NJCAT TECHNOLOGY VERIFICATION

Cascade Separator™

Contech Engineered Solutions

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1. DESCRIPTION OF TECHNOLOGY

The Cascade Separator™ is a hydrodynamic separator designed to protect waterways from stormwater runoff. The device separates and traps trash, debris, sediment and hydrocarbons, even at high flow rates, and provides easy access for maintenance.

The Cascade Separator is commonly used as a standalone stormwater quality control practice and as pretreatment for filtration, detention/infiltration, bioretention, rainwater harvesting systems and Low Impact Development designs.

The Cascade Separator (**Figure 1**) accepts flow through an inlet. Water enters the inlet chamber where a specially designed insert splits the flow into two flumes, creating vortices that rotate in opposite directions in the center chamber. This creates high and low velocity regions in the center chamber that facilitates the settling of particles. As water travels downward through the center chamber, sediment settles into the sump area where it is retained until maintenance is performed. The slanted skirt provides scour protection during peak events and its incline facilitates sediment transport into the sump. Treated stormwater moves upwards, leaves the center cylinder through the outlet window and travels through the outlet channel before exiting the system. Refer to the black flow arrows in **Figure 2** for the treatment flow path. The outlet deck incorporates two pipes that extend downward and allow the system to drain to the outlet pipe invert elevation after the storm event has subsided, while also preventing captured hydrocarbons from leaving the system. The green arrows in **Figure 2** show the flow path through these components.

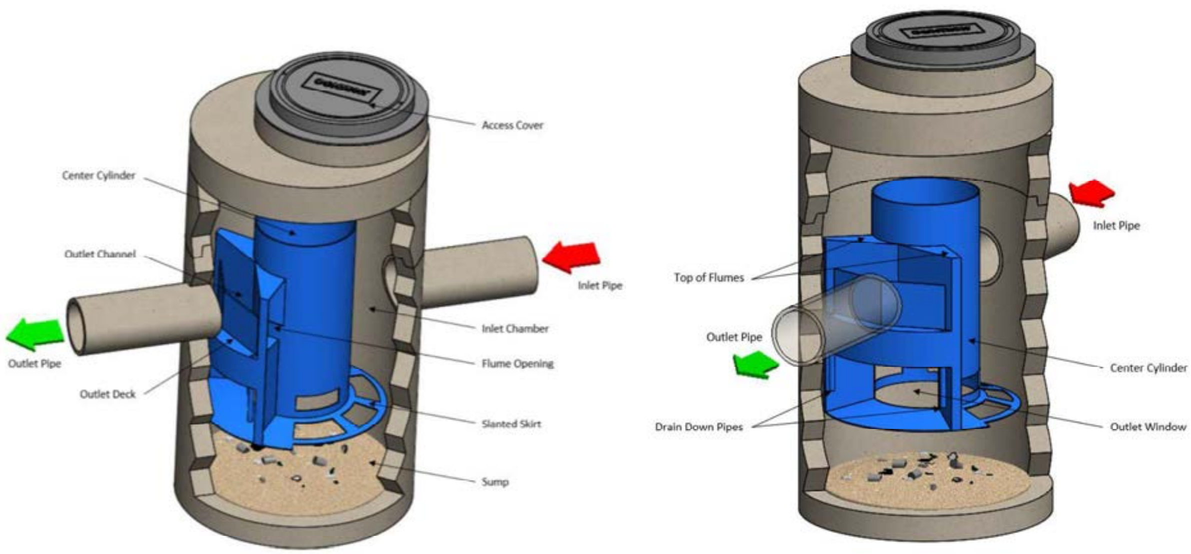

Figure 1: Model of the Cascade Separator

The Cascade Separator is designed to handle high flow rates without scouring previously captured pollutants. The unit is designed to accept a specific treatment flow rate with an internal flow bypass for storm events that exceed the treatment flow rate. While in internal bypass, the unit continues to treat the stormwater that enters the flumes and excess flow passes over the flumes and exits the system untreated. This internal bypass feature allows the Cascade Separator to be installed online, therefore eliminating the need for additional bypass structures. The red arrows in **Figure 2** show how excess flow is bypassed over the flumes.

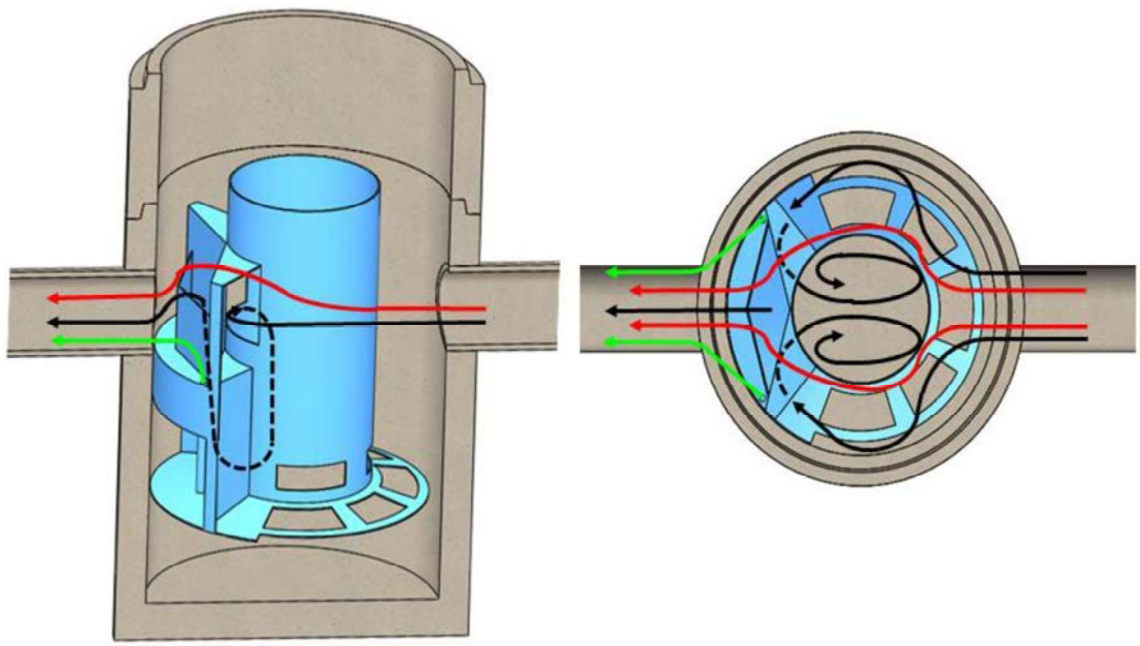

Figure 2: Cascade Separator Flow Paths

2. Laboratory Testing

All testing disclosed in this report was performed in accordance with the New Jersey Department of Environmental Protection (NJDEP) Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device (NJDEP Protocol) dated January 25, 2013.

All removal efficiency and scour testing for this project was carried out at Contech's Portland, Oregon laboratory in April 2019. Independent third-party observation was provided by Scott Wells, Ph.D. and his associate Chris Berger, Ph.D. Dr. Scott Wells and Dr. Chris Berger, from Portland State University, have extensive backgrounds in water quality. Dr. Scott Wells and Dr. Chris Berger have no conflict of interest that would disqualify them from serving as independent third-party observers during this testing process.

Samples for particle size distribution (PSD) were analyzed at Contech's laboratory, under observation, according to ASTM D422-63(2007) Standard Test Method for Particle-Size Analysis of Soils. Test sediment samples for moisture content were analyzed in-house, under observation, according to ASTM D2216-10 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. Samples for suspended solids concentration (SSC) analysis were sent to Apex Labs, an independent analytical facility, for processing according to ASTM D3977-97(2013) Standard Test Methods for Determining Sediment Concentration in Water Samples.

2.1. TEST UNIT

Laboratory testing used a full-scale, dimensionally accurate 4 ft diameter Cascade Separator (CS-4) lab model, whose components and material are comparable to the commercially available product (**Figure 3**). The Cascade Separator was housed in a 4 ft diameter aluminum manhole with aluminum influent and effluent pipes, equivalent in inner diameter to 24 in. PVC pipe (22.5 in. ID). The CS-4 has a depth of 48 in. from housing floor to effluent pipe invert. The CS-4 outlet channel height is 10.5 in. above the outlet pipe invert. The effective treatment area is 12.6 ft^2 and the maximum sediment storage capacity is 18.8 ft^3, or a depth of 18 in. above the floor. Both removal efficiency and scour testing were conducted at 50% of the maximum sediment storage depth. To accomplish this, an aluminum false floor was installed at 50% of the sediment storage depth during removal efficiency testing, or 39 in. below the outlet pipe invert. For scour testing, the false floor was adjusted to 43 in. below the inverts to accommodate the addition of 4 in. of pre-loaded scour sediment. The CS-4 permanent pool volume is 40.8 ft^3 from 50% sediment storage depth to outlet pipe invert. For this testing, the approximate full operation volume of 58.6 ft^3 (50% sediment storage depth to internal bypass elevation, 56 in. height) will be used to calculate the detention time as it is more conservative.

