State of New Jersey

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Commissioner

RECEIVED
AUG 24 2015
HYDRO INTERNATIONAL

August 18, 2015

Lisa Lemont, CPSWQ
Business Development Manager
Hydro International (Stormwater)
94 Hutchins Drive
Portland, ME 04102

Re: Revised MTD Lab Certification for the Downstream Defender Stormwater Treatment Device By Hydro International

TSS Removal Rate 50%

Dear Ms. Lemont:

This letter supersedes the previous certification letter dated January 21, 2015. Hydro International requested a new verification for the Downstream Defender Stormwater Treatment Device from the New Jersey Corporation for Advanced Technology (NJCAT) based on enhanced Maximum Treatment Flow Rate (MTFR).

The Stormwater Management rules under N.J.A.C. 7:8-5.5(b) and 5.7(c) allow the use of manufactured treatment devices (MTDs) for compliance with the design and performance standards at N.J.A.C. 7:8-5 if the pollutant removal rates have been verified by the New Jersey Corporation for Advanced Technology (NJCAT) and have been certified by the New Jersey Department of Environmental Protection (NJDEP). Hydro International has requested a Laboratory Certification for the Downstream Defender Stormwater Treatment Device.

The projects falls under the "Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advance Technology" dated January 25, 2013. The applicable protocol is the "New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" dated January 25, 2013.

NJCAT verification documents submitted to the NJDEP indicate that the requirements of the aforementioned protocol have been met or exceeded. The NJCAT letter also included a recommended certification TSS removal rate and the required maintenance plan. The NJCAT Verification Report with the Verification Appendix for this device is published online at http://www.njcat.org/verification-process/technology-verification-database.html.

The NJDEP certifies the use of the Downstream Defender Stormwater Treatment Device by Hydro International at a TSS removal rate of 50% when designed, operated and maintained in accordance with the information provided in the Verification Appendix.

Be advised a detailed maintenance plan is mandatory for any project with a Stormwater BMP subject to the Stormwater Management Rules, N.J.A.C. 7:8. The plan must include all of the items identified in the Stormwater Management Rules, N.J.A.C. 7:8-5.8. Such items include, but are not limited to, the list of inspection and maintenance equipment and tools, specific corrective and preventative maintenance tasks, indication of problems in the system, and training of maintenance personnel. Additional information can be found in Chapter 8: Maintenance of the New Jersey Stormwater Best Management Practices Manual.

If you have any questions regarding the above information, please contact Mr. Titus Magnanao of my office at (609) 633-7021.

Sincerely,

James J. Murphy, ~~Chief~~
Bureau of Nonpoint Pollution Control

C: Chron File
Richard Magee, NJCAT
Madhu Guru, DLUR
Ravi Patraju, NJDEP
Titus Magnanao, BNPC

NJCAT TECHNOLOGY VERIFICATION

Downstream Defender® Stormwater Treatment Device

Hydro International

August, 2015

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1. Description of Technology

The Downstream Defender® is an advanced vortex separator designed to utilize the principles of swirl-enhanced gravity separation to remove Total Suspended Solids (TSS), trash and hydrocarbons from stormwater runoff. The Downstream Defender has a tangential inlet to introduce a rotary flow path to the precast treatment chamber while crosslink polyethylene (PEX) flow-modifying internal components stabilize the swirling flow path to reduce turbulence **(Fig.1).**

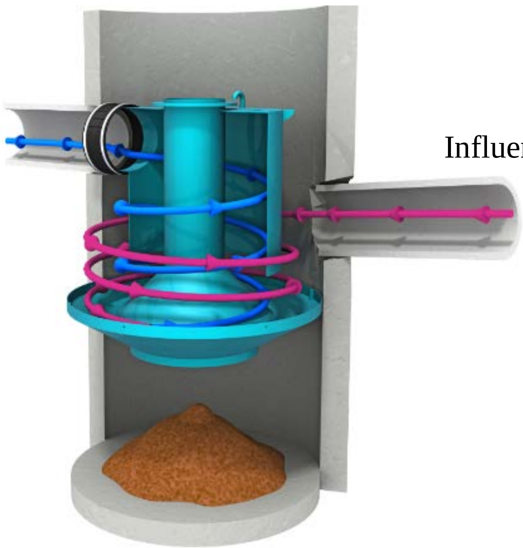

Figure 1 Swirling Flow Path of the Downstream Defender

Stormwater enters the Downstream Defender through a submerged tangential inlet. Hydrocarbons and other floatable solids rise to the surface where they are captured in the chamber as the stormwater spirals downward around the interior cylindrical baffle. When it reaches the center cone the flow changes direction from downward to upward, passing through a zero flow velocity "shear" zone where solids fall out of the flow scheme and into the pollutant storage sump. After flow is deflected upward by the center cone, it spirals upwards around the center shaft inside the cylindrical baffle and discharged via the effluent pipe. To prevent washout, a benching skirt protects settled particles in the pollutant storage sump from high scour velocities.

2. Laboratory Testing

This program was conducted to independently verify the Downstream Defender such that it could be certified by the New Jersey Department of Environmental Protection (NJDEP) as a 50% Total Suspended Solids removal device.

Manufactured treatment devices (MTDs) are evaluated for approval according to The New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured

Treatment Devices dated January 25, 2013 (heretofore referred to as "the Process"). The Process requires that TSS treatment devices that operate solely on the principles of hydrodynamic separation be tested according to the New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device (heretofore referred to as "the Protocol").

In October 2014, a 4-ft Downstream Defender was tested to the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" (NJDEP 2013) and subsequently certified by the NJDEP in January 2015. The testing was conducted in Portland, Maine at Hydro International's hydraulics laboratory under the supervision of an independent third party observer, FB Environmental Associates, Inc. The results shows that at an MTFR of 0.9 cfs, the Weighted Annualized TSS Removal Efficiency of the Downstream Defender was 54.74% **(Table 1)**, which is greater than the 50% TSS removal required by NJDEP for certification.

Table 1 - Downstream Defender Laboratory Testing Results Certified by NJDEP in January 2015

4-ft Downstream Defender Annualized Weighted TSS Removal at 0.90 cfs					
% MTFR	**Mean Flow Rate Tested (cfs)**	**Actual % MTFR**	**Measured Removal Efficiency**	**Annual Weighting Factor**	**Weighted Removal Efficiency**
25%	0.23	25.6%	61.8%	0.25	15.45%
50%	0.45	50.0%	54.8%	0.3	16.44%
75%	0.66	73.3%	53.5%	0.2	10.70%
100%	0.89	98.9%	50.2%	0.15	7.53%
125%	1.14	126.7%	46.2%	0.1	4.62%
Weighted Annualized TSS Removal Efficiency					**54.74%**

Section 5C of the Process document states, "…if the TSS removal efficiency is greater than 50% for HDS MTDs, the TSS removal efficiency shall be rounded down to 50%", thus the results of the 0.9 cfs MTFR testing cannot be used to mathematically calculate the corresponding (higher) MTFR that would equate to a Weighted Annualized TSS Removal Efficiency of 50%.

In April through June of 2015, Hydro International retested the 4-ft Downstream Defender at a higher MTFR of 1.12 cfs to obtain a higher certified approved flow rate from NJDEP. The testing was again conducted at Hydro International's hydraulics laboratory in Portland, Maine under the supervision of FB Environmental Associates, Inc. The particle size distributions of the test sediment samples were analyzed by the independent analytical laboratory GeoTesting Express in Acton, Massachusetts. All water quality samples for the removal efficiency testing were collected, labeled and sealed under the direct supervision of the independent observer from FB Environmental and analyzed by Maine Environmental Laboratory, an independent laboratory located in Yarmouth, Maine.

2.1 Test Setup

The test unit was a 4-ft Downstream Defender comprised of full scale, commercially available 4-ft Downstream Defender internal components installed in a 4-ft round plastic manhole chamber with a sump access/viewing port, which was consistent in all key dimensions with the precast chambers used for commercial sales **(Fig. 2)**. Measurements of the key dimensions were independently confirmed by FB Environmental Associates, Inc.

