CONTECH STORMWATER SOLUTIONS

Product Evaluation

Performance of the Stormwater Management StormFilter Relative to Ecology Performance Goals for Basic Treatment

Overview

The Stormwater Management StormFilter® (StormFilter) is a stand-alone stormwater treatment device that utilizes media filtration to remove contaminants from stormwater. Originally developed in 1995, the StormFilter technology has been subject to continuous improvement, with three patents covering the siphonic design used today by the over 10,000 cartridges installed in the State of Washington.

Prior to 2002, StormFilter technology was subject to approval at the local level. With the release of WADOE (2001) in August 2001, and the accompanying WADOE (2002) in October 2002, a formal process was established for review of stormwater treatment best management practices (BMPs), such as the StormFilter, at the State level. Stormwater Management proactively entered this process in January 2002 with an application for a Conditional Use Designation for Basic Treatment that was issued by the Washington Department of Ecology (Ecology) in October 2002.

Pursuant to the Conditional Use Designation received by Stormwater Management, Inc. for the StormFilter in October 2002, multiple StormFilter installations in the Pacific Northwest were monitored for a 12-month period. Following a year of study, data collected from two StormFilter system installations configured with ZPG™ media and operating at a design filtration rate of 28 L/min/cart (7.5 gpm/cart) was sufficient for review according to WADOE (2002).

Table 1. Combined performance of the HMP and LSN StormFilters relative to Ecology Basic Treatment Performance Goals based upon field testing results.

Influent TSS-WA EMC (mg/L)	
< 100	> 100
Approximately 70% of the qualifying events fall into this category. Of these, approximately half demonstrate effluent EMCs less than 20 mg/L. An arithmetic average of effluent EMCs under this category yields an **annual average effluent TSS-WA EMC of 20 mg/L (n=15).**	Only the aggregate pollutant loading reduction calculation (Method #2) recommended by WADOE (2002) produces a singular performance value on an annual average basis. The resulting performance for this category is an **annual average removal of 89% (n=7).**

Over the course of a year, the two StormFilter systems, utilizing ZPG™ media and operating at 28 L/min/cart, demonstrated satisfaction of the Ecology Basic Treatment Performance Goal (Table 1). 33 storm events were captured, of which 22 qualified according to Ecology-proposed revisions to WADOE (2002) storm event criteria. The qualified storm events document system performance at an average peak operating rate of 110%. As a whole, the TSS-WA data for these qualifying events is characterized by: 1) a silt to silt loam texture; 2) an influent EMC range of 6.85 to 519 mg/L that was not normally distributed and skewed sharply to the right; 3) a peak operating rate range of 56% to 257%; 4) an average influent EMC of 114 mg/L and a median of 83 mg/L. Satisfactory performance was demonstrated by an average effluent TSS-WA EMC of 20 mg/L for influent TSS-WA EMCs less than 100 mg/L and an aggregate pollutant load reduction of 89% for influent TSS-WA EMCs greater than 100 mg/L using data from qualifying storm events. Removal was found to be significant at the >99% level. It was concluded that the StormFilter operating at 28 L/min with ZPG™ media meets the Ecology requirements for Basic Treatment.

Site Descriptions

The sites used for this study were chosen based upon their suitability for a long-term monitoring project. Additionally, historical maintenance records and preliminary site surveys were conducted to confirm their suitability for TSS-WA performance evaluation. Both StormFilter systems underwent major maintenance (solids removal and cartridge replacement) on March 3, 2003, two months prior to the first documented storm events at both sites.

The Heritage Marketplace StormFilter system is installed in the parking lot area of the Heritage Marketplace shopping center, located at 6700 NE 162nd Avenue Vancouver, WA (Lat: 45.67085, Long: -122.50697), and will be referred to as the Heritage Marketplace StormFilter (HMP). The site is anchored by a large grocery store with numerous smaller businesses and receives a great deal of traffic from the surrounding area during normal business hours. The StormFilter system treats runoff from 16,000-m^2 (4.0-ac), primarily from impervious asphalt parking lot. Primary sources of pollution within this drainage area include solids, metals, trash, and debris from automobiles, site maintenance activities, seasonal activities, and atmospheric fallout. Treated runoff is discharged directly into an on-site infiltration gallery.

The Lake Stevens North StormFilter system is installed adjacent to Lake Stevens and east of South Lake Stevens Road at the north end of the bridge deck (Lat: 47.9877442, Long: -122.07719), and will be referred to as the Lake Stevens North StormFilter (LSN). The drainage area is 1,200-m^2 (0.29-ac) of 100% impervious arterial road bridge decking and adjoining roadway. Primary sources of pollution within this drainage area include solids, metals, trash, and debris from automobiles, maintenance activities, and atmospheric fallout. Treated runoff is discharged directly into the adjacent lake.

System Descriptions

The typical StormFilter unit is composed of three bays: the inlet bay, the filtration bay, and the outlet bay. Stormwater first enters the inlet bay of the StormFilter vault through an inlet pipe, which is plumbed to catch basins throughout the drainage area. Stormwater in the inlet bay is then directed through a flow spreader, which traps some floatables, oils, and surface scum, and over the energy dissipater into the filtration bay where treatment will take place. Once in the filtration bay, the stormwater begins to pond and percolate horizontally through the media contained in the StormFilter cartridges. After passing through the media, the treated water in each cartridge collects in the cartridge's center tube from where it is directed into the outlet bay by an under-drain manifold. The treated water in the outlet bay is then discharged through a single outlet pipe.

The StormFilter installed at Heritage Marketplace consists of a 2.4-m x 4.9-m (8-ft x 16-ft) vault housing 23 cartridges. The StormFilter cartridges contain ZPG™ multipurpose media, a proprietary blend of organic and inorganic media. These 23 cartridges operate at a per-cartridge filtration rate of 28 L/min (7.5-gpm), yielding a peak system operating rate of 640 L/min (0.38-cfs) as tested. This operating rate is approximately 5% less than the 680 L/min (0.40-cfs) peak system operating rate recommended for the site based upon the sizing standards specified by Ecology at the time of writing (Western Washington Hydrology Model v2.5A).

