NJCAT TECHNOLOGY VERIFICATION

Bio Clean ™ Multi-Level Screening (MLS) Inlet Filter

Performance Verification of Sediment Capture and Sediment Mass Loading

Bio Clean Environmental Services Inc.

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Contents

List of Tables 3

List of Figures 3

1. Introduction 4

2. Description of Technology 4

3. Laboratory Testing 6

   3.1 Test Setup 6

   3.2 Test Sediment 8

   3.3 Removal Efficiency Testing 10

   3.4 Sediment Mass Loading Testing 11

4. Performance Claims 11

5. Supporting Documentation 12

   5.1 Removal Efficiency 12

   5.2 Sediment Mass Loading 17

   5.3 Filter Driving Head 38

6. Maintenance Plans 39

7. Scaling 40

8. Statements 41

9. References 46

List of Tables

Table 1 PSD of Test Sediment (Lot # 08031725360)........ 9

Table 2 Removal Efficiency Sampling Frequency........ 10

Table 3 Removal Efficiency Water Flow Rate........ 13

Table 4 Removal Efficiency Sediment Feed Rate........ 14

Table 5 Removal Efficiency Drain Down Losses........ 15

Table 6 Removal Efficiency SSC Data........ 16

Table 7 Removal Efficiency Results........ 17

Table 8 Sediment Mass Loading Water Flow Rate........ 19

Table 9 Sediment Mass Loading Sediment Feed Rate........ 21

Table 10 Sediment Mass Loading Drain Down Losses........ 29

Table 11 Sediment Mass Loading SSC Data........ 31

Table 12 Sediment Mass Loading Removal Efficiency Results........ 35

Table 13 Scaling of Bio Clean™ MLS Filter Models........ 41

List of Figures

Figure 1 Grate Bio Clean™ MLS Filter Illustration........ 5

Figure 2 Curb Bio Clean™ MLS Filter Illustration........ 5

Figure 3 Catch Basin Dimensions........ 6

Figure 4 Test Flow Apparatus........ 7

Figure 5 Background Sampling Point........ 8

Figure 6 Effluent Sampling Point........ 8

Figure 7 Average Particle Size Distribution of Test Sediment........ 9

Figure 8 Sediment Captured on Catch Basin Floor........ 18

Figure 9 Removal Efficiency vs. Sediment Mass Loading for the Bio Clean™ MLS Filter........ 38

Figure 10 Increase in Head Loss vs. Sediment Mass Load........ 38

1. Introduction

The Bio Clean™ Multi-Level Screening (MLS) Filter for curb and grate inlets is a filtration manufactured treatment device (MTD) designed by Bio Clean Environmental Services Inc., a Forterra Company. The Bio Clean™ MLS Filter is designed to remove pollutants from stormwater runoff entering catch basins. The test program was conducted by Good Harbour Laboratories (GHL), an independent water technology testing lab based in Ontario, Canada. The study results were submitted to the New Jersey Corporation for Advanced Technology (NJCAT) for verification. NJCAT is a private/public partnership that provides independent technology verification, education and information on emerging environmental and energy technology fields. This testing program was based primarily on the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 25, 2013)*. However, the particle size distribution (PSD) of the test sediment used is larger than what is required for NJDEP certification. This larger PSD is common in many regions throughout the nation and thus is more applicable in these areas. **The performance test results have been submitted to NJCAT for verification only.**

2. Description of Technology

The Bio Clean™ MLS Filter is a first line of defense for treatment of polluted stormwater runoff. The filter system is designed to capture fine to coarse sediments, floatable trash, debris and hydrocarbons conveyed in stormwater runoff. Constructed of 100% high grade stainless steel, it has an 8-year warranty. The multi-level screen configuration provides a balance between flow rate capacity and capture of particulate pollutants such as TSS, and particle bound pollutants such as metals and nutrients. The finest screens are located on the bottom and lower sides of the filter. Moving upward, the screens go from fine to medium-fine, medium and coarse in mesh size allowing the filter to continue to operate and retain larger trash and debris during high flow conditions (**Figures 1 and 2**). The filter is equipped with unimpeded high flow bypass for large storm events and a floating hydrocarbon boom for the capture and retention of oils and grease.

The Bio Clean™ MLS Filter is designed for insertion into existing and new curb and grated type inlets, including combination types. The Bio Clean™ MLS Filter comes in standard sizes and depths but is also offered in custom configurations making it adaptable to regional standards throughout the United States and worldwide. Depths as shallow as 6 inches can be accommodated though flow capacity is reduced. These filters are designed to mount either on the grate flange, under mounted, or in curb inlets with a shelf system. Sizing of the filter is based upon both the treatment and bypass flow rates of the catch basin. Flow rate capacity varies based upon the size/model of the filter. Installation is quick and easy, and all filters are removable as required for access into the catch basin below. Designed with fast and efficient maintenance in mind, the filter can be power washed and vacuumed out using a standard vac truck and 8" metal hose extension.

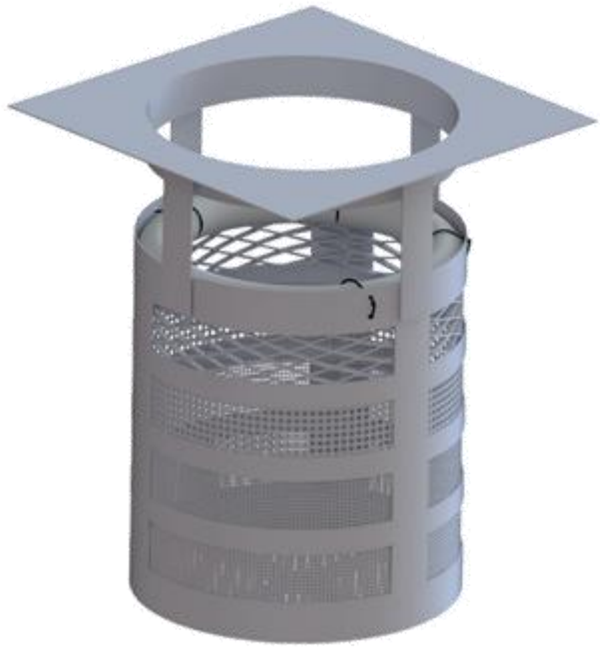

Figure 1 Grate Bio Clean™ MLS Filter Illustration

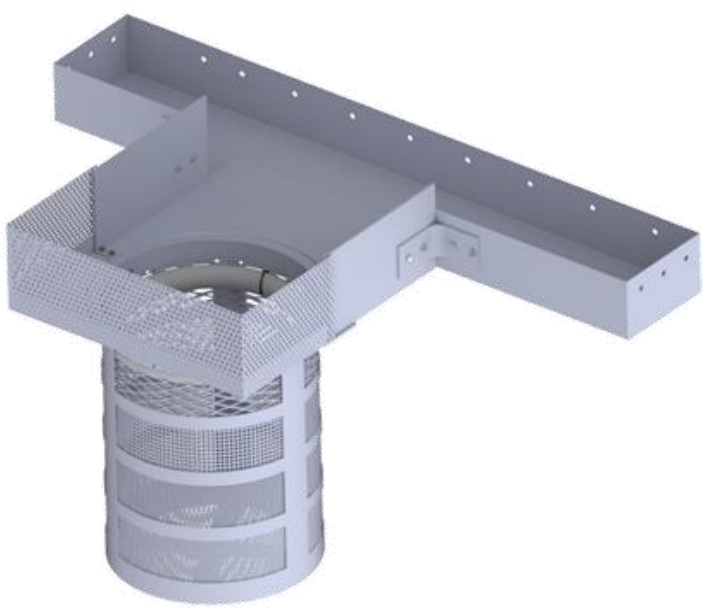

Figure 2 Curb Bio Clean™ MLS Filter Illustration

3. Laboratory Testing

In commercial systems, the filter would typically be fitted inside of a concrete catch basin. For the purposes of laboratory testing, the test apparatus consisted of a simulated City of Toronto catch basin that was constructed out of wood. Using a wooden catch basin in lieu of concrete did not have an impact on system performance. The catch basin had a false floor installed at the invert of a 12″ effluent pipe, eliminating any sump in the catch basin. This type of construction is representative of catch basins located in various regions in the United States such as in southern California. The dimensions of the catch basin are shown in **Figure 3**. The catch basin was covered with a typical City of Toronto grate that was constructed out of PVC rather than metal.

To simulate the sheet flow of water observed as stormwater runoff enters a catch basin, this study pumped water on to a “streetscape”, a plywood sheet 8 ft. long and 2 ft. wide, that directed the water flow to the catch basin grate. The streetscape was sloped towards the catch basin with a 1.5% slope.

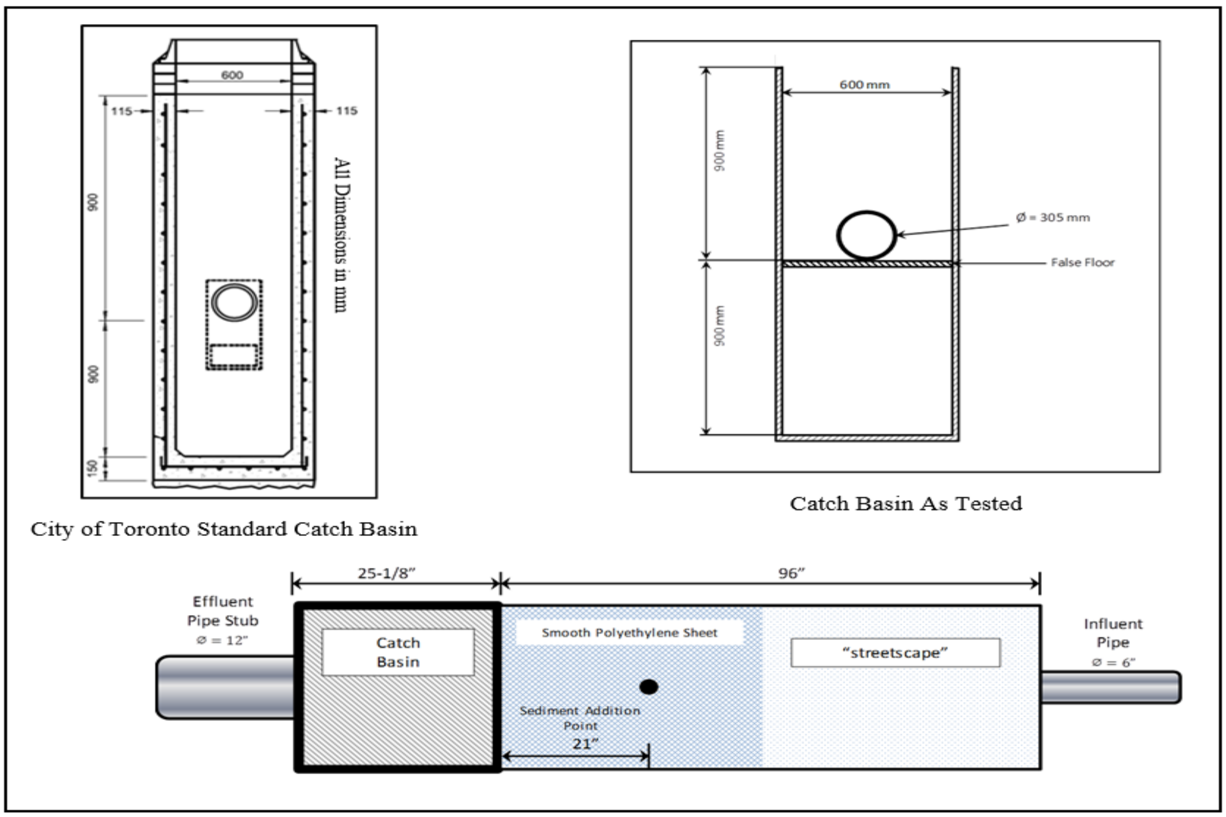

Figure 3 Catch Basin Dimensions

3.1 Test Setup

The laboratory test setup was a water flow loop comprised of water reservoirs, pumps, sediment filter, receiving tank and flow meters. The test flow apparatus is shown in **Figure 4**.

