NJCAT TECHNOLOGY VERIFICATION

Rotondo StormGarden™ Bio-Filter Treatment System

Rotondo Environmental Solutions

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1. Description of Technology

The Rotondo Environmental Solutions StormGarden™ is a modular biofiltration manufactured treatment device which utilizes a proprietary high flow filter media to effectively remove common stormwater pollutants, e.g., Total Suspended Solids. StormGarden™ also includes a vegetative component, typically a small tree, bush, or tall grasses, which adds aesthetic value, and assists in filtration. StormGarden™ units are housed in a precast concrete vault, and can be installed along roadways, in parking lots, in landscaped areas, and more.

StormGarden™ is available in several standard sizes and configurations. Standard StormGarden™ sizes range from 4-foot x 4-foot to 8-foot x 16-foot, with custom sizes available upon request. The StormGarden™ system consists of a 6-inch layer of crushed stone surrounding a perforated PVC underdrain outflow pipe, a 15-inch layer of proprietary Rotondo-ES filter media, and a 5-inch hardwood mulch layer. The precast top-slab has a removable tree grate and a cleanout cover for access to the underdrain pipe and filter bed areas to perform routine maintenance. The StormGarden™ can also be configured without a top slab as an exposed biofiltration bed. **Figure 1** illustrates a cross-sectional view of the standard StormGarden™ system.

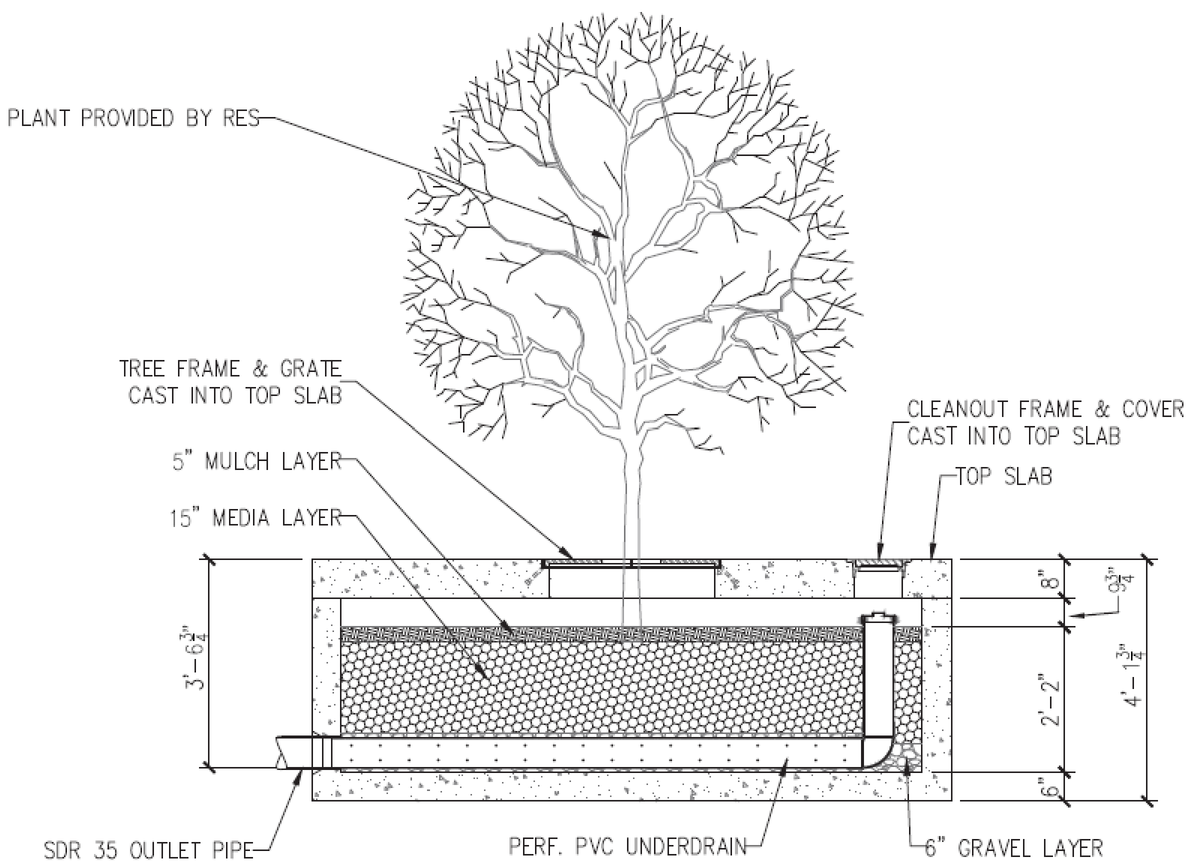

Figure 1 Standard StormGarden™ Cross Section

Stormwater enters the StormGarden™ through a standard curb inlet or inlet pipe. Rip rap is installed on top of the mulch layer at the inlet to prevent scouring. As water flows across the mulch surface, it percolates downward via gravity flow through the mulch and filter media layers. Treated stormwater then exits the StormGarden™ through the underdrain pipe, which can be easily connected to existing stormwater utilities. The StormGarden™ can also be configured with an inlet/pretreatment chamber, a catch basin chamber, an internal bypass, or as a buried vault system to address various site requirements.

StormGarden™ is a preassembled system, with internal components including the underdrain pipe, gravel layer, and proprietary filter media installed at the manufacturing facility to ensure optimal quality and performance, as well as ease of installation. Modules are sealed with filter fabric and plywood during the construction phase to ensure no contaminants enter the unit prior to site stabilization. After the site is stabilized, Rotondo performs the final activation of the units, which consists of unsealing the unit and installing the vegetative component and mulch layer.

2. Laboratory Testing

The test program was conducted at the Verdantas Flow Labs LLC, Alden Campus (Verdantas), Holden, Massachusetts, under the direct supervision of Verdantas' senior stormwater engineer, James Mailloux. Verdantas has performed verification testing on numerous Hydrodynamic Separator and Filtration Manufactured Treatment Devices (MTDs) for manufacturers under various state and federal testing protocols. Particle size distribution (PSD) analysis was conducted by GeoTesting Express, Inc., Acton, Massachusetts. GeoTesting is an ISO/IEC 17025 accredited independent laboratory. Water quality samples collected during the testing process were analyzed in the Verdantas Flow Labs Testing Laboratory.

Laboratory testing was done in accordance with the New Jersey Department of Environmental Protection "Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" January 14, 2022, updated April 25, 2023 (Filtration 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) as per the NJDEP certification process.

2.1 Test Setup

The StormGarden™ test unit, a full-scale commercially available system, was installed in a laboratory tank measuring 4' long x 4' wide x 4' deep. Inflow was conveyed to the test unit by means of a 6" PVC influent pipe set at a 1% slope. The pipe centerline was located 18" to the right of tank center, with the invert 30" above the tank floor. The StormGarden™ consisted of a 6" base of 1/2"-3/4" stone, 15" layer of proprietary engineered soil media and a 5" top layer of hardwood mulch. A layer of 3"-6" river stones were placed in front of the inlet pipe to dissipate the inlet energy. The stones occupied a 12" wide x 24" long area. A 6" perforated PVC underdrain/outlet pipe was installed on-center on the tank floor. A 2" layer of the base stone was installed over the top of the pipe. A 90-degree elbow and vertical bypass pipe was attached to the upstream end of the underdrain. The top of the bypass was located 9.75" above the mulch layer. The system geometry is shown in **Figures 2, 3 and 4**.

