pilot testing was recently completed to confirm performance and design criteria for the 380-ML/d (100-mgd) excess flow high-rate treatment facilities that are being designed for the City of Springfield's wastewater treatment plant. The performance of the compressible media filter pilot demonstrated consistent compliance with all regulatory requirements for CSO treatment and produced average effluent TSS concentrations below 30 mg/L while treating wet-weather flows. Furthermore, dose response testing demonstrated that the effluent from the compressible media filter was consistently amenable to hypochlorite disinfection, requiring doses and contact times equivalent to those typically used for conventional secondary effluents. The new high-rate treatment facilities will consist of new structures and equipment for influent excess flow interception, screening, compressible media filtration, hypochlorite disinfection, bisulfite dechlorination and effluent pumping. Construction of these upgrades is scheduled to be completed in 2014.

KEYWORDS: Wet Weather, High-Rate Treatment, CSO, SSO, Compressible Media Filtration

INTRODUCTION

Like many communities across the United States, the City of Springfield, Ohio is tackling the problem of combined sewer overflows (CSOs) and moving forward with its approved Long Term Control Plan (LTCP). Master planning studies included a variety of storage, conveyance and treatment alternatives, with the final LTCP recommending the addition of 380-ML/d (100-mgd) high-rate treatment (HRT) facilities to the City's publicly owned treatment works (POTW) as well as conveyance improvements to increase the amount of peak wet-weather flows that receive treatment. Advanced facility planning for the HRT system included bid evaluations of solids contact high-rate clarification, ballasted flocculation, and compressible media filtration process alternatives. The WWETCO compressible media filter technology was recommended for the HRT facility, and a pilot unit began operation in the second half of 2010 to confirm design criteria with performance results from onsite demonstrations during actual wet-weather events.

Pilot Testing Objectives

Figure 1 and Table 1 summarize the influent characteristics and key process design criteria that were established for the CMF process during the HRT alternatives evaluations. These criteria

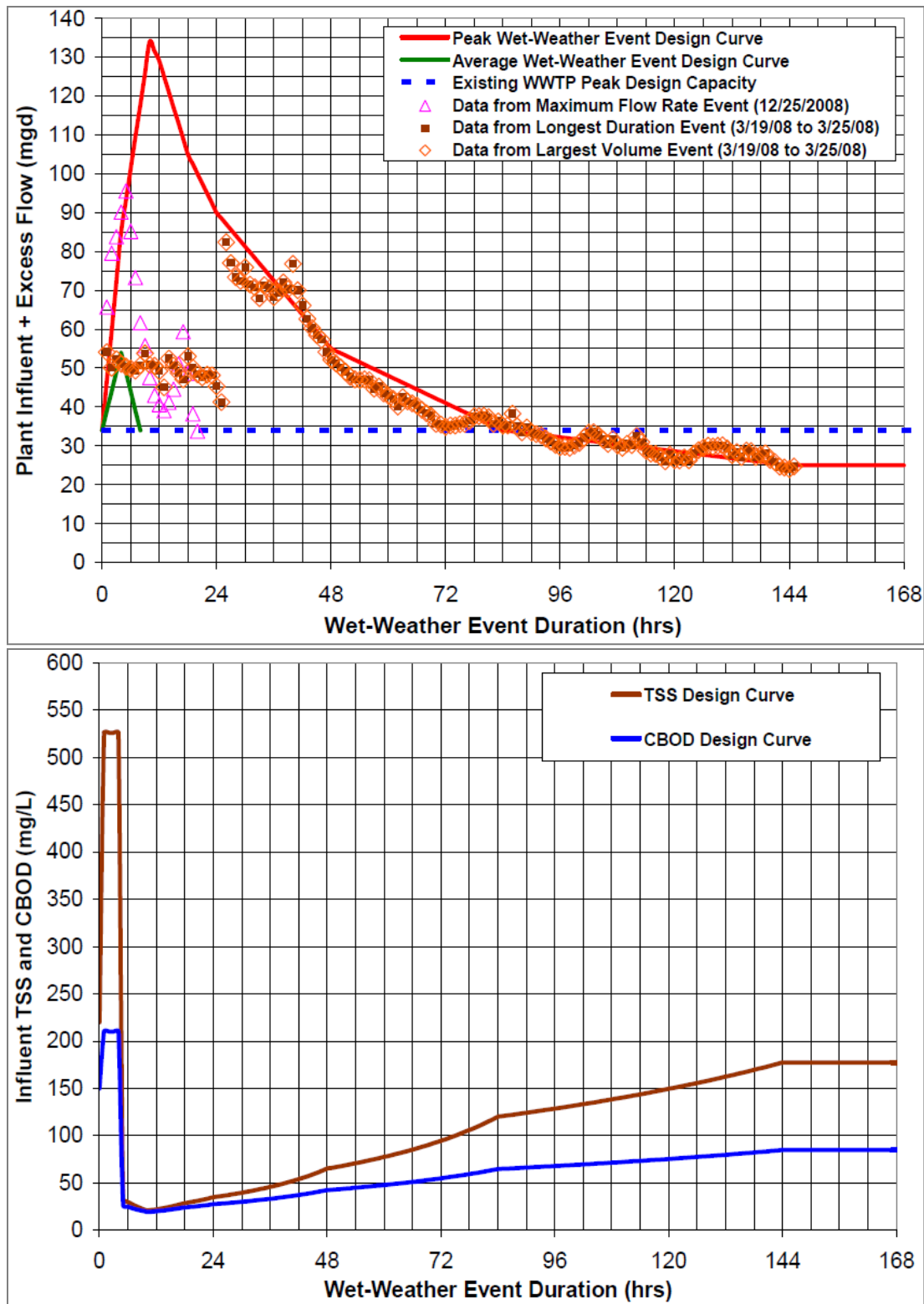


Figure 1. Historical influent flow monitoring and sampling data were used to help develop influent hydrographs and pollutographs that were used during preliminary design and HRT alternatives evaluations.

were developed from historical influent flow monitoring and sampling data along with process design criteria that had been used successfully in other similar HRT applications. These influent hydrographs and pollutographs were also used in the GPS-X full-plant dynamic process model that was developed for advanced facility planning and preliminary design studies to evaluate wet-weather treatment scenarios and anticipated impacts to the existing solids and liquids treatment trains.

Table 1. Process design and effluent quality criteria were developed to evaluate bids for HRT equipment during a pre-selection phase of the project.

Process Design Criteria	Units of Measure	Value
Peak Hydraulic Loading Rate (Note 1)	L/m ² ·s	6.8
	gpm/ft ²	10
Maximum Backwash Air Rate	L/m ² ·s	51
	SCFM/ft ²	10
Maximum Backwash Flow Rate (Note 2)	L/s	420
	gpm	6,600
Event-Average Effluent Total Suspended Solids (Note 3)	mg/L	No measurements >45
		≥80% of measurements ≤30 mg/L
		≥60% of measurements ≤25 mg/L
Notes:		
<ol style="list-style-type: none"> 1. Based on filtration basins in service during peak design flow. 2. Instantaneous rate at peak solids loading. 3. Each measurement shall be an event-average concentration determined from flow-weighted composite samples collected over the discharge event. Statistics shall be based on no less than five treatment events. 		

