NJCAT TECHNOLOGY VERIFICATION

VortSentry® Stormwater Treatment System

December 2005

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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 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 (USEPA), 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 Technology Verification Report

In October 2005, Stormwater360^{TM}, Inc., 200 Enterprise Drive, Scarborough, Maine, 04074, submitted a formal request for participation in the NJCAT Technology Verification Program. The technology proposed, The VortSentry® Stormwater Treatment System, is a hydrodynamic separator designed to enhance gravitational separation of floating and settling materials from stormwater flows. The system was developed in Scarborough, Maine and is described in greater detail later in this report. Through research and field application, the technology has been refined to capture total suspended solids (TSS), sediments, oil and grease, and trash and debris (including floatables and negatively buoyant debris). The request (after pre-screening by NJCAT staff personnel in accordance with the technology assessment guidelines) was accepted into the verification program. This verification report covers the evaluation based upon the performance claim of the vendor, Stormwater360^{TM}, Inc. (see Section 4). The verification report differs from typical NJCAT verification reports in that final verification of the VortSentry® System (and subsequent NJDEP certification of the technology) awaits completed field testing that meets the full requirements of the Technology Acceptance and Reciprocity Partnership (TARP) – Stormwater Best Management Practice Tier II Protocol for Interstate Reciprocity for stormwater treatment technology. This verification report is intended to evaluate the Stormwater360^{TM}, Inc. initial performance claim for the technology based primarily on carefully conducted laboratory studies. This claim is expected to be modified and expanded following completion of the TARP required field-testing.

This project included the evaluation of assembled reports, company manuals, and laboratory testing reports to verify that the VortSentry® System meets the performance claim of Stormwater360^{TM}, Inc.

1.3 Technology Description

1.3.1 Technology Status

In 1990 Congress established deadlines and priorities for USEPA to require permits for discharges of stormwater that are not mixed or contaminated with household or industrial wastewater. Phase I regulations established that a NPDES (National Pollutant Discharge Elimination System) permit is required for stormwater discharge from municipalities with a separate storm sewer system that serves a population greater than 100,000 and certain defined industrial activities. To receive a NPDES permit, the municipality or specific industry has to develop a stormwater management plan and identify best management practices for stormwater treatment and discharge. Best management practices (BMPs) are measures, systems, processes or controls that reduce pollutants at the source to prevent the pollution of stormwater runoff discharge from the site. Phase II stormwater discharges include all discharges composed entirely of stormwater, except those specifically classified as Phase I discharge.

The nature of pollutants emanating from differing land uses are very diverse. Stormwater360^{TM}, Inc. has developed a technology for separating and retaining floating and sinking pollutants including sediment, hydrocarbons and debris under rapid flow conditions using a hydrodynamic separator. The system is designed with a circular treatment chamber that promotes a gentle swirling motion to encourage settling pollutants to migrate to the center of the chamber where they are deposited. Floating pollutants are elevated above the bottom of the baffle wall where they collect over time. Between maintenance events, pollutants accumulate within the system and are therefore removed from the natural environment. These pollutants may otherwise become a human health hazard, an aesthetic issue or may be cycled within the food chain or water table even if trapped in a land based treatment system. Maintenance is performed from above by a vacuum truck and without interference from internal components.

General

The VortSentry® Stormwater Treatment System is a hydrodynamic separator designed to enhance gravitational separation of floating and settling materials from stormwater flows (See Figure 1). Stormwater flows enter the unit tangentially to the treatment chamber, which promotes a gentle swirling motion. As stormwater circles the treatment chamber, pollutants migrate toward the center of the unit where velocities are the lowest. Over time a conical pile tends to accumulate in the bottom of the treatment chamber containing sediment and associated metals, nutrients, hydrocarbons and other pollutants. Floating debris, oil and grease form a floating layer trapped in front of the treatment chamber baffle. These accumulated pollutants can be easily accessed through manholes conveniently located over the treatment chamber. Maintenance is typically performed through the manhole over the treatment chamber.

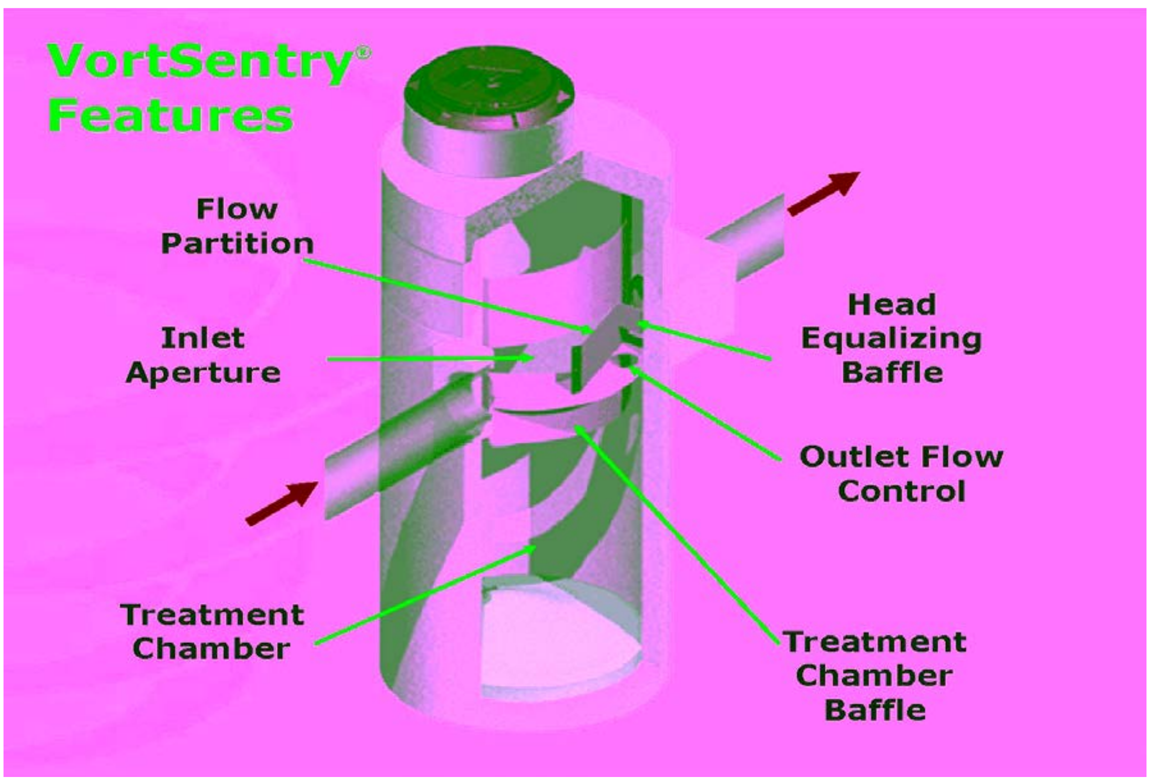

Figure 1. VortSentry® Features

1.3.2 Specific Applicability

The VortSentry® System is well suited to urban stormwater applications due to the following features:

