# NJCAT TECHNOLOGY VERIFICATION

# Oldcastle PerkFilter® System with High Flow Media

## Oldcastle Infrastructure

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## 1. Description of Technology

The PerkFilter® is a stormwater quality treatment system consisting of a treatment structure fitted with a false floor to form an underdrain cavity. Cylindrical filter cartridges are mounted to the floor and hydraulically connected to the underdrain cavity (**Figure 1**). Runoff enters the structure through an inlet pipe and flows through the cartridges for treatment. Treated stormwater is collected in the underdrain cavity and discharged to an outlet pipe. The system is typically housed in a precast concrete vault and can be designed in numerous configurations. Common configurations include single or multiple cartridge catch basins and multiple sizes of precast concrete vaults and manholes. Custom designed modular structures are also available. Typically, each vault is designed and constructed to withstand traffic loads. Several cartridge configurations and/or heights are possible, depending on the site requirements. The width, length, and minimum height of the treatment structure is dependent on the number and height of cartridges required for treatment. The PerkFilter cartridge consists of an 18-inch diameter cylindrical screen with a two-piece plastic center tube that allows for collection and discharge of treated water (**Figure 2**). Cartridges are manufactured in 12-inch and 18-inch heights and may be stacked to produce 24-inch, 30-inch, and 36-inch height options. Cartridges of all heights are 18 inches in diameter. A drawdown function is included with each cartridge to allow the treatment structure to drain between storm events.

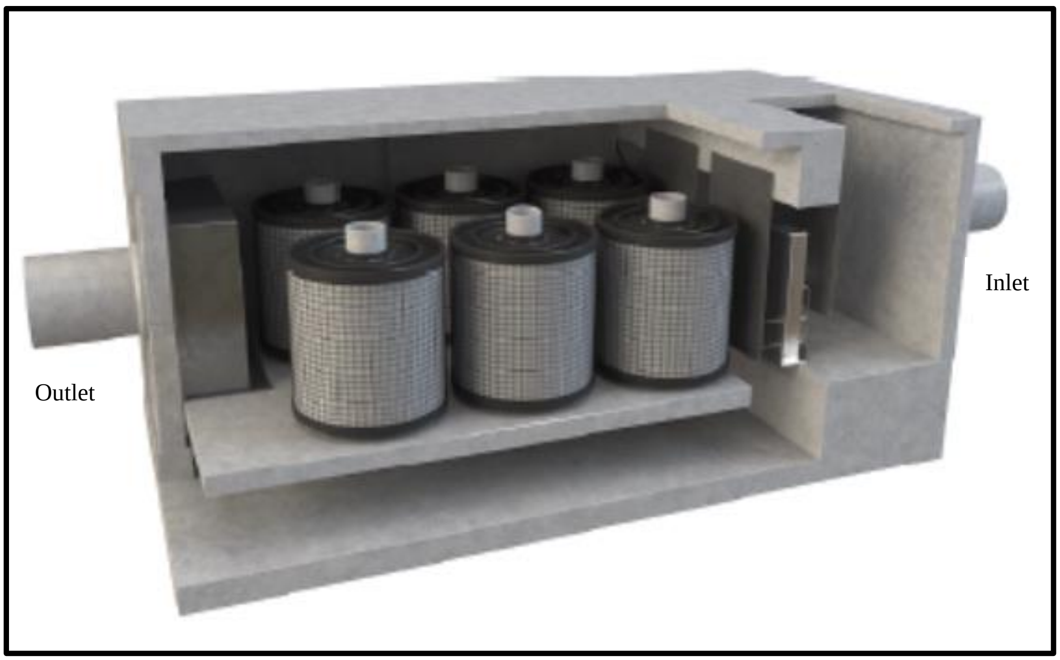


**Figure 1 Rendering of the PerkFilter System**

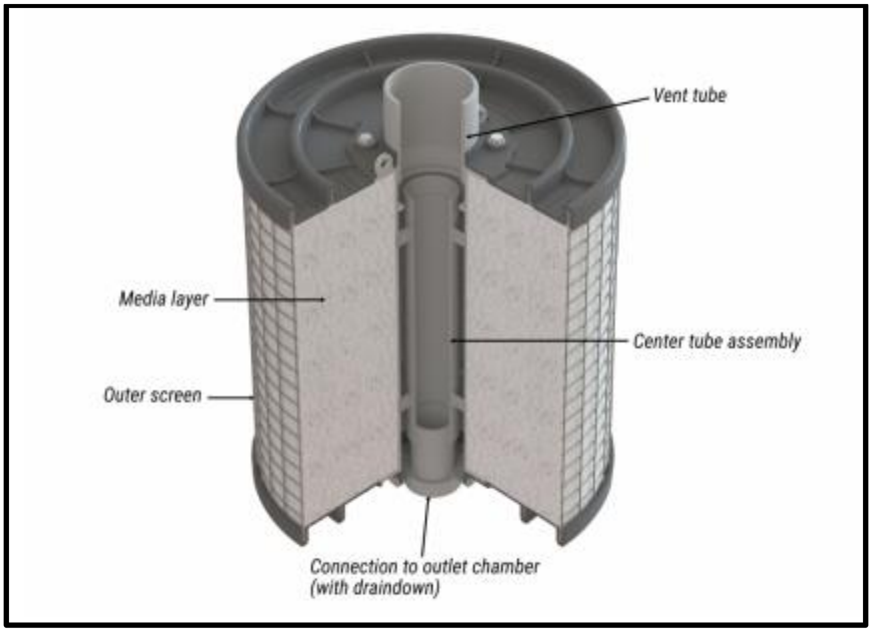


**Figure 2 Rendering of the PerkFilter Cartridge**

The PerkFilter system cartridge was originally tested with ZPC media and verified by NJCAT and certified by NJDEP in 2017. The current variation of the PerkFilter cartridge uses an alternate high flow perlite-based, inorganic media which allows for increased treatment flow and sediment mass loading capacity without requiring an inlet chamber for pre-treatment.

The laboratory test unit consisted of an 18-inch PerkFilter cartridge installed in a test tank in a manner consistent with commercial installations. The test tank was constructed out of plywood, with internal dimensions of 1′-10.5" x 1′-10.5" x 2′-6". The test tank floor was 3.5 $ft^2$ which is consistent with amount of floor surface area per cartridge in a typical commercial installation.

## 2. Laboratory Testing

The test program was conducted by Good Harbour Laboratories, an independent water technology testing lab, at their site in Mississauga, Ontario, Canada. Testing occurred November - December 2021. The PerkFilter system that was tested in the laboratory consisted of a standard 18-inch-tall cartridge housed in a 2-foot by 2-foot vault made of ¾-in plywood. In commercial systems, the cartridges are typically housed in a concrete vault. For this testing however, the use of a plywood vault was proposed due to the difficulties associated with transporting and physically supporting the weight of a concrete vault. The use of the plywood vault in lieu of concrete does not have an effect on system performance.

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 2013)*. 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).

## 2.1 Test Setup

Testing was performed to determine the sediment removal efficiency and the sediment mass loading capacity using the effluent grab sample test method. The PerkFilter test system consisted of an 18-inch diameter by 18-inch tall PerkFilter cartridge, filled with high flow media, housed in a two-foot by two-foot wooden vault (outside dimensions). The wooden vault of the test system provides a vault area to media cartridge ratio typical of commercial installations.

The laboratory test set-up was a water flow loop, capable of moving water at a rate of up to 3 cfs. The test loop is illustrated in **Figure 3** and shown in **Figure 4**. The PerkFilter cartridge installation is shown in **Figure 5**.

