NJCAT TECHNOLOGY VERIFICATION

Up-Flo® Filter EMC

(Extended Maintenance Cartridge)

Hydro International

January 2020

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1. Description of Technology

The Up-Flo® Filter EMC (Extended Maintenance Cartridge) is a stormwater treatment device that incorporates gravitational separation of floating and settling materials with filtration of polluted stormwater to offer treatment train capabilities in a standalone device. Each Up-Flo® Filter product consists of a highly configurable array of cartridges containing engineered filtration media that can be employed as an upward flow media bed filter or as an upward flow membrane filter that utilizes filter ribbons as the media type. The Up-Flo Filter® EMC, a membrane filter, was tested and used for this verification report. Testing and results in this report differ from the December 2016 NJCAT verification report for Up-Flo® Filter with Ribbons given a new configuration of filter ribbons within a cartridge that backwashes the filter material at the end of every storm **(Figure 1)**.

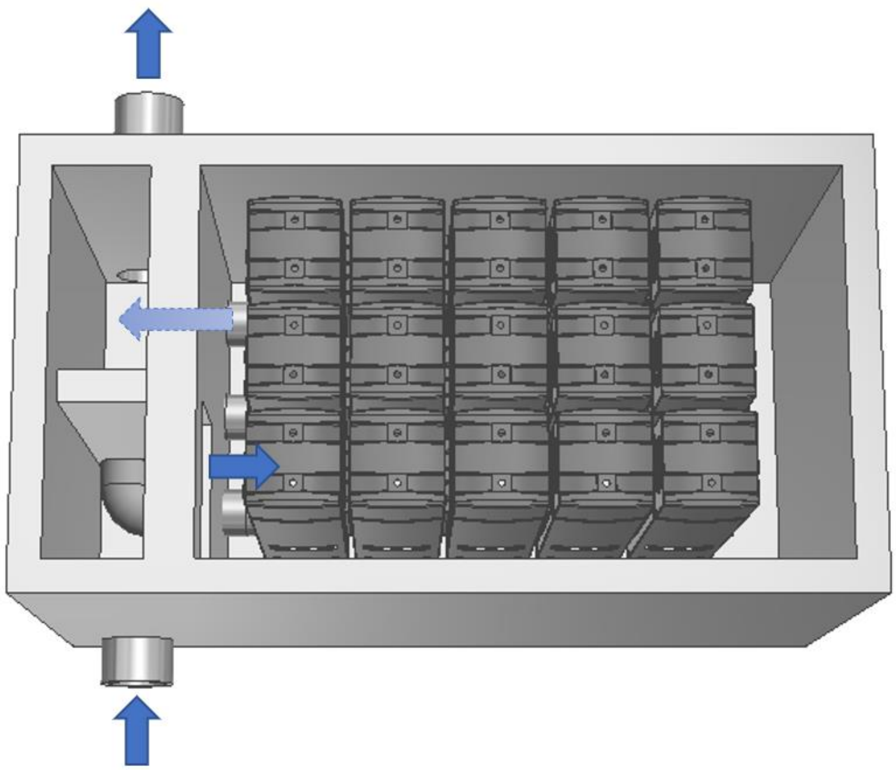

Figure 1 Up-Flo® Filter Configured with Extended Maintenance Cartridge

Operation of the Up-Flo® Filter EMC is initiated during a rainfall event when stormwater is conveyed into the chamber from a pipe or grated inlet. As flow enters the chamber, internal components act as baffles to force gross debris and sediment to settle into the sump and floating debris to rise to the surface.

At the beginning of a storm event, water is introduced to a treatment vault where one or more Up-Flo® Filter EMC cartridges are located. As the water level in the vault increases it starts filling the inside of the filtration zone **(Figure 2)**. As the water level continues to rise past the manifold plate, it is forced to pass through the filter ribbon membranes. The filtered water enters the backwash reservoir through the openings in the manifold. Once the water level reaches the syphon inlet, the syphon is initiated, and the cartridge begins discharging filtered water via the vertical syphon tube into a discharge piping system. The water level in the vault outside of the cartridge will equalize depending on the actual flow rate and occlusion of the filter ribbons.

At the end of a storm event, the water level in the treatment vault drops until the water surface reaches the lower cutout of the filter housing. Air starts entering the system and percolates through the filter ribbons into the backwash reservoir and syphon tube inlet. When enough air has been accumulated, the syphon will break and cease discharging flow from the vault. Since the water in the backwash reservoir is no longer held in place by negative pressure, the remaining backwash water will release from its reservoir causing a reverse flow through the filter membranes. This directional change of the flow and high energy backwash helps to dislodge sediment captured on the filter membranes and thereby extends the life of the filter.

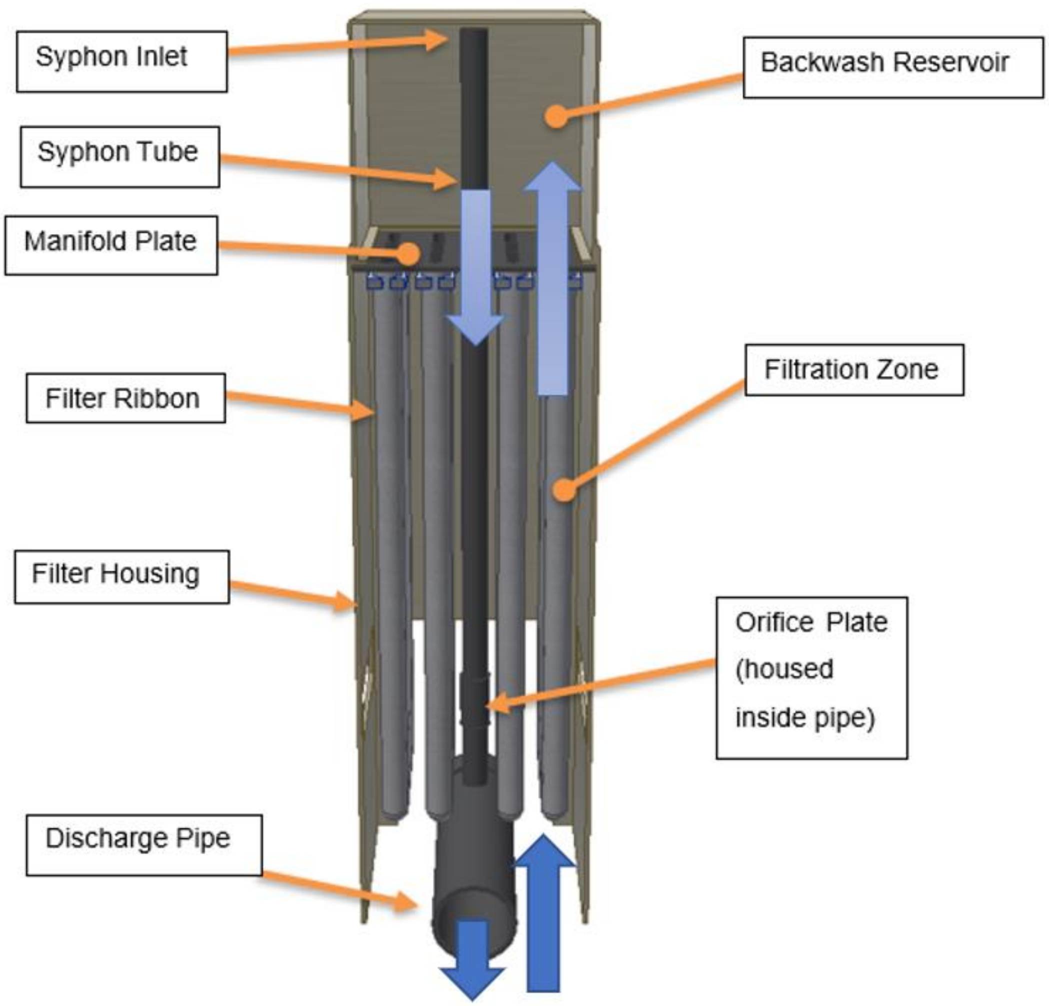

Figure 2 Cut-away of Up-Flo® Filter EMC Showing Filter Ribbons

2. Laboratory Testing

The New Jersey Department of Environmental Protection (NJDEP) maintains a list of certified stormwater manufactured treatment devices (MTDs) that can be installed on newly developed or redeveloped sites to achieve stormwater treatment requirements for Total Suspended Solids (TSS). Manufactured treatment devices are evaluated for certification according to the *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices (January 2013*) (heretofore referred to as "NJDEP Approval Process"). The NJDEP Approval Process requires that TSS treatment devices operating on filtration principles be tested according to the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device* (heretofore referred to as "NJDEP Protocol"). In addition, the NJDEP Approval Process requires submittal of a Quality Assurance Project Plan (QAPP) to the New Jersey Corporation for Advanced Technology (NJCAT) for review and approval prior to testing to ensure that all laboratory procedures will be conducted in strict accordance with the NJDEP Protocol. The QAPP was submitted and approved by NJCAT in May 2019 prior to commencement of testing.

Testing was conducted in May through September 2019 by Hydro International (Hydro) at the company's full-scale hydraulic testing facility in Portland, Maine. Since testing was carried out in-house, Hydro contracted with FB Environmental to provide protocol required third party oversight. FB Environmental representatives were present during all testing procedures. The test program was conducted in accordance with the NJDEP Protocol in two phases: removal efficiency testing and sediment mass loading capacity testing.

The Up-Flo® Filter is supplied as a complete system housed in a precast vault. While this test plan includes procedures that test only one filter cartridge, the NJDEP Protocol allows for scaling rules to be applied to larger commercially available systems using the scaling ratios described in Section 4 of the Protocol. Additionally, these scaling ratios will be used to scale flow rates and allowable treatment areas for shorter filter ribbon and cartridge assemblies.

2.1 Test Setup

A schematic drawing of the laboratory setup is shown in **Figure 3** and key dimensions of the filter test tank are shown in **Figure 4**. Operating as a recirculating closed loop system, a 2,000-gallon supply tank is filled with clean water and is used to fill a secondary supply tank (constant head tank) that maintains a constant head throughout each test run. Opening a butterfly valve near the bottom of the constant head tank allows water to flow through a G2 turbine flow meter and into the test vessel containing the filter cartridge. Discharge from the filter cartridge leaves the test vessel through 4-inch discharge piping. This discharge falls freely into a 200-gallon discharge tank. Once the water elevation in the discharge tank reaches a predetermined level, the treated water is pumped through a fine filtration system that reduces sediment background concentrations before returning to the supply tank. A control loop with a heater and heater pump maintain the water temperature in the supply tank.

Background samples were taken with 1-liter wide mouth bottles at the background sample port located 15.5 inches upstream of the Up-Flo Filter EMC test tank. The port was operated with a 1-

inch ball valve. Before a sample was taken, the line was flushed to ensure influent background samples were representative. The time each background and effluent sample was collected was recorded so that samples could be time stamped.

Water temperature was measured in the constant head tank with a thermocouple connected to the data acquisition unit. This is a representative location to measure water temperature because all test water must pass through this tank immediately before passing through the rest of the test setup. Maximum temperature remained below 80°F for the duration of the test. Temperature was recorded every 10 seconds. The original thermocouple calibration was confirmed by the independent observer prior to testing.

A data acquisition unit, the DATAQ DI-245, is connected to a computer system running WINDAQ software. The flow meter, Dwyer pressure transducer and thermocouple are connected to the DATAQ unit. Test data is recorded throughout the test, saved and submitted with the test report.

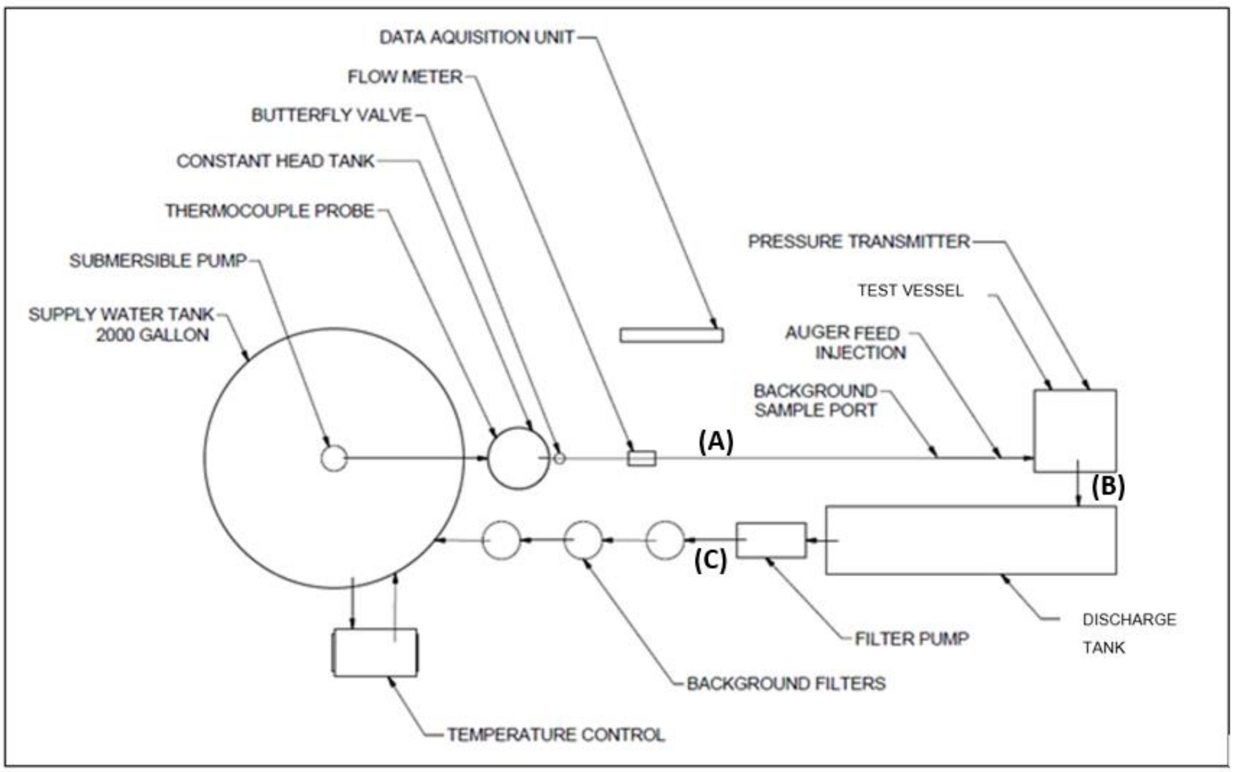

Figure 3 Laboratory Testing Arrangement Diagram. Pipe sizes as follows: (A) 1-1/2-inch inlet piping, (B) 4-inch discharge pipe, (C) 2-inch return piping

Test Unit Description

The Filter Test Tank (**Figure 4**) included one full-scale commercially available Up-Flo® Filter EMC Cartridge fitted with four 32-inch filter ribbons. The internal dimensions of the test vessel are 15.5 inches square (1.7 square feet) and 60 inches high. A background sample port is located 15.5 inches from the test vessel inlet and the auger feed port is located 7 inches from the test vessel inlet. The 1.5-inch diameter inlet center-line is located 62.5 inches from the test vessel floor. The filter discharge port is on the adjacent side and the invert is 2 inches from the test vessel floor. The maximum design driving head is represented by the top of the filter cartridge 48 inches above the discharge invert. The filter test vessel dimensions were confirmed by the independent observer.

