NJCAT TECHNOLOGY VERIFICATION

HydroChain™ Vortex Filter (HCVF) Systems

Xerxes Corporation

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1. Description of Technology

The HydroChain Vortex Filter (HCVF) is a manufactured treatment device provided by the Xerxes Corporation (Xerxes). The filter system consists of HydroChain Filter Cartridges (HCFCs) placed in a manhole with a platform, sediment trap, and flow breakers. The HCVF improves the quality of stormwater runoff before being discharged to a stormwater conveyance network or sensitive receiving waters. This post-construction flow-through system is contained within a single manhole structure that utilizes a combination of two technologies under gravity-flow conditions including pretreatment via vortex-induced sedimentation at the base of the structure followed by up-flow cartridge filtration. The mode of operation is described below.

Influent passes through a drop pipe with a horizontal bend and into a sediment trap below the filter platform. Flow breakers in the sediment trap help reduce turbulence. Large and heavy sediment collects in the sediment trap. Stormwater flows upwards through the filters from hydraulic head pressure. Treated stormwater then flows to the outlet (**Figure 1**). The T-outlet shown is used in Germany for secondary oil removal. In the event of an accidental spillage, oil entering the system is temporarily captured and stored in the system. It was not installed for TSS removal verification testing but can be supplied upon request.

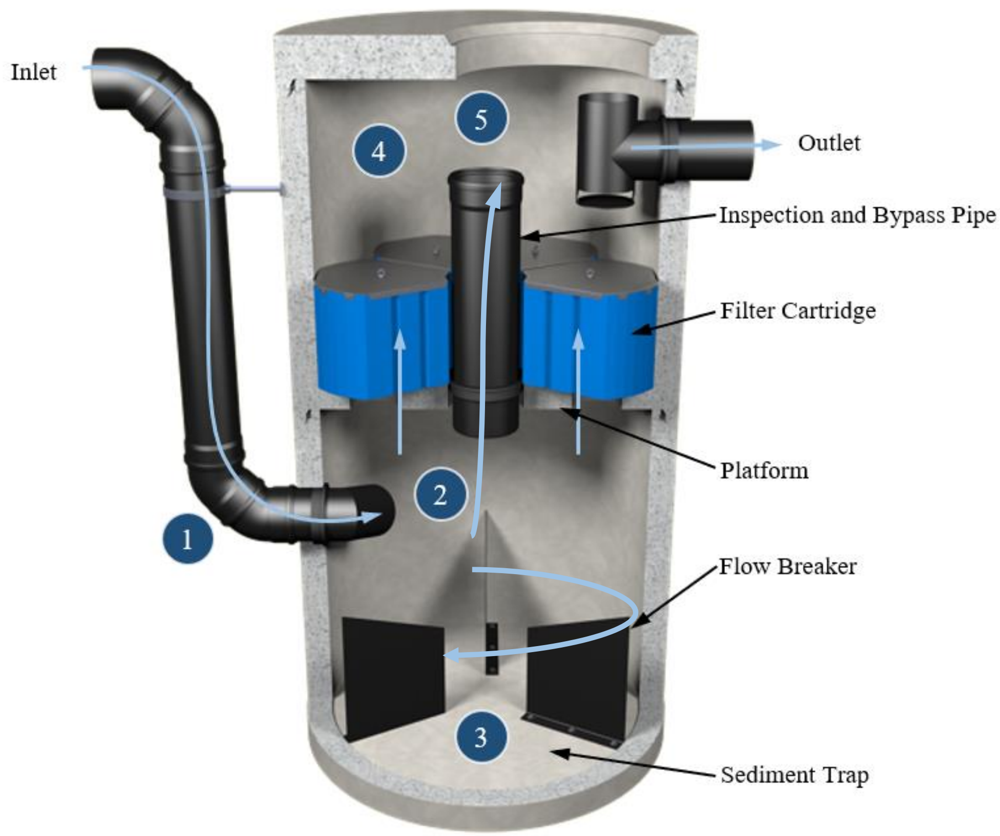

Figure 1 HydroChain Vortex Filter (HCVF-5)

The numbers shown in Figure 1 correspond to the mode of operation as summarized below.

1. Stormwater flows into the sediment trap through a drop pipe.
2. A bend or off-center connection at the inlet creates a vortex flow to encourage settlement. The flow breakers reduce turbulence and scour.
3. Sediment collects in the sediment trap and is periodically removed through the inspection and bypass pipe during routine maintenance.
4. Hydraulic head pushes the water up and through the filter cartridge.
5. Flows above the design maximum treatment flow rate will back up the inlet and may pass through the inspection and bypass pipe if there is sufficient head.

HydroChain Filter Cartridges (HCFC)

The HydroChain Filter Cartridge consists of an enclosed container filled with a filter media blend of activated carbon, calcium carbonate, and synthetic zeolite. The media is held in place by a pervious screen on the top and bottom. Cartridges rest on a platform integral to the manhole and are installed with a watertight gasket that fits around the cartridge inlet and platform opening as shown in **Figure 2** and **Figure 3**. Stormwater enters the cartridge from the bottom and flows up through the bottom screen as shown in **Figure 4**. Stormwater continues flowing up through the filter media where total suspended solids are removed. The treated stormwater then flows out through a screen on the top.

The HydroChain Filter Cartridge comes in two models, the HCFC-4 shown in **Figure 2** and HCFC-5 shown in **Figure 3**. Both models function the same and have the same height of filter media as shown in **Figure 5**. The HCFC-5 has a larger cross-sectional area. This verification is based on testing performed on HCFC-4 cartridges.

