

NJCAT TECHNOLOGY VERIFICATION

Stormceptor[®] OSR

Imbrium[™] Systems Corporation

August 2007

TABLE OF CONTENTS

TABLE OF CONTENTS	2
LIST OF TABLES	3
LIST OF FIGURES	4
1. INTRODUCTION	5
1.1 New Jersey Corporation for Advanced Technology (NJCAT) Program	5
1.2 Technology Verification Report	6
1.3 Technology Description	6
1.4 Project Description	9
1.5 Key Contacts	9
2. EVALUATION OF THE APPLICANT	10
2.1 Corporate History	10
2.2 Organization and Management	10
2.3 Operating Experience with respect to the Proposed Technology	11
2.4 Patents	11
2.5 Technical Resources, Staff and Capital Equipment	11
3. TREATMENT SYSTEM DESCRIPTION	12
4. TECHNICAL PERFORMANCE CLAIM	18
5. TECHNICAL SYTEM PERFORMANCE	18
5.1 NJDEP Total Suspended Solids Laboratory Test Procedure	18
5.2 Laboratory Testing	20
5.3 Test Procedures	27
5.4 Verification Procedures	28
5.5 Size Scaling and Design Flow Rates	33
5.6 Maintenance	34
6. TECHNICAL EVALUATION ANALYSES	34
6.1 Verification of Performance Claim	34
6.2 Limitations	35
7. NET BENEFICIAL EFFECT	36
8. REFERENCES	36

LIST OF TABLES

Table 1. Stormceptor® OSR Models and Dimensions.....	8
Table 2. NJDEP Particle Size Distribution	19
Table 3. NJDEP Weight Factors for Different Treatment Operating Rates	19
Table 4. Summary of Test Results and Calculated NJDEP Weighted SSC Removal Efficiencies	32
Table 5. Stormceptor® OSR Treatment Flow Rates	33

LIST OF FIGURES

Figure 1. 6-foot Insert OSR Modification	13
Figure 2. Perspective View of OSR Insert Assembly	14
Figure 3. Side View of OSR Insert Assembly	14
Figure 4. Perspective View of OSR Assembly with Concrete Enclosure	15
Figure 5. Orifice Plate Enhancement	15
Figure 6. Drop Tee Modifications	16
Figure 7. CFD-Modeled Pathlines Through the Lower Chamber	17
Figure 8. CFD-Modeled Velocity Magnitude Contours at Sediment Bed	17
Figure 9. Stormceptor OSR 250 Test Unit	21
Figure 10. Photograph of the OSR 250 in Alden's Test-Loop	22
Figure 11. Alden's Stormwater Laboratory Flow Loop	23
Figure 12. Photograph of a Sampling Tube Array	24
Figure 13. OK110 Test Sediment from US Silica	26
Figure 14. Percent Finer Curves of Stated and Actual OK110 US Silica sand	27
Figure 15. Hydraulic Capacity Flow Curve (Top Line, Height Relative to Invert of Influent Pipe)	29
Figure 16. Averaged SSC Efficiency Curves	31
Figure 17. SSC Effluent Concentration Curves	31

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 that the technology meets the regulatory intent and that there is a net beneficial environmental effect through the use 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 of protocols with the United States Environmental Protection Agency (USEPA), other local 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 June 2007, ImbriumTM Systems Corporation (9420 Key West Ave, Suite 140, Rockville, MD 20850) submitted a formal request for participation in the NJCAT Technology Verification Program. The request (after pre-screening by NJCAT staff personnel in accordance with the technology assessment guidelines) was accepted into the verification program. The technology proposed by ImbriumTM, the Stormceptor[®] OSR, is an enhanced gravity separator used for the control of sediments and their associated pollutants, oil and floatables in stormwater.

This verification report covers the evaluation based upon the performance claim of the vendor, ImbriumTM (see Section 4). The verification report differs from typical NJCAT verification reports in that final verification of the Stormceptor[®] OSR (and subsequent NJDEP certification of the technology) awaits completed field testing that meets the full requirements of the Technology Acceptance and Reciprocity Partnership (TARP) – Protocol for Stormwater Best Management Practice Demonstrations, and New Jersey Tier II Stormwater Test Requirements. This verification report is intended to evaluate the Stormceptor[®] OSR initial performance claim for the technology based on laboratory studies. This claim is expected to be modified and expanded following completion of the field-testing in accordance with the TARP and New Jersey Tier II Stormwater Test Requirements.

This verification project included the evaluation of assembled company's manuals, literature, and an laboratory testing report to verify that the Stormceptor[®] OSR satisfies the performance claim made by ImbriumTM.

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 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 a Phase I discharge.

The nature of pollutants emanating from differing land uses is very diverse. ImbriumTM Systems Corporation has developed a hydrodynamic source control device for the capture and retention of

free and floating oils, grease, hydrocarbon, petroleum products, and total suspended solids (TSS). 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[®] OSR is a vertically oriented cylindrical structure manufactured from concrete with a 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 while retaining them 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.

The Stormceptor[®] OSR is a different product from the regular Stormceptor[®] STC which was verified by NJCAT in late 2004 (NJCAT, 2004) and should be treated as such. The Stormceptor[®] OSR will be a product added under the Stormceptor[®] portfolio and a new product offering from Imbrium[™] Systems designed to specifically target the removal of fine sand-sized particles. This methodology differs from the original Stormceptor[®] STC platform which focuses on removal of very fine particles.

1.3.2 Specific Applicability

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

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

1.3.3 Range of Contaminant Characteristics

The Stormceptor[®] Systems have been shown to capture a wide range of pollutants of concern. These include: trash and debris, TSS, sediments, and oil and grease. 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® OSR is designed to accommodate a wide range of flows and volumes (see Table 1). The Stormceptor® OSR is a primary treatment device, which requires no pretreatment. However, it can be used as a pretreatment device before detention systems, mitigating wetlands or other polishing systems.

Table 1. Stormceptor® OSR Models and Dimensions

OSR Model	Sedimentation Chamber Diameter (ft)	Sedimentation Chamber Area (ft ²)	Upper Chamber Diameter (ft)	Ratio of Hydraulic Capacity to Settling Chamber Diameter	Theoretical Hydraulic Capacity (cfs)
065	4	12.58	4		0.63
140	6	28.27	6		1.41
250	8	50.27	6	0.0497	2.50
390	10	78.54	6		3.90
560	12	113.10	6		5.62
780*	10	157.08	8		7.81
1125*	12	226.19	8		11.24

* The OSR 780 and 1125 consist of 2 chambers in series that function in parallel.

1.3.5 Material Overview, Handling and Safety

To clean out the Stormceptor® OSR, oil is removed through the 6 in. inspection port, and sediment is removed through the 24 in. diameter outlet riser-pipe. Alternatively, oil could be removed from the 24 in. outlet riser-pipe opening if water is first decanted 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® OSR unit. Solids recovered from the Stormceptor® OSR 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 the appropriate regulatory requirements.

1.4 Project Description

This project included the evaluation of assembled company manuals, literature, and an independent laboratory testing report to verify that the Stormceptor[®] OSR meets the performance claim of Imbrium[™] Systems Corporation.

1.5 Key Contacts

Rhea Weinberg Brekke
Executive Director
NJ Corporation for Advanced Technology
c/o New Jersey EcoComplex
1200 Florence Columbus Road
Bordentown, NJ 08505
609 499 3600 ext. 227
rwbrekke@njcat.org

Daniel Nason
National Engineering Manager
Imbrium[™] Systems Corporation
100 Grove Street
Worcester, Massachusetts 01605
508 792 1190
dnason@imbriumsystems.com

Richard S. Magee, Sc.D., P.E., BCEE
Technical Director
NJ Corporation for Advanced Technology.
15 Vultee Drive
Florham Park, NJ 07932
973 879-3056
rsmagee@rcn.com

Ravi Patraju
Division of Science, Research & Technology
NJ Department of Environmental Protection
401 East State Street
Trenton, NJ 08625-0409
609 292 0125
ravi.patraju@dep.state.nj.us

Qizhong Guo, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental
Engineering
Rutgers, The State University of New Jersey
623 Bowser Road
Piscataway, NJ 08854
732 445 4444
qguo@rci.rutgers.edu

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 illicit discharge/spills capture in industrial applications. Following the sale of the first unit in 1992, the Stormceptor Group of Companies was established. Since then, the Stormceptor System has become a stormwater quality device (having a portfolio of 22 patents and applications filed in nine countries around the world) for the removal of sediment, oil and associated pollutants in stormwater runoff. With over 20,000 installations worldwide, this technology has continually evolved through field monitoring, on-going research and new regulatory requirements imposed across the globe.

In January of 2006, the Stormceptor Group of Companies changed their name to Imbrium[™] Systems. This name change was implemented to support the expansion of the organization's offerings and presence in the stormwater quality industry. Imbrium[™] Systems is a global company with the US headquarters (Imbrium[™] Systems Corporation) located in Rockville, Maryland and the International headquarters (Imbrium[™] Systems Incorporated) located in Toronto, Ontario Canada.

The Stormceptor product is manufactured and distributed in the United States by Rinker Materials[™] and their sub-licensees.

2.2 Organization and Management

Imbrium[™] Systems operates under Monteco Limited, its parent company. Imbrium[™] designs, engineers, patents, markets, manufactures and sells stormwater treatment equipment. Imbrium[™] Systems is comprised of two separate companies including:

- Imbrium[™] Systems Corporation in the United States and
- Imbrium[™] Systems Incorporated in Canada and the remainder of the Globe

These companies own and license the patented Stormceptor[®] System technology.

Imbrium[™] Systems is the licensor of the Stormceptor technology, and Rinker Materials[™], Concrete Pipe Division is the licensee. Imbrium[™] solely licenses Rinker Materials[™] to build, market, sell and distribute the Stormceptor system in the United States including the State of New Jersey. Rinker Materials has Camtek Construction Products representing the product in five east-coast states, including New Jersey and New York.

