NJCAT TECHNOLOGY VERIFICATION

Hydroworks HydroFilter

Hydroworks, LLC

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1. Description of Technology

The Hydroworks HydroFilter is a stormwater management device designed to treat stormwater via filtration. HydroFilter can also be integrated with storage for infiltration to maintain the hydrologic cycle during urbanization. Hydroworks has modified the SWMM model to include infiltration storage to be able to design storage to meet any state recharge requirement. Maintenance of the hydrologic cycle helps prevent flooding, erosion and promotes water quality by maintaining the stream geomorphology. Maintenance of the hydrologic cycle requires infiltration to reduce the additional stormwater volume and reduction in infiltration that occurs with standard development.

The requirement for infiltration is complicated by the fact that urbanization increases pollution, and it would be detrimental to the environment to merely infiltrate this polluted water. Therefore, there is a need to pretreat the water that is to be infiltrated from urbanized areas such as roads and parking lots. HydroFilter provides the pretreatment and infiltration (recharge) in one device.

Many site infiltration practices try to infiltrate all the water at the low point of the site just prior to connection with the municipal storm drain system. This is not the same as predevelopment infiltration which is dispersed all over the site. Centralized infiltration can be problematic since the storm sewer is too deep, requiring an outlet control device to back up water upstream to get the required infiltration volume. Centralized infiltration can cause groundwater mounding and sealing of pores reducing infiltration capacity.

Low Impact Development (LID) practices promote more infiltration at the source. HydroFilter can be considered a LID practice since the intention is to promote dispersed infiltration around the site at each inlet which is a more holistic approach to maintenance of the hydrologic cycle.

As stormwater treatment structures fill up with pollutants, they become less effective in removing new pollution. In separators detention time is reduced and there is greater potential for re-entrainment of settled solids. In filters, the accumulation of solids in the filter requires increased head to achieve the design flowrate, leading to the potential for greater annual bypass volumes and a reduction in the volume of stormwater filtered. Therefore, it is important that stormwater treatment structures be maintained on a regular basis to ensure that they are operating at optimum performance. The HydroFilter is no different in this regard.

Operation

The Hydroworks HydroFilter is a LID device since it promotes the maintenance of the hydrologic cycle. Unlike many infiltration systems however, HydroFilter was designed for dispersed infiltration around the site, such as inlets or catch basins. (See Section 5 Design Limitations, *Infiltration Regulatory Requirements*).

Under normal or low flows, water enters the structure through a grate or inlet. Incoming water builds up around the filters and creates head to drive water radially into the filter cartridges from the outside through to the center of the cartridge. There is a 6” (150 mm) diameter open center that runs through the center of each cartridge. Water reaching the center opening falls by gravity into the base plug and is conveyed out of the structure by a pipe(s) into a storm drain or optionally into the surrounding ground to be infiltrated (**Figure 1**). A solid deflector cone with an air-port is placed on the top filter cartridge to prevent incoming water from entering the 6” (150 mm) diameter opening without passing through the filter.

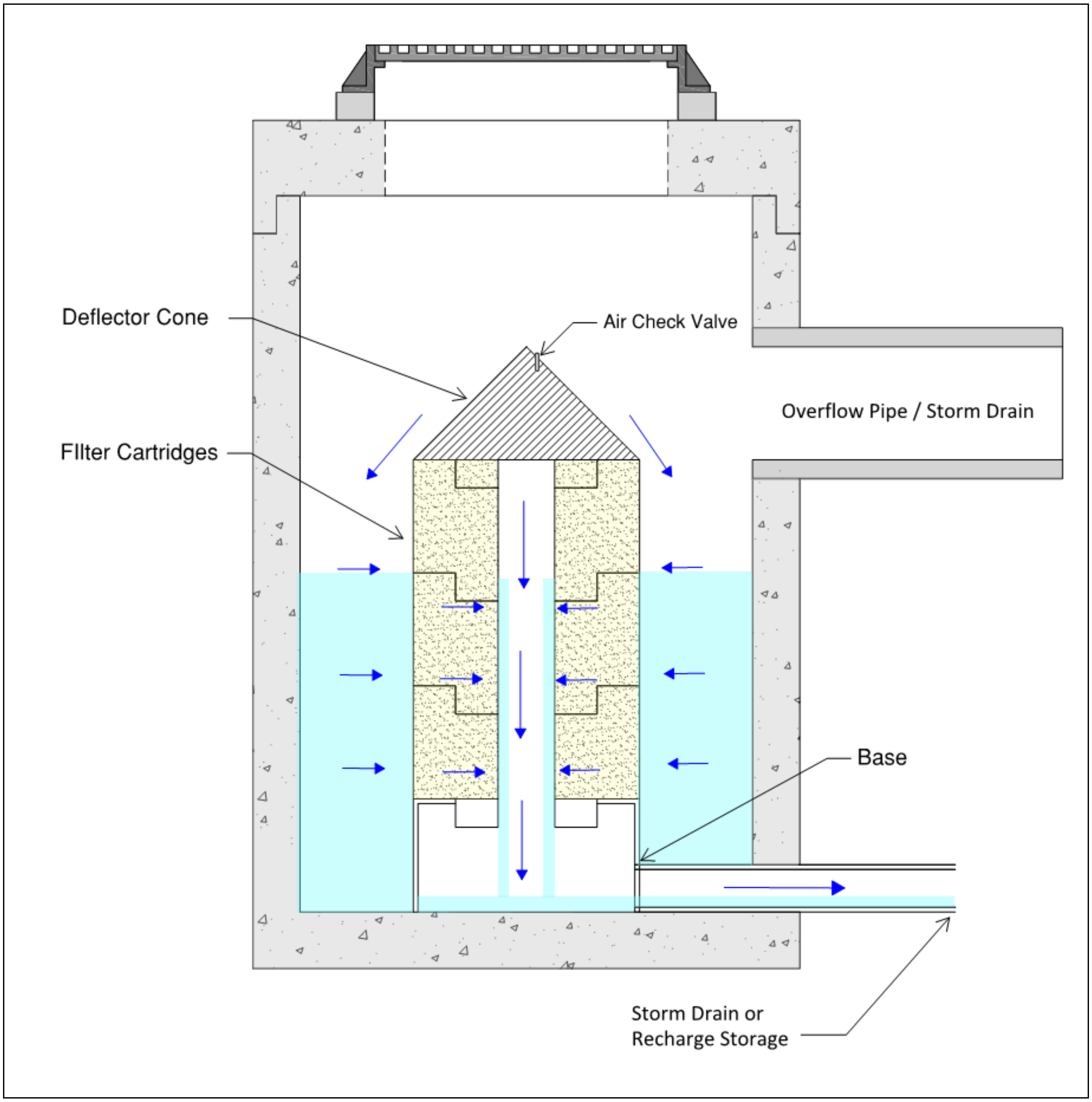

Figure 1 Hydroworks HydroFilter Operation – Low Flow

If the flow rate into the structure exceeds the flow capacity of the filter water will bypass (overflow) into the downstream storm drain (**Figure 2**).

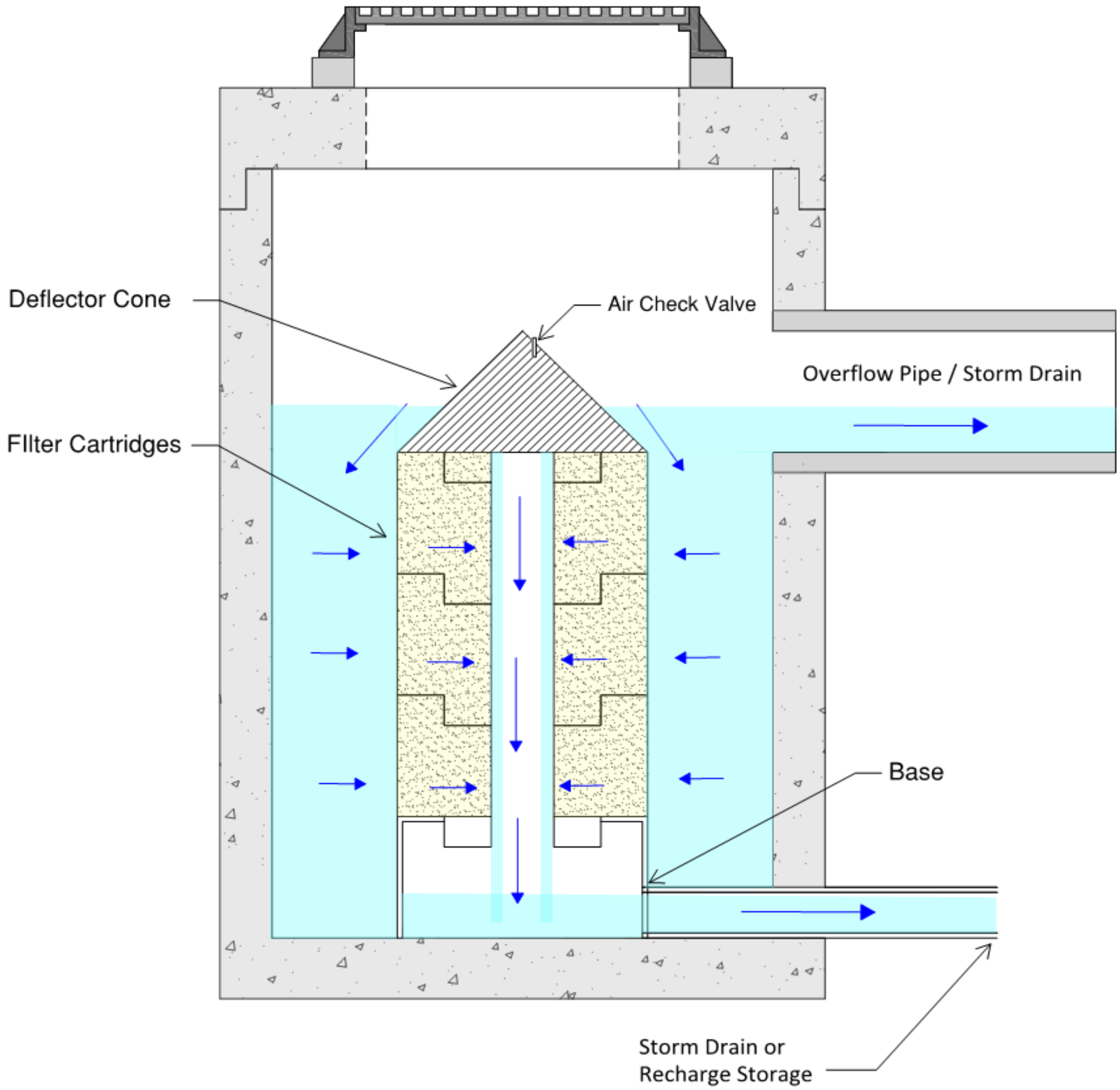

Figure 2 Hydroworks HydroFilter Operation – Bypass

It should be noted that the HydroFilter can be installed in many configurations (round or rectangular structures) with one or more cartridges in a stack and one or more stacks per structure. Therefore, the configuration of the HydroFilter varies depending on the flow rate to be treated and whether the design incorporates infiltration.

