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NJCAT TECHNOLOGY VERIFICATION

R-TANK® Stormwater Storage System Treatment Row

Ferguson Waterworks

November 2023

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1. Description of Technology

R-Tank systems are a type of underground modular storage system. When units are combined, they form a system that provides high void space (95%) stormwater storage for flood mitigation, detention, and infiltration applications. These systems can be outfitted with Treatment Rows to provide treatment of stormwater influent. A Treatment Row is a singular row of R-Tank Access Modules, which are connected to the inflow via a nearby junction structure. The junction structure directs the treatment flow into the Treatment Row, with a weir or raised bypass allowing flows greater than the treatment rate to bypass the treatment row and discharge into the larger system. **Since this technology fits under the infiltration basin BMP, in the New Jersey Stormwater BMP Manual, it is not eligible for NJDEP MTD certification.**

The Treatment Row can be installed at any location within the system, corresponding with the influent connection location. This allows for the units to be installed on the end or internal to the system, as shown in **Figure 1**.

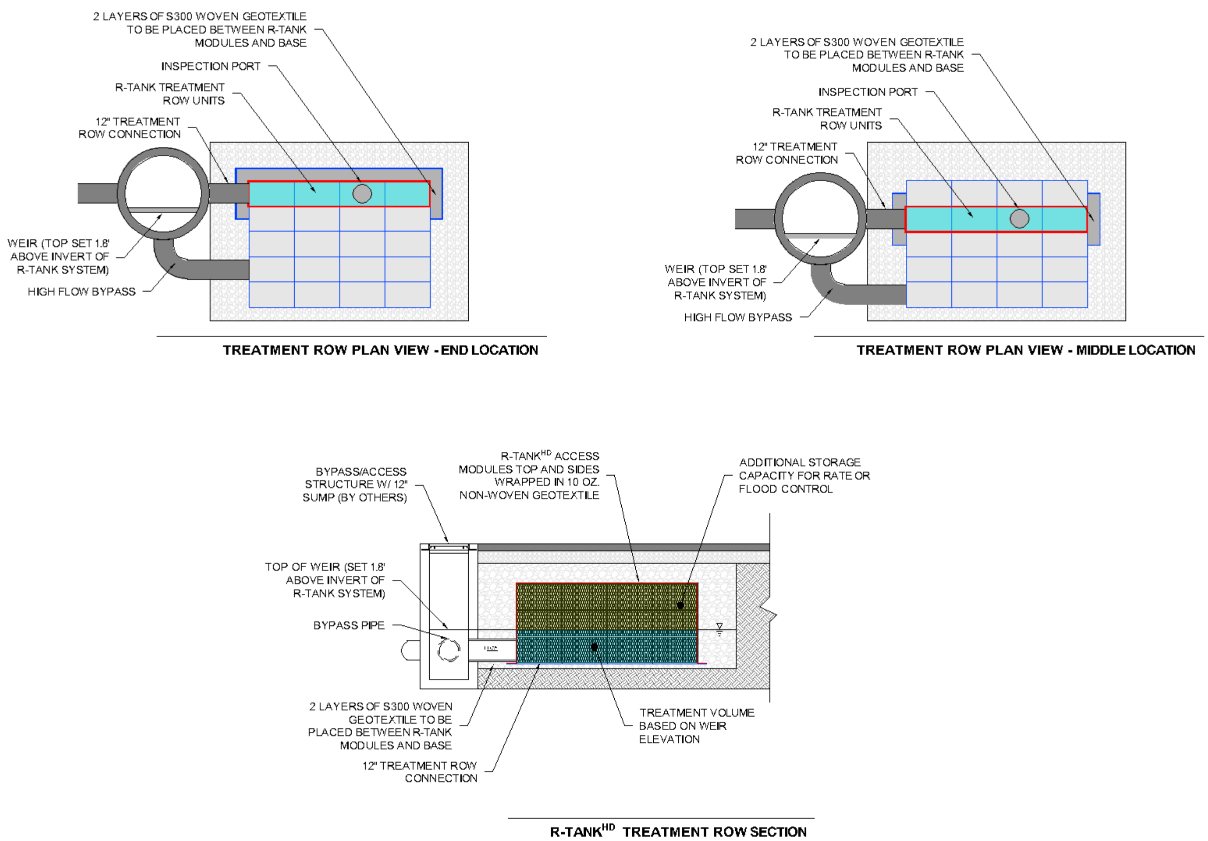


Figure 1 R-Tank Treatment Row Configurations

A standard treatment row consists of a series of modules encapsulated by (2) two layers of woven geotextile fabric beneath the units and a single layer of non-woven geotextile fabric on the side and top of the units. This combination provides settling and filtration of stormwater, retains the sediment within the Treatment Row and provides accessibility for maintenance.

While the R-Tank system is available in four-unit types (HD, SD, UD, XD) shown in the **R-Tank Brochure** at: https://www.fergusongss.com/product/r-tank-stormwater-modules/, the Access Modules are only available for HD or UD Modules, due to the height of the vertical plates. Therefore, since each Treatment Row uses Access Modules, the Treatment Row can only be included in HD and UD systems. Maximum allowable head and treatment capacity are set by the weir elevation, thus only the HD unit was utilized for testing.

2. Laboratory Testing

The test program was conducted at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direct supervision of Alden's senior stormwater engineer, James Mailloux. Alden has performed verification testing on 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 A2LA ISO/IEC 17025 accredited independent laboratory. Water quality samples collected during the testing process were analyzed in Alden's Stormwater Laboratory, which is ISO 17025 accredited.

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

2.1 Test Setup

An R-Tank Treatment Row was constructed and tested to quantify the sediment removal and sediment mass capture efficiency. The tested R-Tank Treatment Row Setup, shown in **Figure 2** consisted of a center row of five HD R-Tank modules and two adjacent rows of HD R-Tank modules, one row either side. **Figure 3** shows a typical R-Tank Treatment Row installed with a bypass/access structure and sump.

