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Final Report

Investigation of Structural Control Measures for New Development

Prepared for:

Sacramento Stormwater Management Program



**County of Sacramento
City of Sacramento
City of Citrus Heights
City of Folsom
City of Galt**

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INTRODUCTION

The Sacramento NPDES Stormwater Permittees include the County of Sacramento and the Cities of Folsom, Galt, and Sacramento. Under the terms of their NPDES permit, the Permittees operate a Comprehensive Stormwater Management Program, with the overall goal of reducing discharges of stormwater pollutants to the maximum extent practicable. The Comprehensive Program includes a New Development Management Program (NDMP) element, intended to improve the quality of stormwater runoff from areas of new development.

Under this program element, the Permittee agencies are responsible for approving the installation of stormwater controls in new developments within their respective jurisdictions. To help guide this approval process, the Permittees require additional information regarding specific structural control devices, especially with respect to the applicability and effectiveness of such devices for treatment of stormwater runoff in the Sacramento area. This report contains the results of research into the performance of selected on-site structural controls. Funding for this investigation was included within the 1998-99 Sacramento Stormwater Monitoring Program consultant contract.

Structural controls for improvement of stormwater quality can be considered to fall into two groups: proprietary devices that are manufactured off site and may be purchased for installation according to the manufacturer's specifications, and non-proprietary controls that can be designed and installed using information available in the public domain. The Permittees selected 14 proprietary devices and four public domain controls for this evaluation, each of which can be incorporated within a site development plan and installed on site. (Off-site or regional controls, such as detention basins, were not included in this investigation). Information was gathered for this report principally through available studies on the performance of public domain controls, and through a questionnaire requesting specific information about each product that was sent to manufacturers of proprietary devices. The information was then compiled and evaluated using a common format.

The Permittees plan to use the results of this investigation to identify stormwater controls considered acceptable for installation in new developments in Sacramento, and to identify areas where additional information is needed.

METHODS

The investigation was carried out under the direction of a working group involving representatives from the Permittee agencies and their consultants. The working group met initially in November 1998 to develop a working strategy and identify a preliminary list of controls for the investigation. In December a two-page questionnaire was prepared and mailed to manufacturers or distributors of the selected proprietary devices. The questionnaire requested specific information about applicability of the controls to the Sacramento area, existing installations, available sizes and capacities, and performance data and costs (see Appendix C for the questionnaire and cover letter). The questionnaire responses were compiled during January and February, 1999.

The investigation was originally intended to cover only proprietary structural controls thought to have potential for successful application in Sacramento. However, the working group determined that inclusion of several of the most commonly-used public domain controls would provide opportunities for appropriate comparisons of the leading available alternatives. The final list of controls established by the working group includes 16 proprietary devices and four public domain controls: grassy swales and three versions of media (sand) filtration technology.

Meanwhile, available information on the performance of the selected public domain controls was also compiled. Key sources of information (especially performance studies) on these controls included the *NDMP Stormwater Control Measure Study Literature Review Update* (LWA, 1998a), and other municipal and state agencies involved in stormwater management.

Working group members met briefly in February, 1999 to discuss the format to be used in evaluating the accumulated performance and cost data. The consultants then compiled the information in this format, and presented the preliminary results to a meeting of the full working group in March, 1999. Key issues addressed by the working group at this meeting included:

1. How to screen the results of the various available studies to determine whether there are sufficient data to demonstrate the effectiveness of the control, including whether the data should be considered to be technically valid?
2. How to “normalize” performance and cost data assembled from various disparate sources for direct comparisons of the various controls studied?
3. How to distill the normalized performance data into a “bottom line” judgement of the acceptability of each type of control for application in new developments in the Sacramento area?

The first issue, having to do with assessing data adequacy, proved to be somewhat complex. Several questions needed to be addressed in making this assessment:

- Do the study data represent hydrological conditions typical of the Sacramento area (in terms of typical storm depth, duration, etc.)?
- Does the influent quality used in the study represent typical new development runoff quality (and not, say, construction site runoff quality)?
- Were the data collected using appropriate techniques (e.g., using flow-weighted composite sampling instead of grabs, with proper attention to QA/QC issues) so as to accurately characterize influent and effluent quality?
- Are there enough data to permit conclusions to be drawn regarding performance and acceptability?
- Do the data indicate acceptable treatment performance in terms of pollutant removals?

To provide a protocol for screening data acceptability, criteria were developed to describe minimum acceptable data requirements, as follows:

- Studies to represent a minimum of two different sites, preferably a retail commercial site, a non-retail commercial site, and/or a residential site.
- Studies to represent typical new development runoff quality.

- Number of storms sampled at each site: 10
- Storm depth ranging from 0.15 to 1.5 inches
- Runoff duration ranging from 2 to 24 hours
- Average storm intensity ranging from 0.02 to 0.25 inches/hour
- Flow weight or time weight composite samples
- Analysis by a certified laboratory
- Removal efficiency with respect to TSS and zinc is reasonably equivalent to what is obtained with grass swales and sand filters. (TSS was chosen because of the preponderance of data. It is the most frequent constituent measured in all studies of stormwater treatment control measures, and serves as a surrogate for the pollutants that in stormwater tend to be primarily in the particulate form, like petroleum products, pesticides, lead, chromium, and phosphorus. Zinc was selected to represent the more soluble constituents, including itself as well as copper, cadmium, and the various nitrogen forms. Also, of the metals, zinc is typically present in runoff in concentrations sufficiently above the detection limit to allow meaningful evaluations of removal efficiency. However, the comparison of performance was limited to TSS at this time, because available data on zinc removal was limited.

The criteria for storm depth, duration, and intensity were selected by bracketing the values resulting from a first-flush design event established by the City and County for on-site control measures. The design event is a 2 year / 6 hour storm having an intensity of 0.18 inches/hour.

This protocol was then used to assess the adequacy of the available performance data for the selected controls. Most of the manufacturers of proprietary devices were able to provide some studies purporting to document the effectiveness of their products, but there were great discrepancies in the number and quality of these studies. Generally speaking, sufficient numbers of studies have been done for the public domain controls, typically by other local stormwater agencies, although the public record of studies for grassy swales is somewhat lacking.

The second issue, involving how to directly compare disparate performance and cost data for the various devices, was addressed by providing the means to “normalize” these data. Performance was assessed graphically, using a variable range of acceptable performance for TSS removal, with higher removal percentages expected at higher influent TSS concentrations. The acceptable range of TSS removal performance was derived principally from performance data produced by studies of properly functioning public domain controls. Cost was normalized to cost per unit flow treated (at approximately 0.1 cfs, 1 cfs, and 10 cfs) for each device where appropriate data were available. However, cost data were not used to assess acceptability of the products, only to provide a general comparison.

The bottom line issue of grading the products according to overall acceptability was addressed by determining the adequacy of the performance data, using the screening protocol described above, and then evaluating the valid data using the performance graph for TSS.

DESCRIPTIONS OF CONTROL MEASURES EVALUATED

Brief descriptions of the physical features, operation, application and limitations of the various proprietary and public domain control measures evaluated in this report are presented below. Summaries of product descriptions and target constituents for removal are presented in Table 1. Illustrations of each device, as available, are presented in Appendix B. For purposes of description, control measures are categorized based on principle of operation and design as follows:

- Wet Vaults
- Swirl Concentrators
- Deflection Screen
- Media Filters
- Drain Inlet Inserts
- Combined Systems
- Grass Swales
- Sand Filters (public domain)

WET VAULTS

Products in this category include the Jensen and Teichert Interceptors, Stormceptor, and Bay Saver.

Jensen and Teichert Interceptors

These two products are very similar in design, consisting of precast, rectangular concrete vaults. The units are typically multi-chambered with interior chambers separated by baffle walls. The number of vaults or vault units are increased to increase the flow capacity. The elevation of the outlet is such as to cause standing water in the vault, in the range of 4 to 4.5 feet. Total depth of the vaults, exclusive of risers, are in the range of 6 feet. Widths are on the order of 4 to 6 feet. These interceptors are essentially wet vaults or API (American Petroleum Institute) gravity separators. Hence, the units should be sized using criteria for either the settling of particles or flotation of petroleum products. Unless sized to treat the full design flow, these units require

separate bypass piping to divert flows in excess of the unit flow capacity to avoid washout of material retained in the vault chambers. Oil adsorption pillows and coalescing plates can be added to the units to enhance capture of oils and grease. Both manufacturers produce several models with a range of flow capacities. Available flow capacities are listed in Table 7 in the Results section.

BaySaver and Stormceptor

Like the Jensen and Teichert Interceptors, these two products are essentially wet vaults designed to remove particulates and floatables, but they are round rather than rectangular. BaySaver and Stormceptor differ from each other in that the Stormceptor consists of one round manhole-like structure, and the BaySaver consists of two structures. The Stormceptor improves the removal of settleable solids over that of a conventional manhole by the use of a flow diverter. Up to a defined flow rate, the stormwater is diverted down and then laterally around the manhole. High flows are bypassed directly across the top of the diverter to the outlet. The diversion of high flows prevents the resuspension of previously settled material. There is some capacity at the top beneath the diverter for the accumulation of floatables.

In the BaySaver, gross settleable solids are removed in the first manhole. Like the Stormceptor, the Baysaver has a diverter, but it passes water into the second manhole where floatables are retained. Fine solids settle in both manholes. High flows are diverted through the second manhole. The purpose of the second manhole is to prevent the loss of previously accumulated floatables and fine sediments. Removal efficiency is highly affected by flow rate.