The key personnel are: Scott Monteith, President and CEO, Monteco Limited; Rick Traylor, Manager of Technical Services, Rinker Materials[™], Hydro Conduit Division; Rob Crossman,

Country Manager, Imbrium™ Systems Corporation; Ernie Carrasco, Stormceptor® Product Manager, Rinker Materials™, Hydro Conduit Division; Scott Perry, Business Development Manager, Imbrium™ Systems Corporation.

2.3 Operating Experience with respect to the Proposed Technology

There are currently no existing field installations for the Stormceptor OSR device since it is a new technology developed by Imbrium™ Systems to meet the current water quality requirements in the State of New Jersey. The Stormceptor® OSR device was developed and laboratory tested with expertise from Imbrium™ Systems and Alden Research Laboratory to specifically target fine sand-sized particulate removal through the use of modifications and enhancements to the existing Stormceptor®STC platform. The unit process of particle settling, based on Stokes Law, for the OSR is the same as the existing Stormceptor® STC product line. The hydraulic principles, field longevity, operation and maintenance of the Stormceptor® OSR mimic the STC device which has undergone numerous laboratory and field evaluations since the early 1990's.

2.4 Patents

The Stormceptor® STC and OSR is protected by one or more of the following United States Patents: #4985148, #5498331, #5725760, #5753115, #5849181, #6068765, #6371690. Specific enhancements implemented within the Stormceptor OSR technology is patent pending.

2.5 Technical Resources, Staff and Capital Equipment

Imbrium™'s technical staff includes a significant number of engineers. Since Imbrium™ Systems is owned by its parent company, Monteco Limited, it collaborates with Monteco's Research and Development Center staff and resources. The Monteco Research and Development Center is located in Ontario, Canada.

Monteco Limited operates a full scale laboratory facility in Ontario, Canada to conduct research on new innovative treatment methods, as well as the development of the current technologies.

Imbrium™ Systems Corporation also works in partnership with Rinker Materials, Concrete Pipe Division, throughout the United States to provide its customers with solutions to unique design situations. Rinker Materials is the sole Stormceptor® licensee in the United States. It is a company with over fifty operations across the United States and has been in business for over forty years. The Rinker Materials Engineering headquarters is located in Houston, Texas and is available to provide assistance.

Imbrium™ also organizes and hosts regular technical meetings with the technical engineering representatives of its worldwide affiliate companies. These meetings are useful in sharing technical expertise and solutions between various geographic and regulatory environments.

The Stormceptor[®] product line is manufactured in Rinker facilities across the United States. This partnership results in standardized manufacturing practices and consistent product quality throughout the United States.

3. TREATMENT SYSTEM DESCRIPTION

Through research and field application, the Stormceptor[®] technology has been refined to successfully separate oil and sediment from stormwater runoff as well as capture oil spills. The Stormceptor[®] OSR has been modified from the original Stormceptor[®] STC platform to specifically target the removal of fine sand-sized particles, such as the OK-110 PSD. Description of the original Stormceptor[®] STC is available from the previous NJCAT verification report (NJCAT, 2004).

Development of the Stormceptor[®] OSR was performed by Imbrium[™] in conjunction with the expertise of Alden Research Laboratory (Alden) in Holden, Massachusetts. Modifications to the existing Stormceptor platform include:

- offset weir
- increased weir height
- enhanced orifice plate
- a series of vertical vanes in the drop tee
- increased back-wall and base on the drop tube (wings)

These modifications were implemented to maximize the treatment flow rate through the lower chamber and are the result of computational fluid dynamics (CFD) analyses and a series of physical tests.

The modified Stormceptor[®] OSR 6-ft insert is shown in Figure 1. Various views of the OSR insert are shown in Figures 2 to 4. The orifice plate enhancement is shown in Figure 5. The drop tee modifications are shown in Figure 6.

Through the use of both CFD and physical modeling, treatment flow rates were maximized for the specific OK-110 PSD based on analyzing the flow patterns (pathlines), particle residence time, velocity magnitudes and shear stress contours in the lower chamber. Results obtained through the CFD analysis were subsequently verified in the laboratory. The CFD-modeled pathlines through the lower chamber are shown in Figure 7. The CFD-modeled velocity magnitude contours at sediment bed are shown in Figure 8.

