

NJCAT TECHNOLOGY VERIFICATION

HC (High Capacity) Kraken[®] Filter Stormwater Treatment Device

**Bio Clean Environmental Services Inc.
a Quikrete Company**

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1. Description of Technology

The HC (High Capacity) Kraken® Filter is a membrane filter system designed by Bio Clean Environmental Services, Inc. a Quikrete company.

The HC Kraken® Filter (KF) is designed to optimize the treatment of entering stormwater utilizing an advanced membrane filtration cartridge. Each cartridge is cylindrical and available in various heights based on treatment requirements and site conditions. The cartridge utilizes a pleated paper design to maximize available surface area. The system has no moving parts and operates utilizing the principles of gravity separation and filtration.

Runoff is directed into the system's filter chamber via an inflow pipe as illustrated in **Figure 1a**. Depending on the configuration of the system, runoff can also enter the filter chamber via an optional upstream pre-treatment or diversion chamber as illustrated in **Figure 1b**. The testing outlined in this report was done on the filter chamber standalone without the pre-treatment or diversion chamber as shown in **Figure 1a**. The inclusion of pre-treatment or diversion and offline bypass is still available on all standard models. Standard models listed in **Table A-3** come with a pre-treatment chamber as shown in **Figure 1c**.

The HC Kraken® Filter cartridge contains an internal riser pipe that has a top opening three inches below the top of the filter. Water will not start processing through the HC Kraken® Filter cartridge until the water level reaches the internal riser pipe opening. Once the water level reaches the internal riser opening, water will process through the filter membrane, travel inward and upward into and down the riser pipe to the opening at the bottom. The internal riser pipes prevent the bottom portion of the HC Kraken® Filter cartridge from operating during fill up/drain-down periods and during dry weather flows. This prevents uneven sediment loading on the cartridge membrane to ensure even loading and longer maintenance intervals. Water leaves the cartridge assembly and into the underdrain rails as shown in **Figure 2**.

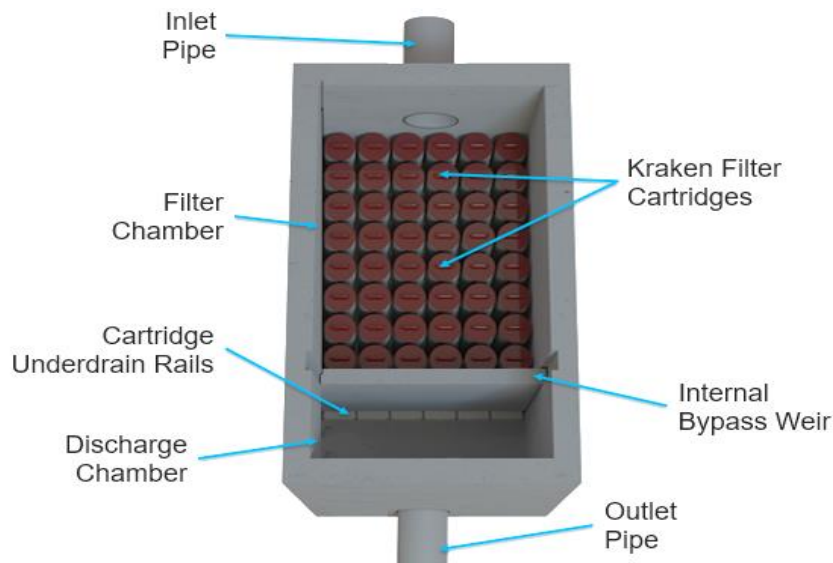


Figure 1a Standalone Filter Chamber (Tested Configuration) - Top View

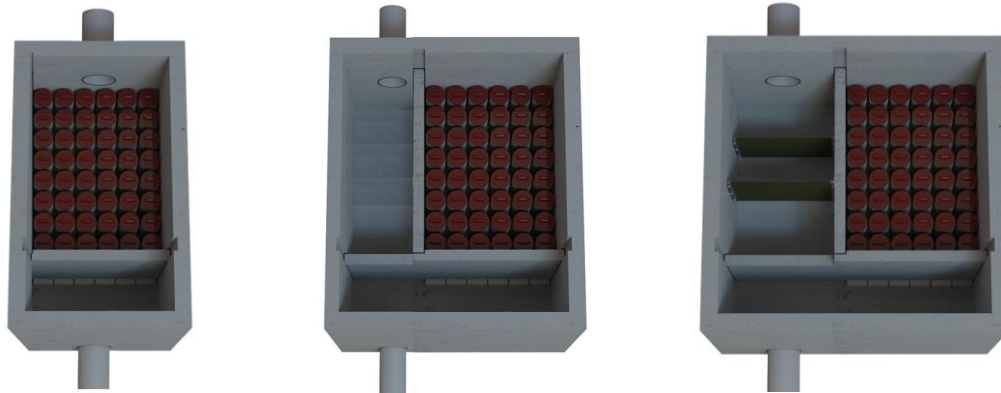


Figure 1b Configurations (Standalone, Diversion, Pre-Treatment) - Top Views

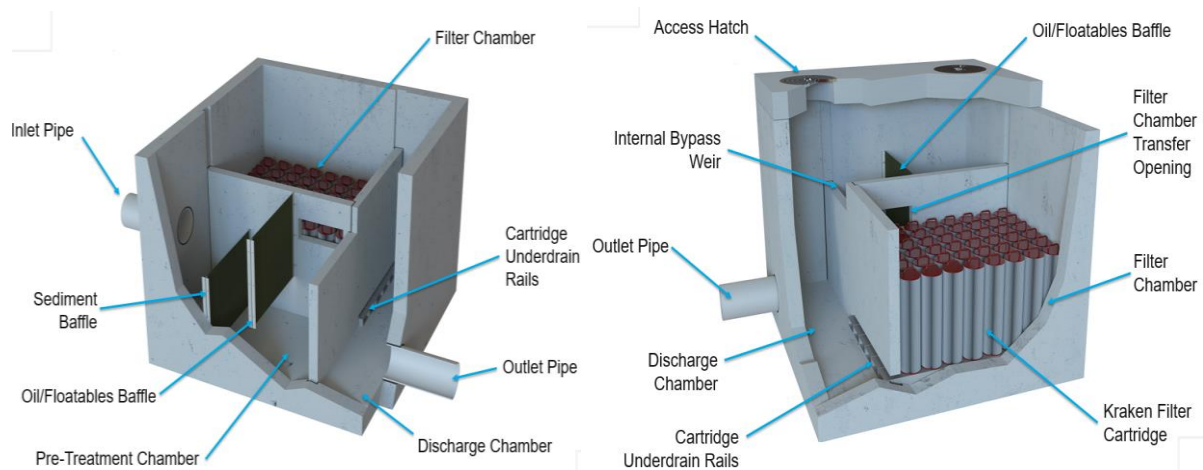


Figure 1c Filter Chamber with Pre-Treatment Chamber (Commercial Configuration) - Isometric Views

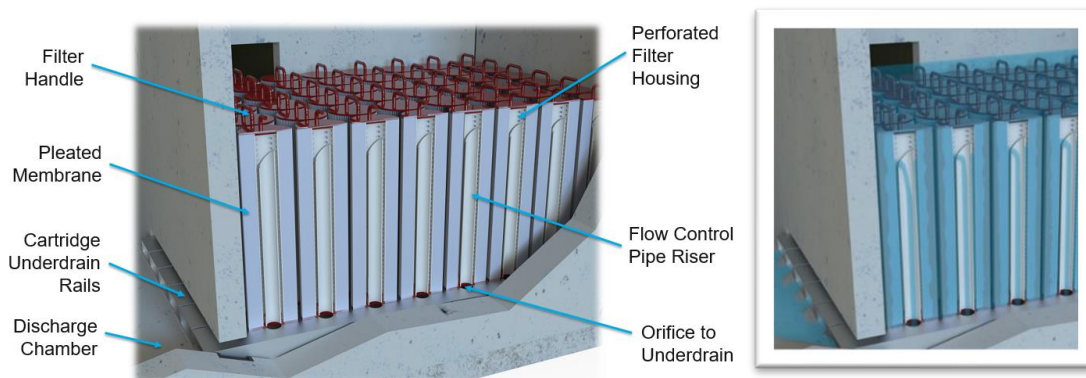


Figure 2 Treatment Flow Path – Side View

As water enters the underdrain rail it flows towards the discharge chamber where it exits the system. Since the internal riser tubes prevents flow until the water nears the top of the filter cartridge, the addition of drain-down filters is required to allow the filtration chamber to drain down between storm events. The drain-down filters are identical to the standard HC Kraken® Filters apart from two small drain-down holes in the bottom of the internal riser pipe as shown in **Figure 3**. The drain down orifices are 0.25 inches in diameter. There is one drain-down filter for every three standard filter cartridges. All filter cartridges are 7.75 inches in diameter.

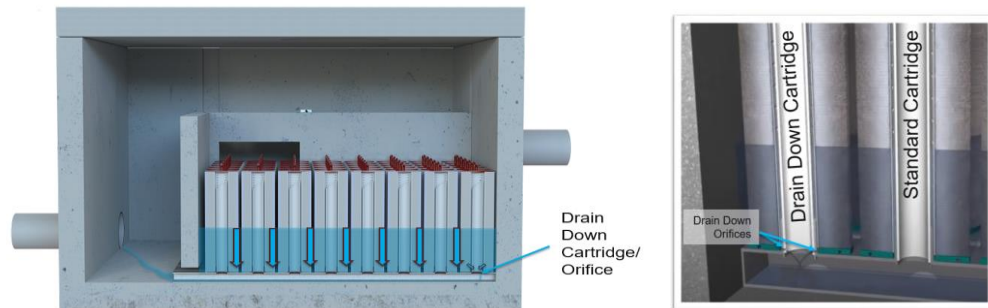


Figure 3 Drain-Down Operation – Side View

The HC Kraken® Filter can be configured with an optional offline bypass that directs water from the pre-treatment/diversion chamber directly into the discharge chamber to prevent scouring of previously captured sediment. Runoff cannot enter into the filter chamber via curb or grate inlet. These types of inlets must be installed upstream of the filter chamber. Round configurations are also available as shown in **Figure 4**. The testing outlined in this report was done on a unit with no pre-treatment chamber and, hence, no offline bypass. The bypass weir is set at an elevation equal to the maximum operating hydraulic grade line (water level) of the HC Kraken® Filter.

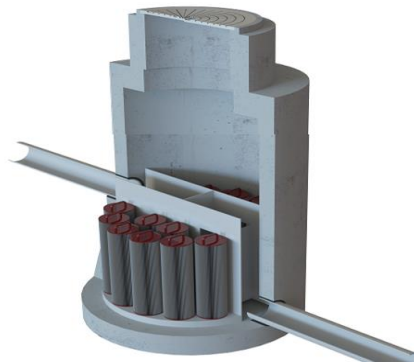


Figure 4 Round Configuration

2. Laboratory Testing

Testing was performed to determine:

- The hydraulic characterization and performance of the test unit.

