NJCAT TECHNOLOGY VERIFICATION

HydroDome (HD) Stormwater Separator

Hydroworks, LLC

May 2021

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Description of Technology

The Hydroworks HydroDome is a hydrodynamic stormwater separator. HydroDome comes complete with an outlet pipe that slides into the outlet pipe of the structure and is then securely attached to the structure wall. (**Figure 1**). All of the flow into the structure passes through the HydroDome. There is no internal high flow bypass. Oil and floatable solids rise to the surface and are immediately separated from the flow. Denser suspended solids settle and are captured in the sump of the concrete structure.

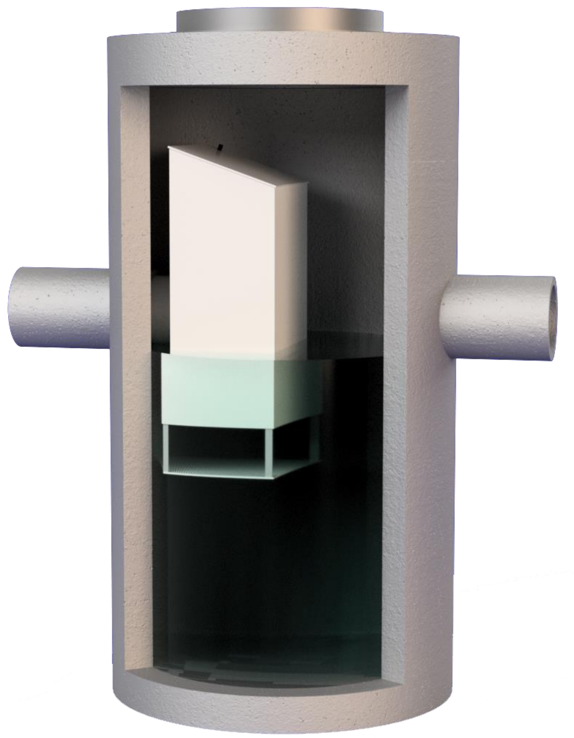

Figure 1 Hydroworks HydroDome

The housing of the HydroDome itself is the primary measure to prevent any floatables or debris from entering the HydroDome. Water flows into the HydroDome through submerged horizontal openings at the bottom of the device (**Figure 2**). Water then enters a low flow path near the center of the HydroDome before exiting through an orifice on the outlet side of the low flow path. A debris screen (inlet protection) is located at the entrance to the low flow path as a secondary measure to prevent any clogging from debris. A perforated plastic scour protection plate at the bottom of the HydroDome minimizes scour by minimizing upward velocities/flow from the structure floor during periods of higher flow. The perforations in the plate, much larger than the largest particle tested, prevent sediment from settling on the plate.

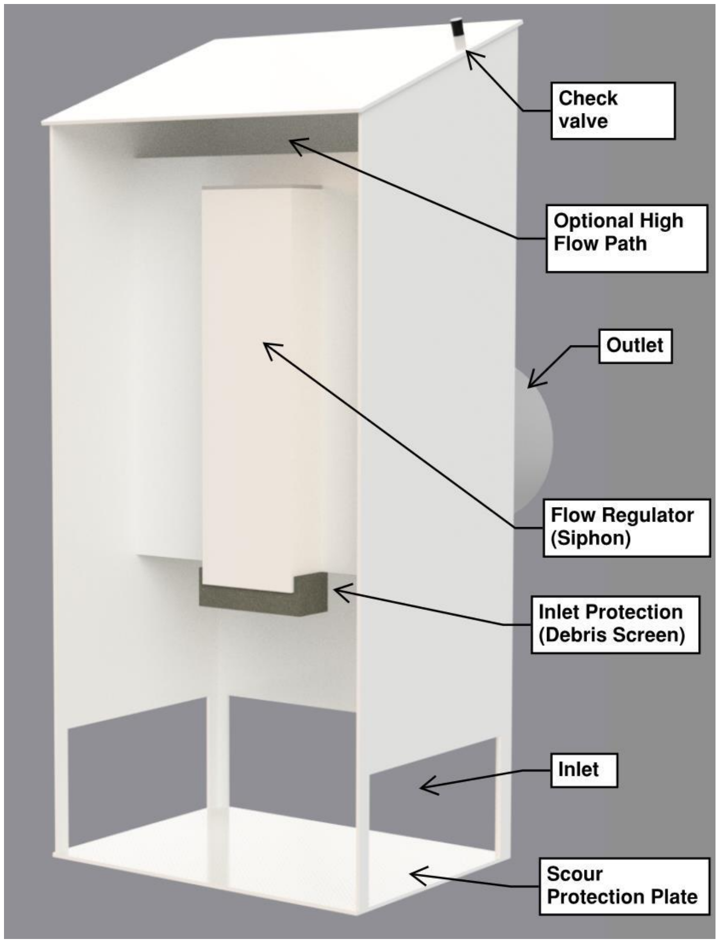

Figure 2 HydroDome Internal Components

The water level continues to rise in the structure depending on the rate of flow into the structure and rate of flow out of the low flow path. If the flow rate into the HydroDome exceeds the low flow path (siphon) rate the water level rises to a high flow weir (as tested in this study). Higher flows are safely conveyed to the outlet over this weir. The weir is optional in other design configurations where a controlled flow rate (only low flow rate) is desired.

2. Laboratory Testing

The test program was conducted at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direct supervision of Alden's senior stormwater engineer, James Mailloux. Alden has performed verification testing on approximately twenty hydrodynamic separator and filtration Manufactured Treatment Devices (MTDs) for multiple manufacturers under various state and federal testing protocols. Water quality samples collected during this testing process were analyzed in Alden's Calibration Laboratory, which is ISO 17025 accredited.

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

2.1 Test Setup

The laboratory test used a full-scale HydroDome (model HD 3) installed in a three (3) foot diameter by nine (9) foot high plastic cylindrical test device. The HD 3 has a sump depth of 5 ft and a sump area of 7.07 ft^2. Aluminum inlet and outlet pipes, 18-inch in diameter, were oriented along the centerline of the unit, with the inverts located 60 inches above the sump floor. The 100% and 50% sediment sump storage depths were 12 inches and 6 inches, respectively. A photograph of the installed unit is shown on **Figure 3.**

Figure 3 HydroDome HD 3 Test Unit Installed in Alden Test Loop

The HD 3 test unit was installed in the Alden test loop, shown on **Figure 4,** which is set up as a recirculation system. The loop is designed to provide metered flow up to approximately 9 cfs, using a calibrated orifice plate and venturi differential-pressure meters. Flow was supplied to the unit using either a 20HP or 50HP laboratory pump (flow dependent), drawing water from a 50,000-gallon supply sump. The test flow was set and measured using a differential-pressure meter and control valve. A Differential Pressure (DP) cell and computer Data Acquisition (DA) program was used to record the test flow. Thirty (30) feet of straight 18-inch influent pipe conveyed the metered flow to the unit. Eight (8) feet of straight 18-inch effluent piping returned the test flow back to the supply sump as a free discharge. The influent and effluent pipes were set at 1.0% slopes. A 12-inch tee was located 5 pipe-diameters (7.5 ft) upstream of the test unit for injecting sediment into the crown of the influent pipe. Sediment injection was accomplished with the use of a volumetric screw feeder. The end-of-pipe grab sampling methodology was used for the scour and removal efficiency tests. An iso-kinetic sampler was installed in the upstream vertical riser pipe for collection of background samples. Filtration of the supply sump, to reduce background concentration, was performed with an in-line filter wall containing 1-micron bag filters.

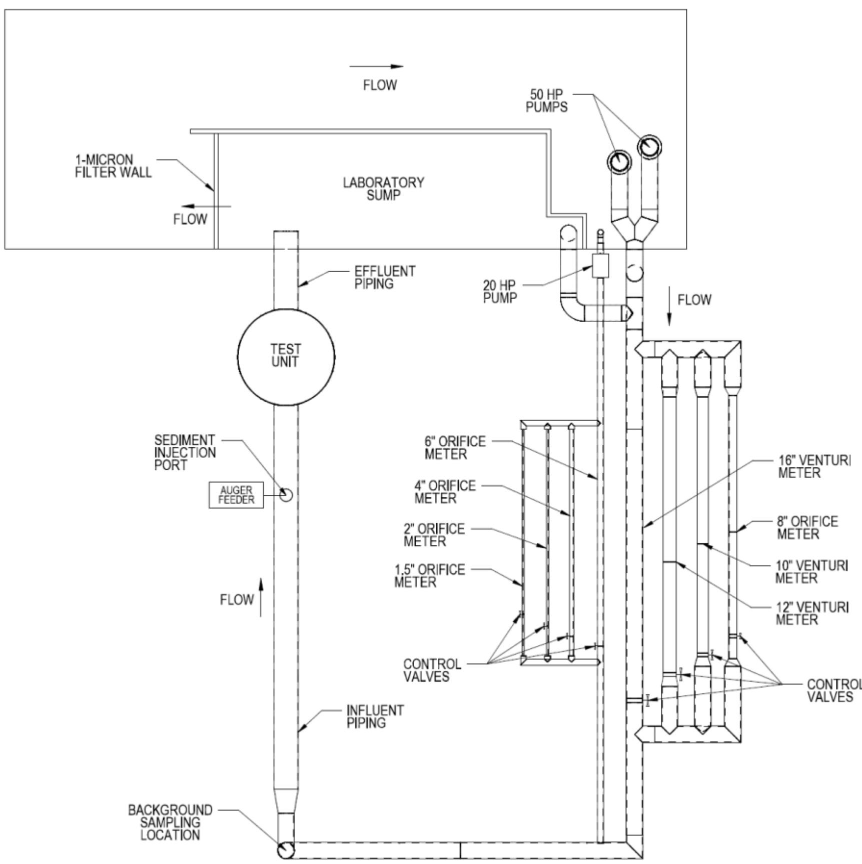

Figure 4 Plan View of Alden Flow Loop

2.2 Hydraulic Testing

The HD 3 unit was tested with clean water to determine its hydraulic characteristic curves. Flow and water level measurements were recorded at steady-state flow conditions using a computer Data-Acquisition (DA) system, which included a data collect program, 0-250" Rosemount Differential Pressure (DP) cell (flow), and Omegadyne 0-2.5 psi Pressure Transducer (PT) (water elevations). Piezometer taps were installed in the invert of the inlet and outlet pipes, one pipe-diameter upstream and downstream of the test unit. An additional tap was installed within the test tank. Manometer tubing was used to connect the taps to the PT, which was installed at a known datum of 1.016 ft below the inlet pipe invert. All measured elevations were adjusted to this datum. Flows were set and measured using calibrated differential-pressure flow meters and control valves. Each test flow was set and operated at steady state for approximately 5 minutes, after which time a minimum of 60 seconds of flow and pressure data were averaged and recorded for each pressure tap location.

2.3 Removal Efficiency Testing

Removal testing was conducted on a clean unit utilizing the end-of-pipe grab sampling methodology. Five sediment removal efficiency tests were conducted at flows corresponding to 25%, 50%, 75%, 100% and 125% of the Maximum Treatment Flow Rate (MTFR). A false floor was installed at the 50% collection sump sediment storage depth of 6", as stated by Hydroworks. All tests were run with clean water containing a sediment solids concentration (SSC) of less than 20 mg/L.

A minimum of 25 lbs of test sediment was introduced into the influent pipe for each test. The moisture content of the test sediment was determined using ASTM D4959-16 for each test conducted.

The test sediment was prepared by Alden to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in **Table 1** (NJDEP, 2013a). The sediment is silica based, with a specific gravity of 2.65. Random samples of the test batch were analyzed for PSD compliance by GeoTesting Express, Inc., Acton, Massachusetts, an independent certified analytical laboratory, using the ASTM D422-63 (2007) analytical method. The average of all the samples was used for compliance with the protocol specification.

The target influent sediment concentration was 200 mg/L (+/-20 mg/L) for all tests. The concentration was verified by collecting a minimum of six timed dry samples at the injector and correlating the data with the measured flow rate. Each sample volume was a minimum of 0.1 liters, with the collection time not exceeding one minute. The allowed Coefficient of Variance (COV) for the measured samples is 0.10. The reported concentration was calculated based on the total mass injected during the test and total volume of water introduced during sediment dosing.