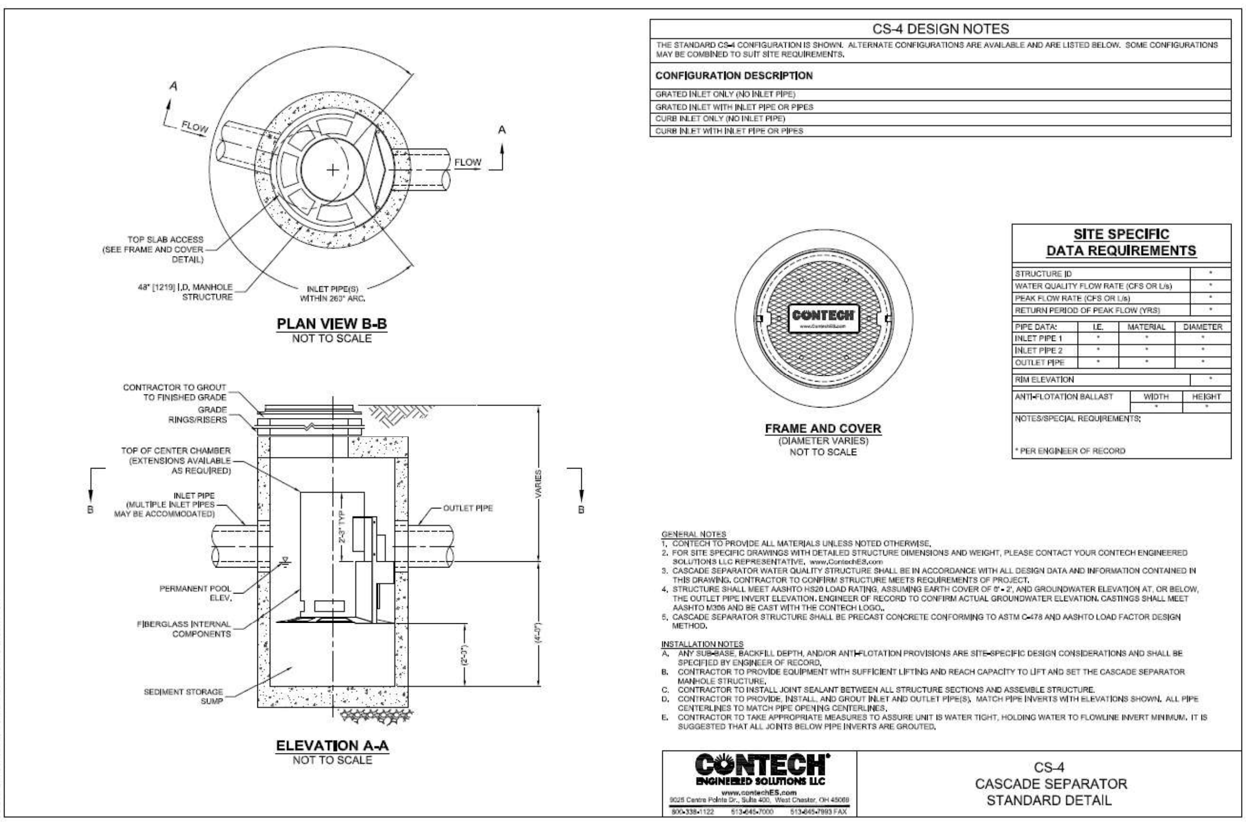

Figure 3: Cascade Separator Standard Detail

2.2. TEST SETUP

The Cascade Separator was tested on a recirculating system capable of delivering flow rates up to 5 cfs. Two distinct flow paths were utilized, one for removal efficiency testing (**Figure 4**) and the other, with additional flow capacity, for scour testing (**Figure 8**).

During removal efficiency tests, clean water was drawn from a 3,500-gal influent tank using a 15 HP, Berkeley B6ZPLS centrifugal pump (Pump 1). Closed loop flow-control was maintained with a proportional-integral-derivative (PID) -controlled variable frequency drive (VFD). The feedback signal to the VFD was provided from a Seametrics IMAG 4700 8 in. flowmeter. All flow from Pump 1 to the test unit was measured by the flowmeter and logged at 5 sec intervals. Influent flow traveled into a surge tank, which dampens variation in inlet water surface level (WSL). To ensure a steady-state flow condition and confirm the accuracy of the flow meter, the WSL in the surge tank was measured and logged at 5 sec intervals by a U-GAGE T30WXICQ8 ultrasonic level sensor. Water travelled from the surge tank into the influent pipe where background SSC samples were taken from a ¾ in. PVC pipe sampling port at the bottom of the influent pipe, upstream of the sediment injection point (**Figure 5**). Influent water was then dosed with sediment at the crown of the pipe from an Auger Feeders VF2 volumetric sediment feeder, located 112.5 in. upstream of the test unit (**Figure 6**). Influent water entered the manhole housing, was treated by the Cascade Separator, and exited the unit via the effluent pipe. Water exited the effluent pipe in a free-fall stream, where effluent SSC grab samples were taken by making a single sweeping pass through the cross section of the effluent stream before it entered the 2,350 gal effluent tank (**Figure 7**).

Effluent water traveled through an array of bag filters located inside the effluent tank and was then pumped through cartridge filter housings using a 25 HP Berkeley B5ZPBHS centrifugal pump (Pump 2). To maintain water balance between the isolated influent and effluent tanks, a closed-looped flow-control on Pump 2 was maintained using feedback from a Seametrics IMAG 4700 8 in. flowmeter. The filtered water was discharged into the influent tank for re-use. When necessary, clean water was brought into the system for dilution while excess effluent water was sent to an offline storage tank or drain. Flocculants were not used to reduce background SSC at any time.

The test water temperature was maintained using a Coates 32024CPH 24 kW heater, which recirculated influent water. Water temperature was measured in the surge tank with an Omega HSRTD-3-100-B-80-E resistance temperature detector and logged at 5 sec intervals.

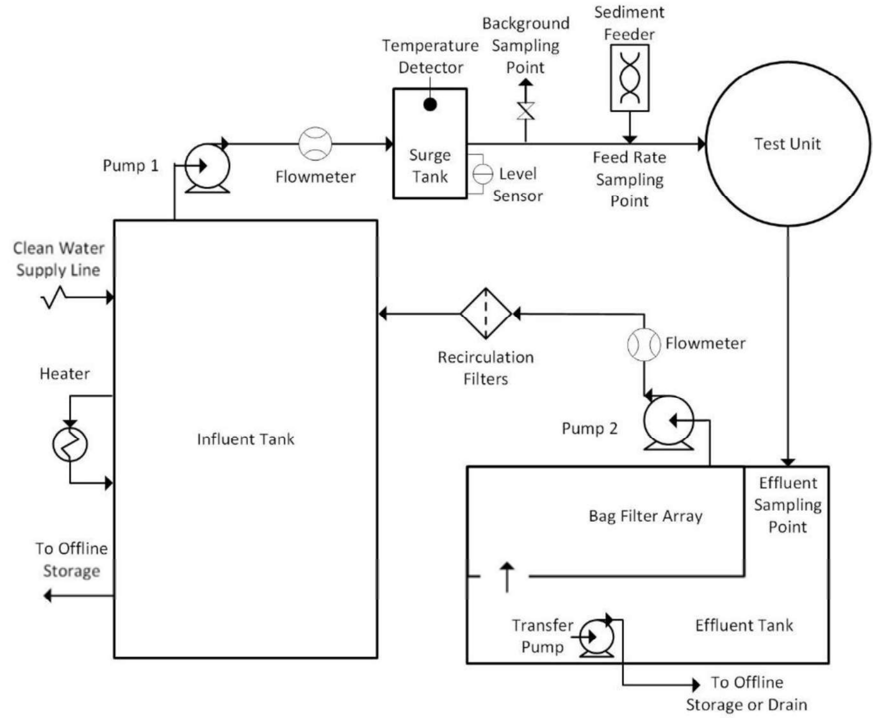

Figure 4: Lab Setup for Removal Efficiency Tests

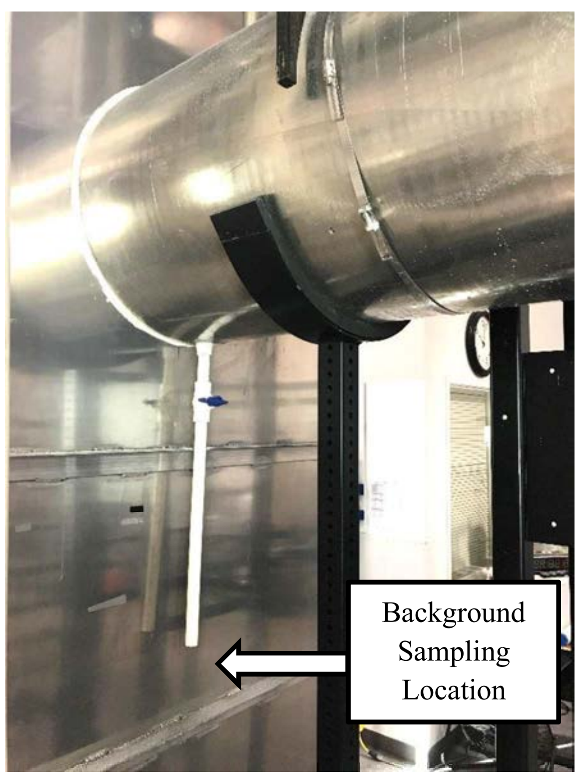

Figure 5: Background Sampling Location

Figure 6: Sediment Injection Location and Feed Rate Sampling Point

Figure 7: Manhole and Effluent Grab Sampling Location

To achieve the higher flow rates required for scour testing, the flow path shown in **Figure 8** was utilized. Target flow was achieved by directing the flow from Pump 1 and Pump 2 into the surge tank. The flow meters on each line measured flow from their respective pumps and the logged data was summed, representing the total flow to the test unit. Sediment was not injected into the influent stream with the feeder. Effluent water from the test unit was discharged into the effluent tank. At this point, water was either drawn by Pump 2 or directed to the influent tank via the transfer pumps and open connection pipe. It was necessary to direct effluent water to the influent tank to maintain water balance in the test system. While the transferred effluent water was unfiltered, background SSC remained below 20 mg/L because the effluent water concentration was also below 20 mg/L. The background and effluent SSC sampling points and all other functions of the test system were identical to the removal efficiency configuration.