- The sediment cumulative removal efficiency (80% target) using the grab sample test method.
- The sediment mass load capacity reached (until >10% reduction in flow capacity) or a reduction in cumulative sediment removal efficiency below 80%; and
- Potential for sediment scour with system's filter chamber pre-loaded with sediment that is greater than 50% manufacturers recommended maximum storage volume (at the maximum intended conveyance flow rate).

Bio Clean Laboratories, a state-of-the-art water technology testing laboratory based in Oceanside, California, was commissioned by Bio Clean Environmental Services, Inc. to test the HC Kraken[®] Filter 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)*. Note: Bio Clean laboratories is wholly owned by Bio Clean Environmental Services, Inc, but operates as an independent division. Independent third-party observation was provided by Luke Russell, Staff II Engineer at Terraphase Engineering. Mr. Russell has extensive background in water quality. Mr. Russell has no conflict of interest that would disqualify him from serving as the independent third-party observer during this testing process.

The test unit is a 17.5-inch by 17.5-inch unit consisting of commercially supplied internal components housed in a wooden structure. It is designed to house four 30-inch tall HC Kraken[®] Filters. In commercial systems, the internal components are typically housed in a concrete, plastic, or fiberglass structure. The wooden structure of the test unit, illustrated in **Figure 5**, is equivalent to the commercial concrete structure in all key dimensions. The Bio Clean Laboratory has limited lifting capacity and available space, so a lightweight structure was necessary.

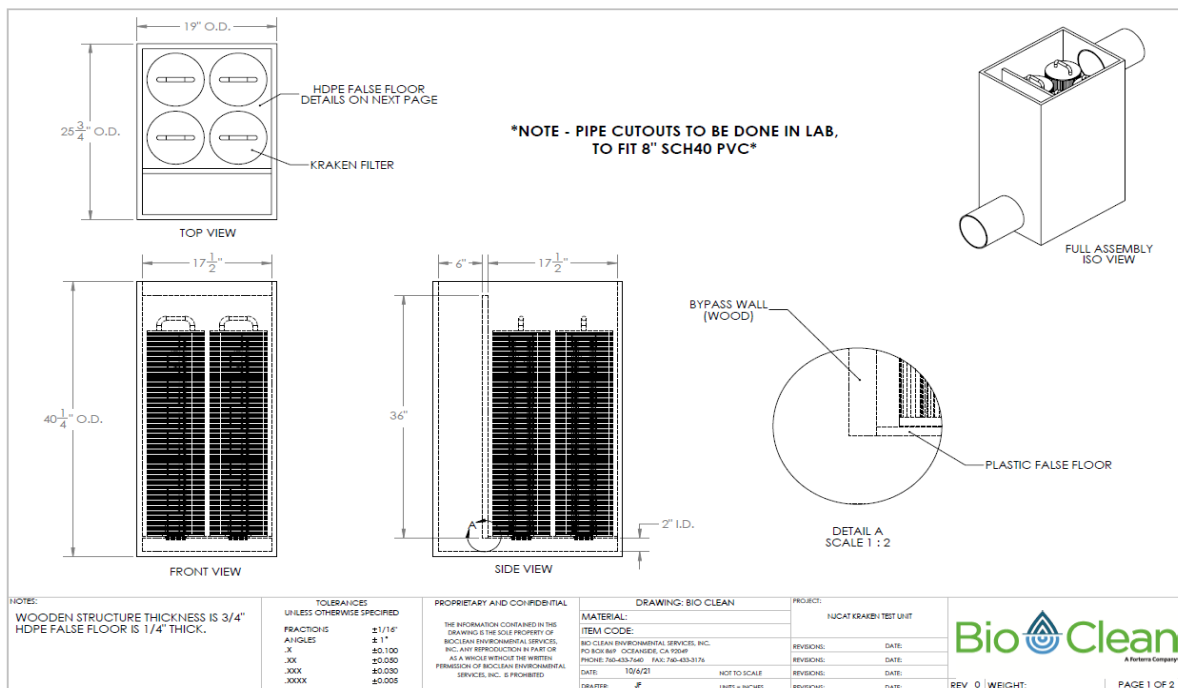


Figure 5 High Capacity Kraken Filter Model KF-1.5-1.5

2.1 Test Setup

The design specifications of the HC Kraken® Filter Model KF-1.5-1.5 tested are provided in **Table 1**. The test unit had a total of four cartridges (one was a drain-down cartridge) with a surface area of 168.2 ft² per cartridge. The maximum treatment flow rate (MTFR) tested on the HC Kraken® Filter test unit was 68 gpm, or 0.152 cfs.

Table 1 HC Kraken® Filter Test Unit Dimensions

MTFR		Length (in)	Width (in)	Height at Bypass (in)	Total Surface Area per Cartridge (ft ²)	Total Cartridges (#)	Loading Rate (gpm/ft ²)
(cfs)	(gpm)						
0.152	68	17.5	17.5	36	168.2	4	0.101

The laboratory test set-up was a recirculating water flow loop, capable of moving water at a rate of several cubic feet per second (cfs). The test loop, illustrated in **Figure 6**, was comprised of water reservoirs, pumps, sediment filters, receiving tanks and flow meters. The configuration for performance and mass load testing utilized a centrifugal pump and water flow through a pressurized filter vessel. The configuration for scour testing was the same as the sediment removal testing, as the pump could handle the increased flow rate.

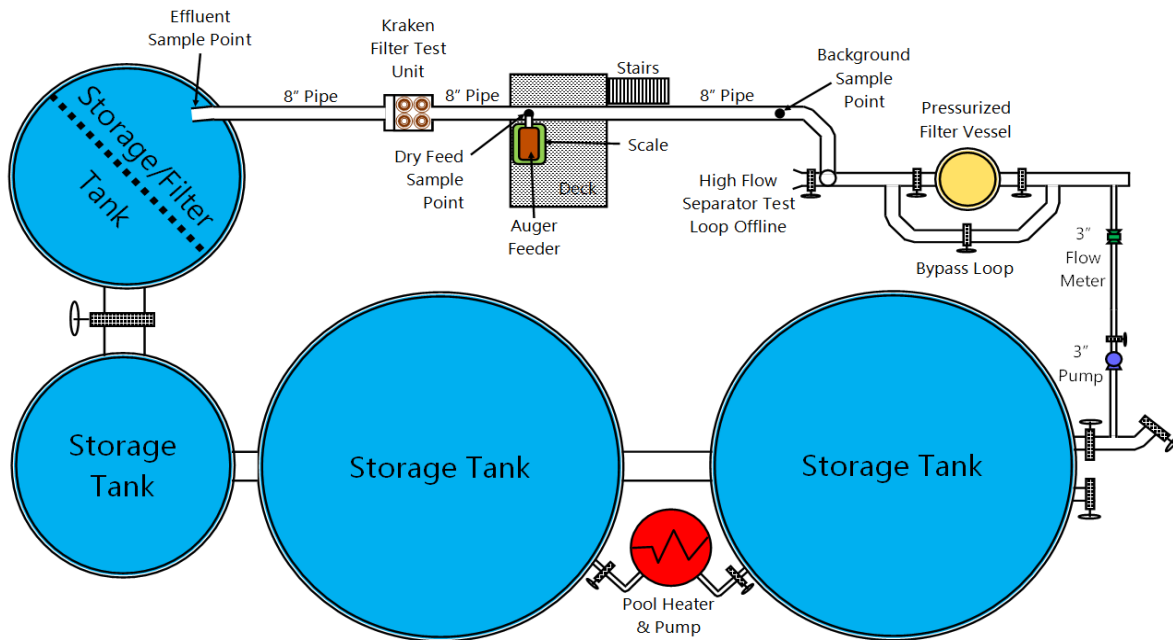


Figure 6 Test Flow Apparatus – Sediment Removal and Scour Testing

Water Flow and Measurement

From the water supply storage tanks, water was pumped using a Xylem AC e-1500, 3x3x9.5C 5 HP (10 - 200 gpm) centrifugal pump during removal efficiency, mass loading, and scour testing. The pump was controlled by an Aquavar IPC AVA20200B0F0x0x1 Variable Frequency Drive (VFD). Flow measurement was done using a Toshiba LF654 Flanged Mount Magmeter (combined type) with 3-inch flanges, an electromagnetic flow meter with an accuracy of $\pm 0.5\%$ of reading. The data logger was a MadgeTech CurrentX4 30MA, 4-Channel Current type and related software, configured to record a flow measurement once every 5 seconds.

The water in the flow loop was circulated through a filter housing containing high-efficiency, high-surface area pleated paper filters with a 0.5 micron (μm) absolute rating. The influent pipe was 8 inches in diameter with a slope of 1.1%. Sediment addition was done through a port at the crown of the influent pipe, directly upstream of the HC Kraken[®] Filter. The sediment auger feeder was an Acrison Model 105X volumetric screw feeder with a spout attachment and motor controller. The feeder has a 1 cubic foot hopper at the upper end of the auger to provide a constant supply of sediment.

Water flow exited the HC Kraken[®] Filter and terminated with a free-fall into a receiving tank to complete the flow loop. The length of the 8-inch diameter outlet pipe is 108 inches with a slope of 1.2%. Observations documented that no sediment was deposited in either the inlet or outlet pipe during any of the test runs.

Sample Collection

Background water samples were grabbed by hand in a 1-L bottle from a sampling port located upstream of the sediment auger feeder. The sampling port was controlled manually by a ball valve that was opened approximately 0.5 seconds prior to sampling to purge any collected sediment (**Figure 7**).

Effluent samples were also grabbed by hand. The effluent pipe discharged freely into the receiving tank and the effluent samples were taken at that point (**Figure 8**). The sampling technique used was to take the grab sample by sweeping a wide-mouth 1-L bottle through the stream of effluent flow such that the jar was full after a single pass.



Figure 7 Background Sampling Point



Figure 8 Effluent Sampling Point

Other Instrumentation and Measurement

Water temperature was taken inside the filter chamber using an Elitech RC-5+ PDF USB Temperature Data Logger that automatically logs the temperature in 1-minute intervals. The maximum temperature from each run is presented in **Table 10** and **Table 11**.

A water surface level (WSL) reading was recorded manually at the beginning and end of each run within the filter chamber. A yardstick mounted to the inside of the wall of the filter chamber was visually observed to record the levels. The ending water levels in both chambers were used to time the two drain-down samples based on two-thirds and one-third of the volume during that run. Run and sampling times were measured using a Thomas Scientific NIST traceable stopwatch, manufactured by Control Company Model 8788V77.

The sediment feed samples taken during each run were collected in 500 mL jars and weighed on a precision balance (Mettler Toledo, MS1003TS/00). The mass sediment in the auger at the beginning and at the end of each run was weighed on a balance (Arlyn Scales, Model-SAW-MXL Ultra Precision). This balance was placed permanently under the auger and allows the before and after weights to be taken without manually removing the sediment after each run. The additional sediment came from a 5-gallon container and was added into the auger during the test run. The container was weighed on a balance (Mettler Toledo, PBA655-B60 US) at the beginning and end of each run.

2.2 Test Sediment

The test sediment was fed through an opening in the crown of the influent pipe, 39.5 inches upstream of the HC Kraken® Filter. A 5-inch diameter hole was used to direct the sediment into the pipe (**Figure 9**).