- Laboratory testing has demonstrated that the system is capable of meeting stormwater treatment requirements;
- Below grade installation allows multiple land uses;
- Each system is custom designed to meet the hydraulic demands of site;
- Spill storage and sediment storage volumes can be increased as necessary;
- Technical support is available at no cost before and after the sale;
- There are no expendable or moving parts and a low cleanout volume minimizes operating costs.

The VortSentry® System is a compact, below grade system that is fabricated near the jobsite from concrete and marine grade aluminum. There are six standard precast models available, ranging from three to eight feet in diameter. In some regions VortSentry® systems are available in diameters up to 12 feet, but this is dependant on the capabilities of local precasters. Standard VortSentry® model sizes and dimensions are provided in Table 1.

Table 1. Standard VortSentry® Model Sizes and Dimensions

VortSentry® Model	Treatment Chamber Diameter		Depth (below invert)		Recommended Maximum Inlet / Outlet Pipe Size	
	(ft)	(m)	(ft)	(m)	(in)	(mm)
VS30	3	0.9	5.4	1.7	12	300
VS40	4	1.2	6.5	2.0	18	450
VS50	5	1.5	7.4	2.3	18	450
VS60	6	1.8	8.3	2.5	24	600
VS70	7	2.1	9.1	2.8	30	762
VS80	8	2.4	10.1	3.0	30	762

1.3.3 Range of Contaminant Characteristics

VortSentry® Systems have been shown to capture a wide range of pollutants of concern. These include: trash and debris (including floatables and negatively buoyant debris); total suspended solids; sediments; and oil and grease.

1.3.4 Range of Site Characteristics

Routine operation

Runoff from low intensity precipitation makes up the vast majority of the total annual flow volume from all sites. During low intensity precipitation events, all flow is diverted into the treatment chamber by the flow partition. The flow partition is designed to work in combination with the outlet flow control orifice to submerge the influent pipe during the water quality design storm. The effect of submerging the inlet pipe is to reduce inlet velocity and turbulence by increasing the cross sectional area of the flow path. Removal rates of sediment and floating pollutants are very high during routine operation since turbulence and internal velocities are very low, and residence times are relatively high. See Figure 2 for an illustration of routine VortSentry®operation.

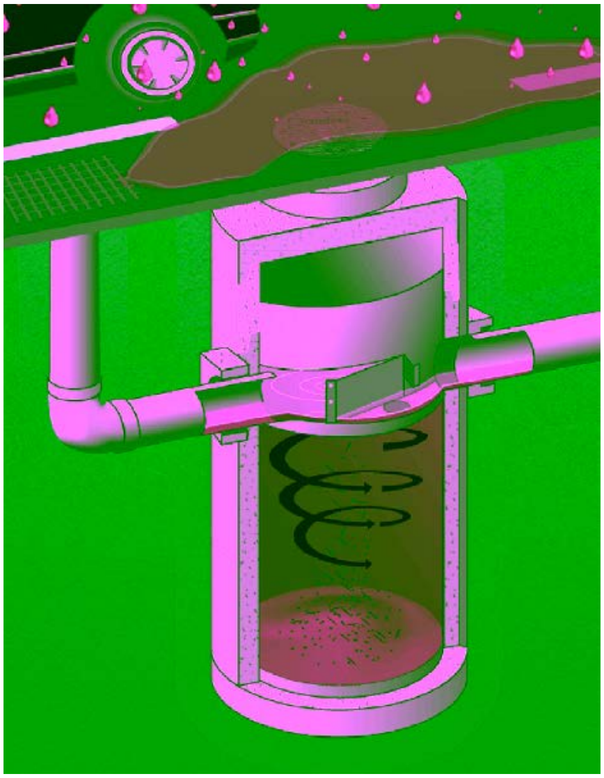

Figure 2. Routine VortSentry® Operation

Moderate intensity operation

As storm intensities and flow rates increase, the operating rate (gpm/ft3) in the VortSentry® also increases proportionally. At flow rates typical of moderate intensity storm events, a portion of flow begins to spill over the flow partition. Partitioning a portion of flow around the treatment chamber keeps velocities low in the treatment chamber. This allows the VortSentry® to continue to remove a high percentage of the pollutants from the runoff flowing through the treatment chamber. Maintaining low velocities in the treatment chamber also prevents scour of previously captured pollutants. The rising water surface elevation within the treatment chamber carries floating contaminants such as trash and oil and grease away from the inlet and above the bottom of the baffle wall. This effectively prevents re-entrainment by separating contaminants from the higher velocity zones within the system. The swirling action increases, which promotes the migration of particles toward the center of the treatment chamber where the particles then form a stable conical pile. See Figure 3 for an illustration of moderate intensity VortSentry® operation.