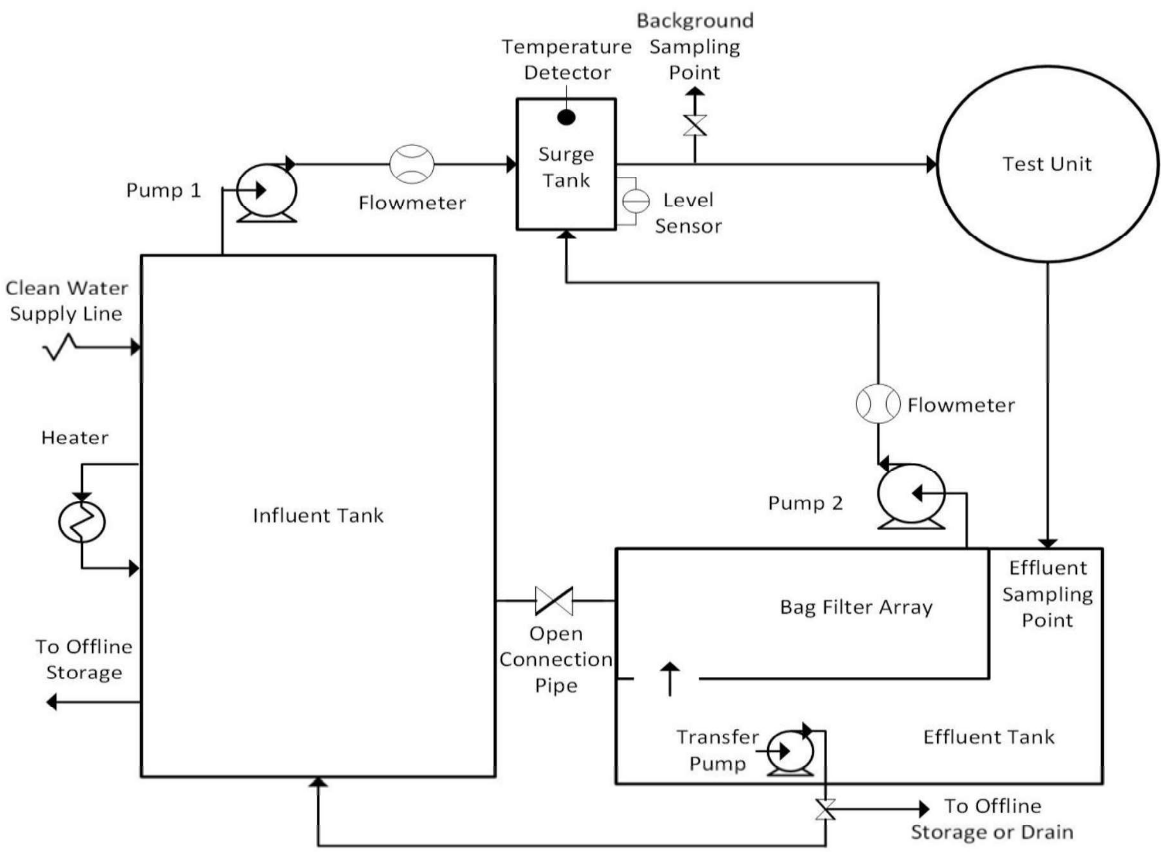

Figure 8: Lab Setup for Scour Test

2.3. Test Sediment

The sediment used for removal efficiency tests was a custom silica blend with a specific gravity of 2.65, provided by AGSCO corporation. Sediment sampling and analysis were conducted in-house, under third party observation prior to testing. The test sediment was batched, labeled and stored in covered bins for the duration of this project. Twelve subsamples, taken from various locations within the test sediment bins were composited. From the composite, three samples were taken for PSD analysis and three samples for moisture content analysis. The average PSD was used to determine compliance with the target PSD, outlined in Table 1, column 2 of the NJDEP Protocol. The average sediment moisture content was used in feed rate calculations (**Equation 1**) and influent mass calculations (**Equation 2**).

The sediment used for scour testing was a custom silica blend with a specific gravity of 2.65, also provided by AGSCO corporation. Sediment sampling and analysis were conducted in-house, under third party observation prior to testing. The test sediment was labeled and stored in either the manufacturer's bags or covered buckets. Twelve subsamples were taken from three randomly chosen bags and buckets and then composited. From the composite, three samples were taken for PSD analysis and three samples for moisture content analysis. The average PSD was used to determine compliance with the target PSD, outlined in Table 1, column 3 of the NJDEP Protocol. Moisture content was not used in any calculations.

2.4. Removal Efficiency Testing Procedure

Removal efficiency testing followed the effluent grab sampling test method outlined in Section 5 of the NJDEP Protocol. Discrete removal efficiency tests were performed at targets 25%, 50%, 75%, 100% and 125% of the 4-ft Cascade Separator maximum treatment flow rate (MTFR) of 1.80 cfs. All removal tests were conducted on a clean unit.

For each trial, testing commenced once the flow rate was stabilized at the target value for a minimum of three detention times. The flow rate was held steady during the test at ±10% of the target value with a coefficient of variation (COV) less than the allowed 0.03. Water temperature remained below 80 °F during all testing.

For each flow rate tested, sediment was injected at a known rate to produce a target average influent concentration of 200 mg/L (± 10%) with a COV of less than the allowed 0.10. Samples were collected in clean, 1 L bottles. Each sample was timed to the nearest 0.01 second with a Thomas Scientific 1235026 traceable stopwatch and was a minimum of 0.1 L or collected for 1 minute, whichever came first. The samples were weighed (in-house) to the nearest mg on a calibrated Ohaus AR3130 balance and feed rate was calculated using **Equation 1**. The influent mass per test was determined by measuring the sediment mass in the feeder before and after testing, subtracting the mass collected for feed rate samples, and correcting for moisture content (**Equation 2**). The feeder sediment mass was measured to the nearest 0.01 kg on a calibrated Fairbanks 70-2453-4 scale. Average influent SSC was calculated by dividing the influent mass by the volume of water sent to the test unit during sediment injection using **Equation 3**.

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

(Equation 1)

$$Influent\ Mass\ (kg) = (1 - Sediment\ Moisture\ Content) \times \left[Mass_{pre\cdot test}\ (kg) - Mass_{post\cdot test}(kg)\right] - \sum Mass_{feed\ samples}(g) \times \left(\frac{kg}{1E3\ g}\right)$$

(Equation 2)

$$Average\ Influent\ SSC\ \left({}^{mg}/_{L}\right) = \frac{Influent\ Mass\ (kg) \times \left(\frac{1E6\ mg}{kg}\right)}{Average\ Flow\ Rate\ \left({}^{ft^3}/_{s}\right) \times \left(\frac{28.3168\ L}{ft^3}\right) \times \left(\frac{60\ s}{min}\right) \times Time_{sediment\ injection}(min)}$$

(Equation 3)

Fifteen effluent grab samples were collected at evenly spaced intervals during each removal efficiency test. When the sediment stream was interrupted for feed rate sampling, effluent sampling began after a minimum of three detention times passed. Each sample volume was a minimum of 0.5 L. Samples were collected in clean, 1 L bottles by sweeping the bottle through the cross-section of the free-discharge effluent stream in a single pass.

Fifteen background SSC samples were taken at paired sampling times with effluent SSC samples during each removal efficiency test. Each sample was a minimum of 0.5 L and collected in a clean, 1 L bottle from the background sampling port. Samples were collected after the port valve was opened and the line was flushed. Average background concentration did not exceed 20 mg/L during any test. In cases where SSC was reported as non-detect, a value of half the reported detection limit was substituted. Paired background SSC was used to adjust effluent SSC and the adjusted effluent SSC values were averaged (**Equation 4**).

$$Average\ Adjusted\ Effluent\ SSC\ \left({}^{mg}/_{L}\right) = \frac{1}{15}\sum_{i=1}^{15}\left[Effluent\ SSC\left({}^{mg}/_{L}\right) - Background\ SSC\ \left({}^{mg}/_{L}\right)\right]_i$$ **(Equation 4)**

Removal efficiency at each flow rate was calculated using (**Equation 5**). The discrete removal efficiencies were then weighted, using the weighting factors outlined in Table 1 of Appendix A, Section A in the NJDEP Protocol. The weighted removal efficiencies were summed and reported as the annualized weighted removal efficiency at the MTFR.

$$Removal\ Efficiency\ (\%) = \frac{Average\ Influent\ SSC\ \left({}^{mg}/_{L}\right) - Average\ Adjusted\ Effluent\ \left({}^{mg}/_{L}\right)}{Average\ Influent\ SSC\ \left({}^{mg}/_{L}\right)} \times 100$$ **(Equation 5)**

2.5. Scour Testing Procedure

The Cascade Separator was tested under online installation conditions following the procedure described in Section 4 of the NJDEP Protocol. The false floor was adjusted to 4 in. below the 50% sediment storage capacity height and pre-loaded with 4 in. of leveled scour test sediment. The unit was filled with tap water and testing commenced within 72 hrs.

The test began when flow was directed to the pre-loaded unit. The flow rate was gradually increased over a 5 min period until it reached the target of 4.0 cfs (222% of the MTFR). For the remainder of the test, the flow rate was held steady at ±10% of the target rate with a COV less than the allowed 0.03. Water temperature remained below 80 °F during the test.

Once the target flow was reached at 5 min after the start of the test, the sampling period began. Effluent was sampled at the beginning of the sampling period and every 2 min after, until a total of 15 samples were taken. The duration of the sampling period was 28 min. Each grab sample was at least 0.5 L and was collected in a clean, 1 L bottle by sweeping the bottle through the cross-section of the free-discharge effluent stream in a single pass.

Fifteen background SSC samples were taken at paired sampling times with effluent SSC samples during the scour test. Each sample was a minimum of 0.5 L and collected in a clean, 1 L bottle from the background sampling port. Samples were collected after the port valve was opened and the line was flushed. In cases where SSC was reported as non-detect, a value of half the reported detection limit was substituted. Paired background SSC was used to adjust effluent SSC. The adjusted effluent SSC values were averaged (**Equation 4**) and the average value did not exceed 20 mg/L. In addition, average background concentration did not exceed 20 mg/L.

3. Performance Claims

The following performance claims are specific to the 4 ft Cascade Separator, the model size tested following the NJDEP Protocol. Additional information for all available models is provided in **Table A-1**.

Verified Total Suspended Solids Removal Rates

The CS-4 exceeded the annualized weighted total suspended solids (TSS) removal rate of 50% at an MTFR of 1.80 cfs. The removal rate of 54.8% was determined according to the procedure and calculations described in the NJDEP Protocol and rounded down to 50% per Section C in the Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (NJDEP Verification Procedure) dated January 25, 2013.

Maximum Treatment Flow Rate

The 4-ft Cascade Separator MTFR was determined to be 1.80 cfs or 808 gpm. The corresponding hydraulic loading rate is 64.3 gpm/ft^2 of effective treatment area.

Maximum Sediment Storage Depth and Volume

The maximum sediment storage depth is 18 in. on all Cascade Separator models. The CS-4 has a maximum sediment storage volume of 18.8 ft^3 and a 50% full sediment storage volume of 9.4 ft^3.