Figure 9 Sediment Addition Point

The test sediment purchased and used for the removal efficiency study was custom blended by GHL (Good Harbours Laboratories, Mississauga, Ontario, Canada) using various commercially available silica sands; this batch was GHL lot A029-151. GHL sent out three samples of sediment for particle size analysis using the methodology of ASTM method 6913 (Standard Test Method for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis) and ASTM D7928 (Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis). The samples were composite samples created by taking samples throughout the blending process and in various positions within the blending drum. The testing laboratory was Bureau Veritas, an independent test laboratory also located in Mississauga, Ontario, Canada. Bio Clean received three sealed drums from GHL.

Each drum was opened, and security seals were removed for this sampling. Representative samples were taken from each drum (at the top, middle and bottom of the drum) and were composited into three separate five-gallon buckets. When all drums were sampled and composites placed into the buckets, the buckets were thoroughly mixed, and a single sample taken from each bucket to be sent for analysis. Samples of approximately 500 grams were placed into glass jars, which were then sealed, labelled, and packaged for transport to the testing laboratory for analysis. Sample jars were immediately packaged and shipped to IAS Laboratories in Phoenix, AZ for analysis using the same ASTM test methodology used by Bureau Veritas. Drum number three (drum serial #2371549) was used during HC Kraken[®] Filter testing. All opening and closing of the drum and removal and replacement of security tags was done in the presence of the third-party observer. The PSD results are summarized in **Table 2** and shown graphically in **Figure 10**.

Table 2 PSD of Removal Efficiency Test Sediment

Particle Size (Microns)	Test Sediment Particle Size (% Less Than) ¹				Specification ² (Minimum % Less Than)	QA/QC
	Sample 1	Sample 2	Sample 3	Average		
1000	100.0	100.0	100.0	100.0	100	PASS
500	95.4	95.4	95.4	95.4	95	PASS
250	88.9	88.8	88.8	88.8	90	PASS
150	80.0	79.9	79.0	79.6	75	PASS
100	60.0	60.1	60.2	60.1	60	PASS
75	51.4	51.4	51.4	51.4	50	PASS
50	48.3	46.5	48.3	47.7	45	PASS
20	44.9	39.8	40.9	41.8	35	PASS
8	30.3	30.3	30.3	30.3	20	PASS
5	25.2	24.3	24.3	24.6	10	PASS
2	15.2	14.5	14.5	14.7	5	PASS
d ₅₀	64	68	64	65	≤ 75 μm	PASS

¹ Where required, particle size data has been interpolated to allow for comparison to the required NJDEP particle size specification.

² Per NJDEP, a measured value (three-sample average) may be lower than a target minimum % less than value by up to two percentage points provided that the measured d₅₀ value does not exceed 75 microns.

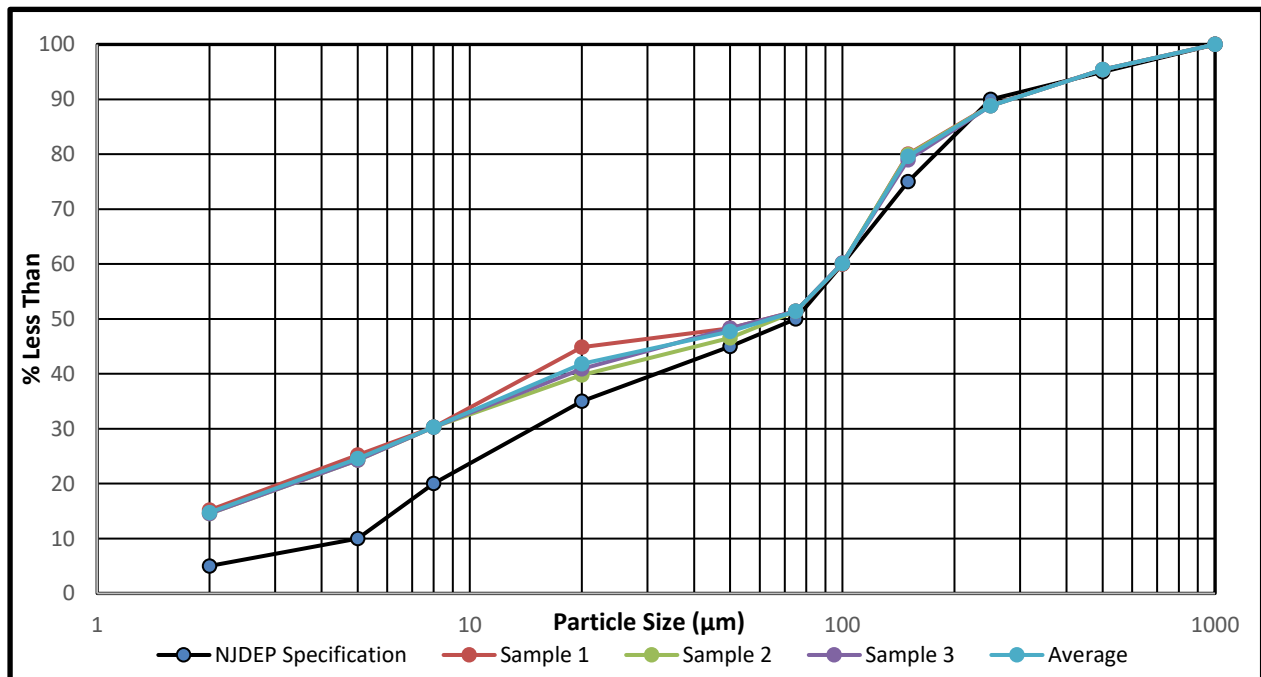


Figure 10 Average Particle Size Distribution of Removal Efficiency Test Sediment

2.3 Removal Efficiency Testing Procedure

Removal testing was conducted on a clean unit. Removal efficiency testing was performed as specified in Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. While the protocol only requires 10 runs for removal efficiency testing additional runs were completed in case of any unforeseen QC issues with specific runs.

The test sediment feed was sampled three times per run to confirm the sediment feed rate. Each sediment feed sample was collected in a 500-mL bottle over an interval timed to the nearest hundreds of a second and was a minimum 0.1 liter or the collection interval did not exceed one minute, whichever came first. Feed samples were started the precise moment the effluent sample collection was completed (passed through flow stream) when occurring at the same time intervals.

Effluent grab sampling began following more than three MTD detention times after the initial sediment feed sample was taken. The time interval between sequential samples was 5 minutes, however, when the test sediment feed was interrupted for measurement, the next effluent sample was collected following more than three MTD detention times from the time the sediment feed was re-established. A total of 6 effluent samples were taken during each run.

Two evenly spaced volume paced drawdown samples were taken at one-third and two-thirds of the drawdown volume after the flow was cut off at the end of each run. The ending water level in the HC Kraken[®] Filter chamber after each run was used to establish the water levels that each of the two samples should be taken. As the ending water level increased over the course of the testing, the levels when the samples were taken changed proportionally. Prior to testing, calculations were performed to find the drawdown volume and these calculations were performed by filling the unit with clean water and quantifying the volume. The drawdown mass was calculated using Equation 6 (page 14).

Background water samples were taken with the odd-numbered effluent samples. Alpha Analytical Laboratories, Inc. of Carlsbad, California performed analysis of all background, drawdown, and effluent samples under test method ASTM D3977-97 (2019) “Standard Test Methods for Determining Sediment Concentrations in Water Samples”.

2.4 Scour Testing Procedure

Following all of the removal efficiency testing, the HC Kraken[®] Filter sat undisturbed and allowed to completely drain until the sediment scour testing was ready to begin. The unit sat for 1 hour between the last removal efficiency testing run and the beginning of the scour testing. Up until the time of scour testing, a total of 87.21 lbs of sediment was injected into the test unit. Based upon removal efficiency results, the total sediment retained in the system prior to scour testing was 76.0 lbs. This corresponds to 19.0 lbs of sediment retained per cartridge. The levels of sediment inside the filter chamber were recorded by the third-party observer. Nothing was disturbed between removal efficiency testing and scour testing.

The scour test was conducted at a target flow rate of 140 gpm (actual average was 138.2 gpm) greater than two times the MTFR. The actual average excludes the 5-minute ramp-up time preceding the scour test.

During the scour test, the water flow rate was recorded using a MadgeTech CurrentX4 30MA, 4-Channel Current type data logger and related software, configured to record a flow measurement once every five seconds. The MadgeTech software was calibrated to the Toshiba Flow meters. Water temperature was taken using an Elitech RC-5+ PDF USB Temperature Data Logger that automatically logs the temperature in 1-minute intervals. The Temperature Data Logger was suspended inside the HC Kraken[®] Filter chamber. The maximum temperature recorded is shown in the QA/QC run summary data below (**Table 10**).

Run and sampling times were measured using a Thomas Scientific NIST traceable stopwatch, manufactured by Control Company Model 8788V77.

Testing commenced by gradually increasing the water flow into the system until the target flow rate of greater than 200% of the MTFR (203%) was achieved (within five minutes of commencing the test). Effluent and background grab samples were taken once every two minutes, starting after achieving the target flow rate, until a total of 15 effluent samples were taken. A total of 15 background water samples were collected at evenly spaced intervals throughout the scour test at the same time effluent samples were collected.

3. Performance Claims

Total Suspended Solids (TSS) Removal Rate

The HC Kraken[®] Filter exceeded the NJDEP required total suspended solids (TSS) removal rate of 80% at an MTFR of 68 gpm for 4 cartridges (one cartridge included drain down orifices). A removal efficiency of 80.75% was determined based on the first 10 runs according to the procedure and calculations described in the NJDEP Protocol and rounded down to 80% per Section C in the Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (Verification Procedure) dated January 25, 2013.

Maximum Treatment Flow Rate (MTFR).

The HC Kraken[®] Filter unit tested demonstrated a maximum treatment flow rate (MTFR) of 0.152 cfs (68 gpm). This corresponds to a hydraulic loading rate of 0.101 gpm/ft² of effective membrane filter area.

Effective Filtration Treatment Area (EFTA)

Each 30-inch HC Kraken[®] Filter has an effective filtration treatment area of 168.2 ft². This is the measurement of the total surface area of pleated filtration paper in one singular 30-inch tall HC Kraken[®] Filter.

Effective Sedimentation Treatment Area (ESTA).

The HC Kraken[®] Filter test unit (Model KF-1.5-1.5) had a 17.5 x 17.5-inch sedimentation area. This corresponds to a total ESTA of 2.13 ft². Each of the four filters had a corresponding ESTA of 0.53 ft². This does not account for the filters surface area that would reduce the ESTA.

Sediment Mass Load Capacity

The HC Kraken[®] Filter unit tested received a mass load of 87.2 lbs over the 20 runs and a mass load that was captured of 76.0 lbs, which equates to 19.0 lbs per cartridge, or 0.113 lbs/ft² of effective membrane surface area.

Maximum Allowable Inflow Drainage Area

Each 30-inch Kraken[®] Filter can treat 0.032 acres based on a sediment mass capture of 19.0 lbs. and an annual sediment load of 600 pounds per acre.