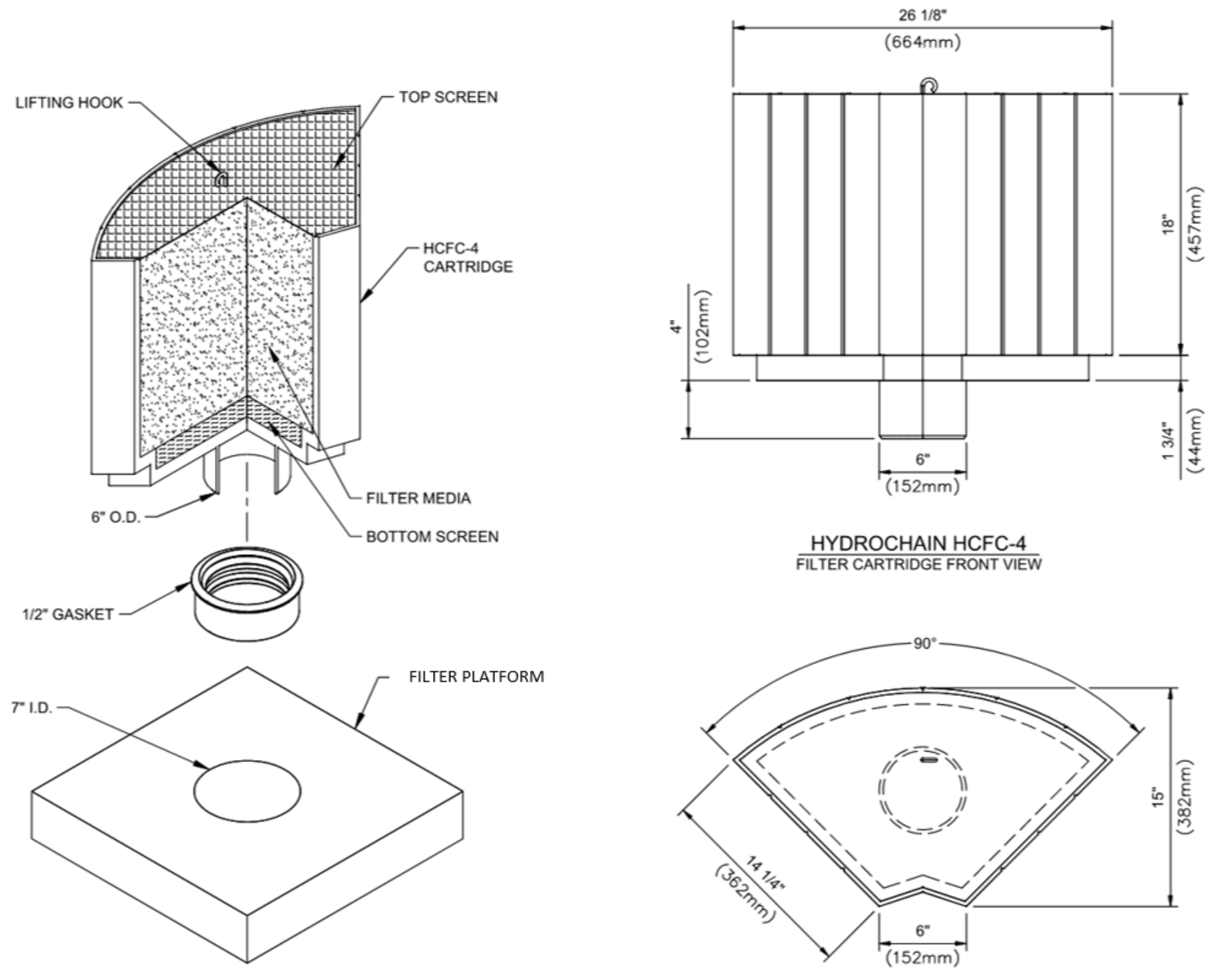

Figure 2 HydroChain Filter Cartridge HCFC-4 Detail

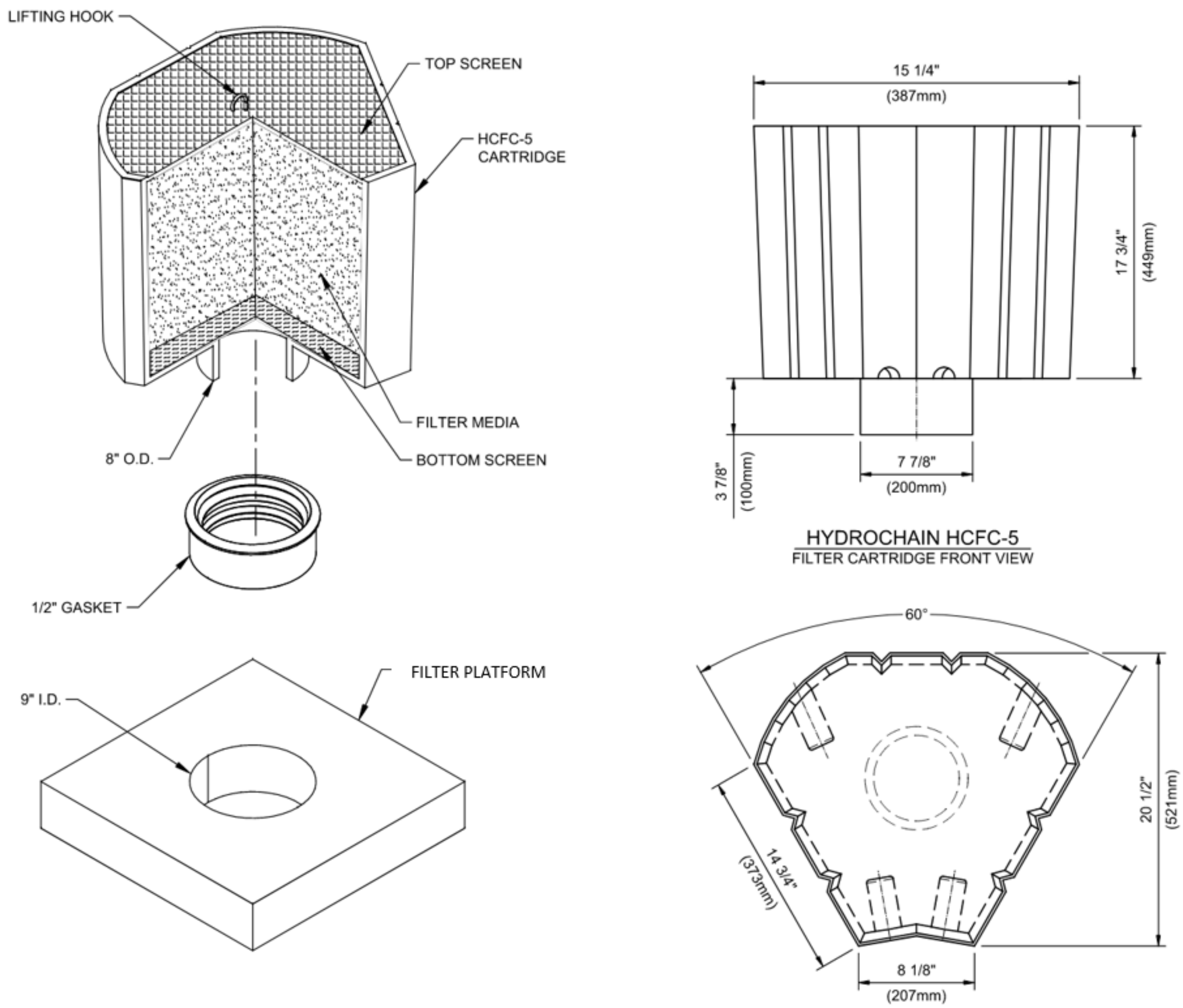

Figure 3 HydroChain Filter Cartridge HCFC-5 Detail

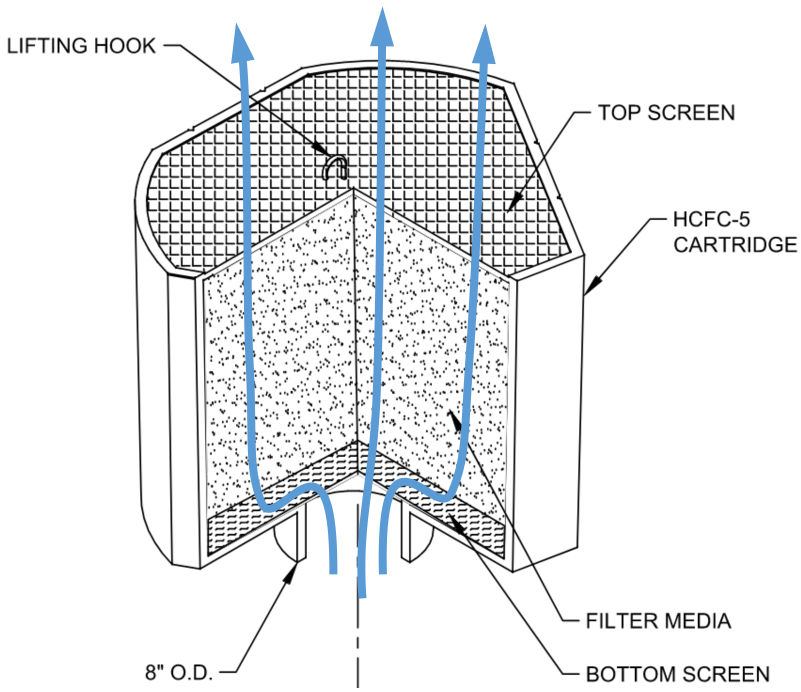

Figure 4 Flow Through Filter Cartridge

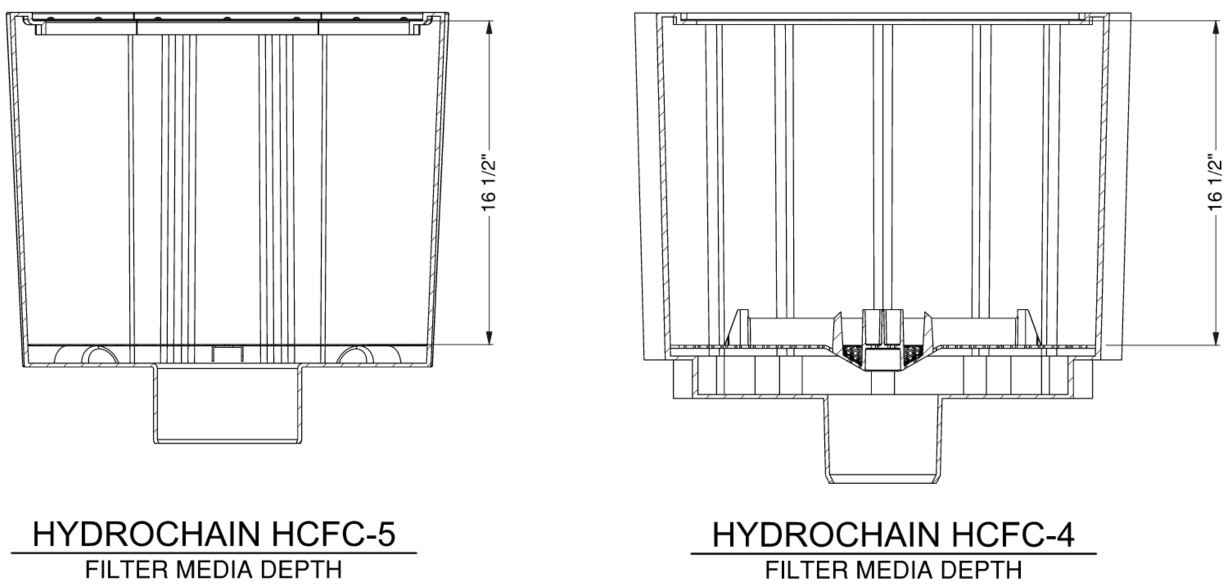

Figure 5 HCFC-4 and HCFC-5 Filter Media Depth

Over time, cartridges used to remove total suspended solids will accumulate fine solids inside the filter media. The cartridge service life is extended by periodic flushing of the cartridges which removes the sediment from the filter media. Cartridges that are saturated with sediment and cannot be flushed are replaced. Cartridges are removed from the platform by lifting on the center lifting hook. Refer to Section 6 for maintenance information.

The modular design of HydroChain Filter Cartridges allows them to be installed in different sized manholes. The number and arrangement of cartridges depends on the required treatment flow.

2. Laboratory Testing

The New Jersey Department of Environmental Protection (NJDEP) maintains a list of certified stormwater manufactured treatment devices (MTDs) that can be installed on newly developed or redeveloped sites to achieve stormwater treatment requirements for Total Suspended Solids (TSS). Manufactured treatment devices are evaluated for certification according to the *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices (NJDEP 2013a*) (hereafter referred to as "NJDEP Approval Process"). The NJDEP Approval Process requires that TSS treatment devices operating on filtration principles be tested according to the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (NJDEP 2013b)* (hereafter referred to as "NJDEP Filtration Protocol"). In addition, the NJDEP Approval Process requires submittal of a Quality Assurance Project Plan (QAPP) to the New Jersey Corporation for Advanced Technology (NJCAT) for review and approval prior to testing to ensure that all laboratory procedures will be conducted in strict accordance with the *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (NJDEP 2021).* The QAPP was submitted and approved by NJCAT in March 2020 prior to commencement of testing.

Laboratory testing was performed at the 3P Technik Filtersysteme GmbH (3P Technik) full scale test facility in Bad Überkingen, Germany, under the direct supervision of an independent third-party observer, Dr.-Ing. Martina Dierschke from Frankfurt University of Applied Sciences.

2.1 Test Unit

The tested unit is a HydroChain Vortex Filter system model HCVF-4 consisting of four HCFC-4 filter cartridges in a 1-meter (39.37 inch) concrete manhole as this is a standard metric sized manhole in Europe where the testing was conducted. **Figure 6** shows the inside of the test unit. Four (4) filter cartridges are placed 90 degrees around the manhole. The green pipe is the center maintenance pipe and the black pipe on the right is the T-outlet (removed for testing).

Figure 6 View from Top into a Concrete Manhole Version (HCFC-4)

An equivalent system in the United States would be installed in a 48-inch manhole. The only difference would be the distance from the exterior of the cartridges to the ID of the manhole which does not affect the performance of the filter cartridges. The larger diameter increases the effective sedimentation treatment area beneath the cartridges, which would reduce the mass loading on the filters. The dimensions of the tested system can be seen in **Figure 7** and **Figure 8**. The system dimensions were confirmed by the third-party observer.

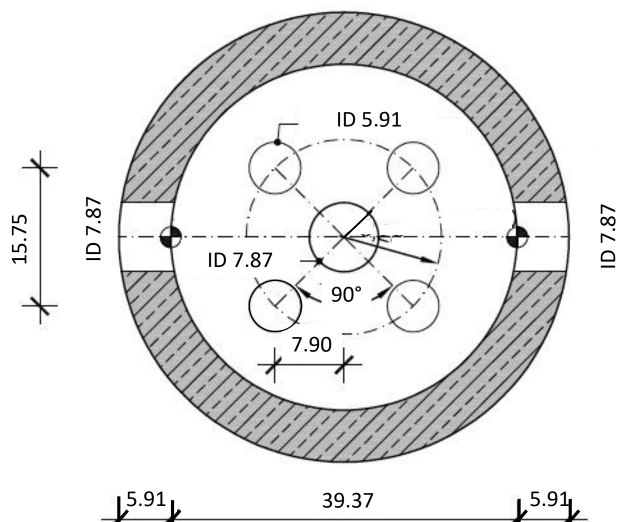

Figure 7 Dimensions of the Test System (Inches)

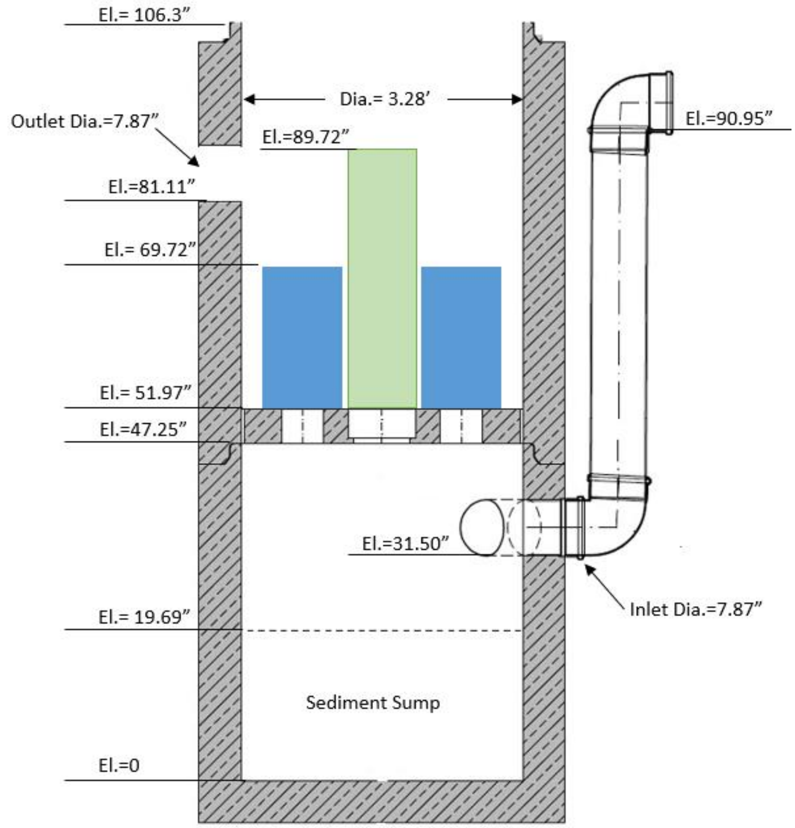

Figure 8 Dimensions of the test system (inches), inlet on the right (Flow breakers not shown for clarity)

2.2 Test Setup

The test setup is shown on **Figure 9** and **Figure 10**.