2. Laboratory Testing

The test program was conducted at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direct supervision of Alden's senior stormwater engineer, James Mailloux. Alden has performed verification testing on Hydrodynamic Separator and Filtration Manufactured Treatment Devices (MTDs) for manufacturers under various state and federal testing protocols. Particle size distribution (PSD) analysis was conducted by GeoTesting Express, Inc., Acton, Massachusetts. GeoTesting is an AALA ISO/IEC 17025 accredited independent laboratory. Water quality samples collected during the testing process were analyzed in Alden's Calibration Laboratory, which is ISO 17025 accredited.

Laboratory testing was done in accordance with the New Jersey Department of Environmental Protection "Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (January 2013a) (NJDEP Filter Protocol). Prior to starting the performance testing program, a quality assurance project plan (QAPP) was submitted to, and approved by, the New Jersey Corporation for Advanced Technology (NJCAT) as per the NJDEP certification process.

2.1 Test Setup

The tested treatment filter was comprised of two (2) 24"-diameter x 12" high stacked interlocking filter cartridges installed in a 3-ft diameter tank. Each cartridge contained a proprietary filter media. The inner and outer flow surfaces of the cartridges were perforated. A 24"-diameter by approximately 12"-high deflection cone was installed on the top cartridge. The filter assembly was installed in a 24"-diameter by 12"-high base pedestal, which was sealed to the tank floor. Water was conveyed into the tank by means of an 8"-diameter inlet pipe, which discharged onto a sloped inlet containing a 24" storm grate. The flow was deflected around the annular space between the filter and tank and was conveyed radially through the cartridges. A 6" center opening in each cartridge conveyed the treated flow down into the base pedestal and into a 6" outlet pipe located at the bottom of the tank. The pipe was sealed to the pedestal and tank wall. A 6" bypass pipe was installed with the invert elevation at 3.04 ft. The pipe was connected to a tee in the outlet pipe upstream of the sampling point. The annular area around the base pedestal (3.93 ft^2) was designed as a settling area for larger particles. A series of anti-scour flaps were installed at the height of the pedestal (dry-weather condition) to protect the captured sediment from scour.

Drawings of the HydroFilter test unit are shown on **Figure 3**. Photographs showing the filter installed in the test loop are shown on **Figure 4, Figure 5,** and **Figure 6**. The bottom riser section shown in the photographs was used to elevate the tank for sampling purposes and was not part of the treatment system.

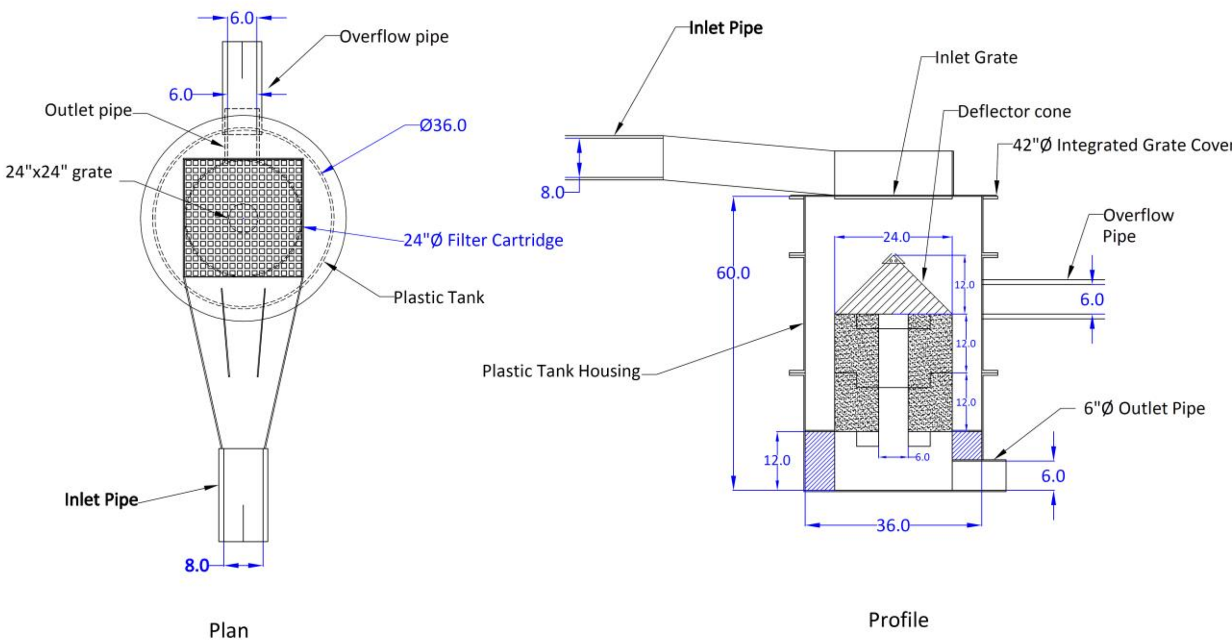

Figure 3 Drawing of the Hydroworks HydroFilter

Figure 4 Hydroworks HydroFilter Test Set-up

Figure 5 Test Loop Grated Inlet

Figure 6 Outlet and Bypass Piping

The HydroFilter system was installed in the Alden test loop, shown on **Figure 7,** which was set up as a recirculation system. The loop was designed to provide metered flow up to approximately 1 cfs. Flow was supplied to the unit with a 20HP laboratory pump, drawing water from a 50,000-gallon supply sump. The test flow was set using a 1.5” orifice plate differential-pressure (DP) meter and corresponding control valve. A DP cell and computer Data Acquisition (DA) program was used to record the test flow. Twenty-five (25) feet of straight 8” PVC influent pipe conveyed the metered flow to a sloped inlet tray containing a 24” x 24” horizontal inlet grate. Two (2) feet of 6” PVC pipe free-discharged the effluent flows to an effluent channel, which returned the flow to the supply sump. The influent and effluent pipes were set at 1% slopes. An 8” tee was located 3 pipe-diameters (2 ft) upstream of the sloped inlet, for injecting sediment into the crown of the influent pipe using a variable-speed auger feeder. Filtration of the supply sump was performed with an in-situ filter wall containing 1-micron bag filters.

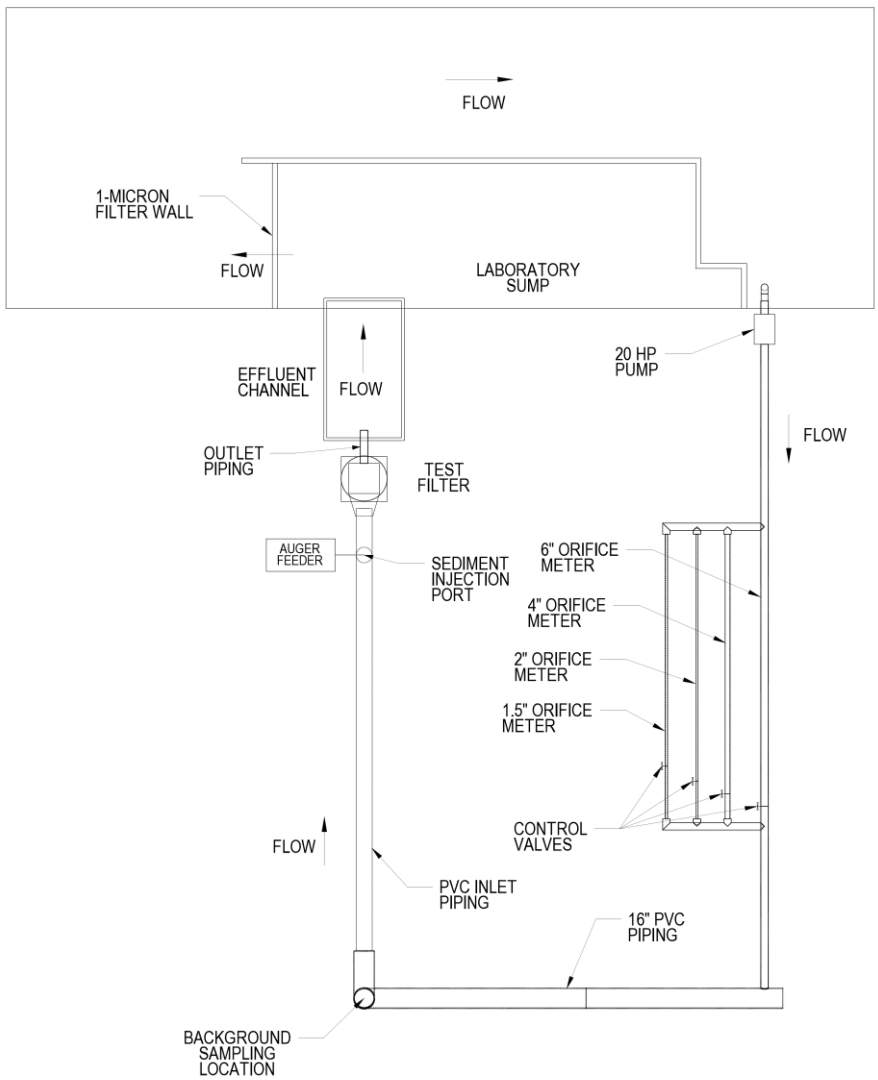

Figure 7 Plan View of Alden Flow Loop

2.2 Removal Efficiency Testing

Sediment testing was conducted to determine the removal efficiency, as well as sediment mass loading capacity. The sediment testing was conducted on an initially clean system at the 100% MTFR of 25 gpm (as selected by Hydroworks). A minimum of ten (10) 30-minute test runs were required to be conducted to meet the removal efficiency criterion. Additional runs were conducted to determine the maximum mass loading. The captured sediment was not removed from the system between test runs. The total mass injected into the system was quantified at the conclusion of all the runs. This data was used for determination of the required maintenance frequency.

The test sediment was prepared by Alden to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in column 2 of **Table 1**. The sediment was silica based, with a specific gravity of 2.65. Three random PSD samples of the test sediment were analyzed by GeoTesting Express, an independent certified analytical laboratory using ASTM D 422-63 (2007) "Standard Test Method for Particle Size Analysis of Soils". The average of the three samples was used for compliance with the protocol. Additional discussion of the sediment is presented in **Section 4.1**.

Table 1 Test Sediment Particle Size Distribution

Table 1: Test Sediment Particle Size Distribution[1]	
Particle Size (Microns)	**Target Minimum % Less Than[2]**
1,000	100
500	95
250	90
150	75
100	60
75	50
50	45
20	35
8	20
5	10
2	5

1. The material shall be hard, firm, and inorganic with a specific gravity of 2.65. The various particle sizes shall be uniformly distributed throughout the material prior to use.
2. A measured value may be lower than a target minimum % less than value by up to two percentage points, A measured value may be lower than a target minimum % less than value by up to two percentage points (e.g., at least 3% of the particles must be less than 2 microns in size [target is 5%]), provided the measured d50 value does not exceed 75 microns..

The target influent sediment concentration was 200 mg/L (+/-20 mg/L) for all tests. The concentration was verified by collecting three timed dry samples at the injector and correlating the data with the measured average flow to verify the influent concentration values for each test. The allowed Coefficient of Variance (COV) for the measured samples was ≤ 0.10. The moisture content of the test sediment was determined using ASTM D4959-07. The protocol requires the temperature of the supply water to be ≤ 80 degrees F.