Detention Time and Volume

The maximum operational wet volume (WV) of 6.38 ft³ for our 17.5 x 17.5-inch HC Kraken[®] Filter test unit produces a detention time of 0.70 minutes at 68 gpm. The associated water level for this maximum operational wet volume was 36 inches, the height of the bypass wall. Except for run 20, all other runs of the 20 completed runs experienced water levels below the bypass.

Online/Offline Installation

Based on the scour testing results shown in Section 4.4, the HC Kraken[®] Filter qualifies for online installation up to 203% of the MTFR.

4. Supporting Documentation

To support the performance claims, 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. were provided to NJCAT for review. NJDEP agreed that if such documentation could be made available upon request, it would not be prudent or necessary to include all this information in this verification report. All supporting documentation will be retained securely by Bio Clean Laboratories and has been provided to NJCAT and is available upon request.

4.1 Removal Efficiency and Mass Load Capacity Results

A total of 15 removal efficiency testing runs were completed in accordance with the NJDEP Filtration protocol. The target flow rate was 100% MTFR and the target influent sediment concentration was 200 mg/L. The removal efficiency from the first 10 runs was 80.75%, qualifying the HC Kraken[®] Filter for an 80% TSS removal efficiency certification. An additional 5 runs were completed (four completed, fifth went into bypass during the run) for sediment mass capacity testing, at the same target flow rate and an influent sediment concentration of 400 mg/L. Hence, a total of 19 qualifying runs were completed. The water level breached the 36-inch bypass wall at exactly 8 minutes and 4 seconds into Run 20 and testing was immediately halted and run 20 results abbreviated to those collected prior to the bypass occurring. Equations 7 and 8 (page 14) were used to calculate the individual run efficiency and overall cumulative run efficiency.

The total water volume and average flow rate per run were calculated from the data collected by the flow data logger, one reading every 5 seconds. The average influent sediment concentration for each test flow was determined by mass balance using Equation 2. The amount of sediment fed into the auger feeder during dosing, and the amount remaining at the end of a run, was used to determine the amount of sediment fed during a run. The sediment mass was corrected for the mass of the three feed rate samples taken during the run. The mass of the sediment fed was divided by the volume of water that flowed through the HC Kraken[®] Filter during dosing to determine the average influent sediment concentration for each run using Equation 3. The total cumulative sediment mass injected and retained were calculated using Equations 9 and 10.

Three sediment feed rate samples were collected, at evenly spaced time intervals, during the run to ensure the rate was stable. The COV (coefficient of variance) of the samples had to be ≤ 0.10 per the NJDEP protocol. Feed rate was calculated using Equation 1. The feed rate samples were also used to calculate an influent concentration to double-check the concentration calculated by mass balance.

The average effluent sediment concentration was adjusted for the background sediment concentration using Equation 4. In cases where the reported background sediment concentration was less than 1.0 mg/L (the method quantitation limit), 0.5 mg/L was used in calculating the adjusted effluent concentration. Removal efficiencies, drawdown adjustments, and mass load capacities for each test run were computed using the following equations:

$$\text{Feed Rate (g/min)} = \left(\frac{\text{Mass}_{\text{sample+bottle (g)}} - \text{Mass}_{\text{bottle (g)}}}{\text{Time collection (s)} \times \left(\frac{\text{min}}{60 \text{ s}}\right)} \right) \times (1 - \text{Sediment Moisture Content})$$

(Equation 1)

$$\begin{aligned} \text{Influent Mass (kg)} &= (1 - \text{Sediment Moisture Content}) \times [\text{Mass}_{\text{pre test (kg)}} - \text{Mass}_{\text{post test (kg)}}] \\ &\quad - \sum \text{Mass}_{\text{feed sample (g)}} \times \left(\frac{\text{kg}}{1\text{E}3 \text{ g}}\right) \end{aligned}$$

Equation 2)

$$\begin{aligned} \text{Average Influent Concentration (mg/L)} &= \left(\frac{\text{Influent Mass (kg)} \times \left(\frac{1\text{E}6 \text{ mg}}{\text{kg}}\right)}{\text{Avg. Flow Rate} \left(\frac{\text{ft}^3}{\text{s}}\right) \times \left(\frac{28.3168\text{L}}{\text{ft}^3}\right) \times \left(\frac{60 \text{ s}}{\text{min}}\right) \times \text{Time}_{\text{sediment injection (min)}}} \right) \end{aligned}$$

(Equation 3)

$$\begin{aligned}
& \textbf{Average Adjusted Effluent SSC Concentration (mg/L)} \\
& = \text{Avg. Effluent Concentration (mg/L)} - \text{Avg. Background Concentration (mg/L)}
\end{aligned}
\tag{Equation 4}$$

$$\begin{aligned}
& \textbf{Effluent Mass (mg)} \\
& = \text{Avg. Adjusted Effluent SSC (mg/L)} \times ((\text{Time}_{\text{sediment injection}} (\text{min}) \times \text{Average Flow Rate (gpm)}) \\
& - \text{Drain Down Volume (gal)}) \times 3.78541
\end{aligned}
\tag{Equation 5}$$

$$\begin{aligned}
& \textbf{Drawdown Flow Mass (mg)} \\
& = (\text{Avg. Drawdown Effluent SSC (mg/L)} \\
& - \text{Avg. Background SSC (mg/L)}) \times \text{Drawdown Flow Volume (L)}
\end{aligned}
\tag{Equation 6}$$

$$\textbf{Removal Efficiency (\%)} = \left(\frac{\text{Influent Mass (mg)} - \text{Effluent Mass (mg)} - \text{Drawdown Mass (mg)}}{\text{Influent Mass (mg)}} \right) \times 100
\tag{Equation 7}$$

$$\textbf{Cumulative Removal Efficiency (\%)} = \left(\frac{\sum \text{Influent Mass (mg)} - \sum \text{Effluent Mass (mg)} - \sum \text{Drawdown Mass (mg)}}{\sum \text{Influent Mass (mg)}} \right) \times 100
\tag{Equation 8}$$

$$\textbf{Cumulative Mass Load (lbs)} = \frac{\sum \text{Influent Mass (mg)}}{\frac{453,592 \text{ mg}}{\text{lb}}}
\tag{Equation 9}$$

$$\textbf{Cumulative Mass Load Capacity (lb)} = \left(\frac{\sum \text{Influent Mass (mg)} - \sum \text{Effluent Mass (mg)} - \sum \text{Drawdown Mass (mg)}}{\frac{453,592 \text{ mg}}{\text{lb}}} \right)
\tag{Equation 10}$$

NOTE: it was found that the moisture content was negligible and therefore no correction was required. Table 2 of the sediment report titled “Particle Size Characterization of GHL Silica Blend Lot A028-151 for use in Hydrodynamic Separator Removal Efficiency Testing” shows that the percentage moisture was below the detectable limit of 0.3% for all three samples.

The data collected for all removal efficiency runs is presented below:

Table 3 Removal Efficiency and Sediment Mass Capacity Sampling Schedule

Elapsed Time	Feed Rate Sample	Effluent Sample	Background Sample ¹
0:00:00	1		
0:07:00		1	1
0:12:00		2	
0:17:00		3	2
0:17:30	2		
0:24:00		4	
0:29:00		5	3
0:34:00		6	
0:34:30	3		
1/3 Drawdown		7	
2/3 Drawdown		8	

¹Background sample was pulled 10 seconds after the effluent sample.

Table 4 Removal Efficiency Results

PERFORMANCE SUMMARY – Removal Efficiency Testing											
Run #	Total Water Volume (gal)	Sediment Mass Injected - (lb)	Influent TSS Based on Mass Injected (mg/L)	Average Adjusted Effluent TSS (mg/L)	Effluent Mass (lb)	Average Adjusted Draw-down TSS (mg/L)	Draw-down Volume (gal)	Draw-down Mass (lb)	Cumulative Mass Captured (lb)	Removal Efficiency (%)	Cumulative Removal Efficiency (%)
1	2216	3.70	200.0	39.5	0.718	89.4	37.5	0.028	2.954	79.83%	79.83%
2	2213	3.71	201.1	37.3	0.677	191.5	38.4	0.061	5.925	80.09%	79.96%
3	2210	3.84	208.0	40.1	0.727	234.5	39.1	0.077	8.962	79.08%	79.66%
4	2216	3.86	208.7	35.9	0.653	260.5	38.9	0.085	12.084	80.89%	79.97%
5	2213	3.83	207.3	34.2	0.621	320.5	39.4	0.105	15.188	81.03%	80.19%
6	2210	3.60	195.1	33.6	0.609	424.0	38.8	0.137	18.041	79.27%	80.04%
7	2272	3.63	196.7	32	0.580	302.5	38.9	0.098	20.993	81.31%	80.22%
8	2213	3.67	198.6	37.6	0.683	280.5	38.6	0.090	23.890	78.93%	80.06%
9	2213	3.79	205.2	34.2	0.621	262.5	38.4	0.084	26.975	81.39%	80.21%
10	2216	3.88	210.0	30	0.546	57.1	38.8	0.018	30.290	85.46%	80.75%
11	2216	3.85	208.2	28.7	0.522	38.2	38.6	0.012	33.606	86.12%	81.25%
12	2213	3.89	210.6	27.7	0.503	41.9	39.1	0.014	36.980	86.72%	81.72%
13	2213	3.87	209.3	26	0.472	30.5	39.4	0.010	40.367	87.54%	82.18%
14	2213	3.80	205.6	22.8	0.414	38.3	39.4	0.013	43.741	88.77%	82.65%
15	2213	3.85	208.2	19.3	0.350	30.9	40.3	0.010	47.230	90.63%	83.20%

Table 5 Mass Load Capacity Results

PERFORMANCE SUMMARY – Sediment Mass Capacity Testing											
Run #	Total Water Volume (gal)	Sediment Mass Injected - (lb)	Influent TSS Based on Mass Injected (mg/L)	Average Adjusted Effluent TSS ¹ (mg/L)	Effluent Mass (lb)	Average Adjusted Draw-down TSS (mg/L)	Draw-down Volume (gal)	Draw-down Mass (lb)	Cumulative Mass Captured (lb)	Removal Efficiency (%)	Cumulative Removal Efficiency (%)
16	2216	7.49	405.2	33.4	0.607	14.1	40.6	0.005	54.109	91.84%	84.20%
17	2193	7.39	403.7	17	0.305	19.1	45.1	0.007	61.186	95.77%	85.40%
18	2203	7.38	401.3	24.6	0.444	102.8	46.1	0.040	68.083	93.45%	86.15%
19	1992	6.68	401.7	15	0.244	20.1	45.1	0.008	74.511	96.24%	86.93%
20	466	1.5	385.1	1.3	0.005	36.3	47.7	0.014	76.992	98.73%	87.14%

