NJCAT TECHNOLOGY VERIFICATION

Aqua-SwirlÔ Concentrator and Aqua-FilterÔ Stormwater Treatment Systems

SEPTEMBER 2005
(Revised December 2005)

****August 2007Addendum to this report starts on page 24**

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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 January 2005, AquaShield™ Inc. (2733 Kanasita Dr. Suite B, Chattanooga, TN 37343) submitted a formal request for participation in the NJCAT Technology Verification Program. The technologies proposed by AquaShield™ Inc., the Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Filtration System, reduce non-point source (NPS) pollution in stormwater through the use of gravitational and hydrodynamic forces and filtration media. The proposed technology eliminates or reduces the amount of debris, oil, grease, sediment, hydrocarbons, heavy metals, and nutrients from stormwater. More specifically, the Aqua-Swirl™ Concentrator has been designed to capture floatable debris, oils and grease, and sediment. The Aqua-Filter™ Stormwater Filtration System has been designed to remove or eliminate fine sediment, nutrients, metals, and other pollutants.

This verification report covers the evaluation based upon the performance claims of the vendor, AquaShield™ Inc. (see Section 4). At the request of NJDEP, it has been revised from the September 2005 report to include an expanded description of the operation of the stormwater filtration system. No other changes were made to the report. The verification report differs from typical NJCAT verification reports in that final verification of the Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Filtration 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 AquaShield™ Inc.'s initial performance claims for the technologies based on carefully conducted laboratory studies. These claims are expected to be modified and expanded following completion of the TARP required field-testing.

1.3 Technology Description

1.3.1 Specific Applicability

The Aqua-Swirl™ Concentrator is used on commercial, military, industrial, urban, residential (single and multi-family), and retail types of land uses. Each Aqua-Swirl™ Concentrator is constructed of High-Density Polyethylene (HDPE) and is therefore modular, lightweight, and durable, eliminating the need for special heavy lifting equipment during installation.

The Aqua-Filter™ Stormwater Filtration System is used on commercial, military, industrial, urban, residential (single and multi-family), and retail types of land uses where sensitive receiving waters are to be protected. The Aqua-Filter™ Stormwater Filtration System is also constructed of High-Density Polyethylene (HDPE) and is therefore modular, lightweight, and durable, eliminating the need for special heavy lifting equipment during installation.

The AquaShield™ Stormwater Treatment Systems (i.e., The Aqua-Swirl™ Concentrator and The Aqua-Filter™ Stormwater Filtration System) are adaptable and custom designed to be specified on practically any new development project. The design allows for easy retrofit into existing facilities. Typical applications include:

- Retail/Commercial Developments
- New and Existing Industrial Facilities
- Highway/Transportation Facilities
- Watershed Protection
- Redevelopment/Retrofit Sites
- Government Facilities
- Military Installations, Bases and Berthing Wharfs
- Vehicle and Equipment Wash Rack Areas
- Fueling Centers and Convenience Stores
- Fast Food Restaurants
- Office Complexes
- Residential Developments
- Coastal Communities
- Drinking Water Well-head Protection Areas.

1.3.2 Range of Contaminant Characteristics

The Aqua-Swirl™ Concentrator has been designed to capture sediment, free-oil, and floatable debris. The Aqua-Filter™ Stormwater Filtration System has been designed to remove or eliminate fine sediment, nutrients, metals, and other pollutants.

1.3.3 Range of Site Characteristics

The Aqua-Swirl™ Concentrator, with a conveyance flow diversion system, allows simple installation by connecting directly to the existing storm conveyance pipe and provides full treatment of the "first flush" or the determined water quality flow while the peak design storm is diverted and channeled through the main conveyance pipe. The Aqua-Swirl™ Concentrator sizing chart for various models is provided in Table 1.

The Aqua-Filter™ Stormwater Filtration System uses a "treatment train" approach. The system includes an Aqua-Swirl™ Concentrator designed for gross contaminant removal which pre-treats stormwater before entering the Filtration Chamber. A variety of natural filter media are used in the 6 ft diameter filtration chamber to complete the treatment process by polishing the stormwater, removing fine sediments and water-borne pollutants. The Aqua-Filter™ Stormwater Filtration System sizing chart for various models is provided in Table 2.

1.3.4 Material Overview, Handling and Safety

Free-floating oil and floatable debris can be removed directly through the 30" service access provided on the Aqua-Swirl™ Concentrator. When the sediment pile is within 30" to 36" of the water surface, cleaning is required. A vacuum truck can be used to remove the accumulated sediment and debris. The entire sediment storage area can be accessed with a vacuum hose from the surface. All materials removed are to be handled and disposed of in accordance with local and state requirements.

Table 1. Aqua-SwirlÔ Concentrator Sizing Chart

Aqua-Swirl™ Model	Swirl Chamber Diameter (ft)	Maximum Stub-Out Pipe Outer Diameter (in)		Water Quality Treatment Flow[2] (cfs)	Oil/Debris Storage Capacity (gal)	Sediment Storage Capacity (ft^3)
		On/Offline	CFD[1]			
AS-2	2.50	8	12	1.1	37	10
AS-3	3.25	10	16	1.8	110	20
AS-4	4.25	12	18	3.2	190	32
AS-5	5.00	12	24	4.4	270	45
AS-6	6.00	14	30	6.3	390	65
AS-7	7.00	16	36	8.6	540	90
AS-8	8.00	18	42	11.2	710	115
AS-9	9.00	20	48	14.2	910	145
AS-10	10.0	22	54	17.5	1130	180
AS-12	12.0	24	60	25.2	1698	270
AS-XX*	Custom	--	--	>26	--	--

*Higher water quality treatment flow rates can be designed with multiple swirls.

Notes:

(1) The Aqua-Swirl™ Conveyance Flow Diversion (CFD) provides full treatment of the "first flush," while the peak design storm is diverted and channeled through the main conveyance pipe.

(2) Many regulatory agencies are establishing "water quality treatment flow rates" for their areas based on the initial movement of pollutants into the storm drainage system. The treatment flow rate of the Aqua-Swirl™ system is engineered to meet or exceed the local water quality treatment criteria. This "water quality treatment flow rate" typically represents approximately 90% to 95% of the total annual runoff volume.

Table 2. Aqua-FilterÔ Stormwater Filtration System Sizing Chart

Aqua-Filter™ Model	Water Quality Filtered Flow Rate[1]		Filtration Chamber Length	Approx. Treatment Train Length[2]
	(cfs)	(gpm)	(ft)	(ft)
AF - 3.1	0.13	60	9.6	16
AF - 3.2	0.27	120	12.0	18
AF - 3.3	0.40	180	14.3	21
AF - 4.4	0.53	240	16.6	24
AF - 4.5	0.67	300	18.7	28
AF - 4.6	0.80	360	21.0	31
AF - 5.7	0.94	420	23.6	34
AF - 5.8	1.07	480	25.9	36
AF - 6.9	1.20	540	28.2	38
AF - 6.10	1.34	600	30.5	40
AF - 6.11	1.47	660	32.8	42
AF - 6.12	1.60	720	35.6	45
AF - X.XX*	> 1.60	>720	Custom	Custom

***Higher water quality filtered flow rates can be designed with multiple Filter Chambers & larger Swirl Concentrator.**

Notes:

(1) The **Water Quality Filtered Flow Rate** is engineered and based on removal of SCS 106 sediment with a d_{50} particle size of 22 microns

(2) The Aqua-Filter™ Stormwater Filtration System is a two (2)-component treatment train utilizing an Aqua-Swirl™ & Filter Chamber.

The filter media of the Aqua-Filter™ Stormwater Filtration System is initially light tan or white in color. When the media turns black it has become saturated from pollutant loading and requires replacement. Replacement of the filter media typically requires entry into the filter chamber by one of a two member maintenance crew. Confined space entry precautions should be taken by the maintenance crew when removing and replacing the filters. The filter media does not allow captured contaminants to be released once absorbed into the material. The spent filters and sediment generally do not require any special treatment or handling for disposal. All materials removed during maintenance are to be handled and disposed of in accordance with local and state requirements.

1.4 Project Description

This project included the evaluation of assembled reports, company manuals, literature, and laboratory testing reports to verify that the Aqua-Swirl™ Concentrator and the Aqua-Filter™ cartridge meet the performance claims of AquaShield™ Inc.

1.5 Key Contacts

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2. Evaluation of the Applicant

2.1 Corporate History

AquaShield's™ commitment to providing quality environmental solutions began in the early 1980's with its founder, J. Kelly Williamson, solving surface water (NPDES) and groundwater contaminant issues at industrial and commercial facilities through his previously owned environmental consulting/contracting companies. In 1997 the first product, a catch basin insert (now the Aqua-Guard™ Catchbasin Insert), was introduced for use at point source problem sites such as gas stations, fast food restaurants, and high traffic parking lots. The AquaShield™ Stormwater Filtration technology expanded to underground structures in 1999 with installing a "treatment train" design utilizing pretreatment sediment removal incorporated with a filtration chamber to remove fine contaminants. This is now known as the Aqua-Filter™ Stormwater Treatment System.

Early in 2000, AquaShield™ Inc. was formed with its corporate office in Chattanooga, Tennessee. Recognizing the increasing compliance standards for water borne pollutants sets AquaShield™ Inc. apart in a fast growing industry with patenting a treatment system integrating hydrodynamic swirl separation technology for pretreatment with high flow filtration technology in a single device. In 2001, the Aqua-Swirl™ Concentrator, a stand alone hydrodynamic swirl concentrator, was introduced to meet the increasing requests for primary pollutant removal of sediment and floatable debris and oils.

Accordingly, AquaShield™ Inc. offers its customers three essential alternatives for treating stormwater and industrial runoff; the Aqua-Swirl™ Concentrator, the Aqua-Filter™ Stormwater Treatment System and the Aqua-Guard™ Catchbasin Insert. Other derivatives of these core products have been adapted for exclusive customers needing further enhanced water treatment. AquaShield's™ products distinguish themselves with their HDPE construction materials providing flexibility and adaptation to site specific conditions. Each product arrives at the project job site completely assembled and ready for installation.

All AquaShield™ products are fabricated and hydrostatically tested prior to shipment under rigorous quality control procedures at three plants in the central United States. Plans are underway to open additional plants in California and Maryland to assist with logistics.

The performance evaluations of the AquaShield™ products are conducted and confirmed by independent sources such as Universities and state licensed laboratories to maintain the integrity of the study. Computational fluid dynamic (CFD) computer modeling by Universities and independent contract laboratories is used to confirm hydraulic capabilities of existing products as well as for developing new technology and designs. Field performance tests are under grant funded projects in Washington, New Hampshire and Georgia. There are two (2) new products being developed and tested with patent applications pending.

AquaShield™ Inc.'s goal is to understand the customer's needs and offer the best cost efficient solution in a timely manner. AquaShield™ accomplishes this goal through its growing team of sixteen (16) Independent Sales Agents across the United States and a corporate engineering and customer service staff in Chattanooga. AquaShield™ has licensees in Korea, Puerto Rico, Malaysia, Philippines, Middle East, Mexico, and Central America. This exponential growth has allowed AquaShield™ Inc. to be recognized the past two years as one of Tennessee's 50 fastest growing privately held companies. AquaShield™, Inc. was also awarded the "Krusei Spirit of Innovation" in the Spring of 2004.

2.2 Organization and Management

The corporate office of AquaShield™ Inc. is in Chattanooga, Tennessee where the engineering, design, research and development, maintenance, accounting and customer support personnel are located. AquaShield™ Inc.'s team of Independent Sales Agents are covering 39 states in the United States while independent licensees are providing Puerto Rico, Korea, Malaysia, Philippines, Middle East, Mexico, and Central America local customer support. The leadership of AquaShield™ Inc. consists of J. Kelly Williamson - President and Founder; Eric Rominger – Director, Engineering Sales and Marketing; Heather Jones – Accounting Manager; Thomas Dingler -. CAD/Engineering; Teresa Hardin – Project Coordinator; and Anna Sutton – Maintenance Coordinator. The fabrication plants operate under self-sufficient management structure with the guidance of the corporate organization.