Table 1 NJDEP Target Test Sediment Particle Size Distribution

	TSS Removal Test PSD	Scour Test Pre-load PSD
Particle Size (Microns)	Target Minimum % Less Than[2]	Target Minimum % Less Than[3]
1,000	100	100
500	95	90
250	90	55
150	75	40
100	60	25
75	50	10
50	45	0
20	35	0
8	20	0
5	10	0
2	5	0

1. The material shall be hard, firm, and inorganic with a specific gravity of 2.65. The various particle sizes shall be uniformly distributed throughout the material prior to use.

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

3. This distribution is to be used to pre-load the MTD's sedimentation chamber for off-line and on-line scour testing.

Eight (8) background samples of the supply water were collected using an isokinetic sampler at evenly-spaced intervals throughout each test. Collected samples were analyzed for Suspended Solids Concentration (SSC) using ASTM D3977-97 (2019). A 3rd-order curve and corresponding equation was developed for calculating the adjusted effluent concentrations. A correction was made to each timestamp to account for the detention time between the background and effluent sampling locations.

Fifteen (15) effluent samples were collected from the end of the effluent pipe at evenly-spaced intervals, using 1-L wide-mouth bottles. Sampling was started after a minimum of three (3) detention times following the initiation of sediment injection, as well as after the interruption of sediment feed for injection verification.

2.4 Scour Testing

A sediment scour test was conducted to evaluate the ability of the HydroDome to retain captured material during high flows. A commercially-available AGSCO NJDEP50-1000 certified sediment mix was utilized for the scour test. Three samples of the batch mix were analyzed in accordance with ASTM D422-63 (2007), by CTLGroup, Skokie, Illinois, an ISO/IEC 17025 accredited independent laboratory, and provided with the sediment shipment. The unit was pre-loaded with 50-1000-micron sediment to the 50% Hydroworks recommended sump storage level (6 inches). All test sediment was evenly distributed and levelled prior to testing.

The unit was filled with clean water (< 20 mg/L background) to the dry-weather condition prior to testing. Testing was conducted at a temperature not exceeding 80 degrees F. The test was initiated within 96 hours of filling the unit.

The test was conducted at ≥200% MTFR for online certification. Testing consisted of conveying the selected target flow through the unit and collecting 15 time-stamped effluent samples (every 2 minutes) for SSC analysis, and a minimum of eight (8) time-stamped background samples evenly spaced throughout the test. The target flow was reached within 5 minutes of commencement of the test. Flow data were continuously recorded every 5 seconds throughout the test and correlated with the samples.

Each effluent grab sample for sediment concentration analysis was collected from the end of the effluent pipe by sweeping a 1-L large-mouth bottle through the effluent stream.

2.5 Instrumentation and Measuring Techniques

Flow

The inflow to the test unit was measured using one of five (5) calibrated differential-pressure flow meters (1.5", 2", 4", 6" or, 8"). Each meter was fabricated per ASME guidelines and calibrated in Alden's Calibration Department. Flows were set with a control valve and the differential head from the meter was measured using a Rosemount® 0 to 250-inch Differential Pressure (DP) cell, also calibrated at Alden. The test flow was averaged and recorded every 5-20 seconds (flow dependent) throughout the duration of the test using an in-house computerized data acquisition (DA) program. The accuracy of the flow measurement is ±1%. The maximum allowable Coefficient of Variance (COV) for flow documentation was 0.03. A photograph of the flow meter array is shown on **Figure 5.**

Figure 5 Photograph Showing Laboratory Flow Meters

Temperature

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

Pressure Head

Pressure head measurements were recorded at multiple locations using piezometer taps and an Omegadyne PX419, 0 - 2.5 psi pressure transducer (PT), calibrated at Alden prior to testing. Accuracy of the readings is ± 0.001 ft. The cell was installed 1.016 ft below the inlet pipe invert, allowing for elevation readings through the full range of flows. A minimum of 60 seconds of pressure data were averaged and recorded for each pressure tap during steady-state hydraulic testing, using the computerized DA program. A photograph of the pressure measurement instrumentation is shown on **Figure 6.**

.

Figure 6 Pressure Measurement Instrumentation

Sediment Injection

The test sediment was injected into the crown of the influent pipe using an Auger® volumetric screw feeder, model VF-1, shown on **Figure 7.** The feeder has a hopper at the upper end of the auger to provide a constant supply of dry test sand. The feed screws used in testing ranged in size from 0.5-inch to 1.0-inch, depending on the test flow. Each auger screw, driven with a variable-speed drive, was calibrated with the test sediment prior to testing, to establish a relationship between the auger speed (0-100%) and feed rate in mg/minute. The pre-test calibration, as well as test verification of the sediment feed was accomplished by collecting dry samples at a maximum collection time of 1-minute and weighing them on a calibrated Ohaus® 4000g x 0.1g, model SCD-010 digital scale. The maximum allowable COV for sediment feed was 0.10.

Figure 7 Photograph Showing Variable-Speed Auger Feeder

Sample Collection

Background concentration samples were collected from the center of the vertical riser pipe upstream of the test unit with the use of a 0.75-inch isokinetic sampler, shown on **Figure 8**. The sampler was calibrated for each test flow. The end-of-pipe effluent samples were collected by sweeping a 1-L wide mouth bottle through the free discharge of the outlet pipe. All collected samples were a minimum of 0.5 L in volume.

Figure 8 Photograph Showing the Background Isokinetic Sampler

Sample Concentration Analysis

Effluent and background concentration samples were analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (Re-approved 2019), "Standard Test Methods for Determining Sediment Concentration in Water Samples". Alden has assigned a Non-Detection Limit (NDL) of 1.0 mg/L. To be conservative, all concentrations below the NDL were assigned a value of 0.5 mg/L.

2.6 Data Management and Acquisition

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

A personal computer running an Alden in-house Labview® Data Acquisition program was used to record all data related to instrument calibration and testing. A 16-bit National Instruments®

NI6212 Analog to Digital (A/D) board was used to convert the signal from the pressure cells to a voltage. Alden's in-house data collection software, by default, collects one-second averages of data collected at a raw rate of 250 Hz. The system allows very long contiguous data collection by continuously writing the collected 1-second averages and their RMS values to disk. The data output from the program is in tab delimited text format with a user-defined number of significant figures.

Test flow and pressure data were continuously collected at a frequency of 250 Hz. The flow data was averaged and recorded to file every 5 to 30 seconds, depending on the duration of the test. Steady-state pressure data was averaged and recorded over a duration of 60 seconds for each point. The recorded data files were imported into Excel for further analysis and plotting.

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

2.7 Quality Assurance and Control

All instruments were calibrated prior to testing and periodically checked throughout the test program. Instrumentation calibrations were provided to NJCAT.

Flow

The flow meters and pressure cells were calibrated in Alden's Calibration Laboratory, which is ISO 17025 accredited. All flow meter pressure lines were purged of air prior to initiating each test. A standard water manometer board and Engineers Rule were used to measure the differential pressure and verify the computer measurement of the selected flow meter.

Sediment Injection

The sediment feed (g/min) was verified with the use of a NIST digital stop watch and 4000g calibrated digital scale. The tare weight of the sample container was recorded prior to collection of each sample. The samples were a minimum of 0.1 liters in size, with a maximum collection time of 1-minute. The reported overall mass/volume sediment concentrations were adjusted for moisture.

Sediment Concentration Analysis

All sediment concentration samples were processed in accordance with the ASTM D3977-97 (2019) analytical method. Gross sample weights were measured using a 4000g x 0.1g calibrated digital scale. The dried sample weights were measured with a calibrated 0.0001g analytical balance. The change in filter weight due to processing was accounted for by including three control filters with each test set. The average of the three values, which was typically (+/-

0.1mg), was used in the final concentration calculations.

Analytical accuracy was verified by preparing two blind control samples and processing using the ASTM method. The final calculated values were within 0.26% and 0.87% of the theoretical sample concentrations, with an average of 0.57% accuracy.

3. Performance Claims

Per the NJDEP verification procedure, the following are the performance claims for the Hydroworks HD 3 based on the results of the laboratory testing conducted.

Total Suspended Solids (TSS) Removal Efficiency

The TSS removal rate of the Hydroworks HD 3 was calculated using the weighted method required by the NJDEP HDS MTD protocol. Based on a MTFR of 0.85 cfs (381.5 gpm), the HD 3 achieved a weighted TSS removal rate of 58.5%.

Maximum Treatment Flow Rate (MTFR)/Surface loading Rate

The Hydroworks HD 3 had an effective treatment sedimentation area of 7.07 ft^2 and demonstrated a maximum treatment flow rate (MTFR) of 0.85 cfs (381.5 gpm). This corresponds to a surface loading rate of 54.0 gpm/ft^2 of sedimentation area.

Maximum Sediment Storage Depth and Volume

The maximum sediment storage depth of the HD 3 is 12 inches which equates to 7.07 ft^3 of sediment storage volume. A sediment storage depth of 6 inches corresponds to 50% full sediment storage capacity (3.5 ft^3).

Effective Treatment Sedimentation Area

The effective treatment sedimentation area is 7.07 ft^2.

Detention Time and Wet Volume

The wet volume for the HD 3 is 344 gallons. The detention time of the HD 3 is dependent upon flow rate. At the MTFR, the detention time in the HD 3 is 54 seconds.

Online/Offline Installation

Based on the scour testing results the Hydroworks HD 3 qualifies for online installation.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013b) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that "copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc." be included in this section. This was discussed with NJDEP and it was agreed that as long as such documentation could be made available by NJCAT upon request that it would not be prudent or necessary to include all this information in this verification report. This information was provided to NJCAT and is available upon request.

4.1 Test Sediment PSD Analysis

Sediment test batches of approximately 35 lbs were prepared in individual 5-gallon buckets, which were arbitrarily selected for each removal efficiency test. A well-mixed sample was collected from each test batch and analyzed for PSD by GeoTesting Express. The average of the samples was used for compliance to the protocol specifications. The PSD data of the samples are shown in **Table 2** and the corresponding curves are shown on **Figure 9**.

Table 2 Removal Efficiency Test Sediment Particle Size Distribution

Particle size (µm)	NJDEP Target	NJDEP Minimum Allowance	Test Sediment Particle Size Distribution (percent-finer)								QA / QC Compliant
			Bucket 2	Bucket 3	Bucket 8	Bucket 9	Bucket 10	Bucket 14	Bucket 15	Average	
1000	100%	98%	100%	100%	100%	100%	100%	100%	100%	**100%**	Yes
500	95%	93%	95%	95%	95%	96%	95%	95%	95%	**95%**	Yes
250	90%	88%	89%	89%	89%	89%	89%	89%	89%	**89%**	Yes
150	75%	73%	75%	75%	75%	76%	75%	75%	75%	**75%**	Yes
100	60%	58%	63%	62%	63%	63%	63%	63%	63%	**63%**	Yes
75	50%	50%	55%	54%	55%	55%	55%	55%	55%	**55%**	Yes
50	45%	43%	45%	44%	45%	45%	45%	45%	45%	**45%**	Yes
20	35%	33%	33%	33%	33%	34%	33%	33%	34%	**33%**	Yes
8	20%	18%	21%	21%	22%	22%	22%	21%	22%	**21%**	Yes
5	10%	8%	14%	15%	16%	15%	17%	15%	16%	**15%**	Yes
2	5%	3%	6%	7%	8%	7%	7%	8%	7%	**7%**	Yes
D_{50}	75	75	61	63	62	61	61	62	61	**62**	Yes

The sediment particle size distribution (PSD) used for removal efficiency testing exceeded the NJDEP PSD sediment specifications (**Table 1**) across the entire distribution. The D_{50} of 62 microns was less than the required 75 microns.