The inlet pipe is fitted with a tee to distribute flow around the filter cartridge as it enters the test vessel. The filter cartridge discharge pipe is mounted to the side of the test vessel at the filtrate discharge port. Treated discharge from the filter cartridge is discharged through the wall of the test vessel through a 4-inch pipe.

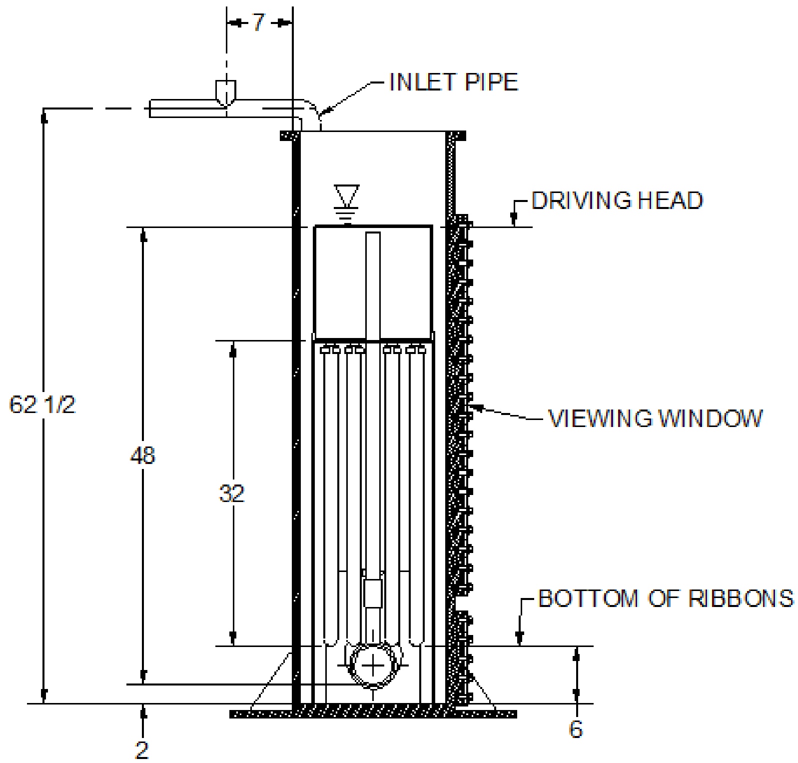

Figure 4 Key Dimensions of Test Vessel

Head measurements are determined by measuring the height of water in the filter test tank relative to the discharge pipe invert, not the sump floor. Given the syphon cartridge is 48 inches from the invert of the discharge pipe, this water level is referred to as the "maximum driving head".

2.2 Test Sediment

The test sediment was a blend of commercially available silica sand grades. The sediment was blended by Hydro and the particle size distribution was independently verified by GeoTesting Express of Acton, Massachusetts certifying that the supplied silica meets the specification within tolerance as described in Section 5B of the protocol. Results of particle size gradation testing are shown in **Table 1** and **Figure 5** below. The D_{50} of the test sediment blend is 60 microns.

Table 1 Particle Size Distribution Results of Test Sediment Samples

Particle Size (µm)	% Finer				Test Sediment Average	Diff. from Protocol
	Protocol	Sample 1	Sample 2	Sample 3		
1000	100	100	100	100	100.00	0.0
500	95	99	99	99	99.00	-4.0
250	90	95	94	95	94.67	-4.7
150	75	86	83	86	85.00	-10.0
100	60	66	66	66	65.83	-5.8
75	50	54	58	54	55.33	-5.3
50	45	44	50	45	46.42	-1.4
20	35	34	37	34	34.98	0.0
8	20	19	22	19	20.04	0.0
5	10	12	16	14	13.85	-3.8
2	5	7	11	8	8.48	-3.5

Figure 5 Average PSD of Test Sediment Compared to Protocol Specification

2.3 Sediment Removal Efficiency Testing

The Up-Flo® Filter EMC performance was determined by testing its sediment removal efficiency. In accordance with the NJDEP filtration protocol Section 5, this was tested in the laboratory by seeding the system with a known test sediment gradation and determining what proportion of the material is retained within the filtration device. The removal efficiency testing occurred by repeatedly testing the unit at the maximum treatment flow rate (MTFR) for 10 repetitions as specified in the Protocol.

Background samples were taken at the background sample port located upstream of the Up-Flo® Filter EMC test setup. Influent background samples were taken in correspondence with the odd numbered effluent samples (first, third, and fifth). The time each background and effluent sample was collected was recorded. The background data was used to adjust the effluent samples for background concentration.

The test sediment feed rate and total mass of test sediment introduced during each test run was a known quantity. The target influent concentration was 200 mg/L. Total mass introduced was determined by weighing the mass in the auger hopper at the start and end of the test with an Ohaus D25WR laboratory balance.

Three sediment feed calibration samples were taken from the injection point at the start, middle and just prior to the conclusion of dosing during each test. Samples were taken by interrupting the dry sediment feed from the auger and weighing a one-minute sample with an Ohaus AX224 laboratory balance. The concentration coefficient of variance (COV) of these samples was not to exceed 0.10.

A G2 turbine flow meter is located between the filter test tank and constant head tank, 47 inches from the latter. Flow rates are recorded every 10 seconds. The flow meter calibration was confirmed by the independent observer using the "time to fill" method prior to testing.

Water level in the filter test tank was measured with a Dwyer pressure transducer located in the bottom of the tank. The water level was recorded every 10 seconds. The Dwyer pressure transducer calibration was confirmed by the independent observer prior to testing.

Once a constant feed of test sediment and flow rate was established, the first effluent sample was collected after a minimum of three MTD detention times had passed. The effluent samples were collected from the test vessel discharge pipe and time stamped in 1-liter bottles using the grab sample method as described in Section 5G of the Protocol.

The time interval between sequential samples was evenly spaced during the test sediment feed period to achieve six effluent samples. However, when the test sediment feed was interrupted for measurement, the next effluent sample collected was following a minimum of three MTD detention times. An example sampling schedule is given in **Table 2**.

Table 2 Example Sampling Time for TSS Removal Efficiency Testing

Sampling Schedule 100% MTFR			
Time	Auger Feed Sample	Effluent Sample	Background Sample
0:00:00	1		
0:10:11		1	1
0:12:11		2	
0:14:11		3	2
0:16:11	2		
0:26:21		4	
0:28:21		5	3
0:30:21		6	
0:32:21	3		

All effluent samples were analyzed for TSS in accordance with ASTM 3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples." Samples were sealed by the independent observer and delivered to Maine Environmental Laboratory of Yarmouth, Maine (NELAC Accredited and certified by the states of Maine and New Hampshire) for processing.

The removal efficiency of the filter is determined by calculating the mass of test media introduced to the system during sediment addition and subtracting the calculated mass leaving the system during that same time period. At the end of the test, a small volume of treated water remains in the system until the syphon breaks. This operational water volume is calculated using the system geometry and the resulting mass is subtracted from the captured mass along with the calculated effluent mass. As described above, removal efficiency was calculated per **Equation 1**.

$$Removal\ Eff.(\%) = \frac{\begin{pmatrix} Avg.Inf.TSS\ Conc.\times \\ Total\ Vol.of \\ Test\ Water\ during\ Sed.Add. \end{pmatrix} - \begin{pmatrix} Adj.Eff.TSS\ Conc.\times \\ Total\ Vol.of \\ Test\ Water\ during\ Sed.Add. \end{pmatrix} - \begin{pmatrix} Adj.Eff.TSS\ Conc.\times \\ Operational\ Water\ Vol. \\ Remaining\ in\ System \end{pmatrix}}{Avg.Inf.TSS\ Conc.\times Total\ Vol.of\ Test\ Water\ during\ Sed.Add.} \times 100$$

Equation 1 Equation for Calculating Removal Efficiency

2.4 Sediment Mass Loading Capacity Testing

Upon completing the Removal Efficiency Testing, the protocol continued with Sediment Mass Loading Capacity Testing used to determine the maximum mass of test sediment that can be captured by the MTD at the MTFR prior to passing the maximum driving head. The influent flow rate was then reduced to 90% of the MTFR and testing continued until the maximum driving head was again exceeded.

2.5 Scour Testing

No scour testing was conducted. The efficiency measurements produced will be applicable to off-line configurations designed to divert flows in excess of the MTFR away from the filter cartridges.

2.6 Quality Objectives and Criteria

Samples sent to the external lab were shipped to the lab for analysis as soon as possible following the test run. Samples analyzed in-house were observed by the third-party witness and were conducted immediately following sample collection.

A Chain of Custody form was used for externally analyzed samples to record sample containers and sampling date and time for each test run. A copy of these forms was also maintained by Hydro. Sample bottles were labeled to identify the test run and sample type (background or effluent), which corresponded to the sample identification on the Chain of Custody form. All sample marking and transportation was conducted by the third-party witness.

Data were recorded and maintained in accordance with standard laboratory procedures used at Hydro. Hard copies of all original data sets are maintained on site.

The following quality criteria were used to compare to results from individual test runs:

- Background TSS concentrations exceed 20 mg/L
- Temperature of test water exceeds 80 degrees Fahrenheit
- Variation in calculated influent concentration exceeds 10% of target concentration
- COV of dry calibration samples exceeds 0.10

The 2013 protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device published by the NJDEP specifies that flow rates used in testing HDS systems must not vary more than 10% from the target flow rate and must maintain a COV of 0.03. This guidance and prior filtration testing precedent was used as a guideline for the filter test program.

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the Up-Flo® EMC Filter, the following are the performance claims made by Hydro.

Total Suspended Solids (TSS) Removal Efficiency

The Up-Flo® Filter when configured with Extended Maintenance Cartridges, housed in a 1.7 square foot test vessel with 6 inch sump operating under a hydraulic loading rate of 17 gpm per Filter Cartridge and evaluated in accordance with the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device* achieved a cumulative removal efficiency of the NJDEP specified gradation of silica of 82.48%.

Maximum Treatment Flow Rate (MTFR)

The MTFR for the tested Up-Flo® Filter EMC system equates to 17 gpm per 48-inch cartridge. For other size cartridges, this equates to 0.96 gpm per square foot of filter media.

Effective Sedimentation Area

The Effective Sedimentation Area is the surface area of a 15.5-inch square tank. This is 240.25 square inches and equates to 1.7 square feet.

Wet Volume and Detention Time

The Wet Volume is defined as the sump and wet influent piping of a filtration MTD and is determined by the maximum driving head above the floor of the test vessel and area of the filter test tank or 50 inches × 240.25 square inches. The resulting Wet Volume was 7 cubic feet (197 liters or 52 gallons). This corresponded to a detention time of 184 seconds at the MTFR.

Effective Filtration Treatment Area

As tested, the effective filtration treatment area (EFTA) for a single filter ribbon insert is 32 inches long and 10 inches wide or 320 square inches. Flow enters from both sides of the ribbon, so the total filtration area is 640 square inches per ribbon and 2560 square inches (17.78 square feet) for the four ribbons installed in the single cartridge test set up.

Minimum Sedimentation Area

The minimum sedimentation area for a single backflush cartridge with four filter ribbons is 1.7 square feet of sedimentation area per 2560 square inches of filter ribbon or 0.096 square feet of sedimentation area per square foot of EFTA.

Sediment Mass Load Capacity

Considering the change in operating head relative to the sediment mass captured, the Up-Flo® Filter EMC has a mass loading capacity of 97 lbs per 48-inch cartridge. For other size cartridges, this equates to 5.46 lbs per square foot of EFTA.

Maximum allowable inflow drainage area

To ensure the drainage area and expected annual sediment load does not cause higher than intended bypass flows, the sediment mass capture capacity of 97 pounds per cartridge is used to limit the treatable drainage area per cartridge. Given the protocol requirements for "Maximum Allowable Inflow Drainage Area" the Up-Flo® Filter EMC with 48-inch cartridges can effectively treat 0.16 acres per cartridge at 600 lbs per acre of drainage area annually. For other size cartridges, this equates to 0.01 acres per square foot of EFTA.

4. 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. This information was provided to NJCAT and is available upon request.

4.1 Removal Efficiency

During initial testing, 10 removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate and influent sediment concentration were 17 gpm and 200 mg/L respectively.

The flow meter and data logger took a reading every 10 seconds. The flow data has been summarized in **Table 3** including the compliance to the QA/QC acceptance criteria. The average flow rate for all removal efficiency runs was 16.94 gpm. The maximum temperature data is summarized in **Table 4**.

Influent Sediment Concentrations are summarized in **Table 5**, Background Sediment Concentrations are summarized in **Table 6**, and Adjusted Effluent Concentrations are summarized in **Table 7**, along with compliance to NJDEP protocol QA/QC criteria.

The remaining tables report all other parameters measured that are required to demonstrate compliance to NJDEP protocol QA/QC criteria. **Table 8** summarizes the cumulative removal efficiencies for the first 10 test runs. The cumulative removal efficiency for test runs 1-10 was 82.48%.

