FINAL

NJCAT TECHNOLOGY VERIFICATION

Stormceptor®

September 9, 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 (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 August 2003, the Stormceptor® Group of Companies (12 Madison Avenue, Toronto, Canada, M5R 2S1) submitted a formal request for participation in the NJCAT Technology Verification Program. The technology proposed – The Stormceptor® System, Oil and Sediment Separator – is a patented water quality improvement device applicable for treatment of stormwater in a variety of development situations. The Stormceptor® concept was developed in the late 1980's with the first patent filed in 1990. The original application of the technology was for spills capture, containment and detection in industrial areas. The first unit was sold in 1992. Since then, the Stormceptor® concept has evolved as field monitoring and on-going research present new opportunities to improve the Stormceptor® product line and environmental awareness regarding stormwater quality control increased.

Through research and field application, the technology has been refined to separate oil and sediment from stormwater runoff as well as capturing oil spills during dry weather conditions. 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, Stormceptor® Group of Companies (see Section 4). The verification report differs from typical NJCAT verification reports in that final verification of the Stormceptor® 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 Stormceptor® System 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.

In August 2003, the Stormceptor® Corporation in association with Rinker Materials™, Hydro Conduit Division, submitted a Verification Acceptance to NJCAT's verification program for review and approval. After this initial submittal, a meeting was held with Stormceptor® representatives, NJCAT and NJDEP to discuss the preliminary review of the verification package and NJDEP's recently released draft Total Suspended Solids (TSS) laboratory testing procedure. Based upon this meeting and subsequent discussions, the Stormceptor® Corporation decided to conduct additional laboratory tests in accordance with NJDEP's draft TSS laboratory testing procedure. A laboratory testing protocol was developed by the Stormceptor® Corporation and submitted to NJCAT and NJDEP for their review and comment. In June 2004, the Stormceptor® Corporation submitted a Full Scale Laboratory Evaluation of Stormceptor® Model STC 900 for removal of TSS (Applying NJDEP particle size distribution (PSD) & Weight Factor). This project included the evaluation of these assembled reports, company manuals, literature, and laboratory testing reports to verify that the Stormceptor® System meets the performance claims of Stormceptor® Corporation.

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 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 (BMPs) for stormwater treatment and discharge. 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 is very diverse. Stormceptor® Corporation has developed a hydrodynamic source control device for the capture and retention of free and floating oils, grease, hydrocarbons, petroleum products, and total suspended solids. Sorbed contaminants that are transported by the fine suspended solids such as nutrients, heavy metals, and hydrocarbon and petroleum products are removed from stormwater, thus improving water quality. The Stormceptor® System is a vertically oriented cylindrical structure manufactured from concrete and fiber reinforced plastic (fiberglass) insert. A weir and orifice plate on the fiberglass insert controls flow rates and operational velocities, which are minimized in order to facilitate the capture of fine suspended solids and hydrocarbons, and retaining it over a range of subsequent hydrological conditions. 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 above ground by a vacuum truck and without interference from internal components.

General

The patented Stormceptor® System is a pollution prevention technology that removes hydrocarbons and fine sediment from stormwater runoff and provides oil spill control from entering downstream ponds, lakes and rivers. The technology follows the philosophy of treating pollution at its source. Treating pollution at the source is the preferred methodology for water quality improvement because treatment effectiveness decreases with dilution as drainage area increases.

Storm sewers are designed to convey a specific flow determined from a design event. The design event is typically the event with the highest flow that may be encountered for a return period, measured in years. Typical design storms are based on the 2 year, 5 year, or 10 year return storms and are characterized by rainfall depth, rain duration, time distribution of rainfall, and the spatial distribution of rainfall. These design principles can be impractical when they are applied for stormwater quality. By definition, *design storms occur infrequently* and *typically* *account for a very small fraction of the annual rainfall volume*. Designing for stormwater quality using principles for sizing sewers becomes impracticable and uneconomical in that BMPs would have to be designed to contain a large volume of runoff created by a design storm which would in turn be used on a very infrequent basis. For this reason, the Stormceptor® System is designed intentionally to treat the *majority* of the total annual rainfall volume and only a portion of the peak flow volumes. Small frequently occurring events make up the majority of rainfall events in North America as observed from continuous historical rainfall data. By treating the small frequent events to a high degree and bypassing a portion of the infrequent high flows scouring of previously capture hydrocarbons and fine sediment is minimized and a high level of long term efficiency can be achieved. The weir and orifice plate feature on the Stormceptor® System achieves control of flow rates and operational velocities entering the treatment chamber, thus facilitating conditions necessary for capture of fine suspended solids and hydrocarbons, and retention of these pollutants even under peak flow events. The Stormceptor® System performance is based on the long-term removal average of TSS loading over the complete range of hydrological conditions including infrequent peak rainfall events. The sizing methodology of the Stormceptor® System includes the analysis of the actual hydrology of the site from geographic continuous long-term historical data to determine the TSS removal performance of each Stormceptor® model over the long-term.

1.3.2 Specific Applicability

Stormceptor® is a water quality improvement device applicable for treatment of stormwater in a variety of development situations including:

- stormwater quality retrofits for existing development;
- pretreatment of natural BMPs;
- industrial and commercial parking lots;
- automobile service stations;
- airports;
- areas susceptible to spills of material lighter than water (bus depots, transfer stations, etc.);
- new residential developments (as part of a treatment train); and
- re-development in the urban core.

1.3.3 Range of Contaminant Characteristics

Stormceptor® Systems have been shown to capture a wide range of pollutants of concern. These include: free and floating oils; grease; hydrocarbons; petroleum products; and total suspended solids. Sorbed contaminants that are transported by the fine suspended solids such as nutrients, heavy metals, and hydrocarbon and petroleum products may also be removed from stormwater.

1.3.4 Range of Site Characteristics

The Stormceptor® System is designed to accommodate a wide range of flows and volumes (see Table 1). The Stormceptor® System is manufactured in 12 different sizes using precast concrete base, barrel and cap sections ranging from 4 ft (1200 mm) to 12 ft (3600 mm) in diameter. The 6 ft (1800 mm) insert divides the tank into two components, an upper and lower chamber. The key benefit of the system is a built-in bypass that prevents high flows from entering the lower chamber (storage chamber) to prevent stored contaminants from being flushed out.

Table 1. Stormceptor® System Standard Sizes

Stormceptor® Models					
Model	Design Capacity [a] (gpm)	Orifice Diameter (inches)	Sediment Capacity [b] (ft^3)	Oil Capacity (US Gal.)	Total Holding Capacity (US Gal.)
STC 450	124 (9 L/s)	6 (150 mm)	9 (0.3 m^3)	86 (0.3 m^3)	470 (1.8 m^3)
STC 900	285 (18 L/s)	6 (150 mm)	19 (0.5 m^3)	251 (0.9 m^3)	952 (3.6 m^3)
STC 1200	285 (18 L/s)	6 (150 mm)	25 (0.7 m^3)	251 (0.9 m^3)	1234 (4.7 m^3)
STC 1800	285 (18 L/s)	6 (150 mm)	37 (1.0 m^3)	251 (0.9 m^3)	1833 (6.9 m^3)
STC 2400	475 (30 L/s)	8 (200 mm)	49 (1.4 m^3)	840 (3.2 m^3)	2462 (9.3 m^3)
STC 3600	475 (30 L/s)	8 (200 mm)	75 (2.1 m^3)	840 (3.2 m^3)	3715 (14.1 m^3)
STC 4800	793 (50 L/s)	10 (250 mm)	101 (2.9 m^3)	909 (3.4 m^3)	5059 (19.1 m^3)
STC 6000	793 (50 L/s)	10 (250 mm)	123 (3.5 m^3)	909 (3.4 m^3)	6136 (23.2 m^3)
STC 7200	1110 (70 L/s)	12 (300 mm)	149 (4.2 m^3)	1059 (4.0 m^3)	7420 (28.1 m^3)
STC 11000**s**	1585 (100 L/s)	10 (250mm)	224 (6.3 m^3)	2797 (10.6 m^3)	11194 (42.5 m^3)
STC 13000**s**	1585 (100 L/s)	10 (250 mm)	268 (7.6 m^3)	2797 (10.6 m^3)	13348 (50.5 m^3)
STC 16000**s**	2219 (140 L/s)	12 (300 mm)	319 (9.0 m^3)	3055 (11.6 m^3)	15918 (60.3 m^3)

Notes:
a –Water quality treatment is the intent of the Stormceptor® design, therefore the use of this design capacity for single event design storm sizing (e.g. Rational Method) is not appropriate. The Stormceptor® Corporation recommends using the Stormceptor® Sizing Program version 4.0.0 to properly select a Stormceptor® unit.
b – Sediment capacity prior to recommended maintenance.
s – These are series units which consist of two structures installed in series that are designed to operate in parallel. The sediment, oil and total holding capacity are based on both structures combined.

1.3.5 Material Overview, Handling and Safety

To clean out the Stormceptor® System, oil is removed through the 6 in. (150 mm) inspection/cleanout port, and sediment is removed through the 24 in. (610 mm) diameter riser pipe. Alternatively, oil could be removed from the 24 in. (610 mm) opening if water is first removed from the lower chamber in order to lower the oil level below the riser pipe.

The depth of sediment can be measured from the surface of the Stormceptor® unit with a dipstick tube equipped with a ball valve. A vacuum truck is generally the most convenient and efficient method to remove the sediment from the Stormceptor® unit. Solids recovered from the Stormceptor® 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, company manuals, literature, and laboratory testing reports to verify that the Stormceptor® System meets the performance claims of Stormceptor® Corporation.

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2. Evaluation of the Applicant

2.1 Corporate History

The Stormceptor® concept was developed in the late 1980's with the first patent filed in 1990. The original application of the technology was for spills capture, containment and detection in industrial areas. The first unit was sold in 1992. Since then, the Stormceptor® concept has evolved as field monitoring and on-going research present new opportunities to improve the Stormceptor® product line and environmental awareness regarding stormwater quality control increased.