Effective Treatment Area

The effective treatment area, or sedimentation area is 12.6 ft^3 on the CS-4.

Detention Time and Volume

The permanent pool volume of the CS-4 is 40.8 ft^3 from the 50% maximum sediment storage depth to invert. The full operation volume is approximately 58.6 ft^3 from the 50% maximum sediment storage depth to the internal bypass height. Detention time will vary by flow rate, **Table 4** shows the detention times (using the full operation volume) for the average flow rates tested according to the NJDEP Protocol.

Online or Offline Installation

The Cascade Separator qualifies for online installation by meeting the NJDEP Protocol scour requirements at 4.0 cfs, over 200% of the CS-4 MTFR.

4. SUPPORTING DOCUMENTATION

The NJDEP Verification Procedure, Section 5.D 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 the New Jersey Corporation for Advanced Technology (NJCAT) upon request that it would not be prudent or necessary to include all this information in this verification report.

4.1. TEST SEDIMENT PSD

The average removal efficiency test sediment PSD and NJDEP specification are presented in **Table 1.** For a clear comparison, the percent finer values were interpolated to match the particle diameters listed in Table 1 of the NJDEP Protocol. The test sediment distribution was finer than the specification, with a d50 particle size of 57 µm. The average moisture content was determined to be 0.1%.

The average scour test sediment PSD and NJDEP specified requirements are presented in **Table 2.** For a clear comparison, the percent finer values were interpolated to match the particle diameters listed in Table 1 of the NJDEP Protocol. The test sediment distribution was finer than the specification, with a d50 particle size of 192 µm.

Table 1: Average Removal Efficiency Test Sediment PSD

Particle Diameter (µm)	Percent Finer by Mass (%)		
	NJDEP Specification	NJDEP Minimum Allowable	Average Removal Efficiency Test Sediment
1000	100	98	99
500	95	93	96
250	90	88	91
150	75	73	81
100	60	58	65
75	50	48	55
50	45	43	47
20	35	33	36
8	20	18	25
5	10	8	18
2	5	3	8
d50	< 75 µm	-	57 µm

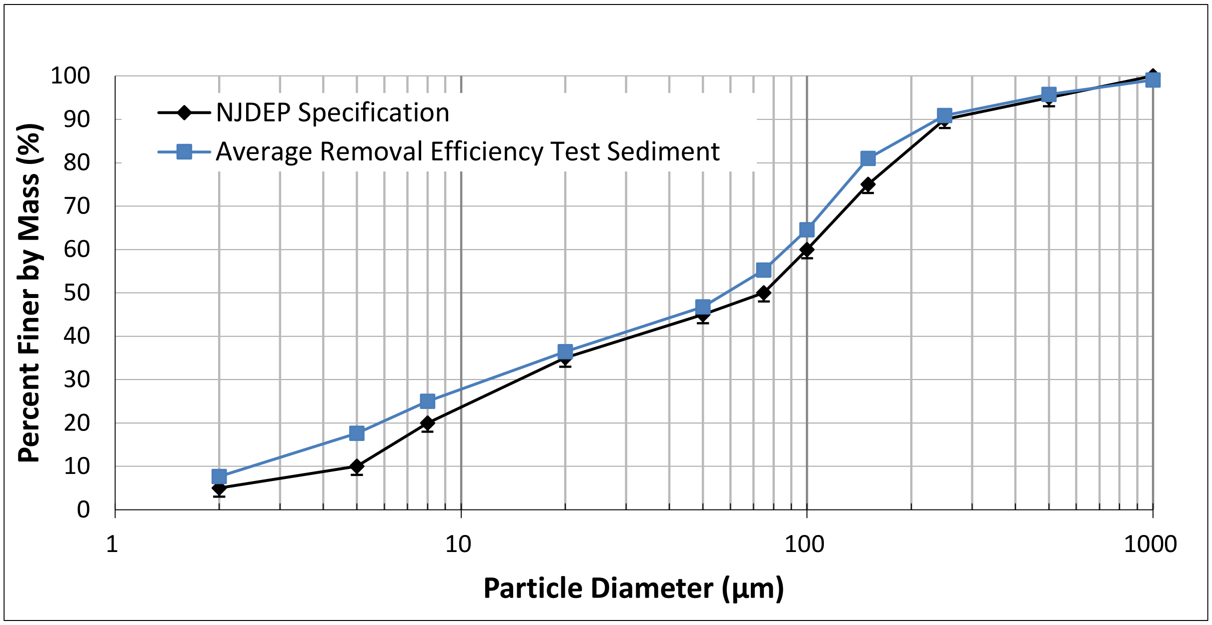

Figure 9: Average Removal Efficiency Test Sediment PSD

Table 2: Average Scour Test Sediment PSD

Particle Diameter (µm)	Percent Finer by Mass (%)		
	NJDEP Specification	NJDEP Minimum Allowable	Average Scour Test Sediment
1000	100	98	100
500	90	88	91
250	55	53	59
150	40	38	44
100	25	23	26
75	10	8	15
50	0	0	2
20	0	0	0
8	0	0	0
5	0	0	0
2	0	0	0
d50	-	-	192 µm

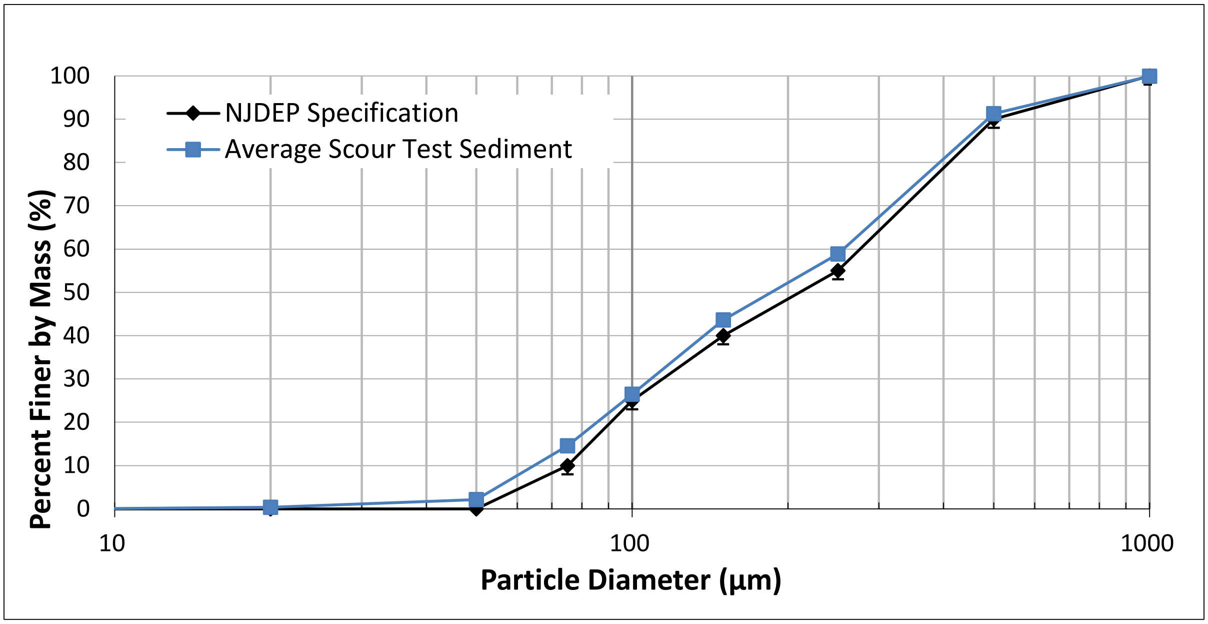

Figure 10: Average Scour Test Sediment PSD

4.2. Removal Efficiency Testing

The Cascade Separator achieved an annualized weighted removal efficiency of 54.8% at an MTFR of 1.80 cfs. The removal efficiency results are summarized in **Table 3** and **Figure 11**. All tests met the NJDEP Protocol requirements and QA/QC parameters (**Table 4**).

Table 3: Summary of Removal Efficiency Results

PERFORMANCE SUMMARY						
Test ID	Average Flow Rate (ft^3/s)	Average Influent SSC (mg/L)	Average Adjusted Effluent SSC (mg/L)	Removal Efficiency (%)	Weighting Factor	Weighted Removal Efficiency (%)
25%	0.46	199	63.7	68.1	0.25	17.0
50%	0.91	199	80.2	59.6	0.30	17.9
75%	1.36	198	97.1	51.0	0.20	10.2
100%	1.81	200	116	42.0	0.15	6.3
125%	2.26	191	127	33.5	0.10	3.3
Annualized Weighted Removal Efficiency at MTFR of 1.80 cfs (%):						**54.8**

