NJCAT TECHNOLOGY VERIFICATION

VORTECHNICS, INC.

MAY 4, 2004

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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, 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 November 2003, Vortechnics, Inc., 200 Enterprise Drive, Scarborough, ME, 04074 submitted a formal request for participation in the NJCAT Technology Verification Program. The technology proposed – The Vortechs® Stormwater Treatment System – is a patented hydrodynamic separator designed to enhance gravitational separation of floating and settling materials from stormwater flows. The system was developed in Scarborough, Maine in 1988, 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, oils and greases, 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 claims of the vendor, Vortechnics Inc. (see Section 4). The verification report differs from typical NJCAT verification reports in that final verification of the Vortechs® 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 Vortechnics 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.

A number of telephone discussions and email exchanges were conducted to solicit relevant materials and to refine specific claims from the vendor. This project included the evaluation of assembled reports, conference proceedings, company manuals, literature and a CD, and laboratory testing reports to verify that the Vortechs® System meets the performance claims of Vortechnics Inc.

1.3 Technology Description

1.3.1 Technology Status: general description including elements of innovation/uniqueness/ competitive advantage.

In 1990 Congress established deadlines and priorities for EPA to require permits for discharges of stormwater that is 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. Vortechnics 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 grit 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 vacuum truck and without interference from internal components.

General

The Vortechs® Stormwater Treatment System is a hydrodynamic separator designed to enhance gravitational separation of floating and settling materials from stormwater flows. Stormwater flows enter the unit tangentially to the grit chamber, which promotes a gentle swirling motion. As stormwater circles the grit chamber, pollutants migrate toward the center of the unit where velocities are the lowest. The majority of settlable solids are left behind as stormwater exits the grit chamber via two apertures on the perimeter of the chamber. Next, buoyant debris, oil and grease are separated from water as it flows under the baffle wall. Stormwater then exits the system through the flow control wall and ultimately through the outlet pipe. At this point it is relatively free of floating and settling pollutants.

Over time a conical pile tends to accumulate in the center of the unit containing sediment and associated metals, nutrients, hydrocarbons and other pollutants. Floating debris, oil and grease form a floating layer trapped in front of the baffle wall. These accumulated pollutants can be easily accessed through manholes conveniently located over each chamber. Maintenance is typically performed through the manhole over the grit chamber.

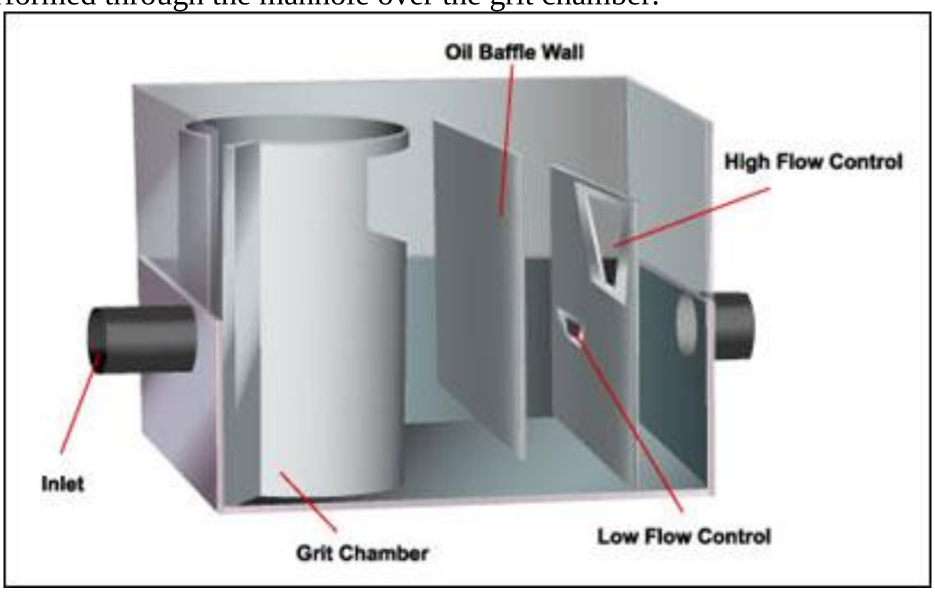


Figure 1

1.3.2 Specific Applicability

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

- Independent studies have shown that the system is capable in some cases of reducing the net total suspended solids load exported from a site by 80 percent or more.
- Infrequent flow rates can be treated without bypassing the System due to high treatment capacities.
- Below grade installation allows multiple land uses.
- Each system is custom designed to meet hydraulic demands of the site.
- Spill storage and sediment storage volumes can be increased as necessary.
- Technical support is available at no cost before and after the sale.
- No expendable or moving parts and a low cleanout volume minimize operating costs.

The Vortechs® System is a compact, below grade system that is fabricated near the jobsite from concrete and marine grade aluminum. There are nine standard precast models available, treating flow rates up to 25 cfs (11,310 gpm). Larger models can be cast in place to provide treatment of higher flows. Standard sizes are listed in Table 1.

Vortechs® Model	Grit Chamber Diam./Area (ft/ft^2)	Peak Design Flow cfs (gpm)	Sediment Storage (yd)	Approx. Size L x W (ft)
1000	3/7	1.6 (724)	0.75	9 x 3
2000	4/13	2.8 (1,267)	1.25	10 x 4
3000	5/20	4.5 (2,036)	1.75	11 x 5
4000	6/28	6.0 (2,714)	2.5	12 x 6
5000	7/38	8.5 (3,845)	3.25	13 x 7
7000	8/50	11.0 (4,976)	4.0	14 x 8
9000	9/64	14.0 (6,334)	4.75	15 x 9
11000	10/79	17.5 (7,917)	5.5	16 x 10
16000	12/113	25.0 (11,310)	7.0	18 x 12

Table 1

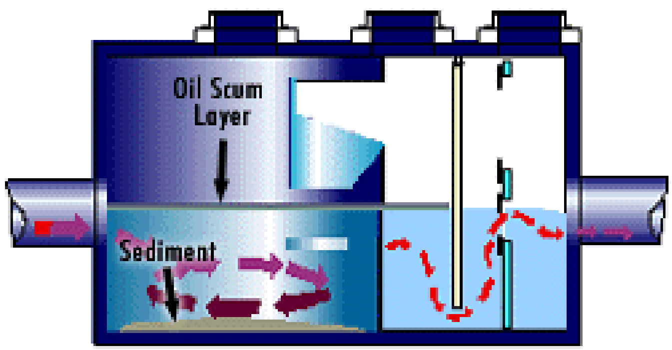
1.3.3 Range of Contaminant Characteristics