2.2 Organization and Management

The Stormceptor® Group of Companies (SGC) is a group of companies that design, engineer, patent, and market stormwater treatment equipment. Stormceptor® Group of Companies is comprised of three separate companies including:

- **Stormceptor® Corporation** in the United States;
- **Stormceptor® Canada, Inc.** in Canada; and
- **X-Ceptor™ International** in the remainder of the world.

These companies own and license the patented Stormceptor® System technology. Since 1992, over 14,000 units have been installed worldwide through a network of licensed manufacturers (affiliates).

2.3 Operating Experience with the Proposed Technology

The Stormceptor® System was designed and developed in the laboratory and has been tested in numerous field studies and other laboratory studies. Since 1990, the Stormceptor® group of companies and its affiliates have allocated over $1,000,000 (US) towards field monitoring in a continuing effort to define the operating characteristics of the product. All the Stormceptor® monitoring is completed by engineering consultants and follows a monitoring protocol based on flow proportional monitoring upstream and downstream of the Stormceptor® system.

2.4 Patents

Currently, 22 patents and applications relating to the original system and improvements upon it are filed in nine countries around the world including the United States, Canada, Australia, New Zealand, Malaysia, Indonesia, Korea, China, and Japan.

In the United States Stormceptor® Corporation holds six patents including the following:

Improved Separator Tank Construction:	US Patent no 4,985,148
Enhanced Separator Tank:	US Patent no 5,725,760
Submerged Pipe Separator Tank:	US Patent no 5,753,115
Tank Interceptor:	US Patent no 5,498,331
Catchbasin Interceptor:	US Patent no 5,849,181
Separator Tank:	US Patent no 6,068,765
Apparatus for Water at Low & High Feed Rates:	US Patent no 6,371,690

2.5 Technical Resources, Staff and Capital Equipment

Stormceptor® Corporation works in partnership with its affiliated companies to provide its customers with solutions to unique situations throughout the design process. Rinker Materials™-Hydro Conduit is a successful established company with 50 operations across the United Sates that has been in operation for over forty years. The Stormceptor® Corporation has been providing stormwater quality solutions for over 12 years.

Technical Resources

Technical assistance is provided by local Rinker Materials – Hydro Conduit representatives in the state of New Jersey. The Rinker Materials™-Hydro Conduit head office in Houston, Texas is available to provide assistance as well as the Stormceptor® Corporation office in Toronto, Canada.

Stormceptor® Corporation operates a full scale laboratory facility in Ontario Canada, to conduct research on new innovative treatment methods, as well as development of the current product line. If necessary, this facility is available to analyze and simulate individual site-specific issues as well. Stormceptor® Corporation also organizes bi-annual technical meetings with the technical representatives of its worldwide affiliate companies. These meeting are useful in sharing technical expertise and solutions between various geographic and regulatory environments.

The Stormceptor® System is widely used around the world. For Stormceptor® units specified in the State of New Jersey, the concrete portion of the Stormceptor® system is manufactured locally in New England, while the fiberglass insert is manufactured in Ontario, Canada.

For a given project, the Stormceptor® unit is typically sized by a consulting engineer using the publicly available Stormceptor® Sizing Program v 4.0.0. Site details, along with unit size are then forwarded to the local Rinker Materials™-Hydro Conduit facility for development of construction drawings. Drawings are forwarded to the contractor for confirmation of layout. After confirmation from the contractor, the final product is delivered onsite along with installation instructions. The amount of lead time required for ordering a unit is approximately 2 to 4 weeks.

3. Treatment System Description

Figure 1 shows parts that make up the Stormceptor® System. The Stormceptor® System is a vertically oriented cylindrical structure manufactured from concrete and fiber reinforced plastic, designed to remove hydrocarbons and fine sediment from stormwater.

It is comprised of precast concrete circular riser and slab components which make up the tank and a fiberglass disk partition, also referred to as the "fiberglass insert". A fiberglass insert is mounted inside the precast chamber and functions to achieve the following:

1. Separates the chamber into two components: an upper chamber and a lower chamber;
2. A weir on the fiberglass insert allows head build-up to a maximum of 9 inches (229 mm) which drives flows (up to the treatment capacity of the unit) through the orifice plate and into the lower chamber. The remainder of the high flows will overflow the weir and bypass the system under infrequently occurring large storm events;
3. The orifice plate controls the flow rate and velocities entering the lower chamber. High flows and velocities need to be minimized in order to prevent re-suspension, loss of fine suspended solids material, and emulsification of collected hydrocarbons; and
4. The separation between chambers allows a portion of the infrequent high flows that over tops the weir to bypass the system thus preventing re-suspension or the scour of previously deposited material.

Stormwater flows into the Stormceptor® System through the upper chamber via the storm sewer pipe. Low flows are diverted into the lower chamber by a weir and drop tee arrangement (See Figure 2). The drop tee is constructed with two holes directing the water to follow the inside circumference of the unit to maximize detention time. Water flows up through the riser pipe based on the head at the inlet weir, and is discharged back into the upper chamber downstream of the weir. The downstream section of the upper chamber is connected to the outlet sewer pipe.

Oil and floatables with a specific gravity less than water will rise in the lower chamber and become trapped since the riser pipe is submerged. Sediment will settle to the bottom of the lower chamber by gravity. The circular design of the lower chamber is critical to prevent turbulent eddy currents and to promote settling. The Stormceptor® System does not remove dissolved and emulsified pollutants from water.

During high flow conditions, a portion of the stormwater that exceeds the treatment capacity, in the upper chamber will overflow the weir and be conveyed to the outlet sewer directly (See Figure 3). Water that overflows the weir decreases the head differential between the inlet and outlet pipe whereby ensuring that excessive high flows and velocities will not be forced into the lower chamber, which could scour or re-suspend the settled material. The high flow internal bypass is an integral part of the Stormceptor®.

Installation

The installation of the Stormceptor® System should conform in general to state and local specifications. Top soil that is removed during the excavation for the Stormceptor® unit should be stockpiled in designated areas and should not be mixed with subsoil or other materials. Topsoil stockpiles and the general site preparation for the installation of the Stormceptor® unit should conform to local specifications.