Both systems are sized for the peak of the specified design event with consideration for the total volume of the manhole or manholes. According to Stormceptor the volume also must be considered when determining efficiency. Both manufacturers produce several models with a range of flow capacities. Available flow capacities are listed in Table 7 in the Results section. The hydraulic capacity of each model offered by both manufacturers is greater than the treatment flow capacity.

Table 1. Summary of Product Descriptions

Product	Company	Product Description	Target Constituents¹
Jensen Interceptor	Jensen Precast	A wet vault consisting of multiple chambers in series separated by baffles. Contains standing water, or dead storage, which enhances treatment.	Settleable and floatable solids, oil/grease and particulate pollutants
Teichert Interceptor	Teichert Precast	A wet vault consisting of multiple chambers in series separated by baffles. Contains standing water, or dead storage, which enhances treatment.	Settleable and floatable solids, oil/grease and particulate pollutants
BaySaver	BaySaver, Inc.	Consists of two standard manholes. The first is for removal of sediment and separation of floatables which are diverted by a special device into the second manhole for storage. Diversion device passes extreme flows through the unit.	Settleable and floatable solids, oil/grease and particulate pollutants
Stormceptor	CSR Hydro Conduit	A weir insert is placed in a round manhole vault to improve hydraulics thereby improving removal efficiency and retention of sediment. During low flows the insert directs the flow downward and then laterally towards the walls of the sump. Above the treatment flow rate, the excess flow above the design flow rate flows directly across the insert device towards the outlet.	Settleable and floatable solids, oil/grease and particulate pollutants
Downstream Defender	H.I.L. Technology, Inc.	Uses vortex separation with device installed in a round single manhole vault.	Settleable and floatable solids, oil/grease and particulate pollutants
Vortechs	Vortechics	Vortex separation with the swirl device placed in a rectangular, shallow vault. Comes in nine standard sizes.	Settleable and floatable solids, oil/grease and particulate pollutants
V2B1	Kistner Concrete	Two manholes in series. Vortex separation removes particulates and floatables in first manhole. Floatables move to a chamber in second manhole for storage. Diverter in first manhole bypasses high flows from first to second manhole.	Settleable and floatable solids, oil/grease and particulate pollutants
CDS	CDS Technologies	Circular device; flow is directed to create circular flow like a vortex, but removal occurs as the water passes through a screen around the outer perimeter. Removal induced by countercurrent flows on opposite sides of the screen which also prevents clogging of the screen.	Settleable and floatable solids, oil/grease and particulate pollutants
StormFilter	Stormwater Management	Vertical cylinder with media of various types placed in the cylinder. Water enters laterally through the filter, enters a vertical center well which exits to an underdrain system. One standard size cylinder (15 gpm). Number of cylinders is a function of design peak flow. Pretreatment desirable under circumstances as defined by the manufacturer.	Varies with media. All reduce settleable solids. Some remove dissolved P. or dissolved metals.
Envirodrain	Envirodrain	Insert device: Rectangular unit consisting of one to three trays. Media include Absorbent W, activated carbon.	Petroleum hydrocarbons, sediment, litter.
Fossil Filter	KriStar Enterprises	Insert device: Rectangular, square or circular body with an upper removable tray. Tray is trough extended around the circumference of the drain inlet. Open in the center for high flows. Activated alumina media placed in tray.	Petroleum hydrocarbons and other constituents that are not water soluble
HydroKleen	Weaver Manufacturing, LLC	Two types: box and tapering cylinder. Box: water directed to vertical chamber on one side for sediment. Water overflows to second chamber where it falls through media. Tapering unit collects sediment in perimeter trough; water overflows to center to pass downward through media.	Hydrocarbons, organically bound metals, PCBs, many pesticides, VOCs, sulfides.
Ultra-Urban Filter	Abtech Industries	Insert device: Rectangular box for side curb inlet drain inlets. Media in bags attached to two sides and bottom through which water passes. Sorbent polymer for media.	Petroleum hydrocarbons, debris, suspended solids
StormTreat	Storm Treat Systems, Inc.	Circular device with two concentric chambers: closed inner chamber for settleables/floatables; open outer chamber with wetland plants in gravel. One size, about 9.5 diameter, off-line with live volume of 1400 gallons. Fills each storm, slowly drains in 5 to 10 days. Requires detention system to retain treatment volume plus several units placed together with flow manifold to match design volume. Pretreat to remove gross solids/debris.	Settleable and dissolved solids, oil/grease, particulate pollutants, and bacteria

1. As stated by each manufacturer.

SWIRL CONCENTRATORS

Products employing the swirl concentrator or vortex separation mechanism include Vortechs, V2B1, and Downstream Defender. All products are designed to remove settleable and floatable solids, oil and grease, and particulate pollutants.

Downstream Defender, Vortechs, and V2B1

The flow entry into these devices is designed so as to cause a swirling motion “around” the removal chamber. The three devices differ with regard to shape, number of units in the basic configuration, and inlet and outlet designs. Downstream Defender consists of one round manhole like structure. Water enters and passes around the outside of a circular chamber placed within the manhole. Settleable solids move to the bottom of the chamber. The Downstream Defender and the Vortechs have storage chambers below the vortex separation area. The Vortechs is rectangular, although the removal chamber that rests within the box is circular. The V2B1 consists of two manholes. The entry manhole is the vortex separator and the second, downstream manhole stores floatables within an inner chamber. Floatable pass from the first to the second chamber through a connecting pipe. High flows are bypassed through the entry manhole to the second manhole but past, rather than through, the storage chamber. Removal efficiency is highly effected by flow rate.

Each product is available in several flow capacities as reported in Table 7 in the Results section. The products are typically not sized based on flow capacity; rather they are sized to achieve an average of 80 percent removal of TSS over time. The resulting treatment flow capacity to achieve 80 percent TSS removal is approximately one quarter the maximum hydraulic flow capacity listed for the units, which the peak flow that can be safely passed through the unit. The estimated treatment flow capacities are used as the basis for comparison of these products.

DEFLECTION SCREEN

The deflection screen mechanism is employed in the CDS Continuous Deflective Separation device.

CDS

The CDS device is similar to the above swirl concentrators in two respects. The device has a circular removal chamber and flow moves in a circular motion. However, vortex separation is not induced. Rather, removal is accomplished with a screen located around the outer perimeter of the removal chamber. Water moves through the screen. The relatively high velocity of the water in the entry chamber is reduced to a very low level by the fact that the water in the outer chamber, around the screen, moves counter current to the outlet. The settleable solids “drop” down at the interface of the screen; the floatables pass upward. This hydraulic action also prevents clogging of the screen. The device, originally developed in Australia, was designed to retain floatables, which has been of greater concern in Australia than the United States. The screen sizes currently offered (2400 and 4700 micron openings) are too large to effectively remove settleable solids less than 100 to 200 μm , which are of concern in the United States. However, research has demonstrated that the screens are capable of removing solids much smaller than the screen opening. While the 2400 screen is still too large to effectively remove the smaller particles of interest, it is not necessary to have, for example, a screen with openings equal to the size of the particle of interest. CDS is currently experimenting with a 1200 micron screen which may prove sufficiently small to remove the particle sizes of interest.

The peak flow of the prescribed design event is used to size the unit. The manufacturer offers models having a wide range of flow capacities as indicated in Table 7 in the Results section. According to the manufacturer, performance is not affected by flow rate.

MEDIA FILTERS

Filtration through proprietary media is employed in the StormFilter device.

StormFilter

StormFilter is a vertical filter cylinder or cartridge with a unit capacity of 15 gpm. The desired total system capacity, based on the peak of the prescribed design event, is achieved by using a

multiple cartridges. The cartridges are placed in a precast or cast-in-place vault. The cartridges are placed in a line. The number of lines depend on the vault capacity. Water enters radially (horizontally) through the filter media into an inner cylinder. The filtered water passes downward to an underdrain system that is contained in the bottom slab. A uniqueness of the system is the hydraulic control. To maximize the flow-through rate, each cartridge contains a simple, non-mechanical vacuum device that prevents water from flowing through the cylinder until the water has risen to the top of the cartridge. When this occurs the vacuum within the inner chamber is broken and water passes through until the water level reaches the bottom of the cartridge at which time the vacuum is reestablished. This action also apparently causes solids that have accumulated on the outer surface of the media to be released from the media to settle to the bottom of the vault, thereby extending the maintenance cycle. Several different media are offered, singly or in combination, depending on the treatment objective. Primary constituents targeted for removal include dissolved metals and nutrients. Pretreatment, which is typically provided to remove gross solids, extends the maintenance cycle period. Some pretreatment occurs in the cartridge vault, but pretreatment may also be provided in a separate smaller vault or manhole located upstream of the cartridge vault. If included, a detention facility located upstream of the StormFilter may be sufficient to provide the desired pretreatment depending on the sizing criteria for the detention facility.

DRAIN INLET INSERTS

Products installed as inserts into drain inlets or catch basins include Fossil Filter, Ultra-Urban Filter, Hydro-Kleen, and Envirodrain. The other products reviewed are considered end-of-pipe devices because they are applied after stormwater has been collected in a piped stormwater conveyance system.

Envirodrain, HydroKleen, Fossil Filter, and Ultra-Urban Filter

These four systems actually function as media filtration devices, but are grouped together because they are installed by insertion into standard drain inlet configurations. Each product is described in Table 1. They differ as to their basic configuration, boxes or trays, and the types of media. Different constituents may be targeted for removal by selecting different types of proprietary media. Each offers several different models, differing by shape, capacity, and therefore size. The issue is whether inserts can provide treatment levels equivalent to either the

manufactured products presented above or the public-domain systems that are currently allowed by the Sacramento jurisdictions.