From the water supply tanks, water was pumped using a WEG Model FC00312 (1 – 200 gpm) centrifugal pump. Flow measurement was done using a 3” Toshiba Model GF630 electromagnetic type flow meter with an accuracy of ± 0.5% of reading. Flow measurements were recorded using a flow data logger, a MadgeTech Process 101A, configured to record a flow measurement once every minute.

The water in the flow loop was circulated through a filter housing containing high-efficiency pleated bag filters with a 0.5 µm absolute rating and then pumped onto the streetscape where the challenge sediment was added.

The test sediment was dropped onto the streetscape by means of an auger feeder (Auger Feeders Model VF-1 volumetric screw feeder). The sediment was added onto the center of the streetscape, approximately 21 inches upstream of the catch basin. The streetscape was painted with a waterproofing resin to prevent water leaks. To ensure that any sediment added onto the streetscape flowed into the catch basin, the floor of the streetscape underneath the sediment addition point was lined with a smooth polyethylene sheet. Baffles were also placed on the streetscape to direct water towards the sediment and help wash it onto the catch basin. Visually, no sediment remained on the streetscape at the end of each run.

Piping to Streetscape | Sediment Addition | Catch Basin

Figure 4 Test Flow Apparatus

The sediment loaded water flowed into the catch basin and was treated by a Bio Clean MLS Inlet Filter model # BIO-GRATE-MLS-24-24-24. The water exited the catch basin through the effluent pipe where it terminated with a free fall into a receiving tank.

Sample Collection

Background water samples were collected in 1L jars from a sampling port located upstream of the streetscape. The sampling port was controlled manually by a ball valve (**Figure 5**) that was opened approximately 5 seconds prior to sampling.

Effluent samples were also grabbed by hand. The effluent pipe drained freely into the Receiving Tank and the effluent sample was taken at that point **(Figure 6**). The sampling technique was to take the grab sample by sweeping a wide-mouth 1 L jar through the stream of effluent flow such that the jar was full after a single pass.

Figure 5 Background Sampling Point

Figure 6 Effluent Sampling Point

Other Instrumentation and Measurement

Water level and temperature in the Bio Clean™ MLS Filter were taken using a Solinst 3001 Levelogger, configured to take a reading once every 10 seconds. The level logger was set in the filter basket during each run.

Run and sampling times were measured using a NIST traceable stopwatch, Control Company Model 62379-460.

The sediment feed samples that were taken during the run were collected in 500 mL jars and weighed on an analytical balance (Mettler Toledo, AB204-S).

3.2 Test Sediment

The test sediment used for this study was the #100 - 140 silica blend supplied by AGSCO Corporation, lot # 08031725360. Eight 50-lbs. bags of sediment were used for this study. To determine the particle size distribution (PSD) of the sediment, three replicate composite samples were prepared by collecting a sample from each of the eight bags.

The PSD was determined by GHL using the methodology of ASTM method D422-63 (2007), *Standard Test Method for Particle-Size Analysis of Soils*. Since the PSD of the sediment was expected to have a very low fraction below 75 µm, no hydrometer testing was performed. The test results are summarized in **Table 1** and shown graphically in **Figure 7.**

The three replicate composite samples were also analyzed for moisture content by GHL based on ASTM Method D4959-07, *Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating.* The results were all below the Method Detection Limit (MDL) of 0.068%.

Table 1 PSD of Test Sediment (Lot # 08031725360)

Particle Size (Microns)	Test Sediment Particle Size (% Less Than)			
	Sample 1	Sample 2	Sample 3	Average
1000	100.00	100.00	100.00	100.00
850	100.00	100.00	100.00	100.00
425	99.74	99.77	99.78	99.76
250	91.70	92.48	92.26	92.15
212	78.01	80.60	80.10	79.57
150	36.85	40.93	38.65	38.81
106	5.09	5.80	5.42	5.44
75	0.67	0.83	0.71	0.74
d_{50}	170 µm	164 µm	167 µm	167 µm

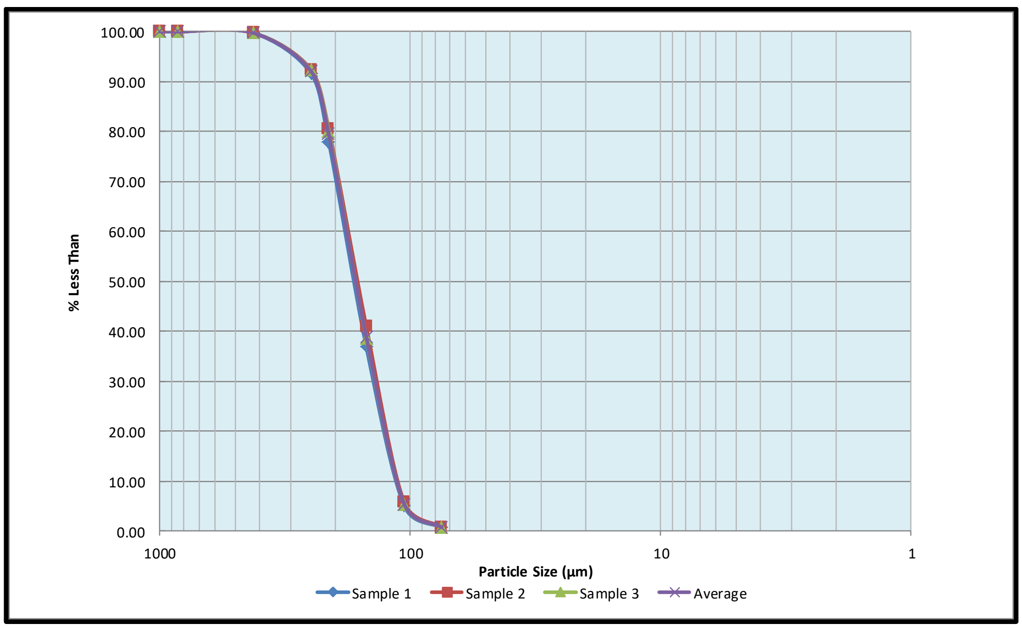

Figure 7 Average Particle Size Distribution of Test Sediment

3.3 Removal Efficiency Testing

Removal Efficiency Testing was conducted primarily based on Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. Testing was conducted at a flow rate of 0.223 cfs (100 gpm) and a target influent sediment concentration of 200 mg/L.

Effluent grab samples were taken 6 times per run (at evenly spaced intervals), with each run lasting 13 minutes in duration, followed by a drain down period. In addition to the effluent samples, background samples were taken with every odd-numbered effluent sample (1st, 3rd and 5th). As the filtration MTD did not have a sump, there was no minimum detention time requirement; however, a 2-minute interval was used to allow the system to establish equilibrium once sediment addition began. When the test sediment feed was interrupted for measurement, the next effluent sample was collected following the 2-minute delay. Sampling times for Removal Efficiency testing are summarized in **Table 2**. Effluent and background samples were collected in clean 1L wide-mouth jars.

Three sediment feed samples were collected during each run to confirm the sediment feed rate, one sample at the start of dosing, one sample in the middle of the test run and one sample just prior to the conclusion of dosing. Each sediment feed rate sample was a minimum of 100 mL and collected in a clean 500 mL jar. Sediment sampling was timed to the nearest 1/100th of a second using a calibrated stop watch and samples were weighed to the nearest 0.1 mg.

Table 2 Removal Efficiency Sampling Frequency

Sample/ Measurement Taken	Run Time (min.)								
	0	2	4	6	8	10	12	END OF RUN	13.5
Sediment Feed	X			X			X		
Effluent		X	X	X	X	X	X		
Background		X		X		X			
Drain down									X

An effluent drain down sample was collected at the end of each removal efficiency run, 30 seconds after the pump had been switched off, to estimate the amount of sediment lost during the drain down period. As the filter had no sump, the drain down period lasted less than 1 minute, however this did increase as sediment began to collect in the filter over time. Because it was not physically possible to directly measure the water level inside of the filter during the run to adjust the timing of the drain down sample, the sampling time was held at 30 seconds. This was considered a worst-case scenario as the sediment concentration tends to decrease over time. By basing the drain-down concentration on the 30 second sample, the drain-down sediment concentration was being over-estimated.

3.4 Sediment Mass Loading Testing

The Sediment Mass Loading Capacity of the filter was determined as a continuation of the Removal Efficiency testing. All aspects of the test procedure remained the same except that the target influent sediment concentration was increased from 200 to 400 mg/L. Sediment Mass Loading Capacity testing began after 12 runs of Removal Efficiency testing had been completed.

4. Performance Claims

The following are the performance claims made and/or established via the laboratory testing conducted on the Bio Clean™ (BC) MLS Inlet Filter Model # BIO-GRATE-MLS-24-24-24 (BC MLS Filter Model 24-24-24).

Verified Total Suspended Solids (SSC) Removal Rate

Based on the laboratory testing conducted, the BC MLS Filter Model 24-24-24 achieved an overall removal efficiency of 86.6% of the test sediment (d_{50} of 167 μm) prior to reaching the sediment mass loading capacity.