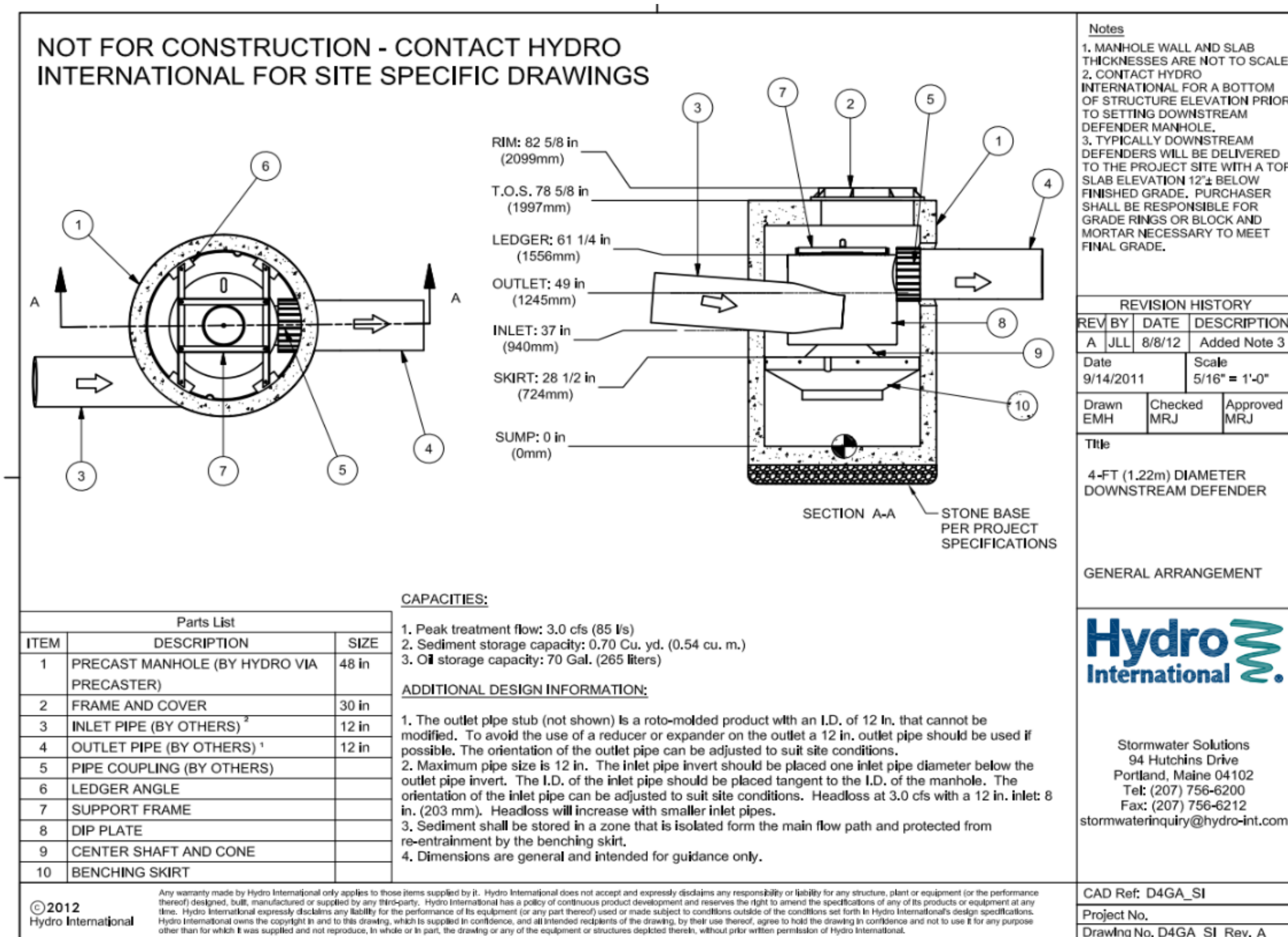

Figure 2 4-ft Downstream Defender

The laboratory setup consisted of a recirculating closed loop system with an 8-inch submersible Flygt pump that conveyed water from a 23,000 gallon reservoir through a PVC pipe network to the 4-ft Downstream Defender **(Fig. 3)**. The flow rate of the pump was controlled by a GE Fuji Electric AF-300 P11 Adjustable Frequency Drive and measured by an EMCO Flow Systems 4411e Electromagnetic Flow Transmitter.

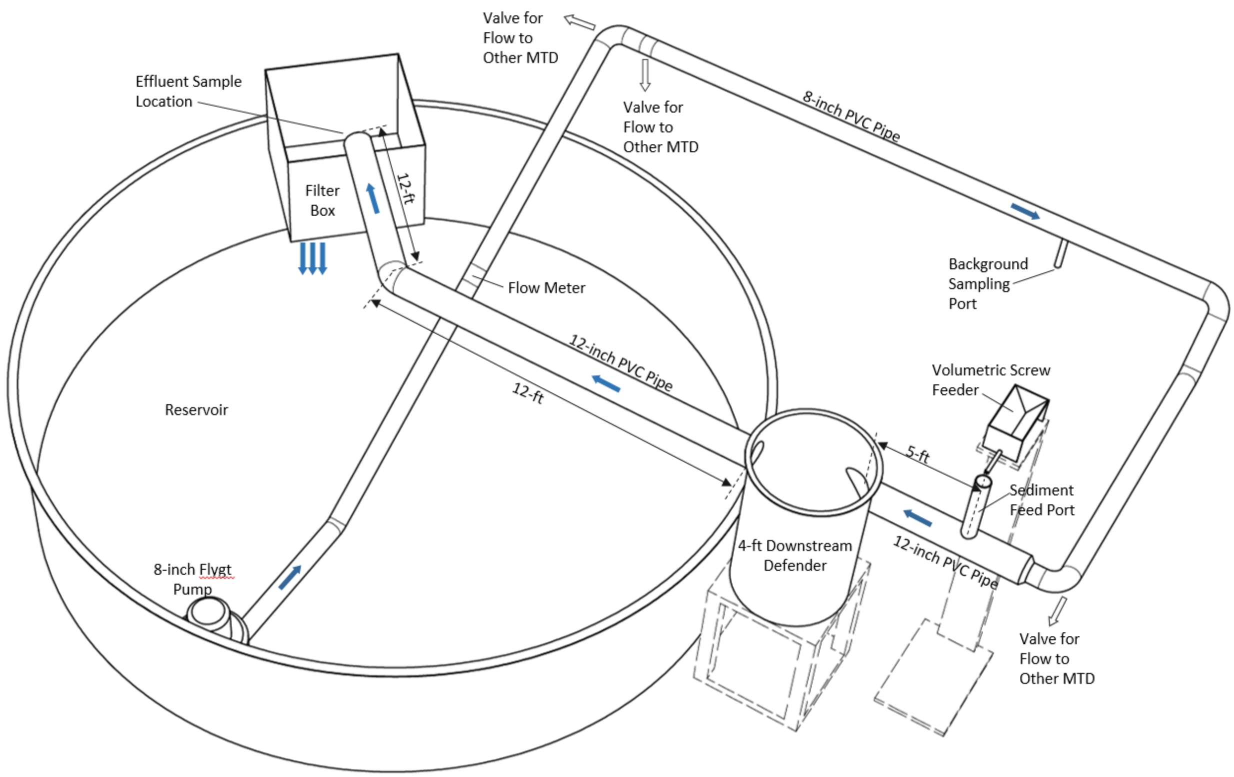

Figure 3 Laboratory Testing Arrangement

A series of three flow isolation valves were located between the Flygt pump and the Downstream Defender, which would allow flow to bypass the Downstream Defender if fully opened. These valves were installed as part of the piping network to direct flow to three other manufactured stormwater and wastewater treatment systems installed at the test facility along the same piping network, and were fully closed throughout the entire period from March 1, 2015 to June 11, 2015 when the Downstream Defender set-up and testing were conducted.

A background sampling port was installed about 27 feet upstream of the Downstream Defender. The Downstream Defender effluent discharged freely from the effluent pipework, where grab samples were taken. The free discharge flowed through a filter box fitted with 1 micron filter socks in order to remove the majority of fine sediment that remained in the flow stream **(Fig. 4)**. The filter box was located on the opposite side of the reservoir as the submersible pump in order to keep the background concentration from surpassing the maximum allowable limit over the duration of the removal efficiency tests.

Figure 4 Effluent Sampling Location Situated above the Filter Box

The water temperature within the reservoir was regulated by a Hayward 350FD pool heater, which is used to reduce any volatility in the test data that could potentially be caused by variability in water temperatures between test runs. The night before a test run the Hayward 350FD was set to 80°F. It was then turned off the morning of each test run at least one hour before the test began. The Hayward 350FD assembly includes a small recirculation pump that causes a gentle current in the reservoir, which could potentially cause high background concentration readings during testing by carrying sediment discharged during a test run back to the main reservoir feed pump more quickly. Turning the heater off allowed any water movement in the reservoir to stop before the beginning of testing. The Hayward 350FD remained off throughout the entire duration of each test run. The test reservoir temperature was measured and recorded at 30 second intervals by a Lascar thermometer and temperature logger over the duration of each test.

Total Suspended Solids Removal Efficiency Laboratory Test Setup

For the removal efficiency test runs, test sediment was introduced into the flow at a consistent, calibrated rate by an Auger Feeder Model VF-2 volumetric screw feeder situated atop a 4-inch port located 5 feet upstream of the Downstream Defender test unit. The location of the port is shown in **Fig. 5a**.

The Downstream Defender sump measures 18 inches in height from the bottom of the internal components. In line with the protocol requirements, it was fitted with a false bottom positioned 9 inches from the true sump bottom to simulate a 50% full condition **(Fig. 5b).** It was secured to the chamber and sealed around the edges to prevent any material from collecting below.

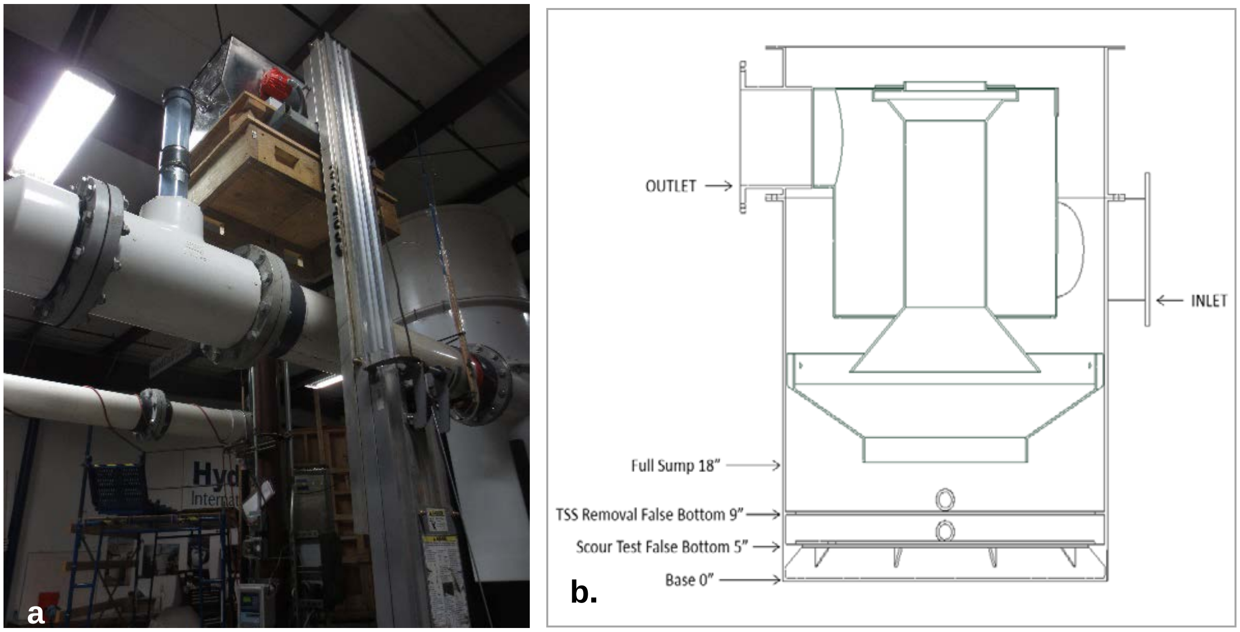

Figure 5 a) Influent Feed Port for Removal Efficiency Testing, b) False Bottom Locations

The test vessel has a rectangular access port located on the sump wall (**Fig. 6a-b**). The access port eliminates the need for confined space entry into the Downstream Defender to clean the unit between test events.