Technology Overview

Compressible media filtration (CMF) has been used in full-scale wet-weather treatment applications for over a decade and was part of the Combined Sewer Overflow (CSO) Demonstration Facility in Columbus, Georgia, which was the subject of a peer-reviewed study by the Water Environment Research Foundation (WERF, 2003). The Columbus project was partially funded by the United States Environmental Protection Agency (USEPA), which considers CMF to be an innovative technology for wet-weather management (USEPA, 2008). Wet-weather pilot studies conducted in Kansas and Missouri in 2008 and 2009 compared CMF side-by-side to other high-rate filtration alternatives as well as high-rate sedimentation alternatives and further substantiated CMF as a viable alternative for wet-weather treatment applications (Fitzpatrick *et al.*, 2010).

CMF is commercially available as either the Schreiber Fuzzy Filter® or the WesTech WWETCO FlexFilter™ (both are proprietary technologies covered by patents or pending patents). Both technologies rely on a bed of synthetic fiber spheres (see Figure 2) to filter pollutants from the liquid stream; however, the two technologies differ in various aspects, including the exact composition of the synthetic fibers, the method of bed compression and media washing details.



Figure 2. Compressible media filtration relies on a bed of synthetic fiber spheres to filter pollutants from the liquid stream.

As illustrated on Figure 3, influent to the WWETCO FlexFilter™ flows down through the filter bed that is approximately 760 mm (30 inches) deep. Reinforced rubber sidewalls on the bottom of the filter vessel compress the bottom of the filter bed more than the top of the filter bed, establishing a porosity gradient through the filter bed to capture the largest particles in the upper portion of the filter bed while reserving the deeper portions of the bed to trap finer particles. As particles collect within the media bed, the influent level above the bed rises to a point that signals the need for the media to be cleaned.

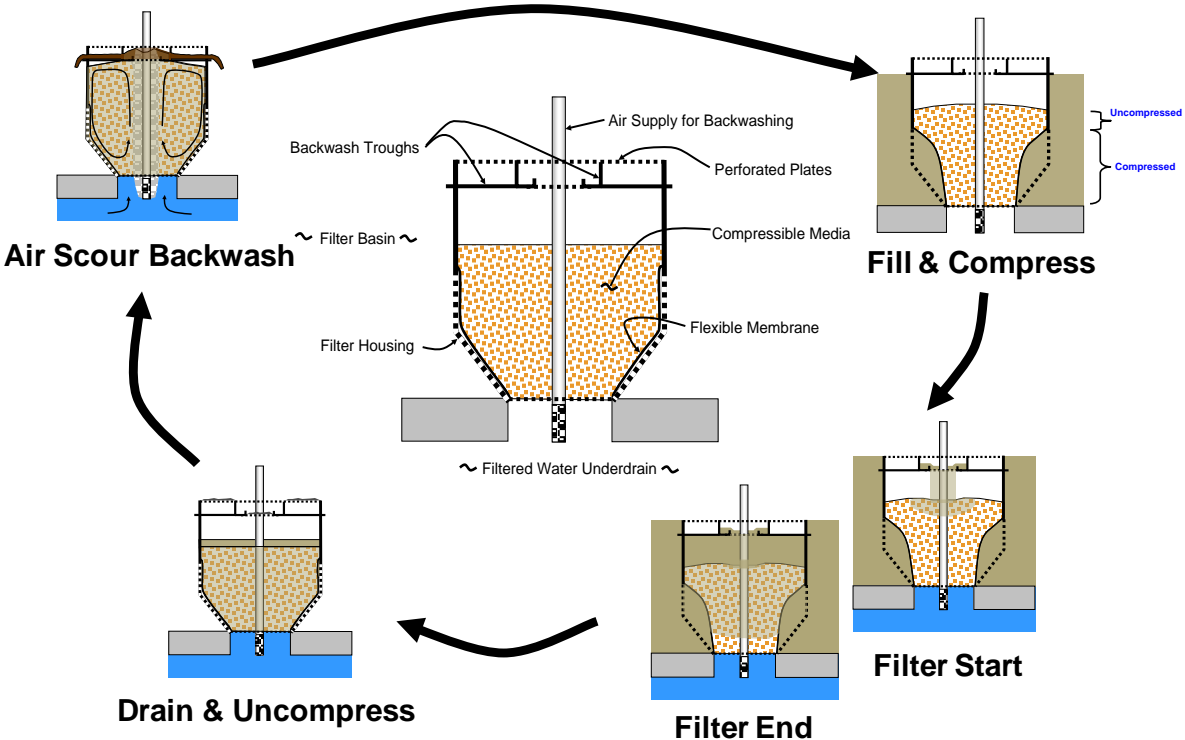


Figure 3. The WWETCO FlexFilter™ uses influent hydrostatic pressure and reinforced flexible sidewalls to compress the filter bed transversely to the flow direction.

The basin is then drained which allows the filter vessel sidewalls to flex outward, releasing the bed compression. An air-scoured backwash step then fluidizes and cleans the media bed. As influent is re-introduced to the basin, it hydraulically flexes the filter sidewalls inward, compressing the media bed for the next filtration cycle. The CMF system is usually operated as a constant rate filter with the effective duration of the filtration cycle dependent upon the solids loading rate. The process is generally automated with filter headloss instrumentation and timers used to monitor and control the process.

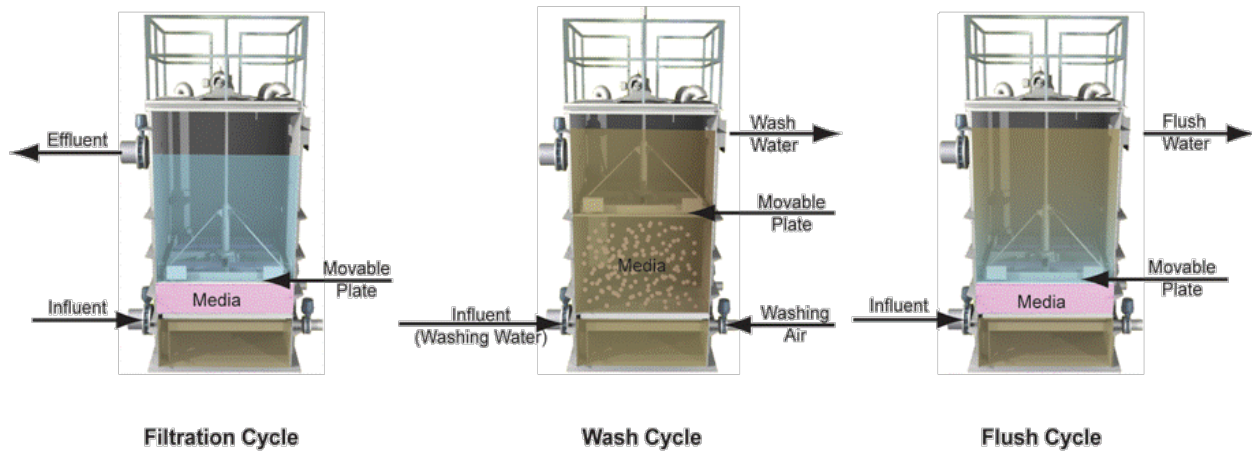


Figure 4. The Fuzzy Filter® uses a movable perforated plate to change the media compression during the filtration and wash cycles (diagram provided by Schreiber LLC).

The Fuzzy Filter® is generally arranged in an upflow configuration as illustrated on Figure 4, with the media bed compressed between two perforated plates. At the beginning of the wash cycle, the upper plate is raised to release the compression on the media bed, allowing it to expand and be fluidized. Air is used to scour the media and transfer captured particles to a wash water stream that flows to residuals treatment processes. At the end of the wash cycle, the movable plate recompresses the media bed, and the filter vessel is flushed clean for the next filtration cycle.

