Mitchell Community College
Stormwater Treatment System Field Evaluation:

Stormwater Management StormFilter® with PhosphoSorb Media at 1 gpm/ ft^2

Abstract

This report presents the results of a twenty month field study conducted at The Mitchell Community College testing site located in the Town of Mooresville, NC. The study was conducted in an effort to demonstrate the effectiveness of The Stormwater Management StormFilter® (StormFilter) Stormwater Treatment System (system) in treating stormwater runoff with respect to the removal of solid and nutrient pollutants.

Testing of the StormFilter system was conducted for Total Suspended Solids (TSS), Suspended Sediment Concentration (SSC), Total Volatile Suspended Solids (TVSS), Total Phosphorus (TP), Dissolved Phosphorus (Diss. P), Ortho-phosphate (Ortho-P), and Particulate Phosphorus (PP) in accordance with the approved Project Plan, (Contech, 2010) as well as the conditions outlined in the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ) Preliminary Evaluation Period (PEP) program, (NCDENR, 2007).

Results from the twenty month study, that represented a total of 13 storm events and 23.73 inches of precipitation, show that the StormFilter system tested was highly effective in removing solid and nutrient pollutants from stormwater runoff. Significant reductions for solid and nutrient pollutants were observed between influent and effluent sampling locations using the Efficiency Ratio (ER) efficiency calculation (TSS 90.4% and TP 86.1%) and Summation of Load (SOL) efficiency calculation methods (TSS 90.9% and TP 87.1%).

Keywords

BMP; stormwater; TP; TSS; NCDENR DWQ PEP; StormFilter; media filter cartridge

Introduction

Contech Engineered Solutions LLC (formerly Contech Construction Products Inc., Stormwater360 Inc., and Stormwater Management Inc.) is the leading provider of innovative, long-term, stormwater treatment solutions, offering a variety of products, maintenance, laboratory, and engineering support to meet stormwater treatment needs. Contech Engineered Solutions LLC's patented product, the Stormwater Management StormFilter® (StormFilter) Stormwater Treatment System (system) is a Best Management Practice (BMP) designed to meet federal, state, and local requirements for treating stormwater runoff in compliance with the Clean Water Act. The StormFilter system improves the quality of stormwater runoff before it enters receiving waterways through the use of customizable filter media, which removes non-point source pollutants, including sediment particles, oil and grease, soluble metals, nutrients, and organics.

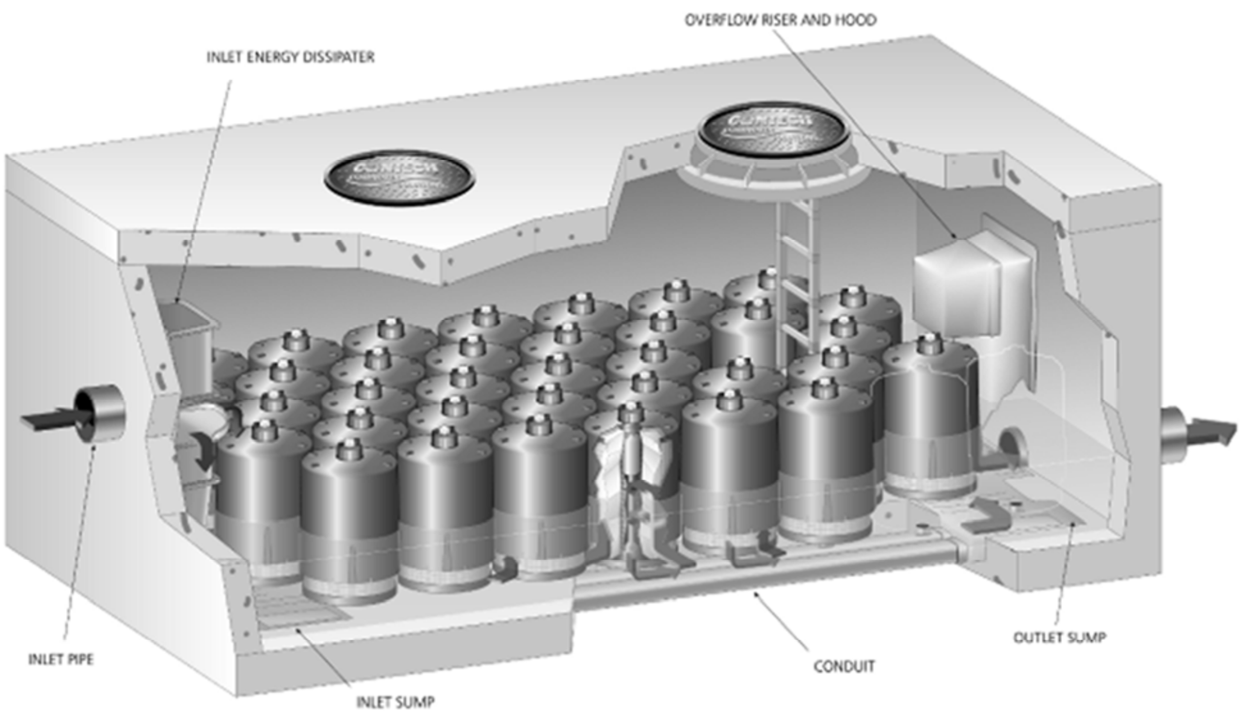

Figure 1. Standard StormFilter® Configuration.

The StormFilter system, as seen in Figure 1, is typically comprised of a vault that houses rechargeable, media-filled, filter cartridges. Stormwater entering the system percolates horizontally through these media-filled cartridges, where pollutant removal processes occur. Once filtered through the media, the treated stormwater is directed to a collection pipe and discharged to an open channel drainage way or storm sewer.

The StormFilter system is offered in a variety of configurations or containers depending on the specific application and site conditions: precast vault, box culvert vault, panel vault, manhole, and cast-in-place concrete. The StormFilter system is also offered in a steel catch basin or a concrete curb inlet configuration. The precast, manhole, and inlet configuration models utilize standard pre-manufactured units and arrive at the construction site with the filter cartridges and other internal components already in place to ease the installation process; the box culvert, panel vault, and cast-in-place units are customized for larger flows and require installation of cartridges at the site.