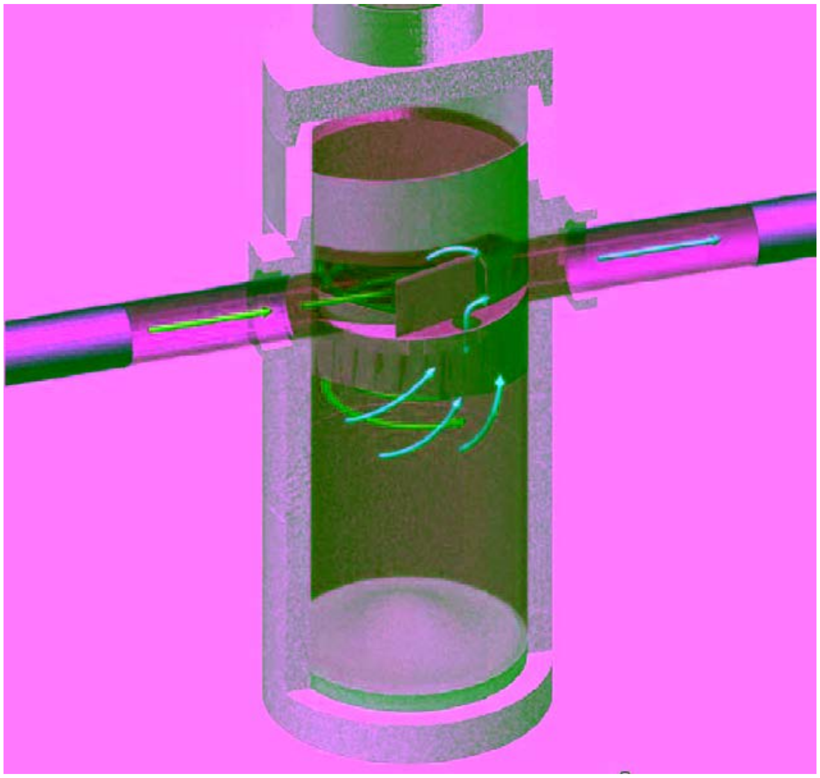

Figure 3. Moderate Intensity VortSentry® Operation

High Intensity Operation

At peak hydraulic capacity, the water surface elevation within the VortSentry® System increases and a substantial portion of the total flow passes over the flow partition submerging the head equalizing baffle. VortSentry® Systems are designed so that peak conveyance rates are representative of storm events such as the 5-yr or 10-yr rain event. Sediment and hydrocarbon removal rates are low, but previously captured materials remain trapped. This is accomplished by increasing the water surface elevation in the treatment chamber to isolate previously captured floatables and by maintaining low flow velocities in the treatment chamber. To accommodate large, infrequent storms, Stormwater360™, Inc. can also assist with the design of an external bypass to route peak-flows around the treatment unit.

Storm subsidence

As a storm subsides, treated runoff continues to flow out of the VortSentry® System through the outlet orifice until the water level returns to the dry-weather volume. This process typically takes several minutes after runoff has ceased.

1.3.5 Material Overview, Handling and Safety

Accumulated pollutants can easily be accessed through the manhole located above the treatment chamber. To clean out the VortSentry® System with a vacuum truck, it is generally most convenient and efficient to clean all captured pollutants including sediment, oil and grease, and floating debris through the manhole over the treatment chamber. Access to the treatment chamber is unrestricted making the vactor operation a simple task. Once the treatment chamber and captured pollutants have been vacuumed from the unit, the manhole cover is simply replaced to complete the maintenance event.

Solids recovered from the VortSentry® System can typically be land filled or disposed of at a wastewater treatment plant. It is possible that there may be some specific land use activities that create contaminated solids, which will be captured in the system. Such material would have to be handled and disposed of in accordance with hazardous waste management requirements.

1.4 Project Description

This project included the evaluation of assembled reports, company manuals, and laboratory testing reports to verify that VortSentry® Systems meet the performance claim of Stormwater360™, Inc.

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2. Evaluation of the Applicant

2.1 Corporate History

Stormwater Management, Inc. and Vortechnics, Inc. united as Stormwater360^{TM}, Inc. in April 2005. The two companies share over 25 years of experience in the stormwater industry. As a combined entity, their goal continues to be preserving and protecting water resources worldwide.

The joint company treats stormwater runoff from commercial, municipal and industrial sites, applying various technologies to address regulatory and customer requirements. Founded in 1988 and based in Scarborough, Maine, Vortechnics built their business on the development of hydrodynamic separation technology. Based in Portland Oregon, Stormwater Management led in the development of filtration technology, introducing a horizontal bed configuration with CSF leaf compost media in 1995.

In state-of-the-art laboratories at both locations, engineers and scientists continue to conduct research to further the understanding of nonpoint source pollution and develop practical product solutions. The parent company of Stormwater360^{TM}, Inc. is Contech Construction Products, Inc., a leading civil engineering site solutions products and services company involved in highway, drainage, sewage, and site-improvement. In 2004, Vortechnics was purchased by Contech; and in April 2005, Contech purchased Stormwater Management.

2.2 Organization and Management

The company Stormwater360^{TM}, Inc. is jointly headquartered in Scarborough, Maine, and Portland, Oregon with 19 regional sales offices throughout the United States and Canada. The management team consists of: David Miley, president and CEO; David Pollock, COO and VP of Sales; Jim Lenhart, Chief Technology Officer; Eric Roach, Chief Financial Officer; Fran Tighe, VP of Marketing; and Tom Gorrivan, National Sales Manager. The company has 23 regional sales managers, who report to Tom Gorrivan and work out of regional offices based in Maine, Maryland, Georgia, Texas, Ohio, California, Washington, Oregon, Wisconsin, Pennsylvania, Massachusetts, Nova Scotia, and Ontario.

2.3 Operating Experience with the Proposed Technology

Stormwater360^{TM}, Inc. has more than 15 years of experience with stormwater technology, and after several years of research and development the VortSentry® was released in 2003. Currently there are more than 300 installations throughout the United States and Canada. Most importantly, the technology is backed by years of full scale laboratory testing and rigorous field testing is ongoing, including third party studies from several universities and organizations.

2.4 Patents

Stormwater360™ has filed for patent protection for the VortSentry® System with the US Patent Office, and a patent is currently pending.

2.5 Technical Resources, Staff and Capital Equipment

Stormwater360™ completes all design work at its corporate headquarters in Scarborough, Maine and Portland, Oregon. Once a system design is complete, shop drawings are issued to a precast concrete contractor local to the installation site. Representatives from each precast company are trained in VortSentry® construction to ensure the details of construction are properly executed. Different contractors may elect to cast the system differently depending on their equipment and construction capabilities. For example, a precaster would have input regarding the details of construction such as how many pieces per system. They would also determine how the joints are formed and what type of lifting equipment is cast in. Stormwater360™, Inc. ultimately reviews all construction and installation decisions made by the precaster.

The VortSentry® System is delivered to the site by the precaster on the day of installation. VortSentry® systems typically arrive on site in three or more pieces and require some assembly. VortSentry® models VS30-VS50 typically do not require the use of a crane for installation. Once delivered to the site by the precaster the contractor is responsible for assembling and sealing the VortSentry® sections. VortSentry® models VS60 and larger typically require a crane for installation and additional sealing of the aluminum components onsite. The site contractor is responsible for making arrangements to have a crane on site, completing excavation prior to delivery and setting the system into the ground. The contractor is also responsible for grouting the inlet and outlet pipe into the VortSentry® System, backfilling around the system and bringing the manhole frames and covers up to grade. Any work required on components inside the system is typically the responsibility of the Stormwater360™ precast contractor. Installation for all model sizes can typically be completed in two to four hours. Heaviest pick weight will be confirmed by Stormwater360™ staff and communicated to the contractor prior to delivery.