Table 6 Individual Run Data – Removal Efficiency Testing

PERFORMANCE CONCENTRATIONS – Removal Efficiency Testing											
Run #	Effluent 1 (mg/L)	Effluent 2 (mg/L)	Effluent 3 (mg/L)	Effluent 4 (mg/L)	Effluent 5 (mg/L)	Effluent 6 (mg/L)	Draw-down 1 (mg/L)	Draw-down 2 (mg/L)	Back-ground 1 (mg/L)	Back-ground 2 (mg/L)	Back-ground 3 (mg/L)
1	40.4	41.8	40.6	39.2	38.5	39.3	99.9	79.8	0.5	0.5	0.5
2	36.3	38.7	38.4	41.4	35.4	36.6	132	252	0.5	0.5	0.5
3	35.9	36.7	55.9	43.0	36.2	36.1	276	194	0.5	0.5	0.5
4	37.4	37.3	36.2	36.6	35.9	35.0	288	234	0.5	0.5	0.5
5	36.3	36.4	33.7	33.0	35.4	33.2	350	292	0.5	0.5	0.5
6	33.0	36.8	36.6	34.6	33.4	30.4	485	364	0.5	0.5	0.5
7	34.6	35.3	31.6	30.2	32.2	31.3	378	228	0.5	0.5	0.5
8	53.9	37.5	35.4	34.5	33.6	33.8	323	239	0.5	0.5	0.5
9	37.4	37.3	33.1	33.3	34.9	32.0	318	208	0.5	0.5	0.5
10	34.7	33.4	31.2	30.6	27.1	26.1	64.8	50.4	0.5	0.5	0.5
11	32.5	30.7	29.2	29.1	27.8	25.7	38.4	39.0	0.5	0.5	0.5
12	31.7	30.4	29.7	26.7	26.4	24.4	39.8	44.9	0.5	0.5	0.5
13	31.4	29.0	27.4	26.3	22.3	22.6	29.2	32.8	0.5	0.5	0.5
14	30.2	26.3	25	21.8	19.3	17.2	39.6	38.0	0.5	0.5	0.5
15	29.0	24.6	19.9	17.4	16.1	11.5	27.8	35.0	0.5	0.5	0.5

Table 7 Individual Run Data – Mass Load Capacity Testing

PERFORMANCE CONCENTRATIONS – Mass Load Testing											
Run #	Effluent 1 (mg/L)	Effluent 2 (mg/L)	Effluent 3 (mg/L)	Effluent 4 (mg/L)	Effluent 5 (mg/L)	Effluent 6 (mg/L)	Draw-down 1 (mg/L)	Draw-down 2 (mg/L)	Back-ground 1 (mg/L)	Back-ground 2 (mg/L)	Back-ground 3 (mg/L)
16	63.3	49.9	38.6	28.6	16.5	6.23	17.4	11.7	0.5	0.5	0.5
17	52.1	19.1	16.4	6.8	5.74	4.8	28.8	10.4	0.5	0.5	0.5
18	59.5	40.6	26.4	9.36	7.46	7.28	195	11.6	0.5	0.5	0.5
19	47.8	17.7	11.2	7.09	5.14	4.09	32.2	8.94	0.5	0.5	0.5
20 ¹	10.90	N/A	N/A	N/A	N/A	N/A	64.2	9.35	0.5	N/A	N/A

¹Due to the system breaching the bypass weir wall at 8:04, Effluent sample 2-6 and drawdown sample 2 on run 20 were left as N/A

4.2 Water Surface Levels and Detention Times

The water levels were monitored during each test run in the HC Kraken® Filter chamber. Water levels slowly increased over the course of the testing until the flow rate was reduced to 90% of the MTR. As shown in **Table 8** and **Table 9** the observed water levels were less than the maximum water levels used prior to official testing and used to calculate the detention time. Thus, detention times were longer than required by the protocol and provided a safety factor.

Table 8 Removal Efficiency Detention Times and Water Levels

DETENTION TIME AND WATER LEVELS – Removal Efficiency Testing							
Run #	Average Inflow Rate (gpm) (+10%)	Filter Chamber Water Level (in)	Active Wet Volume (cu ft)	Detention Time (min)	3X Detention Time (min)	Time Used In Sampling Schedule (min)	Detention Time Compliant?
1	68.2	28.25	5.01	0.55	1.65	6.0	YES
2	68.1	29.00	5.14	0.56	1.69	6.0	YES
3	68.0	29.50	5.23	0.58	1.73	6.0	YES
4	68.2	29.38	5.21	0.57	1.71	6.0	YES
5	68.1	29.75	5.27	0.58	1.74	6.0	YES
6	68.1	29.25	5.18	0.57	1.71	6.0	YES
7	68.0	29.38	5.21	0.57	1.72	6.0	YES
8	68.1	29.13	5.16	0.57	1.70	6.0	YES
9	68.1	29.00	5.14	0.56	1.69	6.0	YES
10	68.2	29.25	5.18	0.57	1.71	6.0	YES
11	68.2	29.13	5.16	0.57	1.70	6.0	YES
12	68.1	29.50	5.23	0.57	1.72	6.0	YES
13	68.1	29.75	5.27	0.58	1.74	6.0	YES
14	68.1	29.75	5.27	0.58	1.74	6.0	YES
15	68.1	30.38	5.38	0.59	1.77	6.0	YES

Table 9 Sediment Mass Capacity Detention Times and Water Levels

DETENTION TIME AND WATER LEVELS Sediment Mass Capacity Testing							
Run #	Average Inflow Rate (gpm) ($\pm 10\%$)	Filter Chamber Water Level (in)	Active Wet Volume (cu ft)	Detention Time (min)	3X Detention Time (min)	Time Used In Sampling Schedule (min)	Detention Time Compliant?
16	68.2	30.63	5.43	0.60	1.79	6.0	YES
17	67.5	34.00	6.03	0.67	2.00	6.0	YES
18	67.8	34.75	6.16	0.68	2.04	6.0	YES
19	61.3	34.00	6.03	0.74	2.21	6.0	YES
20	61.6	36.00	6.38	0.77	2.32	6.0	YES

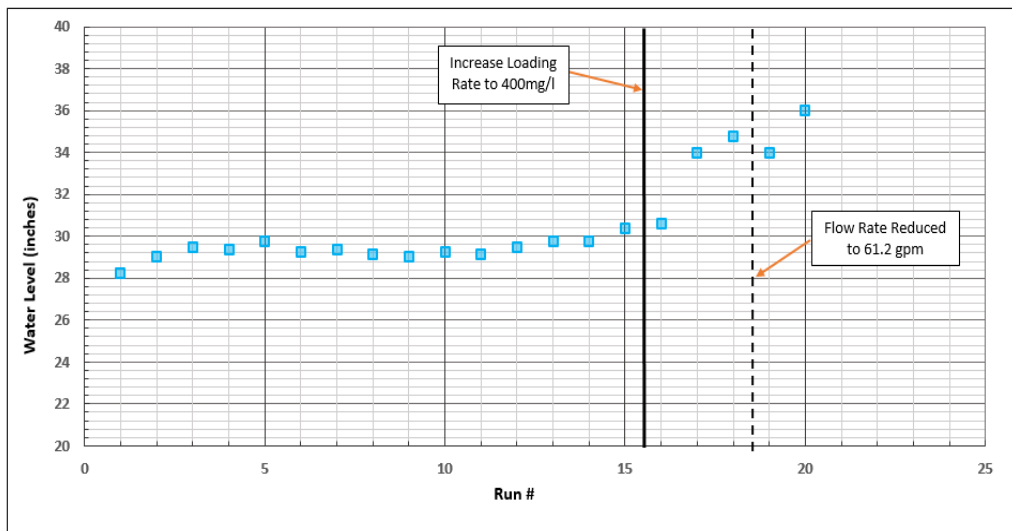


Figure 11 Water Levels in the Treatment Chamber Per Run

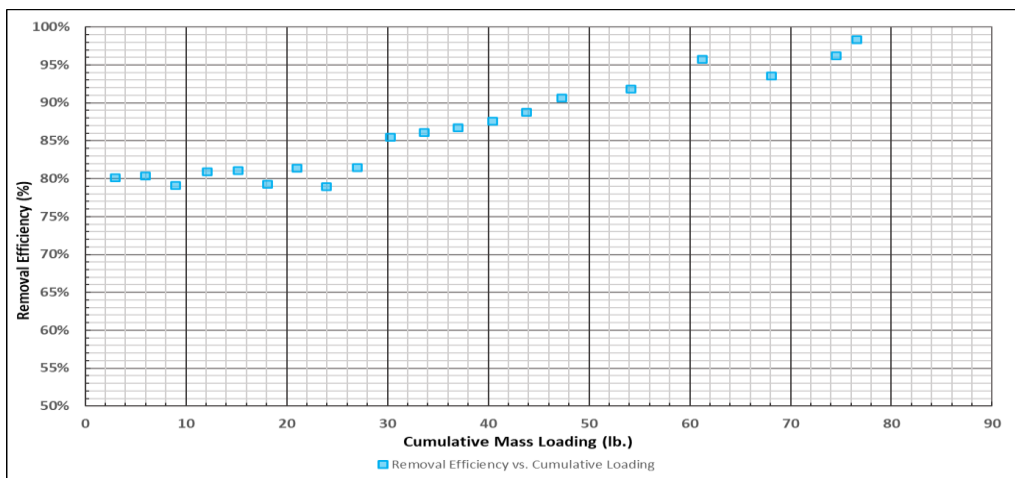


Figure 12 Removal Efficiencies vs. Cumulative Mass Loading

4.3 QA/QC

The average inflow rate was within 10% variation from the target flow rate for each of the 20 runs as shown in **Table 10**. The associated COV was also within compliance of the NJDEP protocol. All runs had temperatures less than 80° F. Each background and effluent sample were weighed (subtracting out the weight of the empty bottle) after the test run and recorded. As shown in **Table 11**, all samples were greater than the SSC Sample Volume of 0.5 L minimum requirement in the protocol.

Table 10 Summary of Removal Efficiency Flow Rates and Temperature

FLOW RATE AND WATER TEMPERATURE – Removal Efficiency Testing					
Run #	QA/QC PASS/FAIL	Target Inflow Rate (gpm)	Average Inflow Rate (gpm) (±10%)	Inflow Rate COV (≤0.03)	Maximum Water Temperature (°F) (≤80 ° F)
1	PASS	68.0	68.2	0.003	64.5
2	PASS	68.0	68.1	0.002	64.5
3	PASS	68.0	68.0	0.002	64.7
4	PASS	68.0	68.2	0.003	64.9
5	PASS	68.0	68.1	0.002	64.9
6	PASS	68.0	68.1	0.002	65.1
7	PASS	68.0	68.0	0.002	64.9
8	PASS	68.0	68.1	0.002	64.9
9	PASS	68.0	68.1	0.002	65.1
10	PASS	68.0	68.2	0.002	65.1
11	PASS	68.0	68.2	0.002	65.3
12	PASS	68.0	68.1	0.003	65.3
13	PASS	68.0	68.1	0.003	65.1
14	PASS	68.0	68.1	0.002	65.1
15	PASS	68.0	68.1	0.003	65.1
16	PASS	68.0	68.2	0.002	65.3
17	PASS	68.0	67.5	0.007	65.3
18	PASS	68.0	67.8	0.007	65.3
19	PASS	61.2	61.3	0.003	65.3
20	PASS	61.2	61.6	0.006	65.3

