AquaShield™
STORMWATER TREATMENT SOLUTIONS
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Capability of the Aqua-Swirl® Concentrator to Remove Trash from Stormwater Runoff

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The purpose of this document is to demonstrate the capability of the Aqua-Swirl® Concentrator to capture trash from stormwater runoff. Trash is defined herein as material having a minimum diameter of 5 millimeters (mm). Discussions pertaining to Mode of Operation, General Equipment Design, Particle Settling Velocity Calculations, Field Testing, Field Observations, and Inspections and Maintenance are provided below.

MODE of OPERATION

The Aqua-Swirl® is a custom engineered, post-construction flow-through stormwater treatment system designed to remove trash, sediment, floating debris and free-floating oil by utilizing swirl technology, or hydrodynamic vortex-enhanced sedimentation separation (Figure 1). The United States patent "Drainwater Treatment System for Use in a Horizontal Passageway," U.S. Patent No. 6,190,545 applies to the Aqua-Swirl®:

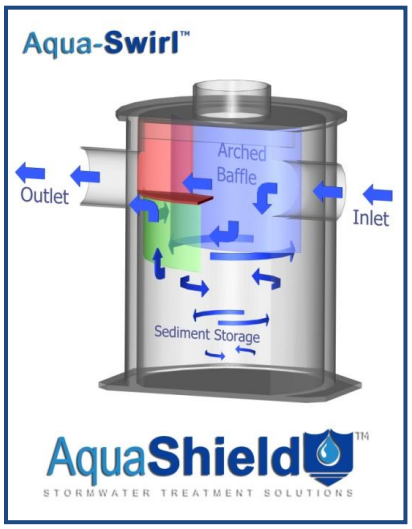

Figure 1. Diagram of Aqua-Swirl® showing circular flow of water in the swirl chamber.

Aqua-Swirl® technology has no moving parts and operates on gravity flow or movement of the stormwater runoff entering the structure. Operation begins when stormwater enters the swirl chamber of the Aqua-Swirl® device by means of its tangential inlet pipe thereby inducing a circular (swirl or vortex) flow pattern. The swirl chamber represents the effective treatment area of the device whereby both the capture and storage of materials is accomplished. A combination of gravitational and hydrodynamic drag forces results in solids dropping out of the flow and migrating to the center of the swirl chamber where velocities are the lowest. Floatables and trash remain in the swirl chamber behind an arched inner baffle that extends partially downward into the swirl chamber. This baffle serves to retain floatable materials and trash in the swirl chamber. The treated flow exits the Aqua-Swirl® behind the arched inner baffle. The top of the baffle is sealed across the treatment channel to eliminate floatable pollutants from escaping the swirl chamber. A vent pipe is extended up the riser to expose the backside of the baffle to atmospheric conditions, thus preventing a siphon from forming at the bottom of the baffle.

GENERAL EQUIPMENT DESIGN

The Aqua-Swirl® can operate in either an "offline" or "inline" ("online") configuration. The inline design uses an internal conveyance flow diversion (CFD) design. The Aqua-Swirl® is available with maximum stub-out inner pipe diameters for offline systems ranging from 7.61 to 22.52 inches (193 to 572 mm) depending on model size. The CFD models use inner pipe diameters of 11.97 to 45.05 inches (304 to 1,144 mm). These pipe diameters will allow for the conveyance of most trash sized particles and debris contained in stormwater runoff.

The diameter of the swirl chamber varies from 2.5 to 12 feet (0.7 to 3.6 meters) depending on model size. The height of a standard swirl chamber ranges from 8.67 to 9.5 feet (2.64 to 2.9 meters) and the length of the access risers are influenced by the final surface and drainage pipe elevations of the site. The bottom of the swirl chamber is approximately 5.67 feet (1.73 meters) below the invert of the inlet pipe which provides water and sediment storage within the swirl chamber.

Table 1 summarizes the available Aqua-Swirl® models, swirl chamber inner diameters, and storage capacities for trash/oil and sediment.