The Mitchell Community College StormFilter system installation (located in Mooresville, NC) was evaluated over a twenty month period following system maintenance in November of 2010. This project was managed by Contech in cooperation with the site owner and the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ). Independent oversight of all aspects of the project was provided by Ryan Winston, M.S., Extension Associate Engineer in the Department of Biological and Agricultural Engineering at North Carolina State University. Independent sample handling services were provided by Pace Analytical Services (Pace) of Huntersville, NC, and independent laboratory work was conducted by Pace and Test America of Beaverton, OR. Monitoring over a twenty month period resulted in the collection of 13 qualified storm events representing 23.73 inches of cumulative precipitation.

Site and System Description

The Mitchell Community College testing site is located in the Town of Mooresville, NC. Mooresville is located in southern Iredell County in the Piedmont region of North Carolina. The town is located between the Charlotte metropolitan area and the city of Statesville, the County seat. Mooresville is located within 15 miles of three interstate highways and is approximately 23 miles from the Charlotte-Douglas International Airport. The testing site was located at the intersection of West Moore Avenue and North Academy Street, (Lat: 35°35'3.60"N, Lon: 80°48'47.76"W, Elevation AMSL: 862ft). The site was owned and operated by Mitchell Community College and used primarily for parking. The site was swept periodically, however minor amounts of sediment and organic debris were typically present on site. Based on information provided by the design engineer, the site was 68% impervious and the total drainage area for the site was 1.08 acres. An aerial view of the site from 2010 is shown in Figure 2. Stormwater runoff from the contributing drainage area was directed to the StormFilter system before eventually discharging into Reed’s Creek Basin and ultimately Lake Norman.

Stormwater treatment for the site was provided by a StormFilter system, designed as a capture-and-treat system. The storage component of the system (tank) was comprised of a 30 inch diameter corrugated metal pipe (CMP) network designed to capture 75% of the calculated water quality volume (i.e. the runoff volume associated with the 1.0 inch event). The treatment component (StormFilter) was designed on a mass-loading basis and was required to meet the annual pollutant loading requirements of the site with a minimum estimated interval between maintenance of 1 year. The StormFilter contained a total of eight 18 inch tall, media filled filter cartridges operating at a maximum surface area specific flow rate of 1 gpm/ft^2 (7.5 gpm/cartridge). Each of the filter cartridges was filled with an innovative coated reactive perlite media (PhosphoSorb). The PhosphoSorb media employs both physical straining and adsorption as primary and secondary pollutant removal mechanisms respectively thus allowing the media to sequester both particulate and dissolved pollutants.

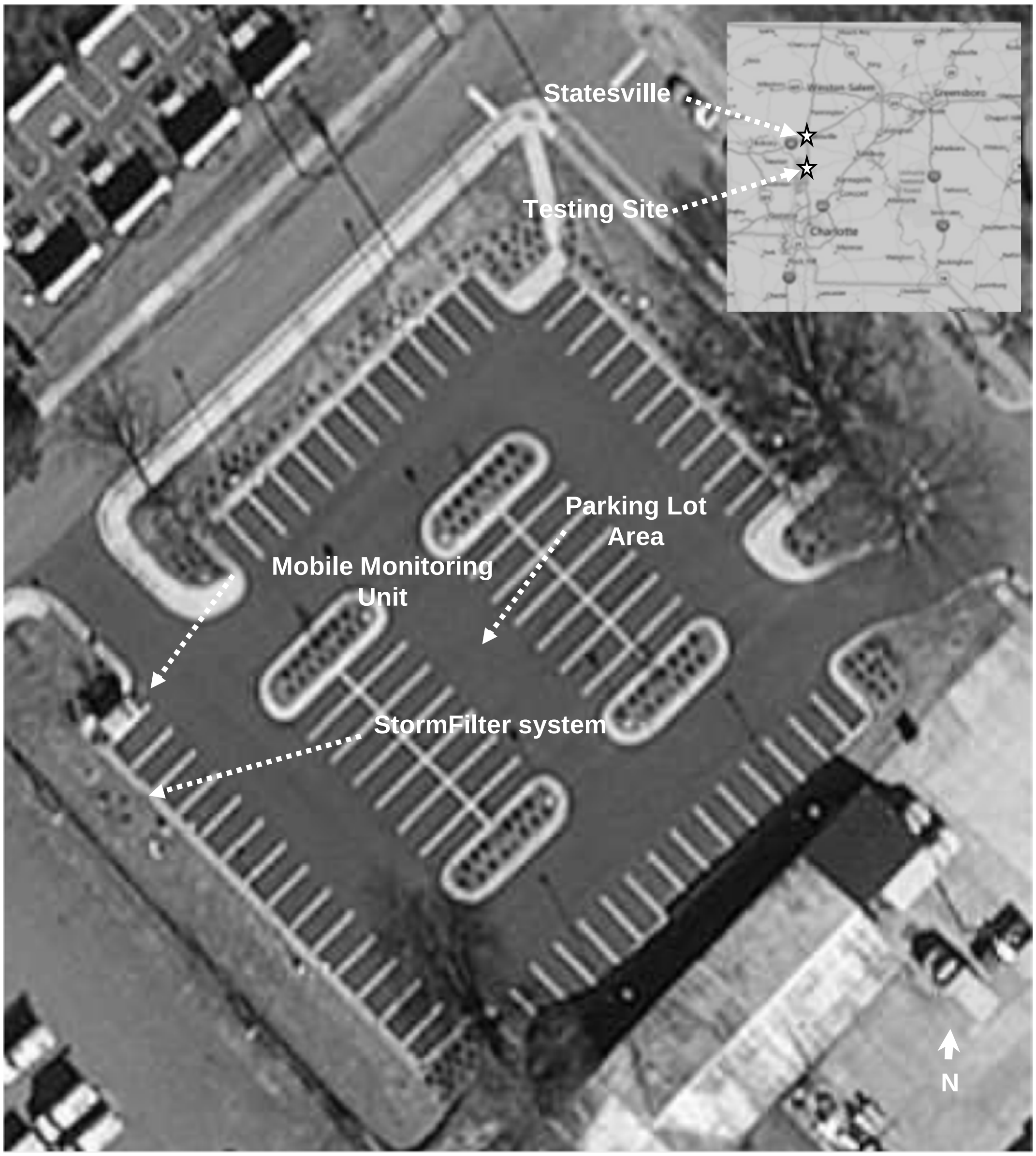

Figure 2. Aerial view of the Mitchell Community College testing site.