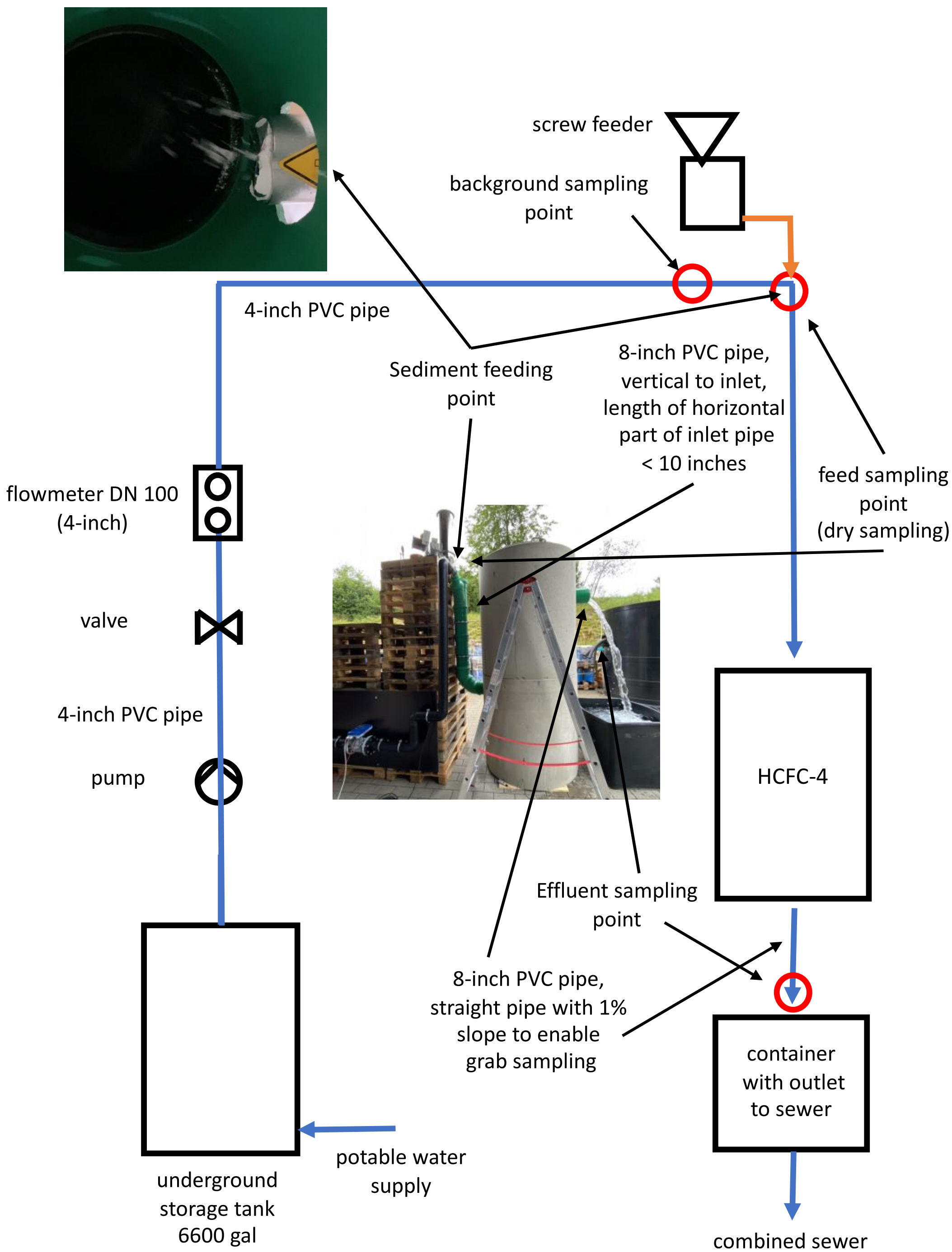

Figure 9 Test Setup Schematic

Figure 10 Picture of the Test Setup

Influent water was drawn from two 6,600-gallon (25 m^3) underground tanks filled with drinking water. The water met the background TSS concentration criteria of ≤ 20 mg/L TSS concentration. An electric pump conveyed the water to the test stand. Water temperature in the storage tank was measured manually three times during each test run. The temperature was confirmed by the third-party observer. The flowrate into the system was controlled by a calibrated magnetic inductive flowmeter (Krohne Optiflux 2050 C/W). Flow rates were logged, and time stamped once a minute using a data logger (Voltcraft DL-191A CD current logger). The flowmeter was installed in accordance with the manufacturer's manual.

A K-Tron Design screw feeder was used to supply test sediment to the inlet flow. Screw feeding units use Coperion K-Tron's unique Powersphere design with horizontal agitation to provide a uniform fill of material into the discharge screw thus improving feeding accuracy. A twin-screw configuration was used. The model used is a K-TRON K-MV-KT20 (**Figure 11**). The feeding point was protected against wind so that all of the total mass of the sediment fed reached the inflow pipe.

Figure 11 K-Tron Screw Feeder from Inside

The scales used for weighing sediment and drawdown fluid were a Kern RFC and Kern EMB 100-3, respectively.

2.3 Test Sediment

The test sediment (quartz) was mixed according to NJDEP Filtration Protocol requirements. The specific density of the material is 2.65 g/cm^3. The test sediment was a blend of commercially available silica sand grades supplied by Quarzwerke GmbH, Frechen/Germany. The sediment was blended by 3P Technik under observation of the third-party observer. Ten dry sediment random sample sub-samples were taken from the total batch of test sediment whenever the feeder was re-filled. The sampling was witnessed by the third-party observer. The sub-samples were mixed and homogenized to a composite sample. Three sub-samples of the composite sample were sent to RMB Environmental Laboratories, Hibbing MN/USA to verify that the supplied sediment met the requirements of Section 5B of the NJDEP Filtration Protocol.

The PSD of the material used for this testing is given in **Table 1**.

Table 1 Particle Size Distribution Results of Test Sediment Samples

Particle Size (microns)	Target Minimum % Less Than	Sample 1	Sample 2	Sample 3	**Average**
μm	%	%	%	%	**%**
1.000	100	100.0	100.0	100.0	**100.0**
500	95	98.0	97.6	98.0	**97.9**
250	90	91.3	90.0	91.3	**90.9**
150	75	77.7	73.8	77.8	**76.4**
100	60	67.8	63.9	67.7	**66.5**
75	50	62.9	59.0	62.6	**61.5**
50	45	49.1	48.8	49.4	**49.1**
20	35	34.1	35.5	32.2	**33.9**
8	20	21.9	21.5	22.1	**21.8**
5	10	15.0	16.1	15.6	**15.6**
2	5	7.9	8.0	7.2	**7.7**
d_{50}	≤75	48	49	47	**48**

Note: A measured value may be lower than a target minimum % less than value by up to two percentage points, A measured value may be lower than a target minimum % less than value by up to two percentage points (e.g., at least 3% of the particles must be less than 2 microns in size [target is 5%]), provided the measured d_{50} value does not exceed 75 microns.

Figure 12 shows the PSD of the test sediment compared to NJDEP Filtration Protocol requirements.

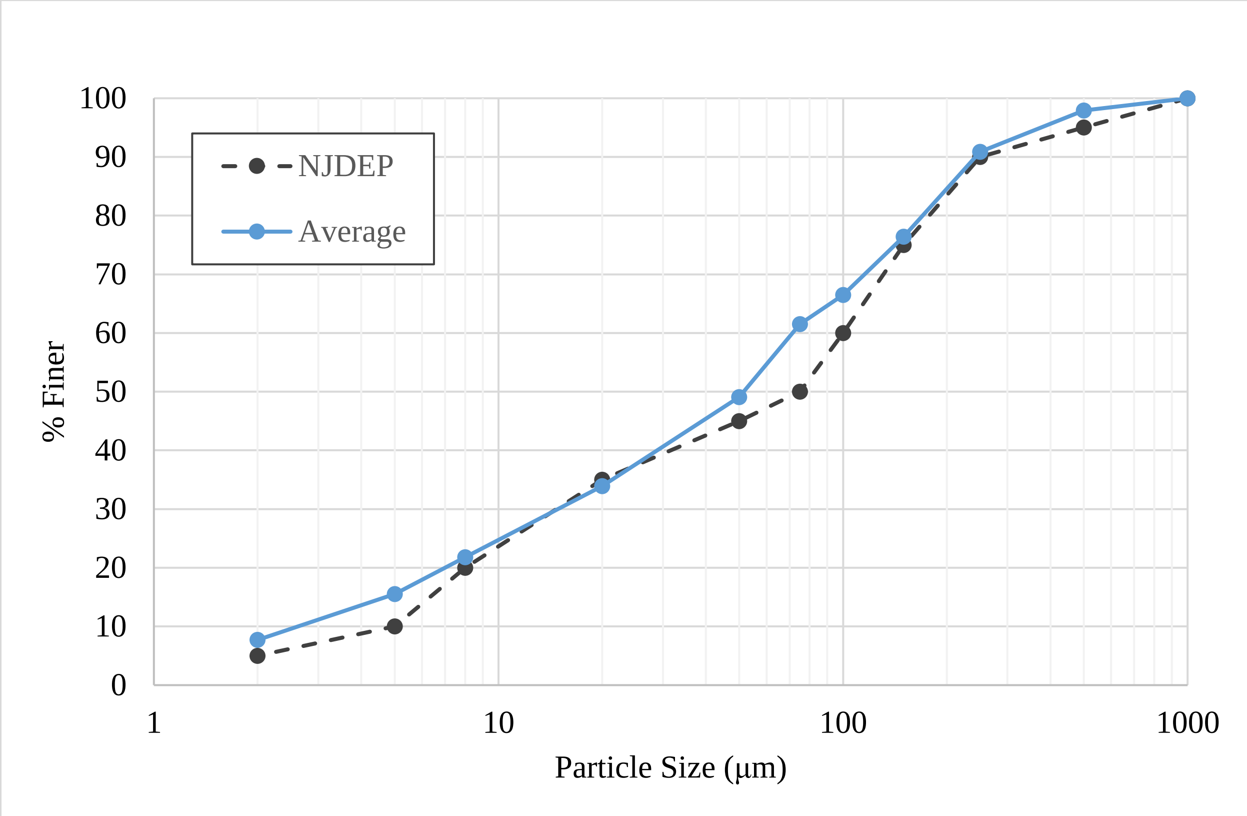

Figure 12 Average PSD of Test Sediment Compared

2.4 Sediment Removal Efficiency Testing

The system was tested for its sediment removal efficiency in accordance with the NJDEP Filtration Protocol Section 5. The required 10 sediment mass removal efficiency test runs were followed by mass loading capacity testing designed to be carried out by repeatedly testing the unit at the maximum treatment flowrate (MTFR) until the maximum design operating head (level of water in the bypass pipe above calm water level, shown in **Figure 13** was reached or the cumulative mass removal efficiency drops below 80%. The maximum operating head is 20 inches (508 mm).

Sediment feeding of all test runs was carried out with an accuracy of ± 10 %. The sediment was injected directly into the 7.87 in (200 mm) inner diameter inflowing pipe. The turbulence in the downpipe guaranteed a mixing of the sediment before it enters the treatment unit.

Three (3) calibration samples were taken from the sediment feeder (dry samples) with an accuracy of 0.1 g to demonstrate consistency of feed rate. The time for each background and effluent sample was recorded. The samples were collected in clean 1,000 ml PE-bottles. If the test sediment feed was interrupted for measurement, the next effluent sample was collected following a minimum of three detention times.

The operating head in the system was manually measured by recording the water height in the inspection and bypass pipe (**Figure 14**). The head measurements were recorded every five minutes during each test run.

The drawdown sampling was spaced volumetrically for the first test run. Samples for following runs were spaced based on the drawdown time (time-based) from the first run. The drawdown time and volume are consistent for each run because the drawdown is driven by the head on the system.

The drawdown volume was quantified by capturing the entire drawdown discharge into a container. The container and fluid were weighed, and the fluid weight and volume calculated. The drawdown volume was 18.5-gallons (2.472-ft^3, 70-liters).

Two TSS samples were collected for each drawdown after the test run. The results are included in the removal efficiency calculations.

The test sediment feed rate was 200 mg/L ±10% during the test runs. 10 runs were performed to demonstrate a cumulative mass removal efficiency of at least 80%.

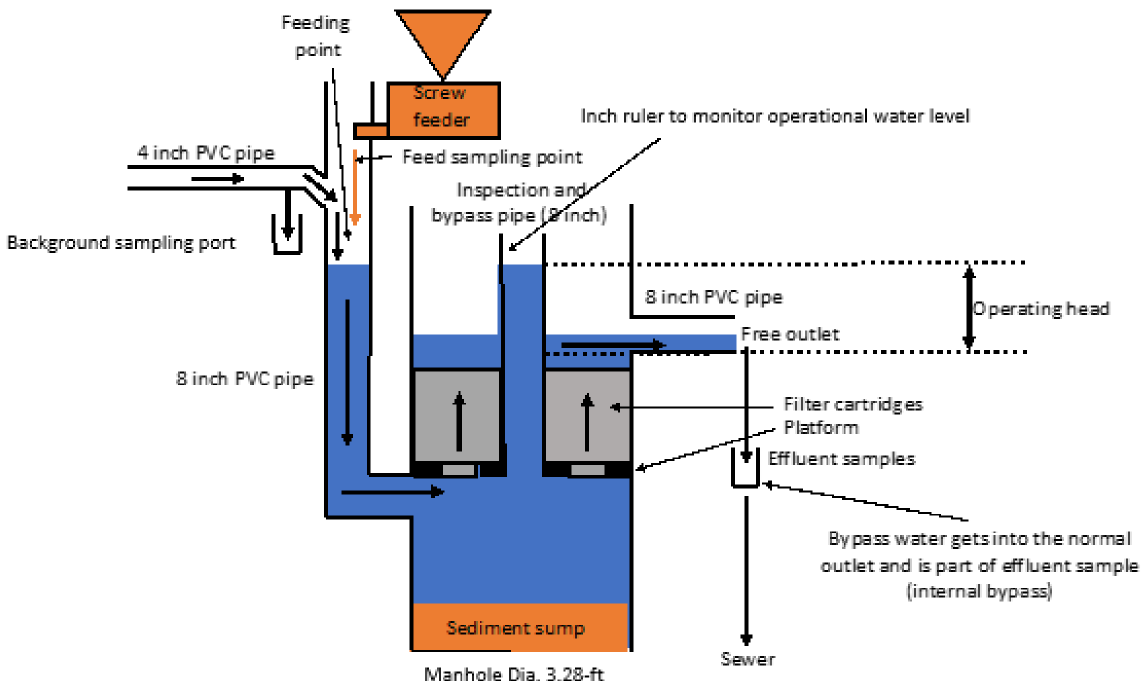

Figure 13 HydroChain HCVF-4 Test Stand Details (Flow breakers not shown for clarity)

Figure 14 Fixed Ruler to Measure Driving Head

The first effluent samples were taken after a constant feed of test sediment and flow rate was established and at least three MTD detention times had passed following the sediment calibration sample. Background samples were collected in clean 500 ml PE- bottles. The sampling times were recorded during each test run. If the test sediment feed was interrupted for a measurement, then the next effluent sample was collected after a minimum of three detention times. The time interval between effluent samples did not exceed 15 minutes and the time interval between sequential samples was evenly spaced. After the water flow was stopped, two evenly spaced volumetric samples were collected for the drawdown effluent and the flow was volumetrically quantified. The drawdown volume was 70 liters. The sampling plan for each test run is given in **Table 2**.