COMBINED SYSTEMS

A treatment-train approach, in which treatment processes are combined in series, is employed in the StormTreat system.

StormTreat

The StormTreat system is an off-line system consisting of two prefabricated concentric cylinders. The outer chamber has a diameter of about 9.5 feet and a height of 4 feet. Water flows directly into and around the inner chamber from either a detention facility or a pretreatment vault or manhole. Further settling of finer material occurs in this chamber. The water passes to the outer chamber, which is filled with gravel to support the growth of wetland plants. This outer chamber removes fine solids and dissolved pollutants. The capacity of the inner chamber is 1,400 gallons. This chamber fills during the storm. The release rate from the outer chamber is controlled at about 1 to 2 gpm. This slow withdrawal is necessary to obtain high levels of removal. The unit takes on the order of five to ten days to drain. Hence, to achieve treatment of the desired volume of water, detention storage must be located upstream of the StormTreat unit. This stored volume gradually flows through the unit over a period of five to ten days. Hence, it is important to recognize the inter-event time between storms when sizing the system. If the inter-event time for the Sacramento area is less than ten days, the potential exists for the unit to have residual volume of water when the next storm arrives. To avoid this problem, the volume of the detention/StormTreat system must be greater than the specified treatment volume. This can only be accomplished by incorporating the statistical nature of storms into the design process.

PUBLIC DOMAIN SYSTEMS

Grass swales and sand filters are the two public-domain treatment systems that are most commonly used at this time in the Sacramento region. The term “public-domain” is used to distinguish them from the manufactured or proprietary control measures that are evaluated in this report. These public domain systems are used as the basis of comparing the performances of the proprietary devices.

Grass Swales

Grass swales are gently-sloped grass-lined channels to which runoff is directed and which is used to convey runoff to a storm-drain piping system. Treatment takes place through a variety of physical, chemical and biological mechanisms as the runoff flows to and along the grass swale. Treatment efficiency is largely a function of depth of flow relative to grass height and velocity of flow.

Sand Filters

Sand filters are media filtration devices, but use sand as the filter media as opposed to a proprietary media product. With sand filters there are three configurations of interest: lineal boxes, open surface basins, and closed vaults. The three configurations are illustrated in Figure 1.

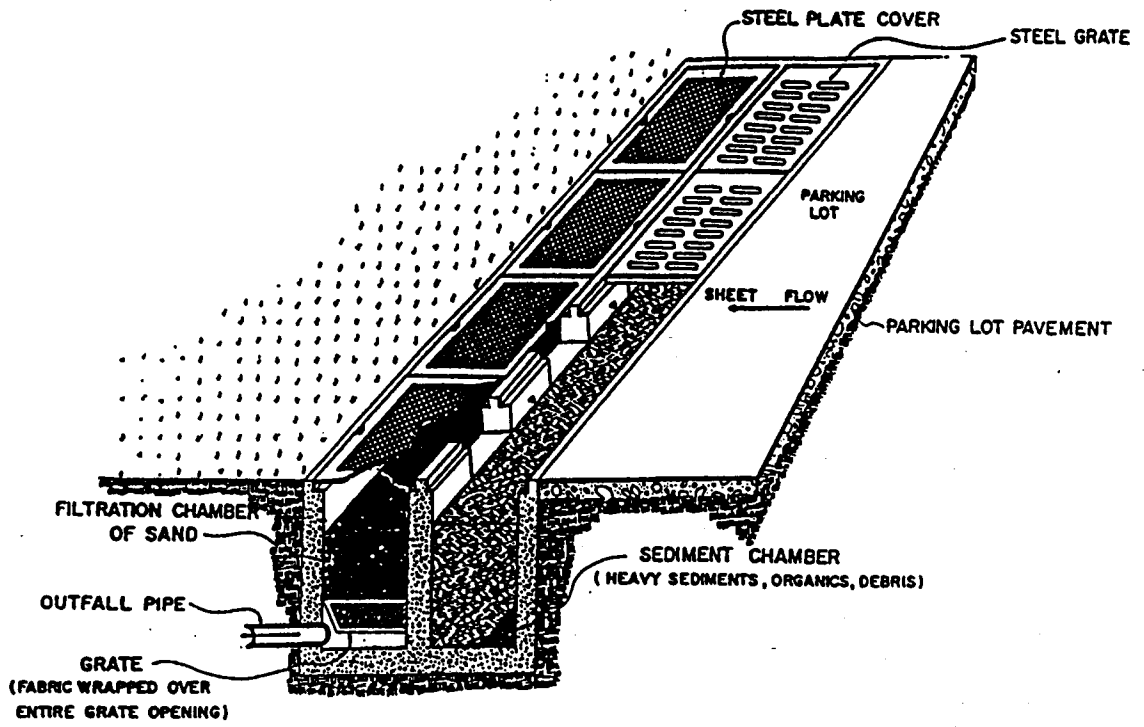


Figure 1a . Lineal Box Sand Filter

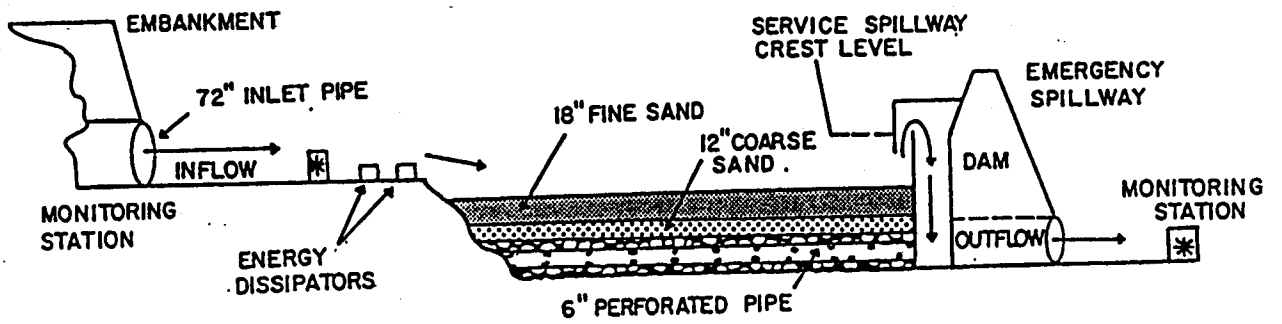


Figure 1b . Open Basin Sand Filter

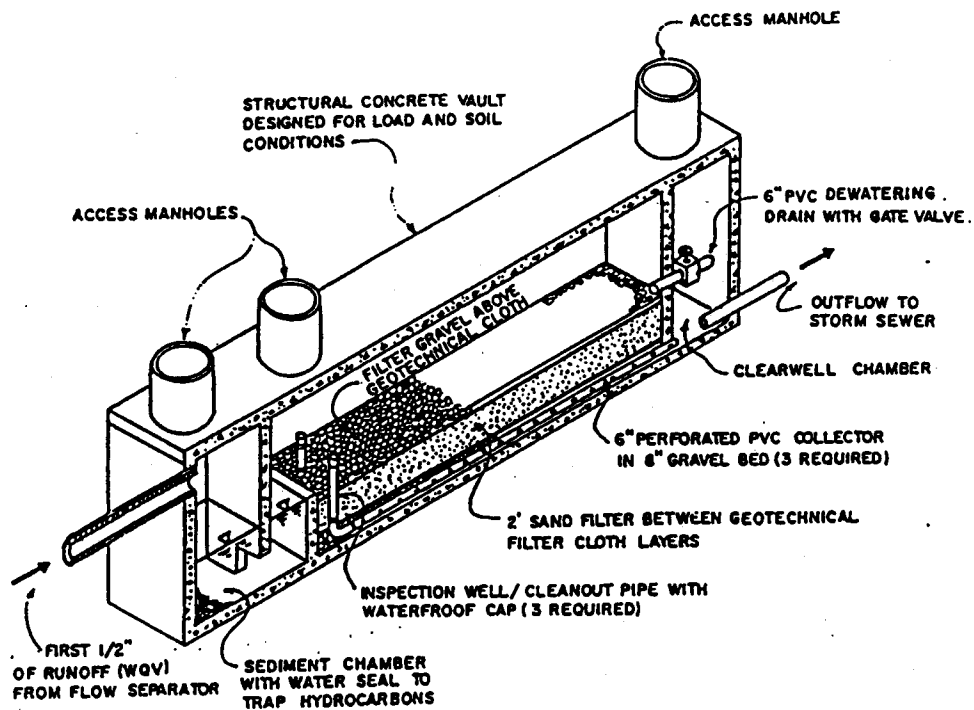


Figure 1c . Closed Vault Sand Filter

RESULTS

The results of this investigation include the following information and data:

- Summary of questionnaire responses
- Summary of performance data for proprietary control measures
- Summary of performance data for public domain control measures
- Summary of cost data for proprietary control measures
- Evaluation of proprietary control measures

QUESTIONNAIRE RESPONSES AND OTHER SOURCES OF INFORMATION

Questionnaire responses were received from manufactures or representatives of all the proprietary control measures of interest. The types of response data and information received about each product are summarized in Table 2. The information materials provided by product companies included a completed questionnaire, product brochures and technical literature, copies of available study reports, separate performance data, cost data, and design criteria. The number of product installations in California were extracted from the completed questionnaire and are listed in Table 2. Products that are no longer manufactured (Ecostar Oil/Water Separator) or are not appropriate as a stormwater control measures (Romag Stormwater Screen) were not further evaluated in this study.