Vortechs® 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

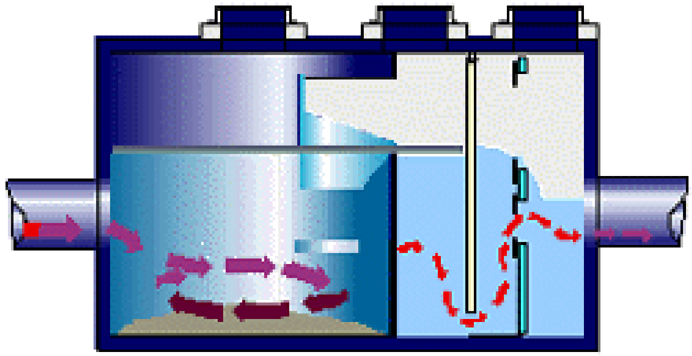
Routine operation

Runoff from low intensity precipitation makes up the vast majority of the total annual flow from all sites. The lower flow control, commonly referred to as the orifice, is designed to pass 20 percent of the system capacity with the water surface elevation at the crown of the inlet pipe. The effect of submerging the inlet pipe is to reduce inlet velocity and turbulence by increasing the cross sectional area of the flow path. Detention times during routine operation are typically longer than four minutes. Removal rates of sediment and floating pollutants are very high during this time since turbulence and internal velocities are very low. In off-line configurations, bypass is not allowed to begin at less than 20 percent of capacity.



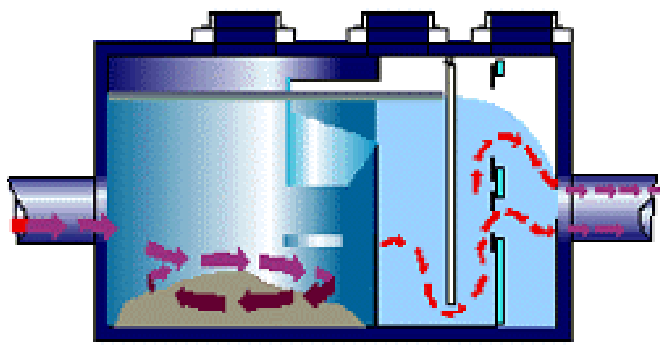
Moderate intensity operation

As storm intensities and flow rates increase, the operating rate (gpm/ft^2) in the Vortechs® System also increases proportionally. As the inflow rates exceed the capacity of the low flow orifice, water begins to spill over the high flow control weir. The rising water surface elevation within the tank carries floating contaminants such as trash, oil and grease away from the inlet pipe and above the bottom of the baffle wall. This effectively prevents re-entrainment by separating contaminants from the higher velocity zones within the system. At these operating rates, between 20 percent and 70 percent of capacity, coarser influent sediment is removed efficiently, and previously captured fine sediment remains trapped in the grit chamber. The swirling action increases, which promotes the migration of particles toward the center of the grit chamber where they then form a stable conical pile. During an event of this magnitude, it is important to limit the amount of flow that is bypassed since velocities through the collection system may scour catch basins and other upstream areas where sediment has accumulated during routine flows. These larger materials are likely to be captured by the Vortechs® System.



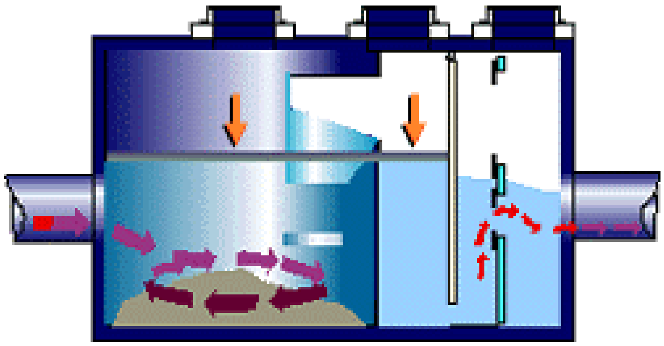
Full capacity

At peak treatment capacity the water surface elevation within the Vortechs® System is at the crown of the high flow weir. These operating rates are seen very infrequently. Sediment and hydrocarbon removal rates are low, but previously captured materials remain trapped. This is accomplished by increasing the water surface elevation in the system to increase residence times and decrease turbulence. To accommodate large, infrequent storms, Vortechnics can assist with the design of a bypass to route peak-flows around the unit.



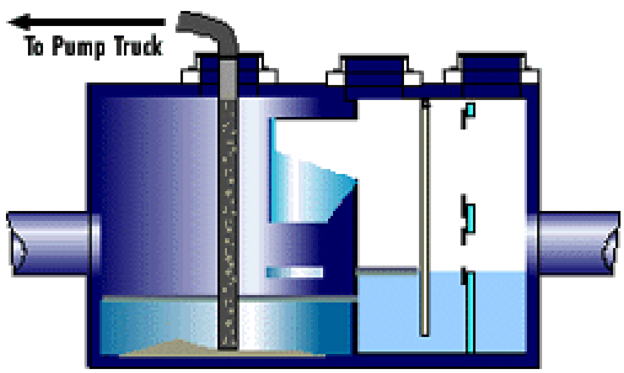
Storm subsidence

As a storm subsides, treated runoff is decanted out of the Vortechs® System through the flow controls, restoring the water level to a low dry-weather volume. Accumulated pollutants can easily be observed through the access manhole located above the grit chamber. The low resting water level reduces maintenance costs by reducing the overall pump-out volume.



1.3.5 Material Overview, Handling and Safety

To clean out the Vortechs® System, a vacuum truck is generally the most convenient and efficient method. Only the manhole cover above the grit chamber needs to be accessed to remove pollutants trapped there. The grit chamber is sealed around the bottom and sides, so when it is emptied, oily liquids and floatable debris within the oil chamber decant into the grit chamber and thus, can be removed along with accumulated sediment and debris. This water lock feature reduces pump out volumes and ensures that the bottom of the baffle wall always remains submerged, preventing the transfer of floatables to the outlet during cleaning or during the next storm.



Solids recovered from the Vortechs® System can typically be land filled or disposed of at a waste water 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, conference proceedings, company manuals, literature and a CD, and laboratory testing reports to verify that Vortechs® Systems meet the performance claims of Vortechnics Inc.

1.5 Key Contacts

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2. Evaluation of the Applicant

2.1 Corporate History

Founded in 1988 and based in Scarborough, Maine, Vortechnics has built its business on the development of stormwater treatment products, including its flagship product the Vortechs® System, an award-winning hydrodynamic separator for the treatment of contaminated stormwater flows. Thomas Adams an engineer from Portland, Maine, launched the privately held company to market his two product inventions, the Vortechs® System and the hydro-brake. In 1993, Adams met David Miley, now CEO of Vortechnics, and Francis Tighe, now Vice President of Business Development, and demonstrated the engineering behind his two products. Miley and Tighe, intrigued by the possibilities of the Vortechs® System in particular, proposed to Adams that they partner to bring the system to market. In exchange for equity in the company, Tighe and Miley provided unsalaried "sweat equity" for two years, working to bring the system to market.