Table 11 Summary of Removal Efficiency Feed Rate and Concentration

FEED RATE AND CONCENTRATIONS - Removal Efficiency Testing									
Run #	QAQC PASS/FAIL	Target Influent SCC (mg/L)	Average Influent SSC (mg/L) (±10%)	Feed Rate (g/min)			Feed Rate COV (≤0.10)	Average Background SSC (≤20 mg/L)	Minimum SSC/DD Sample Volume (≥0.5 L)
1	PASS	200	200.0	52.573	53.407	53.344	0.009	0.5	0.740
2	PASS	200	201.1	50.534	52.186	53.967	0.033	0.5	0.751
3	PASS	200	208.0	52.312	50.225	53.424	0.031	0.5	0.760
4	PASS	200	208.7	52.799	53.607	52.440	0.011	0.5	0.722
5	PASS	200	207.3	52.508	53.817	53.260	0.012	0.5	0.756
6	PASS	200	195.1	51.574	54.647	50.440	0.042	0.5	0.750
7	PASS	200	196.7	51.834	51.534	52.262	0.007	0.5	0.751
8	PASS	200	198.6	51.334	51.908	51.380	0.006	0.5	0.704
9	PASS	200	205.2	53.618	52.634	52.579	0.011	0.5	0.751
10	PASS	200	210.0	53.807	53.192	53.986	0.008	0.5	0.710
11	PASS	200	208.2	51.882	52.434	53.959	0.020	0.5	0.754
12	PASS	200	210.6	52.996	52.143	53.460	0.013	0.5	0.735
13	PASS	200	209.3	53.491	52.934	53.913	0.009	0.5	0.741
14	PASS	200	205.6	52.949	53.361	53.467	0.005	0.5	0.731
15	PASS	200	208.2	52.447	54.298	54.013	0.019	0.5	0.736
16	PASS	400	405.2	102.561	105.076	102.631	0.014	0.5	0.722
17	PASS	400	403.7	100.534	102.780	104.755	0.021	0.5	0.680
18	PASS	400	401.3	103.602	102.780	102.604	0.005	0.5	0.763
19	PASS	400	401.7	91.688	93.606	92.234	0.011	0.5	0.734
20 ¹	PASS	400	385.1	91.542	N/A	N/A	N/A	0.5	0.874

¹Due to the system breaching the bypass weir wall on Run 20 @ 8:04, feed rate sampling was not conducted.

4.4 Scour Results

Scour testing was conducted in accordance with Section 4 of the 2013 NJDEP Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration MTD. Testing was conducted at a target flow rate of 140 gpm, more than 200% (136 gpm) of the maximum treatment flow rate (MTFR).

Scour testing began by gradually increasing the flow rate to the target flow within a five-minute period. Effluent and background samples were taken from the same locations as for the removal efficiency test, starting 2 minutes after target flow rate was sustained and the ramp up period had ended. The sampling frequency is summarized in **Table 12**.

Table 12 Scour Test Sampling Frequency

Sample/ Measurement Taken	Run Time (min.)															
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Effluent		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Background		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Note: The Run Time of 0 minutes was the end of the 5-minute flow ramp up period.

Water temperature was below the 80-degree maximum allowable as shown in **Table 13**. The water flow rate is shown in **Table 13** and on **Figure 12**.

Table 13 Water Flow and Temperature - Scour Test

Run Parameters	Water Flow Rate (GPM)				Maximum Water Temperature (°F)
	Target	Actual	Difference	COV	
	140	138.3	-1.19%	0.002	65.4
QA/QC Limit	-	-	±10% PASS	0.03 PASS	80 PASS

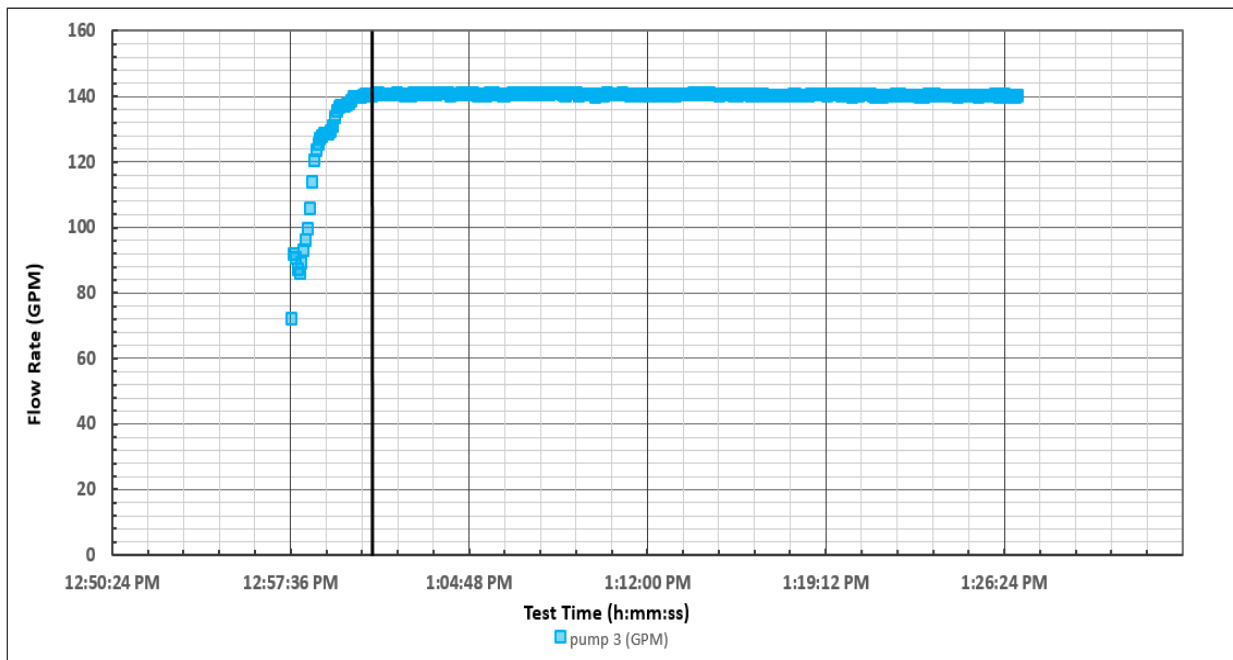


Figure 13 Water Flow - Scour Test

The effluent and background SSC results are reported in **Table 14**. The adjusted effluent concentration was calculated as:

$$\begin{aligned} \text{Adjusted Effluent Concentration } \left(\frac{\text{mg}}{\text{L}}\right) \\ = \text{Measured Effluent Concentration } \left(\frac{\text{mg}}{\text{L}}\right) - \text{Background Concentration} \left(\frac{\text{mg}}{\text{L}}\right) \end{aligned}$$

(Equation 11)

The TSS method reporting limit was 1.0 mg/L. Any test results below this value were reported as 0.5 mg/L (1/2 detection limit) for calculation purposes. A total of 15 samples were collected for both effluent and background concentrations to have matching pairs and eliminate the need for interpolation. The average adjusted effluent concentration was 0.5 mg/L. Therefore, when operated up to 203% of the MTRF, the HC Kraken® Filter can be used for online conveyance.

Table 14 Suspended Sediment Concentrations for Scour Test

Sample #	Scour Suspended Sediment Concentration (mg/L)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Effluent		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Background		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Adjusted Effluent		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Average Adjusted Effluent Concentration							0.5 mg/L ¹									

¹All official results were < 1.0 mg/L. Due the 1.0 mg/L method quantitation limit, 0.5 mg/L was used in calculating the adjusted effluent concentration.

5. Design and Installation Limitations

Bio Clean Environmental Services, Inc. provides engineering support to clients on all projects. Each system prior to submittal is evaluated and professionally designed/sized to meet site-specific conditions including treatment and bypass flow rates, load rating requirements, and pipe depth/inlet design details. All site and design constraints will be addressed during the design and manufacturing process.

Delivery and Unloading/Lifting

Bio Clean Environmental Services, Inc. delivers the unit(s) to the site in coordination with the Contractor. The Contractor requires spreader bars, a set of suitable lifting hooks, knuckles, shackles, and eyebolts and chains/cables to lift the main structure and risers safely and securely.

(See project specific drawings for weights and lifting details. Contact Bio Clean for additional lifting details.)

Inspection

Inspection of the Bio Clean vault units and all parts contained in or shipped outside of the unit shall be inspected at time of delivery by the site Engineer/Inspector and the Contractor. Any non-conformance to approved drawings or damage to any part of the system shall be documented on the Bio Clean vault shipping ticket. Damage to the unit during and after unloading shall be corrected at no cost to Bio Clean Environmental. Any necessary repairs to the Bio Clean vault units shall be made to the acceptance of the Engineer/Inspector.

Site Preparation

The Contractor is responsible for providing adequate and complete vault protection when the Bio Clean vault unit is installed prior to final site stabilization, such as full landscaping, grass cover, final paving, and street sweeping completed. The Contractor shall adhere to all jurisdictional and/or OSHA safety rules in providing temporary shoring of the excavation. The Contractor or Owner is responsible for appropriately barricading the Bio Clean vault unit from traffic in accordance with local codes.

Installation

Each unit shall be constructed based on the locations and elevations according to the sizes shown on the approved drawings. Any modifications to the elevation or location shall be at the direction of and approved by the Engineer. Changes to the approved drawings may incur additional charges from Bio Clean Environmental. The unit shall be placed on level, compacted sub-grade with a minimum 6-inch gravel base. Compact undisturbed sub-grade materials per Geotechnical/Soils report. Unsuitable material below sub-grade shall be replaced to site engineer's approval. Once the unit is set, the top section shall be sealed onto the base section before backfilling, using a non-shrink grout, butyl rubber, or similar watertight sealant.

Pipe connections shall be aligned and sealed to meet the approved drawings with modifications necessary to meet site conditions and local regulations. The inlet and outlet will be marked separately on the Bio Clean vault. Once the unit is set, the system shall be protected from entering construction runoff. Contractor will be responsible for cleaning and replacing media, filters, screens, and internal components if unit is contaminated by such construction runoff and associated pollutants and damage (i.e. concrete wash water). Backfilling shall be performed in a careful manner, bringing the appropriate fill material up in 6-inch lifts on all sides. Precast sections shall be set in a manner that will result in a watertight joint.

In all instances, installation of the Bio Clean vault unit shall conform to ASTM specification C891 "Standard Practice for Installation of Underground Precast Utility Structures" unless specified otherwise in contract documents. If required, it is the responsibility of the Contractor to provide curb and gutter and transition to the Bio Clean vault unit for proper stormwater flow into the system through the throat, pipe, or grate opening. A standard drawing of the throat and gutter detail is available; however, the plans and contract documents supersede all standard drawings. Several variations of the standard design are available. Effective bypass for an offline Bio Clean vault unit is essential for correct operation (i.e. bypass to an overflow at lower elevation).

Requirements pertaining to maintenance of the HC Kraken® Filter will vary depending on pollutant loading and individual site conditions. It is recommended that the system be inspected at least twice during the first year to determine loading conditions for each site. These first-year inspections can be used to establish inspection and maintenance frequency for subsequent years.