Five (5) time-stamped effluent samples were collected from the end of the outlet pipe during each run. A minimum of three detention times were allowed to pass before collecting a sample after the start of sediment feed and when the feed was interrupted for injection measurements. Three (3) background samples of the supply water were collected during each run. The samples were collected with each odd-numbered effluent sample (1, 3 & 5). Collected samples were analyzed for Suspended Solids Concentration (SSC) using ASTM D3977-97 (2019).

At the conclusion of a run, the injection feed was stopped and time-stamped. The flow was stopped after a duration of 10-seconds had passed. Two (2) volume-based evenly-spaced effluent samples were collected from the pipe during drawdown.

2.3 Scour Testing

Scour testing was conducted at the conclusion of the removal efficiency and mass loading testing, to qualify the filter as an on-line system. The target flow (200% MTFR) was reached within 5 minutes of initiating the test. A total of fifteen (15) effluent samples were collected over a period of 30 minutes (every 2 minutes), starting 2 minutes after reaching the target flow. Each effluent grab sample for sediment concentration was collected from the end of the effluent pipe by sweeping a 2-liter beaker through the effluent stream. Eight background samples were collected during the test, in conjunction with each odd-numbered effluent sample (1, 3, 5, etc.). The system qualified for on-line installation if the average effluent concentration (adjusted for background) was ≤ 20 mg/L.

An additional scour test was conducted at 50 gpm (200% MTFR) on the fully loaded HydroFilter with the vault preloaded to 3” using 1-1000 micron particles shown in **Table 8**. The vault settling area was cleaned prior to preload.

2.4 Instrumentation and Measuring Techniques

Flow

The inflow to the test unit was measured using a 1.5” calibrated orifice plate differential-pressure flow meter. The meter was fabricated per ASME guidelines and calibrated in Alden’s Calibration Department prior to the start of testing. The high and low pressure lines from the meter were connected to manifolds containing isolation valves. Flows were set with a control valve and the differential head from the meter was measured using a Rosemount® 0 to 250-inch Differential Pressure cell, also calibrated at Alden prior to testing. All pressure lines and cells were purged of air (bled) prior to the start of each test. The test flow was averaged and recorded every 5 seconds throughout the duration of each test run using an in-house computerized data acquisition program. The accuracy of the flow measurement is ±1%. A photograph of the flow meters is shown on **Figure 8.**

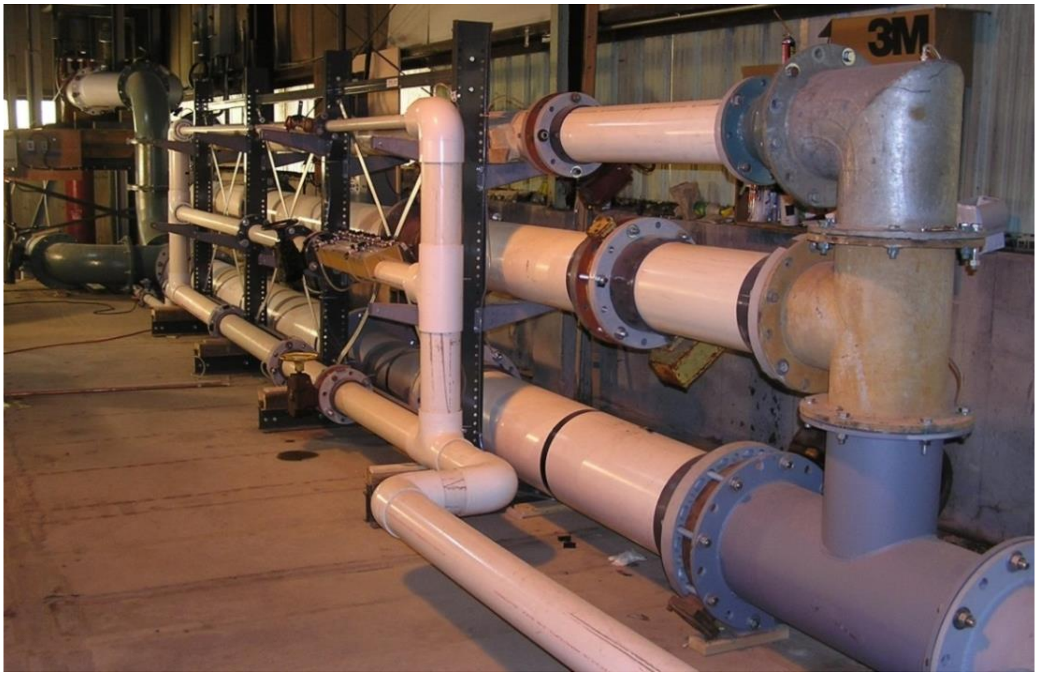

Figure 8 Photograph Showing Laboratory Flow Meters

Temperature

Water temperature measurements within the supply sump were obtained using a calibrated Omega® DP25 temperature probe and readout device. The calibration was performed at the Alden laboratory prior to testing. The temperature measurement was documented at the start and end of each test, to ensure an acceptable testing temperature of ≤ 80 degrees F.

Pressure Head

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Pressure head (water level) measurements were recorded in the test tank using a piezometer tap and an Omegadyne PX419, 0 - 2.5 psi pressure transducer (PT). The PT was calibrated at Alden prior to testing. Accuracy of the readings is ± 0.001 ft. The PT was installed at a known datum in relation to the tank floor. Water level (driving head) measurements were averaged and recorded every 5 seconds during each test run. A photograph of the pressure instrumentation is shown on **Figure 9**.

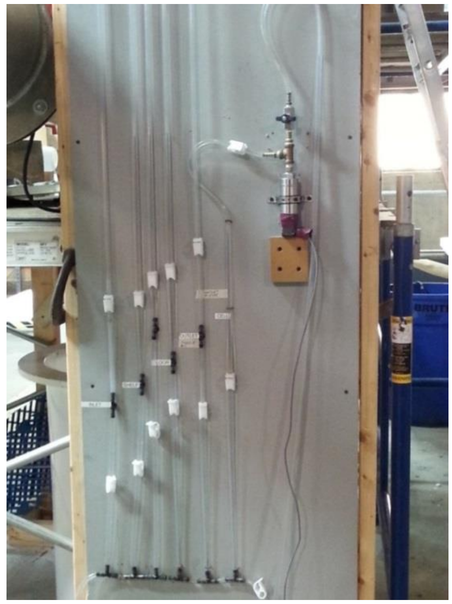

Figure 9 Pressure Measurement Instrumentation

Sediment Injection

The test sediment was injected into the crown of the influent pipe using an Auger® volumetric screw feeder, model VF-1, shown on **Figure 10**. The auger feed screw, driven with a variable-speed drive, was calibrated with the test sediment prior to testing. The calibration, as well as test confirmation of the sediment feed was accomplished by collecting timed dry samples of 0.1-liter, up to a maximum of 1-minute, and weighing them on an Ohaus® 4000g x 0.1g, model SCD-010 digital scale. The feeder has a hopper at the upper end of the auger to provide a constant supply of dry test sediment. The allowable Coefficient of Variance (COV) for the injection is 0.10.

Figure 10 Photograph Showing Variable-Speed Auger Feeder

Sample Collection

Effluent samples were collected in 2-liter containers from the end of the 6” effluent pipe. Background concentration samples were collected from the center of the vertical pipe upstream of the test unit with the use of a calibrated isokinetic sampler, shown on **Figure 11**.

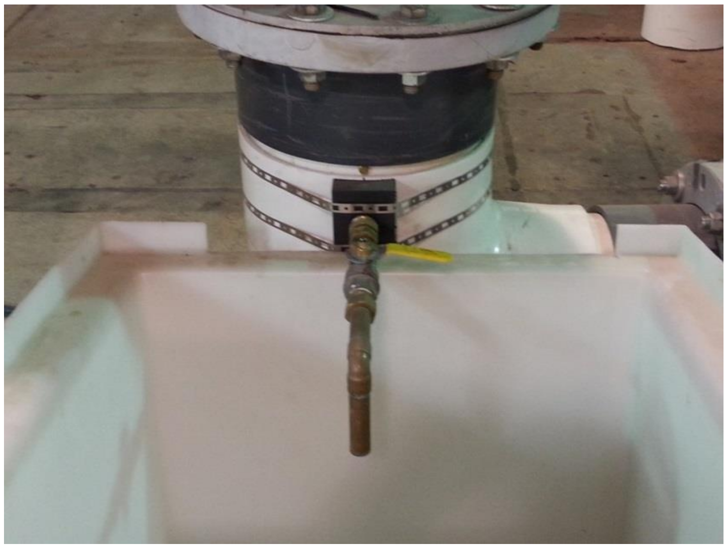

Figure 11 Photograph Showing the Background Isokinetic Sampler

Sample Concentration Analysis

Effluent and background concentration samples were analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (2019), “Standard Test Methods for Determining Sediment Concentration in Water Samples”. The required silica sand used in the sediment testing did not result in any dissolved solids in the samples and therefore, simplified the ASTM testing methods for determining sediment concentration.

2.5 Data Management and Acquisition

A designated Laboratory Records Book was used to document the conditions and pertinent data entries for each test conducted. All entries were initialed and dated.

A personal computer running an Alden in-house Labview® Data Acquisition program was used to record all data related to instrument calibration and testing. A 16-bit National Instruments® NI6212 Analog to Digital board was used to convert the signal from the pressure cells. Alden’s in-house data collection software, by default, collects one second averages of data collected at a raw rate of 250 Hz. The system allows very long contiguous data collection by continuously writing the collected 1-second averages and their RMS values to disk. The data output from the program is in tab delimited text format with a user-defined number of significant figures.

Test flow and pressure data were continuously collected at a frequency of 250 Hz. The flow data was averaged and recorded to file every 5 seconds. The recorded data files were imported into a spreadsheet for further analysis and plotting.

Excel based data sheets were used to record all data used for quantifying injection rate, effluent and background sample concentrations. The data were input to the designated spreadsheet for final processing.

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the Hydroworks HydroFilter, the following are the performance claims made by Hydroworks, LLC.

Total Suspended Solids (TSS) Removal Efficiency

Based on the laboratory testing conducted, the HydroFilter two cartridge filter system tested achieved an 85.3% cumulative TSS removal efficiency.

Maximum Treatment Flow Rate (MTFR)

The HydroFilter two cartridge filter system has an MTFR of 25 gpm (0.06 cfs) and an effective filtration treatment area (EFTA) of 12.57 ft^2 (loading rate = 2.0 gpm/ft^2).

Detention Time and Volume

The HydroFilter two cartridge filter system maximum wet volume is 7.85 ft^3, and the detention time varied from 2.4 to 3.9 minutes over the course of the testing at the test flow rate of 25 gpm.

Effective Sedimentation Treatment Area

The Effective Sedimentation Treatment Area (ESTA) for the test system is 3.93 ft^2 and the ratio ESTA/EFTA is 0.31.

