Chapter 16 – Hydrodynamic Separators

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16.1 Overview of Practice

The following design example provides guidance for the implementation of manufactured oil / water hydrodynamic separation devices for purposes of runoff quality management on VDOT facilities projects.

Hydrodynamic separation devices are designed to remove settleable solids, oil and grease, debris, and floatables from stormwater runoff through gravitational settling. Oil / water separation devices are not intended to mitigate the peak rate of runoff from their contributing watershed. Their implementation is solely for water quality enhancement in urban and ultra-urban areas where surface BMPs are not feasible. These manufactured systems are designed as flow-through structures. In contrast to conventional BMP measures capable of storing a designated water quality volume, flow into a manufactured hydrodynamic separator is regulated by its inflow pipe or other structural hydraulic devices. When the maximum design inflow is exceeded, the inflow may be regulated by a pipe restrictor, causing stormwater to back up into the upstream conveyance system or associated storage facility. When structural devices are employed to regulate flow into the hydrodynamic separator, flows in excess of the desired treatment volume either bypass the structure completely or bypass the separator's treatment chamber (VADCR, 2000).

Hydrodynamic separators are often employed as pretreatment measures for high-density or ultra urban sites, or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. Hydrodynamic separators *cannot be used for the removal of dissolved or emulsified oils and pollutants such as coolants, soluble lubricants, glycols and alcohol* (Georgia Stormwater Manual 2001). Hydrodynamic separators are limited in application by the following:

- Hydrodynamic separators are not capable of removing more than 80 percent of total suspended solids TSS.
- Dissolved pollutants are not effectively removed by these BMPs.
- Frequent maintenance is required to maintain desired pollutant removal performance levels.
- Hydrodynamic separators do not reduce peak rates of runoff to pre-developed levels.

Hydrodynamic separation devices are generally categorized as *Chambered Separation Structures* or *Swirl Concentration Structures*.

Chambered separation devices rely on gravitational settling of particles and, to a lesser degree, centrifugal forces to remove pollutants from stormwater. Chambered systems exhibit an upper bypass chamber and a lower storage / separation chamber. Runoff enters the structure in the upper bypass chamber and is channeled through a downpipe into the lower storage / separation, or treatment chamber. The system is designed such that when inflow exceeds the operating capacity, flow "jumps" the downpipe and completely bypasses the lower treatment chamber (VADCR, 1999).

Swirl separation structures are characterized by an internal mechanism that creates a swirling motion. This motion results in the settling of solids to the bottom of the chamber. Additional chambers serve to trap oil and other floating pollutants. Swirl separators do not exhibit a means for bypassing large runoff producing events. Larger flows simply pass through the structure untreated; however, due to the swirling motion within the structure, large flow events do not re-suspend previously trapped particulates. (VADCR, 1999)

16.2 Design Considerations

The design process for a specific installation of a hydrodynamic separator usually begins with a review of various vendor publications and use of preliminary sizing guidelines provided by the vendor. The specific design criteria for the hydrodynamic separator being considered should be obtained from the manufacturer or vendor to ensure that the latest design and sizing criteria are used. At the very least, the design for a particular site should be reviewed by the manufacturer to ensure that the system is adequately sized and located. The following criteria are intended to serve only as general guidelines.

- The use of oil-grit hydrodynamic separators should be limited to the following applications:
    - Pretreatment for other structural controls.
    - High-density, ultra urban or other space-limited development sites.
    - Hotspot areas where the control of grit, floatables, and/or oil and grease is required.

- Hydrodynamic separators are typically limited in use to drainage areas less than five acres. It is recommended that the contributing drainage area to any single separator be limited to one acre or less of impervious cover.

- Manufactured separation systems can be used in almost any soil or terrain. Additionally, since located underground, aesthetic and public safety issues are rarely encountered.

- Separation devices are sized based on *rate* of runoff. This design criteria contrasts with most BMPs, which are sized for a designated runoff *volume*.

- Hydrodynamic separators are typically designed to bypass runoff flows in excess of the design flow rate. This bypass may be accomplished by a built in bypass mechanism or a diversion weir or flow splitter located upstream of the separator in the runoff conveyance system. As with all runoff control structures, an adequately stabilized outfall must be provided at the separator's discharge point.

- The separator units should be watertight to prevent possible groundwater contamination.

- The separation chamber must provide three distinct storage volumes:
    - Volume for separated oil storage at the chamber top
    - Volume for settleable solids at the chamber bottom

    - Volume to provide adequate flow-through detention time (volume to ensure maximum horizontal velocity of 3 ft/min through the chamber)
- The total wet storage of the gravity separator unit should be at least 400 cubic feet per contributing impervious acre.

- The minimum depth of the permanent pools should be four feet.

- Hydrodynamic separators require a much more intensive maintenance schedule than other BMP measures. A typical maintenance schedule is shown as follows:

Activity	Schedule
Inspect the gravity separator unit.	Quarterly
Clean out sediment, oil and grease, and floatables, using catch basin cleaning equipment (vacuum pumps). Manual removal of pollutants may be necessary.	As needed

Table 16.1. Typical Maintenance Activities for Gravity Separators

- All specific design criteria should be obtained from the manufacturer.

Source: Georgia Stormwater Management Manual, published by the Atlanta Regional Commission, Atlanta, Georgia, 2001

16.3 Manufactured Products

The following discussion of manufactured hydrodynamic separators is intended only to serve as a description of the most widely used proprietary systems. The products discussed in this design example do not constitute an exhaustive list of all hydrodynamic separation devices available. Presentation of the following products does not preclude the use of other available systems, nor does it constitute an endorsement of any one system.

16.3.1 Stormceptor

Stormceptor is a precast, modular, vertical cylindrical tank divided into an upper bypass and lower storage chamber. The Stormceptor functions by diverting flow through a downpipe into the lower storage / separation chamber. Flow is then routed horizontally around the circular walls of the separation chamber. The circular flow motion, along with gravitational settling, traps sediments and other particulate pollutants. Flow then exits the Stormceptor through an outlet riser pipe. The outlet pipe is submerged, thus preventing trapped floatables from exiting the structure. The configuration also prevents turbulent flow in the storage / separation chamber, thus preventing resuspension of trapped particulates. The Stormceptor has no moving parts, and requires no external power source. (VADCR, 1999)

During large runoff producing events, flow entering the Stormceptor floods over the diversion weir and through the bypass chamber into the downstream conveyance system. The overflow of the system is controlled by the incoming stormwater velocity

and the hydraulics of the diversion weir. The bypass configuration does result in a backwater condition in the upstream conveyance system. (VADCR, 1999)

It is generally recommended that Stormceptor systems be fully pumped a minimum of once per year. This frequency must be increased if high levels of sediment loading are observed. Schematic details of the Stormceptor system are presented as follows.