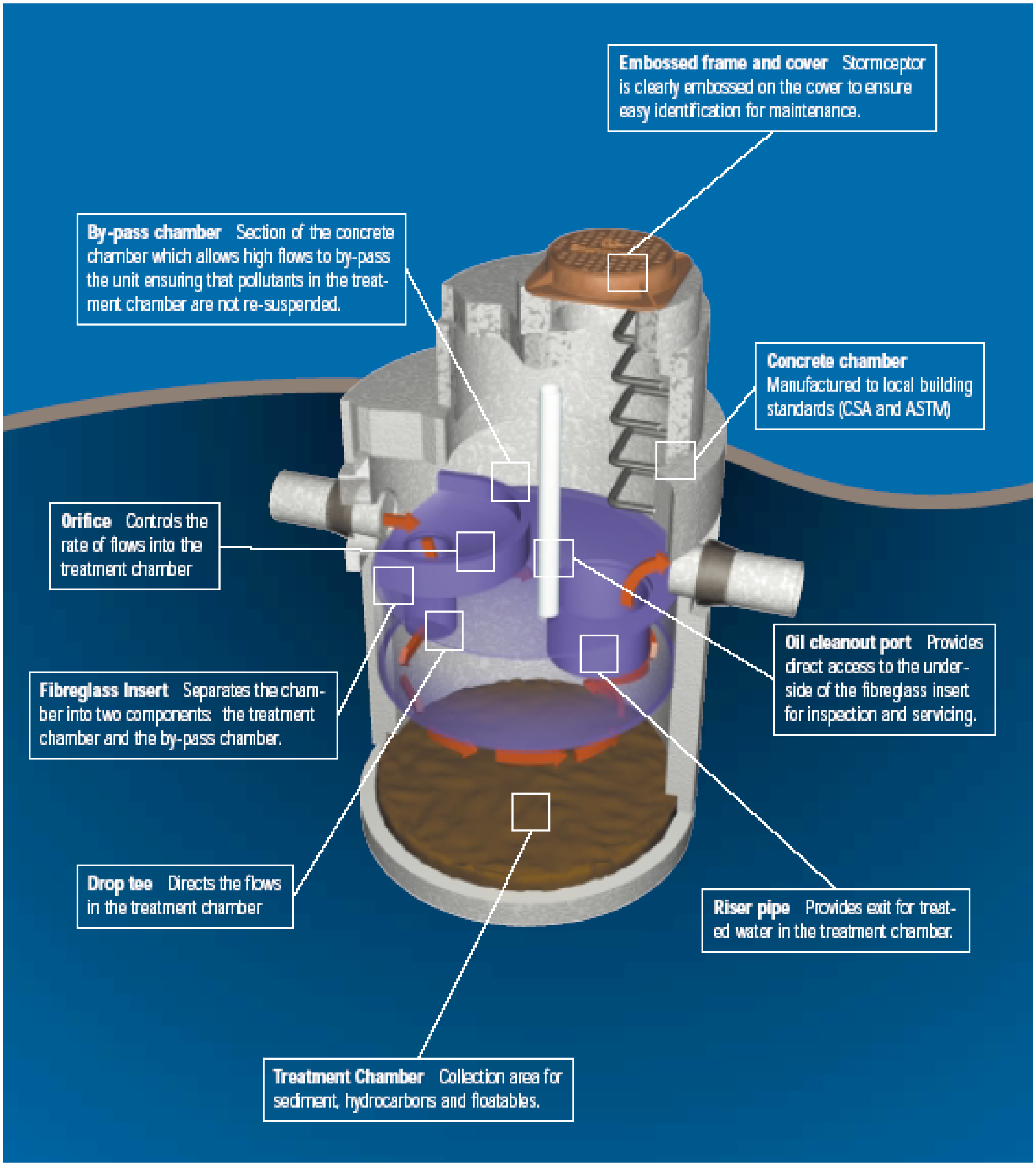

Figure 1. Stormceptor® System Components

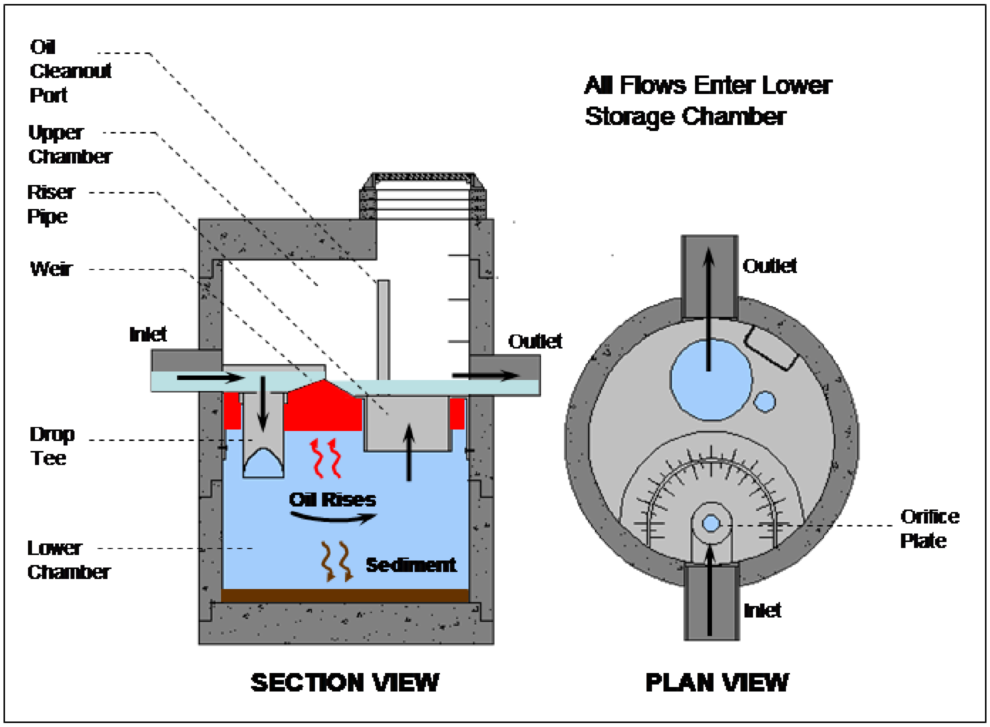

Figure 2. Stormceptor® Operation during Average Flow Conditions

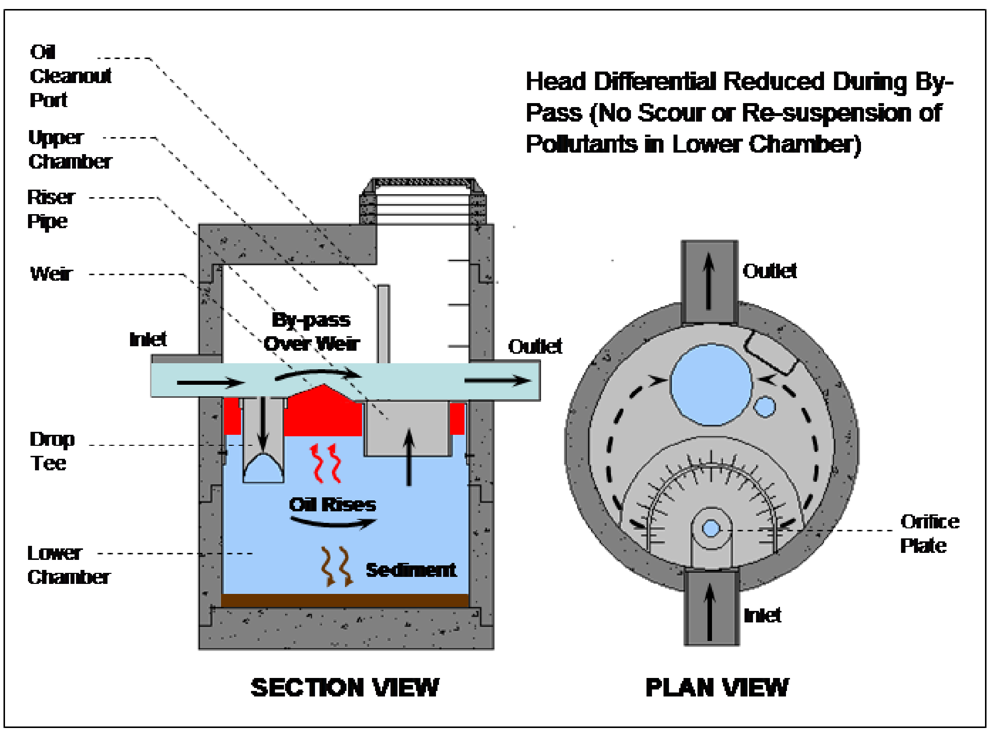

Figure 3. Stormceptor® Operation during High Flow Conditions

Stormceptor® units should not be installed on frozen ground. Excavation should extend a minimum of 12 inches from the precast concrete surfaces plus an allowance for shoring and bracing where required. If the bottom of the excavation provides an unsuitable foundation additional excavation may be required. Areas with a high water table may require continuous de-watering to ensure that the excavation is stable and free of water.

Backfilling

Backfill material should conform to provincial or local specifications. Backfill material should be placed in uniform layers not exceeding 12 inches (300 mm) in depth and compacted to local specifications.

Stormceptor® Construction Sequence

Rinker Materials™ provides a detailed site specific installation instruction at the time of order to the installer.

The instructions detail the stacking sequence of each precast component and identify the specific depths from the inlet pipe to the bottom of the base. Only the site specific installation instruction should be used for installation purposes. The concrete Stormceptor® unit is installed in sections in the following sequence:

1. aggregate base
2. base slab
3. lower chamber section
4. upper chamber section
5. assembly of fiberglass insert components (drop tee, riser pipe, oil cleanout port and orifice plate)
6. remainder of upper chamber
7. frame and access cover

The precast base should be placed level at the specified elevation. The entire base should be in contact with the underlying compacted granular material. Subsequent sections, complete with rubber gaskets, should be installed in accordance with Rinker Materials™ recommendations for precast concrete.

Adjustment of the Stormceptor® unit can be performed by lifting the upper sections free of the excavated area, re-leveling the base, and re-installing the sections. Damaged sections and gaskets should be repaired or replaced as necessary.

The timing for installation of a Stormceptor® unit ranges from 2 to 6 hours, depending on the unit size and site conditions.

All Stormceptor® units are manufactured according to ASTM C-478 (Specification for Precast Reinforced Concrete Manhole Sections) and designed for an AASHTO HS-20 live load (units can be designed to meet other live loads, for example Aircraft loading).

All Stormceptor® units utilize a rubber gasket to form a watertight seal at all the joints. The joint is designed according to ASTM C-443 (Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets) and takes into consideration gasket deformation and fully out-of-round and off-centered product.

All Stormceptor® units have been checked for buoyancy based on the combination of the following design assumptions:

A. The elevation of the water table is at the finished grade.
B. A total depth of 8.0 feet (2.44 m) is assumed from the inlet invert elevation to the finished grade elevation.
C. The lower chamber is empty.

4. Technical Performance Claim

Claim: The Stormceptor® System Model STC 900 provides 75% "Bulk TSS" removal efficiency (as per NJDEP treatment efficiency calculation methodology) for laboratory simulated stormwater runoff with an average influent concentration of 295 mg/L and an average d_{50} particle size of 97 microns. TSS removal testing was conducted with sediment pre-loaded in the lower chamber to 50% sediment capacity for the STC 900.

5. Technical System Performance

The Stormceptor® System STC 900 has been tested in a full-scale hydraulic laboratory. The laboratory tests were completed for NJDEP recommended PSD with gradations ranging from 1 to 1,000 microns. Tests were performed with TSS influent concentrations ranging from 100 to 300 mg/L at various increments of the operating rate (i.e., 25%, 50%, 75%, 100%, and 125%). The operating rate of the STC 900 is 0.63 cubic feet per second (cfs) or 283 gallons per minute (gpm) or 18 litres per second. In addition to specific testing, Stormceptor® has developed the Stormceptor® Sizing Model that estimates long term TSS removal efficiencies based on site information, local precipitation patterns and laboratory performance data. The Stormceptor® System has been tested extensively in the field by Stormceptor® staff as well as independent researchers (Applied Hydrology Associates, 2003; Associated Earth Sciences, Inc., 2001; Pollutech Environmental Limited, 2001; Waschbusch, 1999; Winkler, 1997)

5.1 Laboratory Studies

Stormceptor® Corporation conducted laboratory testing to evaluate the TSS removal efficiency of the STC 900 systems under the NJDEP TSS protocol. This section provides details of the laboratory system setup, particulars on the initial sediment loading in the lower chamber and the procedures followed in the test.

System Description

A schematic of the laboratory layout is illustrated in Figure 4. All the tanks are filled with water prior to system startup. While the lower chamber of the Stormceptor® unit is full of water (and 50% of recommended sediment capacity before recommended servicing), the Stand Pipe, Plunge Pool and Storage Tank (all of which are open tanks) are filled with water to the invert of the inlet or outlet pipes. A ball valve located between the pump and stand pipe is adjusted to achieve the desired flow rate for the system. Approximately 10 ft (3m) upstream of the Stormceptor® unit, an area velocity flow logger is installed to measure the depth of flow, velocity and flow rate of the influent water.

Water is pumped to the stand pipe and overflows into the plunge pool, where partial pipe flow similar to what is observed in gravity sewers begins to occur. Water exits the plunge pool (a cylindrical tank) through a 15 in. (381 mm) internal diameter PVC pipe directed to the Stormceptor® unit.

A slurry mixture, contained in a 65 gallon cone-bottom tank (0.25 m^3), is introduced to the partial pipe flow near the plunge pool exit pipe via a peristaltic pump. Sediment in the batch slurry mixture is kept in suspension using a mixer and a diaphragm pump. The diaphragm pump draws from the bottom of the cone bottom tank and pumps the slurry back into the top and side of the slurry tank. Turbulent flow within a portion of this 15.8 ft (4.8 m) long pipe provides mixing of the slurry/water mixture prior to entering the Stormceptor® unit.