Sampling Design

The equipment and sampling techniques used for this study were in accordance with the Project Plan (Contech, 2010) developed by Contech in consultation with NCDENR DWQ. The Project Plan met the conditions outlined in the NCDENR DWQ preliminary evaluation period (PEP) program. Contech personnel were responsible for the installation, programming, and maintenance of the sampling equipment. Pace analytical provided independent sample retrieval, system reset, and sample submittal activities. Water sample processing and analysis was performed by Pace and Test America.

A Mobile Monitoring Unit (MMU) was provided, installed, maintained, and operated by Contech for sampling purposes. The MMU is a towable, fully enclosed, self-contained stormwater monitoring system specially designed and built by Contech for remote, extended-deployment stormwater monitoring. The design allows for remote control of sampling equipment, eliminates confined space entry requirements, and streamlines the sample and data collection process. The MMU installed at the Mitchell Community College testing site is shown in Figure 3.

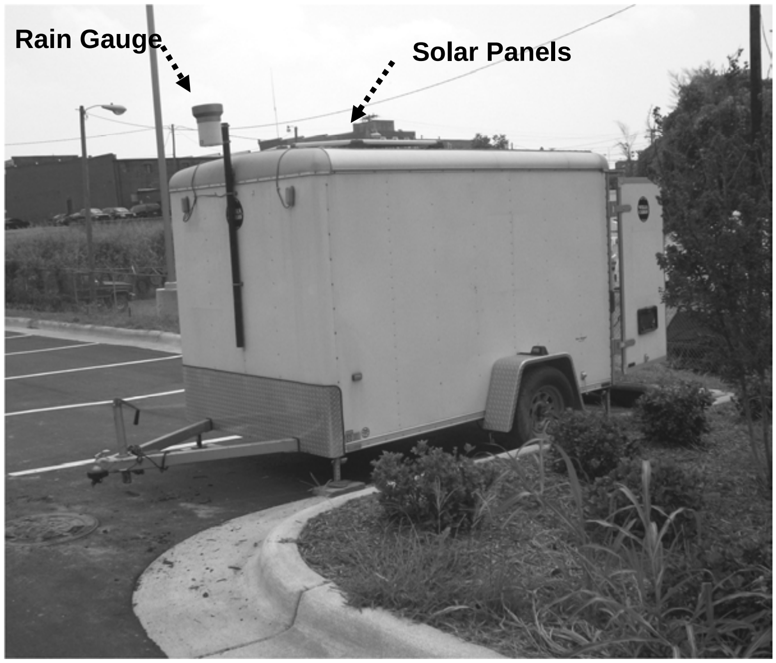

Figure 3. View of the Mobile Monitoring Unit (MMU) installed at the Mitchell Community College testing site.

Influent and effluent water quality samples were collected using individual ISCO 6712 Portable Automated Samplers configured for standard, individual, round, 1 liter wide-mouth HDPE bottles with sample bottles in the 1 through 12 positions for sample collection. The samplers were connected to individual 12V DC batteries recharged with solar panels. The influent sampler was equipped with an ISCO 750 Area Velocity Flow Module with a Low Profile Area Velocity Flow Sensor for flow analysis and influent sample pacing. The effluent sampler was equipped with an ISCO 730 Bubbler Flow Module used in conjunction with a 6 inch diameter Thel-Mar Weir for flow analysis and effluent sample pacing. Each sampler was also connected to an ISCO SPA 1489 Digital Cell Phone Modem to allow for remote communication and data access. Rainfall was measured using a 0.01-in resolution Texas Electronics TR-4 tipping bucket-type rain gauge. The sample intake for each automated sampler was connected to a stainless steel sample strainer (9/16″ diameter, 6″ length, with multiple ¼″ openings) via a length of 3/8″ ID Acutech Duality FEP/LDPE tubing. Sample strainers and flow measurement equipment were secured to the invert of the influent and effluent pipes using stainless steel spring rings.

Following a precipitation event, Contech personnel remotely communicated with the automated sampling equipment to confirm sample collection and dispatch personnel from Pace to retrieve the samples and reset the automated sampling equipment. Samples were delivered to Pace and Test America on ice (<4 degrees C) and accompanied by chain-of-custody documentation. Sample bottles were combined by Pace to create composite samples. Sample bottles were thoroughly shaken and sieved through a 2000µm sieve. Samples were then emptied into a cone splitter to obtain a single, composite sample (USGS, 1980). Composite samples were then submitted for analysis according to the analytical methods specified in Table 1. The field monitoring methods used for this study represent the current state-of-the practice, and are very similar to those used by researchers in North Carolina and elsewhere to evaluate Stormwater BMPs.

Table 1. Analytical methods used for analytical parameters of interest.

Parameter	Analytical Method
Total Suspended Solids (TSS)	SM2540 D
Suspended Sediment Conc. (SSC)	ASTM D3977
Total Volatile Suspended Solids (TVSS)	EPA 160.4
Total Phosphorus (TP)	EPA 365.1
Dissolved Phosphorus (Diss. P)	EPA 365.1

As per the Project Plan, the following quality control samples were used to assess the quality of both field sampling and analytical activities: equipment rinsate blanks, equipment field blanks, method blank, and duplicate analysis. Sample processing blank samples were not taken. Except for solids analyses that employ the use of the whole sample volume (SSC), all method blanks and duplicate analyses were handled by Pace and Test America. Since solids analyses that employ the use of whole sample volume (SSC) consume the entire sample volume, replicate samples were prepared in place of duplicate samples and analyzed to allow for the assessment of analytical accuracy. The results of equipment rinsate blanks and equipment field blanks are shown in Table 2 accompanied by associated decisions and action items for instances of detection. Equipment rinsate blanks and equipment field blanks were submitted for analysis of the following parameters TSS, TVSS, and TP.

Table 2. Instances of detection in equipment rinsate blank and equipment field blank samples.

Date	Blank Type	Detections	Action	% of Sample Pairs Affected
7/8/2011	Rinsate	None	None	0
6/28/2011	Field	None	None	0
6/14/2012	Field	None	None	0

Precipitation Measurement

Precipitation was measured with a Texas Electronics TR-4 tipping bucket-type rain gauge. The rain gauge was connected to an ISCO 6712 Automated Sampler programmed to record the total number of tips (0.01 inch per tip) every 5 minutes. Equipment calibrations performed on site during the monitoring period indicated that the rain gauge was working properly during the monitoring period.