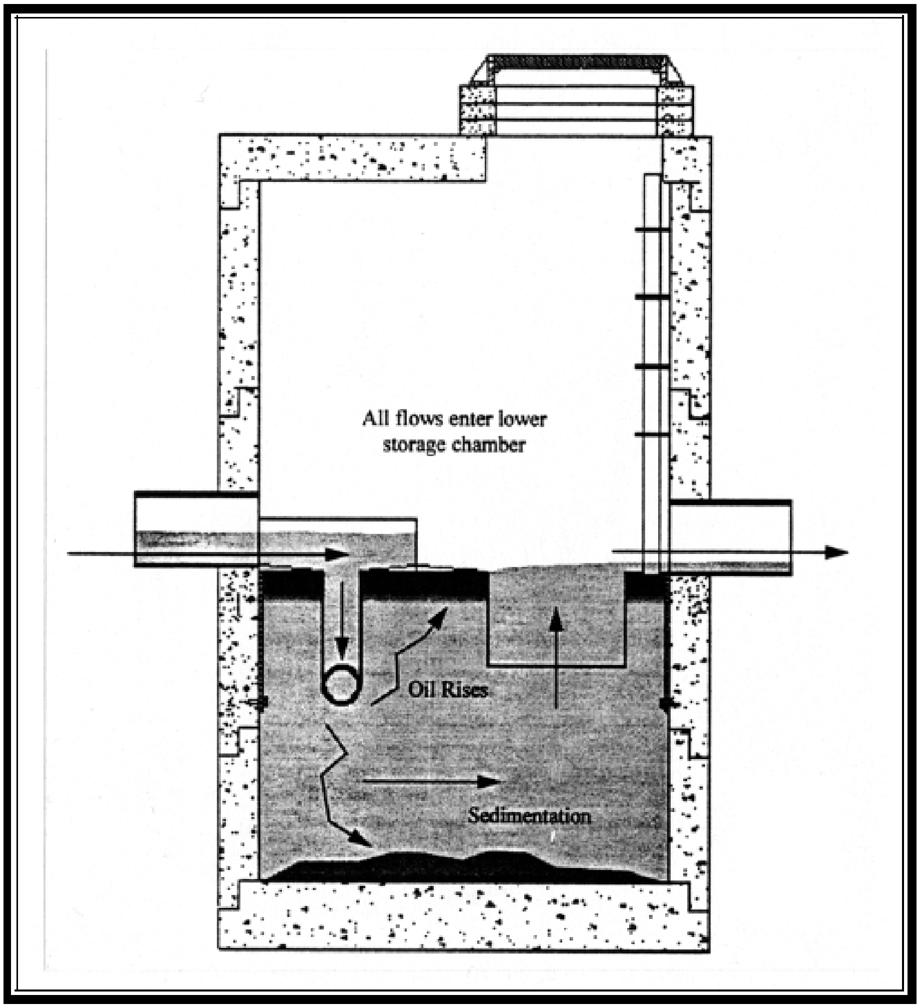

Figure 16.1. Stormceptor During Normal Flow Conditions

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

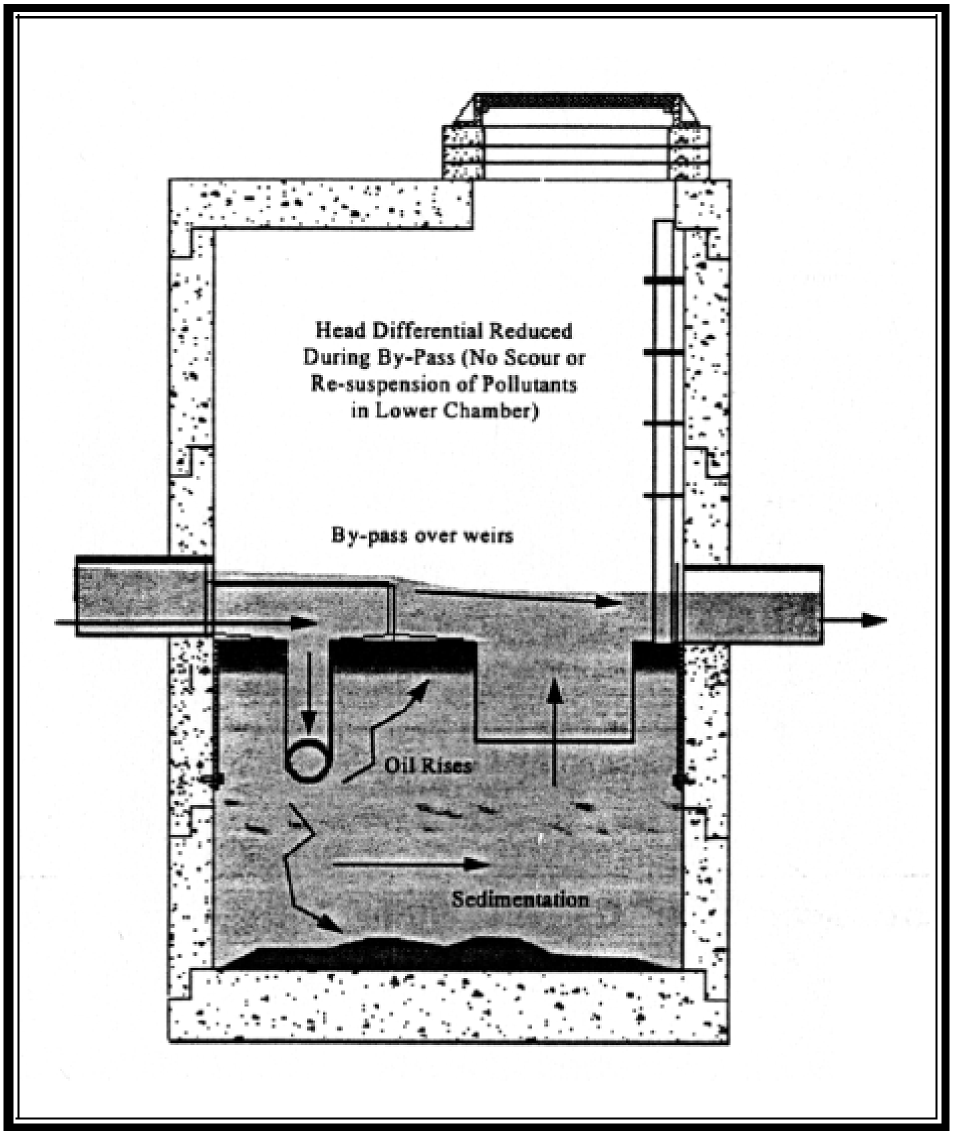

Figure 16.2. Stormceptor During High Flow Conditions

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

Current Stormceptor product information and vendor contacts can be obtained at: http://www.stormceptor.com

16.3.2 Vortechs Stormwater Treatment System

The Vortechs Stormwater Treatment System is a precast rectangular unit composed of three chambers. The first chamber serves as a grit chamber, and creates a swirling motion that directs settleable solids toward the center where they become trapped. The Vortechs system is an all-inclusive proprietary system, with the swirl-inducing mechanism self contained within the unit. Flow is then slowly released from this chamber into the oil chamber. The oil chamber contains a barrier which traps oil and grease and other floatable pollutants. The final chamber is the flow control chamber, which forces water to back up, thus reducing velocities and turbulence. The Vortechs Stormwater Treatment System contains no moving parts and requires no external power source. (VADCR, 1999)