The semi-circular weir on the Stormceptor® insert directs the flow to the lower chamber through an orifice plate and drop tee arrangement. The semi-circular weir and orifice plate restrict the quantity of flow entering the lower chamber up to the operating rate. The drop tee channels the flow around the inside circumference of the lower chamber. The head differential between the inlet and outlet of the unit allows water to exit the bottom chamber through a riser pipe. Automatic samplers are placed at the inlet and outlet pipes of the Stormceptor® unit to collect influent and effluent samples, respectively. Water exiting the STC 900 is channeled via a 42.5 in. (1080 mm) diameter half pipe, modified with a circular insert designed to simulate a 15 in. (375 mm) outlet pipe. This pipe feeds effluent into the storage tank. A 10 ft (3 m) diameter, 1-µm filter bag covers the storage tank and functions to filter out sediment that may be in the effluent prior to re-circulating back into the system from the storage tank.

Initial Sediment in STC 900

The total sediment capacity of the STC 900, which is based on the depth when servicing or maintenance of the unit is recommended, is determined by calculating 15% of the total depth of the lower chamber. For the STC 900, the actual total depth of the lower chamber is 5 ft 6" (1.7 m). At 15% of the total depth, the depth is approximately 10 in. (244 mm). As such, the depth of 10 in. (244 mm) is referred to as "100% sediment capacity" of the unit (See Figure 5). At 50% sediment capacity (See Figure 6), the depth of sediment in the lower chamber is approximately 5 in. (122 mm).

All the TSS tests and one scour test were conducted with the lower chamber of the STC 900 initially loaded with 50% of the sediment capacity. For the second scour test, the treatment chamber was filled to 100% of the sediment capacity (the recommended depth before servicing). Both scour tests were conducted at an operating rate of 125%.

While the NJDEP did not specify the particle gradation required in the lower chamber prior to testing, the same particle gradation required for the influent PSD was assumed for initial sediment loading. As a result, the sediment placed in the lower chamber consisted of 50% SIL-CO-SIL® 250 and 50% Mason Sand.

The actual sediment in the bottom of the chamber was measured by finding the distance from the top of the tank to the top of the sediment pile and subtracting it from the total height of the tank. The volume of sediment was then calculated using the average sediment depth determined and the diameter of the tank.

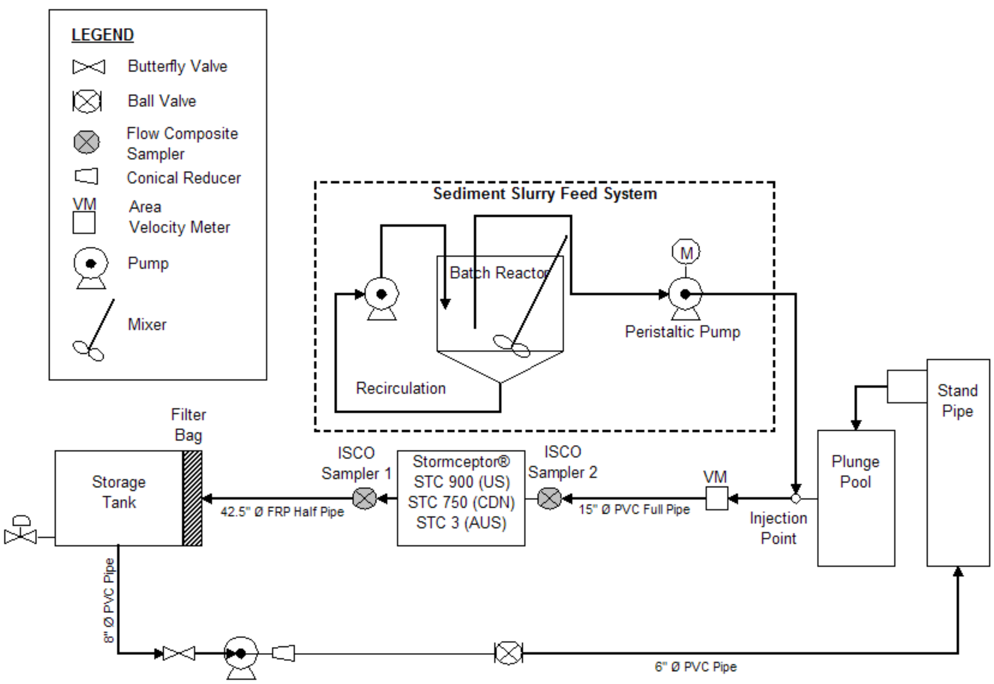

Figure 4. Process Flow Diagram of Laboratory Configuration

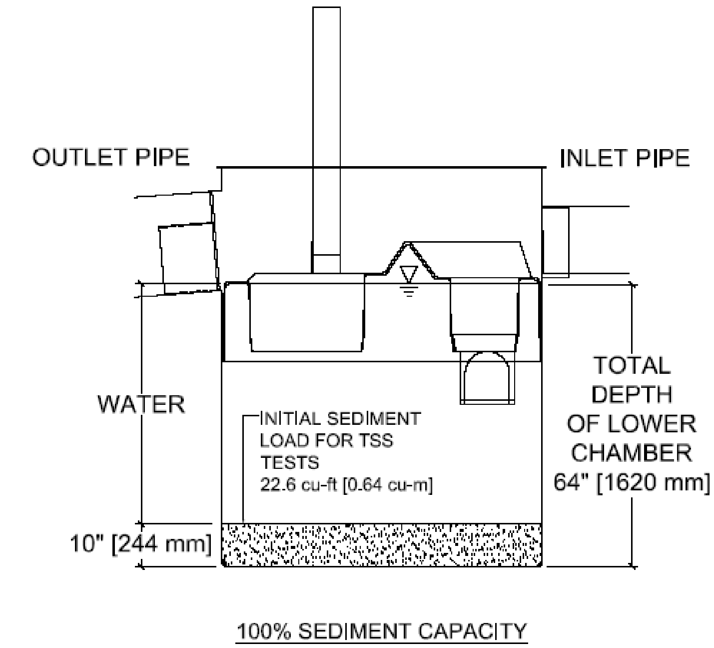

Figure 5. Theoretical Initial Sediment Depth of 100% in the Lower Chamber

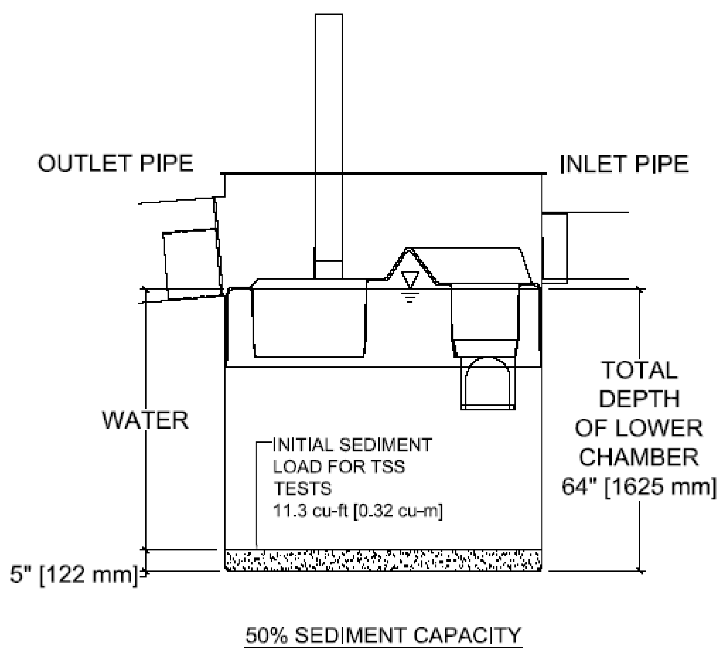

Figure 6. Theoretical Initial Sediment Depth of 50% in the Lower Chamber

Procedure

The test procedure followed in this test was approved by NJCAT and by the NJDEP. The test procedure was written in accordance to the NJDEP Protocol. During the test preparation, the protocol was updated to reflect the change in the number of samples to be collected. The main test methodology remained the same. The protocol followed for the testing can be found in the Stormceptor® TSS removal laboratory testing protocol dated April 12, 2004 as discussed below.

Note that the only deviation from the Stormceptor® protocol occurred at the 25% operating rate where one additional field blank was taken at the end of the run for a total of four field blanks. This was taken to ensure that there was no additional background loading due to recirculation of water through the Stormceptor® unit. One blank is allocated for internal laboratory analysis and the remainder is for external laboratory testing.

Quality Control Summary

The following is a summary of quality control measures followed:

Field Blanks	Background concentrations were measured by collecting three field blanks in the influent pipe prior to sediment injection for external laboratory analysis. The measured field blanks represented TSS concentrations already existing in the water due to recirculation. Grab samples were taken at the inlet pipe of the STC 900.
Initial Setup Condition	To prevent sample contamination from previous runs, a clean system must exist prior to the start of each run. To ensure each run started with a clean system, the inlet/outlet pipes and the surfaces of the insert were sprayed down to remove any material from the previous test run.
Sediment Source	Sil-Co-Sil® 250 and Mason sand (supplied by Lafarge Canada, Inc.) were used for the experiment. Sediment from each source was not sieved prior to use. The particle size distribution for the Sil-Co-Sil® 250 ranges from 0.1 µm to 212 µm (note that the 0.1 µm is based on measured samples completed by Maxxam Analytics, Inc. obtained from the test runs). The particle size distribution for the Mason sand ranges from 75 µm to 2,360 µm.
Sediment Slurry Mix	Through systematic testing, it was determined that a 40/60 ratio of Sil-Co-Sil® 250/Mason Sand mix would provide a particle size distribution representative of that prescribed in the NJDEP Protocol, when the peristaltic pump operates at a constant speed of 1.59 US gallons per minute (gpm) or 6.0 litres per minute for all runs. To ensure that the PSD was within range of the target NJDEP PSD, sediment slurry from each run was taken for external laboratory analysis to verify the quality of the run. The PSD from the inlet and outlet automatic samplers were also analyzed to better determine what was happening during each run. The sediment slurry was mixed in a 65 gal. cylindrical (0.25 m^3)cone-bottom tank with a 0.5 horsepower (hp) mixer. Slurry was drawn from the bottom of the tank via a 42 gpm (150 L/s) capacity diaphragm pump (operated at 25 pounds per square inch or 172 kilo Pascals) and re-circulated back into the top of the slurry tank directed to the inside wall. Prior to sediment injection to the system, sediment slurry samples were collected for external TSS and PSD analysis. At the end of the run, another slurry sample was taken to verify the slurry concentration through TSS analysis.

