NJCAT TECHNOLOGY VERIFICATION

StormKeeper® Chamber Sediment Strip®

Lane Enterprises Inc.

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1. Introduction

1.1 New Jersey Corporation for Advanced Technology (NJCAT) Program

NJCAT is a not-for-profit corporation to promote in New Jersey the retention and growth of technology-based businesses in emerging fields such as environmental and energy technologies. NJCAT provides innovators with the regulatory, commercial, technological and financial assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization;
- Identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated;
- Facilitate funding and developing commercial relationships/alliances to bring new technologies to market and new business to the state; and
- Assist in the identification of markets and applications for commercialized technologies.

The technology verification program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals are formed to implement a comprehensive evaluation of vendor specific performance claims. Thus, suppliers have the competitive edge of an independent third party confirmation of claims.

Pursuant to N.J.S.A. 13:1D-134 et seq. (Energy and Environmental Technology Verification Program) the New Jersey Department of Environmental Protection (NJDEP) and NJCAT have established a Performance Partnership Agreement (PPA) whereby NJCAT performs the technology verification review and NJDEP certifies the net beneficial environmental effect of the technology. In addition, NJDEP/NJCAT work in conjunction to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the verified/certified technology.

The PPA also requires that:

- The NJDEP shall enter into reciprocal environmental technology agreements concerning the evaluation and verification protocols with the United States Environmental Protection Agency, other local required or national environmental agencies, entities or groups in other states and New Jersey for the purpose of encouraging and permitting the reciprocal acceptance of technology data and information concerning the evaluation and verification of energy and environmental technologies; and

- The NJDEP shall work closely with the State Treasurer to include in State bid specifications, as deemed appropriate by the State Treasurer, any technology verified under the Energy and Environment Technology Verification Program.

1.2 Description of Technology

The StormKeeper® Sediment Strip® is a row of StormKeeper® chambers utilizing a woven fabric wrapping to treat storm water and remove sediment. The sediment strip can act as a stand – alone device or as a pretreatment device in series with other water quality treatment devices and storm water retention and detention systems. The Sediment Strip is constructed from open bottom StormKeeper® chambers wrapped with a woven geotextile. The chambers are connected to each other with an overlapping joint allowing the sediment strip to be sized as needed by adding chambers to the row. The chambers are isolated with the placement of an endcap at each end of the row. The end caps are also wrapped with the woven geotextile fabric meeting AASHTO M288 Class 1.

Each sediment strip is designed with a diversion structure to allow the initial runoff at the beginning of a storm to enter the strip for filtration. The diversion structure is most commonly a manhole with a diversion weir but could be some other type of structure based on the requirements of the site. After the first flush volume or flow rate has been exceeded the remaining water will continue into the detention or retention system that is being utilized (**Figure 1)**.

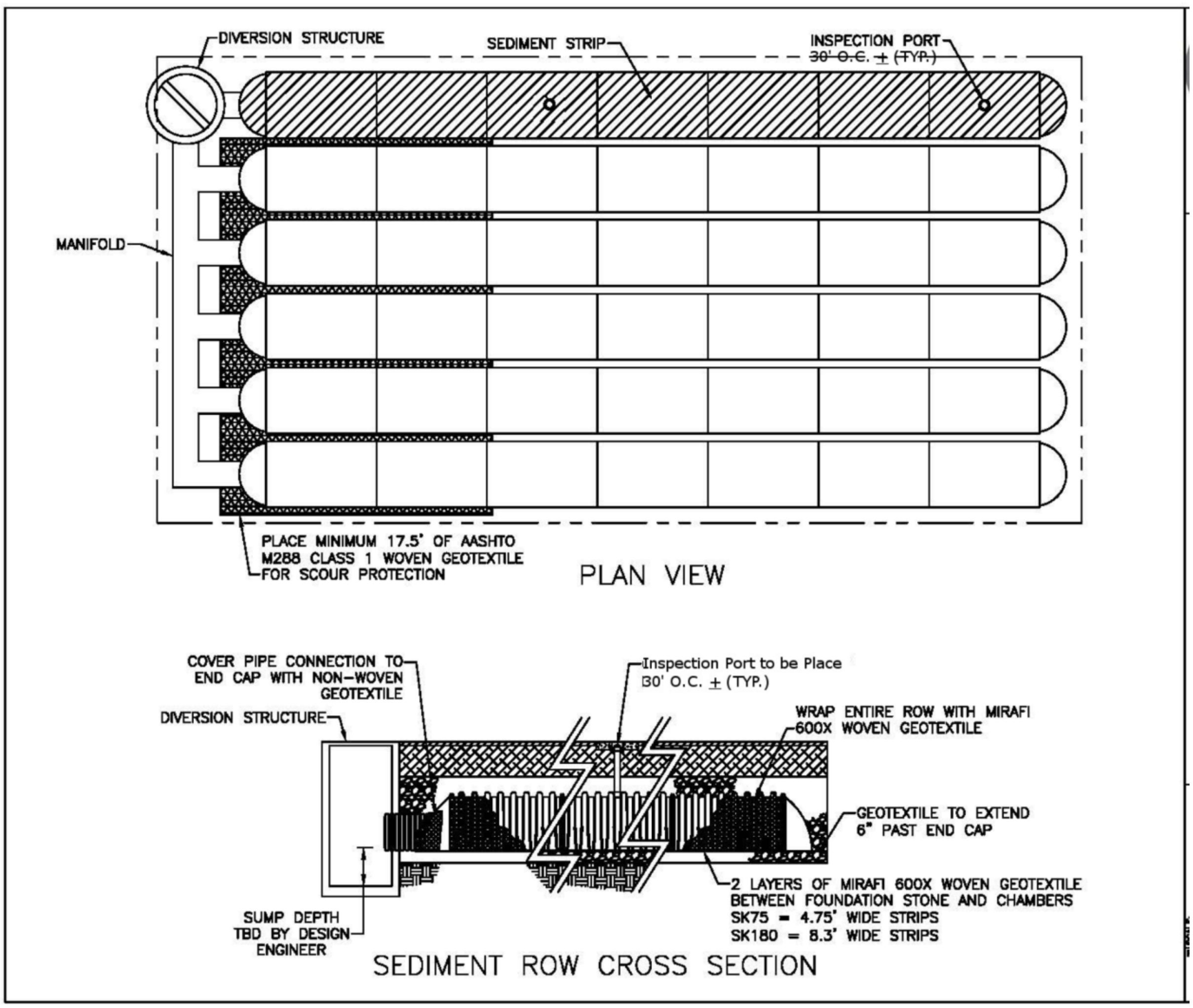


Figure 1 Conceptual Layout with Sediment Row

As the first flush water enters the chamber system it is forced to exit through the bottom of the chamber and through the woven geotextile surrounding the chamber. This results in a filtration of the storm water allowing the water to be treated and the sediment and pollutants to be left behind while the treated water is infiltrated into the ground if soil permeability studies allow. The diversion structure also provides access for jetting the system to flush the sediment and other stormwater pollutants to a manhole or other structure.

Prinsco, Inc. and **Lane Enterprises, Inc.** jointly developed the open bottom chamber. Lane uses the StormKeeper trade name and markets and sells the SK75 and SK180 StormKeeper Chamber Sediment Strip. Prinsco uses the HydroStor™ trade name and markets and sells the HS75 and HS180 Sediment Row. The Sediment Strip and Sediment Row chambers are identical products and produced during the same production runs.

2. Laboratory Testing

The purpose of the testing was to define the performance characteristics of the StormKeeper® Chamber Sediment Strip® under controlled laboratory conditions, utilizing established standard testing methodologies. The testing was conducted in accordance with *"New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device",* 2013, to establish the following parameters:

- Hydraulic Characteristic Curves
- Sediment Removal Efficiency at Maximum Treatment Flow Rate (MTFR)
- Filter Blinding (Occlusion)

Testing was conducted at Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts. **It is not planned to submit this verification report to NJDEP for certification at this time.**

2.1 Test Unit

The SK75 StormKeeper® Chamber Sediment Strip® test unit was an arched stormwater detention/retention sediment collection and filtering device, measuring approximately 51" wide x 30" high x 7 ft long, constructed from polypropylene Open Bottom StormKeeper® chambers and Mirafi® 600X geotextile. The geotextile is composed of high-tenacity polypropylene yarns, which are woven into a stable network such that the yarns retain their relative position. 600X is inert to biological degradation and resistant to naturally encountered chemicals, alkalis, and acids. Both ends of the chamber were sealed with the use of end caps. A water-tight tank was used to house the test chamber system. The chamber was installed on top of a 1-ft base of ¾"-2" double-washed stone containing a 6" underdrain pipe, which penetrated the downstream tank wall. (The purpose of the 12" stone was to allow for the underdrain to be put in for testing in the laboratory boxed in condition as opposed to buried in the ground. The stone does not contribute to the treatment of the sediment strip and is only necessary for foundation support. It is not part of the field installation.)