Specific installation instructions and requirements are provided. Stormwater360™ tries to have a representative onsite during installation, but occasionally this is not possible. However, support representatives are always available to address questions that may arise during installation.

When the system arrives on site, it is inspected by the contractor. Any damage due to shipping and handling up to that point must be corrected by the precaster. Once the contractor takes delivery of the unit, it is their responsibility to lift it from the truck, place it in the ground, and connect the inlet and outlet pipes and backfill around it. The contractor will perform a final check against the VortSentry® Specification and the site plan before backfilling is initiated. If there are any installation errors at that point, the contractor will fix them and the system will be back filled.

Adjustments for buoyancy issues, calculation of pick weights, and other custom design items are confirmed before delivery. The inlet and outlet are clearly marked to avoid improper installation. It is especially important that the system be set in such a way that the inlet pipe is at a 90 degree angle to the side of the tank to encourage proper treatment chamber flow dynamics. This orientation is checked prior to backfilling the unit since a significantly different influent pipe angle may increase inlet turbulence or cause short-circuiting of the treatment chamber.

VortSentry® Systems are typically available within four to six weeks of shop drawing approval.

3. Treatment System Description

The VortSentry® Stormwater Treatment System was designed to capture a wide range of pollutants from stormwater including: trash and debris (including floatables and negatively buoyant debris); total suspended solids; sediments; and oil and grease. Figure 1 displays a simple schematic of the VortSentry® System. The VortSentry® is a compact, below grade stormwater treatment system that employs vortex technology to enhance gravitational separation of floating and settling pollutants from stormwater flows. The device has no moving parts and is fabricated from concrete and marine grade aluminum. The main components of the system are a flow partition, inlet aperture, head equalizing baffle, treatment chamber, outlet flow control orifice, and treatment chamber baffle. The system is also equipped with a manhole for easy inspection and maintenance access.

During operation, stormwater runoff enters the unit tangentially to promote a gentle swirling motion in the treatment chamber. As polluted water circles within the chamber, settleable solids fall into the sump and are retained. Buoyant debris and oil and grease rise to the surface and are separated from the water as it flows under the baffle wall. Finally, treated water exits the treatment chamber through a flow control orifice located behind the baffle wall.

During low-flow conditions, all runoff is diverted into the treatment chamber by the flow partition. At higher flow rates, a portion of the runoff spills over the flow partition and is diverted around the treatment chamber to prevent re-suspension and washout of previously trapped pollutants. Water that spills over the partition flows into the head equalization chamber above the treatment chamber outlet. As the head equalization chamber fills, the head differential driving flow through the treatment chamber collapses. The result is that flow rates in the treatment chamber remain relatively constant even as total flow rates increase substantially. This configuration further reduces the potential for re-suspension or washout.

There are typically six (6) precast VortSentry® System models available to meet the hydraulic and water quality needs of large and small projects (See Table 1). The VortSentry® Systems have the ability to treat a wide range of flows. In certain regions, larger systems are available to accommodate higher flow rates.

4. Technical Performance Claim

Claim - The VortSentry® Stormwater Treatment System, Model VS40, sized at a loading rate of 9.8 gpm/ft^3 (0.022cfs/ft^3) of treatment volume, has been shown to have a 69% total suspended solids (TSS) removal efficiency, as measured as suspended solids concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency) for F-95 silica sand with an average d_{50} particle size of 120 microns, an average influent concentration of 209 mg/L and 50% initial sediment loading in laboratory studies using simulated stormwater.

5. Treatment System Performance

The VortSentry® System has been tested at the Stormwater360™, Inc. full-scale hydraulic laboratory. The laboratory tests were completed using F-95, a commercially available silica sand gradation. The particle size distribution is shown in Figure 4. Tests were performed with sediment influent concentrations ranging from 88 to 521 mg/l at operating rates from 0.27 to 1.35 cfs. In addition to specific testing, Stormwater360™, Inc. has developed the Rational Rainfall Method™, a model that estimates long term field performance based on site information, local precipitation patterns and laboratory performance data. The VortSentry® System is currently being tested in the field by Stormwater360™, Inc. staff as well as by independent researchers.

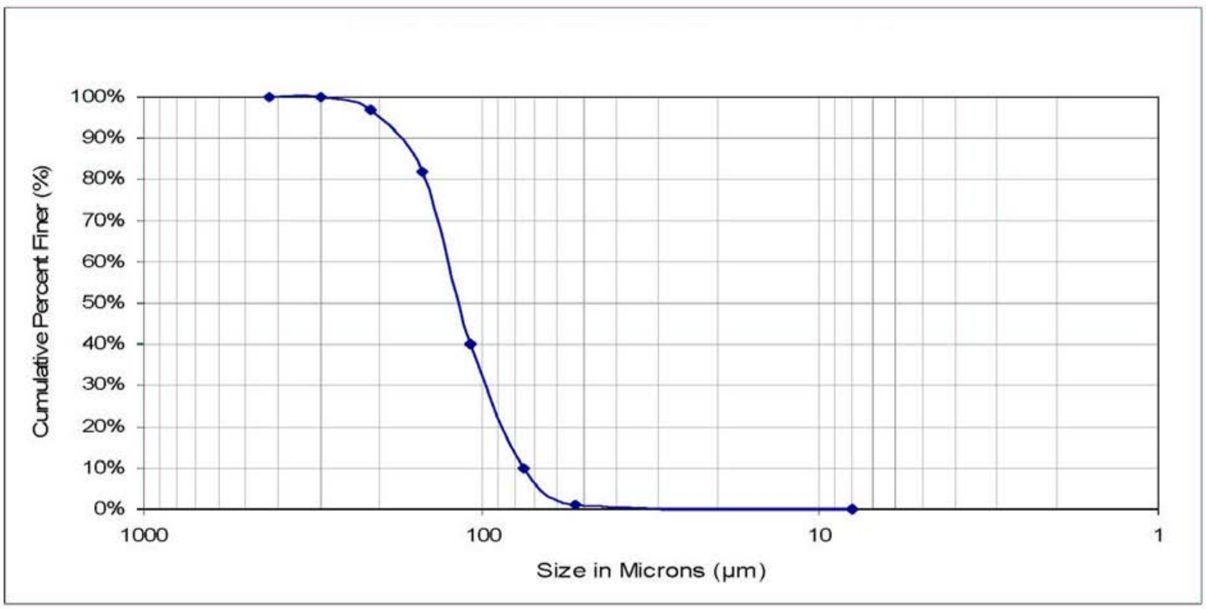

Figure 4. US Silica F-95 Particle Size Distribution

5.1 NJDEP Recommended TSS Laboratory Testing Procedure

Stormwater360™, Inc. designed their laboratory testing to comply with NJDEP's recommended TSS Laboratory Testing Procedure; the NJDEP testing procedure is presented herein. The NJDEP has prepared a Total Suspended Solids Laboratory Testing Procedure to help guide vendors as they prepare to test their stormwater treatment systems prior to applying for NJCAT verification.