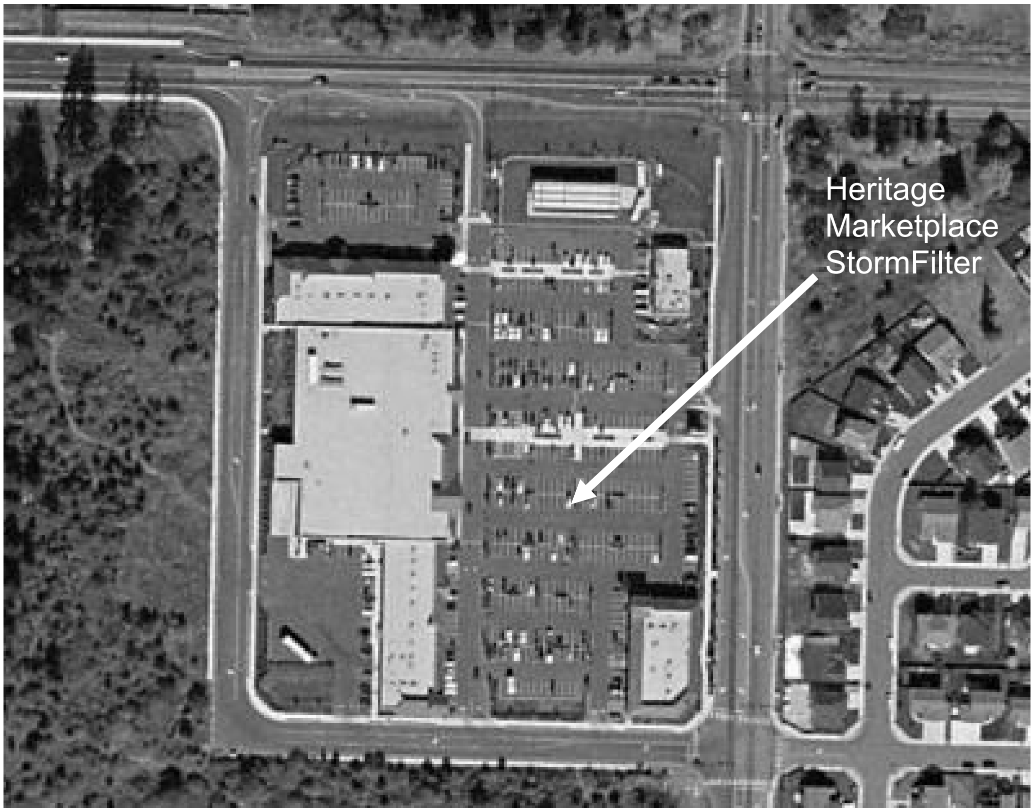

Figure 1. Aerial view of the Heritage Marketplace StormFilter site.

Figure 2. View of part of the Heritage Marketplace StormFilter site drainage area in proximity to the StormFilter.

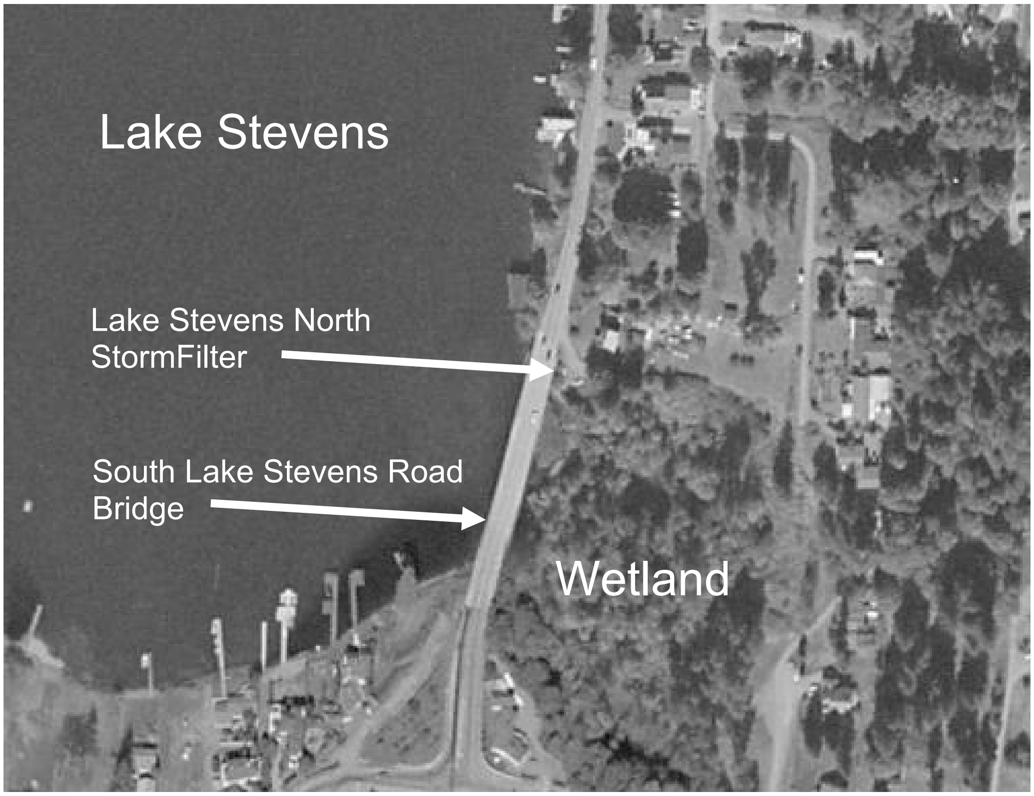

Figure 3. Aerial view of the Lake Stevens North StormFilter site.