A comparison of monthly precipitation totals measured at the NOAA NWS COOP weather station in Statesville, NC during the monitoring period to the 30 year monthly mean precipitation totals shows that precipitation in the area was below normal in 15 of the 20 months studied (Table 3). Rainfall was above normal in March (2011), July (2011), September (2011), November (2011), and May (2012) as seen in Table 3.

Table 3. Monthly precipitation totals compared to 30 year monthly mean precipitation totals (NOAA NWS COOP Weather Station Statesville, NC)

Month	NOAA NWS COOP Station Statesville, NC Precipitation Total (in.)	Percent of Monthly Precipitation Total Normal (%)	30 Year Monthly Precipitation Total Normal (in.)
November (2010)	1.08	33	3.30
December (2010)	2.63	72	3.64
January (2011)	1.59	42	3.83
February (2011)	1.76	50	3.55
March (2011)	5.66	127	4.45
April (2011)	2.72	80	3.42
May (2011)	3.82	92	4.15
June (2011)	1.78	40	4.49
July (2011)	6.26	158	3.95
August (2011)	3.29	90	3.67
September (2011)	4.89	120	4.07
October (2011)	2.39	69	3.45
November (2011)	4.14	125	3.30
December (2011)	3.32	91	3.64
January (2012)	1.8	47	3.83
February (2012)	1.81	51	3.55
March (2012)	2.64	59	4.45
April (2012)	1.77	52	3.42
May (2012)	6.43	155	4.15
June (2012)	4.36	97	4.49

For sampled storm events, rainfall durations ranged from 8 to 36 hours, rainfall depth ranged from 0.85 to 4.41 inches, and 15 and 30 minute maximum intensities were 3.28 and 1.90 inches/hour respectively. Based on design information provided by the design engineer, runoff was calculated using the Curve Number Method using a CN of 89. Calculated runoff volumes ranged from 5796 to 94,133 gallons as seen in Table 4.

Table 4. Precipitation and runoff statistics for sampled events at the Mitchell Community College testing site.

Event ID	Duration of storm event (hours)	Total Precipitation (in.)	P15 (in/hr)	P30 (in/hr)	Calculated Runoff Volume (gal)
MCC041611	8	1.04	1.32	0.96	9086
MCC051011	8	0.93	1.24	0.80	7126
MCC051611	22	1.04	0.40	0.26	9086
MCC062811	24	2.06	1.36	1.00	31611
MCC070811	13	4.41	3.28	1.90	94133
MCC073111	19	1.37	2.04	1.88	15674
MCC090511	36	1.94	1.92	0.96	28694
MCC092111	13	3.75	2.16	1.60	75933
MCC110311	24	1.40	0.56	0.50	16316
MCC111611	14	1.01	1.68	1.34	8538
MCC051312	21	1.82	1.28	0.92	25828
MCC052112	30	0.85	1.68	0.86	5796
MCC060612	30	2.11	1.00	0.88	32841

Flow Measurement

An ISCO 750 Area Velocity Flow Module with a Low Profile Area Velocity Flow Sensor was used to measure flow and pace sample collection at the influent sample location. An ISCO 730 Bubbler Flow Module was used in conjunction with a 6 inch diameter Thel-Mar Weir to measure flow and pace sample collection at the effluent sample location. Level measurements were adjusted by applying corrections that reflected differences between recorded and measured water surface elevations at the influent and effluent sampling locations. On average, 105% of the calculated total rainfall volume as runoff was measured, as effluent for the monitored events, as shown in Table 5.

Table 5. Percentage of calculated rainfall runoff volumes represented by actual measured runoff volumes at the Mitchell Community College testing site.

Event ID	Calculated Runoff Volume (gal)	Effluent Volume (gal)	Effluent Volume / Calc. Runoff Volume (%)
MCC041611	9086	12748	140
MCC051011	7126	9392	132
MCC051611	9086	18104	199
MCC062811	31611	26364	83
MCC070811	94133	49090	52
MCC073111	15674	16093	103
MCC090511	28694	35039	122
MCC092111	75933	67321	89
MCC110311	16316	20220	124
MCC111611	8538	9926	116
MCC051312	25828	13154	51
MCC052112	5796	4879	84
MCC060612	32841	21569	66

Stormwater Data Collection Requirements

Of the 13 qualifying storm events sampled; 1) the total rainfall was greater than 0.1 inches for all storm events sampled, 2) the minimum inter-event period was greater than 6 hours for all storm events sampled, 3) the minimum number of influent and effluent aliquots collected per storm event was ≥ 5, 4) influent flow-weighted composite samples covered ≥ 50% of the total storm flow for all storm events sampled with the exception of the MCC070811, MCC090511, MCC092111, MCC110311,MCC051312, and MCC060612 events, and 5) effluent flow-weighted composite samples covered ≥ 50% of the total storm flow for all storm events sampled. All events have been determined to meet the conditions outlined in the PEP program as shown in Table 6.

Table 6. Stormwater data collection requirement results.

Event ID	Influent Coverage	Effluent Coverage	Influent Number of Aliquots	Effluent Number of Aliquots	Antecedent Dry Period > 6 hours	Event Depth (in.)
MCC041611	101%	100%	18	14	√	1.04
MCC051011	91%	79%	6	6	√	0.93
MCC051611	79%	90%	8	8	√	1.04
MCC062811	98%	97%	19	13	√	2.06
MCC070811	41%	98%	24	24	√	4.41
MCC073111	97%	98%	16	16	√	1.37
MCC090511	46%	90%	29	26	√	1.94
MCC092111	49%	93%	48	48	√	3.75
MCC110311	34%	60%	48	48	√	1.40
MCC111611	100%	100%	39	40	√	1.01
MCC051312	36%	92%	28	48	√	1.82
MCC052112	100%	74%	31	5	√	0.85
MCC060612	46%	73%	42	48	√	2.11

Data Analysis

Of the 13 qualifying storm events sampled, data verification and validation did not lead to the outright disqualification of any events due to obvious monitoring, handling or analytical errors, or the substantial exceedance of the design operating parameters. Event Mean Concentrations (EMC) from influent and effluent samples are summarized in Table 7-9.