The Testing Procedure has three components:

1. Particle size distribution

2. Full scale laboratory testing requirements
3. Measuring treatment efficiency

1. Particle size distribution:

The following particle size distribution was utilized to evaluate a manufactured treatment system (See Table 2). A natural/commercial soil representing the USDA definition of a sandy loam material was used. This hypothetical distribution was selected as it represents the various particles that would be associated with typical stormwater runoff from a post construction site.

Specifically, the following distribution can be utilized:

Table 2. Particle Size Distribution

Particle Size (microns)	**Sandy loam (percent by mass)**
500-1000 (coarse sand)	5.0
250-500 (medium sand)	5.0
100-250 (fine sand)	30.0
50-100 (very fine sand)	15.0
2-50 (silt)	(8-50 um, 25%) (2-8 um, 15%)*
1-2 (clay)	5.0

Notes:

1. Recommended density of particles ≤2.65 g/cm3

*The 8 um diameter is the boundary between very fine silt and fine silt according to the definition of American Geophysical Union. The reference for this division/classification is: Lane, E. W., et al. (1947), "Report of the Subcommittee on Sediment Terminology," Transactions of the American Geophysical Union, Vol. 28, No. 6, pp. 936-938.

2. Full scale lab test requirements
   A. At a minimum, complete a total of 15 test runs including three (3) tests each at a constant flow rate of 25, 50, 75, 100, and 125 percent of the treatment flow rate. These tests should be operated with initial sediment loading of 50% of the unit's capture capacity.
   B. The three tests for each treatment flow rate will be conducted for influent concentrations of 100, 200, and 300 mg/L.
   C. For an online system, complete two tests at the maximum hydraulic operating rate. Utilizing clean water, the tests will be operated with initial sediment loading at 50% and 100% of the unit's capture capacity. These tests will be utilized to check the potential for TSS resuspension and washout.
   D. The test runs should be conducted at a temperature between 73-79 degrees Fahrenheit or colder.

3. Measuring treatment efficiency
   A. Calculate the individual removal efficiency for the 15 test runs.
   B. Average the three test runs for each operating rate.

C. The average percent removal efficiency will then be multiplied by a specified weight factor (see Table 3) for that particular operating rate.
D. The results of the five numbers will then be summed to obtain the theoretical annual TSS load removal efficiency of the system.

Table 3. Treatment Operating Rates and Weight Factors

Treatment operating rate	Weight factor
25%	.25
50%	.30
75%	.20
100%	.15
125%	.10

Notes:

Weight factors were based upon the average annual distribution of runoff volumes in New Jersey and the assumed similarity with the distribution of runoff peaks. This runoff volume distribution was based upon accepted computation methods for small storm hydrology and a statistical analysis of 52 years of daily rainfall data at 92 rainfall gages.

5.2 Laboratory Studies

In June of 2005, Stormwater360™ initiated a VortSentry® laboratory testing program in accordance with the New Jersey Department of Environmental Protection's (NJDEP) Total Suspended Solids Laboratory Test Procedure. All testing was conducted in the Stormwater360™ laboratory in Scarborough, ME on a full scale 4-ft diameter VortSentry® model VS40. The ultimate objective of the testing program was to provide a sufficient body of performance data to warrant an interim certification from the NJDEP. In order to comply with the requirements of the NJDEP testing protocol and to provide a data set that is comparable to the data sets of other stormwater treatment technologies that have completed the Tier I testing program, Stormwater360™ modeled its VortSentry® test plan to be consistent with the test plans for other technologies that have participated in the Tier I testing program.

All testing was conducted using F-95, a commercially available silica sand gradation (See Figure 4). Sediment was mixed with tap water in a 55-gallon recirculating slurry bin. A peristaltic pump was utilized to meter the slurry mixture into the influent line upstream of the test apparatus at a known rate.

Influent samples were collected at a 6-inch gate valve located upstream of the VortSentry® System. Effluent samples were collected by sweeping a sample bottle through the free discharge of a down-turned 90° PVC elbow, which discharges into a catch tank downstream of the VortSentry® System. All samples were collected in 500 ml HDPE sample bottles. Once the system was stabilized at the desired flow rate the metering pump was activated, starting the delivery of sediment to the VortSentry® System. Once sediment introduction was initiated, the system was run for a period of time equal to three times the detention time of the system before the first samples were collected. This allows the system to reach equilibrium. After three detention times have passed, a series of ten paired influent and effluent samples were taken at one minute intervals. Effluent samples were staggered from influent samples by the detention time of the test unit. Once ten influent and effluent samples were collected, the system was shut down. Sediment was not removed from the test system after each test effectively allowing additional sediment to accumulate within the treatment chamber sump.

To reduce recirculation of material within the test system, a silt fence was constructed in the catch tank to filter the effluent before it was pumped back to the water supply tank. Background samples were drawn from the water supply tank using a GLI Automatic Vacuum Sampler to monitor the sediment concentration in the source water. If the mean sediment concentration in the source water exceeded 10 mg/l during a test, the water supply tank was drained and cleaned, and the test was then repeated.

5.2.1 Performance Testing Procedure

1. Prior to the start of each test, the VortSentry® System was filled to 50% of its sediment capture depth (1.5ft) with F-95 sediment.
2. A sediment/water slurry was prepared in a ratio of 1.25 lb of sediment/gallon of water in the slurry mixer.
3. Adequate mixing was ensured by starting the slurry mixture at least five minutes before the start of the sediment metering pump.
4. The inlet flow control valve was opened and the flow rate through the VortSentry® System was stabilized at the target flow rate. The system was considered stable when the flow rate remained stable for approximately one minute.
5. The metering pump was started at the target rpm rate (rate required to produce target influent concentration). This was time 0:00.
6. After three detention times, the first background sample was collected. Background samples were collected at a one minute interval for the duration of the test.
7. One minute after the first background sample was taken, the first influent sample was collected. Influent samples were collected at one minute intervals until ten samples are taken.