During large runoff producing events, the flow control chamber of the Vortechs system forces runoff to fill the structure. As this occurs, the swirling action in the grit chamber increases, keeping sediment concentrated at the center of the chamber. Because the swirling action of the system increases as the volume of runoff entering the structure increases, the resuspension of previously deposited material is eliminated. The Vortechs system is capable of providing limited flow attenuation within its storage capacity. When the volume of runoff entering the structure exceeds the capacity of the three chambers, the conveyance system leading to the Vortechs system will experience a backwater condition.

To ensure proper performance, the Vortechs system must be cleaned when it becomes full of pollutant material. During the first year of operation, the manufacturer recommends monthly inspections since contaminant loading rates vary greatly. Cleaning of the system is most readily accomplished by use of a vacuum truck.

Schematic details of the Vortechs system are presented as follows.

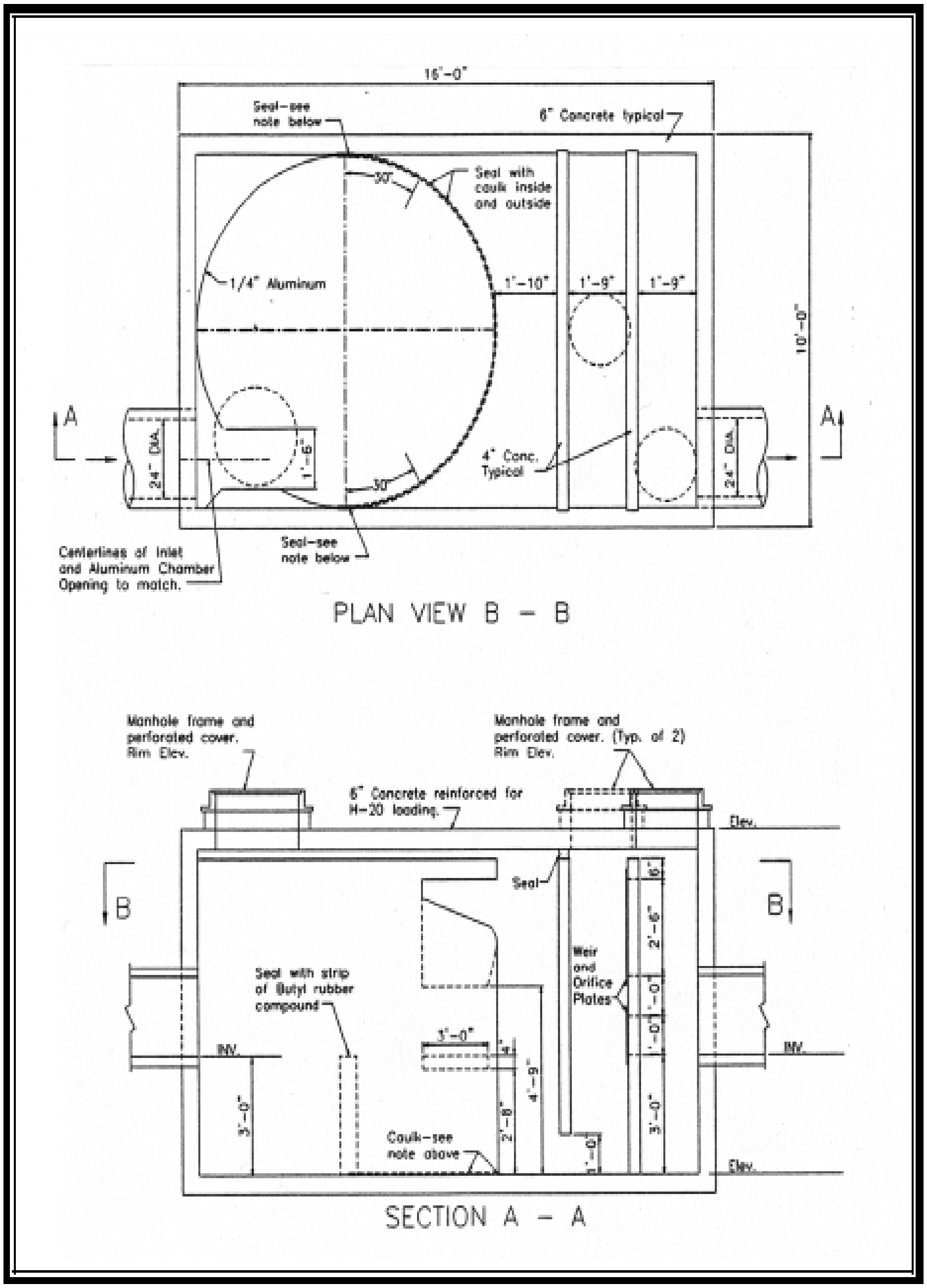

Figure 16.3. Vortechs Stormwater Treatment System

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

Current Vortechs product information and vendor contacts can be obtained at: www.vortechnics.com

16.3.3 Downstream Defender

The Downstream Defender system is adaptable to all types of land uses. Additionally, the Downstream Defender can be installed in existing pipe systems as a retrofit.