Tested Treatment Flow Rate (TTFR)

The BC MLS Filter Model 24-24-24 was tested at a flow rate of 0.223 cfs (100 gpm) which corresponds to a filtration treatment area ratio, based on a total screen surface area of 7.52 ft^2, of 0.030 cfs/ft^2 (13.3 gpm/ft^2).

Effective Treatment/Sedimentation Area

The BC MLS Filter Model 24-24-24 had a maximum operating head of 19-1/3" during testing. This correlates to an active filtration screen area of 6.85 ft^2 (91% of total screen surface area).

Detention Time and Wet Volume

The BC MLS Filter Model 24-24-24 does not have a sump; the detention time and wet volume will vary with time and will increase as sediment accumulates in the filter.

Sediment Mass Loading Capacity

The sedimentation mass loading capacity of the BC MLS Filter Model 24-24-24 was determined to be 199.3 lbs.

On-line/Off-line Installation

At this time no scour testing has been performed; therefore, the BC MLS Filter Model 24-24-24 would only qualify for off-line use.

Maximum Allowable Inflow Drainage Area

Varies based on region, treatment intensities, and loading conditions.

5. Supporting Documentation

The NJDEP Procedure (NJDEP 2013a) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that "copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc." be included in this section. This was discussed with NJDEP and it was agreed that as long as such documentation could be made available by NJCAT upon request that it would not be prudent or necessary to include all this information in this verification report.

5.1 Removal Efficiency

A total of 12 removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate and influent sediment concentration were 100 gpm and 200 mg/L respectively. The results from all 12 runs were used to calculate the overall removal efficiency of the Bio Clean™ MLS Filter Model 24-24-24.

Flow Rate

The flow rate was measured using a mag-type flow meter and data logger configured to take a reading once every minute. For each run, the flow rate was to be maintained within 10% of the target flow with a COV (coefficient of variation) less than 0.03.

The flow data has been summarized in **Table 3**, including the compliance to the QA/QC acceptance criteria. The average flow for all removal efficiency runs was 99.9 gpm.

Sediment Addition

The target sediment concentration was 200 ± 20 mg/L with a COV less than 0.10. The sediment feed rate for each run was checked three times during each run. The average influent sediment concentration for each test flow was determined by mass balance. The amount of sediment fed into the auger feeder and the amount remaining at the end of a run was used to determine the amount of sediment fed. The sediment mass was corrected for the mass of the three feed rate samples taken during the run. The mass of the sediment fed was divided by the volume of water that flowed through the Bio Clean™ MLS Filter during dosing to determine the average influent sediment concentration for each run.

The sediment weight checks, feed rates, final concentrations and compliance to QA/QC criteria are summarized in **Table 4**.

Filter Drain Down

The Bio Clean™ MLS Filter has a post-operation drain down. As per the NJDEP protocol, the amount of sediment that escapes the filter during the drain down period must be accounted for.

The volume of water in the Bio Clean™ MLS Filter was determined by:

$$Water\ Volume = H_W \times A_M$$

where,

H_W = the height of the water measured in filter basket

A_M = the horizontal area of the filter basket

The effluent sample taken during the drain down period was analysed for SSC to permit estimation of the amount of sediment that was lost during drain down. The sampling data for the drain down periods are presented in **Table 5**.

Table 3 Removal Efficiency Water Flow Rate

Run #	Runtime (min)	Water Flow Rate				QA/QC Compliance (COV < 0.03)	Max. Water Temperature (°F)
		Target (gpm)	Actual (gpm)	% Diff.	COV		
1	13	100	99.9	-0.09	0.021	PASS	68.3
2	13	100	100.2	0.15	0.011	PASS	59.7
3	13	100	99.8	-0.24	0.003	PASS	59.8
4	13	100	99.7	-0.29	0.002	PASS	59.9
5	13	100	99.9	-0.11	0.002	PASS	67.0
6	13	100	100.3	0.28	0.004	PASS	60.0
7	13	100	99.6	-0.36	0.001	PASS	60.1
8	13	100	100.4	0.41	0.003	PASS	60.1
9	13	100	99.7	-0.34	0.002	PASS	60.2
10	13*	100	100.0	-0.01	0.002	PASS	60.3
11	13	100	100.0	-0.01	0.006	PASS	68.6
12	13	100	99.7	-0.29	0.001	PASS	60.4

* During this run, the auger feeder was accidentally turned off after the calibration sample was taken at 6 min. The feeder was restarted after 40 s and the total run time was extended for an additional 40 s to compensate for the error. This run was excluded from the removal efficiency calculation however the sediment mass added during the run was counted towards the total sediment mass loading.

Table 4 Removal Efficiency Sediment Feed Rate

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance$^{\Delta}$	Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance$^{\Delta}$
1	0	77.8757	60.03	77.84	207.0	PASS	7	0	75.8534	58.87	77.31	206.1	PASS
	6	77.6554	59.84	77.86				6	77.4033	59.94	77.48		
	12	78.3844	59.85	78.58				12	77.9078	59.97	77.95		
	COV			0.005				COV			0.004		
2	0	74.5232	59.06	75.71	204.9	PASS	8	0	77.0070	59.75	77.33	205.8	PASS
	6	76.7232	59.91	76.84				6	77.5926	59.93	77.68		
	12	77.6241	60.03	77.59				12	77.9256	59.78	78.21		
	COV			0.012				COV			0.006		
3	0	78.7362	59.90	78.87	211.4	PASS	9	0	78.5645	59.88	78.72	210.2	PASS
	6	79.5072	59.78	79.80				6	79.2303	59.88	79.39		
	12	78.9541	59.84	79.17				12	79.2232	59.97	79.26		
	COV			0.006				COV			0.004		
4	0	76.4556	59.81	76.70	205.9	PASS	10	0	79.6390	59.65	80.11	215.3	PASS
	6	78.0102	59.87	78.18				6	80.3972	59.97	80.44		
	12	78.2965	59.93	78.39				12	79.7222	59.87	79.90		
	COV			0.012				COV			0.003		
5	0	74.3597	59.72	74.71	200.9	PASS	11	0	73.8021	58.94	75.13	202.6	PASS
	6	75.2255	59.91	75.34				6	76.4815	60.00	76.48		
	12	75.9134	59.82	76.14				12	76.4698	59.87	76.64		
	COV			0.010				COV			0.011		
6	0	75.9855	59.18	77.04	204.7	PASS	12	0	75.1635	59.90	75.29	199.6	PASS
	6	77.0631	59.84	77.27				6	74.9842	59.97	75.02		
	12	78.2478	59.87	78.42				12	76.1754	60.13	76.01		
	COV			0.010				COV			0.007		

* Based on sediment mass balance and average water flow rate
$^{\Delta}$ Average concentration 180 – 220 mg/L and COV < 0.1

Table 5 Removal Efficiency Drain Down Losses

Run #	Maximum Water Level (inches)	Total Water Volume (L)	Average Sediment Concentration of Drain Down Samples (mg/L)	Total Sediment Lost (g)
1	0.973	5.0	4.7	0.024
2	1.231	6.3	2.0	0.013
3	1.806	9.3	4.1	0.038
4	2.127	11.0	4.2	0.046
5	7.538	38.8	2.0	0.078
6	7.363	37.9	2.0	0.076
7	8.059	41.5	2.0	0.083
8	8.880	45.7	2.0	0.091
9	9.042	46.6	2.0	0.093
10	9.052	46.6	2.7	0.126
11	9.336	48.1	2.0	0.096
12	9.169	47.2	2.0	0.094

Removal Efficiency Calculations

All of the effluent and background samples for SSC were analysed by Good Harbour Laboratories utilizing ASTM D3977-97 *"Standard Test Methods for Determining Sediment Concentration in Water Samples".* The results are summarized in **Table 6**.

The required background SSC concentration was < 20 mg/L. The limit of quantitation for the analytical method was 2.3 mg/L. For the purposes of calculation, any result that was reported as being below the limit of quantitation (<LOQ), was assigned a value of 2 mg/L. The adjusted average sediment concentration was determined by:

Average effluent concentration – Average background concentration

Table 6 Removal Efficiency SSC Data

Run #	Suspended Sediment Concentration, SSC (mg/L)								QA/QC Compliance (background SSC < 20 mg/L)
	Run Time (min)	2	4	6	8	10	12	Average	
1	Background	2		2		2		2	YES
	Effluent	13.0	8.1	11.0	20.1	18.7	18.0	14.8	
2	Background	2		2		2		2	YES
	Effluent	14.0	30.9	20.5	11.0	13.0	18.2	17.9	
3	Background	2		2		2		2	YES
	Effluent	7.6	13.0	13.0	12.0	12.0	10.0	11.3	
4	Background	2		2		2		2	YES
	Effluent	6.1	8.7	11.0	15.3	12.0	13.4	11.1	
5	Background	2		2		2		2	YES
	Effluent	20.8	25.8	14.0	17.0	18.3	15.3	18.5	
6	Background	2		2		2		2	YES
	Effluent	3.7	2.5	7.2	3.5	2	2.5	3.6	
7	Background	2		2		2		2	YES
	Effluent	6.4	7.4	4.6	2.7	2.8	4.6	4.8	
8	Background	2		2		2		2	YES
	Effluent	4.9	4.4	2.3	2.4	3.6	2	3.3	
9	Background	2		2		2		2	YES
	Effluent	4.4	2.4	3.0	2	2.3	2.5	2.8	
10	Background	2		2		2		2	YES
	Effluent	5.2	2.4	3.3	3.0	2	2	3.0	
11	Background	2		2		2		2	YES
	Effluent	3.5	3.2	3.2	2.4	2	2.6	2.8	
12	Background	2		2		2		2	YES
	Effluent	3.6	2	2.4	2	3.1	2	2.5	

The analytical results, along with the run data, were used to calculate the removal efficiency for each run, mass loading and overall removal efficiency average; the results are tabulated in **Table 7.** The removal efficiency was calculated as:

$$Removal\ Efficiency\ (\%) = \frac{\begin{pmatrix} Average\ Influent \\ SS\ Concentration\ X \\ Total\ Volume \\ of\ Test\ Water \end{pmatrix} - \begin{pmatrix} Adjusted\ Effluent \\ SS\ Concentration\ X \\ Total\ Volume \\ of\ Effluent\ Water \end{pmatrix} - \begin{pmatrix} Drain\ down\ Flow \\ SS\ Concentration\ X \\ Total\ Volume \\ of\ Drain\ down\ Water \end{pmatrix}}{\begin{matrix} Average\ Influent\ SS\ Concentration\ X \\ Total\ Volume\ of\ Test\ Water \end{matrix}} \times 100$$

Table 7 Removal Efficiency Results

Run #	Avg. Influent SSC (mg/L)	Adjusted Effluent SSC (mg/L)	Total Water Volume (L)	Average Drain Down SSC (mg/L)	Volume of Drain Down Water (L)	Removal Efficiency (%)	Mass of Captured Sediment (Lbs.)
1	207.0	12.8	3773	4.7	5.0	93.8	1.615
2	204.9	15.9	3787	2.0	6.3	92.2	1.578
3	211.4	9.3	3774	4.1	9.3	95.6	1.682
4	205.9	9.1	3774	4.2	11.0	95.6	1.638
5	200.9	16.5	3781	2.0	38.8	91.8	1.538
6	204.7	1.6	3804	2.0	37.9	99.2	1.704
7	206.1	2.8	3779	2.0	41.5	98.7	1.694
8	205.8	1.3	3803	2.0	45.7	99.4	1.714
9	210.2	0.8	3773	2.0	46.6	99.6	1.742
10	215.3	1.0	3787	2.7	46.6	99.5	1.789
11	202.6	0.8	3792	2.0	48.1	99.6	1.687
12	199.6	0.5	3775	2.0	47.2	99.7	1.657
Average Removal Efficiency*						96.8 %	
Captured Sediment Mass						20.0 lbs.	