Using SSC (<500µm) EMC results, the percent of corresponding SSC (<2000µm) EMC results was calculated. The calculated percentages of corresponding SSC (<2000µm) EMC results indicated the portion of material that was less than 500µm in size and are summarized in Table 10.

Using TVSS EMC results, the percent of corresponding SSC results was calculated. The calculated percentages of corresponding SSC (<2000µm) and SSC (<500µm) results indicated the percent of combustible materials that are assumed to be organic in nature and are summarized in Table 11.

Non-parametric statistical methods were used to evaluate correlations and differences between non-transformed influent and effluent EMCs since influent and effluent EMCs were generally not from the same statistical distribution. To test for positive correlations between influent and effluent EMCs, the Spearman Rank Order Correlation test was used (USGS, 1991). To evaluate the significance of differences between influent and effluent EMCs, the Mann-Whitney Rank Sum Test was used (USGS, 1991). For the Mann-Whitney Rank Sum Test the null hypothesis was that the two samples were not drawn from populations with different medians. A significant difference between influent and effluent EMCs was concluded when $P<0.05$.

Detectible concentrations were observed for all parameters analyzed except for TSS for the MCC051011, MCC051611, MCC062811, MCC073111, MCC090511, MCC092111, MCC110311, and MCC060612 events; SSC (<2000µm) for the MCC073111, MCC051312, and MCC060612 events; SSC (<500µm) for the MCC051611, MCC051312, and MCC060612 events; TVSS (<2000µm) for the MCC111611 event; TVSS (<500µm) for the MCC110311 and MCC111611 events; TP for the MCC05161, MCC062811, MCC070811, MCC092111, MCC110311, MCC111611, MCC051312, MCC052112, and MCC060612 events ; Diss. P for the MCC041611, MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; Ortho-P for the MCC041611, MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; For values that were reported as non-detect, substitutions were made using half of the Method Reporting Limit (MRL) for statistical testing and calculation of efficiencies. For calculated parameters values calculated as ≤ 0 were reported as 0 for statistical testing and calculation of efficiencies.

Performance was calculated using the Efficiency Ratio (ER) efficiency calculation method. The ER method defines the efficiency as the average event mean concentration of pollutants over some time period.

$$ER = 1 - \frac{mean\ effluent\ EMC}{mean\ influent\ EMC}$$

The ER method assumes; 1) The weight of all storm events is equal regardless of the relative magnitude of the storm event and 2) that if all storm events at the site had been monitored, the average inlet and outlet EMCs would be similar to those that were monitored (URS/ EPA 1999). ER efficiency calculations for the 13 events sampled at the Mitchell Community College testing site are summarized in Tables 7-19.

Performance was also calculated using the Summation of Loads (SOL) efficiency calculation method. The SOL method defines the efficiency as a percentage based on the ratio of the summation of all influent loads to the summation of all effluent loads.

$$SOL = 1 - \frac{sum\ of\ all\ effluent\ loads}{sum\ of\ all\ influent\ loads}$$

The SOL method assumes; 1) monitoring data accurately represents the actual entire total loads in and out of the BMP for a period long enough to overshadow any temporary storage or export of pollutants and 2) any significant storm events that were not monitored had a ratio of inlet to effluent loads similar to the storms events that were monitored (URS/ EPA 1999). In an effort to eliminate the introduction of potential bias associated with observed discrepancies between influent and effluent measured volumes it was assumed that the influent volume was equal to the effluent volume. Measured effluent volume was used to calculate loads for both the influent and effluent sample locations. Sum of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site are summarized in Tables 12,13, and 14.

Results

Based on the use of the Spearman Rank Order correlation test, positive correlations (P<0.05) were determined between influent and effluent EMCs for Ortho-P.

Based on the use of the Mann-Whitney Rank Sum test, the difference in the median values between the influent and effluent EMCs is greater than would be expected by chance. Therefore, a statistically significant difference (P<0.05) was observed for TSS, SSC (<2000µm), SSC (<500µm), TVSS (<2000µm), TP, and PP as seen in Tables 7, 8, and 9.

Based on the use of the Mann-Whitney Rank Sum test, the difference in the median values between the influent and effluent EMCs is not great enough to exclude the possibility that the difference is due to random sampling variability. A statistically significant difference ($P > 0.05$) was not observed for TVSS (<500µm), Diss. P, and Ortho-P as seen in Tables 7, 8, and 9.

Suspended Solids Parameters

Influent EMCs for TSS ranged from 10.3 mg/l to 98.2 mg/l with a median of 27.6 mg/l and a mean of 34.6 mg/l. Corresponding effluent EMCs ranged from 1.3 mg/l to 6.6 mg/l with a median of 2.8 mg/l and a mean of 3.3 mg/l, resulting in an ER efficiency of 90.4%. Total event loadings for the study were 32.7 kg at the influent and 3.0 kg at the effluent sampling location, resulting in an SOL TSS efficiency of 90.9%.

Influent EMCs for SSC (<2000µm) ranged from 17.7 mg/l to 2080.0 mg/l with a median of 53.4 mg/l and a mean of 231.0 mg/l. Corresponding effluent EMCs ranged from 1.9 mg/l to 7.2 mg/l with a median of 3.4 mg/l and a mean of 3.9 mg/l, resulting in an ER efficiency of 98.3%.Total event loadings for the study were 222.0 kg at the influent and 3.9 kg at the effluent sampling location, resulting in an SOL SSC efficiency of 98.3%. In general, the relationship between TSS and SSC (<2000µm) was determined not to be significant based on the linear regression results for both influent (R^2 =0.0130) and effluent (R^2 =0.410) EMCs.

Influent EMCs for SSC (<500µm) ranged from 9.0 mg/l to 393.0 mg/l with a median of 28.6 mg/l and a mean of 66.1 mg/l. Corresponding effluent EMCs ranged from 1.7 mg/l to 10.0 mg/l with a median of 2.8 mg/l and a mean of 4.4 mg/l, resulting in an ER efficiency of 93.4%.Total event loadings for the study were 63.3 kg at the influent and 4.0 kg at the effluent sampling location, resulting in an SOL efficiency of 93.7%. For each storm event, the percent of SSC (<2000µm) represented by SSC (<500 µm) was calculated (Table 11). Influent and effluent median percentages of SSC (<2000µm) were 68.0% and 94.2%, respectively. The percentage of corresponding SSC (<2000µm) results indicated the portion of material that were less than 500µm in size.