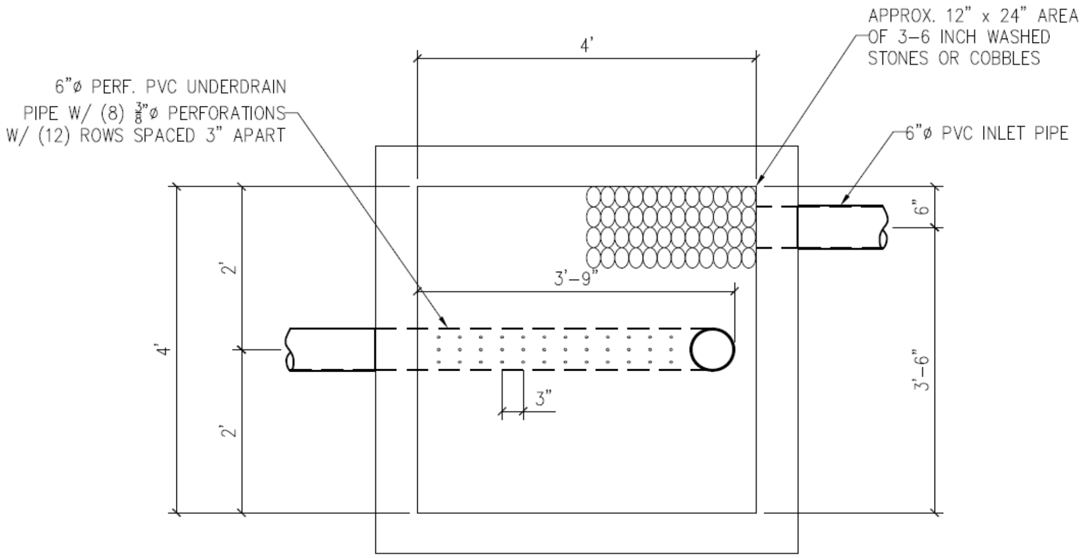

Figure 2 StormGarden™ Plan View

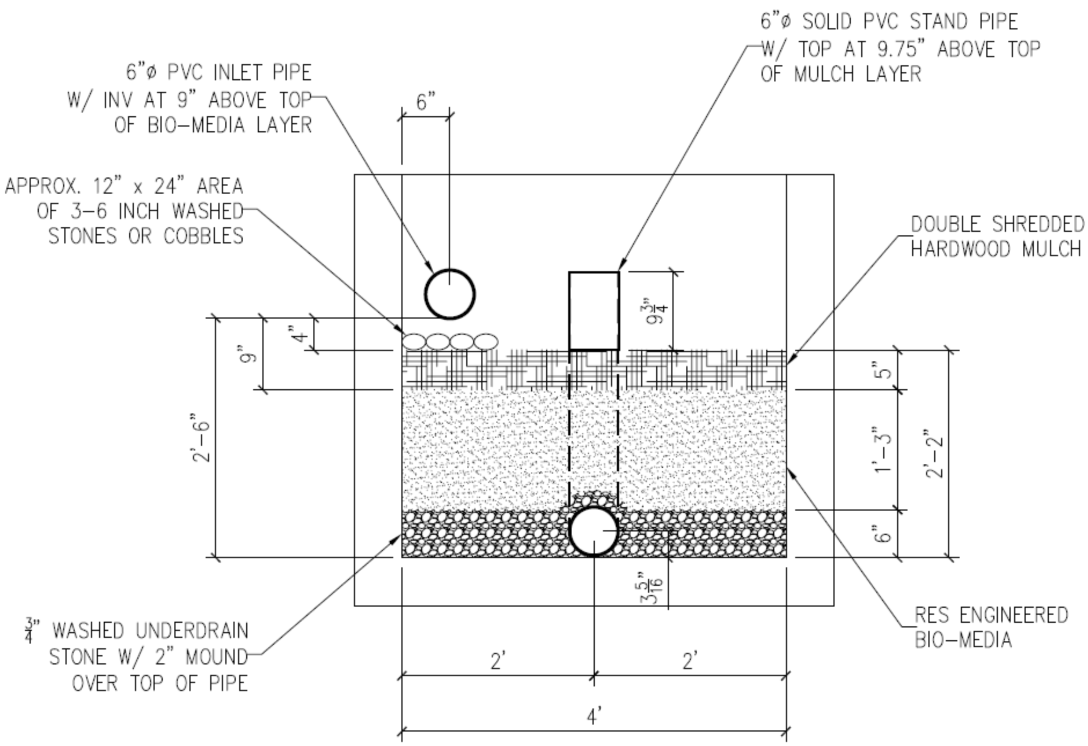

Figure 3 StormGarden™ Section View

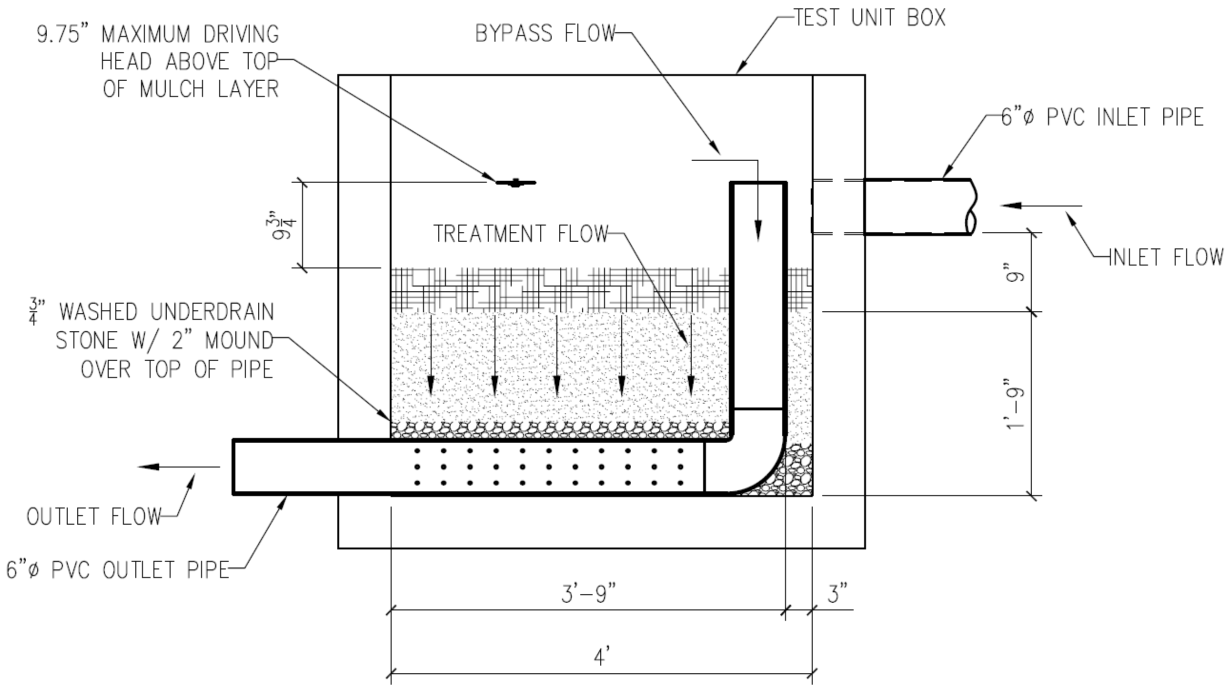

Figure 4 StormGarden™ Section View

The StormGarden™ was installed in a test loop in the Verdantas Stormwater Testing Facility, shown on **Figure 5**. A water-tight test tank was utilized for installing the StormGarden™. The installation was conducted in the same manner as in the field to meet the specifications of the protocol. All stone used for the test set-up was washed prior to installation. All pipe penetrations were sealed prior to testing. Flow was supplied to the unit with a laboratory pump drawing water from a 45,000-gallon supply sump, which can be heated or cooled to maintain a target temperature of approximately 68° F. The test flow was set and measured using a flow control valve and calibrated 1.5" orifice-plate flow meter, constructed to ASME guidelines. Flow measurement accuracy is within ±1%. During all test runs, the allowable flow variation was ±10% of the target flow and the coefficient of variance (COV) was ≤0.03.

Flow was conveyed to the test unit by means of a straight 6" diameter smooth-wall PVC influent pipe with a length of approximately 20 pipe diameters. The pipe was set with a 1% slope. A 6" tee was located 2' upstream of the test unit for injecting the test sediment into the crown of the influent pipe. Sediment injection was accomplished with the use of a volumetric screw feeder. A calibrated isokinetic sampler was installed in the upstream vertical riser pipe for collection of the background samples. The system outflow discharged into an effluent channel containing a calibrated V-notch weir and returned to the sump. Filtration of the supply sump flow was performed with an inline filter wall containing 1-micron rated filter bags.

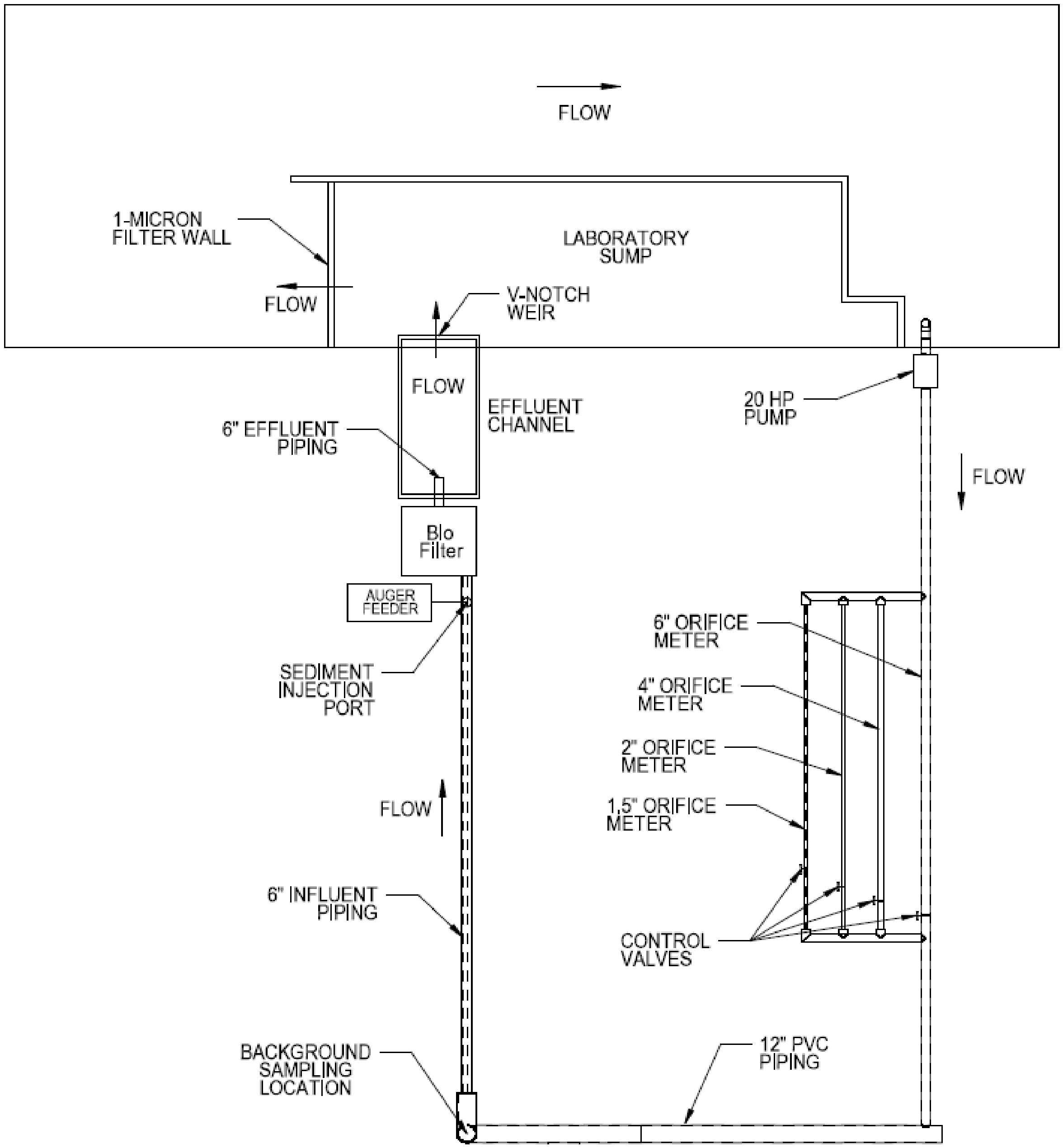

Figure 5 Verdantas Stormwater Test Loop

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 laboratory prior to testing. The temperature measurement was documented at the start and end of each test, to assure an acceptable testing temperature of ≤ 80 degrees F. A mid-test temperature reading was not necessary, as the test loop was a recirculating closed-loop system.