Table 2 Test Run Sampling Plan

Scheduled Time (hh:min:sec)	TSS Sampling or Reading				Remarks
	Sediment Feed Rate	Effluent	Background	Drawdown	
00:00:00					Constant flowrate is established, constant sediment feed rate is established
00:01:00	No. 1				
00:16:00		No. 1	No. 1		
00:31:00		No. 2			
00:32:00	No. 2				
00:47:00		No. 3	No. 2		
01:02:00		No. 4			
01:03:00	No. 3				
01:18:00		No. 5	No. 3		
01:19:00					Pump is stopped, feeder is stopped
01:21:00[1]				No. 1	
01:23:00[1]				No. 2	
01:25:00[2]					End of test run

[1] Time for drawdown TSS samples were determined before each trial, using the previous trial´s drawdown duration.
[2] The end of the test run is the time at which the drawdown effluent starts to drip.

Background and effluent samples were tested for SSC per ASTM 3977-97 "Standard Test Methods for Determining Sediment Concentrations in Water Samples" by an accredited laboratory (Fredericktowne Environmental Testing Labs Inc., 3020 Ventrie Court, Myersville. MD 21773).

The average influent TSS concentration was calculated by the total mass of the test sediment added during dosing divided by the volume of water that flowed through the MTD during dosing as follows:

$$\text{Average Influent Concentration} = \frac{\text{Total mass added}}{\begin{array}{c}\text{Total volume of water}\\ \text{flowing through the MTD}\\ \text{during addition of test sediment}\end{array}}$$

Equation 1 Calculation for Average Influent Concentration

The total volume of water that flows through the MTD is calculated by multiplying the average flow rate by the time of sediment injection only.

Removal efficiency is calculated as follows:

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

Equation 2 Equation for Calculating Removal Efficiency

Where:

- Test Water: Volume of water flowing through filtration MTD during addition of test sediment. (Average flow rate × time of test sediment addition).
- Influent Mass: Average Influent TSS Concentration × Total Volume of water flowing through the filtration MTD during the addition of test sediment or Total Mass Added (Equation 1).
- Effluent Mass: Adjusted (for background TSS concentration) Effluent TSS Concentration × Total Volume of water flowing through the filtration MTD during the addition of test sediment (Total volume of test water minus total volume of drawdown water).
- Drawdown Mass: Average Drawdown TSS Concentration × Total Volume of water flowing from the filtration MTD during drawdown.

2.5 Sediment Mass Loading Capacity Testing

Sediment Mass Loading Capacity testing was conducted as a continuation of the TSS removal efficiency testing using an influent concentration of 200 mg/L. The goal of the testing was to determine the maximum mass of test sediment captured prior to either unacceptable loss of hydraulic capacity at design driving head, unacceptable headloss at MTFR, or an unacceptable reduction in pollutant removal efficiency at MTFR. The filter was not blocked or clogged following 20 test runs and the maximum design operating head was not exceeded. Nevertheless, sediment mass loading capacity testing was terminated, and the cumulative mass load obtained at the end of the 20 test runs.

2.6 Scour Testing

Scour testing was carried out at 200 % of the MTFR of the system. The test was carried out under the following conditions:

- The sediment sump was filled to 50 % of the sediment trap volume using a combination of bricks and sediment per **Table 1**. Bricks were used to construct a false floor to 4-inches below the 50% volume level, which was 5.85 inches. The test sediment was then used to fill in voids between the bricks. Finally, a minimum of 4-inches of test sediment was placed on top of the bricks to reach or exceed the 50% volume, which was at a height of 9.85 inches from the sump floor.
- The same filters used for TSS removal testing were used for the scour test. TSS removal testing was conducted first to pre-load the filters.
- The system was filled with water from the underground storage tanks to its normal operating depth. Testing commenced within 96-hours after preloading per protocol.
- The flowrate was adjusted to the target flowrate within 5 minutes.
- Background TSS concentration was less than 20 mg/L. Eight background samples of the clear water were taken during the test at evenly spaced intervals. Grab samples were taken from the inflow at the background sampling point. The samples were graphed based on the time of collection.
- Effluent samples were collected every 2 minutes. Fifteen (15) total samples were collected over the duration of the test.
- The flow rate was recorded every minute during the test using a data logger (Voltcraft DL 191A).
- Effluent samples were collected using the grab sampling method.

The MTD qualifies for online installation if the average adjusted effluent TSS concentration measured during scour testing is no more than 20 mg/L, and the maximum conveyance rate of the drainage system does not exceed the maximum conveyance rate used for scour testing.

2.7 Quality Objectives and Criteria

PSD and SSC samples were evaluated by RMB Environmental Laboratories, Hibbing. MN/USA, and Fredericktowne Environmental Testing Labs Inc., 3020 Ventrie Court, Myersville. MD 21773. Feeder sample weights were confirmed by the third-party observer immediately after the sample collection. A certified calibrated scale was used.

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the HydroChain HCVF-4, the following performance claims are made by Xerxes for installations up to 200% of the MTFR.

Total Suspended Solids (TSS) Removal Efficiency

The cumulative removal efficiency of TSS is > 80% at the MTFR.

Effective Sedimentation Treatment Area (ESTA)

The effective sedimentation area of the tested HydroChain HCVF-4 is 8.45 ft^2 (2.11 ft^2 per filter cartridge).

Effective Filtration Treatment Area (EFTA)

The effective filtration treatment area of the tested HydroChain HCVF-4 is 6.50 ft^2 (1.63 ft^2 per filter cartridge HCFC-4).

ESTA/EFTA

The ratio of the Effective Sedimentation Treatment Area to the Effective Filtration Treatment Area is 1.30.

Maximum Treatment Flow Rate (MTFR)

The maximum treatment flow rate (MTFR) for the tested HydroChain HCVF-4 with four cartridges is 53.57 gpm (0.1193 cfs).

Flow Rate per Standard Filter Cartridge at MTFR

The flowrate per standard filter cartridge HCFC-4 at the MTFR is 13.39 gpm. This equates to a MTFR/EFTA of 8.24 gpm/ft^2.

Maximum Driving Head

The maximum driving head is 20 inches (**Figure 13**).

Online Installation

Based on the Scour Test results described in Section 4.4, the HydroChain Filter Cartridge qualifies for online installation up to 200% MTFR.

Wet Volume

The operational wet volume of the HCVF-4 system is 329.1 gal. (44.00 cf) based on the water volume of the sediment trap plus the water volume above the platform and below the outlet invert.

Ratio of Wet Volume to Effective Filtration Treatment Area

The ratio of the operational wet volume to the effective filter treatment area is 6.77.

Sediment Mass Load Capacity

The sediment mass load capacity for the tested system is 117.64 lbs (captured) out of 140.1 lbs delivered to the system. (29.4 lbs/filter cartridge)

Maximum Allowable Inflow Drainage Area

Although the mass load capacity testing was terminated before the filter cartridges showed sign of occluding, the total mass load after the 20 test runs that were completed showed that 117.64 lbs of sediment was captured. Based on this mass, the maximum allowable inflow drainage area for the tested HydroChain HCVF-4 is 0.20 acres, which is equivalent to 0.05 acres per filter 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 such documentation would be made available to NJCAT upon request and therefore was not prudent or necessary to include all the information in this verification report. This information was provided to NJCAT and is available upon request.

4.1 Removal Efficiency Results

During sediment removal testing, 10 test runs were carried out in accordance with the NJDEP Filtration Protocol. The average flowrate (MTFR) was 53.57 gpm, and the average influent sediment concentration was 201.7 mg/L.

The flowrates of each test run are summarized in **Table 3**. Flowrates were maintained between 52.68 gpm and 55.44 gpm. The COV was maintained below 0.03 per NJDEP Filtration Protocol requirements.

The first two test runs were carried out with rainwater from the tanks, afterwards the tanks were continuously refilled with drinking water. The temperature of the drinking water was below 60 °F. The temperature results of the ten test runs are shown in **Table 4**. TSS background concentrations were well below the 20 mg/L allowable limit (**Table 5**). The results of the adjusted effluent grab samples are shown in **Table 6**. Drawdown TSS concentrations are shown in **Table 7**.

The target influent TSS sediment concentration to the system was 200.0 mg/L. The influent concentration using data from the three calibration samples ranged between 200.6 mg/L and 216.5 mg/L demonstrating that the sediment feed rate was within 10% of the targeted value of 200.0 mg/L (180.0 – 220.0 mg/L) influent concentration per the NJDEP Filtration Protocol requirement. The COV for reach of the ten test runs was ≤0.10. Test results are summarized in **Table 8**.

Table 9 shows the results of the ten sediment removal efficiency test runs. The overall sediment removal efficiency calculated is 80.1 % based on a cumulative sediment mass basis.

After completing the ten test runs the bend of the inlet pipe was inspected with a camera. No sediment was observed in the pipe, so the total mass of the test sediment added to the inflow reached the MTD.

Table 3 Removal Efficiency Test Flow Rates

Test Run No.	Mean Flowrate (gpm)	Standard Deviation (gpm)	Standard Deviation (%)	QA/QC (≤ 10%)	COV	QA/QC (COV ≤ 0.03)
1	55.44	0.27	0.50	YES	0.005	YES
2	53.48	0.61	1.14	YES	0.011	YES
3	53.29	0.57	1.06	YES	0.011	YES
4	52.68	0.33	0.63	YES	0.006	YES
5	53.52	0.42	0.78	YES	0.008	YES
6	53.29	0.39	0.73	YES	0.007	YES
7	53.50	0.31	0.58	YES	0.006	YES
8	53.49	0.25	0.46	YES	0.005	YES
9	53.58	0.29	0.54	YES	0.005	YES
10	53.44	0.25	0.48	YES	0.005	YES
Avg.	53.57					

Table 4 Removal Efficiency Test Temperatures

Test Run No.	Max. Temp (°F)	QA/QC Compliance (≤ 80 °F)
1	54.1	YES
2	54.0	YES
3	57.9	YES
4	59.0	YES
5	59.2	YES
6	57.9	YES
7	58.6	YES
8	59.7	YES
9	59.7	YES
10	59.7	YES

Table 5 Removal Efficiency Test Background Sediment Concentrations

Test Run No.	Background Samples* (m/L)			Average (mg/L)	QA/QC (Max ≤ 20 mg/L)
	Sample 1	Sample 2	Sample 3		
1	1.0	< 1.0	1.0	0.8	YES
2	2.0	2.0	1.0	1.7	YES
3	3.0	2.0	1.0	2.0	YES
4	3.0	< 1.0	3.0	2.2	YES
5	3.0	1.0	1.0	1.7	YES
6	2.0	1.0	1.0	1.3	YES
7	1.0	< 1.0	< 1.0	0.7	YES
8	1.0	1.0	< 1.0	0.8	YES
9	1.0	< 1.0	< 1.0	0.7	YES
10	2.0	< 1.0	1.0	1.2	YES

* Samples below the reporting Limit of 1 mg/L are written as < 1.0.