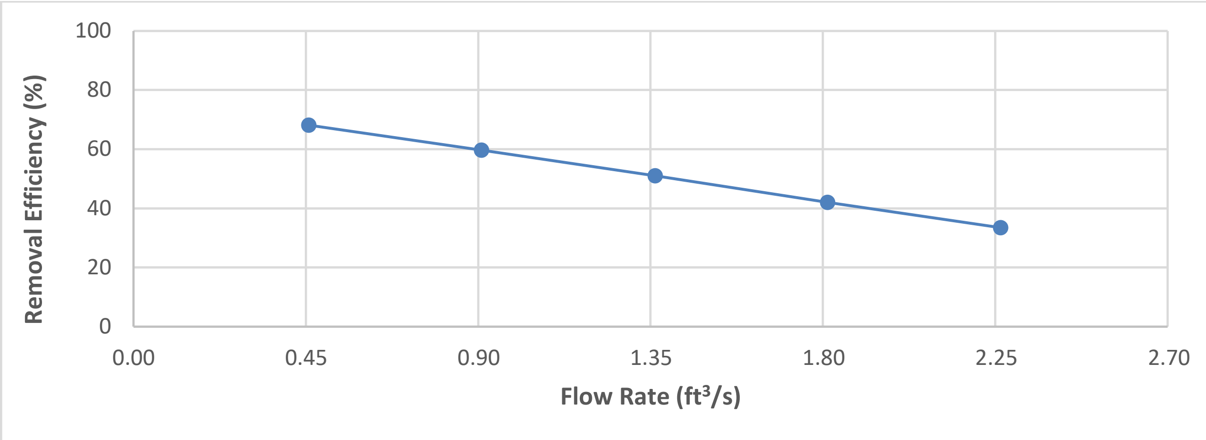

Figure 11: Removal Efficiency Results

Table 4: Summary Removal Efficiency QA/QC Results

FLOW RATE AND WATER TEMPERATURE							
Test ID	**QAQC PASS/FAIL**	**Target Flow Rate (ft^3/s)**	**Average Flow Rate (ft^3/s)** (± 10%)	**Detention Time (min)**	**Flow Rate COV** (< 0.03)	**Surge Tank WSL COV**	**Maximum Water Temperature (°F)** (< 80 °F)
25%	PASS	0.45	0.46	2.14	0.01	0.002	75.7
50%	PASS	0.90	0.91	1.08	0.01	0.003	75.7
75%	PASS	1.35	1.36	0.72	0.01	0.006	76.0
100%	PASS	1.80	1.81	0.54	0.01	0.007	73.8
125%	PASS	2.25	2.26	0.43	0.01	0.009	75.2
INFLUENT AND BACKGROUND CONCENTRATION							
Test ID	**QAQC PASS/FAIL**	**Target Influent SSC (mg/L)**	**Average Influent SSC (mg/L)** (± 10%)	**Feed Rate COV** (< 0.10)	**Average Background SSC** (< 20 mg/L)	**Minimum SSC Sample Volume (mL)** (> 500 mL)	
25%	PASS	200	199	0.03	0.72	692	
50%	PASS	200	199	0.02	0.68	659	
75%	PASS	200	198	0.01	0.62	710	
100%	PASS	200	200	0.01	0.89	741	
125%	PASS	200	191	0.02	7.74	722	

25% MTFR Results

The Cascade Separator removed 68.1% of influent mass at an average flow rate of 0.46 cfs (**Table 3**). All NJDEP Protocol requirements and QA/QC parameters were met (**Table 4**). Background SSC, effluent SSC and feed rate measurements along with their corresponding sampling times are shown in **Table 5**.

Table 5: 25% MTFR Background SSC, Effluent SSC and Feed Rate Measurements

Background Sample ID	Test Time (mm:ss)	Reported Background SSC (mg/L)	Corresponding Detection Limit (mg/L)	Background SSC (mg/L)
BACK 1	07:45	ND	1.29	0.65
BACK 2	08:00	ND	1.28	0.64
BACK 3	08:15	ND	1.25	0.63
BACK 4	16:15	ND	1.30	0.65
BACK 5	16:30	ND	1.28	0.64
BACK 6	16:45	ND	1.28	0.64
BACK 7	24:45	ND	1.19	0.60
BACK 8	25:00	ND	1.29	0.65
BACK 9	25:15	ND	1.22	0.61
BACK 10	33:15	ND	1.43	0.72
BACK 11	33:30	ND	1.33	0.67
BACK 12	33:45	ND	1.30	0.65
BACK 13	41:45	ND	1.11	0.56
BACK 14	42:00	1.25	1.25	1.25
BACK 15	42:15	1.21	1.21	1.21
			Average	**0.72**

Effluent Sample ID	Test Time (mm:ss)	Effluent SSC (mg/L)	Paired Background SSC (mg/L)	Adjusted Effluent SSC (mg/L)
EFF 1	07:45	64.0	0.65	63.4
EFF 2	08:00	63.3	0.64	62.7
EFF 3	08:15	65.1	0.63	64.5
EFF 4	16:15	63.3	0.65	62.7
EFF 5	16:30	60.5	0.64	59.9
EFF 6	16:45	61.3	0.64	60.7
EFF 7	24:45	64.2	0.60	63.6
EFF 8	25:00	62.7	0.65	62.1
EFF 9	25:15	65.7	0.61	65.1
EFF 10	33:15	65.8	0.72	65.1
EFF 11	33:30	67.2	0.67	66.5
EFF 12	33:45	67.1	0.65	66.5
EFF 13	41:45	66.2	0.56	65.6
EFF 14	42:00	66.3	1.25	65.1
EFF 15	42:15	62.8	1.21	61.6
			Average	**63.7**

Feed Rate Sample ID	Test Time (mm:ss)	Moisture Corrected Sample Mass (g)	Sampling Duration (s)	Feed Rate (g/min)	Calculated Influent SSC (mg/L)
FEED 1	00:00	140.155	55.19	152.370	196
FEED 2	08:30	138.976	55.22	151.006	194
FEED 3	17:00	143.888	55.22	156.343	201
FEED 4	25:30	140.121	55.10	152.582	196
FEED 5	34:00	148.123	55.12	161.236	207
FEED 6	42:31	144.796	55.09	157.701	203
			Average	**155.207**	

Influent Mass (kg)	Injection Duration (min)	Influent Water Volume (L)	Average Influent SSC (mg/L)
5.88	37.92	29,468	199

50% MTFR Results

The Cascade Separator removed 59.6% of influent mass at an average flow rate of 0.91 cfs (**Table 3**). All NJDEP Protocol requirements and QA/QC parameters were met (**Table 4**). Background SSC, effluent SSC and feed rate measurements along with their corresponding sampling times are shown in **Table 6**.

Table 6: 50% MTFR Background SSC, Effluent SSC and Feed Rate Measurements

Background Sample ID	Test Time (mm:ss)	Reported Background SSC (mg/L)	Corresponding Detection Limit (mg/L)	Background SSC (mg/L)
BACK 1	04:15	ND	1.21	0.61
BACK 2	04:30	ND	1.35	0.68
BACK 3	04:45	ND	1.24	0.62
BACK 4	09:15	ND	1.39	0.70
BACK 5	09:30	ND	1.21	0.61
BACK 6	09:45	ND	1.28	0.64
BACK 7	14:15	ND	1.22	0.61
BACK 8	14:30	ND	1.35	0.68
BACK 9	14:45	ND	1.36	0.68
BACK 10	19:15	ND	1.30	0.65
BACK 11	19:30	1.21	1.21	1.21
BACK 12	19:45	ND	1.20	0.60
BACK 13	24:15	ND	1.35	0.68
BACK 14	24:30	ND	1.27	0.64
BACK 15	24:45	ND	1.30	0.65
			Average	**0.68**

Effluent Sample ID	Test Time (mm:ss)	Effluent SSC (mg/L)	Paired Background SSC (mg/L)	Adjusted Effluent SSC (mg/L)
EFF 1	04:15	77.6	0.61	77.0
EFF 2	04:30	75.5	0.68	74.8
EFF 3	04:45	77.3	0.62	76.7
EFF 4	09:15	82.0	0.70	81.3
EFF 5	09:30	80.1	0.61	79.5
EFF 6	09:45	86.1	0.64	85.5
EFF 7	14:15	78.3	0.61	77.7
EFF 8	14:30	83.6	0.68	82.9
EFF 9	14:45	82.0	0.68	81.3
EFF 10	19:15	78.4	0.65	77.8
EFF 11	19:30	83.4	1.21	82.2
EFF 12	19:45	78.6	0.60	78.0
EFF 13	24:15	83.7	0.68	83.0
EFF 14	24:30	83.3	0.64	82.7
EFF 15	24:45	83.3	0.65	82.7
			Average	**80.2**

Feed Rate Sample ID	Test Time (mm:ss)	Moisture Corrected Sample Mass (g)	Sampling Duration (s)	Feed Rate (g/min)	Calculated Influent SSC (mg/L)
FEED 1	00:00	180.868	35.10	309.176	200
FEED 2	05:00	185.801	35.03	318.244	206
FEED 3	10:00	177.532	35.13	303.214	196
FEED 4	15:00	188.480	35.16	321.638	208
FEED 5	20:00	180.920	35.03	309.883	201
FEED 6	25:00	179.492	35.09	306.914	199
			Average	**311.512**	

Influent Mass (kg)	Injection Duration (min)	Influent Water Volume (L)	Average Influent SSC (mg/L)
6.77	22.08	34,087	199

75% MTFR Results

The Cascade Separator removed 51.0% of influent mass at an average flow rate of 1.36 cfs (**Table 3**). All NJDEP Protocol requirements and QA/QC parameters were met (**Table 4**). Background SSC, effluent SSC and feed rate measurements along with their corresponding sampling times are shown in **Table 7.**

Table 7: 75% MTFR Background SSC, Effluent SSC and Feed Rate Measurements

Background Sample ID	Test Time (mm:ss)	Reported Background SSC (mg/L)	Corresponding Detection Limit (mg/L)	Background SSC (mg/L)
BACK 1	02:45	ND	1.16	0.58
BACK 2	03:00	ND	1.16	0.58
BACK 3	03:15	ND	1.16	0.58
BACK 4	06:15	ND	1.18	0.59
BACK 5	06:30	ND	1.27	0.64
BACK 6	06:45	ND	1.13	0.57
BACK 7	09:45	ND	1.25	0.63
BACK 8	10:00	ND	1.30	0.65
BACK 9	10:15	ND	1.35	0.68
BACK 10	13:15	ND	1.31	0.66
BACK 11	13:30	ND	1.32	0.66
BACK 12	13:45	ND	1.33	0.67
BACK 13	16:45	ND	1.11	0.56
BACK 14	17:00	ND	1.14	0.57
BACK 15	17:15	ND	1.28	0.64
			Average	**0.62**

Effluent Sample ID	Test Time (mm:ss)	Effluent SSC (mg/L)	Paired Background SSC (mg/L)	Adjusted Effluent SSC (mg/L)
EFF 1	02:45	89.2	0.58	88.6
EFF 2	03:00	94.5	0.58	93.9
EFF 3	03:15	92.2	0.58	91.6
EFF 4	06:15	94.3	0.59	93.7
EFF 5	06:30	102	0.64	101
EFF 6	06:45	105	0.57	104
EFF 7	09:45	93.4	0.63	92.8
EFF 8	10:00	98.5	0.65	97.9
EFF 9	10:15	98.8	0.68	98.1
EFF 10	13:15	97.0	0.66	96.3
EFF 11	13:30	96.5	0.66	95.8
EFF 12	13:45	96.5	0.67	95.8
EFF 13	16:45	98.3	0.56	97.7
EFF 14	17:00	105	0.57	104
EFF 15	17:15	104	0.64	103
			Average	**97.1**

Feed Rate Sample ID	Test Time (mm:ss)	Moisture Corrected Sample Mass (g)	Sampling Duration (s)	Feed Rate (g/min)	Calculated Influent SSC (mg/L)
FEED 1	00:00	194.252	25.22	462.139	200
FEED 2	03:30	190.581	25.00	457.395	198
FEED 3	07:00	188.105	25.15	448.760	194
FEED 4	10:30	192.013	25.05	459.912	199
FEED 5	14:00	195.787	25.13	467.458	202
FEED 6	17:30	193.037	25.06	462.180	200
			Average	**459.641**	

Influent Mass (kg)	Injection Duration (min)	Influent Water Volume (L)	Average Influent SSC (mg/L)
7.07	15.41	35,659	198

100% MTFR Results

The Cascade Separator removed 42.0% of influent mass at an average flow rate of 1.81 (**Table 3**). All NJDEP Protocol requirements and QA/QC parameters were met (**Table 4**). Background SSC, effluent SSC and feed rate measurements along with their corresponding sampling times are shown in **Table 8**.