PILOT TESTING METHODS AND MATERIALS

As depicted on Figure 5, CMF pilot facilities were designed so that the filter could be fed primary influent, secondary effluent, or blends thereof to demonstrate performance over a range of feed characteristics and to evaluate the potential for different treatment modes.

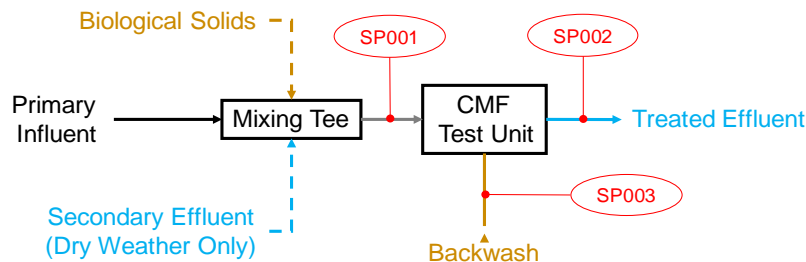


Figure 5. The Springfield CMF pilot facilities were configured to allow testing of multiple

influent characteristics during both wet-weather and dry-weather conditions.

In October 2010, the pilot CMF facilities pictured on Figure 6 began operation at the Springfield Wastewater Treatment Plant (WWTP). During peak wet-weather flow conditions, the pilot unit received screened and degritted influent from the existing headworks, which consisted of 12-mm (0.5-inch) bar racks, aerated grit basins or detritor).



Figure 6. The CMF pilot facilities in Springfield (Ohio) included a filter vessel with media, backwash blower, influent and backwash feed pumps, automatic valves, instrumentation and control panel with PLC. Also pictured are the media bed and representative samples of wet-weather influent and effluent.

The pilot unit was operated jointly by the system supplier and the City's WWTP personnel, who also provided sampling and laboratory analytical services using the same methods routinely used to demonstrate compliance with their NPDES permit. Test protocols included 5-minute measurements of turbidity, headloss, and flow rate and flow-weighted composite sampling (10-minute aliquots) of the influent and filter effluent with automatic composite sampling units. Analytical methods used during the study are summarized in Table 2.

Hypochlorite dose response tests were also conducted on the treated effluent using fecal coliform and *E. coli* as disinfection indicators. These tests were conducted by mixing the effluent sample in a beaker, adding a measured dose of sodium hypochlorite, and withdrawing a time-series of samples from the test beaker for laboratory analysis. Each sample collected from the test beaker was immediately dechlorinated and preserved for laboratory analysis.

Table 2. Samples were analyzed by the City of Springfield laboratory staff using the same methods normally used to demonstrate compliance with the City’s NPDES permit.

Analyte	Method	Sample Preservation (Note A)	Maximum Sample Hold Time	Comments
Turbidity	SM 2130 B	Cool, ≤6°C	48 hours	Field measure immediately with Hach 2100P Turbidimeter.
Total Suspended Solids (TSS)	SM 2540 D	Cool, ≤6°C	7 days	
Carbonaceous Biochemical Oxygen Demand, 5-day (CBOD ₅)	SM 5210 B	Cool, ≤6°C	48 hours	
Fecal coliform	SM 9222 D	Cool, <10°C, 0.0008% Na ₂ S ₂ O ₃ (Note B)	6 hours	
<i>E. coli</i>	EPA 1603	Cool, <10°C, 0.0008% Na ₂ S ₂ O ₃ (Note B)	6 hours	
Notes: A. Samples preserved within 15 minutes of collection unless analyzed within 15 minutes. B. Testing conducted on chlorinated samples; therefore, samples collected in pre-preserved sample containers.				

RESULTS AND DISCUSSION

After receiving initial training from the system supplier, City staff began operating the pilot facilities in October 2010. The pilot system included level instrumentation and a PLC to automatically operate valves, pumps and blowers through the filtration and backwash cycles based on the influent water level above the filter bed. Operator tasks mainly consisted of process monitoring and sampling. As summarized on Figure 7, approximately 120 filter cycle test runs were conducted on primary influent between October 14, 2010 and June 16, 2011.

As illustrated on this figure, the CMF pilot was tested under a variety of influent loading conditions while onsite during the fall, winter and spring seasons. Although not discussed in this paper, test runs were also conducted on secondary effluent to help evaluate potential tertiary applications.

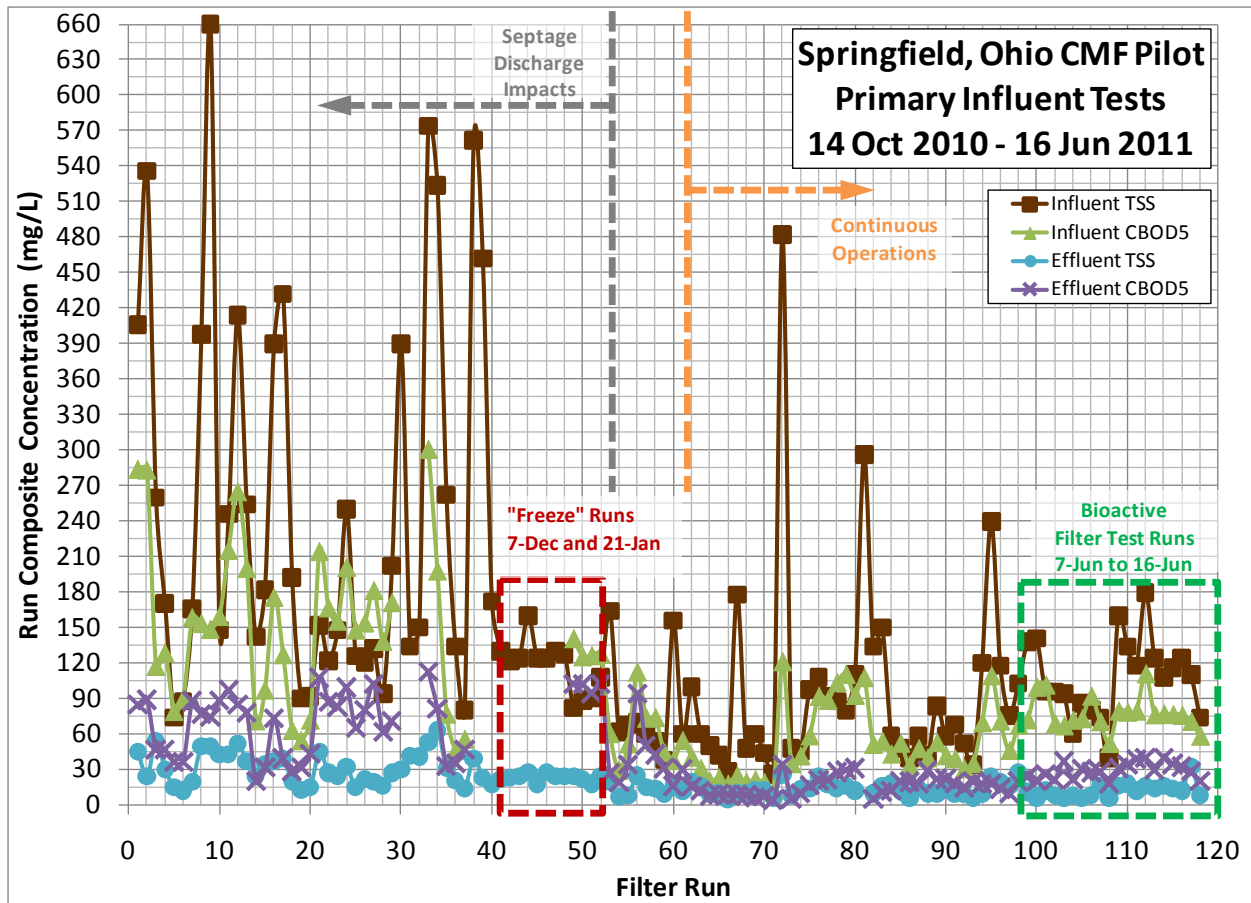


Figure 7. The CMF pilot testing included approximately 120 filter runs with primary influent during multiple wet-weather events.