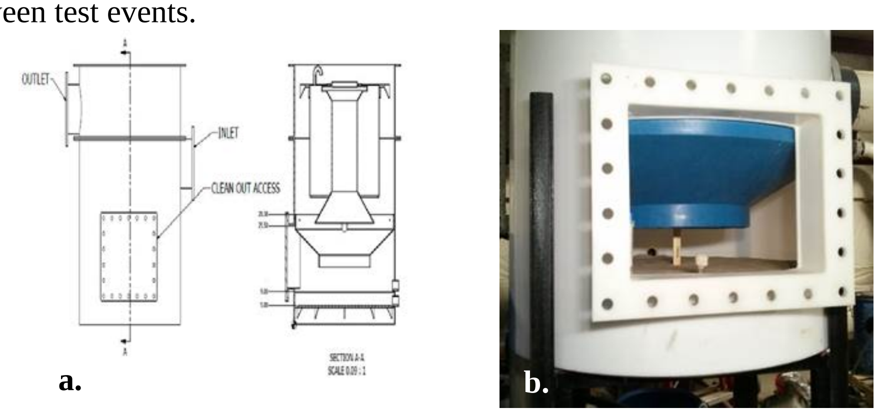

Figure 6 a) Schematic Showing Location of Sump Access Port below Active Separation Zone, b) A Photo of the Sump through the Sump Clean-Out Port

To ensure dimensional consistency with a commercial unit, the inside of the sump access port is fitted with an insert fabricated to be flush with the interior of the cylindrical manhole wall (**Fig.7**). Therefore it does not provide any additional sump storage capacity and the interior of the test vessel is dimensionally consistent to a standard commercial Downstream Defender.

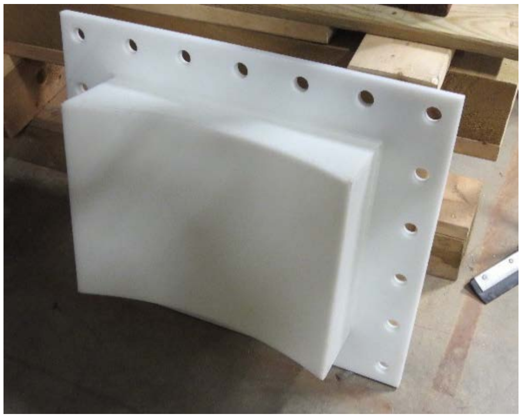

Figure 7 Sump Access Port sits Flush with Interior Manhole Wall

Scour Test Laboratory Setup

To simulate the 50% full condition for the scour test, the false bottom was set 5 inches above the sump floor and 4 inches of the scour test sediment blend was pre-loaded on top of the false bottom, bringing the level of sump contents to 9 inches from the sump bottom **(Fig. 5b)**.

2.2 Test Sediment

Test Sediment Feed for Suspended Solids Removal Efficiency Testing

The test sediment used for the Suspended Solids Removal Efficiency Testing was an in-house blend of high purity silica (SiO_2 99.8%) supplied by two different commercial silica suppliers. Prior to the start of the removal efficiency testing, 4 large batches of test sediment were blended by Hydro International in the presence of the independent observer. Three sediment samples approximately 400 mL in volume were composited from 100 mL subsamples collected from each of the four batches under the supervision of the independent observer. Under the supervision of the independent observer, the 4 batches were sealed in 5 gallon buckets and set aside until testing began. The three composited samples were sealed, signed and packaged for independent transport to the outside laboratory under the supervision of the independent observer. The independent laboratory, GeoTesting Express, analyzed the particle size distribution of each of the three samples using ASTM D 422-63. The particle size distributions of each of the 3 samples were averaged and reported as the overall particle size distribution.

Scour Test Sediment

The test sediment used for the Scour Testing was high purity (99.8% SiO_2) silica blended by an independent commercial silica supplier to meet the specified particle size distribution of the protocol. The scour test sediment was delivered to Hydro International prepackaged, in sealed 50-lb bags. Under observation of the independent observer, three 250 mL subsamples were taken from randomly selected areas of the sump. The subsamples were then sealed and signed under observation of the independent observer and transported to GeoTesting Express for particle size analysis. The reported particle size distribution is the average of the three subsample particle size distributions reported by GeoTesting Express.

2.3 Removal Efficiency Testing Procedure

Removal efficiency testing was conducted in accordance with Section 5 of the NJDEP Laboratory Protocol for HDS MTDs. A total of five flow rates were tested: the 25%, 50%, 75%, 100% and 125% MTFRs. FB Environmental acted as the independent observer for the duration of all testing and water quality sample analysis. Captured test sediment was removed from the sump between each flow rate trial.

The test sediment mass was fed into the flow stream at a known rate using a screw auger with a calibrated funnel. Sediment was introduced at a rate within 10% of the targeted value of 200 mg/L influent concentration throughout the duration of the testing.

Six calibration samples were taken from the injection point. The calibration samples were timed at evenly spaced intervals over the total duration of the test for each tested flow rate and timed such that no collection interval would exceed 1 minute in duration. Each calibration sample was a minimum of 100 mL collected in a clean 1-liter container over an interval timed to the nearest second. These samples were weighed to the nearest milligram. The average influent TSS concentration was calculated using the total mass of the test sediment added during dosing divided by the volume of water that flowed through the Downstream Defender during dosing (**Equation 1)**. The mass extracted for calibration samples was subtracted from the total mass introduced to the system when removal efficiency was subsequently calculated. The volume of water that flowed through the Downstream Defender was calculated by multiplying the average flow rate by the time of sediment injection only.

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

Equation 1 Calculation for Average Influent Concentration

During each flow rate test, the flow meter data logger recorded flow rate at a minimum of once per minute. The Effluent Grab Sampling Method was used as per Section 5D of the protocol. Once a constant rate of flow and test sediment feed were established, a minimum of three Downstream Defender detention times passed before the first effluent sample was collected. All effluent samples were collected in clean half-liter bottles using a sweeping grab sampling motion through the effluent discharge as described in Section 5D of the protocol. Samples were then time stamped and placed into a box for transportation to the analytical laboratory.

The time interval between sequential samples was evenly spaced during the test sediment feed period to obtain 15 samples for each flow rate. The water temperature was recorded for each sample time to ensure that it did not exceed 80 degrees Fahrenheit at any time.

Background samples were taken at the background sample port located upstream of the Downstream Defender test setup. Influent background samples were taken at the same time as odd numbered effluent grab samples (first, third, fifth, etc.). The collection time for each background and effluent sample was recorded. Each collected sample was time stamped, sealed and signed by the independent observer.

At the conclusion of the test when all of the collected effluent and background water quality samples were placed into the delivery box, the box was sealed and the seal was signed by the independent observer. All samples were analyzed by Maine Environmental Lab in accordance with ASTM D3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples".

Background data were plotted on a curve for use to adjust the effluent samples for background concentration; the removal efficiency for each flow rate test was calculated as per **Equation 2**.

$$\textbf{Removal Efficiency (\%)} = \frac{\left(\begin{array}{c}\text{Average Influent}\\\text{Concentration}\end{array} - \begin{array}{c}\text{Adjusted}\\\text{Average Effluent*}\\\text{Concentration}\end{array}\right)}{\text{Average Influent Concentration}} \times 100$$

* Adjusted for background concentration

Equation 2 Equation for Calculating Removal Efficiency

2.4 Scour Testing Procedure

To simulate a 50% full sump condition, the Downstream Defender sump false bottom was set to a height of 5 inches and then topped with 4 inches of scour test sediment. The sediment was leveled, then the Downstream Defender was filled with clear water at a slow rate so as to not disturb the sediment prior to the beginning of testing. In line with the protocol, scour testing was begun less than 96 hours after the sump was pre-loaded with test sediment.

Scour testing began by slowly introducing flow and, in less than 5 minutes, ramping up the flow rate until it reached >200% of the MTFR. The flow rate was recorded at a minimum of once per minute so that the effluent samples could be compared to corresponding flow rates. The flow rate remained constant at the target maximum flow rate for the remainder of the test duration.

Effluent samples were collected and time stamped every 2 minutes after the target flow rate was reached. A minimum of 15 effluent samples were taken over the duration of the test. The effluent samples were collected in half liter bottles using the grab sampling method as described in Section 5D of the protocol. Temperature readings of the feed water were taken with each effluent sample to ensure it did not exceed 80 degrees Fahrenheit at any point during the test.

Eight background samples were collected at evenly spaced intervals throughout the duration of the target maximum flow rate testing. The background samples were drawn from the background sample port located upstream of the Downstream Defender.

All background and effluent samples were analyzed in accordance with ASTM D3977-97 (re-approval 2007) by Maine Environmental Laboratory.

All setup, measurements, testing and sample analysis was observed by the independent observer.

3. Performance Claims

Per the NJDEP verification procedure document (NJDEP, 2013a), the following are the performance claims made by Hydro International and/or established via the laboratory testing conducted.

Total Suspended Solids Removal Rate

The TSS removal rate of the Downstream Defender is dependent upon flow rate, particle density and particle size. For the particle size distribution and weighted calculation method required by the NJDEP HDS MTD protocol (NJDEP, 2013b), the Downstream Defender at a MTFR of 1.12 cfs will demonstrate at least 50% TSS removal efficiency.

Maximum Treatment Flow Rate (MTFR)

The MTFR for the 4-ft Downstream Defender was demonstrated to be 503 gpm (1.12 cfs), which corresponds to a surface loading rate of 40.0 gpm/sf.

Maximum sediment storage depth and volume

The maximum sediment storage depth and available sediment storage volume varies with each Downstream Defender model, as Downstream Defender model dimensions are scaled geometrically (in all three dimensions).

The available sump volume for a 4-ft Downstream Defender model is 0.70 cubic yards. The maximum sediment storage depth is 9 inches, which corresponds to a 50% full sump capacity (or 0.35 cubic yards) for the standard model.

Effective treatment area

The effective treatment and sedimentation area of the Downstream Defender model varies with model size, as it corresponds to the surface area of the Downstream Defender model diameter. The tested 4-ft Downstream Defender model has a treatment surface area of 12.56 square feet.

Detention time and volume

The detention time of the Downstream Defender depends on flow rate and model size. For the tested 4-ft Downstream Defender model at the MTFR of 1.12 cfs, the detention time is 45 seconds.

Effective sedimentation area

The effective sedimentation area and effective treatment area for the Downstream Defender Stormwater Treatment System are identical.

Online installation

Based on the testing results shown in Section 4.4 the Downstream Defender Stormwater Treatment System qualifies for online installation.

4. Supporting Documentation

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

4.1 Test Sediment PSD Analysis – Removal Efficiency Testing

Hydro International purchased two different grades of high purity silica (SiO_2 99.8%) supplied by two different commercial silica suppliers. These silica blends were mixed together at the proportions required to generate a test sediment that complied with the particle size distribution requirements specified in the NJDEP HDS MTD protocol.