2.3 Operating Experience with the Proposed Technology

The AquaShield™ Stormwater Treatment Technologies are based on 20 years of experience in providing treatment solutions for impaired water resources. AquaShield™ systems have been installed at numerous locations world wide for a variety of applications. The following is a listing of sample installations in the United States:

Aqua-Swirl™ Concentrator

- Vehicle Washdown Area in Grand Rapids, MI
- Industrial Facility Parking Lot in Olancha, CA
- Church Parking Lot in Hixson, TN
- Shopping Center Parking Lot in Honolulu, HI
- Storage Yard in Charlotte, NC
- Maintenance Facility in Eugene, OR
- Housing Subdivision in Macomb County, MI
- Fueling Station in Knoxville, TN
- Roadway Project in Grand Rapids, MI
- Naval Air Station in San Diego, CA
- Grocery Store in Emmett, ID
- Residential Development/Golf Course in Indianapolis, IN

- University Housing in Indianapolis, IN
- Department of Transportation Center in Knoxville, TN
- News/Publishing Facility in Honolulu, HI
- Correctional Facility in Indianapolis, IN

Aqua-Filter™ Stormwater Filtration System*

- Housing Subdivision in Anchorage, AK
- Industrial Facility Parking Lot in Massena, NY
- Institutional Parking Facility in Kalamazoo, MI
- Truck Wash in Oklahoma City, OK
- Department of Public Works Facility in Wayne, MI
- Roadway Project/Test Facility in Seattle, WA
- Commercial Facility Parking Lot in Rockville, MD
- Roadway Project in Novi, MI
- Hotel Parking Lot in Dumphries, VA
- Highway/Stream Re-development in Jackson, WY
- Navy Base Pier in San Diego, CA
- Department of Transportation in Portsmouth, RI
- Parking Lot Expansion in Golden Valley, MN
- Town Homes in Weaton, MD
- Corporate Building Site in Kalamazoo, MI

* All Aqua-Filter™ Stormwater Filtration Systems are installed in a treatment train with an Aqua-Swirl™ Concentrator.

2.4 Patents

Currently, two (2) patents apply to the Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Treatment System:

- Drainwater Treatment System for Use in a Horizontal Passageway – US Patent No. 6,190,545
- Gravitational Separator and Drainwater Treatment System for Use in a Horizontal Passageway – US Patent No. 6,524,473

2.5 Technical Resources, Staff and Capital Equipment

AquaShield™ Inc. provides direct interaction with government regulators, design engineers/architects and property owners/developers with their corporate office and local representatives. All design work for each AquaShield™ product is completed at AquaShield™ Inc.'s corporate office. Drawings and specifications of standard product designs and sizes are provided through several sources to expedite the permitting and installation process. AquaShield™ Inc.'s Technical Manual is available in written and compact disc (CD) format which explains details of each product, fabrication and installation methods, inspection and maintenance procedures, and performance and testing information.

The operation of the Aqua-Swirl™ Concentrator is available in 3-D animation that can be manipulated by the viewer on their website www.aquashieldinc.com. The operation of the Aqua-Filter™ Stormwater Treatment System is also provided in simple animation.

A video CD is available that describes the design, manufacturing, handling, installation and maintenance of the AquaShield™ products.

A Sizing Program is available for design engineers/architects through the local Sales Agents and corporate engineering staff for the Aqua-Swirl™ Concentrator. The Sizing Program uses National Climatic Data Center (NCDC) information from approximately 7,000 recording stations in the United States combined with performance information and the rational method to recommend the correct size or model Aqua-Swirl™ Concentrator for a site.

AquaShield™ Inc. has a Project Design Assistant (PDA) that grants registered users access to standard drawings and project information at the convenience of their personal computers from the internet. Site specific information can be transmitted directly to corporate engineers to expedite final Auto CAD drawings of the correct model Aqua-Swirl™ Concentrator or Aqua-Filter™ Stormwater Treatment System. The PDA expedites the process from project concept, to specific design, to permitting, to fabrication and installation. During this process, local Sales Agents and engineering staff are in communication with the design engineers/architects to maintain customer relations.

Calculations are provided by the AquaShield™ engineering staff for traffic loading (H-20 and greater), buoyancy and stress/strain conditions, as appropriate for projects.

Each AquaShield™ product is fabricated at one of three plants and shipped to the project site in less than four (4) weeks of receiving final approved shop drawings. AquaShield™ makes arrangements for all shipping and delivery with the project contractor. A representative from AquaShield™ is available for assisting with the installation of the products.

An AquaShield™ Maintenance Coordinator is available to ensure the proper and timely inspection and maintenance of the AquaShield™ products. Local contractors are used to complete the cleaning and correct filter replacements of the systems. AquaShield™ also has product liability insurance and can supply a certificate of insurance to the customer upon request.

3. Treatment System Description

Operation of Aqua-SwirlÔ Concentrator

The patented Aqua-Swirl™ Concentrator provides for the removal of sediment, floating debris, and free-oil. The Aqua-Swirl™ Concentrator is constructed of High-Density Polyethylene (HDPE) and is modular, lightweight and durable, which eliminates the need for heavy lifting equipment during installation. Inspection and maintenance are made easy, with oversized risers that allow for both examination and cleanout without entering the chamber. A schematic of the Aqua-Swirl™ Concentrator is provided in Figure 1.

Operation begins when stormwater enters the Aqua-Swirl™ Concentrator by means of its tangential inlet pipe, which induces a circular (or vortex) flow pattern. The Aqua-Swirl™ Concentrator retains water between storm events providing both "quiescent and dynamic" settling of inorganic solids. The dynamic settling occurs during each storm event, while the quiescent settling takes place between successive storms. A combination of gravitational and hydrodynamic drag forces results in solids dropping out of the flow and migrating to the center of the chamber where velocities are the lowest. The treated flow exits the Aqua-Swirl™ Concentrator behind the arched outer baffle. The top of the baffle is sealed across the treatment channel. This eliminates floatable pollutants from escaping the system. A vent pipe is extended up the riser to expose the backside of the baffle to atmospheric conditions, preventing a siphon from forming at the bottom of the baffle.

Operation of Aqua-FilterÔ Stormwater Filtration System

The Aqua-Filter™ Stormwater Filtration System is designed for sites that require advanced treatment of stormwater runoff discharging to sensitive receiving waters. The Aqua-Filter™ Stormwater Filtration System is a stand-alone custom engineered two-component structure, which utilizes a "treatment-train" approach for stormwater pollutant removal. This patented configuration begins with a Swirl Concentrator (using vortex enhanced sedimentation technology) designed for pre-treatment of stormwater runoff followed by a Filtration Chamber (using media filtration technology) capable of removing finer sediments and water-borne pollutants. A schematic of the Aqua-Filter™ Stormwater Filtration System is provided in Figure 2.

Each Filter Chamber has an inside diameter of approximately 72-inches (an outside diameter of 80.75-inches) containing rows of adjoining porous filters fixed horizontally in the chamber and positioned perpendicular to the water flow. There are 3 filter sections per row; each has a surface area of approximately 4-square feet, therefore supplying a total of 12-square feet per row of filters. There are open grids on the bottom of each filter section where 4, 6-inch thick filters, are placed to form 2 layers in a pattern to avert short-circuiting of the water flow. Accordingly, there are 12 filters and approximately 12-cubic feet of filter media per row. Similar 1-inch thick open grates are firmly fixed above the filters to facilitate distribution of the pretreated water across the filter bed. The length of a single Filter Chamber can be extended up to 35-feet to accommodate additional rows of filters increasing the filter surface area based on the calculated water quality flow to be treated. Furthermore, the Filter Chambers have been customized in parallel designs to process exceptionally large water quality flow rates.

The Filter Chamber is designed to facilitate distribution of the pretreated water above the filter bed and control the flow rate to each row using proprietary post filtration hydraulic restraints. Bulkheads are positioned at each end of the filter bed to evenly distribute and restrain incoming water, create gravitational pressure for water to permeate the filters, contain captured pollutants during peak flows and provide structural support. The bulkhead design allows a maximum 10-inch water level above the filters. The principals of the post filtration flow are based on controlling flow through orifices. The post filtration hydraulic restraints ensure each row of filters receives a maximum flow of 60gpm (20gpm per filter).

The Aqua-Filter™ Stormwater Filtration System operates under gravitational and hydrodynamic forces with no moving parts or valves, which simplifies the treatment process. The Aqua-Filter™ Stormwater Filtration System operates in an offline configuration, thereby treating the more frequent 6-month to 1-year design storms (or roughly 90% of the annual rainfall on a given site in New Jersey).

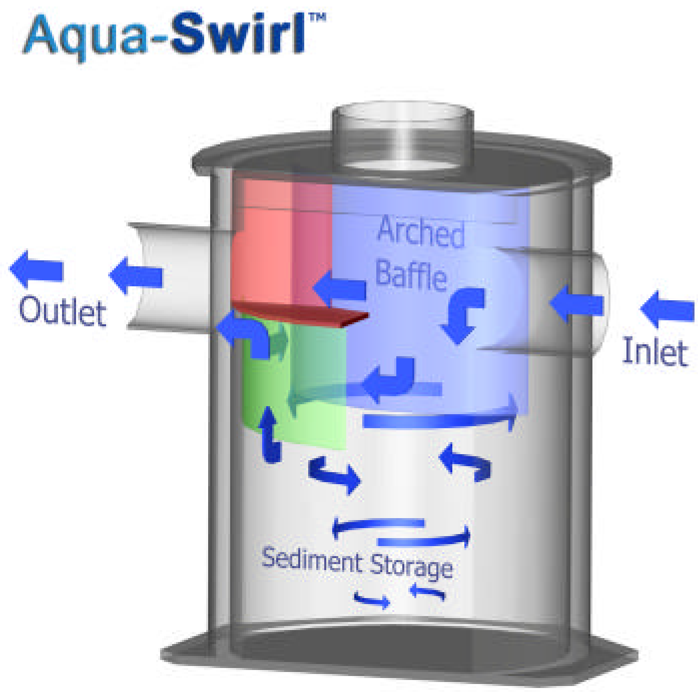
Installation of Aqua-SwirlÔ Concentrator

The Aqua-Swirl™ Concentrator has been designed and fabricated as a modular unit with no moving parts or assembly required on site. Since the system is fabricated from HDPE, the Aqua-Swirl™ Concentrator can be installed without the use of heavy lifting equipment. Lifting supports/cables are provided to allow easy offloading and installation with a backhoe. In addition, manufactured stub-outs for the inlet and outlet are provided. This allows the contractor to simply attach the Aqua-Swirl™ Concentrator directly to the main conveyance storm pipe with couplings. An AquaShield™ representative is typically on-site to assist in the installation process.

All Aqua-Swirl™ Concentrators are supplied with an octagonal base plate, which extends a minimum of six inches beyond the outside diameter of the swirl chamber. The function of the extension of this base plate is to provide additional surface area to counter any buoyant force exerted on the system. The forces created on the base plate by the weight of the surrounding fill material offsets the buoyant force generated within the system. If needed, concrete can be poured directly onto the base plate to provide additional resistive force.

When installed in traffic areas, the system is designed to withstand H-20 loading. A reinforced concrete pad is poured in place above the system under this scenario.

The Aqua-Swirl™ Concentrator is designed so that it can easily be used for retrofit applications. With the invert of the inlet and outlet pipe at the same elevation the Aqua-Swirl™ Concentrator can easily be connected directly to the existing storm conveyance drainage system. Because of the lightweight nature and small footprint of the Aqua-Swirl™ Concentrator, existing infrastructure utilities (i.e., wires, poles, trees) are unaffected in installation.



AquaShield™ STORMWATER TREATMENT SOLUTIONS

Figure 1. Aqua-SwirlÔ Concentrator

Installation of Aqua-FilterÔ Stormwater Filtration System

As with the Aqua-Swirl™ Concentrator, no special lifting equipment is required to off load the system due to the lightweight durable nature of HDPE. Lifting supports are provided on each unit, and typically installation can be accomplished with an excavator or track-hoe.

Stub-outs for the inlet and outlet are provided. AquaShield™ will furnish the coupling between the Swirl Concentrator and Filter Chamber. This requires the contractor to attach the pipes to the Stormwater Filtration System with couplings. An AquaShield™ representative is typically on-site to assist in the installation process.

All Aqua-Filter™ Stormwater Filtration Systems are supplied with anchor feet at each end of the filter chamber. These anchor feet provide additional surface area to counter any buoyant force exerted on the system. The forces created on these anchor feet by the weight of the surrounding fill material helps offset the buoyant force generated. If needed, concrete can be poured directly onto the anchors to provide additional surface area for resistive force.

When installed in traffic areas, the system is designed to withstand H-20 loading. A reinforced concrete pad is poured in place above the system under this scenario. The Aqua-Filter™ Stormwater Filtration System is designed so that it can be used for retrofit applications. The filtration system can be installed both above and below grade and can be used for industrial applications to meet new, more stringent permit requirements.