The Downstream Defender is characterized by a concrete cylindrical structure with stainless steel components, and an internal 30^o sloping base. Runoff entering the structure passes through a tangential inlet pipe, resulting in a swirling motion. The flow then spirals downward along the perimeter of the structure. During this downward path, heavier particles settle out by gravity and by drag forces exerted along the wall and base of the structure. As flow rotates about the vertical axis, these solids are directed toward the base of the structure, where they are stored. The system's internal components direct the main flow away from the structure's perimeter and back up the middle of the vessel as a narrower spiraling column rotating at a slower velocity than the outer downward flow. When this upward flow reaches the top of the structure, it is virtually free of solids, and is then discharged through the outlet pipe. The Downstream Defender has no moving parts and requires no external power source.

During the first 12 months of operation, inspections should be conducted frequently following runoff-producing events in order to determine the sediment loading rate. After this time, a probe may be used after storm events to determine a maintenance schedule. H.I.L. Technology, Inc. recommends inspection and clean-out of the Downstream Defender system a minimum of twice per year.

Schematic details of the Downstream Defender system are presented as follows:

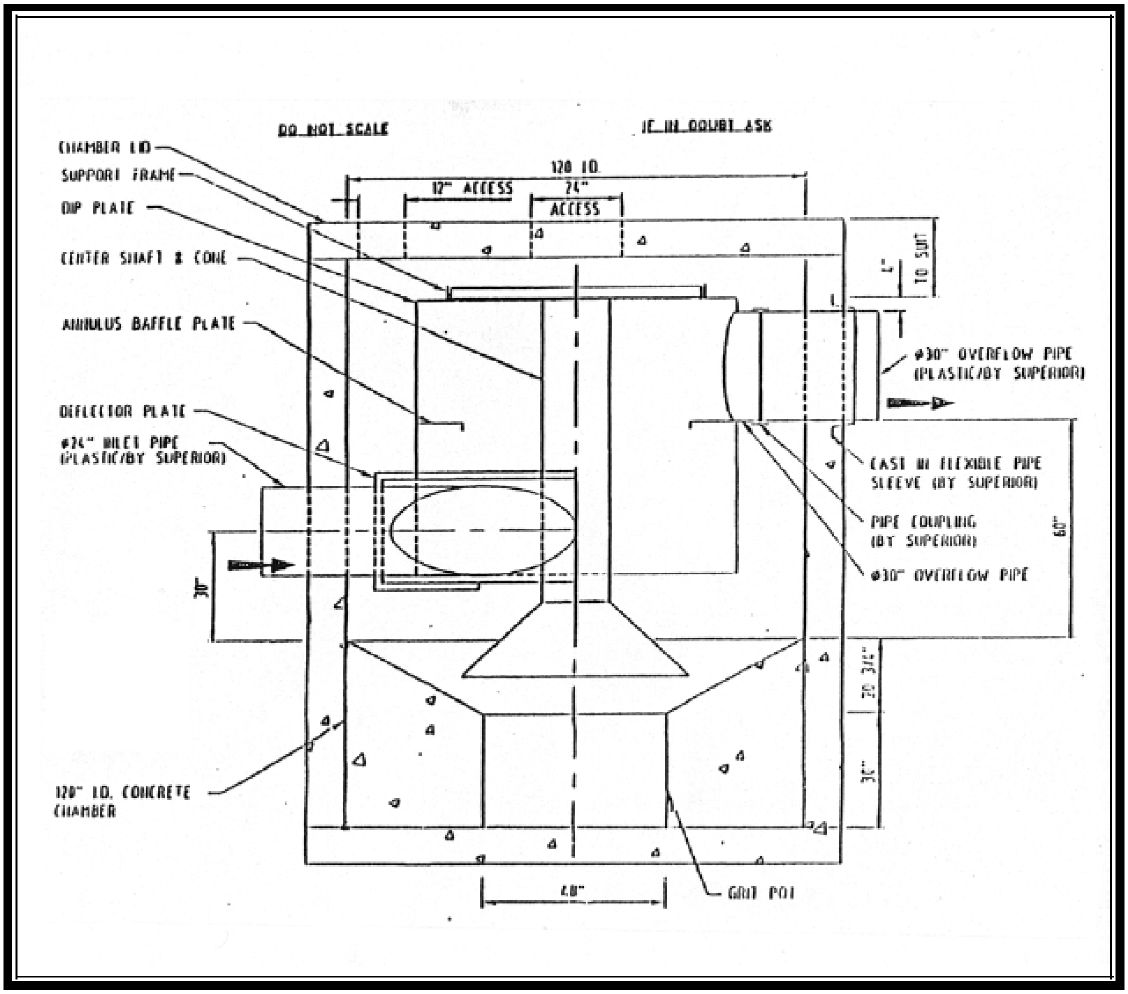

Figure 16.4. Section View of Downstream Defender System

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

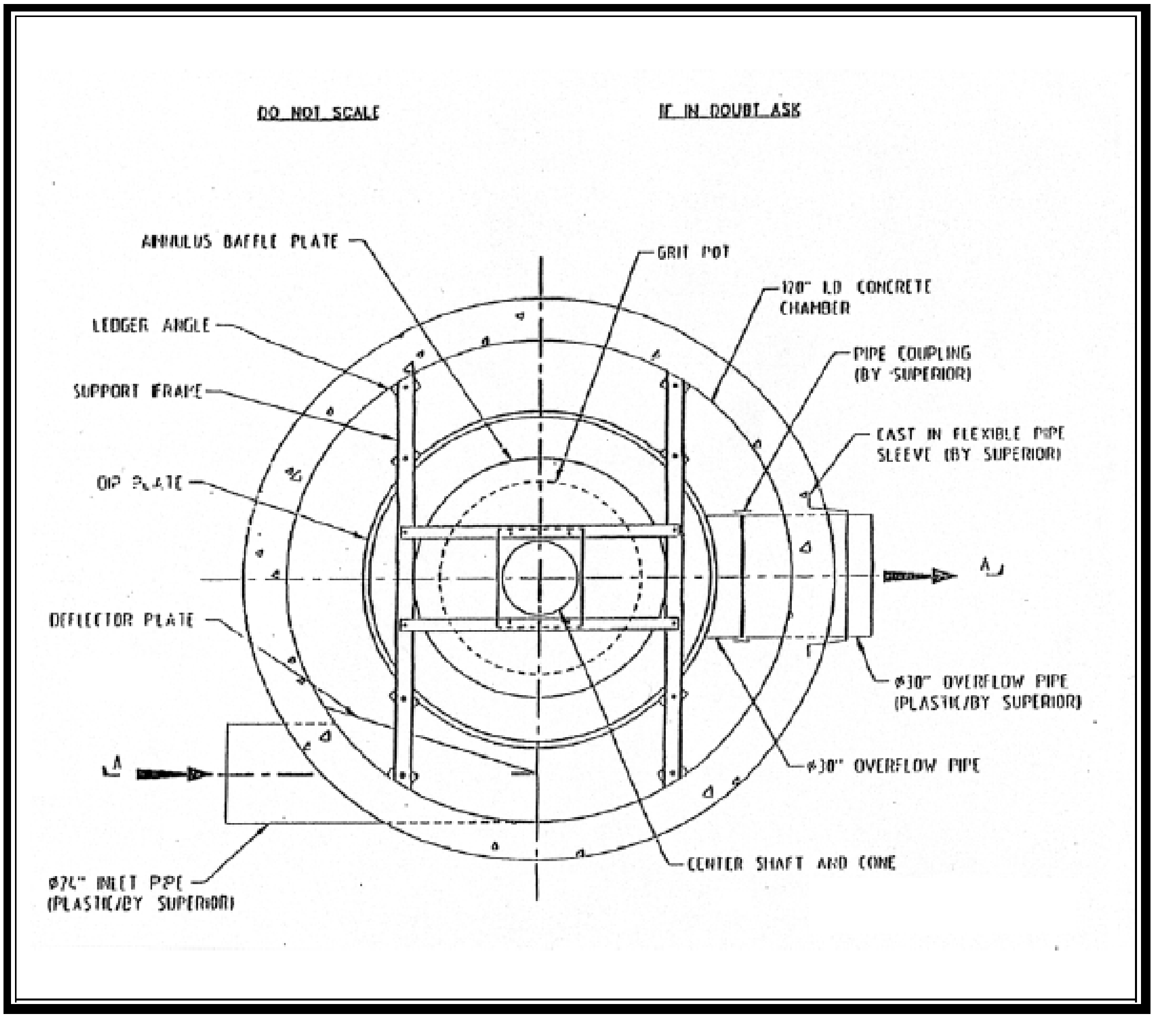

Figure 16.5. Plan View of Downstream Defender System

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

Current Downstream Defender product information and vendor contacts can be obtained at:
www.hil-tech.com

16.3.4 BaySaver

The BaySaver system is composed of three main components: the primary separation manhole, the secondary storage manhole, and the BaySaver Separator Unit. Runoff enters the system through the primary separation manhole. The larger sediments contained in the runoff settle into the primary separation manhole whose flow exits through a trapezoidal weir. The runoff leaving the primary separation manhole carries with it floating contaminants, debris, and fine sediment which are then treated in the secondary storage manhole. The BaySaver system employs three potential flowpaths for runoff entering the system. First flush and low flows are diverted into the second manhole for the most efficient treatment. As the water level rises in the primary separation manhole, more water flows over the skimming weir and into the secondary manhole. The majority of oils and fine sediments are removed by this flow path. During more intense storms, water can flow through 90-degree elbow pipes located in the primary separation manhole. Because the elbows are situated below the surface, the water entering the secondary storage manhole is free from floating contaminants. During large, infrequent storm events, the BaySaver system bypasses the treatment stages, conveying water directly from inlet to outlet. Bypassed flows are prevented from entering the sedimentation manholes, and thus resuspension of contaminants does not occur. The BaySaver system contains no moving parts and requires no external power source. (VADCR, 1999)

It is generally recommended that BaySaver systems be fully pumped a minimum of once per year. This frequency may be increased if high levels of sediment loading are observed.

Schematic details of the BaySaver system are presented as follows.