Table 1. Aqua-Swirl® Standard Models and Storage Capacities

Aqua-Swirl® Model	**Swirl Chamber Inner Diameter (ft/mm)**	**Trash/Oil Storage Capacity (gal)**	**Sediment Storage Capacity (ft^3)**
AS-2	2.50 / 762	37	10
AS-3	3.25 / 991	110	20
AS-4	4.25 / 1,295	190	32
AS-5	5.00 / 1,524	270	45
AS-6	6.00 / 1,829	390	65
AS-7	7.00 / 2,134	540	90
AS-8	8.00 / 2,438	710	115
AS-9	9.00 / 2,743	910	145
AS-10	10.00 / 3,048	1,130	180
AS-12	12.00 / 3,658	1,698	270

While the Aqua-Swirl® is not designed to operate identically to an oil-water separator, the technology does provide a high level of treatment for the capture and retention of free-floating oil. Oil is retained in the swirl chamber behind the arched inner baffle in a similar means by which other floatables are retained in the swirl chamber.

The Aqua-Swirl® is also designed so that it can easily be used for retrofit applications. When the invert of the inlet and outlet pipes of the Aqua-Swirl® is positioned at the same elevation, the unit can easily be connected directly to the existing storm conveyance drainage system.

PARTICLE SETTLING VELOCITY CALCULATIONS

Since hydrodynamic separators such as the Aqua-Swirl® utilize gravitational forces as the primary means of sediment removal, its performance (removal efficiency) will improve given a larger particle of the same specific gravity. This functionality can be calculated by using the Peclet number as a means to scale performance between various sized particles. The Peclet number is a function of:

- Flow (Q),
- Horizontal flow dimension (diameter, D),
- Vertical flow dimension (depth, h), and
- Settling velocity (V_s computed by Stoke's Law) of a given sized particle.

The following equation is used to derive the Peclet number (Pe):

$$Pe = (D*h*V_s) / Q$$

In order to evaluate Aqua-Swirl® performance against suspended sediment, a scaled Aqua-Swirl® Model AS-5 was independently tested by the Civil Engineering Department of Tennessee Technological University. This laboratory study demonstrated that the Aqua-Swirl® achieved 89% sediment removal efficiency at a flowrate of 0.20 cubic feet per second (cfs) against test sediment manufactured by U.S. Silica, OK-110 silica sand. The OK-110 material has a specific gravity of 2.65 and exhibits a particulate gradation from 50 to 150 microns (µm, or 0.05 to 0.15 mm). The reported median particle size (d_{50}) of OK-110 is 110 µm (0.11 mm).

From Stoke's Law, the settling velocity of a 110 µm particle with a specific gravity of 2.65 is 0.027 ft/sec. The inner diameter of the swirl chamber of the tested Aqua-Swirl® unit is 3.3 feet, having a depth of 3.83 feet from the inlet pipe invert to the floor of the unit. Thus, the Peclet number at a flowrate of 0.20 cfs is computed as follows:

$$Pe = (3.3*3.83*0.027) / 0.20$$
$$Pe = 1.71$$

The settling velocity for a 5 mm (5,000µm) particle with a specific gravity of 2.65 is established at 0.9455 ft/sec. Given the Pe of 1.71 at 0.20 cfs, the flowrate (Q) at which the AS-3 should remove 89% of 5 mm particles is computed as:

$$Q = (3.3*3.83*0.9455) / 1.71$$
$$Q = 8.99cfs$$

The maximum hydraulic capacity of the tested unit was 1.80 cfs. If the sediment removal efficiency performance curve generated from the test data is adjusted for 5 mm particles, the Aqua-Swirl® exhibits 99% sediment removal of those particles with a specific gravity of 2.65 up to the unit's maximum hydraulic capacity.