In addition to the information provided by the product manufacturers, information and data from the recent literature review prepared for the Permittees (Larry Walker, 1998a) and the professional literature were used in compiling information about the various controls, particularly the public domain stormwater controls discussed latter in this section.

PERFORMANCE DATA SUMMARY — PROPRIETARY CONTROL MEASURES

Performance data supplied by the manufacturers and extracted from study reports and the professional literature are summarized in Table 3 for proprietary control measures.

Performances are reported in terms of percent removal of total suspended solids (TSS), copper

(Cu), lead (Pb), zinc (Zn), and oil and grease (O&G). These constituents are typically of concern in stormwater runoff and are most often monitored. Other notable removal data are also

Table 2. Summary of Questionnaire Responses

Company Name	Product	Response			Performance Data	Cost Data	Design Criteria	California Installations	Comments
		Quest.	Brochure	Studies					
Jensen Precast	Precast Stormwater Interceptor	Y	Y	Y	Y	(Y)	Y	300+	
Teichert Precast	Precast Interceptor	Y	Y	N	N	Y	(Y)	54	
Ecostar	Oil/Water Separator	N	N	N	N	N	N	0	Out of business
Bay Saver, Inc.	Bay Saver Separation System	Y	Y	1	Y	Y	Y	0	
CSR Hydro Conduit	Stormceptor	Y	Y	Y	Y	Y	Y	52	Many studies
H.I.L. Technology, Inc.	Downstream Defender	Y	Y	Y	Y	Y	Y	0	
Vortech	Vortechs Stormwater Treatment System	Y	Y	Y	Y	Y	(Y)	3	
Kistner Concrete	V2B1	Y	Y	1 ongoing	(Y)	Y	(Y)	0	
CDS Technologies	Continuous Deflective Separation	Y	Y	Y	Y	Y	Y	7	Detailed information
Stormwater Management	StormFilter/CSF Treatment System	Y	Y	Y	Y	Y	(Y)	8	Independ. studies
Envirodrain	Envirodrain (Insert)	Y	Y	N	(Y)	Y	(Y)	25±	
KriStar Enterprises	Fossil Filter (Insert)	Y	Y	Y	Y	Y	(Y)	5000	
Weaver Manufacturing	Hydro-Kleen (Insert)	Y	Y	1 ongoing	(Y)	Y	Y	15	
Abtech Industries	Ultra-Urban Filter (Insert)	Y	Y	Y	Y	Y	(Y)	(on order)	
StormTreat Systems, Inc.	StormTreat	Y	Y	1	Y	Y	Y	0	
Waterlink - Hycore	Romag Stormwater Screen	Y	Y	1	(Y)	Y	Y	0	Combined sewer device - N/A

Y = Reponse received

(Y) = Limited reponse received

N = No reponse received

N/A = Not applicable

Table 3. Performance Comparison Summary for Proprietary Stormwater Structural Control Products

<i>Product</i>	<i>Performance Data (% Removals)</i>						<i>Data Source/ Reference</i>	<i>Notes</i>
	TSS	Cu	Pb	Zn	O&G	Other		
Jensen Interceptor	24	12	13	29	38	Diesel (+16) Motor Oil (+33)	Piner, 1994	1 storm w/ in/out grab samples. (+) = increase in concentration
	63/50	33/25	47/33	26/18	Non-detect	TOC (+19/+15)	Kinnetic, 1996	6 storms monitored w/ in/out flow-weighted composite samples. Grab samples for O&G for 2 storms. Removals for intercepted flow/total flow
Teichert Interceptor								No Studies
Bay Saver Separation System	80 est.						BaySaver, 1998	Field study of 3 storms w/ auto samplers. EMC not computed. Effluent TSS at irreducible levels. Field study planned at U. of Maryland
Stormceptor	80					TKN (41)	Service, 1998	4 storms for TSS; 5 storms for TKN. No significant inlet conc. for others
	26			21		PAH (36)	Greb, 1998	45 storms monitored. Removals based on EMC and total mass
	93					TPH (82)	Environ. Sampling, 1997	3 storm events for TSS; 1 event for TPH. Removals based on EMC
	53	21	51	39	43		Labatiuk, 1997	4 storm events. Removals based on EMC
Downstream Defender								Only reliable data are for sediment analysis. 90% removal of particles > 150µ. Field study planned
Vortechs	80						Vortechnics	Lab test at design operating rate of 24 gpm/ft ²
	84						Vortechnics, 1998	7 storm events. Removals based on EMC
V2B1								Only lab data on sediment removal. Field studies planned
CDS	84						Schwarz, 1999	Lab test. Percent mass capture of sand particles at 125 gpm
	70						Walker, 1999	4700 micron screen not effective for TSS < 75 mg/L
StormFilter	92	65	82	83	81	COD (70) TPH(84)	Stormwater, 1994	7 storm events. Removals based on EMC
	43	33	50	29			Lief, 1998	8 storm events
					74/69		Woodward, 1998	Lab tests with compost and Perlite filter media

Table 3. Performance Comparison Summary for Proprietary Stormwater Structural Control Products (continued)

<i>Product</i>	<i>Performance Data (% Removals)</i>						<i>Data Source/ Reference</i>	<i>Notes</i>
	TSS	Cu	Pb	Zn	O&G	Other		
Enviro-Drain						TRPH – 95 (25gpm) TRPH – 82 (60gpm)		Lab summary sheets only – no report
Fossil Filter					55	Diesel (98.6) Motor Oil (94.8)	Enetch, 1996	Lab test of absorbent exposure study
							Eagle, 1998 Sandine, 1996	Hydraulic capacity tests confirmed rating of 12 gpm /LF
					41	N&P increased slightly	Ambient, 1997	1 storm event w/ composite samples
	32/38	18	46	24/26		Diazinon (34/+4) Clorpyrifos (69/	Larry Walker, 1998b	Results from 2 storm events
Hydro-Kleen								Manufacturers field study indicates non-detect levels – no report. Study in progress by CSUC
Ultra-Urban Filter					83		AbTech , Note 1	Lab test with simulated stormwater
					91		AbTech , Note 2	Lab test repeated with unit after 2 months in field
							AbTech , Note 3	lab leaching test indicated no sheen in leachate with average concentration of 1.6 mg/L oil
StormTreat	95		65	90		TPH –90 TP – 89 TDN – 44 COD – 75 FC- 83	Allard, 1999	4 storms sampled. Types of samples or storm characteristics not indicated
	99		77	90		TPH –90 TP – 89 TDN – 44 COD – 82 FC – 97	Horsely, 1995	5 storms sampled. Types of samples or storm characteristics not indicated

summarized in the respective tables along with notes of interest regarding the studies from which the data were obtained. For sand filters there are no performance data for closed vaults. Nonetheless, as closed vaults are essentially underground basins, the data from open basins should represent the expected performance of closed vaults.

PERFORMANCE DATA SUMMARY — PUBLIC DOMAIN CONTROL MEASURES

Performance of public domain control measures, sand filters and grass swales, is of interest, as their performance is used as a basis for comparing the performances of the proprietary devices. Performance data for public domain control measures extracted from the professional literature are summarized in Table 4. The performances of grass swales and sand filters were evaluated with respect to TSS and zinc. TSS was chosen because of the preponderance of data. It is the most frequent constituent measured in all studies of stormwater treatment control measures, and serves as a surrogate for the pollutants that in stormwater tend to be primarily in the particulate form, like petroleum products, pesticides, lead, chromium, and phosphorus. Zinc was selected to represent the more soluble constituents, including itself as well as copper, cadmium, and the various nitrogen forms. Also, of the metals, zinc is typically present in runoff in concentrations sufficiently above the detection limit to allow meaningful evaluations of removal efficiency.

Plotted in Figures 2 and 3 are the TSS and zinc removal data for grass swales, respectively. Plotted in Figures 4 and 5 are the TSS and zinc removal data for sand filters, respectively. Efficiency is plotted as a function of influent concentration. This general relationship has recently been recognized (Bell, 1995) for sand filters but appears to exist for other treatment BMPs as well, like grass swales and wet ponds. Figures 2 through 5 clearly establish this fact. Presented in each of Figures 2 through 5 are two types of data points: individual storms and the overall calculated average efficiency in each study.