Table 3 Removal Efficiency Flow Rates

Run #	Target Flow Rate (gpm)	Average Flow Rate (gpm)	Var. (gpm)	% Var.	QA/QC (Var < 10%)	COV	QA/QC (COV < 0.03)
1	17.00	17.01	0.01	0.05%	YES	0.004	YES
2	17.00	17.00	0.00	0.01%	YES	0.005	YES
3	17.00	16.96	0.04	0.21%	YES	0.004	YES
4	17.00	16.96	0.04	0.26%	YES	0.004	YES
5	17.00	16.92	0.08	0.46%	YES	0.004	YES
6	17.00	17.00	0.00	0.01%	YES	0.005	YES
7	17.00	16.91	0.09	0.53%	YES	0.004	YES
8	17.00	16.84	0.16	0.92%	YES	0.004	YES
9	17.00	16.88	0.12	0.72%	YES	0.004	YES
10	17.00	16.96	0.04	0.23%	YES	0.004	YES
AVG	**17.00**	**16.94**	**0.06**	**0.34%**		**0.004**	

Table 4 Removal Efficiency Maximum Temperatures

Run #	Maximum Temp (F)	QA/QC (< 80 F)
1	78.05	YES
2	79.07	YES
3	75.68	YES
4	75.42	YES
5	76.21	YES
6	76.21	YES
7	75.68	YES
8	76.21	YES
9	77.13	YES
10	77.66	YES
AVG	**76.73**	

Table 5 Removal Efficiency Influent Sediment Concentrations

Run #	Target Conc. (mg/L)	Inf. Conc. (mg/L)	Var. (mg/L)	% Var.	QA/QC Var<10%	Feed Rate Samples (mg/s)			COV	QA/QC COV<0.1
1	200	199.22	0.78	0.39%	YES	199.50	209.62	209.07	0.028	YES
2	200	213.43	13.43	6.72%	YES	213.53	219.40	216.68	0.014	YES
3	200	202.48	2.48	1.24%	YES	209.00	217.53	215.77	0.021	YES
4	200	214.64	14.64	7.32%	YES	215.15	226.40	225.05	0.028	YES
5	200	200.31	0.31	0.16%	YES	199.00	208.90	207.83	0.026	YES
6	200	218.47	18.47	9.23%	YES	209.93	238.63	225.88	0.064	YES
7	200	206.77	6.77	3.39%	YES	206.50	217.40	214.03	0.026	YES
8	200	191.03	8.97	4.48%	YES	202.55	204.15	198.37	0.015	YES
9	200	188.51	11.49	5.74%	YES	203.52	195.73	199.30	0.020	YES
10	200	199.62	0.38	0.19%	YES	207.12	207.22	208.58	0.004	YES
AVG	**200**	**203.45**	**7.77**	**3.89%**					**0.024**	

Table 6 Removal Efficiency Background Sediment Concentrations

Run #	Background Samples (mg/L)			Mean (mg/L)	QA/QC (Max<20 mg/L)
1	3.50	0.80	1.20	1.833	YES
2	4.20	3.40	4.80	4.133	YES
3	1.70	1.20	2.30	1.733	YES
4	3.90	3.50	4.50	3.967	YES
5	2.20	2.80	6.60	3.867	YES
6	8.00	8.10	7.10	7.733	YES
7	1.80	0.90	2.20	1.633	YES
8	3.80	3.60	4.30	3.900	YES
9	2.40	0.70	7.20	3.433	YES
10	5.50	4.30	5.10	4.967	YES

Table 7 Removal Efficiency Effluent Concentrations

Run #	Effluent Samples (mg/L)						Mean (mg/L)
1	35	36	37	39	38	40	37.5
2	43	44	44	45	46	46	44.7
3	38	40	39	39	40	39	39.2
4	42	43	42	43	44	46	43.3
5	36	38	37	36	38	42	37.8
6	45	46	50	46	44	45	46.0
7	32	34	32	37	35	37	34.5
8	35	37	36	37	37	39	36.8
9	26	28	30	32	33	32	30.2
10	34	36	34	38	37	37	36.0

Table 8 Removal Efficiency Results

Run #	Inf. Conc. (mg/L)	Avg. Eff. Conc (mg/L)	Avg. Bkg. Conc (mg/L)	Avg. Adj. Eff. Conc. (mg/L)	Test Vol. (L)	Mass Added (kg)	Test Mass Escaped (kg)	Op Vol Mass Escaped (kg)	Cumulative Mass Captured (kg)	Run Efficiency	Cumulative Removal Efficiency
1	199.223	37.500	1.833	35.667	1954.017	0.389	0.070	0.001	0.318	81.72%	81.72%
2	213.435	44.667	4.133	40.533	1953.212	0.417	0.079	0.002	0.654	80.60%	81.14%
3	202.481	39.167	1.733	37.433	1949.037	0.395	0.073	0.002	0.974	81.11%	81.13%
4	214.640	43.333	3.967	39.367	1948.065	0.418	0.077	0.002	1.314	81.26%	81.16%
5	200.310	37.833	3.867	33.967	1944.147	0.389	0.066	0.001	1.636	82.67%	81.46%
6	218.468	46.000	7.733	38.267	1953.299	0.427	0.075	0.002	1.986	82.11%	81.57%
7	206.771	34.500	1.633	32.867	1942.768	0.402	0.064	0.001	2.323	83.76%	81.88%
8	191.033	36.833	3.900	32.933	1935.064	0.370	0.064	0.001	2.627	82.39%	81.94%
9	188.511	30.167	3.433	26.733	1938.966	0.366	0.052	0.001	2.940	85.51%	82.31%
10	199.624	36.000	4.967	31.033	1948.672	0.389	0.060	0.001	3.267	84.12%	82.48%

4.2 Sediment Mass Loading Capacity

The Sediment Mass Loading Capacity study was a continuation of the removal efficiency study. As required by the protocol, all aspects of the testing remained the same, except for the flow rate which was reduced to 90% of the MTFR after the maximum driving head was exceeded.

In this portion of the test protocol a target influent concentration of either 200 or 400 mg/L is allowable. The unit was tested at 400 mg/L for Tests 11-27 after which it was reduced back down to 200 mg/L for the remainder of the testing. Maximum driving head of 48 inches was reached at Test Run 109 and the flow rate was reduced to 90% of the MTFR (15.3 gpm) for Test Runs 110-117. During test run 117 the maximum driving head was exceeded again and the test program was ended.

The relationship between removal efficiency and sediment mass loading is illustrated in **Figure 6**. A summary of the Sediment Mass Loading Capacity flow rate is shown in **Table 9.** Also included are recorded maximum temperatures **(Table 10)**, Influent Concentrations **(Table 11)**, Background Concentrations **(Table 12)**, Effluent Concentrations **(Table 13)** and Removal Efficiencies **(Table 14).**

Table 9 Mass Load Capacity Flow Rates

Run #	Target Flow Rate (gpm)	Average Flow Rate (gpm)	Variance (gpm)	% Var	QA/QC (Var < 10%)	COV	QA/QC (COV < 0.03)
11	17.00	16.93	0.07	0.44%	YES	0.004	YES
12	17.00	17.05	0.05	0.28%	YES	0.004	YES
13	17.00	17.03	0.03	0.19%	YES	0.005	YES
14	17.00	17.03	0.03	0.18%	YES	0.005	YES
15	17.00	16.91	0.09	0.54%	YES	0.004	YES
16	17.00	16.93	0.07	0.40%	YES	0.004	YES
17	17.00	16.95	0.05	0.29%	YES	0.004	YES
18	17.00	16.90	0.10	0.60%	YES	0.004	YES
19	17.00	16.87	0.13	0.74%	YES	0.004	YES
20	17.00	16.97	0.03	0.20%	YES	0.004	YES
21	17.00	17.00	0.00	0.02%	YES	0.005	YES
22	17.00	17.01	0.01	0.05%	YES	0.004	YES
23	17.00	16.91	0.09	0.55%	YES	0.004	YES
24	17.00	17.03	0.03	0.17%	YES	0.005	YES
25	17.00	17.00	0.00	0.01%	YES	0.004	YES
26	17.00	17.04	0.04	0.25%	YES	0.005	YES
27	17.00	17.02	0.02	0.11%	YES	0.004	YES
28	17.00	16.98	0.02	0.15%	YES	0.005	YES
29	17.00	16.94	0.06	0.34%	YES	0.004	YES

Run #	Target Flow Rate (gpm)	Average Flow Rate (gpm)	Variance (gpm)	% Var	QA/QC (Var < 10%)	COV	QA/QC (COV < 0.03)
30	17.00	16.87	0.13	0.78%	YES	0.004	YES
31	17.00	16.95	0.05	0.28%	YES	0.004	YES
32	17.00	16.89	0.11	0.65%	YES	0.004	YES
33	17.00	16.97	0.03	0.20%	YES	0.004	YES
34	17.00	16.92	0.08	0.48%	YES	0.004	YES
35	17.00	16.95	0.05	0.32%	YES	0.004	YES
36	17.00	17.00	0.00	0.01%	YES	0.004	YES
37	17.00	16.98	0.02	0.12%	YES	0.004	YES
38	17.00	16.97	0.03	0.17%	YES	0.004	YES
39	17.00	16.96	0.04	0.23%	YES	0.004	YES
40	17.00	17.00	0.00	0.03%	YES	0.004	YES
41	17.00	16.97	0.03	0.16%	YES	0.004	YES
42	17.00	16.98	0.02	0.15%	YES	0.004	YES
43	17.00	16.99	0.01	0.03%	YES	0.004	YES
44	17.00	16.94	0.06	0.38%	YES	0.003	YES
45	17.00	17.01	0.01	0.07%	YES	0.004	YES
46	17.00	16.94	0.06	0.34%	YES	0.004	YES
47	17.00	16.92	0.08	0.50%	YES	0.004	YES
48	17.00	16.98	0.02	0.10%	YES	0.004	YES
49	17.00	16.96	0.04	0.24%	YES	0.004	YES
50	17.00	16.95	0.05	0.31%	YES	0.004	YES
51	17.00	16.93	0.07	0.44%	YES	0.004	YES
52	17.00	16.99	0.01	0.05%	YES	0.004	YES
53	17.00	16.95	0.05	0.30%	YES	0.004	YES
54	17.00	16.92	0.08	0.46%	YES	0.004	YES
55	17.00	16.95	0.05	0.29%	YES	0.004	YES
56	17.00	16.96	0.04	0.22%	YES	0.004	YES
57	17.00	16.97	0.03	0.16%	YES	0.004	YES
58	17.00	16.95	0.05	0.27%	YES	0.004	YES
59	17.00	16.91	0.09	0.54%	YES	0.004	YES
60	17.00	16.95	0.05	0.32%	YES	0.004	YES
61	17.00	17.00	0.00	0.00%	YES	0.004	YES
62	17.00	16.99	0.01	0.06%	YES	0.004	YES
63	17.00	17.02	0.02	0.09%	YES	0.004	YES
64	17.00	16.94	0.06	0.38%	YES	0.004	YES
65	17.00	16.96	0.04	0.22%	YES	0.004	YES
66	17.00	16.96	0.04	0.22%	YES	0.004	YES

Run #	Target Flow Rate (gpm)	Average Flow Rate (gpm)	Variance (gpm)	% Var	QA/QC (Var < 10%)	COV	QA/QC (COV < 0.03)
67	17.00	16.95	0.05	0.32%	YES	0.004	YES
68	17.00	16.95	0.05	0.28%	YES	0.004	YES
69	17.00	16.91	0.09	0.51%	YES	0.004	YES
70	17.00	16.98	0.02	0.10%	YES	0.004	YES
71	17.00	16.95	0.05	0.30%	YES	0.004	YES
72	17.00	16.94	0.06	0.34%	YES	0.004	YES
73	17.00	16.89	0.11	0.65%	YES	0.004	YES
74	17.00	17.05	0.05	0.28%	YES	0.004	YES
75	17.00	16.99	0.01	0.05%	YES	0.005	YES
76	17.00	17.01	0.01	0.03%	YES	0.004	YES
77	17.00	16.93	0.07	0.39%	YES	0.004	YES
78	17.00	17.01	0.01	0.06%	YES	0.005	YES
79	17.00	16.93	0.07	0.40%	YES	0.004	YES
80	17.00	16.85	0.15	0.87%	YES	0.005	YES
81	17.00	17.05	0.05	0.32%	YES	0.004	YES
82	17.00	16.89	0.11	0.64%	YES	0.004	YES
83	17.00	16.99	0.01	0.09%	YES	0.004	YES
84	17.00	16.94	0.06	0.36%	YES	0.004	YES
85	17.00	16.95	0.05	0.29%	YES	0.004	YES
86	17.00	16.89	0.11	0.63%	YES	0.004	YES
87	17.00	16.97	0.03	0.20%	YES	0.004	YES
88	17.00	16.95	0.05	0.29%	YES	0.004	YES
89	17.00	16.91	0.09	0.53%	YES	0.004	YES
90	17.00	17.00	0.00	0.02%	YES	0.004	YES
91	17.00	16.94	0.06	0.36%	YES	0.004	YES
92	17.00	16.92	0.08	0.47%	YES	0.004	YES
93	17.00	16.93	0.07	0.42%	YES	0.004	YES
94	17.00	16.94	0.06	0.36%	YES	0.004	YES
95	17.00	16.99	0.01	0.05%	YES	0.005	YES
96	17.00	16.98	0.02	0.10%	YES	0.004	YES
97	17.00	16.98	0.02	0.11%	YES	0.004	YES
98	17.00	16.98	0.02	0.11%	YES	0.004	YES
99	17.00	17.00	0.00	0.03%	YES	0.005	YES
100	17.00	16.92	0.08	0.46%	YES	0.004	YES
101	17.00	16.92	0.08	0.48%	YES	0.004	YES
102	17.00	16.99	0.01	0.08%	YES	0.004	YES
103	17.00	16.94	0.06	0.35%	YES	0.004	YES

Run #	Target Flow Rate (gpm)	Average Flow Rate (gpm)	Variance (gpm)	% Var	QA/QC (Var < 10%)	COV	QA/QC (COV < 0.03)
104	17.00	16.97	0.03	0.16%	YES	0.004	YES
105	17.00	16.99	0.01	0.08%	YES	0.004	YES
106	17.00	16.95	0.05	0.30%	YES	0.004	YES
107	17.00	17.00	0.00	0.02%	YES	0.005	YES
108	17.00	16.98	0.02	0.13%	YES	0.004	YES
109	17.00	16.93	0.07	0.41%	YES	0.004	YES
AVG	**17.00**	**16.96**	**0.05**	**0.28%**		**0.004**	
110	15.3	15.19	0.11	0.69%	YES	0.002	YES
111	15.3	15.17	0.13	0.82%	YES	0.003	YES
112	15.3	15.22	0.08	0.49%	YES	0.003	YES
113	15.3	15.30	0.00	0.02%	YES	0.004	YES
114	15.3	15.23	0.07	0.43%	YES	0.003	YES
115	15.3	15.21	0.09	0.62%	YES	0.002	YES
116	15.3	15.21	0.09	0.61%	YES	0.002	YES
117	15.3	15.25	0.05	0.31%	YES	0.003	YES
AVG	**15.30**	**15.22**	**0.08**	**0.50%**		**0.003**	

Table 10 Mass Load Capacity Maximum Temperatures

Run #	Maximum Temp (F)	QA/QC Temp < 80F
11	75.42	YES
12	76.21	YES
13	76.08	YES
14	76.60	YES
15	76.21	YES
16	75.42	YES
17	75.42	YES
18	78.05	YES
19	77.66	YES
20	77.26	YES
21	77.53	YES
22	75.81	YES
23	75.81	YES
24	76.60	YES
25	76.47	YES
26	75.81	YES

Run #	Maximum Temp (F)	QA/QC Temp < 80F
27	75.81	YES
28	76.87	YES
29	77.13	YES
30	75.81	YES
31	76.34	YES
32	75.81	YES
33	76.34	YES
34	76.08	YES
35	76.21	YES
36	76.08	YES
37	75.95	YES
38	77.53	YES
39	77.26	YES
40	75.68	YES
41	75.95	YES
42	76.87	YES
43	76.74	YES
44	75.42	YES
45	75.81	YES
46	77.26	YES
47	76.34	YES
48	77.00	YES
49	76.87	YES
50	78.32	YES
51	77.13	YES
52	74.36	YES
53	75.15	YES
54	76.34	YES
55	76.74	YES
56	73.97	YES
57	74.10	YES
58	76.60	YES
59	77.66	YES
60	76.34	YES
61	76.74	YES
62	75.68	YES
63	76.34	YES
64	75.42	YES