Two layers of Mirafi® 600X geotextile were placed between the stone base and chamber to collect particulate contaminants, as well as protect the stone base from scouring. The geotextile had an open-area of 1% and opening size of 425 microns. The top geotextile layer was used to fully wrap the chamber and end caps. The chamber floor filtration area was approximately 30 ft^2. Drawings and specifications of the SK75 test unit are shown on **Figure 2** and **Figure 3.**

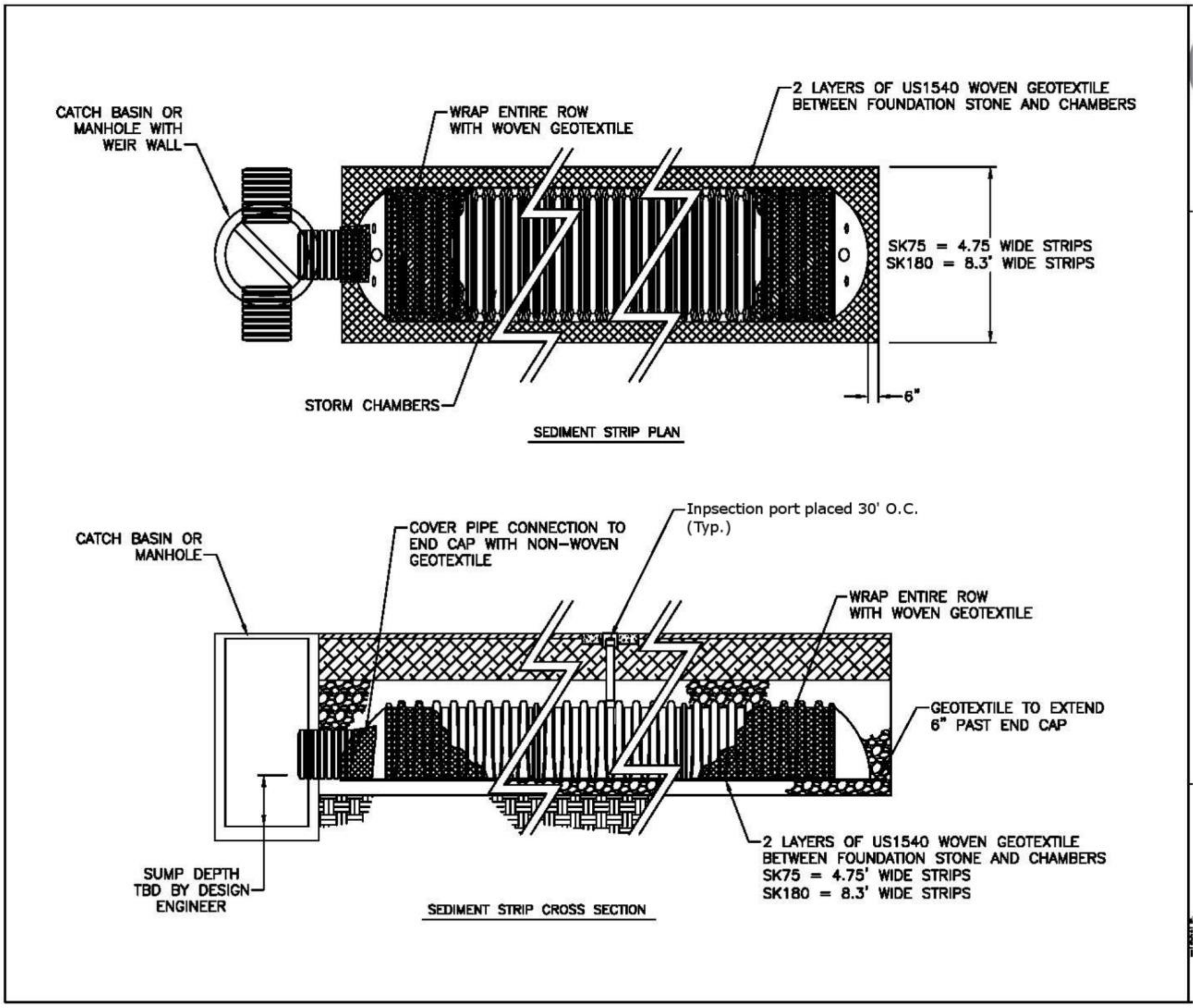
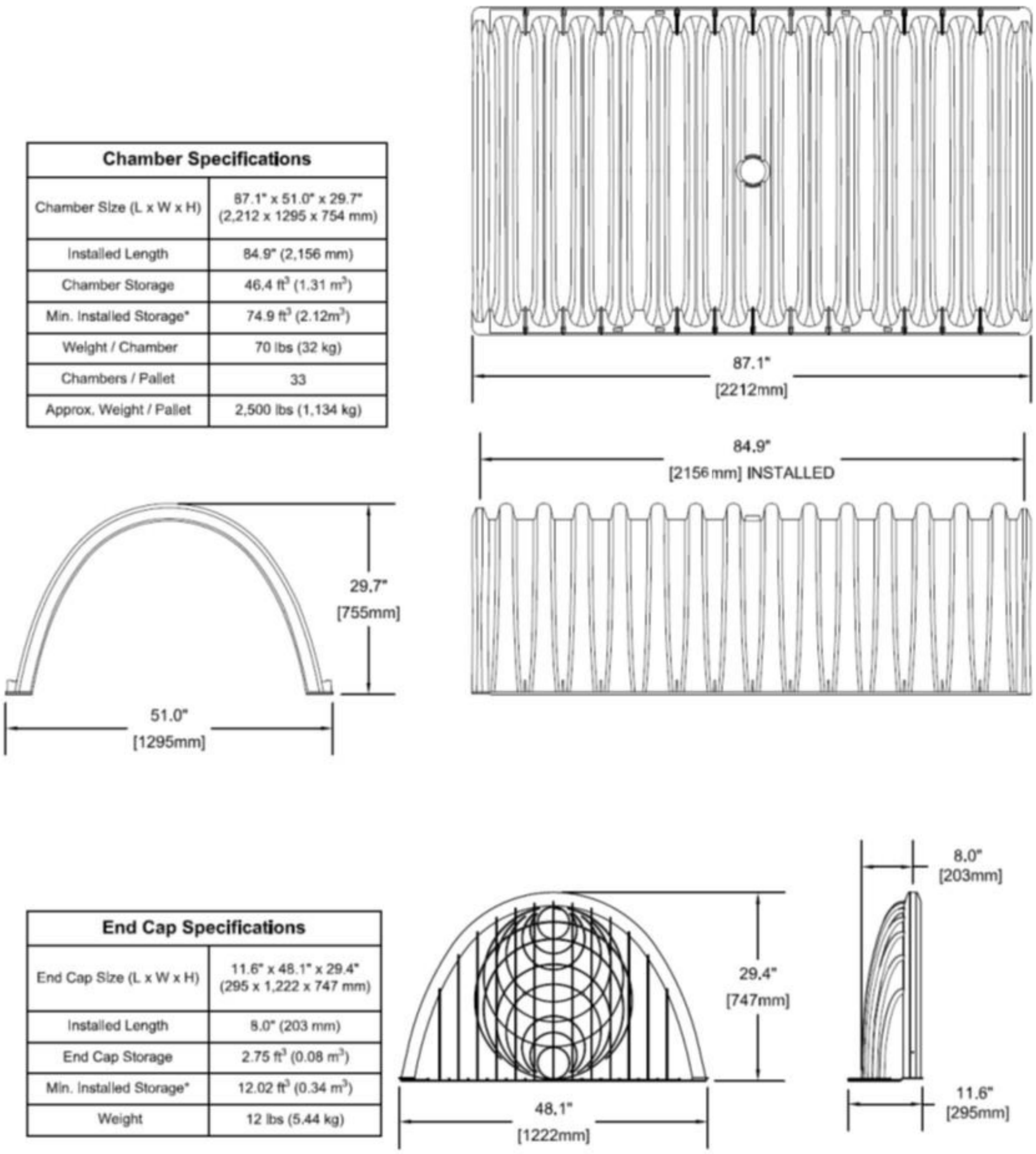


Figure 2 Stormkeeper Chambers Sediment Strip Detail

Water was conveyed into the chamber by means of a 12" diameter inlet pipe, which penetrated the upstream end cap. The junction was wrapped in non-woven fabric. The invert of the pipe was approximately flush with the chamber floor. Additional stone was installed around the outside of the chamber until fully buried. A 4" diameter x 2-ft tall PVC standpipe was installed into the crown of the chamber. In a typical field installation, water passing through the base fabric seeps into the stone base and is either re-infiltrated into the surrounding soil, enters the underdrain and is conveyed into an outlet control structure, or is distributed into other chambers in the stormwater management system. Although the primary function of the sediment strip chamber is to capture and retain sediment particles, the geotextile membrane possesses filtering characteristics and therefore, was tested as such. On-line scour testing was not conducted, as the system is designed for an off-line application with the inclusion of an upstream bypass weir. The bypass weir was not included in the laboratory set-up.