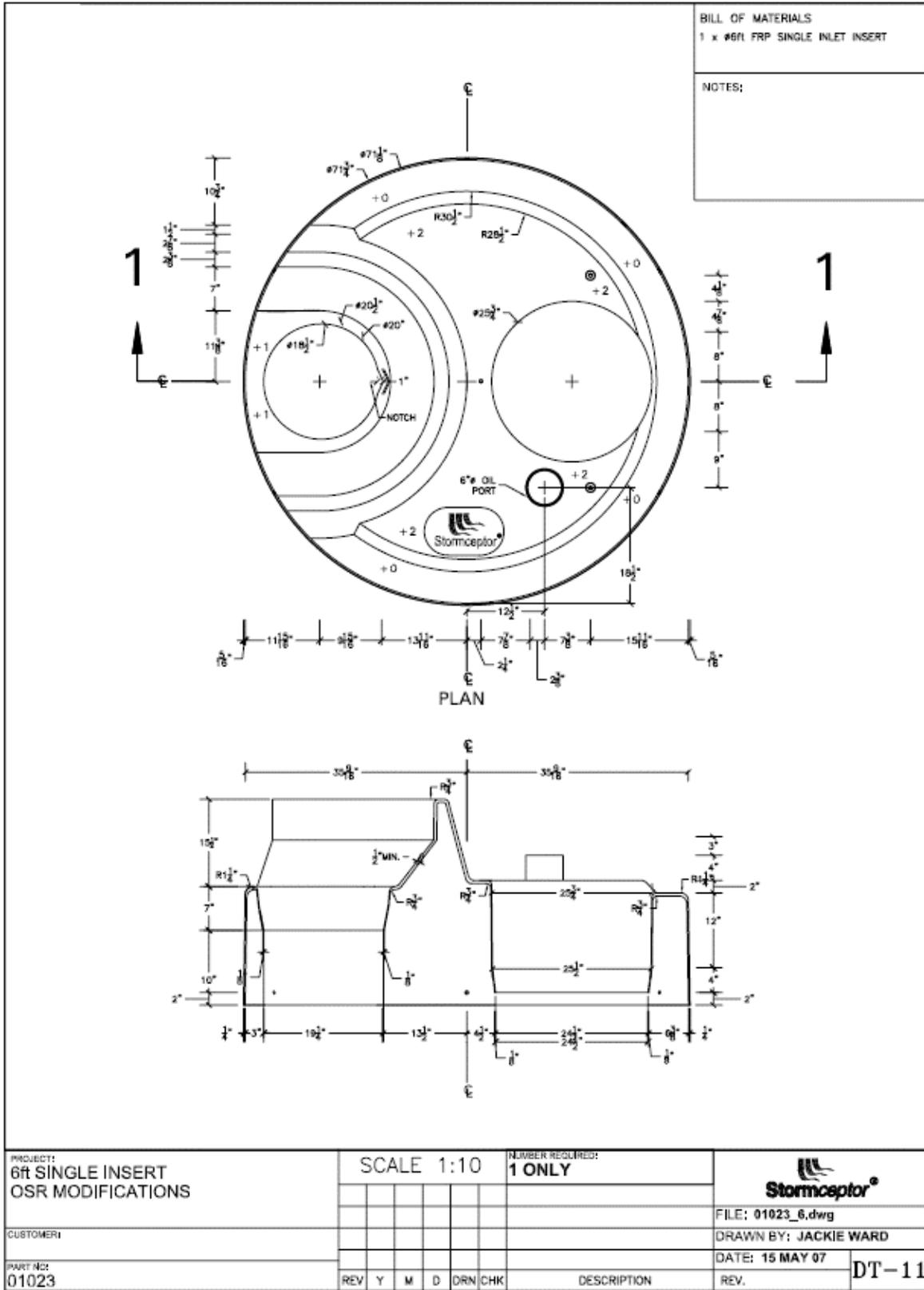


Figure 1. 6-foot Insert OSR Modification

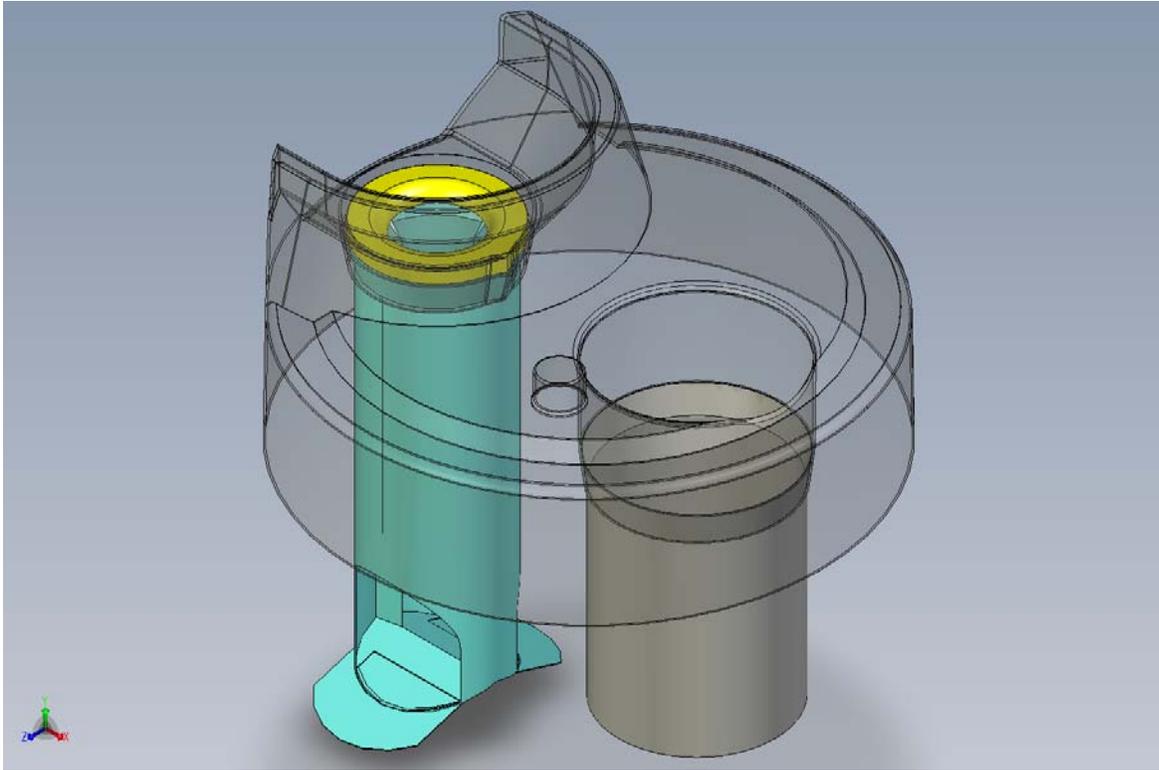


Figure 2. Perspective View of OSR Insert Assembly

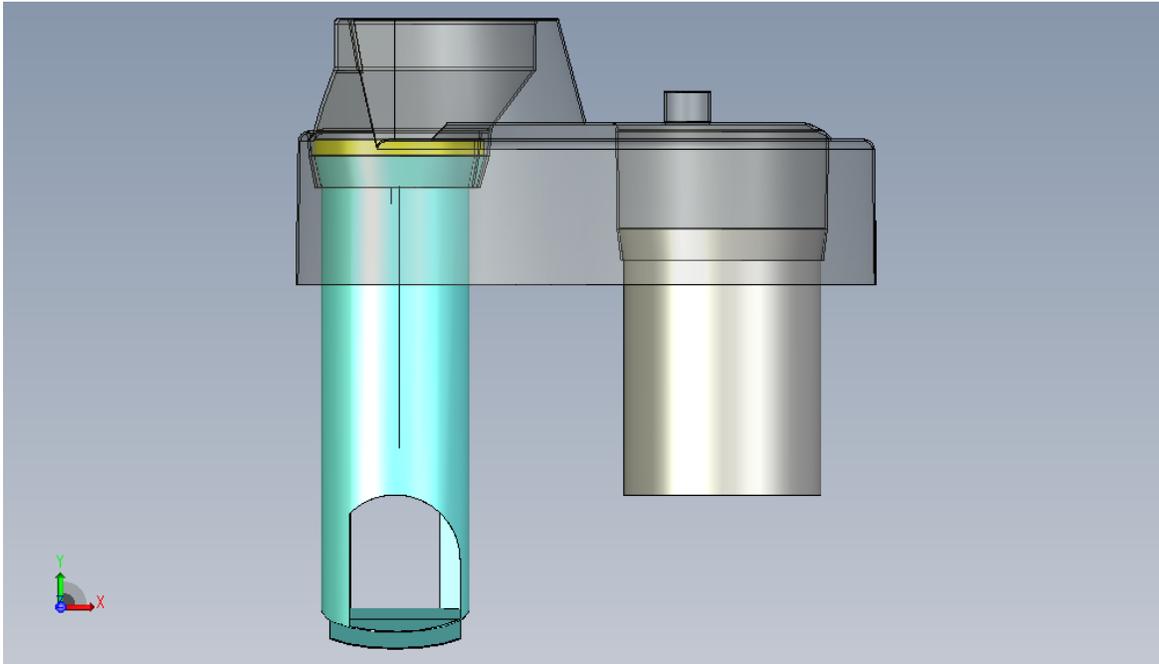


Figure 3. Side View of OSR Insert Assembly

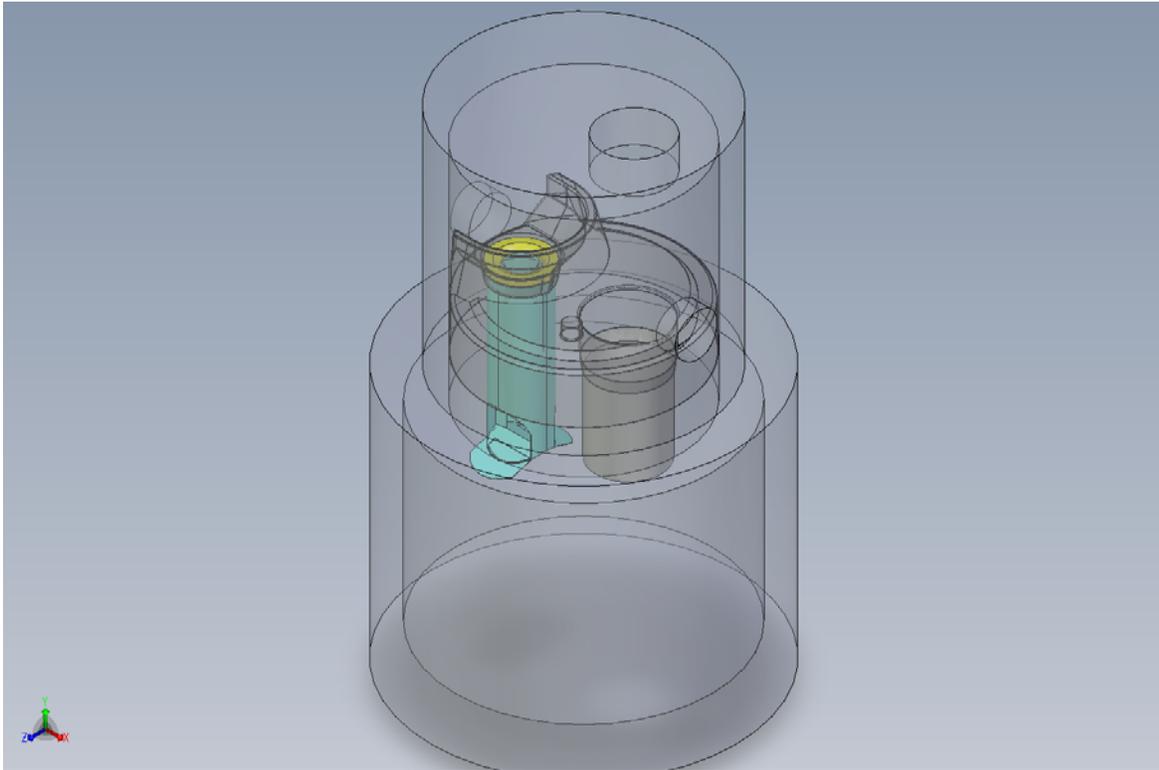


Figure 4. Perspective View of OSR Assembly with Concrete Enclosure

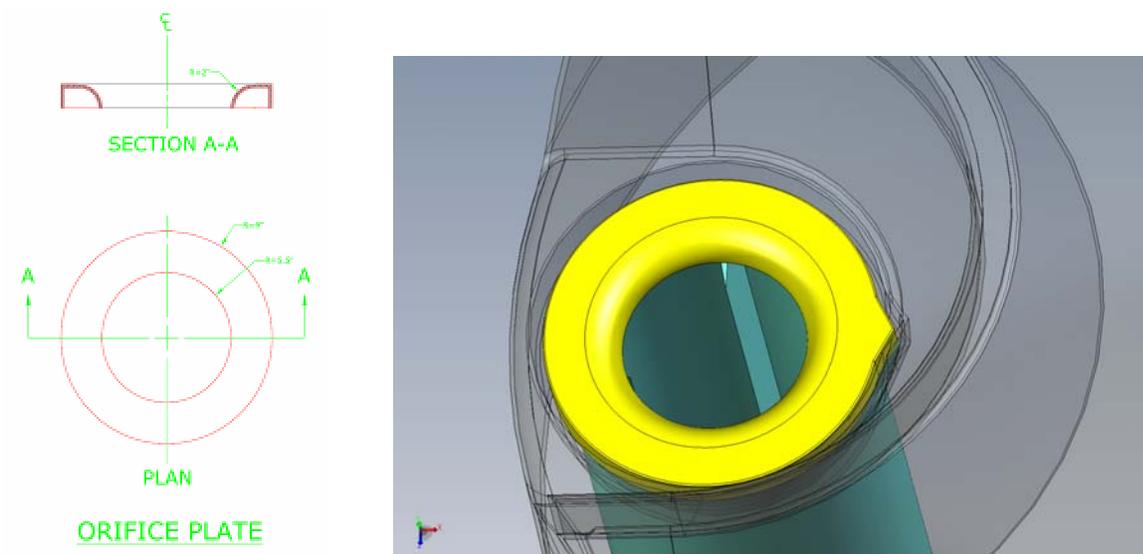
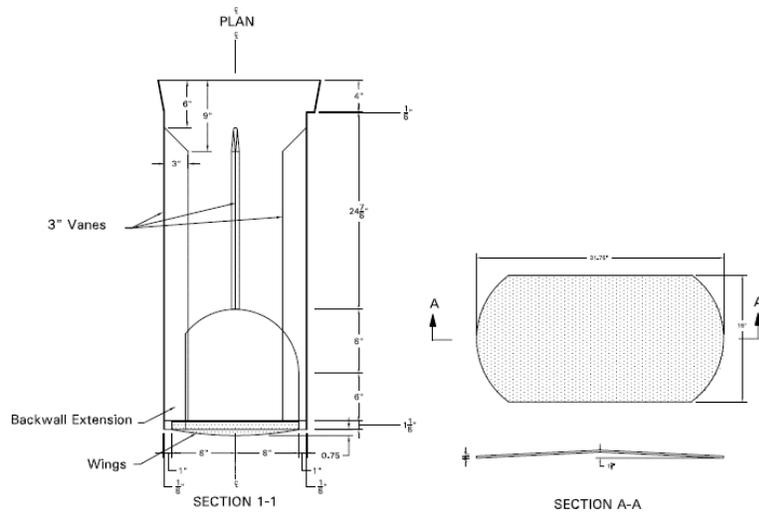
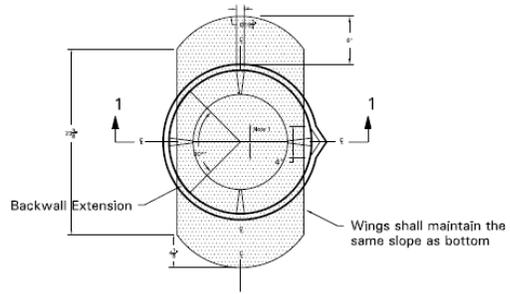