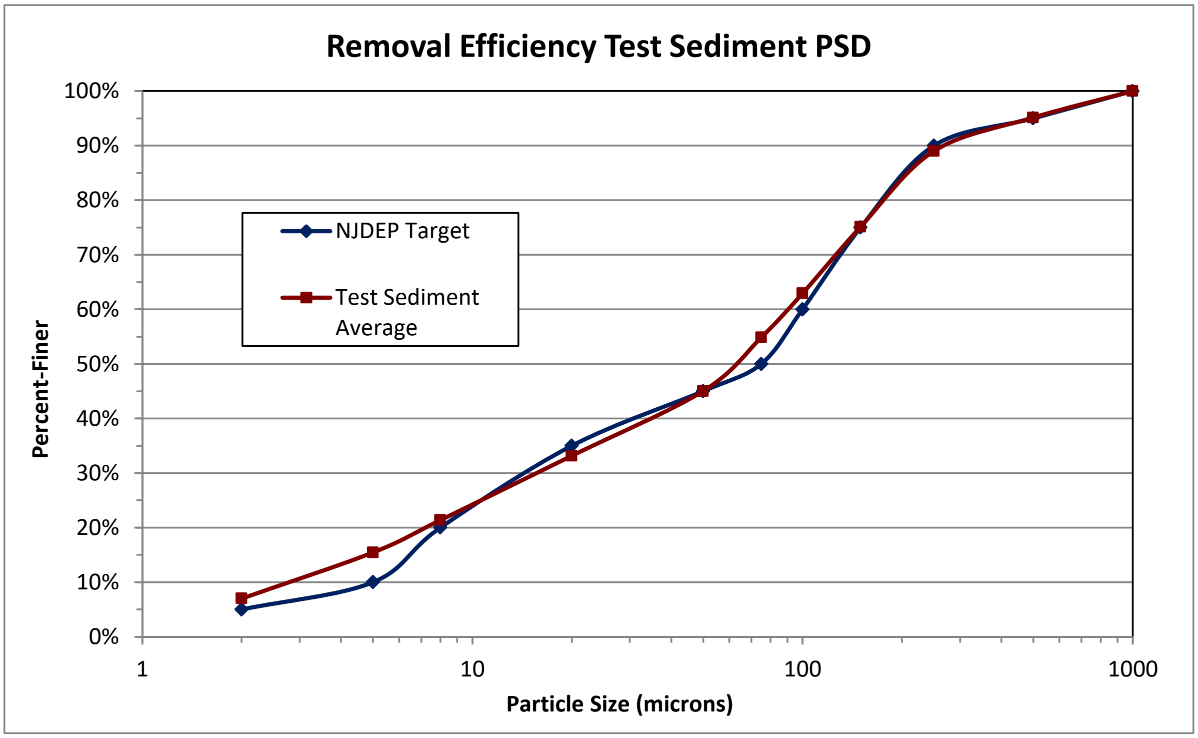

Figure 9 Removal Efficiency Test Sediment PSD Curves

4.2 Removal Efficiency Testing

Summary

Removal efficiency tests were conducted at the five (5) required flows of 25%, 50%, 75%, 100% and 125% MTFR. The 100% MTFR was 0.85 cfs (381.5 gpm), resulting in target flows of 0.21 cfs (95.4 gpm), 0.43 cfs (190.8 gpm), 0.64cfs (286.1 gpm), 0.85 cfs (381.5 gpm) and 1.06 cfs (476.9 gpm). All measured flows were within the ±10% target flow protocol requirement. All the influent concentrations were within the ±10% protocol target influent sediment concentration of 200 mg/l.

No measurable sediment was collected on either the inlet debris protection or the perforated scour protection plate during any of the TSS removal tests.

The target and measured flow and temperature parameters are shown in **Table 3** and the injected sediment and background data summary is shown in **Table 4**.

Table 3 Test Flow and Temperature Summary

Target Flow		Measured Flow		Deviation from Target	Flow Measurement COV	Maximum Temperature	QA / QC Compliant
cfs	gpm	cfs	gpm			Deg. F.	
0.21	95.4	0.21	94.4	-1.1%	0.001	65.4	Yes
0.43	190.8	0.39	173.9	-8.8%	0.002	64.9	Yes
0.64	286.1	0.64	286.3	0.0%	0.002	62.6	Yes
0.85	381.5	0.78	352.3	-7.7%	0.002	63.8	Yes
1.06	476.9	0.98	439.7	-7.8%	0.002	60.8	Yes

Table 4 Injected Sediment Summary

Flow	Average Injected Concentration	Injector Measurement COV	Mass/Volume Concentration	Injected Mass	Maximum Background Concentration	QA / QC Compliant
gpm	mg/L		mg/L	Lbs	mg/L	
94.4	200	0.007	206	28.7	7.0	Yes
173.9	199	0.004	196	28.1	2.7	Yes
286.3	199	0.001	220	30.0	7.6	Yes
352.3	201	0.004	188	28.7	8.0	Yes
439.7	201	0.008	190	30.7	8.4	Yes

The calculated removal efficiencies ranged from 41.8% to 69.9%, with a weighted removal of 58.5% for the 5 flows tested. The MTFR removal summary is shown **Table 5**.

Additional Tests

Two additional tests were conducted at 243 gpm and 538 gpm during performance testing. These test flow rates fell outside of the allowable 10% for the MTFR and could therefore not be used for calculating the weighted removal efficiency (**Table 5**). However, when all seven tests are included in a removal efficiency curve the corresponding removal efficiency equation (**Figure 10**), yields a weighted removal at the target MTFR (381.5 gpm) of 54.9%, exceeding the 50% required for verification.

Table 5 Removal Efficiency Summary

Flow	Influent Concentration	Average Effluent Concentration	Removal Efficiency	NJDEP Weight Factor	NJDEP Wt'd Removal Efficiency
gpm	mg/L	mg/L	%		%
94.4	206	70.6	**65.8**	0.25	**16.4**
173.9	196	59.1	**69.9**	0.30	**21.0**
286.3	220	106.3	**51.7**	0.20	**10.3**
352.3	188	106.4	**43.6**	0.15	**6.5**
439.7	190	110.7	**41.8**	0.10	**4.2**
				1.0	**58.5**

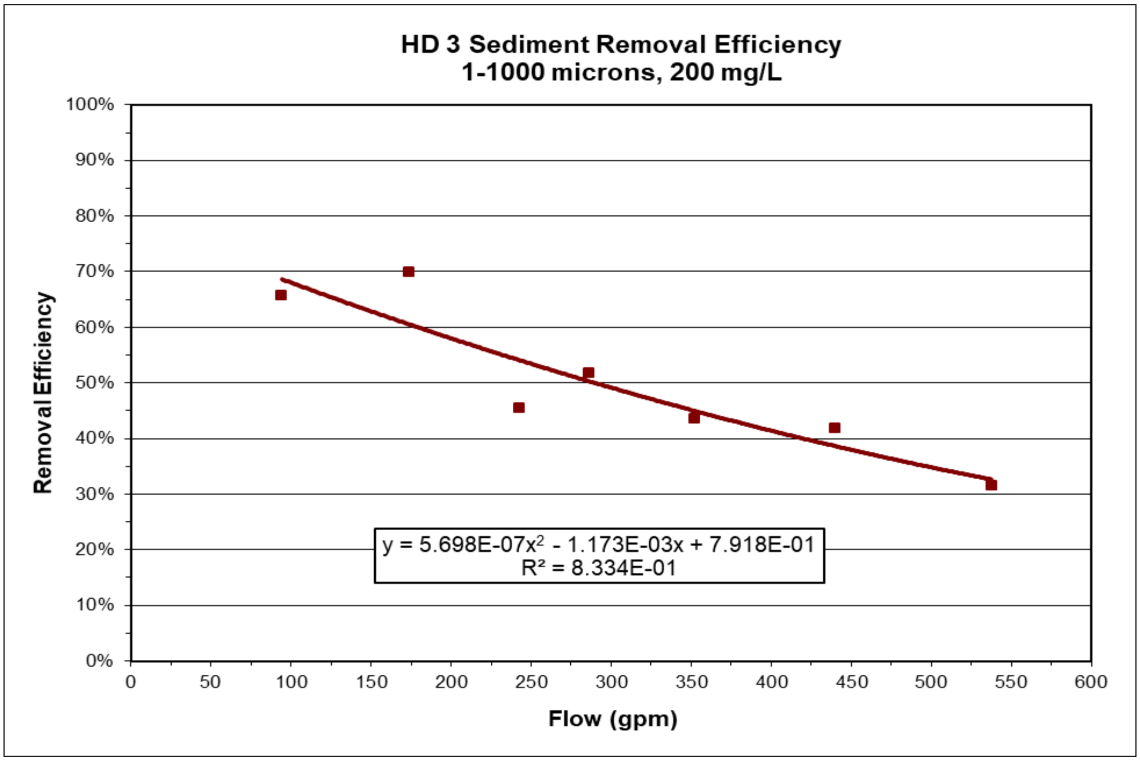

Figure 10 Hydroworks HD 3 Removal Efficiency Curve

25% MTFR (95 gpm)

The test was conducted at 94 gpm over a period of 3 hours. The test parameters and sampling results are shown in **Table 6**.

The resulting removal efficiency was 65.8%. The test flow was averaged and recorded every 20 seconds throughout the test. The average recorded test flow was 94.4 gpm, with a COV of 0.001. The recorded temperature for the test did not exceed 66 degrees F.

The injection feed rate of 71.2 g/min was verified by collecting 1-minute weight samples from the injector. Six influent injection measurements were taken throughout the test duration. The calculated concentrations for the full test ranged from 199 to 203 mg/L, with a mean of 200 mg/L and COV of 0.01. The total mass injected into the unit was 28.7 lbs. The calculated mass-flow concentration for the test was 206 mg/L. The measured influent concentration and flow data for the complete test is shown on **Figure 11**.

Eight (8) background concentrations samples were collected throughout the test and ranged from 0.7 (NDL) to 7.0 mg/L. A 3rd-order curve and corresponding equation was developed for calculating the background concentrations used for the adjusted effluent concentrations.

Table 6 25% MTFR Test Parameters and Collected Data

Injection Sample	**Sample Time** minutes	**Sample ID**	**Sample Time** minutes	**Effluent Concentration** mg/L	**Background Concentration** mg/L	**Adjusted Effluent** mg/L
Inj 1	1	**Eff 1, BG 1**	15	75.6	0.5	75.1
Inj 2	36	**Eff 2**	22	72.5	0.5	72.0
Inj 3	71	**Eff 3, BG 2**	29	67.9	0.5	67.4
Inj 4	106	**Eff 4**	50	73.6	1.7	71.9
Inj 5	141	**Eff 5, BG 3**	57	67.8	2.0	65.8
Inj 6	176	**Eff 6**	64	69.6	2.2	67.3
Injection Sampling Duration (seconds)	60	**Eff 7, BG 4**	85	73.1	3.0	70.2
		Eff 8	92	77.3	3.2	74.1
		Eff 9, BG 5	99	71.9	3.5	68.4
Detention Time (minutes)	3.7	**Eff 10**	120	79.3	4.3	75.0
		Eff 11, BG 6	127	78.1	4.6	73.6
		Eff 12	134	74.7	4.9	69.8
Total Run Time (minutes)	183.7	**Eff 13, BG 7**	155	77.9	6.0	71.9
		Eff 14	162	76.0	6.4	69.6
		Eff 15, BG 8	169	73.4	6.8	66.6
Mass/Volume Influent Concentration (mg/L)	206	**94 gpm**			**Average**	**70.6**
					Removal Efficiency	**65.8%**