Table 6 Adjusted Removal Efficiency Test Effluent Concentrations

Test Run (No.)	Effluent Samples (mg/L)					Mean (mg/L)
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	
1	43.2	42.2	45.2	44.2	43.2	43.6
2	39.3	41.3	39.3	46.3	42.3	41.7
3	41.0	39.0	40.0	40.0	41.0	40.2
4	36.8	37.8	40.8	47.8	36.8	40.0
5	35.3	37.3	45.3	39.3	46.3	40.7
6	35.7	34.7	40.7	35.7	37.7	36.9
7	38.3	35.3	36.3	39.3	35.3	36.9
8	39.2	35.2	40.2	40.2	36.2	38.2
9	39.3	39.3	41.3	45.3	41.3	41.3
10	34.8	46.8	41.8	41.8	40.8	41.2

Table 7 Removal Efficiency Test Drawdown Concentrations

Test Run No.	Drawdown Samples (mg/L)		Mean (mg/L)
	Sample 1	Sample 2	
1	42	30	36.0
2	38	32	35.0
3	39	40	39.5
4	38	35	36.5
5	30	31	30.5
6	33	26	29.5
7	35	32	33.5
8	35	36	35.5
9	36	33	34.5
10	40	41	40.5

Table 8 Removal Efficiency Test Influent Sediment Calibration Concentrations

Test Run No.	Inf. Conc (mg/L)	St. Dev. (mg/L)	St. Dev. (%)	QA/QC (Var < 10 %)	Feed rate samples (g/min)			COV	QA/QC (COV ≤ 0.10)
					Sample 1	Sample 2	Sample 3		
1	200.6	1.49	0.8	YES	41.67	40.86	43.74	0.04	YES
2	216.5	0.69	0.3	YES	43.27	43.61	44.59	0.02	YES
3	215.8	0.23	0.1	YES	43.51	43.77	43.31	0.01	YES
4	212.8	1.06	0.5	YES	43.40	42.59	41.30	0.02	YES
5	206.0	1.11	0.6	YES	40.69	41.60	42.90	0.03	YES
6	211.0	0.36	0.2	YES	42.93	42.54	42.22	0.01	YES
7	210.8	0.60	0.3	YES	43.06	42.00	43.02	0.01	YES
8	209.4	0.54	0.3	YES	41.80	42.53	42.85	0.01	YES
9	211.1	0.75	0.4	YES	43.40	43.05	41.97	0.02	YES
10	206.3	0.56	0.3	YES	41.10	41.92	42.16	0.01	YES

Table 9 Removal Efficiency Test Results

Test Run No.	Average Influent TSS Conc. (mg/L)	Total Volume of Test Water (L)	Adjusted Effluent TSS Conc. (mg/L)	Total Volume of Effluent Water (L)	Average Drawdown Flow TSS Conc. (mg/L)	Total Volume of Drawdown Water (L)	Mass Load per Test Run (lbs)	Cum. Mass Load (lbs)	Mass Capture per Test Run (lbs)	Cum. Mass Capture (lbs)	Mass Removal Efficiency per Run (%)	Cum. Mass Removal Efficiency (%)
1	192.7	15,949	43.6	15,879	36.0	70	6.774	6.774	5.243	5.243	77.4%	77.4%
2	207.9	15,385	41.7	15,315	35.0	70	7.053	13.826	5.638	10.881	79.9%	78.7%
3	207.3	15,330	40.2	15,260	39.5	70	7.006	20.832	5.647	16.528	80.6%	79.3%
4	204.4	15,157	40.0	15,087	36.5	70	6.829	27.661	5.491	22.020	80.4%	79.6%
5	197.8	15,397	40.7	15,327	30.5	70	6.716	34.376	5.335	27.355	79.4%	79.6%
6	202.7	15,332	36.9	15,262	29.5	70	6.850	41.226	5.605	32.960	81.8%	79.9%
7	202.5	15,392	36.9	15,322	33.5	70	6.871	48.097	5.618	38.578	81.8%	80.2%
8	201.1	15,388	38.2	15,318	35.5	70	6.823	54.920	5.528	44.106	81.0%	80.3%
9	202.7	15,414	41.3	15,344	34.5	70	6.889	61.809	5.486	49.592	79.6%	80.2%
10	198.1	15,376	41.2	15,306	40.5	70	6.716	68.525	5.319	54.911	79.2%	80.1%
Percent Cumulative Sediment Mass Removal												**80.1%**

4.2 Sediment Mass Loading Capacity

After sediment removal testing, ten additional mass loading capacity test runs were carried out in accordance with the NJDEP Filtration Protocol. The average flowrate was 56.31 gpm (MTFR), and the average adjusted influent sediment concentration was 200.6 mg/L.

The flowrates of each test run are summarized in **Table 10.** Flowrates were between 55.57 gpm and 57.45 gpm. The COV was maintained below 0.03 per NJDEP Filtration Protocol requirements.

The tanks were continuously refilled with drinking water. The temperature of the drinking water was below 50 °F. The temperature results of the ten mass loading capacity test runs are shown in **Table 11**. TSS background concentrations were well below the 20 mg/L allowable limit (**Table 12**). The results of the adjusted effluent grab samples are shown in **Table 13**. Drawdown TSS concentrations are shown in **Table 14**.

The target influent TSS sediment concentration to the system was 200.0 mg/L. The influent concentration using data from the three calibration samples ranged between 195.3 mg/L and 227.5 mg/L demonstrating that the sediment feed rate was within 10% of the targeted value of 200.0 mg/L (180.0 – 220.0 mg/L) influent concentration per the NJDEP Filtration Protocol requirement except for test runs 12 and 13. However, the influent concentrations calculated from Equation 1 were all within 10% of the targeted value of 200.0 mg/L. The COV for reach of the ten test runs was ≤0.10. Test results are summarized in **Table 15**.

Table 16 shows the results of the ten sediment mass loading capacity test runs. The overall sediment mass capture efficiency calculated for the 20 test runs was 84.0% based on a cumulative sediment mass basis. The total sediment mass capture was 117.64 lbs. Cumulative sediment mass removal efficiency for the 18 runs (excluding test runs 12 and 13 per NJCAT protocol interpretation) was 83.1%.

After completing the ten sediment mass loading capacity test runs the bend of the inlet pipe was inspected with a camera. No sediment could be seen in the pipe, so the total mass of the test sediment entered the HCVF sump.

Table 10 Mass Loading Capacity Test Flow Rates

Test Run No.	Mean Flowrate (gpm)	Standard Deviation (gpm)	Standard Deviation (%)	QA/QC (< 10%)	COV	QA/QC (≤ 0.03)
11	56.68	1.40	2.47	YES	0.025	YES
12	55.57	1.19	2.14	YES	0.021	YES
13	55.76	1.63	2.92	YES	0.029	YES
14	57.45	1.00	1.73	YES	0.017	YES
15	56.94	1.10	1.94	YES	0.019	YES
16	55.84	1.26	2.26	YES	0.023	YES
17	55.76	1.60	2.87	YES	0.029	YES
18	57.02	1.26	2.22	YES	0.022	YES
19	55.80	0.94	1.68	YES	0.017	YES
20	55.79	1.18	2.12	YES	0.021	YES

Table 11 Mass Loading Capacity Test Temperatures

Test Run No.	Max. Temp (°F)	QA/QC Compliance (≤ 80 °F)
11	45.7	YES
12	45.1	YES
13	45.7	YES
14	45.7	YES
15	45.1	YES
16	45.1	YES
17	46.8	YES
18	45.7	YES
19	45.9	YES
20	46.8	YES

Table 12 Mass Loading Capacity Test Background Sediment Concentrations

Test Run No.	Background Samples (mg/L)			Average (mg/L)	QA/QC (≤ 20 mg/L)
	Sample 1	Sample 2	Sample 3		
11	1.0	1.0	< 1.0*	0.8	YES
12	< 1.0	< 1.0	< 1.0	0.5	YES
13	< 1.0	< 1.0	< 1.0	0.5	YES
14	< 1.0	< 1.0	< 1.0	0.5	YES
15	< 1.0	< 1.0	< 1.0	0.5	YES
16	< 1.0	< 1.0	2.0	1.0	YES
17	2.0	< 1.0	< 1.0	1.0	YES
18	< 1.0	< 1.0	< 1.0	0.5	YES
19	< 1.0	< 1.0	< 1.0	0.5	YES
20	< 1.0	< 1.0	< 1.0	0.5	YES

* Samples below the reporting Limit of 1 mg/L are written as < 1.0.

Table 13 Adjusted Mass Loading Capacity Test Effluent Concentrations

Test Run No.	Effluent Samples (mg/L)					Mean (mg/L)
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	
11	44.2	41.2	37.2	23.2	20.2	33.2
12	24.5	17.5	22.5	24.5	20.5	21.9
13	23.5	13.5	19.5	15.5	16.5	17.7
14	13.5	13.5	18.5	15.5	14.5	15.1
15	20.5	21.5	22.5	25.5	10.5	20.1
16	22.0	28.0	15.0	27.0	22.0	22.8
17	20.0	30.0	26.0	45.0	48.0	33.8
18	25.5	27.5	37.5	24.5	28.5	28.7
19	26.5	20.5	31.5	22.5	36.5	27.5
20	26.5	27.5	28.5	30.5	32.5	29.1

Table 14 Mass Loading Capacity Test Drawdown Concentrations

Test Run No.	Drawdown Samples (mg/L)		Mean (mg/L)
	Sample 1	Sample 2	
11	17	14	15.5
12	10	11	10.5
13	15	13	14.0
14	18	12	15.0
15	17	13	15.0
16	21	18	19.5
17	2	6.0	4.0
18	24	21	22.5
19	22	15	18.5
20	20	18	19.0

Table 15 Mass Loading Capacity Test Influent Sediment Calibration Concentrations

Test Run No.	Inf. Conc (mg/L)	St. Dev. (mg/L)	St. Dev. (%)	QA/QC (< 10%)	Feed rate samples (g/min)			COV	QA/QC (≤ 0.10)
					Sample 1	Sample 2	Sample 3		
11	214.9	1.22	0.6	YES	47.50	45.27	45.54	0.026	YES
12	227.5	2.09	0.9	NO	45.44	49.14	48.97	0.044	YES
13	220.1	2.81	1.3	NO	48.56	47.54	43.26	0.061	YES
14	214.0	2.82	1.3	YES	49.76	45.36	44.50	0.061	YES
15	205.8	1.02	0.5	YES	45.34	44.44	43.31	0.023	YES
16	200.5	0.72	0.4	YES	43.15	42.27	41.73	0.017	YES
17	195.3	1.43	0.7	YES	40.37	42.87	40.42	0.035	YES
18	195.8	2.32	1.2	YES	39.58	43.73	43.46	0.055	YES
19	207.0	0.71	0.3	YES	42.92	44.00	44.25	0.016	YES
20	207.7	0.75	0.4	YES	44.73	43.42	43.43	0.017	YES

Table 16 Mass Loading Test Capacity Results

Test Run No.	Average Influent TSS Conc. (mg/L)	Total Volume of Test Water (L)	Adjusted Effluent TSS Conc. (mg/L)	Total Volume of Effluent Water (L)	Average Drawdown Flow TSS Conc. (mg/L)	Total Volume of Drawdown Water (L)	Mass Load per Test Run (lbs)	Cum. Mass Load (lbs)	Mass Capture per Test Run (lbs)	Cum. Mass Capture (lbs)	Mass Removal Efficiency per Run (%)	Cum. Mass Removal Efficiency. (%)
11	206.4	16,305	34.0	16,235	15.5	70	7.420	75.945**	6.230	61.141**	84.0%	80.5%
12*	218.5	15,987	21.9	15,917	10.5	70	7.701	(83.645) *	6.931	(68.071) *	90.0%	80.5%
13*	211.4	16,041	17.7	15,971	14.0	70	7.476	(91.121) *	6.851	(74.922) *	91.6%	80.5%
14	205.6	16,528	15.1	16,458	15.0	70	7.490	83.435	6.940	68.081	92.7%	81.6%
15	197.7	16,380	20.1	16,310	15.0	70	7.140	90.574	6.415	74.495	89.8%	82.2%
16	192.6	16,065	22.8	15,995	19.5	70	6.821	97.395	6.014	80.509	88.2%	82.7%
17	187.6	16,041	33.8	15,971	4.0	70	6.634	104.029	5.443	85.952	82.1%	82.6%
18	188.1	16,403	27.5	16,333	18.5	70	6.801	110.830	5.808	91.760	85.4%	82.8%
19	198.8	16,053	27.5	15,983	18.5	70	7.037	117.867	6.065	97.825	86.2%	83.0%
20	199.5	16,051	29.1	15,981	19.0	70	7.059	124.925	6.031	103.855	85.4%	83.1%
Percent Cumulative Mass Removal Efficiency (Runs 1-11, 14-20)												83.1%
Total Mass Load (Runs 1-20)												140.102 lbs
Total Mass Capture (Runs 1-20)												117.637 lbs
Percent Cumulative Mass Capture (Runs 1-20)												**84.0%**

*Non–conforming test. Results cannot be used to calculate cumulative mass removal efficiency but are used to calculate the overall sediment mass loading capacity. Hence, the reported cumulative removal efficiencies shown are based on removal of the mass added and mass captured from Runs 12 and 13.
**Carryover from runs 1-10 in Table 9.

The cumulative mass load versus the cumulative TSS removal efficiency is shown in **Figure 15**.