Sediment Metering	Sediment slurry was drawn from the bottom third of the slurry tank via a flexible hose from a peristaltic pump. The peristaltic pump discharged at a rate of 1.59 gpm (6 L/min). A flexible hose was anchored by a stainless steel rod inside the slurry tank to restrict movement and to maintain a consistent depth in the tank. The other end of the flexible tube was placed into the top of the inlet pipe located approximately 3 ft (0.91 m) away from the plunge pool. The peristaltic pump was calibrated using a graduated cylinder and stop watch.
Gravity Flow in Storm Sewer Conditions	To best simulate field conditions, the laboratory testing system is set-up to represent uniform normal flow conditions under the action of gravity in storm sewers. Water is pumped from the storage tank to the stand pipe via pressure flow using a 7.5 hp Armstrong Series 4380 pump through 6 in. (150 mm) diameter PVC pipe. Water is then directed into a stand pipe that is open to the atmosphere. Water overflows the stand pipe into a plunge pool that acts similar to a maintenance hole, and diverts water into the influent pipe simulating normal flow conditions that exist within pipe line systems in the field. Water then flows into the Stormceptor® unit via a 14.8 ft (4.5 m) long, 15 in. (375 mm) I.D. PVC inlet pipe, partially full under the action of gravity in accordance with empirical formulas such as Manning's Equation or Colebrook White.
Flow Calibration, Regulation and Measurement	Calibration of flows is achieved by measuring the depth of flow upstream of the area velocity probe and comparing it to the area velocity flow logger depth readings. Flow Link 4® is the ISCO software used to display the readings from the low profile velocity meter. The area velocity flow logger is set to display measurements for flow at increments of 5 seconds. For the purpose of ensuring that flow readings are consistent, depth of flow, velocity and flow rates are recorded with each sample bottle that is taken. A ball valve located between the centrifugal pump and stand pipe is used to regulate the flow rate for the system. The ball valve is open or closed until the target flow rate is reached. Once the target flow rate is achieved, the system is left to run for a minimum of 5 minutes to ensure that the flow rates have stabilized.
Sample Collection	Influent and effluent samples are collected using automatic samplers (ISCO). The automatic samplers are pre-programmed to collect 500 mL water samples every minute for a total of 12 samples per automatic sampler at the end of each individual test run. The samplers are pre-programmed to purge the tubing before and after each sample is drawn to prevent contamination. Sampling from the effluent automatic sampler is initiated once the detention time for the unit is reached. The detention time is a function of the operating rate and varies depending on the operating rate of the individual test runs. At the end of the run, 10 samples from each automatic sampler were emptied into clean 500 mL plastic sample bottles provided by the external analytical laboratory for TSS analysis. While one out of the ten samples was dedicated for internal laboratory analysis, the remaining 9 samples were sent out to an external laboratory for TSS analysis. The final two 500 mL samples were combined in a 1 L container for particle size distribution analysis. To ensure that all solid particles are properly transferred to the new labeled jars, the sample bottles are vigorously agitated to ensure suspension of particles. This step may be repeated if, through visual observation, sediment is still adhered to the transfer bottles. All samples are carefully labeled and placed in a cooler prior to shipping to an external laboratory for analysis.

Sample Handling and Transport	Samples are stored in a cooler maintained at a temperature of 39 degree Fahrenheit (^{o}F). A chain of custody is completed to document travel designation, receipt time, sample numbers and IDs submitted and type of analysis to be performed for each respective sample. All chain of custodies were signed by the receiving personnel to verify receipt.
Independent Laboratory Analysis	TSS analysis was performed by an external laboratory (AMEC Earth & Environmental Limited (AMEC), accredited by the Ontario Ministry of the Environment). APHA method 2540D (modified) was used, where the whole sample was analyzed. PSD analysis of the slurry, influent and effluent samples was performed by an external laboratory (Maxxam Analytics Inc., accredited by the Ontario Ministry of the Environment). Due to the nature of PSD analysis, the samples were sent out by Maxxam Analytics Inc. to their laboratory in Alberta. The instrument used to perform PSD analysis on the sediment/water samples was a Malvern Mastersizer 2000. It is used to measure particles in an aqueous suspension by diffracting a laser beam.

TSS vs. SSC

In the preparation of the protocol for this study, the Stormceptor® Corporation reviewed laboratory tests for the determination of the total suspended solids concentration of the water samples to determine the most appropriate testing methodology. There are currently two recognized types of tests being used in the stormwater industry including:

1) APHA Method 2540 D, a traditional TSS test, where only a sub-sample of the overall sample for suspended solids content is tested; and
2) ASTM D 3977-97 (Re-approved 2002), "Suspended-Sediment Concentration (SSC)" test where the entire sample volume is tested.

The APHA Method 2540 D TSS protocol requires that a 500 mL sample be agitated to homogenize the slurry. A 50 mL sub-sample is then drawn and filtered to find the "total suspended sediment" concentration. In the case of analysis of sediment and water, maintaining a homogeneous mixture is difficult to achieve as particle dispersion is dependent on particle size and weight. As a result, extraction of a representative sample is unlikely to be achieved.

Conversely, the SSC method uses the entire sample submitted to the laboratory for testing. By analyzing the entire sample, potential for error from agitation and sub-sample extraction is eliminated.

Stormceptor® regards the SSC or "Bulk TSS" method as a more accurate indicator of the actual concentration of suspended solids of a given sample since the entire sample is used for analysis. These methods eliminate multiplying errors that can result from taking sub-samples; therefore, "Bulk TSS" analysis is the preferred method for suspended solids measurement.

For the purpose of the Stormceptor® testing program, a local laboratory that was familiar with the ASTM D 3977-97 (Re-approved 2002) could not be sourced. As an alternative, a government licensed laboratory that could provide a “modified” TSS test as per APHA Method 2540 D procedures was selected. This modified APHA Method 2540 D was termed as “Bulk TSS” test and analyzes TSS using the entire sample volume submitted.

It is important to note that the NJDEP TSS removal criterion for stormwater management systems is based upon TSS, not SSC or “Bulk TSS”. Through the definition of their draft TSS laboratory testing procedure, NJDEP has defined a particle size distribution that ranges from 1 to 1,000 microns, therefore defining TSS as particles smaller than 1,000 microns. Since the Stormceptor® Corporation used the NJDEP recommended particle size distribution in their laboratory experiments, an argument can be made that the use of SSC or “Bulk TSS” would be appropriate for determining a system removal efficiency for TSS, since only TSS (as defined by NJDEP) were present in the experiment. If the particle size distribution used in the experiments contain particles greater in size than 1,000 microns, these larger particles would have resulted in higher influent SSC concentrations, translating into higher removal efficiencies. Although precautions should be taken in conducting field verification studies where the influent to the system may contain particles larger than 1,000 microns, the Stormceptor® approach yields a good representation of the removal efficiency of the STC 900 system.

5.2 Verification Procedures

All the data provided to NJCAT were reviewed to fully understand the capabilities of the Stormceptor® System. To verify the Stormceptor® claim, the Stormceptor® laboratory data were reviewed and compared to the draft NJDEP TSS laboratory testing procedure.

Claim: The Stormceptor® System Model STC 900 provides 75% “Bulk TSS” removal efficiency (as per NJDEP treatment efficiency calculation methodology) for laboratory simulated stormwater runoff with an average influent concentration of 295 mg/L and an average d_{50} particle size of 97 microns. TSS removal testing was conducted with sediment pre-loaded in the lower chamber to 50% sediment capacity for the STC 900.

5.2.1 NJDEP Recommended TSS Laboratory Testing Procedure

The NJDEP has prepared a draft TSS 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 2) using a natural/commercial soil representing United States Department of Agriculture (USDA) 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.

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 re-suspension and washout.
    D. The test runs should be conducted at a temperature between 73-79 degrees Fahrenheit (°F) 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.

Table 2. Particle Size Distribution

Particle Size (microns)	Sandy loam (percent by mass)
500-1,000 (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 µm, 25%) (2-8 µm, 15%)*
1-2 (clay)	5.0

Notes:
1. Recommended density of particles ≤2.65 g/cm3

*The 8 µm 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.

Table 3. Weight Factors for different Treatment Operating Rates

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.

5.2.2 Laboratory Testing

The results of the laboratory testing that were performed by the Stormcepto*r*® Group are presented in Table 4. Testing was performed for three influent TSS target concentrations of 100, 200 and 300 mg/L. These tests were performed at various increments of the operating rate (i.e., 25%, 50%, 75%, 100%, and 125%). The NJDEP weighting factors were applied to the test results to generate weighted average removal efficiency. Based upon the data presented in Table 4, the removal efficiency of the system is 75%, thereby verifying the Stormceptor® Claim.

To confirm these results, a mass balance was completed. Results of the mass balance and NJDEP weight factors are listed in Tables 5 and 6.

The influent mass was determined by first calculating the average slurry concentration (in mg/L), which was measured at the beginning and at the end of the run, and multiplying it by the injection rate (in L/min) to determine the mass flow rate (in mg/min). This mass flow rate was then multiplied by the duration (in min.) that the slurry was being injected. The average of the initial slurry sample (SL1) and final slurry sample (SL4) was used to estimate the average suspended solids concentration injected during the course of the run.

In between test runs, the slurry tank was cleaned and refilled with water and new sediment. During the cleaning process, the remaining sediment in the slurry tank was not measured. In hindsight, the remaining sediment in the slurry tank should have been measured to help verify the mass of sediment injected. As a result, the average of the two slurry concentrations (SL1 and SL4) was used to estimate the total amount of sediment injected.