Sediment Load Capacity/Mass Load Capture Capacity

Based on laboratory testing results, the HydroFilter two cartridge filter system has a mass loading capacity of 31.8 lbs and a mass loading capture capacity of 27.1 lbs (2.1 lbs/ft^2 of filter area).

Maximum Allowable Inflow Drainage Area

Laboratory testing results show that 31.8 lbs of sediment can be loaded onto a HydroFilter two cartridge filter system while achieving a cumulative sediment mass removal efficiency of 85.3% (mass loading capture capacity = 27.1 lbs). Per the NJDEP Filter Protocol, to calculate the maximum inflow drainage area, the total sediment load captured mass observed during the test

(27.1 lbs) is divided by 600 lbs/acre. Thus, the maximum inflow drainage area is 0.05 acres.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013b) 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.

4.1 Test Sediment PSD Analysis

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1-1000 micron silica particles, as shown in **Table 1**. The Specific Gravity (SG) of the sediment mixes was 2.65. Commercially-available silica products were provided by AGSCO Corp., a QAS International ISO-9001 certified company, and blended by Alden as required. Test batches were prepared in individual 5-gallon buckets, which were arbitrarily selected for the removal testing. A well-mixed sample was collected from three random test batches and analyzed for PSD in accordance with ASTM D422-63 (2007), by GeoTesting Express, an ISO/IEC 17025 accredited independent laboratory. The average of the samples was used for compliance to the protocol specifications listed in Column 2 of **Table 1**. The D_{50} of the samples ranged from 56 to 65 microns, with an average of 60 microns. The PSD data of the samples are shown in **Table 2** and the corresponding curves are shown on **Figure 12**.

Table 2 PSD Analyses of Alden NJDEP 1-1000 Mix

Particle size (μm)	NJDEP Specification	Sample 1	Sample 2	Sample 3	Average
1000	100%	100%	100%	100%	100%
500	95%	96%	96%	97%	96%
250	90%	91%	91%	93%	92%
150	75%	76%	76%	75%	76%
100	60%	60%	60%	61%	60%
75	50%	53%	53%	52%	53%
50	45%	48%	48%	46%	47%
20	35%	33%	34%	35%	34%
8	20%	18%	19%	19%	19%
5	10%	12%	13%	15%	13%
2	5%	4%	5%	4%	4%
75	D_{50}	56	59	65	60

The sediment particle size distribution (PSD) used for removal efficiency testing exceeded the NJDEP PSD sediment specifications (**Table 1**) across the entire distribution. The D_{50} of 60 microns was less than the required 75 microns.

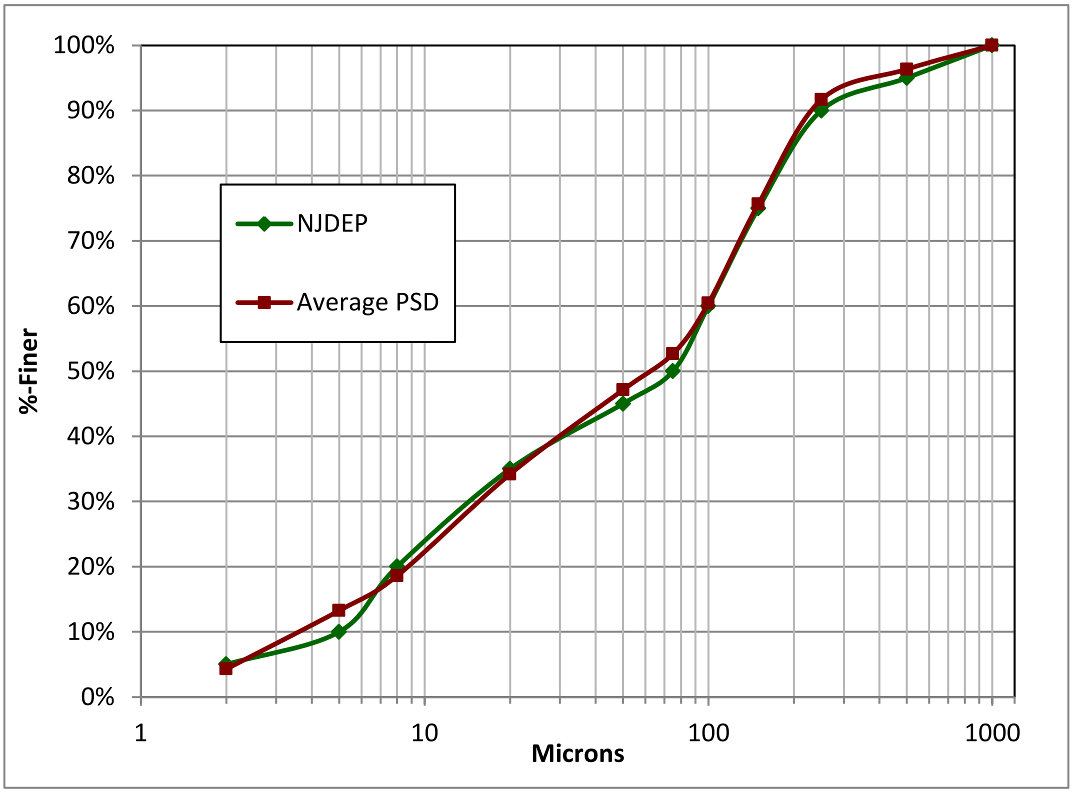

Figure 12 PSD Curves of 1-1000 micron Test Sediment and NJDEP Specifications

4.2 Removal Efficiency and Mass Loading Testing

Testing Summary

Ten (10) removal efficiency tests (runs 1-10) and ten (10) mass loading tests (runs 11-20) were conducted at a target flow of 25 gpm (100% MTFR). The mass loading tests were a continuation of the removal efficiency testing. The duration of the runs ranged from 35 to 38 minutes, with a target influent sediment concentration of 200 mg/l. All test runs met or exceeded the protocol testing criteria.

The removal efficiencies were calculated using the average injected influent concentrations shown in **Table 4,** and the adjusted effluent and drawdown sediment concentrations and influent, effluent and drawdown volumes shown in **Table 3** using **Equation 1.** The measured and calculated data for the 20 runs are shown in **Table 4** and **Table 5**. The injected and captured mass are shown in **Table 6.** The removal efficiency vs mass loading is shown on **Figure 13.** The recorded driving head at the end of each run vs mass loading is shown on **Figure 14**.

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

Equation 1 Equation for Calculating Removal Efficiency

Removal Efficiency Testing

The measured flow ranged from 24.9 gpm to 25.0 gpm, with an average flow of 25.0 gpm. The calculated COV was 0.002 for all test runs. The maximum recorded temperatures ranged from 69.2 to 75.8 degrees F. The measured injected influent concentrations ranged from 198 to 206 mg/L, with an average concentration of 202 mg/L. The injection COV ranged from 0.007 to 0.018 for all test runs. The injected mass was quantified at the end of the removal tests (run 10). The calculated total mass injected/total test water volume influent concentration was 211 mg/L. The average adjusted effluent concentrations ranged from 22.9 to 46.4 mg/L and the average drawdown concentrations ranged from 13.9 to 23.1 mg/L. The drawdown duration for the runs increased sequentially from 19 minutes to approximately 45 minutes. The calculated removal efficiencies utilizing the injected concentration ranged from 77.3% to 88.8%, with a cumulative average sediment removal of 85.1%. The end-of-test average removal efficiency using the mass/volume concentration was 86.2%. The maximum driving head, which was recorded at the end of run 10, was 2.64 ft, which correlates to 0.40 ft below bypass.

The calculated injected mass was 15.09 lbs, while the quantified mass was 15.81 lbs (approximately 5% higher).

Mass Loading Testing

The measured flow ranged from 24.9 gpm to 25.1 gpm, with an average flow of 25.0 gpm. The calculated COV was 0.002 for all test runs. The maximum recorded temperatures ranged from 73.4 to 76.5 degrees F. The measured injected influent concentrations ranged from 198 to 206 mg/L, with an average concentration of 202 mg/L. The injection COVs ranged from 0.010 to 0.019 for all test runs. The injected mass was quantified at the end of mass loading tests (run 20). The calculated total mass injected/total test water volume influent concentration was 205 mg/L, with a calculated average concentration of 208 mg/L for all test runs (1-20). The average adjusted effluent concentrations ranged from 24.7 to 37.4 mg/L and the average drawdown concentrations ranged from 13.8 to 23.7 mg/L. The drawdown duration for the runs increased sequentially from approximately 45 to 110 minutes. The calculated removal efficiencies utilizing the injected concentration ranged from 82.0% to 88.0%, with a cumulative average removal of 85.3% for all twenty (20) runs. The end-of-test average removal efficiency using the mass/volume concentration was 86.2%. The maximum driving head, which was recorded at the end of run 20, was 2.96 ft, which correlates to 0.08 ft below bypass.

The calculated injected mass for runs 11-20 was 15.78 lbs, while the quantified mass was 16.00 lbs. The total quantified mass injected during all runs was 31.81 lbs, which was approximately 3% higher than the calculated injected mass of 30.87 lbs.

Table 3 Removal Efficiency Summary

Run #	Average Influent Concentration	Average Adjusted Effluent Concentration	Average Adjusted Drawdown Concentration	Influent Volume	Effluent Volume	Drawdown Volume	Removal Efficiency	Cumulative Average
	mg/L	mg/L	mg/L	L	L	L		
1	203	27.6	19.3	3353	3253	100	**86.5%**	**86.5%**
2	202	28.8	16.6	3350	3238	113	**86.0%**	**86.2%**
3	202	31.4	23.1	3352	3226	126	**84.6%**	**85.7%**
4	200	46.4	21.7	3364	3229	135	**77.3%**	**83.6%**
5	203	35.1	22.0	3360	3216	144	**83.0%**	**83.5%**
6	200	24.2	13.9	3361	3211	150	**88.1%**	**84.2%**
7	202	22.9	16.5	3356	3199	157	**88.8%**	**84.9%**
8	202	30.7	22.6	3357	3193	164	**85.0%**	**84.9%**
9	203	33.0	17.6	3547	3375	171	**84.1%**	**84.8%**
10	200	24.7	15.6	3548	3369	178	**87.9%**	**85.1%**
11	203	24.7	15.8	3538	3356	182	**88.0%**	**85.4%**
12	201	26.8	21.0	3561	3374	187	**86.8%**	**85.5%**
13	202	35.7	17.9	3543	3351	192	**82.8%**	**85.3%**
14	203	31.0	18.2	3545	3348	196	**85.1%**	**85.3%**
15	201	26.2	19.7	3547	3348	199	**87.1%**	**85.4%**
16	202	37.4	19.1	3554	3349	205	**82.0%**	**85.2%**
17	202	27.6	13.8	3557	3351	206	**86.7%**	**85.3%**
18	201	27.5	22.4	3553	3342	211	**86.5%**	**85.3%**
19	202	32.6	18.0	3545	3333	212	**84.3%**	**85.3%**
20	202	27.4	23.7	3548	3333	215	**86.5%**	**85.3%**