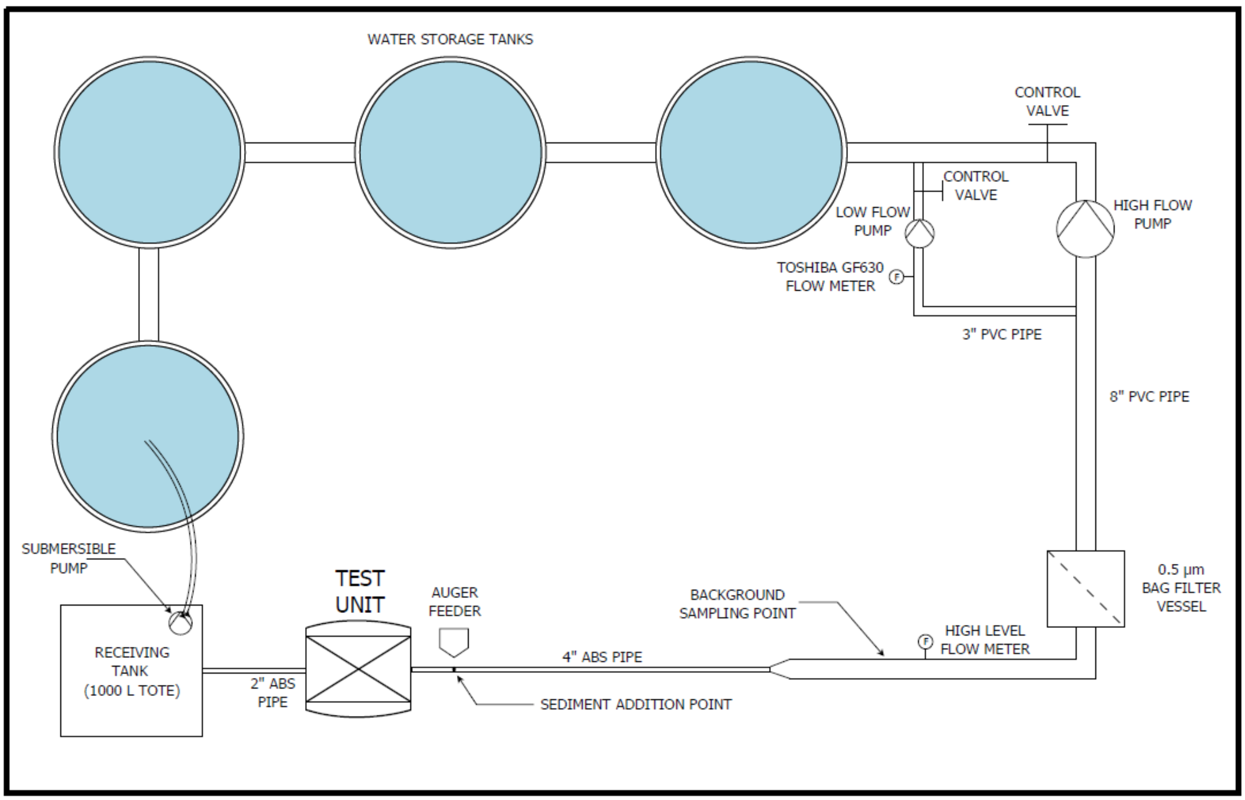


**Figure 3 Plan View of Laboratory Test Setup**

**Figure 4 Test Flow Loop**

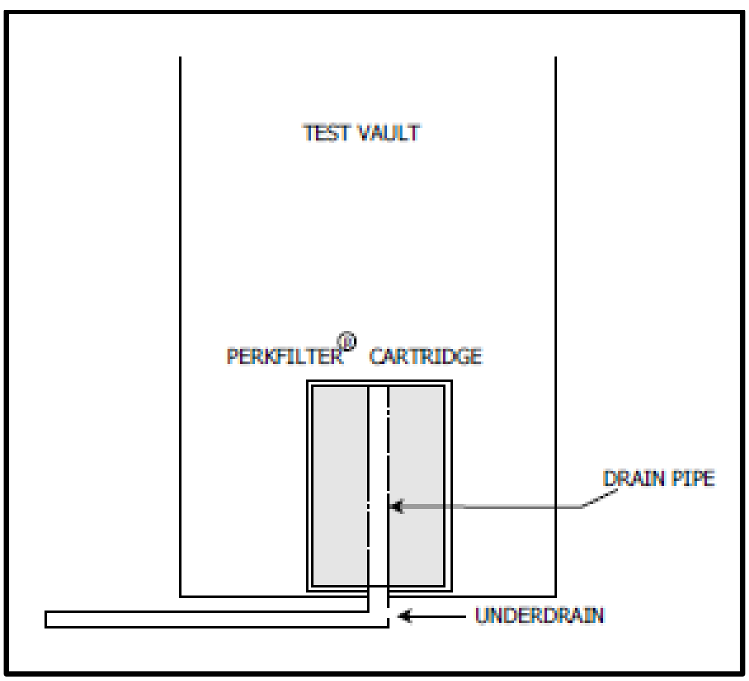


**Figure 5 Profile View of PerkFilter Cartridge**

*Water Flow and Measurement*

From the storage tanks, water was pumped through a filtration system (Fil-Trek model ELPA30-1012-8F-150), where it passed through 0.5µm (absolute) pleated bag filters to remove background particulates. Flow measurement was made using a Toshiba Model GF630 mag-type flow meter and recorded with a MadgeTech Process 101A data logger. The data logger was configured to record a flow measurement every minute. From the bag filters, water flowed through a 4-inch inlet pipe with 1% slope to the PerkFilter inlet.

Water flow exited the PerkFilter cartridge through a 2-in effluent pipe that terminated with a free-fall into the receiving tank (**Figure 6**). The effluent pipe was also installed with 1% slope. From the receiving tank, water was pumped back into the water storage tanks to complete the flow loop.

**Figure 6 PerkFilter Effluent Pipe**

*Water Sample Collection*

Background water samples were collected in 1L jars from a sampling port located upstream of the auger feeder, and downstream of the sediment filtration system. The sampling port was controlled manually by a ball valve (**Figure 7**) that was opened approximately 5 seconds prior to sampling.

Effluent samples were also grabbed by hand. The sampling technique was to collect the grab sample by holding a wide-mouth 1 L jar at the narrowest point of the effluent stream flow, until the jar was full.

*Other Instrumentation and Measurement*

Water temperature was taken during each run using a MadgeTech MicroTemp data logger that was placed inside the plywood vault. The MicroTemp was configured to take a temperature reading once every minute.

Head loss measurements were taken using an engineering rule with a resolution of 0.125-in. The rule was affixed to the inside wall of the tank in one of the corners. Water level was recorded at five-minute intervals, as well as at the start and end of each test run, and when samples were collected.

Run and sampling times were measured using a calibrated stopwatch (Control Company Model X4C50200C).

**Figure 7 Background Sampling Point**

## 2.2 Test Sediment

The test sediment used for the removal efficiency study was custom blended by GHL using various commercially available silica sands; this batch was GHL lot # A027-058. Three samples of sediment were sent out for particle size analysis using the methodology of ASTM test methods

D6913-17 and ASTM D7928-17. 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. The PSD results are summarized **Table 1** and shown graphically in **Figure 8**.

**Table 1 Particle Size Distribution of Test Sediment**

| Particle Size (Microns) | Test Sediment Particle Size (% Less Than) ◊ | | | | NJDEP Minimum Specification* (% Less Than) | QA/QC |
|---|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Average | | |
| 1000 | 100 | 100 | 100 | 100 | 100 | PASS |
| 500 | 95 | 95 | 96 | 96 | 95 | PASS |
| 250 | 90 | 90 | 90 | 90 | 90 | PASS |
| 150 | 79 | 79 | 79 | 79 | 75 | PASS |
| 100 | 60 | 60 | 60 | 60 | 60 | PASS |
| 75 | 52 | 53 | 52 | 52 | 50 | PASS |
| 50 | 45 | 47 | 45 | 45 | 45 | PASS |
| 20 | 38 | 37 | 38 | 38 | 35 | PASS |
| 8 | 22 | 21 | 21 | 21 | 20 | PASS |
| 5 | 14 | 14 | 15 | 14 | 10 | PASS |
| 2 | 7 | 7 | 7 | 7 | 5 | PASS |
| $d_{50}$ | 68 µm | 64 µm | 68 µm | 67 µm | ≤ 75 µm | PASS |

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

* A measured value may be lower than a target minimum % less than value by up to two percentage points provided the measured $d_{50}$ value does not exceed 75 microns.

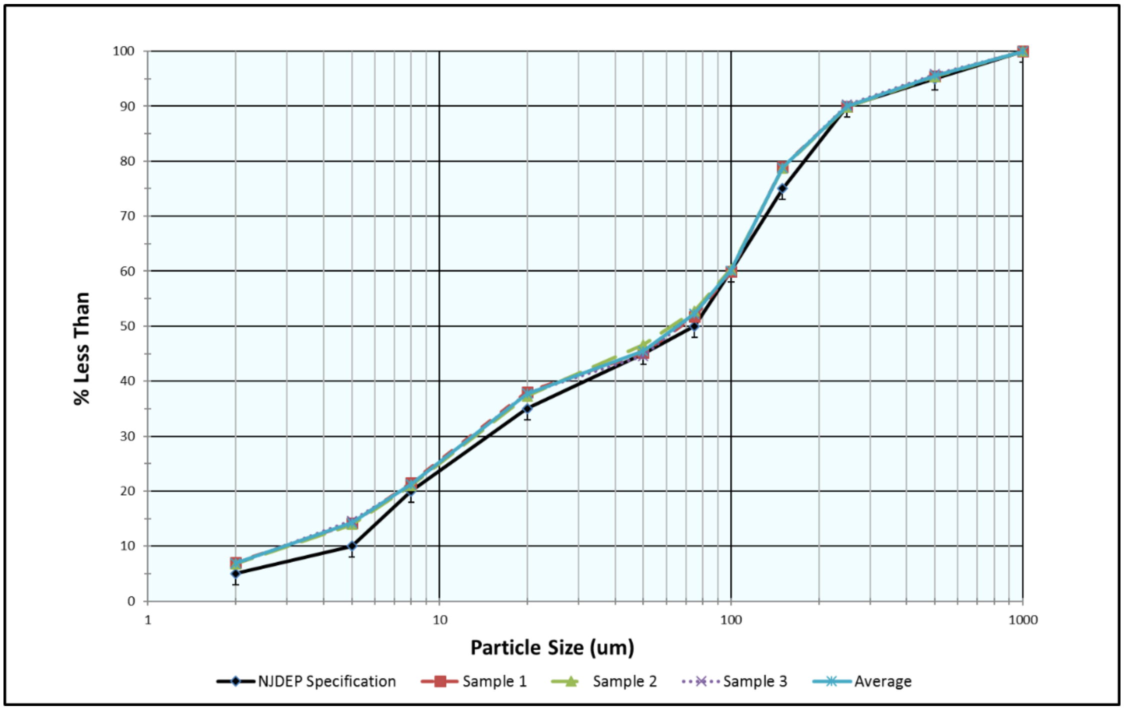


**Figure 8 Average Particle Size Distribution of Test Sediment**

In addition to particle size distribution, Bureau Veritas also performed a moisture analysis of the test sediment and determined the water content to be < 0.30%, the method detection limit. This amount of moisture is not considered significant and therefore no correction for moisture in the sediment mass was made.

The blended test sediment was found to meet the NJDEP particle size specification and was acceptable for use. With a $d_{50}$ of 67 µm, the test sediment was slightly finer than the sediment required by the NJDEP test protocol.

## 2.3 Sediment Addition

Sediment addition occurred through the crown of the inlet pipe, 19-in (4.75 pipe diameters) upstream of the vault (**Figure 9**). The sediment feeder was an Auger Feeders Model VF-1 volumetric screw feeder with a 5/8-in auger, spout attachment and 1.5 cubic foot hopper. The test sediment was weighed to the nearest 0.005 kg before loading the hopper and after each run.

During each run, sediment feed samples were collected by holding a 500 mL jar under the spout attachment for approximately 60 s. Samples were weighed to the nearest milligram to determine the coefficient of variance (COV) of the sediment feed.