Chamber Specifications	
Chamber Size (L x W x H)	87.1" x 51.0" x 29.7" (2,212 x 1295 x 754 mm)
Installed Length	84.9" (2,156 mm)
Chamber Storage	46.4 ft³ (1.31 m³)
Min. Installed Storage*	74.9 ft³ (2.12m³)
Weight / Chamber	70 lbs (32 kg)
Chambers / Pallet	33
Approx. Weight / Pallet	2,500 lbs (1,134 kg)

End Cap Specifications	
End Cap Size (L x W x H)	11.6" x 48.1" x 29.4" (295 x 1,222 x 747 mm)
Installed Length	8.0" (203 mm)
End Cap Storage	2.75 ft³ (0.08 m³)
Min. Installed Storage*	12.02 ft³ (0.34 m³)
Weight	12 lbs (5.44 kg)

Figure 3 Drawing and Specifications of the SK 75 Treatment Unit

Photographs showing the wrapped SK75 installed in the test tank prior to backfilling and after final installation are shown on **Figure 4** and **Figure 5.**

Figure 4 SK75 Test Unit Installed in the Test Tank Prior to Backfilling

Figure 5 SK75 Test Unit Fully Installed in the Test Tank

A photograph of the test set up is shown on **Figure 6.**

Figure 6 Photograph of the Test Set Up

2.2 Test Setup

The SK75 test unit was installed in the Alden test loop, shown in **Figure 7,** which is set up as a recirculation system.

The loop is designed to provide metered flow up to approximately 17 cfs. Flow was supplied to the unit with one or two selected laboratory pumps (20HP, 50HP), drawing water from a 50,000-gallon supply sump. The test flow was set and measured using one of six differential-pressure meters and corresponding control valves (2”, 4”, 6”, 8”, 10”, or 12”). A Differential Pressure (DP) cell and computer Data Acquisition (DA) program was used to record the test flow. Twenty-five (25) feet of straight 12-inch PVC influent pipe conveyed the metered flow to the test unit. Two (2) feet of 6” PVC pipe free-discharged the effluent flows to a receiving tank, which contained a calibrated V-notch weir at the downstream end for measuring the drawdown flow. The influent and effluent pipes were set at 1% slopes. A 12-inch tee was located 4 pipe-diameters (4 ft) upstream of the test unit for injecting sediment into the crown of the influent pipe using a variable-speed auger feeder.

Filtration of the supply sump, to further reduce background concentration, was performed with an in-situ filter wall containing 1-micron filter bags.

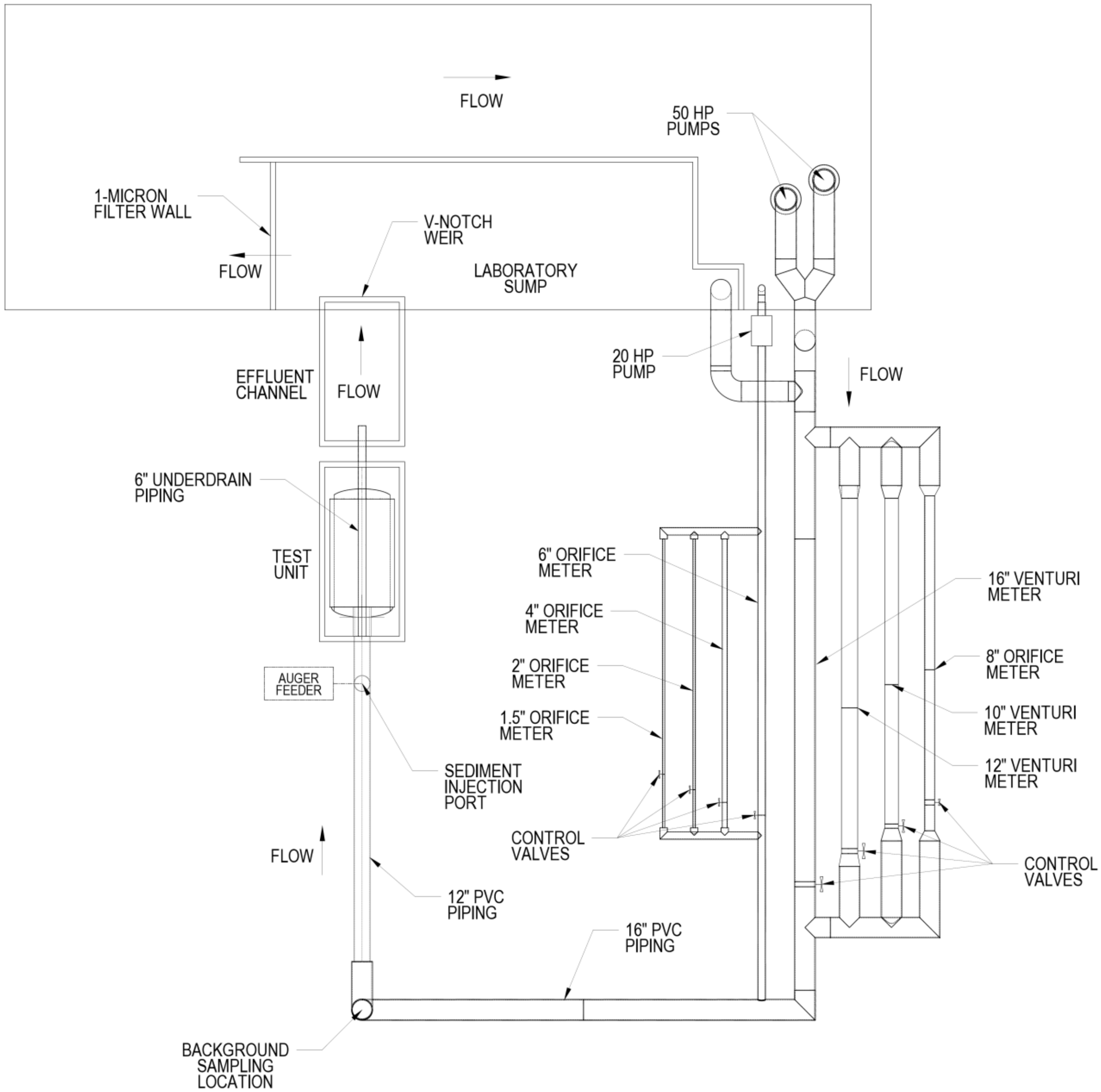


Figure 7 Plan View of Alden Flow Loop

2.3 Hydraulic Testing

The SK75 unit was tested with clean water to determine its hydraulic characteristic curves, including loss coefficients (Cd's) and/or K factors. Flow and water level measurements were recorded during steady-state flow conditions using a computerized Data-Acquisition (DA) system, which included a data collect program, 0-250" Rosemount Differential Pressure (DP) cell (flow), and Omegadyne PX419 0-2.5 psi Single-ended Pressure (SP) cell (water elevations). Flows were set and measured using the calibrated flow meters and control valves. Each test flow was set and operated at steady state for approximately 10 minutes, after which time a minimum of 30 seconds of flow and pressure data were averaged and recorded for each pressure tap location. Water elevations were measured above and below the fabric layer outside of the chamber. Measurements within the influent and effluent pipes were taken one pipe-diameter upstream and downstream of the unit.

2.4 Removal Efficiency Testing

Sediment testing was conducted to determine the removal efficiency, as well as sediment mass loading capacity. The sediment testing was conducted on an initially clean system at the 100% MTFR of 120 gpm (as selected by Lane). A minimum of ten 30-minute test runs were required to be conducted. The captured sediment was not removed from the chamber between tests.

The total mass injected into the system was quantified at the conclusion of the 10 runs. This data was used for determination of the required maintenance frequency.

The test sediment was prepared by Alden to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in column 2 of **Table 1**. The sediment is silica based, with a specific gravity of 2.65. Three random PSD samples of the test sediment were analyzed by an independent certified analytical laboratory using ASTM D 422-63 (Reapproved 2007) "Standard Test Method for Particle Size Analysis of Soils". The average of the three samples was used for compliance with the protocol.