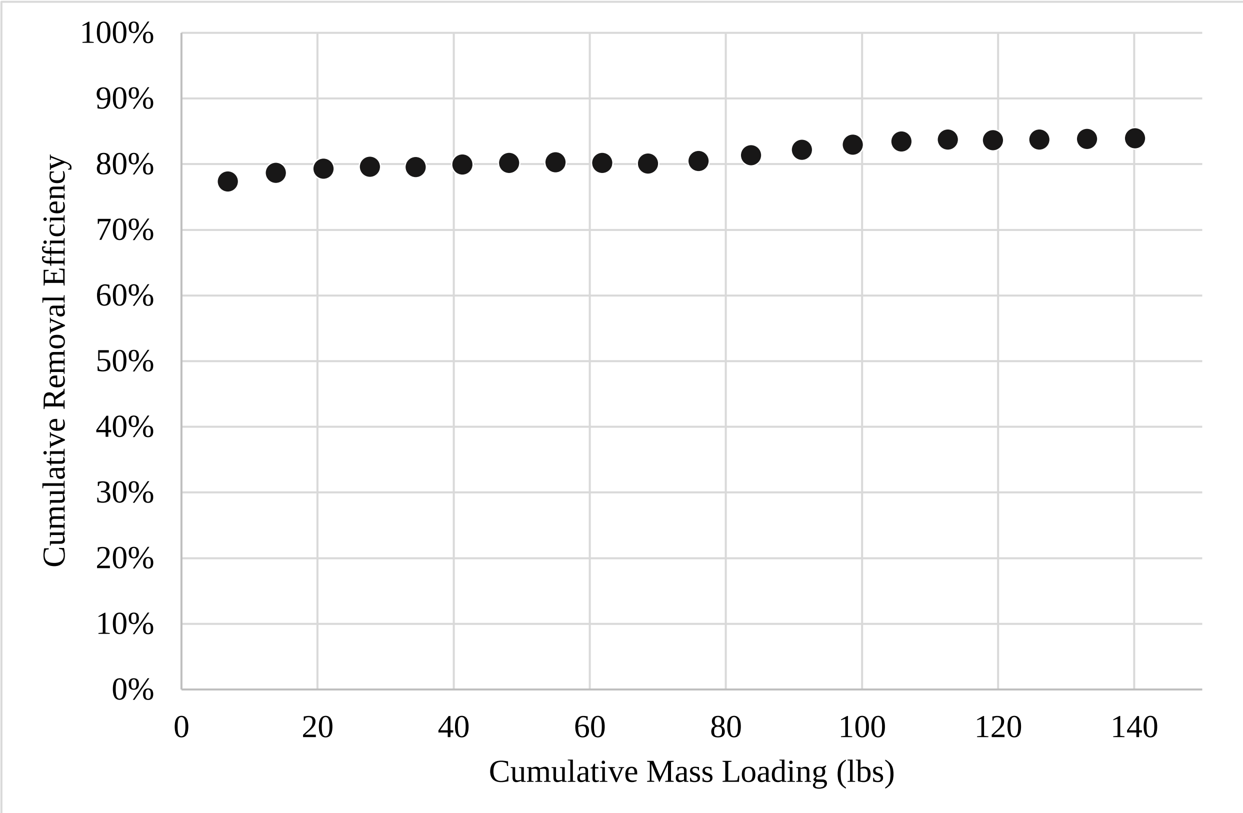

Figure 15 Cumulative Mass Load vs. Cumulative Removal Efficiency at MTFR

4.3 Operating Head

The operating head is defined as the height difference between the dry weather water level and the water level within the overflow/maintenance pipe (**Figure 13)**. **Table 17** and **Table 18** show the driving heads over the test runs. Based on the 20 test runs, the driving head was not influenced by the mass loading.

Table 17 Removal Efficiency Test Driving Head Summary

Test Run No.	Head Level (in)	Cumulative Mass Captured (lbs)
1	7-7/8	5.243
2	6-7/8	10.881
3	6-4/8	16.528
4	6-1/8	22.020
5	5-7/8	27.355
6	6-1/8	32.960
7	6	38.578
8	5-7/8	44.106
9	5-7/8	49.592
10	5-7/8	54.911

Table 18 Mass Load Capacity Test Driving Head Summary

Test Run No.	Head Level (in)	Cumulative Mass Captured (lbs)
11	6-2/8	61.141
12	6-1/8	68.071
13	6-2/8	74.922
14	6-2/8	81.862
15	6-1/8	88.277
16	6	94.291
17	5-7/8	99.734
18	6	105.541
19	5-7/8	111.606
20	5-7/8	117.637

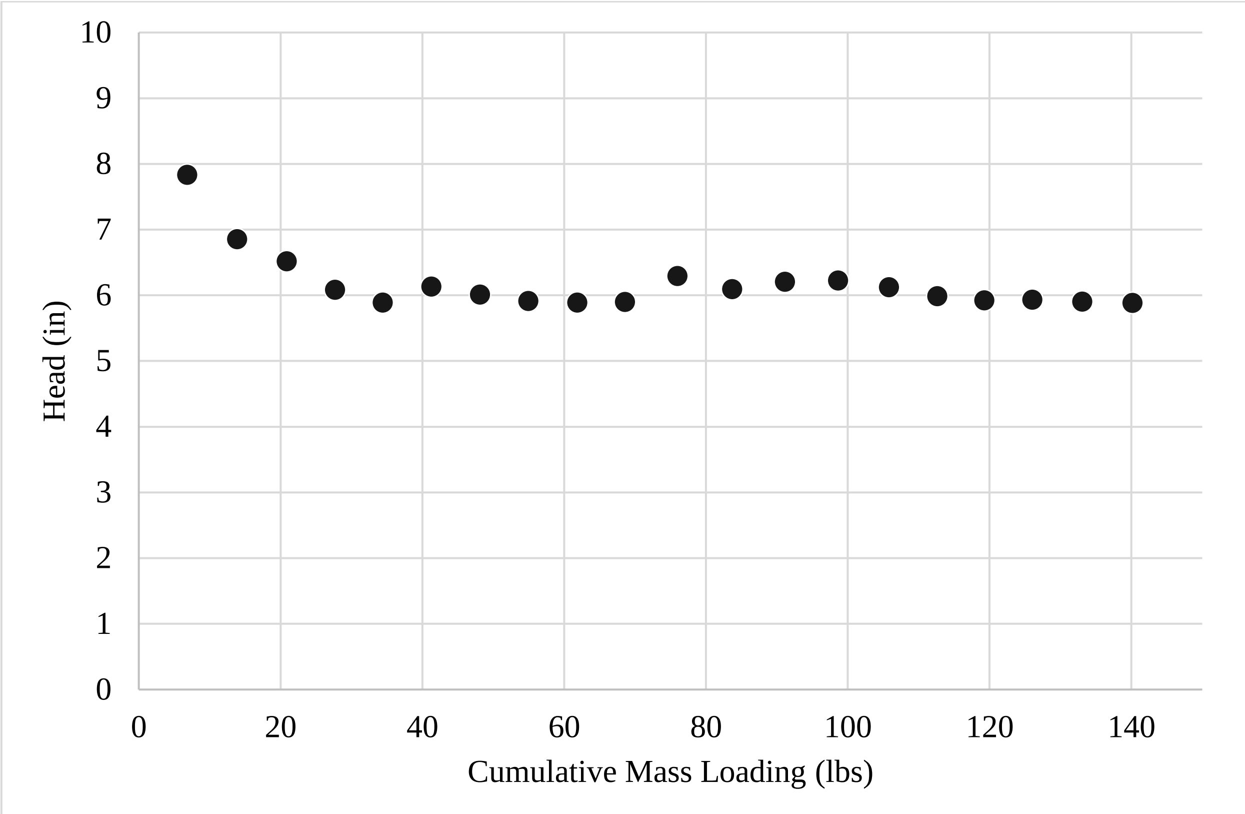

Figure 16 Cumulative Mass Loading vs. Head at MFTR

4.4 Scour Testing Results

Scour testing was carried out according to the NJDEP Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (NJDEP 2013b). Testing was performed at a target flow rate of 110.0 gpm which is >200% of the maximum treatment flow rate (MTFR). As described in Section 2.6 Scour Testing, following sediment mass loading capacity testing, a false floor consisting of bricks and sediment was filled to 4 inches below 50% of the volume capacity. Four inches of dry sediment in accordance with **Table 1** was then added into the HCVF-4 sump bringing the sediment volume to 50% capacity. The sediment layer was levelled prior to the system being filled with drinking water from the water tanks to the normal static water level. The scour test run started approximately one hour after filling with water.

The scour test sampling frequencies are given in **Table 19**.

Table 19 Scour Test Sampling Plan

Scheduled Time (min:sec)	Effluent TSS Sample	Background TSS Sample	Remarks
00:00			Constant flowrate is established within five (5) minutes
01:00	No. 1	No. 1	
03:00	No. 2		
05:00	No. 3	No. 2	
07:00	No. 4		
09:00	No. 5	No. 3	
11:00	No. 6		
13:00	No. 7	No. 4	
15:00	No. 8		
17:00	No. 9	No. 5	
19:00	No. 10		
21:00	No. 11	No. 6	
23:00	No. 12		
25:00	No. 13	No. 7	
27:00	No. 14		
29:00	No. 15	No. 8	
31:00			Water flow is stopped

The effluent sample results from the scour test are adjusted for background concentration [effluent sample = recorded effluent sample – background (maximum allowable background is 20 mg/L)]. Each background and effluent sample time was recorded.

Figure 17 shows the flowrate summary of the scour test. The mean flowrate was 109.56 gpm, the COV was ≤ 0.03. The minimum and maximum recorded test flow rates were 108.31 gpm and 111.61 gpm respectively.

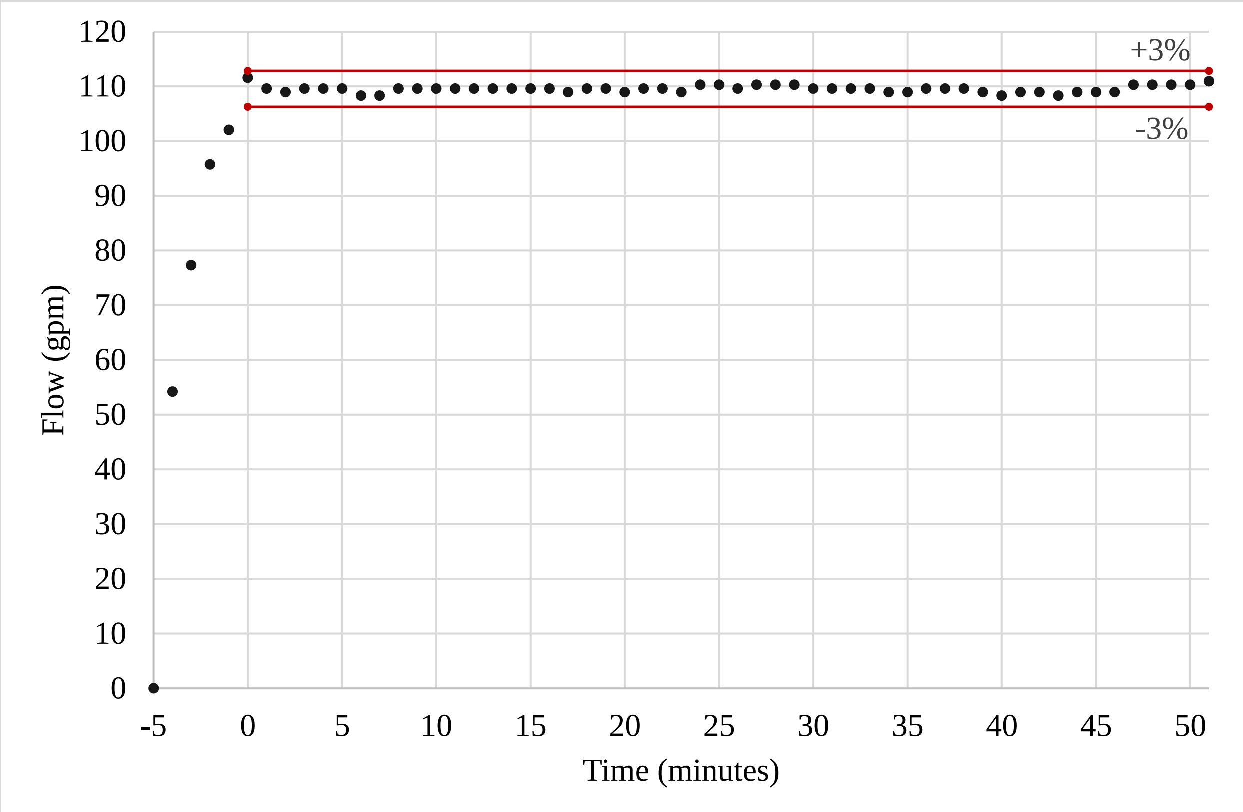

Figure 17 200% MTFR Scour Test Flow Data

Table 20 summarizes the background sediment concentration of the influent feed water.

Table 20 Scour Test Background Sediment Concentration

Run time (min)	Sample No.	TSS concentration (mg/L)	QA/QC Compliance (≤ 20 mg/L)
1	1	5.0	YES
5	2	3.0	YES
9	3	2.0	YES
13	4	1.0	YES
17	5	1.0	YES
21	6	2.0	YES
25	7	1.0	YES
29	8	1.0	YES
Average	**-**	**2.0**	**YES**

The background data are plotted on **Figure 18** for use in adjusting the effluent samples for background concentration.