**Figure 9 Sediment Addition Point**

## 2.4 Removal Efficiency Testing

Removal Efficiency Testing was conducted in accordance with Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. Testing was completed at a target flow rate of 20.4 gpm and a target sediment concentration of 200 mg/L.

Effluent grab samples were taken 5 times per run (at evenly spaced intervals), with each run lasting 40 minutes in duration, followed by a drawdown period. In addition to the effluent samples, 3 background samples were taken with every odd-numbered effluent sample (1st, 3rd and 5th). In all cases, effluent sampling did not start until the PerkFilter had been in operation for a minimum of three detention times (4.2 minutes). When the test sediment feed was interrupted for measurement, the next effluent sample was collected following a minimum of three detention times. Sampling times for removal efficiency testing are summarized in **Table 2**. Effluent and background samples were collected in clean 1L wide-mouth jars.

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

**Table 2 Removal Efficiency Sampling Frequency**

| Sample/ Measurement Taken | Run Time (min.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 8 | 16 | 24 | 32 | 40 | END OF RUN | TBD | TBD |
| Sediment | X | | | X | | X | | | |
| Effluent | | X | X | X | X | X | | | |
| Background | | X | | X | | X | | | |
| Drawdown | | | | | | | | X | X |

Notes: (1) The detention time (DT) at the MTFR is 1.4 min therefore 3 x DT = 4.2 min.
(2) The background sampling preceded the effluent sampling by approximately 30 seconds at each timepoint.
(3) The drawdown time was determined based on water volume in the vault.

The effluent drawdown samples were collected at the end of each removal efficiency run, after the pump had been switched off and the sediment feed stopped. The effluent was volumetrically quantified based on the liquid level in the PerkFilter vault at the end of each run. The drawdown samples were taken at the same spot as the normal operation effluent samples. Two evenly volumetric spaced samples were collected to determine SSC concentration. The first volumetrically spaced sample was taken after 1/3 of the water volume had drained from the vault and the second after 2/3 of the volume had drained.

## 2.5 Sediment Mass Loading Capacity

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

## 2.6 Scour Testing

Scour testing was not assessed for the PerkFilter system. The PerkFilter system is only intended for offline use.

## 2.7 Laboratory Proficiency

Prior to the start of testing, blind, spiked SSC samples were prepared using the same test sediment that was used for the filter performance test. The samples were submitted to the GHL analytical lab for testing in accordance with ASTM D3977 and the following results were obtained:

| Sample ID | Actual Concentration (mg/L) | Test Result (mg/L) | % Recovery |
|---|---|---|---|
| Control A | 47.7 | 45.6 | 95.6 |
| Control B | 21.6 | 20.4 | 94.4 |
| Control C | 20.3 | 18.7 | 92.1 |
| Control D | 52.9 | 50.1 | 94.7 |

Based on the recovery of the spiked samples, the lab has demonstrated acceptable proficiency in the test method.

## 3. Performance Claims

Per the NJDEP verification procedure, the following are the performance claims made by Oldcastle Infrastructure and/or established via the laboratory testing conducted for the PerkFilter.

*Total Suspended Solids Removal Efficiency*

Based on the laboratory testing conducted in accordance with the NJDEP Filter Protocol, the tested PerkFilter system demonstrated greater than 80% SSC removal efficiency. In accordance with the NJDEP process for obtaining approval of a stormwater treatment device from NJCAT (Procedure; NJDEP 2013) the SSC removal efficiency is rounded down to 80%.

*Maximum Treatment Flow Rate (MTFR)*

The MTFR increases with the PerkFilter system size and the corresponding number of filter cartridges. For the PerkFilter tested system, the MTFR was 0.045 cfs (20.4 gpm, 2.91 gpm/ft$^2$ of EFTA).

*Effective Sedimentation Treatment Area (ESTA)*

The ESTA for the 18-inch PerkFilter cartridge tested is 3.5 ft$^2$ (ESTA/EFTA = 0.5).

*Detention Time and Wet Volume (WV)*

The single PerkFilter cartridge tested had a maximum wet volume of 3.92 ft$^3$ (WV/EFTA = 0.56) which corresponded to a detention time of 1.4 minutes at the test flow rate of 0.045 cfs.

*Effective Filtration Treatment Area (EFTA)*

The EFTA varies with the height and number of cartridges installed in a PerkFilter system. The PerkFilter tested system had an EFTA of 7.0 ft$^2$.

*Sediment Mass Loading Capacity*

The single 18-inch PerkFilter cartridge tested exhibited a sediment mass loading capacity of 42.2 lbs (6.03 lbs/$ft^2$ of EFTA).

*Maximum Allowable Inflow Drainage Area*

Based on the NJDEP requirement to determine maximum allowable inflow area using 600 lbs of sediment per acre annually and the tested sediment mass loading capacity for the PerkFilter tested system of 42.2 lbs (6.03 lbs/$ft^2$ of EFTA), the PerkFilter system has a maximum allowable inflow drainage area of 0.070 acres per 18-inch cartridge.

## 4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013) 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.

### 4.1 Removal Efficiency Testing

A total of 12 removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate and influent sediment concentration were 20.4 gpm and 200 mg/L respectively. The results from all 12 runs were used to calculate the overall removal efficiency of the PerkFilter system.

*Flow Rate*

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

The flow data has been summarized in **Table 3**, including the compliance to the QA/QC acceptance criteria. The average flow for all removal efficiency runs was 20.5 gpm.

*Sediment Addition*

The target sediment concentration was 200 ± 20 mg/L with a COV $\leq 0.10$. The sediment feed rate was checked three times during each run. The average influent sediment concentration for each test flow was determined by mass balance. The amount of sediment fed into the auger feeder and the amount remaining at the end of a run was used to determine the amount of sediment fed. The sediment mass was corrected for the mass of the three feed rate samples taken during the run. The mass of the sediment fed was divided by the volume of water that flowed through the PerkFilter test unit during dosing (average flowrate x time of dosing) to determine the average influent sediment concentration for each run.

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

*Filter Drawdown*

The PerkFilter cartridge has a post-operation drawdown feature. All drawdown flow passes through the filter media prior to discharge. As per the NJDEP protocol, the amount of sediment that escapes the filter during the drawdown period must be included when calculating removal efficiency.

The volume of water in the PerkFilter test vault was determined empirically by filling the vault, fitted with a PerkFilter cartridge to the normal operating level. The water was drained into buckets and weighed to determine the volume. The wet volume of the system was determined to be 29.33 gallons.

The two effluent samples taken during the drawdown period were analysed for SSC to permit estimation of the amount of sediment that was lost. The sampling data for the drawdown periods is presented in **Table 5**.

**Table 3 Removal Efficiency Water Flow Rate**

| Run # | Runtime | Water Flow Rate | | | | QA/QC Compliance (COV ≤ 0.03) | Max. Water Temperature (°F) |
|---|---|---|---|---|---|---|---|
| | (min) | Target (GPM) | Actual (GPM) | % Diff. | COV | | |
| 1 | 40 | 20.4 | 20.6 | 1.04 | 0.006 | Pass | 61.9 |
| 2 | 40 | 20.4 | 20.6 | 0.80 | 0.007 | Pass | 59.7 |
| 3 | 40 | 20.4 | 20.6 | 0.85 | 0.005 | Pass | 59.5 |
| 4 | 40 | 20.4 | 20.6 | 0.85 | 0.010 | Pass | 63.5 |
| 5 | 40 | 20.4 | 20.5 | 0.41 | 0.007 | Pass | 60.6 |
| 6 | 40 | 20.4 | 20.4 | 0.05 | 0.012 | Pass | 60.8 |
| 7 | 40 | 20.4 | 20.2 | -0.78 | 0.009 | Pass | 61.3 |
| 8 | 40 | 20.4 | 20.4 | -0.20 | 0.005 | Pass | 61.0 |
| 9 | 40 | 20.4 | 20.4 | 0.06 | 0.011 | Pass | 62.4 |
| 10 | 40 | 20.4 | 20.5 | 0.31 | 0.007 | Pass | 60.3 |
| 11 | 40 | 20.4 | 20.5 | 0.45 | 0.006 | Pass | 60.3 |
| 12 | 40 | 20.4 | 20.6 | 0.84 | 0.005 | Pass | 60.4 |