*Excludes Run #10

The overall average removal efficiency was 96.8% for the first 12 runs. During the Removal Efficiency testing, 20 pounds of sediment was captured in the Bio Clean™ MLS Filter.

5.2 Sediment Mass Loading

The Sediment Mass Loading Capacity testing was a continuation of the Removal Efficiency testing. All aspects of the testing remained the same, except that the feed concentration was increased to 400 mg/L, up from the 200 mg/L used for the Removal Efficiency testing. The sediment mass loading continued for an additional 7 runs at which point testing was stopped because of time constraints.

Following a 2-month break, the mass loading was resumed. During the break, the sediment in the catch basin remained undisturbed. An additional 54 mass loading runs were completed for a total of 73 runs. The Bio Clean™ MLS Filter performance did not meet the criteria for terminating the mass loading test as specified in the NJCAT test protocol. The test was stopped early because the filter had demonstrated sufficient capacity to ensure that the filter installation would not be limited by sediment loading.

For Runs 13-73, the mass loading water flow rates, sediment feed rates, drain down loses, SSC data and removal efficiencies are presented in **Table 8** to **Table 12** respectively.

The total mass of sediment captured in the Bio Clean™ MLS Filter was 202 lbs. and the overall removal efficiency was 87.6% (**Table 12)**. The relationship between removal efficiency and sediment mass loading is shown in **Figure 9** (page 38).

It was observed that there was a wide variation in effluent sediment concentration within some runs. For example, during Run # 38, the following effluent concentrations were reported: effluent sample #3 - 37.1 mg/L, effluent sample #4 - 172.7 mg/L, and effluent sample #5 - 27.1 mg/L. No correction was made to the average effluent concentration when this occurred; the effluent spikes were included in the performance calculations as a worst-case scenario.

The reason for such variable concentrations was opined to be an occasional washout of sediment that was deposited beneath the Bio Clean™ MLS Filter in the catch basin. The catch basin used for the study did not have a sump to retain this material which allowed for this occasional washout. The Bio Clean™ MLS Filter was very effective at dissipating the energy of the falling water. As a result, sediment settled and accumulated on the floor of the catch basin, as shown in **Figure 8**. At the end of testing, the sediment was collected, dried and weighed. The weight of sediment was 2.7 lbs, which results in an adjusted amount of sediment captured of 199.3 lbs and an adjusted overall removal efficiency of 86.6%.

Figure 8 Sediment Captured on Catch Basin Floor

Table 8 Sediment Mass Loading Water Flow Rate

Run #	Runtime (min)	Water Flow Rate				QA/QC Compliance (COV < 0.03)	Max. Water Temperature (°F)
		Target (gpm)	Actual (gpm)	% Diff.	COV		
13	13	100	100.7	0.66	0.002	Pass	60.5
14	13	100	99.7	-0.29	0.002	Pass	60.5
15	13	100	100.5	0.53	0.001	Pass	60.6
16	13	100	101.7	1.71	0.002	Pass	61.0
17	13	100	101.0	0.96	0.002	Pass	64.6
18	13	100	101.4	1.35	0.002	Pass	59.1
19	13	100	101.4	1.44	0.002	Pass	59.2
20	13	100	99.7	-0.26	0.002	Pass	73.9
21	13	100	100.3	0.25	0.003	Pass	67.0
22	13	100	99.7	-0.26	0.002	Pass	67.2
23	13	100	99.8	-0.25	0.003	Pass	67.1
24	13	100	99.6	-0.36	0.002	Pass	71.5
25	13	100	99.9	-0.06	0.003	Pass	68.0
26	13	100	100.3	0.30	0.003	Pass	68.1
27	13	100	100.4	0.37	0.004	Pass	68.3
28	13	100	99.8	-0.17	0.001	Pass	68.3
29	13	100	99.9	-0.11	0.002	Pass	75.9
30	13	100	100.5	0.49	0.002	Pass	70.7
31	13	100	100.1	0.14	0.002	Pass	70.8
32	13	100	100.4	0.41	0.002	Pass	70.7
33	13	100	99.9	-0.14	0.002	Pass	70.7
34	13	100	100.0	-0.04	0.002	Pass	70.7
35	13	100	100.1	0.10	0.003	Pass	78.8
36	13	100	100.7	0.69	0.001	Pass	71.3
37	13	100	100.2	0.19	0.002	Pass	71.2
38	13	100	100.0	0.04	0.006	Pass	71.1
39	13	100	100.4	0.44	0.003	Pass	71.1
40	13	100	100.2	0.24	0.005	Pass	71.0
41	13	100	99.9	-0.08	0.002	Pass	75.9
42	13	100	100.5	0.49	0.003	Pass	71.2

Table 8 Cont'd

Run #	Runtime (min)	Water Flow Rate				QA/QC Compliance (COV < 0.03)	Max. Water Temperature (°F)
		Target (gpm)	Actual (gpm)	% Diff.	COV		
43	13	100	100.4	0.39	0.001	Pass	71.1
44	13	100	100.3	0.34	0.003	Pass	71.1
45	13	100	100.3	0.25	0.002	Pass	74.8
46	13	100	100.4	0.36	0.002	Pass	71.5
47	13	100	100.5	0.53	0.002	Pass	71.4
48	13	100	100.5	0.54	0.002	Pass	71.3
49	13	100	100.2	0.17	0.001	Pass	71.2
50	13	100	100.5	0.46	0.002	Pass	71.2
51	13	100	100.4	0.35	0.002	Pass	75.9
52	13	100	100.4	0.35	0.002	Pass	71.4
53	13	100	100.3	0.28	0.002	Pass	71.3
54	13	100	100.7	0.65	0.002	Pass	71.2
55	13	100	100.4	0.44	0.002	Pass	71.1
56	13	100	100.6	0.58	0.003	Pass	71.0
57	13	100	100.6	0.59	0.002	Pass	73.3
58	13	100	100.8	0.75	0.002	Pass	70.5
59	13	100	100.4	0.39	0.002	Pass	70.5
60	13	100	100.4	0.41	0.002	Pass	70.5
61	13	100	100.5	0.53	0.002	Pass	70.5
62	13	100	100.7	0.66	0.001	Pass	71.7
63	13	100	100.4	0.36	0.002	Pass	69.5
64	13	100	100.7	0.66	0.002	Pass	69.5
65	13	100	100.4	0.39	0.002	Pass	69.4
66	13	100	100.6	0.60	0.002	Pass	69.4
67	13	100	100.4	0.36	0.002	Pass	69.4
68	13	100	100.4	0.44	0.002	Pass	72.0
69	13	100	100.3	0.31	0.002	Pass	69.9
70	13	100	100.4	0.44	0.002	Pass	69.8
71	13	100	100.4	0.41	0.001	Pass	69.7
72	13	100	100.4	0.38	0.002	Pass	69.7
73	13	100	100.5	0.49	0.002	Pass	69.7

Table 9 Sediment Mass Loading Sediment Feed Rate

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance$^{\Delta}$
13	0	152.2234	59.78	152.78	407.6	Yes
	6	153.8062	60.00	153.81		
	12	155.8470	60.00	155.85		
	COV			0.010		
14	0	153.3801	59.81	153.87	411.0	Yes
	6	154.8873	59.81	155.38		
	12	155.8917	59.88	156.20		
	COV			0.008		
15	0	157.9079	59.72	158.65	422.3	Yes
	6	159.8469	59.93	160.03		
	12	160.6890	59.69	161.52		
	COV			0.009		
16	0	153.6775	59.60	154.71	403.7	Yes
	6	155.3389	60.00	155.34		
	12	156.1118	59.78	156.69		
	COV			0.006		
17	0	149.2514	59.78	149.80	394.0	Yes
	6	150.4473	60.00	150.45		
	12	149.3137	59.94	149.46		
	COV			0.003		
18	0	148.0615	59.85	148.43	406.7	Yes
	6	147.5142	59.91	147.74		
	12	149.4875	59.88	149.79		
	COV			0.007		
19	0	147.7006	60.00	147.70	393.8	Yes
	6	150.4889	59.90	150.74		
	12	150.8665	59.82	151.32		
	COV			0.013		
20	0	142.2774	58.97	144.762	386.3	Yes
	6	143.8857	59.85	144.246		
	12	143.5221	59.97	143.594		
	COV			0.004		

* Based on sediment mass balance and average water flow rate
$^{\Delta}$ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance[Δ]
21	0	144.6368	59.00	147.088	383.4	Yes
	6	145.5989	59.87	145.915		
	12	142.9191	59.93	143.086		
	COV			0.014		
22	0	147.0387	60.03	146.965	388.0	Yes
	6	146.7221	60.12	146.429		
	12	145.2337	59.97	145.306		
	COV			0.006		
23	0	144.9429	59.91	145.161	380.9	Yes
	6	143.8966	60.03	143.825		
	12	142.7005	59.97	142.772		
	COV			0.008		
24	0	143.5259	59.63	144.416	382.5	Yes
	6	142.4922	59.88	142.778		
	12	141.1655	59.93	141.330		
	COV			0.011		
25	0	142.8673	58.91	145.511	377.7	Yes
	6	143.7350	59.87	144.047		
	12	142.4651	59.88	142.751		
	COV			0.010		
26	0	158.4479	59.91	158.686	417.6	Yes
	6	158.8272	59.90	159.092		
	12	157.2129	59.97	157.292		
	COV			0.006		
27	0	157.2364	59.03	159.820	420.7	Yes
	6	160.7948	60.19	160.287		
	12	159.7519	59.91	159.992		
	COV			0.001		
28	0	160.6420	59.93	160.830	420.7	Yes
	6	157.7979	59.78	158.379		
	12	157.2945	59.94	157.452		
	COV			0.011		