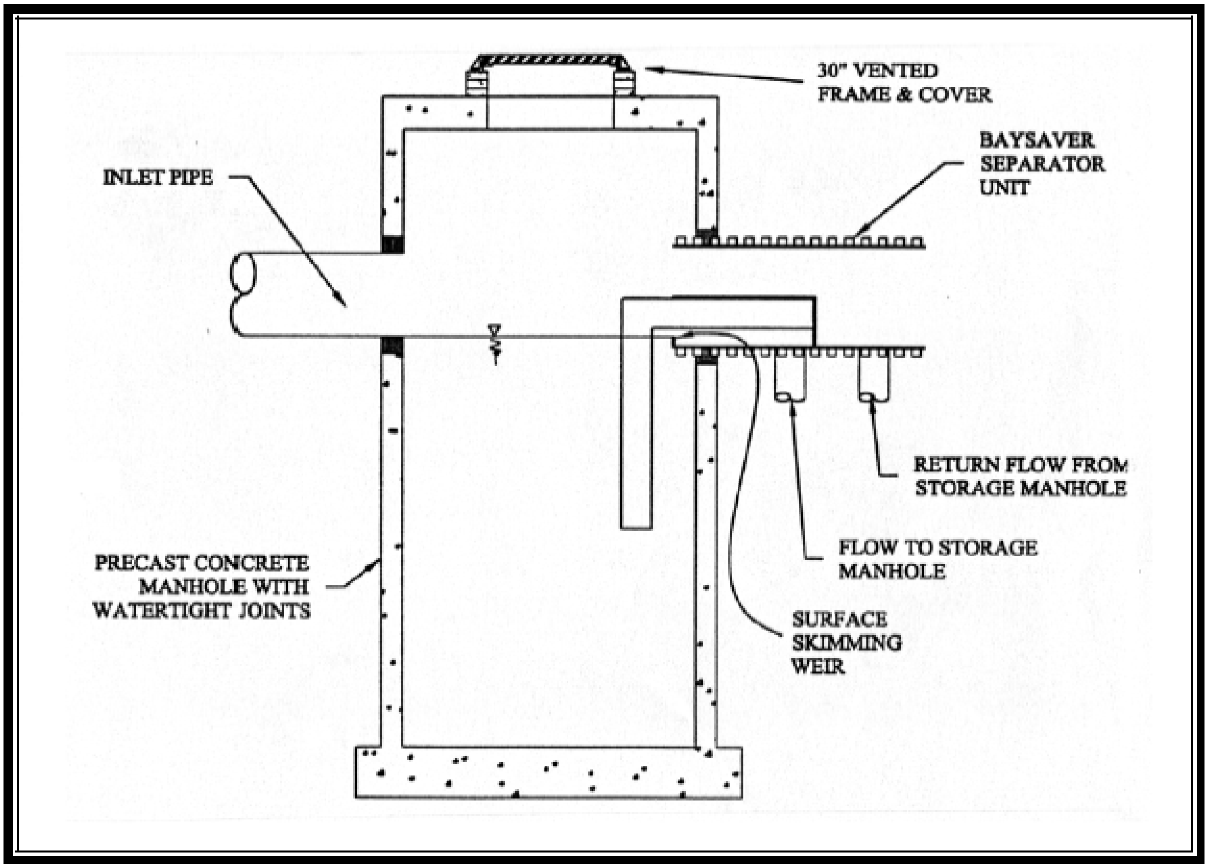

Figure 16.6. BaySaver Primary Separation Manhole

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

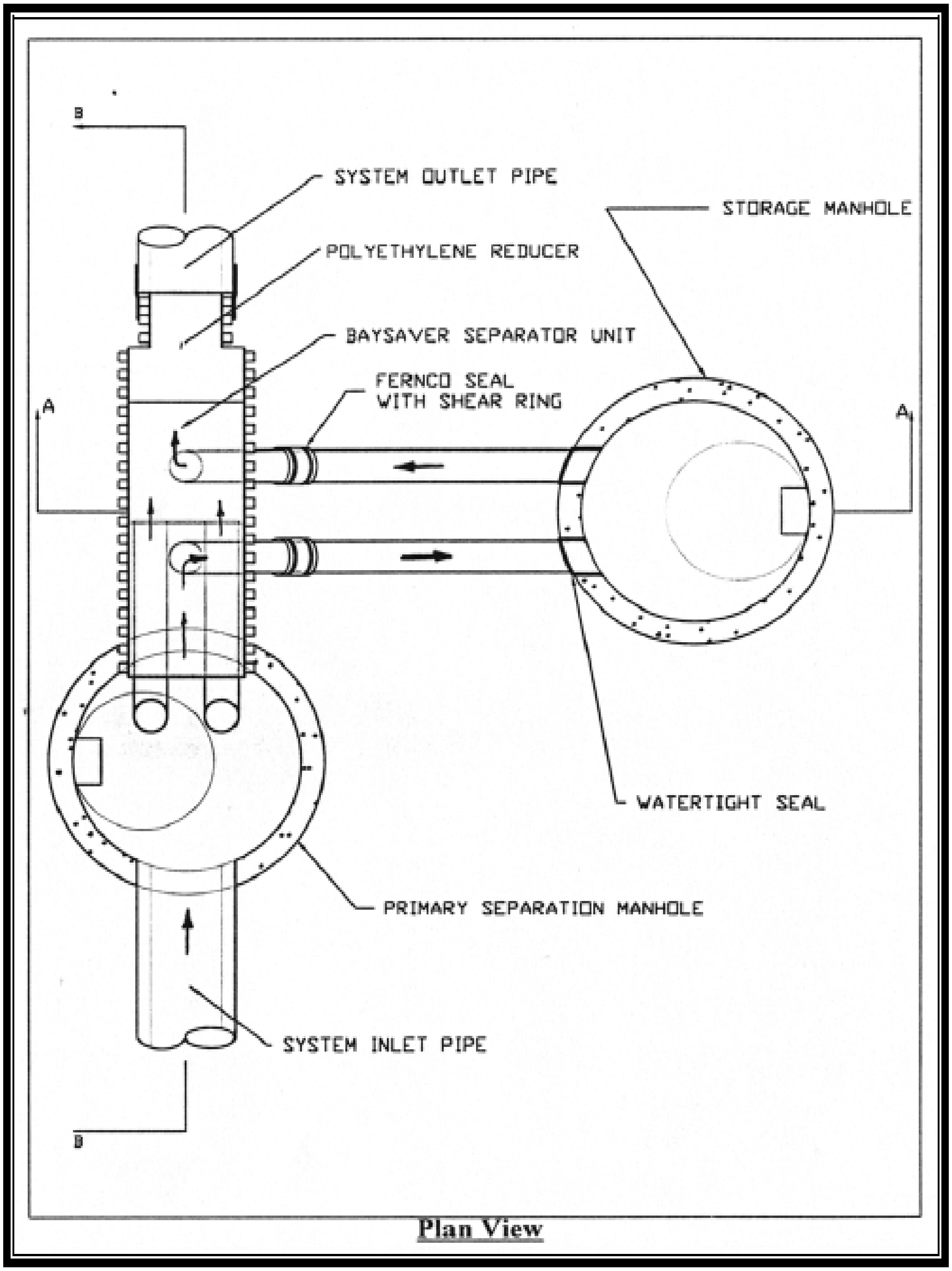

Figure 16.7. Plan View of BaySaver System

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999.