Figure 5. Orifice Plate Enhancement



18" DROP TEE W/ VANES,
BACKWALL & WINGS

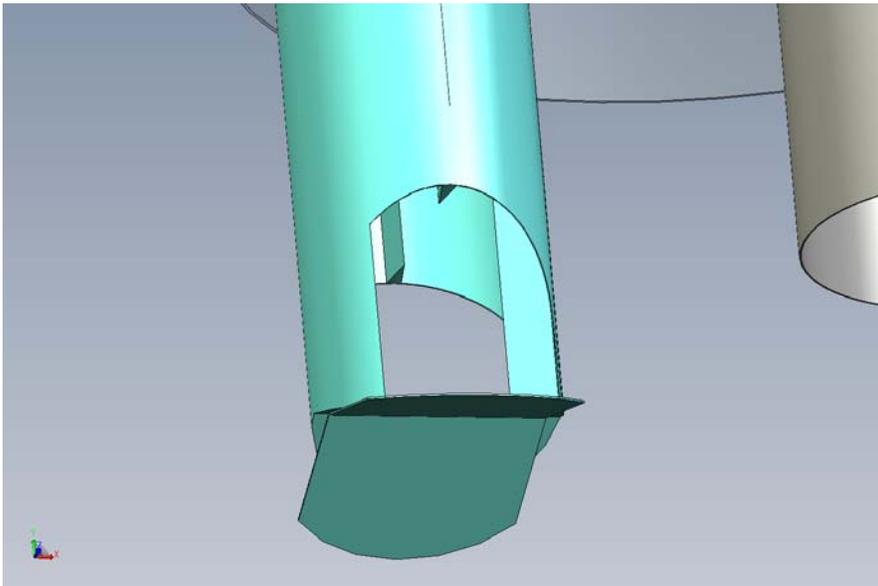


Figure 6. Drop Tee Modifications

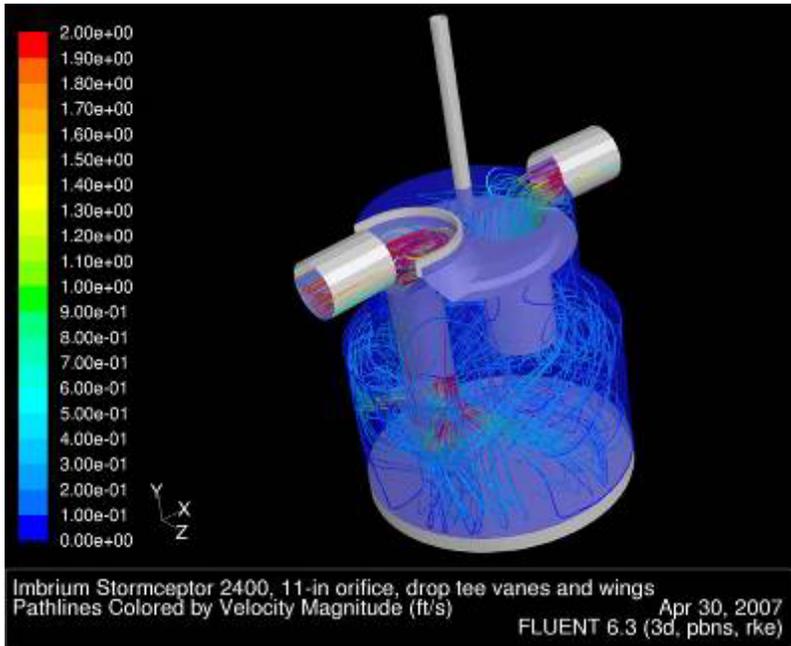


Figure 7. CFD-Modeled Pathlines Through the Lower Chamber

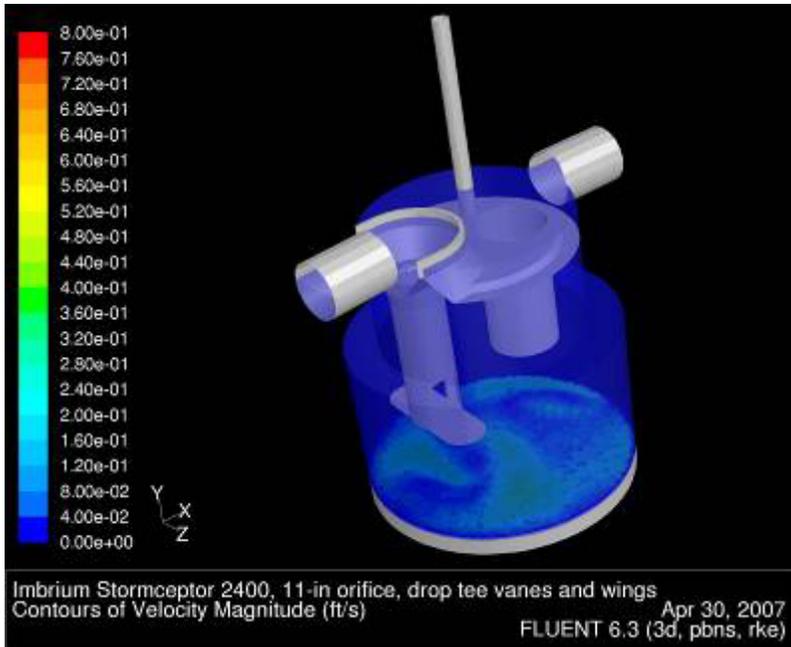


Figure 8. CFD-Modeled Velocity Magnitude Contours at Sediment Bed

4. TECHNICAL PERFORMANCE CLAIM

Claim: The Stormceptor® OSR Model 250 at a flow rate of 1,120 gpm (2.50 ft³/s), has been shown to have a 69% Total Suspended Solids (TSS) removal efficiency, as measured as suspended solids concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency) using OK-110 silica sand with an average d₅₀ particle size of approximately 100 microns, an average influent concentration of 202 mg/L and 50% initial sediment loading in laboratory studies using simulated stormwater.

5. TECHNICAL SYTEM PERFORMANCE

5.1. NJDEP Total Suspended Solids Laboratory Test Procedure

NJDEP has prepared a 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. Particle size distribution:

The following particle size distribution will be utilized to evaluate a manufactured treatment system (See Table 2) using a natural/commercial soil representing the 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.

Table 2. NJDEP 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 $\leq 2.65 \text{ g/cm}^3$

*The 8 μm diameter is the boundary between very fine silt and fine silt according to the definition of the 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.

3. Measuring treatment efficiency

- A. Calculate the individual removal efficiency for the 15 test runs.
- B. Average the three test runs for each operating rate.
- C. The average percent removal efficiency will then be multiplied by a specified weight factor (See Table 3) for that particular operating rate.
- D. The results of the 5 numbers will then be summed to obtain the theoretical annual TSS load removal efficiency of the system.

Table 3. NJDEP 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 gauges.

5.2 Laboratory Testing

5.2.1 Introduction

Verification testing of an 8 ft diameter Stormceptor[®] OSR Model 250 Stormwater Treatment Unit (OSR 250) was conducted at Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under a contract from Imbrium[™] Systems Corporation (Mailloux 2007). Testing was conducted according to the protocols set forth by the New Jersey Department of Environmental Protection (NJDEP), as described above. Testing consisted of establishing the unit's hydraulic capacity and determining the sediment removal efficiencies using OK110 silica sand.

The OSR 250 is a two-stage cylindrical separating device consisting of a 6-foot diameter by approximately 6-foot high upper receiving chamber and 8-foot diameter by approximately 6-foot high lower settling chamber. Within the upper chamber is mounted the one-piece Stormceptor[®] fiberglass insert. The insert incorporates a semi-circular bypass weir, 11-inch diameter orifice plate, 18-inch inlet drop tee, 24-inch vertical outlet riser-pipe and 6-inch inspection port. The test unit had 24-inch diameter inlet and outlet pipes, with the inlet invert tangent to the insert floor and inlet to outlet differential of 1-inch. The inlet pipe is oriented with a 1% slope and both pipes are centered within the unit. Figure 9 shows a layout drawing of the OSR 250 test unit and Figure 10 shows a photograph of the unit installed in Alden's test facility. The test unit supplied by Imbrium[™] included four (4) 24-inch viewing windows, located approximately 30 inches above the floor, to facilitate observations and documentation of sediment movement.

5.2.2 Test Facility Description

Figure 11 shows the closed test loop, located in Alden's laboratory/test facility, which was used to test the OSR 250 Treatment Unit. The test loop consisted of two pumps (20 HP and 50 HP with flow capacities of 3 and 9 cfs, respectively) drawing water from a 50,000-gallon heated laboratory sump (60+ degrees). Five calibrated flow meters (2, 4, 6, 8 and 12-inch), connected to a 12-inch diameter manifold, carried the test flow to a section of 12-inch piping, a 90-degree elbow, 24-inch diameter by 24-foot long influent pipe, test unit and 24-inch diameter effluent pipe, to return the water to the laboratory sump. Isokinetic sampling-tube arrays were located within the 12-inch influent piping and 24-inch effluent piping, approximately 6-ft upstream of the 24-inch influent pipe and 4-ft downstream of the test unit, to collect the influent and effluent sediment concentration samples. As shown in Figure 12, each array consisted of one (1) to three (3) vertically adjustable sampling tubes (water level dependent), containing a flow-control shut-off valve. Sediment was injected into the crown of the influent pipe through a vertical pipe connected to a tee. The tee was located approximately 10 influent pipe diameters upstream of the influent sampling ports. The influent pipe diameter from the injector to downstream of the sampling ports varied from 8 inches to 12 inches (depending on the test flow), in order to produce a sufficiently high velocity to maintain sediment suspension at the samplers.