Table 4 Measured Test Parameters

Run #	Test Duration	Measured Flow		Max Temp	Max Background	Influent Concentration (mg/L)				QA/QC Compliant
	minutes	gpm	COV	Deg. F	mg/L	Minimum	Maximum	Average	COV	
1	35.5	25.0	0.002	70.0	0.5	201	204	203	0.007	**Y**
2	35.5	24.9	0.002	69.2	0.5	199	206	202	0.018	**Y**
3	35.5	25.0	0.002	69.7	0.5	200	203	202	0.007	**Y**
4	35.5	25.0	0.002	69.8	0.5	199	202	200	0.008	**Y**
5	35.5	25.0	0.002	70.2	0.5	201	206	203	0.013	**Y**
6	35.5	25.0	0.002	74.6	0.5	198	203	200	0.013	**Y**
7	35.5	25.0	0.002	74.5	0.5	199	205	202	0.015	**Y**
8	35.5	25.0	0.002	74.5	0.5	199	205	202	0.015	**Y**
9	37.5	25.0	0.002	75.7	0.5	201	204	203	0.008	**Y**
10	37.5	25.0	0.002	75.8	2.6	199	202	200	0.008	**Y**
11	37.5	24.9	0.002	76.4	0.5	200	206	203	0.013	**Y**
12	37.5	25.1	0.002	76.5	1.2	198	203	201	0.012	**Y**
13	37.5	25.0	0.002	74.8	0.5	199	206	202	0.019	**Y**
14	37.5	25.0	0.002	74.8	1.5	200	206	203	0.015	**Y**
15	37.5	25.0	0.002	73.4	0.5	199	203	201	0.010	**Y**
16	37.5	25.0	0.002	73.4	1.0	199	206	202	0.018	**Y**
17	37.5	25.1	0.002	73.9	0.5	199	206	202	0.016	**Y**
18	37.5	25.0	0.002	74.1	1.1	199	204	201	0.013	**Y**
19	37.5	25.0	0.002	75.3	1.0	199	205	202	0.015	**Y**
20	37.5	25.0	0.002	75.4	1.3	199	206	202	0.019	**Y**

Mimimum Detection Limit (MDL) = 1.0 mg/L. Concentrations below the MDL are considered non-detect and are reported as 0.5 mg/L.

Table 5 Measured Sample Concentrations

Run #	Adjusted Effluent Concentrations (mg/L)						Adjusted Drawdown Concentrations (mg/L)		
	#1	#2	#3	#4	#5	**Average**	#1	#2	**Average**
1	27.0	28.2	26.1	28.0	28.8	**27.6**	17.8	20.9	**19.3**
2	32.0	29.4	31.2	24.2	27.4	**28.8**	20.0	13.1	**16.6**
3	35.6	31.8	33.3	27.8	28.7	**31.4**	29.8	16.5	**23.1**
4	53.1	65.3	44.1	35.3	34.3	**46.4**	28.2	15.2	**21.7**
5	50.4	34.0	30.5	29.7	30.7	**35.1**	33.5	10.6	**22.0**
6	24.9	24.5	24.8	23.9	23.0	**24.2**	21.6	6.1	**13.9**
7	21.3	22.2	22.6	24.4	24.1	**22.9**	25.8	7.2	**16.5**
8	31.9	32.7	32.2	29.2	27.7	**30.7**	37.4	7.7	**22.6**
9	33.1	34.4	34.6	31.6	31.6	**33.0**	29.2	6.0	**17.6**
10	25.9	26.3	25.0	23.5	22.7	**24.7**	27.3	3.9	**15.6**
11	24.7	26.4	24.4	24.3	23.9	**24.7**	26.4	5.2	**15.8**
12	27.1	28.9	27.9	24.4	26.0	**26.8**	37.3	4.7	**21.0**
13	35.9	36.9	36.3	35.1	34.2	**35.7**	31.0	4.9	**17.9**
14	33.2	32.4	32.3	28.6	28.4	**31.0**	31.1	5.3	**18.2**
15	25.2	24.8	26.0	28.1	26.9	**26.2**	32.9	6.5	**19.7**
16	41.8	41.7	41.9	31.4	30.4	**37.4**	33.6	4.6	**19.1**
17	30.9	29.4	28.3	25.2	24.4	**27.6**	24.2	3.5	**13.8**
18	30.5	28.9	27.1	25.0	25.9	**27.5**	40.3	4.4	**22.4**
19	36.1	34.1	32.8	30.1	30.1	**32.6**	31.9	4.1	**18.0**
20	30.8	26.5	29.2	24.9	25.5	**27.4**	41.2	6.1	**23.7**

Table 6 Injected Mass

Run #	Injected Mass	Cumulative Mass Injected	Mass Captured	Total Mass Captured
	lbs	lbs	lbs	lbs
1	1.50	1.50	1.30	1.30
2	1.49	2.99	1.29	2.58
3	1.49	4.49	1.26	3.84
4	1.49	5.97	1.15	4.99
5	1.50	7.47	1.25	6.24
6	1.48	8.95	1.30	7.54
7	1.49	10.45	1.33	8.87
8	1.49	11.94	1.27	10.14
9	1.58	13.52	1.33	11.47
10	1.57	15.09	1.38	12.85
11	1.58	16.68	1.40	14.24
12	1.57	18.25	1.37	15.61
13	1.58	19.83	1.31	16.91
14	1.58	21.41	1.35	18.26
15	1.57	22.98	1.37	19.63
16	1.58	24.56	1.29	20.92
17	1.58	26.14	1.37	22.29
18	1.57	27.72	1.36	23.65
19	1.58	29.29	1.33	24.98
20	1.58	30.87	1.37	26.35
Quantified Mass		31.81		
Δ %		3.1		

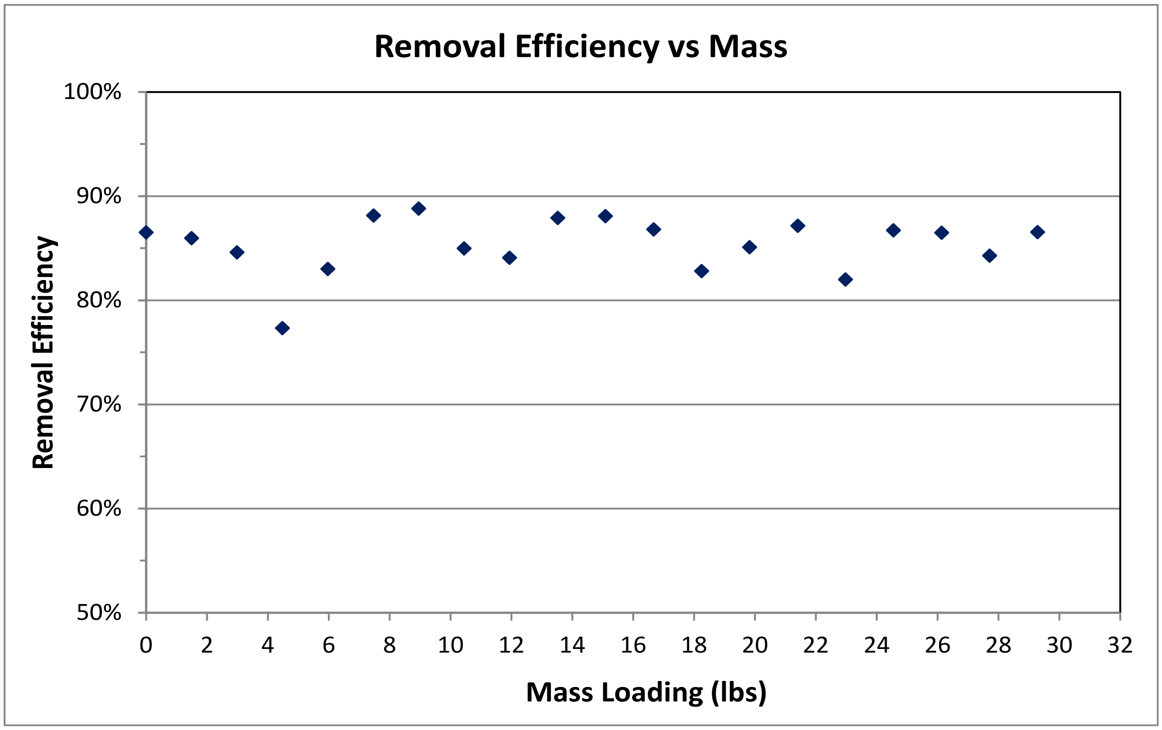

Figure 13 Hydroworks HydroFilter Removal Efficiency vs Mass Loading

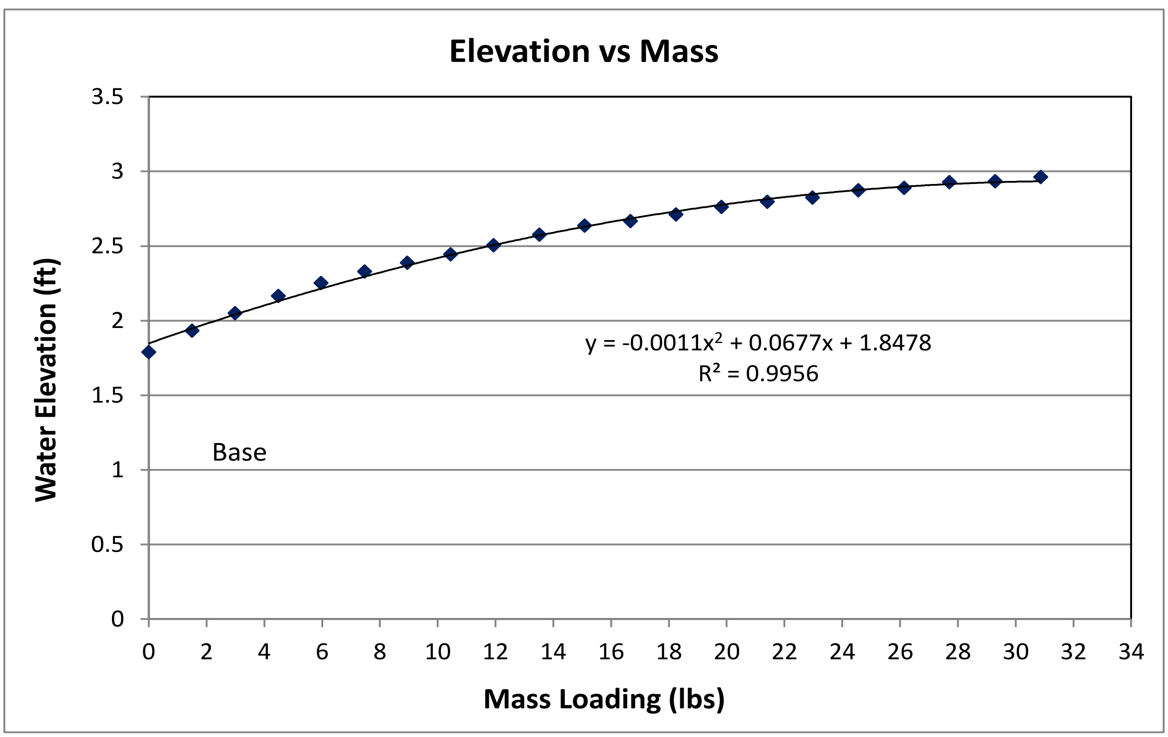

Figure 14 Recorded Driving Head Elevations vs Mass Loading

4.3 Scour Tests

The Hydroworks HydroFilter system is designed with an internal bypass for on-line operation. Scour testing was conducted on the filter to qualify it as an on-line system. The test was conducted after the conclusion of the mass loading tests on the fully loaded HydroFilter System.