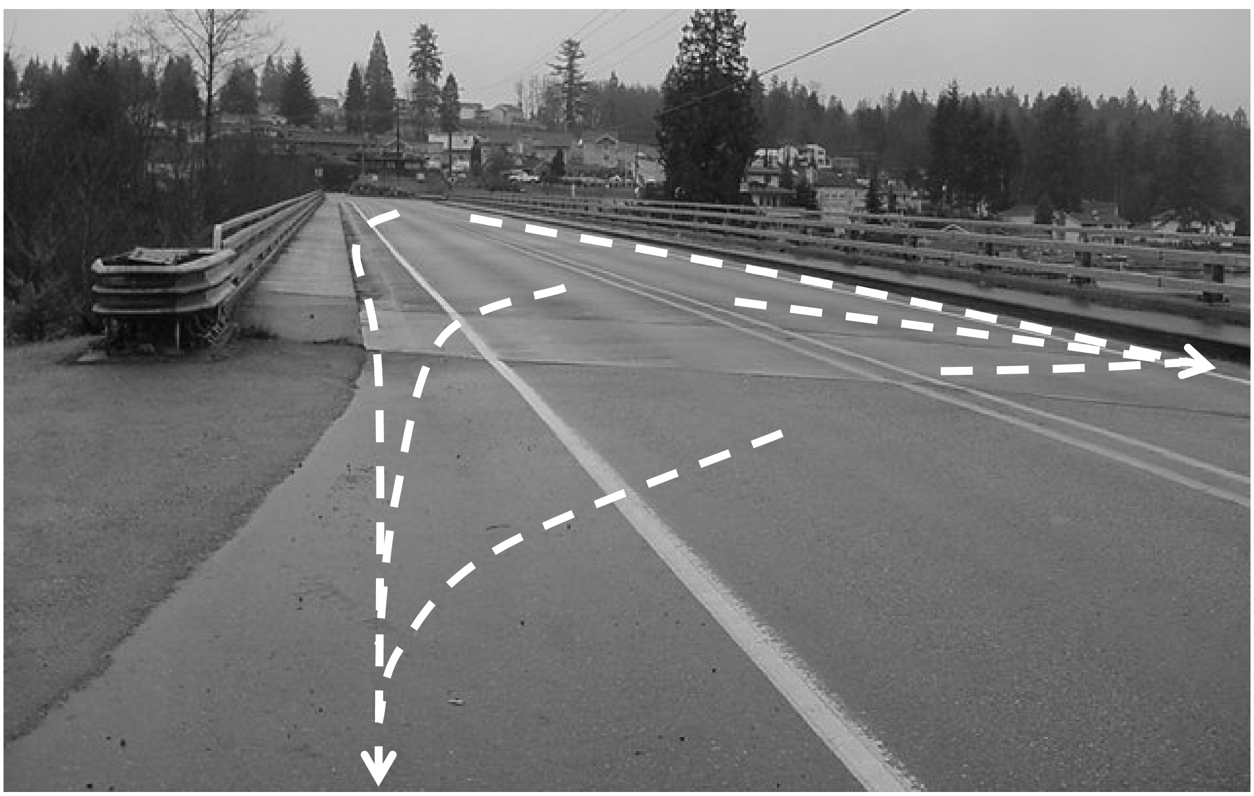

Figure 4. View of part of the Lake Stevens North StormFilter site drainage area. Arrows indicate flow to the StormFilter system via gutters and catchbasins located at the foot of the bridge.

The StormFilter installed at Lake Stevens consists of a 1.8-m x 3.7-m (6-ftx12-ft) vault housing 10 cartridges. As with the Heritage Marketplace StormFilter, the cartridges in this StormFilter also contain ZPG™ multipurpose media. These 10 cartridges operate at a per-cartridge filtration rate of 28 L/min (7.5-gpm), yielding a peak system operating rate of 280 L/min (0.17-cfs) as tested. This operating rate is approximately 10% less than the 320 L/min (0.19-cfs) peak system operating rate recommended for the site based upon the sizing standards specified by Ecology at the time of writing (Western Washington Hydrology Model v2.5A).

Undersizing increases the bypass potential for the two StormFilters. High flow bypass configuration differs slightly between the two sites. While some bypass still occurs within the Heritage Marketplace StormFilter via the internal bypass mechanism during flows in excess of design, the majority of the excess flow at this site is handled by an upstream bypass structure, and thus the Heritage Marketplace StormFilter is considered by Ecology to be "offline" with respect to bypass. For the LSN StormFilter, flows in excess of design are bypassed via an internal bypass mechanism, and thus this StormFilter is considered by Ecology to be "online" with respect to bypass. Regardless of the overall bypass strategy employed at either site, this study documents the performance of the StormFilter vault only. Thus effluent water quality data corresponding to bypass events reflects combined flows (treated and internally bypassed) within the StormFilter.

Water Quality Sampling Methods

The equipment and sampling techniques used for this study are in accordance with the Quality Assurance Project Plan (SMI, 2003) developed in accordance with WADOE (2002) and approved by Ecology in February 2003. For the Heritage Marketplace study, SMI personnel were responsible for the installation and maintenance of the sampling equipment, sample retrieval, system reset, and sample submittal activities. For Lake Stevens North, SMI was responsible for the installation and maintenance of the sampling equipment. Taylor Associates, Inc. of Seattle, WA, was utilized for sample retrieval, system reset, and sample submittal activities for Lake Stevens North. A general overview is provided.

Equipment Specifications

Samples were collected using ISCO 6700-series portable automated samplers configured for 24, 1000-ml, polypropylene, ISCO wedge shaped bottles. Each sampler was connected to individual 12-VDC, deep cycle power supplies. Flow measurements were made using ISCO 750 area velocity modules with low profile area velocity sensors. Additionally, samplers installed at Lake Stevens North used factory installed modems to permit remote communication and a solar panel array for power supply regeneration.