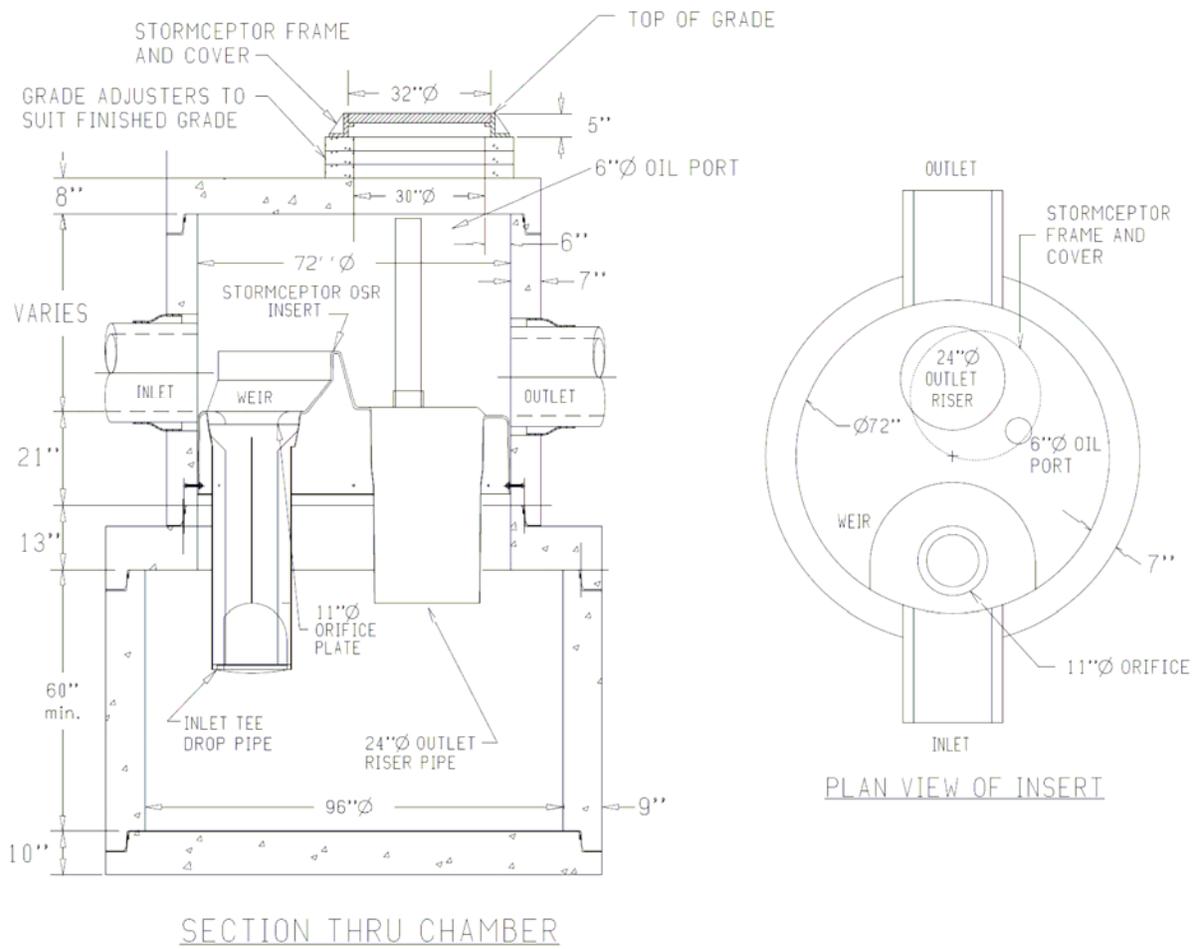


Figure 9. Stormceptor OSR 250 Test Unit



Figure 10. Photograph of the OSR 250 in Alden's Test-Loop

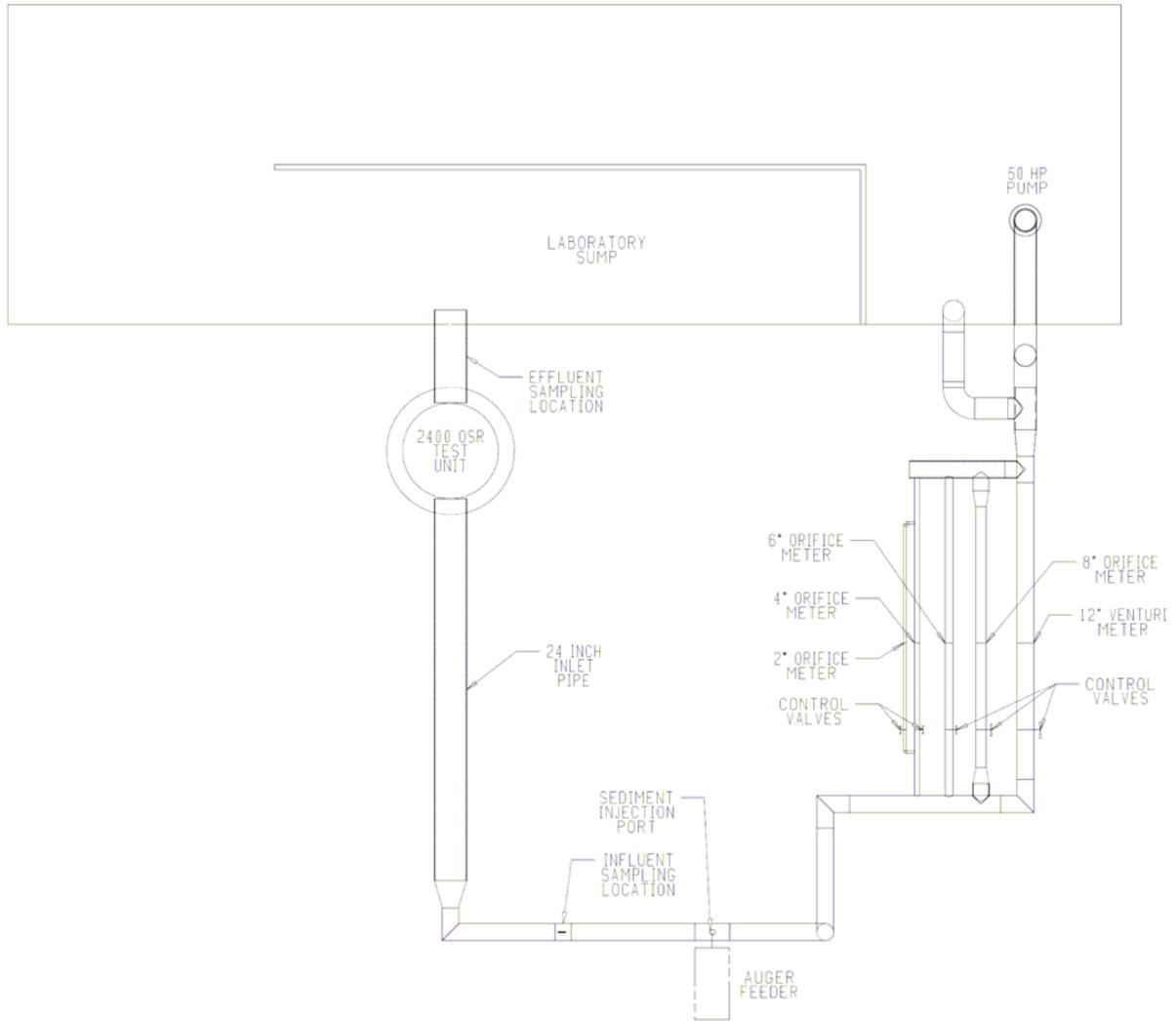


Figure 11. Alden's Stormwater Laboratory Flow Loop



Figure 12. Photograph of a Sampling Tube Array

5.2.3 Instrumentation and Measuring Techniques Flow

Flow

The inflow to the test unit was measured using one of five calibrated flow meters. Each meter was fabricated per ASME guidelines and calibrated in Alden's Calibration Department prior to the start of testing. Flows were set with a butterfly valve and the differential head from the meter was measured using a Rosemount® 0 to 250-inch Differential Pressure (DP) cell, also calibrated at Alden prior to testing. The test flow was averaged and recorded every 5 seconds throughout the duration of the test, using a computerized data acquisition (DA) program. The accuracy of the flow measurement is estimated at $\pm 2\%$.

Temperature

Water temperature measurements within the sump were obtained using a calibrated Omega® DP41 temperature probe and readout device. The calibration was performed at the laboratory prior to testing. The temperature reading was entered into the DA program at the start of each test for use in the flow measurement calculations.

Pressure Head

The pressure head readings within the influent and effluent pipes were measured using a Rosemount® 0 to 24-inch DP cell. The pressure cell was calibrated at Alden prior to testing. Five (5) 30-second averages were recorded using a computerized DA program.

Sediment Injection

OK-110 silica sand, with a Specific Gravity of 2.65, was used to test the OSR Model 250 unit. The test sand was introduced into the influent pipe using an Auger® volumetric screw feeder, model VF-1. The Auger feed screws used in testing ranged in size from 1.0 to 1.5 inches, depending on the test flow. The auger screw, driven with a variable speed drive, was calibrated with the test sediment prior to testing, in order to establish a relationship between screw RPM and feed rate in mg/minute. The feeder has a 1.5 cubic foot hopper at the upper end of the auger to provide a constant supply of dry test sand.

Sample Collection

As described in Subsection 5.2.2, isokinetic sampling tubes were located within the influent and effluent piping to collect the sediment concentration samples. The tubes ranged from 0.50 to 1.0 inches in diameter, depending on the pipe diameter, test flow and location within the pipe. Each tube array was vertically adjusted and calibrated prior to testing, to match the velocities for each flow condition.

Sample Concentration Analyses

Sample concentrations can be analyzed using one of two analytical methods: Suspended Solids Concentration (SSC), or Total Suspended Solids (TSS). SSC methodology utilizes the entire sample in the analysis, as opposed to the TSS method, which requires the sample to be split prior to processing. Two sets of samples (approximately one liter each) were collected to allow both analytical methods to be used for the present study. The SSC samples were processed at Alden as described below and the TSS samples were processed at Alpha Analytical Labs per EPA method 160.2.