# Table 4 Removal Efficiency Sediment Feed Rate

| Run # | Run Time (min) | Weight (g) | Duration (s) | Feed Rate (g/min) | Conc.* (mg/L) | QA/QC Compliance$^{\Delta}$ | Run # | Run Time (min) | Weight (g) | Duration (s) | Feed Rate (g/min) | Conc.* (mg/L) | QA/QC Compliance$^{\Delta}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 16.6035 | 59.94 | 16.620 | 215.8 | Yes | 7 | 0 | 15.3190 | 59.84 | 15.360 | 205.6 | Yes |
| | 24 | 16.5705 | 59.97 | 16.579 | | | | 24 | 14.8834 | 60.04 | 14.873 | | |
| | 40 | 17.0128 | 60.06 | 16.996 | | | | 40 | 16.0578 | 60.06 | 16.042 | | |
| | COV | | | 0.014 | | | | COV | | | 0.038 | | |
| 2 | 0 | 15.8261 | 59.85 | 15.866 | 197.0 | Yes | 8 | 0 | 16.2988 | 59.87 | 16.334 | 207.5 | Yes |
| | 24 | 15.7362 | 59.88 | 15.768 | | | | 24 | 16.1487 | 60.06 | 16.133 | | |
| | 40 | 15.7016 | 60.03 | 15.694 | | | | 40 | 14.7826 | 59.94 | 14.797 | | |
| | COV | | | 0.005 | | | | COV | | | 0.053 | | |
| 3 | 0 | 15.6360 | 59.90 | 15.662 | 213.4 | Yes | 9 | 0 | 15.0116 | 59.57 | 15.120 | 200.3 | Yes |
| | 24 | 17.1551 | 59.90 | 17.184 | | | | 24 | 16.4340 | 59.88 | 16.467 | | |
| | 40 | 15.4513 | 60.00 | 15.451 | | | | 40 | 15.2924 | 60.03 | 15.285 | | |
| | COV | | | 0.059 | | | | COV | | | 0.047 | | |
| 4 | 0 | 16.0798 | 60.00 | 16.080 | 195.3 | Yes | 10 | 0 | 14.8534 | 59.97 | 14.861 | 206.8 | Yes |
| | 24 | 15.3285 | 59.97 | 15.336 | | | | 24 | 15.4393 | 60.00 | 15.439 | | |
| | 40 | 15.7278 | 60.06 | 15.712 | | | | 40 | 15.8443 | 59.96 | 15.855 | | |
| | COV | | | 0.024 | | | | COV | | | 0.032 | | |
| 5 | 0 | 16.6456 | 60.03 | 16.637 | 204.5 | Yes | 11 | 0 | 16.2971 | 60.00 | 16.297 | 214.7 | Yes |
| | 24 | 15.0134 | 59.88 | 15.043 | | | | 24 | 15.9187 | 60.00 | 15.919 | | |
| | 40 | 15.8074 | 60.00 | 15.807 | | | | 40 | 14.7953 | 59.94 | 14.810 | | |
| | COV | | | 0.050 | | | | COV | | | 0.049 | | |
| 6 | 0 | 15.5187 | 60.03 | 15.511 | 198.7 | Yes | 12 | 0 | 15.3167 | 60.00 | 15.317 | 208.9 | Yes |
| | 24 | 14.8804 | 60.10 | 14.856 | | | | 24 | 15.1353 | 59.94 | 15.150 | | |
| | 40 | 16.2463 | 60.00 | 16.246 | | | | 40 | 16.4335 | 60.03 | 16.425 | | |
| | COV | | | 0.045 | | | | COV | | | 0.044 | | |

* Based on sediment mass balance and average water flow rate

$^{\Delta}$ Average concentration 180 – 220 mg/L and COV $\leq$ 0.1

**Table 5 Removal Efficiency Drawdown Losses**

| Run # | Water Level at End of Run (inches) | Total Water Volume (L) | Average Sediment Concentration of Drawdown Samples (mg/L) | Total Sediment Lost (g) |
|---|---|---|---|---|
| 1 | 19 1/8 | 106.0 | 9.2 | 0.97 |
| 2 | 19 1/4 | 106.6 | 9.4 | 1.00 |
| 3 | 19 1/4 | 106.6 | 10.0 | 1.06 |
| 4 | 19 1/2 | 107.9 | 9.0 | 0.97 |
| 5 | 19 1/2 | 107.9 | 9.1 | 0.98 |
| 6 | 19 1/2 | 107.9 | 11.8 | 1.27 |
| 7 | 19 1/2 | 107.9 | 11.5 | 1.24 |
| 8 | 19 3/8 | 107.3 | 13.3 | 1.42 |
| 9 | 19 1/2 | 107.9 | 12.1 | 1.31 |
| 10 | 19 5/8 | 108.5 | 11.9 | 1.29 |
| 11 | 19 5/8 | 108.5 | 12.0 | 1.30 |
| 12 | 19 1/2 | 107.9 | 11.0 | 1.18 |

*Removal Efficiency Calculations*

All effluent, background and drawdown samples for SSC were analysed by Good Harbour; the results are summarized in **Table 6.**

The required background SSC concentration was < 20mg/L. The limit of quantitation for the analytical method was 2.3 mg/L. For the purposes of calculation, any result that was reported as being below the limit of quantitation (<LOQ), was assigned a value of 1.15 mg/L. The adjusted effluent sediment concentration for a sample was determined by:

*Adjusted effluent sediment concentration = effluent sediment concentration – background sediment concentration*

## Table 6 Removal Efficiency SSC Data

| Run # | Suspended Sediment Concentration, SSC (mg/L) | | | | | | | QA/QC Compliance (Background SSC < 20 mg/L) |
|---|---|---|---|---|---|---|---|---|
| | Run Time (min) | 8 | 16 | 24 | 32 | 40 | Average | |
| 1 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 24.9 | 24.8 | 26.4 | 25.7 | 26.1 | 25.6 | |
| 2 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 24.5 | 23.5 | 24.0 | 23.2 | 22.8 | 23.6 | |
| 3 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 26.5 | 27.9 | 28.3 | 24.5 | 27.8 | 27.0 | |
| 4 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 24.9 | 26.0 | 23.6 | 23.0 | 24.9 | 24.5 | |
| 5 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 31.2 | 28.1 | 25.5 | 25.2 | 25.7 | 27.1 | |
| 6 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 25.1 | 28.4 | 26.0 | 26.9 | 27.8 | 26.8 | |
| 7 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 31.4 | 31.6 | 29.0 | 31.4 | 32.3 | 31.1 | |
| 8 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 31.8 | 31.8 | 27.1 | 27.7 | 27.1 | 29.1 | |
| 9 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 29.9 | 29.4 | 30.8 | 29.5 | 31.4 | 30.2 | |
| 10 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 34.5 | 33.6 | 30.2 | 31.0 | 31.9 | 32.2 | |
| 11 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 37.3 | 35.7 | 34.5 | 34.9 | 30.9 | 34.7 | |
| 12 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 34.5 | 36.2 | 31.9 | 35.8 | 34.9 | 34.7 | |

Interpolated value

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

$t_r = Total\ run\ time$

$t_s = Total\ time\ for\ auger\ feeder\ sediment\ sampling$

$t_d = t_r - t_s = time\ of\ sediment\ dosing\ to\ filter$

$\bar{Q} = Average\ flow\ rate\ during\ total\ run\ time$

$V = \bar{Q} \times t_d = volume\ of\ water\ during\ sediment\ dosing\ (test\ water)$

$M_{sa} = Mass\ of\ sediment\ added\ to\ auger\ at\ start\ of\ run$

$M_{sr} = Mass\ of\ sediment\ recovered\ from\ auger\ at\ end\ of\ run$

$M_{ss} = Combined\ mass\ of\ sediment\ calibration\ samples$

$M_t = M_{sa} - M_{sr} - M_{ss} = total\ mass\ of\ sediment\ added\ to\ filter\ during\ run$

$C_e = Average\ sediment\ concentration\ in\ effluent\ samples$

$C_b = Average\ graph\text{-}interpolated\ sediment\ concentration\ of\ background\ samples$

$C_d = Average\ sediment\ concentration\ in\ drawdown\ samples$

$V_d = Total\ volume\ of\ drawdown\ water$

$V_e = V - V_d = Total\ volume\ of\ effluent\ water$

$$Removal\ Efficiency\ (\%) = \frac{M_t - (C_e - C_b)V_e - C_d V_d}{M_t} \times 100$$

The cumulative mass removal efficiency was 86.8% for the first 12 runs. During the removal efficiency testing, 13.92 pounds of sediment was captured by the PerkFilter cartridge system.

**Table 7 Removal Efficiency Results**

| Run # | Avg. Influent SSC (mg/L) | Adjusted Effluent SSC (mg/L) | Total Water Volume (L) | Average Drawdown SSC (mg/L) | Volume of Drawdown Water (L) | Run Removal Efficiency (%) | Mass of Captured Sediment (Lbs.) | Cumulative Mass Removal Efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 215.8 | 24.4 | 2,965 | 9.2 | 106.0 | 88.9 | 1.25 | 88.9 |
| 2 | 197.0 | 22.5 | 2,958 | 9.4 | 106.6 | 88.8 | 1.14 | 88.9 |
| 3 | 213.4 | 25.9 | 2,960 | 10.0 | 106.6 | 88.2 | 1.23 | 88.6 |
| 4 | 195.3 | 23.3 | 2,959 | 9.0 | 107.9 | 88.3 | 1.13 | 88.6 |
| 5 | 204.5 | 26.0 | 2,947 | 9.1 | 107.9 | 87.6 | 1.16 | 88.4 |
| 6 | 198.7 | 25.7 | 2,936 | 11.8 | 107.9 | 87.3 | 1.12 | 88.2 |
| 7 | 205.6 | 30.0 | 2,912 | 11.5 | 107.9 | 85.7 | 1.13 | 87.9 |
| 8 | 207.5 | 28.0 | 2,929 | 13.3 | 107.3 | 86.8 | 1.16 | 87.7 |
| 9 | 200.3 | 29.1 | 2,937 | 12.1 | 107.9 | 85.8 | 1.11 | 87.5 |
| 10 | 206.8 | 31.1 | 2,944 | 11.9 | 108.5 | 85.3 | 1.15 | 87.3 |
| 11 | 214.7 | 33.5 | 2,948 | 12.0 | 108.5 | 84.8 | 1.18 | 87.1 |
| 12 | 208.9 | 33.5 | 2,959 | 11.0 | 107.9 | 84.4 | 1.15 | 86.8 |
| **Cumulative Mass Removal Efficiency (Runs #1-12)** | | | | | | 86.8% | | |
| **Captured Sediment Mass (Runs #1-12)** | | | | | | 13.92 lbs. | | |

## 4.2 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. The sediment mass loading continued until the cumulative mass removal efficiency was observed to fall below 80% after Run 27. The sediment mass loading capacity study was terminated at that point.

An additional 14 successful runs were completed for sediment mass loading capacity testing for a total of 26 runs overall. For Runs 13 – 26, the mass loading water flow rates, sediment feed rates, drawdown losses, SSC data and removal efficiencies are presented in **Table 8** to **Table 12** respectively.

The total mass of sediment captured during the 26 runs was 42.2 lbs. and the cumulative mass removal efficiency was 80.2%. The relationship between removal efficiency and sediment mass loading is illustrated in **Figure 10**.