Shown in Figures 2 and 4 is a line called the “Line of Comparative Performance©”, developed by Dr. Gary Minton of Resource Planning Associates. The line is a reasonable first approximation of the expected performance of public domain control measures with respect to the removal of TSS. The expectation is that data points must fall above and to the left of the line: this is loosely defined as acceptable performance. The line was developed from an evaluation of the performance data of several treatment systems studied in western Washington:

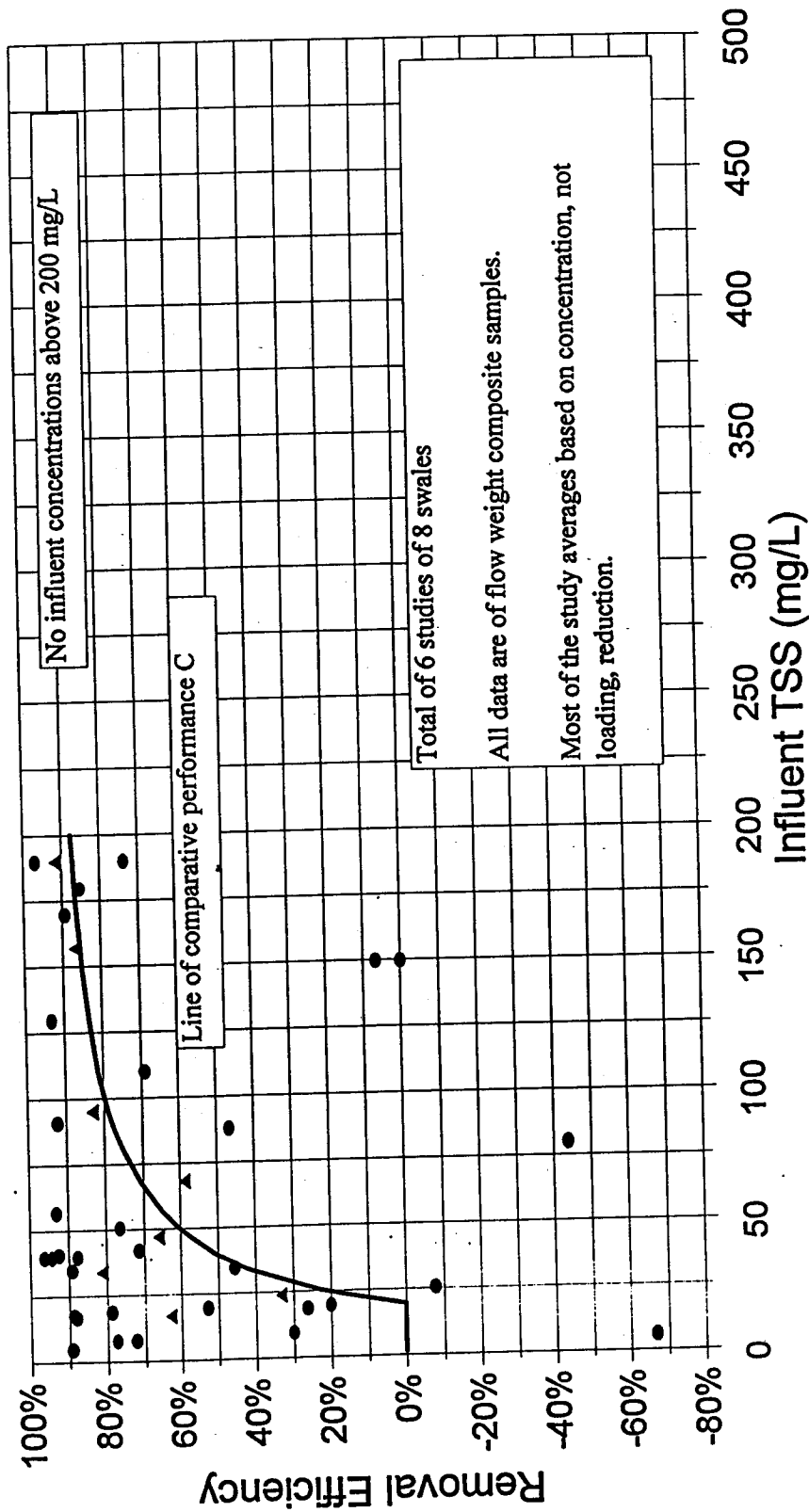
Table 4. Performance Comparison Summary for Selected Public Domain Stormwater Structural Controls

<i>Product</i>	<i>Performance Data (% Removals)</i>						<i>Data Source/ Reference</i>	<i>Notes</i>
	TSS	Cu	Pb	Zn	O&G	Other		
Grass swale	83	46	67	63	75	TP-29;FC-(70)	Khan, 1992	200' swale, 6 storms, flow weight composite, aggregate removal.
	72	10	25	15	49	TP-50; FC-64	Khan, 1992	100' swale, 6 storms, flow weight composite, aggregate removal.
	68	42 (21)	62			TN-31; TP 4.5	Goldberg, 1993	8 storms, flow weight composite, aggregate removal, (dissolved).
	67	-35	6	-3		TP-39	King, 1995	15 storms, flow weight composite, aveages of storms, wetland veg
	87,85		17,41	91,75		TOC-51,53 FC-neg	Barrett, 1998	Two areas, not a swale but vegetated area between freeway lanes, infiltration significant factor.
	81	56	50	69		TN-52;TP-17 Cr-37	Schueler, 1994(a)	11 storms, swale had standing water pool
	87	89	90	90		TN-84; TP-83 Cr-88	Schueler, 1994(a)	16 storms
	65	28	41-55	49		TKN-17; TP-41 Cr, 12-16	Schueler, 1994(b)	Swale 1 (Virginia), 9 storms
	-85	14	18-92	47		TKN-9; TP-12 Cr, 22-72	Schueler, 1994(b)	Swale 2 (Maryland), 4 storms
	98	62-67	67-94	81		TKN-48; TP-18 Cr, 51-61	Schueler, 1994(b)	Swale 3 (Florida), 8 storms, high removals may be due to infiltration
60	66 (0)	62	94(82)		TP-40	Evans, 1994	2 storms, filter swale with lime included and underdrain, (dissolved)	
Sand filter basin	95	76 (38)	73	96 (77)		TN-23; TP-67	Shapiro, 1998	18 storms, data for 1997 wet season, composite samples, diverted flow only; dissolved metals in parens, efficiencies are of treated flow excluding bypass. Including bypass reduced TSS removal to 84%
	97	66	80	94			Shapiro, 1998	Data for 1996 season
	42					TP-55	King Co.	3 storms, 2 quite small, grab samples, filter follows swale instead of sed basin
	81					TP-95	Harper, 1993	6 storms
	89	72	79	76		TN-17; TP-59 BOD-51;TOC-(4) FC- neg.	Austin, 1996	7 storms

Table 4. Performance Comparison Summary for Selected Public Domain Stormwater Structural Controls (Continued)

<i>Product</i>	<i>Performance Data (% Removals)</i>						<i>Data Source/ Reference</i>	<i>Notes</i>	
	TSS	Cu	Pb	Zn	O&G	Other			
Sand filter basin	88	29	71	50		TOC-52; TN-37 TP-21; FC-45	Austin, 1996	Highwood unit; efficiencies of all four units exclude overflows	
	79	44	90	79		TOC-49; TN-34 TP-60; FC-40	Austin, 1990	BCSM unit	
	87	60	81	80		TOC-62; TN-32 TP-61; FC-37	Austin, 1990	Jollyville unit	
	92	80	89	91		TOC-93; TN-71 TP-80; FC-83	Austin, 1990	Brodie Oaks unit	
Sand vaults	No studies								
Lineal sand filter (Delaware)	79	25		91		TOC-66; TN-47 TP-63	Bell, 1995	20 storms for most constituents, found filters can at times become anaerobic.	
	83	22		33	84	TP-33	Horner, 1995	Filter 1, 14 storms	
	8	31		69	69	TP-20	Horner, 1995	Filter 2, 6 storms, much lower influent TSS than Filter 1	