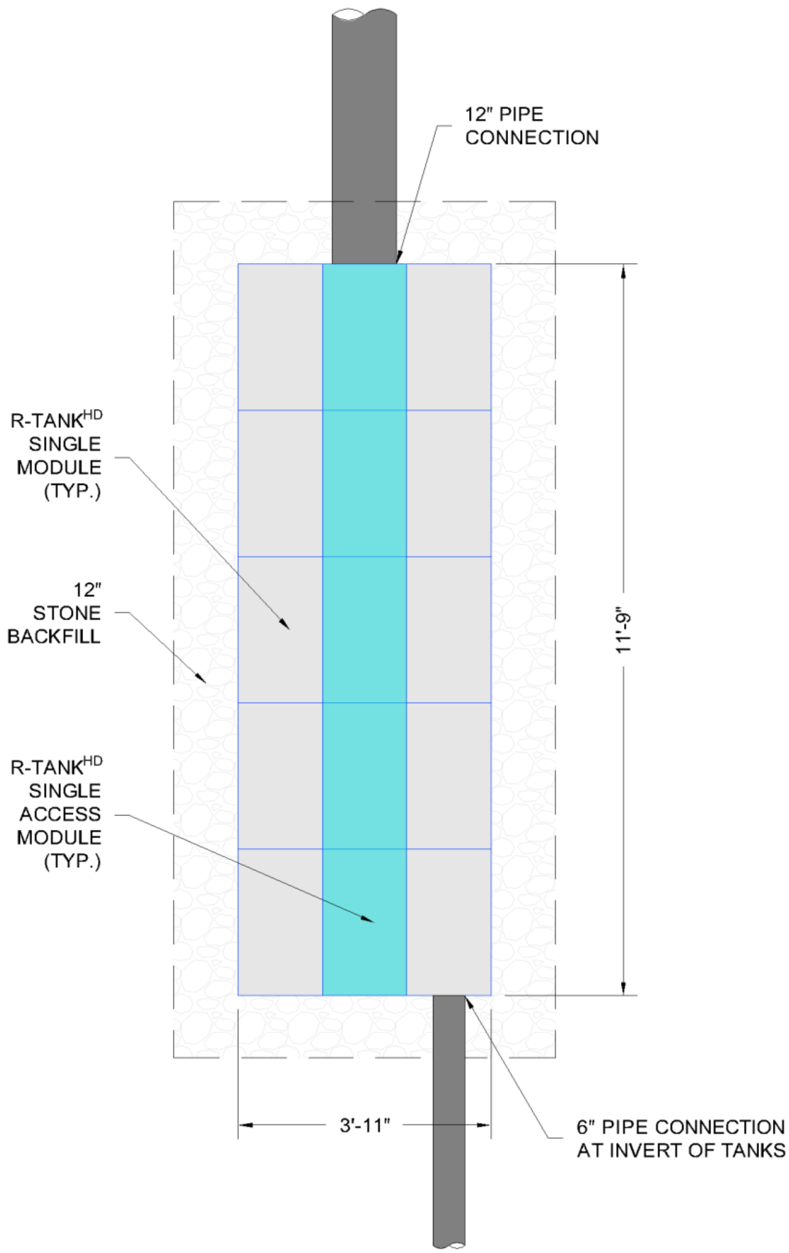
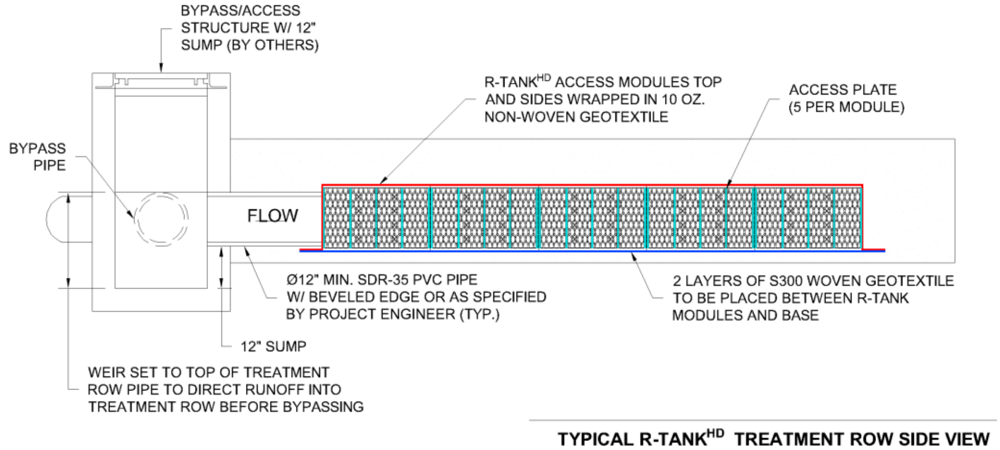


Figure 2 R-Tank Treatment Row Test Setup Plan View



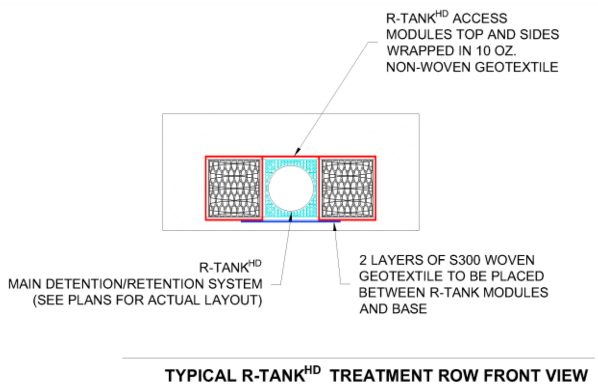


Figure 3 Typical R-Tank Treatment Row Section

The modules sit on a 3" base of AASHTO #57 (3/4"-1.5") double-washed angular granite. Two layers of woven geotextile fabric are installed between the base stone and R-Tank Modules. The fabric extends approximately 12" beyond the center treatment row. The outside of the treatment row is wrapped in non-woven geotextile fabric, which extends along the stone base. The adjacent modules are installed on the fabric, which is then wrapped over the top of the entire system. The perimeter volume is backfilled with the same stone as the base. A 12" influent pipe, set at a 1% slope, is located at the center of the treatment module row and a 6" outlet pipe is located flush with the bottom of an adjacent row. Custom fabric boots are used to seal the influent and effluent pipes to the modules.

The R-Tank Treatment Row was installed in a test loop in Alden's Stormwater Testing Facility, shown in **Figure 4**. A water-tight test flume, approximately 14'L x 6'W x 3'H was utilized for installing and testing the R-Tank Treatment Row. 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 setup 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 40,000-gallon supply sump, which can be heated or cooled to maintain a target temperature of approximately 68° F +/- 5° F. The test flow of 197 gpm (4 gpm/ft^2) was set and measured using a flow control valve and a calibrated 4” orifice-plate flow meter, constructed to ASME guidelines. Flow measurement accuracy is within ±1%. During all test runs, the allowable variation is ±10% of the target flow and the Coefficient of Variance (COV) must be ≤ 0.03.