The water level at the V-notch weir was measured with the use of a Piezometer tap, water manometer and a calibrated pressure transducer. The flow and water elevations were measured and recorded every 5 seconds throughout the duration of each test run, including the drawdown period. The water elevation within the treatment unit was measured at the end of each test run with the use of a mounted staff gage. Photographs of the test setup are shown in **Figure 6** and **Figure 7**. A photograph of the influent flow dissipating stones and internal bypass is shown in **Figure 8**.

Figure 6 StormGarden™ Test Setup

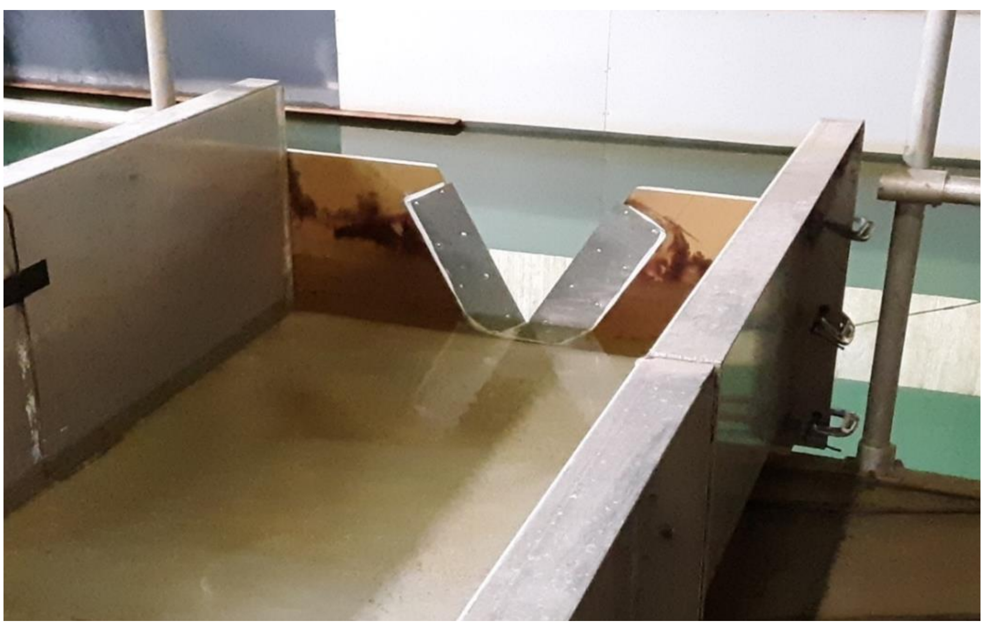

Figure 7 Effluent Channel V-notch Weir

Figure 8 StormGarden™ at 40 GPM

2.2 Removal Efficiency and Mass Loading Capacity Testing

Sediment testing was conducted to determine sediment removal efficiency, as well as sediment mass loading capacity. The sediment testing was conducted on an initially clean system at the target 100% MTFR of 40 gpm (2.5 gpm/ft^2) selected by Rotondo. A minimum of ten (10) 30-minute test runs were required to be conducted to meet the removal efficiency criterion. Additional runs were conducted to determine the maximum mass loading. The captured sediment was not removed from the system between test runs. The total mass injected into the system was quantified for each run by subtracting the mass remaining in the feeder, mass collected for the feed rate calibrations and any sediment in the inlet pipe from the starting mass. This value was used in calculating the influent mass/volume concentration. The total mass captured in the system was quantified at the conclusion of testing and used for the determination of the maximum inflow drainage area (acres) per the NJDEP protocol.

From the data collected, the following graphs were produced to show the life-cycle performance of the StormGarden™ Bio-Filter:

- Driving Head vs. Sediment Mass Loading
- Removal Efficiency vs. Sediment Mass Loading

The test sediment was prepared by Verdantas to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in column 2 of **Table 1**. The sediment was silica based, with a specific gravity of 2.65. PSD samples of the test sediment from three randomly selected test buckets were analyzed by GeoTesting Express, an independent certified analytical laboratory using ASTM D6913/ D6913M-17 (2017), "Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis" and ASTM D7928-21e1 (2021), "Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis". The average of the three samples was used for compliance with the protocol. Additional discussion of the sediment is presented in **Section 4.1**.

Table 1 NJDEP Sediment Particle Size Distribution

Table 1: Test Sediment Particle Size Distribution[1]

Particle Size (Microns)	Target Minimum % Less Than[2]
1,000	100
500	95
250	90
150	75
100	60
75	50
50	45
20	35
8	20
5	10
2	5

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, A measured value may be lower than a target minimum % less than value by up to two percentage points (e.g., at least 3% of the particles must be less than 2 microns in size [target is 5%]), provided the measured d50 value does not exceed 75 microns..

All sediment testing was conducted using the indirect (sampling) methodology, as per the NJDEP protocol. A minimum of five effluent samples were collected using 2-L beakers and the end-of-pipe grab sampling methodology. The required background samples were collected upstream of the influent pipe using 2-L beakers and a calibrated isokinetic sampler installed in the center of the upstream vertical riser of the inflow piping.

For each 30-minute test run, a minimum of five 1-L effluent samples were collected. Samples were collected three detention times after the initiation of sediment dosing, as well as after the interruption of dosing for injection measurements. A minimum of three evenly spaced background samples were collected in correspondence with the odd-numbered effluent samples (first, third, fifth). At the termination of the test run, two evenly volume-spaced effluent samples were collected during the drawdown period and used in the removal efficiency calculation. The drawdown volume was calculated by measuring the effluent using a calibrated V-notch weir located at the end of the effluent channel. All effluent and drawdown concentrations were adjusted for background.

The target influent sediment concentration was 200 mg/L (±20 mg/L) for all tests. Verification of the injected sediment concentration was achieved by taking a minimum of three timed dry samples from the auger feeder, including one sample at the start of dosing, one sample in the middle of each run, and one sample just prior to the conclusion of dosing. The samples were collected over a duration of one minute. The collected samples were weighed to establish the g/min feed rate for each sample. The sample concentration COV did not exceed 0.10. The influent concentration was calculated using the following two methods:

1. The auger sediment feed rate data was used in conjunction with the corresponding recorded flow data to establish an influent concentration of 200 mg/L (±10%) throughout the test run and demonstrate that the feed rate COV was ≤0.10.

2. The sediment mass in the volumetric screw feeder was quantified at the start and end of each test run and corrected for the three feed calibration samples to determine the mass fed into the test unit and any sediment deposited in the inlet pipe. This mass was divided by the total volume of water flowing through the test unit during sediment dosing to determine the average influent TSS concentration and used in the removal efficiency calculation.

2.3 Scour Testing

Rotondo decided to not conduct scour testing on a 50% loaded bed at this time. The StormGarden™ Bio-Filter will be designated as an offline system.

2.4 Instrumentation and Measuring Techniques

Flow

The inflow to the test unit was measured using a 1.5” calibrated orifice plate differential-pressure flow meter. The meter was fabricated per ASME guidelines and calibrated in the Verdantas Flow Labs Calibration Laboratory prior to the start of testing. The high- and low-pressure lines from the meter were connected to manifolds containing isolation valves. 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 cell, also calibrated in the Verdantas laboratory prior to testing. All pressure lines and cells were purged of air (bled) prior to the start of each test. The test flow was averaged and recorded every 5 seconds throughout the duration of each test run using an in-house computerized data acquisition program as described in Section 2.5. The accuracy of the flow measurement is ±1%. A photograph of the flow meters is shown on **Figure 9** and the laboratory pumps on **Figure 10.**

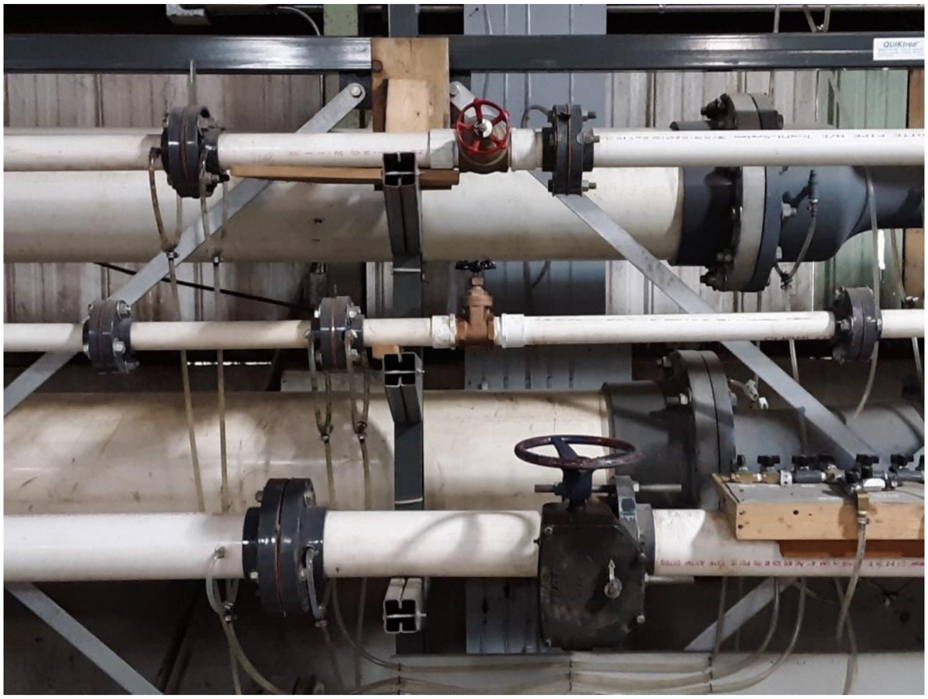

Figure 9 Photograph of Laboratory Flow Meters

Figure 10 Photograph of Laboratory Pumps

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 Verdantas laboratory prior to testing. The temperature measurement was documented at the start and end of each test, to ensure a Protocol required testing temperature of ≤ 80 degrees F.