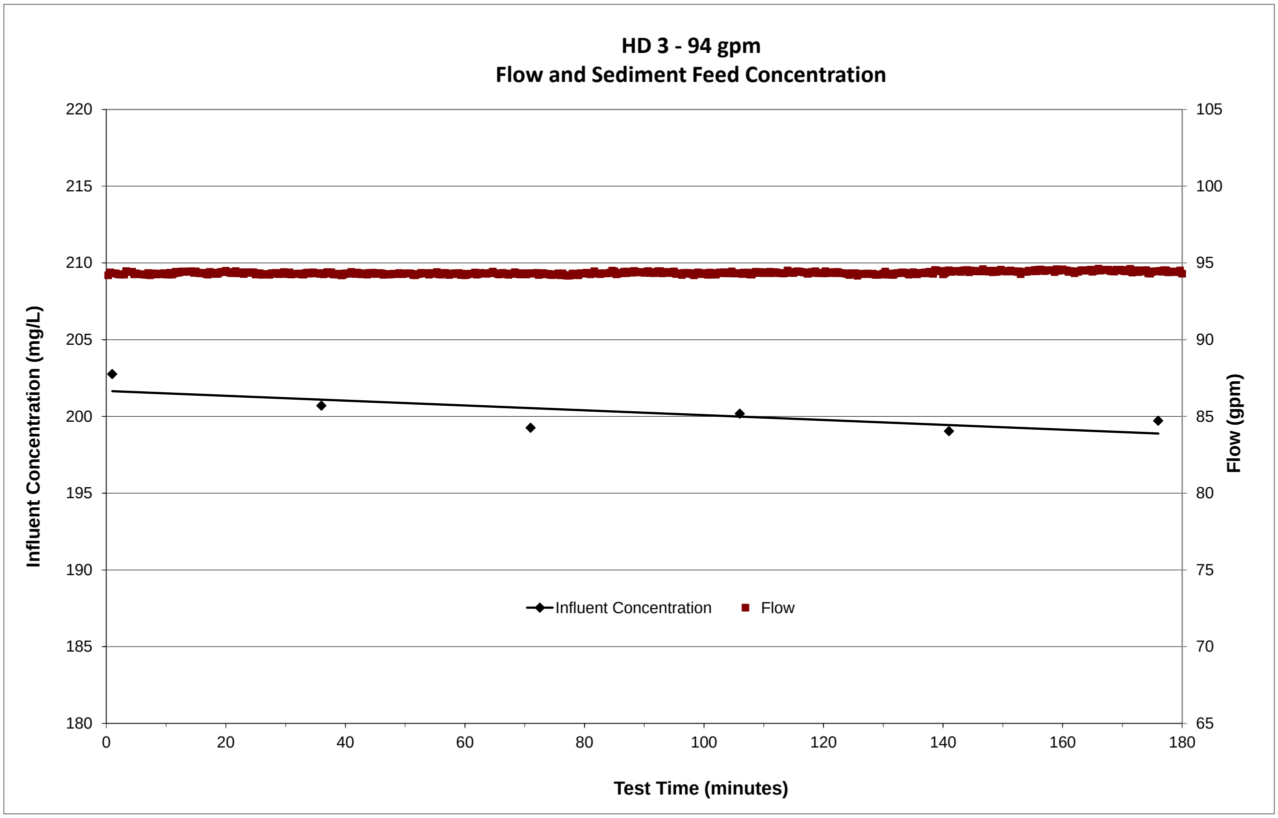

Figure 11 25% MTFR Measured Flow and Influent Concentrations

50% MTFR (191 gpm)

The test was conducted at 174 gpm over a period of 1.75 hours. The test parameters and sampling results are shown in **Table 7**.

The resulting removal efficiency was 69.9%. The test flow was averaged and recorded every 10 seconds throughout the test. The average recorded test flow was 173.9 gpm, with a COV of 0.002. The recorded temperature for the test did not exceed 65 degrees F.

The injection feed rate of 131.6 g/min was verified by collecting 1-minute weight samples from the injector. Six influent injection measurements were taken throughout the test duration. The calculated concentrations for the full test ranged from 198 to 200 mg/L, with a mean of 199 mg/L and COV of 0.00. The total mass injected into the unit was 28.1 lbs. The calculated mass-flow concentration for the test was 196 mg/L. The measured influent concentration and flow data for the complete test is shown on **Figure 12**.

Eight (8) background concentrations samples were collected throughout the test and ranged from 0.0 (NDL) to 2.7 mg/L. A 3rd-order curve and corresponding equation was developed for calculating the background concentrations used for the adjusted effluent concentrations.

Table 7 50% MTFR Test Parameters and Collected Data

Injection Sample	Sample Time minutes	Sample ID	Sample Time minutes	Effluent Concentration mg/L	Background Concentration mg/L	Adjusted Effluent mg/L
Inj 1	1	**Eff 1, BG 1**	10	45.7	0.5	45.2
Inj 2	19	**Eff 2**	13	63.8	0.5	63.3
Inj 3	37	**Eff 3, BG 2**	16	45.1	0.5	44.6
Inj 4	55	**Eff 4**	28	41.0	0.5	40.5
Inj 5	73	**Eff 5, BG 3**	31	45.3	0.5	44.8
Inj 6	91	**Eff 6**	34	46.2	0.5	45.7
Injection Sampling Duration (seconds)	60	**Eff 7, BG 4**	46	60.3	0.5	59.8
		Eff 8	49	51.8	0.6	51.1
		Eff 9, BG 5	52	49.6	0.5	49.1
Detention Time (minutes)	1.98	**Eff 10**	64	66.7	1.2	65.5
		Eff 11, BG 6	67	53.7	1.4	52.3
		Eff 12	70	53.4	1.5	51.9
Total Run Time (minutes)	105	**Eff 13, BG 7**	82	94.1	2.3	91.7
		Eff 14	85	96.2	2.6	93.6
		Eff 15, BG 8	88	90.1	2.8	87.3
Mass/Volume Influent Concentration (mg/L)	196	**173 gpm**			**Average**	**59.1**
					Removal Efficiency	**69.9%**

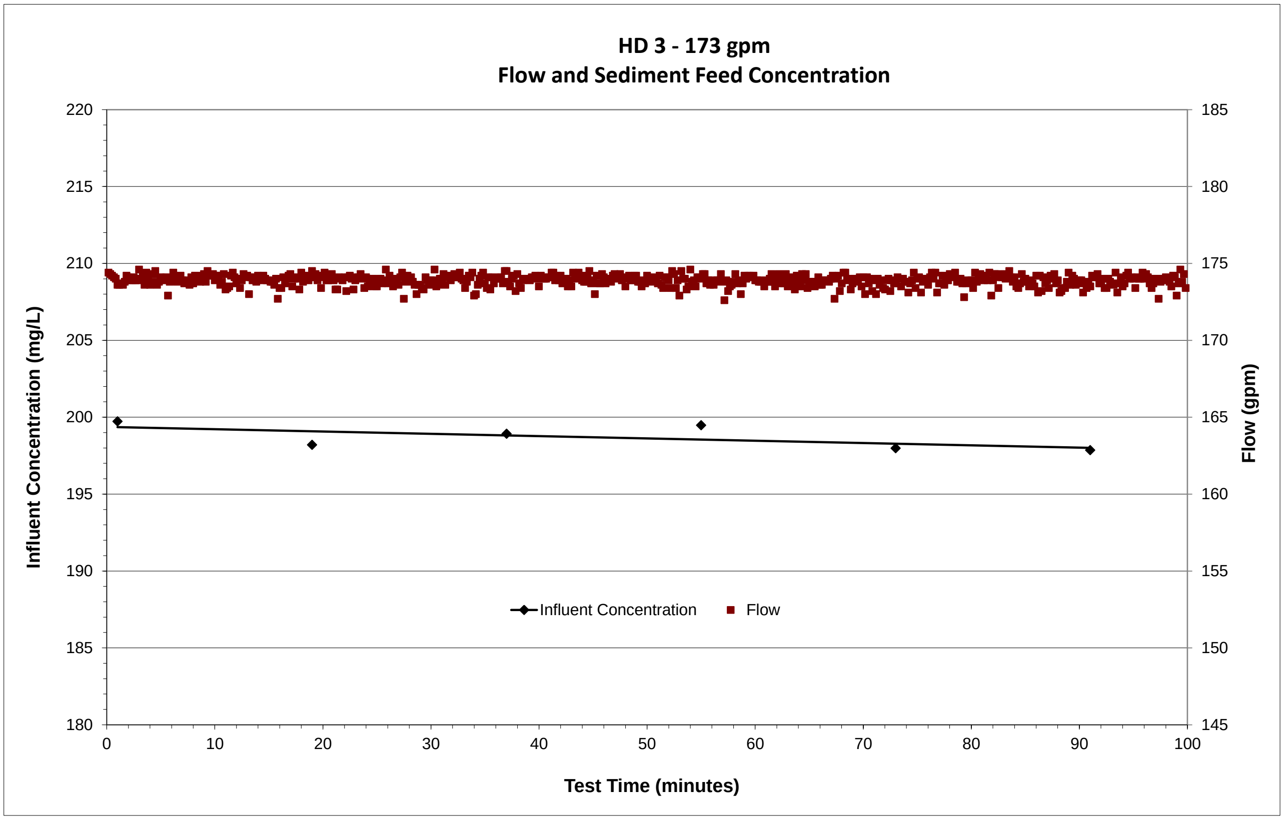

Figure 12 50% MTFR Measured Flow and Influent Concentrations

75% MTFR (286 gpm)

The test was conducted at 286 gpm over a period of 1 hour. The test parameters and sampling results are shown in **Table 8**.

The resulting removal efficiency was 51.7%. The test flow was averaged and recorded every 10 seconds throughout the test. The average recorded test flow was 286.3 gpm, with a COV of 0.002. The recorded temperature for the test did not exceed 63 degrees F.

The injection feed rate of 216.6 g/min was verified by collecting 1-minute weight samples from the injector. Six influent injection measurements were taken throughout the test duration. The calculated concentrations for the full test ranged from 198 to 199 mg/L, with a mean of 199 mg/L and COV of 0.00. The total mass injected into the unit was 30.0 lbs. The calculated mass-flow concentration for the test was 220 mg/L. The measured influent concentration and flow data for the complete test is shown on **Figure 13**.

Eight (8) background concentrations samples were collected throughout the test and ranged from 2.3 to 7.6 mg/L. A 3rd-order curve and corresponding equation was developed for calculating the background concentrations used for the adjusted effluent concentrations.

Table 8 75% MTFR Test Parameters and Collected Data

Injection Sample	Sample Time (minutes)	Sample ID	Sample Time (minutes)	Effluent Concentration (mg/L)	Background Concentration (mg/L)	Adjusted Effluent (mg/L)
Inj 1	1	**Eff 1, BG 1**	6	98.0	2.1	95.9
Inj 2	13	**Eff 2**	8	102.0	2.4	99.6
Inj 3	25	**Eff 3, BG 2**	10	105.8	2.6	103.2
Inj 4	37	**Eff 4**	18	119.2	3.1	116.1
Inj 5	49	**Eff 5, BG 3**	20	106.4	3.2	103.2
Inj 6	60	**Eff 6**	22	111.2	3.2	107.9
Injection Sampling Duration (seconds)	60	**Eff 7, BG 4**	30	120.2	3.5	116.7
		Eff 8	32	119.1	3.5	115.6
		Eff 9, BG 5	34	102.5	3.6	98.9
Detention Time (minutes)	1.20	**Eff 10**	42	100.5	4.2	96.3
		Eff 11, BG 6	44	105.8	4.5	101.3
		Eff 12	46	108.1	4.8	103.3
Total Run Time (minutes)	64	**Eff 13, BG 7**	54	116.7	6.6	110.0
		Eff 14	56	122.1	7.2	114.9
		Eff 15, BG 8	58	118.9	8.0	111.0
Mass/Volume Influent Concentration (mg/L)	220	**286 gpm**			**Average**	**106.3**
					Removal Efficiency	**51.7%**