SSC Analysis:

Collected samples were filtered and analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (Re-approved 2002), “Standard Test Methods for Determining Sediment Concentration in Water Samples”. The required silica sand used in the sediment testing did not result in any dissolved solids in the samples and therefore, simplified the ASTM testing methods for determining sediment concentration.

Samples were collected in graduated 2-Liter beakers which were cleaned, dried and weighed to the nearest 0.1-gram (using an Ohaus® 4000g x 0.1g digital scale, model SCD-010), prior to sampling. Collected samples were also weighed to the nearest 0.1-gram using the Ohaus® digital scale. Each collected sample was filtered through a pre-rinsed Whatman® 934-AH, 47-

mm, 1.5-micron, glass microfiber filter paper, using a laboratory vacuum-filtering system. Prior to processing, each filter was rinsed and placed in a designated dish and dried in an Oakton® StableTemp gravity convection oven, model 05015-59, at 225 degrees F for a minimum of 2 hours. Each dried filter/dish set was then weighed to the nearest 0.0001 gram, using an AND® analytical balance, model ER-182A. Once filtered, each sample and dish was dried at a temperature between 175 and 220 degrees F (below boiling) for 20 to 30 minutes until visually dry. The oven temperature was increased to 225 degrees F and the samples were dried for an additional 2-½ to 3 hours. The dry samples and dishes were then weighed to the nearest 0.0001 gram, using the AND® balance. Net sediment weight (in mg) was determined by subtracting the dried filter weight from the dried sample weight and multiplying the result by 1,000. The net sample volume, in liters, was determined by subtracting the beaker and net sediment weight from the overall sample weight and dividing by 1,000. Each sample sediment concentration, in mg/liter, was determined by dividing the net sediment weight by the net sample volume.

Test Sediment and Particle Size Distribution

OK-110 silica sand, available from US Silica, was used to test the OSR Model 250 unit. Figure 13 shows the theoretical PSD as stated by US Silica and Figure 14 shows the corresponding Percent-Finer curve as compared to those of two random batch samples of the test sediment. The PSD of the two random samples was measured using the sieve method. The D₅₀ size of the test sediment was measured to be approximately 100 microns, which is smaller than the theoretical 110 microns as stated by US Silica.

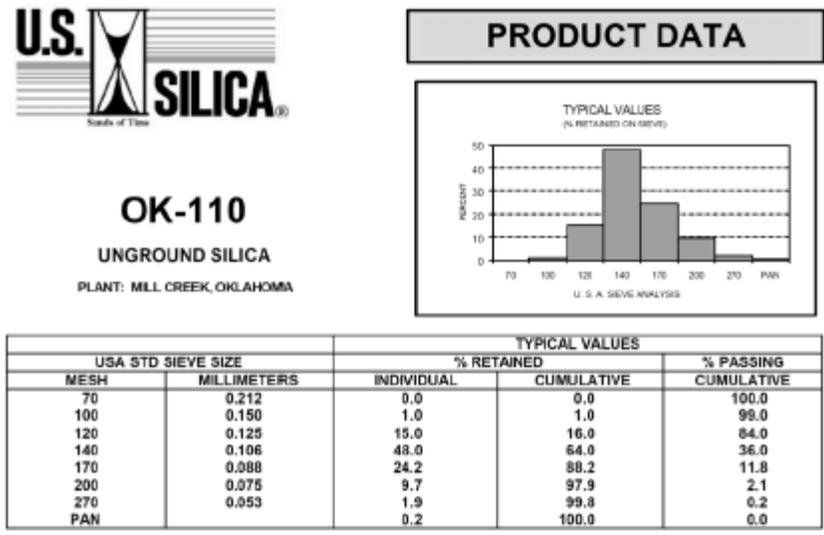


Figure 13. OK110 Test Sediment from US Silica

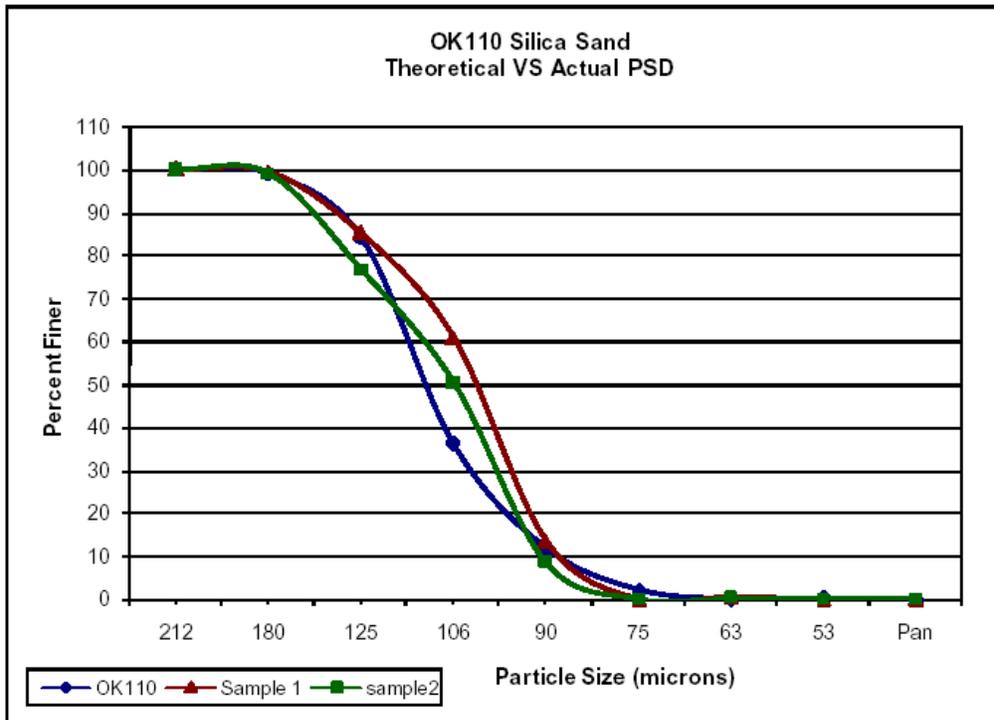


Figure 14. Percent Finer Curves of Stated and Actual OK110 US Silica sand

5.3 Test Procedures

The OSR Model 250 was tested in accordance with the NJCAT testing protocol for Stormwater Treatment Devices (see Section 5.1). The guideline requires, at a minimum, documentation showing the capture efficiency of the selected test sediment, for five (5) flows, at 100, 200 and 300 mg/L concentration per flow. The test unit was filled to 50% (6 inches, 24.5 ft³) of the recommended sediment maintenance depth for a Stormceptor® OSR Model 250 (12 inches, 49 ft³), as stated by Imbrium™. The test matrix was expanded to include the Suspended Sediment Concentration (SSC) analysis.

Testing of the OSR Model 250 was conducted in two phases, as described below:

5.3.1 Phase 1 - Hydraulic Capacity

The unit was tested without sediment to determine its maximum hydraulic capacity (MHC). Flow and pressure head measurements across the unit were recorded for multiple conditions. Each test flow was set and allowed to reach steady state, at which time a minimum of 3 minutes of flow and pressure data was recorded and averaged. Observations were documented

throughout the test, including conditions at the bypass weir, as well as water elevations in the influent and effluent pipes.

5.3.2 Phase 2 - Sediment Removal Efficiency Testing

The unit was pre-loaded with the OK-110 sediment to a depth of 6 inches, corresponding to 50% of the stated capacity (12 inches), as claimed by Imbrium™. Sediment removal efficiency testing was performed using the indirect method (sampling), as described below.

The test flow was set and allowed to reach steady state. The test sediment was introduced into the inflow line and three (3) system volumes were allowed to pass through the test-loop prior to the collection of samples. A minimum of 5 pairs of influent/effluent samples, of approximately 1 Liter each, were collected during each test, with each effluent sample taken one residence time after the influent sample. At the completion of the sample collections, sediment injection was stopped and the system continued to operate for the duration of time necessary to assure that all the sediment has entered the unit. Background samples were taken throughout the test at a location upstream of the injection point, to establish the sediment concentration level of the influent flow. Each collected sample was processed as described in Subsection 5.2.3.

In addition to the collection of influent samples, verification of the injected sediment concentration was achieved by taking timed dry samples from the auger feeder at regular intervals throughout each test. The collected samples were weighed to establish the mg/min feed rate for each sample. The additional calculated concentrations are reported in the data sets as “Adjusted Influent Concentrations”. Coupled with the recorded flow data, Alden’s position is that this methodology for establishing the average influent concentration has shown to have a higher degree of accuracy over the indirect sampling. This is due to the many variables, including the turbulent flow regime, velocity at the samplers, as well as the mixing and dispersion of the test sediment within the pipe. The effluent samples were used in the efficiency calculation, as the fine particles are fully mixed and suspended throughout the pipe.

5.4 Verification Procedures

All the data provided to NJCAT were reviewed to fully understand the capabilities of the Stormceptor® OSR Model 250. To verify Imbrium™’s claim, the Stormceptor® OSR model 250 laboratory procedures and data were reviewed and compared to the NJDEP TSS laboratory testing procedure.

Claim: The Stormceptor® OSR Model 250 at a flow rate of 1,120 gpm (2.50 ft³/s), has been shown to have a 69% Total Suspended Solids (TSS) removal efficiency, as measured as suspended solids concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency) using OK-110 silica sand with an average d₅₀ particle size of approximately 100 microns, an average influent concentration of 202 mg/L and 50% initial sediment loading in laboratory studies using simulated stormwater.

5.4.1 Laboratory Testing Results

Results of the tests are summarized below. The detailed results are presented in the lab testing report prepared by the Alden Lab (Mailloux 2007).

Hydraulic Capacity

Flow (gpm) and water level (inches) within the unit were measured for multiple flows from 0 to 1,554 gpm (3.46 cfs). The Flow vs. Head curve, seen in Figure 15 (the top line labeled as “Weir Height”), shows a consistent curve through the range of flows. The maximum flow attained prior to overtopping the bypass weir was 1,120 gpm (2.5 cfs).