Table 1 Test Sediment Particle Size Distribution

Particle Size[1] (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, provided the measured d_{50} value does not exceed 75 microns.

The target influent sediment concentration was 200 mg/L (+/-20 mg/L) for all tests. The concentration was verified by collecting a minimum of six timed dry samples at the injector and correlating the data with the measured average flow to produce the resulting influent concentration values for each test. The allowed Coefficient of Variance (COV) for the measured samples is 0.10.

The moisture content of the test sediment was determined using ASTM D4959-07 for each test conducted and was utilized in the final removal calculation.

The protocol requires the temperature of the supply water to be below 80 degrees F.

Five (5) time-stamped effluent samples were collected from the end of the outlet pipe during each run. A minimum of three detention times were allowed to pass before collecting a sample after the start of sediment feed and when the feed was interrupted for measurements. Three (3) background samples of the supply water were collected during each run. The samples were collected with each odd-numbered effluent sample (1, 3 and 5). Collected samples were analyzed for Suspended Solids Concentration (SSC) using the ASTM D3977-97 (2013).

At the conclusion of a run, the injection feed was stopped and time-stamped. The flow was stopped after one (1) detention time had passed. The drawdown flow was measured at the V-notch weir every five (5) seconds until the effluent was reduced to 1% of the test flow. Two (2) evenly-spaced effluent samples were collected from the pipe during drawdown.

2.5 Instrumentation and Measuring Techniques

Flow

The inflow to the test unit was measured using one of six (6) calibrated differential-pressure flow meters (2”, 4”, 6”, 8”, 10”, or 12”). Each meter is fabricated per ASME guidelines and calibrated in Alden’s Calibration Department prior to the start of testing. The high and low pressure lines from each meter were connected to manifolds containing isolation valves. Flows were set with a butterfly valve, and the differential head from the selected meter was measured using a Rosemount® 0 to 250-inch Differential Pressure (DP) cell, also calibrated at Alden 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 the test using an in-house computerized data acquisition (DA) program. The accuracy of the flow measurement is ±2%. A photograph of the flow meters is shown on **Figure 8** and the pumps on **Figure 9.**

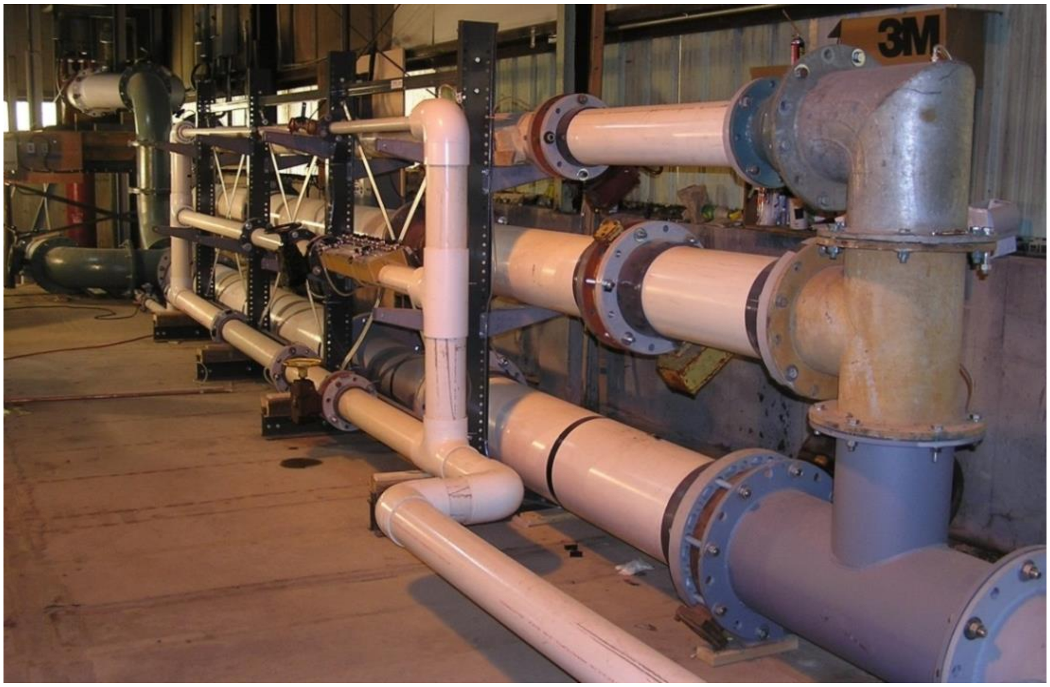


Figure 8 Photograph Showing Laboratory Flow Meters

Figure 9 Photograph Showing Laboratory Pumps

Drawdown Flow

The drawdown flow was measured with the use of a V-notch weir installed at the end of the effluent tank. The weir was fabricated in accordance with the Bureau of Reclamation Water Measurement Manual guidelines. The calculated (theoretical) curve was obtained using equation 7-3 found in Chapter 7, Section 7, of the "Water Measurement Manual", U.S. Department of the Interior Bureau of Reclamation, Third Edition, 2001. The measured curve is the V-notch weir calibration performed at Alden. The points were obtained by running steady-state flows through a selected calibrated flow meters and measuring the water elevation above the invert of the V-notch using a calibrated absolute pressure cell and computerized data acquisition system.

The calculated and measured weir curves are shown on **Figure 10.** The measured (calibrated) curve equation was used to calculate the instantaneous flow passing over the weir, based on the corresponding recorded pressure readings, which were taken every 1-second during drawdown.

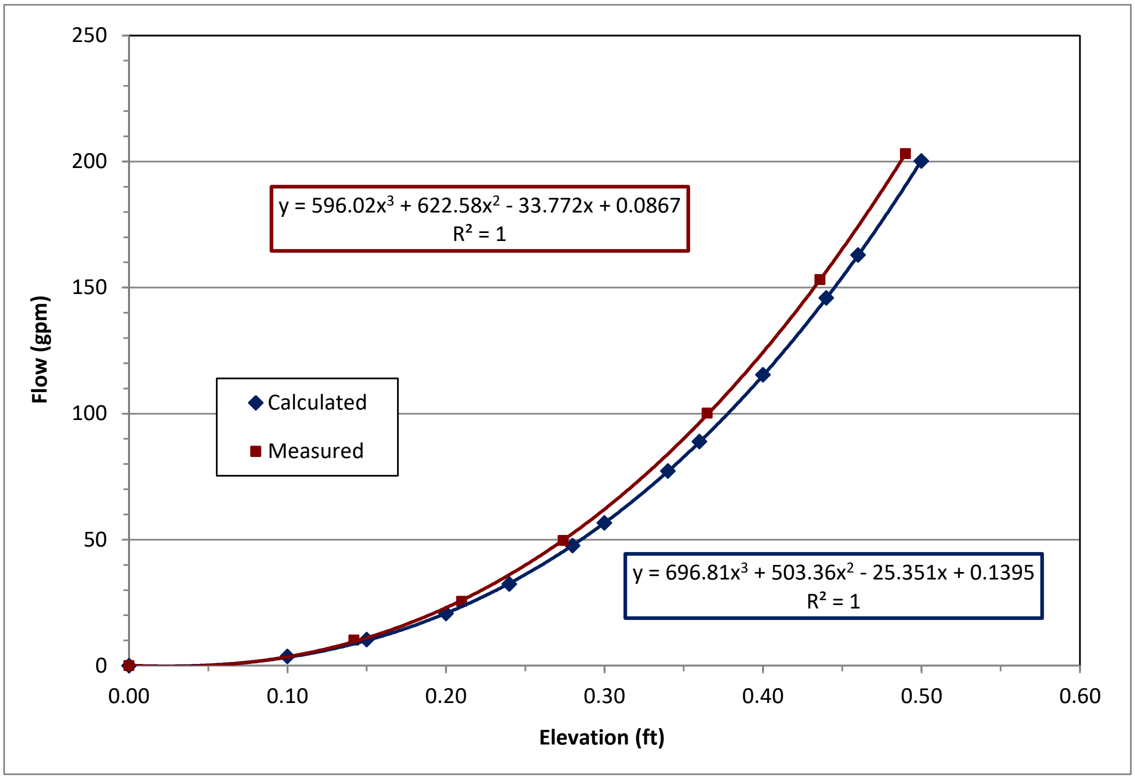


Figure 10 Drawdown V-notch Weir Flow vs Head Curves

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 laboratory prior to testing. The temperature reading was documented at the start and end of each test, to assure an acceptable testing temperature of less than 80 degrees F.