Prior to the start of removal efficiency testing trials in April 2015, four batches of test sediment were blended by Hydro International in the presence of the independent observer. Three composite sediment samples approximately 400 mL in volume were blended using approximately 100 mL of sediment collected from each of the four batches under the supervision of the independent observer. Under the supervision of the independent observer, the four batches were sealed in 5 gallon buckets and set aside until testing began. The three composited samples were sealed, signed and packaged for independent transport to the outside laboratory under the supervision of the independent observer. The independent laboratory, GeoTesting Express, analyzed the particle size distribution of each of the three samples using ASTM D 422-63. The particle size distributions of each of the 3 samples were averaged and reported as the overall particle size distribution, as shown in **Table 2**.

Table 2 - Particle Size Distribution Results of Test Sediment Samples

Sample 1		Sample 2		Sample 3	
µm	**% Finer**	**µm**	**% Finer**	**µm**	**% Finer**
4750	100%	4750	100%	4750	100%
2000	100%	2000	100%	2000	100%
1000	100%	1000	100%	1000	100%
500	95%	500	95%	500	95%
250	90%	250	90%	250	90%
150	74%	150	76%	150	74%
110	64%	110	66%	110	64%
75	52%	75	53%	75	52%
53	48%	53	48%	53	48%
32.1	43%	32.1	45%	32.1	44%
21	35%	21.1	37%	20.7	38%
12.3	29%	12.4	32%	12.2	27%
8.9	23%	9	23%	8.9	21%
6.4	18%	6.4	19%	6.4	16%
4.5	13%	4.6	14%	4.5	13%
3.3	9%	3.3	11%	3.3	8%
1.4	5%	1.4	5%	1.4	4%
1	0%	1	0%	1	0%

The average of the test sediment samples is shown below in **Table 3**. The test sediment was found to be slightly finer than the sediment blend specified by the protocol, with a d_{50} of 63 micron (**Fig.8**).

Table 3 - Test Sediment Average Particle Size Distribution Compared to Protocol Specification

Particle Size	% Finer Than		Difference
µm	Test Sediment Average	Protocol Specification	Percentage Points
1000	100.00%	100%	0.0%
500	95.00%	95%	-0.3%
250	90.00%	90%	0.0%
150	74.67%	75%	0.3%
100	61.14%	60%	-1.1%
75	52.33%	50%	-2.3%
50	47.43%	45%	-2.4%
20	35.92%	35%	-0.9%
8	20.62%	20%	-0.6%
5	14.41%	10%	-4.4%
2	6.14%	5%	-1.1%

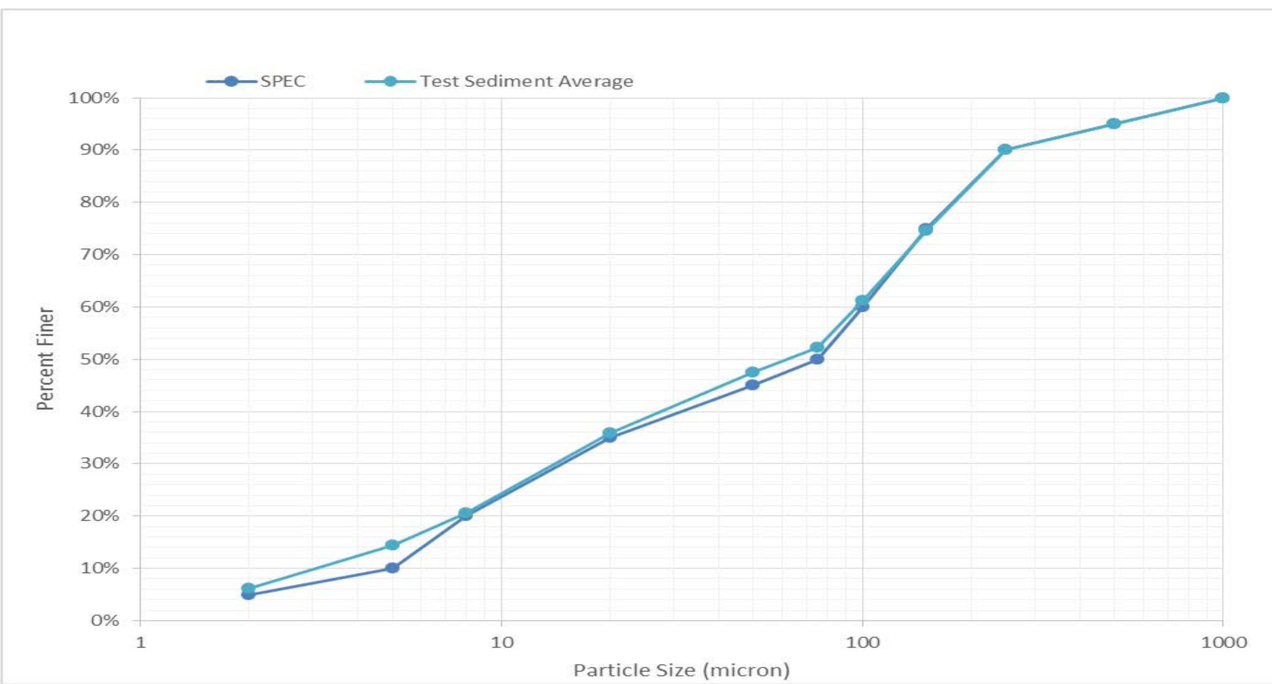

Figure 8 Average Particle Size Distribution of Test Sediment Compared to Protocol Specification

4.2 Removal Efficiency Testing

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on the Downstream Defender (DD) 4-ft. unit in order to establish the ability of the DD to remove the specified test sediment at 25%, 50%, 75%, 100% and 125% of the target MTFR. The target MTFR was 1.12 cfs (503 gpm). This target was chosen based on the ultimate goal of demonstrating greater than 50% annualized weighted solids removal as defined in the Protocol.

All results reported in this section were derived from test runs that fully complied with the terms of the protocol. None of the collection intervals of the calibration samples exceeded one minute in duration for any of the reported tests. The inlet feed concentration coefficient of variance (COV) did not exceed 0.10 for any flow rate trials.

The mean influent concentration was calculated using Equation 1 from *Section 2.3 Removal Efficiency Test Procedure*. The mean effluent concentration was adjusted by subtracting the measured background concentrations. No background TSS concentrations exceeded the 20 mg/L maximum allowed by the protocol. At no point did the water temperature exceed 80 ^{o}F.

25% MTFR Results

The 25% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.28 cfs (125 gpm). A summary of test readings, measurements and calculations are shown in **Table 4**. Feed calibration results are shown in **Table 5**. Background and effluent sampling measurements are shown in **Table 6**. The 4-ft Downstream Defender removed 59.4% of the test sediment at a flow rate of 0.27 cfs (120 gpm). **Table 7** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable protocol parameter specifications.

Table 4 – Summary of 4-ft Downstream Defender 25% MTFR Test

4-ft Downstream Defender 25% MTFR Trial Summary					
Trial Date	**Target Flow (cfs) / (gpm)**	**Detention Time (sec)**	**Target Sediment Concentration (mg/L)**	**Target Feed Rate (mg/min)**	**Test Duration (Min)**
5/14/2014	0.28 / 125	180	200	95,136	1:01:01
Measured Values					
Mean Flow Rate (cfs) / (gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max Water Temperature °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
0.27 / 120	194.3	79.4°	78.9	59.4%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 5 – 4-ft Downstream Defender 25% MTFR Test Calibration Results

4-ft Downstream Defender 25% MTFR Feed Rate Calibration Sample Results					
Target Concentration	200 mg/L	Target Feed Rate		95,136 mg/min	
Sample ID	Sample Time (min)	Sample Weight (g)	Sample Duration (sec)	Feed Rate (mg/min)	Calculated Influent Concentration (mg/L)
Feed Rate 1	0:00	92.179	60	92,179	203
Feed Rate 2	12:01	91.551	60	91,551	201
Feed Rate 3	24:01	86.482	60	86,482	190
Feed Rate 4	36:02	86.819	60	86,819	191
Feed Rate 5	48:02	89.683	60	89,683	197
Feed Rate 6	1:00:03	93.928	60	93,928	207
			Mean	**90,107**	**198**

Table 6 – 4-ft Downstream Defender 25% MTFR Background and Effluent Measurements

4-ft Downstream Defender 25% of MTFR Background and Effluent Sample Results				
Sample ID	Time (min)	Concentration (mg/L)		
Background 1	10:01	2		
Background 2	12:01	2		
Background 3	23:01	5		
Background 4	34:02	7		
Background 5	36:02	8		
Background 6	47:02	10		
Background 7	58:03	12		
Background 8	1:00:03	13		
Sample ID	Time (min)	Concentration (mg/L)	Associated Background Concentration	Adjusted Concentration (mg/L)
Effluent 1	10:01	77	2	75
Effluent 2	11:01	77	2	75
Effluent 3	12:01	77	2	75
Effluent 4	22:01	84	3.5	81
Effluent 5	23:01	86	5	81
Effluent 6	24:01	84	6	78

Effluent 7	34:02	90	7	83
Effluent 8	35:02	84	7.	77
Effluent 9	36:02	86	8.	78
Effluent 10	46:02	91	9.	82
Effluent 11	47:02	86	10	76
Effluent 12	48:02	89	11	78
Effluent 13	58:03	92	12	80
Effluent 14	59:03	93	12.5	81
Effluent 15	1:00:03	98	13	85
	Mean	**86.3**	**7**	**78.9**

Table 7 – 4-ft Downstream Defender 25% MTFR Trial QA/QC Results

4-ft Downstream Defender 25% MTFR QA/QC Parameters			
Flow Rate			
Target (gpm)	Mean (gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
125	120	0.029	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
95,136	88,488	0.03	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	194.3	0.03	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	13	7.4	<20

50% MTFR Results

The 4-ft Downstream Defender 50% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 252 gpm (0.56 cfs). The 50% MTFR test results are shown in **Table 8**. Calibration results are shown in **Table 9**. Background and effluent results are shown in **Table 10**.

The 4-ft Downstream Defender removed 53.4% of the test sediment at a flow rate of 249 gpm (0.55 cfs). **Table 11** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable protocol parameter specifications.