   Note: Immediately before each influent sample was taken, the gate valve was flushed by quickly opening and closing it. This cleared any settled material from the mouth of the valve.
8. One detention time after the first influent sample was taken, the first effluent sample was collected.
9. Effluent samples were collected at a one minute interval until ten samples were taken.
10. After ten influent and effluent samples were collected, the metering pump and slurry tank mixer were stopped.
11. The background sampler was then stopped.
12. The VortSentry® System was shut down.

5.2.2 Washout Testing Procedure

Upon completion of the required performance testing, two washout trials were conducted to determine the potential for material to be scoured from the VortSentry® System. The first trial was conducted with the VortSentry® model VS40 filled to 50% (19 ft^3) of its sediment capture volume with F-95. The second trial was conducted with the VortSentry® System filled to 100% (38 ft^3) of its sediment capture volume. Both of these trials were conducted at the system's peak hydraulic capacity. Both trials were conducted with clean water. No sediment was injected into the influent stream. Upon start up, the system was brought to its peak operating capacity. Effluent sampling was started as soon as flow was introduced to the unit and continued in 30-second intervals until the conclusion of the test. Sampling before the unit had reached its hydraulic capacity was allowed for documentation of any material that was scoured before the VortSentry® System reaches hydraulic capacity. Once the system had reached hydraulic capacity, sampling continued in 30 second intervals for five minutes. Given the relatively short detention time of the unit under peak operating conditions, this was ample time to determine the unit's scour potential.

5.2.3 Sample Analysis

Sample analysis was conducted at the Stormwater360™, Inc. laboratory by trained laboratory technicians. Samples were analyzed in compliance with ASTM D 3977-97 a whole sample variation of the TSS method, also referred to as the suspended sediment concentration (SSC) method.

5.2.4 Description of Laboratory Testing Facility

All VortSentry® System performance testing was conducted at the Stormwater360™, Inc. research laboratory in Scarborough, Maine. Water was stored in a 5,600 gallon supply tank and delivered to the VortSentry® System through a gravity fed 12-inch diameter PVC pipe. Flow through the pipe was regulated by a 12 inch butterfly valve located upstream of the VortSentry® System. A 1/3 horse power Dayton split phase motor was used to mix sediment and water into a slurry in a 55 gallon conical bottom mixing bin. The slurry was then metered into the 12 inch PVC pipe just downstream of the butterfly valve with a Watson Marlow peristaltic pump. The conical bottom slurry tank was equipped with an under drain which remained open during the test to allow the slurry to be continuously recirculated within the bin with a Randolph Model 750 peristaltic pump. Influent samples were collected through a 6 inch PVC gate valve located directly downstream of the sediment metering port. Flow was monitored with an ISCO 4250 Area Velocity flow meter that was installed in the influent pipe. Effluent discharged from a down turned 12 inch PVC elbow into an aluminum catch tank. A silt fence, consisting of standard landscaping fabric mounted to a frame, was installed in the catch tank to filter effluent before it was recirculated to the water supply tank. Two ten horsepower Zoeller sewage pumps returned flow from the catch tank to the supply tank. The layout of the VortSentry® System test setup is shown in Figure 5.

5.2.5 Laboratory Testing Results

Results of the 15 individual tests conducted in accordance with the NJDEP laboratory testing protocol are summarized in Table 4. The target flow rate for each test was determined assuming the target treatment flow rate was 1.1 cfs. The target treatment flow rate was identified through preliminary testing to gauge system performance. The actual flow rate as reported in Table 4 represents the mean flow rate measured during each test. The removal efficiency reported for each test represents the mean suspended solids load reduction for that test and is calculated using the following equation:

Removal Efficiency = (Influent Conc. – Effluent Conc.) / Influent Conc.

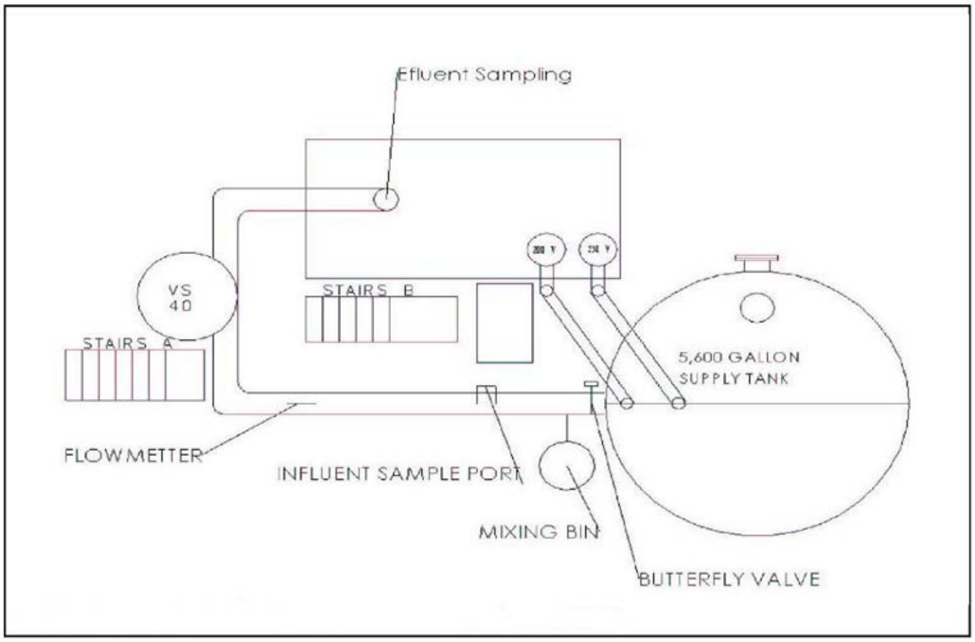

Figure 5. Laboratory Testing Facility for the VortSentry® System

Table 4. Summary of VortSentry® Laboratory Testing Results with F-95 Grade Silica