The effluent mass was determined by measuring the dry mass of the sediment in the filter bags. Filter bags were numbered, for identification purposes, and the dry weight recorded prior to use. After every test, the filter bag was removed from the outlet storage tank and left to dry at room temperature. Once the filter bag was dried, it was weighed and the mass of dry sediment was determined after allowing for the initial mass of the filter bag.

There were some problems with determining the mass balance due to the inability to completely dry the sampling bags and the high variability of slurry TSS concentration as measured at the beginning and the end of the experiment. At times, the slurry TSS concentration as measured at the end of the experiment was 50% of the concentration measured at the beginning of the experiment. Even though there are some questions to the accuracy of the mass balance calculation, the results do support the results from the calculated efficiency based upon samples collected by the automatic sampler of the influent and effluent (See Table 4).

During the laboratory experiments, Stormceptor® measured the particle size distribution of the slurry mix and the influent taken by the automatic sampler. The average d_{50} of the slurry mix was measured to be 47 microns while the average d_{50} of the influent was measured to be 97 microns. Stormceptor® suggests that this difference in average d_{50} particle size results from the inlet automatic sampler and sediment slurry samples taken at the beginning of the run may be due to the automatic samplers extracting a greater proportion of coarser material than what is actually present within the flow. It is postulated that the coarser material, being heavier, may have a tendency to travel closer to the bottom of the pipe due to their weight and size, despite the turbulent flow that exists in the inlet pipe. Data have not been presented by Stormceptor® to validate this hypothesis. The average d_{50} of the NJDEP particle size distribution is approximately 67 microns, slightly lower than the average d_{50} measured at the inlet during the Stormceptor® laboratory experiments. Additional analyses may be needed to determine if the hypothesis put forth by Stormceptor® (i.e., that the automatic sampler did not collect a truly representative sample due to coarser material travel near the bottom of the inlet pipe) is valid.

Table 4. Summary of Automatic Sampler TSS Concentrations and Removal Efficiencies

Operating Rate	Influent Target: 100 mg/L			Influent Target: 200 mg/L			Influent Target: 300 mg/L			Overall Ave. Removal Efficiency %	NJCAT Weight Factor	NJCAT Weighted Ave. Removal Efficiency %
	Ave. Inlet Conc. mg/L	Ave. Outlet Conc. mg/L	Ave. Removal Efficiency %	Ave. Inlet Conc. mg/L	Ave. Outlet Conc. mg/L	Ave. Removal Efficiency %	Ave. Inlet Conc. mg/L	Ave. Outlet Conc. mg/L	Ave. Removal Efficiency %			
25%	203	25	88%	355	50	86%	599	79	87%	87%	0.25	22%
50%	129	34	74%	218	68	69%	416	106	75%	72%	0.30	22%
75%	147	42	71%	266	85	68%	381	135	65%	68%	0.20	14%
100%	187	31	83%	303	90	70%	425	148	65%	73%	0.15	11%
125%	98	16	84%	223	114	49%	486	108	78%	70%	0.10	7%
Overall Ave.	153	30	80%	273	82	68%	461	115	74%			75%

Table 5. Mass Balance Results

Operating Rate	Mass In lbs (kg)	Mass Out Lbs (kg)	Mass Balance Performance (%)
25%	6.26 (2.84)	1.59 (0.72)	75%
50%	18.82 (8.54)	4.63 (2.10)	75%
75%	22.36 (10.14)	6.61 (3.00)	70%
100%	24.425 (11.08)	8.95 (4.06)	63%
125%	42.907 (19.46)	11.95 (5.42)	72%

Table 6. NJDEP Weighted Mass Balance Performance

Treatment Operating Rate	NJDEP Weight Factor	Average % Removal: Mass Balance	NJCAT Weighted Avg. Removal:
25%	0.25	75%	18.8%
50%	0.30	75%	22.5%
75%	0.20	70%	14.0%
100%	0.15	63%	9.5%
125%	0.10	72%	7.2%
Total			72%

5.2.3 Field Studies

Based upon the earlier Stormceptor® submittal of field testing, several of the data points were represented of reasonable influent TSS concentration and reasonable flow rates. The Como Park study (Rinker Materials, 2002) met these conditions on two days: August 7, 1998 and August 27, 1998. The influent TSS concentrations were 318 and 196 mg/l, respectively and the peak flow rate was approximately 68% of the operating rate. The TSS removals for these events were 81.4 and 70.4, respectively. The only other relevant data point was collected during the Greenwood Village study (Applied Hydrology Associates, 2003) on August 6, 2002 where influent TSS concentration was 122 mg/l and the peak flow was 23% of the operating rate. This system achieved a 77% TSS removal rate.

These field data generally support the removal efficiency that was measured in the laboratory experiment.

5.2.4 Scour Test

The Stormceptor® unit was tested to check the potential for TSS re-suspension. The scour test was performed at 125% of the operating rate and with initial sediment loading of 50% and 100% in the lower chamber of the Stormceptor® unit. Attempts were made to eliminate or reduce the background concentration in the recirculating water by draining and cleaning the storage reservoir, plunge pool and stand pipe, and replacing it with "clean water". In doing so, an average background concentration of 59 mg/L and 21 mg/L was observed for the 50% and 100% initial sediment loaded scour test, respectively. This is expected as some fine particles cannot be filtered out by the 1 µm filter bag and therefore recirculates through the system.

Table 7 summarizes the results from the scour tests performed at 125% of the operating rate. The adjusted outlet TSS concentration was -3 mg/L when the lower chamber contained 50% of its sediment capacity; thus, indicating that no scouring occurs when the unit is 50% full of sediment. It also confirms that some removal is still achieved at 125% of the operating rate.

Minimal TSS concentration in the outlet was observed in the 100% sediment capacity scour test, where the average outlet concentration was 3.3 mg/L. While this suggests that slight re-suspension of material can occur when the unit is at maximum sediment capacity, it also confirms that maintenance is important when the sediment capacity is reached.

The Stormceptor testing protocol for scouring was approved by NJDEP and NJCAT prior to testing. Based upon the data generated under this protocol, the scour test suggests that the system does not resuspend particles that have already been collected.

Table 7. Scour Test TSS Results

Scour Test at 125% Operating Rate			
Sediment Capacity in Storm*ceptor*® Unit	**Average Inlet Concentration**	**Average Outlet Concentration**	**Adjusted Outlet Concentration**
50%	59 mg/L	56 mg/L	-3 mg/L
100%	21 mg/L	25 mg/L	3.3 mg/L

5.3 Inspection and Maintenance

The Stormceptor® 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

The Stormceptor® unit should be inspected at least once every six months using a dipstick or a similar device to measure the sediment depth and oil level contained in the lower chamber of the unit. Once the sediment depth reaches the recommended levels as indicated by the Stormceptor® model numbers presented in Table 8, the units should be serviced. If any large presence of oil is measured, the oil should be removed and properly disposed. It should be noted that maintenance frequency can vary with site conditions and therefore it is recommended that frequency of maintenance be increased or reduced based on local site conditions.

The depth of oil in the Stormceptor® unit can be determined by inserting a dipstick in the:

- 6 in. (150 mm) oil inspection /cleanout pipe (“disc” design”);
- 36 in. (914 mm) central access way (“spool” design); or
- 5 in. (125 mm) cleanout pipe (“Inlet” design).

Similarly, the depth of sediment can be measured from the surface without entry into the Stormceptor® via a dipstick tube equipped with a ball valve (sludge judge). This tube would be inserted in the:

- central opening (“spool” design);
- 24 in. (610 mm) opening (“disc” design); or
- 4 in. (102 mm) cleanout pipe (“inlet” design).

Stormceptor® maintenance is performed as follows:

- “spool” design: through the large central 36 in. (914 mm) diameter opening for both the oil and sediment.
- “disc” design: oil is removed through the 6 in. (152 mm) oil inspection/cleanout pipe and sediment is removed through the 24 in. (610 mm) diameter outlet riser pipe. Alternatively, oil could be removed from the 24 in. (610 mm) opening if water is removed from the lower chamber to lower the oil level to the level of the drop pipes.
- “inlet” design: oil is removed from the 4 in. (102 mm) oil/inspection cleanout pipe and sediment is removed though the 12 in. (300 mm) inlet drop pipe.

5.3.2 Maintenance

Once the sediment depth has reached the recommended depth for maintenance, the Stormceptor® unit should be serviced. A vacuum truck company licensed for solid waste disposal should be contracted to clean out the unit. Without any inspection, as a rule of thumb, the Stormceptor® unit should be serviced a minimum of once per year.

The oil should be removed first and contained separately from any water or sediment removed from the system. Oil is removed by pumping or skimming the top of the water through the oil cleanout port. Once the oil is removed, the water and sediment may be removed from the unit through the riser pipe. Where available, a secondary containment tank may be used to hold the water until the sediment is removed from the Stormceptor® unit. Once the sediment is removed, the water may be introduced back into the lower chamber of the Stormceptor® unit. Any petroleum waste products collected in a Stormceptor® due to oil, chemical or fuel spills should be removed by a licensed waste management company.

Table 8. Sediment Depths Indicating Requirement for Servicing

Model	Sediment Depth (inches)
STC 450	8 in. (200 mm)
STC 900	8 in. (200 mm)
STC 1200	10 in. (250 mm)
STC 1800	15 in. (375 mm)
STC 2400	12 in. (300 mm)
STC 3600	17 in. (425 mm)
STC 4800	15 in. (375 mm)
STC 6000	18 in. (450 mm)
STC 7200	15 in. (375 mm)
STC 11000**s**	15 in. (375 mm)
STC 13000**s**	18 in. (450 mm)
STC 16000**s**	15 in. (375 mm)

5.3.3 Solids Disposal

Solids recovered from the Stormceptor® 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 Stormceptor® 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 Stormceptor® Claim: The Stormceptor® System Model STC 900 provides 75% “Bulk TSS” removal efficiency (as per NJDEP treatment efficiency calculation methodology) for laboratory simulated stormwater runoff with an average influent concentration of 295 mg/L and an average d_{50} particle size of 97 microns. TSS removal testing was conducted with sediment pre-loaded in the lower chamber to 50% sediment capacity for the STC 900.