Table 8 – Summary of 4-ft Downstream Defender 50% MTFR Test

4-ft Downstream Defender 50% MTFR Trial Summary					
Trial Date	**Target Flow (cfs) / (gpm)**	**Detention Time (sec)**	**Target Sediment Concentration (mg/L)**	**Target Feed Rate (mg/min)**	**Test Duration (Min)**
4/27/2015	0.56 / 252	90	200	190,272	33:27
Measured Values					
Mean Flow Rate (cfs) / (gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max Water Temperature °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
0.55 / 249	209.7	79.1°	97.7	53.4%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 9 – 4-ft Downstream Defender 50% MTFR Test Calibration Results

4-ft Downstream Defender 50% MTFR Feed Rate Calibration Sample Results					
Target Concentration	**200 mg/L**	**Target Feed Rate**		**190,272 mg/min**	
Sample ID	**Sample Time (min)**	**Sample Weight (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	197.711	60	197,711	210
Feed Rate 2	6:29	198.898	60	198,898	211
Feed Rate 3	12:58	197.996	60	197,996	210
Feed Rate 4	19:28	198.009	60	198,009	210
Feed Rate 5	25:57	196.906	60	196,906	209
Feed Rate 6	32:26	197.493	60	197,493	210
			Mean	197,836	**210**

Table 10 – 4-ft Downstream Defender 50% MTFR Background and Effluent Measurements

4-ft Downstream Defender 50% of MTFR Background and Effluent Sample Results				
Sample ID	**Time (min)**	**Concentration (mg/L)**		
Background 1	5:29	2		
Background 2	6:29	2		
Background 3	12:28	2		
Background 4	18:28	2		
Background 5	19:28	4		
Background 6	25:27	9		
Background 7	31:26	11		
Background 8	32:26	12		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration (mg/L)**	**Adjusted Concentration (mg/L)**
Effluent 1	5:29	91	2	89
Effluent 2	5:59	99	2	97
Effluent 3	6:29	96	2	94
Effluent 4	11:58	102	2	100
Effluent 5	12:28	103	2	101
Effluent 6	12:58	103	2	101
Effluent 7	18:28	101	2	99
Effluent 8	18:58	100	3	97
Effluent 9	19:28	101	4	97
Effluent 10	24:57	104	6.5	98
Effluent 11	25:27	105	9	96
Effluent 12	25:57	107	10	97
Effluent 13	31:26	118	11	107
Effluent 14	31:56	105	11.5	94
Effluent 15	32:26	111	12	99
	Mean	**103.1**	**5**	**97.7**

Table 11 – 4-ft Downstream Defender 50% MTFR Trial QA/QC Results

4-ft Downstream Defender 50% MTFR QA/QC Parameters			
Flow Rate			
Target (gpm)	Mean (gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
252	249	0.011	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
190,272	197,604	0.003	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	209.7	0.003	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	12	5.5	<20

75% MTFR Results

The 4-ft Downstream Defender 75% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 377 gpm (0.84 cfs). The 75% MTFR test results are shown in **Table 12**. Calibration results are shown in **Table 13**. Background and effluent results are shown in **Table 14**.

The 4-ft Downstream Defender removed 45.4% of the test sediment at a flow rate of 375 gpm (0.83 cfs). **Table 15** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable protocol parameter specifications.

Table 12 – Summary of 4-ft Downstream Defender 75% MTFR Test

4-ft Downstream Defender 75% MTFR Trial Summary					
Trial Date	**Target Flow (gpm) / (cfs)**	**Detention Time (sec)**	**Target Sediment Concentration (mg/L)**	**Target Feed Rate (mg/min)**	**Test Duration (Min)**
4/29/2015	377 / 0.84	60	200	285,408	25:57
Measured Values					
Mean Flow Rate (cfs) / (gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max. Water Temperature °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
0.83 / 375	215.4	78.9°	117.6	45.4%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 13 – 4-ft Downstream Defender 75% MTFR Test Calibration Results

4-ft Downstream Defender 75% MTFR Feed Rate Calibration Sample Results					
Target Concentration	**200 mg/L**	**Target Feed Rate**		**285,408 mg/min**	
Sample ID	**Sample Time (min)**	**Sample Weight (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	296.195	60	296,195	209
Feed Rate 2	4:59	303.225	60	303,225	214
Feed Rate 3	9:59	298.148	60	298,148	210
Feed Rate 4	14:58	307.800	60	307,800	217
Feed Rate 5	19:58	311.657	60	311,657	220
Feed Rate 6	24:57	309.787	60	309,787	218
			Mean	**304,469**	**215**

Table 14 – 4-ft Downstream Defender 75% MTFR Background and Effluent Measurements

4-ft Downstream Defender 75% of MTFR Background and Effluent Sample Results				
Sample ID	**Time (min)**	**Concentration (mg/L)**		
Background 1	3:59	2		
Background 2	4:59	2		
Background 3	9:29	2		
Background 4	13:58	2		
Background 5	14:58	4		
Background 6	19:28	6		
Background 7	23:57	9		
Background 8	24:57	12		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration (mg/L)**	**Adjusted Concentration (mg/L)**
Effluent 1	3:59	106	2	104
Effluent 2	4:29	119	2	117
Effluent 3	4:59	112	2	110
Effluent 4	8:59	118	2	116
Effluent 5	9:29	123	2	121
Effluent 6	9:59	119	2	117
Effluent 7	13:58	126	2	124
Effluent 8	14:28	113	3	110
Effluent 9	14:58	118	4	114
Effluent 10	18:58	131	5	126
Effluent 11	19:28	131	6	125
Effluent 12	19:58	132	7.5	125
Effluent 13	23:57	128	9	119
Effluent 14	24:27	115	10.5	105
Effluent 15	24:57	144	12	132
	Mean	**122.3**	**4.7**	**117.6**

Table 15 – 4-ft Downstream Defender 75% MTFR Trial QA/QC Results

4-ft Downstream Defender 75% MTFR QA/QC Parameters			
Flow Rate			
Target (gpm)	Mean (gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
377	375	0.009	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
285,408	305,279	0.021	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	215.4	0.021	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	12	4.9	<20

100% MTFR Results

The 4-ft Downstream Defender 100% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 502 gpm (1.12 cfs). The 100% MTFR test results are shown in **Table 16**. Calibration results are shown in **Table 17**. Background and effluent results are shown in **Table 18**.

The 4-ft Downstream Defender removed 42.0% of the test sediment at a flow rate of 506 gpm (1.13 cfs). **Table 19** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable protocol parameter specifications.

Table 16 – Summary of 4-ft Downstream Defender 100% MTFR Test

4-ft Downstream Defender 100% MTFR Trial Summary					
Trial Date	**Target Flow (gpm) / (cfs)**	**Detention Time (sec)**	**Target Sediment Concentration (mg/L)**	**Target Feed Rate (mg/min)**	**Test Duration (Min)**
5/05/2014	502 / 1.12	45	200	380,544	22:16
Measured Values					
Mean Flow Rate (cfs) / (gpm)	**Mean Influent Concentration (mg/L)[1]**	**Max. Water Temperature °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
1.13 / 506	196.8	79.2°	114.1	42.0%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 17 – 4-ft Downstream Defender 100% MTFR Test Calibration Results

DD-4 100% MTFR Feed Rate Calibration Sample Results					
Target Concentration	**200 mg/L**	**Target Feed Rate**		**380,544 mg/min**	
Sample ID	**Sample Time (min)**	**Sample Weight (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	393.114	60	393,114	205
Feed Rate 2	4:15	385.904	60	385,904	201
Feed Rate 3	8:29	380.496	60	380,496	199
Feed Rate 4	12:44	370.393	60	370,393	193
Feed Rate 5	16:59	368.689	60	368,689	192
Feed Rate 6	21:14	371.331	60	371,331	194
			Mean	378,321	**197**

Table 18 – 4-ft Downstream Defender 100% MTFR Background and Effluent Measurements

4-ft Downstream Defender 100% of MTFR Background and Effluent Sample Results				
Sample ID	**Time (min)**	**Concentration (mg/L)**		
Background 1	3;15	2		
Background 2	4:15	2		
Background 3	7:59	2		
Background 4	11:44	2		
Background 5	12:44	2		
Background 6	16:29	6		
Background 7	20:14	13		
Background 8	21:14	15		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration (mg/L)**	**Adjusted Concentration (mg/L)**
Effluent 1	3:15	121	2	119
Effluent 2	3:45	113	2	111
Effluent 3	4:15	116	2	114
Effluent 4	7:29	115	2	113
Effluent 5	7:59	119	2	117
Effluent 6	8:29	119	2	117
Effluent 7	11:44	110	2	108
Effluent 8	12:14	120	2	118
Effluent 9	12:44	119	2	117
Effluent 10	15:59	121	4	117
Effluent 11	16:29	120	6	114
Effluent 12	16:59	122	10	112
Effluent 13	20:14	124	13	111
Effluent 14	20:44	126	14	112
Effluent 15	21:14	126	15	111
	Mean	**119.4**	**5.3**	**114.1**

Table 19 – 4-ft Downstream Defender 100% MTFR Trial QA/QC Results

4-ft Downstream Defender 100% MTFR QA/QC Parameters			
Flow Rate			
Target (gpm)	Mean (gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
502	506	0.008	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
380,544	377,371	0.03	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	196.8	0.03	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	15	5.5	<20

125% MTFR Results

The 4-ft Downstream Defender 125% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 628 gpm (1.40 cfs). The 125% MTFR test results are shown in **Table 20**. Calibration results are shown in **Table 21**. Background and effluent results are shown in **Table 22**.

The 4-ft Downstream Defender removed 41.0% of the test sediment at a flow rate of 603 gpm (1.34 cfs). **Table 23** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable protocol parameter specifications.