Pressure Head

Pressure head measurements were recorded at multiple locations using piezometer taps and a Omegadyne PX419, 0 - 2.5 psi cell. The pressure cell was calibrated at Alden prior to testing. Accuracy of the readings is ± 0.001 ft. The cell was installed at a known datum in relation to the tank floor, allowing for elevation readings through the full range of flows. A minimum of 30 seconds of pressure data was averaged and recorded for each pressure tap during hydraulic testing, under steady-state flow conditions, using the computerized DA program. Driving head and effluent weir measurements were averaged and recorded every 5 seconds during removal efficiency testing. A photograph of the pressure instrumentation is shown on **Figure 11**.

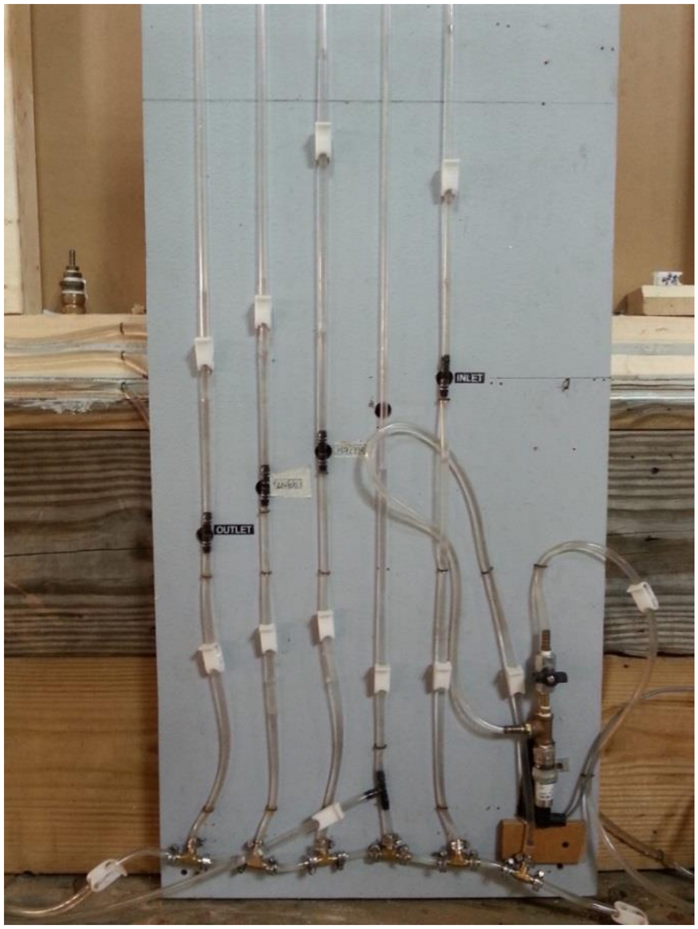


Figure 11 Pressure Measurement Instrumentation

Sediment Injection

The test sediment was injected into the crown of the influent pipe using an Auger® volumetric screw feeder, model VF-1, shown on **Figure 12**. The auger feed screw, driven with a variable-speed drive, was calibrated with the test sediment prior to testing, to establish a relationship between the auger speed (0-100%) and feed rate in grams/minute. 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® 4000g x 0.1g, model SCD-010 digital scale. The feeder has a hopper at the upper end of the auger to provide a constant supply of dry test sand. The allowable Coefficient of Variance (COV) for the injection is 0.10.

Sample Collection

Effluent samples were collected in 2-liter containers from 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, shown on **Figure 13**.

Figure 12 Photograph of Variable-Speed Auger Feeder

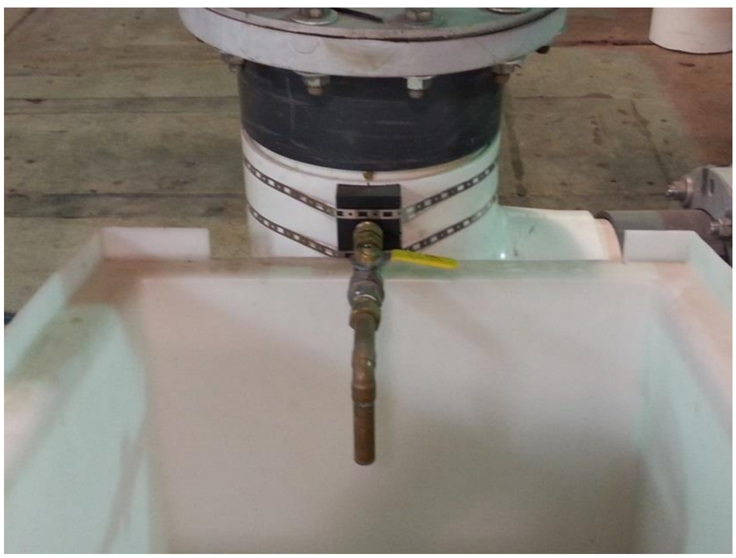


Figure 13 Photograph of Background Isokinetic Sampler

Sample Concentration Analysis

Effluent and background concentration samples were analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (Reapproved 2013), "Standard Test Methods for Determining Sediment Concentration in Water Samples". The required silica sand used in the sediment testing did not result in any dissolved solids in the samples and therefore, simplified the ASTM testing methods for determining sediment concentration. Associated instrumentation included:

- 2-Liter collection beakers
- Ohaus® 4000g x 0.1g digital scale, model SCD-010
- Oakton® StableTemp gravity convection oven, model 05015-59
- Sanplatec Dry Keeper® desiccator, model H42056-0001
- AND® 0.0001-gram analytical balance, model ER-182A
- Advantec 3-way filtration manifold
- Whatman® 934-AH, 47-mm, 1.5-micron, glass microfiber filter paper

Samples were collected in graduated 2-Liter beakers which were cleaned, dried and weighed to the nearest 0.1-gram, using an Ohaus® 4000g x 0.1g digital scale, model SCD-010, prior to sampling. Collected samples were also weighed to the nearest 0.1-gram using the Ohaus® digital scale. Each collected sample was filtered through a pre-rinsed Whatman® 934-AH, 47-mm, 1.5-micron, glass microfiber filter paper, using a laboratory vacuum-filtering system. Prior to processing, each filter was rinsed with distilled water and placed in a designated dish and dried in an Oakton® StableTemp gravity convection oven, model 05015-59, at 225 degrees F for a minimum of 2.5 hours. Each dried filter was placed in a Sanplatec Dry Keeper® desiccator, model H42056-0001, to cool and then weighed to the nearest 0.0001-gram to determine the tare weight, using an AND® analytical balance, model ER-182A. Once filtered, each sample and dish was dried at a temperature between 175 and 210 degrees F (below boiling) for 20 to 30 minutes until visually dry. The oven temperature was increased to 225 degrees F and the samples were dried for an additional 2.5 hours. The dry samples and dishes were then cooled in the desiccator and weighed to the nearest 0.0001-gram, using the AND® balance. Net sediment weight (mg) was determined by subtracting the dried filter weight (tare) from the dried sample weight and multiplying the result by 1,000. The net sample volume, in liters, was determined by subtracting the beaker and net sediment weight from the overall sample weight and dividing by 1,000. Each sample sediment concentration, in mg/L, was determined by dividing the net sediment weight by the net sample volume.

2.6 Data Management and Acquisition

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

A personal computer running an Alden in-house Labview® Data Acquisition program was used to record all data related to instrument calibration and testing. A 16-bit National Instruments® NI6212 Analog to Digital board was used to convert the 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 a user-defined number of significant figures.

Test flow and pressure data was continuously collected at a frequency of 250 Hz. The flow data was averaged and recorded to file every 5 seconds. Steady-state pressure data was averaged and recorded over a duration of 30 seconds for each point. The recorded data files were imported into a spreadsheet 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. The data was input to the designated spreadsheet for final processing.

2.7 Laboratory Analysis

The following Test Methods were used to analyze the dry and aqueous sediment samples:

- Sediment Concentration
  ASTM Designation: D 3977-97 (Reapproved 2013), "Standard Test Methods for Determining Sediment Concentration in Water Samples"

- Sediment Moisture Content
  ASTM Designation: D4959-07, "Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating"

- Dry Sediment Particle Size Distribution
  ASTM D422-63 (2007), "Standard Test Method for Particle Size Analysis of Soils"

2.8 Quality Assurance and Control

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

Flow

The flow meters and pressure cells were calibrated in Alden's Calibration Laboratory, which is ISO/IEC 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 from the meter and verify the computer measurement of each flow meter.

Sediment Injection

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

Sediment Concentration Analysis

All sediment concentration samples were processed in accordance with the ASTM D3977-97 (2013) analytical method. Gross sample weights were measured using a 4000g x 0.1g calibrated digital scale. The dried sample weights were measured with a calibrated 0.0001g analytical balance. Any change in filter weight due to processing was accounted for by including three control filters with each test set. The average of the three values, which was +/- 0.1-0.5 mg, was used in the final concentration calculations.