Water Levels

The ponding water level above the mulch layer was recorded to the nearest 1/16” fifteen seconds prior to shutting off the flow at the end of each test run with the use of a staff gauge mounted to the inside of the test tank.

Drawdown Flow

The drawdown flow was measured at the conclusion of each test run with the use of the calibrated V-notch weir. The water level at the weir was recorded every 5 seconds using a piezometer tap, Omegadyne PX419, 0 - 2.5 psi pressure transducer (PT), and computer DA program. The PT and weir were calibrated as a system prior to testing. Accuracy of the readings is ± 0.001 ft.

Sediment Injection

The test sediment was injected into the crown of the influent pipe using a Schenk® volumetric screw feeder. The auger feed screw, driven with a variable-speed drive, was calibrated with the test sediment prior to testing. The calibration, as well as test verification of the sediment feed was accomplished by collecting timed dry samples of 0.1-liter, up to a maximum of 1-minute, and weighing them on an Ohaus® 2200g x 0.1g, model SPX2201 digital scale. The allowable Coefficient of Variance (COV) for the injection was ≤0.10.

Sample Collection

Effluent samples were collected in 2-liter containers from the free-discharge at the end of the 6-inch effluent pipe. Background concentration samples were collected from the center of the vertical pipe upstream of the test unit with the use of a calibrated isokinetic sampler, (**Figure 11)**.

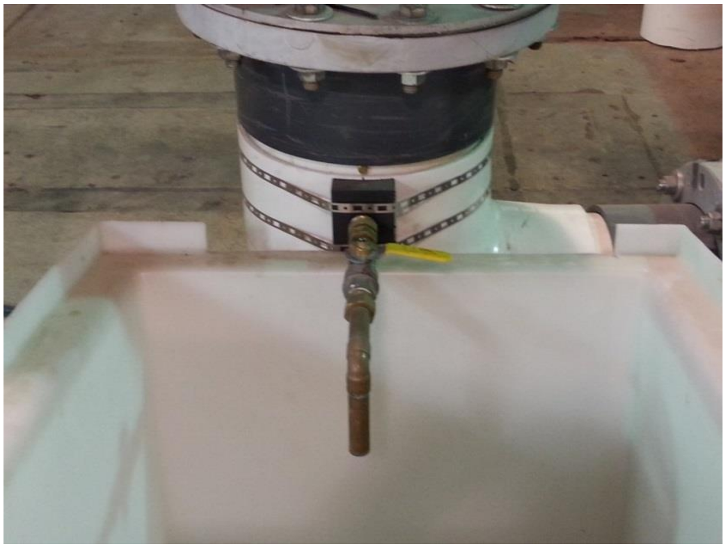

Figure 11 Photograph of the Background Isokinetic Sampler

Sample Concentration Analysis

Effluent and background concentration samples were analyzed by Verdantas in accordance with Method B, as described in ASTM Designation: D 3977-97 (2019), “Standard Test Methods for Determining Sediment Concentration in Water Samples”. Verdantas is ISO 17025 accredited for conducting the ASTM D3977 analysis. Verdantas has assigned a Minimum Detection Limit (MDL) of 1.0 mg/L. To be conservative, all concentrations below the MDL were assigned a value of 0.5 mg/L.

2.5 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 were initialed and dated.

A personal computer running an 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 board was used to convert the voltage signal from the pressure cells. The Verdantas 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 seconds. The recorded data files were imported into Excel for further analysis and plotting.

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

2.6 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 the Verdantas Calibration Laboratory, which is ISO 17025 accredited. All 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 traceable digital stopwatch and a 2200 g x 0.1 g 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 one minute. The reported overall mass/volume sediment concentrations were adjusted for moisture.

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the Rotondo StormGarden™ Bio-Filter Treatment System (StormGarden™), the following are the performance claims made by Rotondo Environmental Solutions.

Total Suspended Solids (TSS) Removal Efficiency

Based on the laboratory testing conducted, the tested StormGarden™ achieved a 93.8% cumulative TSS removal efficiency rounded down to 80% per the NJDEP protocol.

Maximum Treatment Flow Rate (MTFR)

The tested system has an MTFR of 40 gpm (0.089 cfs) and an effective filtration treatment area (EFTA) of 16.0 ft^2 (loading rate = 2.5 gpm/ft^2).

Effective Filtration Treatment Area

The Effective Filtration Treatment Area (EFTA) for the test system is 16.0 ft^2.

Sediment Load Capacity/Mass Load Capture Capacity

Based on laboratory testing results, the test system has a mass loading capacity of 80.04 lbs and a mass loading capture capacity of 75.03 lbs (4.69 lbs/ft^2 of filter area).

Maximum Allowable Inflow Drainage Area

Per the NJDEP filter protocol, to calculate the maximum inflow drainage area, the total sediment load captured mass observed during the test (75.03) is divided by 600 lbs/acre. Thus, the maximum inflow drainage area for the tested system is 0.125 acres.

4. Supporting Documentation

The NJDEP procedure (NJDEP, 2021) 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 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

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1-1000 micron silica particles, as shown in **Table 1**. The Specific Gravity (SG) of the sediment mixes was 2.65. Commercially-available silica products were provided by AGSCO Corp., a QAS International ISO-9001 certified company, and blended by Verdantas as required. Test batches were prepared in individual 5-gallon buckets, which were arbitrarily selected for the removal testing. A well-mixed sample was collected from three random test batches and analyzed for PSD in accordance with ASTM D6913 (2017) and ASTM D7928 (2021), by GeoTesting Express, an ISO/IEC 17025 accredited independent laboratory. The average of the samples was used for compliance to the protocol specifications listed in Column 2 of **Table 1**. The median D_{50} of the samples was 69 microns. The PSD data of the samples are shown in **Table 2** and the corresponding curves are shown on **Figure 12**.

Table 2 PSD Analyses of Verdantas NJDEP 1-1000 Micron Mix

Particle Size µm	Bucket 3	Bucket 9	Bucket 18	Average	NJDEP Minimum Allowed Values
1000	99%	99%	99%	99%	98%
500	95%	94%	94%	94%	93%
250	89%	89%	88%	89%	88%
150	74%	74%	73%	74%	73%
100	58%	59%	57%	58%	58%
75	51%	51%	50%	51%	50%
50	46%	47%	46%	46%	43%
20	40%	39%	37%	39%	33%
8	21%	19%	18%	19%	18%
5	14%	12%	11%	12%	8%
2	6%	5%	5%	5%	3%
D_{50}	69	64	74	69	75