Driving Head

Driving head will vary for a given HC Kraken® Filter model based on the site-specific configuration. Maximum treatment flow, maximum peak flow rate for online units, pipe slope and diameter will be assessed. At the conclusion of mass load testing the water level reached 36 inches. This should be used as the minimum driving head requirement for design. It is recommended that pipe fall between the inflow and outflow pipe be provided to minimize or eliminate the amount of sur-charge required during lower flows. The actual required head pressure due to the internal riser tube in each cartridge is 9.0 inches (36 inches minus the 27-inch riser tube). Bio Clean Environmental provides design support for each project. Site-specific drawings (cut sheet) will be provided that show pipe inverts, finish surface elevation, flow rates, and hydraulic grade lines. The hydraulic grade line will be assessed for its effect on the overall drainage system to ensure no flooding at peak flow.

Installation Limitations

With each installation, Bio Clean Environmental provides contractors with instructions prior to delivery. Contractors can request onsite assistance from an installation technician during delivery and installation. Pick weights and lifting details are also provided prior to delivery so the contractor can have appropriate equipment onsite to set the unit.

Configurations

The HC Kraken® Filter can be installed online or offline. The HC Kraken® Filter has an internal bypass, which allows for it to be installed online without the need for any external high flow diversion structure up to 203% MTFR conveyance. Standard models utilize an upstream external bypass that is the primary path for higher flows. The HC Kraken® Filter was tested standalone with filter cartridges in a singular filter chamber and discharge chamber. Therefore, various upstream diversion can be used into the system and enter via pipe, curb, or grated inlets.

Structural Load Limitations

The HC Kraken® Filter is housed in a pre-cast concrete structure. Most standard structures are designed to handle indirect traffic loads with open planter configurations. For deeper installation, or installation requiring direct traffic rating or higher, the structure will be designed and modified with potentially thicker tops, bottoms and/or walls to handle the additional loading. Various access hatch options are available for parkway, indirect traffic, direct traffic, and other higher loading requirements such as airports or loading docks.

Pre-treatment Requirements

The HC Kraken® Filter was tested in a standalone configuration with no pre-treatment chamber. Water was pumped directly into the filter chamber, which contains the HC Kraken® Filter cartridges. Therefore, pre-treatment/separation chamber prior to the filter chamber is not a requirement of this approval. Standard models listed in **Table A-2** do have pre-treatment chambers, which are used for offline bypass and to maintain consistency with current models used

nationwide. Bio Clean reserves the rights to modify configuration within the parameters of the tested and verified designs.

Limitations in Tailwater

Site-specific tailwater conditions must be assessed on each individual project. Tailwater conditions increase the amount of driving head required for optimal system operation. The manufacturer's internal protocols require that these conditions are discussed with the engineer of record and that a solution be implemented to adjust for any design variations caused by tailwater conditions at both treatment and bypass flow rates.

Depth to Seasonal High-Water Table

High groundwater conditions will not affect the operation of the HC Kraken® Filter, as it is a closed system. In conditions where high groundwater is present, various measures are employed by Bio Clean Environmental Services' engineering department to ensure that there are no negative consequences caused by the high groundwater. Various measures can be employed such as waterproofing the inside and outside of the structure with an approved coating. A footing can also be added to the bottom of the structure to increase its footprint and offset any buoyancy concerns.

6. Maintenance Plans

As with all stormwater BMPs, inspection and maintenance on the HC Kraken® Filter is necessary. Stormwater regulations require that all BMPs be inspected and maintained to ensure they are operating as designed to allow for effective pollutant removal and provide protection to receiving water bodies. It is recommended that inspections be performed multiple times during the first year to assess site specific loading conditions. This is recommended because pollutant loading can vary greatly from site to site. Variables such as nearby soil erosion or construction sites, winter sanding of roads, amount of daily traffic and land use can increase pollutant loading on the system. The first year of inspections can be used to set inspection and maintenance intervals for subsequent years. If in subsequent years observations show a need for changed inspection and maintenance protocols, they should be implemented. Without appropriate maintenance, a BMP can exceed its storage capacity, which can negatively affect its continued performance in removing and retaining captured pollutants. The HC Kraken® Filter Operation and Maintenance Manual is available at: <https://www.conteches.com/Portals/0/Documents/Maintenance%20Guides/Kraken%20Filter%20Maintenance%20Guide.pdf?ver=Z4nbcyEEjtHDs8e19vGCIg%3d%3d>

Inspection Equipment

Following is a list of equipment to allow for simple and effective inspection of the HC Kraken® Filter:

- Bio Clean Environmental Inspection Form.
- Flashlight.
- Manhole hook or appropriate tools to access the device via hatches and covers.
- Appropriate traffic control signage and procedures.
- Measuring pole and/or tape measure.

- Protective clothing and eye protection.
- Note: entering a confined space requires appropriate safety and certification. However, it is generally not required for routine inspections of the system that can be accomplished from the surface.

Inspection Steps

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

The HC Kraken® Filter can be inspected through visual observation without entry into the system. All necessary pre-inspection steps must be carried out before inspection occurs, especially traffic control and other safety measures to protect the inspector and near-by pedestrians from any dangers associated with an open access hatch or manhole. Once these access covers have been safely opened, the inspection process can proceed:

- Prepare the inspection form by writing in the necessary information including project name, location, date and time, unit number and other info (see inspection form).
- Observe the inside of the system through the access hatches. If minimal light is available and vision into the unit is impaired utilize a flashlight to see inside the system and all of its chambers.
- Look for any out of the ordinary obstructions in the inflow pipe, pre-treatment/diversion chamber, filter chambers, discharge chamber or outflow pipe. Write down any observations on the inspection form.
- Through observation and/or digital photographs estimate the quantity of floatable debris accumulated in the pre-treatment/diversion chamber, and/or the filter chamber. Record this information on the inspection form. Next utilizing a tape measure or measuring stick estimate the amount of sediment accumulated in the pre-treatment/diversion and filter chambers. Record this depth on the inspection form. Through visual observation, inspect the condition of the filter cartridges. Look for excessive build-up of sediments on the surface and any build-up on the top of the cartridges. Record this information on the inspection form.
- Finalize inspection report for analysis by the maintenance manager to determine if maintenance is required

Maintenance Indicators

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

- Missing or damaged internal components or cartridges.

- Obstructions in the system or its inlet or outlet.
- Excessive accumulation of floatables in the pre-treatment chambers in which the length and width of the chamber behind the oil/floatables skimmer is fully impacted. Also, applies to the diversion chamber area in some configurations.
- Excessive accumulation of sediment in the primary sedimentation chamber of more than 18-inches in depth. Also, applies to the diversion chamber area in some configurations.
- Excessive accumulation of sediment in the filter chambers of more than 3-inch on average.
- Substantial build-up of sediments on the filter membrane of the filter cartridges that will have a very dark appearance indicating the membrane may be fully saturated with sediment.

Maintenance Procedures

It is recommended that maintenance occurs at least three days after the most recent rain to allow for drain down of the system and any upstream detention systems designed to drain down over an extended period of time. Maintaining the system while flows are still entering it will increase the time and complexity required for maintenance. Cleaning of the pre-treatment/diversion chamber (if provided) can be performed from the finish surface without entry into the vault utilizing a vacuum truck. Once all safety measures have been set up cleaning of the pre-treatment/diversion chamber can proceed as followed:

- Using an extension on a boom on the vacuum truck position the hose over the opened access hatch and lower into the center of the primary sedimentation or diversion chamber. Remove debris, standing water and sediment from the chamber. A power washer can be used to assist if sediments have become hardened and stuck to the walls. Repeat the same procedure for the secondary sedimentation chamber (applies to pre-treatment chamber configuration only).

If maintenance is required on the filter cartridges the following procedure can be followed after maintenance on the pre-treatment or diversion chamber is performed:

- Following rules for confined space entry use a gas meter to detect the presence of any hazardous gases. If hazardous gases are present, do not enter the vault. Following appropriate confined space procedures take steps, such as utilizing venting system, to address the hazard. Once it is determined to be safe, enter utilizing appropriate entry equipment such as a ladder and tripod with harness.
- Once entry into the system has been established, the maintenance technicians should position themselves to stand in the pre-treatment or diversion chamber. From here, the removal of the cartridges can commence.
- Each cartridge is connected in place with a quarter-turn coupler and includes a handle for easy removal. To remove a cartridge simply grab the handle and turn counter clockwise 90 degrees and pull up to remove. Removal of the cartridge should be done by hand with minimal effort and requires no tools.
- Once the cartridges are removed, they should be lifted out from the vault and brought up to the finish surface for cleaning. First, fill a larger garbage can or container with water. Dunk and spin each cartridge by hand to remove larger sediments and debris. Then move

into an empty container and proceed to use a pressure washer to spray off and clean each cartridge thoroughly by spinning in place until all pleats are clean.

- Each filter chamber should be power washed and vacuumed clean before re-inserting the cleaned cartridges. Pay close attention to the couplers.
- After all cartridges have been washed, they can be replaced back into the vault. To replace each cartridge simply slide cartridge down into the coupler. Turn clockwise 90 degrees until it hits the stop and locks into place. If filters become damaged or worn out new ones should be ordered.
- The last step is to close and replace all access hatch lids and remove all traffic control.
- All removed debris and pollutants shall be disposed of following local and state requirements.

7. Statements

The following attached pages are signed statements from the manufacturer (Bio Clean Environmental Services Inc.), the third-party observer (Luke Russell from Terraphase Engineering), and NJCAT. These statements are a requirement of the 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.



Date: 6/2/2022

To Whom It May Concern,

We are providing this letter as our statement certifying that the protocol titled "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) has been strictly followed. Testing performed at Bio Clean Laboratories, in Oceanside, CA on the HC Kraken® Filter in May of 2022 under the strict supervision of Luke Russell, of TerraPhase, was conducted in full compliance with protocol requirements. All required documentation, data, and calculations have been provided in addition to the accompanying report.

We certify that all requirements and criteria were met and/or exceeded during testing of the HC Kraken® Filter.

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

Sincerely,

Zachariha J. Kent
VP of Product Management
Bio Clean, a Quikrete Company

Signature: _____

Date: 6/2/2022



6/17/22

Richard S. Magee Sc.D., P.E., BCEE
Executive Director
New Jersey Corporation for Advanced Technology
Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
973-879-3056
rsmagee@rcn.com

Re: Statement of Third-Party Observer
Performance Verification of the Bio Clean HC Kraken Filter for 80% RE

Dr. Magee,

Terraphase Engineering, Inc. has been Engaged by Bio Clean to act as the third-party observer for the Performance Verification Testing of their HC Kraken Filter as required by *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (NJCAT)*. Performance Verification Testing was performed by Bio Clean personnel under the direction of Mr. Zach Kent, Managing Director, and began on March 8, 2022, and ended on May 25, 2022. The Performance Verification was performed at Bio Clean Laboratories located at 398 Via El Centro, Oceanside, California 92008.

Working under the responsible charge of Eric Strecker, PE, I, Luke Russell, was personally on site to observe the testing and I remained on site while all testing was underway to observe the testing for its full duration. My review of the flow rates and frequency of sampling (including on-site measurements and collection of samples for laboratory analysis) reported by Bio Clean for the performance tests as reported in their report "NJCAT Technology Verification" of June 2022 were reported accurately. Grain size analysis and sediment concentration in water samples collected by Bio Clean for analysis was performed offsite by third party laboratories. The sampling occurred under my observation and the samples were transported under my direction and control to the laboratories. The verification testing used applicable protocols as outlined in the Quality Assurance Project Plan (QAPP). I have personally reviewed the reported sampling methods and data sets in the Report referenced data files by Bio Clean dated May 2022 and hereby state they conform to my recorded observations while acting as third-party observer.