In order to account for floatables and organic material in the runoff, the specific gravity of the 5 mm particle can be lowered to 1.85. The settling velocity then decreases to 0.4856 ft/sec from the V_s cited above. The flowrate (Q) then becomes 1.80 cfs and equal to the maximum hydraulic capacity of the tested unit.

It is evident through the particle settling velocity calculations that the Aqua-Swirl® can achieve 89% removal of trash particles of at least 5 mm in diameter against influent materials having a specific gravity of 1.85 or greater up to the maximum hydraulic capacity of the device.

AQUA-SWIRL® FIELD TESTING

An Aqua-Swirl® Model AS-5 was independently field tested in Silver Spring, Maryland (metro Washington D.C.) over a 27 month period in accordance with the Technology Acceptance Reciprocity Partnership (TARP) Tier II field testing protocols. Testing was performed from March 2009 to June 2011. The purpose of the AS-5 field test is to gain technology verification by the New Jersey Corporation for Advanced Technology (NJCAT), followed by Field Test Certification by the New Jersey Department of Environmental Protection (NJDEP). The AS-5 demonstrated a net annual TSS removal efficiency of 86% against a clay loam textured sediment.

All particles size distribution (PSD) analyses were performed by the serial filtration method. Influent PSD data is summarized below in Table 2. Data indicates that 94% of the particulate is finer grained than 500 µm (0.5 mm), while 72% of the particulate is less than 63 µm (0.063 mm) in size. Thus, the influent d_{50} is less than 63 µm. Organic material in the influent averages 33.2% of the TSS concentration. In general, organic material will have a specific gravity of 1.0 or less. The TSS removal efficiency of the AS-5 remained high while operating in the presence of approximately 30% (floatable) organic material.

Table 2. AS-5 Influent PSD Summary
(values listed as percent finer than each sieve/filter)

Storm	**1,000 µm**	**500 µm**	**250 µm**	**125 µm**	**63 µm**	**1.5 µm**
9/12/2010	100.00	97.41	92.48	84.44	62.96	0.00
12/1/2010	100.00	93.16	90.99	87.19	73.71	0.00
12/11/2010	100.00	92.04	91.59	85.08	78.56	0.00
Average	**100.00**	**94.20**	**91.68**	**85.57**	**71.74**	**0.00**
	Sand				**Silt**	

The AS-5 field test demonstrated that the Aqua-Swirl® is very effective at removing sand and silt sized particles as well as floatable organic material from stormwater runoff. Given these abilities, the Aqua-Swirl® technology will effectively remove larger sized particles including trash and floatable debris from runoff.

AQUA-SWIRL® FIELD OBSERVATIONS

Numerous field observation examples are available to demonstrate that the Aqua-Swirl® is capable of capturing and retaining gross pollutants and floatables. Figures 2, 3 and 4 are example site photographs that clearly support the trash capture and retention capabilities of the Aqua-Swirl® technology.

Figure 2. Floatables in swirl chamber of an AS-7. The effluent pipe is located on the left side of the photograph and below the vent pipe visible also on the left side of the swirl chamber.

Figure 3. Trash and floatables in an AS-6. Vent pipe is visible in the bottom of the photograph.

Figure 4. Trash and floatables in an AS-5. Vent pipe is at the top of the photograph.

INSPECTION & MAINTENANCE

The Aqua-Swirl® is easily inspected and maintained from the ground surface without the need to enter the swirl chamber. The swirl chamber is directly observed and accessible through the riser with no inaccessible chambers deeper within the device. As shown in the photographs above, materials are easily viewed within the swirl treatment chamber. A vacuum truck is typically used for maintenance event. Most maintenance events can be completed in less than 30 minutes provided that there are no access restrictions to the device itself. Additional information concerning inspections and maintenance can be provided.

CONCLUSIONS

As evident from the information provided herein, Aqua-Swirl® technology can achieve a very high level of performance for the removal of trash and sediment from stormwater runoff. The practicality of the Aqua-Swirl® design also allows for the facilitation of inspections and maintenance events thereby maximizing long term functionality and minimizing operational costs.

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