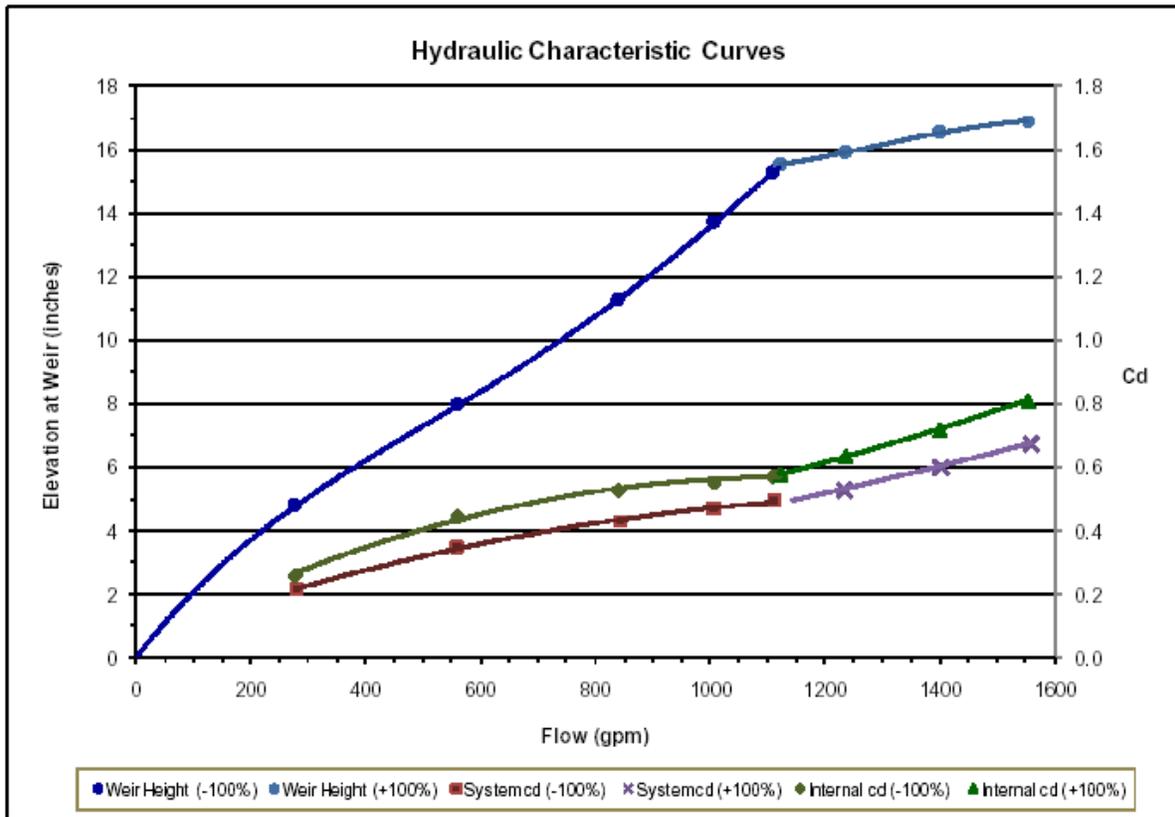


Figure 15. Hydraulic Capacity Flow Curve (Top Line, Height Relative to Invert of Influent Pipe)

Values of the “System Cd” and “Internal Cd” in Figure 15 were calculated using the following equation:

$$Cd = A * \text{sqrt} (2 * g * \Delta H)$$

The cross-sectional area (A) used in the calculations is that for the 11-inch influent orifice (=0.66ft²). The ΔH for the system Cd is the difference between the influent and effluent pipe water elevations, using the effluent invert as a datum. The ΔH for the internal Cd is the difference in water elevation upstream and downstream of the weir. The downstream elevation was measured next to the oil port.

Sediment Removal Efficiency

The removal efficiency reported for each test represents the mean suspended solids load reduction for that test and is calculated using the following equation:

$$\text{Removal Efficiency} = 100 \left(\frac{\text{Influent Conc.} - \text{Effluent Conc.}}{\text{Influent Conc.}} \right)$$

Removal efficiency tests were conducted at five (5) flows ranging from 281 to 1,403 gpm (0.63 to 3.13 cfs) with influent sediment concentrations of 100, 200 and 300 mg/l.

As stated in Subsection 5.3.2, verification of each injected sediment concentration was achieved by taking timed dry samples from the auger feeder at regular intervals throughout each test. The difference between the collected sample concentrations and adjusted concentrations ranged from 1% to approximately 28%, resulting in differences up to 10% in the removal efficiency. Figure 16 shows the average sediment removal efficiency curves for the adjusted and unadjusted SSC analyses. The effluent curve for each concentration is shown on Figure 17. The testing data summary is shown on Table 1, which includes the NJDEP weighted efficiencies.

Water Temperature

Water temperature during the tests varied from 75.2 to 78.7 degree F.

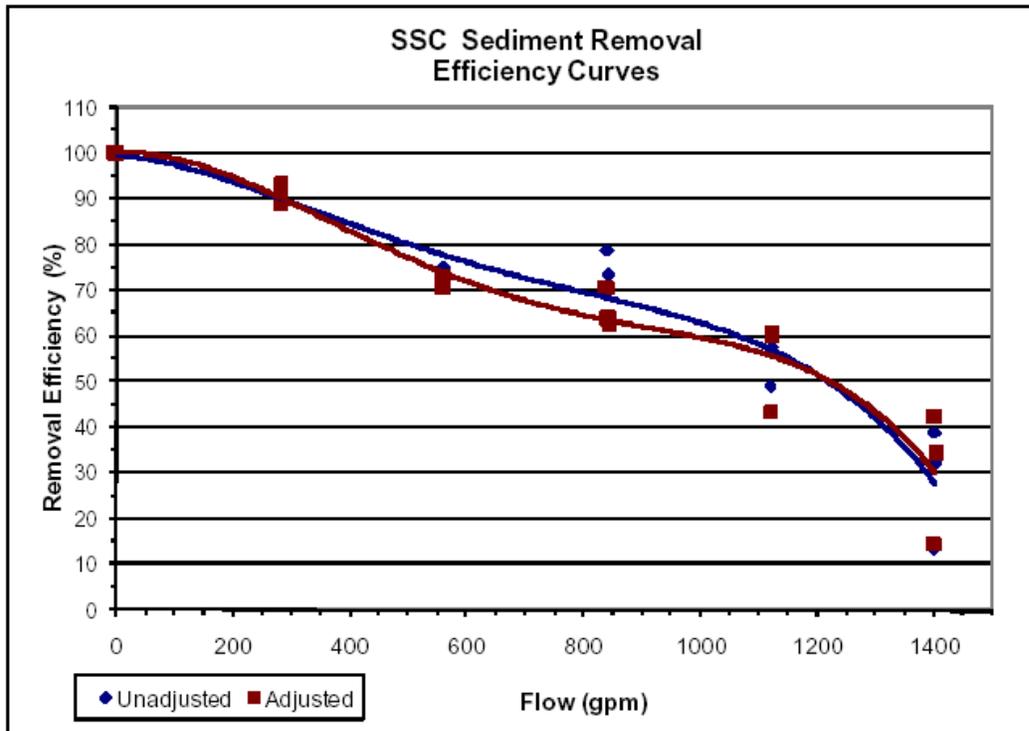


Figure 16. Averaged SSC Efficiency Curves

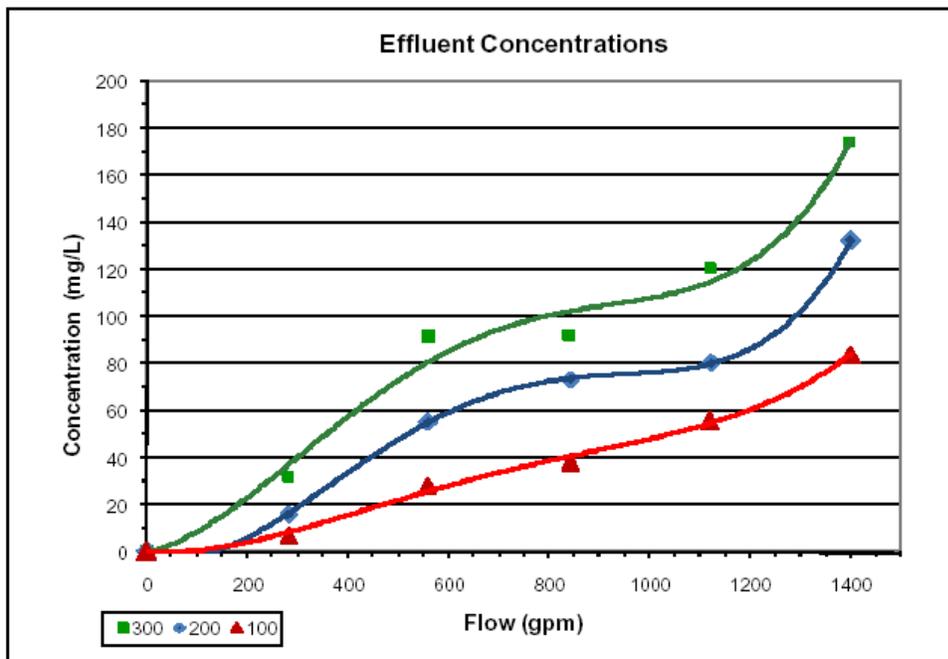


Figure 17. SSC Effluent Concentration Curves

Table 4. Summary of Test Results and Calculated NJDEP Weighted SSC Removal Efficiencies