Tighe and Miley, both of whom had backgrounds in construction, engineering and most importantly starting up businesses, worked with Adams to install the first Vortechs® Systems into projects in New England. The initial business concept was to license the Vortechs® technology to concrete precasters, who would sell the products to site and excavating contractors. Using this model, some of the first Vortechs® Systems were installed at the Cole Haan headquarters in Yarmouth and an L.L. Bean facility in Freeport.

Within a year, it was clear to Miley and Tighe that key to growing the business was cultivating relationships with specifying engineers and stormwater regulators. Concrete precasters did not have the relationships needed with these decision-makers. Miley and Tighe decided to build the team internally to generate and support sales. In early 1995, they began hiring engineers to drive sales and production and invest in the marketing of the business.

Meanwhile, the company was also building its first in-house lab, which allowed it to do full-scale testing of stormwater treatment systems. In a nascent industry, this type of commitment to research and development was unprecedented. In 1997, Vortechnics won its first of three environmental technology awards, the New England Environmental Award, for significant contributions to the improvement of the quality of the environment. Vortechnics expanded its lab to include three separate full-scale test facilities.

In 1998, the company saw its third straight year of 60% growth, and won two more honors, this time a finalist in the CERF Charles Pankow Award for Innovation and an EPA Environmental Technology Innovator Award both in recognition of the Vortechs® System's contribution to protecting the nation's water resources. By then the sales team had grown into five regional offices and Vortechnics products were being installed around the country, with sales still largely driven by the flagship Vortechs® System. The company opened an office in Canada in 2000. The increasing rollout of NPDES into Phase II cities (those with less than 50,000 population), continued to drive sales to $10 million in 2001.

In January 2002, Vortechnics signed a sales representative agreement with CONTECH, a national construction products sales organization with 150 sales engineers who market and sell Vortechnics products across the country. With this exclusive relationship, Vortechnics has been able to dramatically expand its sales and service capabilities throughout the United States. The company also added representatives in Canada, including Ontario and British Columbia.

In the summer of 2002, the company celebrated the grand opening of its new corporate headquarters to continue its commitment to lead the market through a program of rigorous product testing and aggressive product development. In addition to a state-of-the-art 3,500 square foot lab, the headquarters also features an outdoor testing facility that allows Vortechnics to monitor the next generation of stormwater treatment systems *in situ.* This onsite testing and product development enables Vortechnics to explore new ways to improve water quality to an even higher standard than currently required by stormwater regulations.

In the fall of 2003, Vortechnics launched a new product, the VortSentry™, another hydrodynamic separator product with a compact design and backed by full laboratory testing. The company also ramped up its commitment to R&D and product development by expanding its staff and technology budgets.

Currently Vortechnics has 44 employees, and experienced sales growth exceeding 50% in 2003. More than 3,500 Vortechs® Systems have been installed throughout the United States and Canada.

2.2 Organization and Management

The company is headquartered in Scarborough, Maine, with nine regional sales offices throughout the United States and Canada. David Miley, president and CEO, and Fran Tighe, Vice President of Business Development, are co-owners of this privately held company. The company promotes a flat management structure with six functional managers overseeing its primary business areas: R&D: Dan Cobb; Operations: Ted Jones; Marketing: Kim West; Sales: Tom Gorrivan; Information Technology: Mike Haskell; and Finance: Dave Pierce. The company has nine regional sales managers, who report to Tom Gorrivan and work out of the regional offices based in Maine, Virginia, Georgia, Texas, Ohio, California, Washington, and Nova Scotia.

2.3 Operating Experience with the Proposed Technology

Vortechnics has more than 15 years of experience with the proposed technology, including more than 3,500 installations throughout the United States and Canada. Most importantly, the award-winning technology is backed by almost 10 years of full scale laboratory testing and rigorous field testing, including third party studies from several universities and organizations. The company has developed numerous case studies and technical papers on the installation, use and maintenance of its technology, all of which have been reviewed, published and accepted by the general stormwater business community.

2.4 Patents

On June 2, 1998, the Vortechnics technology was granted a United States patent (Patent Number: 5,759,415).

2.5 Technical Resources, Staff and Capital Equipment

Vortechnics completes all design work at the corporate headquarters in Scarborough, Maine. 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 complete a formal Vortechs® Construction Training Course where the details of construction are established. 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 may elect to cast the system in two bathtub halves or a bottom slab, two riser sections and a top slab. They would also determine how the joints are formed and what type of lifting equipment is cast in. Vortechnics, Inc. ultimately reviews all construction and installation decisions made by the precaster.

The Vortechs® System is delivered to the site by the precaster on the day of installation. Vortechs® Models 1000 through 4000 arrive in one piece fully assembled. Larger models may arrive on site in two or more pieces and may require some assembly. 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 System, backfilling around the System and bringing the manhole frames and covers up to grade. Any work required on components inside the System is the responsibility of the Vortechnics precast contractor.

Installation requires a crane and can typically be completed in two to four hours. Heaviest pick weight will be confirmed by Vortechnics staff and communicated to the contractor prior to delivery.

Vortechnics makes an installation video available to the installation contractor.

Structural integrity of the system is checked by the precaster before shipment. A "Vortechs® System Assembly Checklist" is completed and sent to the Vortechnics office at this time. 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, connect the inlet and outlet pipes and backfill around it. The contractor will perform a final check against the Vortechnics 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.

Whenever possible a Vortechnics representative other than the pre-cast contractor will be on site to assure that the system arrives and is installed as designed.

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 grit 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 grit chamber.

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

3. Treatment System Description

The Vortechs® Stormwater Treatment Systems are designed to remove gross pollutants, including sediments, from stormwater using a hydrodynamic separator technology. Each unit has three basic components: 1) a circular grit chamber that promotes a gentle swirling motion of the incoming stormwater, 2) an oil baffle wall, and 3) a flow control wall for controlling high and low flows.

Figure 1 displays a simple schematic of the Vortechs® System. Stormwater flows enter the unit tangentially to the grit chamber, which promotes a gentle swirling motion. As stormwater circles the grit chamber, pollutants migrate toward the center of the unit where velocities are the lowest. The majority of settlable solids are left behind as stormwater exits the grit chamber via two apertures on the perimeter of the chamber. Next, buoyant debris, oil and grease are separated from water as it flows under the baffle wall. As stormwater exits the system through the flow control wall and ultimately the outlet pipe, it is relatively free of floating and settling pollutants.
Over time a conical pile tends to accumulate in the center of the unit containing sediment and associated metals, nutrients, hydrocarbons and other pollutants. Floating debris and oil and grease form a floating layer trapped in front of the baffle wall. Accumulation of these pollutants can easily be accessed through manholes located over each chamber. Maintenance is typically performed through the manhole over the grit chamber.