Test Number	Percent of Treatment Flow (%)	Target Flow Rate (cfs)	Target Conc. (mg/l)	Actual Flow Rate (cfs)	Influent Conc. (mg/l)	Effluent Conc. (mg/l)	Removal Efficiency (%)
1	25	0.27	100	0.27	88	6	93
2	25	0.27	200	0.27	200	12	94
3	25	0.27	300	0.26	266	13	95
4	50	0.55	100	0.56	92	23	75
5	50	0.55	200	0.54	219	60	73
6	50	0.55	300	0.54	521	121	77
7	75	0.82	100	0.84	130	44	66
8	75	0.82	200	0.83	142	53	63
9	75	0.82	300	0.81	304	122	60
10	100	1.10	100	1.11	95	49	48
11	100	1.10	200	1.10	167	80	52
12	100	1.10	300	1.09	277	164	41
13	125	1.35	100	1.35	137	102	26
14	125	1.35	200	1.24	233	163	30
15	125	1.35	300	1.35	263	179	32

5.2.6 Washout Testing Results

As required by the NJDEP laboratory testing protocol, a washout analysis was conducted at both 50 and 100 percent of the VortSentry® System sediment storage capacity. The protocol required each trial to be conducted at the maximum hydraulic operating rate of the unit. Due to the driving head limitations of the water supply tank in the laboratory, the maximum hydraulic operating rate for the model VS40 VortSentry® System was approximately 1.8 cfs. A VortSentry® model VS40 can be configured with additional hydraulic capacity, but this additional flow was directed over the flow partition and did not significantly impact the flow rate or velocity of flow through the treatment chamber. By limiting the flow rate and velocity through the treatment chamber, resuspension of previously captured material is unlikely.

The mean flow rate for the washout tests at both 50 and 100 percent of sediment storage capacity was 1.77 cfs. Results for both tests are shown in Table 5. During both tests the sediment concentration in the source water was monitored and subtracted from the VortSentry® System effluent concentration. Solids in the source water are typically attributable to recirculation of material during previous tests. With the sump filled to 50 percent of the VortSentry® System sediment storage capacity (1.5 feet), no washout was observed. The mean effluent concentration for suspended solids was less then the mean background concentration indicating a net removal of solids from the source water as it passed through the VortSentry® System. With the sump filled to 100 percent of the VortSentry® System sediment storage capacity (three feet), minimal washout was observed. The mean effluent concentration for suspended solids was slightly higher then the mean background concentration indicating a small amount of material was exported from the system. The mean effluent solids concentration after accounting for background solids was 8 mg/l, which is quite low; fine particles were present in the F-95 stock as a result of manufacture and handling. Most of the sediment was manually loaded into the VortSentry® System for this testing as opposed to being captured by the unit, so it is likely that residual fine material that would not typically be present in the sump was subsequently lost from the unit.

Table 5. Results of Washout Testing at 50% and 100% of the VortSentry® Sediment Storage Capacity

	Average Background Concentration (mg/l)	Average Effluent Concentration (mg/l)	Mean Adjusted Effluent Concentration (mg/l)
50% of sediment storage capacity (1.5 ft)	8	5	-3
100% of sediment storage capacity (3 ft)	5	14	8

5.3 Verification Procedures

All the data provided to NJCAT were reviewed to fully understand the capabilities of the VortSentry® System. To verify the Stormwater360™, Inc. claim, the laboratory data were reviewed and compared to the NJDEP Laboratory Testing Protocol. Although Stormwater360™, Inc. attempted to design their laboratory experiment to satisfy the NJDEP TSS laboratory testing protocol, there are two distinct differences between Stormwater360™, Inc. laboratory testing and the NJDEP protocol. The NJDEP protocol is for total suspended solids (TSS) laboratory testing, while Stormwater360™, Inc. analyzed their samples as suspended sediment concentration (SSC). Also, the d_{50} of the NJDEP recommended sediment is approximately 67 microns, while the d_{50} of the F-95 silica used in the Stormwater360™, Inc. laboratory testing was 120 microns.

The NJDEP weighting factors were used with the laboratory data that were presented in Table 4. The resulting overall removal efficiency based upon the NJDEP methodology is presented below in Table 6.

Since the treatment volume of the VS40 system is 50 ft^3, the tested flow rate of 1.1 cfs can be converted to 9.8 gpm/ft^3(0.022 cfs/ft^3). Based upon the data presented in Table 6, the removal efficiency of the system is 69%, thereby verifying the Stormwater360™, Inc. claim.

Based upon the wash out laboratory data presented by Stormwater360™, Inc., there is virtually no potential of re-suspension and wash out of sediment contained in the VortSentry® System.

Table 6. Weighted Removal Efficiency for the VortSentry® System

Percent of Treatment Flow Rate (%)	Target VS40 Flow Rate (cfs)	Removal Efficiency (%)	Weight factor	Weighted Removal Efficiency (%)
25	0.27	94	0.25	24
50	0.55	75	0.30	22
75	0.82	63	0.20	13
100	1.10	47	0.15	7
125	1.35	29	0.10	3
Weighted Removal Efficiency =				**69**

5.3.1 Verified Treatment Flow

In order to appropriately scale any hydraulic structure, there must be similitude between the proposed model and the tested laboratory prototype. Geometric similitude is achieved by maintaining a constant aspect ratio of 0.9 for all models. For modeling purposes, the treatment depth is considered to be the distance from the top of the flow partition to the top of the 3' deep storage sump.

It has been shown in the laboratory that VortSentry® removal rates are dependent on the volumetric operating rate. Therefore, treatment flow rates for models other than the tested unit have been calculated which provide the same volumetric operating rate of 9.8 gpm/ft^3 (0.022 cfs/ft^3). Table 7 shows these peak treatment flow rate for each VortSentry® model.

Table 7. VortSentry Treatment Flows Assuming Volumetric Scaling

Model Number	Diameter (ft)	Treatment Volume (ft^3)	Treatment Flow Rate		Operating Rate	
			(cfs)	(gpm)	(cfs/ft^3)	(gpm/ft^3)
VS30	3	21	0.46	207	0.022	9.8
VS40	4	50	1.1	494	0.022	9.8
VS50	5	98	2.15	965	0.022	9.8
VS60	6	170	3.71	1,665	0.022	9.8
VS70	7	269	5.90	2,648	0.022	9.8
VS80	8	402	8.80	3,950	0.022	9.8
VS100*	10*	785	17.19	7,715	0.022	9.8
VS120*	12*	1,357	29.70	13,330	0.022	9.8

* 10 and 12 ft. diameter units are not available in all markets.