Sample intakes from each of the automated samplers' peristaltic pumps were connected to 3-m (10-ft) lengths of 10-mm (0.4-in) diameter Acutech Duality FEP/LDPE suction line. A stainless-steel, low-profile sample strainer (14-mm (0.56-in) diameter with multiple 6-mm (0.25-in) openings) was installed at the end of the suction line to protect the pump head. All fittings were polyethylene in composition.

Internal overflow was monitored using an Overflow Detection System (ODS) consisting of a float switch connected to a Onset Hobo State Logger. Rainfall was monitored using an Onset RG2 data logging rain gauge.

Equipment Installation

All sampling and flow monitoring equipment was installed inside the vault for security and protection reasons. The automated samplers and 12-VDC batteries within the vault were installed to achieve minimal suction line length and eliminate dips in the suction line. Maximum inline velocity (≥ 2 ft/s) was maintained by avoiding extraneous suction line length, excessive bends, and kinks in suction lines. The rain gauge was placed atop an adjacent structure such as a building or utility post with no overhead obstructions.

Individual automated samplers, suction lines, and flow sensors were used to monitor the influent entering and effluent exiting the StormFilter systems; one sampler, flow sensor, and suction line was assigned to the inlet pipe and another sampler, sensor, and suction line was assigned to the outlet pipe. Thus, each sampler was independently controlled: the influent sampler by flow entering the system and the effluent sampler by flow leaving the system.

The flow sensors and suction lines were mounted on ISCO stainless steel spring rings sized to match the inner pipe diameter at the sampling locations shown in Appendix A. The spring rings were inserted as far up into the pipe as possible, keeping the suction lines and flow sensors in a fixed position at the invert of the pipe with no vertical offset. The suction lines and flow sensor cables were bound together and routed out of the pipe and up to the samplers. Samples were taken as water entered and exited the StormFilter vault and did not measure pollutant removal associated with treatment by upstream structures or catch basins.

The Overflow Detection System (ODS) was attached to a cartridge located towards the rear of the filtration bay such that the switch would activate at a water surface elevation of 21-in from the floor of the filtration bay (design internal overflow elevation). The state logger was placed in a waterproof housing and secured to a cartridge inside the vault.

Equipment Operation

Flow meters were set to take measurements every 1 to 5 minutes, allowing for extended deployment and minimal power usage during colder weather. To further minimize power consumption and avoid false starts caused by dry weather flows, samplers were programmed to begin sample acquisition and data recording after a minimum flow rate condition was met. Once enabled, the equipment recorded flow measurements and collected samples on a volume-paced basis.

Sample Collection Program

The sample program input into each of the automated samplers was a two-part program developed to maximize both the number of subsamples collected and the coverage of an individual storm event. The first part of the program sequentially filled the first set of bottles every X-gal. The second part of the program sequentially filled the remaining bottles every 2X-gal. This increased the probability of adequate coverage of both small and large precipitation events by allowing the use of subsamples collected according to X or 2X sample pacing. The sample pacing value was changed on an as-needed basis based upon anticipated storm size. Program changes were recorded by both the automated sampler and SMI staff.

Sample Retrieval and Analysis

The sampling equipment was inspected for samples following precipitation events. Sample bottles were capped, labeled, and transferred from the sampler base section directly to a cooler stocked with gel ice packs. The samples were then taken to an SMI or Taylor Associates facility and composited and split using an appropriately sized churn sample splitter (Bel-Art Products) to create flow-weighted, influent and effluent, event mean concentration (EMC) sub-samples for submittal to North Creek Analytical, Inc. of Beaverton, OR (Heritage Marketplace) or Bothell, WA (Lake Stevens North) for analysis. Both Analytical Laboratories are Oregon and Washington State accredited. Samples were analyzed for TSS-WA.

The term TSS-WA is used to indicate the use of a 500-um pre-screening step and analysis using a “whole volume” method. Ecology defines TSS as suspended solids less than

500-um in size[1], and samples were passed through a certified 500-um sieve as sub-sample bottles were filled from the churn splitter. Also, Ecology recommends the use of a "whole volume" analytical method for suspended solids analysis[2]. This is a deviation from the commonly used EPA method 160.2, which only uses the partial volume of a sample, and thus ASTM D3977 was used. ASTM D3977 is functionally identical to EPA 160.2 and unlike EPA 160.2 specifies the use of the whole sample volume.

Field QC

To avoid contamination issues, disposable and certified clean materials were used whenever possible. Upon installation of the sampling equipment, new sampler tubing was used so as to avoid the need for decontamination and the associated equipment rinsate blank. During the course of the project, wedge-shaped ISCO bottles were only used once and sent to North Creek Analytical for cleaning and acid-washing. During and upon completion of the study, sampling equipment field blanks were collected from the influent sampling equipment.

Sampling equipment field blanks were performed according to SMI (2004c), and involved pumping deionized water through the fully assembled samplers. Samples were then submitted to North Creek Analytical and analyzed for suspended solids. The field blank samples returned non-detect values for suspended solids.

Residual Solids Assessment Methods

At the end of the study period, the StormFilter systems were maintained for the purpose of assessing the quantity and quality of the solids captured by the system. This procedure was performed according to SMI (2004a) and SMI (2004b) and involved the following activities: 1) the removal of the StormFilter cartridges and selection of two cartridges for solids content and media analysis; 2) the manual removal of residual solids from the system for direct volume measurement (as opposed to estimation); 3) the methodical collection of a large (20-L to 30-L), composite sample of the residual solids for analysis; and 4) the installation of new cartridges.

The StormFilter cartridges selected for the assessment were analyzed using direct methods as much as possible. The cartridges were first allowed to drip-dry indoors and the media was then emptied into shallow, tared trays for compositing and sun-drying. Upon the stabilization of the moisture content of the media, the trays were weighed and representative samples were collected for analysis according to Table 2. Data for the two cartridges for each system was averaged and used to represent the other cartridges within each system.

The composite samples of the residual solids were homogenized by hand and representatively sampled for analysis. Samples were submitted for the analytes shown in Table 2. Data for this material was used in conjunction with the volume of residual solids removed from the system in order to determine the mass of contaminants contained within the residual solids on a dry weight basis.