FIGURE 2 GRASS SWALES TSS Removal



May 1

● Individual storm ▲ Study average

FIGURE 3 GRASS SWALES Zinc Removal

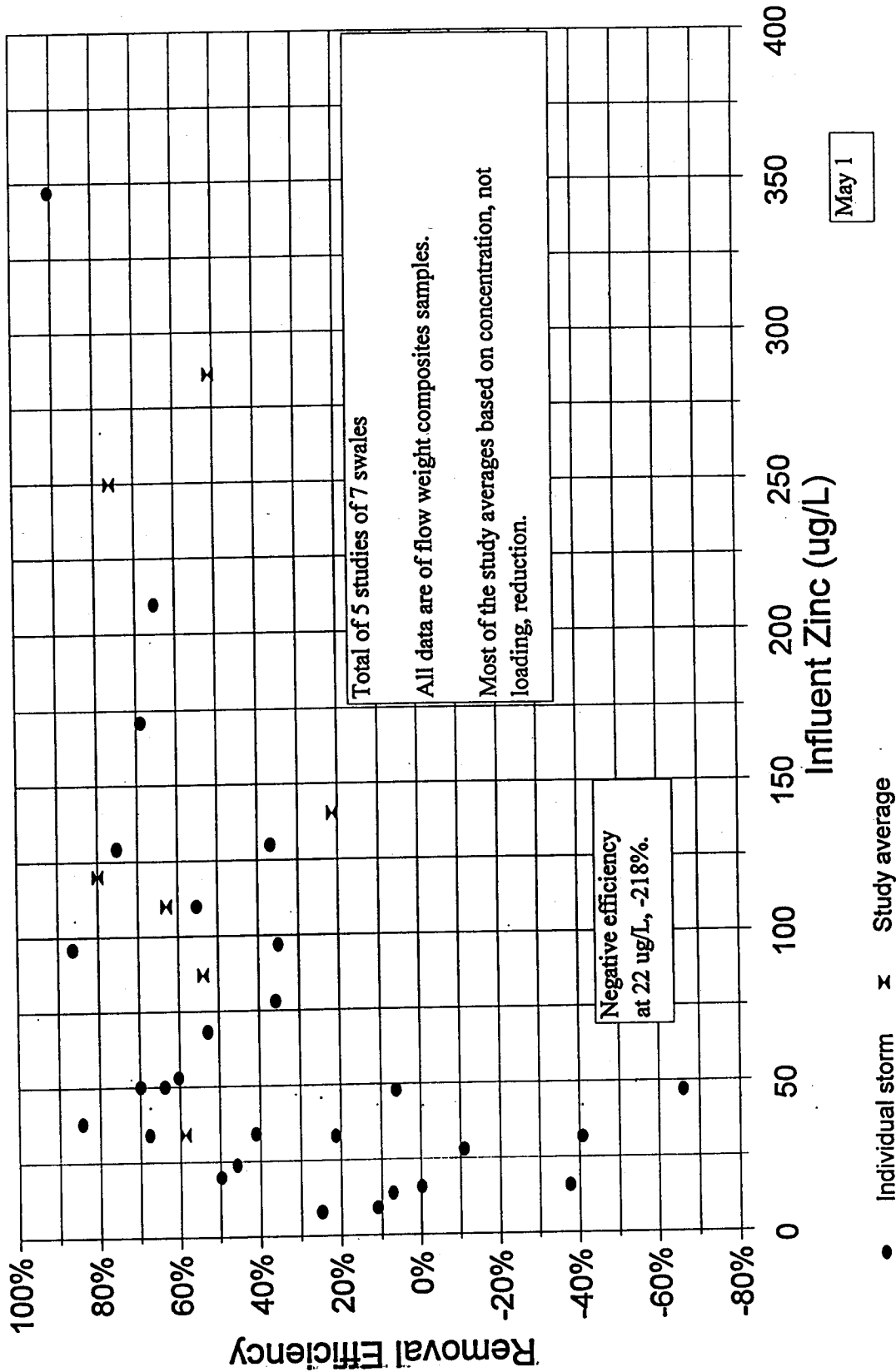
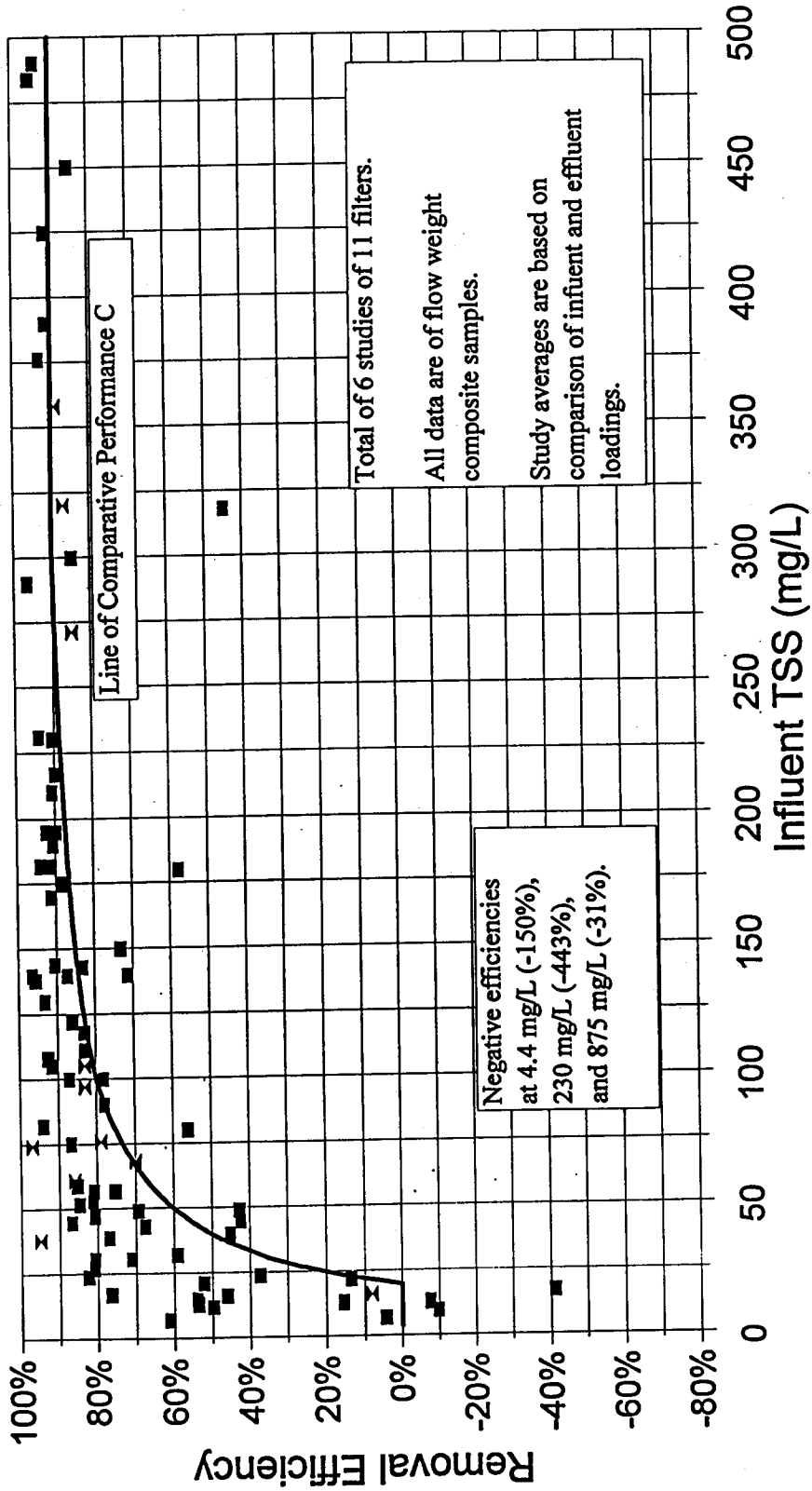


FIGURE 4 SAND FILTERS

TSS Removal

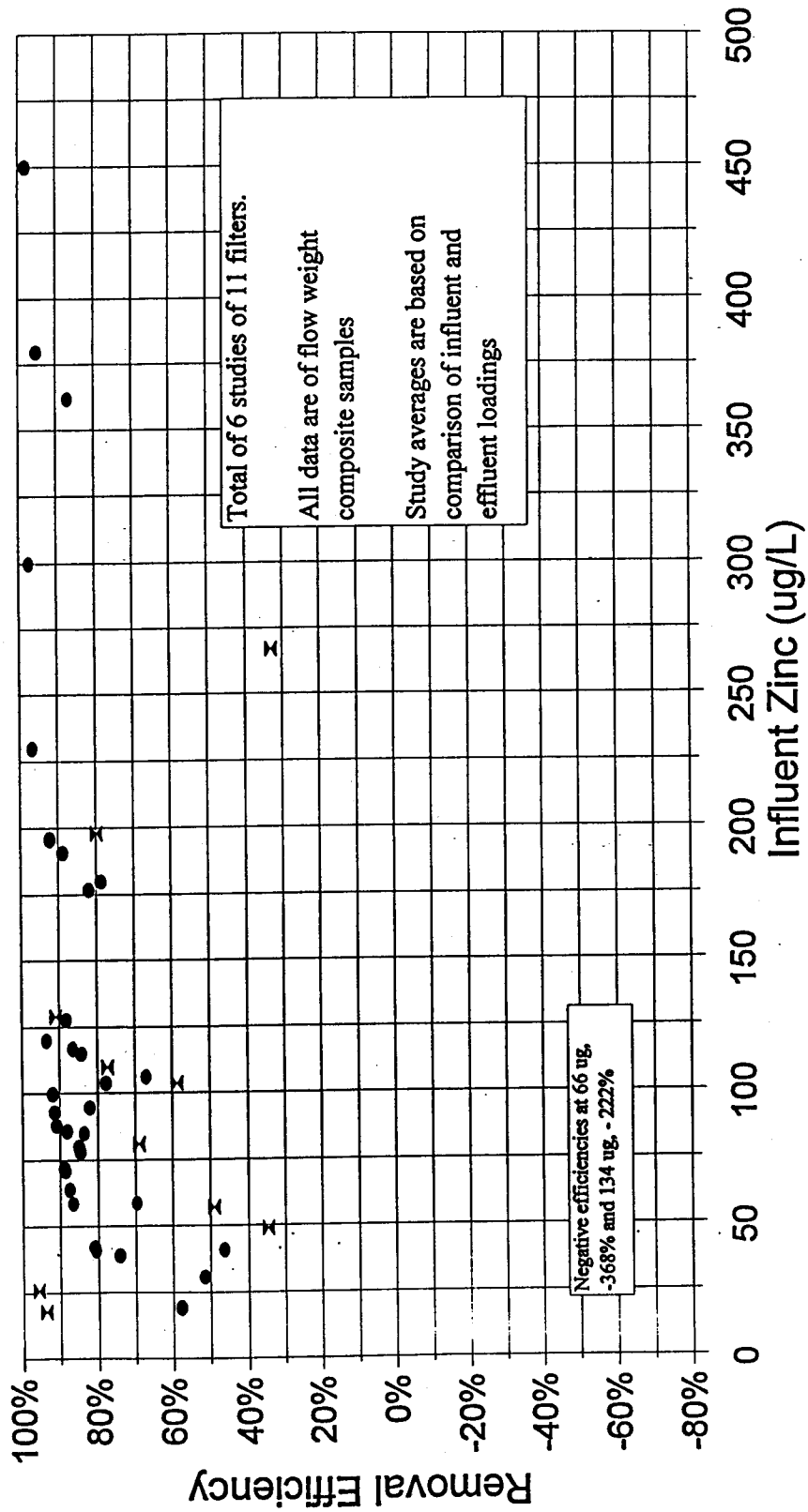


■ Individual storm x Study average

May 1

FIGURE 5 SAND FILTERS

Zinc Removal



● Individual storm x Study average

May 1

grass swales, wet ponds\wetlands, and sand filters. These lines are useful in evaluating the performance of proprietary control measures.