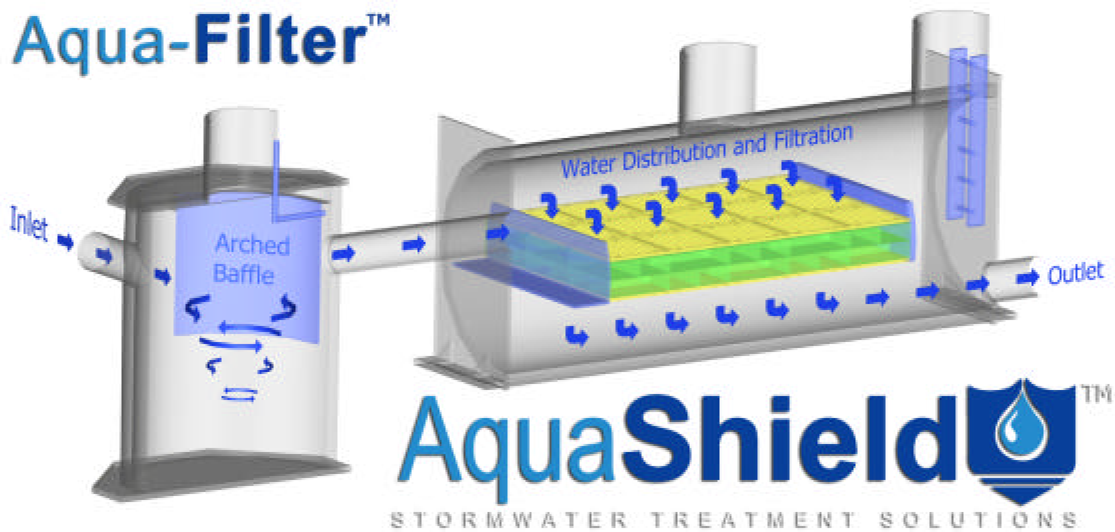


Figure 2. Aqua-FilterÔ Stormwater Filtration System

4. Technical Performance Claims

Claim 1: The Aqua-Swirl™ Concentrator, Model AS-3, has been shown to have a total suspended solids (TSS) removal efficiency (as measured as suspended sediment concentration (SSC)) of 60% when operated at 60% of its water quality treatment flow using OK-110 unground silica with a d_{50} particle size of 110 microns, an average influent concentration of 320 mg/L and zero initial sediment loading in laboratory studies using simulated stormwater.

Claim 2: At a flow rate of 20 gpm, the coarse perlite media filtration cartridge used in the Aqua-Filter™ Stormwater Treatment System has been shown to have an average TSS removal efficiency of 80.5% for SIL-CO-SIL 106 silica with a d_{50} particle size of 22 microns at influent concentrations of 90, 155, 176, and 280 mg/L in laboratory studies using simulated stormwater.

5. Technical System Performance

For Claim 1, the Aqua-Swirl™ Concentrator Model AS-3 was tested by the Department of Civil and Environmental Engineering at Tennessee Tech University, Cookeville, TN. The removal efficiencies measured in the laboratory experiment were then used to calculate SSC removal efficiency. For Claim 2, the Analytical Industrial Research Laboratories (AIRL), Cleveland, TN conducted experiments using the perlite media to determine removal efficiencies for TSS.

5.1 Laboratory Study for Claim 1 – Aqua-Swirl™ Concentrator

The Department of Civil and Environmental Engineering at Tennessee Tech University conducted laboratory testing to evaluate the TSS removal efficiency of the Aqua-Swirl™ Concentrator Model AS-3. These tests were conducted in accordance with the protocol prepared by Tennessee Tech University, "Performance Evaluation of Aqua-Swirl™ Concentrator" and the American Public Works Association (APWA) Protocol, "Appendix B: An Approach to Lab Testing of Stormwater Treatment Facilities." This section provides details of the laboratory system setup and the procedures followed in the test.

System Description

A full scale Model AS-3 unit was tested for a range of flows from 0.2 cfs to 1.2 cfs (9.31 gpm/ft^2 to 55.88 gpm/ft^2). The sediment used in the experiment was OK-110 Unground Silica with a specific gravity of 2.65 and a grain size ranging from 50 to 150 microns (See particle size distribution in Figure 3). The testing system consisted of high capacity pumps, a continuous recording flow meter, a supply tank, feed piping, a tailwater (catch) tank, sediment dosing pumps with mixing tanks, and automated samplers. A schematic of the laboratory testing system was provided. To assure complete mixing, the sediment was introduced into the system ten (10) pipe diameters upstream of the AS-3 system. Water was recirculated from the catch tank to the supply tank. The system did not have an initial sediment load in the storage chamber prior to testing.

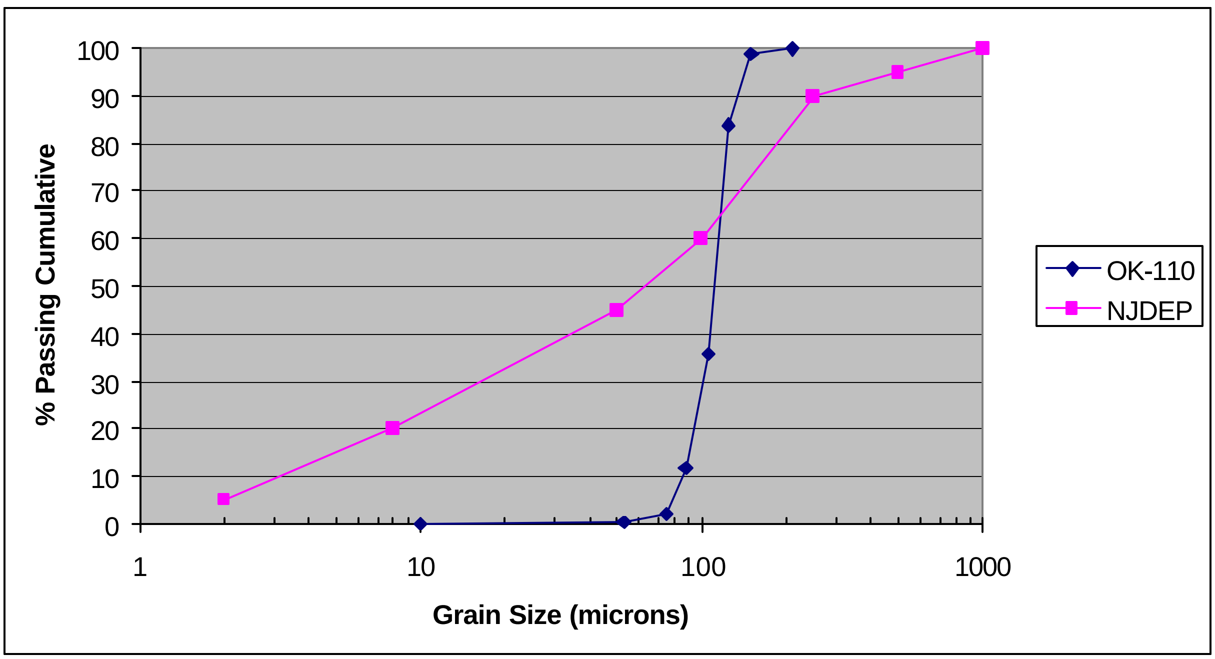


Figure 3. Comparison of Particle Size Distribution between NJDEP's Recommended PSD and OK-110 PSD

Procedure

The detention time of the system was determined for all tested flow rates. The influent and effluent samples were timed so that the same water would be sampled at the inlet and outlet. After achieving steady-state flow conditions for the desired testing flow rate, sediment was introduced into the inlet pipe at a target concentration of 200 mg/L using a variable speed, positive-displacement metering pump.. Five influent and five effluent samples were collected for each flow test. These data are presented in Table 3. The water samples were collected for analysis of (TSS) using the SSC methods described by USGS.

Table 3. Measured Influent and Effluent Suspended Solids Concentration (SSC) for AS-3 Experiment

Flow Rate (cfs)	Influent SSC (mg/L)	Effluent SSC (mg/L)	Removal Efficiency (%)
0.2	142	56.7	
0.2	544	38.1	
0.2	425	101	
0.2	544	38.2	
0.2	518	11.8	
AVG:	**434.6**	**49.16**	**88.7%**
0.5	342	12.3	
0.5	590	42.6	
0.5	396	139	
0.5	508	105	
0.5	476	118	
AVG:	**462.4**	**83.38**	**82.0%**
0.8	146	205	
0.8	253	91.4	
0.8	399	173	
0.8	266	53.7	
0.8	247	42	
AVG:	**262.2**	**113.02**	**56.9%**
1.2	26.7	37	
1.2	96.4	87.8	
1.2	122	137	
1.2	128	86.9	
1.2	223	140	
AVG:	**119.22**	**97.74**	**18.0%**

5.2 Laboratory Studies for Claim 2 – Aqua-Filter™ Cartridge

AIRL evaluated the filter media perlite cartridge for the removal of TSS. AIRL is a full service environmental laboratory with over 25 years of experience. It maintains accreditations with the States of Tennessee, Kentucky, Louisiana and North Carolina, and certifications with the US Environmental Protection Agency (USEPA) and the US Department of Agriculture (USDA). These sample analyses were conducted in accordance with EPA Method 0160.2, Residue, Nonfilterable and Total Suspended Solids for TSS. This section provides details of the laboratory system setup and the procedures followed in the tests.

System Description

A cylindrical one thousand (1,000) gallon polymer tank was used to contain water discharged at a controlled flow rate onto a filter cartridge. Coarse perlite media filtration bags filled the 24x24x24 inch cartridge enclosure 12 inches deep.. A variable speed pump delivered a TSS slurry mixture into a ten foot PVC mixing tube (six inch diameter) connecting the 1,000 gallon tank of dilution water to the perlite filtration unit that contained the testing cartridge. A flow regulator valve was position at the upstream end of the six (6) inch PVC pipe near the base of the polymer tank. The dilution water from the 1,000 gallon holding tank mixed with the TSS slurry. This mixture was gravity fed over a water displacement baffle and onto the perlite media cartridge. The flow regulator was manually adjusted to control the release of water from the tank to maintain the desired flow rate and the measured head of less than one (1) inch above the filter cartridge.

Procedure

Prior to the experimental testing, the perlite cartridge was flushed with 800 gallons of water to remove any residual dust within the media, thereby creating typical wet operating conditions. A total of ten (10) samples were obtained at four (4) minute intervals during the continuous flow of 800 gallons of water. The water level in the polymer tank was noted to the nearest 0.25 inch level for each of the ten (10) tests as well as the final end point of the 800 gallon run at the end of the 40 minute (+/- 2.5 minutes) test period The flow rate was checked for accuracy by this method at least once between each of the ten (10) sampling events to ensure that the 20 gpm flow rate was maintained. Testing was performed using a synthetically graded commercial silica product (SIL-CO-SIL 106) manufactured by the US Silica Company. The PSD for SIL-CO-SIL 106 has a d_{50} particle size of 22 microns. For the TSS testing, ten simulation tests were performed using an influent TSS ranging from 112 mg/L to 193 mg/L at a filtration rate of 20 gallons per minute (target concentration of 150 mg/L). Each test was run for four minutes with 80 gallons of influent. The TSS testing results are presented in Table 4. Additional tests were conducted with varying influent TSS concentrations (targets of 100, 200 and 300 mg/l). These results are shown in Tables 5-7.

Table 4. Measured Influent and Effluent TSS Concentrations for Aqua-Filter™ Cartridge Experiments at a Flow Rate of 20 gpm with SIL-CO-SIL 106 and Target Influent TSS Concentration of 150 mg/l (AIRL, January 24, 2005)

Simulation No.	Influent TSS Conc. (mg/L)	Effluent TSS Conc. (mg/L)	TSS % Removal
1	167	14	92
2	188	23	88
3	125	17	86
4	135	24	82
5	112	26	77
6	155	25	84
7	193	28	85
8	145	30	79
9	187	35	81
10	142	42	70
Average:	**155**	**26**	**83**

Table 5. Measured Influent and Effluent TSS Concentrations for Aqua-Filter™ Cartridge Experiments at a Flow Rate of 20 gpm with SIL-CO-SIL 106 and Target Influent TSS Concentration of 300 mg/l (AIRL, March 3, 2005)

Simulation No.	Influent TSS Conc. (mg/L)	Effluent TSS Conc. (mg/L)	TSS % Removal
1	266	65	76
2	292	53	82
3	319	49	85
4	332	55	83
5	274	45	84
6	237	42	82
7	286	59	79
8	309	55	82
9	262	51	81
10	225	44	80
Average:	**280**	**52**	**82**

Table 6. Measured Influent and Effluent TSS Concentrations for Aqua-Filter™ Cartridge Experiments at a Flow Rate of 20 gpm with SIL-CO-SIL 106 and Target Influent TSS Concentration of 200 mg/l (AIRL, March 3, 2005)

Simulation No.	Influent TSS Conc. (mg/L)	Effluent TSS Conc. (mg/L)	TSS % Removal
1	170	26	85
2	173	39	77
3	221	39	82
4	193	32	83
5	178	42	76
6	170	48	72
7	160	33	79
8	173	38	78
9	160	32	80
10	158	43	73
Average:	**176**	**37**	**79**

Table 7. Measured Influent and Effluent TSS Concentrations for Aqua-Filter™ Cartridge Experiments at a Flow Rate of 20 gpm with SIL-CO-SIL 106 and Target Influent TSS Concentration of 100 mg/l (AIRL, March 3, 2005)

Simulation No.	Influent TSS Conc. (mg/L)	Effluent TSS Conc. (mg/L)	TSS % Removal
1	74	25	66
2	95	28	71
3	92	17	82
4	90	18	80
5	104	17	84
6	95	26	73
7	81	16	80
8	74	14	81
9	86	20	77
10	113	16	86
Average:	**90**	**20**	**78**

5.3 Verification Procedures for All Claims

All the data provided to NJCAT were reviewed to fully understand the capabilities of the Aqua-Swirl™ Concentrator Model AS-3. To verify the AquaShield™ claim for the Aqua-Swirl™

Concentrator, the laboratory data were reviewed and compared to the NJDEP TSS laboratory testing procedure.