5.4 Inspection and Maintenance

The VortSentry® System requires minimal routine maintenance. However, it is important that the system be inspected at regular intervals and cleaned when necessary to ensure optimum performance. The rate at which the system collects pollutants will depend more on site activities than the size of the unit (i.e., heavy winter sanding will cause the treatment chamber to fill more quickly but regular sweeping will slow accumulation).

5.4.1 Inspection

Inspection is the key to effective maintenance, and it is easily performed. Stormwater360™, Inc. recommends ongoing quarterly inspections of accumulated pollutants. Sediment accumulation may be especially variable during the first year after installation as catch basin sumps are filled and as construction disturbances and landscaping stabilize. Quarterly inspections are typically sufficient to ensure that systems are cleaned out at the appropriate time. Inspections may need to be performed more often in the winter months in climates where sanding operations may lead to rapid accumulations or in other areas with heavy sediment loading. It is very useful to keep a record of each inspection.

The VortSentry® System should be cleaned when inspection reveals that the sediment depth has accumulated to three feet in the treatment chamber sump. This determination can be made by taking two measurements with a stadia rod or similar measuring device. One measurement should be taken from the manhole opening to the top of the sediment pile and the other from the manhole opening to the water surface. The system should be cleaned out if the difference between the two measurements is three feet or more.

Note: To avoid underestimating the volume of sediment in the chamber, the measuring device must be lowered to the top of the sediment pile carefully. Finer, silty particles at the top of the pile may offer less resistance to the end of the rod than larger particles toward the bottom of the pile.

5.4.2 Maintenance

Maintaining the VortSentry® System is easiest when there is no flow entering the system. For this reason it is a good idea to schedule the cleanout during dry weather. Cleanout of the VortSentry® System with a vacuum truck is generally the most effective and convenient method of excavating pollutants from the system. If such a truck is not available, a "clamshell" grab may be used, but it is difficult to remove all accumulated pollutants with these devices.

Accumulated sediment is typically evacuated through the manhole over the treatment chamber. Simply remove the cover and insert the vacuum hose into the treatment chamber. All contents of the treatment chamber should be removed with the vacuum hose. The treatment chamber will contain a combination of liquid, sediment, floating debris, and oil and grease.

Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use adsorbent pads since they are usually cheaper to dispose of than the oil water emulsion that may be created by vacuuming the oily layer. In VortSentry® System installations where there is little risk of petroleum spills, liquid contaminants may not accumulate as quickly as sediment. However, any oil or gasoline spill should be cleaned out immediately. Trash can be netted out if it needs to be separated from the other pollutants.

Manhole covers should be securely seated following cleaning activities, to ensure that surface runoff does not leak into the unit from above.

5.4.3 Solids Disposal

Solids recovered from the VortSentry® System can typically be land filled or disposed of at a wastewater treatment plant, but local regulations will ultimately govern disposal procedures.

5.4.4 Damage Due to Lack of Maintenance

It is unlikely that the VortSentry® System will become damaged due to lack of maintenance since there are no fragile internal parts. However, adhering to a regular maintenance plan ensures optimal performance of the system.

6. Technical Evaluation Analysis

6.1 Verification of Performance Claim

Based on the evaluation of the results from laboratory studies, sufficient data is available to support the Stormwater360™, Inc. claim: The VortSentry® Stormwater Treatment System, Model VS40, sized at a loading rate of 9.8 gpm/ft^3 (0.022cfs/ft^3) of treatment volume, has been shown to have a 69% total suspended solids (TSS) removal efficiency, as measured as suspended solids concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency) for F-95 silica sand with an average d_{50} particle size of 120 microns, an average influent concentration of 209 mg/L and 50% initial sediment loading in laboratory studies using simulated stormwater.

6.2 Limitations

6.2.1 Factors Causing Under-Performance

If the VortSentry® System is designed and installed correctly, there is minimal possibility of failure. There are no moving parts to bind or break, nor are there parts that are particularly susceptible to wear or corrosion. Lack of maintenance may cause the system to operate at a reduced efficiency, and it is possible that eventually the system will become totally plugged with sediment.

6.2.2 Pollutant Transformation and Release

The VortSentry® System will not increase the net pollutant load to the downstream environment. However, pollutants may be transformed within the unit. For example, organic matter may decompose and release nitrogen in the form of nitrogen gas or nitrate. These processes are similar to those in wetlands but probably occur at slower rates in the VortSentry® System due to the absence of light and mixing by wind, thermal inputs and biological activity. Accumulated sediment will not be lost from the system under normal operating conditions.

6.2.3 Sensitivity to Heavy or Fine Sediment Loading

The VortSentry® System requires no pretreatment. Heavy loads of sediment will increase the needed maintenance frequency but will not negatively affect overall performance.

6.2.4 Bypass Flow

The VortSentry® System is typically designed such that a portion of the total conveyance flow through the system is bypassed around the treatment chamber. Flow rates exceeding the treatment capacity of the system are typically routed around the treatment chamber over the flow partition.

6.2.5 Mosquitoes

The VortSentry® System design incorporates standing water in the treatment chamber sump, which can be a breeding site for mosquitoes. To address this potential problem Stormwater360™ sells an optional manhole cover insert that allows outgassing but will prevent mosquitoes from entering the system through the manhole covers. A flap valve can be installed at the terminal end of the outlet pipe to prevent mosquitoes from entering the unit from the downstream side.

7. Net Environmental Benefit

The NJDEP encourages the development of innovative environmental technologies (IET) and has established a performance partnership between their verification/certification process and NJCAT's third party independent technology verification program. The NJDEP, in the IET data and technology verification/certification process, will work with any company that can demonstrate a net beneficial effect (NBE) irrespective of the operational status, class or stage of an IET. The NBE is calculated as a mass balance of the IET in terms of its inputs of raw materials, water and energy use and its outputs of air emissions, wastewater discharges, and solid waste residues. Overall the IET should demonstrate a significant reduction of the impacts to the environment when compared to baseline conditions for the same or equivalent inputs and outputs.

Once VortSentry® Systems have been certified for interim use within New Jersey, Stormwater360™, Inc. will then proceed to install and monitor systems in the field for the purpose of achieving goals set by the Tier II Protocol and final certification. At that time, a net environmental benefit evaluation will be completed. However, it should be noted that the Stormwater360™, Inc. technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

8. References

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