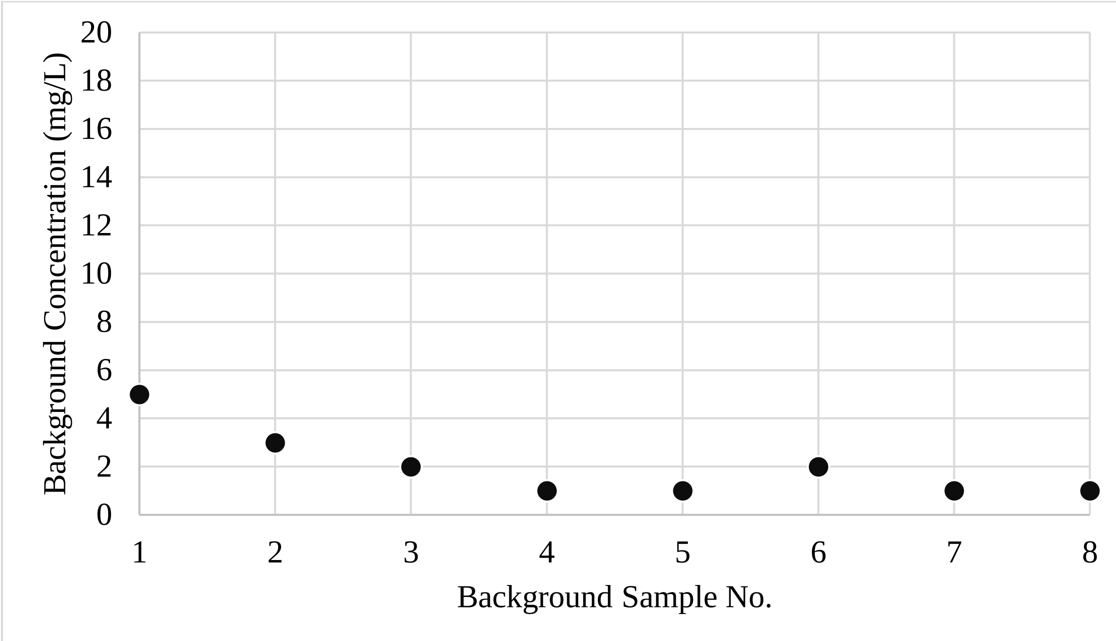

Figure 18 Results of the Scour Test Background Samples

The adjusted effluent TSS concentrations from the scour test are shown in **Table 21.**

Table 21 Scour Test Effluent Sediment Results

Run time (min)	Sample No.	Effluent Concentration (mg/L)	Background Concentration (mg/L)	Adjusted Concentration (mg/L)
1	1	93.0	5.0	88.0
3	2	46.0		42.0
5	3	22.0	3.0	19.0
7	4	24.0		21.5
9	5	15.0	2.0	13.0
11	6	16.0		14.5
13	7	17.0	1.0	16.0
15	8	12.0		11.0
17	9	11.0	1.0	10.0
19	10	14.0		12.5
21	11	14.0	2.0	12.0
23	12	8.0		6.5
25	13	7.0	1.0	6.0
27	14	7.0		6.0
29	15	7.0	1.0	6.0
			Average	**18.9**

The HCVF system is verified for online installation up to 200% of the MTFR.

5. Design Limitations

The HydroChain Vortex Filter is an engineered system for which Xerxes engineers work with site designers to generate a detailed engineering submittal package for each installation. As such, design limitations are typically identified and managed during the design process. Design parameters and limitations are discussed in general terms below.

Required Soil Characteristics

The HCVF system is a flow-through MTD contained within a watertight structure. Therefore, the HCVF system can be installed and function as intended in all soil types.

Slope

Xerxes recommends contacting our design engineers when the HCVF system is going to be installed on a drainage line with a slope. With steeply sloping pipe, site specific parameters such as pipe size, online vs. offline arrangement of the HCVF system and the frequency of peak flow are taken into consideration by Xerxes engineers.

Maximum Treatment Flow Rate (MTFR)

The MTFR of the HCVF system is dependent upon the filter cartridge model (HCFC-4 or HCFC-5), number of filters and manhole diameter (**Table A-1** and **Table A-2**).

Maintenance Requirements

For all stormwater quality control systems, effective performance requires regular and proper maintenance. Maintenance frequency and requirements are dependent on the 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. A detailed discussion of inspection and maintenance requirements is discussed in Section 6.

Operating Head

There is an operational head loss associated with each HydroChain Vortex Filter. The head loss is dependent on the structure design and the cartridge layout 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.

Installation limitations

HydroChain Vortex Filter systems have few installation limitations. Systems are typically delivered to the site with all necessary components. The contractor is responsible for installation of the system following any requirements that would apply for any manhole structure. This typically includes preparing the appropriate excavation and base layer; providing and using the appropriate lifting equipment to unload and set the filter cartridges and components; providing and connecting the inlet and outlet piping; and following the construction plans for selection of backfill material and placement. Pick weights and installation procedures vary slightly with configuration and model size. Xerxes provides contractors with project-specific unit pick weights and installation instructions prior to delivery. The contractor is responsible for protecting the HCVF system from construction runoff until site construction is complete.

Configurations

There are two commercially available filter cartridge models, HCFC-4 and HCFC-5, that are used in different manhole sizes ranging from 4-ft to 12-ft. in diameter. **Table A-2** includes a list of HydroChain Vortex Filter models and respective sizing criteria based on the tested unit and scaling ratios defined by the Filtration Protocol.

Structural Load Limitations

The HydroChain Vortex Filter system is intended for use inside a structure designed for HS-20 traffic load rating or other load rating depending on the installed location. Xerxes provides full-service technical design support throughout design and installation to ensure the system is constructed for the appropriate structural load requirements.

Pretreatment Requirements

HCVF systems have no pre-treatment requirements.

Limitations on Tailwater

Xerxes recommends working with their engineering team if tailwater is present to increase the available driving head to ensure that the full water quality treatment flow rate is treated consistent with Filtration Protocol requirements.

Depth to seasonal high-water table

The operation of HCVF systems is not impacted by the seasonal high-water table when the system is constructed watertight and anchored in accordance with the installation manual instructions. High-water may impact the buoyancy of the housing structure. Specific project conditions must be assessed as part of the design process.

6. Maintenance

HydroChain Vortex Filters must be inspected and maintained at regular intervals like all stormwater treatment facilities. A copy of the Installation, Operation, and Maintenance Manual can be obtained at: Xerxes HydroChain Filter Installation O&M

The HCVF system owner is responsible for inspection and maintenance in accordance with the governing regulations. It is recommended that the site owner establish an inspection and maintenance schedule based on the following factors:

- Manhole size and configuration
- Site and environmental conditions

- Drainage area
- Annual rainfall
- Volume of stormwater runoff
- Volume of sediment, dirt, debris, and trash entering the system
- Volume and type of pollutants collected

It is recommended that after installation, the system be inspected a minimum of every 6 months. To ensure that the system is functioning as designed, it is recommended to inspect the system immediately after the first major rainfall or storm event after installation.

It is recommended that the system be cleaned at regular intervals. Typically, the manhole is emptied of sediment every three to six years. However, the actual frequency of cleaning required will depend on the factors listed above.

Based on 20 years of installation experience in Germany with varying site conditions, filter cartridges can be functional up to 10 years from initial installation if properly flushed and maintained. Depending on the annual sediment and pollutant loading, filters need to be flushed (or replaced) every 3 to 6 years. It is recommended that filters be flushed no more than twice.

The site owner is responsible for creating, recording, and retaining inspection and maintenance records in accordance with their own site requirements and applicable regulations. An example log is provided in the Installation, Operation, and Maintenance Manual.

Proper and optimum operation of the HCVF system requires following these recommended inspection, maintenance, and cleaning guidelines. Exceeding the recommended maximum volume of suspended solids and hydrocarbons will jeopardize the effectiveness of the filters.

Inspection

The inspection should proceed as follows:

1. Visually inspect the HCVF system at each access point.
2. Remove the access cover and record the inspection location.
3. Visually inspect for floating waste to determine if maintenance is required.
4. If there is floating waste, remove it.
5. Visually inspect the bypass system, such as bypass and internal piping, weirs, and baffles.
6. If the water level rises above the center bypass pipe, it indicates that the system is clogged, and maintenance and/or cleaning of the filters and/or manhole is required.
7. Sediment visibly accumulating on top of the Filter Cartridges indicates that the system is clogged and cleaning of the filters and/or manhole is required.
8. A sheen of free oil floating above the filters indicates the presence of hydrocarbons, for which maintenance is required.

If the system is inspected when there are no flows, the height of the water level will be the same across the bypass pipe and outlet.

To determine the level of standing water and accumulated sediment, follow this procedure:

1. Measure the distance between the top of the access riser and the top of the standing water. This is measurement #1.
2. Measure the distance between the top of the access riser to the top of the sediment in the lower chamber. This is measurement #2.
3. Measure the distance between the top of the access riser and the floor of the manhole. This is the measurement #3.

A method to determine measurements #2 and #3 is to lower a stadia rod towards the bottom of the manhole until resistance is encountered. If sediment has collected, this is the top of the collected sediment (#2). Push the stadia rod through the sediment to the manhole (#3).

4. Subtract measurement #2 from #3. If the value is greater than one half the depth of the sediment trap, it indicates that maintenance and/or cleaning of the manhole is required.
5. Replace the access cover.
6. Record recommended or required maintenance on the inspection and maintenance log (provided by site owner).

Maintenance

It is recommended to use a pump-out vehicle equipped with suction and flushing capabilities, or a submersible sediment (sludge) pump with hoses, such as a hydrovac truck. A truck with sufficient storage capacity is necessary to remove floatables, standing water and sediment.

Before beginning maintenance and cleaning, review the inspection record to see recommended or required maintenance, and the amount of standing water and sediment to be removed.

Determine the equipment needed for maintenance and cleaning. If the filters are to be cleaned onsite:

- Place a flushing washtub close to the manhole.
- Prepare a clean protected area to hold the cleaned cartridges before re-installation.

Flushing washtubs (**Figure 21**) can be purchased from Xerxes by calling 952-887-1890.

To begin maintenance and cleaning, remove the access cover. Suction out the water in the manhole until the water level is below the filter platform. When the filters need to be cleaned, this allows them to drain (and be lighter in weight) for easier removal.

To remove the accumulated sediment from the bottom of the chamber, insert a suction hose (**Figure 19** and **Figure 20**) in the bypass piping and vactor the sediment and remaining water from below the filter platform. If cleaning of the manhole or flushing of the filters is required in addition to removing the accumulated sediment, remove each filter with a davit crane connected to the filter's lifting ring (**Figure 22**). If undamaged, the filter gaskets may be reused. If damaged, purchase new gaskets from Xerxes.

Figure 19 Emptying Out the Sediment Sump

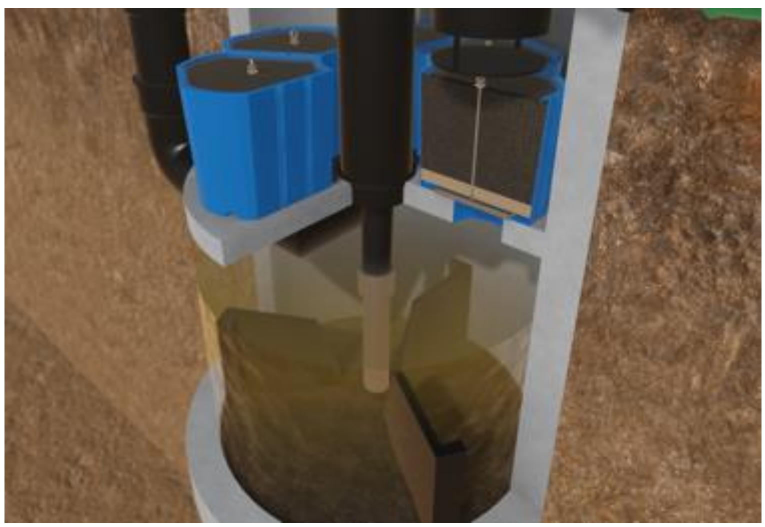

Figure 20 Accessibility of the Sediment Sump by the Central Maintenance Bypass Pipe

To clean the chamber after removing the filters, use a hose with a spray nozzle to power wash the walls and floors of the manhole above and below the filter platform. Water accumulating during the cleaning process may need to be removed periodically before the entire chamber is cleaned.

To clean filters onsite, install saturated filters into the flushing washtub (**Figure 21**) and prime the washtub with water and pressurized air. Flush the filters in the washtub by cycling flushes of water and air, releasing solids and oils upward out of the filter media. Repeat this process until the water flushed through the filter appears clear, which typically takes 5-15 minutes.