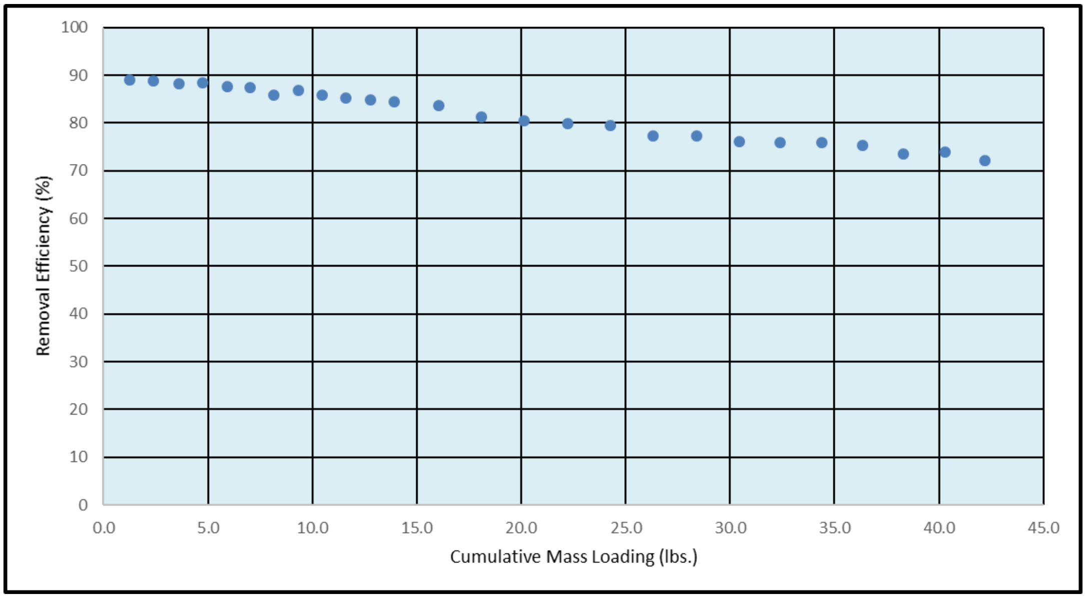


**Figure 10 Removal Efficiency vs. Sediment Mass Loading for the PerkFilter**

**Table 8 Sediment Mass Loading Water Flow Rate**

| Run # | Runtime (min) | Water Flow Rate Target (gpm) | Actual (gpm) | % Diff. | COV | QA/QC Compliance (COV ≤ 0.03) | Max. Water Temperature (°F) |
|---|---|---|---|---|---|---|---|
| 13 | 40 | 20.4 | 20.4 | 0.14 | 0.005 | Pass | 62.8 |
| 14 | 40 | 20.4 | 20.6 | 0.80 | 0.004 | Pass | 60.3 |
| 15 | 40 | 20.4 | 20.6 | 0.85 | 0.004 | Pass | 59.9 |
| 16 | 40 | 20.4 | 20.6 | 1.00 | 0.004 | Pass | 60.6 |
| 17 | 40 | 20.4 | 20.2 | -0.80 | 0.010 | Pass | 60.3 |
| 18 | 40 | 20.4 | 20.2 | -0.74 | 0.005 | Pass | 63.9 |
| 19 | 40 | 20.4 | 20.3 | -0.57 | 0.008 | Pass | 61.0 |
| 20 | 40 | 20.4 | 20.3 | -0.32 | 0.008 | Pass | 61.2 |
| 21 | 40 | 20.4 | 20.4 | 0.17 | 0.006 | Pass | 61.5 |
| 22 | 40 | 20.4 | 20.5 | 0.26 | 0.003 | Pass | 61.3 |
| 23 | 40 | 20.4 | 20.3 | -0.33 | 0.003 | Pass | 63.0 |
| 24 | 40 | 20.4 | 20.4 | -0.19 | 0.005 | Pass | 63.0 |
| 25 | 40 | 20.4 | 20.4 | 0.05 | 0.006 | Pass | 63.3 |
| 26 | 40 | 20.4 | 20.5 | 0.64 | 0.014 | Pass | 62.8 |

## Table 9 Sediment Mass Loading Sediment Feed Rate

| Run # | Run Time (min) | Weight (g) | Duration (s) | Feed Rate (g/min) | Conc.* (mg/L) | QA/QC Compliance^Δ | Run # | Run Time (min) | Weight (g) | Duration (s) | Feed Rate (g/min) | Conc.* (mg/L) | QA/QC Compliance^Δ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 0 | 29.1786 | 59.85 | 29.252 | 393.2 | Yes | 20 | 0 | 31.0564 | 59.91 | 31.103 | 410.6 | Yes |
| | 24 | 31.5693 | 59.93 | 31.606 | | | | 24 | 31.3047 | 59.94 | 31.336 | | |
| | 40 | 28.8048 | 59.97 | 28.819 | | | | 40 | 31.4369 | 59.81 | 31.537 | | |
| | COV | | | 0.050 | | | | COV | | | 0.007 | | |
| 14 | 0 | 30.8936 | 59.78 | 31.007 | 382.1 | Yes | 21 | 0 | 31.1169 | 59.82 | 31.211 | 397.3 | Yes |
| | 24 | 29.2771 | 59.97 | 29.292 | | | | 24 | 31.0799 | 59.87 | 31.147 | | |
| | 40 | 29.4685 | 60.06 | 29.439 | | | | 40 | 29.8743 | 59.91 | 29.919 | | |
| | COV | | | 0.032 | | | | COV | | | 0.024 | | |
| 15 | 0 | 29.6371 | 59.63 | 29.821 | 388.5 | Yes | 22 | 0 | 31.4484 | 59.59 | 31.665 | 407.5 | Yes |
| | 24 | 30.7543 | 59.88 | 30.816 | | | | 24 | 33.0695 | 59.97 | 33.086 | | |
| | 40 | 29.3898 | 59.81 | 29.483 | | | | 40 | 31.1780 | 59.88 | 31.240 | | |
| | COV | | | 0.023 | | | | COV | | | 0.030 | | |
| 16 | 0 | 31.8908 | 59.94 | 31.923 | 399.7 | Yes | 23 | 0 | 30.9034 | 59.87 | 30.971 | 401.0 | Yes |
| | 24 | 31.3488 | 59.87 | 31.417 | | | | 24 | 29.5220 | 60.00 | 29.522 | | |
| | 40 | 32.0546 | 60.00 | 32.055 | | | | 40 | 31.7901 | 60.03 | 31.774 | | |
| | COV | | | 0.011 | | | | COV | | | 0.037 | | |
| 17 | 0 | 30.5692 | 59.69 | 30.728 | 407.0 | Yes | 24 | 0 | 32.7155 | 59.94 | 32.748 | 409.6 | Yes |
| | 24 | 28.6033 | 59.88 | 28.661 | | | | 24 | 30.5384 | 60.18 | 30.447 | | |
| | 40 | 30.8332 | 59.81 | 30.931 | | | | 40 | 32.0180 | 59.91 | 32.066 | | |
| | COV | | | 0.042 | | | | COV | | | 0.037 | | |
| 18 | 0 | 31.4943 | 59.78 | 31.610 | 406.9 | Yes | 25 | 0 | 32.4379 | 59.91 | 32.487 | 423.2 | Yes |
| | 24 | 32.0442 | 60.12 | 31.980 | | | | 24 | 33.1475 | 60.07 | 33.109 | | |
| | 40 | 31.0704 | 59.78 | 31.185 | | | | 40 | 31.7714 | 59.88 | 31.835 | | |
| | COV | | | 0.013 | | | | COV | | | 0.020 | | |
| 19 | 0 | 30.1615 | 59.88 | 30.222 | 424.7 | Yes | 26 | 0 | 32.4390 | 59.85 | 32.520 | 407.2 | Yes |
| | 24 | 32.9238 | 59.75 | 33.062 | | | | 24 | 32.0621 | 59.91 | 32.110 | | |
| | 40 | 32.2220 | 59.65 | 32.411 | | | | 40 | 32.8175 | 59.97 | 32.834 | | |
| | COV | | | 0.047 | | | | COV | | | 0.011 | | |

* Based on sediment mass balance and average water flow rate

Δ Average concentration 360 – 440 mg/L and COV < 0.1

**Table 10 Sediment Mass Loading Drawdown Losses**

| Run # | Water Level at End of Run (inches) | Total Water Volume (L) | Average Sediment Concentration of Drawdown Samples (mg/L) | Total Sediment Lost (g) |
|---|---|---|---|---|
| 13 | 19 5/8 | 108.5 | 17.6 | 1.91 |
| 14 | 19 1/2 | 107.9 | 21.9 | 2.36 |
| 15 | 19 1/2 | 107.9 | 24.4 | 2.63 |
| 16 | 19 5/8 | 108.5 | 25.7 | 2.78 |
| 17 | 19 1/2 | 107.9 | 31.1 | 3.35 |
| 18 | 19 1/2 | 107.9 | 30.4 | 3.27 |
| 19 | 19 1/2 | 107.9 | 32.0 | 3.45 |
| 20 | 19 1/2 | 107.9 | 33.8 | 3.65 |
| 21 | 19 1/2 | 107.9 | 32.6 | 3.51 |
| 22 | 19 1/2 | 107.9 | 36.8 | 3.97 |
| 23 | 19 5/8 | 108.5 | 32.2 | 3.49 |
| 24 | 19 5/8 | 108.5 | 34.7 | 3.76 |
| 25 | 19 5/8 | 108.5 | 28.6 | 3.10 |
| 26 | 19 3/4 | 109.1 | 32.5 | 3.54 |