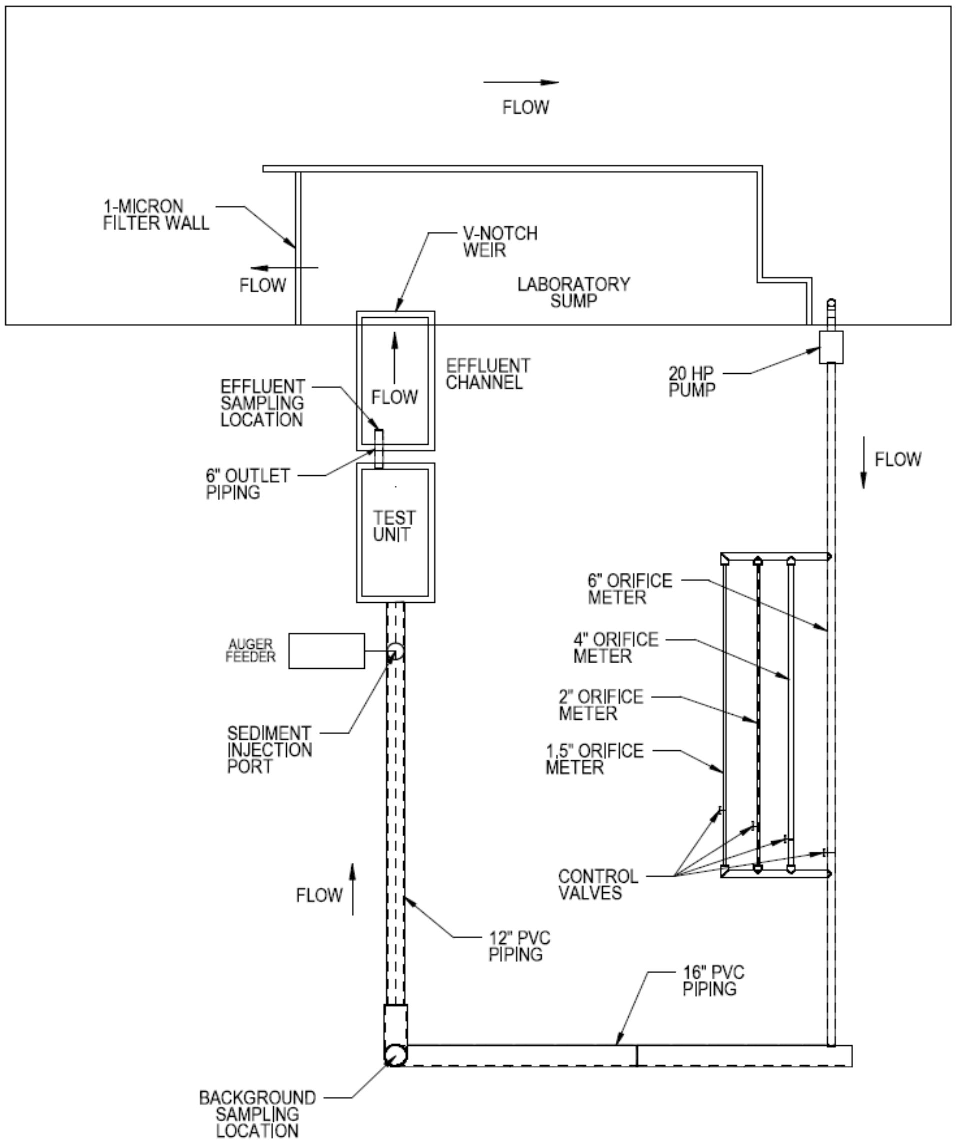


Figure 4 Alden’s Stormwater Test Loop

Flow was conveyed to the test unit by means of a straight 12” diameter smooth-wall PVC influent pipe, with a length of approximately 20 pipe diameters. The pipe was set with a 1% slope. A 12-inch tee was located 2 ft 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 from the underdrain discharged into an effluent channel containing a calibrated V-notch weir and returned to the sump. Sediment that is captured by the treatment device results in a gradual blinding of the filter fabric causing water levels to rise within the Treatment Row since the MTFR is not decreased. Measuring the elevation at the end of each run and test program allowed monitoring the increase in driving head, and the manufacturer to set an upstream bypass level to prevent surcharging. Filtration of the supply sump flow was performed with an inline filter wall containing 1 micron filter bags.

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 it was a recirculating closed-loop system.

Water levels within the chamber and at the V-notch weir were measured with the use of Piezometer taps, water manometers and a calibrated pressure transducer. The low and water elevations were measured and recorded every 5 seconds throughout the duration of each test run, including the drawdown period. Photographs of the test setup are shown on **Figure 5** to **Figure 7**.

Figure 5 R-Tank Treatment Row Test Setup

Figure 6 Installed R-Tank Treatment Row System

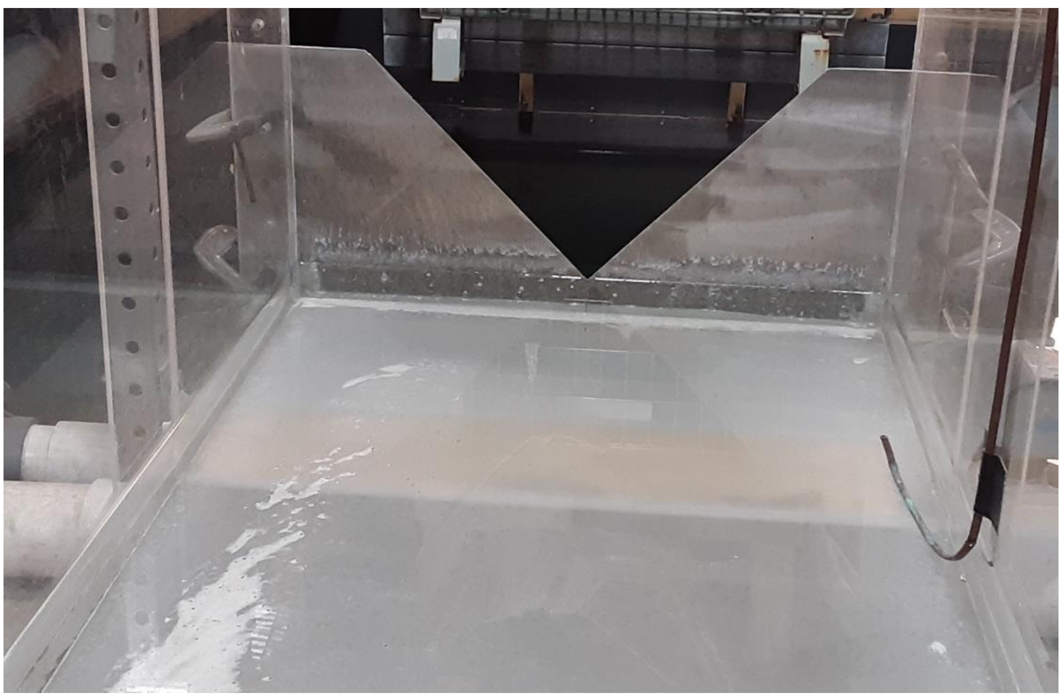


Figure 7 Effluent Channel V-notch Weir

2.2 Removal Efficiency Testing

Sediment removal testing was conducted to determine sediment removal efficiency. All tests were run with clean water containing a background sediment solids concentration (SSC) of ≤ 20 mg/L.