Volatile Suspended Solids Parameters

Influent EMCs for TVSS (<2000µm) ranged from 1.1 mg/l to 99.2 mg/l with a median of 11.9 mg/l and a mean of 23.8 mg/l. Corresponding effluent EMCs ranged from 0.5 mg/l to 6.7 mg/l with a median of 3.0 mg/l and a mean of 2.9 mg/l, resulting in an ER efficiency of 87.7%.Total event loadings for the study were 24.6 kg at the influent and 2.9 kg at the effluent sampling location, resulting in an SOL efficiency of 88.2%. For each storm event, the percent of SSC (<2000 µm) represented by TVSS (<2000µm) was calculated (Table 12). Influent and effluent median percentages of SSC (<2000µm) were 29.0% and 65.1%, respectively. Percentage of corresponding SSC (<2000µm) results indicated the percent of combustible materials that were assumed to be organic in nature.

Influent EMCs for TVSS (<500µm) ranged from 1.1 mg/l to 48.0 mg/l with a median of 7.3 mg/l and a mean of 11.6 mg/l. Corresponding effluent EMCs ranged from 0.6 mg/l to 5.3 mg/l with a median of 3.4 mg/l and a mean of 3.1 mg/l, resulting in an ER efficiency of 73.4%.Total event loadings for the study were 9.9 kg at the influent and 3.3 kg at the effluent sampling location, resulting in an SOL efficiency of 67.1%. For each storm event, the percent of SSC (<500µm) represented by TVSS (<500µm) was calculated (Table 12). Influent and effluent median percentages of SSC (<500µm) were 31.4% and 86.4% respectively. Percentage of corresponding SSC (<500µm) results indicated the percent of combustible materials that were assumed to be organic in nature.

Phosphorus Parameters

Influent EMCs for TP ranged from 0.07 mg/l to 0.90 mg/l with a median of 0.14 mg/l and a mean of 0.22 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.06 mg/l with a median of 0.03 mg/l and a mean of 0.03 mg/l, resulting in an ER efficiency of 86.1%. Total event loadings for the study were 218.6 g at the influent and 28.1 g at the effluent sampling location, resulting in an SOL efficiency of 87.1%.

Influent EMCs for Diss. P ranged from 0.03 mg/l to 0.85 mg/l with a median of 0.05 mg/l and a mean of 0.16 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.16 mg/l with a median of 0.05 mg/l and a mean of 0.04 mg/l, resulting in an ER efficiency of 74.2%. Total event loadings for the study were 109.6 g at the influent and 35.9 g at the effluent sampling location, resulting in an SOL efficiency of 67.3%.

Influent EMCs for Ortho-P ranged from 0.03 mg/l to 0.86 mg/l with a median of 0.03 mg/l and a mean of 0.14 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.03 mg/l with a median of 0.03 mg/l and a mean of 0.03 mg/l, resulting in an ER efficiency of 82.5%. Total event loadings for the study were 102.8 g at the influent and 22.4 g at the effluent sampling location, resulting in an SOL efficiency of 78.2%.

Calculated influent EMCs for PP, calculated as the difference between TP and Diss. P, ranged from 0.02 mg/l to 0.23 mg/l with a median of 0.06 mg/l and a mean of 0.08 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.00 mg/l with a median of 0.00 mg/l and a mean of 0.01 mg/l, resulting in an ER efficiency of 91.3%. Total event loadings for the study were 97.7 g at the influent and 3.5 g at the effluent sampling location, resulting in an SOL efficiency of 96.4%.

Table 7. Suspended Solids Efficiency Ratio (ER) Efficiency Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TSS (mg/l)		SSC (<2000µm) (mg/l)		SSC (<500µm) (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	21.2	6.2	55.7	7.2	45.8	7.3
MCC051011	98.2	5.1	90.6	4.6	104.0	5.1
MCC051611	21.8	2.8	51.0	6.2	9.6	1.9
MCC062811	10.3	1.4	18.0	3.0	9.0	2.6
MCC070811	18.2	3.3	29.7	3.8	16.0	3.0
MCC073111	28.4	2.5	17.7	2.7	29.1	4.0
MCC090511	25.1	2.5	81.8	2.5	74.5	2.4
MCC092111	27.6	1.3	86.0	1.9	20.4	1.7
MCC110311	23.6	1.3	2080.0	2.4	393.0	1.8
MCC111611	56.9	3.4	186.0	2.7	16.3	2.5
MCC051312	52.4	5.7	27.0	5.0	28.0	10.0
MCC052112	28.2	6.6	NT	NT	NT	NT
MCC060612	38.0	1.3	48.0	5.0	48.0	10.0
Min	10.3	1.3	17.7	1.9	9.0	1.7
Max	98.2	6.6	2080.0	7.2	393.0	10.0
Median	27.6	2.8	53.4	3.4	28.6	2.8
Mean	34.6	3.3	231.0	3.9	66.1	4.4
Efficiency Ratio	90.4%		98.3%		93.4%	
Mann-Whitney U statistic	0.000		0.000		4.000	
P value for U statistic	<0.001		<0.001		<0.001	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 8. Total Volatile Suspended Solids Efficiency Ratio (ER) Efficiency Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm) (mg/l)		TVSS (<500µm) (mg/l)	
	Influent	**Effluent**	**Influent**	**Effluent**
MCC041611	30.8	4.1	24.0	5.3
MCC051011	53.0	6.7	48.0	4.2
MCC051611	13.0	3.1	10.4	3.6
MCC062811	10.8	3.4	4.8	4.3
MCC070811	8.0	2.1	7.6	3.3
MCC073111	19.6	3.8	3.4	3.9
MCC090511	7.4	2.8	4.2	3.4
MCC092111	27.3	1.7	6.1	1.5
MCC110311	99.2	1.6	13.3	1.0
MCC111611	1.1	0.5	1.1	0.6
MCC051312	8.4	3.2	9.2	3.2
MCC052112	NT	NT	NT	NT
MCC060612	7.2	2.2	7.0	2.8
Min	1.1	0.5	1.1	0.6
Max	99.2	6.7	48.0	5.3
Median	11.9	3.0	7.3	3.4
Mean	23.8	2.9	11.6	3.1
Efficiency Ratio	87.7%		73.4%	
Mann-Whitney U statistic	11.000		0.000	
P value for U statistic	<0.001		0.667	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 9. Phosphorus Efficiency Ratio (ER) Efficiency Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TP (mg/l)		Diss. P (mg/l)		Ortho-P (mg/l)		PP (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	0.160	0.058	0.025	0.025	0.025	0.025	0.135	0.033
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	0.110	0.025	NT	NT	NT	NT	NT	NT
MCC062811	0.130	0.025	0.025	0.160	0.025	0.025	0.105	0.000
MCC070811	0.065	0.025	0.025	0.025	0.025	0.025	0.040	0.000
MCC073111	0.140	0.057	0.061	0.025	0.025	0.025	0.079	0.032
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	0.250	0.025	0.025	0.025	0.025	0.025	0.225	0.000
MCC110311	0.900	0.025	0.850	0.025	0.860	0.025	0.050	0.000
MCC111611	0.100	0.025	0.081	0.025	0.063	0.025	0.019	0.000
MCC051312	0.088	0.025	0.054	0.025	0.025	0.025	0.034	0.000
MCC052112	0.200	0.025	NT	NT	NT	NT	NT	NT
MCC060612	0.310	0.025	0.250	0.025	0.210	0.025	0.060	0.000
Min	0.065	0.025	0.025	0.025	0.025	0.025	0.019	0.000
Max	0.900	0.058	0.850	0.160	0.860	0.025	0.225	0.033
Median	0.140	0.025	0.054	0.025	0.025	0.025	0.060	0.000
Mean	0.223	0.031	0.155	0.040	0.143	0.025	0.083	0.007
Efficiency Ratio	86.1%		74.2%		82.5%		91.3%	
Mann-Whitney U statistic	0.000		23.000		27.000		2.000	
P value for U statistic	<0.001		0.074		0.077		<0.001	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 10. Calculated Percentages of material less than 500µm for the 13 events sampled at the Mitchell Community College testing site.