Please let me know if you have any questions or need any clarification to these statements.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Luke Russell'.

Luke Russell, EIT
luke.russell@terraphase.com

A handwritten signature in blue ink, appearing to read 'Eric Strecker'.

Eric Strecker, PE (CA and OR), BCEE
eric.strecker@terraphase.com
(503) 805-0479



5/26/22

Richard S. Magee Sc.D., P.E., BCEE
Executive Director
New Jersey Corporation for Advanced Technology
Center for Environmental Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
973-879-3056
rsmagee@rcn.com

Re: Third-Party Observer Statement of Disclosure/ Disclosure Record

Dr. Magee,

In accordance with the *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (January 25, 2013) Section 4. B Conflict of Interest*, Terraphase Engineering, Inc. would like to inform NJCAT that we have no disclosures that would represent a conflict of interest. Terraphase Engineering, Inc. has no personal, professional, or financial interest in the outcome of the Performance Verification Testing performed by Bio Clean, and has no personal, professional, or financial interest in Bio Clean or its parent company.

This Engagement with Bio Clean does not present a personal, professional, or financial conflict of interest as the engagement does not include:

- Having an ownership stake in the company
- Receiving commission for selling a Manufactured Treatment Device for a manufacturer
- Having a licensing agreement with the manufacturer; or
- Receiving funding or grants not associated with a testing program from the manufacturer.

Please let either of us know if you have any questions or need any clarification to these statements.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Luke Russell'.

Luke Russell, EIT
Luke.russell@terrphase.com

A handwritten signature in blue ink, appearing to read 'Eric Strecker'.

Eric Strecker, PE, BCEE
eric.strecker@terrphase.com
(503) 805-0479



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

July 25, 2022

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 a full-scale, commercially available HC Kraken[®] Filter (30” tall cartridge – 4 total cartridges) at the Bio Clean Laboratories, based in Oceanside, California, 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 consistent with the NJDEP Approval Process. Independent third-party observation was provided by Luke Russell, E.I.T., of Terraphase Engineering. Specifically:

Test Sediment Feed

The test sediment purchased and used for the removal efficiency study was custom blended by GHL (Good Harbours Laboratories, Ontario, Canada) using various commercially available silica sands. GHL sent out three samples of sediment for particle size analysis using the methodology of ASTM method 6913 (Standard Test Method for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis) and ASTM D7928 (Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis). The samples were composite samples created by taking samples throughout the blending process and in various positions within the blending drum. The testing lab was Bureau Veritas, an independent test lab also located in Ontario, Canada. Bio Clean received three sealed drums from GHL.

Before using the test sediment, Bio Clean Laboratories performed additional PSD analysis to confirm the results provided by Bureau Veritas. Under the supervision of a third party observer

each drum was sampled and composites placed into three separate five-gallon buckets, the buckets thoroughly mixed, and a single sample taken from each bucket and sent for analysis to IAS Laboratories in Phoenix, AZ using the same ASTM test methodology used by Bureau Veritas. The test sediment PSD exceeded the NJDEP specifications and had a d_{50} of $65\mu\text{m}$ less than the $<75\mu\text{m}$ requirement.

Scour Test Sediment

The same sediment was used for scour testing.

Removal Efficiency Testing

Removal efficiency testing followed the effluent grab sampling test method outlined in Section 5 of the NJDEP Protocol. The sediment removal efficiency of the HC Kraken[®] Filter (four 30" tall cartridges) at the MTFR (68 gpm, 0.152 cfs) was 80.75% after 10 runs, qualifying the HC Kraken[®] Filter for an 80% TSS removal efficiency certification. An additional five runs were conducted to ensure that 10 qualifying removal efficiency runs were obtained.

Sediment Mass Loading Capacity

The Sediment Mass Loading Capacity study was a continuation of the Removal Efficiency study. All aspects of the testing remained the same, except that the target feed concentration was increased to 400 mg/L, up from the 200 mg/L used for the Removal Efficiency test. An additional 5 runs were completed for sediment mass capacity testing. The feed rate COV ≤ 0.10 and the flow rate COV ≤ 0.03 both were within protocol requirements.

The total mass of sediment captured for the 20 runs was 76.0 lbs. and the cumulative mass removal efficiency was 87.14%.

Scour Testing

Scour testing of the HC Kraken[®] Filter (four 30" tall cartridges) was conducted in accordance with Section 4 of the NJDEP Protocol at a target flow rate greater than 200% of the MTFR to qualify the MTD for online conveyance installation. The test flow rate was 203% of the 0.152 cfs MTFR. The average adjusted effluent concentration for this test was 0.5 mg/L, which is less than the 20 mg/L limit, qualifying the HC Kraken[®] Filter for online conveyance installation up to 203% MTFR.

Sincerely,



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

8. References

1. NJDEP 2013. New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology. January 25, 2013.
2. NJDEP 2013. New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device. January 25, 2013.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Bio Clean Environmental Services Inc., 398 Via El Centro, Oceanside, CA 92058. Website: <http://www.biocleanenvironmental.com> Phone: 760-433-7640.
- HC Kraken® Filter – Bio Clean HC Kraken® Filter verified cartridge heights and models are shown in **Table A-1**.
- TSS Removal Rate – 80%
- Online conveyance installation up to 203% MTR

Detailed Specification

- NJDEP sizing tables and physical dimensions of the Bio Clean HC Kraken® Filter verified models are attached (**Table A-1**).
- New Jersey requires that the peak flow rate of the NJWQ Design Storm event of 1.25 inch in 2 hours shall be used to determine the appropriate size for the MTD. The HC Kraken® Filter 30” Tall Cartridge has a maximum treatment flow rate (MTR) of 0.038 cfs (17 gpm), which corresponds to a media surface loading rate of 0.101 gpm/ft².
- Pick weights and installation procedures vary slightly with model size. Design support is given by Bio Clean for each project and pick weights and installation procedures will be provided prior to delivery.
- Kraken Filter Operations and Maintenance Manual is at:
<https://www.conteches.com/Portals/0/Documents/Maintenance%20Guides/Kraken%20Filter%20Maintenance%20Guide.pdf?ver=Z4nbcyEEjtHds8e19vGCIg%3d%3d>
- Under N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow a filtration device such as the HC Kraken® Filter to be used in series with another filtration device to achieve an enhanced TSS removal rate.

Table A-1 HC Kraken Filter Cartridge Heights and New Jersey Treatment Capacities

Cartridge Height (in)	Filter Media Surface Area (sq ft) ¹	Hydraulic Loading Rate (gpm/sf) ²	Cartridge MTFR		Mass Capacity Loading Rate (lbs/sq ft) ¹	Mass Load Capture Capacity (lbs)	Maximum Treatment Area (ac) ³
			(gpm)	(cfs)			
30	168.2	0.101	17.0	0.038	0.113	19.0	0.032
20	104.5	0.101	10.6	0.024	0.113	11.8	0.020
10	49.0	0.101	4.9	0.011	0.113	5.5	0.009
1. From manufacturer. 2. Based on test results from tested model (KF-1.5-1.5) 3. Based on 600 lbs of sediment per acre annually.							

Table A-2 HC Kraken Filter Model Treatment Capacities

Models	Number of Cartridges ¹	30" Cartridge		20" Cartridge		10" Cartridge	
		MTFR (cfs)	Maximum Treatment Area (ac)	MTFR (cfs)	Maximum Treatment Area (ac)	MTFR (cfs)	Maximum Treatment Area (ac)
KF-1.5-1.5 (Tested model)	4	0.15	0.13	0.09	0.08	0.04	0.04
KF-4-4	16	0.61	0.51	0.38	0.31	0.18	0.15
KF-4-6	24	0.91	0.76	0.56	0.47	0.26	0.22
KF-4-8	32	1.21	1.01	0.75	0.63	0.35	0.29
KF-8-8	48	1.82	1.52	1.13	0.94	0.53	0.44
KF-8-10	64	2.42	2.03	1.51	1.26	0.71	0.59
KF-8-12	76	2.88	2.41	1.79	1.50	0.84	0.70
KF-8-14	96	3.64	3.04	2.26	1.89	1.06	0.88
KF-8-16	112	4.24	3.55	2.64	2.20	1.23	1.03
KF-10-16	152	5.76	4.81	3.58	2.99	1.68	1.40
KF-10-20	192	7.27	6.08	4.52	3.78	2.12	1.77
KFR-4 (round)	8	0.30	0.32	0.24	0.2	0.11	0.09
KFR-6 (round)	28	1.06	0.95	0.71	0.59	0.33	0.28
KFR-8 (round)	52	1.97	1.65	1.22	1.02	0.57	0.48
1. One drain down cartridge per every three standard filters.							

Table A-3 HC Kraken Filter Model Ratio

Models	Filter Chamber ESTA (sq ft) ²	30" Cartridge Bypass Height – 36" (tested height)		20" Cartridge Bypass Height – 26"		10" Cartridge Bypass Height – 16"	
		ESTA/EFTA ¹	WV/EFTA ¹	ESTA/EFTA ¹	WV/EFTA ¹	ESTA/EFTA ¹	WV/EFTA ¹
KF-1.5-1.5 (tested model)	2.13	0.0032	0.009	0.0051	0.011	0.0109	0.014
KF-4-4	8.63	0.0032	0.010	0.0052	0.011	0.0110	0.015
KF-4-6	13.21	0.0033	0.010	0.0053	0.011	0.0112	0.015
KF-4-8	17.38	0.0032	0.010	0.0052	0.011	0.0111	0.015
KF-8-8	25.57	0.0032	0.009	0.0051	0.011	0.0109	0.015
KF-8-10	33.98	0.0032	0.009	0.0051	0.011	0.0108	0.014
KF-8-12	40.41	0.0032	0.009	0.0051	0.011	0.0109	0.014
KF-8-14	51.14	0.0032	0.009	0.0051	0.011	0.0109	0.015
KF-8-16	59.37	0.0032	0.009	0.0051	0.011	0.0108	0.014
KF-10-16	80.87	0.0032	0.009	0.0051	0.011	0.0109	0.014
KF-10-20	101.80	0.0032	0.009	0.0050	0.011	0.0108	0.014
KFR-4 (round)	7.11	0.0053	0.016	0.0085	0.018	0.0181	0.024
KFR-6 (round)	16.88	0.0036	0.011	0.0058	0.012	0.0123	0.016
KFR-8 (round)	32.33	0.0037	0.011	0.0059	0.013	0.0127	0.017
<ol style="list-style-type: none"> 1. ESTA/EFTA and WV/EFTA ratios for all models must be equal to or greater to the ratios shown for the tested model and cartridge height as indicated by bold text. 2. ESTA is the area of the filter chamber within the vault or manhole. Excludes pre-treatment, diversion, and/or discharge chambers. 3. The wet volume (WV) is calculated by multiplying the actual measured ESTA for each model by the maximum water level, which is the cartridge height plus 6 inches. 							