Analytical accuracy was verified by preparing two blind control samples and processing using the ASTM method. The final calculated values were within 0.26% and 0.87% of the theoretical sample concentrations, with an average of 0.57% accuracy. This value was not corrected for particles smaller than the filter designation of 1.5 microns and therefore is considered conservative.

3. Performance Test Results

The test sediment PSD analysis, removal efficiency test results and mass loading capacity results are summarized in this section.

3.1 Test Sediment PSD Analysis

The sediment particle size distribution (PSD) used for removal efficiency testing and sediment mass loading capacity was comprised of 1-1000 micron silica particles, as shown in **Table 1**. The Specific Gravity (SG) of the sediment mixes was 2.65. A commercially-available blend of each mix was provided by AGSCO Corp., a QAS International ISO-9001 certified company, and adjusted by Alden as required. Samples were collected from random bags and analyzed in accordance with ASTM D422-63 (2007), by GeoTesting Express, an ISO/IEC 17025 accredited independent laboratory. The average %-finer values of the stock material were found to be outside of the NJDEP acceptance criteria of 2% for particle sizes ≤ 20 microns. The Alden test mix was adjusted to within the NJDEP acceptance criteria with the addition of commercially-available US-Silica Min-U-Sil 10, with a PSD of approximately 1-25 microns. Test batches of approximately 30 lbs each, were prepared in individual 5-gallon buckets, which were arbitrarily selected for the removal testing. A well-mixed random sample was collected from three random test batches and analyzed for PSD by GeoTesting Express. The average of the samples was used for compliance to the protocol specifications listed in Column 2 of **Table 1**. The D_{50} of the samples ranged from 61 to 63 microns, with an average of 62 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 Alden NJDEP 1-1000 µm Mix

Particle size (µm)	NJDEP	Sample 1	Sample 2	Sample 3	Average
1000	100%	100%	100%	100%	100%
500	95%	96%	95%	96%	96%
250	90%	92%	91%	92%	92%
150	75%	79%	79%	79%	79%
110	60%	65%	65%	65%	65%
75	50%	53%	53%	53%	53%
53	45%	48%	47%	47%	47%
20	35%	34%	32%	36%	34%
8	20%	20%	19%	19%	19%
5	10%	14%	13%	13%	13%
2	5%	4%	4%	4%	4%
75	D_{50}	61	63	63	62

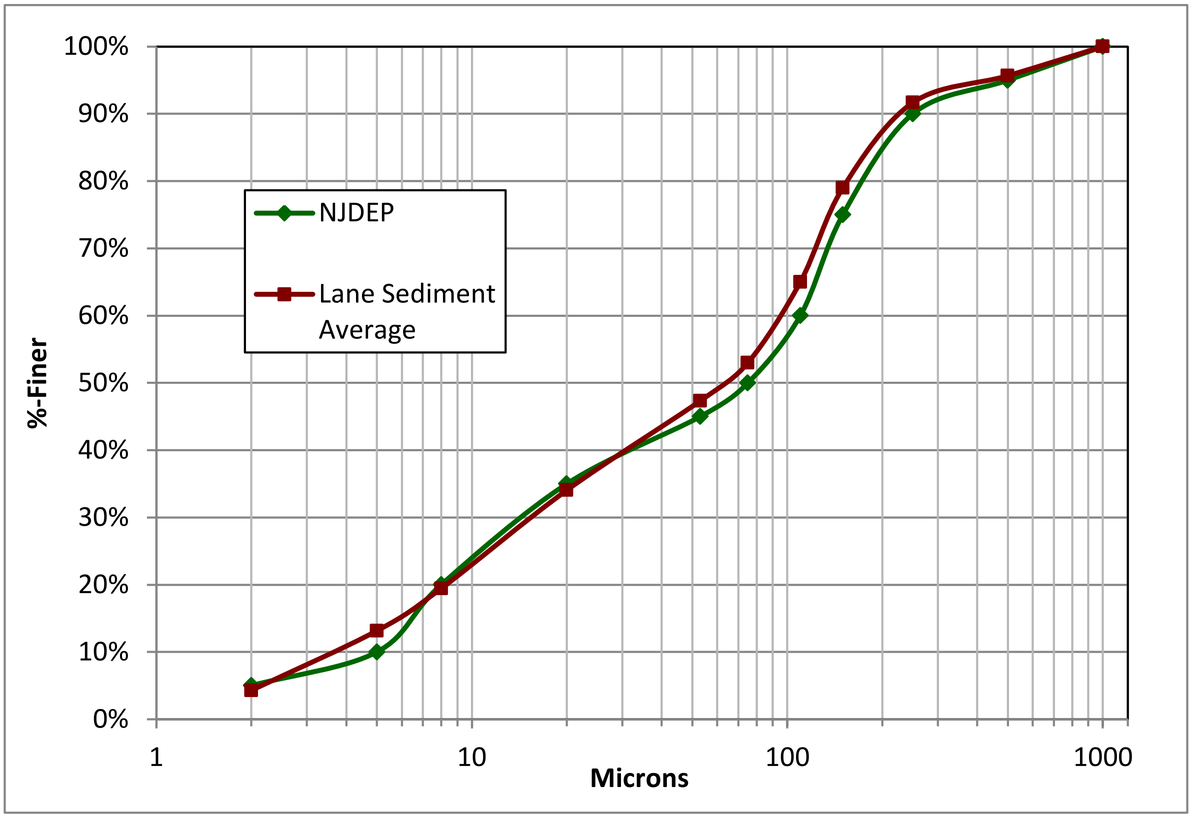


Figure 14 PSD Curves of Alden 1-1000 µm Test Sediment vs NJDEP Specifications

3.2 Removal Efficiency Testing

Ten (10) removal efficiency test runs were conducted at a target flow of 120 gpm (100% MTFR), corresponding to a normalized flow of 4 gpm/ft^2 of geotextile fabric. The minimum duration of the runs was 38 minutes, with a target influent sediment concentration of 200 mg/l. All test runs met or exceeded the protocol testing criteria. An additional run (Run11) was conducted at a flow of 108 gpm (90% MTFR) and influent concentration of 200 mg/L, to meet the mass loading capacity testing protocol. The duration of the run was 69 minutes, during which nine (9) effluent samples (11 including drawdown) and five (5) background samples were collected.

The measured flow for the 10 runs ranged from 119.5 gpm to 120.8 gpm, with an average flow of 119.9 gpm. The calculated COVs ranged from 0.001 to 0.004. The average measured flow for the mass loading run was 107.7 gpm, with a COV of 0.001. The maximum recorded temperature for all the runs ranged from 67.2 to 78.4 degrees F. The calculated mass/volume influent concentrations ranged from 189 to 207 mg/L, with an average concentration of 201 mg/L. The measured injected influent concentrations ranged from 198 to 203 mg/L, with an average concentration of 200 mg/L. The injection COVs ranged from 0.001 to 0.005. (**Table 3**)

The average adjusted effluent concentrations ranged from 29.2 to 41.5 mg/L, the maximum background concentration never exceeded 6.6 mg/L and the average drawdown concentrations ranged from 5.0 to 25.7 mg/L. The drawdown duration for the eleven (11) runs increased sequentially from 29 minutes to approximately 80 minutes. (**Table 4)**

Table 3 Measured Influent Parameters

Run #	Measured Flow		Max Temp	Influent Concentration (mg/L)		
	gpm	COV	Deg. F	mass/volume	Injector Concentration	Injector COV
1	120.8	0.004	78.4	198	198	0.002
2	119.6	0.001	78.1	207	201	0.002
3	119.7	0.002	74.8	189	200	0.003
4	119.7	0.001	74.6	203	200	0.001
5	119.5	0.001	74.8	204	201	0.001
6	120.2	0.001	70.5	202	200	0.001
7	119.7	0.001	70.7	204	200	0.002
8	120.1	0.001	69.7	196	199	0.002
9	119.8	0.001	68.6	204	200	0.002
10	119.9	0.001	67.2	203	200	0.001
11 (90% MTFR)	107.7	0.001	71.7	199	203	0.005
Average #1-10	**119.9**		**Average**	**201**	**200**	