Table 2. Analytical methods for residual solids and media sample analysis.

Analyte	Analytical Method
Percent Solids	NCA SOP
Total Solids	EPA 160.3 (modified)
Total Volatile Solids	EPA 160.4
Particle Size Distribution	SMI SOP

[1] WADOE (2002), page 17
[2] WADOE (2002), page 39, Table C-1

Calculations

Most of the data collected during the study were based upon direct measurement. Some reported values such as average event coverage and the volume used for aggregate load reduction calculation were based upon calculated values.

Event coverage was calculated by multiplying the number of sample aliquots representing the influent or effluent of a storm event by the volume used to pace the sample collection program and expressing this value as a percentage of the total influent or effluent volume recorded by the flow meter. Average event coverage was then determined by averaging influent and effluent event coverage values.

In order to properly use the aggregate load reduction performance summarization method for data from multiple sites, the volumes associated with each event at respective sites were normalized by determining event volume on a per-cartridge basis. These normalized volumes were then multiplied by the average event coverage for the corresponding event so as to truly represent the volume of water represented by the sampling effort.

Results

Suspended Solids Representativeness and Data Pooling

Both the representativeness of the suspended solids associated with the HMP and LSN sites and the validity of pooling the data from the two sites was evaluated by examining the particle size distribution. Since influent particle size analysis was not performed[‡], influent TSS-WA particle size distributions were reconstructed based upon hydrometer and sieve analysis of settled material found within the systems at the conclusion of the monitoring project. The reconstruction process involved the following steps: 1) development of particle size distribution and dry mass of residuals found on the vault floor; 2) measurement of the dry mass of residuals found captured by the cartridges; and 3) the estimation of the dry mass of materials lost in the effluent from the system[†] and based upon the conclusions of SMI (2004d) regarding the maximum sizes of particles entering and leaving the StormFilter cartridge. The materials filtered by the cartridges and contained in the effluent were then integrated on a mass-weighted basis into the particle size distribution of the materials found on the vault floor.

[‡] Methods for the direct measurement of suspended solids in small-volume stormwater samples are currently being studied by the professional community. All other particle counting methods currently being employed for particle analysis require broad assumptions in order to convert particle count data into particle size distribution by mass. The effect of these assumptions on the results obtained from various methods is currently under review. Due to the previous use of the hydrometer and sieve method by SMI for the studies upon which the Ecology Conditional Use Designation was based, this method was also employed for this project. This is consistent with discussion on page 16 of WADOE (2002) concerning the issue of particle size distribution.

[†] Estimation based upon the assumption that residuals found in the vault (settled and filtered) constitute 80% of the total mass that entered the StormFilters.

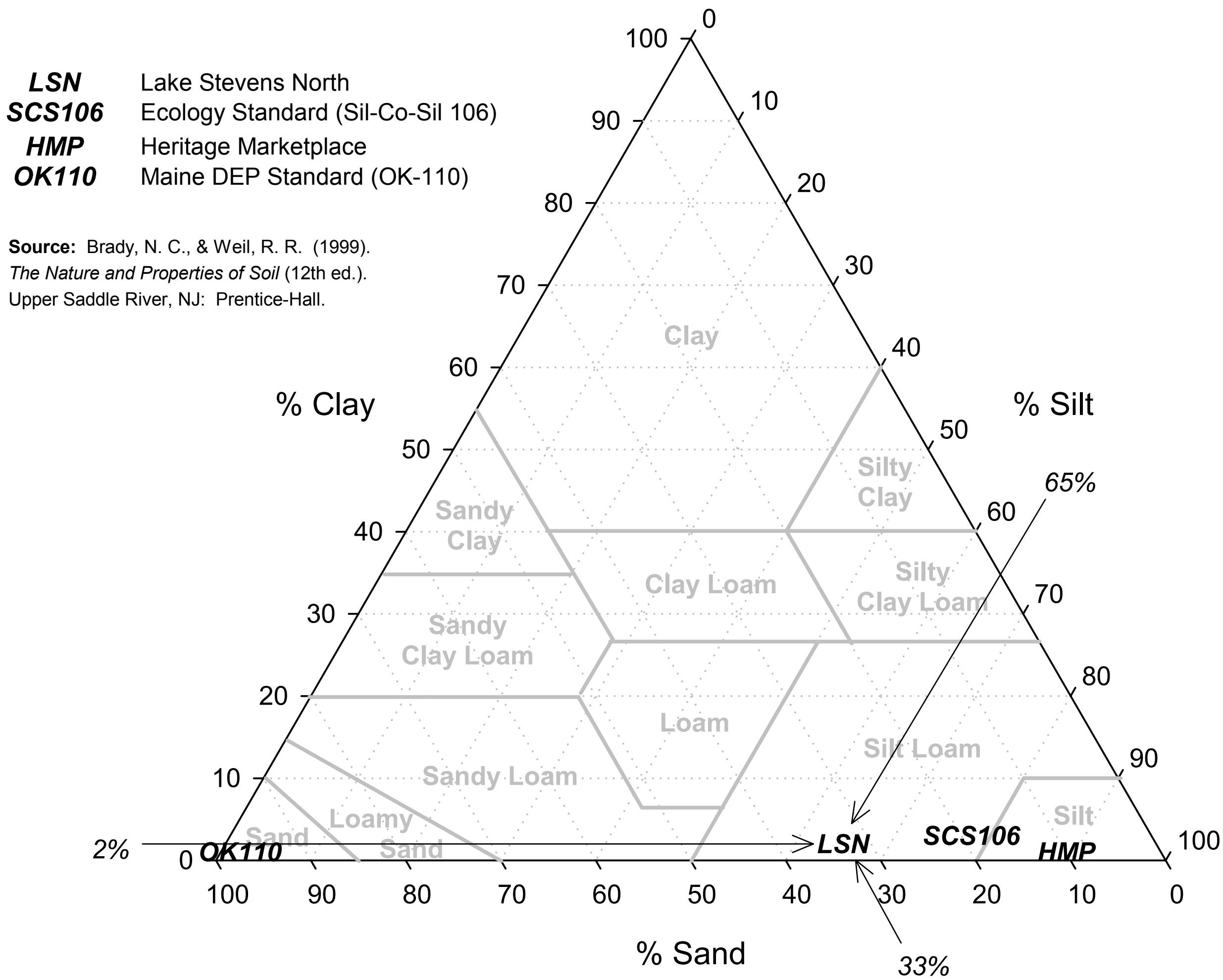

Figure 5. Ternary plot of sediment textures (USDA). Determination of texture for the LSN site is provided as an example.