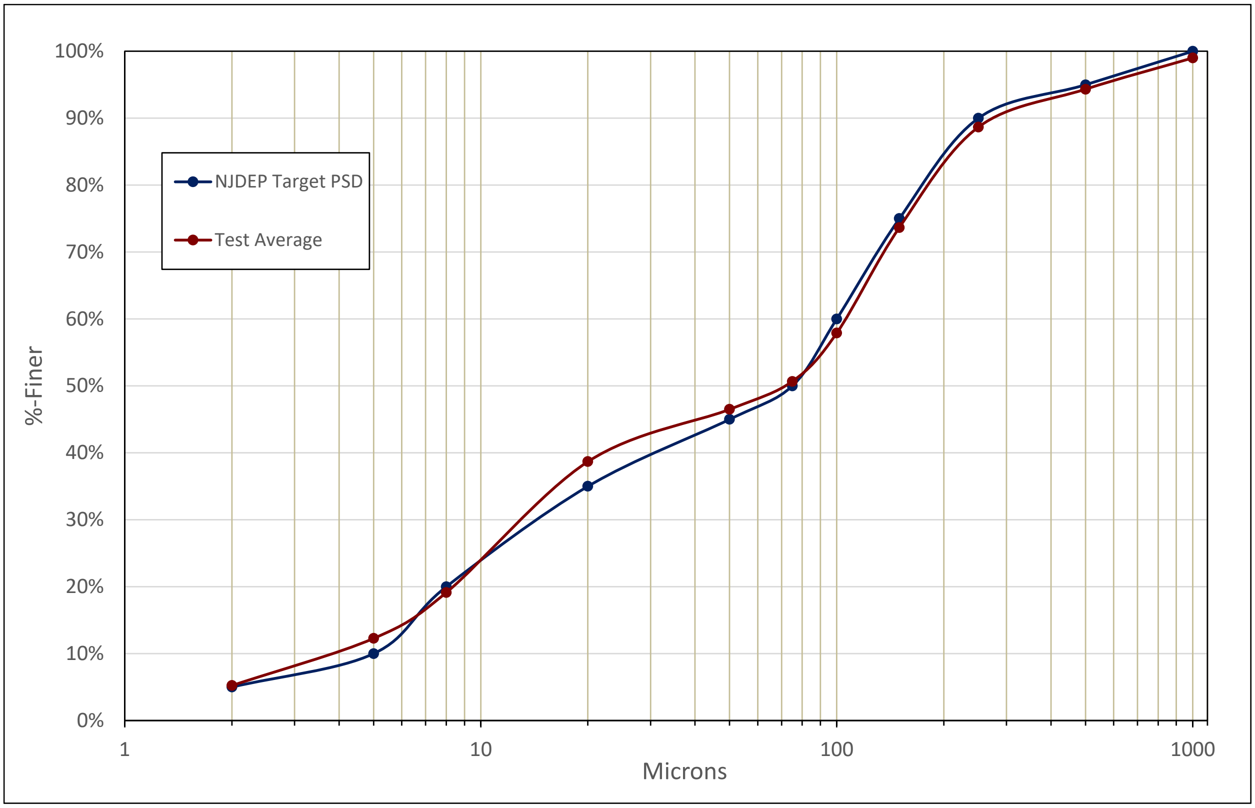

Figure 12 PSD Curves of 1-1000 Micron Test Sediment

4.2 Removal Efficiency and Mass Loading Testing

Testing Summary

Ten tests were conducted at the target flow of 40 gpm. The measured 100% MTFR flows ranged from 40.0 gpm to 40.1 gpm. The calculated COV for the test runs ranged from 0.001 to 0.002. The system went into bypass during test Run 11 and was terminated. The testing was continued at the 90% MTFR flow of 36 gpm until the system went into bypass at test run #36. The measured 90% MTFR flow was 36.0 gpm for all tests conducted. The calculated COV for the 90% test runs ranged from 0.001 to 0.002. The maximum recorded temperatures for all tests ranged from 59.8 to 71.6 degrees F. The measured injected influent concentration averages ranged from 187.4 to 215.9 mg/L. The injection COV ranged from 0.003 to 0.084. The calculated mass/volume influent concentrations ranged from 183.6 to 216.9 mg/L. The mass/volume influent concentration exceeded the allowable limit of 220 mg/L on test Runs 17, 19 and 25. The injected and captured mass for those tests were included in the total, but the measured removal efficiencies were not included in the cumulative average. There was no sediment in the inlet pipe at the conclusion of each test run.

The calculated removal efficiencies from **Equation 1** ranged from 91.5% to 95.8%, with a total cumulative average removal of 93.8%. The total cumulative injected and captured mass was 80.04 lbs and 75.03 lbs, respectively. The maximum end-of-run elevation above the mulch layer was 0.810 ft (9.725 in) prior to entering bypass.

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

Equation 1 Equation for Calculating Removal Efficiency

The sampling collection times for the three injected sediment samples, the three background samples, the five effluent samples and the two drawdown samples for each run are shown in **Table 3.** The measured flowrate, flowrate COV, maximum water temperature, end of run water elevation above the mulch layer, influent sediment concentration and QA/QC compliant (Y/N) are shown in **Table 4.** Note that Runs 17, 19, and 25 were non-compliant as previously mentioned.

The maximum background, effluent, adjusted effluent, drawdown and adjusted drawdown concentrations are shown in **Table 5.** Removal efficiency test results are summarized in **Table 6**, and injected mass, mass captured, individual run removal efficiency and cumulative sediment removal efficiency are shown in **Table 7**.

The removal efficiency vs mass loading is shown on **Figure 13.** The recorded driving head at the end of each run vs mass loading is shown on **Figure 14**.

Table 3 Sample Collection Timestamps (minutes)

Run #	Injection 1	Eff 1, BG 1	Eff 2	Eff 3, BG 2	Injection 2	Eff 4	Eff 5, BG 3	Injection 3	DD 1	DD 2
1	1	13	15	17	19	31	33	35	38.25	39.75
2	1	13	15	17	19	31	33	35	38.25	39.75
3	1	13	15	17	19	31	33	35	38.33	40.50
4	1	13	15	17	19	31	33	35	38.75	41.25
5	1	13	15	17	19	31	33	35	38.67	40.83
6	1	13	15	17	19	31	33	35	38.67	41.83
7	1	13	15	17	19	31	33	35	38.67	41.58
8	1	13	15	17	19	31	33	35	38.75	41.33
9	1	13	15	17	19	31	33	35	38.67	41.42
10	1	13	15	17	19	31	33	35	38.33	40.42
11	System in Bypass									
12	1	13	15	17	19	31	33	35	38.50	41.42
13	1	13	15	17	19	31	33	35	39.00	42.33
14	1	13	15	17	19	31	33	35	38.92	41.75
15	1	13	15	17	19	31	33	35	38.50	40.33
16	1	13	15	17	19	31	33	35	38.67	41.50
17	1	13	15	17	19	31	33	35	39.25	43.33
18	1	13	15	17	19	31	33	35	39.50	44.67
19	1	13	15	17	19	31	33	35	39.08	42.00
20	1	13	15	17	19	31	33	35	39.50	42.42
21	1	13	15	17	19	31	33	35	39.17	42.25
22	1	13	15	17	19	31	33	35	39.33	42.58
23	1	13	15	17	19	31	33	35	39.33	42.83
24	1	13	15	17	19	31	33	35	39.00	41.83
25	1	13	15	17	19	31	33	35	38.92	41.50
26	1	13	15	17	19	31	33	35	38.67	41.00
27	1	23	25	27	30	52	54	56	60.17	63.00
28	1	25	27	29	33	57	59	61	65.67	69.00
29	1	18	20	22	24	41	43	45	49.50	52.50
30	1	18	20	22	24	45	47	49	53.25	56.00
31	1	20	22	24	26	45	47	49	53.67	56.67
32	1	18	20	22	24	36	38	40	44.33	47.25
33	1	13	15	17	19	31	33	35	39.50	42.50
34	1	13	15	17	19	31	33	35	39.42	42.25
35	1	13	15	17	19	31	33	35	39.67	42.83

Table 4 Removal Efficiency Test Parameters

Test Run #	Measured Flow		Maximum Water Temperature	End of Run Water El. Above Mulch	Influent Concentration (mg/L)					QA/QC Compliant
	gpm	COV	Deg. F	ft	Minimum	Maximum	Average	COV	Mass/Volume	
1	40.1	0.002	71.6	0.125	203.5	209.2	205.8	0.015	203.1	**Y**
2	40.0	0.002	69.9	0.125	199.5	207.9	202.7	0.022	202.9	**Y**
3	40.0	0.001	69.1	0.146	190.9	205.6	199.7	0.039	201.8	**Y**
4	40.0	0.001	68.8	0.229	195.4	203.1	199.5	0.019	208.1	**Y**
5	40.0	0.001	68.6	0.167	191.0	199.6	196.3	0.024	206.4	**Y**
6	40.0	0.002	67.5	0.146	199.4	217.2	206.2	0.047	216.2	**Y**
7	40.0	0.002	67.7	0.479	197.5	205.7	201.3	0.021	211.1	**Y**
8	40.1	0.001	68.1	0.208	201.5	215.0	207.3	0.033	206.6	**Y**
9	40.0	0.001	70.0	0.198	192.1	202.2	196.1	0.027	199.6	**Y**
10	40.0	0.001	69.9	0.104	181.8	195.7	188.3	0.037	191.5	**Y**
11	Terminated - system in bypass									
12	36.0	0.002	65.2	0.313	185.5	216.8	204.4	0.082	196.3	**Y**
13	36.0	0.002	65.5	0.438	191.6	207.8	199.1	0.041	211.9	**Y**
14	36.0	0.002	64.8	0.333	182.2	208.0	198.9	0.073	199.8	**Y**
15	36.0	0.002	63.8	0.104	196.8	207.5	203.7	0.029	206.8	**Y**
16	36.0	0.002	63.9	0.250	206.1	215.9	210.1	0.024	216.9	**Y**
17	36.0	0.001	65.8	0.479	214.5	215.7	215.1	0.003	**223.9**	**N**
18	36.0	0.001	64.8	0.708	195.3	214.7	203.4	0.050	195.1	**Y**
19	36.0	0.001	62.8	0.479	204.9	218.4	213.2	0.034	**237.8**	**N**
20	36.0	0.002	62.2	0.729	181.1	206.9	194.5	0.067	199.9	**Y**
21	36.0	0.002	62.9	0.500	185.0	198.2	191.0	0.035	210.4	**Y**
22	36.0	0.001	59.8	0.625	182.3	192.9	187.4	0.028	197.8	**Y**
23	36.0	0.002	63.2	0.573	185.8	195.6	189.7	0.027	183.6	**Y**
24	36.0	0.002	65.8	0.417	182.3	206.4	194.9	0.062	206.1	**Y**
25	36.0	0.002	65.5	0.396	183.8	214.3	195.4	0.084	**222.7**	**N**
26	36.0	0.001	66	0.292	205.9	216.4	209.6	0.028	187.5	**Y**
27	36.0	0.001	66.2	0.563	185.3	198.0	193.1	0.035	200.4	**Y**
28	36.0	0.002	66	0.810	199.4	203.4	201.6	0.010	203.2	**Y**
29	36.0	0.001	65.6	0.667	191.1	208.5	199.6	0.044	216.0	**Y**
30	36.0	0.002	66.7	0.583	185.6	207.6	196.5	0.056	214.7	**Y**
31	36.0	0.001	66.1	0.740	198.7	206.5	203.7	0.021	212.7	**Y**
32	36.0	0.001	65.1	0.708	191.1	216.2	203.7	0.062	216.8	**Y**
33	36.0	0.002	66.5	0.792	184.7	203.1	196.8	0.053	199.5	**Y**
34	36.0	0.002	66.3	0.740	185.8	202.9	195.8	0.046	216.3	**Y**
35	36.0	0.002	65.2	0.792	206.7	217.4	213.1	0.027	208.6	**Y**