Freezing Conditions

Test runs were conducted on December 7, 2010 and January 21, 2011 to evaluate operational impacts from freezing weather. The air temperature during the test runs on December 7 ranged from approximately -9 to -5 °C (15 to 22 °F). The filter system was initiated and cycled through a filtration and backwash sequence. Since the normal operating sequence requires the filter bed to be drained (see Figure 3), the system started with the filter vessel drained from the previous test day; however, some residual moisture was retained by the media between test runs. It was observed that this residual moisture did freeze; however, the bed was not frozen into a large rigid mass. Instead the media only appeared “frosted” and separated relatively easily when touched. No adverse operational or performance impacts were observed. The media bed appeared to compress as normal and any residual frozen moisture immediately thawed upon contact with the influent. The subsequent filtration, drain, backwash and compression steps proceeded as normal and did not appear to be adversely impacted by the freezing conditions. Similar observations were made during the test runs on January 21 when the air temperatures were somewhat colder, ranging from approximately -13 to -10 °C (9 to 14 °F). Sampling during these test runs indicated that influent TSS ranged from approximately 80 to 160 mg/L while the CMF produced effluent with TSS ranging from approximately 18 to 28 mg/L.

Correction for Septage Impacts

During the first half of the study it was determined that a significant number of the test runs were adversely impacted by discharges of hauled septage at the WWTP headworks. Since the full-scale HRT facilities would be intercepting flows upstream of the existing headworks and would not be receiving septage loads, the results from these test runs were deemed to not be representative of system performance during peak wet-weather flow conditions. Approximately 60 filter runs were conducted between March 5 and June 16, 2011 that did not appear to be adversely impacted by septage loads. Notes and observations from these data included the following:

- Measurements of the filter run composite samples indicated highly variable influent TSS concentrations with a peak value of approximately 480 mg/L. The average influent TSS concentration was approximately 100 mg/L with a standard deviation of 72 mg/L. Influent CBOD₅ concentrations were also highly variable, averaging approximately 62 mg/L with a standard deviation of 28 mg/L and a peak value of 121 mg/L.
- Effluent TSS and CBOD₅ from the CMF system were relatively consistent. The average effluent TSS concentration was approximately 13 mg/L with a standard deviation of approximately 6 mg/L and a peak value of 32 mg/L. The average effluent CBOD₅ concentration was approximately 21 mg/L with a standard deviation of 10 mg/L and a peak value of 40 mg/L.

Wet-Weather Flow Events

The primary influent test runs discussed above included data from both wet-weather and dry-weather conditions. Monitoring and sampling data collected during the pilot study were used to develop influent hydrographs and pollutographs such as those shown on Figure 8. These graphs were then used to help determine which pilot test runs were representative of wet-weather influent conditions. An evaluation of the resulting wet-weather dataset suggested the following:

- Approximately 53 of the filter runs from October 14 through June 16 appeared to be representative of wet-weather excess flow conditions that would likely be encountered by the full-scale HRT facility. These 53 individual filter run cycles occurred over approximately 16 test events, suggesting that the system sequenced through 3 to 4 filtration and backwash cycles during a typical test event.
- The influent TSS concentrations were highly variable with an average value of 136 mg/L and a standard deviation of 145 mg/L. The peak, median and minimum influent TSS concentrations were 574, 80 and 26 mg/L, respectively. The influent CBOD₅ concentrations were also highly variable with an average value of 63 mg/L and a standard deviation of 49 mg/L. The peak, median and minimum influent CBOD₅ concentrations were 301, 51 and 12 mg/L, respectively. The influent TSS and CBOD₅ data gathered during the pilot study agreed reasonably well with the pollutant concentration trends used during preliminary designs and evaluations of HRT technology alternatives.

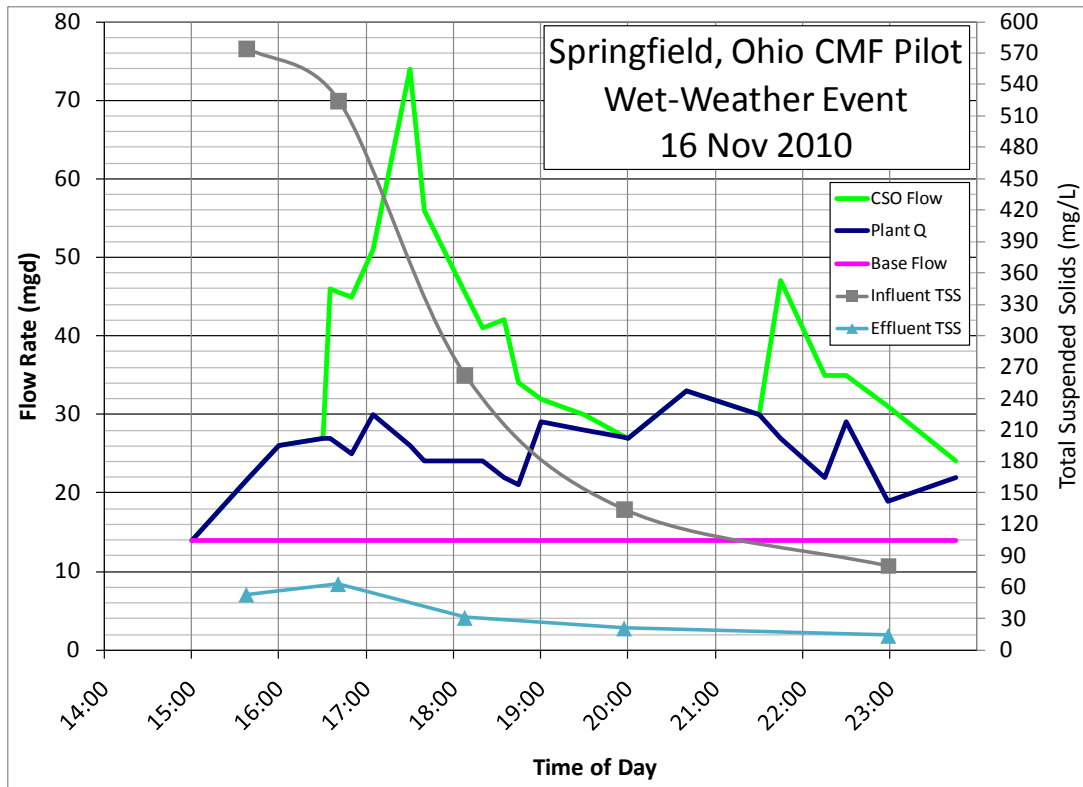


Figure 8. Sampling and monitoring data gathered during the pilot study were used to develop event hydrographs and pollutographs such as these to confirm wet-weather influent characteristics and process design parameters such as hydraulic loading rates, solids loading rates, and backwashing requirements.