* Based on sediment mass balance and average water flow rate
Δ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance^Δ
29	0	153.5223	59.03	156.045	411.4	Yes
	6	154.0616	59.90	154.319		
	12	154.0469	60.03	153.970		
	COV			0.007		
30	0	157.3605	58.97	160.109	419.9	Yes
	6	156.6209	59.22	158.684		
	12	158.2445	60.03	158.165		
	COV			0.006		
31	0	158.7294	59.72	159.474	420.6	Yes
	6	157.2062	60.00	157.206		
	12	158.4495	60.00	158.450		
	COV			0.007		
32	0	159.1804	59.78	159.766	419.5	Yes
	6	159.2462	59.78	159.832		
	12	157.1043	60.13	156.765		
	COV			0.011		
33	0	156.8975	59.85	157.291	422.2	Yes
	6	157.8254	60.09	157.589		
	12	154.4244	59.88	154.734		
	COV			0.010		
34	0	157.3926	59.88	157.708	411.7	Yes
	6	154.9466	59.85	155.335		
	12	155.2679	59.90	155.527		
	COV			0.008		
35	0	157.8292	59.87	158.172	420.6	Yes
	6	159.6461	59.90	159.913		
	12	158.7748	60.00	158.775		
	COV			0.006		
36	0	162.1631	59.84	162.597	421.3	Yes
	6	161.0520	59.91	161.294		
	12	160.2726	60.00	160.273		
	COV			0.007		

* Based on sediment mass balance and average water flow rate
Δ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance^Δ
37	0	155.4016	58.87	158.385	422.8	Yes
	6	158.7076	59.94	158.866		
	12	158.5914	60.28	157.855		
	COV			0.003		
38	0	156.3193	59.84	156.737	416.7	Yes
	6	158.5133	59.90	158.778		
	12	155.6039	60.07	155.423		
	COV			0.011		
39	0	161.8018	59.82	162.289	421.2	Yes
	6	160.5071	59.81	161.017		
	12	157.8718	59.78	158.453		
	COV			0.012		
40	0	158.0608	59.96	158.166	415.9	Yes
	6	157.8214	59.84	158.243		
	12	156.3638	59.90	156.625		
	COV			0.006		
41	0	160.0230	59.72	160.773	421.6	Yes
	6	158.2916	60.00	158.292		
	12	156.9173	59.88	157.232		
	COV			0.011		
42	0	158.9289	59.75	159.594	419.0	Yes
	6	159.2821	59.85	159.681		
	12	157.5232	59.94	157.681		
	COV			0.007		
43	0	158.3744	59.84	158.798	412.8	Yes
	6	156.1816	59.97	156.260		
	12	156.0488	60.06	155.893		
	COV			0.010		
44	0	157.3251	59.00	159.992	421.2	Yes
	6	158.1512	59.94	158.310		
	12	158.6881	59.87	159.033		
	COV			0.005		

* Based on sediment mass balance and average water flow rate
Δ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance$^{\Delta}$
45	0	159.1182	59.90	159.384	418.0	Yes
	6	157.5362	59.97	157.615		
	12	156.2102	60.00	156.210		
	COV			0.010		
46	0	158.8482	59.75	159.513	414.9	Yes
	6	158.1052	60.00	158.105		
	12	156.9006	59.91	157.136		
	COV			0.008		
47	0	159.1052	59.87	159.451	413.5	Yes
	6	156.8836	59.90	157.146		
	12	155.8384	59.94	155.994		
	COV			0.011		
48	0	156.6709	59.71	157.432	411.6	Yes
	6	155.2676	60.00	155.268		
	12	155.6656	60.03	155.588		
	COV			0.007		
49	0	159.1107	59.87	159.456	417.0	Yes
	6	157.7215	59.94	157.879		
	12	156.3686	59.97	156.447		
	COV			0.010		
50	0	159.3636	59.75	160.030	421.7	Yes
	6	158.6036	59.91	158.842		
	12	157.8249	59.94	157.983		
	COV			0.006		
51	0	158.1396	59.87	158.483	414.3	Yes
	6	157.0296	59.91	157.265		
	12	155.2062	59.96	155.310		
	COV			0.010		
52	0	157.6154	59.78	158.195	408.4	Yes
	6	155.2219	59.90	155.481		
	12	151.2090	59.84	151.613		
	COV			0.021		

* Based on sediment mass balance and average water flow rate
$^{\Delta}$ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance^Δ
53	0	156.4064	59.88	156.720	412.9	Yes
	6	157.1320	59.97	157.211		
	12	153.2497	59.94	153.403		
	COV			0.013		
54	0	157.9417	59.93	158.126	412.8	Yes
	6	154.9051	59.96	155.008		
	12	155.0222	60.00	155.022		
	COV			0.012		
55	0	159.5976	59.88	159.917	417.0	Yes
	6	158.0736	59.87	158.417		
	12	157.0261	59.97	157.105		
	COV			0.009		
56	0	155.3062	58.87	158.287	415.0	Yes
	6	156.5550	59.85	156.947		
	12	155.8510	59.81	156.346		
	COV			0.006		
57	0	152.1920	58.94	154.929	405.7	Yes
	6	153.0459	59.90	153.301		
	12	152.8484	59.97	152.925		
	COV			0.007		
58	0	155.6767	59.06	158.154	414.5	Yes
	6	156.0560	59.97	156.134		
	12	155.0744	59.87	155.411		
	COV			0.009		
59	0	155.4493	58.87	158.433	415.4	Yes
	6	157.4718	59.87	157.814		
	12	154.8352	60.00	154.835		
	COV			0.012		
60	0	159.6384	59.81	160.146	415.8	Yes
	6	157.1373	59.97	157.216		
	12	156.8322	60.00	156.832		
	COV			0.011		

* Based on sediment mass balance and average water flow rate
Δ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC ComplianceΔ
61	0	157.9606	59.72	158.701	415.7	Yes
	6	156.7077	59.97	156.786		
	12	156.8162	60.00	156.816		
	COV			0.007		
62	0	153.4021	59.03	155.923	410.2	Yes
	6	155.3993	60.00	155.399		
	12	155.3890	59.91	155.622		
	COV			0.002		
63	0	157.8493	59.81	158.351	414.8	Yes
	6	155.5198	60.16	155.106		
	12	155.2624	59.90	155.522		
	COV			0.011		
64	0	158.0604	59.81	158.563	416.0	Yes
	6	155.7644	60.00	155.764		
	12	155.8193	59.94	155.975		
	COV			0.010		
65	0	156.8835	59.85	157.277	416.7	Yes
	6	156.2461	59.91	156.481		
	12	157.8223	60.15	157.429		
	COV			0.003		
66	0	158.9536	59.88	159.272	412.9	Yes
	6	156.3964	59.96	156.501		
	12	156.4041	59.88	156.718		
	COV			0.010		
67	0	156.9761	59.84	157.396	410.0	Yes
	6	155.4800	60.00	155.480		
	12	153.5228	59.97	153.600		
	COV			0.012		
68	0	158.1377	59.81	158.640	413.5	Yes
	6	154.2770	59.75	154.923		
	12	155.2960	59.94	155.451		
	COV			0.013		

* Based on sediment mass balance and average water flow rate
Δ Average concentration 180 – 220 mg/L and COV < 0.1

Table 9 Cont'd

Run #	Run Time (min)	Weight (g)	Duration (s)	Feed Rate (g/min)	Conc.* (mg/L)	QA/QC Compliance^Δ
69	0	158.7824	59.78	159.367	417.8	Yes
	6	157.9253	60.00	157.925		
	12	156.0956	60.07	155.914		
	COV			0.011		
70	0	159.3646	59.87	159.711	413.8	Yes
	6	157.2761	59.91	157.512		
	12	155.4203	59.84	155.836		
	COV			0.012		
71	0	157.2593	59.84	157.680	412.9	Yes
	6	155.4672	59.88	155.779		
	12	153.5096	59.78	154.075		
	COV			0.012		
72	0	156.7835	59.84	157.203	413.2	Yes
	6	155.7410	59.91	155.975		
	12	156.6542	59.97	156.733		
	COV			0.004		
73	0	159.1429	59.91	159.382	412.5	Yes
	6	157.0586	60.00	157.059		
	12	155.5408	59.93	155.722		
	COV			0.012		

* Based on sediment mass balance and average water flow rate
Δ Average concentration 180 – 220 mg/L and COV < 0.1

Table 10 Sediment Mass Loading Drain Down Losses

Run #	Maximum Water Level (inches)	Total Water Volume (L)	Average Sediment Concentration of Drain Down Samples (mg/L)	Total Sediment Lost (g)
13	12.055	62.1	2.0	0.124
14	11.660	60.0	3.0	0.180
15	11.812	60.8	6.8	0.414
16	9.835	50.6	13.1	0.663
17	12.820	66.0	12.2	0.805
18	13.410	69.0	19.8	1.367
19	13.534	69.7	20.1	1.401
20	13.667	70.4	29.9	2.104
21	14.306	73.7	49.2	3.624
22	14.846	76.4	78.0	5.962
23	15.076	77.6	59.1	4.587
24	15.722	80.9	51.1	4.136
25	15.281	78.7	56.4	4.437
26	15.704	80.8	65.3	5.279
27	16.019	82.5	79.4	6.548
28	16.079	82.8	63.5	5.256
29	15.423	79.4	58.6	4.653
30	15.716	80.9	60.0	4.855
31	16.335	84.1	84.8	7.131
32	16.126	83.0	69.2	5.745
33	16.566	85.3	59.3	5.057
34	16.603	85.5	56.2	4.804
35	16.601	85.5	72.3	6.179
36	16.613	85.5	75.0	6.415

Table 10 Cont'd

Run #	Maximum Water Level (inches)	Total Water Volume (L)	Average Sediment Concentration of Drain Down Samples (mg/L)	Total Sediment Lost (g)
37	16.854	86.8	71.2	6.178
38	16.234	83.6	73.2	6.118
39	16.841	86.7	75.2	6.520
40	16.704	86.0	59.1	5.082
41	16.472	84.8	62.5	5.300
42	17.093	88.0	87.5	7.700
43	17.380	89.5	89.2	7.981
44	18.104	93.2	91.1	8.490
45	17.969	92.5	55.2	5.107
46	18.013	92.7	88.4	8.198
47	18.089	93.1	74.9	6.975
48	18.051	92.9	58.7	5.455
49	18.137	93.4	94.7	8.842
50	18.137	93.4	63.0	5.882
51	17.401	89.6	77.4	6.934
52	18.164	93.5	67.0	6.265
53	18.284	94.1	104.0	9.790
54	18.301	94.2	151.4	14.264
55	18.343	94.4	92.6	8.745
56	18.373	94.6	97.0	9.175
57	17.793	91.6	130.3	11.935
58	18.183	93.6	67.8	6.347
59	18.178	93.6	139.4	13.045
60	18.449	95.0	125.0	11.872