The results of the analysis of data from western Washington are considered applicable to the Sacramento area because of similarities in rainfall characteristics between the two regions, in particular average rainfall intensity (0.04"/hour in Seattle; 0.05"/hour in Sacramento), which appears to be a significant determinant of the TSS concentration in untreated stormwater (Roundtree, 1995). This general observation can be seen in the comparison of data from three regions: Seattle, Los Angeles and Austin. In a recent analysis of data collected for Caltrans District 7, the mean TSS concentration was determined to be 97 mg/L (Brown and Caldwell, 1997). A similar study in the Seattle area (Merrill, et al., 1989) determined a mean concentration of 71 mg/L from highways. In contrast, stormwater from a freeway in the Austin area had a median concentration of 202 mg/L (Barrett, et. al., 1998 and pers. comm.) where the average rainfall intensity is 0.12"/hour. Median values are usually lower than mean values. Unfortunately, there are no data in California on control measure performance to compare to the data that have been generated in western Washington.

Grass swales

Data were obtained for eight swales from six studies as listed in Table 5. However, only the swales studied by Khan (1992) were specifically designed for the treatment of stormwater. Four swales treated stormwater from retail commercial or residential areas; two treated stormwater from an urban freeway, and the drainage areas of two swales was not identified. TSS data are plotted in Figure 2 and zinc data in Figure 3.

Table 5. Performance Studies of Grass Swales

STUDY	LOCATION	TYPE OF SWALE	LAND USE	STUDY PERIOD
Barrett (1995)	Austin, Texas	Wide grassed area (two) between freeway lanes	Urban freeway	1994
Goldberg (1993)	Seattle, Washington	Designed grass swale, 570 ft. length	Residential	1992
Khan (1992)	Mountlake Terrace, Washington	Designed grass swale, 200 ft length.	Residential	1991
King County (1995)	Issaquah, Washington	Designed wetland swale, 350 ft. length.	Residential	1994
Oakland (1983)	Durham, New Hampshire	Designed grass swale, 200 ft length.	Supermarket	1982
Schueler (1994)	Central Florida	Two swales of 210 ft. length, one with wet pool, one with high infiltrative bottom.	Not provided	1987

Figures 2 and 3 suggest that the performance of grass swales is less consistent than sand filters (see Figures 4 and 5). A greater percentage of the data points fall to the right of the line in Figure 2, in comparison to Figure 4. There is considerably more scatter in zinc removals in Figure 3 in comparison to Figure 5. It is likely that the greater scatter is due to the variation in the designs of the swales that were evaluated, and the condition of the vegetation. Frequently, the design procedure does not take into consideration the need to have a wide swale with a flat bottom (rather than curved). A Manning's "n" on the order of 0.20 to 0.25 should be used rather than 0.05 to 0.07, the value typically used to size grass channels (Khan, et al., 1992). Swales that are too narrow result in channelized flow with water depths that exceed the height of the grass. To be effective at pollutant removal, the depth of the stormwater must not exceed the height of the grass. These conditions were likely present with the swale that was studied by Welborn et al. (1987). The authors evaluated a large swale, in terms of both length and width, treating stormwater from a medium density residential development. Essentially no pollutant removal

occurred in 19 storms. The authors provided no insights as to the reason(s) for the poor performance. However, pictures were provided in the report, which show a swale with a pronounced curved or sloped, rather than flat, bottom and grass that is closely cropped although apparently thick and in good health.

Sand Filters

Data have been obtained of 11 filters from six studies as listed in Table 6. Eight filters were of the open basin type and three were lineal filters. Nine filters treated stormwater from retail commercial or residential areas; two treated stormwater from an industrial site. TSS data are plotted in Figure 4 and zinc data in Figure 5.

The data in Figure 4 indicate that sand filters are effective in the removal of TSS and are generally consistent in their performance from storm to storm, as the vast majority of data points tend to fall on or to the left of the Line of Comparative Performance. There does not appear to be differences in performance between the three regions represented by the data (western Washington, Austin, and Washington, D.C.). However, negative efficiencies have been observed in individual storms as noted in Figure 4 (from Horner et al., 1995 and Welborn, et al., 1987). In Washington, D.C., anecdotal observations of vault filters suggests that sediments previously deposited on the filter surface are scoured during large storms (Karikari, pers. comm.). Vaults, however, do not have bypasses, nor do lineal sand filters, except to the extent that inflow is limited by the capacity of the grate. However, the sand basins in Austin are off-line, suggesting that scour should not be an issue. However, negative removals were observed by Welborn, et al. (1987) in large storms.

The pattern of removal efficiency of zinc shown in Figure 5 is similar to TSS. More scatter in the data points might be expected given that a significant fraction of zinc is in the soluble form, which presumably would not be removed by sand. However, in two studies it was found that sand does remove dissolved zinc (Shapiro, 1998; Welborn, et al, 1987). The one significant outlier in Figure 4 (study average of 31% at influent concentration of 267 $\mu\text{g/L}$) was from the study by Horner et al. (1995) of lineal filters at an industrial site. The rather low efficiency is the result of the mathematical effect of one high-flow incident with a negative efficiency. Were this one incident excluded, the zinc removal would have been 87% over the test period.

Table 6. Performance Studies of Sand Filters

STUDY	LOCATION	TYPE OF FILTER	LAND USE	STUDY PERIOD
Austin (1990)	Austin, Texas	Open filter basin preceded by dry pond.	Residential - 2 filters Shopping mall- 1 filter Roadway - 1 filter	1984-1989
Austin (1996)	Austin, Texas	Open filter basin preceded by dry pond.	Shopping mall	1993-1995
Welborn (1987)	Austin, Texas	Open filter basin preceded by dry pond.	Shopping mall	1982-1984
Bell (1995)	Alexandria, Virginia	Lineal filter which contains a lineal wet vault.	Rental car parking lot	1994
Shapiro (1998)	Seattle, Washington	Open filter basin preceded by wet vault	Residential	1995-1997
Horner (1995)	Seattle, Washington	Lineal filter which contains a lineal wet vault.	Waterfront bulk cargo yard.	1994
King County (undated)	Seattle, Washington	Open sand filter basin preceded by grass swale.	Shopping mall	1993

COST DATA SUMMARY FOR PROPRIETARY CONTROLS

Cost data provided by manufacturers of proprietary control measures, including purchase, installation and annual operation and maintenance costs are summarized in Table 7. The products are listed alphabetically by type. Many of the control measures are available in several sizes and unit flow capacities. The costs of the various sized units and their associated flow capacities are listed in Table 7. To provide a means of comparing costs, a normalized, or unit cost, in terms of dollars (purchase plus installation) per cfs of rated capacity was computed for each control measure in three flow capacity ranges (approximately 0.1, 1.0, and 10 cfs). The normalized costs are reported in Table 7. A review of these unit costs reveals that, in general, drain inlet inserts cost in the range of \$3,000 to \$5,000 per cfs flow capacity, while the other end-of-pipe devices, with the exception of media filters, cost in the range of \$10,000 to \$20,000 per cfs flow capacity. Media filters cost in the range of \$40,000 to \$75,000 per cfs flow capacity, but these devices target removal of dissolved constituents and provide a higher level of treatment. The unit cost were developed only for the purpose of general comparison and were not used as a basis for determining acceptance of the products. It is recognized that product performance is not a linear function of flow. A more comprehensive cost comparison may consider cost per annual flow volume treated. Such an analysis is beyond the scope of this report.

Costs of public domain control measures were not evaluated as part of this report. In most cases the cost of grass swales will be incorporated into the cost of landscaping a particular site. Some additional engineering costs may be incurred to properly size the swales for the design flow conditions. Sand filters are installed treatment devices, similar in this respect to the proprietary devices. The cost of sand filters will vary with size and complexity of construction.

Table 7. Cost Comparison Summary for Proprietary Stormwater Structural Control Products

<i>PRODUCT</i>	<i>COMPANY NAME</i>	<i>TYPE OF DEVICE</i>	<i>APPLICATION/ LIMITATIONS</i>	<i>UNIT FLOW CAPACITIES</i>	<i>COSTS, \$</i>			<i>UNIT COST</i>
					<i>Purchase</i>	<i>Install</i>	<i>O&M/yr</i>	<i>\$/cfs</i>
Jensen Interceptor	Jensen Precast	Gravity separator	Removes particulates and floatables. Separate bypass required for flow > capacity	0.17 – 0.22 cfs	\$2000 – 2750			\$11,800
				0.26 – 0.33 cfs	\$3300 – 4100			
				0.44 - 0.55 cfs	\$55 00 – 6900			
				0.67 - 0.89 cfs	\$8300 – 11,000			\$12,400
				1.1 cfs	\$13,7500			
Teichert Interceptor	Teichert Precast	Gravity separator	Removes particulates and floatables. Separate bypass required for flow > capacity	0.54 cfs	\$3000	85%	\$500 - \$3000	\$8,700
				0.85 cfs	\$4000	85%		
				1.28 cfs	\$5000	85%		
Bay Saver Separation System	Bay Saver, Inc.	Gravity separator	Removes particulates and floatables.	2.4 cfs	\$6,500	25-40%	\$500+	\$3,700
				7.2 cfs	\$10,500			\$1,750
				11.0 cfs	\$14,000			
Stormceptor	CSR Hydro Conduit	Gravity separator	Removes particulates and floatables	0.17 cfs	\$4500	25%	\$500 – 1000	\$33,100
				0.635 cfs	\$7830 – 11,130	25%		
				1.06 cfs	\$14,390-17,200	25%		\$16,700
				1.78 cfs	\$22,700-26,600	25%		
				2.47 cfs	\$34,570	25%		

Table 7. Cost Comparison Summary for Proprietary Stormwater Structural Control Products (continued)