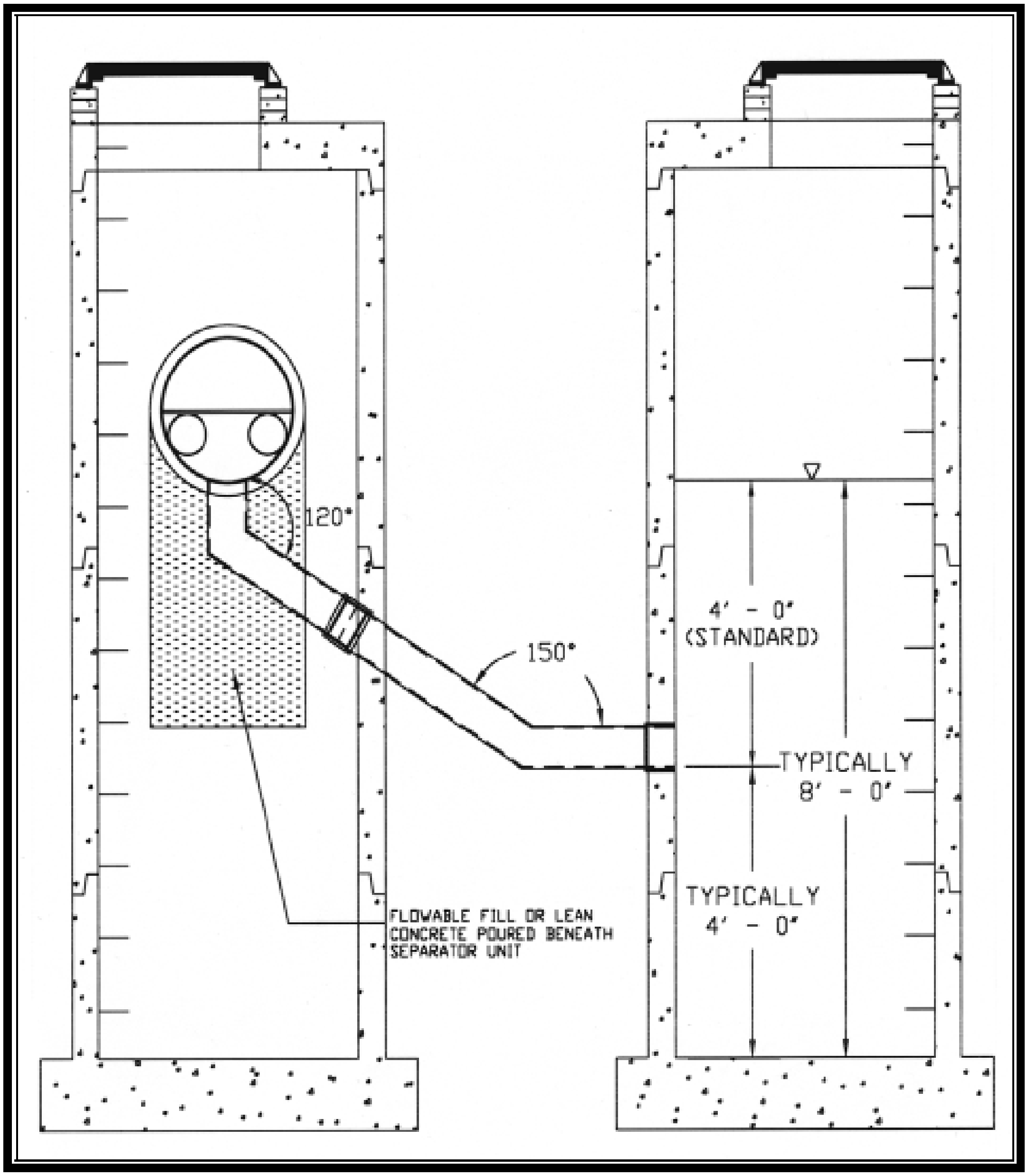

Figure 16.8. Section through BaySaver Storage Manhole

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999

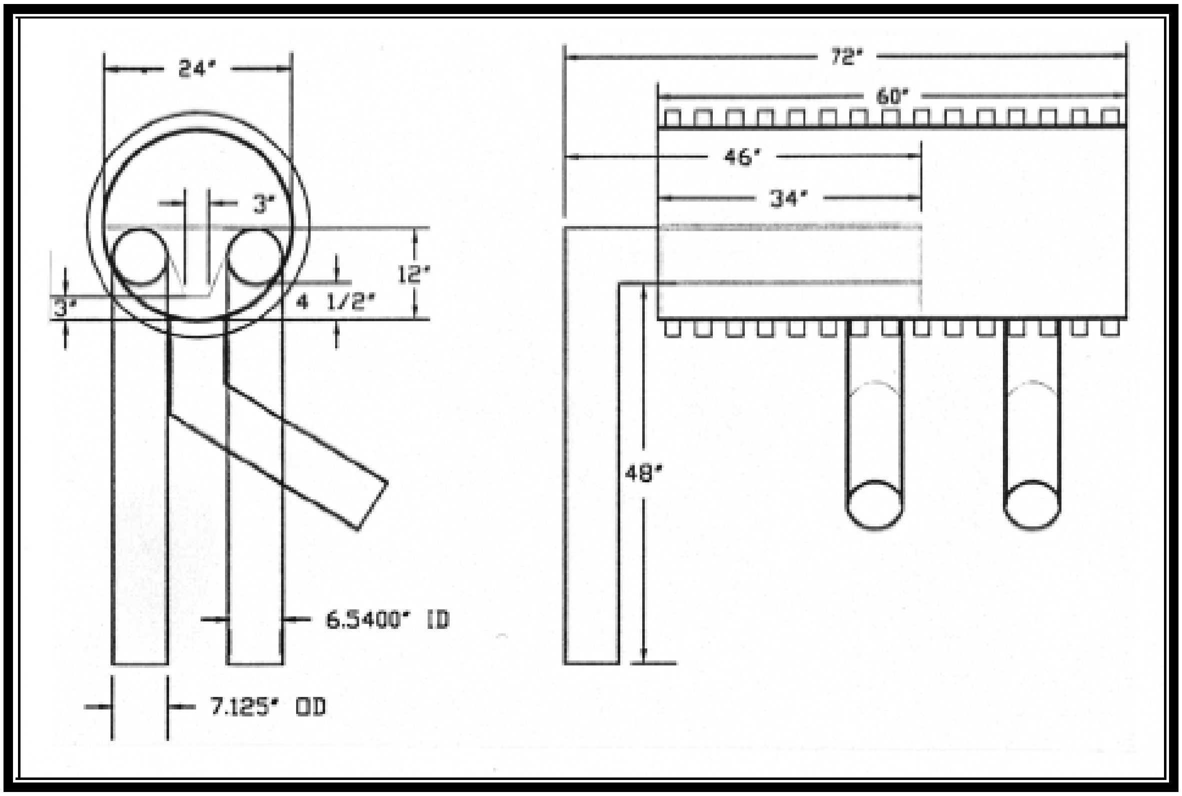

Figure 16.9. BaySaver Separation Unit

Source: Virginia Department of Conservation and Recreation. Virginia Stormwater Management Handbook. Richmond, Virginia, 1999

Current Baysaver product information and vendor contacts can be obtained at: http://www.baysaver.com/

The Virginia Transportation Research Council, via contract with University of Virginia, has constructed the following information matrices for the most widely used hydrodynamic separators, as of 2004. The user is referred to the following for the originally published matrices:

Virginia Transportation Research Council. VDOT Manual of Practice for Stormwater Management. Charlottesville, Virginia, 2004.