## Table 11 Sediment Mass Loading SSC Data

| Run # | Suspended Sediment Concentration, SSC (mg/L) | | | | | | | QA/QC Compliance (background SSC < 20 mg/L) |
|---|---|---|---|---|---|---|---|---|
| | Run Time (min) | 8 | 16 | 24 | 32 | 40 | Average | |
| 13 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 65.7 | 59.2 | 68.5 | 72.6 | 70.5 | 67.3 | |
| 14 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 73.0 | 73.1 | 70.2 | 76.3 | 80.0 | 74.5 | |
| 15 | Background | 2.4 | 3.0 | 3.6 | 3.25 | 2.9 | 3.0 | YES |
| | Effluent | 80.5 | 77.5 | 77.9 | 84.6 | 82.6 | 80.6 | |
| 16 | Background | 3.1 | 3.25 | 3.4 | 4.15 | 4.9 | 3.8 | YES |
| | Effluent | 86.3 | 82.8 | 83.8 | 87.6 | 89.2 | 85.9 | |
| 17 | Background | 4.4 | 4.8 | 5.2 | 6.0 | 6.8 | 5.4 | YES |
| | Effluent | 88.9 | 90.3 | 83.8 | 95.8 | 94.5 | 90.7 | |
| 18 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 98.8 | 93.8 | 88.4 | 103 | 97.0 | 96.2 | |
| 19 | Background | 3.3 | 3.35 | 3.4 | 3.55 | 3.7 | 3.5 | YES |
| | Effluent | 95.9 | 105 | 102 | 107 | 104 | 102.8 | |
| 20 | Background | 4.6 | 5.25 | 5.9 | 5.65 | 5.4 | 5.4 | YES |
| | Effluent | 109 | 104 | 103 | 108 | 105 | 105.8 | |
| 21 | Background | 4.1 | 5.45 | 6.8 | 7.4 | 8.0 | 6.4 | YES |
| | Effluent | 106 | 106 | 103 | 103 | 105 | 104.6 | |
| 22 | Background | 5.8 | 6.3 | 6.8 | 7.65 | 8.5 | 7.0 | YES |
| | Effluent | 110 | 106 | 104 | 108 | 108 | 107.2 | |
| 23 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 99.9 | 94.1 | 97.7 | 114 | 110 | 103.1 | |
| 24 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 116 | 109 | 106 | 115 | 116 | 112.4 | |
| 25 | Background | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | YES |
| | Effluent | 118 | 117 | 109 | 118 | 113 | 115 | |
| 26 | Background | 1.15 | 1.15 | 1.15 | 1.98 | 2.8 | 1.6 | YES |
| | Effluent | 129 | 119 | 110 | 118 | 115 | 118.2 | |

Interpolated value

**Table 12 Sediment Mass Loading Removal Efficiency Results**

| Run # | Avg. Influent SSC (mg/L) | Adjusted Effluent SSC (mg/L) | Total Water Volume (L) | Average Drawdown SSC (mg/L) | Volume of Drawdown Water (L) | Run Removal Efficiency (%) | Mass of Captured Sediment (Lbs.) | Cumulative Mass Removal Efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| 13 | 393.2 | 66.2 | 2,939 | 17.6 | 108.5 | 83.6 | 2.13 | 86.4 |
| 14 | 382.1 | 73.4 | 2,958 | 21.9 | 107.9 | 81.3 | 2.03 | 85.8 |
| 15 | 388.5 | 77.6 | 2,960 | 24.4 | 107.9 | 80.5 | 2.04 | 85.2 |
| 16 | 399.7 | 82.2 | 2,964 | 25.7 | 108.5 | 80.0 | 2.09 | 84.7 |
| 17 | 407.0 | 85.2 | 2,912 | 31.1 | 107.9 | 79.6 | 2.08 | 84.2 |
| 18 | 406.9 | 95.1 | 2,913 | 30.4 | 107.9 | 77.2 | 2.02 | 83.6 |
| 19 | 424.7 | 99.3 | 2,919 | 32.0 | 107.9 | 77.2 | 2.11 | 83.1 |
| 20 | 410.6 | 100.4 | 2,926 | 33.8 | 107.9 | 76.1 | 2.02 | 82.6 |
| 21 | 397.3 | 98.3 | 2,940 | 32.6 | 107.9 | 75.9 | 1.95 | 82.2 |
| 22 | 407.5 | 100.2 | 2,943 | 36.8 | 107.9 | 76.0 | 2.01 | 81.8 |
| 23 | 401.0 | 102.0 | 2,925 | 32.2 | 108.5 | 75.2 | 1.94 | 81.4 |
| 24 | 409.6 | 111.3 | 2,929 | 34.7 | 108.5 | 73.5 | 1.94 | 81.0 |
| 25 | 423.2 | 113.9 | 2,936 | 28.6 | 108.5 | 73.8 | 2.02 | 80.6 |
| 26 | 407.2 | 116.6 | 2,954 | 32.5 | 109.1 | 72.1 | 1.91 | 80.2 |
| **Cumulative Mass Removal Efficiency (Runs 1 – 26):** | | | | | | 80.2 % | | |
| **Captured Sediment Mass (Runs 1 – 26):** | | | | | | 42.22 lbs. | | |

## 4.3 Filter Driving Head

The water level in the PerkFilter vault, as measured using the engineering rule, is tabulated in **Table 5** and **Table 10**. **Figure 11** illustrates the increase in water level inside the vault as sediment was captured.

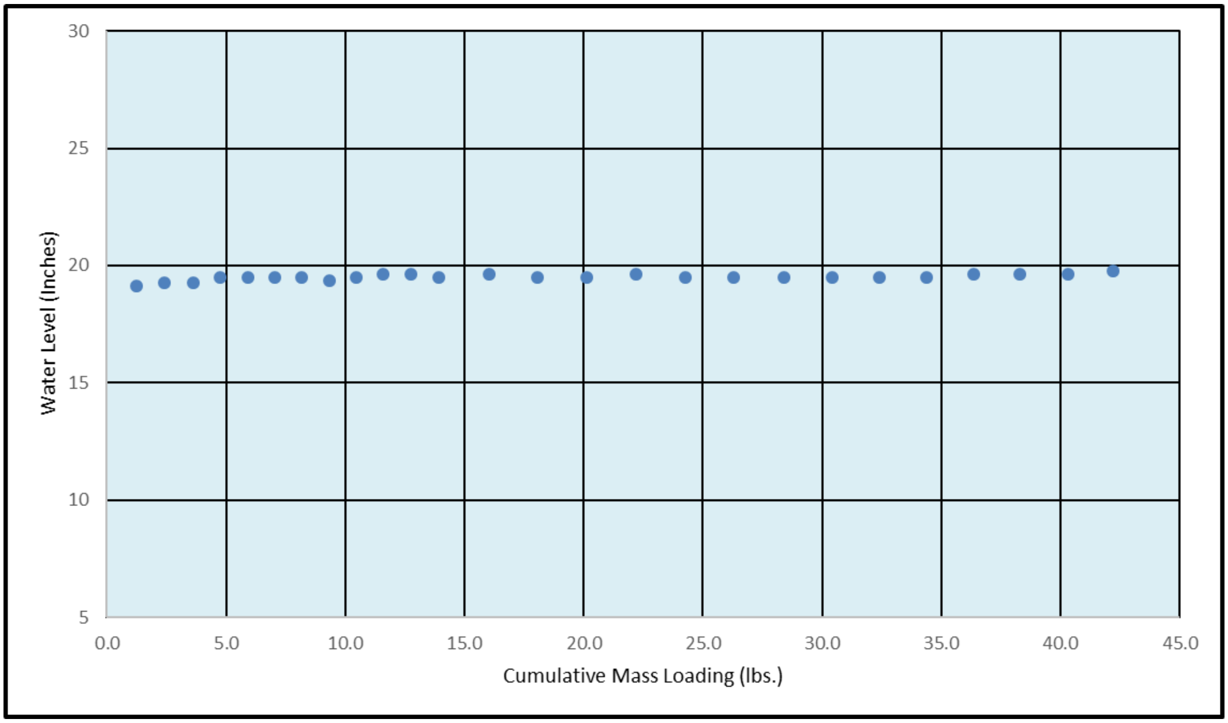


**Figure 11 Increase in Driving Head vs. Sediment Mass Load**

## 5. Design Limitations

*Required Soil Characteristics*

The PerkFilter system is suitable for installation in all soil types.

*Slope*

The PerkFilter system is typically recommended for installation with no slope to ensure proper, consistent operation of the cartridges. However, the top slab can be installed at a slope to meet finished grade.

*Maximum Treatment Flow Rate (MTFR)*

The maximum treatment flow rate for the PerkFilter system is a function of the number and height of cartridges installed. The PerkFilter system is rated for a cartridge loading rate of up to 2.91 gpm/ft$^2$ of cartridge filtration area.

*Allowable Head Loss*

There is an operational head loss associated with each PerkFilter system. The head loss is dependent on the structure design and the cartridge stack configuration. Site specific treatment flow rates, peak flow rates, pipe diameters and pipe slopes are evaluated to ensure there is appropriate head for the system to function properly.

*Maintenance Requirements*

For all successful stormwater quality control systems, effective performance requires proper and regular maintenance. Maintenance requirements and frequency are dependent on the actual conditions and pollutant loading of each site. In general, it is recommended that inspections and/or maintenance be conducted on a regularly occurring basis to ensure continued functionality of the system. Maintenance activities could also be required in the case of an extreme rainfall event, chemical spill, or heavier than anticipated pollutant loading.

*Installation Limitations*

The PerkFilter system has few installation limitations. The PerkFilter system is typically delivered to the site with all internal components, including the cartridges, in place. The contractor is then responsible for installation of the system following any requirements that would apply for any precast concrete structure. This typically includes preparing the appropriate excavation and baselayer; providing and using the appropriate lifting equipment to unload and set the PerkFilter vault components; providing and connecting the inlet and outlet piping; and following the construction plans for selection of backfill material and placement. The contractor is also responsible for protecting the PerkFilter from construction runoff until site construction is complete. Oldcastle Infrastructure provides full-service technical support throughout the installation process.

*Configurations*

The PerkFilter system is available in multiple configurations, including single- or multiple-cartridge catch basins, multiple sizes of precast concrete vaults and manholes, and custom-designed modular concrete structures, allowing maximum design flexibility.