- The CMF system produced effluent whose event-average concentrations over the 16 test events were calculated to have the following statistics: maximum value of 36 mg/L, 80th percentile value of 22 mg/L and 60th percentile value of 15 mg/L. These statistics all met the effluent quality criteria outlined in Table 1.
- The event-average effluent CBOD₅ concentrations over the 16 events were calculated to have an average value of approximately 26 mg/L with a standard deviation of 15 mg/L and a peak value of 62 mg/L.

In addition to verifying the effluent quality criteria in Table 1, the pilot data were also used to confirm the process design to treat the 380-ML/d (100-mgd) hydrograph and associated TSS loadings calculated from the design criteria on Figure 1. Pilot filter run times were correlated to the influent solids loading rate (SLR) and this correlation was then used in a spreadsheet model to evaluate the proposed filter cell matrix design and determine the number of filter cells required to be in filtration mode versus backwash mode during each hour of the design event. Outputs from this spreadsheet model are shown on Figure 9.

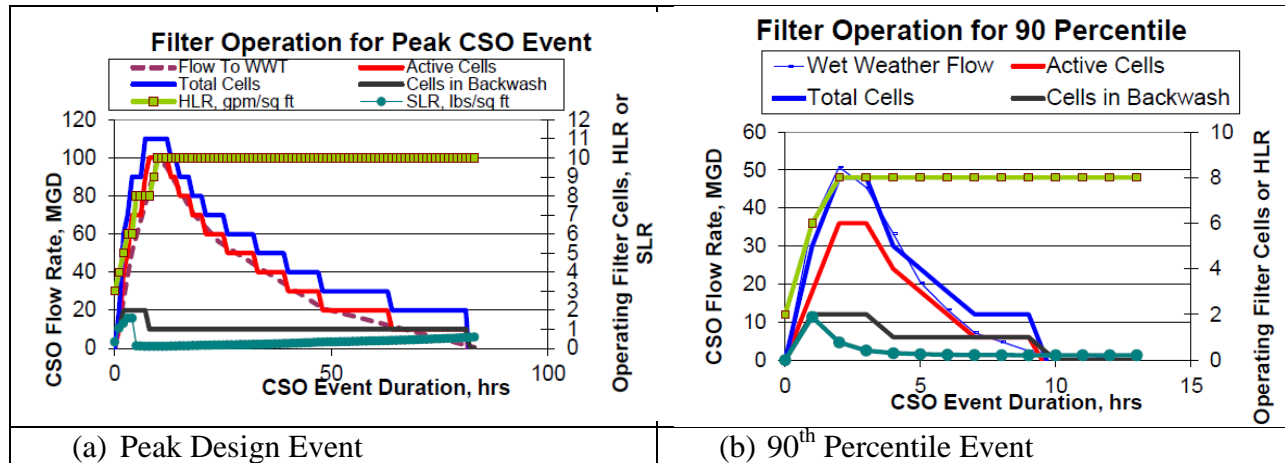


Figure 9. Filter run-time correlations from the pilot testing were used in a spreadsheet model to evaluate the filter cell matrix design and confirm process design criteria.

In addition to the results shown on Figure 9, the spreadsheet model also calculated the backwash flows that would be generated throughout the event. These results indicated that the proposed 11-cell matrix would be able to treat the projected peak design event at the hydraulic loading rate (HLR) of $6.8 \text{ L/m}^2\cdot\text{s}$ (10 gpm/ft^2) without exceeding the maximum allowed backwash flow rate of 420 L/s ($6,600 \text{ gpm}$). Additional observations from these data included:

- The pilot data demonstrated that the filter could treat SLRs up to $9.8 \text{ kg/m}^2\cdot\text{h}$ (2 lb/hr/ft^2) without exceeding backwash frequency constraints. The model output on Figure 9(a) shows that an 11-cell matrix could treat the projected peak design event at HLRs up to $6.8 \text{ L/m}^2\cdot\text{s}$ (10 gpm/ft^2) with a peak SLR of $7.8 \text{ kg/m}^2\cdot\text{h}$ (1.6 lb/hr/ft^2). Note that the peak solids and hydraulic loadings are projected to occur at different times in this model.
- Historical data suggest that a large majority of wet-weather events would likely have peak flows significantly less than the 380-ML/d (100-mgd) peak design event. For comparison, Figure 9(b) shows operating conditions for the projected 90th percentile event which would require 8 of the 11 cells to be brought into operation at a lower HLR.
- Many of the smaller, more frequent events would be completely captured within the volume of the filter basins.

CMF Effluent Disinfection

Results from the hypochlorite dose response tests that were conducted on the CMF effluent in February, March and April are summarized on Figure 10. A review of these data indicated the following:

- The CMF effluent was consistently amenable to hypochlorite disinfection at doses within the range that are typically used for conventional secondary effluents. A hypochlorite dose of 2 mg/L reduced fecal coliform concentrations to below $1,000 \text{ cfu/100 ml}$ within 8 minutes of contact time. *E. coli* responded similarly, falling below 100 cfu/100 mL for the same hypochlorite dose and contact time.