Table 10 Cont'd

Run #	Maximum Water Level (inches)	Total Water Volume (L)	Average Sediment Concentration of Drain Down Samples (mg/L)	Total Sediment Lost (g)
61	18.267	94.0	89.7	8.436
62	18.395	94.7	59.2	5.606
63	18.906	97.3	122.0	11.875
64	19.005	97.8	133.5	13.062
65	18.931	97.5	81.0	7.894
66	18.953	97.6	109.0	10.636
67	19.078	98.2	111.0	10.902
68	18.497	95.2	115.0	10.951
69	18.933	97.5	82.6	8.051
70	19.102	98.3	66.0	6.491
71	19.189	98.8	104.0	10.274
72	19.276	99.2	238.8	23.698
73	19.333	99.5	390.3	38.846

Table 11 Sediment Mass Loading SSC Data

Run #	Suspended Sediment Concentration, SSC (mg/L)								QA/QC Compliance (background SSC < 20 mg/L)
	Run Time (min)	2	4	6	8	10	12	Average	
13	Background	2		2		2		2	YES
	Effluent	5.6	3.8	4.3	2.3	3.8	10.0	5.0	
14	Background	2		2		2		2	YES
	Effluent	11.0	5.2	5.0	2.8	5.5	17.4	7.8	
15	Background	2		2		2		2	YES
	Effluent	6.0	2.8	11.0	13.2	21.2	27.5	13.6	
16	Background	2		2		2		2	YES
	Effluent	7.8	12.0	19.0	17.2	17.6	22.1	16.0	

Table 11 Cont'd

Run #	Suspended Sediment Concentration, SSC (mg/L)								QA/QC Compliance (background SSC < 20 mg/L)
	Run Time (min)	2	4	6	8	10	12	Average	
17	Background	2		2		2		2	YES
	Effluent	12.0	13.0	18.7	21.8	21.5	23.9	18.5	
18	Background	2		2		2		2	YES
	Effluent	25.5	22.7	29.9	23.2	22.0	21.5	24.1	
19	Background	2		2		2		2	YES
	Effluent	28.8	27.6	30.8	25.5	21.6	25.9	26.7	
20	Background	2		2		2		2	YES
	Effluent	22.9	33.4	23.3	37.7	32.1	33.4	30.5	
21	Background	2		2		2		2	YES
	Effluent	75.2	53.2	26.9	40.6	42.5	40.5	46.5	
22	Background	2		2		2		2	YES
	Effluent	83.3	45.6	34.9	30.4	29.8	32.3	42.7	
23	Background	2		2		2		2	YES
	Effluent	32.6	37.1	39.4	28.7	44.5	33.8	36.0	
24	Background	2		2		2		2	YES
	Effluent	41.6	29.7	33.0	24.9	35.8	33.9	33.2	
25	Background	2		2		2		2	YES
	Effluent	34.2	31.3	47.1	44.4	32.4	28.5	36.3	
26	Background	2		2		2		2	YES
	Effluent	41.8	47.5	39.6	32.5	43.0	28.4	38.8	
27	Background	2		2		2		2	YES
	Effluent	61.7	41.7	31.3	26.4	36.1	27.0	37.4	
28	Background	2		2		2		2	YES
	Effluent	43.9	38.9	54.8	31.0	24.2	31.3	37.4	
29	Background	2		2		2		2	YES
	Effluent	38.8	33.2	40.9	25.3	26.0	26.3	31.8	
30	Background	2		2		2		2	YES
	Effluent	54.4	56.7	42.0	21.9	26.9	42.6	40.8	
31	Background	2		2		2		2	YES
	Effluent	64.5	32.7	38.2	35.2	37.1	42.9	41.8	
32	Background	2		2		2		2	YES
	Effluent	71.6	63.1	56.6	42.6	29.6	28.2	48.6	

Table 11 Cont'd

Run #	Run Time (min)	2	4	6	8	10	12	Average	QA/QC Compliance (background SSC < 20 mg/L)
	Suspended Sediment Concentration, SSC (mg/L)								
33	Background	2		2		2		2	YES
	Effluent	45.4	33.1	44.6	36.5	48.3	24.5	38.7	
34	Background	2		2		2		2	YES
	Effluent	47.0	37.1	34.8	33.7	36.4	24.4	35.6	
35	Background	2		2		2		2	YES
	Effluent	64.7	43.5	41.8	27.6	24.6	21.0	37.2	
36	Background	2		2		2		2	YES
	Effluent	33.6	28.1	49.5	30.5	26.3	31.8	33.3	
37	Background	2		2		2		2	YES
	Effluent	34.3	43.0	32.8	35.4	26.2	22.7	32.4	
38	Background	2		2		2		2	YES
	Effluent	38.0	53.4	45.8	37.1	172.7	27.1	62.4	
39	Background	2		2		2		2	YES
	Effluent	29.3	46.9	29.1	40.5	27.6	29.6	33.8	
40	Background	2		2		2		2	YES
	Effluent	57.5	43.0	42.3	86.7	33.7	31.3	49.1	
41	Background	2		2		2		2	YES
	Effluent	32.0	56.1	59.4	35.6	33.0	38.0	42.4	
42	Background	2		2		2		2	YES
	Effluent	47.8	38.0	36.7	40.2	34.8	28.4	37.7	
43	Background	2		2		2		2	YES
	Effluent	53.7	48.7	34.8	34.0	37.2	29.4	39.6	
44	Background	2		2		2		2	YES
	Effluent	56.2	44.9	33.7	34.6	28.7	27.9	37.7	
45	Background	2		2		2		2	YES
	Effluent	75.7	44.3	121.3	36.0	24.6	45.2	57.9	
46	Background	2		2		2		2	YES
	Effluent	98.5	63.8	51.8	36.5	19.2	33.6	50.6	
47	Background	2		2		2		2	YES
	Effluent	93.6	55.2	58.1	32.4	59.2	31.1	54.9	
48	Background	2		2		2		2	YES
	Effluent	98.6	53.3	120.9	43.7	53.0	39.9	68.2	

Table 11 Cont'd

Run #	Suspended Sediment Concentration, SSC (mg/L)								QA/QC Compliance (background SSC < 20 mg/L)
	Run Time (min)	2	4	6	8	10	12	Average	
49	Background	2		2		2		2	YES
	Effluent	69.4	63.6	54.8	29.3	95.4	36.4	58.2	
50	Background	2		2		2		2	YES
	Effluent	69.8	90.7	27.5	66.9	37.5	32.2	54.1	
51	Background	2		2		2		2	YES
	Effluent	52.3	56.7	116.0	33.1	27.0	45.8	55.2	
52	Background	2		2		2		2	YES
	Effluent	86.6	51.2	82.2	40.1	47.9	31.8	56.6	
53	Background	2		2		2		2	YES
	Effluent	58.8	74.2	91.6	33.9	37.3	43.4	56.5	
54	Background	2		2		2		2	YES
	Effluent	43.8	102.0	78.4	54.2	45.1	44.8	61.4	
55	Background	2		2		2		2	YES
	Effluent	74.4	262.1	35.3	39.1	33.7	46.1	81.8	
56	Background	2		2		2		2	YES
	Effluent	67.6	72.0	38.6	39.2	54.7	54.4	54.4	
57	Background	2		2		2		2	YES
	Effluent	102.0	66.5	62.9	50.5	41.0	46.3	61.5	
58	Background	2		2		2		2	YES
	Effluent	78.0	47.6	40.0	61.2	77.6	68.7	62.2	
59	Background	2		2		2		2	YES
	Effluent	75.4	70.9	57.2	51.9	87.4	55.6	66.4	
60	Background	2		2		2		2	YES
	Effluent	95.8	71.5	60.9	62.7	73.9	65.1	71.7	
61	Background	2		2		2		2	YES
	Effluent	125.7	135.0	59.7	60.4	50.5	66.8	83.0	
62	Background	2		2		2		2	YES
	Effluent	152.8	77.8	119.0	109.0	97.8	99.8	109.4	
63	Background	2		2		2		2	YES
	Effluent	113.0	105.0	105.0	154.6	89.6	112.0	113.2	
64	Background	2		2		2		2	YES
	Effluent	126.4	127.8	95.2	113.0	130.4	134.5	121.2	

Table 11 Cont'd

Run #	Run Time (min)	2	4	6	8	10	12	Average	QA/QC Compliance (background SSC < 20 mg/L)
	Suspended Sediment Concentration, SSC (mg/L)								
65	Background	2		2		2		2	YES
	Effluent	79.0	106.0	101.0	68.3	121.3	106.0	96.9	
66	Background	2		2		2		2	YES
	Effluent	105.0	126.2	104.0	132.2	95.1	104.0	111.1	
67	Background	2		2		2		2	YES
	Effluent	94.1	108.0	100.0	110.0	74.5	92.3	96.5	
68	Background	2		2		2		2	YES
	Effluent	103.0	126.0	133.7	98.7	112.0	149.1	120.4	
69	Background	2		2		2		2	YES
	Effluent	110.0	122.0	97.6	83.2	71.8	99.1	97.3	
70	Background	2		2		2		2	YES
	Effluent	111.0	91.5	97.8	74.7	87.4	119.0	96.9	
71	Background	2		2		2		2	YES
	Effluent	106.0	126.3	114.0	113.0	76.2	78.7	102.4	
72	Background	2		2		2		2	YES
	Effluent	139.3	97.7	151.4	120.0	87.5	116.0	118.7	
73	Background	2		2		2		2	YES
	Effluent	115.0	105.0	106.0	113.0	100.0	93.7	105.5	