Since the Aqua-Filter™ cartridge is designed so that all the flow passes through the filter, a flow rate is assigned to the verification, and the NJDEP weighting procedure is not used.

5.3.1 NJDEP Recommended TSS Laboratory Testing Procedure

The 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 8) using a natural/commercial soil representing the 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 9) for that particular operating rate.
    D. The results of the five numbers will then be summed to obtain the theoretical annual TSS load removal efficiency of the system.

Table 8. 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:
Recommended density of particles ≤2.65 g/cm^3
*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 9. Weight Factors for Different Treatment Operating Rates

Treatment operating rate	Weight factor
25%	0.25
50%	0.30
75%	0.20
100%	0.15
125%	0.10

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.

5.3.2 Laboratory Testing for the Aqua-Swirl™ Concentrator

The results of the laboratory testing that were performed by Tennessee Tech are presented in Table 3 and graphed in Figure 4. Testing was performed for an influent TSS target concentration of 200 mg/L. These tests were performed at various increments of the maximum available pumping rate of 1.2 cfs (540 gpm). The tests were performed at 0.2, 0.5, 0.8 and 1.2 cfs (i.e., 90, 225, 360, and 540 gpm). The Tennessee Tech study measured the unit's diameter of 3.50 feet, which is a unit area of 9.6 ft^2. This would result in 0.2 to 1.2 cfs being equivalent to 9.31 gpm/ft^2 to 55.88 gpm/ft^2 as indicated in the Tennessee Tech Report.

Claim 1 refers to 60% of the water quality treatment flow (Table 1). The "Water Quality Treatment Flow" rate is given in the Aqua-Swirl™ Sizing Chart for Model AS-3 as 1.8 cfs (810 gpm). Since the flow rate that is referenced in the claim is referring to the "Water Quality Treatment Flow" rate in the sizing chart, 60% of the 1.8 cfs would be equal to 1.08 cfs (486 gpm or 50.5 gpm/ft^2). Using the values given in Table 3 (also in Figure 5) and the NJDEP weighting factors, the SSC removal efficiency for the system is shown in Table 10.

The average d_{50} of the NJDEP particle size distribution is approximately 67 microns, lower than the average d_{50} of the OK-110 silica that was used in the experiment (d_{50} of OK-110 is approximately 110). Since larger particle size sediment tends to settle more rapidly than finer grain sediment, the laboratory testing results for the Aqua-Swirl™ Concentrator obtained with the OK-110 material show better removal efficiencies than would be expected with the NJDEP recommended test sediment.

Additionally, the water analyses that were performed on the influent and effluent were not for TSS but SSC, which tends to yield higher removal efficiencies. Although SSC may be a more accurate representation of the true removal efficiency of pre-manufactured treatment systems, the NJDEP regulations clearly require stormwater BMPs to remove TSS not SSC.

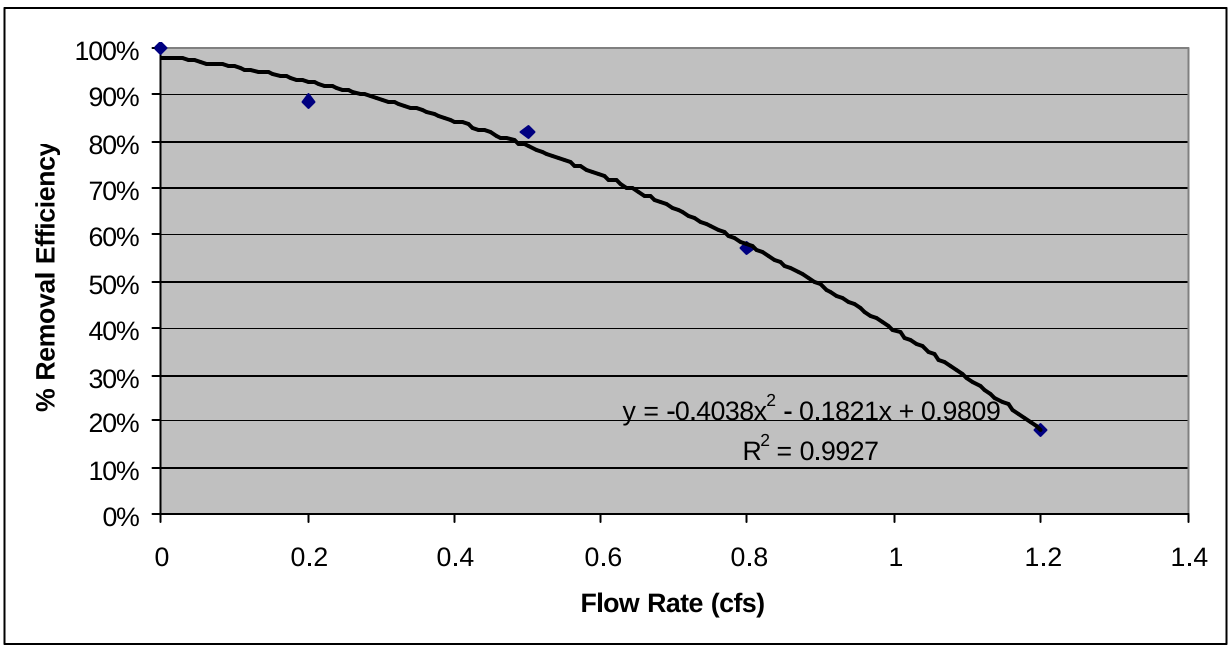


Figure 4. Laboratory Testing SSC Removal Efficiencies for the Aqua-Swirl™ Concentrator Model AS-3 versus Flow Rate

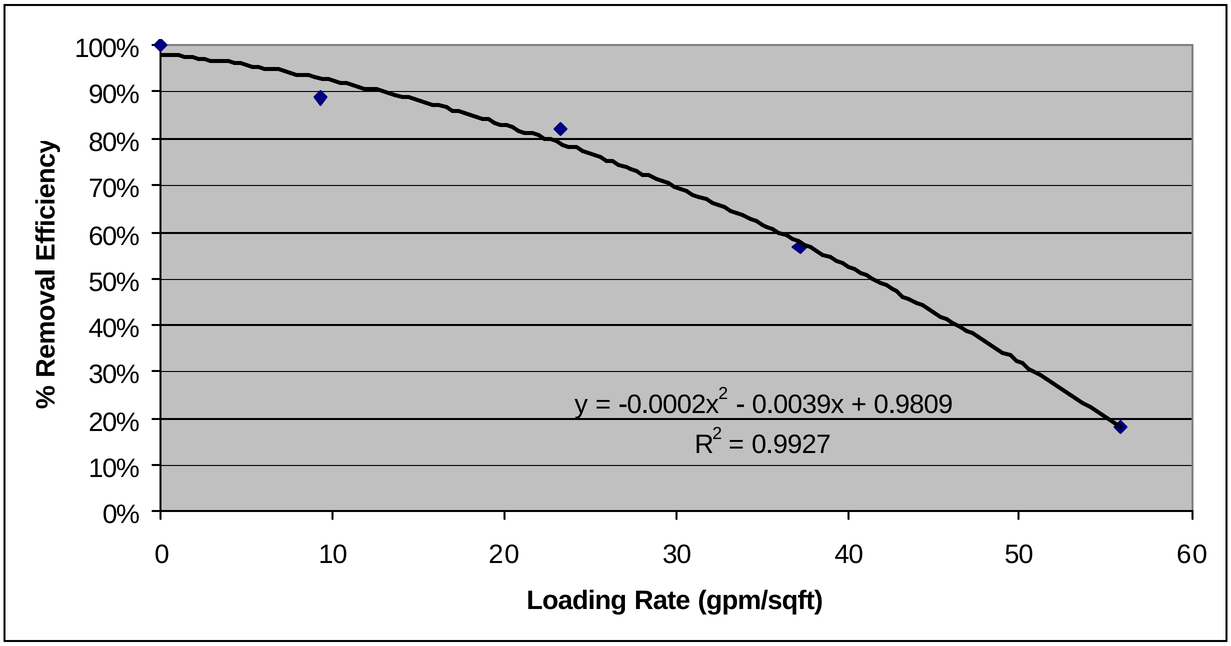


Figure 5. Laboratory Testing SSC Removal Efficiencies for the Aqua-Swirl™ Concentrator Model AS-3 versus Loading Rate

Furthermore, the average influent concentration during the testing was higher than the targeted influent concentration of 200 mg/L. Based upon the data in Table 3, the average influent concentration was 320 mg/L, outside of NJDEP recommended range of 100 to 300 mg/L.

Field testing data and scour testing data has not been made available on the Aqua-Swirl™ Concentrator.

Table 10: NJDEP Weighted Removal Efficiency for 1.08 cfs (486 gpm or 50.5 gpm/ft^2)

Treatment Operating Rate	NJDEP Weight Factor	Loading Rate (gpm/ft^2)	Flow Rate (cfs)	% SSC Removal from Figure 5	NJDEP Weighted % Removal
25%	0.25	12.6	0.27	90.0	22.5
50%	0.30	25.3	0.54	75.5	22.6
75%	0.20	37.9	0.81	54.6	10.9
100%	0.15	50.5	1.08	27.4	4.1
125%	0.10	63.2	1.35	0.0	0.0
Total:					**60.1**

5.3.3 Laboratory Testing for the Aqua-Filter™ Cartridge

The results of the laboratory testing that were performed by AIRL are presented in Tables 4-7 for TSS at a flow rate of 20 gpm. Unlike the testing performed on the Aqua-Swirl™ Concentrator, the samples collected for the laboratory testing of the Aqua-Filter™ cartridge were analyzed for TSS, not SSC. These data confirm an average TSS removal rate of 80.5% at a flow rate of 20 gpm. The PSD of the SIL-CO-SIL 106 is finer material than the recommended NJDEP mixture with a d_{50} particle size of 22 microns (NJDEP's PSD has a d_{50} of approximately 67 microns).

5.4 Calculation of Net Annual Removal Efficiency

AquaShield™ provides a program to calculate Net Annual Removal Efficiency using real rainfall data collected at weather stations across the country. This can be a useful tool in determining compliance with New Jersey state regulations to remove 80% TSS on a net annual basis. AquaShield™ provides a calculation using the data from Table 3 (also shown in Figure 5) and five years of hydrologic data from the Portland, Maine area to demonstrate that 91% net annual removal can be achieved. This calculation assumes that the OK-110 silica used in the laboratory experiment is similar to the sediment in the stormwater runoff in the Portland, Maine area. When these calculations are repeated for the New Jersey area, the net annual SSC removal rates are lower. These calculations should be confirmed with additional field data to verify their accuracy.

5.5 Inspection and Maintenance

The Aqua-Swirl™ Concentrator and Aqua-Filter™ Stormwater Filtration System require minimal routine maintenance. However, it is important that the system be inspected at regular intervals and cleaned when necessary to ensure optimum performance. Initially, the Aqua-Swirl™ Concentrator and Aqua-Filter™ Stormwater Filtration System should be inspected quarterly until information can be gathered to develop an inspection and maintenance routine for the particular site. 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 lower chamber to fill more quickly, but regular sweeping will slow accumulation).

5.5.1 Inspection

The Aqua-Swirl™ Concentrator should be regularly inspected using a flashlight and a measuring rod. Once the sediment depth is within 30 to 36 inches of the water surface, the system should be cleaned out.

The Aqua-Filter™ Stormwater Filtration System should be regularly inspected to determine if the filter media needs replacement. The filter media is light tan or white in color. Once the media turns black, it has become saturated from pollutant loading and requires replacement.

Inspection data sheets are provided by AquaShield™ for both systems. Also, AquaShield™ provides an inspection and maintenance package to all of its customers.

5.5.2 Maintenance

For the Aqua-Swirl™ Concentrator, once the sediment depth has reached the recommended depth for maintenance, the system should be serviced. A vacuum truck company licensed for solid waste disposal should be contracted to clean out the unit.

For the Aqua-Filter™ Stormwater Filtration System, the filter media needs to be replaced. The chamber is equipped with an access manhole and ladder. Confined space training is required for personnel entering the system to replace the filter media. The center row of the filter bed is fitted with removable grate panels. This allows for a six foot tall walkway down the center of the chamber, providing easy access to the full length of the filtration chamber.