*Structural Load Limitations*

The PerkFilter system is typically designed for an H-20 traffic load rating and thus is applicable to all types of applications. Oldcastle Infrastructure provides full-service technical design support throughout the design process and can help ensure the system is designed for the appropriate structural load requirements.

*Pre-treatment Requirements*

The PerkFilter system does not require pretreatment.

*Limitations in Tailwater*

Tailwater conditions may impact the amount of driving head available to the PerkFilter system and thus may impact the operation and/or lifecycle of the system. Specific project conditions should be assessed as part of the design process.

*Depth to Seasonal High-Water Table*

The operation of the PerkFilter system is typically not impacted by the seasonal high-water table. However, the high-water table may impact the buoyancy of the concrete vault. Specific project conditions should be assessed as part of the design process.

## 6. Maintenance Plans

*Maintenance Overview*

State and local regulations require all stormwater management systems to be inspected on a regular basis and maintained as necessary to ensure performance and protect downstream receiving waters. Maintenance prevents excessive pollutant buildup that can limit system performance by reducing the operating capacity and increasing the potential for scouring of pollutants during periods of high flow.

*Inspection and Maintenance Frequency*

The PerkFilter system should be inspected on a regular basis, typically twice per year, and maintained as required. Initially, inspections of a new system should be conducted more frequently to help establish an appropriate site-specific inspection frequency. The maintenance frequency will be driven by the amount of runoff and pollutant loading encountered by a given system. In most cases, the optimum maintenance interval will be one to three years. Inspection and maintenance activities should be performed only during dry weather periods.

*Inspection Equipment*

The following equipment is helpful when conducting PerkFilter system inspections:

- Recording device (pen and paper form, voice recorder, iPad, etc.)
- Suitable clothing (appropriate footwear, gloves, hardhat, safety glasses, etc.)
- Traffic control equipment (cones, barricades, signage, flagging, etc.)
- Socket and wrench for bolt-down access covers
- Manhole hook or pry bar
- Flashlight
- Tape measure
- Measuring stick or sludge sampler
- Long-handled net (optional)

*Inspection Procedures*

PerkFilter system inspections are visual and can be conducted from the ground surface without entering the unit. To complete an inspection, safety measures including traffic control should be deployed before the access covers are removed. Once the covers have been removed, the following items should be checked and recorded on the PerkFilter Inspection and Maintenance Log located in the PerkFilter Inspection and Maintenance Guide (link provided in the Specification Appendix) to determine whether maintenance is required:

- Inspect the internal components and note whether there are any broken or missing parts. In the unlikely event that internal parts are broken or missing, contact Oldcastle Infrastructure at 888-965-3227 to determine appropriate corrective action.
- Note whether the inlet pipe is blocked or obstructed. The outlet pipe is covered by a removable outlet hood and cannot be observed without entering the unit.
- Observe, quantify, and record the accumulation of floating trash and debris in the inlet chamber. The significance of accumulated floating trash and debris is a matter of judgment. A long-handled net may be used to retrieve the bulk of trash and debris at the time of inspection if full maintenance due to accumulation of floating oils or settled sediment is not yet warranted.
- Observe, quantify, and record the accumulation of oils in the inlet chamber. The significance of accumulated floating oils is a matter of judgment. However, if there is evidence of an oil or fuel spill, immediate maintenance by appropriate certified personnel is warranted.
- Observe, quantify, and record the average accumulation of sediment in the inlet chamber and treatment chamber. A calibrated dipstick, tape measure, or sludge sampler may be used to determine the amount of accumulated sediment in each chamber. The depth of sediment may be determined by calculating the difference between the measurement from the rim of the PerkFilter system to the top of the accumulated sediment and the measurement from the rim of the PerkFilter system to the bottom of the structure. Finding the top of the accumulated sediment below standing water takes some practice and a light touch, but increased resistance as the measuring device is lowered toward the bottom of the unit indicates the top of the accumulated sediment.

- Finally, observe, quantify, and record the amount of standing water in the treatment chamber around the cartridges. If standing water is present, do not include the depth of sediment that may have settled out below the standing water in the measurement.

*Maintenance Triggers*

Maintenance should be scheduled if any of the following conditions are identified during the inspection:

- Internal components are broken or missing.
- Inlet piping is obstructed.
- The accumulation of floating trash and debris that cannot be retrieved with a net and/or oil in the inlet chamber is significant.
- There is more than 6” of accumulated sediment in the inlet chamber.
- There is more than 4” of accumulated sediment in the treatment chamber.
- There is more than 4” of standing water in the treatment chamber more than 24 hours after end of rain event.
- A hazardous material release (e.g., automotive fluids) is observed or reported.
- The system has not been maintained for 3 years (wet climates) to 5 years (dry climates).

*Maintenance Equipment*

The following equipment is helpful when conducting PerkFilter system maintenance:

- Suitable clothing (appropriate footwear, gloves, hardhat, safety glasses, etc.)
- Traffic control equipment (cones, barricades, signage, flagging, etc.)
- Socket and wrench for bolt-down access covers
- Manhole hook or pry bar
- Confined space entry equipment, if needed
- Flashlight
- Tape measure
- 9/16” socket and wrench to remove hold-down struts and filter cartridge tops
- Replacement filter cartridges
- Vacuum truck with water supply and water jet

Contact Oldcastle Infrastructure at 888-965-3227 for replacement filter cartridges. A lead time of four weeks is recommended.

*Maintenance Procedures*

Maintenance should be conducted during dry weather when no flow is entering the system. Confined space entry is necessary to maintain vault and manhole PerkFilter system configurations. Only Confined Space Entry trained, and certified personnel may enter underground structures. Confined space entry is not required for catch basin PerkFilter system configurations. Once safety measures such as traffic control are deployed, the access covers may be removed, and the following activities may be conducted to complete maintenance:

- Remove floating trash and debris from the water surface in the inlet chamber using the extension nozzle on the end of the boom hose of the vacuum truck. Continue using the vacuum truck to completely dewater the inlet chamber and evacuate all accumulated sediment from the inlet chamber. Some jetting may be required to fully remove sediment. The inlet chamber does not need to be refilled with water after maintenance is complete. The system will fill with water when the next storm event occurs.
- Remove the hold-down strut from each row of filter cartridges and then remove the top of each cartridge (the top is held on by four 9/16-in bolts) and use the vacuum truck to evacuate the spent media. When empty, the spent cartridges may be easily lifted off their slip couplers and removed from the vault. The couplers may be left inserted into couplings cast into the false floor to prevent sediment and debris from being washed into the outlet chamber during wash-down.
- Once all the spent cartridges have been removed from the structure, the vacuum truck may be used to evacuate all accumulated sediment from the treatment chamber. Some jetting may be required to fully remove sediment. Take care not to wash sediment and debris through the openings in the false floor and into the outlet chamber. All material removed from the PerkFilter during maintenance including the spent media must be disposed of in accordance with local, state, and/or federal regulations. In most cases, the material may be handled in the same manner as disposal of material removed from sump catch basins or manholes.
- Place a fresh cartridge in each cartridge position using the existing slip couplers and urethane bottom caps. If the vault is equipped with stacked cartridges, the existing outer and inner interconnector couplers must be used between the stacked cartridges to provide hydraulic connection. Transfer the existing vent tubes from the spent cartridges to the fresh cartridges. Finally, refit the struts to hold the fresh cartridges in place.
- Securely replace access covers, as appropriate.
- Arrange to return the empty spent cartridges to Oldcastle Infrastructure.

## 7. Statements

The following attached pages are signed statements from the manufacturer (Oldcastle Infrastructure), the independent test laboratory (Good Harbour Labs), 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.

Oldcastle Infrastructure
A CRH COMPANY
7000 Central Park, Suite 800
Atlanta, GA 30328

oldcastleinfrastructure.com

February 4, 2022

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

Re: Verification of PerkFilter according to NJDEP Filtration Laboratory Testing Protocol

Dear Dr. Magee,

Performance of the PerkFilter® System with High Flow Media by Oldcastle Infrastructure was recently verified according to the NJDEP filtration laboratory testing protocol by the research staff at Good Harbour Laboratories, Ltd. in Mississauga, Ontario. Based on work with the GHL staff, observations made during testing, and review of GHL's test report and appendices, Oldcastle Infrastructure believes that all applicable testing protocol requirements were met or exceeded. Additionally, we believe that all the required documentation has been provided to support verification of the PerkFilter® System with High Flow Media.

Please contact either one of us if you have any questions or concerns. Thank you.

Isham Khan
Product Manager
Oldcastle Infrastructure
713-818-7469
isham.khan@oldcastle.com

Jay Holtz, PE
Technical Director
Oldcastle Infrastructure
971-271-0796
jay.holtz@oldcastle.com

February 11, 2022

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

Re: Performance Verification of the Oldcastle PerkFilter® System

Dear Dr. Magee,

Good Harbour Laboratories was contracted by Oldcastle Infrastructure to conduct performance testing of their PerkFilter® System with High Flow Media 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, 2013).

Good Harbour Laboratories is an independent hydraulic test facility located in Mississauga, Ontario Canada. I certify that we evaluated the PerkFilter System from November - December 2021, according to the aforementioned test protocol. The results presented in the NJCAT Verification Report dated January 2022 are accurate and all procedures and requirements stated in the test protocol were met or exceeded. I confirm that all test data that was collected is included or referenced in the report.

GHL provides testing and verification services for numerous water treatment technologies including stormwater treatment devices. GHL has had several different stormwater equipment manufacturers as clients and we have accumulated considerable experience in testing these devices. In order to be able to make this experience available to as many potential clients as possible, GHL is careful to maintain its position as an independent service provider.