200% MTFR (50 gpm)

A scour test was conducted at 50 gpm (200% MTFR). The bypass piping was connected to the outlet pipe upstream of the effluent sampling location. The test was conducted with clean water (≤ 20 mg/L). The measured average flow was 50.4 gpm and the COV was 0.001. The flow was reached within 5 minutes of initiating the test. A total of 15 effluent samples were collected at 2-minute intervals, with the first sample being collected 2 minutes after reaching the target flow. Background samples were collected with each odd-numbered effluent sample, for a total of 8 samples.

The background concentrations were all non-detect and reported as one-half the MDL of 1.0 mg/L. The *unadjusted* effluent concentrations ranged from non-detect, also reported as 0.5 mg/L, to 2.0 mg/L, with an average concentration of 0.7 mg/L. The maximum temperature was 77.4 degrees F. The test results are shown in **Table 7** and flow data shown on **Figure 15.**

Table 7 200% MTFR Scour Data

Sample #	Timestamp (minutes)	Effluent Concentration mg/L	Background Concentration mg/L
1	2	2.0	0.5
2	4	1.4	-
3	6	0.5	0.5
4	8	0.5	-
5	10	0.5	0.5
6	12	0.5	-
7	14	0.5	0.5
8	16	0.5	-
9	18	0.5	0.5
10	20	0.5	-
11	22	0.5	0.5
12	20	0.5	-
13	26	0.5	0.5
14	28	0.5	-
15	30	0.5	0.5
Average		0.7	0.5

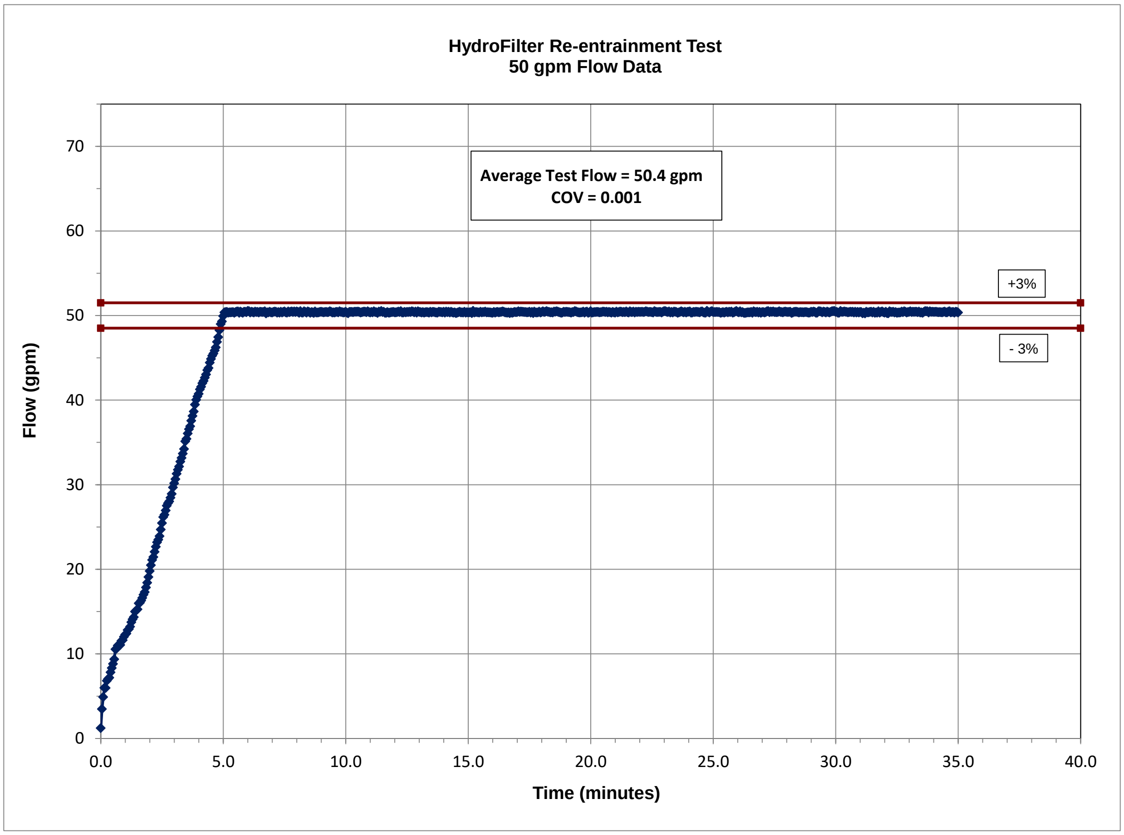

Figure 15 200% MTFR Scour Test Flow Data

200% MTFR (50 gpm) with Preload

An additional scour test was conducted on the fully loaded HydroFilter from the previous 200% scour test at 50 gpm (200% MTFR) with the vault preloaded to 3-in. (50% of maximum sediment depth) using 1-1000 micron particles shown in **Table 8** and on **Figure 16**. (Note: This was a new batch of sediment that was required to complete the testing.) The vault settling area was cleaned prior to preload. The bypass piping was connected to the outlet pipe upstream of the effluent sampling location. The test was conducted with clean water (≤ 20 mg/L). The measured average flow was 50.3 gpm and the COV was 0.001. The flow was reached within 5 minutes of initiating the test. A total of 15 effluent samples were collected at 2-minute intervals, with the first sample being collected 2 minutes after reaching the target flow. Background samples were collected with each odd-numbered effluent sample, for a total of 8 samples.

The maximum background concentration was 1.4 mg/L. The *unadjusted* effluent concentrations were all non-detect (reported as 0.5 mg/L, one-half the MDL). The maximum temperature was 70.4 degrees F. The test results are shown in **Table 9** and flow data shown on **Figure 17.**

Table 8 200% MTFR Scour Test Preload Sediment PSD

Particle size (µm)	NJDEP	Sample 1	Sample 2	Sample 3	Average
1000	**100%**	100%	100%	100%	100%
500	**95%**	97%	97%	97%	97%
250	**90%**	89%	93%	89%	90%
150	**75%**	74%	75%	75%	75%
100	**60%**	61%	61%	64%	62%
75	**50%**	53%	52%	57%	54%
50	**45%**	46%	46%	47%	46%
20	**35%**	34%	35%	35%	35%
8	**20%**	19%	19%	20%	19%
5	**10%**	14%	15%	14%	14%
2	**5%**	7%	4%	7%	6%
D_{50}	**75**	62	65	57	61

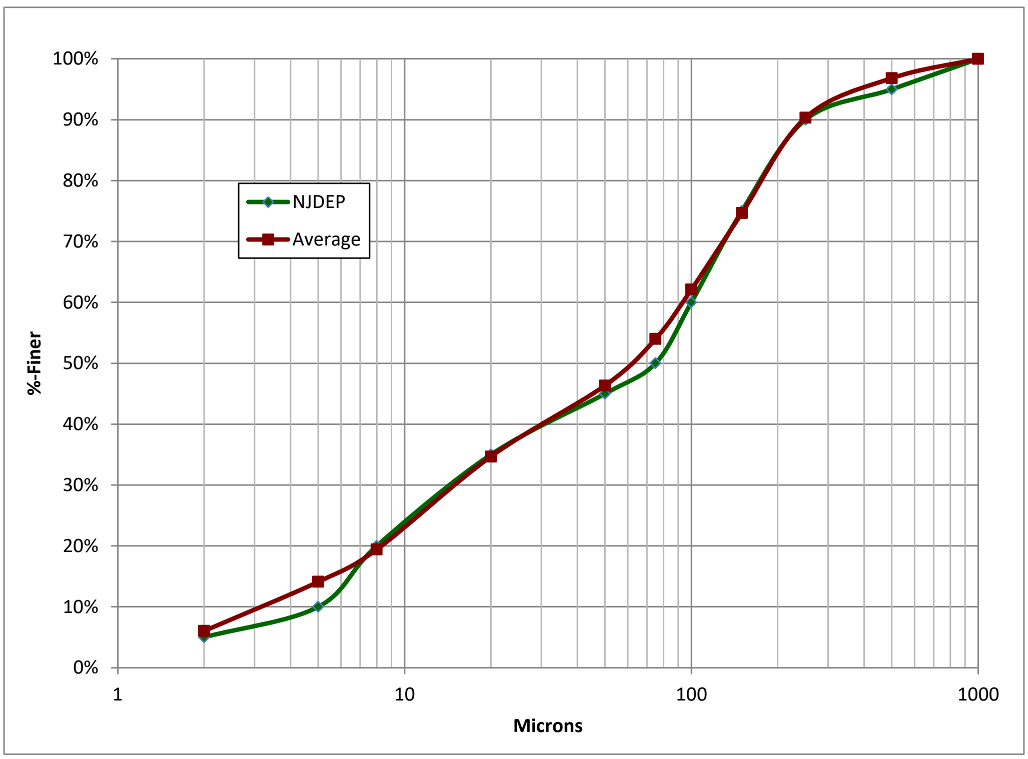

Figure 16 Preload Scour Test PSD and NJDEP Specifications

Table 9 200% MTFR Scour Data with 3-inch Preload

Sample #	Timestamp (minutes)	Effluent Concentration mg/L	Background Concentration mg/L
1	2	0.5	0.5
2	4	0.5	-
3	6	0.5	0.5
4	8	0.5	-
5	10	0.5	0.5
6	12	0.5	-
7	14	0.5	1.4
8	16	0.5	-
9	18	0.5	0.5
10	20	0.5	-
11	22	0.5	0.5
12	20	0.5	-
13	26	0.5	0.5
14	28	0.5	-
15	30	0.5	0.5
Average		0.5	0.6