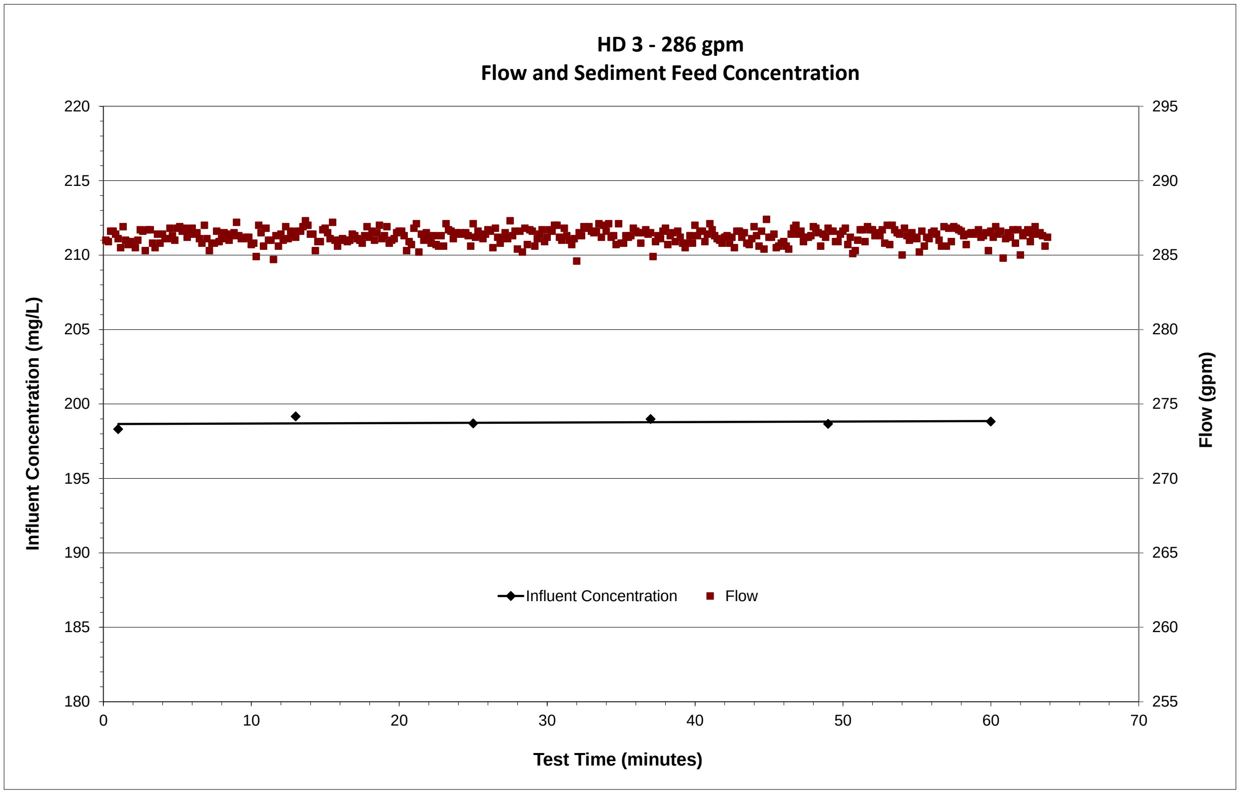

Figure 13 75% MTFR Measured Flow and Influent Concentrations

100% MTFR (382 gpm)

The test was conducted at 352 gpm over a period of 1 hour. The test parameters and sampling results are shown in **Table 9.**

The resulting removal efficiency was 43.6%. The test flow was averaged and recorded every 10 seconds throughout the test. The average recorded test flow was 352.3 gpm, with a COV of 0.002. The recorded temperature for the test did not exceed 64 degrees F.

The injection feed rate of 267.5 g/min was verified by collecting 1-minute weight samples from the injector. Six influent injection measurements were taken throughout the test duration. The calculated concentrations for the full test ranged from 200 to 202 mg/L, with a mean of 201 mg/L and COV of 0.00. The total mass injected into the unit was 28.7 lbs. The calculated mass-flow concentration for the test was 188 mg/L. The measured influent concentration and flow data for the complete test is shown on **Figure 14**.

Eight (8) background concentrations samples were collected throughout the test and ranged from 0.0 (NDL) to 8.0 mg/L. A 3rd-order curve and corresponding equation was developed for calculating the background concentrations used for the adjusted effluent concentrations.

Table 9 100% MTFR Test Parameters and Collected Data

Injection Sample	Sample Time minutes	Sample ID	Sample Time minutes	Effluent Concentration mg/L	Background Concentration mg/L	Adjusted Effluent mg/L
Inj 1	1	**Eff 1, BG 1**	5	109.3	0.5	108.8
Inj 2	12	**Eff 2**	7	112.9	0.5	112.4
Inj 3	23	**Eff 3, BG 2**	9	119.4	0.5	118.9
Inj 4	34	**Eff 4**	16	120.2	0.7	119.5
Inj 5	45	**Eff 5, BG 3**	18	101.1	0.5	100.6
Inj 6	56	**Eff 6**	20	123.0	0.9	122.0
Injection Sampling Duration (seconds)	60	**Eff 7, BG 4**	27	104.6	1.7	102.8
		Eff 8	29	113.4	2.1	111.3
		Eff 9, BG 5	31	102.3	2.4	99.9
Detention Time (minutes)	0.97	**Eff 10**	38	128.0	3.8	124.2
		Eff 11, BG 6	40	121.0	4.3	116.7
		Eff 12	42	125.3	4.8	120.5
Total Run Time (minutes)	58.5	**Eff 13, BG 7**	49	82.3	6.5	75.8
		Eff 14	51	95.4	7.0	88.3
		Eff 15, BG 8	53	81.1	7.5	73.6
Mass/Volume Influent Concentration (mg/L)	188	**353 gpm**			**Average**	**106.4**
					Removal Efficiency	**43.6%**

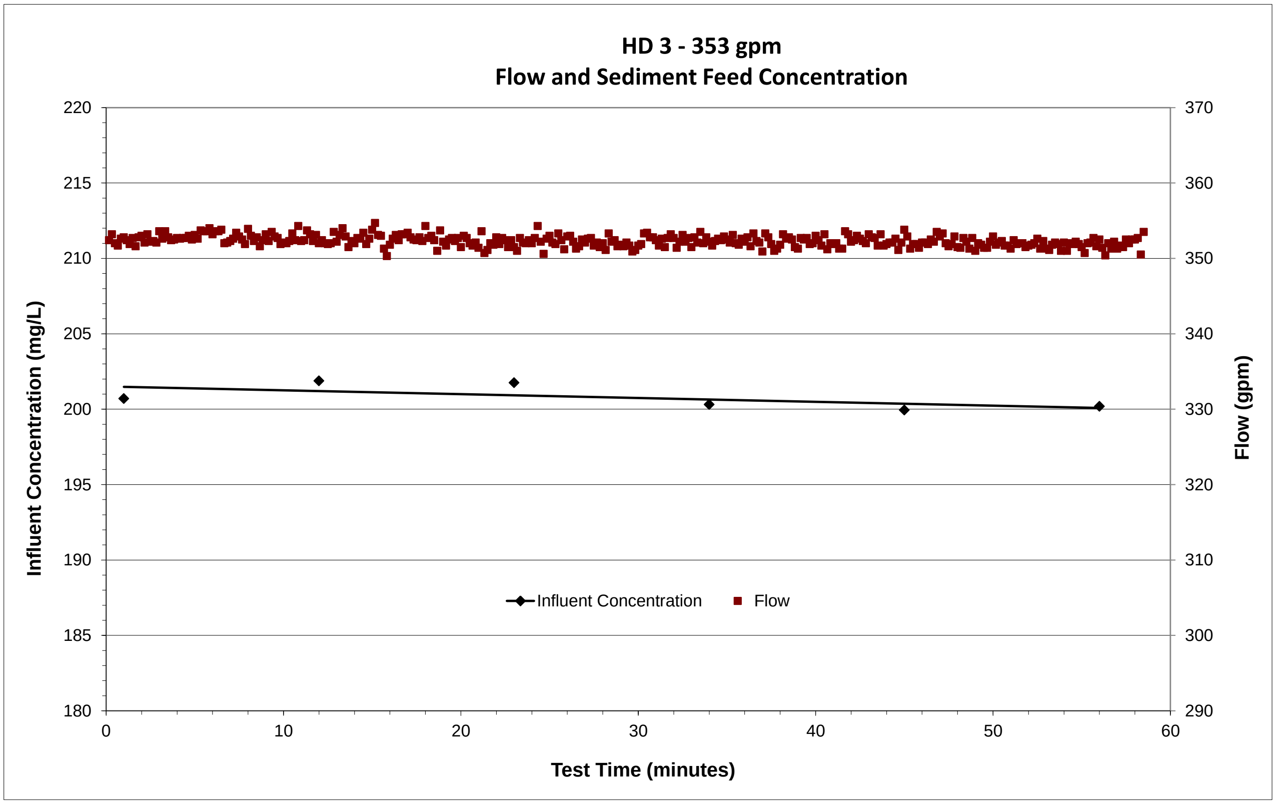

Figure 14 100% MTFR Measured Flow and Influent Concentrations

125% MTFR (477 gpm)

The test was conducted at 442 gpm over a period of 48 minutes. The test parameters and sampling results are shown in **Table 10**.

The resulting removal efficiency was 41.8%. The test flow was averaged and recorded every 10 seconds throughout the test. The average recorded test flow was 439.7 gpm, with a COV of 0.002. The recorded temperature for the test did not exceed 61 degrees F.

The injection feed rate of 334.4 g/min was verified by collecting 30-second weight samples from the injector. Six influent injection measurements were taken throughout the test duration. The calculated concentrations for the full test ranged from 198 to 202 mg/L, with a mean of 201 mg/L and COV of 0.01. The total mass injected into the unit was 30.7 lbs. The calculated mass-flow concentration for the test was 190 mg/L. The measured influent concentration and flow data for the complete test is shown on **Figure 15**.

Eight (8) background concentrations samples were collected throughout the test and ranged from 1.1 to 8.4 mg/L. A 3rd-order curve and corresponding equation was developed for calculating the background concentrations used for the adjusted effluent concentrations.

Table 10 125% MTFR Test Parameters and Collected Data

Injection Sample	Sample Time minutes	Sample ID	Sample Time minutes	Effluent Concentration mg/L	Background Concentration mg/L	Adjusted Effluent mg/L
Inj 1	1	**Eff 1, BG 1**	5	108.8	1.2	107.6
Inj 2	10	**Eff 2**	6	105.3	1.2	104.1
Inj 3	19	**Eff 3, BG 2**	7	121.1	1.1	119.9
Inj 4	28	**Eff 4**	14	123.0	1.4	121.6
Inj 5	37	**Eff 5, BG 3**	15	128.3	1.5	126.9
Inj 6	45	**Eff 6**	16	127.1	1.6	125.5
Injection Sampling Duration (seconds)	30	**Eff 7, BG 4**	23	121.1	2.5	118.6
		Eff 8	24	122.6	2.7	119.9
		Eff 9, BG 5	25	119.2	2.9	116.3
Detention Time (minutes)	0.78	**Eff 10**	32	102.5	4.5	98.0
		Eff 11, BG 6	33	114.7	4.7	110.0
		Eff 12	34	118.1	5.0	113.1
Total Run Time (minutes)	48	**Eff 13, BG 7**	41	104.9	7.0	98.0
		Eff 14	42	111.7	7.3	104.4
		Eff 15, BG 8	43	84.0	7.6	76.4
Mass/Volume Influent Concentration (mg/L)	190	**442 gpm**			**Average**	**110.7**
					Removal Efficiency	**41.8%**