Table 8: 100% MTFR Background SSC, Effluent SSC and Feed Rate Measurements

Background Sample ID	Test Time (mm:ss)	Reported Background SSC (mg/L)	Corresponding Detection Limit (mg/L)	Background SSC (mg/L)
BACK 1	02:15	ND	1.14	0.57
BACK 2	02:30	ND	1.22	0.61
BACK 3	02:45	ND	1.27	0.64
BACK 4	05:15	ND	1.20	0.60
BACK 5	05:30	ND	1.27	0.64
BACK 6	05:45	ND	1.17	0.59
BACK 7	08:15	ND	1.15	0.58
BACK 8	08:30	ND	1.23	0.62
BACK 9	08:45	ND	1.33	0.67
BACK 10	11:15	1.13	1.13	1.13
BACK 11	11:30	ND	1.33	0.67
BACK 12	11:45	1.37	1.25	1.37
BACK 13	14:15	1.70	1.14	1.70
BACK 14	14:30	1.70	1.14	1.70
BACK 15	14:45	1.27	1.27	1.27
			Average	**0.89**

Effluent Sample ID	Test Time (mm:ss)	Effluent SSC (mg/L)	Paired Background SSC (mg/L)	Adjusted Effluent SSC (mg/L)
EFF 1	02:15	109	0.57	108
EFF 2	02:30	117	0.61	116
EFF 3	02:45	121	0.64	120
EFF 4	05:15	114	0.60	113
EFF 5	05:30	115	0.64	114
EFF 6	05:45	115	0.59	114
EFF 7	08:15	115	0.58	114
EFF 8	08:30	123	0.62	122
EFF 9	08:45	115	0.67	114
EFF 10	11:15	121	1.13	120
EFF 11	11:30	117	0.67	116
EFF 12	11:45	113	1.37	112
EFF 13	14:15	115	1.70	113
EFF 14	14:30	129	1.70	127
EFF 15	14:45	118	1.27	117
			Average	**116**

Feed Rate Sample ID	Test Time (mm:ss)	Moisture Corrected Sample Mass (g)	Sampling Duration (s)	Feed Rate (g/min)	Calculated Influent SSC (mg/L)
FEED 1	00:00	206.718	20.00	620.155	201
FEED 2	03:00	204.366	19.91	615.870	200
FEED 3	06:00	203.260	20.09	607.049	197
FEED 4	09:00	210.922	20.09	629.931	205
FEED 5	12:00	261.014	25.40	616.567	200
FEED 6	15:00	206.091	20.12	614.585	200
			Average	**617.360**	

Influent Mass (kg)	Injection Duration (min)	Influent Water Volume (L)	Average Influent SSC (mg/L)
8.17	13.24	40,769	200

125% MTFR RESULTS

The Cascade Separator removed 33.5% of influent mass at an average flow rate of 2.26 cfs (**Table 3**). All NJDEP Protocol requirements and QA/QC parameters were met (**Table 4**). Background SSC, effluent SSC and feed rate measurements along with their corresponding sampling times are shown in **Table 9.**

Table 9: 125% MTFR Background SSC, Effluent SSC and Feed Rate Measurements

Background Sample ID	Test Time (mm:ss)	Reported Background SSC (mg/L)	Corresponding Detection Limit (mg/L)	Background SSC (mg/L)
BACK 1	02:00	1.19	1.19	1.19
BACK 2	02:15	ND	1.29	0.65
BACK 3	02:30	ND	1.21	0.61
BACK 4	04:45	3.50	1.25	3.50
BACK 5	05:00	3.96	1.24	3.96
BACK 6	05:15	4.14	1.25	4.14
BACK 7	07:30	9.14	1.25	9.14
BACK 8	07:45	9.48	1.34	9.48
BACK 9	08:00	9.21	1.12	9.21
BACK 10	10:15	9.20	1.23	9.20
BACK 11	10:30	10.5	1.28	10.5
BACK 12	10:45	11.1	1.37	11.1
BACK 13	13:00	15.3	1.12	15.3
BACK 14	13:15	13.5	1.33	13.5
BACK 15	13:30	14.6	1.27	14.6
			Average	**7.74**

Effluent Sample ID	Test Time (mm:ss)	Effluent SSC (mg/L)	Paired Background SSC (mg/L)	Adjusted Effluent SSC (mg/L)
EFF 1	02:00	122	1.19	121
EFF 2	02:15	128	0.65	127
EFF 3	02:30	121	0.61	120
EFF 4	04:45	116	3.50	113
EFF 5	05:00	123	3.96	119
EFF 6	05:15	133	4.14	129
EFF 7	07:30	131	9.14	122
EFF 8	07:45	137	9.48	128
EFF 9	08:00	143	9.21	134
EFF 10	10:15	141	9.20	132
EFF 11	10:30	145	10.5	135
EFF 12	10:45	144	11.1	133
EFF 13	13:00	142	15.3	127
EFF 14	13:15	149	13.5	136
EFF 15	13:30	142	14.6	127
			Average	**127**

Feed Rate Sample ID	Test Time (mm:ss)	Moisture Corrected Sample Mass (g)	Sampling Duration (s)	Feed Rate (g/min)	Calculated Influent SSC (mg/L)
FEED 1	00:00	179.571	15.00	718.285	187
FEED 2	02:45	186.966	15.19	738.511	192
FEED 3	05:30	190.395	15.15	754.042	196
FEED 4	08:16	187.604	15.16	742.495	193
FEED 5	11:00	187.862	15.10	746.470	194
FEED 6	13:45	191.488	15.22	754.879	196
			Average	**742.447**	

Influent Mass (kg)	Injection Duration (min)	Influent Water Volume (L)	Average Influent SSC (mg/L)
9.16	12.49	48,052	191

4.3. Scour Testing

Scour testing was conducted in accordance with Section 4 of the NJDEP Protocol at a target flow rate greater than 200% of the Cascade Separator MTFR to qualify the MTD for online installation. The average test flow rate was 4.03 cfs or 224% of the 1.80 cfs MTFR. The average adjusted effluent SSC for this test was 3.57 mg/L, well below the maximum allowable SSC of 20 mg/L.

The test passed all QA/QC parameters and NJDEP Protocol requirements (**Table 10**). As described in **Section 2.2**, the flow from two pumps (Pumps 1 and 2) were combined upstream of the test unit, the sum of which represents a total flow rate into the unit (**Figure 12**). The flow rate COV of each pump as well as the total flow rate COV are all below the maximum allowed COV of 0.03.

Table 10: Scour Test QA/QC and Results Summary

QA/QC and RESULTS SUMMARY					
PASS/FAIL	**Target Flow Rate (ft^3/s)**	**Average Total Flow Rate (ft^3/s)** (± 10% of Target)	**Flow Rate as % of MTFR** (≥ 200%)	**Average Pump 1 Flow Rate (ft^3/s)**	**Average Pump 2 Flow Rate (ft^3/s)**
PASS	4.00	4.03	224	2.02	2.01
PASS/FAIL	**Total Flow Rate COV** (< 0.03)	**Pump 1 COV** (< 0.03)	**Pump 2 COV** (< 0.03)	**Surge Tank WSL COV**	**Maximum Water Temperature (°F)** (< 80°F)
PASS	0.01	0.01	0.01	0.02	77.2
PASS/FAIL	**Average Background SSC (mg/L)** (< 20 mg/L)	**Average Adjusted Effluent SSC (mg/L)** (< 20 mg/L)	**Minimum SSC Sample Volume (mL)** (> 500 mL)		
PASS	3.36	3.57	675		

Table 11: Scour Background SSC and Effluent SSC Measurements

Background Sample ID	Test Time (mm:ss)	Background SSC, as Reported (mg/L)	Corresponding Detection Limit (mg/L)	Background SSC (mg/L)
BACK 1	05:00	2.20	1.47	2.20
BACK 2	07:00	1.57	1.43	1.57
BACK 3	09:00	2.94	1.22	2.94
BACK 4	11:00	2.08	1.39	2.08
BACK 5	13:00	2.28	1.27	2.28
BACK 6	15:00	3.77	1.30	3.77
BACK 7	17:00	5.06	1.26	5.06
BACK 8	19:00	4.68	1.30	4.68
BACK 9	21:00	4.38	1.12	4.38
BACK 10	23:00	6.21	1.32	6.21
BACK 11	25:00	4.22	1.28	4.22
BACK 12	27:00	3.77	1.30	3.77
BACK 13	29:00	3.65	1.30	3.65
BACK 14	31:00	4.73	1.31	4.73
BACK 15	33:00	3.31	1.27	3.31
			Average	**3.66**

Effluent Sample ID	Test Time (mm:ss)	Effluent SSC (mg/L)	Background SSC (mg/L)	Adjusted Effluent SSC (mg/L)
EFF 1	05:00	2.27	2.20	0.07
EFF 2	07:00	5.86	1.57	4.29
EFF 3	09:00	4.94	2.94	2.00
EFF 4	11:00	5.82	2.08	3.74
EFF 5	13:00	10.0	2.28	7.72
EFF 6	15:00	6.20	3.77	2.43
EFF 7	17:00	11.7	5.06	6.64
EFF 8	19:00	8.72	4.68	4.04
EFF 9	21:00	8.74	4.38	4.36
EFF 10	23:00	7.68	6.21	1.47
EFF 11	25:00	6.15	4.22	1.93
EFF 12	27:00	8.42	3.77	4.65
EFF 13	29:00	7.25	3.65	3.60
EFF 14	31:00	7.52	4.73	2.79
EFF 15	33:00	7.15	3.31	3.84
			Average	**3.57**