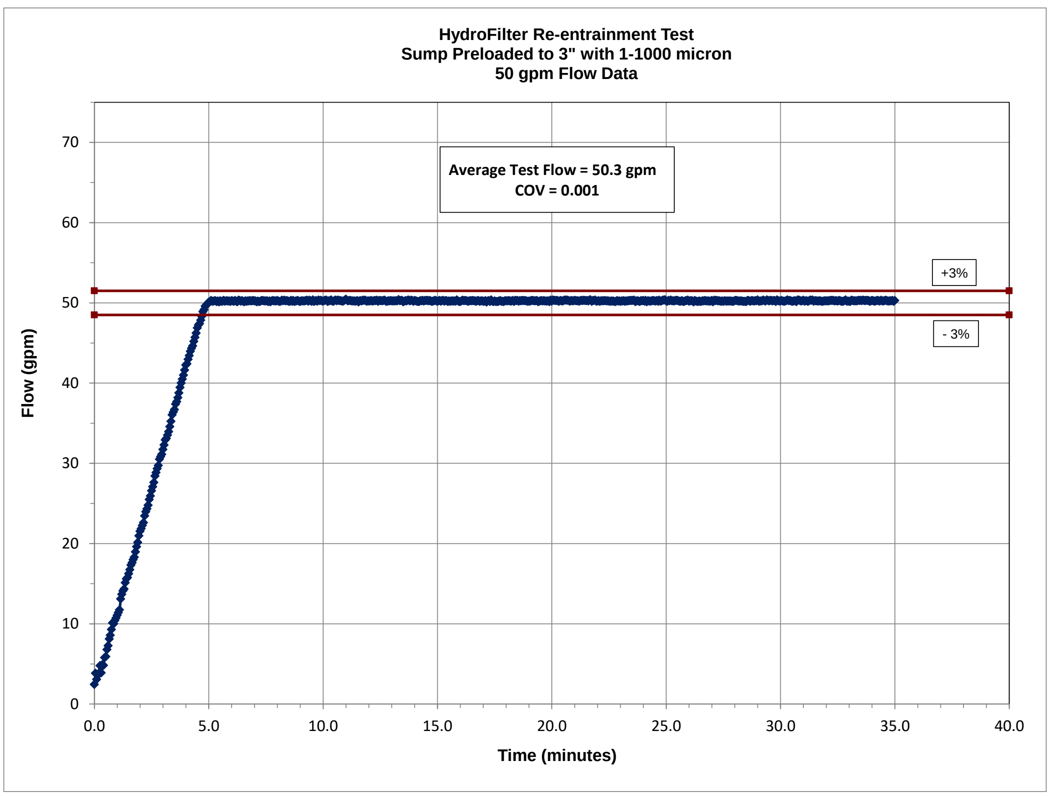

Figure 17 200% MTFR Preload Scour Test Flow Data

Data not included

Two additional scour tests were performed without the anti-scour pads at 200% MTFR to assess the performance of the anti-scour pads on preventing sediment scour. This first test was conducted prior to cleaning out the unit in preparation for the preload test. The average recorded flow was 50.4 gpm, with a COV of 0.003. The maximum temperature was 76.5 degrees F. All background and effluent concentrations were non-detect (MDL = 1.0 mg/L). These results suggest that the anti-scour pads have little if any impact on preventing sediment scour.

The second test without anti-scour pads was conducted following the preloaded scour test (with anti-scour pads) described above. The average recorded flow was 50.4 gpm, with a COV of 0.003. The maximum temperature was 72.4 degrees F. All background concentrations were non-detect (MDL = 1.0 mg/L). The non-adjusted effluent concentrations ranged from 13.2 to 0.5 mg/L (non-detect), with an average concentration of 1.6 mg/L. These results confirmed that the anti-scour pads have minimal impact on preventing sediment scour.

5. Design Limitations

Required Soil Characteristics

The HydroFilter is suitable for installation in all types of soils if only used for filtration. One of the key benefits of the HydroFilter is the ability to use it as a catch basin for dispersed filtration and infiltration. In this application, soils must be deemed suitable for infiltration. This means the soils must have suitable soil percolation rates and the structure base should be an adequate distance from the seasonal high water table and/or bedrock.

Infiltration Regulatory Requirements

For an MTD to be considered “green infrastructure” (GI) in accordance with the March 2, 2020 amendments to the Stormwater Management rules at N.J.A.C. 7:8, the MTD must meet the GI definition noted at amended N.J.A.C. 7:8-1.2. Specifically, the MTD shall (1) treat by infiltration into subsoil; and/or (2) treat stormwater runoff through filtration by vegetation or soil; or (3) store stormwater for reuse.

While the HydroFilter can be designed upstream of an infiltration facility, such as a subsurface infiltration basin, the HydroFilter itself does not provide infiltration of the water quality design storm and does not incorporate any vegetation, soil, or storage of stormwater for reuse. As such, it does not meet the definition of green infrastructure at N.J.A.C. 7:8-1.2. However, like any NJDEP certified filtration MTD, if it is utilized as the required 80% TSS removal pre-treatment for a subsurface infiltration basin designed in accordance with Chapter 9.5 of the New Jersey Stormwater BMP Manual, the overall system will meet the definition of GI, since the subsurface infiltration basin does meet the GI definition.

Slope

The HydroFilter is recommended to be installed at low slopes (0-1%). Hydroworks engineers can assist with designs using greater pipe slopes and vertical inlets to ensure proper installation.

Maximum Flow Rate

The maximum treatment flow rate for the HydroFilter is a function of model size and the number and size of the filter cartridges contained in the unit. The HydroFilter is rated for a hydraulic loading rate of 2 gpm/ft^2 of filter media surface area.

Maintenance Requirements

As is true of all stormwater best management practices, maintenance requirements for each individual HydroFilter installation will be influenced by site specific pollutant loading. Detailed maintenance information is provided in **Section 6**.

Installation Limitations

Soils must have suitable bearing capacity for the precast structure that houses the HydroFilter cartridges. The HydroFilter is shipped with base plugs and without the filter cartridges. The filtration cartridges are shipped to the site after the construction phase once the site is stabilized. The filtration cartridges should not be installed during the construction phase since they will plug prematurely.

Configurations

The HydroFilter is typically comprised of a round or rectangular precast structure that houses the refillable media-filled filter cartridges. The filter cartridges operate consistently regardless of the structure which allows systems to be scaled linearly.

Structural Load Limitations

HydroFilter configurations are designed for H-20 traffic loading. Configurations can be designed for heavier (airport) loadings upon request.

Pre-treatment Requirements

HydroFilter does not require pretreatment since it is itself pretreatment for infiltration. If desirable, pretreatment may be provided upstream of the HydroFilter to reduce the pollutant load reaching the filter media and extend the maintenance frequency of the cartridges. However, sediment capacity and maintenance recommendations assume no additional pretreatment is provided.

Limitations in Tailwater

Frequent tailwater conditions (tidal, etc.) will impact the operation of the HydroFilter. Any applications where the HydroFilter will be subject to frequent tailwater conditions should be reviewed with Hydroworks' engineering team to evaluate the potential impact on operation and performance.

Depth to Seasonal High Water Table

Recharge operation and, hence, performance of the HydroFilter if designed with downstream infiltration will be impacted by high groundwater since the unit will fill with groundwater if designed for infiltration. Surrounding soil testing should confirm that the soil meets all regulatory requirements for the volume of water to be infiltrated (i.e., soil hydraulic conductivity, seasonal high water table, and groundwater mounding) and that the installation design matches site conditions if recharge is designed downstream of the HydroFilter.

6. Maintenance

As storm water treatment structures fill up with pollutants they become less and less effective in removing new pollution. This is especially true of any stormwater treatment practice that utilizes filtration such as HydroFilter. Therefore, it is important that storm water treatment structures be maintained on a regular basis to ensure that they are operating at optimum performance. The HydroFilter is no different in this regard. An Operations and Maintenance Manual provides the owner/operator with the necessary information to inspect and coordinate maintenance of their HydroFilter. This manual can be accessed at: www.hydroworks.com/hfmaintenance.pdf

Inspection

Procedure

The HydroFilter should be inspected 24 hours after rainfall. Inspection within 6 hours of rainfall may not provide useful information regarding maintenance since the unit may be draining down. If the structure has not drained down to the base (bottom of lowest filter cartridge) within 24 hours of the last rainfall, the HydroFilter likely requires maintenance.

In the event of standing water in the structure around the cartridges the cone should be removed from a stack of cartridges. If standing water is visible in the central core of the filter stack consistent with the level of water on the outside of the filter stack this is indicative of high groundwater or slow infiltration and not require filter maintenance.

However, if the water level in the central cartridge is below the bottom of the lowest filter cartridge with standing water around the filter cartridges then filter maintenance is required.

Frequency

Construction Period

If HydroFilter is installed online the filter cartridges **should not** be installed in the HydroFilter system during the construction period since construction sediment will prematurely plug the cartridges requiring excessive maintenance during this period. A plate is installed in the base for the construction period to remind the contractor that the cartridges should only be installed for post construction operation. This plate needs to be removed when the cartridges are installed for post development operation. If the inlet to an offline HydroFilter system can be plugged during the construction period, the filter cartridges can be installed during construction.

Post-Construction Period

The HydroFilter should be inspected twice during the first year of operation for normal stabilized sites (no exposed soil or materials storage). The initial inspections will indicate the required future frequency of inspection and maintenance if the unit was maintained and put into service (filters installed) after the construction period.

It is anticipated that the filter cartridges will need to be replaced annually. However, this will depend on pollutant loadings on the site and off-site activities (nearby construction, etc.).

A filter does not need to be maintained until it’s rated treatment rate decreases to the point where it can no longer provide the required annual percentage of pollutant removal. This is a hydraulic requirement that will depend on the hydrology (rainfall intensity distribution) and characteristics of the site (imperviousness, area, pollutant loading) being designed. That is why the frequency of cleaning is based on the presence of water after a storm since the flow rate is reduced indicating maintenance is required.

Reporting

Reports should be prepared as part of each inspection and include the following information:

1. Date of inspection
2. GPS coordinates of HydroFilter unit
3. Time since last rainfall
4. Date of last inspection
5. Installation deficiencies (missing parts, incorrect installation of parts)
6. Structural deficiencies (concrete cracks, broken parts)
7. Operational deficiencies (leaks, blockages)
8. Presence of oil sheen or depth of oil layer
9. Estimate of depth/volume of floatables (trash, leaves) captured
10. Sediment depth measured
11. Recommendations for any repairs and/or maintenance for the unit

12. Estimation of time before maintenance is required if not required at time of inspection

A sample inspection checklist is provided at the end of the O&M Manual.

<u>Maintenance Procedures</u>

1. Water/Sediment Removal

Maintenance involves removing the water and replacing the filter cartridges. In both cases, sediment that has been collected around the filter cartridges in the sump of the device must be removed. This is typically done by a vacuum truck. In instances where a vacuum truck is not available other maintenance methods can be used, but they will be less effective.

The local municipality should be consulted for the allowable disposal options for both the water and sediments prior to any maintenance operation. Disposal of the sediment/water removed from the structure will depend on local requirements.

It is important to remove all sediment and water from the structure before trying to remove and replace the filter cartridges.

2. Filter Cartridge Replacement

Replacement of filter cartridges is made easy due to the modular nature of each cartridge. The cartridges are stacked vertically on top of each other. Each cartridge has a bell and spigot such that they fit together.

A lifting bar is located in the center of the 6" hollow center of each cartridge near the top of the cartridge. The top cone has a lifting ring on the top of it. Vertical stacks of filters should have an access opening in the structure directly above them or close to being directly above them.

A winch with a hook is lowered down to hook on to the cone lifting ring and the cone is winched out of the structure. Similarly, the winch is hooked under the lifting bar of each successive filter cartridge and they are winched out of the structure. Fresh cartridges are similarly winched in stacking them as required ending each stack with a cone.

3. Filter Cartridge Replenishment

Small HydroFilter systems may be able to be replenished to extend the cartridge replacement frequency. Once the top cone is removed an inflatable pipe plug can be lowered through the central core created by the connected filters to the base and expanded at the bottom to seal the vertical core.

This vertical core or pipe can then be filled with clean water to backflush the filter forcing it to flow from the central core opening back through the filter to the outside of each filter cartridge. This backflush water can then be pumped or vacuumed from the structure with the central core still being full of water.