Run #	Maximum Temp (F)	QA/QC Temp < 80F
65	75.29	YES
66	74.76	YES
67	74.89	YES
68	77.40	YES
69	77.53	YES
70	75.68	YES
71	75.55	YES
72	75.42	YES
73	75.95	YES
74	78.05	YES
75	78.05	YES
76	76.87	YES
77	75.68	YES
78	75.68	YES
79	75.68	YES
80	75.68	YES
81	75.15	YES
82	77.79	YES
83	78.58	YES
84	78.19	YES
85	78.58	YES
86	76.34	YES
87	76.87	YES
88	76.21	YES
89	75.68	YES
90	75.81	YES
91	75.68	YES
92	75.81	YES
93	75.68	YES
94	77.40	YES
95	77.79	YES
96	76.60	YES
97	76.47	YES
98	76.34	YES
99	75.55	YES
100	77.13	YES
101	76.08	YES
102	77.40	YES

Run #	Maximum Temp (F)	QA/QC Temp < 80F
103	77.53	YES
104	75.68	YES
105	75.55	YES
106	76.47	YES
107	76.08	YES
108	78.05	YES
109	77.26	YES
110	77.66	YES
111	77.26	YES
112	76.47	YES
113	77.13	YES
114	76.21	YES
115	76.34	YES
116	75.95	YES
117	76.60	YES

Table 11 Mass Load Capacity Influent Sediment Concentrations

Run #	Targ. Inf. (mg/L)	Avg. Inf. (mg/L)	Var. (mg/L)	% Var.	QA/QC Var<10 %	Feed Rate Samples (mg/s)			COV	QA/QC COV<0.1
11	400	390.16	9.84	2.46%	YES	398.18	416.33	413.07	0.024	YES
12	400	387.92	12.08	3.02%	YES	426.15	410.25	411.35	0.021	YES
13	400	367.60	32.40	8.10%	YES	397.27	393.53	375.05	0.031	YES
14	400	374.58	25.42	6.36%	YES	410.03	401.63	392.32	0.022	YES
15	400	374.39	25.61	6.40%	YES	394.95	392.78	396.97	0.005	YES
16	400	381.13	18.87	4.72%	YES	418.88	397.18	396.73	0.031	YES
17	400	385.26	14.74	3.69%	YES	408.50	405.03	403.07	0.007	YES
18	400	382.85	17.15	4.29%	YES	424.08	420.38	413.70	0.013	YES
19	400	391.15	8.85	2.21%	YES	419.03	411.78	403.17	0.019	YES
20	400	391.90	8.10	2.03%	YES	415.82	423.25	415.57	0.010	YES
21	400	385.14	14.86	3.71%	YES	424.45	413.08	386.77	0.047	YES
22	400	383.62	16.38	4.09%	YES	410.63	406.02	410.68	0.007	YES
23	400	376.83	23.17	5.79%	YES	410.40	409.97	400.00	0.014	YES
24	400	382.71	17.29	4.32%	YES	400.58	400.18	403.27	0.004	YES
25	400	387.38	12.62	3.16%	YES	407.18	399.15	419.63	0.025	YES
26	400	384.63	15.37	3.84%	YES	405.55	415.12	424.62	0.023	YES
27	400	381.20	18.80	4.70%	YES	427.05	398.80	396.83	0.041	YES
28	200	195.59	4.41	2.20%	YES	209.92	218.23	207.18	0.027	YES
29	200	194.89	5.11	2.56%	YES	213.95	212.63	205.88	0.021	YES
30	200	183.93	16.07	8.03%	YES	197.15	202.67	198.80	0.014	YES
31	200	192.56	7.44	3.72%	YES	221.25	207.72	199.97	0.051	YES
32	200	195.05	4.95	2.47%	YES	212.70	199.82	197.07	0.041	YES
33	200	190.67	9.33	4.67%	YES	205.47	199.95	204.22	0.014	YES
34	200	194.94	5.06	2.53%	YES	207.22	195.93	198.78	0.029	YES
35	200	202.88	2.88	1.44%	YES	209.73	206.90	219.87	0.032	YES
36	200	196.75	3.25	1.63%	YES	214.02	206.97	205.88	0.021	YES
37	200	196.99	3.01	1.50%	YES	210.72	201.67	213.72	0.030	YES
38	200	205.84	5.84	2.92%	YES	217.70	215.87	210.50	0.017	YES
39	200	201.01	1.01	0.50%	YES	230.55	204.10	218.98	0.061	YES
40	200	195.74	4.26	2.13%	YES	207.72	212.30	202.83	0.023	YES
41	200	198.10	1.90	0.95%	YES	209.65	210.35	210.28	0.002	YES
42	200	185.93	14.07	7.03%	YES	217.50	190.78	200.87	0.066	YES
43	200	193.43	6.57	3.29%	YES	208.30	205.80	208.75	0.008	YES
44	200	187.27	12.73	6.36%	YES	218.90	200.55	198.12	0.055	YES
45	200	195.39	4.61	2.30%	YES	206.22	210.72	211.18	0.013	YES
46	200	196.80	3.20	1.60%	YES	207.00	202.43	199.53	0.019	YES
47	200	195.32	4.68	2.34%	YES	209.05	208.40	211.35	0.007	YES

Run #	Targ. Inf. (mg/L)	Avg. Inf. (mg/L)	Var. (mg/L)	% Var.	QA/QC Var<10 %	Feed Rate Samples (mg/s)			COV	QA/QC COV<0.1
48	200	193.48	6.52	3.26%	YES	206.55	216.05	202.85	0.033	YES
49	200	210.28	10.28	5.14%	YES	217.53	219.62	218.30	0.005	YES
50	200	192.66	7.34	3.67%	YES	206.37	212.25	208.82	0.014	YES
51	200	192.03	7.97	3.99%	YES	206.32	210.87	200.90	0.024	YES
52	200	186.30	13.70	6.85%	YES	214.90	203.52	210.72	0.027	YES
53	200	198.45	1.55	0.77%	YES	215.62	202.02	210.05	0.033	YES
54	200	194.83	5.17	2.59%	YES	214.97	216.50	210.85	0.014	YES
55	200	233.89	33.89	**16.94%**	**NO**	217.00	215.33	216.33	0.004	YES
56	200	194.85	5.15	2.58%	YES	208.97	207.00	210.33	0.008	YES
57	200	186.89	13.11	6.56%	YES	205.63	207.18	203.70	0.008	YES
58	200	174.21	25.79	**12.89%**	**NO**	210.08	205.02	204.27	0.015	YES
59	200	189.81	10.19	5.10%	YES	207.57	206.92	206.43	0.003	YES
60	200	192.91	7.09	3.55%	YES	210.07	205.33	204.53	0.014	YES
61	200	197.78	2.22	1.11%	YES	215.52	207.85	206.85	0.023	YES
62	200	188.78	11.22	5.61%	YES	211.38	206.35	206.83	0.013	YES
63	200	187.21	12.79	6.39%	YES	205.35	209.98	213.53	0.020	YES
64	200	182.13	17.87	8.93%	YES	199.08	200.42	195.72	0.012	YES
65	200	206.86	6.86	3.43%	YES	214.27	219.15	219.00	0.013	YES
66	200	185.51	14.49	7.24%	YES	216.43	207.60	202.95	0.033	YES
67	200	202.37	2.37	1.18%	YES	222.22	219.85	211.45	0.026	YES
68	200	191.76	8.24	4.12%	YES	204.08	211.70	201.23	0.026	YES
69	200	204.79	4.79	2.40%	YES	216.12	225.23	221.83	0.021	YES
70	200	183.59	16.41	8.21%	YES	210.23	203.98	193.08	0.043	YES
71	200	199.09	0.91	0.45%	YES	213.58	219.80	211.82	0.019	YES
72	200	193.08	6.92	3.46%	YES	199.73	214.40	201.67	0.039	YES
73	200	200.84	0.84	0.42%	YES	214.00	218.88	215.97	0.011	YES
74	200	197.67	2.33	1.16%	YES	224.73	216.62	212.28	0.029	YES
75	200	199.45	0.55	0.28%	YES	207.45	211.17	198.47	0.032	YES
76	200	186.47	13.53	6.76%	YES	217.72	197.32	203.68	0.051	YES
77	200	196.54	3.46	1.73%	YES	205.87	198.58	218.38	0.048	YES
78	200	182.85	17.15	8.58%	YES	226.42	199.07	196.07	0.081	YES
79	200	201.19	1.19	0.59%	YES	220.10	216.05	222.90	0.016	YES
80	200	188.60	11.40	5.70%	YES	202.02	209.27	193.52	0.039	YES
81	200	201.57	1.57	0.79%	YES	219.45	211.37	206.25	0.031	YES
82	200	178.68	21.32	**10.66%**	**NO**	207.83	205.28	195.85	0.031	YES
83	200	186.43	13.57	6.79%	YES	216.02	201.17	210.08	0.036	YES
84	200	209.07	9.07	4.53%	YES	228.32	215.07	221.80	0.030	YES
85	200	193.78	6.22	3.11%	YES	211.30	211.47	205.35	0.017	YES

Run #	Targ. Inf. (mg/L)	Avg. Inf. (mg/L)	Var. (mg/L)	% Var.	QA/QC Var<10 %	Feed Rate Samples (mg/s)			COV	QA/QC COV<0.1
86	200	202.12	2.12	1.06%	YES	223.25	231.37	227.37	0.018	YES
87	200	191.08	8.92	4.46%	YES	202.20	194.53	199.62	0.020	YES
88	200	196.20	3.80	1.90%	YES	215.65	205.68	203.75	0.031	YES
89	200	206.27	6.27	3.13%	YES	219.37	217.17	210.53	0.021	YES
90	200	188.65	11.35	5.67%	YES	211.72	210.60	206.33	0.014	YES
91	200	201.57	1.57	0.78%	YES	215.25	211.52	217.20	0.013	YES
92	200	199.88	0.12	0.06%	YES	206.90	215.73	208.28	0.023	YES
93	200	200.96	0.96	0.48%	YES	204.72	213.47	211.95	0.022	YES
94	200	204.91	4.91	2.45%	YES	217.87	210.82	220.45	0.023	YES
95	200	202.24	2.24	1.12%	YES	225.27	213.77	231.13	0.040	YES
96	200	188.27	11.73	5.86%	YES	202.07	199.38	204.43	0.013	YES
97	200	195.77	4.23	2.12%	YES	206.27	208.85	212.42	0.015	YES
98	200	189.83	10.17	5.08%	YES	207.02	190.43	196.15	0.043	YES
99	200	193.37	6.63	3.31%	YES	209.95	201.62	209.45	0.023	YES
100	200	179.12	20.88	**10.44%**	**NO**	207.05	204.23	210.67	0.016	YES
101	200	197.53	2.47	1.23%	YES	207.45	207.08	216.78	0.026	YES
102	200	190.14	9.86	4.93%	YES	217.37	200.98	201.00	0.046	YES
103	200	196.98	3.02	1.51%	YES	221.27	218.07	202.03	0.048	YES
104	200	191.59	8.41	4.21%	YES	209.77	205.38	203.63	0.015	YES
105	200	196.57	3.43	1.71%	YES	216.72	210.27	209.80	0.018	YES
106	200	201.68	1.68	0.84%	YES	216.72	210.27	209.80	0.018	YES
107	200	198.78	1.22	0.61%	YES	208.55	208.63	216.83	0.023	YES
108	200	184.90	15.10	7.55%	YES	195.67	206.47	201.85	0.027	YES
109	200	205.61	5.61	2.80%	YES	214.05	223.95	222.52	0.024	YES
110	200	203.87	3.87	1.94%	YES	197.15	197.37	190.73	0.019	YES
111	200	198.42	1.58	0.79%	YES	187.98	195.12	190.72	0.019	YES
112	200	201.05	1.05	0.52%	YES	193.67	197.12	194.03	0.010	YES
113	200	194.52	5.48	2.74%	YES	193.88	191.08	185.15	0.023	YES
114	200	199.02	0.98	0.49%	YES	186.02	199.62	182.90	0.047	YES
115	200	194.86	5.14	2.57%	YES	187.63	188.40	182.05	0.019	YES
116	200	192.51	7.49	3.74%	YES	188.83	184.42	181.68	0.020	YES
117	200	214.57	14.57	7.29%	YES	195.28	203.22	206.95	0.030	YES

Table 12 Mass Load Capacity Background Sediment Concentrations

Run #	Background Samples (mg/L)			Mean (mg/L)	QA/QC (Max<20 mg/L)
11	1.20	0.70	4.60	2.167	YES
12	8.50	8.50	11.00	9.333	YES
13	3.20	3.20	5.70	4.033	YES
14	2.10	2.00	5.00	3.033	YES
15	8.00	7.80	11.00	8.933	YES
16	3.70	2.10	4.90	3.567	YES
17	10.00	8.40	11.00	9.800	YES
18	2.70	2.50	5.30	3.500	YES
19	9.60	9.00	12.00	10.200	YES
20	2.20	1.90	5.20	3.100	YES
21	8.70	8.10	14.00	10.267	YES
22	2.30	2.60	3.90	2.933	YES
23	11.00	9.70	13.00	11.233	YES
24	3.60	2.60	5.80	4.000	YES
25	10.00	9.40	12.00	10.467	YES
26	2.40	3.80	5.80	4.000	YES
27	9.50	9.00	12.00	10.167	YES
28	2.30	2.80	3.60	2.900	YES
29	1.20	7.90	3.30	4.133	YES
30	1.70	2.10	3.30	2.367	YES
31	2.60	1.30	2.20	2.033	YES
32	3.10	3.90	5.70	4.233	YES
33	9.00	9.40	3.60	7.333	YES
34	1.60	2.10	2.90	2.200	YES
35	3.40	3.90	4.50	3.933	YES
36	2.40	1.40	2.40	2.067	YES
37	6.30	6.70	7.30	6.767	YES
38	1.50	1.80	5.30	2.867	YES
39	6.40	7.50	7.70	7.200	YES
40	2.90	3.10	4.70	3.567	YES
41	7.00	7.50	8.10	7.533	YES
42	6.50	6.40	7.80	6.900	YES
43	10.00	11.00	12.00	11.000	YES
44	3.70	0.60	3.40	2.567	YES
45	6.70	8.20	2.00	5.633	YES
46	6.70	2.50	7.30	5.500	YES
47	11.00	5.20	7.90	8.033	YES