The sediment testing was conducted on an initially clean system at the 100% MTFR of 197 gpm (4 gpm/ft^2 selected by Ferguson). A minimum of ten (10) qualifying 30-minute test runs were required to be conducted to meet the removal efficiency criterion of a cumulative removal efficiency >80%. 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 from the starting mass corrected for the sediment mass collected for feed rate calibration. This value was used in calculating the influent mass/volume concentration. The total mass captured in the system was quantified at the conclusion of the testing. The data was used for determination of the maximum inflow drainage area (acres) per the NJDEP protocol.

The test sediment was prepared by Alden to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in **Table 1**. The sediment was silica based, with a specific gravity of 2.65. Three random PSD samples of the test sediment were analyzed by GeoTesting Express, an independent accredited analytical laboratory, using ASTM D6913/D6913M-17 (2017), and the results are shown in **Section 3.1**.

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..

Verification/Determination of Sediment Influent Concentrations

The target influent 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 (±20 mg/L) 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 3 feed calibration samples to determine the mass fed into the test unit. 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.

Sampling

All sediment testing was conducted using the indirect (sampling) methodology, as per the NJDEP protocol. A minimum of 5 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 30minute test run, a minimum of five 1 L effluent samples were collected. Samples were collected 3 detention times after the initiation of sediment dosing, as well as after the interruption of dosing for injection measurements. A minimum of 3 evenly spaced background samples were collected in correspondence with the odd-numbered effluent samples (first, third, fifth). At the termination of the test run, 2 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.

Removal Efficiency Calculation

The sediment removal efficiency was calculated as follows:

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

Determination of Sample Concentrations

Effluent and background concentration samples were analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (Re-approved 2019), “Standard Test Methods for Determining Sediment Concentration in Water Samples”. Alden is ISO 17025 accredited for conducting the ASTM D 3977 analysis. Alden has assigned a Method 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.

2.3 Mass Loading Capacity Testing

The sediment mass loading capacity testing is a continuation of the removal efficiency testing and is conducted to determine the point of filter occlusion. The testing was conducted until the following condition had occurred:

- The maximum driving head was reached, at which point the flow was reduced to 90% of the MTFR and testing resumed until the maximum driving head was again reached (cumulative mass removal efficiency average remained >80%).

The total mass captured in the system was quantified at the conclusion of the testing. This data was used for 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 R-Tank System:

- Removal Efficiency vs Sediment Mass Loading (**Figure 9**)
- Driving Head vs Sediment Mass Loading (**Figure 10**)

2.4 Data Management and Acquisition

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

A personal computer running an Alden in-house Labview® Data Acquisition program was used to record all data related to instrument calibration and testing. A 16-bit National Instruments® NI6212 Analog to Digital (A/D) board was used to convert the voltage signal from the pressure cells. Alden’s in-house data collection software, by default, collects one-second averages of data collected at a raw rate of 250 Hz. The system allows very long contiguous data collection by continuously writing the collected 1 second averages and their RMS values to disk. The data output from the program is in tab delimited text format with 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 sediment related data used for quantifying injection rate, effluent and background sample concentrations, flow, pressure, mass, and PSD data. The data was input to the designated spreadsheet for final processing.

2.5 Quality Assurance and Control

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

Flow

The flow meters and pressure cells were calibrated in Alden's Calibration Laboratory, which is ISO 17025 accredited. All 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 flow meter.

Sediment Injection

The sediment feed (g/min) was verified with the use of a NIST traceable digital stopwatch and 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 1 minute. The reported overall mass/volume sediment concentrations were adjusted for moisture.

3. 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.

3.1 Test Sediment PSD Analysis

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1–1000 micron silica particles with a SG of 2.65. The sediment batches were prepared by Alden to meet the protocol specifications using commercially-available silica products. A random sample from each test batch was analyzed in accordance with ASTM D6913/D7928, by GeoTesting Express, an AALA ISO/IEC 17025 accredited independent laboratory. The specified less-than (%-finer) values of the sample average were within the 2 percentage-point tolerance listed in the protocol.

Sediment test batches of approximately 30 lbs each were prepared in individual 5 gallon buckets, which were arbitrarily selected for testing the R-TANK. A well-mixed sample was collected from each test batch and analyzed for PSD by GeoTesting Express. The average of the samples was used for compliance with the protocol specifications. The PSD data of the samples are shown in **Table 2** and the corresponding curves are shown on **Figure 8.**

Table 2 PSD Analyses of Alden NJDEP 1-1000 micron Mix

Particle size (µm)	NJDEP	Batch 5	Batch 3	Batch 6	Batch 16	Batch 2	Average	QA/QC Compliant
1000	100%	99%	99%	99%	99%	99%	99%	Y
500	95%	95%	95%	95%	95%	95%	95%	Y
250	90%	88%	88%	89%	90%	89%	89%	Y
150	75%	79%	79%	79%	73%	73%	77%	Y
100	60%	62%	62%	62%	57%	58%	60%	Y
75	50%	53%	52%	53%	50%	52%	52%	Y
50	45%	45%	45%	46%	46%	47%	46%	Y
20	35%	37%	38%	36%	34%	36%	36%	Y
8	20%	25%	24%	24%	17%	19%	21%	Y
5	10%	17%	17%	16%	10%	11%	14%	Y
2	5%	9%	9%	9%	2%	3%	6%	Y
D50	75	66	66	65	73	65	67	Y

The sediment particle size distribution (PSD) used for removal efficiency testing exceeded the NJDEP PSD sediment specifications (**Table 1**) across the entire distribution. The D_{50} of 67 microns was less than the required 75 microns.