Figure 5 shows the reconstructed influent TSS-WA sediment textures for the LSN and HMP sites, including the texture of the Ecology laboratory testing standard[3]. Maine Department of Environmental Protection laboratory testing standard (OK-110) is also shown for comparative purposes. HMP produces TSS-WA with a silt texture (10% sand, 89% silt, 1% clay) while LSN produces TSS-WA with a silt loam texture (33% sand, 65% silt, 2% clay). The influent TSS-WA generated by LSN and HMP encompasses the texture of the standard specified by Ecology for laboratory testing and are much finer than other existing regulatory standards such as that used by the Maine Dept. of Environmental Protection. Thus TSS-WA removal performance based upon data from the LSN and HMP sites adequately represents the high silt content of stormwater runoff characteristic of the Pacific Northwest.

Data Summarization and Qualification

Between the two systems, a total of 33 storm events were successfully sampled between May of 2003 and March of 2004. Of these 33 storm events, only one was eligible for disqualification due to handling, analytical, or monitoring errors. LSN120203 exceeded the 7 day holding time requirement for TSS-WA by 9 days. However, Ecology did not consider this

[3] WADOE (2002), page 19.

hold-time violation to be serious enough to merit disqualification, and thus disqualification was overturned by Ecology (M. Blosser, personal communication, October 22, 2004). In addition, no storm events were disqualified for substantial internal overflow since the Ecology Basic Treatment Performance Goal includes these events[4]. Thus all of the storm events were deemed representative of system operation within design parameters and were deemed acceptable for qualification through reconciliation with the data quality objectives (DQOs) of SMI (2003).

The DQOs presented in SMI (2003) and used throughout the project were based directly upon the "Storm Event Criteria" (Criteria)[5] and Guidelines[6] presented by WADOE (2002). However, Ecology currently proposes revisions to the Criteria presented by WADOE (2002) (M. Blosser, personal communication, October 22, 2004). These revisions are: 1) reduction of minimum Event Depth from 0.15-in to 0.10-in; 2) elimination of Antecedent Dry Period criteria. In addition, the Ecology-approved TEER Consultant suggested that for the StormFilter system it was reasonable to relax the Guidelines in two respects: 1) accept storm samples with a minimum of 5 rather than 10 aliquots; 2) accept storm samples that represent a minimum of 50% rather than 75% of the storm. Rationale in support of these Guidelines is provided by RPA (2004). Thus the original DQOs presented in SMI (2003) were modified accordingly and are presented in Table 3.

[4] WADOE (2002), page 4
[5] WADOE (2002), page 12
[6] WADOE (2002), pages 12-13

Table 3. Summarized event characteristics and qualification decision for all events.

Event ID	Data Quality Objectives (DQOs)				Qualified for Evaluation	Other Event Characteristics				
	Event Depth (in) [minimum 0.10]	Event Duration (hr) [minimum 1]	Number of Aliquots [minimum of 5 (Inf:Eff)]	Average Event Coverage (%) [minimum of 50]		Influent Volume (gal)	Peak Operating Rate** (%)	Antecedent Dry Period (hr)	Influent TSS-WA* EMC (mg/L)	Effluent TSS-WA* EMC (mg/L)
HMP050303	**0.26**	8	15:16	89	✓	21892	92	**103**	66.4	28.3
HMP050703	**0.19**	9	16:16	90	✓	26541	138^	**55**	519	23
LSN051503	0.18	14	5:6	93	✓	1332	76	4	120	29
HMP051603	0.10	5	3:9	63		11058	17	16	987	18.9
HMP090703	0.14	5	11:18	86	✓	7217	101	384	378	37.2
HMP090903	0.16	4	21:15	76	✓	12965	85	24	76.9	16
HMP091603A	0.05	3	8:4	79		4878	15	120	35.5	11.6
HMP091603B	0.10	2	17:15	96	✓	8744	96	10	96.9	31.2
LSN091603	0.30	15	5:5	97	✓	2591	81	60	99	21
HMP100603	0.27	5	21:21	58	✓	17335	257^	384	117	41.1
LSN100603	0.17	5	6:7	59	✓	2703	77	408	83	22
HMP100803	0.07	3	7:8	93		3866	31	36	43.4	19.9
HMP100903A	0.15	2	14:13	52	✓	13581	142^	18	83.6	40.4
HMP100903B	0.25	2	21:21	39		28521	228^	3	58.2	33.6
HMP101103	0.15	4	21:21	71	✓	15570	71	36	7.53	4.86
LSN101503	0.20	5	4:5	81		2836	71	48	23	10
LSN101603	0.17	5	4:5	80		2790	59	7	17	10
HMP102203	0.17	2	18:18	73	✓	14681	125	62	22.1	9.59
LSN102203	0.28	4	6:8	89	✓	3709	144^	31	95	11
HMP111003	0.14	4	14:17	83	✓	9193	97	264	30.6	22.3
LSN111003	0.97	15	21:21	85	✓	13080	137	48	26	10
HMP111503	0.23	6	18:18	74	✓	16901	96	96	6.85	6.16
HMP111903	**0.96**	7	18:18	12		104132	377^	**26**	29.4	27.8
HMP112103	0.08	4	11:9	86		8189	94	17	85.2	60.1
HMP120203	0.24	8	16:16	29		34988	412^	30	270	163
LSN120203	0.54	5	9:11	85	✓	5474	188	3	264	32.6
HMP120403	**1.10**	18	18:18	10		117340	104	**40**	35.9	20.3
HMP121003	**0.26**	7	13:16	79	✓	20814	78	**42**	28	17.2
HMP121603	0.22	5	10:8	54	✓	22981	79	22	45.9	18.8
LSN012204	0.39	10	6:6	77	✓	3475	87	86	54	46
LSN012904	0.69	8	10:13	68	✓	7007	120	32	170	48
LSN020304	0.19	9	5:4	76		2174	93	34	45	27
LSN030604	0.14	5	6:6	60	✓	2840	56	36	120	26