System Type	Manufacturer	Operation	Sizing and/or Area Treated	Maintenance	Cost	General Performance	Comments
Hydrodynamic Separators							
V2B1	Kistner, Inc.	Swirl concentrator in 2 chambers. Second chamber collects floatables and has outlet. Maintains wet pool. Treats only first flush.	1 – 25 cfs treatment capability. Sized for local 2-month storm. Flows greater than first flush diverted directly to outlet.	Required only in first chamber if regular maintenance. Residuals removed by vacuum truck.	ND	80% TSS removal for first flush.	Floating pollutants isolated from peak storm flows.
Bay Saver®	Bay Saver, Inc.	Gravity treatment in 2 manholes connected by HDPE separator. Primary manhole in-line with the	Either according to flow rate or impervious area. Three units	Required in either chamber when accumulation reaches 2 ft	$7,000 - $18,000 (materials only)	Designed to remove TSS, O&G, and debris,*	
		storm drain. First-flush or low-flow diverted to storage chamber for settling and O&G removal. Outflow from center of static wter column to retain floatables back to primary manhole. Maintains wet pool in storage chamber.	available correspond to range of treatable areas: 1.2 – 8.0 acres impervious area. Largest systems treats maximum up to 11 cfs.				
Stormceptor®	CSR America	Manhole-shaped device. First-flush or low flows divered beneath high-flow platform to settling chamber. Outflow from center of static water column to retain floatables. Maintains wet pool.	8 units available: 900 – 7,200 gal.; 0.55 – 6.7 acres of impervious area. Sized to treat 90% of annual rainfall.	Perform maintenance when stored material reaches 15% total system volume. Recommend quarterly inspections during first year to establish schedule.	Typical installation is $9,000 for 1 acre drainage area. Unit cost: $7,600 - $33,560 per unit. (US EPA, 1999e)	Varying reports. Vendor claims 50 – 80% removal of TSS based on field testing by contracted agencies. Canada ETV reports 81-94% TSS removal; 42-67% TKN removal.	Improper installation compromises system performance. Also, available with inflow configured for curb inlet or submerged application. Over 4,000 installations.
Stormvault™	Jensen Precast	Rectangular footprint. Interior baffles minimize horizontal velocity to enhance settling and prevent resuspension. Bypass available.	Variable sizes afforded by adding modular sections. Sized to treat 85% annual rainfall or runoff. Variable outlet structure allows extended detention.	Large footprint allows extended periods between maintenance. Recommended inspections to establish schedule.	ND	Laboratory testing indicates low horizontal velocity near vault bottom to minimize resuspension. Extensive evaluation provided in Brisbane et al., 2000	Several field monitoring studies are being performed.
Vortechs™	Vortechnics, Inc.	Rectangular footprint comprised of 3 chambers; swirl concentrator, O&G removal, underflow to energy dissipator. Maintains wet pool.	10 units available to treat maximum 10-yr design storms of 1.6 – 25 cfs without bypassing. On-line system sizing criteria based on 1 ft^2 grit chamber surface area per 100 gpm peak flow rate.	Monthly inspection during first year after installation or whenever loading have been high.	$10,000 - $40,000 per unit, not including shipping or installation (US EPA, 1999e)	Vendor claims 80% TSS removal for flow less than or equal to design events. Sediment storage capacity 0.75 – 7.0 yd^3 depending on model.*	Improper installation compromises system performance. 1998 US EPA Environmental Technology Innovator Award.
CDS®	CDS Technologies, Inc.	Non-mechanical screening system. Circular flow maintained within unit	Treats first-flush with bypass option. Precast systems	3 – 4 times per year. Frequent inspection is required	$2,300 - $7,200 per cfs capacity (including	100% of particle size of mesh opening; Over 90% for	Vendor has won several engineering awards in Australia

Table 16.2. Hydrodynamic Separators Information Matrix (VTRC, 2004)

System Type	Manufacturer	Operation	Sizing and/or Area Treated	Maintenance	Cost	General Performance	Comments
		Pollutants settle to sump or remain floating and trapped in center column. Radial flow cleans screens. Maintains wet pool.	available up to 62 cfs. Cast-in-place options can treat up to 300 cfs. Screen size and unit diameter determined for specific applications.	especially during first month after installment. Maintenance includes inspection of screens for damage and measurement of sediment depth.	installation)	particles ½ the size of opening; over 85% for particles 1/3 size of opening; 80-90% O&G using sorbent materials. Complete trash removal*	Installations in the US, Australia and New Zealand.
Downstream Defender™	H.I.L. Technology, Inc.	Swirl concentrator creates a 3D flow path. Sediment settles to bottom of storage area. O&G also stored outside treatment path to prevent re-entrainment. Maintains a wet pool.	4 units range from 0.74 to 13 cfs design flows with corresponding 3 – 25 ft^3 capacity.	Clean-out after 1 – 2.5 ft of sediment accumulates – or annually.	$10,000 - $35,000 per unit (including installation)	PSD trapped sediments 0.001 – 0.01 mm (over 95% measured less than 75 µm). Estimate total solids removal was over 80% for theoretical design flows. Oil storage capacity 70 – 1050 gal.; sediment storage capacity of 0.7 – 8.7 yd^3.	ND

Table 16.2 Cont'd. – Hydrodynamic Separators Information Matrix (VTRC, 2004)