5.5.3 Solids Disposal

Solids recovered from the Aqua-Swirl™ Concentrator can typically be landfilled or disposed of at a waste water treatment plant.

The filter media from the Aqua-Filter™ cartridge does not allow captured contaminants to be released once absorbed to the material. Typically, the media material can be landfilled, but State and local requirements should be reviewed to determine if disposal requirements are in place.

5.5.4 Damage Due to Lack of Maintenance

It is unlikely that the Aqua-Swirl™ Concentrator or the Aqua-Filter™ Stormwater Filtration System will become damaged due to lack of maintenance since there are no fragile internal parts. However, adhering to a regular maintenance plan ensures optimal performance of the system.

6. Technical Evaluation Analysis

6.1 Verification of Performance Claim 1 for the Aqua-Swirl™ Concentrator

Based on the data generated by the Tennessee Tech study, the ability of the Aqua-Swirl™ Concentrator Model AS-3 to remove sediment with a d_{50} of approximately 110 (OK-110 unground silica) is based upon its operating rate. At a stormwater treatment design rate of 50.5 gpm/ft^2, the SSC removal efficiency is approximately 60%, thereby verifying Claim 1.

6.2 Verification of Performance Claim 2 for the Aqua-Filter™ Cartridge

Based upon the laboratory data provided by AIRL and presented in Tables 4-7 the Aqua-Filter™ cartridge can achieve a TSS removal rate of 80% at a flow rate of 20 gpm with SIL-CO-SIL 106 silica, thereby verifying Claim 2.

6.3 Limitations

6.3.1 Factors Causing Under-Performance

If the Aqua-Swirl™ Concentrator and Aqua-Filter™ Stormwater Filtration System are 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.

6.3.2 Pollutant Transformation and Release

The Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Filtration System should 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 Aqua-Swirl™ Concentrator and Aqua-Filter™ Stormwater Filtration 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.

6.3.3 Sensitivity to Heavy Sediment Loading

Heavy loads of sediment will increase the needed maintenance frequency.

6.3.4 Mosquitoes

Although the Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Filtration System are self contained units, these designs do incorporate standing water in the lower chamber, which can be a breeding site for mosquitoes. Although no information has been presented by AquaShield™ 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 the Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Filtration System have been verified and granted interim approval use within the State of New Jersey, AquaShield™ 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 AquaShield™ technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

8. References

American Public Works Association (APWA) Protocol, "Appendix B: An Approach to Lab Testing of Stormwater Treatment Facilities," September 2, 1999.

Analytical Industrial Research Laboratories, Inc. (AIRL). 2005. Evaluation of Filtration Media Perlite Cartridge for the Removal of TSS as per SIL-CO-SIL 106, A Synthetically Graded Silica Material. January 24, 2005.

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Supportive Data for Claim 2 & 3, Facsimile to Chris Obropta from Eric Rominger (Director, Engineering Sales & Marketing), April 28, 2005.

Tennessee Tech University, Department of Civil and Environmental Engineering. Laboratory Evaluation of TSS Removal Efficiency for Aqua-Swirl™ Concentrator Stormwater Treatment System, November 2002.

Williamson, J. Kelly, AquaShield™ Inc. 2005. Verification Acceptance Application for Aqua-Swirl™ Concentrator and Aqua-Filter™ Stormwater Treatment Systems.

- Verification Acceptance – form
- Appendix I – Performance Claim to be Verified
- Attachment B – Technology Description and Operating Conditions
- Attachment C – Soundness of Underlying Scientific and Engineering Principles

- Attachment D – Health and Safety
- AquaShield™ Stormwater Treatment Systems
- AquaSwirl™ Concentrator Stormwater Treatment
- Aqua-Filter™ Stormwater Filtration System
- Aqua-Guard™ Catch Basin Insert
- Fabrication and Installation
- System Maintenance
- Performance Testing and Monitoring
- Attachment E – Training
- Attachment F – Available Documentation

NJCAT TECHNOLOGY VERIFICATION

ADDENDUM REPORT

Aqua-SwirlÔ Concentrator and Aqua-FilterÔ Stormwater Filtration Systems

AUGUST 2007

1. Introduction

NJCAT published a Technology Verification Report on two AquaShield™ Inc. stormwater treatment technologies, the Aqua-Swirl™ Concentrator and the Aqua-Filter™ Stormwater Filtration Systems, in September 2005 (revised December 2005). Subsequently, NJDEP issued a Conditional Interim Certification (CIC) that the Aqua-Swirl™ Concentrator is capable of achieving a TSS removal efficiency of 50%, while operating at 50% of the maximum designed flow rates [50 gpm/ft^2] (Rosen, M., 2005). Further, NJDEP issued a CIC that the Aqua-Filter™ Stormwater Treatment System that at a flow of 20 gpm, the coarse perlite media within each filter section of the Aqua-Filter Filtration Chamber is capable of achieving a TSS removal efficiency of 80% (Rosen, M., 2006).

The Aqua-Filter™ Stormwater Filtration System is a stand-alone custom engineered two-component structure, which utilizes a "treatment-train" approach for stormwater pollutant removal. This patented configuration begins with an Aqua-Swirl™ Concentrator (using vortex enhanced sedimentation technology) designed for pre-treatment of stormwater runoff followed by a Filtration Chamber (using media filtration technology) capable of removing finer sediments and water-borne pollutants. The Filtration Chamber is never offered separately; it is always combined together into a single unit, the Aqua-Filter™ Stormwater Filtration System. Hence the present CICs for the two separate components have caused confusion and uncertainties in both the marketplace and regulatory community when considering the Aqua-Filter™ Stormwater Filtration System for a specific application. Further, the use of the two separate sizing tables in the two CICs has also proven confusing. Hence, AquaShield™ Inc. has submitted additional information in support of:

- Replacing Claim 2 in the Technology Verification Report with a new Aqua-Filter™ coarse perlite media filtration cartridge claim that when used with the previously certified NJDEP Aqua-Swirl™ Concentrator claim and the New Jersey Stormwater Best Management Practices Manual approach for calculating treatment train removal efficiency results in a calculated 84.6% TSS removal efficiency for the Aqua-Filter™ Stormwater Filtration System.

- New sizing charts and methodology.

2. Technical Performance Claim

Claim - At a flow rate of 16.5 gpm/ft^2, the Aqua-Filter™ coarse perlite media filtration cartridge used in the Aqua-Filter™ Stormwater Filtration System has been shown to have an average TSS removal efficiency of 69.2% for Sil-Co-Sil 106, a manufactured silica product with an average (d_{50}) particle size of 22 microns, for influent concentrations of 100, 175 and 250 mg/L, in laboratory studies using simulated stormwater.

3. Technical System Performance

3.1 Laboratory Study

Under a contract from AquaShield, Inc., verification testing of a gravity-flow Aqua-Filter Filtration Cartridge was conducted at Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts (Mailloux, J.T., 2006). Testing consisted of determining sediment removal efficiencies using Sil-Co-Sil 106 (SCS106) silica test sand, provided by the U.S. Silica Company. Figure 1 shows the theoretical particle size distribution of the SCS106 (as stated by U.S. Silica), which ranges from 125 to 0.8 microns. The d_{50} particle size is approximately 22 microns. Efficiency tests were conducted at flows ranging from 10 to 20 gpm/ft^2 (of filtration area), with sediment concentration ranges from approximately 100 to 250 mg/L.

As shown on Figure 2, the Aqua-Filter testing unit consisted of a 2 ft by 2 ft (4 ft^2 of filtration area) by 40-inch high acrylic test tank, housing a lower collection hopper, bottom fiberglass support grate (2-inch high with 1½-inch x 1½-inch open-area mesh), test filter cartridge and top fiberglass grate. Water was introduced to the unit through a 1-inch high by 18-inch long slot in the upstream wall, located approximately ½-inch above the top grate. The filter cartridge consisted of four (4) 1 ft by 2 ft by 0.5 ft high filter bags, filled with a perlite filter media. The bags were arranged in two (2) layers, with the top layer oriented 90-degrees from the bottom layer. The sidewalls of each bag were made of an impervious material, while the top and bottom were of a fine mesh.

The filters were rinsed prior to installation to remove the fine media particles that may pass through the filter mesh and skew the effluent sample data.

Test Facility Description

Figure 3 shows the closed test loop, located in Alden's stormwater test facility, which was used to test the Aqua-Filter Cartridge. To accommodate the range of flows, two (2) configurations of the loop were constructed for testing the filter. The low-flow configuration consisted of a 1.5 HP pump drawing water from a laboratory sump, a 2-inch flow meter, 2-inch influent pipe, test unit and 4-inch effluent piping to return the water back to the sump. Located within the influent piping was a sampling port, approximately 3 feet upstream of the test unit, to collect the influent sediment concentration samples. The sampling port was orientated at a downward 45-degree angle and consisted of a 2-inch tee, 2-inch pipe and quick-turn butterfly valve (see Figure 4). Effluent samples were taken at the free-discharge of the 4-inch effluent pipe, which was connected to the bottom of the collection hopper. The high-flow configuration consisted of a 2 HP pump, a larger capacity 2-inch flow meter, 3-inch influent pipe, test unit and 4-inch effluent piping. The larger influent pipe facilitated the installation of an isokinetic sampling array, which consisted of two (2) vertically adjustable tubes, each containing a flow-control valve and shut-off valve (see Figure 5). Sediment was injected into the crown of the influent pipes through a tee, positioned 15 pipe-diameters upstream of the influent sampling port. Photographs of the test-loop and installed Aqua-Filter Cartridge are shown on Figures 4 and 5.

Instrumentation and Measuring Techniques

The inflow to the test unit was measured using one of two 2-inch orifice meters, which were fabricated per ASME guidelines and calibrated at Alden prior to the start of testing. Flow was set with a butterfly valve and the differential head from the orifice meter was measured using a Rosemount® 0 to 250-inch Differential Pressure 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 ±2%.

Water temperature measurements were obtained using an Omega® DP41 temperature probe and readout device, which was calibrated at the laboratory prior to testing. The temperature reading was entered into the DA program prior to testing, for use in the flow measurement calculations. Temperature readings ranged from 68 to 72 degrees F.

SCS106 silica sand, with a specific gravity of 2.65, was used to test the Aqua-Filter Cartridge. The test sand was introduced into the test loop using an Auger® volumetric screw feeder, model VF-1. A 0.5-inch auger screw, driven with a variable speed motor, was installed and calibrated with the SCS106 sediment prior to testing. The feeder had a 1.5 cubic foot hopper at the upper end of the auger to provide a constant supply of dry test sand.

Total Suspended Solids (TSS) is a generalized term used to describe a condition in which solids within a sample are accounted for by capturing them on a filter with a pore size of approximately 0.45 microns. 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," as described below. The required SCS106 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 a graduated 2-Liter beaker. Prior to sample collection, the clean, dry weight of each beaker was recorded to the nearest 0.1-gram, using an Ohaus® 4000g x 0.1g digital scale, model SCD-010. Collected samples were also weighed to the nearest 0.1-gram using the Ohaus® digital scale. Each sample was filtered through a Whatman® 934-AH, 47 millimeters, 1.5-micron, glass microfiber filter paper, using a laboratory vacuum-filtering system. Each filter was placed in a designated dish and dried prior to filtering, in an Oakton® StableTemp gravity convection oven, model 05015-59, at 225 degrees F for a minimum of 2 hours. Each filter/dish set was then weighed to the nearest 0.0001gram, using an AND® analytical balance, model ER-182A. Each filtered sample and dish was dried at a temperature between 175 and 210 degrees F (below boiling) for 20 to 30 minutes until visually dry. The oven temperature was increased to 225 degrees F and the samples were dried for an additional 2-

½ to 3 hours. The dry samples and dishes were then weighed to the nearest 0.0001gram, using the AND® balance. Net sediment weight, in milligrams, 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. The sediment concentration, in mg/liter, was determined by dividing the net sediment weight by the net sample volume. The removal efficiency for each sample-set was calculated using the following equation:

$$\%\ \text{Efficiency} = \frac{(\text{Mean Influent Concentration} - \text{Mean Effluent Concentration})}{(\text{Mean Influent Concentration})} \times 100$$

Test Procedures

Sediment removal efficiency testing can be performed using either the indirect method (grab samples), or direct method (mass balance). The indirect testing method was used for the present study, as described below.

The test flow was set and allowed to reach steady state. The SCS106 test sand was introduced into the inflow line through the injection port and three 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 1.5 to 2 liters each, were collected during each test, with each effluent sample taken 1 unit residence time after the influent sample. At the completion of the sample collections, sediment injection was stopped and the system continued to operate until all the sediment was clear from the influent pipe. Each sample was processed as described above.