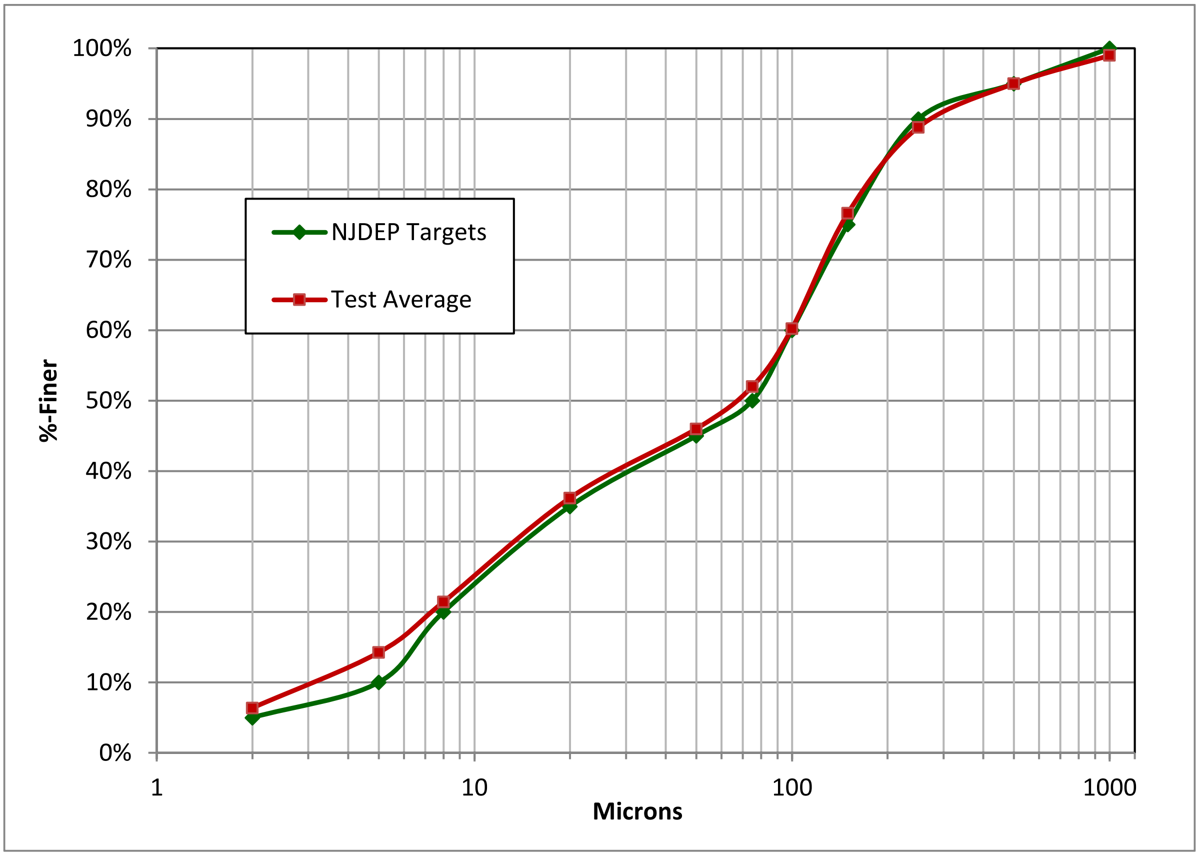


Figure 8 PSD Curves of 1-1000 micron Test Sediment

3.2 Removal Efficiency and Mass Loading Capacity Testing

Testing Summary

Eleven tests were conducted at a target flow of 197 gpm. Test run #10 had to be discarded due to a filtering flask being dropped while processing the sediment concentration samples. The flask shattered, which resulted in 2 samples being contaminated with small shards of glass. The test was repeated (#11) and the removal efficiencies of runs #9 and #11 were averaged to determine the mass captured for run #10. This removal value was not included in the cumulative average calculation. This approach was taken under the recommendation of NJCAT.

The measured 100% MTFR flows ranged from 196.6 gpm to 197.8 gpm, with an average flow of 197.2 gpm. The calculated COV for all test runs ranged from 0.003 to 0.005. The maximum recorded temperatures ranged from 69.7 to 75.1 degrees F. The measured injected influent concentration averages ranged from 195.0 to 199.2 mg/L. The injection COV ranged from 0.005 to 0.033. The calculated mass/volume influent concentrations ranged from 185.2 to 206.1 mg/L. The calculated removal efficiencies ranged from 78.1% to 85.1%, with a cumulative average removal of 81.5%. The total cumulative injected and captured mass was 120.96 Lbs and 98.64 Lbs, respectively. The final end-of-run elevation was 1.80 ft.

The flow was reduced to 90% of the MTFR and another run was conducted in accordance with the protocol. The end-of-run elevation climbed to 1.92 ft, which met the termination condition of the testing.

Recorded and calculated test data are shown in **Tables 3 through 7** and on **Figures 9 and 10**.

Table 3 Testing 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	11	14	17	20	30	33	35	38.25	39.83
2	1	11	14	17	20	30	33	35	38.50	40.25
3	1	11	14	17	20	30	33	35	38.35	40.25
4	1	11	14	17	20	30	33	35	38.50	40.48
5	1	11	14	17	20	30	33	35	38.58	41.00
6	1	11	14	17	20	30	33	35	38.67	41.33
7	1	13	15	17	19	31	33	35	38.75	41.75
8	1	13	15	17	19	31	33	35	38.83	42.08
9	1	13	15	17	19	31	33	35	38.92	42.67
10	1	13	15	17	19	31	33	35	38.92	42.67
11	1	13	15	17	19	31	33	35	39.00	43.25

Table 4 Measured Removal Efficiency Test Parameters

Test Run #	Measured Flow		Maximum Water Temperature	End of Run Water El. Above Module Floor	Influent Concentration (mg/L)					QA/QC Compliant
	gpm	COV	Deg. F	ft	Minimum	Maximum	Average	COV	Mass/Volume	
1	197.4	0.003	70.7	0.875	198.0	200.8	199.2	0.007	199.4	**Y**
2	197.5	0.003	71.3	1.055	197.6	199.5	198.5	0.005	203.6	**Y**
3	196.6	0.005	72.2	1.220	190.2	202.0	196.7	0.030	198.7	**Y**
4	197.6	0.003	72.4	1.282	195.9	198.1	197.2	0.006	206.1	**Y**
5	197.4	0.003	69.8	1.403	196.0	199.0	197.6	0.008	201.1	**Y**
6	197.1	0.003	69.7	1.474	191.5	198.8	195.9	0.020	198.7	**Y**
7	196.6	0.003	73.7	1.643	190.9	202.3	195.0	0.033	200.2	**Y**
8	197.0	0.003	74.4	1.699	196.5	201.6	198.9	0.013	201.0	**Y**
9	197.3	0.003	75.1	1.742	191.0	202.5	197.1	0.029	199.5	**Y**
10	197.8	0.003	74.6	1.732	191.0	202.0	197.8	0.030	185.2	**Y**
11	197.1	0.003	74	1.801	194.5	202.7	198.2	0.021	201.3	**Y**