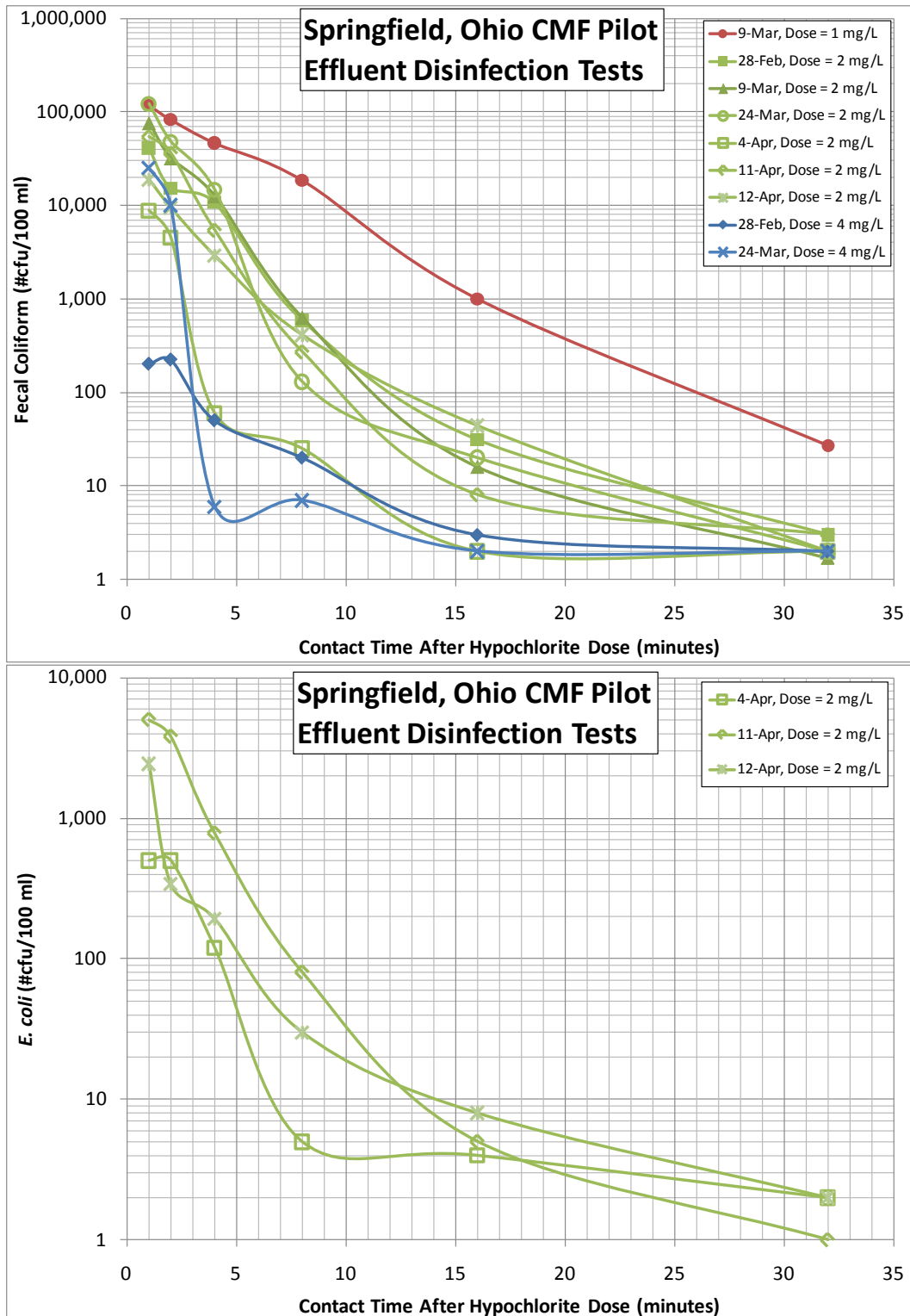


Figure 10. The Springfield piloting demonstrated that CMF effluent was amenable to hypochlorite disinfection with consistent and reasonable doses. Dose response was similar to what would typically be expected for conventional secondary effluents. The *E. coli* dose response followed a similar pattern with concentrations trending approximately an order of magnitude lower than fecal coliform concentrations across the contact time series.

Filter Bioactivity

During the fall and winter seasons, the CMF pilot was operated intermittently with the filter vessel drained and the system placed in standby mode for extended periods between test events. Beginning in March of 2011, the pilot system was operated continuously. As shown on Figure 11, a general decrease of influent total CBOD₅ concentrations was observed during the spring as compared to the fall and winter operations. This decrease was attributed mainly to the fact that samples were not analyzed when there was evidence of discharges from septage loads or digester decanting that would not be received by the new HRT facilities. Influent CBOD₅ concentrations measured during the spring appeared to be much more representative of wet-weather events for the future HRT facility than those measured during many of the fall and winter test runs.

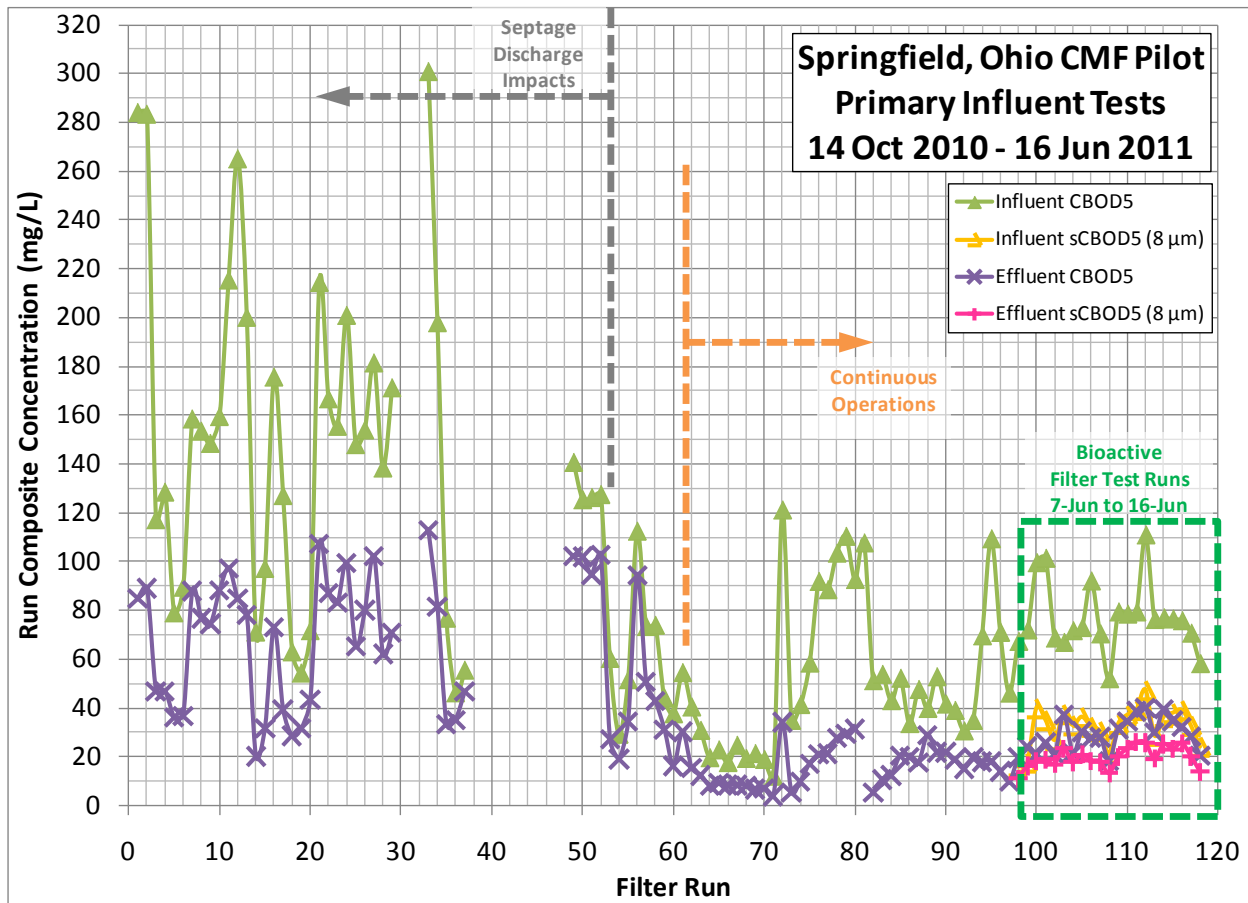


Figure 11. The CMF pilot unit was operated intermittently until March 2011 when continuous operations began.

Generally higher CBOD₅ reductions and higher initial head losses after backwash were also observed during continuous operations as compared to the period with intermittent operations. It was hypothesized that the continuous loading might have promoted biofilm growth within the filter media, potentially increasing the removal of soluble CBOD₅ (sCBOD₅). It was also hypothesized that the addition of waste activated solids (WAS) to the filter feed stream might further increase the removal of sCBOD₅. Test runs in June (during dry-weather conditions) were aimed at evaluating these hypotheses and results are summarized on Figures 12 and 13.