Table 12 Sediment Mass Loading Removal Efficiency Results

Run #	Avg. Influent SSC (mg/L)	Adjusted Effluent SSC (mg/L)	Total Water Volume (L)	Average Drain Down SSC (mg/L)	Volume of Drain Down Water (L)	Removal Efficiency (%)		Mass Loading (Lbs.)	
						Individual	Cumulative	Individual	Cumulative
13	407.6	3.0	3811	2.0	62.1	99.3	97.4	3.399	23.437
14	411.0	5.8	3774	3.0	60.0	98.6	97.5	3.371	26.808
15	422.3	11.6	3805	6.8	60.8	97.3	97.5	3.445	30.253
16	403.7	14.0	3852	13.1	50.6	96.5	97.4	3.310	33.563
17	394.0	16.5	3822	12.2	66.0	95.8	97.3	3.182	36.745
18	406.7	22.1	3836	19.8	69.0	94.6	97.1	3.252	39.997
19	393.8	24.7	3837	20.1	69.7	93.7	96.8	3.123	43.120
20	386.3	28.5	3780	29.9	70.4	92.6	96.5	2.982	46.102

Table 12 Cont'd

Run #	Avg. Influent SSC (mg/L)	Adjusted Effluent SSC (mg/L)	Total Water Volume (L)	Average Drain Down SSC (mg/L)	Volume of Drain Down Water (L)	Removal Efficiency (%)		Mass Loading (Lbs.)	
						Individual	Cumulative	Individual	Cumulative
21	383.4	44.5	3800	49.2	73.7	88.4	96.0	2.838	48.940
22	388.0	40.7	3779	78.0	76.4	89.3	95.6	2.887	51.827
23	380.9	34.0	3777	59.1	77.6	90.9	95.4	2.884	54.710
24	382.5	31.2	3772	51.1	80.9	91.7	95.2	2.918	57.629
25	377.7	34.3	3788	56.4	78.7	90.8	94.9	2.864	60.493
26	417.6	36.8	3797	65.3	80.8	91.0	94.7	3.182	63.675
27	420.7	35.4	3809	79.4	82.5	91.4	94.6	3.227	66.903
28	420.7	35.4	3778	63.5	82.8	91.5	94.4	3.204	70.107
29	411.4	29.8	3788	58.6	79.4	92.6	94.3	3.182	73.289
30	419.9	38.8	3805	60.0	80.9	90.7	94.2	3.194	76.482
31	420.6	39.8	3793	84.8	84.1	90.3	94.0	3.177	79.659
32	419.5	46.6	3801	69.2	83.0	88.8	93.8	3.120	82.780
33	422.2	36.7	3780	59.3	85.3	91.2	93.7	3.208	85.988
34	411.7	33.6	3783	56.2	85.5	91.7	93.6	3.149	89.137
35	420.6	35.2	3789	72.3	85.5	91.4	93.6	3.213	92.349
36	421.3	31.3	3813	75.0	85.5	92.3	93.5	3.270	95.620
37	422.8	30.4	3802	71.2	86.8	92.6	93.5	3.281	98.901
38	416.7	60.4	3790	73.2	83.6	85.5	93.2	2.976	101.876
39	421.2	31.8	3799	75.2	86.7	92.2	93.2	3.252	105.128
40	415.9	47.1	3793	59.1	86.0	88.6	93.1	3.082	108.211
41	421.6	40.4	3783	62.5	84.8	90.3	93.0	3.175	111.386
42	419.0	35.7	3805	87.5	88.0	91.2	92.9	3.206	114.592
43	412.8	37.6	3801	89.2	89.5	90.6	92.9	3.134	117.726
44	421.2	35.7	3801	91.1	93.2	91.2	92.8	3.219	120.945
45	418.0	55.9	3797	55.2	92.5	86.6	92.7	3.032	123.977
46	414.9	48.6	3799	88.4	92.7	88.1	92.5	3.060	127.036
47	413.5	52.9	3804	74.9	93.1	87.1	92.4	3.020	130.056
48	411.6	66.2	3808	58.7	92.9	84.0	92.2	2.901	132.957
49	417.0	56.2	3793	94.7	93.4	86.3	92.1	3.010	135.967
50	421.7	52.1	3804	63.0	93.4	87.6	92.0	3.097	139.064
51	414.3	53.2	3801	77.4	89.6	87.0	91.9	3.021	142.086
52	408.4	54.6	3797	67.0	93.5	86.5	91.7	2.959	145.045

Table 12 Cont'd

Run #	Avg. Influent SSC (mg/L)	Adjusted Effluent SSC (mg/L)	Total Water Volume (L)	Average Drain Down SSC (mg/L)	Volume of Drain Down Water (L)	Removal Efficiency (%)		Mass Loading (Lbs.)	
						Individual	Cumulative	Individual	Cumulative
53	412.9	54.5	3798	104.0	94.1	86.5	91.6	2.990	148.036
54	412.8	59.4	3809	151.4	94.2	85.1	91.5	2.948	150.984
55	417.0	79.8	3801	92.6	94.4	80.8	91.3	2.824	153.807
56	415.0	52.4	3812	97.0	94.6	87.1	91.2	3.038	156.846
57	405.7	59.5	3813	130.3	91.6	84.9	91.1	2.896	159.741
58	414.5	60.2	3819	67.8	93.6	85.4	91.0	2.982	162.723
59	415.4	64.4	3809	139.4	93.6	84.1	90.8	2.932	165.656
60	415.8	69.7	3803	125.0	95.0	82.9	90.7	2.891	168.546
61	415.7	81.0	3809	89.7	94.0	80.5	90.5	2.809	171.355
62	410.2	107.4	3817	59.2	94.7	74.1	90.2	2.559	173.914
63	414.8	111.2	3800	122.0	97.3	73.1	89.9	2.541	176.455
64	416.0	119.2	3811	133.5	97.8	71.3	89.6	2.490	178.945
65	416.7	94.9	3801	81.0	97.5	77.3	89.4	2.700	181.645
66	412.9	109.1	3810	109.0	97.6	73.6	89.1	2.552	184.197
67	410.0	94.5	3803	111.0	98.2	76.9	88.9	2.641	186.839
68	413.5	118.4	3802	115.0	95.2	71.4	88.6	2.474	189.313
69	417.8	95.3	3799	82.6	97.5	77.3	88.4	2.704	192.017
70	413.8	94.9	3801	66.0	98.3	77.2	88.2	2.679	194.696
71	412.9	100.4	3799	104.0	98.8	75.7	88.1	2.617	197.313
72	413.2	116.7	3802	238.8	99.2	71.0	87.8	2.459	199.771
73	412.5	103.5	3802	390.3	99.5	73.1	87.6	2.527	202.299
Average Run Removal Efficiency (Runs 1 – 73):								87.6 %	
Captured Sediment Mass (Runs 1 – 73):								202 lbs.	

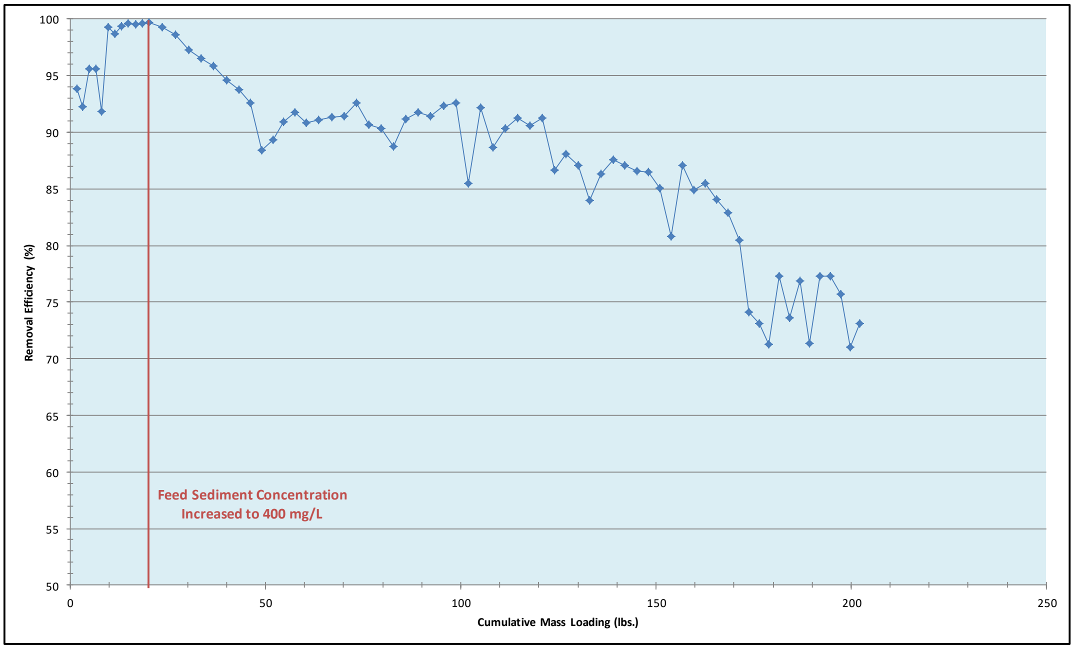

Figure 9 Removal Efficiency vs. Sediment Mass Loading for the Bio Clean™ MLS Filter

5.3 Filter Driving Head

The water level in the Bio Clean™ MLS Filter, as measured with the level data logger, has been reported in **Table 5** and **Table 10**. **Figure 10** illustrates the increase in water level inside the filter as sediment is captured.

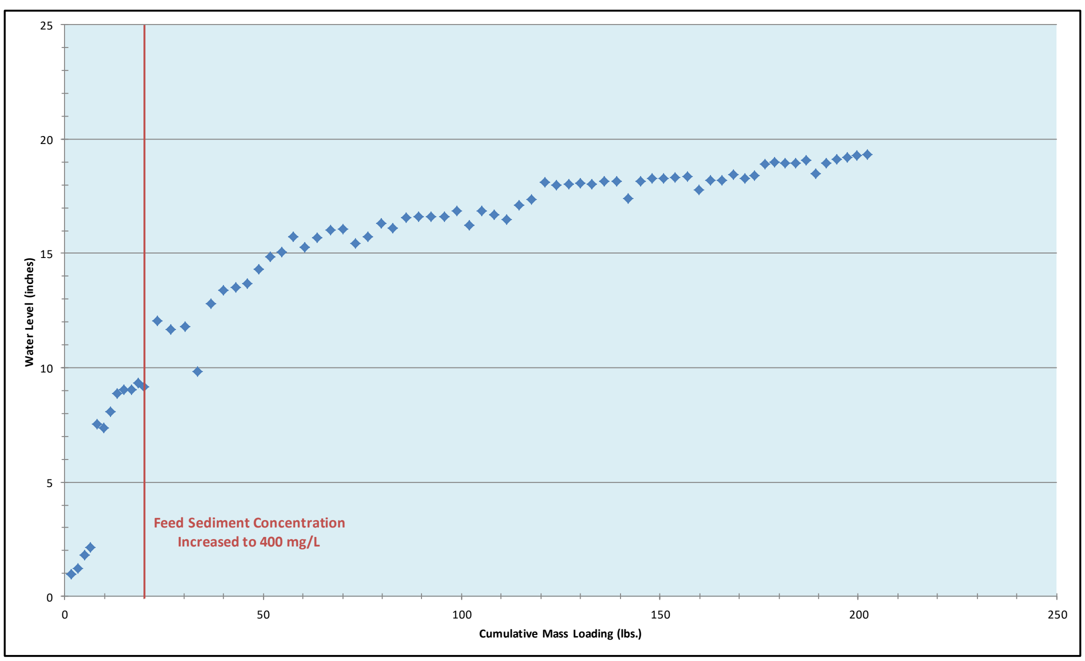

Figure 10 Increase in Head Loss vs. Sediment Mass Load

6. Maintenance Plans

The Bio Clean™ MLS Filter Operations and Maintenance Manual is available at:
http://www.biocleanenvironmental.com/wp-content/uploads/2018/11/Operations-Maintenance-Grate-Inlet-Filter-MLS-Type.pdf

Inspection Equipment

The following is a list of equipment used to allow for simple and effective inspection of the Bio Clean™ MLS Filter. It is recommended that a vacuum truck be utilized to minimize the time required to maintain the CBF, though it can easily be cleaned by hand:

- Bio Clean Environmental Maintenance Form (contained in O&M Manual).
- Manhole hook or appropriate tools to remove access hatches and covers (e.g., grates).
- Appropriate traffic control signage and procedures.
- Protective clothing and eye protection.
- Note: entering a confined space requires appropriate safety and certification. It is generally not required for routine maintenance of the system. A small or large vacuum truck, with pressure washer attachment, is preferred.