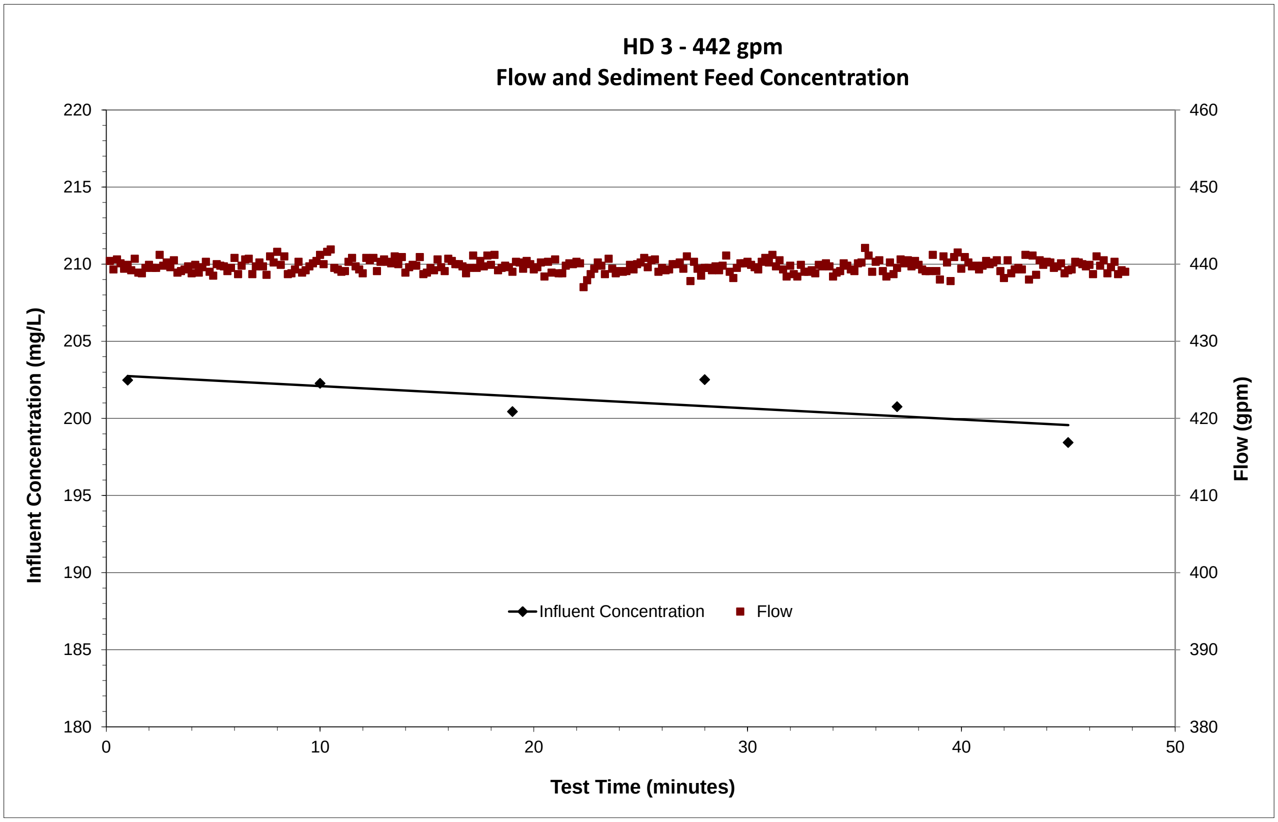

Figure 15 125% MTFR Measured Flow and Influent Concentrations

4.3 Scour Test

The commercially-available AGSCO NJDEP50-1000 certified sediment mix was utilized for the scour test. Three samples of the batch mix were analyzed in accordance with ASTM D422-63 (2007), by CTLGroup, an ISO/IEC 17025 accredited independent laboratory, and provided with the sediment shipment. The specified less-than (%-finer) values of the sample average were within the specifications listed in **Column 3** of **Table** 1, as defined by the protocol. The D_{50} of the 3-sample average was 202 microns. The PSD data of the samples are shown in **Table 11** and the corresponding curves, including the initial AGSCO in-house analysis, are shown in **Figure 16.**

Table 11 Scour Test Sediment Particle Size Distribution

Particle size (µm)	NJDEP %-Finer Specifications	Test Sediment Particle Size (%-Finer)			
		Sample 1	Sample 2	Sample 3	Average
1000	100	100	100	100	**100**
500	90	95	95	95	**95**
250	55	58	58	59	**58**
150	40	41	41	42	**41**
100	25	23	23	23	**23**
75	10	10	10	11	**10**
50	0	1	1	1	**1**

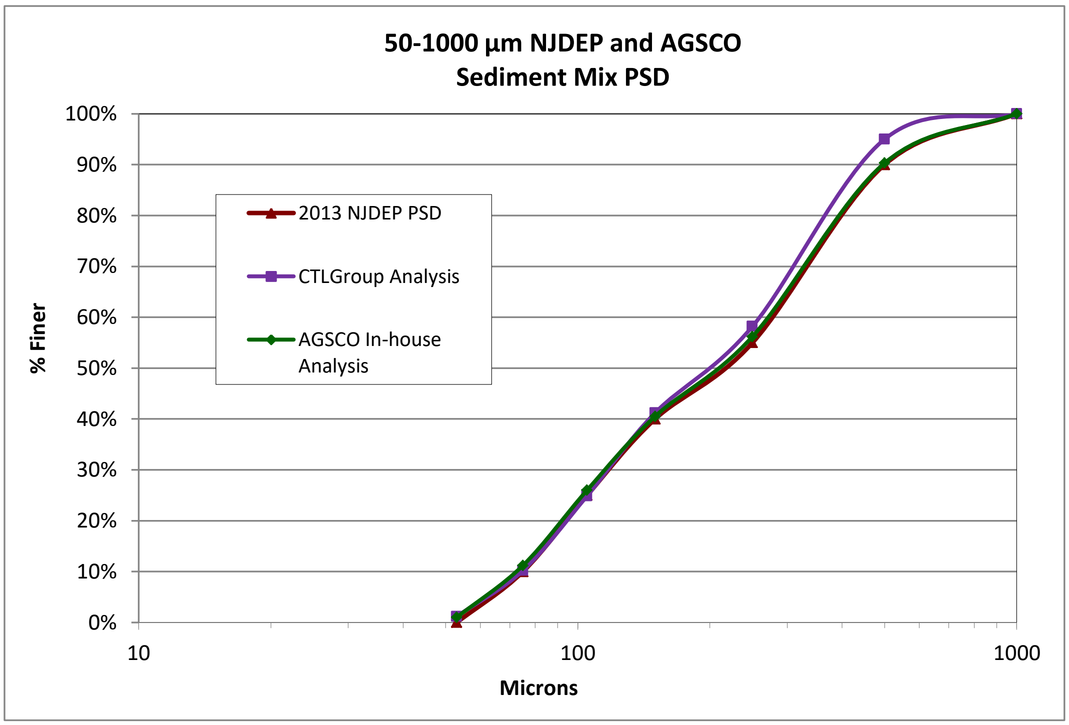

Figure 16 Scour Test Sediment PSD Curves

The scour test was conducted with the sump preloaded with 6" of sediment to the 50% capacity level (6").

The test was conducted at a target flow of 919 gpm, which is equal to 241% MTFR. The flow data was recorded every 5 seconds throughout the test and is shown on **Figure 17.** The target flow was reached within 5 minutes of initiating the test. The average recorded steady-state flow was 919 gpm, with a COV of 0.011. The recorded water temperature was 64.8 degrees F.

Eight background samples were collected throughout the duration of the test. The measured concentrations ranged from 1.9 to 2.5 mg/L, with an average concentration of 2.2 mg/L.

A total of 15 effluent samples were collected throughout the test. The measured concentrations ranged from 1.4 to 2.8 mg/L, with an average unadjusted concentration of 2.2 mg/L. The scour concentration adjusted for background was essentially zero. The effluent and background concentration data are shown in **Table 12** and on **Figure 18**.