4. Technical Evaluation Analysis

The results are presented in two ways: the first is the removal efficiency calculated using the measured influent and effluent sample concentrations collected during testing. The second way is the removal efficiency "corrected" by using the influent concentration calculated from the sediment injection rate (mg/min) and the recorded influent flow. The mean effluent concentration used in the calculation is from the collected samples, as these historically show a high level of repeatability. Alden believes that correcting the influent concentrations removes the random deviations from the sample sets, as well as the uncertainty of the sediment distribution within the cross-sectional area of the influent pipe, resulting in a more realistic sediment removal efficiency value. Although both removal efficiencies are reported, Alden considers the corrected values to be the preferential data set.

Removal efficiency tests were conducted at target flows of 10, 12.5, 16.5 and 20 gpm/ft^2 (of filter area), with a target influent sediment concentration of 100 mg/L. These tests were conducted sequentially without cleaning the filters between tests. Two additional tests were conducted at a target flow of 16.5 gpm/ft^2, with target influent concentrations of 175 and 250 mg/L, respectively. The efficiency dropped-off at the 175 mg/L condition, indicating that accumulated sediment from testing may be leaching through the bed (See discussion on sediment retention capacity in Section 6). It was opted to replace the filters (as opposed to cleaning them) and the 250 mg/L test was conducted with the new filters.

Corrected and uncorrected removal efficiencies are summarized in Table 1. Results of individual tests are shown in Tables 2 through 7. At a flow rate of 16.5 gpm/ft^2, the average sediment removal efficiency for the uncorrected influent concentrations is 65.1% and for the corrected influent concentrations is 69.2%. Alden prefers the corrected data set.

Based on the evaluation of the results from the Alden studies, sufficient data is available to support AquaShield's claim that:

At a flow rate of 16.5 gpm/ft^2, the Aqua-Filter™ coarse perlite media filtration cartridge used in the Aqua-Filter™ Stormwater Filtration System has been shown to have an average TSS removal efficiency of 69.2% for Sil-Co-Sil 106, a manufactured silica product with an average (d_{50}) particle size of 22 microns, for influent concentrations of 100, 175 and 250 mg/L, in laboratory studies using simulated stormwater.

5. Treatment Train Removal Efficiency

Since the Aqua-Filter™ Stormwater Filtration System uses a treatment train approach, the following rationale is used to calculate an 84.6% TSS removal claim for the filtration system. The NJDEP has granted CIC status for the Aqua-Swirl™ Concentrator such that the system is capable of achieving a TSS removal efficiency of 50%, while operating at 50% of the maximum designed flow rates (50 gpm/ft^2). The above-cited Alden testing with an Aqua-Filter™ cartridge demonstrated a corrected TSS removal efficiency of 69.2% at 16.5 gpm/ft^2. In accordance with Equation 4-1 of the New Jersey Stormwater Best Management Practices Manual, February 2004, page 4-3, the combination of these two removal rates provides for the derivation of the Aqua-Filter™ Stormwater Filtration System TSS removal efficiency as follows:

$$R = A + B - [(A \times B) / 100]$$

Where:

R = Total TSS Removal Rate
A = TSS Removal Rate of the First or Upstream BMP
B = TSS Removal Rate of the Second or Downstream BMP

Use of this equation is demonstrated with the above-cited Aqua-Swirl™ Concentrator and the Aqua-Filter™ cartridges filled with coarse perlite medium. The removal rates are as follows:

Where:

A = 50% for Aqua-Swirl™ Concentrator, TSS removal rate approved by NJDEP
B = 69.2% for Aqua-Filter™ cartridge, TSS removal rate determined by Alden tests at 16.5 gpm/ft^2 (verified claim)

$$R = 50 + 69.2 - [(50 \times 69.2) / 100]$$

$R = 119.2 – 34.6$

$R = 84.6\%$ Total TSS Removal Rate

If the uncorrected removal rate of 65.1% is used instead, the removal rate is 82.6

Based on the evaluation of the results from the Alden studies, the NJDEP CIC for the Aqua-Swirl™ Concentrator and the NJDEP Stormwater Best Management Practices Manual methodology for calculating treatment train sediment removal performance, it can be determined that:

The Aqua-FilterÔ Stormwater Filtration System, a stand-alone two component structure, when sized with an Aqua-SwirlÔ pretreatment device at no more than 50 gpm/ft^2 as previously certified by NJDEP, followed by a Filter Chamber containing Aqua-Filter™ cartridges filled with a coarse perlite media sized at no more than 16.5 gpm/ft^2, has been shown to have a calculated 84.6% TSS removal efficiency utilizing the New Jersey Stormwater Best Management Practices Manual approach for calculating treatment train removal efficiency.

6. Sediment Retention Capacity

As mentioned in Section 4, Alden decided to replace the filters after the fifth test, before conducting the final 16.5 gpm/ft^2 test at 250 mg/L since the previous test indicated a reduction in filtering performance. This caused concern during the data review process and NJCAT requested additional information to assist in identifying the reason(s) for this reduction.

Table 5 shows the changing effluent TSS concentrations that occurred during the fifth test performed overall, with a loading rate of 16.5 gpm/ft^2 and target influent TSS concentration of 175 mg/L. The first four tests exhibited consistent effluent TSS concentrations for seven sample sets that were collected during each test (Tables 2, 3, 4 and 7 show results for tests #1, #2, #3 and #4, respectively). At the conclusion of test #4, a total of 7,910 gallons (29,938 liters) of water and 3,000 grams (6.6 lbs) of Sil-Co-Sil 106 sand had been introduced to the filtration cartridge and 2,173 grams (4.8 lbs) had been retained. At the conclusion of test #5 (Table 5), a total of 9,620 gallons (36,412 liters) of water and 4,134 grams (9.1 lbs) of sand had been introduced to the filtration cartridge and 2,859 grams (6.5 lbs) had been retained prior to filter replacement.

Filter media are only able to provide effective treatment for a finite period of time. Sediment loading and particle size distribution are two important factors to consider when predicting TSS removal performance by filtration over time. The ability of a filter media to retain sediment is referred to herein as the sediment retention capacity. Influent conditions and the sediment retention capacity of a filter directly affect performance and maintenance cycles. The Alden data suggests that each Aqua-Filter™ cartridge can provide effective performance while capturing up to approximately 6.5 pounds of Sil-Co-Sil 106 sand. If the influent stormwater conditions for a site are known, then the Aqua-Filter™ Stormwater Filtration System maintenance cycle can be predicted based on the sediment retention capacity of the Aqua-Filter™ cartridge.

7. Aqua-Filter™ Stormwater Filtration System Sizing Procedure

Sizing Tables

AquaShield™ requests that NJDEP adopt the revised sizing Tables 8 and 9 for the Aqua-Swirl™ Concentrator and Aqua-Filter™ Stormwater Treatment System, respectively. Revised Table 8 will replace the current Table 3 for the Aqua-Swirl™, and revised Table 9 will replace the current Table 1 for the Aqua-Filter™ that is included in the NJDEP CIC Findings report. It is also requested that the current use of Table 2 (Aqua-Filter™ models) in the report be discontinued. The current use of Table 2 limits the Aqua-Filter™ to the specific models listed in the table and does not allow for custom designed systems. Tables 8 and 9 include the customization component for designs that utilize multiple or larger swirl and filtration chambers.

Table 8 lists the swirl chamber diameter, stub-out pipe diameters for online/offline and Conveyance Flow Diversion (CFD) designs, water quality treatment (in cfs and gpm), oil/debris storage capacity, and sediment storage capacity. The sizing chart includes this information for the standard Aqua-Swirl™ Models AS-2 through AS-12; and, includes the provision for custom designs with multiple swirl chambers. The CFD configuration provides full treatment for the "first flush," while the peak design storm is diverted internally and channeled through the main conveyance pipe.

Table 9 lists the number of filter media rows needed in the filtration chamber to meet a given water quality flow (WQ_f). The water quality filtered flow rates are listed for systems having one through a maximum of 16 filter media rows. The lengths of the filtration chambers for each filtration row are also listed in Table 9. The provision for custom designs using multiple filtration chambers and multiple and larger swirl chambers is provided in the table.

Sizing Procedure

The first step in the Aqua-Filter™ sizing procedure is to size the primary (upstream) component of the treatment train – the swirl chamber. Based on the New Jersey Stormwater Best Management Practices Manual, Chapter 5, February 2004, the Modified Rational Method is used to calculate the runoff rate (Q) for system sizing purposes as shown below:

$Q = C\ I\ A$

Where:

Q = runoff rate in cfs
C = Rational method runoff coefficient
I = rainfall intensity in inches/hour

A = drainage area in acres

For purposes of an example, a one acre drainage area (A) having a runoff coefficient (C) of 0.95 is used. The intensity (I) value of 0.625 in/hr is taken from the above-cited stormwater manual. Solving for Q:

Q = 0.95 x 0.625 in/hr x 1 acre
Q = 0.59 cfs, **(Requires an Aqua-Swirl™ Model AS-2**)

The sizing nomenclature for an Aqua-Filter™ uses an "AF-a.b" designation, where "AF" refers to Aqua-Filter™, "a" refers to the size of the swirl chamber (Aqua-Swirl™ model) and "b" refers to the number of filter media rows in the filtration chamber. When comparing the above-derived Q value of 0.59 cfs to the attached Table 8 sizing chart for the Aqua-Swirl™, an **Aqua-Swirl™ Model AS-2** (a) is applicable for this water quality flow rate. The next step of the Aqua-Filter™ sizing procedure is to size the filtration chamber (downstream component) by determining the number of filter media rows (b) that is needed to meet Q. A filter media row is comprised of three Aqua-Filter™ cartridges. When Q is known, and the flow capacity of the filter media (F), expressed in cfs/row, is known, the following relationship applies:

b = # of rows = Q / F

For the Aqua-Filter™ cartridge at a loading rate of 16.5 gpm/ft^2, F is calculated to be 0.44 cfs/row (198 gpm/row) as follows:

F = 16.5 gpm/ft^2 x 4 ft^2/cartridge = 66 gpm/cartridge
F = 66 gpm/cartridge x 3 cartridges/row = 198 gpm/row
F = 198 gpm/row / 449 gpm/cfs = 0.44 cfs/row

Hence, the number of filter media rows needed for this example is derived as follows:

b = # of rows = 0.59 cfs / 0.44 cfs/row
b = # of rows = 1.3, or 2 rows

Hence a two row filtration chamber would be needed to treat the water quality flow used for the conditions cited in this example. Since it was determined that an AS-2 swirl chamber is needed; and a two row filtration chamber is needed, an **Aqua-Filter™ Model AF-2.2** would be applicable for this loading design.

In order to further demonstrate the custom design capability and the application of the Aqua-Filter™ nomenclature, three example custom design configurations for the Aqua-Filter™ are illustrated in association with Tables 8 and 9 – an AF-4.3, AF-10.18 and a Twin AF-12.24. These illustrations serve to demonstrate how single or multiple combinations of the swirl and filtration chambers can be applied to meet site-specific requirements.

Using a sizing example where the site WQ_f is determined to be 1.25 cfs, the first step of the sizing procedure is to size the swirl chamber. Table 8 indicates that an Aqua-Swirl^{TM} Model AS-4 provides a WQ_f of 1.6 cfs. This model size provides treatment in excess of the example site WQ_f of 1.25 cfs. The next step is to size the filtration chamber, which is based on the number of filtration rows. From Table 9, it is shown that a filtered water quality flow rate of 1.32 cfs, which exceeds the WQ_f of 1.25 cfs, results in the need of three filtration rows. Thus, an Aqua-Filter^{TM} Model AF-4.3 is the appropriate system to meet the WQ_f for this example site. The configuration of an AF-4.3 is illustrated in association with Table 9.

As a second Aqua-Filter^{TM} sizing example where a WQ_f of 7.5 cfs applies, the swirl chamber is again sized first. Table 1 indicates that an Aqua-Swirl^{TM} Model AS-10 provides a WQ_f of 8.8 cfs, larger than required. From Table 9, a maximum number of 16 filtration rows within a single filtration chamber provides for a filtered water quality flow rate of 7.04 cfs, less than required. Hence, two filtration chambers are needed to meet the WQ_f of 7.5 cfs. The use of two nine-row filtration chambers (total of 18 filtration rows) provides a filtered water quality flow rate of 7.92 cfs (3.96 cfs x 2 = 7.92 cfs). Thus, an Aqua-Filter^{TM} Model AF-10.18 is the appropriate system to meet the WQ_f for this example site. The configuration of an AF-10.18 is illustrated in association with Table 9.