Run #	Background Samples (mg/L)			Mean (mg/L)	QA/QC (Max<20 mg/L)
48	4.10	2.40	5.70	4.067	YES
49	4.40	3.30	5.70	4.467	YES
50	8.00	9.90	13.00	10.300	YES
51	11.00	8.30	13.00	10.767	YES
52	3.50	3.50	5.40	4.133	YES
53	3.30	5.40	4.80	4.500	YES
54	4.50	1.00	2.90	2.800	YES
55	3.60	3.00	3.40	3.333	YES
56	1.90	2.90	0.50	1.767	YES
57	3.70	5.60	6.40	5.233	YES
58	8.60	3.40	4.50	5.500	YES
59	8.90	12.00	11.00	10.633	YES
60	6.20	1.30	7.80	5.100	YES
61	2.60	3.40	1.30	2.433	YES
62	3.40	1.80	4.00	3.067	YES
63	4.70	1.70	4.00	3.467	YES
64	8.70	3.00	13.00	8.233	YES
65	6.80	2.00	3.80	4.200	YES
66	1.20	0.40	4.90	2.167	YES
67	4.10	2.30	6.70	4.367	YES
68	12.00	12.00	10.00	11.333	YES
69	8.30	5.50	16.00	9.933	YES
70	3.10	2.90	6.50	4.167	YES
71	8.00	12.00	7.10	9.033	YES
72	9.30	23.00	12.00	14.767	YES
73	15.00	16.00	2.80	11.267	YES
74	4.20	2.70	5.80	4.233	YES
75	9.60	10.00	5.50	8.367	YES
76	4.30	11.00	3.20	6.167	YES
77	8.30	1.10	8.30	5.900	YES
78	1.00	3.80	0.60	1.800	YES
79	3.70	5.80	2.40	3.967	YES
80	14.00	15.00	16.00	15.000	YES
81	10.00	15.00	11.00	12.000	YES
82	4.60	3.60	4.40	4.200	YES
83	7.60	6.90	11.00	8.500	YES
84	11.00	12.00	16.00	13.000	YES
85	13.00	17.00	12.00	14.000	YES

Run #	Background Samples (mg/L)			Mean (mg/L)	QA/QC (Max<20 mg/L)
86	7.50	3.30	4.70	5.167	YES
87	5.10	7.90	7.20	6.733	YES
88	14.00	13.00	4.00	10.333	YES
89	13.00	13.00	10.00	12.000	YES
90	19.00	3.60	5.70	9.433	YES
91	13.00	15.00	8.10	12.033	YES
92	1.00	2.30	3.40	2.233	YES
93	7.80	4.20	3.30	5.100	YES
94	26.00	25.00	24.00	25.000	**NO**
95	22.00	17.00	24.00	21.000	**NO**
96	3.10	7.90	3.40	4.800	YES
97	11.00	8.60	1.80	7.133	YES
98	13.00	21.00	11.00	15.000	YES
99	26.00	27.00	17.00	23.333	**NO**
100	4.80	15.00	7.50	9.100	YES
101	19.00	13.00	13.00	15.000	YES
102	9.30	6.90	1.90	6.033	YES
103	18.00	4.30	6.70	9.667	YES
104	5.10	6.40	6.90	6.133	YES
105	3.50	7.00	20.00	10.167	YES
106	12.00	8.90	9.60	10.167	YES
107	13.00	12.00	24.00	16.333	YES
108	1.60	2.30	4.30	2.733	YES
109	7.80	3.00	8.20	6.333	YES
110	14.00	9.70	18.00	13.900	YES
111	5.10	11.00	10.00	8.700	YES
112	4.90	19.00	4.90	9.600	YES
113	6.60	3.70	11.00	7.100	YES
114	7.60	7.40	8.40	7.800	YES
115	12.00	13.00	2.10	9.033	YES
116	1.00	1.90	2.30	1.733	YES
117	6.70	4.10	4.90	5.233	YES

Table 13 Mass Load Capacity Effluent Concentrations

Run #	Effluent Samples (mg/L)						Mean (mg/L)
11	64	66	65	69	69	70	67.2
12	69	73	73	79	79	78	75.2
13	61	62	62	62	67	66	63.3
14	61	63	60	62	61	67	62.3
15	64	64	66	69	69	72	67.3
16	58	62	60	64	64	64	62.0
17	65	69	68	72	72	73	69.8
18	46	60	60	61	62	63	58.7
19	65	70	65	69	73	73	69.2
20	56	62	61	66	64	64	62.2
21	68	69	65	70	71	72	69.2
22	56	55	56	59	59	61	57.7
23	62	63	64	65	67	69	65.0
24	52	54	55	57	59	58	55.8
25	61	65	67	67	68	71	66.5
26	53	55	55	55	59	64	56.8
27	63	60	61	67	72	73	66.0
28	25	24	27	25	27	26	25.7
29	22	10	9	13	27	27	18.1
30	25	25	24	25	25	24	24.7
31	37	29	30	28	30	30	30.7
32	22	36	18	31	23	24	25.7
33	29	30	25	30	22	36	28.7
34	24	25	20	24	25	27	24.2
35	29	32	31	32	28	29	30.2
36	3	7	11	7	18	9	9.3
37	28	29	31	27	31	28	29.0
38	9	9	7	30	16	32	17.2
39	31	33	32	32	33	33	32.3
40	23	25	25	24	25	23	24.2
41	29	29	28	30	31	29	29.3
42	28	29	30	27	30	29	28.8
43	34	33	35	35	36	35	34.7
44	8	13	20	12	28	10	15.2
45	30	17	30	14	12	31	22.3
46	24	30	31	31	32	32	30.0
47	35	36	35	38	36	38	36.3

Run #	Effluent Samples (mg/L)						Mean (mg/L)
48	11	8	7	5	4	10	7.5
49	54	21	23	17	26	23	27.3
50	34	36	30	45	42	26	35.5
51	35	51	51	28	45	5	35.8
52	13	10	7	9	14	15	11.2
53	32	23	33	19	35	26	28.0
54	8	7	31	19	19	17	16.7
55	21	28	35	29	27	24	27.3
56	22	23	25	24	28	32	25.7
57	26	33	31	28	29	35	30.3
58	31	33	33	33	32	32	32.3
59	30	38	56	40	39	32	39.2
60	28	5	27	31	31	21	23.8
61	27	4	30	30	16	13	20.0
62	24	29	26	30	29	28	27.7
63	16	27	27	22	21	30	23.8
64	5	13	15	26	16	39	19.1
65	24	25	28	31	27	50	30.8
66	13	22	18	23	21	25	20.3
67	28	28	29	29	30	25	28.2
68	26	43	22	39	25	27	30.3
69	39	29	47	37	24	35	35.2
70	13	25	16	26	22	10	18.7
71	32	34	21	26	32	31	29.3
72	30	25	25	22	28	28	26.3
73	32	33	34	31	34	32	32.7
74	22	18	9	27	19	16	18.5
75	27	32	29	32	33	36	31.5
76	19	18	10	26	23	17	18.8
77	34	17	14	22	25	21	22.2
78	15	23	5	40	1	20	17.3
79	21	38	40	6	22	18	24.2
80	50	11	45	48	64	46	44.0
81	15	46	28	30	45	44	34.7
82	40	48	48	45	35	29	40.8
83	29	35	24	47	26	35	32.7
84	35	35	34	33	37	30	34.0
85	35	35	33	50	44	44	40.2
86	23	38	28	35	27	29	30.0

Run #	Effluent Samples (mg/L)						Mean (mg/L)
87	27	26	24	23	23	22	24.2
88	31	27	33	14	33	12	25.0
89	36	26	40	43	20	28	32.2
90	23	17	29	23	23	23	23.0
91	30	19	20	27	16	23	22.5
92	4	10	16	21	13	14	13.0
93	23	30	27	24	21	23	24.7
94	22	37	40	31	36	24	31.7
95	46	44	45	28	41	35	39.8
96	2	53	2	9	1	25	15.3
97	29	41	7	9	35	43	27.3
98	7	7	17	16	7	22	12.7
99	27	25	30	55	14	34	30.8
100	22	25	29	20	29	28	25.5
101	49	41	28	35	24	39	36.0
102	15	4	19	7	11	15	11.9
103	25	9	23	30	34	22	23.8
104	3	26	6	22	24	6	14.5
105	22	23	29	32	18	17	23.5
106	26	27	25	26	30	26	26.7
107	39	34	33	34	36	31	34.5
108	24	29	11	22	12	16	19.0
109	26	26	30	27	23	14	24.3
110	6	23	14	28	8	11	14.9
111	21	12	20	7	12	9	13.5
112	6	9	8	10	5	16	8.9
113	26	27	23	18	21	16	21.8
114	25	21	26	21	18	17	21.3
115	28	28	29	24	26	23	26.3
116	9	26	15	14	15	18	16.2
117	26	24	25	17	23	18	22.2

Table 14 Mass Load Capacity Removal Efficiency Results

Run #	Inf. Conc. (mg/L)	Avg. Eff. Conc (mg/L)	Avg. Bkg. Conc (mg/L)	Avg. Adj. Eff. Conc (mg/L)	Test Vol. (L)	Mass Added (kg)	Test Mass Escaped (kg)	Op Vol Mass Escaped (kg)	Cumulative Mass Captured (kg)	Run Eff.	Cum. Removal Efficiency	Note
1-10						3.961	0.679	0.0146	3.267		82.48%	
11	390.156	67.167	2.167	65.000	1944.571	0.759	0.126	0.0027	3.897	82.98%	82.56%	
12	387.923	75.167	9.333	65.833	1958.491	0.760	0.129	0.0028	4.525	82.66%	82.58%	
13	367.599	63.333	4.033	59.300	1956.749	0.719	0.116	0.0026	5.125	83.51%	82.69%	
14	374.579	62.333	3.033	59.300	1956.561	0.733	0.116	0.0026	5.740	83.82%	82.81%	
15	374.388	67.333	8.933	58.400	1942.478	0.727	0.113	0.0025	6.351	84.06%	82.92%	
16	381.126	62.000	3.567	58.433	1945.369	0.741	0.114	0.0025	6.976	84.33%	83.05%	
17	385.257	69.833	9.800	60.033	1947.465	0.750	0.117	0.0026	7.607	84.07%	83.13%	
18	382.850	58.667	3.500	55.167	1941.342	0.743	0.107	0.0023	8.241	85.27%	83.29%	
19	391.155	69.167	10.200	58.967	1938.624	0.758	0.114	0.0025	8.882	84.59%	83.39%	
20	391.898	62.167	3.100	59.067	1949.150	0.764	0.115	0.0026	9.529	84.59%	83.47%	
21	385.142	69.167	10.267	58.900	1952.733	0.752	0.115	0.0026	10.163	84.36%	83.52%	
22	383.620	57.667	2.933	54.733	1954.092	0.750	0.107	0.0024	10.803	85.41%	83.63%	
23	376.827	65.000	11.233	53.767	1942.278	0.732	0.104	0.0024	11.428	85.41%	83.73%	
24	382.713	55.833	4.000	51.833	1956.454	0.749	0.101	0.0023	12.073	86.15%	83.85%	
25	387.377	66.500	10.467	56.033	1952.920	0.757	0.109	0.0025	12.718	85.20%	83.92%	
26	384.631	56.833	4.000	52.833	1957.951	0.753	0.103	0.0025	13.365	85.94%	84.02%	
27	381.203	66.000	10.167	55.833	1955.317	0.745	0.109	0.0027	13.999	85.00%	84.06%	

Run #	Inf. Conc. (mg/L)	Avg. Eff. Conc (mg/L)	Avg. Bkg. Conc (mg/L)	Avg. Adj. Eff. Conc (mg/L)	Test Vol. (L)	Mass Added (kg)	Test Mass Escaped (kg)	Op Vol Mass Escaped (kg)	Cumulative Mass Captured (kg)	Run Eff.	Cum. Removal Efficiency	Note
28	195.593	25.667	2.900	22.767	1950.234	0.381	0.044	0.0010	14.335	88.10%	84.15%	
29	194.890	18.050	4.133	13.917	1946.517	0.379	0.027	0.0006	14.686	92.70%	84.34%	
30	183.935	24.667	2.367	22.300	1937.861	0.356	0.043	0.0010	14.999	87.61%	84.40%	
31	192.559	30.667	2.033	28.633	1947.629	0.375	0.056	0.0013	15.317	84.79%	84.41%	
32	195.051	25.667	4.233	21.433	1940.318	0.378	0.042	0.0009	15.653	88.77%	84.50%	
33	190.668	28.667	7.333	21.333	1949.223	0.372	0.042	0.0009	15.982	88.56%	84.58%	
34	194.944	24.167	2.200	21.967	1943.744	0.379	0.043	0.0010	16.317	88.48%	84.66%	
35	202.884	30.167	3.933	26.233	1946.877	0.395	0.051	0.0012	16.660	86.78%	84.70%	
36	196.747	9.333	2.067	7.267	1952.904	0.384	0.014	0.0003	17.029	96.22%	84.92%	
37	196.990	29.000	6.767	22.233	1950.728	0.384	0.043	0.0010	17.369	88.45%	84.98%	
38	205.842	17.200	2.867	14.333	1949.752	0.401	0.028	0.0006	17.742	92.88%	85.14%	
39	201.007	32.333	7.200	25.133	1948.660	0.392	0.049	0.0011	18.084	87.21%	85.18%	
40	195.745	24.167	3.567	20.600	1952.550	0.382	0.040	0.0009	18.425	89.24%	85.25%	
41	198.102	29.333	7.533	21.800	1949.964	0.386	0.043	0.0010	18.768	88.74%	85.31%	
42	185.934	28.833	6.900	21.933	1950.224	0.363	0.043	0.0010	19.086	87.94%	85.35%	
43	193.426	34.667	11.000	23.667	1952.507	0.378	0.046	0.0011	19.417	87.49%	85.39%	
44	187.275	15.183	2.567	12.617	1945.668	0.364	0.025	0.0006	19.756	93.11%	85.51%	
45	195.394	22.333	5.633	16.700	1954.434	0.382	0.033	0.0007	20.105	91.26%	85.60%	
46	196.796	30.000	5.500	24.500	1946.355	0.383	0.048	0.0011	20.439	87.27%	85.63%	
47	195.321	36.333	8.033	28.300	1943.349	0.380	0.055	0.0013	20.762	85.18%	85.62%	
48	193.485	7.467	4.067	3.400	1951.107	0.378	0.007	0.0002	21.133	98.20%	85.81%	
49	210.280	27.333	4.467	22.867	1948.489	0.410	0.045	0.0010	21.497	88.88%	85.86%	
50	192.657	35.500	10.300	25.200	1947.098	0.375	0.049	0.0011	21.822	86.63%	85.88%	
51	192.029	35.800	10.767	25.033	1944.585	0.373	0.049	0.0011	22.146	86.67%	85.89%	
52	186.297	11.150	4.133	7.017	1952.160	0.364	0.014	0.0003	22.495	96.15%	86.03%	