There are nine (9) precast Vortechs® System models available to meet the hydraulic and water quality needs of large and small projects. The Vortechs® Systems have the ability to treat a wide range of flows up to 25 cfs (11,310 gpm). Larger flow Systems can be cast-in-place to accommodate higher flow rates.

4. Technical Performance Claim

Claim - The Vortechs® System sized at a treatment operating rate of no more than 40 gpm/ft^2, with an average influent TSS concentration of 187 mg/L and zero initial sediment loading, has been shown to have a TSS removal efficiency of 64% (per NJDEP treatment efficiency calculation methodology) for coarse silt particles (ranging from 38-75 microns) in laboratory studies using simulated stormwater.

5. Technical System Performance

The Vortechs® System has been tested in a full-scale hydraulic laboratory. The laboratory tests were completed for three different particle size distributions (PSD) with gradations ranging from 38 to 500 microns. For each different PSD, tests were performed with TSS influent concentrations ranging from 100 to 300 mg/L at operating rates from 10 to 100 gpm/ft^2 at 10 gpm/ft^2 intervals. In addition to specific testing, Vortechnics 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 Vortechs® System has been tested extensively in the field by Vortechnics staff as well as independent researchers.

5.1 Laboratory Studies

In 1996, the Vortechnics laboratory-testing program was designed to construct a facility with the capability to test a full scale Vortechs® Model 2000. The laboratory not only provided an opportunity to gather performance data on the Vortechs® System as required by the Rational Rainfall Method™, or as requested by various regulatory agencies, but it also provided opportunities for new product development. Over the past few years, hundreds of engineers and regulators have been able to view the system in operation and witness tests.

The Vortechs® System was initially designed to address rules requiring 80% TSS removal and high efficiency oil and grease removal. Removal efficiency investigations for these pollutants were conducted in the laboratory using a full scale Vortechs® System where a high level of precision could be attained. The laboratory setting also allows all testing programs to progress at an efficient pace, since the rate of testing is not linked to natural precipitation patterns.

Vortechnics moved into a new state of the art facility with a 3,500 square foot laboratory space in June, 2002. Currently there are two test systems installed, each having a flow capacity of 3 cfs. This new laboratory serves as a demonstration area for the Vortechs® System as well as a resource for product development.

Several gradations ranging from 38 to 500 microns were targeted by Vortechnics for testing based on a survey of street sweeping and stormwater runoff PSD information and the availability of source materials for the tests. Once a bulk sample of fine sand and silt was obtained, it was sieved down into various discreet size fractions. Laboratory tests were conducted in a full scale Vortechs® Model 2000 in the Vortechnics Laboratory according to the following protocol:

1. Prepare a 20 to 30 gallon slurry of tap water and a known gradation of sediment particles.
2. Turn on the slurry mixer.
3. Stabilize flow in the Vortechs® System at the target operating rate
4. Set the metering pump to produce an influent concentration between 100 and 300 mg/L and begin metering the slurry into the influent line.
5. At a period of time no less than five times the theoretical detention time of the system after the metering pump is turned on, take the first influent sample.
6. Take the first effluent sample one detention time after the influent sample is taken
7. Repeat steps 4 and 5 for a minimum of 3 sample pairs.

8. Analyze sample pairs according to EPA 160.2, a method for the measurement of total non-filterable solids.
9. Report removal efficiencies as the percent difference between influent and effluent concentrations:

Removal Efficiency = (Influent concentration – Effluent Concentration) / Influent Concentration

This testing process was repeated for several particle size ranges at operating rates from 10 to 100 gpm/ft^2 at 10 gpm/ft^2 intervals. Removal efficiencies for three gradations are displayed in Figure 2.

The 50-micron curve in Figure 2 represents removal of particles passing through a 200-mesh sieve and retained on a 400-mesh sieve. This particle size was selected to represent coarse silt, which is typically present on sites as a result of atmospheric deposition, weathering of site materials, and breakdown of organic matter and vehicular components. The Rational Rainfall Method™ uses laboratory generated performance data for these particles to estimate system performance in the field unless site information warrants using a coarser gradation.

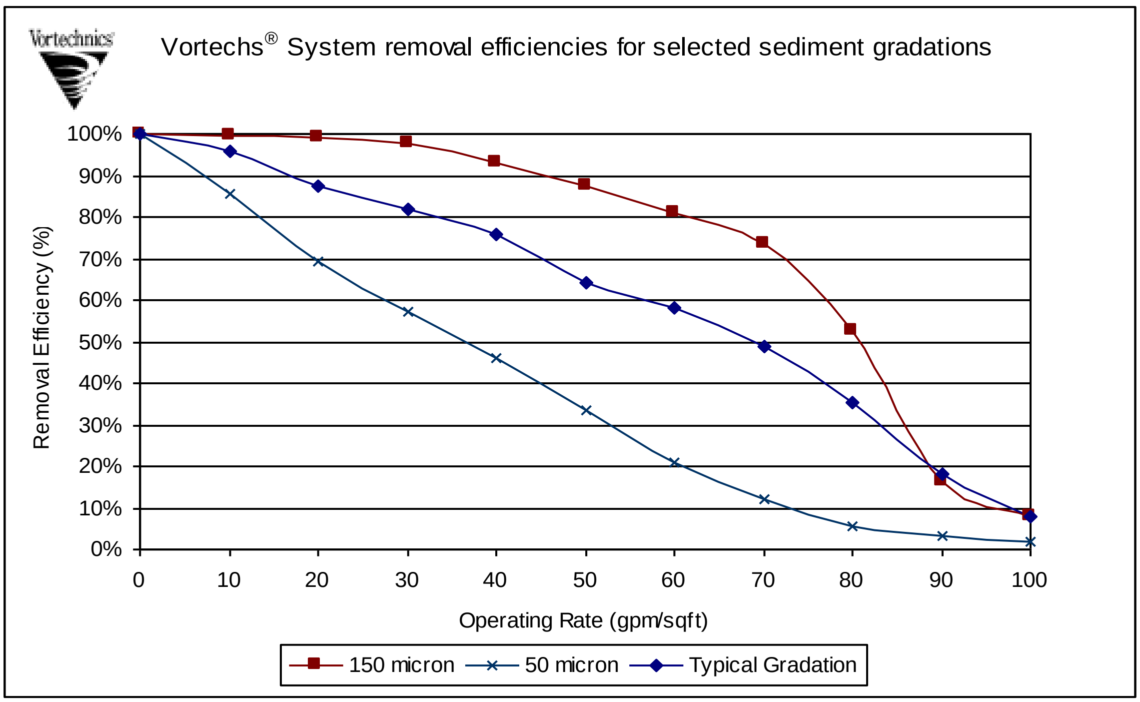

Figure 2

The 50-micron curve is based on the removal efficiency of particles ranging from 38 to 75 microns. Two separate gradations of naturally occurring sediment particles were tested, one ranging from 38 microns to 63 microns and the other between 63 and 75 microns. The results of these tests were plotted and a conservative trend line was fitted through the data to represent the removal efficiency of 50-micron particles.