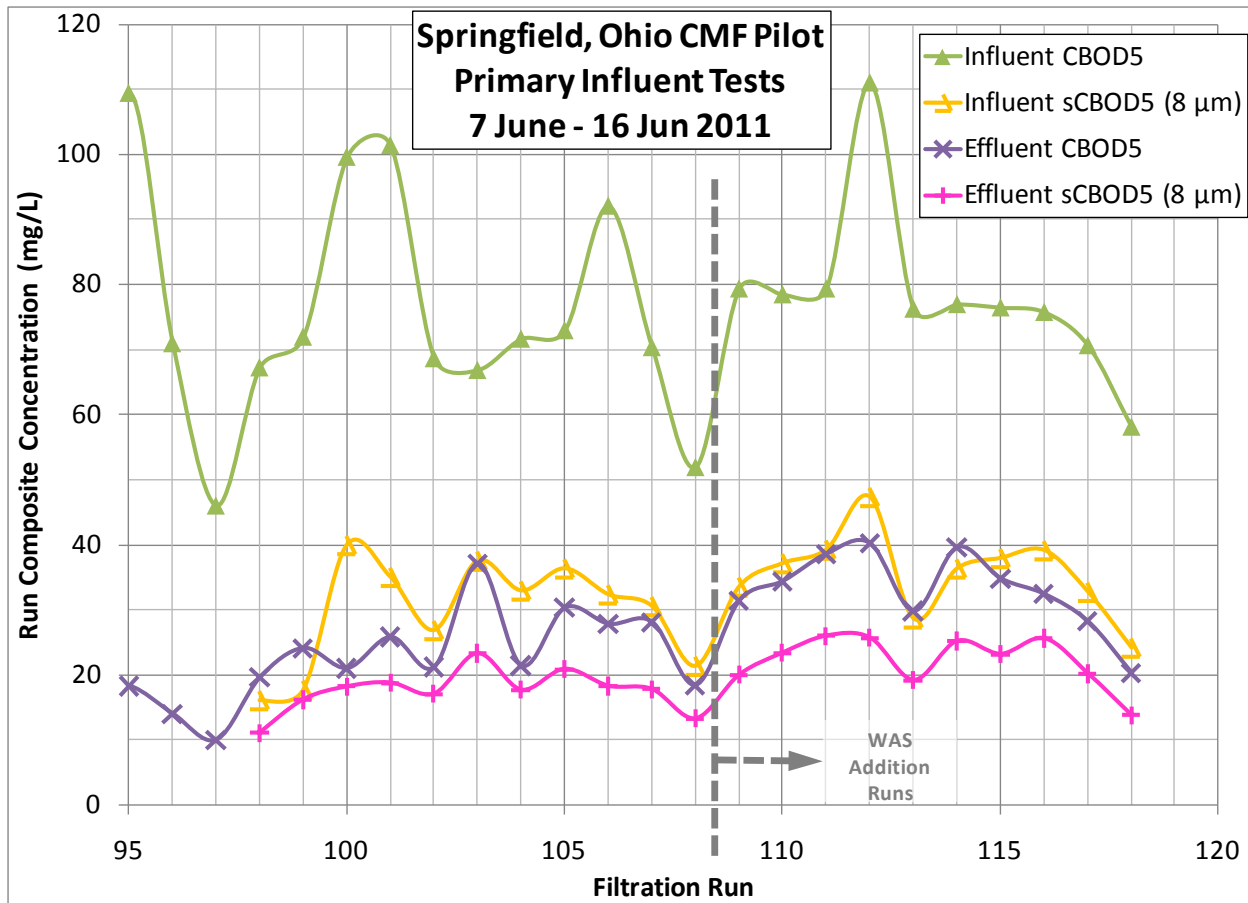


Figure 12. Total and soluble CBOD₅ measurements were taken after the CMF system had been running continuously for an extended period of time.

Observations from the data on these figures included the following:

- Influent total and soluble CBOD₅ during these runs averaged 77 and 33 mg/L, respectively, while effluent total and soluble CBOD₅ averaged 29 and 20 mg/L, respectively. Note that a Whatman 40 filter (8 μm pore size) was used for the soluble CBOD₅ analysis. The effective pore size of the CMF filter itself has been found in previous pilot testing to generally range from between 4 μm to 10 μm, depending upon the flocculant nature of the particles being filtered and the amount of particles that are captured on the filter media at the time of sample collection. Therefore, it was not apparent if the observed reduction in sCBOD₅ was attributable to biofilm adsorption or was a remnant of the laboratory analysis method itself. It is recommended that future research efforts with the CMF technology consider microbiological analysis of media samples along with analysis of influent and effluent samples to determine the complete fractionation of chemical oxygen demand (COD) using 0.45 μm filtration for sample pretreatment to determine “soluble” chemical oxygen demand (sCOD) and also using the flocculated and filtered COD (ffCOD) method proposed by Mamais *et al.* (1993) to provide more insight into potential biofilm treatment mechanisms. These research efforts should be aimed at better determining if such biofilms could provide an adsorption function, or if they would act more like filter aids to improve colloidal removal.

- The addition of WAS did not appear to improve the performance of the filter. It is recommended that future research efforts of the CMF technology consider varying the WAS dose concentration and contact time to better quantify these variables and further evaluate the feasibility and potential for this process alternative.

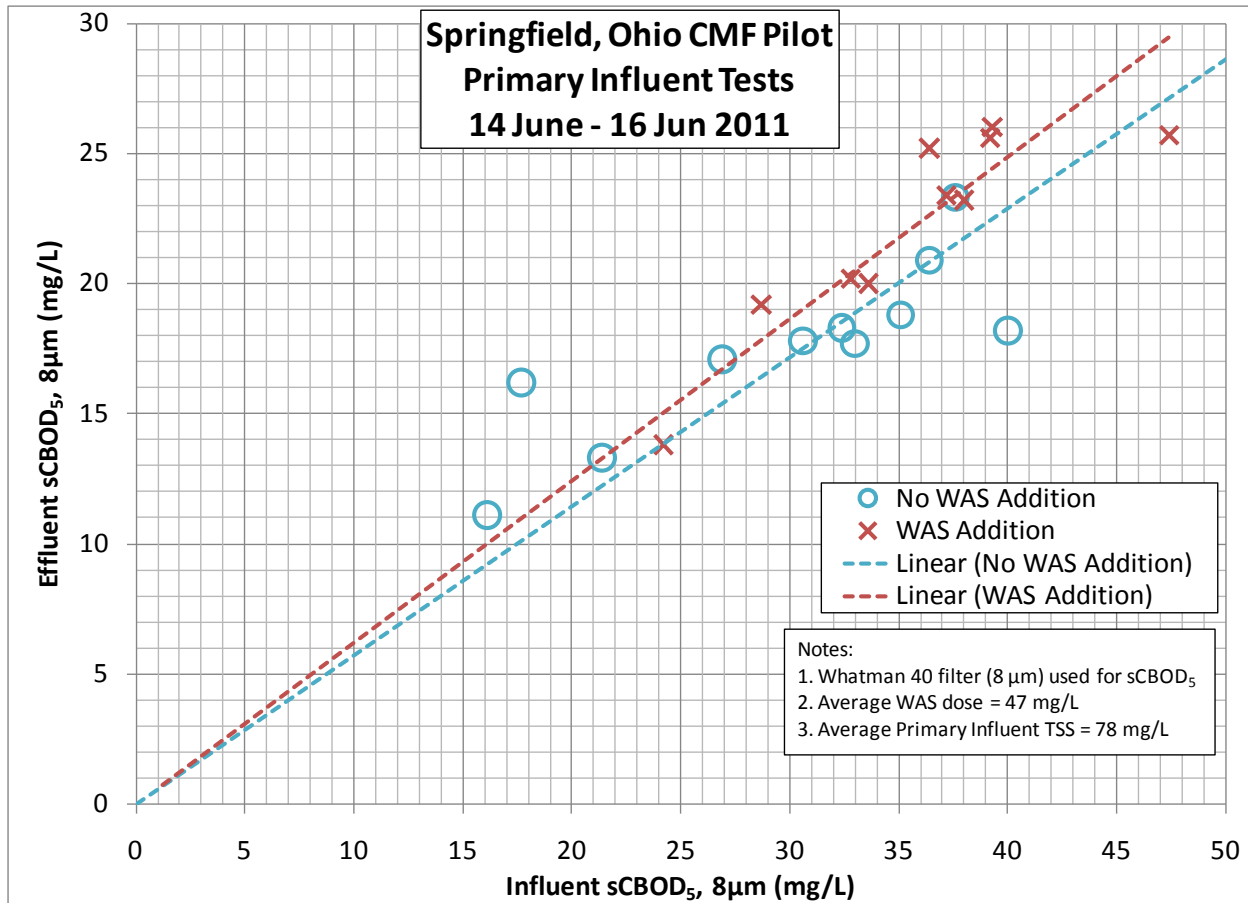


Figure 13. The addition of a relatively small dose of WAS to the CMF feed stream did not appear to improve soluble CBOD₅ removal.