The third sizing example applies to a custom design using multiple swirl and filtration chambers to meet a WQ_f of 20.4 cfs. From Table 8 it is evident that a single Aqua-Swirl^{TM} model AS-12 provides a maximum treatment of 12.6 cfs. In order to meet a WQ_f of 20.4 cfs, two AS-12 Aqua-Swirl^{TM} models can be used in parallel which would double the treatment rate. As a result, twin AS-12 units provide for a WQ_f of 25.2 cfs (2 x 12.6 cfs = 25.2 cfs). Since the size of the filtration chamber is based on the number of filtration rows (b), the following relationship can be used for this example to determine the number of filtration rows needed for the treatment system:

Number of rows = b = WQ_f / F
b = 20.4 cfs / 0.44 cfs/row
b = 46 rows

At this time, 16 is the maximum number of filtration rows that can be used for a single filtration chamber. Accordingly, it is necessary to use multiple filtration chambers to provide the 46 filtration rows requirement. Table 9 shows that a 12 filtration row system provides for a water quality filtered flow rate of 5.28 cfs. If four 12-row filters are used, a water quality filtered flow rate of 21.12 cfs is calculated (4 x 5.28 = 21.12 cfs), larger than the 20.4 cfs requirement. The four 12-row filtration chambers can be connected to the swirl chambers such that two 12-row chambers are connected to each of the two swirl chambers. Thus, a Twin AF-12.24 would be sized for this site. The configuration of a Twin AF-12.24 is illustrated in association with Table 9. The “twin” designation applies to the twin set of AS-12 Aqua-Swirl^{TM} models, while the “24” designation represents twin sets of two 12-row filters (2 x 12 rows = 24 rows per set, or total of 48 rows for entire system).

8. References

Mailloux, J.T. (2006). Verification Testing of the Gravity-Flow Aqua-Filter Filtration Cartridge with SIL-CO-SIL 106. Alden Research Laboratory, Inc.

Rosen, M. (2005). Conditional Interim Certification of AquaShield's Aqua-Swirl™ Concentrator. New Jersey Department of Environmental Protection.

Rosen, M. (2006). Conditional Interim Certification of AquaShield's Aqua-Filter™ Filtration Chamber. New Jersey Department of Environmental Protection

Tables

Table 1
Sediment Removal Efficiency Summary

Flow gpm/ft^2	Concentrations (mg/L) Corrected Influent	Mean Influent	Mean Effluent	% Efficiency Uncorrected	% Efficiency Corrected
10.4	96.3	78.4	19.7	74.9	79.6
12.5	100	85.3	23.6	72.3	76.4
16.4	100.4	82.2	26.6	67.7	73.5
16.5	175.2	172.3	69.4	59.7	60.4
16.5	250.3	206.4	66.0	68	73.6
20.0	99.9	118.0	33.5	71.6	66.5

Table 2
Sediment Removal Efficiency
10.4 gpm/ft^2, 100 mg/l

Sample	Influent mg/L	Effluent mg/L	
Background	negligible		
1	74.2	17.4	
2	88.1	18.7	
3	75.2	18.6	
4	89.0	20.2	
5	74.2	20.0	
6	74.2	20.5	
7	73.8	22.4	
			Efficiency (%)
MEAN	78.4	19.7	**74.9**
	Corrected Influent		
	96.3	19.7	**79.6**

Table 3
Sediment Removal Efficiency
12.5 gpm/ft^2, 100 mg/l

Sample	Influent mg/L	Effluent mg/L	Efficiency (%)
Background	negligible		
1	99.8	22.3	
2	80.5	22.2	
3	96.3	22.9	
4	75.3	22.8	
5	76.6	24.6	
6	93.5	24.7	
7	75.0	25.6	
MEAN	85.3	23.6	**72.3**
	Corrected Influent		
	100.0	23.6	**76.4**

Table 4
Sediment Removal Efficiency
16.5 gpm/ft^2, 100 mg/l

Sample	Influent mg/L	Effluent mg/L	Efficiency (%)
Background	1.16		
1	79.0	27.5	
2	92.5	26.4	
3	80.6	26.3	
4	96.0	26.0	
5	74.6	26.9	
6	78.5	26.6	
7	74.4	26.4	
MEAN	82.2	26.6	**67.7**
	Corrected Influent		
	100.4	26.6	**73.5**

Table 5
Sediment Removal Efficiency
16.5 gpm/ft^2, 175 mg/l

Sample	Influent mg/L	Effluent mg/L	
Background	3.27		
1	182.4	60.5	
2	175.8	66.2	
3	167.5	65.9	
4	166.2	68.2	
5	169.0	71.6	
6	174.3	76.0	
7	170.9	77.2	
			Efficiency (%)
MEAN	172.3	69.4	**59.7**
	Corrected Influent		
	175.2	69.4	**60.4**

Table 6
Sediment Removal Efficiency
16.5 gpm/ft^2, 250 mg/l

Sample	Influent mg/L	Effluent mg/L	
Background	11.58		
1	188.9	64.6	
2	223.3	64.0	
3	212.4	68.9	
4	227.0	66.6	
5	202.2	67.1	
6	193.3	65.9	
7	198.2	64.9	
			Efficiency (%)
MEAN	206.4	66.0	**68.0**
	Corrected Influent		
	250.3	66.0	**73.6**

Table 7
Sediment Removal Efficiency
20.0 gpm/ft^2, 100 mg/l

Sample	Influent mg/L	Effluent mg/L	Efficiency (%)
Background	1.18		
1	150.3	29.5	
2	115.6	32.4	
3	111.2	31.9	
4	82.2	34.2	
5	114.4	33.9	
6	112.0	36.0	
7	139.9	36.3	
MEAN	118.0	33.5	**71.6**
	Corrected Influent		
	99.9	33.5	**66.5**

Table 8
NJDEP Aqua-Swirl™ Concentrator Stormwater Treatment System Sizing Chart

Aqua-Swirl™ Model	Swirl Chamber Diameter (ft)	Maximum Stub-Out Pipe Outer Diameter (in)		Water Quality Treatment Flow (cfs)[2]	Oil/Debris Storage Capacity (gal)	Sediment Storage Capacity (ft^3)
		On/Offline	CFD[1]			
AS-2	2.50	8	12	0.6	37	10
AS-3	3.25	10	16	0.9	110	20
AS-4	4.25	12	18	1.6	190	32
AS-5	5.00	12	24	2.2	270	45
AS-6	6.00	14	30	3.2	390	65
AS-7	7.00	16	36	4.3	540	90
AS-8	8.00	18	42	5.6	710	115
AS-9	9.00	20	48	7.1	910	145
AS-10	10.0	22	48	8.8	1,130	180
AS-12	12.0	24	48	12.6	1,698	270
AS-XX*	Custom/Multiple			>13		

* Higher water quality treatment flow can be designed with multiple swirl chambers.

Notes:

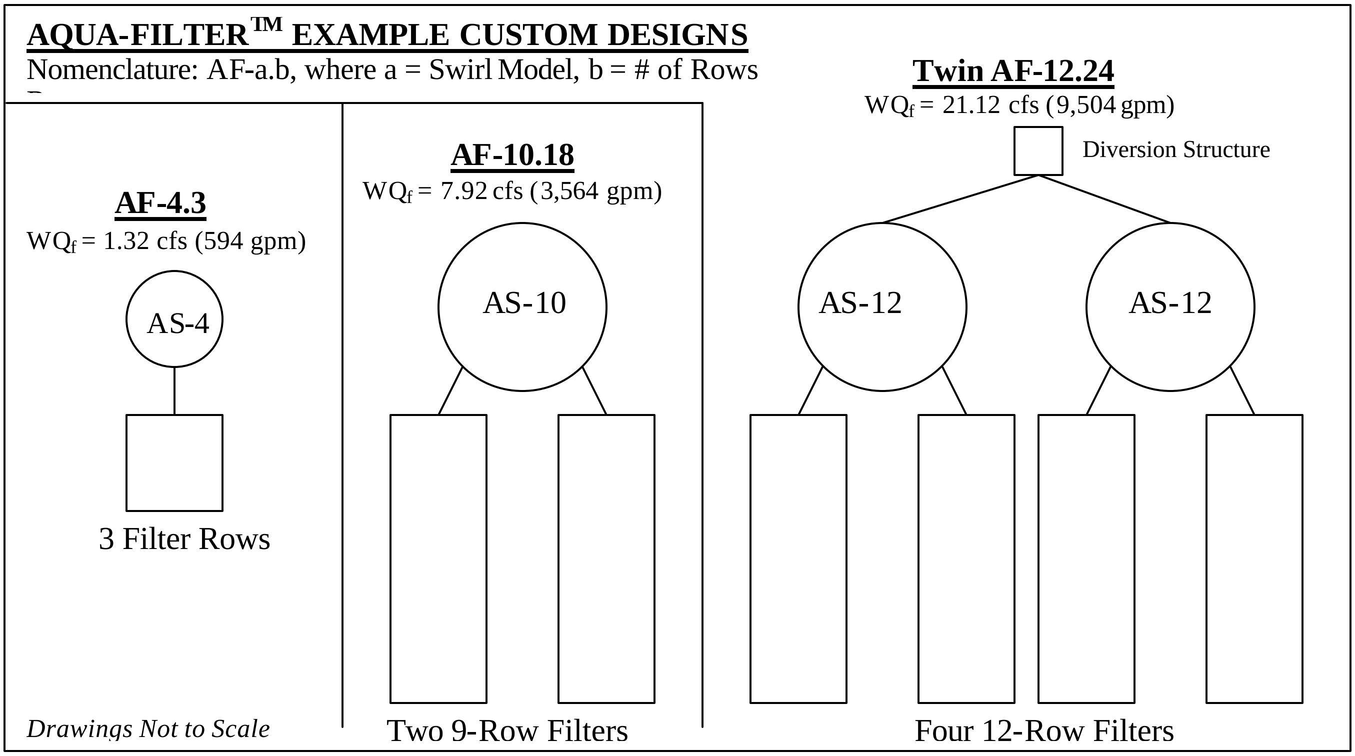
(1) The Aqua-Swirl™ Conveyance Flow Diversion (CFD) provides full treatment for the "first flush," while the peak design storm is diverted internally and channeled through the main conveyance pipe.

(2) The Water Quality Treatment Flow is based on the NJDEP Conditional Interim Certification of 50% of the maximum designed flow rates for TSS removal.

Table 9
NJDEP Aqua-Filter™ Stormwater Filtration System Sizing Chart

Number of Filtration Rows	Water Quality Filtered Flow Rates		Filtration Chamber Lengths
	(cfs)	(gpm)	(ft)
1	0.44	198	8.2
2	0.88	396	10.2
3	1.32	594	12.2
4	1.76	792	14.2
5	2.20	990	16.2
6	2.64	1,188	18.2
7	3.08	1,386	20.2
8	3.52	1,584	22.2
9	3.96	1,782	24.2
10	4.40	1,980	26.2
11	4.84	2,178	28.2
12	5.28	2,376	30.2
13	5.72	2,574	32.2
14	6.16	2,776	34.2
15	6.60	2,970	36.2
16	7.04	3,168	38.2
Custom/Multiple*	>7.04	>3,168	Custom

* Higher water quality filtered flow rates can be designed with multiple filtration chambers and larger swirl chambers (see graphics below).