Table 5 Sample Concentrations

Run #	Max Background	Adjusted Effluent Concentrations (mg/L)						Adjusted Drawdown Concentrations (mg/L)		
	mg/L	E1	E2	E3	E4	E5	**Average**	DD1	DD2	**Average**
1	0.5	11.0	8.0	8.6	9.7	9.5	**9.4**	25.1	37.1	**31.1**
2	0.5	9.2	9.3	9.2	9.0	9.5	**9.3**	30.2	41.8	**36.0**
3	2.1	6.5	6.1	6.4	8.6	8.2	**7.2**	22.7	34.5	**28.6**
4	0.5	6.1	7.4	7.0	7.2	8.0	**7.1**	23.0	30.5	**26.8**
5	0.8	7.0	7.2	6.9	7.2	7.6	**7.2**	28.6	38.7	**33.6**
6	0.5	9.6	8.9	8.8	13.0	8.8	**9.8**	26.7	27.2	**27.0**
7	0.5	7.4	6.9	7.0	7.6	8.2	**7.4**	13.9	35.8	**24.9**
8	1.1	7.6	5.9	6.4	7.2	6.1	**6.6**	13.3	34.8	**24.0**
9	1.6	12.8	14.2	13.1	10.8	10.7	**12.3**	22.4	31.1	**26.8**
10	0.5	8.0	7.8	8.7	9.4	9.2	**8.6**	14.3	40.6	**27.4**
11	Terminated - system in bypass									
12	1.2	12.5	9.5	11.6	10.4	8.7	**10.5**	14.5	33.5	**24.0**
13	1.3	12.5	10.7	12.7	12.0	12.4	**12.1**	12.3	29.8	**21.1**
14	1.2	13.4	13.5	13.5	12.4	11.4	**12.8**	11.1	31.7	**21.4**
15	0.5	7.6	3.3	7.0	13.1	14.0	**9.0**	22.7	42.5	**32.6**
16	1.2	12.9	14.6	14.8	14.1	14.0	**14.1**	15.7	34.7	**25.2**
17	1.1	14.8	15.6	12.9	15.4	14.7	**14.7**	13.3	25.5	**19.4**
18	0.5	12.9	13.7	13.8	14.2	12.2	**13.3**	11.3	22.1	**16.7**
19	0.5	13.1	12.4	12.1	13.8	13.3	**12.9**	12.3	39.0	**25.7**
20	0.5	11.3	12.7	13.3	13.7	13.3	**12.9**	11.6	28.2	**19.9**
21	0.5	11.4	11.5	10.3	12.7	11.4	**11.5**	11.7	34.8	**23.3**
22	0.5	13.0	13.2	13.3	12.2	12.7	**12.9**	11.4	38.6	**25.0**
23	0.5	5.9	5.6	6.1	7.2	6.6	**6.3**	19.7	33.3	**26.5**
24	0.5	9.2	9.0	7.6	9.2	11.2	**9.2**	12.7	38.2	**25.4**
25	0.5	16.8	17.5	15.5	18.6	18.1	**17.3**	15.6	39.8	**27.7**
26	0.5	11.8	12.4	13.1	5.5	9.7	**10.5**	17.6	39.4	**28.5**
27	3.1	9.6	9.8	6.7	8.9	7.5	**8.5**	8.4	22.2	**15.3**
28	0.5	9.4	9.8	12.0	10.8	9.2	**10.2**	14.5	40.0	**27.3**
29	0.5	10.9	8.8	7.6	18.8	16.7	**12.6**	14.7	49.7	**32.2**
30	1.4	9.6	9.5	9.2	14.4	13.6	**11.3**	28.6	56.1	**42.3**
31	1.4	12.1	11.1	10.6	10.1	9.7	**10.7**	23.9	42.4	**33.2**
32	0.5	11.1	10.4	13.3	18.0	16.4	**13.8**	12.8	36.8	**24.8**
33	0.5	21.3	17.8	18.1	7.5	8.5	**14.7**	22.3	27.1	**24.7**
34	0.5	19.6	16.1	14.7	15.4	14.3	**16.0**	11.9	29.4	**20.6**
35	2.2	16.3	15.2	15.6	13.3	12.1	**14.5**	11.0	31.0	**21.0**

Table 6 Removal Efficiency Test Results

Run #	Mass/Volume Influent Concentration	Average Adjusted Effluent Concentration	Average Adjusted Drawdown Concentration	Influent Volume	Effluent Volume	Drawdown Volume	Influent Mass	Effluent Mass	Drawdown Mass
	mg/L	mg/L	mg/L	L	L	L	g	g	g
1	203	9.4	31.1	5079	4625	454	1031	43	14
2	203	9.3	36.0	5073	4626	447	1029	43	16
3	202	7.2	28.6	5065	4562	503	1022	33	14
4	208	7.1	26.8	5065	4537	527	1054	32	14
5	206	7.2	33.6	5072	4516	555	1047	32	19
6	216	9.8	27.0	5071	4525	546	1096	44	15
7	211	7.4	24.9	5068	4384	684	1070	32	17
8	207	6.6	24.0	5076	4502	574	1049	30	14
9	200	12.3	26.8	5074	4570	504	1013	56	13
10	192	8.6	27.4	5075	4540	535	972	39	15
11	Terminated								
12	196	10.5	24.0	4557	3920	637	894	41	15
13	212	12.1	21.1	4562	3934	628	967	47	13
14	200	12.8	21.4	4568	3994	574	913	51	12
15	207	9.0	32.6	4565	4086	479	944	37	16
16	217	14.1	25.2	4562	3963	599	990	56	15
17	224	14.7	19.4	4564	3783	782	1022	56	15
18	195	13.3	16.7	4563	3716	847	890	50	14
19	238	12.9	25.7	4563	3828	736	1085	49	19
20	200	12.9	19.9	4561	3659	902	912	47	18
21	210	11.5	23.3	4565	3807	758	960	44	18
22	198	12.9	25.0	4562	3628	934	903	47	23
23	184	6.3	26.5	4567	3800	768	839	24	20
24	206	9.2	25.4	4568	3875	693	941	36	18
25	223	17.3	27.7	4571	3878	693	1018	67	19
26	187	10.5	28.5	4567	3903	664	856	41	19
27	200	8.5	15.3	7427	6651	776	1488	56	12
28	203	10.2	27.3	8114	7228	885	1649	74	24
29	216	12.6	32.2	5927	5054	874	1280	63	28
30	215	11.3	42.3	6477	5754	723	1390	65	31
31	213	10.7	33.2	6494	5652	841	1381	61	28
32	217	13.8	24.8	5245	4361	884	1137	60	22
33	200	14.7	24.7	4557	3630	927	909	53	23
34	216	16.0	20.6	4565	3707	859	988	59	18
35	209	14.5	21.0	4561	3598	963	951	52	20

Table 7 Removal Efficiency Injected and Captured Mass

Run #	Test Duration	Injected Mass	Total Mass Injected	Mass Captured	Total Mass Captured	Removal Efficiency	Cumulative Average
	minutes	lbs	lbs	lbs	lbs	%	%
1	33.5	2.27	2.27	2.15	2.15	**94.4**	**94.4**
2	33.5	2.27	4.54	2.14	4.29	**94.3**	**94.4**
3	33.5	2.25	6.80	2.15	6.44	**95.4**	**94.7**
4	33.5	2.32	9.12	2.22	8.66	**95.6**	**94.9**
5	33.5	2.31	11.43	2.20	10.85	**95.1**	**95.0**
6	33.5	2.42	13.84	2.29	13.14	**94.6**	**94.9**
7	33.5	2.36	16.20	2.25	15.39	**95.4**	**95.0**
8	33.5	2.31	18.52	2.22	17.60	**95.8**	**95.1**
9	33.5	2.23	20.75	2.08	19.68	**93.1**	**94.9**
10	33.5	2.14	22.89	2.02	21.71	**94.5**	**94.8**
11	Terminated	1.36	24.25	1.27	22.97		
12	33.5	1.97	26.22	1.85	24.82	**93.7**	**94.7**
13	33.5	2.13	28.35	2.00	26.82	**93.7**	**94.6**
14	33.5	2.01	30.37	1.87	28.69	**93.0**	**94.5**
15	33.5	2.08	32.45	1.97	30.65	**94.4**	**94.5**
16	33.5	2.18	34.63	2.03	32.68	**92.8**	**94.4**
17	33.5	2.25	36.88	2.10	34.78	**93.1**	***94.4**
18	33.5	1.96	38.84	1.82	36.60	**92.8**	**94.3**
19	33.5	2.39	41.24	2.24	38.84	**93.7**	***94.3**
20	33.5	2.01	43.25	1.87	40.71	**92.9**	**94.2**
21	33.5	2.12	45.36	1.98	42.69	**93.6**	**94.2**
22	33.5	1.99	47.35	1.84	44.53	**92.2**	**94.1**
23	33.5	1.85	49.20	1.75	46.28	**94.7**	**94.1**
24	33.5	2.08	51.28	1.96	48.23	**94.3**	**94.1**
25	33.5	2.24	53.52	2.05	50.29	**91.5**	***94.1**
26	33.5	1.89	55.41	1.76	52.04	**93.0**	**94.1**
27	57.5	3.28	58.69	3.13	55.17	**95.4**	**94.1**
28	59.5	3.63	62.33	3.42	58.59	**94.0**	**94.1**
29	43.5	2.82	65.15	2.62	61.21	**92.8**	**94.1**
30	47.5	3.07	68.21	2.86	64.07	**93.1**	**94.0**
31	47.7	3.04	71.26	2.85	66.92	**93.6**	**94.0**
32	38.5	2.51	73.76	2.33	69.24	**92.8**	**94.0**
33	33.5	2.00	75.77	1.84	71.08	**91.6**	**93.9**
34	33.5	2.18	77.95	2.01	73.09	**92.2**	**93.8**
35	33.5	2.10	80.04	1.94	75.03	**92.4**	**93.8**