6.2 Limitations

6.2.1 Factors Causing Under-Performance

If the Stormceptor® 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 Stormceptor® 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 Stormceptor® System due to the absence of light and mixing by wind, thermal inputs and biological activity. Accumulated sediment should not be lost from the system at or under the design flow rate.

6.2.3 Sensitivity to Heavy Sediment Loading

Heavy loads of sediment will increase the needed maintenance frequency.

6.2.4 Mosquitoes

Although the Stormceptor® System is a self contained unit, the design does incorporate standing water in the lower chamber, which can be a breeding site for mosquitoes. Although no information has been presented by Stormceptor® in their submittal to NJCAT to address this concern, 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 Stormceptor® Systems have been verified and granted interim approval use within the State of New Jersey, the Stormceptor® Corporation 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 Stormceptor® technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

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NJCAT TECHNOLOGY VERIFICATION ADDENDUM REPORT

Stormceptor® STC

Imbrium® Systems Corporation

July 2010

1. Introduction

NJCAT published a Technology Verification Report on the Stormceptor® STC hydrodynamic separator manufactured by the Stormceptor® Corporation (now Imbrium® Systems Corporation) in September 2004. Since that time Imbrium® Systems along with Rinker Materials™, the United States Stormceptor licensee, has continued performance testing of the Stormceptor STC line. In 2008 Rinker Materials contracted with the Department of Environmental Engineering Sciences, University of Florida, Gainesville, FL 32611 for testing at the Department's Stormwater Unit Operations and Processes (UOPs) Laboratory. In addition to particulate removal efficiency testing, scour tests were conducted to demonstrate the Stormceptor® STC's ability to retain captured sediment at flows greatly exceeding the water quality design flow.

In 2009 the New Jersey Department of Environmental Protection (NJDEP) published a laboratory protocol for testing manufactured hydrodynamic sedimentation devices (NJDEP 2009) that contained procedures to enable manufactured treatment device (MTD) vendors to demonstrate their technology's ability to retain captured sediment and hence be installed on-line. Since the scour testing conducted at the University of Florida (UF) exceeded the NJDEP 2009 protocol test requirements, Imbrium Systems has submitted the UF test report in support of their claim that the Stormceptor® STC qualifies for on-line installation.

2. Technical Performance Claim

Claim – The Stormceptor® STC450i tested at 565% of the Maximum Treatment Flow Rate (MTFR), and with the sump loaded to 125% of the maximum recommended maintenance sediment depth with NJDEP particle size distribution (d_{50} = 67 µm) sediment, had effluent SSC concentrations <10 mg/l.

3. Technical System Performance

3.1 Laboratory Testing

The testing of the Stormceptor® STC450i was conducted at the UOPs laboratory facility. (Note: The "i" designates that this model functions the same as all Stormceptor models and has the ability to accept in-flowing stormwater from both inlet (inlet grate at surface) and/or in-line (pipe under ground).) The site has a footprint area of approximately 9,000 ft^2 and consists of a 40 by 60 feet concrete pad under roof. There is a two-story 20 by 20 feet tower building used as a multipurpose stormwater laboratory. There is a data acquisition room, 10 by 6 feet within the concrete pad, with A/C control for collecting the data during each run. The site is also provided with two 12,000-gallon potable water tanks fed by a pressured municipal water supply line and power (3-phase, 208-volt, 200-amps). The water supplied for the process was at a temperature of 28° C (± 3°C). Mx UltraMag electromagnetic flow meters measure flow rates. A CR3000 Micrologger, manufactured by Campbell Scientific Inc. is used as the real-time data monitoring and data collection unit. An YSI 600 OMS Sonde (YSI Inc.) multi-parameter water quality monitoring probe equipped with a 6136 Turbidity Sensor provided in-situ measurement of turbidity.

The inside diameter of the STC450i unit is 48 inches. The surface area of the unit is 1810 in^2. The sediment chamber volume is 108,520 in^3, which is equal to 470 gallons. The NJDEP certified Maximum Treatment Flow Rate (MTFR) of the STC450i is 0.283 ft^3/s, though the unit tested indicated a 14% higher MTFR (i.e. 0.32 ft^3/s) than previously indicated. This unit has an internal bypass which accommodates overflow of a portion of the influent when there is a high flow rate, and protects previously captured pollutants in the lower treatment chamber. This bypass allows the excess influent volume to discharge to the effluent side of the STC450i insert, without disrupting the treatment or re-suspending previously captured pollutants. For the influent potable water pumped into the unit, an 8" diameter separate hard-plumbed PVC pipe was used.

3.2 Particle Size Distribution (PSD)

The New Jersey Particle Size Distribution (NJPSD) specified for sediment removal efficiency testing was used for preloading the sediment storage volume. This was more conservative than the protocol requirement that only material consistent with the particle distribution for particles 50 microns and greater in the NJPSD be utilized. A combination of four different particle gradations of silica sand particles were chosen for the study; 20/40 Oilfrac, #1 Dry, OK 110 and Sil-Co-Sil 106 were all used to prepare the NJPSD gradation as required by the NJDEP hydrodynamic separator lab testing protocol (NJDEP 2009). The particle size of each silica sand (or silt) gradation supplied by US Silica Company was combined to create the NJPSD (labeled as NJCAT) gradation as shown in Figure 1.

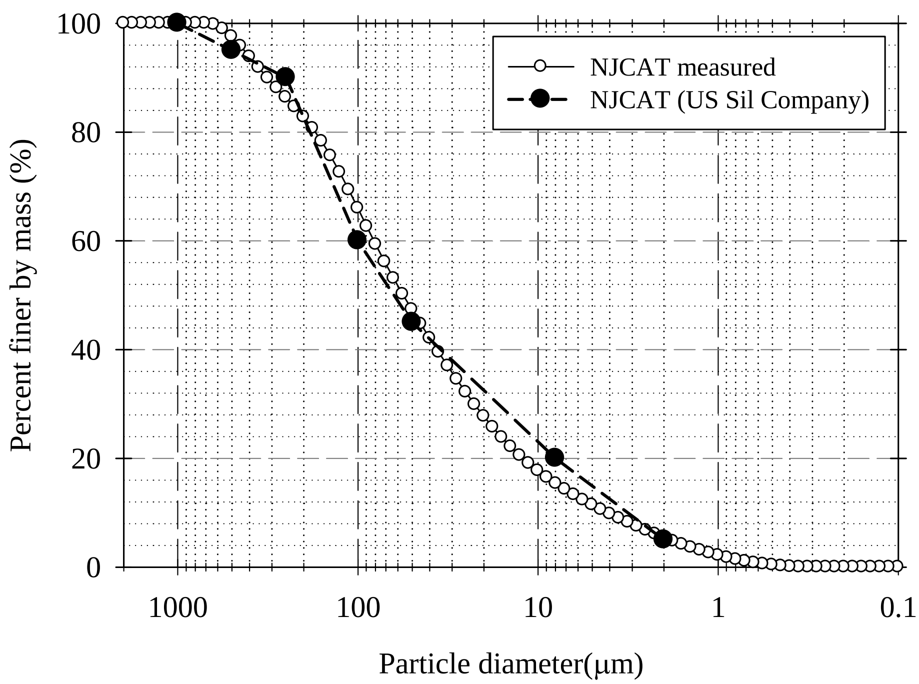

Figure 1 NJPSD target PSD with measured PSD for influent particle mixture consisting of 4 different silica gradations with predetermined mass ratio.

3.3 Scour Test Procedures

Scour testing was carried out at 1.6 cfs (565% of the certified maximum treatment flow rate of 0.283 cfs), at 62.5% and 125% of the maximum recommended maintenance sediment depth in the lower chamber of the STC450i. It was observed that flows which exceeded 0.32 cfs bypassed directly over to the effluent side of the unit without flowing into the unit.

The potential for re-suspension and washout of preloaded NJPSD in the STC450i was examined for two sets of parameters:

1. Flow rate of 565% of the MTFR, and

2. Preload sediment in the unit for 5 inches and 10 inches of depth, equal to 62.5% and 125% of the maximum recommended maintenance sediment depth. These sediment depths are within the range of approximately 8-17% of the volume in the lower chamber.

For the 62.5% sediment depth preloading set-up (5"), the entire surface area of the lower chamber (1810 in²) was filled with a 2 inch deposit of NJPSD gradation, using a movable insert (false-floor) raised up 3 inches from the bottom. For the 125% sediment depth preloading set-up (10"), the entire surface area of the lower chamber (1810 in²) was filled with an NJPSD gradation. This 125% run utilized the movable insert, raised up 8" from the bottom, to create a 2 inch NJPSD deposit. (Note: The NJDEP protocol specifies that "a false bottom may first be placed in the sedimentation chamber at a level below the 50% maximum sediment storage volume level and then covered with sufficient material as specified above to achieve 50% of the maximum sediment storage volume. In doing so, however, the level of the false bottom must be at least 12 inches below the 50% maximum sediment storage volume level or at the 40% maximum sediment storage level, whichever level is lower." This was not done in this testing since it had been conducted prior to the protocol being issued. However, as described in Section 3.4, Verification Procedures, this did not impact the results.)

Once the STC450i was pre-filled with NJPSD gradation sediment, the STC450i was filled with potable water at a very low flow rate to minimize any re-suspension prior to starting the actual test. An additional 20 minutes of quiescent settling time was allowed to ensure that any remaining particulate matter was settled prior to conducting the scour testing.

The procedure followed to evaluate scouring from the STC450i is as follows: The flow monitoring was set at 1.6 cfs (718 gpm) which is 565% of the MTFR (0.283 cfs) and the YSI units were deployed at the inlet and the outlet of the STC450i and activated to record the influent and effluent turbidity. The test was started at "time 0", which represents the time at which the desired steady state flow was achieved. Effluent sampling began instantaneously at "time 0" and a total of 21 individual samples were taken in ~1-L volume duplicates, at consistent sampling intervals calculated based on the flow rate being tested. The total duration of the experimental run was 10 minutes. The effluent samples were then transported to the laboratory, where lab analyses were conducted on the effluent samples. The YSI units were removed and the data was downloaded in the data acquisition room.