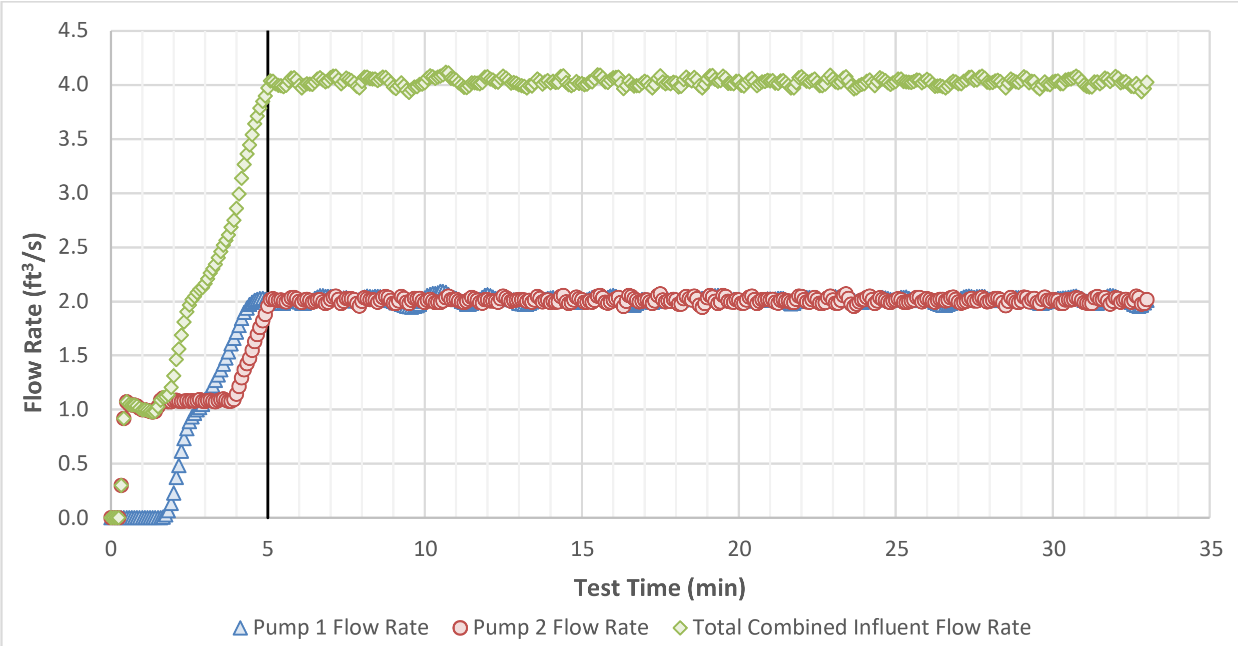

Figure 12: Scour Test Flow Rate

4.4 Excluded Results

The NJDEP Verification Procedure requires disclosure and a discussion of any data excluded from analysis. No data has been excluded from computation of either removal rates or scour performance. All data collected has been made available to NJCAT for verification.

5. Design Limitations

Contech's engineering staff typically works with the site design engineer to ensure all potential constraints are addressed during the specification process and that the Cascade Separator treatment system will function as intended. Each install will have unique limitation or requirements, the following limitations should be considered general and not all inclusive.

Required Soil Characteristics

The Cascade Separator is an enclosed system that is typically housed within a concrete manhole. The functionality of the Cascade Separator system is not affected by existing soil conditions at install location and as such the unit can be installed in all soil types.

Slope

It is generally not advisable to install the Cascade Separator unit with steep pipe slopes. When the Cascade Separator is being considered with pipe slopes exceeding 10%, Contech recommends contacting their engineering staff to evaluate the design prior to specification.

Flow Rate

The hydraulic loading rate of the Cascade Separator is 64.3 gpm/ft^2 of effective treatment area.

MAINTENANCE REQUIREMENTS

The Cascade Separator system must be inspected at regular intervals and maintained when necessary to ensure optimum performance. The rate at which the system collects pollutants depends heavily on specific site activities. See Section 6 for a more detailed discussion of maintenance and inspection requirements.

DRIVING HEAD

The driving head required for a given Cascade Separator model is typically a function of the model size and storm sewer characteristics. Contech's engineering staff consults with the design engineer on each project to ensure there will not be any adverse impacts to the hydraulic grade-line as a result of installing the Cascade Separator unit.

INSTALLATION LIMITATIONS

Prior to installation, Contech provides contractors detailed installation and assembly instructions and is also available to consult onsite during installation. Pick weights for Cascade Separator components are provided prior to delivery so that the contractor can secure proper equipment for lifting Cascade Separator units into place.

CONFIGURATIONS

Cascade Separator units can be installed online or offline. Online units can convey excess flows around the treatment chambers of the unit without the need for an external bypass structure. Cascade Separator can accept multiple inlets pipes and has a grated inlet option. Contech's engineering staff can help determine the pipe size and angle locations based on the site requirements. However, the performance of these configurations has not been verified by NJCAT.

LOAD LIMITATIONS

Cascade Separator units are typically designed for HS-20 loading (32,000 pounds per truck axle). If additional loading is expected it is advisable to contact Contech to assess loading options.

PRETREATMENT REQUIREMENTS

There are no pre-treatment requirements for the Cascade Separator stormwater treatment system.

LIMITATIONS ON TAILWATER

If tailwater is present it is important to increase the available driving head within the unit to ensure that the full design flow rate is still treated prior to any internal bypass.

DEPTH TO SEASONAL HIGH-WATER TABLE

Cascade Separator unit performance is not typically impacted by high groundwater. Occasionally, when groundwater is expected to be within several feet of finished grade it may be necessary to add a base extension to the unit to counter buoyant forces. If high groundwater is expected, Contech's engineering staff can evaluate whether anti-buoyancy measures are required during the design process.

Additional Limitations

Each Cascade Separator has a recommended maximum inlet and outlet pipe size. When the size of the main storm drain exceeds the Cascade Separator maximum pipe size, Contech recommends contacting their engineering staff. In some circumstances a larger pipe can be accommodated. The maximum pipe diameter for each Cascade Separator model is shown in **Table A-1.**

6. Maintenance Plan

The Cascade Separator system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. The rate at which the system collects sediment and debris will depend upon on-site activities and site pollutant characteristics. For example, unstable soils or heavy winter sanding will cause the sediment storage sump to fill more quickly, but regular sweeping of paved surfaces will slow accumulation. Additional information on inspection and maintenance, including a simple Inspection & Maintenance Log form, can be found online at https://www.conteches.com/Portals/0/Documents/Maintenance%20Guides/Cascade-Maintenance%20Guide.pdf?ver=2018-11-05-093254-300

Inspection

Inspection is the key to effective maintenance and is easily performed. Pollutant transport and deposition may vary from year to year and regular inspections will help ensure that the system is cleaned out at the appropriate time. At a minimum, inspections should be performed twice per year (i.e. spring and fall). However, more frequent inspections may be necessary in climates where winter sanding operations may lead to rapid accumulations, or in equipment wash-down areas. Installations should also be inspected more frequently where excessive amounts of trash are expected.

A visual inspection should ascertain that the system components are in working order and that there are no blockages or obstructions in the inlet chamber, flumes or outlet channel. The inspection should also quantify the accumulation of hydrocarbons, trash and sediment in the system. Measuring pollutant accumulation can be done with a calibrated dipstick, tape measure or other measuring instrument. If absorbent material is used for enhanced removal of hydrocarbons, the level of discoloration of the sorbent material should also be identified during inspection. It is useful and often required as part of an operating permit to keep a record of each inspection. A simple form for doing so is provided in the Cascade Separator Inspection and Maintenance Guide available from Contech Engineered Solutions.

Access to the Cascade Separator unit is typically achieved through one manhole access cover. The opening allows for inspection and cleanout of the center chamber (cylinder) and sediment storage sump, as well as inspection of the inlet chamber and slanted skirt. For large units, multiple manhole covers allow access to the chambers and sump.

The Cascade Separator system must be maintained when the level of sediment in the sump has reached a depth of 9 in. or greater to avoid exceeding the maximum 18 in. sediment depth and/or when an appreciable level of hydrocarbons and trash has accumulated. Performance may be impacted when maximum sediment storage capacity is exceeded. The level of sediment is easily determined by measuring from finished grade down to the top of the sediment pile. To avoid underestimating the level of sediment in the chamber, the measuring device must be lowered to the top of the sediment pile carefully. Finer, silty particles at the top of the pile typically offer less resistance to the end of the rod than larger particles toward the bottom of the pile. Once this measurement is recorded, it should be compared to the as-built drawing for the unit to determine if the height of the sediment pile off the bottom of the sump floor exceeds 50% (9 in.) of the total height of sediment storage sump. If sorbent material is used, it must be replaced when significant discoloration has occurred.

Cleaning

Cleaning of a Cascade Separator system should be done during dry weather conditions when no flow is entering the system. The use of a vacuum truck is generally the most effective and convenient method of removing pollutants from the system. Simply remove the manhole cover and insert the vacuum hose down through the center chamber and into the sump. The system should be completely drained down and the sump fully evacuated of sediment. The areas outside the center chamber and the slanted skirt should also be washed off if pollutant build-up exists in these areas.

In installations where the risk of petroleum spills is small, liquid contaminants may not accumulate as quickly as sediment. However, the system should be cleaned out immediately in the event of an oil or gasoline spill. Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use absorbent pads since they are usually less expensive to dispose than the oil/water emulsion that may be created by vacuuming the oily layer. Trash and debris can be netted out to separate it from the other pollutants. Then the system should be power washed to ensure it is free of trash and debris.