*does not include measured removal efficiency

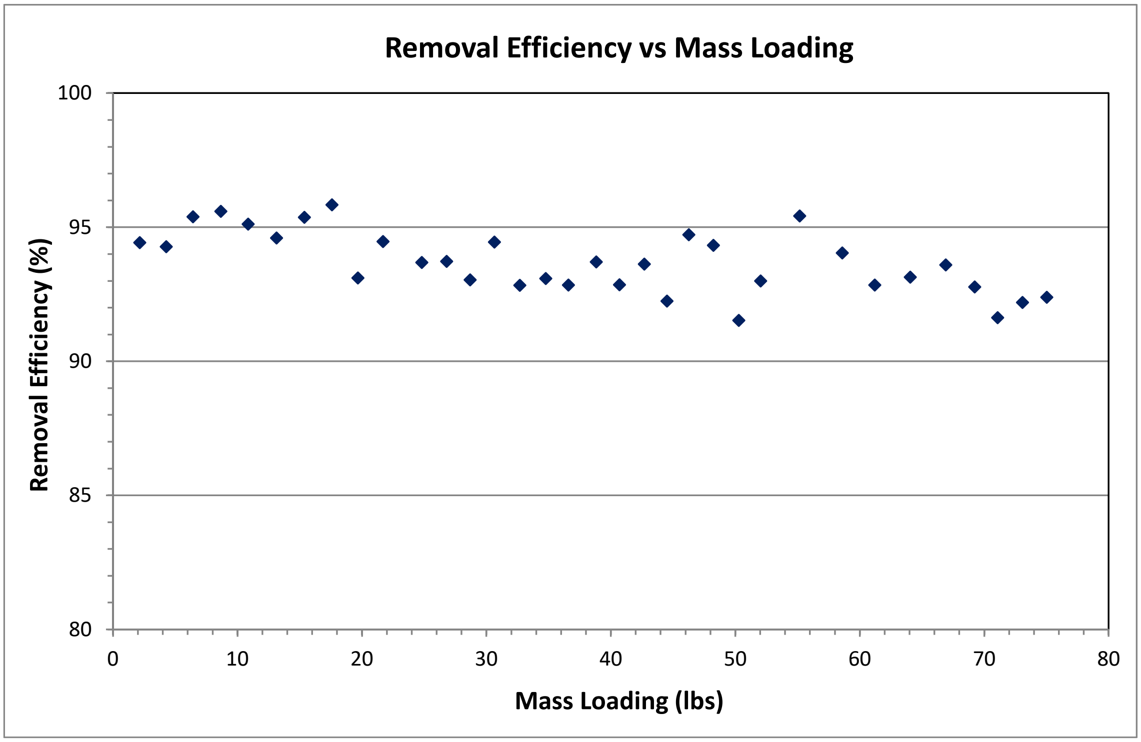

Figure 13 StormGarden™ Removal Efficiency vs Mass Loading

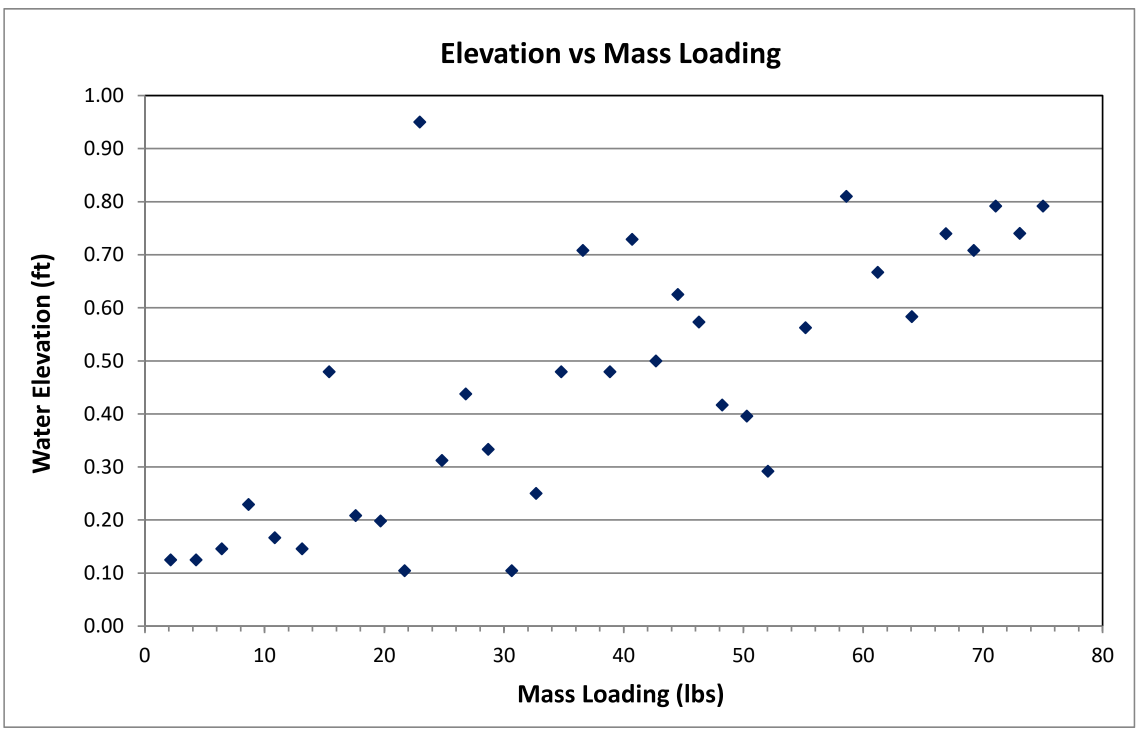

Figure 14 StormGarden™ End-of-Run Water Elevations

Note: Drops in driving head were observed after the system was not tested for several days due to the weekend and scheduled testing on other MTDs. These fluctuations will be observed in the field as well. The maximum driving head reached during testing prior to bypass was 9.725 inches (Run 28).

5. Design Limitations

The engineers at Rotondo Environmental Solutions work with site civil engineers and contractors throughout the design, manufacturing, and installation processes to ensure that once installed the StormGarden™ functions as designed. Each StormGarden™ will have unique design constraints and limitations; the following limitations should be considered general and not all inclusive.

Required Soil Characteristics

The StormGarden™ is installed in a precast concrete vault so it is not affected by the soil conditions; therefore, the StormGarden™ can be installed in all soil types. If native soils allow, the StormGarden™ can be designed with openings in the vault to allow for infiltration. Credit for infiltration will only be taken when permitted.

Slope

Assuming mild slopes, the StormGarden™ can be installed so that the top slab matches the slope at grade, while the base of the filter remains level. If steeper slopes are being experienced around the StormGarden™ it is recommended that Rotondo Environmental Solutions be contacted directly for consultation.

Flow Rate

The hydraulic loading rate of the StormGarden™ is 2.50 gpm/ft^2 of effective filtration treatment area. This is equivalent to an infiltration rate of 241 inches/hr. Based on this, the maximum flow rate for a StormGarden™ filter is equal to the filter bed area multiplied by the hydraulic loading rate.

Maintenance

StormGarden™ includes a 1-year maintenance plan for each installed unit. The maintenance plan includes general inspection of the StormGarden™ and the surrounding area, removal of all debris and trash, mulch replacement, vegetation health evaluation and necessary pruning, and the general clean-up of the StormGarden™ and the surrounding area. Rotondo Environmental Solutions recommends that maintenance is performed at least once a year, however if a specific unit experiences an especially heavier pollutant load it may require more frequent maintenance. Refer to Section 6 for more detailed explanation of Maintenance requirements.

Driving Head

The StormGarden™ bypass elevation was set at 9.75 inches above the surface of the mulch. This would be the minimum value used by the engineer to set the top of pavement, bottom of the curb, and the bypass elevations.

Installation Limitations

Prior to installation, Rotondo Environmental Solutions will provide the contractor with installation guidelines and offer in-field support during installation if any site-specific questions arise. The StormGarden™ is delivered in 2 pieces, the precast concrete vault which comes with the StormGarden™ media pre-installed, and the top slab with the tree grate and any additional access frames and covers included. Pick weights for each piece vary for each unit and will be provided to the contractor prior to installation so that proper installation equipment can be acquired. The StormGarden™ shall not be activated until the entire site is permanently stabilized.

Configurations

The StormGarden™ can handle inflow via curb inlet, grated inlet, pipe, and roof leader. Other potential inflow options could be utilized with coordination from the engineers at Rotondo Environmental Solutions. The StormGarden™ must be installed in an offline configuration, so all bypass flow must occur prior to entering the filter chamber. The StormGarden™ is available in a wide range of configurations, it is recommended that Rotondo Environmental Solutions be contacted to determine how to best utilize any of these configurations. Where allowed, infiltration can be achieved by utilizing openings in the vault to allow for infiltration into the native soils.

Load Limitations

All StormGarden™ units are designed to handle at least HS-20 loads. If larger loads are required, it is recommended that Rotondo Environmental Solutions evaluate what changes are required to the design so that the system can withstand larger design loads.

Pre-Treatment Requirements

There are no pre-treatment requirements for the StormGarden™. However, a pre-treatment chamber can be added to the StormGarden™ filter unit if desired by the design engineer.

Tailwater Limitations

It is generally recommended that the StormGarden™ operate under a free-discharge condition. However, tailwater conditions should be checked and discussed with the engineer of record on a project-by-project basis. The specific design of the StormGarden™ can be addressed during the design phase in a situation where tailwater is above the invert of the outlet pipe.

Depth to Seasonal High Water Table

The seasonal high water table will not typically impact the functionality of the StormGarden™. All components of the StormGarden™ are located within a precast concrete vault, which would be expected to outweigh the displaced water that could cause a buoyant condition. If especially high groundwater is expected, Rotondo Environmental Solutions can verify if any anti-buoyancy measures are required, and recommend solutions as needed.

6. Maintenance

Maintenance of the StormGarden™ is required to ensure optimal performance over the lifespan of the unit. During normal operations, the StormGarden™ will be exposed to items such as trash, silt, and dead vegetation which can accumulate above the filter bed and negatively impact the treatment flow capacity. Removal of trapped trash, silt, and dead vegetation is imperative to ensure the system continues to function as intended. Additional information can be found in Rotondo's O&M Manual at: https://storage.googleapis.com/wzukusers/user-34863465/documents/b4a24c9f05124c67b4855a07ae30ac86/StormGarden%20Maintenance%20Procedures.pdf

Maintenance is included by Rotondo for the first year after activation of the StormGarden™ and can be scheduled and performed at no additional cost to the owner. Rotondo recommends maintenance be performed at least once a year. Additional inspections should be performed after large storm events to check for accumulation of trash, silt, or dead vegetation on the mulch layer. All sites will have different rates of accumulation of trash, silt, and dead vegetation depending on surrounding conditions, and inspections performed during the first year of operation will best determine the required frequency of maintenance.