The lab analyses consisted of SSC analysis (ASTM 1999) and PSD analysis with a Malvern Mastersizer. SSC analysis was carried out by filtering the entire volume (10 L) of replicate composite samples through a prepared and pre weighed nominal 1.0 µm fiberglass filters as specified in the ASTM test method. The filters were then dried in the oven at 105 degree Celsius overnight, cooled in the desiccators, weighed and summed to obtain the total SSC. The concentration was calculated by dividing the SSC collected by the volume filtered.

The intensity of scouring was expressed as scouring rate (g/min) while the magnitude of scouring can be evaluated by effluent concentration (mg/l).

3.4 Verification Procedures

All the data provided to NJCAT were reviewed to fully understand the capabilities of the STC450i. For both the 5-inch (62.5 percent of sediment capacity) and 10-inch (125 percent of sediment capacity) tests, the influent was clean potable water (SSC ~ 0 mg/L).

Scour as a function of time is shown in Figure 2. As would be expected the scour rate (mg/L) decreases with time following an initial washout of fines. All measurements are below 10 mg/L.

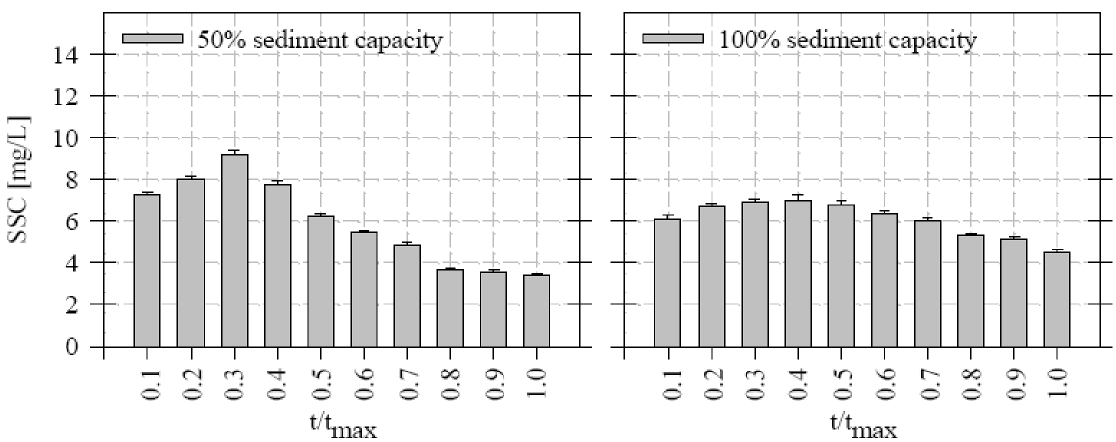

Figure 2 Individual SSC for NJDEP under 50%/100% pre-loaded sediment in STC450i as a function of time normalized to maximum run duration (10 minutes).

The difference in the scouring rate between 62.5% and 125% of sediment capacity was not significant; (13.55 g/min and 14.27 g/min respectively based on measured effluent SSC). The mean effluent SSC was measured to be 5.9 mg/L and 6.1 mg/L for 62.5 % and 125 % sediment capacity, respectively. The plots of effluent concentration as a function of sediment loading in Figure 3 illustrate scour test results at the constant flow rate of 565 % of the MTFR (718 gpm; 1.6 cfs)). Results did not show any significant difference between 62.5% and 125% of sediment preload.

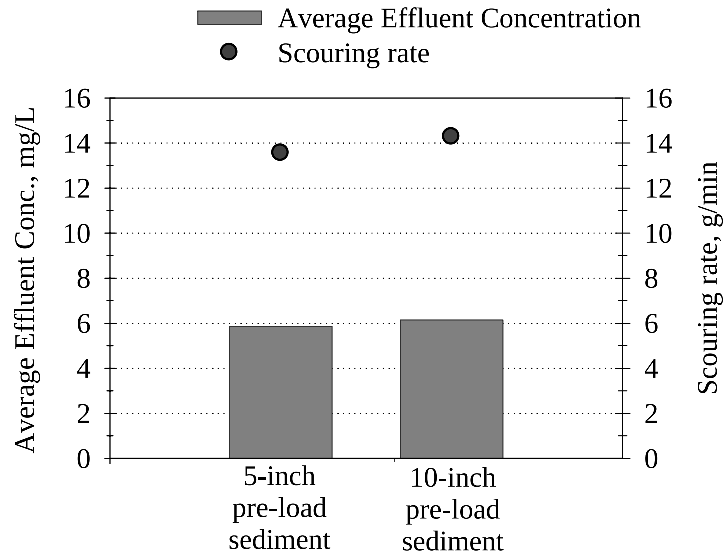

Figure 3 **Scour test results for the STC450i at 565 % of MTFR (718 gpm) at 5-inch and 10-inch of NJPSD sediment pre-loaded conditions.**

The PSD results in Figure 4 illustrate that 90% of scour particles were fine particles with sizes smaller than 25 µm which would not have been present had the 2009 NJDEP protocol been followed.

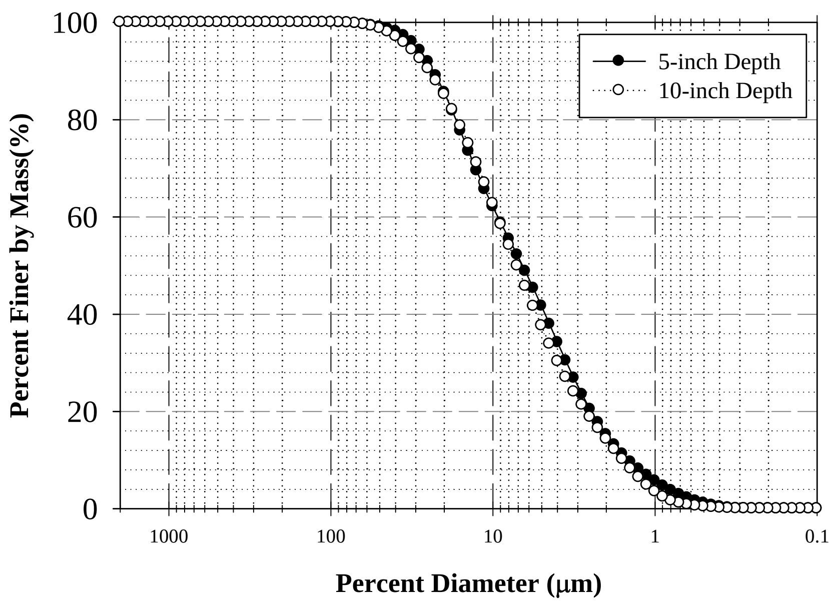

Figure 4 **Scour tests of particle gradations for 5-inch pre-loaded sediment and 10-inch pre-loaded sediment**

4. Verification of Performance Claim

Imbrium Systems Corp. completed scour testing of the Stormceptor STC450i prior to the issuance of the NJDEP 2009 Protocol for Manufactured Hydrodynamic Sedimentation Devices. Consequently their scour test conditions are different than those specified in the protocol. However, since the testing conditions exceed the requirements in the 15 December 2009 protocol the results may be considered conservative. The differences between the NJDEP scour test protocol and the Imbrium scour testing are shown in Table 1.

The Imbrium scour test results clearly show that the Stormceptor® STC450i has the capability to retain collected sediments under flows that are greater than 500% of the unit's MTFR. The measured effluent concentration at this condition was <10 mg/l qualifying the unit to be installed on-line.

Table 1 Comparison between NJDEP Scour Test Protocol and Imbrium Scour Test Procedures

Requirement	Protocol	Imbrium Test	Comment
Preloaded Sediment PSD	Particles 50 microns and greater in NJPSD	Utilized NJPSD (d50 = 67µm)	Conservative. Effluent PSD (d90 ~ 25µm) suggests that the material re-suspended and scoured in test would not have been present with 12-09-09 protocol.
False Bottom	Must be at least 12 in below 50% maximum sediment storage (MSS) volume level or at the 40% MSS, whichever is lower.	8 inch is the maximum recommended maintenance sediment storage (MSS) level in the STC 450i. Sediment depths evaluated were 5 in (62.5%) and 10 in (125%) using a false bottom and a 2 in layer of NJDEP PSD sediment.	Results showed that the maximum sediment lost during the 10 minute scour run was 0.0018 inch (10 in depth) confirming that the 2-in sediment depth was more than sufficient.
Clear Water Run	Water flow at 200% of the selected MTFR for 15 min or until volume of water equal to 5X MTD's MSS volume to demonstrate <10% sediment removed	Not done	Sediment (NJPSD) removal during scour testing confirms that <<10% of preloaded sediment would have been removed. (<0.1% removed) so requirement met.
Scour Test	200% of MTFR	565% of MTFR	Conservative
Run Time	30 min or 10X MSS volume, whichever is greater	10 min; 15X MSS volume	Run time less than 30 min. Exceeded 10X MSS volume
Samples	Minimum of 6 samples	21 samples in duplicate	Met protocol
Effluent Concentration	< 10 mg/L	6.1 mg/L for 10 in depth	Criterion met for more stringent initial PSD loading.
Samples tested	TSS	SSC	SSC is a more conservative metric vs. TSS when measuring scour (mg/l)

5. References

ASTM (1999) Standard Test Method for Determining Sediment Concentration in Water Samples, Annual Book of Standards, Water and Environmental Technology, *ASTM D 3977-97*, Vol. 11.02, p 389-394.

NJDEP (2009). Protocol for Manufactured Hydrodynamic Sedimentation Devices for Total Suspended Solids based on Laboratory Analysis. Dated August 5, 2009, Revised December 9, 2009.

University of Florida (2008). Multi-Phase Physical Model Testing of a Stormceptor® STC 450i – Final report. Submitted to Rinker Materials (20 December 2008)