Table 20 – Summary of 4-ft Downstream Defender 125% MTFR Test

4-ft Downstream Defender 125% MTFR Trial Summary					
Trial Date	**Target Flow (gpm) / (cfs)**	**Detention Time (sec)**	**Target Sediment Concentration (mg/L)**	**Target Feed Rate (mg/min)**	**Test Duration (Min)**
5/18/2015	628 / 1.40	36	200	475,680	18:30
Measured Values					
Mean Flow Rate (cfs) / (gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max. Water Temperature °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
1.34 / 603	203.3	79°	120	41.0%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 21 – 4-ft Downstream Defender 125% MTFR Test Calibration Results

4-ft Downstream Defender 125% MTFR Feed Rate Calibration Sample Results					
Target Concentration	**200 mg/L**	**Target Feed Rate**		**475,680 mg/min**	
Sample ID	**Sample Time (min)**	**Sample Weight (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	372.323	45	496,431	217
Feed Rate 2	3:33	366.016	45	488,021	214
Feed Rate 3	7:05	350.286	45	467,048	205
Feed Rate 4	10:38	340.477	45	453,969	199
Feed Rate 5	14:11	332.506	45	443,341	194
Feed Rate 6	17:44	325.349	45	433,799	190
			Mean	**463,768**	**203**

Table 22 – 4-ft Downstream Defender 125% MTFR Background and Effluent Measurements

4-ft Downstream Defender 125% of MTFR Background and Effluent Sample Results				
Sample ID	**Time (min)**	**Concentration (mg/L)**		
Background 1	2:33	2		
Background 2	3.:33	2		
Background 3	6:35	2		
Background 4	9:38	2		
Background 5	10:38	2		
Background 6	13:41	6		
Background 7	16:44	13		
Background 8	17:44	14		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration**	**Adjusted Concentration (mg/L)**
Effluent 1	2:33	128	2	126
Effluent 2	3:03	126	2	124
Effluent 3	3:33	126	2	124
Effluent 4	6:05	119	2	117
Effluent 5	6:35	126	2	124
Effluent 6	7:05	120	2	118
Effluent 7	9:38	112	2	110
Effluent 8	10:08	128	2	126
Effluent 9	10:38	125	2	123
Effluent 10	13:11	119	4	115
Effluent 11	13:41	118	6	112
Effluent 12	14:11	131	9.5	122
Effluent 13	16:44	126	13	113
Effluent 14	17:14	140	13.5	127
Effluent 15	17:44	134	14	120
	Mean	**125.2**	**5.2**	**120**

Table 23 – 4-ft Downstream Defender 125% MTFR Trial QA/QC Results

4-ft Downstream Defender 125% MTFR QA/QC Parameters			
Flow Rate			
Target (gpm)	Mean (gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
628	603	0.005	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
475,680	464,063	0.05	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	203.3	0.05	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	14	5.4	<20

Excluded Data/Results

Section 5.D, *Verification Report Requirements: Supporting Documentation* of the NJDEP Process document requires that all data from performance evaluation test runs excluded from the computation of the removal rate or verification analysis be disclosed.

Two removal efficiency tests run at the 25% MTFR were discontinued due to the auger feed rate exceeding the specified maximum of 220 mg/L. The first 25% MTFR run was excluded because it had a calibration sample of 231 mg/L. The average influent concentration was 221 mg/L with an average adjusted effluent concentration of 73 mg/L for a calculated removal efficiency of 67.0%. The second 25% MTFR run was excluded because it had a calibration sample of 249 mg/L. The average influent concentration was 218 mg/L and the average effluent concentration was 73 mg/L for a calculated removal efficiency of 66.5%.

The first scour test run conducted at 2.96 cfs (264% of the MTFR) is excluded from the results because the particle size distribution analysis revealed that the test sediment was coarser than allowed by the test protocol. Background concentrations ranged from 4 mg/L to 6 mg/L with a mean of 5 mg/L. Adjusted effluent concentrations range from 2 to 6 mg/L with a mean adjusted effluent concentration of 3 mg/L

No other data is excluded from this report.

Annualized Weighted TSS Removal Efficiency

The NJDEP-specified annual weighted TSS removal efficiency calculation is shown in **Table 24** using the results from the removal efficiency testing.

Testing in accordance with the provisions detailed in the NJDEP HDS Protocol demonstrate that the 4-ft Downstream Defender achieved a 50.35% annualized weighted TSS removal at an MTFR of 1.12 cfs (40.0 gpm/sf). This testing demonstrates that the 4-ft Downstream Defender exceeds the NJDEP requirement that HDS devices demonstrate at least 50% weighted annualized TSS removal efficiency at the MTFR.

Table 24 – Annualized Weighted TSS Removal of the 4-ft Downstream Defender

4-ft Downstream Defender Annualized Weighted TSS Removal at 1.12 cfs					
% MTFR	**Mean Flow Rate Tested (cfs)**	**Actual % MTFR**	**Measured Removal Efficiency**	**Annual Weighting Factor**	**Weighted Removal Efficiency**
25%	0.27	96.4%	59.4%	0.25	14.85%
50%	0.55	98.2%	53.4%	0.3	16.02%
75%	0.83	98.8%	45.4%	0.2	9.08%
100%	1.13	100.9%	42.0%	0.15	6.30%
125%	1.34	95.7%	41.0%	0.1	4.10%
Weighted Annualized TSS Removal Efficiency					**50.35%**

4.3 Test Sediment PSD Analysis - Scour Testing

The scour test sediment, as described in Section 2.2 *Test Sediment*, was high purity (99.8% SiO_2) silica blended by an independent commercial silica supplier to meet the particle size distribution specified by the NJDEP HDS protocol. Test sediment was pre-loaded into the sump. Three 250 mL subsamples were taken from the preloaded material and sent to an outside lab for particle size analysis. The test sediment in the sump was leveled off to a depth of 4 inches.

The outside lab results show that all subsamples of the test sediment were found to be finer than the PSD analysis specified by the protocol **(Table 25)**. A comparison of the PSD specified by the protocol and average PSD of the test sediment is shown in **Fig. 9**.

Table 25 – Scour Test Sediment Particle Size Distribution Comparison

NJDEP Protocol Specification		Scour Test Sediment				
Particle Size (µm)	Percent Finer	Particle Size (µm)	Percent Finer			
			Sample 1	Sample 2	Sample 3	Average
1000	100%	**1000**	100%	100%	100%	100%
500	90%	**500**	97%	97%	96%	97%
250	55%	**300**	70%	72%	71%	71%
150	40%	**150**	45%	45%	44%	45%
100	25%	**110**	27%	31%	30%	29%
75	10%	**75**	12%	11%	11%	11%
50	0%	**53**	1%	1%	1%	1%
		Total	100%	100%	100%	100%

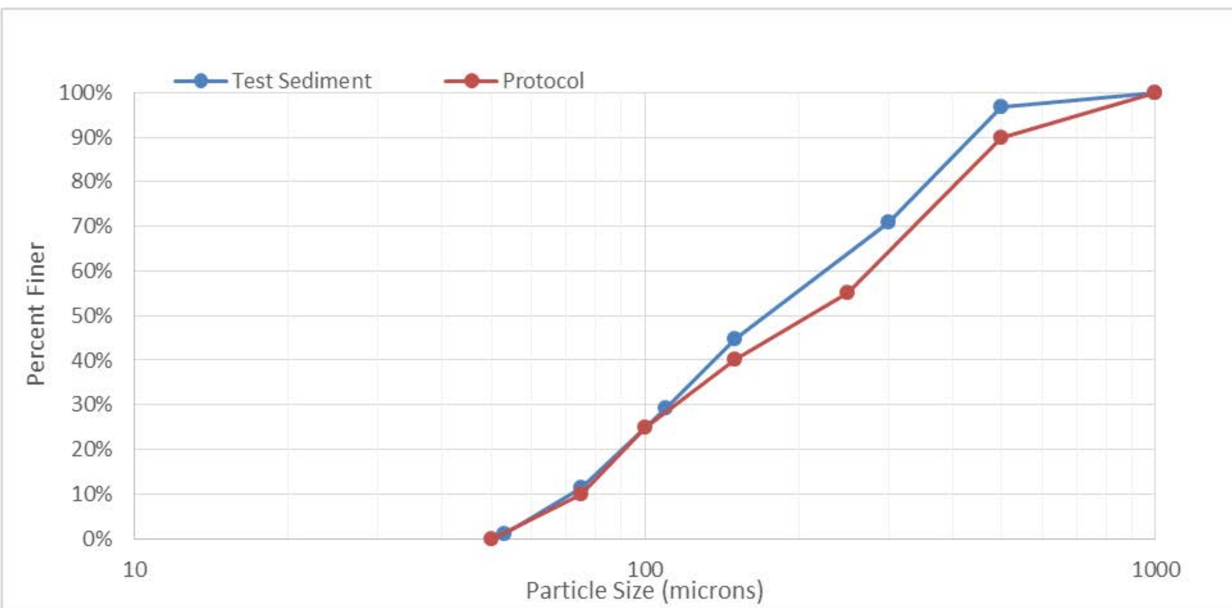

Figure 9 Comparison of Scour Test Sediment PSD to Protocol Scour Test Sediment PSD Specification

4.4 Scour Testing for Online Installation

For the 4-ft Downstream Defender with an MTFR of 502 gpm (1.12 cfs), the average scour test flow rate had to be at least 1,004 gpm (2.24 cfs). The average flow rate for the scour test was 2.95 cfs, which represents 263% of the MTFR. The water temperature did not exceed 78.7°F for the duration of the testing. The flow rate COV was 0.01. Background concentrations ranged from

5 mg/L to 7 mg/L with a mean of 6 mg/L, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Flow and background concentration measurements are shown in **Table 26**.

Table 26 – Background Concentrations for 4-ft Downstream Defender Scour Testing

DD-4 Online Scour Test Results				
Trial Date		6/11/2015	Average Flow Rate =	2.95 cfs
Max. Temperature		78.7° F	Flow Rate COV	0.01
Sample ID	Time (min)	Concentration (mg/L)		
Background 1	02:00	6		
Background 2	06:00	6		
Background 3	10:00	7		
Background 4	14:00	6		
Background 5	18:00	6		
Background 6	22:00	6		
Background 7	26:00	6		
Background 8	30:00	5		

Table 27 – Effluent Concentration Results for 4-ft Downstream Defender Scour Test at 263% MTFR

Sample ID	Time (min)	Effluent Concentration with Background Concentrations (mg/L)	Background Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)
Effluent 1	02:00	16	6	10
Effluent 2	04:00	12	6	6
Effluent 3	06:00	16	6	10
Effluent 4	08:00	12	6.5	6
Effluent 5	10:00	13	7	6
Effluent 6	12:00	13	6.5	7
Effluent 7	14:00	10	6	4
Effluent 8	16:00	11	6	5
Effluent 9	18:00	14	6	8
Effluent 10	20:00	16	6	10
Effluent 11	22:00	12	6	6
Effluent 12	24:00	13	6	7
Effluent 13	26:00	11	6	5
Effluent 14	28:00	10	5.5	5
Effluent 15	30:00	10	5	5
	Mean	**13**	**6**	**7**

Unadjusted effluent concentrations ranged from 10 mg/L to 16 mg/L with a mean of 13 mg/L. When adjusted for background concentrations, the effluent concentrations range from 4 to 10 mg/L. The mean adjusted effluent concentration was 7 mg/L (**Table 27**).