Run #	Inf. Conc. (mg/L)	Avg. Eff. Conc (mg/L)	Avg. Bkg. Conc (mg/L)	Avg. Adj. Eff. Conc (mg/L)	Test Vol. (L)	Mass Added (kg)	Test Mass Escaped (kg)	Op Vol Mass Escaped (kg)	Cumulative Mass Captured (kg)	Run Eff.	Cum. Removal Efficiency	Note
53	198.454	28.000	4.500	23.500	1947.292	0.386	0.046	0.0010	22.835	87.89%	86.06%	
54	194.825	16.700	2.800	13.900	1944.129	0.379	0.027	0.0006	23.186	92.71%	86.15%	
55	233.885	27.333	3.333	24.000	1947.515	0.455	0.047	0.0011	23.594	89.51%	86.15%	1
56	194.846	25.667	1.767	23.900	1948.854	0.380	0.047	0.0011	23.926	87.46%	86.17%	
57	186.886	30.333	5.233	25.100	1950.053	0.364	0.049	0.0011	24.240	86.26%	86.17%	
58	174.213	32.333	5.500	26.833	1947.725	0.339	0.052	0.0012	24.526	84.25%	86.17%	1
59	189.808	39.167	10.633	28.533	1942.540	0.369	0.055	0.0012	24.838	84.63%	86.15%	
60	192.905	23.750	5.100	18.650	1946.930	0.376	0.036	0.0008	25.177	90.11%	86.20%	
61	197.778	19.950	2.433	17.517	1953.173	0.386	0.034	0.0008	25.528	90.94%	86.27%	
62	188.783	27.667	3.067	24.600	1951.932	0.368	0.048	0.0011	25.847	86.67%	86.27%	
63	187.213	23.833	3.467	20.367	1954.808	0.366	0.040	0.0009	26.173	88.87%	86.30%	
64	182.130	19.050	8.233	10.817	1945.728	0.354	0.021	0.0005	26.505	93.93%	86.39%	
65	206.856	30.833	4.200	26.633	1948.735	0.403	0.052	0.0012	26.855	86.83%	86.40%	
66	185.514	20.333	2.167	18.167	1948.863	0.362	0.035	0.0008	27.181	89.98%	86.44%	
67	202.365	28.167	4.367	23.800	1946.822	0.394	0.046	0.0011	27.527	87.97%	86.46%	
68	191.757	30.333	11.333	19.000	1947.677	0.373	0.037	0.0009	27.863	89.86%	86.50%	
69	204.790	35.167	9.933	25.233	1943.085	0.398	0.049	0.0011	28.211	87.39%	86.51%	
70	183.586	18.650	4.167	14.483	1951.062	0.358	0.028	0.0007	28.540	91.93%	86.57%	
71	199.092	29.333	9.033	20.300	1947.167	0.388	0.040	0.0009	28.887	89.56%	86.61%	
72	193.076	26.333	14.767	11.567	1946.494	0.376	0.023	0.0005	29.240	93.87%	86.69%	
73	200.837	32.667	11.267	21.400	1940.447	0.390	0.042	0.0010	29.587	89.09%	86.72%	
74	197.672	18.500	4.233	14.267	1958.589	0.387	0.028	0.0007	29.946	92.61%	86.79%	
75	199.448	31.500	8.367	23.133	1952.145	0.389	0.045	0.0011	30.289	88.13%	86.80%	
76	186.472	18.833	6.167	12.667	1953.673	0.364	0.025	0.0006	30.628	93.05%	86.87%	
77	196.545	22.167	5.900	16.267	1956.146	0.384	0.032	0.0008	30.980	91.53%	86.92%	

Run #	Inf. Conc. (mg/L)	Avg. Eff. Conc (mg/L)	Avg. Bkg. Conc (mg/L)	Avg. Adj. Eff. Conc (mg/L)	Test Vol. (L)	Mass Added (kg)	Test Mass Escaped (kg)	Op Vol Mass Escaped (kg)	Cumulative Mass Captured (kg)	Run Eff.	Cum. Removal Efficiency	Note
78	182.847	17.317	1.800	15.517	1954.268	0.357	0.030	0.0007	31.306	91.31%	86.96%	
79	201.188	24.167	3.967	20.200	1945.294	0.391	0.039	0.0009	31.657	89.72%	86.99%	
80	188.597	44.000	15.000	29.000	1936.088	0.365	0.056	0.0013	31.965	84.26%	86.97%	
81	201.575	34.667	12.000	22.667	1959.355	0.395	0.044	0.0011	32.314	88.48%	86.98%	
82	178.675	40.833	4.200	36.633	1940.654	0.347	0.071	0.0017	32.588	79.02%	86.98%	1
83	186.430	32.667	8.500	24.167	1951.367	0.364	0.047	0.0011	32.904	86.73%	86.98%	
84	209.068	34.000	13.000	21.000	1946.149	0.407	0.041	0.0010	33.269	89.71%	87.01%	
85	193.775	40.167	14.000	26.167	1947.360	0.377	0.051	0.0012	33.594	86.17%	87.00%	
86	202.116	30.000	5.167	24.833	1940.772	0.392	0.048	0.0012	33.937	87.42%	87.01%	
87	191.079	24.167	6.733	17.433	1949.200	0.372	0.034	0.0008	34.274	90.65%	87.04%	
88	196.200	25.000	10.333	14.667	1947.333	0.382	0.029	0.0007	34.627	92.34%	87.09%	
89	206.266	32.167	12.000	20.167	1942.672	0.401	0.039	0.0010	34.988	89.98%	87.12%	
90	188.654	23.000	9.433	13.567	1567.268	0.296	0.021	0.0006	35.262	92.60%	87.17%	
91	201.568	22.500	12.033	10.467	1946.118	0.392	0.020	0.0005	35.633	94.68%	87.24%	
92	199.876	13.017	2.233	10.783	1943.812	0.389	0.021	0.0005	36.000	94.48%	87.31%	
93	200.962	24.667	5.100	19.567	1944.831	0.391	0.038	0.0009	36.352	90.02%	87.34%	
94	204.909	31.667	25.000	6.667	1946.079	0.399	0.013	0.0003	36.737	96.67%	87.34%	2
95	202.240	39.833	21.000	18.833	1952.063	0.395	0.037	0.0009	37.095	90.45%	87.34%	2
96	188.270	15.317	4.800	10.517	1951.151	0.367	0.021	0.0005	37.441	94.28%	87.40%	
97	195.768	27.317	7.133	20.183	1950.886	0.382	0.039	0.0010	37.782	89.43%	87.42%	
98	189.831	12.683	15.000	-2.317	1950.936	0.370	-0.005	-0.0001	38.157	101.25%	87.53%	3
99	193.375	30.833	23.333	7.500	1953.593	0.378	0.015	0.0004	38.520	96.02%	87.53%	2
100	179.117	25.500	9.100	16.400	1944.188	0.348	0.032	0.0008	38.836	90.62%	87.53%	1
101	197.531	36.000	15.000	21.000	1943.799	0.384	0.041	0.0011	39.178	89.09%	87.54%	
102	190.139	11.917	6.033	5.883	1951.584	0.371	0.011	0.0003	39.537	96.83%	87.62%	

Run #	Inf. Conc. (mg/L)	Avg. Eff. Conc (mg/L)	Avg. Bkg. Conc (mg/L)	Avg. Adj. Eff. Conc (mg/L)	Test Vol. (L)	Mass Added (kg)	Test Mass Escaped (kg)	Op Vol Mass Escaped (kg)	Cumulative Mass Captured (kg)	Run Eff.	Cum. Removal Efficiency	Note
103	196.983	23.800	9.667	14.133	1946.152	0.383	0.028	0.0007	39.892	92.64%	87.67%	
104	191.588	14.467	6.133	8.333	1960.670	0.376	0.016	0.0004	40.251	95.54%	87.74%	
105	196.573	23.500	10.167	13.333	1951.604	0.384	0.026	0.0007	40.608	93.03%	87.78%	
106	201.678	26.667	10.167	16.500	1947.191	0.393	0.032	0.0009	40.968	91.60%	87.82%	
107	198.783	34.500	16.333	18.167	1953.568	0.388	0.035	0.0010	41.320	90.61%	87.84%	
108	184.901	19.000	2.733	16.267	1950.528	0.361	0.032	0.0008	41.648	90.97%	87.87%	
109	205.605	24.333	6.333	18.000	1944.987	0.400	0.035	0.0010	42.012	90.99%	87.90%	
110	203.871	14.933	13.900	1.033	1863.543	0.380	0.002	0.0000	42.389	99.48%	87.99%	
111	198.418	13.467	8.700	4.767	1861.063	0.369	0.009	0.0002	42.750	97.54%	88.07%	
112	201.046	8.900	9.600	-0.700	1867.290	0.375	-0.001	0.0000	43.126	100.36%	88.17%	3
113	194.520	21.833	7.100	14.733	1876.173	0.365	0.028	0.0007	43.463	92.23%	88.20%	
114	199.024	21.333	7.800	13.533	1868.378	0.372	0.025	0.0007	43.809	93.02%	88.24%	
115	194.864	26.333	9.033	17.300	1864.927	0.363	0.032	0.0009	44.139	90.88%	88.26%	
116	192.515	16.233	1.733	14.500	1865.108	0.359	0.027	0.0007	44.470	92.28%	88.29%	
117	214.571	22.167	5.233	16.933	1870.663	0.401	0.032	0.0010	44.839	91.86%	88.32%	

Note 1: Run failed influent concentration QA/QC. Run not included in cumulative removal efficiency but included in cumulative mass captured.
Note 2: Run failed background concentration QA/QC. Run not included in cumulative removal efficiency but included in cumulative mass captured.
Note 3: Adjusted effluent concentration negative. Removal efficiency set to 100%.

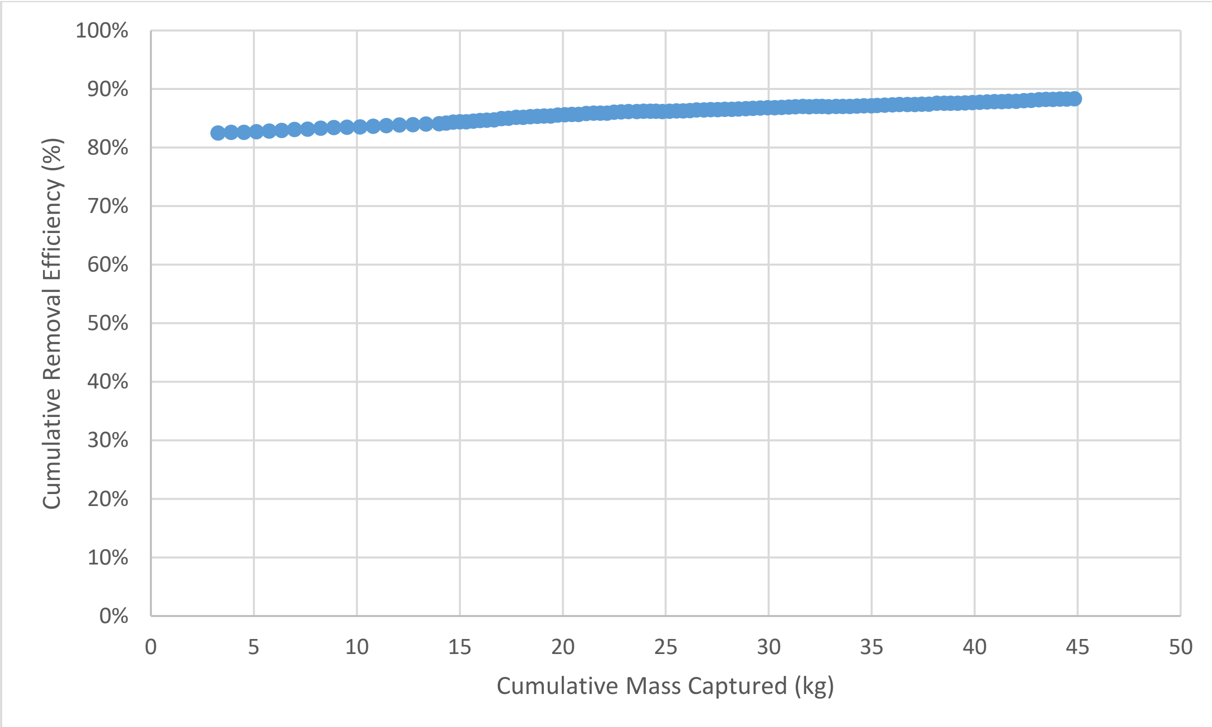

Figure 6 Sediment Mass Load Captured vs Removal Efficiency

4.3 Filter Driving Head

Driving head is defined as the maximum water level recorded during a test run as measured from the invert of the discharge pipe. Thus, the filter driving head was measured from the discharge pipe invert and was observed to increase with sediment mass load. This relationship is shown in **Tables 15 and 16** and in **Figure 7.**

Table 15 Removal Efficiency Driving Head Summary

Run #	Head Level (in)	Cumulative Mass Captured (kg)
1	38.63	0.318
2	39.04	0.654
3	39.01	0.974
4	38.70	1.314
5	38.70	1.636
6	38.84	1.986
7	38.36	2.323
8	38.29	2.627
9	38.36	2.940
10	38.57	3.267

Table 16 Mass Load Capacity Driving Head Summary

Run #	Head Level (in)	Cumulative Mass Captured (kg)
1-10		3.267
11	38.50	3.897
12	38.97	4.525
13	39.01	5.125
14	38.97	5.740
15	38.67	6.351
16	38.80	6.976
17	38.84	7.607
18	38.67	8.241
19	38.74	8.882
20	39.24	9.529
21	39.55	10.163
22	39.58	10.803
23	39.58	11.428
24	40.13	12.073
25	40.43	12.718
26	41.08	13.365
27	41.93	13.999

Run #	Head Level (in)	Cumulative Mass Captured (kg)
28	39.69	14.335
29	39.62	14.686
30	39.04	14.999
31	39.65	15.317
32	39.24	15.653
33	39.79	15.982
34	39.45	16.317
35	39.75	16.660
36	39.89	17.029
37	40.03	17.369
38	39.65	17.742
39	39.79	18.084
40	39.75	18.425
41	39.89	18.768
42	39.72	19.086
43	39.82	19.417
44	39.55	19.756
45	40.06	20.105
46	39.55	20.439
47	39.65	20.762
48	39.72	21.133
49	39.75	21.497
50	39.45	21.822
51	39.52	22.146
52	39.62	22.495
53	39.75	22.835
54	39.21	23.186
55	39.48	23.594
56	39.75	23.926
57	39.75	24.240
58	39.38	24.526
59	39.38	24.838
60	39.79	25.177
61	40.16	25.528
62	40.43	25.847
63	40.57	26.173

Run #	Head Level (in)	Cumulative Mass Captured (kg)
64	39.82	26.505
65	40.23	26.855
66	40.16	27.181
67	40.37	27.527
68	40.30	27.863
69	40.37	28.211
70	40.50	28.540
71	40.81	28.887
72	40.57	29.240
73	40.57	29.587
74	40.84	29.946
75	40.71	30.289
76	40.84	30.628
77	40.91	30.980
78	40.94	31.306
79	41.01	31.657
80	40.47	31.965
81	41.72	32.314
82	40.40	32.588
83	41.38	32.904
84	41.21	33.269
85	41.49	33.594
86	41.25	33.937
87	41.86	34.274
88	41.32	34.627
89	41.89	34.988
90	40.94	35.262
91	41.49	35.633
92	41.32	36.000
93	42.34	36.352
94	42.17	36.737
95	43.05	37.095
96	42.34	37.441
97	43.32	37.782
98	42.88	38.157
99	43.49	38.520