* 500-um pre-filtration, whole volume analysis
** expressed as percentage of effluent design Q
^ internal bypass confirmed by ODS
bold = off-site data used due to equipment error
inversion = analytical PQL substituted for ND value
shading = DQO met

Performance Summarization

The Ecology Basic Treatment Performance Goal is divided into three categories[7]. These categories and their corresponding goals are summarized in Table 4. These goals apply to the following conditions[8]: 1) "to stormwater with a typical particle size distribution"; 2) "on an annual average basis to the entire discharge volume (treated plus bypassed)"; and 3) "to the water quality design storm volume or flow rate".

Table 4. Ecology Basic Treatment Performance.

Category (mg/L)	Goal
Influent TSS-WA EMC < 100	Effluent EMC ≤ 20 mg/L
100 ≤ Influent TSS-WA EMC < 200	80% Removal
Influent TSS-WA EMC ≥ 200	> 80% Removal

Due to the low frequency of influent TSS-WA EMCs greater than 100 mg/L, and the existence of two separate performance goal categories for TSS-WA EMCs greater than 100 mg/L, performance relative to influent TSS-WA EMC concentrations greater than or equal to 100 mg/L was difficult to assess according to the Ecology Basic Treatment Performance Goals. In order to maximize the use of the data, performance for qualifying events with influent TSS-WA concentrations greater than or equal to 100 mg/L were assessed as a group. This is believed to be a conservative measure since two of the seven events that fell under this category were confirmed internal bypass events reflecting performance at peak operating rates of 138% and 257%.

Table 5. Summary of performance based upon qualifying events. Events with confirmed internal bypass substantially exceeding design operating conditions are shown in bold.

	Normalized, Sampled Influent Volume	TSS-WA EMCs by Category					
		All		Inf. EMC < 100		Inf. EMC > 100	
Qualifying Event ID	(gal/cartridge)	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)
HMP050303	842	66.4	28.3	66.4	28.3	---	---
HMP050703	1033	519	23	---	---	519	23
LSN051503	123	120	29	---	---	120	29
HMP090703	270	378	37.2	---	---	378	37.2
HMP090903	428	76.9	16	76.9	16	---	---
HMP091603B	363	96.9	31.2	96.9	31.2	---	---
LSN091603	250	99	21	99	21	---	---
HMP100603	433	117	41.1	---	---	117	41.1
LSN100603	158	83	22	83	22	---	---
HMP100903A	307	83.6	40.4	83.6	40.4	---	---
HMP101103	481	7.53	4.86	7.53	4.86	---	---
HMP102203	463	22.1	9.59	22.1	9.59	---	---
LSN102203	330	95	11	95	11	---	---
HMP111003	332	30.6	22.3	30.6	22.3	---	---
LSN111003	1112	26	10	26	10	---	---
HMP111503	540	6.85	6.16	6.85	6.16	---	---
LSN120203	465	264	32.6	---	---	264	32.6
HMP121003	710	28	17.2	28	17.2	---	---
HMP121603	540	45.9	18.8	45.9	18.8	---	---
LSN012204	268	54	46	54	46	---	---
LSN012904	473	170	48	---	---	170	48
LSN030604	170	120	26	---	---	120	26
Average EMC (mg/L):		114	25	55	20	241	34
Aggreagate Pollutant Load Reduction (%):		82		61		89	

[7] WADOE (2002), page 4
[8] WADOE (2002), page 4

Table 5 shows the TSS-WA for the qualifying storm events assembled and summarized according to three categories. For all qualifying storms irrespective of the influent concentration, the aggregate pollutant loading reduction was 82% with an average effluent EMC of 25 mg/L. Performance relative to the Ecology Basic Treatment Performance Goals is shown in Table 1.

Statistical Confirmation of Positive Performance

Ecology suggests the use of statistical methods to aid both in the experimental design process and in the development of a statistical goal for acceptance of the evaluation analyses. Based upon previous studies in the Pacific Northwest, Ecology suggests the collection of a minimum of 6 influent/effluent data pairs in order to satisfy the recommended statistical approach for Basic Treatment with 95% confidence and 80% power[9]. With 22 data pairs, the qualifying data set more than exceeds the suggested minimum. The statistical test and acceptance level recommended by Ecology for Basic Treatment is 95% confidence that influent does not equal effluent[10].

Both parametric and nonparametric methods are suggested to evaluate the error associated with the performance of the system with respect to the Basic Treatment Performance Goal. However, effluent TSS-WA EMCs are not normally distributed, and the aggregate pollutant loading reduction calculation does not produce paired data, all of which negate the use of parametric statistics. Thus the sign test was used according to the following parameters: one-tailed test (a priori removal assumption); null hypothesis defined as influent EMC = effluent EMC; alternative hypothesis defined as influent EMC > effluent EMC; equal probability of null and alternative hypotheses (P = 0.5). The critical values for this test (n=22) are 16 positive results at the 95% level and 17 positive results at the 99% level. With 22 positive results, the result is rejection of the null hypothesis and the acceptance of the alternative hypothesis at the >99% level. This test confirms with greater than 99% confidence that the qualifying data set presented in Table 5 does indeed demonstrate positive removal performance.