Figure 21 Mobile Filter Cleaning Unit

Drain the flushing washtub of entrained water and remove the flushed filter, placing it in a clean, protected area free of sediment and debris until it can be reinstalled in the filter platform. Dispose of the pollutants per applicable regulations. Repeat the flushing process for each saturated filter.

When the filters have been flushed and the manhole has been cleared of sediment and cleaned, reinstall the filters with the proper orientation and gaskets following the installation instructions above. As there is no manifold system below the filters, simply reinsert them into their existing orifices, making sure the gasket is still in place.

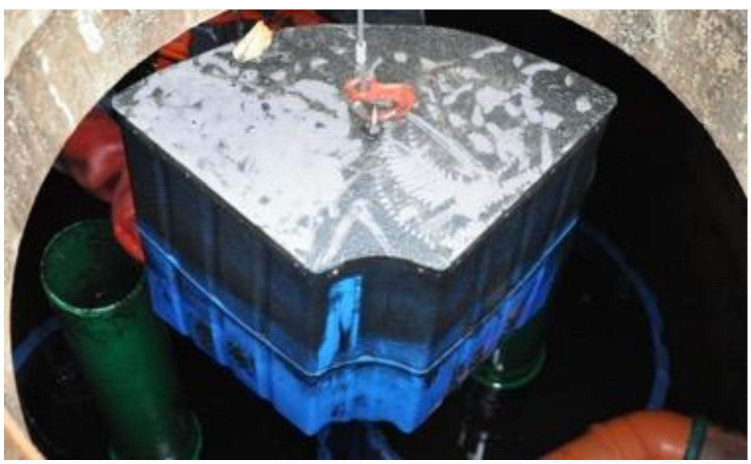

Figure 22 Exchange of a Filter Cartridge

Once the cartridges are reinstalled, reinstall any remaining piping. Close and lock the access cover. Dispose of all removed water and waste material in accordance with applicable regulations. Record details of maintenance performed in the inspection, maintenance and cleaning log provided by the site owner.

7. Statements

The following signed statements from the manufacturer (3P Technik Filtersysteme GmbH), third party observer (Dr.-Ing. Martina Dierschke) and NJCAT are required to complete the NJCAT verification process. In addition, it should be noted that this report has been subjected to public review (e.g., stormwater industry) and all comments and concerns have been satisfactorily addressed.

EXPERTEN WASSER
INGENIEURBÜRO DR. DIERSCHKE

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Dr.-Ing. Martina Dierschke – Friedrichstr. 44 - 67655 Kaiserslautern

To
Jim Merchlewitz
Xerxes®
7901 Xerxes Avenue South, Suite 201
Minneapolis, MN 55431

Kaiserslautern, den 10.01.2022

Subject: Statement of **Third-Party Observer** of Tests performed on the Xerxes® HydroChain™ Filter

I hereby confirm the observation and review of tests performed on the HydroChainTM Vortex filter by Xerxes® in October of 2000 and January 2021 to achieve verification through the New Jersey Corporation for Advanced Technology (NJCAT) and certification through the New Jersey Department of Environmental Protection (NJDEP) according to the New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices (January 2013). The test was performed by 3P Technik Filtersystems GmbH staff at their laboratory located at Robert-Bosch-Straβe 16-18, 73337 Bad Uberkingen/Germany. I verified compliance with the laboratory test protocol above, and I was physically present to observe the full duration of all testing procedures.

I have also reviewed the data, calculations, and conclusions associated with the removal efficiency testing and the scour testing in the NJCAT Technology Verification, "Xerxes® HydroChain™ Vortex Filter", dated January 2022, and state that they conform to what I saw during my supervision as a third-party observer.

Statement of Disclosure – Third Party Observer

The "Ingenieurbüro für Siedlungswasserwirtschaft" (engineering office for urban water management) Dr. Dierschke has no financial conflict of interest regarding the test results of the stormwater device testing outlined in the NJCAT Technology Verification, "Xerxes® HydroChain™ Vortex Filter", dated January 2022, edits incorporated.

Disclosure Record

The "Ingenieurbüro für Siedlungswasserwirtschaft" Dr. Dierschke has provided the service of third-party observer performed for Xerxes, Minneapolis, in October 5-7, 2020 and January 21-22, 2021.

The tests assessed the removal efficiency of the HydroChain™ Vortex Filter to prepare for its designated use of capturing particulate pollutants entering the system as a part of surface runoff.

Beyond this, the "Ingenieurbüro für Siedlungswasserwirtschaft", Dr. Dierschke and Xerxes have no relationship that would constitute a conflict of interest. For example, we have no ownership stake, do not receive commissions, do not have licensing agreements, and do not receive funds or grants beyond those associated with the testing program.

Mit freundlichen Grüßen,

with best regards,

Dr.-Ing. M. Dierschke

(office manager)

XERXES®

January 7th, 2022

New Jersey Corporation for Advanced Technology
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030

Attention: Dr. Richard Magee, Sc.D., P.E., BCEE
Subject: Xerxes HydroChain™ Vortex Filter (HCVF) Verification Report

Dear Dr. Magee,

We certify that the Xerxes HCVF was tested in strict adherence to the New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device (NJDEP, January 1, 2021).

We certify that all requirements and criteria were met or exceeded during testing of the HCPS device.

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

Sincerely,

Jim Merchlewitz
Business Development Manager, Shawcor

7901 Xerxes Avenue South
Suite 201
Minneapolis, MN
55431-1288

o + 1 952-887-1890
xerxes.com | Shawcor.com

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

January 7, 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 Xerxes HydroChain Vortex Filter (HCVF-4) at 3P Technik Filtersysteme GmbH (3P Technik) full scale test facility in Bad Überkingen under the direct supervision of an independent third-party observer, Dr.-Ing. Martina Dierschke from Frankfurt University of Applied Sciences, 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 (quartz) was mixed according to NJDEP Filtration Protocol requirements. The specific density of the material is 2.65 g/cm^3. The test sediment was a blend of commercially available silica sand grades supplied by Quarzwerke GmbH, Frechen/Germany. The sediment was blended by 3P Technik under observation of the third-party observer. Ten dry sediment random sample sub-samples were taken from the total batch of test sediment whenever the feeder was re-filled. The sampling was witnessed by the third-party observer. The sub-samples were mixed and homogenized to a composite sample. Three sub-samples of the composite sample were sent to RMB Environmental Laboratories, Hibbing MN/USA to verify that the supplied sediment met the requirements of Section 5B of the NJDEP Filtration Protocol. The d_{50} test sediment was 48 microns, much lower than the ≤ 75-micron protocol requirement.

Removal Efficiency Testing

Twenty (20) removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. Ten (10) of the 20 test runs were conducted during mass loading and 10 during removal efficiency testing. The average flow rate and influent sediment concentration were 53.6 gpm and 201.7 mg/L. The HCVF-4 demonstrated an average sediment removal efficiency on a cumulative mass basis of 80.1% over the course of the ten removal efficiency test runs and 84.0% for the 20 test runs.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted as a continuation of removal efficiency testing. Mass loading test runs were conducted using identical testing procedures and targets as those used in the removal efficiency runs. The HCVF-4 system demonstrated a mass loading capture capacity of 117.6 lbs.

Scour Testing

To demonstrate the ability of the HCVF to be used as an online treatment device, scour testing was conducted at 200% MTFR. After completion of the sediment mass loading capacity testing the sediment trap was filled to 4 inches below 50% of the volume capacity. Four inches of dry sediment in accordance with Table 1 was then added into the HCVF-4 sediment trap bringing the trap volume to 50% capacity. The first scour sample was taken approximately one hour after filling the unit with clear water and one minute earlier than the protocol requirement resulting in a more conservative test. The average adjusted effluent concentration was 18.9 mg/L, qualifying the HCVF for online installation.

Sincerely,

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

8. References

ASTM D422-63 (2007). *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D3977-97 (2013). *Standard Test Methods for Determining Concentrations in Water Samples*.

NJDEP 2013a. *New Jersey Department of Environmental Protection Laboratory Process for Approval of Use for Manufactured Treatment Devices.* Trenton, NJ. January 25, 2013.

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

NJDEP 2021. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*. Trenton, NJ. August 4, 2021.

VERIFICATION APPENDIX

Introduction

- Manufacturer – 3P Technik Filtersysteme GmbH, Robert-Bosch-Straße 16 – 18 D-73337 Bad Überkingen. *General Phone: +49 (0) 7334 92460-0. Website:* info@3ptechnik.de
- Distributor (North America) – Xerxes, 7901 Xerxes Ave. South Minneapolis, MN USA 55431-1288. *General Phone: 952-887-1890*. *Website:* http://www.xerxes.com/en/.
- TSS Removal Rate – 80%
- Online installation up to 200% MTFR

Detailed Specification

- Standard HydroChain Filter Cartridges Design Specifications (Cartridges) are attached as **Table A-1**.
- HydroChain Vortex Filter configurations maximum treatment flow rates (MTFRs), sediment storage amounts and sediment removal intervals per NJDEP sizing requirements are attached as **Table A-2**.
- Maximum inflow drainage area: The maximum inflow drainage area is governed by the maximum treatment flow rate or sediment loading on the filter for each filter arrangement as presented in **Table A-2**.
- For a reference maintenance plan, download the HydroChain Filter Cartridge Operation & Maintenance Manual at: Xerxes HydroChain Filter Installation O&M
- This device cannot be used in series with another MTD or a media filter (such as a sand filter) to achieve an enhanced removal rate for total suspended solids (TSS) removal per N.J.A.C. 7:8-5.5.

Table A-1 Xerxes HydroChain Filter Cartridges (HCFC) Design Specifications

Filter Model	EFTA[1] (ft^2)	Cartridge Volume[2] (ft^3)	MTFR[3] (gpm)	Max. Sed. Load[4] (lbs)	Scaling Ratios		
					MTFR:EFTA (gpm/ft^2)	ESTA:EFTA	WV[5]:EFTA (ft)
HCFC-4	1.63	2.45	13.39	29.4	8.24	1.30	6.77
HCFC-5	2.44	3.68	20.09	44.1	8.24	≥1.30	≥6.77

[1] EFTA is the cross sectional area of the filter media, i.e. the area perpendicular to the flow. Values were provided by 3P Technik and verified by Lake Superior Consulting.
[2] Provided by 3P Technik.
[3] Flow rate per cartridge is based on the MTFR of the tested HCVF-4 system (53.56 gpm) divided by the number of cartridges in the system (4 HCFC-4 cartridges).
[4] Sediment load per cartridge is based on the sediment load of the tested HCVF-4 system (117.64 lbs) divided by the number of cartridges in the system (4 HCFC-4 cartridges).
[5] The total wet volume is based on the wet volume of the sediment trap plus the wet volume above the platform. The cartridge volume is not included in the wet volume.

Table A-2 Xerxes HydroChain Vortex Filter Configurations and NJDEP Sizing Table

Vortex Filter Model	Manhole Diameter (ft)	Filter Cartridges Model[1]	No. of Cartridges	MTFR[2] (gpm)	EFTA (sq. ft)	ESTA (sq. ft)	Sediment Loading Capacity (lbs)	Max. Allow. Drainage Area[3] (acres)	Wet Volume[4] (cu. ft)
HCVF-4[1]	3.28	HCFC-4	4	53.6	6.5	8.45	117.6	0.20	44
HCVF-4	4	HCFC-4	4	53.6	6.5	12.6	117.6	0.20	59
HCVF-5	5	HCFC-5	6	120.5	14.6	19.6	264.7	0.44	99
HCVF-6	6	HCFC-5	7	140.6	17.1	28.3	308.8	0.51	130
HCVF-7	7	HCFC-5	8	160.7	19.5	38.5	352.9	0.59	182
HCVF-8	8	HCFC-5	12	241.0	29.3	50.3	529.4	0.88	232
HCVF-9	9	HCFC-5	18	361.5	43.9	63.6	794.0	1.32	297
HCVF-10	10	HCFC-5	20	401.7	48.8	78.5	882.3	1.47	358
HCVF-12	12	HCFC-5	32	642.7	78.1	113.1	1,411.6	2.35	529

[1] Test system: HCVF-4 values based on NJCAT testing results for 20 test runs with no unacceptable loss of hydraulic capacity at driving head or unacceptable head loss at MTFR. Other sizes are scaled.

[2] Systems are qualified for online installations up to 200% of the MTFR.

[3] Maximum allowable drainage area is based on the scaled sediment loading capacity from lab testing over an assumed 600 lbs per acre sediment load. Contact Xerxes for projects with other sediment loading capacity and treatment drainage area requirements.

[4] The test system's WV/EFTA scaling ratio was 6.77. Standard systems meet the minimum wet volume requirement with a typical sediment trap depth of 4-feet and an outlet invert set at 1.5 ft. above the platform. For several models (HCVF-5, HCVF-9 and HCVF-12) the outlet invert height above the platform is increased so that the Wet Volume shown for these models is achieved and the WV:EFTA scaling ratio requirement is met.