Table 5 Measured 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	1.7	36.0	41.4	40.3	33.1	34.3	**37.0**	39.7	20.3	**30.0**
2	1.5	28.7	30.9	33.7	26.7	30.5	**30.1**	49.1	15.0	**32.0**
3	1.0	32.3	31.7	37.4	34.2	34.7	**34.1**	60.2	12.5	**36.4**
4	3.1	46.3	40.9	40.4	36.5	33.6	**39.5**	44.9	21.2	**33.0**
5	2.4	45.2	44.7	38.8	43.1	44.6	**43.3**	66.2	37.1	**51.6**
6	5.3	47.3	44.6	41.9	35.0	31.5	**40.1**	47.6	28.7	**38.2**
7	0.5	34.9	39.7	36.0	39.4	39.9	**38.0**	40.6	23.5	**32.1**
8	0.5	39.9	38.9	40.8	36.8	34.3	**38.1**	45.7	16.9	**31.3**
9	1.8	42.3	41.0	37.3	32.9	32.2	**37.1**	37.7	24.9	**31.3**
10										
11	0.5	39.3	36.8	37.5	36.0	33.5	**36.6**	41.4	21.1	**31.3**

Table 6 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	11.00	11.00	8.98	8.98	**81.7**	**81.7**
2	33.5	11.23	22.23	9.57	18.55	**85.1**	**83.4**
3	33.5	10.91	33.15	9.03	27.58	**82.8**	**83.2**
4	33.5	11.38	44.52	9.23	36.81	**81.1**	**82.7**
5	33.5	11.09	55.62	8.66	45.47	**78.1**	**81.8**
6	33.5	10.95	66.57	8.75	54.22	**79.9**	**81.4**
7	33.5	11.00	77.57	8.95	63.17	**81.3**	**81.4**
8	33.5	11.06	88.63	9.00	72.17	**81.4**	**81.4**
9	33.5	11.00	99.63	8.99	81.15	**81.7**	**81.5**
10	33.5	10.24	109.87	8.38	89.54	**81.9**	**81.5**
11	33.5	11.09	120.96	9.10	98.64	**82.1**	**81.5**

Table 7 Removal Efficiency Testing 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	199	37.0	30.0	25024	23375	1648	4989	866	49
2	204	30.1	32.0	25030	23194	1836	5096	698	59
3	199	34.1	36.4	24917	22912	2005	4951	781	73
4	206	39.5	33.0	25045	22919	2125	5161	906	70
5	201	43.3	51.6	25021	22775	2246	5032	986	116
6	199	40.1	38.2	24988	22742	2246	4966	911	86
7	200	38.0	32.1	24927	22494	2433	4990	854	78
8	201	38.1	31.3	24968	22508	2460	5019	858	77
9	200	37.1	31.3	25007	22494	2513	4990	835	79
10	185			25068	22612	2457	4643		
11	201	36.6	31.3	24987	22428	2559	5031	821	80