Run #	Head Level (in)	Cumulative Mass Captured (kg)
100	41.93	38.836
101	43.42	39.178
102	42.88	39.537
103	43.97	39.892
104	43.18	40.251
105	45.12	40.608
106	44.88	40.968
107	46.24	41.320
108	44.07	41.648
109	48.14	42.012
110	40.33	42.389
111	41.59	42.750
112	40.06	43.126
113	43.12	43.463
114	42.81	43.809
115	44.20	44.139
116	42.00	44.470
117	49.03	44.839

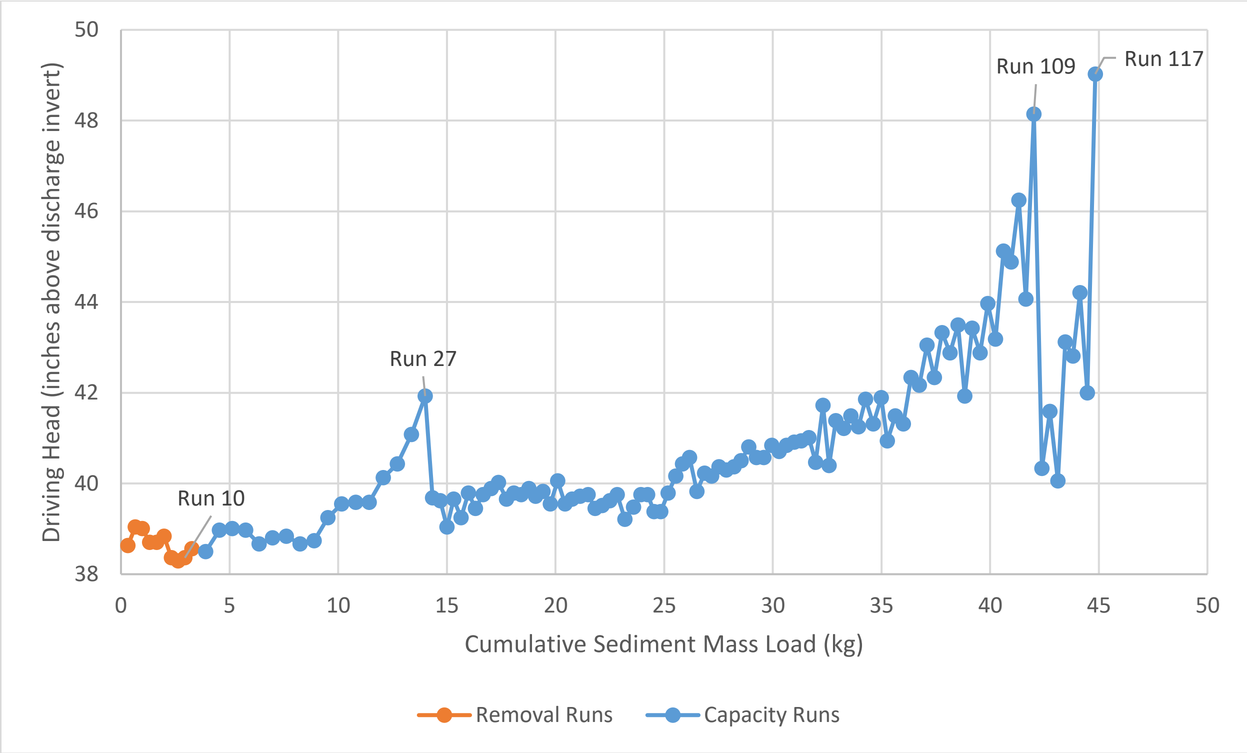

Figure 7 Sediment Mass Load Captured vs Driving Head

5. Design Limitations

If the Up-Flo® Filter EMC is designed and installed correctly, there is minimal possibility of failure. The system will be designed to convey stormwater up to the maximum flow rate of the storm sewer system. Similar to any other correctly designed treatment technology, a change in the characteristics of the contributing drainage area can lead to poor performance. An increase in imperviousness can result in higher peak flows which can exceed the treatment capacity of the Up-Flo® Filter EMC. A change in land use can result in higher solids loading or a change in the type of stormwater pollutants. High solids loading could result in unrealistic maintenance intervals. Different stormwater pollutants may not be treatable with the engineered media, e.g., ribbon filter, that was originally specified. Caution should obviously be used during the design of any stormwater treatment system if changes in the contributing area are expected.

Required soil characteristics

All Up-Flo® Filter EMCs are pre-assembled in concrete structures manufactured by ISO certified precast facilities in accordance with all applicable ASTM specifications and regional regulations. Subsequently all systems are designed to accommodate any site-specific limitations or constraints imposed by soil type, conditions or characteristics. In addition, all internal filter components are molded from polyethylene and PVC with 304 stainless steel hardware.

Slope

The Up-Flo® Filter EMC discharge piping permanently mounts in a fixed horizontal position running through the precast wall either directly outside of the vault or into an outlet chamber. In configurations where the pipe stub connects directly to the outlet pipe, slope is restricted to that permitted by the connecting coupling.

Maximum Filtration Rate

The maximum filtration rate of each Up-Flo® Filter EMC system is contingent on the area of the filter, but more specifically the number of Filter Cartridges and total filter ribbon surface area. Given the test results, the Up-Flo® Filter EMC will be sized to ensure the maximum filtration rate per cartridge will be 0.96 gpm per square foot of filtration area.

Maintenance Requirements

Up-Flo® Filter EMC maintenance requirements vary according to site characteristics such as runoff area, types of surfaces (e.g., paved and/or landscaped), site activities (e.g., short-term or long-term parking), and site maintenance (e.g., sanding and sweeping). At a minimum Hydro recommends inspection and maintenance should be conducted at intervals of no more than six months during the first year of operation. Observations made during these initial service events may be used to derive a lasting site-specific inspection and maintenance program

Operating Head

The maximum Driving Head for the Up-Flo® Filter EMC is 48 inches above the discharge pipe. This is the maximum head required to maintain the MTFR and annual sediment load at the maximum cartridges per row.

Installation limitations

Hydro provides installation instructions as well as product specific manufacturer specifications with each project submittal. Prior to scheduling delivery Hydro notifies the contractor with pick weights and specific handling instructions of/for the structure. Hydro provides remote technical assistance for contractors as well as offers onsite engineering to facilitate/oversee proper installation.

Configurations

The Up-Flo® Filter EMC has modular components to allow for differences in precast manufacture and preferences for source control design. In general, 8-ft wide precast vaults are used to house the filter cartridges. The tested configuration submitted for verification corresponds with offline use of filter cartridges equipped with filter ribbons.

Structural Load limitations

All Up-Flo® Filter EMCs are pre-assembled in concrete structures manufactured by ISO certified precast facilities in accordance with all applicable ASTM specifications and/or site-specific loading requirements. All precast structures will have a minimum wall thickness sufficient to sustain HS20-44 loading requirements.

Pretreatment requirements

The Up-Flo® Filter EMC is designed as a stand-alone device and requires no additional upstream treatment. However, for source control applications having high pollutant loads, inclusion of pretreatment can extend filter media longevity and reduce annual service requirements.

Limitations on tailwater

Tailwater conditions are carefully evaluated for each application. To allow for the backwash system to operate appropriately, a free discharge is required.

Depth of seasonal High-Water table

The Up-Flo® Filter EMC is designed to be connected as part of a self-contained storm sewer network. The precast structure housing each Up-Flo® Filter EMC system is sealed according to regional specifications and designed to account for buoyancy forces.

6. Maintenance

Maintenance activities can be categorized by those that can be performed from outside the Up-Flo® Filter EMC vessel and those that are performed inside the vessel. Maintenance performed from outside the vessel includes removal of floatables and oils that have accumulated on the water surface and removal of sediment from the sump. Maintenance performed inside the vessel includes removal and replacement of filter cartridges. A vactor truck will be needed to remove the standing water within the system before entering for maintenance. Confined space entry protocols should be followed.

Inspection

The frequency of inspection and maintenance can be determined in the field after installation. Based on site characteristics such as contributing area, types of surfaces (e.g., paved and/or landscaped), site activities (e.g., short-term or long-term parking), and site maintenance (e.g., sanding and sweeping), inspection and maintenance should be conducted at intervals of no more than six months during the first year of operation. Typically, maintenance is recommended once per year thereafter.

By removing the manhole cover and observing the water level in the manhole or vault, site personnel can determine when the filter cartridges have become blinded. The water elevation in the precast manhole or vault will not drain down after an event if the ribbons are blinded and will be higher than the tops of the filter cartridges. Otherwise, scheduled inspections will determine when one or more of the following maintenance thresholds have been reached:

- *Sediment depth at sump storage capacity*
  A sediment depth of 6 inches indicates the sump has reached its maximum capacity for Up-Flo® Filter EMC installations configured with filter ribbons. A sediment probe, such as the Sludge-Judge®, can be used to determine the depth of the solids in the sump.

- *Blinding of Filter Ribbons*
  Observing water elevations and inspecting the filter ribbons is required to determine when they require replacement. If the water elevation is higher than the top of the cartridge, the filter should be drained down, inspected and replaced if there is heavy loading or slime coating the filter ribbons.

- *Oil forming a measurable thickness on the surface of the water*
  The Up-Flo® Filter EMC will prevent free oils from passing through the filter cartridges. However, storing volatile hydrocarbons is not recommended. Any free oils on the water surface in excess of 1 inch should be removed.

The site-specific solids loading rate in the sump and in the engineered filtration media will be determined during the first year of Up-Flo® Filter EMC operation. Starting with a clean sump, the solids loading rate in the sump will be calculated by measuring the sediment depth in the sump and dividing the depth by the correlating interval of time since it was cleaned.

After completion of the first year of operation, the inspection and maintenance intervals for cleaning the sump and replacing filter ribbons will be established. Removal of oils and floatables will occur at the same frequency unless the first year of operation indicates otherwise. Keeping to the established maintenance intervals is critical for long term performance of any filtration system.

Maintenance Procedures

The access port located at the top of the manhole or vault provides access to the Up-Flo® Filter EMC vessel for maintenance personnel to enter the vessel and comfortably remove and replace the filter ribbons. The same access would be used for maintenance personnel working from the surface to net or skim debris and floatables or to vactor out sediment, oil, and water. Unless the Up-Flo® Filter EMC has been installed in a very shallow unit, it is necessary to have personnel with OSHA-confined space entry performing the maintenance that occurs inside the vessel. Very shallow units (five feet deep for example) may be installed with a hatch that allow for filter access without confined space entry.

Maintenance activities include inspection, floatables removal, oil removal, sediment removal, and replacement of the ribbon assemblies. Depending on the site, some maintenance activities are required with greater frequency than others. In the case of floatables removal, a vactor truck is not required. Otherwise, a vactor truck is normally required for oil removal, removal of sediment from the sump, and to dewater the vessel for replacing filter ribbons. All inspection and maintenance activities should be recorded in an inspection and maintenance log.

Good housekeeping practices upstream of the Up-Flo® Filter EMC can significantly extend filter ribbon life. For example, sweeping paved surfaces, collecting leaves and grass trimmings, and employing erosion control practices will reduce loading to the system. Filter ribbons should not be installed in the Filter Cartridges until construction activities are complete and site stabilization is effective.

Solids Disposal

Sediment, floatables, gross debris, and spent filter ribbons can generally be disposed of at the local landfill in accordance with local regulations. The toxicity of the residues produced will depend on the activities in the contributing drainage area. Testing of the residues may be required if they are considered potentially hazardous.

Sump water can generally be disposed of at a licensed water treatment facility, but the local sewer authority should be contacted for permission prior to discharging the liquid. Significant accumulations of oils removed separately from sump water should be transported to a licensed hazardous waste treatment facility for treatment or disposal.

In all cases, local regulators should be contacted about disposal requirements. The O&M manual can be accessed at the link below:
https://www.hydro-int.com/sites/default/files/up-flo_filter_emc_operation_maintenance_manual.pdf

7. Statements

The following signed statements from the manufacturer (Hydro), third-party observer (FB Environmental) and NJCAT are required to complete the NJCAT verification process. In addition, it should be noted that this report has been subjected to public review (e.g. stormwater industry) and all comments and concerns have been satisfactorily addressed.

Hydro International

Turning Water Around...®

October 17th, 2019

Dr. Richard Magee, Sc.D., P.E., BCEE
Executive Director
New Jersey Corporation for Advanced Technology
c/o Center for Environmental Systems
Stevens Institute of Technology
One Castle Point on Hudson
Hoboken, NJ 07030

Re: Manufacturers Statement of Compliance

Dear Dr. Magee:

Hydro International has completed verification testing for the Up-Flo® Filter with Extended Maintenance Cartridge in accordance with the *"New Jersey Department of Environmental Protection (NJDEP) Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device"* (January 25, 2013). As required by the *"NJDEP Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (NJCAT)"*, this letter serves as Hydro International's statement that all procedures and requirements identified in the aforementioned protocol and process document were met or exceeded.

Specifically, a single module Up-Flo® Filter fitted with the Extended Maintenance Cartridge was tested at Hydro International's laboratory in Portland, Maine for efficacy and sediment mass loading. To ensure that all procedures and methods were met, a test plan was completed and submitted to NJCAT for review and approval, all testing and sample collection was conducted under the direct supervision of the independent observer, FB Environmental Associates, and all collected samples were sent to either of two independent and certified laboratories; GeoTesting Express for particle size analysis or Maine Environmental Laboratories for measuring suspended solid concentrations. With this in mind, the preparation of the verification report and the documentation contained therein fulfill the submission requirements of the process document and protocol.

If you have any questions or comments regarding the verification please do not hesitate to contact us.

Sincerely,

Jeremy Fink, PE
Pr. Product Development Engineer

Hydro International (Stormwater), 94 Hutchins Drive, Portland ME 04102
Tel: (207) 756-6200 Fax: (207) 756-6212 Web: www.hydro-int.com

S T A T E M E N T O F T H I R D P A R T Y O B S E R V E R

To: **Dave Scott, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: **Third Party Witness of Hydro International Up-Flo® Filter**

Date: September 26, 2019

cc: Andrew Anastasio, Hydro International; Jeremy Fink, Hydro International
Margaret Burns, FB Environmental Associates

Statement of Third Party Observer

FB Environmental served as the third-party observer for tests performed on the Up-Flo® Filter by Hydro International in May through August of 2019 to achieve certification through the New Jersey Department of Environmental Protection (NJDEP) according to the *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices.* The test was performed by Hydro International staff at their laboratory located at 94 Hutchinson Drive in Portland, Maine. A member of our staff verified compliance with the laboratory test protocol above, and our staff member was physically present to observe the full duration of the laboratory test.

We have also reviewed the data, calculations, and conclusions associated with the removal efficiency testing in the *NJCAT Technology Verification: Up-Flo® Filter (With Extended Maintenance Cartridge)* report by Hydro International, dated September 2019, and state that they conform to what we saw during our supervision as a third-party observer.