The average influent concentration across all tests was 187 mg/L with a high concentration of 576 mg/L and a low influent concentration of 65.2 mg/L. The results of individual tests supporting the 50-micron removal efficiency curve and the curve itself are presented in Figure 3.

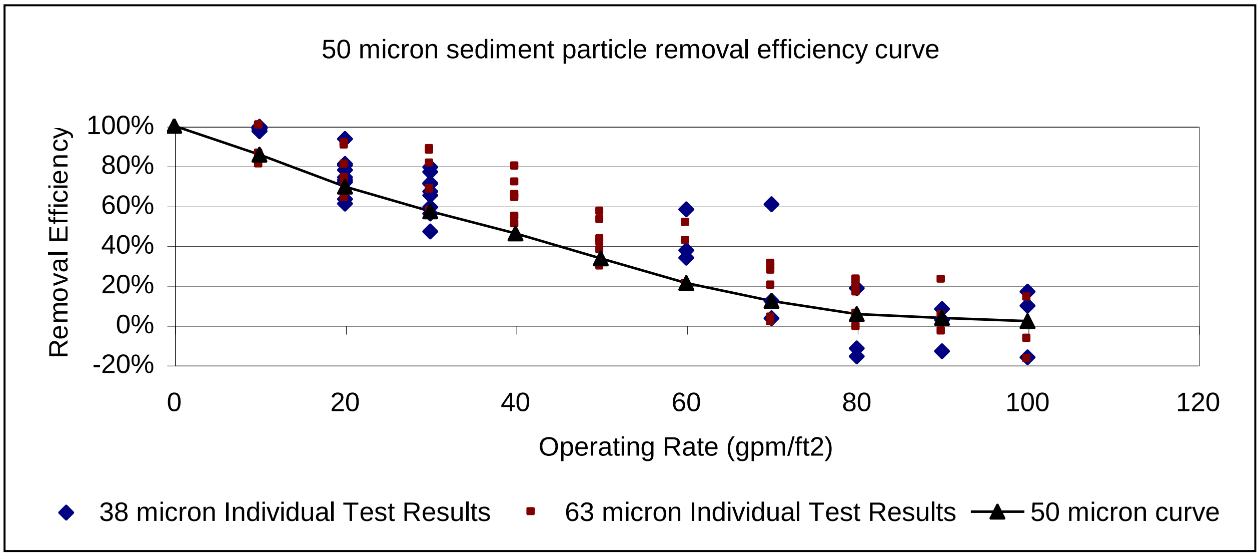

Figure 3

The 150-micron curve (Figure 4) demonstrates the results of tests using particles that passed through a 60-mesh sieve and were retained on a 100-mesh sieve. This particle size represents fine sand which is also present on many sites, especially where landscaping is unconsolidated, where winter sanding occurs or as a result of breakdown of asphalt surfaces. When sediment loads are expected to be relatively heavy and coarse, Vortechs® System design may be based on removal efficiencies for this gradation.

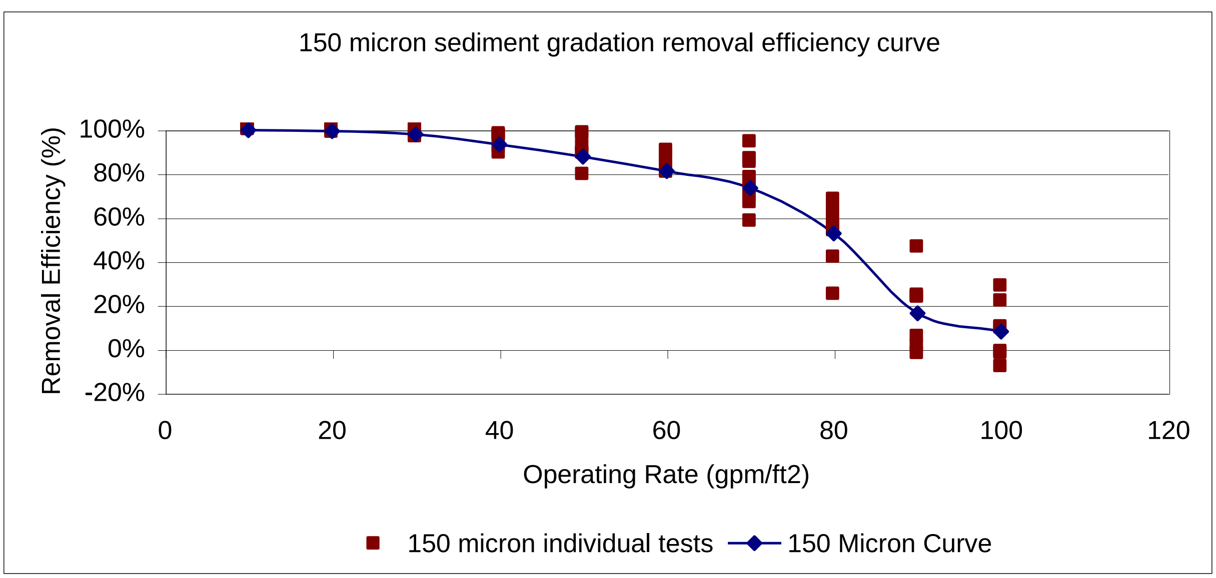

Figure 4

The “typical gradation” has an average particle size (d50) of 80 microns, and contains particles ranging from 38–500 microns in diameter (Figure 5). This particle range includes medium and fine sands as well as coarse silt. Removal efficiencies of this gradation (Figure 6) are used as a basis for sizing Vortechs® Systems when the TSS load is expected to contain a moderate concentration of a wide range of particles.