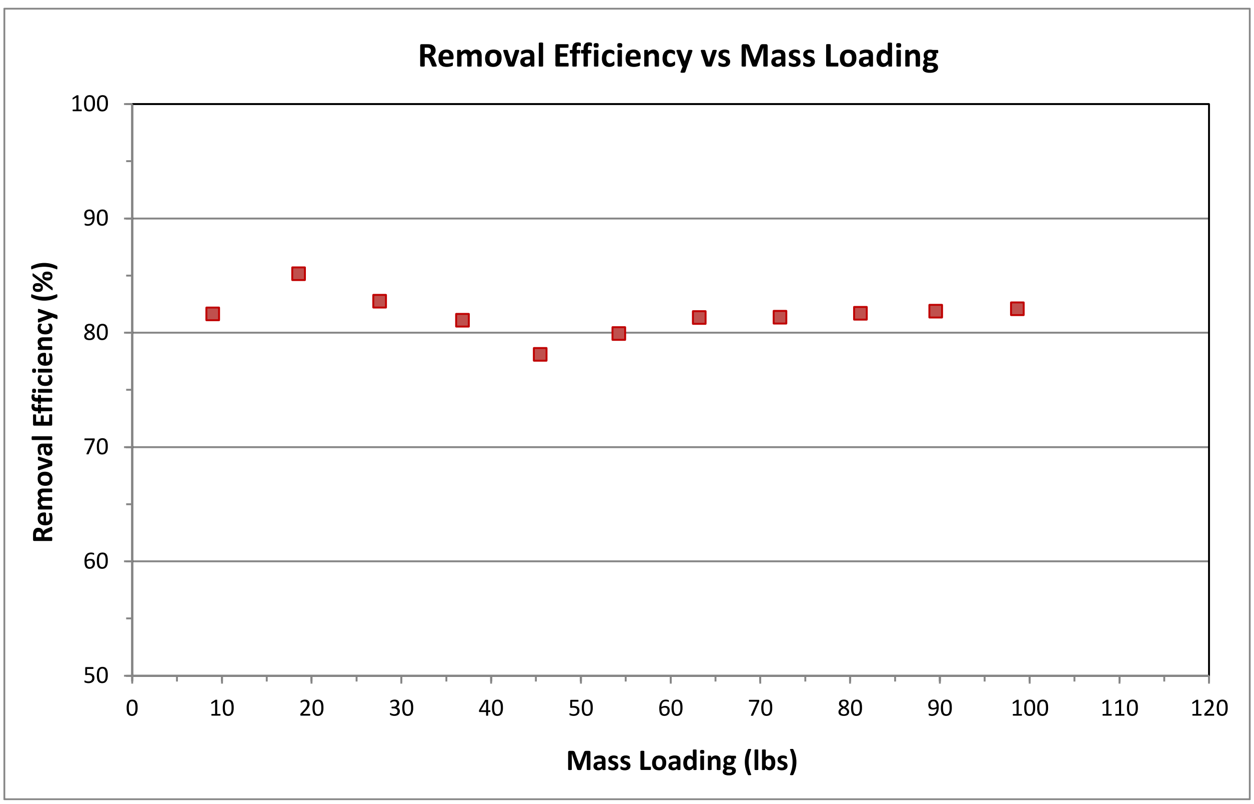


Figure 9 R-Tank Treatment Row Removal Efficiency vs Mass Loading

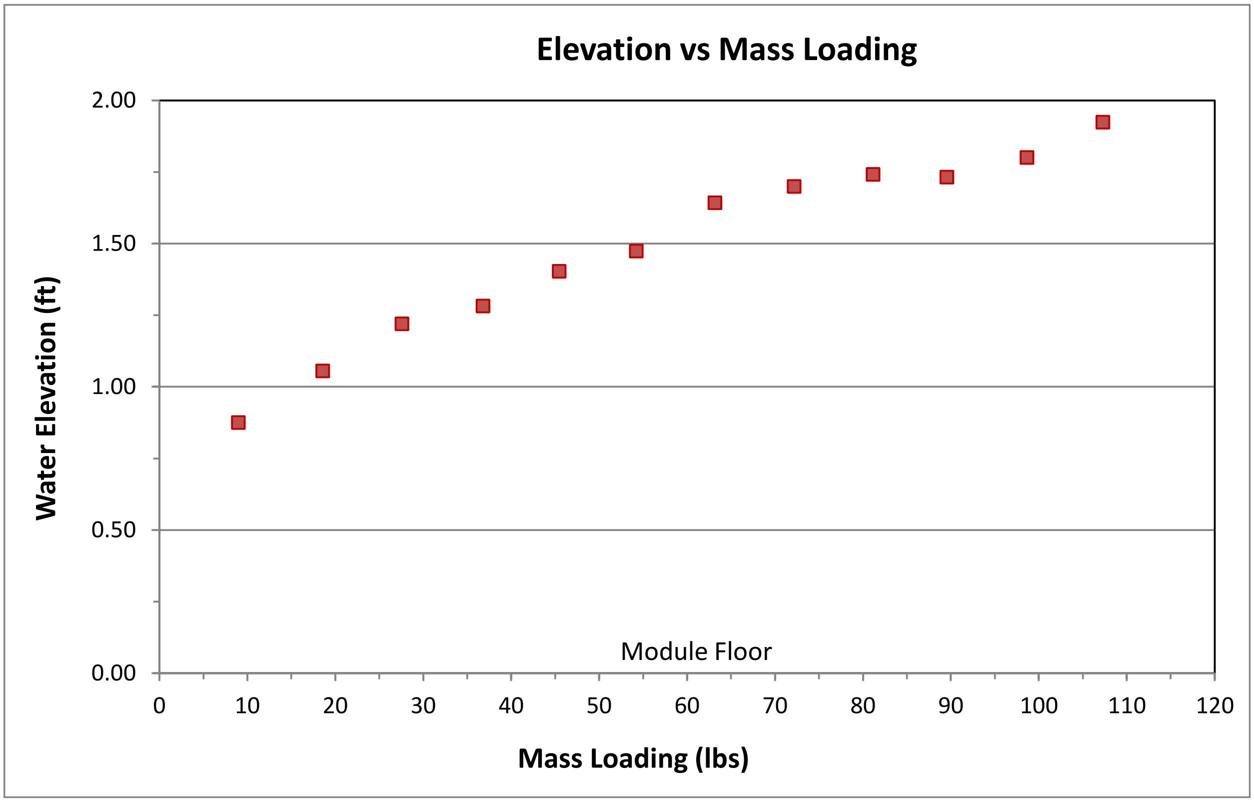


Figure 10 R-Tank Treatment Row End-of-Run Water Elevations

4. Design Limitations

Ferguson Waterworks supports the design of R-Tank systems via the GSI Engineering Services team. This team provides detailed layout drawings and volume calculations for engineer prepared designs. Working closely with the engineers, Ferguson can ensure systems are designed in accordance with manufacturer recommendations. The following design limitations are specific to the R-Tank system.

Maximum Flow Rate

A R-Tank system has an MTFR calculated based on the R-Tank type and number of modules in the system. Refer to **Table 8** for different R-Tank module MTFR's.

Slope

The R-Tank modules are installed on a level base of stone. In rare instances the native soil base is sloped towards an underdrain to generate positive drainage in detention applications. Therefore, since the modules are installed level, there is no impact on the filtering performance.

Allowable Head Loss

There is an operational head loss associated with the R-Tank Treatment Row. The head loss will increase over time due to the sediment loading to the system. Site-specific treatment flow rates, peak flow rates, pipe diameter, and pipe slopes should be evaluated to ensure there is an appropriate head for the system to function properly. A weir or raised bypass pipe may be included if the designed peak storm flows exceed the treatment flow rate. In these cases, and as demonstrated in the testing, the top of the weir or invert of the bypass pipe shall be set 1.8-ft above the invert of the treatment row.

Sediment Load Capacity

Based on laboratory testing results, the R-Tank treatment row has a mass loading capacity of 1.82 lbs/ft^2 of effective filtration treatment area while operating at a sediment removal efficiency greater than 80% without the water elevation exceeding 1.8 ft. This elevation is noted in the Allowable Head Loss section as the elevation at which peak stormwater events can bypass via overflowing a weir or through a raised bypass pipe.

Pre-treatment Requirements

For systems connected to the drainage network, including inlets and manholes, Ferguson recommends the inclusion of pretreatment devices such as connector pipe screens or debris screens to reduce the frequency of maintenance. These screens mount into the inlet for pipes ranging from 6” to 24”. The screens have 3/16” openings to allow stormwater to pass through, while preventing gross sediment from entering the pipe.

Configurations

The R-Tank is integrated into the storage system’s design. Its modular design provides flexibility to meet project specific design volumes or flow rates.

Structure Load Limitations

The R-Tank system has been designed to require a minimum depth of cover, measured from the top of the unit to the finished grade surface, to achieve HS-20 or HS-25 load rating. Depending on the type of R-Tank, the minimum cover varies.

Installation Limitations

An R-Tank system must be installed on soils with adequate bearing capacity.

Maximum Allowable Inflow Drainage Area

The maximum inflow drainage area for an R-Tank system is based on the module type and number of modules.

Depth to Seasonal High-Water Table

Seasonal high groundwater has the potential to impact driving head and when necessary, the R-Tank system can be designed with an impermeable liner and watertight outlet so there is no impact. Depth of seasonal high-water table is typically not an issue when it comes to buoyancy as the weight of the section (R-Tank, Top Stone, Additional Fill, and Finished Surface) will weigh more than the water it displaces. Designers can contact Ferguson Waterworks for technical assistance when trying to meet site-specific requirements.

5. Maintenance

The R-Tank System is designed to function in conjunction with the engineered drainage system on-site, existing municipal infrastructure, and/or the existing soils and geography of the receiving watershed. Unless the site includes certain unique and rare features, the operation of your R-Tank System will be driven by naturally occurring systems and will function autonomously. However, upholding a proper schedule of Inspection & Maintenance is critical to ensuring continued functionality and optimum performance of the system. An R-Tank Operation, Inspection and Maintenance manual is available online at: https://www.fergusongss.com/wp-content/uploads/2022/11/Tech-R-Tank-Operation-Inspection-Maintenance-11-02-22.pdf.

Inspection

Both the R-Tank and pre-treatment devices incorporated into the site must be inspected regularly. R-Tank inspections should be done every six months for the first year of operation, and at least yearly thereafter. For pre-treatment devices, follow manufacturer recommendations.

With the right equipment most inspections and measurements can be accomplished from the surface without entering any confined spaces. If inspection does require confined space entry, inspectors must follow all local, regional, and OSHA requirements. Inspectors shall visually inspect to identify sediment, trash, and other contaminants within the structure.