% MHC	Flow gpm	Concentration mg/L	Unadjusted Data				Adjusted Data			
			Influent mg/L	Effluent mg/L	Efficiency %	Avg. Efficiency %	Influent mg/L	Effluent mg/L	Efficiency %	Avg. Efficiency %
124.8	1400.72	300	284.9	174.1	38.9		304.2	174.1	42.8	
124.9	1401.60	200	196.3	132.3	32.6		201.7	132.3	34.4	
124.9	1401.1	100	97.1	84.0	13.5	28.3	98.4	84.0	14.6	30.6
100.0	1121.9	300	297.5	120.4	59.5		304.2	120.4	60.4	
100.0	1121.6	200	190.1	80.4	57.7		201.1	80.4	60.0	
99.7	1118.3	100	110.3	55.9	49.3	55.5	99.0	55.9	43.5	54.6
74.9	840.7	300	436.8	92.0	78.9		314.9	92.0	70.8	
75.1	842.4	200	276.4	73.4	73.4		202.8	73.4	63.8	
75.0	841.6	100	104.4	37.9	63.7	72.0	101.6	37.9	62.7	65.8
49.9	560.2	300	339.6	91.5	73.0		311.7	91.5	70.6	
49.9	560.4	200	224.7	55.6	75.2		202.7	55.6	72.6	
49.8	558.8	100	114.8	28.4	75.2	74.5	101.4	28.4	72.0	71.7
25.0	280.6	300	331.2	31.8	90.4		293.3	31.8	89.2	
25.0	280.9	200	216.8	16.0	92.6		193.3	16.0	91.7	
25.0	281.06	100	101.6	6.8	93.3	92.1	99.4	6.8	93.1	91.3
	0			0.0	100.0				100.0	
			Weighted Eff.				Weighted Eff.			
			70.9				68.8			

5.4.2 Assessment of Test Methods and Results

The lab tests were well controlled as demonstrated by a good agreement between the desired influent concentrations and the actual influent concentrations. Moreover, the SSC removal efficiencies calculated from the measured influent and effluent concentrations followed the physical trend of decreasing with increasing flow.

To provide an estimate of the deviations from the calculated average overall removal efficiency, the minimum measured removal efficiency at each tested flow rate (Table 4) was used to calculate the minimum overall removal efficiency, and the maximum measured removal efficiency at each tested flow rate (Table 4) was used to calculate the maximum overall removal efficiency. These were calculated to be 66.0% and 74.5%, respectively, for the unadjusted data, and 64.0% to 72.6%, respectively, for the adjusted data. The deviations from the averages (70.9% and 68.8%) are within 5% and are considered to be acceptable.

The test procedures for the Stormceptor® OSR had two deviations from the NJDEP lab testing protocol: (1) OK-110 silica sand, rather than the material of NJDEP-specified PSD, was used in the lab tests; and (2) No re-suspension data was provided.

No TSS data were submitted at the time of this report preparation. Due to the known large variability of the TSS analysis methods (Guo 2006), the TSS data will not be used in the technology verification.

It is concluded: The 8 Ft Diameter Stormceptor OSR 250 Stormwater Treatment Unit, tested at Alden Research Laboratory, achieved a maximum 100% treatment flow of 1,120 gpm (2.50 cfs), when fitted with a 15.5-inch bypass weir. Sediment removal efficiency testing was conducted

for 5 flows ranging from 281 gpm (0.63 cfs) to 1403 gpm (3.13 cfs), with influent sediment concentrations of 100, 200 and 300 mg/L. The removal efficiencies were evaluated using both the indirect sampling method, as well as the sediment injection rate, for the influent concentrations (reported as unadjusted and adjusted efficiencies). The efficiencies ranged from 13.5% to 93.3% for the unadjusted data and 14.6% to 93.1% for the adjusted data. The weighted efficiencies were 70.9% and 68.8% for the unadjusted and adjusted data, respectively.

5.5 Size Scaling and Design Flow Rates

Model OSR 250 of the Stormceptor® OSR series was evaluated above for solids removal performance. There is a need to scale the size up or down in order for other units (shown in Table 1) to take a higher or lower treatment flow rate.

The commonly used scaling factor for design of solids settling basins (clarifiers, sedimentation tanks, etc.) is the surface area, that is, the flow rate is scaled by length to the power of 2.0 (if the particle settling velocity remains the same). This is the Hazen law. The scaling factor of 2.0 was determined based on gravitational settling of discrete particles along the straight path in a rectangular sedimentation basin (see, e.g., Peavy et al. 1985). Sullivan et al. (1972) used the Froude law to design the physical model in their laboratory study of the swirl separator, that is, the flow rate was scaled by length to the power of 2.5 and the particle settling velocity was scaled by length to the power of 0.5.

The exact scaling law is not yet known for hydrodynamic separators. Since the particle size will not change in the actual installation no matter what model is used, application of the Hazen law in the scale-up as well as scale-down appears to be most appropriate at this time. That is, the design flow rate could be expressed in terms of flow rate per unit horizontal area. That is, the verified flow rate of 1,120 gpm for the Stormceptor® OSR could be expressed as 22 gpm per square foot of the (sedimentation chamber) horizontal area. Applying this verified treatment flow rate to other models yields the treatment flow rates for other models (Table 5).

Table 5. Stormceptor® OSR Treatment Flow Rates

Model	Sedimentation Chamber Diameter (ft)	Treatment Flow Rate
065	4	282 gpm (0.63 cfs)
140	6	632 gpm (1.41 cfs)
250	8	1,120 gpm (2.50 cfs)
390	10	1,750 gpm (3.90 cfs)
560	12	2,520 gpm (5.62 cfs)
780*	10	3,500 gpm (7.81 cfs)
1125*	12	5,040 gpm (11.24 cfs)

* The Series OSR units, 780 and 1125 consist of two adjacent models that function in parallel.

For units 780 and 1125 in Table 5, the flow is bisected at the inlet pipe. Half is treated in the first unit the other half is treated in the second unit and then the flows are re-combined at the exit pipe. Therefore, the two units in series function in parallel.

5.6 Maintenance

Maintenance Methods: Maintenance of the OSR device will be performed exactly as the Stormceptor STC. Physical access to the system is obtained through the manhole cover provided with the unit. This cover is field installed at grade and positioned over the 24" outlet riser-pipe and inspection port. Sediment is simply vacuumed (use of a vactor truck or similar device) out of the unit through the outlet riser-pipe assembly (same methodology as the Stormceptor STC).

Maintenance Frequency: As with any stormwater quality treatment practice, routine inspections will predict the long-term maintenance frequency. Depending on the rainfall intensity, duration, volume of runoff, loading (influent concentration), etc, for a particular site, the maintenance frequency may vary. Projections are that the frequency of maintenance will be similar to the STC models (once per year or when the sediment accumulates to 15% of the lower chamber's total volume).

Physical Integrity: The OSR is based primarily on the Stormceptor STC platform. Modifications were made to this platform to maximize the treatment flow rate and optimize the removal of fine-sand particles. These modifications will pose no negative impact to the physical structural integrity of the fiberglass insert or reinforced concrete body as compared to the current Stormceptor STC model line.

Field Monitoring Studies: Since the OSR product is a recently developed device there are currently no field monitoring studies pending or completed. The first field monitoring study to be completed will be the TARP Tier 2 field study.

6. TECHNICAL EVALUATION ANALYSES

6.1 Verification of Performance Claim

Based on the evaluation of the results from laboratory studies, sufficient data are available to support the Imbrium™ Claim: The Stormceptor® OSR Model 250 at a flow rate of 1,120 gpm (2.50 ft³/s), has been shown to have a 69% Total Suspended Solids (TSS) removal efficiency, as measured as suspended solids concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency) using OK-110 silica sand with an average d₅₀ particle size of approximately 100 microns, an average influent concentration of 202 mg/L and 50% initial sediment loading in laboratory studies using simulated stormwater.

6.2 Limitations

The Stormceptor® OSR series does not target the very fine silt and clay.

As with any stormwater quality treatment practice, lack of recommended inspections and maintenance will lead to reduced performance.

6.2.1 Factors Causing Under-Performance

If the Stormceptor® OSR 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 filled with sediment up to the lower edge of the vertical tube, blocking flow.

When a Stormceptor® OSR unit is newly installed, a post-construction inspection is highly recommended. The design of the Stormceptor® OSR unit permits easy inspection. It is recommended that during the year after installation, inspection be performed quarterly for the purpose of noting the rate of sediment and floatables accumulation.

6.2.2 Pollutant Transformation and Release

The Stormceptor® OSR 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® OSR 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® OSR is a self-contained unit, the design does incorporate standing water in the lower chamber. The small area of surface water exposed to air at the orifice and outlet riser-pipe can be a breeding site for mosquitoes.

7. NET BENEFICIAL EFFECT

The NJDEP encourages the development of innovative environmental technologies (IET) that provide a net beneficial effect (NBE) to the environment and human health. 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 and human health when compared to baseline conditions for the same or equivalent inputs and outputs.

Once the Stormceptor[®] OSR has been verified and granted interim certification by the NJDEP, Imbrium[™] 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 beneficial effect evaluation will be completed. However, it should be noted that the Stormceptor[®] OSR technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

8. REFERENCES

Guo, Q. (2006). *Correlation of Total Suspended Solids (TSS) and Suspended Sediment Concentration (SSC) Test Methods*, Final Report, Prepared for New Jersey Department of Environmental Protection, Division of Science, Research, and Technology, Trenton, NJ, Ravi Patraju, Project Manager, November.

Mailloux, J. T. (2007). *VERIFICATION TESTING OF THE IMBRIUM 8 FT DIAMETER STORMCEPTOR OSR Model 250 STORMWATER TREATMENT UNIT*, Submitted to IMBRIUM SYSTEMS, INC., June, Alden Research Laboratories, Inc., Holden, MA.

New Jersey Corporation for Advanced Technology (2004). *NJCAT TECHNOLOGY VERIFICATION, Stormceptor[®]*, September 9.

Peavy, H. S., Rowe, D. R., and Tchobanoglous, G. (1985). *Environmental Engineering*, McGraw-Hill, Inc., New York, NY.

Sullivan, R. H., Cohn, M. M., Coomes, J. P., and Smission, B. S. (1972). *The Swirl Concentrator as a Combined Sewer Overflow Regulator Facility*. USEPA-R2-72-008.