AQUA-FILTER™ EXAMPLE CUSTOM DESIGNS
Nomenclature: AF-a.b, where a = Swirl Model, b = # of Rows
AF-4.3
WQf = 1.32 cfs (594 gpm)
AS-4
3 Filter Rows
AF-10.18
WQf = 7.92 cfs (3,564 gpm)
AS-10
Two 9-Row Filters
Twin AF-12.24
WQf = 21.12 cfs (9,504 gpm)
Diversion Structure
AS-12
AS-12
Four 12-Row Filters
Drawings Not to Scale

Figures

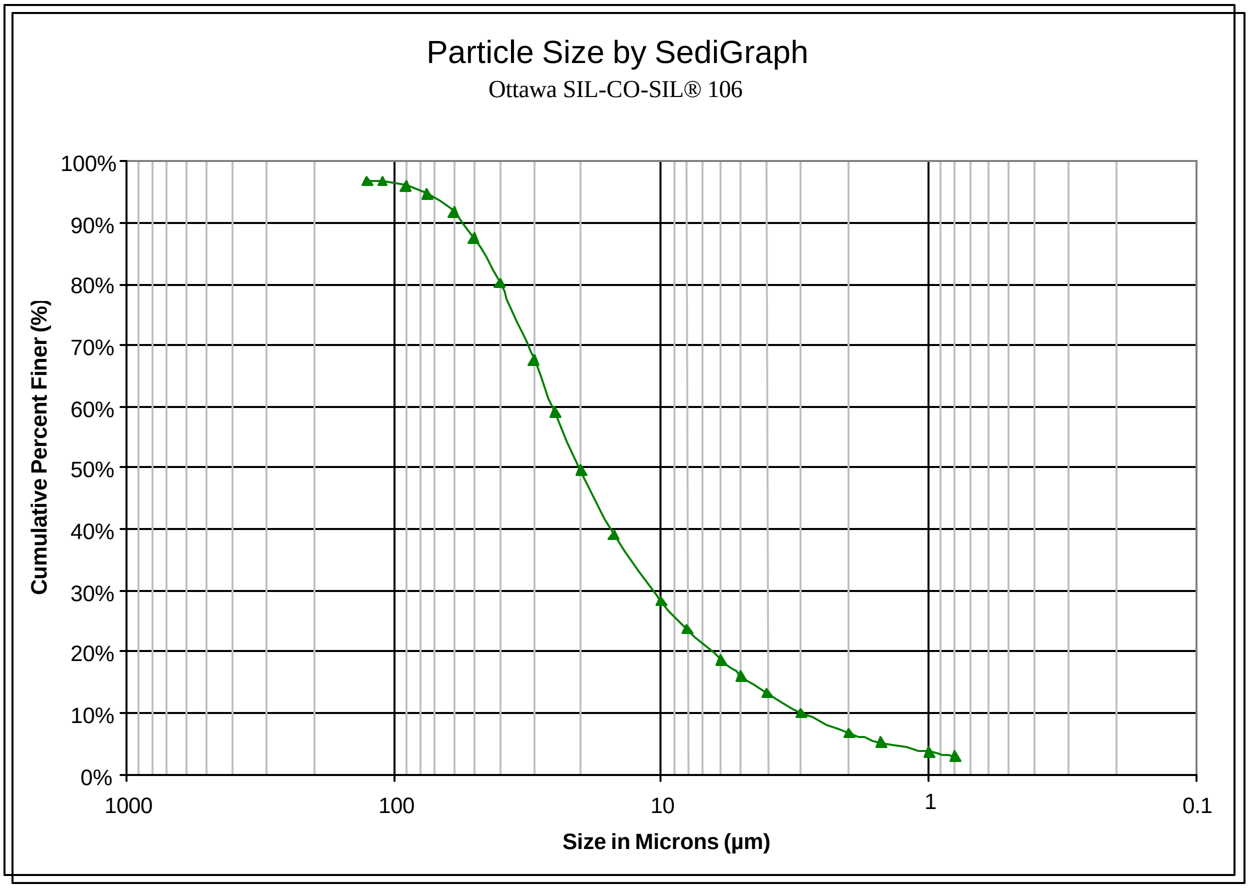


Figure 1: Sil-Co-Sil 106 Particle Size Distribution (source U.S. Silica)

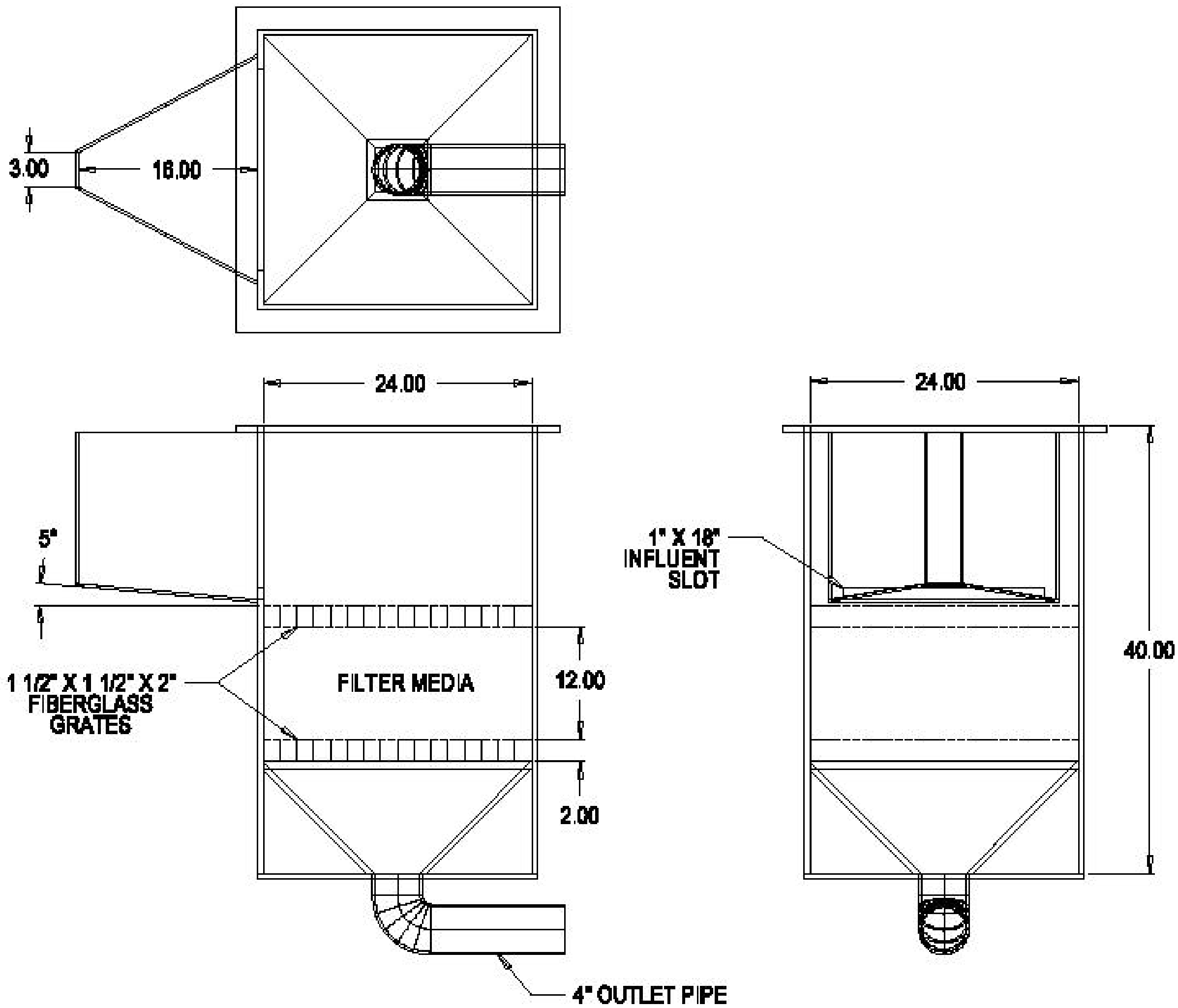


Figure 2: Aqua-Filter Test Tank

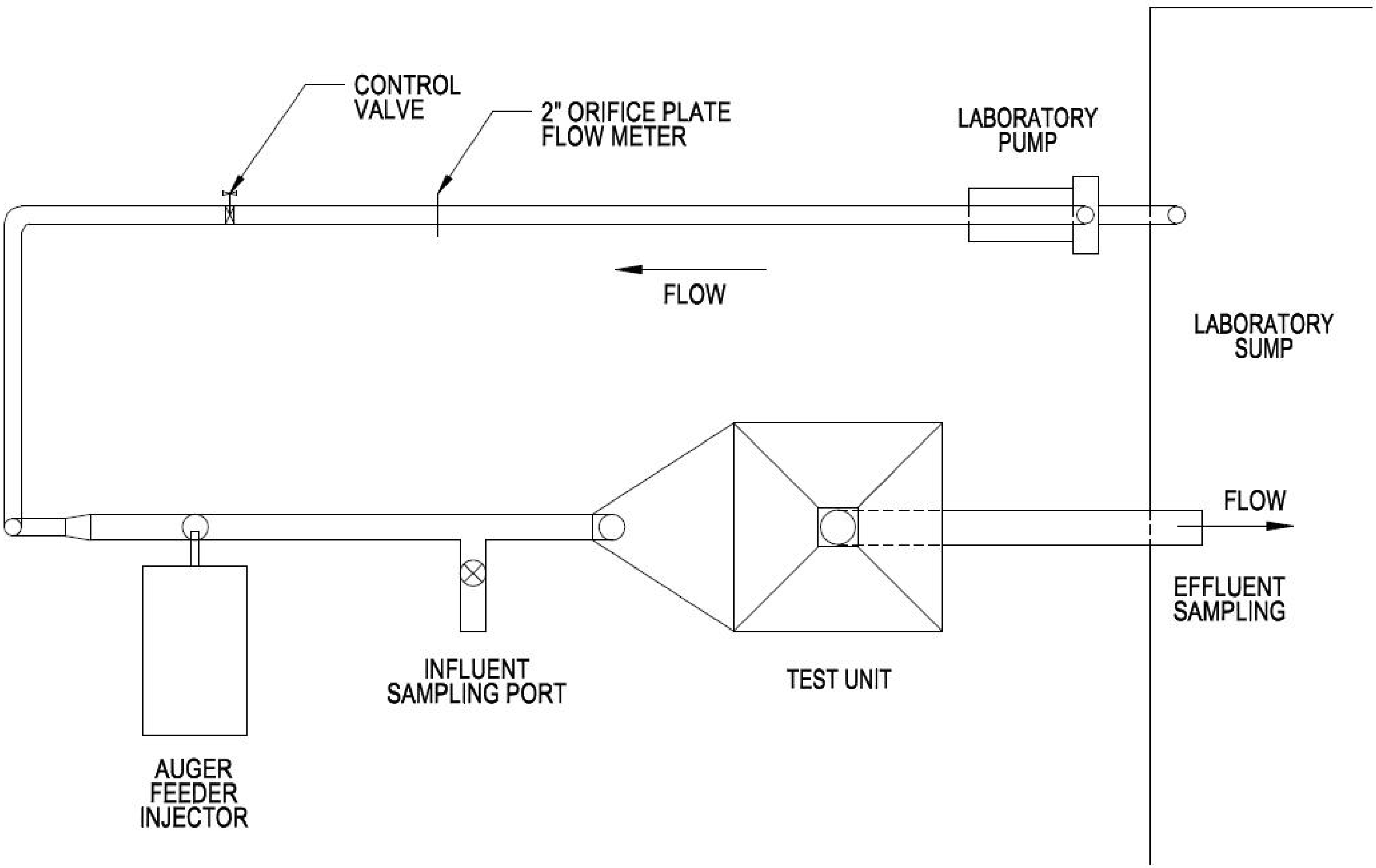
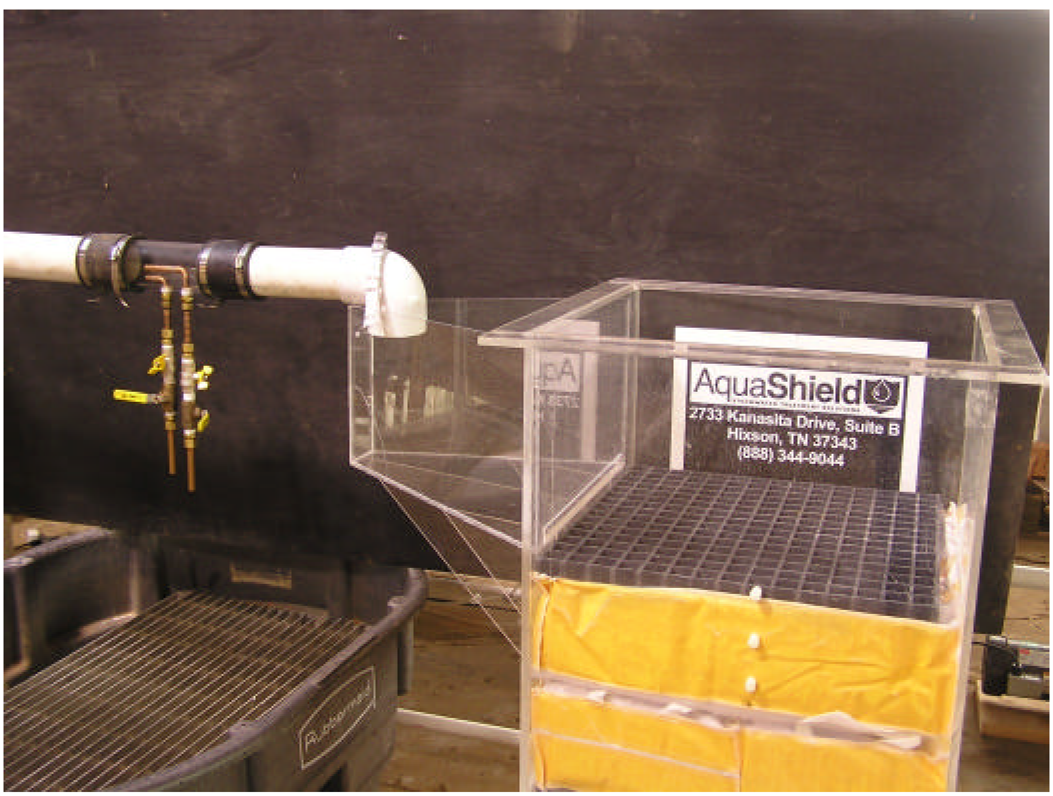


Figure 3: Alden Flow Loop



Figures 4 & 5: Photographs of the Aqua-Filter within Alden's Test-Loop

ALDEN