Manhole covers should be securely seated following cleaning activities to prevent leakage of runoff into the system from above and to ensure proper safety precautions. Confined space entry procedures need to be followed if physical access is required. Disposal of all material removed from the Cascade Separator system must be done in accordance with local regulations. In many locations, disposal of evacuated sediments may be handled in the same manner as disposal of sediments removed from catch basins or deep sump manholes. Check your local regulations for specific requirements on disposal. If any components are damaged, replacement parts can be ordered from the manufacturer.

7. STATEMENTS

The following signed statements from the manufacturer (Contech Engineered Solutions, LLC), third-party observer (Scott A. Wells and associates) and NJCAT are required to complete the verification process.

Contech Engineered Solutions LLC
9025 Centre Pointe Drive, Suite 400
West Chester, OH 45069
Phone: (513) 645-7000
Fax: (513) 645-7993
www.ContechES.com

05/09/2019

Dr. Richard Magee
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: 2019 Verification of the Cascade Separator

Dr. Richard Magee,

This correspondence is being sent to you in accordance with the "*Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology"* dated January 25, 2013. Specifically, the process document requires that manufacturers submit a signed statement confirming that all of the procedures and requirements identified in the aforementioned process document and the *"New Jersey Department of Environmental Protection (NJDEP) Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device"* dated January 25, 2013 have been met. We believe that the testing executed in Contech's laboratory in Portland, Oregon on the Cascade Separator during April of 2019 under the direct supervision of Dr. Scott A. Wells, Ph.D. and associates was conducted in full compliance with all applicable protocol and process criteria. Additionally, we believe that all the required documentation of the testing and resulting performance calculations has been provided within the submittal accompanying this correspondence.

Please do not hesitate to contact me with any additional questions related to this matter.

Respectfully,

Derek M. Berg
Director - Stormwater Regulatory Management - East
Contech Engineered Solutions LLC
71 US Route 1, Suite F | Scarborough, ME 04074
T: 207.885.6174 F: 207.885.9825
DBerg@conteches.com
www.ContechES.com

Scott A. Wells and Associates

Environmental Engineering and Modeling
2382 SW Cedar Street
Portland, OR 97205 USA

May 10, 2019

To Whom It May Concern:

Re: New Jersey Department of Environmental Protection (NJDEP) Assessment of Cascade Separator Removal Efficiency of Suspended Sediment

Performance testing of the Contech Cascade Separator was overseen by Dr. Chris Berger and Dr. Scott Wells in April 2019 at the Contech Portland, Oregon laboratory. All phases of the analytical testing were also observed at the Contech laboratory. These tests included the particle size distribution by hydrometer, sieve analysis, and moisture content. During scour testing, the initial sediment depths (50% of the sediment storage capacity) measured in the sedimentation sump chamber were confirmed by the observer. The flow rates and frequency of sampling reported for the performance and scour tests were observed and are reported accurately. The test used applicable protocol, as outlined in the quality assurance project plan. The test used applicable NJDEP protocol and their report accurately reflects the testing observed by Dr. Berger and Dr. Wells.

Let us know if you have further questions on our observations of the testing performed in the laboratory.

Truly,

Scott A. Wells, P.E., Ph.D. Christopher J. Berger, P. E., Ph.D.

503-935-6379
drswells@outlook.com

Scott A. Wells and Associates

Environmental Engineering and Modeling
2382 SW Cedar Street
Portland, OR 97205 USA

May 10, 2019

To Whom It May Concern:

Scott A. Wells and Associates provides environmental consulting services focusing on water quality and hydrodynamic models of hydraulic structures, rivers, reservoirs, and estuary systems. We are familiar with stormwater treatment research having conducted many studies in the past on the efficiency of particle and oil and grease removal using a CDS device. We also are familiar with the use of an analytical laboratory to process samples, proper sample technique, and calculations of flow, pollutant concentration, and pollutant loading. Our clients include the federal government (EPA, USBR, Corps of Engineers), state government (such as the Washington Department of Ecology and Departments of Environmental Quality in Idaho and Oregon), private consulting firms and government organizations in both the United States and abroad (China, Israel, Brazil, Canada). Either Scott Wells, Ph.D., P.E., or Chris Berger, Ph.D., P.E., will served as observers for this series of tests.

Scott Wells and Associates has provided the service of third party review of stormwater device testing to Contech Engineered Solutions between 2007 and 2018. Beyond this past review work, Scott Wells and Associates and Contech have no relationships that would constitute a conflict of interest, as outlined in *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP 2013). For example, we have no ownership stake, do not receive commissions, do not have licensing agreements, do not receive funds or grants beyond those associated with the testing program.

Let me know if you have further questions on potential conflicts of interest.

Truly,

Scott A. Wells, P.E., Ph.D. Christopher J. Berger, P. E., Ph.D.

503-935-6379
drswells@outlook.com

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

May 20, 2019

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

Dear Mr. Mahon,

Based on my review, evaluation and assessment of the testing conducted on a full-scale, commercially available Contech Cascade Separator (CS-4) at Contech's Portland, Oregon laboratory facility with Scott Wells, Ph.D., from Portland State University, and associates providing independent third-part oversight, the test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) were met consistent with the NJDEP Approval Process. Specifically:

Test Sediment Feed

The sediment used for removal efficiency tests was a ground and whole-grain silica blend with a specific gravity of 2.65. Twelve subsamples, taken from varying locations within the test sediment batch were composited. Three samples taken from the composite were pulled and analyzed for PSD and moisture content according to ASTM D422-63 (2007). The sampling and analysis were conducted in-house, under third party observation prior to testing. The sediment met the NJDEP Protocol specifications and the d_{50} of the sediment was 57 µm, significantly less than the NJDEP specification of <75 µm. The average moisture content was determined to be 0.1%.

Scour Test Sediment

The test sediment used for the scour testing was a blend of whole-grain silica with a specific gravity of 2.65. Prior to testing, twelve subsamples were taken from three randomly chosen bags of the sediment batch and composited. Three samples taken from the composite were then analyzed for PSD according to ASTM D422-63 (2007). The sampling and analysis were conducted in-house, under third party observation prior to testing. The sediment met the NJDEP Protocol specifications.

Removal Efficiency Testing

Removal efficiency testing followed the effluent grab sampling test method outlined in Section 5 of the NJDEP Protocol. The weighted sediment removal efficiency of the Cascade Separator (CS-4) (MTFR 808 gpm, 1.80 cfs) was 54.8%.

Scour Testing

Scour testing of the Cascade Separator (CS-4) was conducted in accordance with Section 4 of the NJDEP Protocol at a target flow rate greater than 200% of the Cascade Separator MTFR to qualify the MTD for online installation. The average test flow rate was 4.03 cfs or 224% of the 1.80 cfs MTFR. The average adjusted effluent SSC for this test was 3.57 mg/L, well below the maximum allowable SSC of 20 mg/L, qualifying the Contech Cascade Separator for online installation.

Sincerely,

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

VERIFICATION APPENDIX

INTRODUCTION

- Contech Engineered Solutions is the manufacturer of the Cascade Separator hydrodynamic separation MTD.

  Contech Engineered Solutions
  9025 Centre Point Drive
  West Chester, OH 45069
  Phone: (513) 645-7000
  Fax: (513) 645-7993
  www.ContechES.com

- MTD: Contech Cascade Separator™. Verified Contech Cascade models are shown in **Table A-1**

- TSS removal rate: 50%.

- The Cascade Separator MTD qualifies for offline or online installation for the New Jersey Water Quality Design Storm (NJWQDS).

DETAILED SPECIFICATION

- NJDEP sizing table for the Cascade Separator is attached (**Table A-1**).

- New Jersey requires that the peak flow rate of the NJWQDS event of 1.25 inch in 2 hours shall be used to determine the appropriate size for the MTD. The Cascade Separator CS-4 has a maximum treated flow (MTFR) of 1.80 cfs (808 gpm), which corresponds to a surface loading rate of 64.3 gpm/ft^2 of effective treatment area.

- Prior to installation, Contech provides contractors detailed installation and assembly instructions and is also available to consult onsite during installation.

- Maximum sediment depth for all units is 18 in. Recommended sediment depth prior to cleaning is 9 inches.

- See Contech Cascade Separator Inspection and Maintenance Guide for additional detailed information at: https://www.conteches.com/Portals/0/Documents/Maintenance%20Guides/Cascade-Maintenance%20Guide.pdf?ver=2018-11-05-093254-300
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- A hydrodynamic separator, such as the Cascade Separator, cannot be used in series with another hydrodynamic separator to achieve an enhanced TSS removal rate under N.J.A.C. 7:8-5.5.

Table A- 1: Cascade Separator MTFR, Sediment Removal Interval and Standard Dimensions

Model Number	Manhole Diameter (ft)	MTFR (cfs)	Hydraulic Loading Rate[1] (gpm/ft²)	50% Maximum Sediment Storage Depth (in)	50% Maximum Sediment Storage Volume (ft³)	Required Sediment Removal Interval[2] (years)
CS-4	4	1.80	64.3	9	9.4	3.1
CS-5	5	2.81	64.3	9	14.7	3.1
CS-6	6	4.05	64.3	9	21.2	3.1
CS-8	8	7.20	64.3	9	37.7	3.1
CS-10	10	11.3	64.3	9	58.9	3.1
CS-12	12	16.2	64.3	9	84.8	3.1

Model Number	Effective Treatment Area (ft²)	Effective Treatment Depth[3] (in)	Chamber Depth[4] (in)	Aspect Ratio[5]	Maximum Pipe Diameter (in)
CS-4	12.6	39	48	0.81	24
CS-5	19.6	45	54	0.75	30
CS-6	28.3	51	60	0.71	42
CS-8	50.3	66	75	0.69	48
CS-10	78.5	83	92	0.69	60
CS-12	113.1	99	108	0.69	72

[1] Hydraulic loading rate is defined as the ratio of MTFR to effective treatment area

[2] Sediment removal interval is calculated using the equation (years) presented in Appendix A, Section B of the NJDEP Protocol

[3] Effective treatment depth is defined as depth from effluent invert to 50% maximum sediment storage depth

[4] Chamber depth is defined as depth from effluent invert to sump floor

[5] Aspect ratio is defined as the ratio of effective treatment depth to manhole diameter. All models are geometrically proportional to the tested CS-4 within the allowable ±15% (0.69 -0.93) tolerance