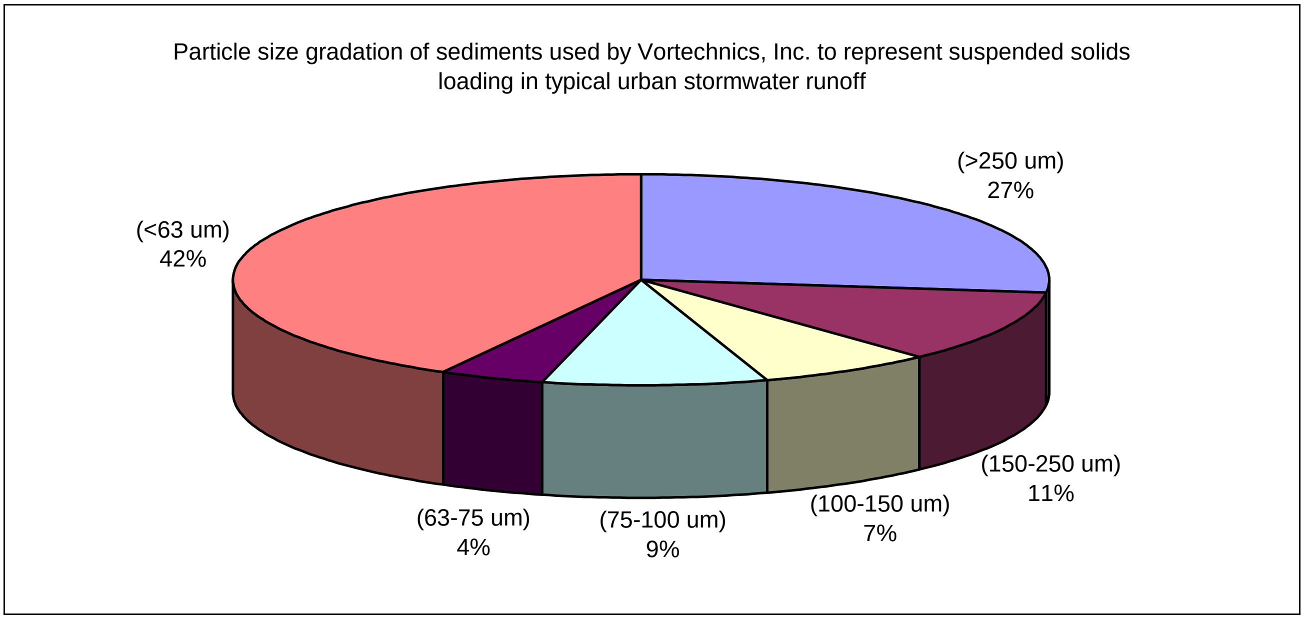

Figure 5

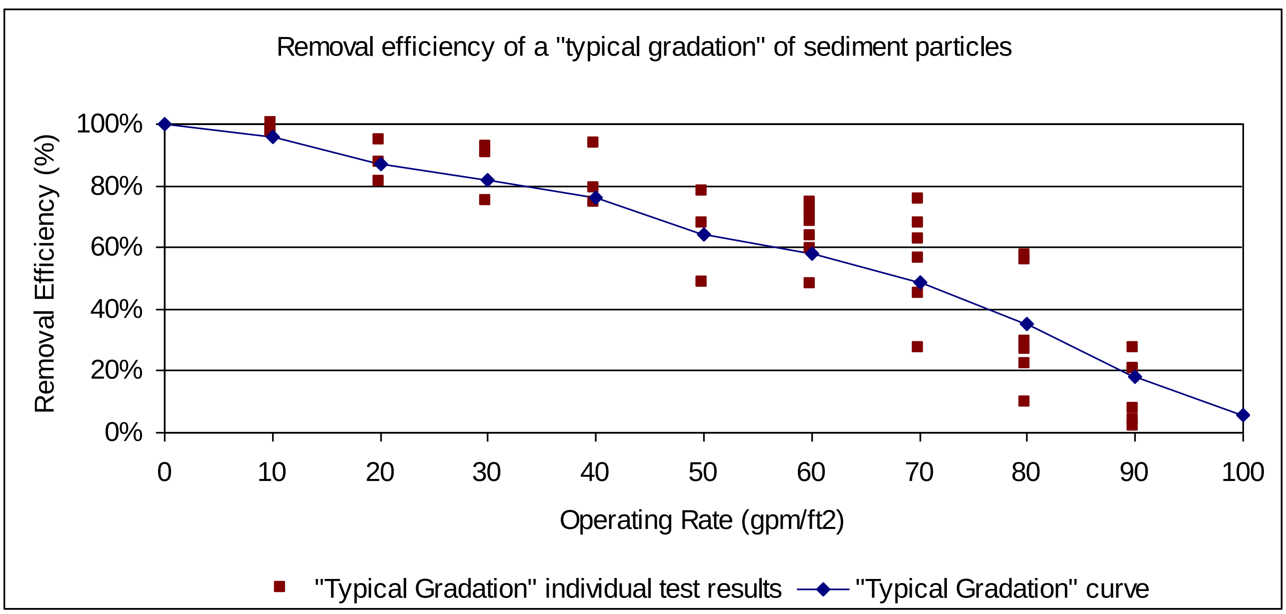

Figure 6

These performance curves are unique in that they disclose the performance of the system at all operating rates up to the point of washout. Figures 2-6 show that removal efficiencies decrease with operating rate. This is due to reductions in detention time and increased turbulence at higher operating rates.

On two occasions, May 9, 2001 and May 1, 2002, Mr. Jeff Dennis from the Maine Department of Environmental Protection witnessed laboratory testing of the Vortechs® System. On May 9, 2001, the Vortechs® System was tested for a targeted flow rate of 1.17 cfs or 42 gpm/ft^2 using the F-95 sand slurry. The PSD of the F-95 unground silica is shown in Table 2. Influent TSS concentrations ranged from 378.8 to 453.9 mg/L. Effluent concentrations ranged from 57.4 mg/L to 74.0 mg/L. When adjusting for the recycled background concentrations, the removal efficiencies indicated by inflow/outflow pairs ranged from 82.8% up to 86.5%, with a mean of 85.0%.

USA STD Sieve Size	Millimeters	% Retained		Cumulative % Passing
		Individual	Cumulative	
30	0.600	0.0	0.0	100.0
40	0.425	0.2	0.2	99.8
50	0.300	1.0	1.2	98.8
70	0.212	9.0	10.2	89.8
100	0.150	30.0	40.2	59.8
140	0.106	42.0	83.3	17.8
200	0.075	15.0	97.2	2.8
270	0.053	2.5	99.7	0.3
Pan		0.3	100.0	

Table 2

On May 1, 2002, the Vortechs® System was tested for a targeted flow rate of 1.04 cfs or 37 gpm/ft^2 using the OK-110 sand slurry. The PSD of the OK-110 unground silica is shown in Table 3. Influent TSS concentrations ranged from 169.2 mg/L to 220.8 mg/L. Effluent concentrations ranged from 38.5 mg/L to 51.9 mg/L. When adjusting for the recycled background concentrations, the removal efficiencies indicated by inflow/outflow pairs ranged from 76.8% up to 85.7%, with a mean of 81.5%.