Forrest Bell   September 26, 2019

Signed: Date:

STATEMENT OF DISCLOSURE – THIRD PARTY OBSERVER

To: **Dave Scott, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: **Third Party Observer Statement of Disclosure under *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices***

Date: September 26, 2019

cc: Andrew Anastasio, Hydro International; Jeremy Fink, Hydro International; Margaret Burns, FB Environmental Associates

Statement of Disclosure – Third Party Observer

FB Environmental has no financial conflict of interest regarding the test results of the stormwater device testing outlined in the *NJCAT Technology Verification: Up Flo® Filter (With Extended Maintenance Cartridge)* by Hydro International, dated September 2019.

Disclosure Record

FB Environmental has provided the service of third party observer for tests performed by Hydro International in May through August of 2019. The tests assessed the removal efficiency of the Up-Flo® Filter using gravitational separation of floating and settling materials with filtration of polluted stormwater to offer treatment train capabilities in a standalone device. Beyond this, FB Environmental and Hydro International have no relationships that would constitute a conflict of interest. For example, we have no ownership stake, do not receive commissions, do not have licensing agreements, and do not receive funds or grants beyond those associated with the testing program.

Forrest Bell (signature) September 26, 2019

Signed: Date:

Center for Environmental Systems
Stevens Institute of Technology
One Castle Point
Hoboken, NJ 07030-0000

October 28, 2019

Gabriel Mahon, Chief
NJDEP
Bureau of Non-Point Pollution Control
Bureau of Water Quality
401 E. State Street
Mail Code 401-02B, PO Box 420
Trenton, NJ 08625-0420

Dear Mr. Mahon,

Based on my review, evaluation and assessment of the testing conducted on the Hydro Up-Flo® Filter EMC (Extended Maintenance Cartridge) at the company's full-scale hydraulic testing facility in Portland, Maine, under the third party oversight of FB Environmental, 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, January 2013) were met or exceeded. Specifically:

Test Sediment Feed

The test sediment was a blend of commercially available silica sand grades. The sediment was blended by Hydro and the particle size distribution was independently verified by GeoTesting Express certifying that the blended silica meets the specification within tolerance as described in Section 5B of the NJDEP filter protocol and was acceptable for use.

Removal Efficiency Testing

One hundred seventeen (117) removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. One hundred seven (107) of the 117 test runs were conducted during mass loading and 10 during removal efficiency testing. The target flow rate and influent sediment concentration were 17 gpm and 200 mg/L (increased to 400 mg/L for tests 11-27, after which it was reduced back down to 200 mg/L) respectively. Maximum driving head of 48" was reached at Test Run 109 and the flow rate was reduced to 90% of the MTFR (15.3 gpm) for Test Runs 110-

117 per the filter protocol. The Up-Flo Filter EMC demonstrated an average sediment removal efficiency on a cumulative mass basis of 82.48% over the course of the 10-removal efficiency test runs and 88.32% for the 117 test runs.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted as a continuation of removal efficiency testing. Mass loading test runs were conducted using identical testing procedures and targets as those used in the RE runs, the only change was to increase the target influent concentration to 400 mg/L for tests 11-27, after which it was reduced back to 200 mg/L for tests 28-117. Testing concluded after 117 test runs due to exceedance of the design driving head at 90% of the design flow rate.

The Up-Flo Filter EMC has a mass loading capacity of 97 lbs per cartridge.

No maintenance was performed on the test system during the entire testing program.

Scour Testing

The Up-Flo Filter EMC is designed for off-line installation. Consequently, scour testing is not required.

Sincerely,

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

8. References

ASTM D422-63. *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D3977-97. *Standard Test Methods for Determining Concentrations in Water Samples*.

NJDEP 2013a. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*. Trenton, NJ. January 25, 2013.

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

NJDEP 2013c. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device.* Trenton, NJ. January 25, 2013.

NJDEP 2013d. *NJCAT Technology Verification: Up-Flo Filter.* Trenton, NJ. November 2008.

NJDEP 2013e. *NJCAT Technology Verification: Up-Flo Filter*. Trenton, NJ. January 2015.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Hydro International, 94 Hutchins Drive, Portland, ME 04102. *General Phone: (207)756-6200*. *Website:* www.hydro-int.com/us.
- MTD – Typical Up-Flo® Filter EMC (Extended Maintenance Cartridge) Design Specifications are shown in **Table A-1**.
- TSS Removal Rate – 80%
- Media – Filter Ribbons
- Off-line installation

Detailed Specification

- Up-Flo® Filter EMC (Extended Maintenance Cartridge) vault arrangements, MTFR, and maximum drainage area per NJDEP sizing requirements are attached (**Table A-2 - Table A-5**).
- Maximum inflow drainage area
  - The maximum inflow drainage area is governed by the maximum treatment flow rate or sediment loading on the filter for each cartridge design and vault arrangement as presented in **Table A-2** – **Table A-5.**
- Product O&M Manual can be accessed at the link below:
  - https://www.hydro-int.com/sites/default/files/up-flo_filter_emc_operation_maintenance_manual.pdf
- This verification does not extend to the enhanced removal rates under NJAC 7:8-5.5 through the addition of settling chambers (such as hydrodynamic separators) or media filtration practices (such as a sand filter).

Table A-1 Cartridge Design Specifications

Cart. Ht. (in)	Sump Depth (inches)	Ribbon Length (inches)	Res. Depth (inches)	MTFR (gpm)	EFTA (sq.ft.)	ESA (sq.ft.)	WV (cu.ft.)	Max. Drainage Area (ac)	MTFR/ EFTA	Acres/ EFTA	Lbs/ EFTA	ESA/ EFTA	ESA/EFTA >.09	WV/ EFTA	WV/EFTA >.39
48	50	32.00	12.00	17.0	17.8	1.7	7.0	0.16	0.96	0.01	5.46	0.09	Tested	0.39	Tested
36	38	23.27	8.73	12.4	12.9	1.7	5.3	0.12	0.96	0.01	5.46	0.13	YES	0.41	YES
27	29	16.73	6.27	8.9	9.3	1.7	4.0	0.08	0.96	0.01	5.46	0.18	YES	0.43	YES
18	20	10.18	3.82	5.4	5.7	1.7	2.8	0.05	0.96	0.01	5.46	0.29	YES	0.49	YES

Table A-2 Typical Vault Arrangement with Bypass (48-inch Cartridge)

Vault Size (ft)	Width (ft)	Vault Length (ft)	No. Carts.	MTFR (gpm)	Max Drain Area (ac)	EFTA (sq.ft.)	MTFR/ EFTA	MTFR/ EFTA <= .96	WV (cu.ft.)	WV/ EFTA	WV/ EFTA > 0.39	ESA (sq.ft.)	ESA/ EFSA	ESA/ EFSA > .09
4x4	4	4	6	102	0.97	106.7	0.96	YES	51.39	0.48	YES	12.33	0.12	YES
4x6	4	6	11	187	1.78	195.6	0.96	YES	84.72	0.43	YES	20.33	0.10	YES
4x8	4	8	15	255	2.43	266.7	0.96	YES	115.28	0.43	YES	27.67	0.10	YES
6x6	6	6	15	255	2.43	266.7	0.96	YES	118.75	0.45	YES	28.50	0.11	YES
6x8	6	8	23	391	3.72	408.9	0.96	YES	163.83	0.40	YES	39.32	0.10	YES
6x10	6	10	28	476	4.53	497.8	0.96	YES	204.17	0.41	YES	49.00	0.10	YES
6x12	6	12	34	578	5.50	604.4	0.96	YES	243.75	0.40	YES	58.50	0.10	YES
6x14	6	14	39	663	6.31	693.3	0.96	YES	279.17	0.40	YES	67.00	0.10	YES
8x8	8	8	29	493	4.69	515.6	0.96	YES	205.56	0.40	YES	49.33	0.10	YES
8x10	8	10	36	612	5.82	640.0	0.96	YES	258.33	0.40	YES	62.00	0.10	YES
8x13	8	13	46	782	7.44	817.8	0.96	YES	329.17	0.40	YES	79.00	0.10	YES
8x14	8	14	49	833	7.92	871.1	0.96	YES	352.78	0.40	YES	84.67	0.10	YES
8x15	8	15	53	901	8.57	942.2	0.96	YES	376.39	0.40	YES	90.33	0.10	YES
8x18.5	8	18.5	64	1088	10.35	1137.8	0.96	YES	454.17	0.40	YES	109.00	0.10	YES
8x24	8	24	79	1343	12.77	1404.4	0.96	YES	563.89	0.40	YES	135.33	0.10	YES

Table A-3 Typical Vault Arrangement with Bypass (36-inch Cartridge)

Vault Size (ft)	Width (ft)	Length (ft)	No. Carts.	MTFR (gpm)	Max Drain Area (ac)	EFTA (sq.ft.)	MTFR/ EFTA	MTFR/ EFTA <= .96	WV (cu.ft.)	WV/ EFTA	WV/ EFTA > 0.39	ESA (sq.ft.)	ESA/ EFSA	ESA/ EFSA > .09
4x4	4	4	6	74	0.71	77.6	0.96	YES	39.06	0.50	YES	12.33	0.16	YES
4x6	4	6	11	136	1.29	142.2	0.96	YES	64.39	0.45	YES	20.33	0.14	YES
4x8	4	8	15	185	1.76	193.9	0.96	YES	89.72	0.46	YES	28.33	0.15	YES
6x6	6	6	17	210	2.00	219.8	0.96	YES	93.42	0.43	YES	29.50	0.13	YES
6x8	6	8	23	284	2.70	297.4	0.96	YES	128.25	0.43	YES	40.50	0.14	YES
6x10	6	10	30	371	3.53	387.9	0.96	YES	162.45	0.42	YES	51.30	0.13	YES
6x12	6	12	35	433	4.12	452.5	0.96	YES	193.17	0.43	YES	61.00	0.13	YES
6x14	6	14	41	507	4.82	530.1	0.96	YES	223.25	0.42	YES	70.50	0.13	YES
8x8	8	8	30	371	3.53	387.9	0.96	YES	165.93	0.43	YES	52.40	0.14	YES
8x10	8	10	38	470	4.47	491.3	0.96	YES	206.89	0.42	YES	65.33	0.13	YES
8x13	8	13	50	618	5.88	646.5	0.96	YES	272.33	0.42	YES	86.00	0.13	YES
8x14	8	14	53	655	6.23	685.3	0.96	YES	290.28	0.42	YES	91.67	0.13	YES
8x15	8	15	57	705	6.70	737.0	0.96	YES	308.22	0.42	YES	97.33	0.13	YES
8x18.5	8	18.5	70	865	8.23	905.1	0.96	YES	382.11	0.42	YES	120.67	0.13	YES
8x24	8	24	87	1076	10.23	1124.8	0.96	YES	469.72	0.42	YES	148.33	0.13	YES

Table A-4 Typical Vault Arrangement with Bypass (27-inch Cartridge)

Vault Size (ft)	Width (ft)	Length (ft)	No. Carts.	MTFR (gpm)	Max Drain Area (ac)	EFTA (sq.ft.)	MTFR / EFTA	MTFR/ EFTA <= .96	WV (cu.ft.)	WV/ EFTA	WV/ EFTA > 0.39	ESA (sq.ft.)	ESA/ EFSA	ESA/ EFSA > .09
4x4	4	4	6	53	0.51	55.8	0.96	YES	29.81	0.53	YES	12.33	0.22	YES
4x6	4	6	11	98	0.93	102.2	0.96	YES	49.14	0.48	YES	20.33	0.20	YES
4x8	4	8	15	133	1.27	139.4	0.96	YES	68.47	0.49	YES	28.33	0.20	YES
6x6	6	6	17	151	1.44	158.0	0.96	YES	71.29	0.45	YES	29.50	0.19	YES
6x8	6	8	24	213	2.03	223.0	0.96	YES	100.29	0.45	YES	41.50	0.19	YES
6x10	6	10	30	267	2.54	278.8	0.96	YES	126.88	0.46	YES	52.50	0.19	YES
6x12	6	12	37	329	3.13	343.8	0.96	YES	152.98	0.44	YES	63.30	0.18	YES
6x14	6	14	44	391	3.72	408.9	0.96	YES	181.98	0.45	YES	75.30	0.18	YES
8x8	8	8	31	275	2.62	288.1	0.96	YES	130.50	0.45	YES	54.00	0.19	YES
8x10	8	10	40	355	3.38	371.7	0.96	YES	165.30	0.44	YES	68.40	0.18	YES
8x13	8	13	49	435	4.14	455.4	0.96	YES	202.19	0.44	YES	83.67	0.18	YES
8x14	8	14	57	507	4.82	529.7	0.96	YES	235.22	0.44	YES	97.33	0.18	YES
8x15	8	15	61	542	5.15	566.9	0.96	YES	254.56	0.45	YES	105.33	0.19	YES
8x18.5	8	18.5	75	666	6.34	697.0	0.96	YES	308.53	0.44	YES	127.67	0.18	YES
8x24	8	24	96	853	8.11	892.1	0.96	YES	397.94	0.45	YES	164.67	0.18	YES

Table A-5 Typical Vault Arrangement with Bypass (18-inch Cartridge)

Vault Size (ft)	Width (ft)	Length (ft)	No. Carts.	MTFR (gpm)	Max Drain Area (ac)	EFTA (sq.ft.)	MTFR/ EFTA	MTFR/ EFTA <= .96	WV (cu.ft.)	WV/ EFTA	WV/ EFTA > 0.39	ESA (sq.ft.)	ESA/ EFSA	ESA/ EFSA > .09
4x4	4	4	6	32	0.31	33.9	0.96	YES	20.56	0.61	YES	12.33	0.36	YES
4x6	4	6	11	60	0.57	62.2	0.96	YES	33.89	0.54	YES	20.33	0.33	YES
4x8	4	8	15	81	0.77	84.8	0.96	YES	47.22	0.56	YES	28.33	0.33	YES
6x6	6	6	17	92	0.87	96.2	0.96	YES	49.17	0.51	YES	29.50	0.31	YES
6x8	6	8	24	130	1.23	135.8	0.96	YES	69.17	0.51	YES	41.50	0.31	YES
6x10	6	10	31	168	1.59	175.4	0.96	YES	89.17	0.51	YES	53.50	0.31	YES
6x12	6	12	38	206	1.95	214.9	0.96	YES	109.17	0.51	YES	65.50	0.30	YES
6x14	6	14	45	243	2.31	254.5	0.96	YES	127.50	0.50	YES	76.50	0.30	YES
8x8	8	8	32	173	1.65	181.0	0.96	YES	92.22	0.51	YES	55.33	0.31	YES
8x10	8	10	41	222	2.11	231.9	0.96	YES	116.67	0.50	YES	70.00	0.30	YES
8x13	8	13	55	298	2.83	311.1	0.96	YES	156.67	0.50	YES	94.00	0.30	YES
8x14	8	14	59	319	3.03	333.7	0.96	YES	167.33	0.50	YES	100.40	0.30	YES
8x15	8	15	63	341	3.24	356.4	0.96	YES	180.67	0.51	YES	108.40	0.30	YES
8x18.5	8	18.5	80	433	4.12	452.5	0.96	YES	227.33	0.50	YES	136.40	0.30	YES
8x24	8	24	102	552	5.25	577.0	0.96	YES	290.00	0.50	YES	174.00	0.30	YES