With the above in mind I, the undersigned, on behalf of GHL, confirm:

- that I do not have any conflict of interest in connection to the contracted testing;

- that I will inform NJCAT, without delay, of any situation constituting a conflict of interest or potentially giving rise to a conflict of interest;

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- that I have not granted, sought, attempted to obtain or accepted and will not grant, seek, attempt to obtain, or accept any advantage, financial or in kind, to or from any party whatsoever, constituting an illegal or corrupt practice, either directly or indirectly, as an incentive or reward relating to the outcome of the testing.

Sincerely, Date

Roland G. DuBois

February 11, 2022

Roland DuBois, P.Eng.
Managing Director
Good Harbour Laboratories

CC: Jay Holtz, Oldcastle Infrastructure
Isham Khan, Oldcastle Infrastructure



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

February 8, 2022

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 Oldcastle PerkFilter® System with High Flow Media by Good Harbour Laboratories, an independent water technology testing lab, at their site in Mississauga, Ontario Canada, 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 Filter Protocol) were met or exceeded. Specifically,

*Test Sediment Feed*

The test sediment used for the removal efficiency study was custom blended by GHL using various commercially available silica sands; this particular batch was GHL lot # A027-058. Three samples of sediment were sent out for particle size analysis using the methodology of ASTM test methods D6913-17 and ASTM D7928-17. 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.

The blended test sediment was found to meet the NJDEP particle size specification and was acceptable for use. With a $d_{50}$ of 67 µm, the test sediment was slightly finer than the sediment required by the NJDEP test protocol.

*Removal Efficiency Testing*

A total of 12 removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate and influent sediment concentration were 20.4 gpm and 200 mg/L respectively. For each run, the flow rate was maintained within 10% of the target flow with a

COV (coefficient of variation) less than 0.03. The target sediment concentration was 200 ± 20 mg/L with a COV less than 0.10.

The cumulative mass removal efficiency was 86.8% for these 12 runs. During the Removal Efficiency testing, 13.92 pounds of sediment was captured by the PerkFilter cartridge system.

*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. The feed rate COV ≤ 0.10 and the flow rate COV ≤ 0.03 both were within protocol requirements.

The sediment mass loading continued until the cumulative mass removal efficiency was observed to fall below 80% after Run 27. The Mass Loading Capacity study was terminated at that point. The total mass of sediment captured for the 26 runs was 42.2 lbs. and the cumulative mass removal efficiency was 80.2%.

*Scour Testing*

Scour testing was not assessed for the PerkFilter system, since the PerkFilter system is only intended for offline use at this time.

Sincerely,

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

## 8. References

NJDEP 2013a. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*. August 04, 2021.

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

Quality Assurance Project Plan (QAPP) for the Laboratory Performance Testing of an Oldcastle PerkFilter in Accordance with the NJDEP Laboratory Testing Protocol (2013). Prepared by Good Harbour Laboratories, August 2021.

## VERIFICATION APPENDIX

### *Introduction*

- Manufacturer: Oldcastle Infrastructure, 7000 Central Parkway, Suite 800, Atlanta, GA 30328. *Phone*: (888) 965-3227. *Website: www.oldcastleinfrastructure.com*

- MTD: Oldcastle PerkFilter® System with High Flow Media. Verified PerkFilter™ cartridge configurations are shown in **Table A-1.**

- TSS Removal Rate: 80%

- PerkFilter system verified for offline application. Flows exceeding the MTFR shall be diverted around the treatment chamber.

### *Detailed Specification*

- **Table A-1** includes PerkFilter cartridge configurations and New Jersey treatment capabilities that are used in catch basins, manholes, vaults, and larger custom units that are typically made from concrete or steel, although other structural materials may be applicable.

- Pick weights and installation procedures vary with system size. Oldcastle Infrastructure provides contractors with project-specific unit pick weights and installation instructions as warranted prior to delivery.

- Each PerkFilter cartridge's drain down flow is regulated by two drain down orifice openings, sized so that an empty bed (clean) filter drains down within 30 minutes.

- Driving head remained constant at 19 1/8 – 19 3/4 inches throughout the 26 runs.

- The PerkFilter Inspection and Maintenance Guide is available at: https://oldcastleinfrastructure.com/wp-content/uploads/2022/04/OSS_PerkFilter_InspMaint_Apr-2022_v2.pdf

- According to N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow the PerkFilter system to be used in series with a settling chamber (such as a hydrodynamic separator) or a media filter (such as a sand filter) to achieve an enhanced TSS removal rate.

## Table A-1 PerkFilter Cartridge Configurations and New Jersey Treatment Capabilities

| Cartridge Height (in) | Surface Area (sf) | Hydraulic Loading Rate (gpm/sf) | Cartridge MTFR | | Mass Load (lbs) | Maximum Treatment Area (ac)[1] |
|---|---|---|---|---|---|---|
| | | | (gpm) | (cfs) | | |
| 12 | 4.7 | 2.91 | 13.6 | 0.030 | 28.1 | 0.047 |
| 18 | 7.0 | 2.91 | 20.4 | 0.045 | 42.2 | 0.070 |
| 24 | 9.3 | 2.91 | 27.2 | 0.060 | 56.2 | 0.094 |
| 30 | 11.7 | 2.91 | 34.0 | 0.076 | 70.3 | 0.117 |
| 36 | 14.0 | 2.91 | 40.8 | 0.091 | 84.4 | 0.141 |

| Standard Models by Model Number | Structure ESA (sf)[4] | Maximum Cartridge Count by Cartridge Height (ea) | | | | |
|---|---|---|---|---|---|---|
| | | 12" | 18" | 24" | 30" | 36" |
| **CF-48PFV-YZ[2,3]** | 22.0 | 9 | 6 | 4 | 3 | 3 |
| **CF-68PFV-YZ** | 33.0 | 14 | 9 | 7 | 5 | 4 |
| **CF-612PFV-YZ** | 45.0 | 19 | 12 | 9 | 7 | 6 |
| **CF-812PFV-YZ** | 72.0 | 30 | 20 | 15 | 12 | 10 |
| **CF-816PFV-YZ** | 104.0 | 44 | 29 | 22 | 17 | 14 |
| **CF-820PFV-YZ** | 132.0 | 56 | 37 | 28 | 22 | 18 |
| **CF-48PFMH-YZ** | 12.6 | 3 | 3 | 2 | 2 | 1 |
| **CF-60PFMH-YZ** | 19.6 | 5 | 5 | 4 | 3 | 2 |
| **CF-72PFMH-YZ** | 28.3 | 8 | 8 | 6 | 4 | 4 |
| **CF-96PFMH-YZ** | 50.3 | 14 | 14 | 10 | 8 | 7 |

| Standard Models by Model Number | Structure ESA (sf)[1] | Maximum MTFR by Cartridge Height (cfs) | | | | |
|---|---|---|---|---|---|---|
| | | 12" | 18" | 24" | 30" | 36" |
| **CF-48PFV-YZ[2,3]** | 22.0 | 0.272 | 0.273 | 0.242 | 0.227 | 0.273 |
| **CF-68PFV-YZ** | 33.0 | 0.423 | 0.409 | 0.423 | 0.378 | 0.363 |
| **CF-612PFV-YZ** | 45.0 | 0.575 | 0.545 | 0.544 | 0.530 | 0.545 |
| **CF-812PFV-YZ** | 72.0 | 0.907 | 0.909 | 0.907 | 0.908 | 0.909 |
| **CF-816PFV-YZ** | 104.0 | 1.331 | 1.318 | 1.331 | 1.287 | 1.272 |
| **CF-820PFV-YZ** | 132.0 | 1.694 | 1.681 | 1.694 | 1.665 | 1.636 |
| **CF-48PFMH-YZ** | 12.6 | 0.091 | 0.136 | 0.121 | 0.151 | 0.091 |
| **CF-60PFMH-YZ** | 19.6 | 0.151 | 0.227 | 0.242 | 0.227 | 0.182 |
| **CF-72PFMH-YZ** | 28.3 | 0.242 | 0.363 | 0.363 | 0.303 | 0.363 |
| **CF-96PFMH-YZ** | 50.3 | 0.423 | 0.636 | 0.605 | 0.605 | 0.636 |

| Standard Models by Model Number | Structure ESA (sf)[1] | Maximum Treatment Area by Cartridge Height (ac) | | | | |
|---|---|---|---|---|---|---|
| | | 12" | 18" | 24" | 30" | 36" |
| **CF-48PFV-YZ[2,3]** | 22.0 | 0.421 | 0.422 | 0.375 | 0.351 | 0.422 |
| **CF-68PFV-YZ** | 33.0 | 0.656 | 0.633 | 0.656 | 0.586 | 0.563 |
| **CF-612PFV-YZ** | 45.0 | 0.890 | 0.844 | 0.843 | 0.820 | 0.844 |
| **CF-812PFV-YZ** | 72.0 | 1.405 | 1.407 | 1.405 | 1.406 | 1.407 |
| **CF-816PFV-YZ** | 104.0 | 2.060 | 2.040 | 2.060 | 1.992 | 1.969 |
| **CF-820PFV-YZ** | 132.0 | 2.622 | 2.602 | 2.622 | 2.577 | 2.532 |
| **CF-48PFMH-YZ** | 12.6 | 0.140 | 0.211 | 0.187 | 0.234 | 0.141 |
| **CF-60PFMH-YZ** | 19.6 | 0.234 | 0.352 | 0.375 | 0.351 | 0.281 |
| **CF-72PFMH-YZ** | 28.3 | 0.375 | 0.563 | 0.562 | 0.469 | 0.563 |
| **CF-96PFMH-YZ** | 50.3 | 0.656 | 0.985 | 0.936 | 0.937 | 0.985 |

*Notes:*

1. *Based on 600lbs of sediment per acre annually*
2. *Y = Cartridge Quantity*
3. *Z = Cartridge Size (12, 18, 24, 30, 36)*
4. *Area available for cartridge placement*

Example: 6'x12' PerkFilter Vault with twelve 18" cartridges = CF-612PFV-12-18