USA STD Sieve Size	Millimeters	% Retained		Cumulative % Passing
		Individual	Cumulative	
70	0.212	0.2	0.2	99.8
100	0.150	1.0	1.2	98.8
120	0.125	15.0	16.2	83.8
140	0.106	41.0	57.0	43.0
170	0.088	25.0	82.0	18.0
200	0.075	15.0	97.0	3.0
270	0.053	3.0	100.0	0.0
Pan		0.0	100.0	0.0

Table 3

5.2 Verification Procedures

All the data provided to NJCAT were reviewed to fully understand the capabilities of the Vortechs® System. To verify Vortechnics claim, the Vortechnics laboratory data were reviewed and compared to the draft NJDEP Laboratory Testing Protocol. Only the data that closely compared to the draft NJDEP Laboratory Testing Protocol was used to verify Vortechnics claim.

Claim - The Vortechs® System sized at a treatment operating rate of no more than 40 gpm/ft^2, with an average influent TSS concentration of 187 mg/L and zero initial sediment loading, has been shown to have a TSS removal efficiency of 64% (per NJDEP treatment efficiency calculation methodology) for coarse silt particles (ranging from 38-75 microns) in laboratory studies using simulated stormwater.

5.2.1 NJDEP Recommended TSS Laboratory Testing Procedure

The NJDEP has prepared a draft 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. <u>Particle size distribution:</u>

The following particle size distribution will be utilized to evaluate a manufactured treatment system (See Table 4). A natural/commercial soil representing U.S.D.A. definition of a sandy loam material. 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:

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

Table 4

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 5) for that particular operating rate.
    D. The results of the 5 numbers will then be summed to obtain the theoretical annual TSS load removal efficiency of the system.

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

Table 5

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.

5.2.2 Laboratory Testing

The removal efficiency of the Vortechs® System is a function of sediment particle size and influent flow rate to the system (See Figure 2). As the flow rate increases, detention times of the system decreases, thereby reducing the time for particles to settle out and lower the system's removal efficiency. Detention times of the laboratory Vortechs® System 2000 were provided by Vortechnics and ranged from 8.1 to 1.3 minutes for flow rates of 10 to 100 gpm/ft^2, respectively. Also, as the particle sizes get larger, the settling of the particles increases due to the increased weight of the particles.

Since Vortechnics uses the 50 micron PSD in sizing their systems and the 50 micron distribution in the laboratory testing was the closest to the PSD provided in the NJDEP Laboratory Testing Protocol, the data for the 50 micron distribution were used to verify Vortechnics claim. Using the data for the 50 micron distribution provided in Figure 2 and a design operating rate of 40 gpm/ft^2, removal rates were determined from Figure 2 and are shown in Table 6.

Treatment operating rate	Operating Rate (gpm/ft^2)	Weight factor	Removal Efficiency (%)
25%	10	.25	85.5
50%	20	.30	69.5
75%	30	.20	57.0
100%	40	.15	46.0
125%	50	.10	33.4

Table 6

Based upon the data presented in Table 6, the removal efficiency of the system is 64%, thereby verifying the Vortechnics Claim.

Although the laboratory experiments using the F-95 and OK-110 unground silica resulted in higher TSS removal rates, both of these distributions are outside of the range of PSD as specified in the NJDEP Laboratory Testing Protocol. The results for the 150 micron sediment gradation and the typical gradation also yielded higher removal efficiencies but these two gradations were also outside of the range of the PSD as specified in the NJDEP Laboratory Testing Protocol. Therefore, these data could not be used in verifying higher removal efficiencies for the Vortechs® System.

Data were not available on the potential of re-suspension and wash out of initial sediment contained in the Vortechs® System. In order for the particle to be re-entrained, the flow velocity over the surface of the particle must create enough suction to pick it up. This is complicated by armoring (shielding of smaller particles by larger particles) or by the tendency of particles of various diameters to interlock in a matrix that provides some protection from scouring flows. Specific operating rates or velocities that will cause re-suspension of particles with various settling velocities have not been determined by Vortechnics.

5.2.3 Field Performance Modeling

The Rational Rainfall Method™ model may prove to be useful in developing estimates of field performance provided additional field data can be collected to validate the model. The Rational Rainfall Method™ model combines site information (drainage area and runoff coefficient) with local precipitation and laboratory data for the 50 micron PSD to produce an estimate of field performance. Vortechnics provides an example removal efficiency calculation for Springfield, New Jersey using the Rational Rainfall Method™ (see Table 7). If the Rational Rainfall Method™ model can be calibrated and verified for New Jersey conditions, the Springfield example suggests that the Vortechs® System can achieve higher TSS removal efficiencies in the field on an annual basis.

VORTECHS SYSTEM NET ANNUAL TSS REMOVAL EFFICIENCY ESTIMATE
Typical Vortechs System
Springfield, NJ
Model 4000

Design Ratio[1] = (3 acres) x (0.8) x (449 gpm/cfs) / (28.3 sf) = 38.1

Rainfall Intensity "/hr	Operating Rate[2] gpm/sf	% Total Rainfall Volume[3]	Removal Efficiency[4] (%)	Relative Efficiency (%)
0.08	3.0	33.7%	95.8%	32.3%
0.16	6.1	19.8%	91.2%	18.0%
0.24	9.1	11.4%	87.1%	9.9%
0.32	12.2	7.2%	82.2%	5.9%
0.40	15.2	4.4%	77.4%	3.4%
0.48	18.3	3.4%	72.3%	2.5%
0.56	21.3	2.3%	68.1%	1.6%
0.64	24.4	1.9%	64.2%	1.2%
0.72	27.4	1.7%	60.4%	1.0%
0.80	30.5	1.7%	57.1%	1.0%
0.88	33.5	1.1%	53.9%	0.6%
0.96	36.6	0.9%	50.7%	0.4%
1.04	39.6	1.6%	47.1%	0.8%
1.12	42.7	0.8%	43.7%	0.3%
1.20	45.7	0.9%	39.5%	0.4%
1.28	48.8	0.6%	36.0%	0.2%
1.36	51.8	0.9%	32.1%	0.3%
1.44	54.9	1.1%	28.3%	0.3%
1.52	57.9	0.2%	24.4%	0.0%
1.60	61.0	0.2%	21.0%	0.0%
1.80	68.6	0.6%	13.6%	0.1%
2.00	76.2	1.1%	7.8%	0.1%
			Total =	80%
			% rain falling at >2"/hr =	2.6%
			Assumed Removal Efficiency of remaining % =	0.0%
			Net Annual TSS Removal Efficiency Estimate=	**80%**

1 - Design Ratio = (Total Drainage Area) x (Runoff Coefficient) x (cfs to gpm conversion) / Grit Chamber Area
- The Total Drainage Area and Runoff Coefficient is specified by the site engineer.
- The conversion factor from cfs to gpm is 449.