7. Statements

The following signed statements from the manufacturer (Hydroworks, LLC), independent testing laboratory (Alden Research Laboratory) 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.

July 23, 2020

New Jersey Corporation for Advanced Technology
Stevens Institute of Technology
Castle Point on Hudson

Hoboken, NJ 07030

Attention: Dr. Richard Magee, Sc.D., P.E., BCEE

Subject: HydroFilter Verification Report

Dear Dr. Magee,

We certify that the Hydroworks HydroFilter filtration device was tested in strict adherence to the New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (NJDEP, January 2013).

We certify that all requirements and criteria were met or exceeded during testing of the HydroFilter filtration/infiltration device.

Please do not hesitate to contact us if you have any questions regarding this letter.

Sincerely,

HYDROWORKS LLC,

Graham Bryant, M.Sc., P.Eng.
President

July 20, 2020

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

Conflict of Interest Statement

Alden Research Laboratory (ALDEN) is a non-biased independent testing entity which receives compensation for testing services rendered. ALDEN does not have any vested interest in the products it tests or their affiliated companies. There is no financial, personal or professional conflict of interest between ALDEN and Hydroworks LLC.

Protocol Compliance Statement

Alden performed design research testing, as well as the final certification testing on the Hydroworks HydroFilter stormwater treatment unit. The Technical Report and all required supporting data documentation has been submitted to NJCAT as required by the protocol.

Testing performed by ALDEN on the Hydroworks HydroFilter met or exceeded the requirements as stated in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device", (January 25, 2013).

James T. Mailloux

James T. Mailloux

Principal Engineer
Alden Research Laboratory
jmailloux@aldenlab.com

(508) 829-6000 x6446

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

July 23, 2020

Gabriel Mahon, Chief
NJDEP
Bureau of Non-Point Pollution Control
Division 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 Hydroworks HydroFilter at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direct supervision of Alden's senior stormwater engineer, James Mailloux, the test protocol requirements contained in the *"New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 25, 2013)"* (NJDEP HDS Protocol) were met or exceeded. Specifically

Test Sediment Feed

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1-1000 micron silica particles. The Specific Gravity (SG) of the sediment mixes was 2.65. Commercially-available silica products were provided by AGSCO Corp., a QAS International ISO-9001 certified company, and blended by Alden as required. Test batches were prepared in individual 5-gallon buckets, which were arbitrarily selected for the removal testing. A well-mixed sample was collected from three random test batches and analyzed for PSD in accordance with ASTM D422-63 (2007), by GeoTesting Express, an ISO/IEC 17025 accredited independent laboratory. The average of the samples was used for compliance to the protocol specifications. The D_{50} of the samples ranged from 56 to 65 microns, with an average of 60 microns, well below the < 75 micron protocol requirement.

Removal Efficiency Testing

Twenty (20) removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. Ten (10) of the 20 test runs were conducted during mass loading and 10 during removal efficiency testing. The target flow rate and influent sediment concentration were 25 gpm and 200 mg/L. The HydroFilter demonstrated an average sediment removal efficiency on a cumulative mass basis of 85.1% over the course of the 10-removal efficiency test runs and 85.3% for the 20 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 removal efficiency runs. The HydroFilter system demonstrated a mass loading capture capacity of 27.1 lbs (2.1 lbs/ft^2 of filter area).

Scour Testing

To demonstrate the ability of the HydroFilter to be used as an online treatment device, scour testing was conducted at 200% MTFR. One scour test was conducted on the HydroFilter system following the mass loading capacity (100% system mass loading) testing. A second test was conducted on the fully loaded HydroFilter from the previous 200% scour test, with the test vessel preloaded with 3-inch of sediment (50% of the sediment capture level (6-in). The maximum unadjusted effluent concentration for the 100% system mass loading testing was 2.0 mg/L; for the preloaded sediment test it was < 1.0 mg/L.

The HydroFilter is qualified for on-line installation.

Sincerely,

Richard S. Magee

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

8. References

ASME (1971), *"Fluid Meters Their Theory and Application- Sixth Edition".*

ASTM (2007), *"Standard Test Method for Particle Size Analysis of Soils"*, Annual Book of ASTM Standards, D422-63, Vol. 04.08.

ASTM (2016), *"Standard Test Methods for Determination of Water (Moisture) Content of Soil by Direct Heating"*, Annual Book of ASTM Standards, D4959-07, Vol. 04.08.

ASTM (2019), *"Standard Test Methods for Determining Sediment Concentration in Water Samples",* Annual Book of ASTM Standards, D3977-97, Vol. 11.02.

NJDEP 2013a. *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 2013b. *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.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Hydroworks, LLC, 257 Cox Street, Roselle, NJ 07203. www.hydroworks.com (888)-290-7900.
- Hydroworks HydroFilter verified models are shown in **Table A-1**.
- TSS Removal Rate – 80%
- On-line installation up to 200% MTFR

Detailed Specification

- HydroFilter models, MTFR, and maximum drainage area per NJDEP sizing requirements are attached (**Table A-1**).
- 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 filter arrangement as presented in **Table A-1.**
- The O&M manual can be accessed at: www.hydroworks.com/hfmaintenance.pdf
- This device cannot be used in series with another MTD or a media filter (such as a sand filter) to achieve an enhanced removal rate for total suspended solids (TSS) removal under N.J.A.C. 7:8-5.5.

Table A-1 NJDEP HydroFilter Models, MTFRs and Maximum Drainage Area								
Model	Round/ Box	D or L (ft)	W (ft)	Stacks	cart/stack	MTFR (cfs)	ESTA/EFTA	Max Drainage Area (ac)
HF-B4-1-2	B	4	2.5	1	2	0.06	0.55	0.05
HF-R3-1-2	R	3		1	2	0.06	0.31	0.05
HF B4-2-2	B	4	3.5	2	2	0.11	0.31	0.09
HF R4-1-4	R	4		1	4	0.14	0.38	0.09
HF-B8-6-1	B	8	4	6	1	0.17	0.35	0.14
HF B4.5-2-3	B	4.5	4	2	3	0.17	0.31	0.14
HF B8-6-1	B	8	5	6	1	0.17	0.56	0.14
HF R5-2-3	R	5		2	3	0.17	0.35	0.14
HF B8.5-4-2	B	8.5	3.5	4	2	0.22	0.34	0.18
HF B5.5-2-4	B	5.5	4	2	4	0.22	0.31	0.18
HF R6-4-2	R	6		4	2	0.22	0.31	0.18
HF B8-9-1	B	8	6	9	1	0.25	0.35	0.20
HF R6-3-3	R	6		3	3	0.25	0.33	0.20
HF B8-5-2	B	8	5	5	2	0.28	0.39	0.23
HF R7-5-2	R	7		5	2	0.28	0.36	0.23
HF B8-12-1	B	8	8	12	1	0.33	0.35	0.27
HF R7-4-3	R	7		4	3	0.33	0.34	0.27
HF R7-3-4	R	7		3	4	0.33	0.39	0.27
HF B8-6-2	B	8	6	6	2	0.39	0.39	0.27
HF R8-7-2	R	8		7	2	0.39	0.32	0.32
HF B8-5-3	B	8	6	5	3	0.42	0.34	0.34
HF R8-5-3	R	8		5	3	0.42	0.37	0.34
HF R10-15-1	R	10		15	1	0.42	0.33	0.34
HF B8-4-4	B	8	6	4	4	0.45	0.35	0.36
HF B10-15-1	B	10	8	15	1	0.45	0.35	0.34
HF R8-4-4	R	8		4	4	0.45	0.38	0.36
HF B8-9-2	B	8	8	9	2	0.50	0.32	0.41
HF B12-18-1	B	12	8	18	1	0.50	0.35	0.41
HF R12-20-1	R	12		20	1	0.56	0.40	0.45
HF B8-7-3	B	8	8	7	3	0.59	0.32	0.47
HF B14-21-1	B	14	8	21	1	0.59	0.35	0.47
HF B10-11-2	B	10	8	11	2	0.61	0.33	0.50
HF R10-11-2	R	10		11	2	0.61	0.32	0.50
HF B8-5-4	B	8	8	5	4	0.67	0.38	0.45
HF B16-24-1	B	16	8	24	1	0.67	0.35	0.54
HF R10-8-3	R	10		8	3	0.67	0.35	0.54
HF B10-9-3	B	10	8	8	3	0.75	0.36	0.54
HF B18-27-1	B	18	8	27	1	0.75	0.35	0.61
HF B10-7-4	B	10	8	7	4	0.78	0.33	0.63
HF B12-13-2	B	12	8	13	2	0.78	0.34	0.59
HF R10-7-4	R	10		7	4	0.78	0.32	0.63

Table A-1 NJDEP HydroFilter Models, MTFRs and Maximum Drainage Area								
Model	Round/ Box	D or L (ft)	W (ft)	Stacks	cart/stack	MTFR (cfs)	ESTA/EFTA	Max Drainage Area (ac)
HF B20-30-1	B	20	8	30	1	0.84	0.35	0.68
HF B14-16-2	B	14	8	16	2	0.89	0.31	0.72
HF R12-16-2	R	12		16	2	0.89	0.31	0.72
HF B12-10-3	B	12	8	10	3	0.92	0.34	0.68
HF B22-33-1	B	22	8	33	1	0.92	0.35	0.74
HF B12-8-4	B	12	8	8	4	1.00	0.35	0.72
HF B14-12-3	B	14	8	12	3	1.00	0.33	0.81
HF B16-18-2	B	16	8	18	2	1.00	0.32	0.81
HF B24-36-1	B	24	8	36	1	1.00	0.35	0.81
HF R12-9-4	R	12		9	4	1.00	0.38	0.81
HF R12-12-3	R	12		12	3	1.00	0.33	0.81
HF B14-10-4	B	14	8	10	4	1.12	0.32	0.90
HF B16-14-3	B	16	8	14	3	1.17	0.32	0.95
HF B18-20-2	B	18	8	20	2	1.17	0.32	0.90
HF B20-22-2	B	20	8	22	2	1.28	0.33	0.99
HF B16-11-4	B	16	8	11	4	1.34	0.34	0.99
HF B18-16-3	B	18	8	16	3	1.34	0.31	1.08
HF B22-25-2	B	22	8	25	2	1.39	0.31	1.13
HF B20-18-3	B	20	8	17	3	1.51	0.33	1.15
HF B18-13-4	B	18	8	13	4	1.45	0.32	1.17
HF B20-14-4	B	20	8	14	4	1.56	0.33	1.26
HF B24-27-2	B	24	8	27	2	1.56	0.32	1.22
HF B22-19-3	B	22	8	19	3	1.67	0.32	1.28
HF B22-16-4	B	22	8	16	4	1.78	0.31	1.44
HF B24-21-3	B	24	8	21	3	1.84	0.32	1.42
HF B24-17-4	B	24	8	17	4	2.01	0.32	1.53

*Model numbers based on current precast availability and a maximum of 4 cartridges per stack. More model numbers / configurations of stacks and cartridges per stack are available. Please contact Hydroworks at 888-290-7900 for available options in your area.