Discussion

Due to the predominance of storm events with influent TSS-WA EMCs less than 100 mg/L, performance of the system with regard to the "Influent EMC < 100" category was very straight forward. For the very same reason, performance relative to the two categories for influent TSS-WA EMC concentrations greater than or equal to 100 mg/L was difficult to assess in a reasonable fashion. Therefore, the two categories for influent TSS-WA EMC concentrations greater than or equal to 100 mg/L were combined.

The qualifying data set is conservative based upon the peak operating rates it embodies. As shown in Figure 6, half of the qualifying data set represents performance in the 75% to 100% peak operating rate range, and the majority of the remainder represents performance in excess of design (>100%). Additionally, evidence that inline bypass (online) StormFilters continue to perform well under overflow conditions (in excess of design; >100% peak operating rate) suggests that the StormFilter is a robust design.

[9] WADOE (2002), page 31, Table 1
[10] WADOE (2002), page 30, Recommended Statistical Approach step #2

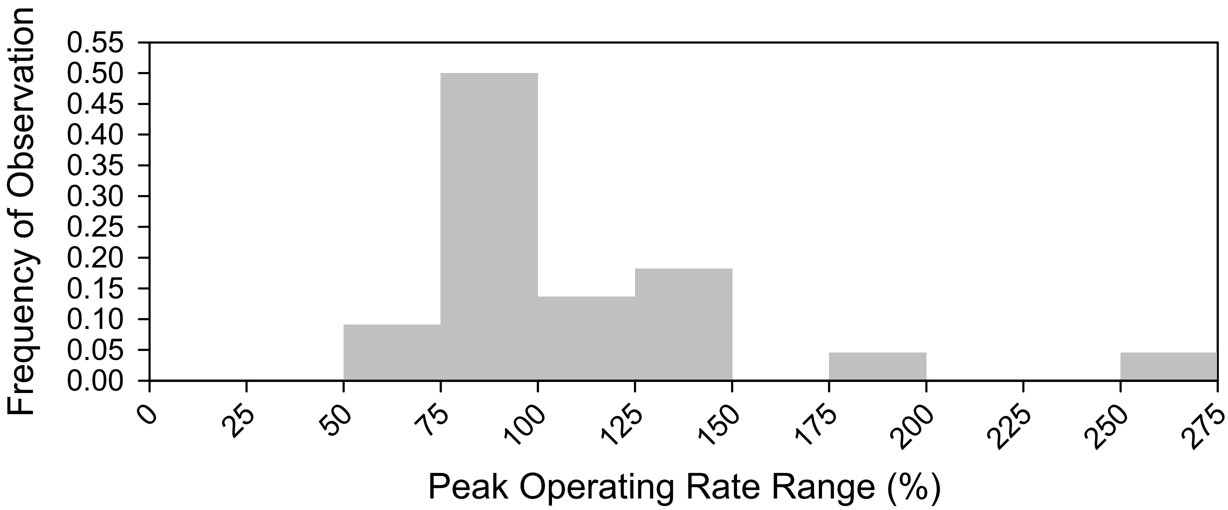

Figure 6. Frequency distribution of peak operating rates represented by the 22 qualifying events.

Conclusion

Two similarly configured StormFilter systems with influent solids characteristic of the Pacific Northwest were monitored over the course of a year for the purpose of fulfilling the requirements of a Conditional Use Designation issued by Ecology in October 2002. The monitoring approach and associated activities were in accordance with WADOE (2002) for the purpose of assessing removal performance relative to WADOE (2002) Basic Treatment Performance Goals. The combined data from the two sites indicates that the performance of a StormFilter system configured for inline bypass* with ZPG™ media and a 28 L/min/cartridge filtration rate meets Ecology performance goals for Basic Treatment.

Stormwater360, Stormwater Management Inc, and Vortechnics Inc. are now CONTECH Stormwater Solutions Inc.

References

Maine Department of Environmental Protection (MEDEP). (n.d.). Laboratory Testing Protocol for Manufactured Stormwater Treatment Systems. Portland, Maine: Author

Resource Planning Associates (RPA). (2004). Technology Evaluation Engineering Report for the Stormwater Management StormFilter. Seattle, WA: Author

Stormwater Management Inc. (SMI). (2003). Stormwater Management Inc. StormFilter Quality Assurance Project Plan (Confidential). Portland, Oregon: Author.

Stormwater Management Inc (SMI). (2004a). Maintenance Guidelines for The Stormwater Management StormFilter: Cast-In-Place, Precast, and Linear Units. Portland, Oregon: Author. Available Online: http://www.stormwaterinc.com/products/documents/StormFilter_Maintenance_000.pdf

Stormwater Management Inc (SMI). (2004b). Standard Operating Procedure: Post-Monitoring Solids Assessment (Report No. SOP-04-005.0). Portland, Oregon: Author.

* 0.05 m^3/s (1.8-cfs) per flow spreader

Stormwater Management Inc (SMI). (2004c). Standard Operating Procedure: Sampling Equipment Rinsate Blank (Report No. SOP-04-002.0). Portland, Oregon: Author.

Stormwater Management Inc (SMI). (2004d). The role of settling within the Stormwater Management StormFilter® System (Report No. PD-04-005.0). Portland, Oregon: Author.

Washington State Department of Ecology (WADOE). (2001). Stormwater Management Manual for Western Washington (Publication Numbers 99-11 to 99-15). Olympia, Washington: Author. Available Online:
http://www.sddot.com/pe/projdev/docs/stormwater/ConstructionBMPs.pdf

Washington State Department of Ecology (WADOE). (2002). Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol—Ecology (Publication Number 02-10-037). Olympia, Washington: Author. Available Online:
http://www.ecy.wa.gov/pubs/0210037.pdf

Revision Summary

PE-E072
Document rebranded.

PE-E071
Document number changed; document rebranded; no substantial changes.

PE-04-007.0
Original