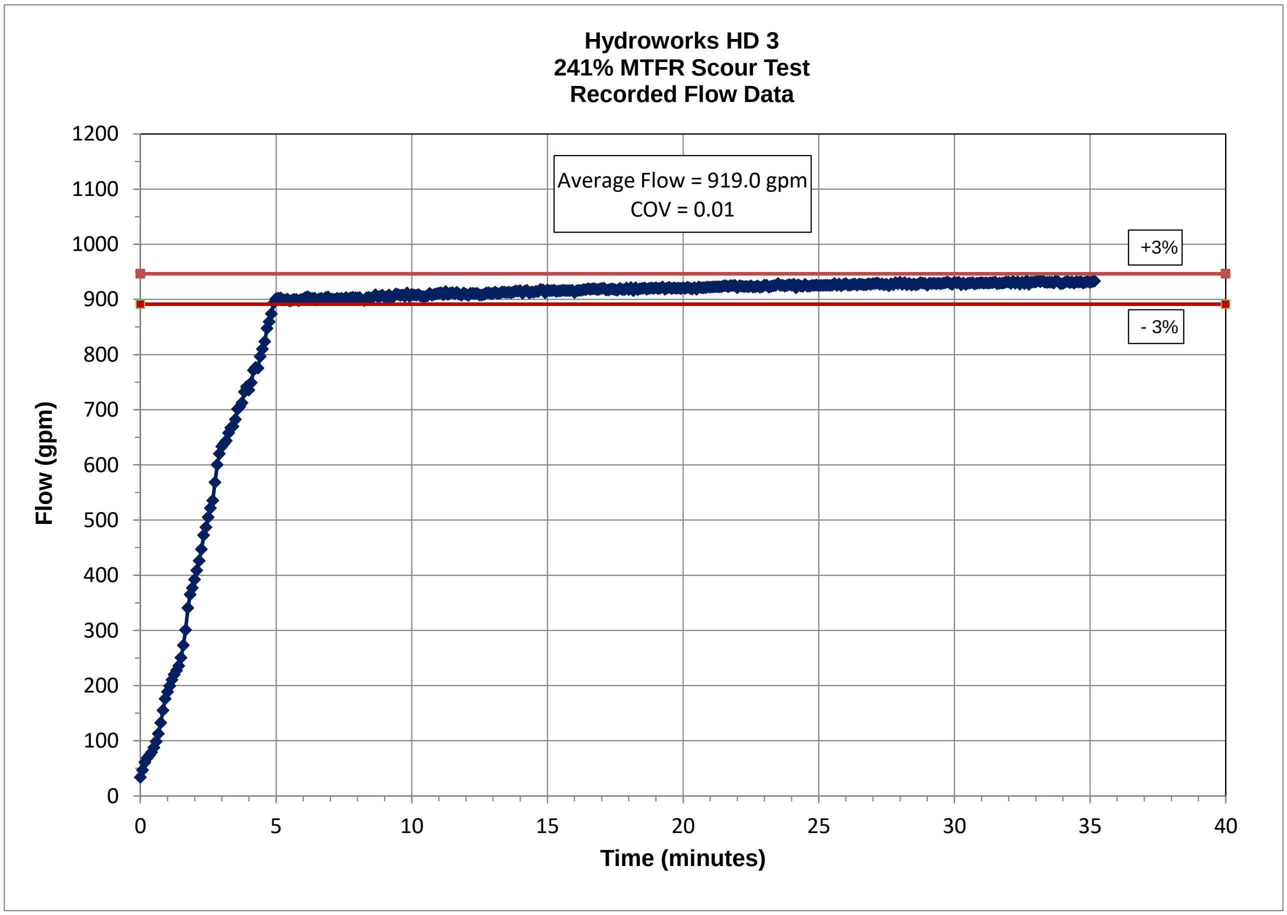

Figure 17 Scour Test Flow Data

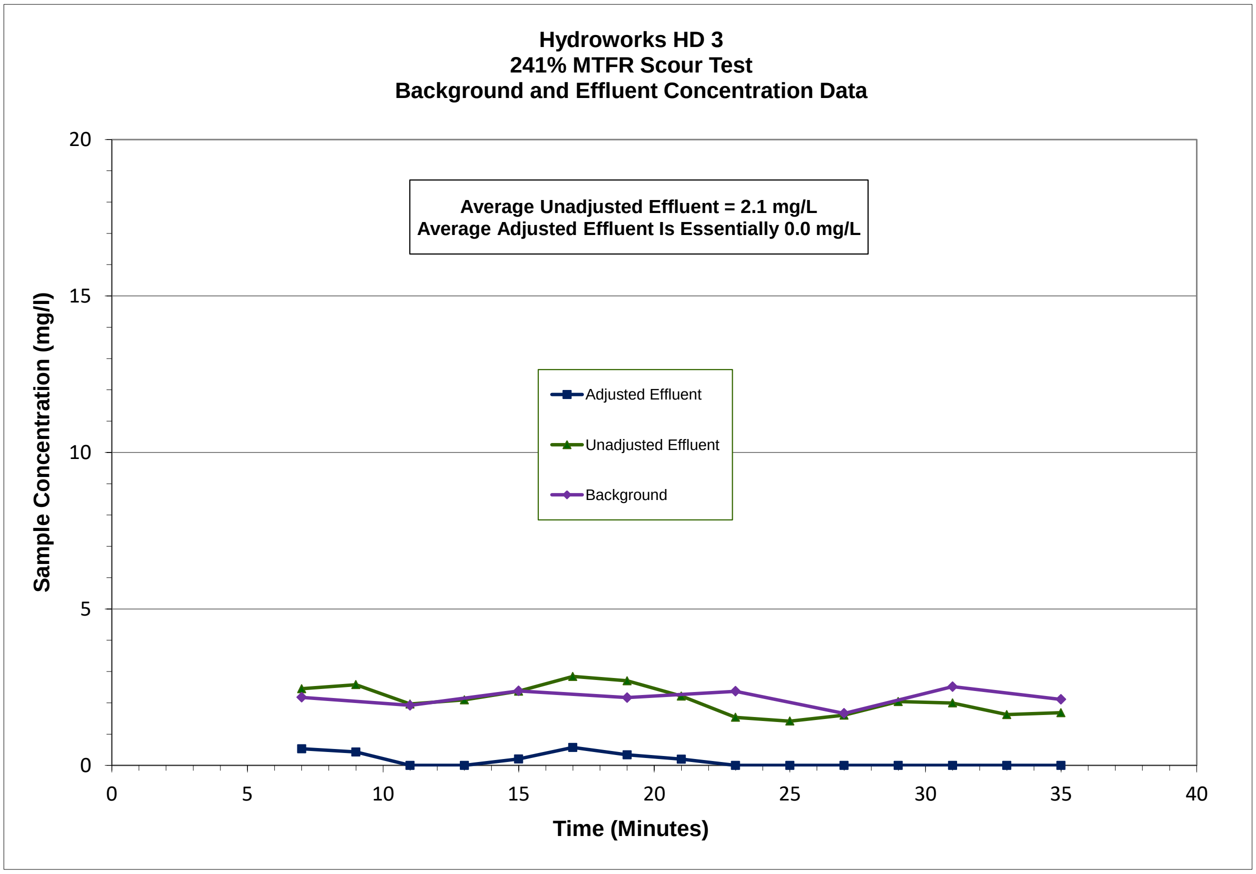

Figure 18 Scour Test Background and Effluent Concentrations

Table 12 Scour Test Unadjusted Effluent Concentration Data

Sample ID	Timestamp (minutes)	Effluent Concentration (mg/L)	Background Concentration (mg/L)
EFF 1	7	2.45	2.18
EFF 2	9	2.58	2.05
EFF 3	11	1.96	1.92
EFF 4	13	2.09	2.15
EFF 5	15	2.37	2.38
EFF 6	17	2.84	2.27
EFF 7	19	2.70	2.17
EFF 8	21	2.21	2.27
EFF 9	23	1.53	2.37
EFF 10	25	1.42	2.01
EFF 11	27	1.60	1.66
EFF 12	29	2.04	2.09
EFF 13	31	1.99	2.52
EFF 14	33	1.62	2.31
EFF 15	35	1.68	2.11
	Average	**2.07**	**2.16**

4.4 Hydraulics

Piezometer taps were installed in the unit as described in **Section 2.5** (Pressure head). Flow (gpm) and water level (ft) within the system were measured for 12 flows ranging from 50 gpm to 1105 gpm (2.5 cfs). The recorded elevation data and system loss are shown in **Table 13.** The outlet flow oscillated within the pipe at low flows and consequently, it was necessary to interpolate the elevation at 100 gpm, as the measured depth was uncharacteristically low. The Elevation Curves for each pressure tap location are shown on **Figure 19.** The system loss decreased with the outlet velocity head as shown on **Figure 20**. The pressure data for the inlet and outlet pipes were corrected for velocity head. The greatest calculated loss was realized at the lowest flow, as the inlet elevation was fairly constant in comparison to the outlet elevation.

Table 13 Recorded Flow and Elevation Data

Flow		Water Elevations (measured)			Water Elevations (adjusted to inlet)			Losses			
		Inlet Pipe	Tank	Outlet Pipe	Inlet Pipe	Tank	Outlet Pipe	Inlet El. (A')	Outlet El. (C')	System Energy Loss	
gpm	cfs	A	B	C	A	B	C	Corrected for V-head	Corrected for V-head	A'-C'	Outlet V-head
		ft	ft	ft	ft	ft	ft	ft	ft	ft	ft
0	0	1.016		0.973							
50.5	0.11	2.985	2.985	1.039	1.969	1.969	0.023	1.969	0.330	1.639	0.264
100.1	0.22	3.040	3.040	*1.061	2.024	2.024	0.045	2.024	0.529	1.496	0.441
150.0	0.33	3.083	3.083	1.084	2.067	2.067	0.068	2.068	0.609	1.459	0.498
201.4	0.45	3.100	3.098	1.090	2.084	2.082	0.074	2.085	0.886	1.199	0.769
274.2	0.61	3.139	3.139	1.112	2.123	2.123	0.096	2.125	0.996	1.128	0.857
349.7	0.78	3.175	3.174	1.138	2.159	2.158	0.122	2.162	1.008	1.154	0.843
450.6	1.00	3.221	3.217	1.172	2.205	2.201	0.156	2.210	1.009	1.201	0.810
550.7	1.23	3.247	3.248	1.200	2.231	2.232	0.184	2.238	1.052	1.186	0.825
652.5	1.45	3.274	3.261	1.222	2.258	2.245	0.206	2.269	1.136	1.133	0.887
804.2	1.79	3.324	3.318	1.239	2.308	2.302	0.223	2.324	1.379	0.945	1.113
952.1	2.12	3.390	3.376	1.248	2.374	2.360	0.232	2.396	1.693	0.704	1.418
1105.0	2.46	3.398	3.402	1.272	2.382	2.386	0.256	2.412	1.801	0.611	1.502
				*Interpolated							

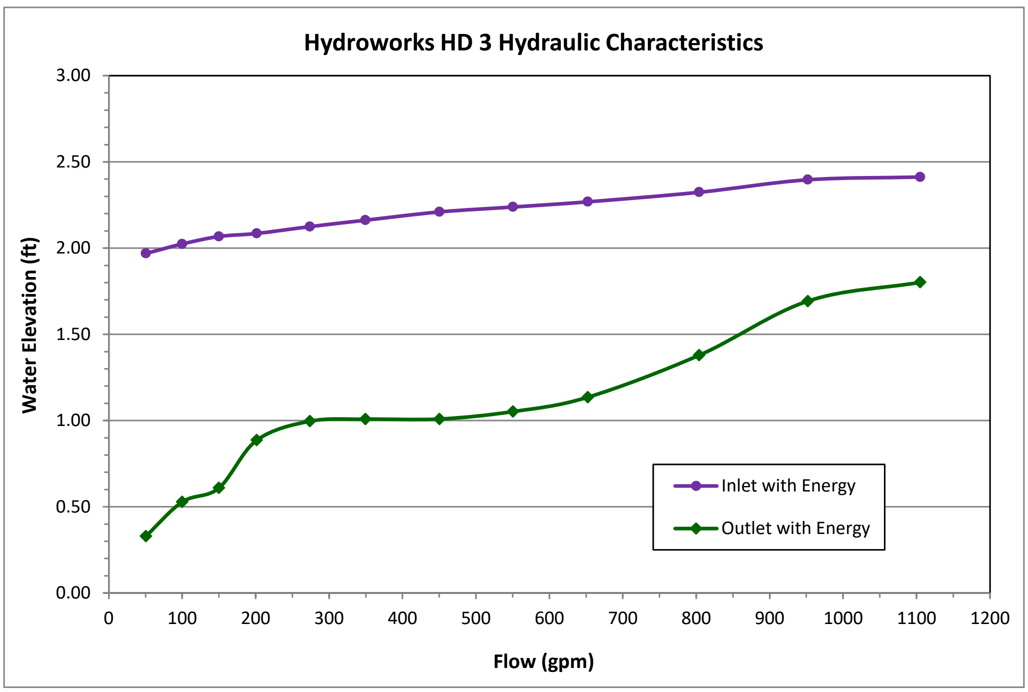

Figure 19 Measured Flow vs Water Elevations

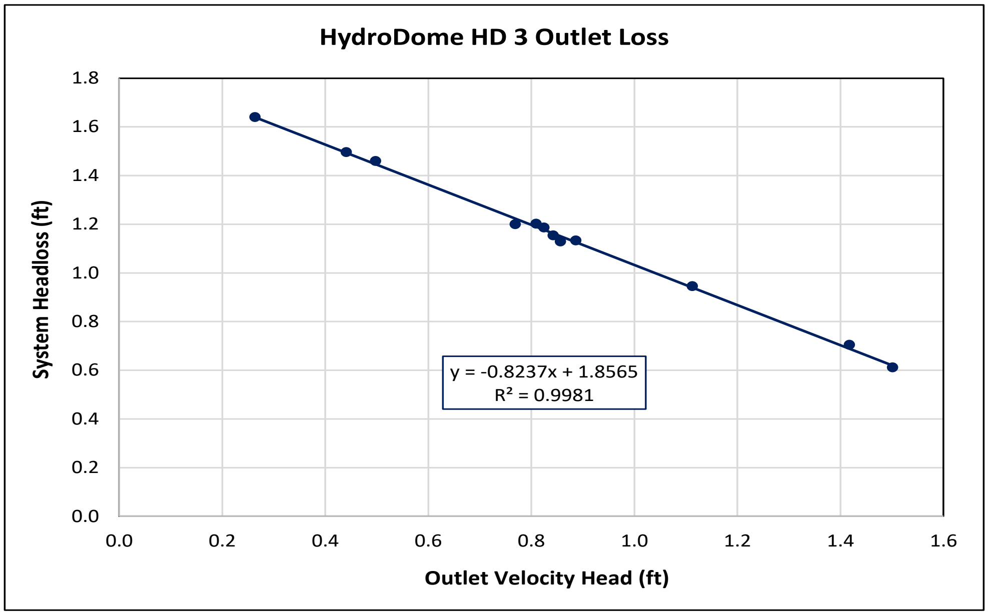

Figure 20 Calculated Outlet Losses

5. Design Limitations

Hydroworks has been designing separators for site specific applications for over 15 years. Site constraints and design requirements are addressed on a project specific basis. Sizing calculations are performed based on site specific criteria and submittals are provided upon request. Hydraulic assessments including hydraulic gradeline calculations and buoyancy calculations are provided as part of the design when requested.

Required Soil Characteristics

The hydrodynamic separator can be modified to account for most soil conditions (bearing capacity, chemistry, contamination) through changes in footprint, materials, and coatings.

Pipe Slope

The Hydroworks HD was tested with a horizontal inlet and outlet pipe. HydroDome is not sensitive to pipe slope since it creates a full pipe velocity condition at the inlet.

Invert to Grade

The depth of pipe burial (invert to grade) needs to be reviewed to ensure proper pipe cover for traffic loading and frost requirements as well as constructability/conflicts with minimum product dimensions (height of HD above pipe invert, thickness of top cap/height of frame and cover).

Most design conditions can be accommodated through site specific design changes (e.g., embedding frame and cover in the top cap) although shallow invert to grade applications may prevent the use of HydroDome.

Maximum Flow Rate

HydroDome is typically designed to convey the flow rate of the outlet pipe as designed or the required controlled flow rate if flow control is required. The Hydroworks HD will be sized in New Jersey for water quality control based upon the NJCAT tested hydraulic loading rate of 54 gallons per minute per square foot of settling surface area.

Ensuring Proper Installation

The contractor is provided with drawings that show the orientation of the cap, inlet and outlet pipes orientation and size, rim and invert elevations, the number of concrete pieces, and heaviest picks. Instructions and material (stainless steel bolts, caulking, gaskets) are provided to the contractor for the installation of the HD insert in the outlet pipe of the structure. Match lines are provided on the precast pieces to ensure the top cap is properly oriented for maintenance access. The cast iron frame and grate or cover is provided with the structure and is embossed with "Hydroworks" to ensure the structure is easily located for maintenance.