Inspection Procedures

The core to any successful stormwater BMP maintenance program is routine inspections. The inspection steps required on the Bio Clean™ MLS Filter are quick and easy. The first year should be seen as the maintenance interval establishment phase. During the first year more frequent inspections should occur in order to gather loading data and maintenance requirements for that specific site. This information can be used to establish a base for long-term inspection and maintenance interval requirements.

The Bio Clean™ MLS Filter can be inspected though visual observation. All necessary pre-inspection steps must be carried out before inspection occurs, such as safety measures to protect the inspector and nearby pedestrians from any dangers associated with an open grated or curb inlet. Once the grate or manhole has been safely removed the inspection process can proceed.

- Prepare the inspection form by writing in the necessary information including project name, location, date & time, unit number and other info (see inspection form).
- Observe the filter with the grate removed.
- Look for any out of the ordinary obstructions on the grate, catch basin or in the filter and its bypass. Write down any observations on the inspection form.
- Through observation and/or digital photographs estimate the amount of trash, foliage and sediment accumulated inside the filter basket. Record this information on the inspection form.
- Observe the condition and color of the hydrocarbon boom. Record this information on the inspection form.
- Finalize inspection report for analysis by the maintenance manager to determine if maintenance is required.

Based upon observations made during inspection, maintenance of the system may be required based on the following indicators:

- Missing or damaged internal components.
- Obstructions in the filter basket and its bypass.
- Excessive accumulation of trash, foliage and sediment in the filter basket. (Note. Maintenance is required when the basket is greater than half-full).

Maintenance Procedures

It is recommended that maintenance occurs at least two days after the most recent rain event to allow debris and sediments to dry out. Maintaining the system while flows are still entering it will increase the time and complexity required for maintenance. Cleaning of the Bio Clean™ MLS Filter can be performed utilizing a vacuum truck. Once all safety measures have been set up, cleaning of the filter can proceed as follows:

- Remove grate or manhole (traffic control and safety measures to be completed prior).
- Using an extension on a vacuum truck, position the hose over the opened catch basin. Insert the vacuum hose down into the filter basket and suck out trash, foliage and sediment. A pressure wash is recommended and will assist in spraying off any debris stuck on the side or bottom of the filter basket. Power wash off the filter basket sides and bottom.
- Next remove the hydrocarbon boom that is attached to the inside of the filter basket. Assess the color and condition of the boom. If replacement is required install and fasten on a new hydrocarbon boom. Booms can be ordered directly from the manufacturer.
- The last step is to replace the grate or manhole and remove all traffic control.
- All removed debris and pollutants shall be disposed of following local and state requirements.
- Disposal requirements for recovered pollutants may vary depending on local guidelines. In most areas the sediment, once dewatered, can be disposed of in a sanitary landfill. It is not anticipated that the sediment would be classified as hazardous waste.

In the case of damaged components, replacement parts can be ordered from the manufacturer. Hydrocarbon booms can also be ordered directly from the manufacturer as previously noted.

7. Scaling

Based on the test results of the Bio Clean™ Multi-Level Screening (MLS) Inlet Filter (Model BIO-GRATE-MLS -24-24-24) the MTFR of other model sizes has been determined based on the verified loading rate of 13.3 gpm/ft^2 of total screen surface area as shown in **Table 13**.

Table 13 Scaling of Bio Clean™ MLS Filter Models

Model Number[1]	Filter Diameter (ft)	Filter Height (ft)	Total Screen Surface Area (ft^2)	Loading Rate[2] (gpm/ft^2)	MTFR[3] (gpm)	MTFR (cfs)
BIO-GRATE -MLS-12-12-18	0.833	1.5	0.88	13.3	12	0.03
BIO-GRATE-MLS-18-18-18	1.333	1.5	3.56	13.3	47	0.11
BIO-CURB-MLS 20-24	1.5	2	5.92	13.3	79	0.18
BIO-GRATE-MLS-24-24-24	1.75	2	7.52	13.3	100	0.22
BIO-GRATE-MLS-30-30-24	2.25	2	10.78	13.3	143	0.32
BIO-GRATE-MLS-25-38-24	2.0	2	9.88	13.3	131	0.29
BIO-GRATE-MLS-36-36-24	2.75	2	14.45	13.3	192	0.43
BIO-GRATE-MLS-48-48-18	3.667	1.5	18.35	13.3	244	0.54

1. First two numbers of model number for grate types designate size of mounting flange in inches. Last number designates filter depth in inches. For curb type the first number designates flange diameter and second the filter depth. Other models available. Please contact manufacturer for available sizes and associated flow rates.
2. Based on tested flow rate of 100 gpm for the BIO-GRATE-MLS-24-24-24.
3. MTFR for shallower or deeper filters will be based upon 13.3 gpm/sq. ft of the total screen surface area.

8. Statements

The following attached pages are signed statements from the manufacturer (Bio Clean Environmental, Inc.), the testing lab (Good Harbour Labs), and NJCAT. These statements are a requirement of the verification process.

July 18, 2018

Dr. Richard Magee, ScD., P.E., BCEE
Executive Director, New Jersey Corporation for Advanced Technology

Re: Performance Verification of the Bio Clean™ Catch Basin Filter

Dear Dr. Magee,

Good Harbour Laboratories was contracted by Bio Clean Environmental Services Inc., A Forterra Company, to conduct a performance verification of their Catch Basin Filter in accordance, as nearly as possible, with New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January, 2013). The Catch Basin Filter is a slightly different application from a more typical vault filter and it was tested with a coarser material than specified in the protocol so the results are not intended for certification by the New Jersey Department of Environmental Protection (NJDEP). The D_{50} of the tested sediment was 167 µm.

Good Harbour Laboratories is an independent hydraulic test facility located in Mississauga, Ontario Canada. I certify that we have evaluated the Bio Clean™ Catch Basin Filter from March 21-26 and May 24-June 11, 2018 according to the aforementioned test protocol. The results presented in the NJCAT Verification Report dated July, 2018 are accurate and all procedures and requirements stated in the test protocol were met or exceeded, with the exception noted previously. Good Harbour Laboratories has no vested interest in the test results or financial conflict of interest in providing independent testing services to BioClean Environmental Services Inc.

Sincerely,

Dr. Greg Williams, P.Eng.
Managing Director, Good Harbour Laboratories

Good Harbour Laboratories
T: 905.696.7276 | F: 905.696.7279
A: 2596 Dunwin Drive, Mississauga, ON L5L 1J5
www.goodharbourlabs.com

Bio Clean
A Forterra Company

Date 7/17/2018

To Whom It May Concern,

We are providing this letter as our statement certifying that the protocol titled New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 25, 2013) has been strictly followed with these exceptions. A larger particle size distribution (PSD) was used having a mean of 167 microns (d50) which replicates a size more commonly found as an influent entering catch basins on roadways and parking lots.

With exception of the above deviations, we certify that all requirements and criteria were met and/or exceeded during testing of the Bio Clean™ Catch Basin Filter.

If you have any questions please contact us at your convenience.

Sincerely,

Zachariha J. Kent
Vice President of Research & Development and Regulatory Compliance
Bio Clean, a Forterra Company.

Signature: ______________________ Date: 7/17/2018

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Center for Environmental Systems

Stevens Institute of Technology

One Castle Point

Hoboken, NJ 07030-0000

September 4, 2018

Mr. Zach J. Kent
VP of Product Development & Regulatory Compliance
Bio Clean Environmental Services Inc.
398 Via El Centro
Oceanside, CA 92058

Dear Mr. Kent,

Based on my review, evaluation and assessment of the testing on the Bio Clean™ MLS Filter conducted by Good Harbour Laboratories, Ltd., Mississauga, Ontario, Canada, the test protocol requirements contained in the *"New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device"* (NJDEP Filter Protocol) were met with one exception: the sediment test particle size distribution (PSD) was coarser than specified in the NJDEP protocol. Consequently, the verification report does not qualify for NJDEP certification.

Test Sediment Feed -The mean PSD of the test sediment utilized for removal efficiency testing was significantly coarser than the PSD criteria established by the NJDEP Filter protocol (167 µm vs 75 µm).

Removal Efficiency Testing – The Bio Clean™ MLS Filter Model 24-24-24 achieved an overall removal efficiency of 86.6% of the test sediment (d_{50} of 167 µm) prior to reaching the sediment mass loading capacity.

Sediment Mass Loading Capacity – The sedimentation mass loading capacity of the Bio Clean™ MLS Filter Model 24-24-24 was determined to be 199.3 lbs.

All other criteria and requirements of the NJDEP Filter Protocol were met. These include: flow rate measurements COV <0.03; test sediment influent concentration COV <0.10; test sediment influent concentration within 10% of the targeted value of 200 mg/L (or 400 mg/L); influent background concentrations <20 mg/L; and water temperature <80 ^{o}F.

Sincerely,

Richard S. Magee

Richard S. Magee, Sc.D., P.E., BCEE
Executive Director

8. References

1. NJDEP 2013. New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device. January 25, 2013.

2. GHL Laboratory Notebook: A020, pp. 129-160; A021, pp. 1-36