Event ID	SSC (<500µm)/ SSC (<2000µm) (%)	
	Influent	**Effluent**
MCC041611	82.2	100.0
MCC051011	100.0	100.0
MCC051611	18.9	31.1
MCC062811	49.8	86.0
MCC070811	53.9	79.9
MCC073111	100.0	100.0
MCC090511	91.1	98.4
MCC092111	23.7	85.9
MCC110311	18.9	75.2
MCC111611	8.8	90.1
MCC051312	100.0	100.0
MCC052112	NT	NT
MCC060612	100.0	100.0
Min	8.8	31.1
Max	100.0	100.0
Median	68.0	94.2
Mean	62.3	87.2

NT = Not tested
QC DQ = Quality Control Disqualification

Table 11. Calculated percentages of combustible materials that were assumed to be organic in nature for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm)/ SSC (<2000µm) (%)		TVSS (<500µm)/ SSC (<500µm) (%)	
	Influent	Effluent	Influent	Effluent
MCC041611	55.3	56.9	52.4	72.6
MCC051011	58.5	100.0	46.2	81.9
MCC051611	25.5	50.0	100.0	100.0
MCC062811	60.0	100.0	53.6	100.0
MCC070811	26.9	55.6	47.5	100.0
MCC073111	100.0	100.0	11.7	98.7
MCC090511	9.0	100.0	5.6	100.0
MCC092111	31.7	88.5	29.9	90.9
MCC110311	4.8	66.1	3.4	54.9
MCC111611	0.6	18.3	6.7	22.4
MCC051312	31.1	64.0	32.9	32.0
MCC052112	NT	NT	NT	NT
MCC060612	15.0	44.0	14.6	28.0
Min	0.6	18.3	3.4	22.4
Max	100.0	100.0	100.0	100.0
Median	29.0	65.1	31.4	86.4
Mean	34.9	70.3	33.7	73.5

NT = Not tested
QC DQ = Quality Control Disqualification

Table 12. Suspended Solids Summation of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TSS (kg)		SSC (<2000µm) (kg)		SSC (<500µm) (kg)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	1.0	0.3	2.7	0.3	2.2	0.4
MCC051011	3.5	0.2	3.2	0.2	3.7	0.2
MCC051611	1.5	0.2	3.5	0.4	0.7	0.1
MCC062811	1.0	0.1	1.8	0.3	0.9	0.3
MCC070811	3.4	0.6	5.5	0.7	3.0	0.6
MCC073111	1.7	0.2	1.1	0.2	1.8	0.2
MCC090511	3.3	0.3	10.8	0.3	9.9	0.3
MCC092111	7.0	0.3	21.9	0.5	5.2	0.4
MCC110311	1.8	0.1	159.2	0.2	30.1	0.1
MCC111611	2.1	0.1	7.0	0.1	0.6	0.1
MCC051312	2.6	0.3	1.3	0.2	1.4	0.5
MCC052112	0.5	0.1	NT	NT	NT	NT
MCC060612	3.1	0.1	3.9	0.4	3.9	0.8
Sum	32.7	3.0	222.0	3.9	63.3	4.0
SOL Efficiency	90.9%		98.3%		93.7%	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 13. Total Volatile Suspended Solids Summation of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm) (kg)		TVSS (<500µm) (kg)	
	Influent	Effluent	Influent	Effluent
MCC041611	1.5	0.2	1.2	0.3
MCC051011	1.9	0.2	1.7	0.1
MCC051611	0.9	0.2	0.7	0.2
MCC062811	1.1	0.3	0.5	0.4
MCC070811	1.5	0.4	1.4	0.6
MCC073111	1.2	0.2	0.2	0.2
MCC090511	1.0	0.4	0.6	0.5
MCC092111	7.0	0.4	1.6	0.4
MCC110311	7.6	0.1	1.0	0.1
MCC111611	0.0	0.0	0.0	0.0
MCC051312	0.4	0.2	0.5	0.2
MCC052112	NT	NT	NT	NT
MCC060612	0.6	0.2	0.6	0.2
Sum	24.6	2.9	9.9	3.3
SOL Efficiency	88.2%		67.1%	