Configurations

The Hydroworks HD separator is available in various configurations. The units can be installed online or offline. The HydroDome has been scour tested to the NJDEP protocol and proven to have negligible scour at 241% percent of the rated treatment rate.

Structural Load Limitations

The structural load limitations depend on the structure in which the HydroDome is installed. If the HD is installed in a precast concrete structure the HD will be designed for traffic loading based on the standard AASHTO HS20 design standard. If the HD is installed in fiberglass, plastic, or a metal structure the structural design will be based on the site-specific loading requirement.

Pre-treatment Requirements

The Hydroworks HydroDome has no pre-treatment requirements.

Tailwater Considerations

Tailwater increases the required upstream driving head to convey a certain flow rate through the drainage system. The overall head differential through the HydroDome, however, will remain the same with, or without, tailwater. Increasing upstream head elevations, and associated premature bypass, are not an issue with HydroDome since it does not have an internal bypass. Therefore, the HydroDome will not experience premature bypass or loss of floatables control with tailwater that could/would affect a separator with an internal or external bypass. Accordingly, the performance for TSS removal or floatable control are not affected by tailwater unlike a traditional separator with internal bypass weirs. The hydraulic gradeline of the overall system is affected by tailwater, and Hydroworks should be consulted to assist in the assessment of tailwater impacts on the hydraulic gradeline.

Allowable Headloss

Headloss for the HydroDome separator is a function of flow velocity in the piping system and the geometry of the internal separator components. The sensitivity of a drainage system to headloss and upstream flooding is site-specific based on downstream tailwater elevations, and the design of the drainage system itself. The introduction of any structure to a drainage system will increase the headloss and hydraulic gradeline. Hydroworks can provide calculations to determine the headloss through the HydroDome separator based on the hydraulic tests performed at Alden Labs. The engineer of record can determine if the calculated headloss is acceptable for the drainage system in question.

Depth to Seasonal High-Water Table

High groundwater conditions will not affect the operation of the Hydroworks HD. Although the drainage system is intended to be a sealed system the water table is typically reduced to the level of drainage pipes since water infiltrates the storm network and/or flows through pipe bedding. However, some agencies require buoyancy calculations based on an empty vessel with the water table at the surface. The base of the concrete structure can be made with an extension in these cases to satisfy any site-specific or specified anti-buoyancy criteria.

6. Maintenance

Routine inspection and maintenance of the Hydroworks HydroDome ensures optimal performance. Stormwater regulations require that all BMPs be inspected and maintained to ensure they are operating as designed to allow for effective pollutant removal and provide protection to receiving water bodies. The frequency of inspection and maintenance depends on numerus factors including land use, average daily traffic, nearby construction activities, on-site material storage, site spill potential, winter sanding activities, and how the separator was sized with respect to annual TSS removal, particle size distribution of TSS and required sediment storage.

Typically, drainage structures are installed during the early stages of construction. Even if they are not installed to provide sediment and erosion control, they will provide this function if installed prior to stabilization of the site. Therefore, it is recommended that the separator be cleaned at the end of the construction period. The Hydroworks HD should be inspected once during the first year of operation for stabilized sites and twice for hot spot installations. Hot spots include:

- High spill potential
- On-site material storage
- Nearby construction or unstabilized site conditions
- High average daily traffic (> 500 vehicles/day)

The inspection and maintenance period can be lengthened or shortened based on the results from the first, and subsequent inspections.

Procedures for inspection, as well as a checklist, are provided in the HydroDome O&M Manual at: www.hydroworks.com\hdmaintenance.pdf. Hydroworks recommends the use of a coring tube (Core Pro; Sludge Judge) to determine depths of oil and sediment in the unit. Sediment collected in the separator has a high-water content and can be fine. It is difficult to measure sediment depths in these circumstances with rods or measuring sticks. A coring tube provides the best way to measure sediment depth in a separator.

Depths are provided in the maintenance manual as well as in the Verification Appendix for sediment depths prior to maintenance. Increasing the depth of the structure will also increase the depth for sediment accumulation prior to maintenance, and therefore, needs to be considered for any site-specific application.

The Hydroworks HydroDome separator can be cleaned using any standard drainage structure cleaning equipment.

7. Statements

The following signed statements from the manufacturer (Hydroworks, LLC), independent testing laboratory (Alden Research Laboratory) and NJCAT are required to complete the NJCAT verification process.

In addition, it should be noted that this report has been subjected to public review (e.g., stormwater industry) and all comments and concerns have been satisfactorily addressed.

April 8, 2021

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: Hydroworks HydroDome HD 3 Verification Testing Certification

Dear Dr. Magee,

Hydroworks certifies that the Hydroworks HydroDome HD 3 hydrodynamic separator was tested in strict accordance with the New Jersey Department of Environmental Protection Laboratory Protocol to Assess the Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device (NJDEP HDS Protocol, January 2013).

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

Please to not hesitate to contact the undersigned if you have any questions regarding this certification.

Sincerely,

Hydroworks, LLC

Graham Bryant, MSc. P.Eng.

President

April 28, 2021

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

Conflict of Interest Statement

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

Protocol Compliance Statement

Alden performed design research testing, as well as the final certification testing on the Hydroworks HD 3 HydroDome stormwater treatment device. The Technical Report and all required supporting data documentation has been submitted to NJCAT as required by the protocol.

Testing performed by ALDEN on the Hydroworks HD 3 HydroDome met or exceeded the requirements as stated in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device", (January 25, 2013).

James T. Mailloux

James T. Mailloux

Principal Engineer
Alden Research Laboratory
jmailloux@aldenlab.com

(508) 829-6000 x6446

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

April 10, 2021

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 Hydroworks HydroDome (HD) stormwater separator at the Alden Research laboratory, Inc. in Holden, MA, 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 HDS Protocol, January 2013) were met consistent with the NJDEP Approval Process. Specifically:

Test Sediment Feed

The sediment used for removal efficiency tests was prepared by Alden to meet the NJDEP test sediment PSD for sediment removal efficiency testing. The sediment was silica based, with a specific gravity of 2.65. Sediment test batches of approximately 35 lbs were prepared in individual 5-gallon buckets, which were arbitrarily selected for each removal efficiency test. A well-mixed sample was collected from each test batch and analyzed for PSD by GeoTesting Express, Inc. Acton, Massachusetts. GeoTesting is an AALA ISO/IEC 17025 accredited independent laboratory. The average of the samples was used for compliance to the protocol specifications. The d_{50} of the sediment was 62 µm, significantly less than the NJDEP specification of <75 µm.

Scour Test Sediment

A commercially-available AGSCO NJDEP50-1000 certified sediment mix was utilized for the scour test. Three samples of the batch mix were analyzed in accordance with ASTM D422-63 (2007), by CTLGroup, Skokie, Illinois, an ISO/IEC 17025 accredited independent laboratory, and provided with the sediment shipment. The specified less-than (%-finer) values of the sample average were within the specifications as defined by the protocol. The D_{50} of the 3-sample average was 202 microns.

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 HydroDome (model HD 3) Separator (MTFR 381.5 gpm, 0.85 cfs) was 58.5%.

Scour Testing

Scour testing of the HydroDome separator was conducted in accordance with Section 4 of the NJDEP Protocol at a target flow rate greater than 200% of the HD 3 MTFR to qualify the MTD for online installation. The average test flow rate was 241% of the 0.85 cfs MTFR. The average unadjusted effluent concentration for this test was 2.1 mg/L (background concentration 2.2 mg/L), essentially indicating no sediment scour, qualifying the HydroDome for on-line installation.

Sincerely,

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

8. References

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

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

ASTM (2007), *"Standard Test Methods for Determination of Water (Moisture) Content of Soil by Direct Heating"*, Annual Book of ASTM Standards, D4959-07, Vol. 04.08.

ASTM (2013), *"Standard Test Methods for Determining Sediment Concentration in Water Samples",* Annual Book of ASTM Standards, D3977-19, Vol. 11.02.

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

NJDEP 2013b. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*. Trenton, NJ. January 25, 2013.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Hydroworks, LLC. National Headquarters 257 Cox Street, Roselle, NJ 07203. www.hydroworks.com (888)-290-7900
- Hydroworks HydroDome verified models are shown in **Table A-1** and **Table A-2**.
- TSS Removal Rate – 50%
- Online or offline installation

Detailed Specification

- NJDEP sizing tables and physical dimensions of the Hydroworks HydroDome verified models are attached (**Table A-1** and **Table A-2**).
- New Jersey requires that the peak flow rate of the NJWQ Design Storm event of 1.25 inch in 2 hours shall be used to determine the appropriate size for the MTD. The HD 3 model has a maximum treatment flow rate (MTFR) of 0.85 cfs (381.5 gpm), which corresponds to a surface loading rate of 54 gpm/ft^2 of sedimentation area.
- Maximum recommended sediment depth prior to cleanout is 6 inches for all model sizes based on the depths provided in **Table A-2**. Hydroworks can increase the overall depth of any model to increase the sediment storage depth for any site-specific storage/maintenance criteria.
- Operations and Maintenance Guide is at: www.hydroworks.com\hdmaintenance.pdf
- The maintenance frequency for all the HydroDome models is 2.5 years (30 months).
- Under N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow a hydrodynamic separator such as the HydroDome to be used in series with another hydrodynamic separator to achieve an enhanced TSS removal rate.

Table A-1 MTFRs and Sediment Removal Intervals for HydroDome Models

Model	Diameter (ft)	Maximum Treatment Flow Rate[1] (cfs)	Treatment Area (ft^2)	Hydraulic Loading Rate (gpm/ft^2)	50% Maximum Sediment Storage[3] (ft^3)	Sediment Removal Interval[2] (years)
HD 3	3	0.85	7.1	54.0	3.5	2.5
HD 4	4	1.51	12.6	54.0	6.3	2.5
HD 5	5	2.36	19.6	54.0	9.8	2.5
HD 6	6	3.40	28.3	54.0	14.1	2.5
HD 7	7	4.63	38.5	54.0	19.2	2.5
HD 8	8	6.04	50.3	54.0	25.1	2.5
HD 10	10	9.44	78.5	54.0	39.3	2.5
HD 12	12	13.60	113.0	54.0	56.5	2.5

1. Based on a verified loading rate of 54.0 gpm/ft^2 for test sediment with a mean particle size of 62 µm and an annualized weighted TSS removal of at least 50% using the methodology in the current NJDEP HDS protocol.
2. Sediment Removal Interval (years) = (50% HDS MTD Max Sediment Storage Volume) / (3.366 * MTFR * TSS Removal Efficiency) calculated using equation in Appendix B, Part B of the NJDEP HDS Protocol.
3. 50% Sediment Storage Capacity is equal to manhole area x 6 inches of sediment depth. Each HydroDome separator has a 12-inch-deep sediment sump.

Table A-2 Standard Dimensions for HydroDome Models

Model	Diameter (ft)	Maximum Treatment Flow Rate (cfs)	Total Chamber Depth (ft)	Treatment Chamber Depth[1] (ft)	Aspect Ratio[2] (Depth/Diameter)	Sediment Sump Depth (ft)
HD 3	3	0.85	5.00	4.50	1.50	1.0
HD 4	4	1.51	5.00	4.50	N/A	1.0
HD 5	5	2.36	7.00	6.50	1.30	1.0
HD 6	6	3.40	8.15	7.65	1.28	1.0
HD 7	7	4.63	9.50	9.00	1.29	1.0
HD 8	8	6.04	10.75	10.25	1.28	1.0
HD10	10	9.44	13.25	12.75	1.28	1.0
HD 12	12	13.60	16.00	15.50	1.29	1.0

1. Treatment chamber depth is defined as the total chamber depth minus ½ the sediment storage depth.
   The aspect ratio is the unit's treatment chamber depth/diameter. The aspect ratio for the tested unit (HD 3) is 1.50. Larger models (>250% MTFR of the unit tested, >2.1 cfs) must be geometrically proportionate to the test unit. A variance of 15% is allowable (1.275 to 1.725).
2. For units <250% MTFR (HD 4), the depth must be equal or greater than the depth of the unit treated.