2 - Operating Rate (gpm/sf) = intensity ("/hr) x Design Ratio
3 - Based on 10 years of 15-minute rainfall data from NCDC Station 8423 in Springfield, NJ
4 - Based on Vortechnics laboratory verified removal of 50 micron particles (see Technical Bulletin #1).

Table 7

5.2.4 Field Studies

Although field testing is important to calibrate and verify models such as the Rational Rainfall Method™, it is difficult to obtain data that are representative of a wide range of operating conditions. A very limited number of data points collected in Vortechnics field studies are suitable for verifying the Vortechnics Claim. Many of the field data are collected at very low operating rates and TSS influent concentrations are typically outside the range of concentrations that are typically observed in New Jersey (i.e., 100 to 300 mg/L). Although the field data are limited, additional data will be collected by Vortechnics as they move forward to complete the TARP required field testing. It is expected that the collection of additional field data to calibrate and verify the Rational Rainfall Method™ model will result in modified and expanded claims from Vortechnics on the removal efficiency of their system. Since the laboratory data are sufficient to verify the initial claim by Vortechnics, a further examination of the field data will not be included in this verification report.

5.3 Inspection and Maintenance

The Vortechs® 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 grit chamber to fill more quickly but regular sweeping will slow accumulation.

5.3.1 Inspection

Inspection is the key to effective maintenance and it is easily performed. Vortechnics 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 Vortechs® System should be cleaned when inspection reveals that the sediment depth has accumulated to within six inches of the dry-weather water level. 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 six inches or less.

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.

5.3.2 Maintenance

Maintaining the Vortechs® 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 Vortechs® 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 grit chamber. Simply remove the cover and insert the vacuum hose into the grit chamber. As water is evacuated, the water level outside of the grit chamber will drop to the same level as the crest of the lower aperture of the grit chamber. It will not drop below this level due to the fact that the bottom and sides of the grit chamber are sealed to the tank floor and walls. This unique "water lock" feature prevents water from migrating into the grit chamber, exposing the bottom of the baffle wall. Floating pollutants will decant into the grit chamber as the water level there is drawn down. This allows most floating material to be withdrawn from the same access point above the grit chamber.

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 Vortechs® 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.

If maintenance is not performed as recommended, sediment may accumulate outside the grit chamber. If this is the case, it may be necessary to pump out all chambers. It is a good idea to check for accumulation in all chambers during each maintenance event to prevent sediment build up there. Typically, accumulation outside the grit chamber will be negligible compared to the volume of solids captured in the grit chamber. Since flow velocities are higher outside the grit chamber than inside it, any particles that leave the grit chamber are unlikely to be trapped in subsequent chambers.

Manhole covers should be securely seated following cleaning activities, to ensure that surface runoff does not leak into the unit from above. Typical maintenance volumes are listed in Table 8.

Typical Maintenance Volumes							
Model Size	Maximum Treatment Capacity (cfs)	Grit Chamber Diameter (ft)	Footprint (LxW)	Depth below invert* (ft)	Maintenance "Pump Out" volume* (gal)	Sediment storage capacity* (yd^3)	Floatable material storage capacity* (gal)
1000	1.6	3	10x4	3	185	0.7	114
2000	2.8	4	11x5	3	332	1.2	166
3000	4.4	5	12x6	3	506	1.8	225
4000	6.3	6	13x7	3	706	2.4	292
5000	8.6	7	14x8	3	952	3.2	365
7000	11.2	8	15x9	3	1244	4.0	446
9000	14.2	9	16x10	3	1582	4.8	533
11000	17.5	10	17x11	3	1947	5.6	628
16000	25.2	12	19x13	3	2774	7.1	839
***These volumes can be increased or decreased to meet specific site needs at no additional cost**							

Table 8

5.3.3 Solids Disposal

Solids recovered from the Vortechs® System can typically be land filled or disposed of at a waste water treatment plant.

5.3.4 Damage Due to Lack of Maintenance

It is unlikely that the Vortechs® 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 Claims

Based on the evaluation of the results from laboratory studies, sufficient data is available to support the Vortechnics Claim: The Vortechs® System sized at a treatment operating rate of no more than 40 gpm/ft^2, with an average influent TSS concentration of 187 mg/L and zero initial sediment loading, has been shown to have a TSS removal efficiency of 64% (per NJDEP treatment efficiency calculation methodology) for coarse silt particles (ranging from 38-75 microns) in laboratory studies using simulated stormwater.

6.2 Limitations

6.2.1 Factors Causing Under-Performance

If the Vortechs® 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 filled with sediment.

6.2.2 Pollutant Transformation and Release

The Vortechs® 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 Vortechs® 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 Vortechs® System requires no pretreatment. Heavy loads of sediment will increase the needed maintenance frequency, but will not affect overall performance. Heavy loads of fine sediment will not affect system operation.

6.2.4 Bypass Flow

The Vortechs® System has been tested at operating rates up to 100 gpm/ft^2 of swirl chamber surface area, which corresponds to the peak treatment capacity for each model, and has been found to provide positive removal efficiencies of suspended solids throughout this range. Flow rates exceeding the treatment capacity of the system may cause re-suspension of previously captured material, therefore it may be necessary to route peak flow around treatment via an external bypass.

6.2.5 Mosquitoes

The Vortechs® System design incorporates standing water in the separation chamber and containment sump, which can be a breeding site for mosquitoes. To address this potential problem Vortechnics 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 New Jersey Department of Environmental Protection (NJDEP or Department) 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 Department 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 Vortechs® Systems have been recommended and verified for interim use within the State of New Jersey, Vortechnics 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 Vortechnics technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

8. References

Dennis, J. (2002) Vortechs OK-110 Sand SSC (TSS) Removal Confirmation Test, dated May 1, 2002, State of Maine, Department of Environmental Protection, Division of Watershed Management.

Dennis, J. (2001) Vortechs F-95 Sand SSC (TSS) Removal Confirmation Test, dated May 9, 2001, State of Maine, Department of Environmental Protection, Division of Watershed Management.

Patel, M. (2003) Draft Total Suspended Solids Laboratory Testing Procedures, dated December 23, 2003, New Jersey Department of Environmental Protection, Office of Innovative Technology and Market Development.

Vortechnics Inc. (2003) Vortechs Stormwater Treatment system Technology Report, dated November 2003, prepared for New Jersey Corporation for Advanced Technology.

Witherill, D. (2001) Letter to Francis Tighe, Vortechnics, Inc., dated May 24, 2001.

Witherill, D. (2002) Letter to Kevin McKee, Vortechnics, Inc., dated June 5, 2002.