CONCLUSIONS AND RECOMMENDATIONS

The operation of the pilot unit was found to be simple and straightforward. After operator initiation, the system PLC automatically sequenced valves, feed pumps and the backwash blower to cycle the unit between filtration and backwash modes based on the water level above the filter bed. The filter consistently produced an effluent void of visible solids from the beginning to the end of each filtration cycle.

The influent flow monitoring and sample analysis during the CMF pilot tests confirmed the appropriateness of the influent characteristics developed for the evaluation of process and technology alternatives and used as the basis of design for the new HRT facilities.

The pilot testing confirmed the capability of the CMF process to consistently achieve the effluent quality criteria established during the preliminary design phases of the project. The CMF pilot performance exceeded primary clarification equivalency, which is the minimum requirement of the federal CSO Control Policy (USEPA, 1994). Furthermore, the performance compared favorably to that of other high-rate treatment technologies that have successfully demonstrated their long-term ability to increase the peak flow treatment capacity of secondary treatment facilities (Fitzpatrick *et al.*, 2008).

The pilot testing also confirmed the process design criteria established during preliminary design. At the time of this writing, the design of the 380-ML/d (100-mgd) HRT facilities was near the 60% submittal stage. As depicted on Figure 14, new structures and equipment will be added for excess flow interception and screening, compressible media filtration, hypochlorite disinfection, bisulfite dechlorination, and effluent pumping. Construction of the new facilities is scheduled to be completed in 2014.

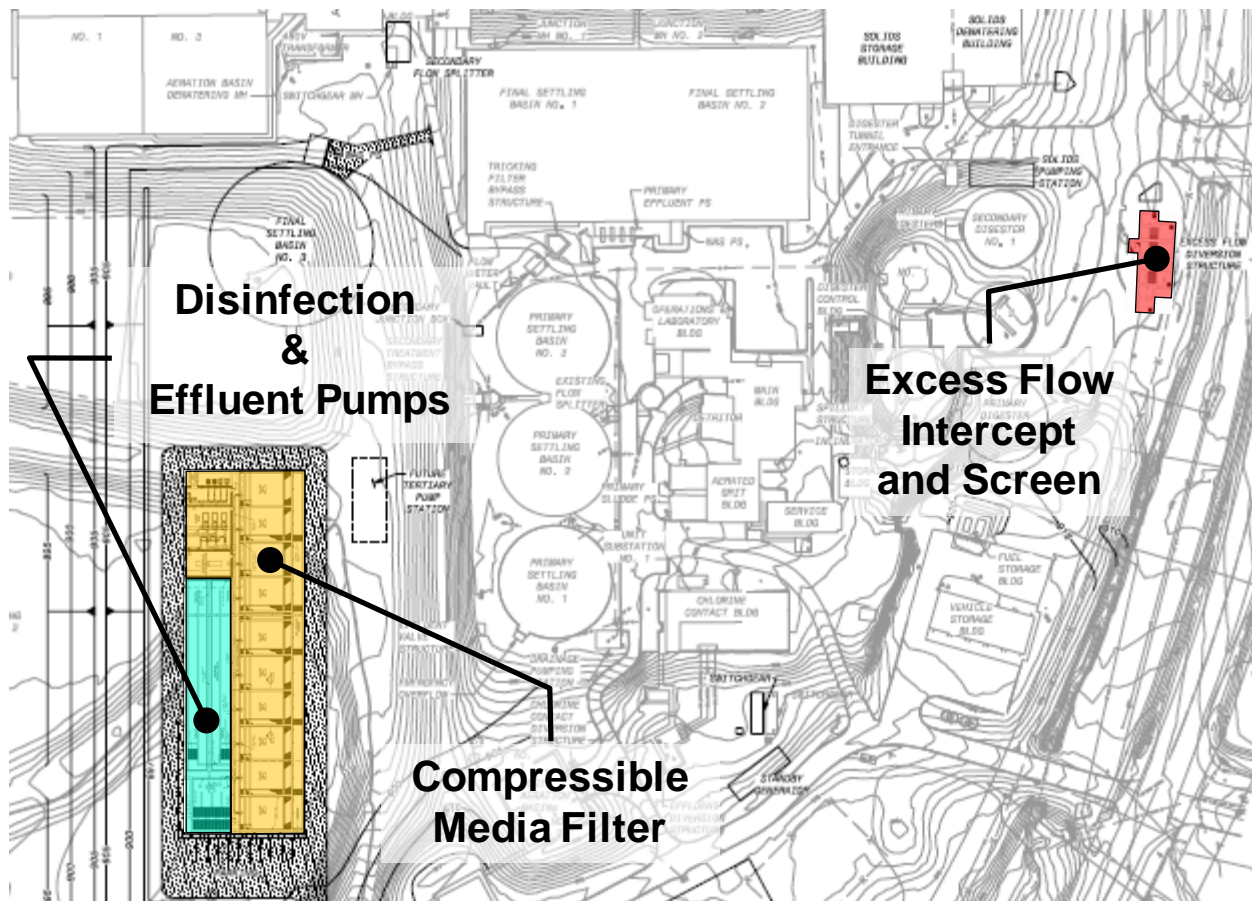


Figure 14. The 380-ML/d (100-mgd) HRT facilities at the Springfield (Ohio) WWTP will consist of excess flow intercepting and screening, compressible media filtration, hypochlorite and bisulfite disinfection, and effluent pumping.

ACKNOWLEDGMENTS

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REFERENCES

- Fitzpatrick, J.; Gilpin, D.; Kadava, A.; Kliwer, 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
- Fitzpatrick, J.; Long, M.; Wagner, D.; Middlebrough, C. (2008) Meeting Secondary Effluent Standards at Peaking Factors of Five and Higher, *Proceedings of the 81st Annual Water Environment Federation Technical Exhibition and Conference*, Chicago, IL.
- Mamais, D.; Jenkins, D.; Pitt, P. (1993) A Rapid Physical-Chemical Method for the Determination of Readily Biodegradable Soluble COD in Municipal Wastewater, *Water Research*, Vol. 27, No. 1, 195-197.
- Standard Methods for the Examination of Water and Wastewater*, 21st Edition (2005). American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF).
- USEPA (1994), Combined Sewer Overflow (CSO) Control Policy, *Federal Register*, Vol. 59, No. 75, 18688-18698.
- USEPA (2008), *Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Flow Management*, EPA 832-R-06-006, U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, DC.
- WERF (2003), *Peer Review: Wet Weather Demonstration Project in Columbus, Georgia*, Water Environment Research Foundation, Alexandria, VA and IWA Publishing, London, UK.