5. Design Limitations

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

Required Soil Characteristics

The Downstream Defender is a flow-through system contained within a water tight manhole. Therefore the Downstream Defender can be installed and function as intended in all soil types.

Slope

Hydro International recommends contacting our design engineers when the Downstream Defender is going to be installed on a drainage line with a slope greater than 10%. With steeply sloping pipe, site specific parameters such as pipe size, online vs. offline arrangement of the Downstream Defender and the frequency of peak flow are taken into consideration by the Hydro International design team.

Maximum Flow Rate

The maximum treatment flow rate (MTFR) of the Downstream Defender is dependent upon model size. The recommended maximum peak flow rate is dependent on Downstream Defender model size and other design and performance specifications. Hydro International recommends contacting their engineering staff with questions about managing high peak flow rates.

Maintenance Requirements

The Downstream Defender should be inspected and maintained in line with the recommendations and guidelines set forth in the O&M Manual (http://www.hydro-int.com/UserFiles/downloads/DD-Operation%20And%20Maintenance%20Manual_0.pdf). The sediment accumulation rate in the Downstream Defender is dependent on site-specific characteristics such as site usage and topography. A more detailed discussion of inspection and maintenance requirements is discussed later in Section 6.

Driving Head

Independent testing conducted according to ASTM Standard Test MethodsC1745 / C1745M – 11: Standard Test Method for Measurement of Hydraulic Characteristics of Hydrodynamic Stormwater Separators and Underground Settling Devices has shown that the head-loss across the Downstream Defender is a function of flow rate and pipe velocities. Generally, the Downstream Defender head-loss is estimated using **Equation 3**.

$$H_L = (h_u + \frac{V_u^2}{2g}) - (h_d + \frac{V_d^2}{2g})$$

Where H_L = Downstream Defender head-loss
H_u = measured pressure head or water elevation in the inlet or upstream pipe
H_d = measured pressure head or water elevation in the outlet or downstream pipe
G = gravitational constant, 32.2 ft/sec^2
V_u, V_d = calculated average flow velocities in the upstream and downstream pipes
respectively

Equation 3-Flow Dependent Head-loss of the Downstream Defender

Installation Limitations

Pick weights and installation procedures vary slightly with model size. Hydro International provides contractors with project-specific unit pick weights and installation instructions prior to delivery.

Configurations

The Downstream Defender can be installed online or offline. The Downstream Defender design includes a submerged tangential inlet pipe. The crown of the inlet pipe is set to the same elevation as the invert of the outlet pipe as shown in **Fig. 10**.

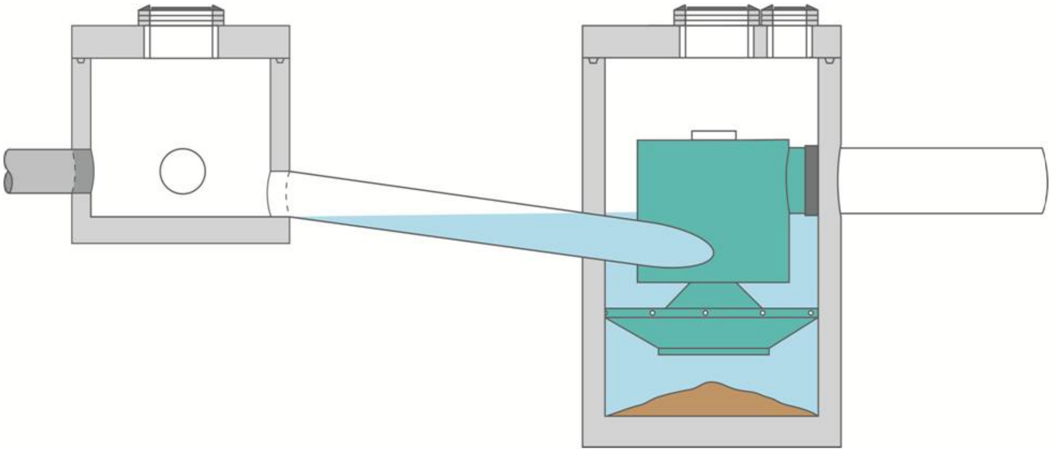

Figure 10 Inlet Crown of the Downstream Defender Set at the Same Elevation as Outlet Pipe Invert

In some cases, multiple inlet pipes can be accommodated depending on pipe size and pipe angles. Contact Hydro International for design assistance with multiple inlet pipes.

The Downstream Defender design can accommodate nearly any inlet-to-outlet pipe angle as long as 6 linear inches of concrete remain between the openings for the inlet pipe and outlet pipe (**Fig. 11**).

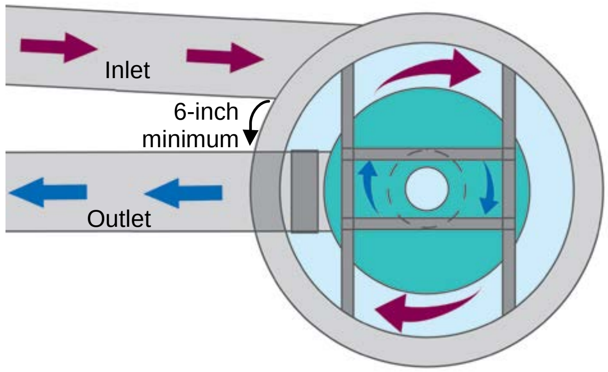

Figure11 Downstream Defender Design Accommodates Nearly Any Pipe Angle

Structural Load Limitations

Standard Downstream Defender units are designed for HS-20 loading. Contact Hydro International engineering staff when heavier load ratings are required.

Pretreatment Requirements

The Downstream Defender has no pre-treatment requirements.

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Limitations in Tailwater

A tail water condition in a detention system or pond will not adversely impact the operation of a Downstream Defender. An online Downstream Defender does not contain internal flow control devices (weirs or orifices) that will be bypassed by a rising tail water; consequently, any flow that passes through the Downstream Defender will be treated.

Depth to Seasonal High Water Table

Although the functionality of the Downstream Defender is not impacted by high groundwater, Hydro International recommends consulting their engineering staff to determine whether the addition of anti-flotation collars to the base of the Downstream Defender chamber are necessary to counterbalance buoyant forces.

Pipe Size

Each Downstream Defender model has a maximum recommended inlet and outlet pipe size.

When the diameter of the main storm drain line exceeds the recommended Downstream Defender maximum, it is recommended that the Downstream Defender be designed in an offline configuration. The maximum recommended inlet and outlet pipe diameter for each Downstream Defender model is shown in **Table A-2** of the Verification Appendix.

Minimum Installation Depth

Each Downstream Defender model has a minimum recommended design depth from the rim elevation to the invert elevation of the outlet pipe (**Fig.12**). These minimum depths vary by model size and can be found in **Table A-2** of the Verification Appendix.

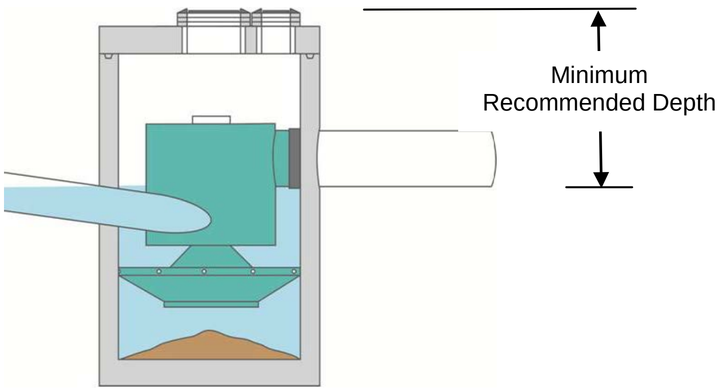

Figure 12 Minimum Recommended Design Depth from Rim to Invert of the Outlet Pipe

6. Maintenance Plans

The Downstream Defender treats stormwater by removing pollutants from stormwater runoff and capturing them in the pollutant storage sump. Periodic removal of these captured pollutants is essential to the continuous, long-term functioning of the Downstream Defender. When sediment and oil storage capacities are reached, the Downstream Defender will no longer be able to store removed sediment and oil.

Inspection and maintenance of the Downstream Defender are relatively simple procedures conducted from the surface. Neither inspection nor maintenance requires purchasing spare parts or tools from Hydro International.

The 4-ft Downstream Defender has one manhole lid to provide inspection and maintenance access to both the oil and sediment storage zones. All other Downstream Defender model sizes have two manhole lids – one centrally located for access to the pollutant storage sump (**Fig.13a**); the other situated over the outer annulus of the internal plastic components to allow for easier access to captured floatable trash and accumulated hydrocarbons (**Fig.13b**).

a.

b.

Figure 13 a) Single Access Lid, b) Two Access Lids

Inspection

The required frequency of cleanout depends on site use and other site specific characteristics and should therefore be determined by inspecting the unit after installation. During the first year of operation, the unit should be inspected at least every six months to determine the rate of sediment and floatables accumulation. More frequent inspections are recommended at sites that would generate heavy solids loads, like parking lots with winter sanding or unpaved maintenance lots. A dipstick can be used to measured accumulated oil; a sediment probe can be used to determine the level of accumulated solids stored in the sump.

The Downstream Defender will capture and retain sediment and oil until the sediment and oil storage volumes are full to capacity, but Hydro International recommends that the units are cleaned when sediment volumes reach 50% sump capacity. The standard pollutant storage capacities of the Downstream Defender vary with model size and are shown in **Table 28**. When sediment and oil depths are measured during inspection, they should be recorded on the Operation & Maintenance manual log and compared to the as-built drawings of the Downstream Defender to assess whether accumulated sediment has reached 50% capacity.

Table 28 – Pollutant Storage Capacities of the Downstream Defender

Model	Max. Oil Storage Volume	Max. Oil Storage Depth	Sediment Volume at 50% Sump Capacity	Sediment Depth at 50% Sump Capacity	Max. Sediment Sump Volume	Max. Sediment Sump Depth
	(gal)	(in)	(yd^3)	(in)	(yd^3)	(in)
4-ft DD	70	16	0.35	9	0.70	18
6-ft DD	216	23	1.05	12	2.10	24
8-ft DD	540	33	2.32	15	4.65	30
10-ft DD	1,050	42	4.35	18	8.70	36
12-ft DD	1,770	49	7.35	21	14.70	42

Maintenance

The interval of required clean-out should be determined by post-installation inspection of pollutant accumulation rates. If post-installation inspection cannot be conducted for some reason, Hydro International recommends the Downstream Defender be cleaned out at least once per year.