Table 4 Measured Sample Concentrations

Run #	Maximum Background	Adjusted Effluent Concentrations (mg/L)						Drawdown Concentrations (mg/L)		
	mg/L	#1	#2	#3	#4	#5	**Average**	#1	#2	**Average**
1	1.7	21.39	19.71	19.94	43.56	41.30	**29.18**	12.33	39.14	**25.73**
2	3.0	19.75	23.25	25.22	63.47	44.35	**35.21**	9.19	5.51	**7.35**
3	4.3	38.33	35.94	39.79	40.91	39.69	**38.93**	9.39	4.76	**7.07**
4	0.9	37.31	40.21	41.01	41.24	41.60	**40.28**	7.32	3.43	**5.37**
5	1.0	36.04	37.24	41.02	40.58	41.34	**39.24**	7.86	3.11	**5.48**
6	0.2	37.81	37.48	41.27	40.86	40.02	**39.49**	7.60	3.28	**5.44**
7	0.6	37.44	39.24	40.07	42.90	43.45	**40.62**	7.69	3.77	**5.73**
8	1.0	39.21	39.05	41.13	42.64	40.48	**40.50**	6.50	3.39	**4.95**
9	0.9	38.24	41.77	42.78	41.84	42.91	**41.51**	9.69	4.58	**7.14**
10	6.6	32.24	35.76	46.27	39.88	36.87	**38.20**	12.14	5.56	**8.85**
Mass Loading Test		#1 / #2	#3 / #4	#5 / #6	#7 / #8	#9				
11	1.1	36.06 / 38.25	41.89 / 39.93	38.14 / 37.42	40.14 / 36.55	39.92	**38.70**	9.82	6.09	**7.95**

The removal efficiency on a mass removal basis (mass captured/mass loading) for the 10 removal test runs varied from 83.2% to 85.5%, with an average removal efficiency of 83.9% (**Table 5).**

Table 5 Removal Efficiency Test Results

Run #	Average Influent TSS	Average Adjusted Effluent TSS	Average Adjusted Drawdown TSS	Influent Volume	Effluent Volume	Drawdown Volume	Mass Loading	Mass Captured	Removal Efficiency by Mass
	(mg/L)	(mg/L)	(mg/L)	(L)	(L)	(L)	(g)	(g)	(%)
1	198.3	29.2	25.7	18,962	16,448	2,514	3760.1	3215.5	85.5
2	200.9	35.2	7.3	15,384	12,636	2,748	3090.1	2625.1	85.0
3	199.8	38.9	7.1	15,392	12,950	2,442	3075.1	2570.9	83.6
4	200.0	40.3	5.4	15,390	12,614	2,776	3078.3	2570.3	83.5
5	200.6	39.2	5.5	15,364	12,631	2,734	3081.5	2585.8	83.9
6	199.5	39.5	5.4	15,454	12,590	2,864	3083.4	2586.2	83.9
7	199.8	40.6	5.7	15,397	12,667	2,730	3076.6	2562.1	83.3
8	199.2	40.5	4.9	15,447	12,752	2,695	3077.0	2560.5	83.2
9	199.8	41.5	7.1	15,406	12,728	2,678	3078.7	2550.3	82.8
10	199.8	38.2	8.8	15,419	12,740	2,678	3080.7	2594.0	84.2
						Total Mass (kg)	**31.48**	**26.42**	
								Average Removal Efficiency by Mass	**83.9**

The maximum driving head, 3.26 ft, was recorded at the end of Run 10, which is 0.76 ft above the crown of the chamber. This value was set as the driving head criteria for sediment mass loading capacity testing. Lane SK75 recorded driving head elevations during the 10 sediment removal efficiency tests are shown in **Table 6** and on **Figure 15**.

Table 6 SK75 Recorded Driving Head Elevations

Run #	Driving Head (ft)
1	1.820
2	2.276
3	2.323
4	2.512
5	2.611
6	3.008

7	3.187
8	3.210
9	3.209
10	3.257
11	3.261

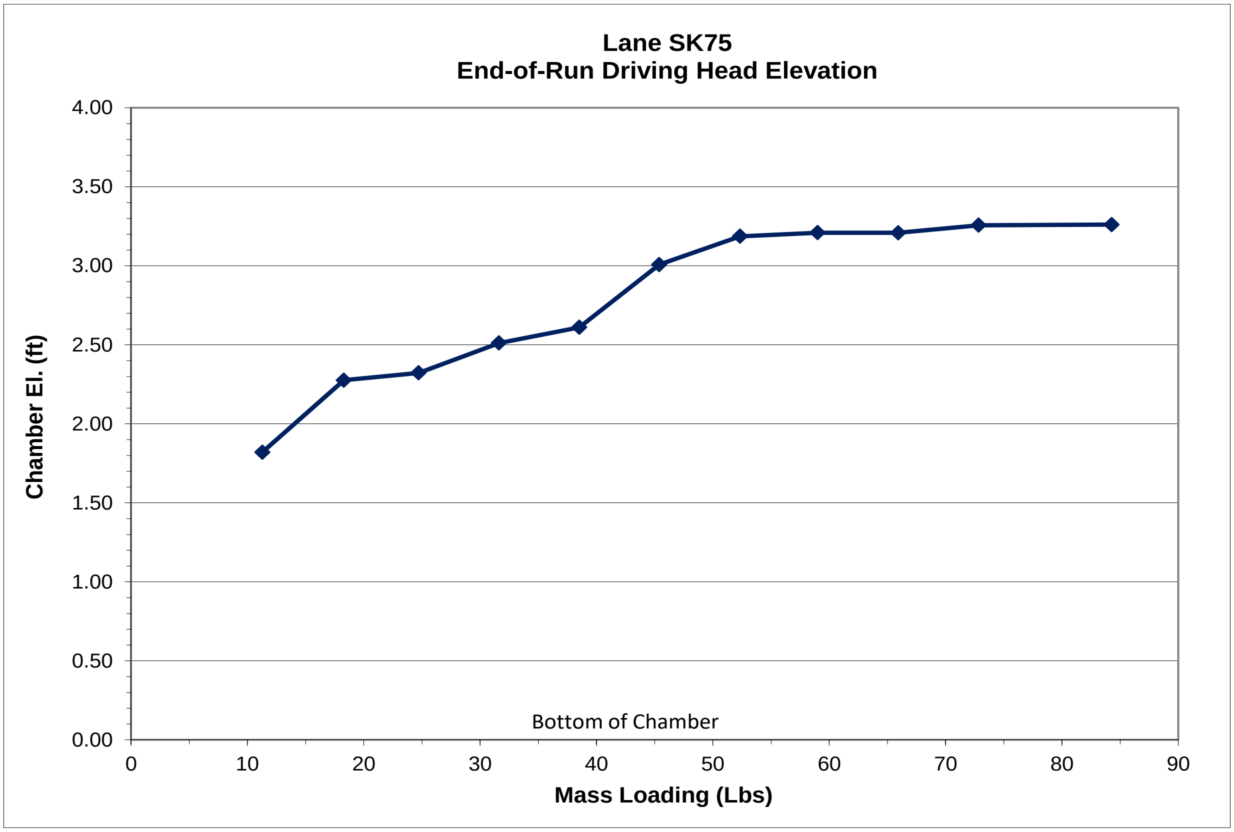


Figure 15 SK75 Recorded Driving Head Elevations

3.3 Sediment Mass Loading Capacity Testing

As mention previously, an additional run (Run 11) was conducted at 90% of the MTFR since the maximum driving head was reached during Run 10. It was anticipated that the lower MTFR would result in a lower driving head. This did not happen. The driving head remained essentially the same as at the end of Run 10. Hence it was concluded that the sediment mass loading capacity had been reached and testing was terminated. An additional 4.38 kg was captured by the SK75 Stormkeeper Chamber Sediment Strip during Run 11 increasing the total sediment captured for the 11 test runs to 30.8 kg (67.8 lb). This equates to 2.26 lb/geotextile fabric surface area. The maximum impervious inflow drainage area **per** SK75 Stormkeeper Chamber Sediment Strip calculated by the equation in the Appendix in the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (January 2013)* is 0.11 acre.

3.4 Hydraulic Characteristics

Steady-state pressure measurements were recorded on the clean chamber to establish the hydraulic characteristic curves. Recorded flows ranged from 10 to 353 gpm (0.33 to 11.75 gpm/ft^2). The recorded data is shown in **Table 7** and corresponding curves on **Figure 16**.