Maintenance

For modules taller than 40" the R-Tank System should be back-flushed once sediment accumulation has reached 6". For modules less than 40" tall, perform maintenance when sediment depths are greater than 15% of the total system height. If your system includes a Treatment Row with linear access through the modules from the inlet pipe, backflush this area when sediment depths reach 6".

Maintenance is accomplished using a standard vacuum truck with jetting equipment. A high-pressure water nozzle is used to scour and suspend pollutants, which are then removed via the vacuum hose. Each R-Tank system is installed with a minimum 10" diameter inspection/maintenance port to allow for the access of the nozzle and/or vacuum hose into the Treatment Row.

6. Performance Claims

The R-Tank Treatment Row with the HD module achieved a cumulative sediment removal efficiency of 81.5% for the 11 runs conducted at an average 197.2 gpm, using 1-1000 micron NJDEP sediment, meeting the NJDEP filtration testing protocol criteria. The total mass introduced into the unit was 120.96 lbs for the 11 test runs, with a calculated captured mass of 98.64 lbs (19.73 lbs per HD module). The normalized treatment flow for the system was 4.0 gpm/ft^2. The R-Tank Treatment Row is designated as an offline system since no scour testing was conducted.

Table 8 R-Tank Treatment Row Single Module MTFRs and Maximum Drainage Areas

R-Tank Treatment Row Module	Surface Loading Rate[1] (gpm/ft^2)	Single Module EFTA[2] (ft^2)	Single Module MTFR[3] ((gpm)	Single Module Mass Loading Capacity[4] (lbs)	Single Module Drainage Area[5] (acres)
HD	4.00	9.85	39.4	19.7	0.033
UD	4.00	8.52	34.1	17.0	0.028

Notes:

1. The surface loading rate is based on the tested R-Tank with five HD modules, which has a total effective filtration treatment area (EFTA) of 49.34 ft^2 and a flow rate of 197 gpm.
2. The EFTA is the bottom area and side area of a single module.
3. The MTFR is calculated using the EFTA of a single module and the surface loading rate of 4.0 gpm/ft^2.
4. Mass loading capacity based on 2.0 lbs/EFTA.
5. Drainage area based on NJDEP Filter Protocol calculations that assume an annual sediment loading rate of 600 lbs./acre.

7. Statements

The following statements are from Alden Research Laboratory (Alden), the independent laboratory that conducted the verification testing and NJCAT. These statements are included as a requirement for the verification process.

September 8, 2023

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

Conflict of Interest Statement

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

Protocol Compliance Statement

Alden performed the verification testing on the R-Tank Treatment Row. The Technical Report and all required supporting data documentation has been submitted to NJCAT as required by the protocol.

Testing performed by ALDEN on the R-Tank Treatment Row 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", (April 2023).

James T. Mailloux

Senior Consultant

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October 14, 2023

Robert Woodman, PE, CPESC, NGICP, LEED Green Associate
Director – Engineering & Green Stormwater Infrastructure
Ferguson Waterworks
2831 Cardwell Rd
Richmond, VA 23234

Dear Mr. Woodman,

Based on my review, evaluation and assessment of the testing conducted on the Ferguson Waterworks R-Tank® Stormwater Storage System Treatment Row at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direction of Alden's senior stormwater engineer, James Mailloux, the test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" January 2022 (updated April 2023) were met or exceeded. Specifically:

Test Sediment Feed

The test blend was custom-blended using various commercially available silica sands by Alden to meet the protocol specifications. A random sample from each test batch was analyzed in accordance with ASTM D6913/D7928, by GeoTesting Express, an AALA ISO/IEC 17025 accredited independent laboratory. The specified less-than (%-finer) values of the sample average were within the 2 percentage-point tolerance listed in the protocol. The D50 of 67 microns was less than the NJDEP protocol required 75 microns.

Removal Efficiency Testing

Eleven (11) removal efficiency test runs were completed in accordance with the NJDEP filter protocol. The target MTFR was 197 gpm (4.0 gpm/ft^2 of effective filtration treatment area (EFTA), and the target influent sediment concentration was 200 mg/L. The average flow rate for all 11 runs was 197.2 gpm, with a coefficient of variation (COV) that ranged well below the flow compliance (COV) $\leq$ 0.1 for all the runs. Likewise, for all runs the sediment feed rate COV met the $\leq$ 0.03 protocol limit. The R-Tank Stormwater Storage System Treatment Row demonstrated a cumulative sediment removal efficiency after 11 runs of 81.5%. The final end-of-run elevation was 1.80 ft, Ferguson's design limit.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted concurrently with removal efficiency testing. The measured water elevation met the target water elevation of 1.8 ft at the end of the eleventh run. Per the protocol, the flow was reduced to 90% of the MTFR and a twelfth run was conducted at which the target water elevation was exceeded (1.92 ft). Testing was stopped, and the mass capture loading finalized based on the results from the eleven removal efficiency test runs. The R-Tank Treatment Row tested system (5 HD modules) has a mass loading capture capacity of 98.6 Lbs (2.0 lbs/ft^2 of filtration area).

No maintenance was performed on the test system during the entire testing program.

Scour Testing

No scour testing was performed. Hence the R-Tank system is verified for offline installation only.

Sincerely,

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

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 24, 2023).
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U.S. Department of the Interior, Bureau of Reclamation, *"Water Measurement Manual"*, 3rd edition (2001)

Specifications

Introduction

- Manufacturer – Rainsmart Solutions, 13 Butterfield St., Blacktown NSW 2148, Australia
- Distributed by: Ferguson Enterprises, 12500 Jefferson Avenue, Newport News, VA 23602-4314
- Website: https://www.fergusongss.com/ Phone: 1-800-448-3636
- R-Tank treatment Row verified modules are shown in **Table 8**
- TSS Removal Rate – 80%
- Offline installation

Detailed Specification

- Only R-Tank HD and UD modules can be installed with a treatment row. **Table 8** provides MTFR and maximum drainage area per HD and UD module. Designers shall select the required number of modules to provide the required water quality treatment per the NJDEP Quality Design Storm Event of 1.25" in 2 hours (NJAC 7:8-5.5(a)).
- Maximum inflow drainage area
  - The maximum inflow drainage area is governed by the mass loading capacity of each R-Tank Treatment Row module as presented in **Table 8**.
- Ferguson Waterworks provides technical support and guidance documents for numerous topics, including design, installation and O&M. An R-Tank Operation, Inspection and Maintenance manual is available online at: https://www.fergusongss.com/wp-content/uploads/2022/11/Tech-R-Tank-Operation-Inspection-Maintenance-11-02-22.pdf.