Typical maintenance procedures include:

- Inspection of StormGarden™ and surrounding area
- Removal of tree grate and erosion control stones
- Removal of debris, trash, and mulch
- Mulch replacement
- Plant health evaluation and pruning or replacement as necessary
- Cleaning of area around StormGarden™
- Completion of paperwork

It has been found that in regions receiving between 30-50 inches of annual rainfall, two (2) site visits per year may be required; regions with less rainfall often only require one (1) visit per year. Sites with higher-than-average trash, sediment, and/or leaf accumulation may require more frequent maintenance. Owners must promptly notify the maintenance contractor of any damage to the plant(s), which constitute(s) an integral part of the biofiltration technology. Owners should also advise other landscape or maintenance contractors to leave all maintenance (i.e., no pruning or fertilizing) to Rotondo during the first year.

Clean up due to major contamination such as oils, chemicals, toxic spills, etc. will result in additional cost and are not covered under the maintenance contract. Should a major contamination event occur the owner must block off the outlet pipe of the StormGarden™ (where the cleaned runoff drains to, such as drop inlet) and block off the throat of the StormGarden™. Rotondo should be informed immediately after a major contamination event.

Standard StormGarden™ units do not require any special certifications to maintain, though certain configurations such as buried vault systems may require confined space certification. Ideal tools include camera, bucket, shovel, broom, pruners, hoe/rake, and tape measure. Appropriate Personal Protective Equipment (PPE) should be used in accordance with local or company procedures. This may include impervious gloves where the type of trash is unknown, high visibility clothing and barricades when working in close proximity to traffic and also safety hats and shoes. A T-Bar or crowbar should be used for moving the tree grates (up to 170 lbs. ea.). Most visits require minor trash removal and a full replacement of mulch. See the table in the O&M Manual for the quantity of bags of mulch required for various filter sizes. Mulch should be a double shredded, hardwood variety. Some visits may require additional StormGarden™ engineered soil media available from Rotondo.

7. Statements

The following signed statements from the manufacturer (Rotondo), independent testing laboratory (Verdantas) 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.

ROTONDO
Environmental Solutions LLC

June 6, 2024

Dr. Richard S. Magee, Sc.D., P.E., BCEE
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 the StormGarden™ Biofiltration System

Dr. Richard Magee,

Rotondo Environmental Solutions is pleased to provide this letter as our statement certifying that the protocol, "*New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device*" (NJDEP Filter Protocol, January 14, 2022), was strictly followed while testing our StormGarden™ Biofiltration system. The testing was performed at the Verdantas Flow Labs laboratory, located at 30 Shrewsbury Street, Holden, MA under the direct supervision of James Mailloux in full compliance with all applicable protocol and process criteria. All data pertaining to the StormGarden™ Biofiltration system NJDEP Protocol test is included in the Verification Report.

Sincerely,

John Rotondo, PE
Rotondo Environmental Solutions, LLC

2560 Huntington Ave., Suite 303, Alexandria, VA 22304 V 703-212-4830 W rotondo-es.com

verdantas

May 21, 2024

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

Verdantas Flow Labs, LLC is a non-biased independent testing entity which receives compensation for testing services rendered. Verdantas 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 Verdantas and Rotondo Environmental Solutions.

Protocol Compliance Statement

Verdantas conducted the performance testing on the Rotondo Environmental Services StormGarden™. The Technical Report and all required supporting data documentation has been submitted to NJCAT as required by the protocol.

Testing performed by Verdantas on the StormGarden™ 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 Filtration Manufactured Treatment Device", January 14, 2022, (Updated April 25, 2023).

James T. Mailloux

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

Dear Mr. Mahon,

Based on my review, evaluation and assessment of the testing conducted on the Rotondo StormGarden™ Bio-Filter Treatment System (StormGarden™) at Verdantas Flow Labs LLC, Alden Campus (Verdantas), Holden, Massachusetts, under the direct supervision of Alden's senior stormwater engineer, James Mailloux, the test protocol requirements contained in the *"New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 14, 2022, updated April 25, 2023)"* (NJDEP Filtration Protocol) were met or exceeded. Specifically:

Test Sediment Feed

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1-1000 micron silica particles. The Specific Gravity (SG) of the sediment mixes was 2.65. Commercially-available silica products were provided by AGSCO Corp., a QAS International ISO-9001 certified company, and blended by Alden as required. Test batches were prepared in individual 5-gallon buckets, which were arbitrarily selected for the removal testing. A well-mixed sample was collected from three random test batches and analyzed for PSD in accordance with ASTM D6913 (2017) and ASTM D7928 (2021), by GeoTesting Express, an ISO/IEC 17025 accredited independent laboratory. The average of the samples was used for compliance to the protocol specifications. The average D_{50} of the samples was 69 microns, below the less than 75 micron protocol requirement.

Removal Efficiency Testing

Thirty-five (35) removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. Ten (10) of the 35 test runs were conducted during removal efficiency testing and 25 during mass loading capacity testing. The target flow rate and influent sediment concentration were 40 gpm and 200 mg/L during sediment removal testing and 36 gpm and 200 mg/L during mass loading capacity testing. The StormGarden™ demonstrated an average sediment removal efficiency on a cumulative mass basis of 94.8% over the course of the 10-removal efficiency test runs and 93.8% for the 35 test runs.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted as a continuation of removal efficiency testing. Mass loading test runs were conducted at 36 gpm and 200 mg/L using identical testing procedures as those used in the removal efficiency runs. The StormGarden™ demonstrated a mass loading capture capacity of 75.03 lbs (4.69 lbs/ft^2 of filter area).

Since no scour testing was conducted, the StormGarden™ is only qualified for offline installation.

Sincerely,

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

8. References

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

ASTM (2017), *"Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis",* Annual Book of ASTM Standards, D6913 / D6913M-17, Vol. 4.09

ASTM (2019), *"Standard Test Methods for Determining Sediment Concentration in Water Samples"*, Annual Book of ASTM Standards, D3977-97, Vol. 11.02.

ASTM (2019), *"Standard Test Methods for Determination of Water (Moisture) Content of Soil by Direct Heating"*, Annual Book of ASTM Standards, D2216, Vol. 04.08.

ASTM (2021), *"Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis",* Annual Book of ASTM Standards, D7928-21e1, Vol. 4.09.

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

NJDEP 2022. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device.* Trenton, NJ. January 14, 2022 (Updated April 25, 2023).

VERIFICATION APPENDIX

Introduction

- Manufacturer of StormGarden™ - Rotondo Environmental Solutions, 2560 Huntington Ave, Suite 303, Alexandria, VA 22303. Phone (703)-212-4830. www.rotondo-es.com

- MTD: Rotondo StormGarden™, see **Table A-1** for StormGarden™ standard sizes.

- TSS Removal Rate: 80%

- StormGarden™ is qualified for offline installation for the New Jersey Water Quality Design Storm (NJWQDS).

Detailed Specification

- StormGarden™ models, MTFR, and maximum drainage area per NJDEP sizing requirements are attached (**Table A-1**).
- Maximum inflow drainage area
    - The maximum inflow drainage area is governed by the maximum treatment flow rate or sediment loading on the filter for each filter arrangement as presented in **Table A-1.**

- The maximum treated flow (MTFR) for the StormGarden™ is 241 inches/hour, or 2.50 gpm/ft^2 of effective filter treatment area.

- Maximum driving head is 9.75 inches above the surface of the mulch.

- Rotondo Environmental Solutions will provide installation and assembly instructions to the contractor prior to installation. A representative from Rotondo will be available for consultation during the installation.

- The StormGarden™ Operation and Maintenance Manual can be accessed at: https://storage.googleapis.com/wzukusers/user-34863465/documents/b4a24c9f05124c67b4855a07ae30ac86/StormGarden%20Maintenance%20Procedures.pdf

- This StormGarden™ cannot be used in series with another MTD or a media filter (such as a sand filter) to achieve an enhanced removal rate for total suspended solids (TSS) removal under N.J.A.C. 7:8-5.5.

Table A-1. NJ StormGarden™ Sizing Table (MTFR and Maximum Allowable Drainage Area)

Designation	Filter Width (ft)	Filter Length (ft)	Effective Filter Treatment Area (sf)	MFTR[1] (gpm)	MFTR[1] (cfs)	Maximum Drainage Area[2] (ac.)
SG-NJ-0404	4	4	16	40	0.089	0.125
SG-NJ-0406	4	6	24	60	0.134	0.188
SG-NJ-0408	4	8	32	80	0.178	0.250
SG-NJ-0410	4	10	40	100	0.223	0.313
SG-NJ-0412	4	12	48	120	0.267	0.375
SG-NJ-0606	6	6	36	90	0.201	0.281
SG-NJ-0608	6	8	48	120	0.267	0.375
SG-NJ-0610	6	10	60	150	0.334	0.469
SG-NJ-0612	6	12	72	180	0.401	0.563
SG-NJ-0713	7	13	91	227.5	0.507	0.711
SG-NJ-0816	8	16	128	320	0.713	1.001

1. MTFR is based on 2.5 gpm/ft^2 (0.0036 cfs/ft^2) of effective filtration treatment area.
2. The maximum Allowable Inflow Drainage Area is based on 4.69 lbs/ft^2 mass loading rate and the equation in the NJDEP Filtration Protocol Appendix, where drainage area is calculated on 600-lbs of mass contributed per acre of drainage area annually.