NT = Not tested
QC DQ = Quality Control Disqualification

Table 14. Phosphorus Summation of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TP (g)		Diss. P (g)		Ortho-P (g)		PP (g)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	7.7	2.8	1.2	1.2	1.2	1.2	6.5	1.6
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	7.5	1.7	NT	NT	NT	NT	NT	NT
MCC062811	13.0	2.5	2.5	16.0	2.5	2.5	10.5	0.0
MCC070811	12.1	4.6	4.6	4.6	4.6	4.6	7.4	0.0
MCC073111	8.5	3.5	3.7	1.5	1.5	1.5	4.8	1.9
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	63.7	6.4	6.4	6.4	6.4	6.4	57.3	0.0
MCC110311	68.9	1.9	65.1	1.9	65.8	1.9	3.8	0.0
MCC111611	3.8	0.9	3.0	0.9	2.4	0.9	0.7	0.0
MCC051312	4.4	1.2	2.7	1.2	1.2	1.2	1.7	0.0
MCC052112	3.7	0.5	NT	NT	NT	NT	NT	NT
MCC060612	25.3	2.0	20.4	2.0	17.1	2.0	4.9	0.0
Sum	218.6	28.1	109.6	35.9	102.8	22.4	97.7	3.5
SOL Efficiency	87.1%		67.3%		78.2%		96.4%	

NT = Not tested
QC DQ = Quality Control Disqualification

Residual Solids Assessment Results

In an effort to verify the capture of materials by the StormFilter system over the course of the monitoring period, a qualitative assessment of materials captured by the StormFilter system was performed during the site visit conducted on November 3, 2011. The mass of materials contained in the system was estimated using a mean depth measurement and a texture based bulk density estimate. The mean depth of material captured by the StormFilter at the time of inspection was determined to be approximately 3 inches. A composite sample of the material captured by the StormFilter was collected and texture was determined in the field by hand texturing of the sample. Hand texture analysis of the composite sample revealed that the materials captured by the StormFilter had a loamy sand texture (USDA classification). The estimated mass of materials contained in the StormFilter, using the mean depth of material captured by the StormFilter and a bulk density assumption for loamy sand texture soils of 1.65 gm/cc, was approximately 150 kg.

Following the maintenance of the system on November 3, 2011 which involved the removal of accumulated solids from the system as well as the replacement of cartridges, a qualitative assessment of materials captured by the StormFilter system was performed during the site visit conducted on June 14, 2012. The mass and texture of materials contained in the system was estimated as described above. The mean depth of material captured by the StormFilter was determined to be approximately 0.5 inches; and had a loamy sand texture (USDA classification). The estimated mass of materials was approximately 25 kg.

Summary and Conclusion

The primary purpose of this report was to document StormFilter system performance with respect to solid and nutrient pollutant removal and quantify performance in accordance with the conditions outlined in the NCDENR DWQ PEP program. Between November (2010) and June (2012), a total of 13 qualifying storm events were monitored and were determined to meet the storm data collection requirements as per the conditions outlined in the NCDENR DWQ PEP program.

Significant reductions for solid and nutrient pollutant concentrations were observed between influent and effluent sampling locations using the Efficiency Ratio (ER) efficiency calculation (TSS 90.4% and TP 86.1%) and Summation of Load (SOL) efficiency calculation methods (TSS 90.9% and TP 87.1%). The capture of solids by the system was verified as part of the residual solids assessment during site visits conducted on November 3, 2011 and June 14, 2012.

Given that the solid performance standard for this project is based solely on TSS removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate suspended sediment removal efficiency based on specific particle size ranges, SSC samples were sieved prior to analysis. The particle size ranges that were isolated for this study included 2000µm to 1.5µm and 500µm to 1.5µm. The isolation of suspended solids removal efficiencies based on particles 2000µm to 1.5µm and particles between 500µm and 1.5 µm resulted in an overall removal efficiency of 98.3% and 93.4% respectively using the ER efficiency calculation method and 98.3% and 93.7% respectively using the SOL efficiency calculation method. These results demonstrate performance greater than the performance goal of 85% removal of TSS. In addition to these results demonstrating performance greater than the performance goal of 85% removal of TSS, research by (Rutgers/ NJDEP, 2006) suggests the difference between TSS and SSC results becomes smaller as the particle size of the material analyzed becomes finer.

Given that the phosphorus removal performance standard for this project is based solely on TP removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate phosphorus removal efficiency based on speciation TP, Diss. P, Ortho-P, and PP results were isolated. TP, Diss. P, and Ortho-P results were provided by the analytical lab. PP was calculated as the difference between TP and Diss. P. Removal efficiencies for TP, Diss. P, Ortho-P, and PP results resulted in an overall removal efficiency 86.1%, 74.2%, 82.5%, and 91.3% respectively using the ER efficiency calculation method. Removal efficiencies for TP, Diss. P, Ortho-P, and PP results resulted in an overall removal efficiency of 87.1%, 67.3%, 78.2%, and 96.4% using the SOL efficiency calculation method. These results not only demonstrate that the system was able to meet the performance goal but was able to attenuate TP captured by the system over the course of the study.

Results from the twenty month study, that represented a total of 13 storm events and 23.73 inches of precipitation, show that the StormFilter system tested was highly effective in removing solid and nutrient pollutants from the stormwater runoff.

References

Contech Stormwater Solutions Inc. (Contech) (2010). The Mitchell Community College Stormwater Management StormFilter Field Evaluation Project Plan Portland, Oregon: Author.

North Carolina Department of Environment and Natural Resources (NCDENR), Division of Water Quality (2007). Stormwater Best Management Practices Manual (Publication Number). Raleigh, NC: Available online: http://portal.ncdenr.org/web/wq/ws/su/bmp-manual

URS Greiner Woodward Clyde, Urban Drainage and Flood Control District, Urban Water Resources Research Council (UWRRC) of ASCE, Office of Water, US Environmental Protection Agency (URS/EPA) (1999). Development of Performance Measures Task 3.1 – Technical Memorandum Determining Urban Stormwater Best Management Practice (BMP) Removal Efficiencies. Washington, D.C.: Author.

U.S. Geological Survey (USGS). (1980). Water Resources Division by Office of Water Quality (OWQ) Technical Memorandum No. 80.17.

U.S. Geological Survey (USGS). (1991) U.S. Geological Survey, Techniques of Water-Resources Investigations Reston, Virginia. D.R. Helsel and R.M. Hirsch.

Revision History

Original