There is no need for man entry into the Downstream Defender during maintenance. However, if man entry does occur, then proper confined space entry procedures must be followed.

Floatable trash and debris can be removed by lifting the floatable access lid and using a netted skimming pole or a vactor truck to skim trash from the surface of the standing water. Accumulated oil must be vactored from the surface using a vactor truck or sump vac. Accumulated sediment can be removed by lifting the central access lid and dropping a vactor hose down the center shaft to the sump. The entire sump liquid volume does not necessarily need to be removed from the Downstream Defender during maintenance.

When all pollutants have been removed from the Downstream Defender, the manhole lids should be put securely back in place. Removed pollutants should be disposed of in accordance with local regulations and ordinances.

7. Statements

The following signed statements from the manufacturer, third-party observer 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.

STATEMENT OF DISCLOSURE – THIRD PARTY OBSERVER

To: **Lisa Lemont, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: Third Party Observer Statement of Disclosure under *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP, January 25 2013)[1]

Date: July 9, 2015

Att:

cc: Andrew Anastasio, Hydro International
Margaret Burns, FB Environmental Associates

Statement of Disclosure – Third Party Observer

FB Environmental has no financial conflict of interest regarding the test results of the stormwater device testing outlined in the *Verification Testing Report for the Downstream Defender® Stormwater Treatment Device* by Hydro International, dated July 2, 2015.

Disclosure Record

FB Environmental has provided the service of third party observer for tests performed by Hydro International in April through June of 2015. The tests assessed the total suspended solids (TSS) removal efficiency by a hydrodynamic sedimentation unit located within the Downstream Defender® stormwater treatment device as outlined in the *Verification Testing Report for the Downstream Defender® Stormwater Treatment Device* by Hydro International, dated July 2, 2015. Beyond this, FB Environmental and Hydro International 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, and do not receive funds or grants beyond those associated with the testing program.

July 9, 2015

Signed: Date:

STATEMENT OF THIRD PARTY OBSERVER

To: **Lisa Lemont, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: Third Party Review under *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP, January 25 2013)[1]

Date: July 9, 2015

Att:

cc: Andrew Anastasio, Hydro International; Jeremy Fink, Hydro International
Margaret Burns, FB Environmental Associates

Statement of Third Party Observer

FB Environmental has served as the third-party observer for tests performed by Hydro International in April through June 2015. The tests assessed the total suspended solids (TSS) removal efficiency by a hydrodynamic sedimentation unit located within the Downstream Defender® stormwater treatment device. Tests were performed by hydro international staff at their laboratory located at 94 Hutchinson Drive in Portland, Maine, to meet the standards described in *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP, January 25 2013)[1]. On May 10, 2014, we also submitted a statement of qualifications, as required by NJCAT MTD process.

A member of our staff verified compliance with the laboratory test protocol above, and our staff member was physically present to observe the full duration of all laboratory testing. We have also reviewed the data, calculations, and conclusions associated with the removal efficiency testing in the *Verification Testing Report for the Downstream Defender® Stormwater Treatment Device* by Hydro International, dated July 2, 2015, and state that they conform to what we saw during our supervision as third-party observer.

July 9, 2015

Signed: Date:

Stormwater Solutions

Turning Water Around...®

July 2, 2015

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

Re: Verification of Downstream Defender to NJDEP HDS Laboratory Testing Protocol

Dear Dr. Magee:

Hydro International's Downstream Defender® vortex separator for stormwater treatment recently underwent verification testing according to the NJDEP HDS Laboratory Testing Protocol. As required by the "Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology", this letter serves as Hydro International's statement that all procedures and requirements identified in the aforementioned protocol and process document were met or exceeded. The 4-ft Downstream Defender removal efficiency and scour testing at Hydro International's laboratory facility in Portland, Maine was conducted under the direct supervision of FB Environmental Associates. Analysis of all water quality samples was conducted by the independent analytical laboratory, Maine Environmental Laboratory. The particle size gradations of all sediment samples were analyzed by the independent analytical laboratory, GeoTesting Express. Additionally, the preparation of the verification report and the documentation contained therein fulfill the submission requirements of the process document and protocol.

If you have any questions or comments regarding the verification of the Downstream Defender, please do not hesitate to contact us.

Sincerely,

Lisa Lemont, CPSWQ
Business Development Manager

Andrew Anastasio
Product Development Engineer

Hydro International (Stormwater), 94 Hutchins Drive, Portland ME 04102
Tel: (207) 756-6200 Fax: (207) 756-6212 Web: www.hydro-int.com

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

July 20, 2015

Lisa Schafer
Environmental Engineer
New Jersey Department of Environmental Protection
Bureau of Nonpoint Pollution Control
401-02B, PO Box 420
Trenton, NJ 08625-0420

Dear Ms. Schafer,

Based on my review, evaluation and assessment of the testing conducted on the Downstream Defender® Stormwater Treatment Device by Hydro International and observed by FB Environmental Associates, the test protocol requirements contained in the "New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" (NJDEP HDS Protocol) were met or exceeded. Specifically:

Test Sediment Feed

The mean PSD of Hydro Internationals test sediments comply with the PSD criteria established by the NJDEP HDS protocol. The Hydro International removal efficiency test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification. The test sediment was shown to be slightly finer than the sediment blend specified by the protocol. The Hydro International scour test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification and shown to be much finer than specified by the protocol.

Removal Efficiency Testing

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on the 4-ft. laboratory unit in order to establish the ability of the Downstream Defender to remove the specified test sediment at 25%, 50%, 75%, 100% and 125% of the target MTFR. Prior to the start of testing Hydro International reviewed existing data and decided to utilize a target MTFR of 1.12 cfs. This target was chosen based on the ultimate goal of demonstrating greater than 50% annualized weighted solids removal as defined in the NJDEP HDS Protocol. The flow rates, feed rates and influent concentration all met the NJDEP HDS test protocol's coefficient of variance requirements and the background concentration for all five test runs never exceeded 20 mg/L.

Scour Testing

In order to demonstrate the ability of the Downstream Defender to be used as an online treatment device scour testing was conducted at greater than 200% of MTFR in accordance with the NJDEP HDS Protocol. The average flow rate during the online scour test was 2.28 cfs, which is equivalent to 263% of the MTFR (MTFR = 1.12 cfs). Background concentrations ranged from 5 mg/L to 7 mg/L with a mean of 6 mg/L, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Unadjusted effluent concentrations ranged from 10 mg/L to 16 mg/L with a mean of 13 mg/L. When adjusted for background concentrations, the effluent concentrations range from 4 to 10 mg/L with a mean of 7 mg/L. These results confirm that the 4-ft. Downstream Defender did not scour at 263% MTFR and meets the criteria for online use.

Maintenance Frequency

The predicted maintenance frequency for all models exceeds 6 years.

Sincerely,

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

8. References

ASTM D422-63. *Standard Test Method for Particle-size Analysis of Soils.*

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

Hydro International 2015. *Quality Assurance Project Plan for Downstream Defender® NJDEP Testing.* Prepared by H.I.L. Technology, Inc. dba Hydro International. March 20, 2015.

Hydro International 2015. *Verification Testing Report for the Downstream Defender Stormwater Treatment Device*. Prepared by H.I.L. Technology, Inc. dba Hydro International. July 2, 2015

New Jersey Corporation for Advanced Technology. *Downstream Defender® Stormwater Treatment Device: Hydro International*. January 2015.

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

NJDEP 2013b. *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.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Hydro International, 94 Hutchins Drive, Portland, ME 04102. *General Phone: (207)756-6200*. *Website:* www.hydro-int.com/us.

- MTD – Downstream Defender Stormwater Treatment Device. Verified Downstream Defender Models are shown in Table A-1

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- TSS Removal Rate – 50%

- On-line installation

Detailed Specification

- NJDEP sizing tables attached as Table A-1 and 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.

- Pick weights and installation procedures vary slightly with model size. Hydro International provides contractors with project-specific unit pick weights and installation instructions prior to delivery.

- Maximum recommended sediment depth prior to cleanout is 9 inches.

- For a reference maintenance plan, download the Downstream Defender Operation & Maintenance Manual at: http://www.hydro-int.com/UserFiles/downloads/DD-Operation%20And%20Maintenance%20Manual_0.pdf

- Under N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow a hydrodynamic separator such as the Downstream Defender to be used in series with another hydrodynamic separator to achieve an enhanced total suspended solids (TSS) removal rate.

Table A-1 MTFRs and Required Sediment Removal Intervals for Downstream Defender Models

Downstream Defender Model	Manhole Diameter (ft)	NJDEP 50% TSS Maximum Treatment Flow Rate (cfs)	Treatment Area (ft^2)	Hydraulic Loading Rate (gpm/ft^2)	50% Max Sediment Storage Volume (ft^3)	Required Sediment Removal Interval[1] (Months)
4-ft	4-ft	1.12	12.6	40.0	9.45	60
6-ft	6-ft	2.52	28.3	40.0	28.35	80
8-ft	8-ft	4.49	50.3	40.0	62.78	99
10-ft	10-ft	7.00	78.5	40.0	117.45	119
12-ft	12-ft	10.08	113.1	40.0	198.45	140

[1] Required sediment removal interval was calculated using the equation specified in Appendix B Part B of the NJDEP Laboratory Protocol for HDS MTDs:

$$\text{Sediment Removal Interval (months)} = \frac{\text{(50\% HDS MTD Max Sediment Storage Volume * 3.57)}}{\text{(MTFR * TSS Removal Efficiency)}}$$

Table A-2 Standard Dimensions for Downstream Defender Models

Downstream Defender Model and Manhole Diameter (ft)	Treatment Chamber Depth (ft)	Treatment Chamber Wet Volume (ft^3)	Total Wet Volume (ft^3)	Aspect Ratio Depth:Dia	Detention Time at MTFR (sec)	Maximum Pipe Diameter (in)	Sediment Sump Depth (ft)	50% Max Sediment Storage Volume (ft^3)
4-ft	1.71	21.6	51.5	0.43	46	12	1.5	9.45
6-ft	2.74	77.5	167.1	0.46	66	18	2.0	28.35
8-ft	3.73	187.6	385.6	0.47	86	24	2.5	62.78
10-ft	4.71	369.7	740.8	0.47	106	30	3.0	117.45
12-ft	5.85	661.6	1264.7	0.49	125	36	3.5	198.45