Table 7 Measured Hydraulic Data

Flow			Inlet El. (A') Corrected for Energy ft	Outlet El. (D') Corrected for Energy ft	System Energy Loss A'-D'
gpm	cfs	gpm/sq-ft			
0	0				
10.1	0.02	0.34	**1.281**	**0.389**	**0.892**
25.4	0.06	0.85	**1.331**	**0.446**	**0.886**
49.6	0.11	1.65	**1.385**	**0.513**	**0.873**
100.1	0.22	3.34	**1.494**	**0.619**	**0.875**
153.1	0.34	5.10	**1.578**	**0.708**	**0.870**
203.1	0.45	6.77	**1.832**	**0.787**	**1.046**
246.1	0.55	8.20	**2.112**	**0.855**	**1.257**
305.5	0.68	10.18	**2.583**	**0.939**	**1.644**
352.5	0.79	11.75	**2.984**	**1.010**	**1.975**

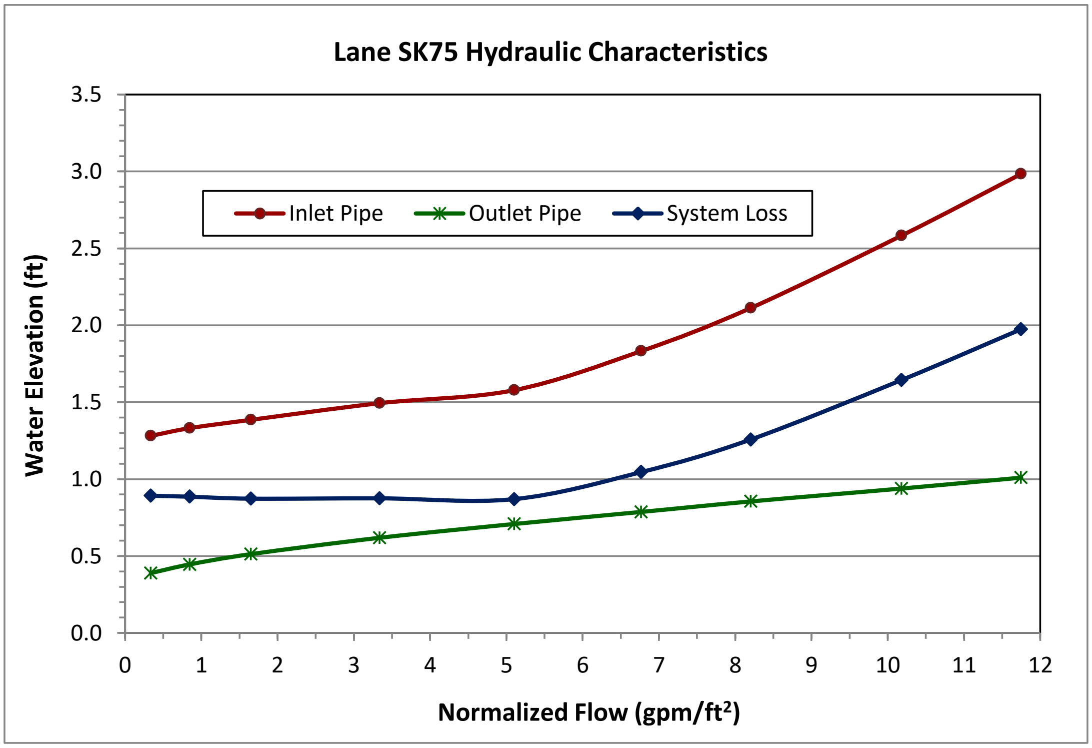


Figure 16 SK75 Hydraulic Characteristic Curves

4. Maintenance

Maintenance is accomplished by jetting the system to flush the sediment and other storm water pollutants to a manhole or other structure. Once the material has been flushed to the structure, the contaminants are moved from the system via a vacuum truck or similar operation. Inspection ports are installed along the length of the sediment strip to determine when maintenance is required. The Stormkeeper Chambers should be inspected every 6 months during the first year of operation. The inspection interval should be adjusted based on previous observations of sediment accumulation and standing water levels. If sediment is at or above 3-inches, or standing water remains 24 hours after a storm event, the chambers should be cleaned out using a Jet-Vac (jetting) process. In general, the system should be maintained yearly. A greater interval can be specified once the site has stabilized and monitoring has occurred.

During the life of the StormKeeper Sediment Strip, the woven polypropylene fabric will be subject to repeated loading of sediment and cleaning by forces that may cause abrasion and degradation. Although unlikely to be needed, due to the extremely high abrasion resistance of polypropylene, a method has been established to replace the fabric without creating the need to excavate the entire system. The following protocol describes methods for inspecting and replacing the fabric if necessary.

Inspection

The sediment strip is designed to allow inspection ports to be installed in any chamber along the length of the strip. Inspection ports are installed on approximately 30 foot intervals to facilitate regular inspections and maintenance activities. The inspection ports are typically 6 inches in diameter and are used to determine the amount of sediment in the structure as well as the quality of the fabric under the system. In most cases the fabric under the system will never have to be replaced due to the inherent high resistance to abrasion of polypropylene. Removal of sediment is covered under a separate document for the Lane StormKeeper System. After the system has been cleaned during a maintenance cycle, the fabric should be inspected to determine its condition. Should the fabric show excessive wear the top layer shall be subject to a replacement procedure. Wear of the fabric is indicated by frayed edges, discoloration, and broken filaments in the fabric. Should the amount of wear cover an area of over 25% of the fabric surface area, then replacement or patching in accordance with the manufacturer's recommendations will be required.

Fabric Replacement

Should the fabric require replacement the following steps should be followed:

A. Excavate to the top of the Sediment Strip row on one end of the system. It is not necessary to excavate the entire row. If there is a header system, the access port can be placed at either end. If there is only one header, the access port should be at the end opposite of the header.
B. Once the top of the Sediment Strip has been located an 18-inch access port should be cut centered on the top of the chamber and at least 12 inches from the end of the chamber row. Care should be taken to prevent material from entering the system through the access port.

C. An 18-inch riser section can be connected to the chamber to prevent material from entering the system.
D. Once the access port has been installed, entrance into the system is possible. Adequate confined space entry protocols should be followed.
E. The existing top layer of fabric should be removed. Removal is completed by cutting the fabric where it meets the foot of the chamber and disposing of it properly.
F. A new fabric will be the same fabric as specified in the original specifications or meeting the same material properties.
G. New woven geotextile will be folded lengthwise and pulled through the 18-inch access port which was installed. The fabric can be pulled through sediment strip row either by hand or using mechanical means. The header can be utilized to pull fabric through the length of the sediment strip if required.
H. Once the fabric has been pulled through the length of the sediment strip it is unfolded to cover the bottom of the chamber floor and the existing fabric which has remained in place.
I. The new fabric is attached to the floor of the chamber by welding the edges of the fabric to the feet of the chambers. Both materials are polypropylene allowing them to be attached to each other via welding. A qualified professional plastics welder should perform the work utilizing appropriate tools and welding rod.
J. A continuous weld should be run along all edges of the fabric and chamber to connect the fabric permanently to the chamber bottom. At the ends, the fabric shall be secured to the endcaps via welding.
K. Once installation of the new fabric is complete the chamber access can either be removed or left in place. If left in place, a flowable low strength concrete fill should be placed around the structure up to 12 inches above the chamber and 12 inches around the structure. If the structure is removed, a polypropylene patch should be placed over the chamber and welded in place. #57 stone should be placed around and above the patch up to 12 inches. Remaining backfill should be placed as required for the surface finish above the sediment strip.

Surface Treatment

Upon completion of the fabric replacement, the backfill and ground finish above the patch will be matched to the surrounding ground finish or as directed by the owner.

5. Performance Verification

The SK75 StormKeeper® Chamber Sediment Strip® test unit wrapped with Mirafi® 600X geotextile demonstrated an 83.9% average TSS removal efficiency and a sediment mass loading capacity of 2.26 lb/geotextile fabric filtration area when operated with a driving head <3.26 ft at a hydraulic loading rate of 4 gpm/ft^2 of geotextile fabric filtration area. The MTFRs and maximum allowable drainage area for other Lane and Prinsco models are shown in **Table 8**.

Table 8 Lane and Prinsco Model MTFRs and Maximum Allowable Drainage Area

Model	Driving Head (ft)	Hydraulic Rate (gpm/ft^2)	MTFR (gpm)	Mass Loading Capacity (lb/ft^2)	Mass Storage Capacity (lb)	Maximum Allowable Drainage Area (acres)[1]
Lane						
SK75	3.26	4.0	120	2.26	67.8	0.113
SK180	3.26	4.0	240	2.26	135.6	0.226
Prinsco						
HS75	3.26	4.0	120	2.26	67.8	0.113
HS180	3.26	4.0	240	2.26	135.6	0.226

1. Based upon the equation in the NJDEP Filter Protocol: Maximum Inflow Drainage Area (acres) = Weight of TSS Captured before Efficiency Drops below 80% / 600 lbs per Acre of Drainage Area Annually.

6. References

ASTM (2013), *"Standard Test Methods for Determining Sediment Concentration in Water Samples"*, Annual Book of ASTM Standards, D3977-97, Vol. 11.02.

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

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

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

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