PRODUCT	COMPANY NAME	TYPE OF DEVICE	APPLICATION/ LIMITATIONS	UNIT FLOW CAPACITIES	COSTS, \$			UNIT COST
					Purchase	Install	O&M/yr	\$/cfs
Downstream Defender	H.I.L. Technology, Inc.	Swirl concentrator	Removes particulates and floatables.	3.0 (0.8) cfs ¹	\$10,300	25% (assumed)	\$500+	\$16,100 ²
				8.0 (2.0) cfs ¹	\$13,300			
				15.0 (3.8) cfs ¹	\$20,000			
				25.0 (6.2) cfs ¹	\$26,000			\$5,200 ²
Vortechs Stormwater Treatment System	Vortechics	Swirl concentrator	Removes particulates and floatables	1.6 (0.4) cfs ¹	\$10,500	25-50%	\$400+	\$36,750 ²
				2.8 (0.7) cfs ¹	\$12,000			
				4.5 (1.1) cfs ¹	\$14,000			\$17,500 ²
				6.0 (1.5) cfs ¹	\$16,000			
				8.5 (2.1) cfs ¹	\$18,000			
				11.0 (2.8) cfs ¹	\$20,000			
				14.0 (3.5) cfs ¹	\$24,000			
				17.5 (4.4) cfs ¹	\$30,000			
25.0 (6.2) cfs ¹	\$40,000	\$9,000 ²						
V2B1	Kistner Concrete	Swirl concentrator	Removes particulates and floatables. Head loss limitation	2.8 (0.7) cfs ¹	\$8,000-11,000	25%	Variable	\$17,000 ²
				4.3 (1.1) cfs ¹	\$9,000-12,000			\$11,900 ²
				6.2 (1.5) cfs ¹	\$11,000-14,000			
				8.5 (2.1) cfs ¹	\$14,000-18,000			
				11.1 (2.8) cfs ¹	\$19,000-23,000			
				17.4 (4.4) cfs ¹	\$25,000-30,000			
25.2 (6.3) cfs ¹	\$30,000-40,000	\$6,900 ²						

1. Capacities in parentheses indicate recommended design capacity for 80 percent TSS removal

2. Based on recommended design capacity for 80 percent TSS removal

Table 7. Cost Comparison Summary for Proprietary Stormwater Structural Control Products (continued)

PRODUCT	COMPANY NAME	TYPE OF DEVICE	APPLICATION/ LIMITATIONS	UNIT FLOW CAPACITIES	COSTS, \$			UNIT COST	
					Purchase	Install	O&M/yr	\$/cfs	
Continuous Deflective Separation (CDS)	CDS Technologies	Deflection screen	Removes trash, particulates and floatables	1.1 cfs	\$9,600	\$3,400	\$400+	\$11,800	
				3 cfs	\$15,700	\$7,300	\$400+		
				9-11 cfs	\$34,500	\$40,500	\$400+	\$7,500	
				26 cfs	\$61,800	\$63,200	\$525+		
				62 cfs	\$121,800	\$128,200	\$675+		
				148 cfs	\$202,600	\$217,400	\$1200-1450		
				270 cfs	\$303,750	\$293,250	\$1200-1450		
				300 cfs	\$332,500	\$297,500	\$1200-1450		
StormFilter/CSF Treatment System	Stormwater Management	Cartridge Media filter	Removes particulates, O&G, and dissolved constituents. Pretreatment recommended	0.13 cfs	\$8,000	15-20%	\$500-4500	\$73,800	
				0.17 cfs	\$11,500				
				0.30 cfs	\$15,300				
				0.60 cfs	\$24,600				
				0.84 cfs	\$28,000				
				1.0 cfs	\$33,000				
Envirodrain	Envirodrain	Drain inlet insert media filter	Removes petroleum hydrocarbons.	0.4 cfs	\$1,800	No Charge	\$3/unit filter replace	\$4,500	
				0.6 cfs	\$2,100				
				0.75 cfs	\$2,300				\$3,100
				Other sizes available					
Fossil Filter	KriStar Enterprises	Drain inlet insert media filter	Removes petroleum hydrocarbons. Unsuitable for large amounts of sediment or debris and snow areas	12 gpm /LF of filter		\$50 – \$65 /unit	\$600 – \$720		
				Circular units – 18" to 36" diam	\$450 – 500				
				Square units – 24" x 24" to 48" x 48"	\$425 – 700			\$3,100	

Table 7. Cost Comparison Summary for Proprietary Stormwater Structural Control Products (continued)

PRODUCT	COMPANY NAME	TYPE OF DEVICE	APPLICATION/LIMITATIONS	UNIT FLOW CAPACITIES	COSTS, \$			UNIT COST
					Purchase	Install	O&M/yr	\$/cfs
Hydro-Kleen	Weaver Manufacturing, LLC	Drain inlet insert dual-media filter	Removes hydrocarbons, organics and complexed metals.	0.10 cfs	\$960	Drop-in installation		\$9,600
				0.17 cfs	\$1120			\$3,900
				0.40 cfs	\$1520			
				0.50 cfs	\$1920			
				0.62 cfs	\$2400			
				0.9 cfs	\$3500			
				High Sediment Unit				
				0.2 cfs	\$2280			\$11,400
				0.24 cfs	\$2880			
	0.31 cfs	\$3600						
	0.44 cfs	\$4200	\$9,550					
Ultra-Urban Filter	Abtech Industries	Drain inlet insert media filter	Removes trash, particulates and floatables. Drain inlet must be larger than module size	35 gpm /module Module size: 13.75"x14"x23"	\$250/module	\$100+ based on multiple installation	\$400+	\$4,500
StormTreat	StormTreat Systems, Inc.	Gravity separator +wetland plant	Removes particulates, O&G, and dissolved constituents. Equalization required upstream	14,000 gal/unit	\$5,600/unit	\$750-1,500 per unit		not comparable

EVALUATION OF PROPRIETARY CONTROL MEASURES

The relevant questions are whether the available performance data for each of the proprietary control measures are acceptable in terms of collection and analytical protocols and whether the products perform as well as sand filters and grass swales, the two public domain control measures that are most commonly used at this time in the Sacramento region. Each of the proprietary control measures considered in the report was evaluated using the screening process described below. Those products that pass the screening process (i.e. provide acceptable data and are reasonably equivalent in performance to the public domain control measures) are considered acceptable for implementation as a stormwater control measure without condition and are recommended as devices to be accepted by the Permittees. Those products that do not pass the screening process are recommended as either “conditionally acceptable” or “not acceptable”, depending on the deficiencies in the performance data.

Screening Criteria

Screening criteria, including sample collection and analysis protocols and data reporting protocols, were developed to determine the acceptability of each of the proprietary control measures. This comprehensive set of protocols is presented in Appendix A. These protocols are recommended as requirements to be adopted by the Permittees for acceptance of any future performance evaluation reports submitted by manufacturers of proprietary control measures seeking approval of their products for use in the Sacramento jurisdiction. Review of the studies currently available for the proprietary control measures considered in this report revealed that none of the products provided all of the requisite information listed in these comprehensive protocols. Because of the lack of this information, none of the technologies is considered acceptable at this time for placement on an “Acceptable” list. Consequently, a less-stringent set of criteria, as described in the Methods section and in Appendix A of this report, was developed to determine whether a product should be recommended as “conditionally acceptable” or “not acceptable” at this time.

The selection of the screening criteria was judgmental, based on what is reasonable given the number of studies and information about sand filters and grass swales. A review of Tables 5

and 6 suggest that the specification of two sites with 10 storms at each site is reasonable. The storm specifications outlined above are to ensure that the storms that were monitored are comparable to typical storms of the Sacramento region and that the range of storms brackets the City and County design storm for on-site control measures (2-year/6 hour storm).

Screening Results and Discussion

The available performance evaluation studies for each of the proprietary control measures were evaluated using the screening criteria described in preceding subsection. Results of this screening process are summarized in Table 8. Discussions of each of the control measures are presented below including recommendations regarding the products' current acceptability as stormwater control measures for Sacramento Stormwater Permittees. A summary of recommendations for product acceptance and follow-up is presented in Table 9.

Table 8. Summary Evaluation of Products

Product	Data Source/ Reference	TSS Removal %	Land Use	No. of Storms	Sample Type	Storm Depth Range (inches)	Storm Duration Range (hours)	Storm Intensity Range (in/hour)	Comments
Screening Criteria		See Figure 2 and 4		10	Flow wt. composites	0.15 to 1.50	2 to 24	0.05 to 0.25	See Appendix A
Jensen Interceptor	Piner, 1994	24		1					
	Kinnetic, 1996	50	Employee parking lot	6	Flow wt. composites	0.63 to 1.47	5 to 31	0.02 to 0.21	Construction impacts
Teichert Interceptor									No field studies have been done
BaySaver	BaySaver, 1998	80	School parking lot	3	Multiple grabs	0.10 to 1.25	4 to 5	0.06 to 0.10	Two storms were very small
Stormceptor	Service, 1998	80	Parking lot in a park	6	Composites	0.05 to 0.77"	8 to 14	0.01 to 0.22	Requisite number of studies have been done, although the required number of storms has been met in only one study.
	Greb, 1998	26	Maintenance shop yard	45	Flow wt composites	0.02 to 1.31"	Meets criteria	Meets criteria	
	Environmental, 1997	93	Industrial parking lot	3	Composites	0.18 to 0.25	3 to 7	0.03 to 0.06	
	Labatiuk, 1997	53	Shopping mall	5	Composites	Not in report	Not in report	Not in report	
Downstream Defender									No field studies have been done
Vortechs	Vortechics 1998	84	Office parking lot	7	Time composites				Only one study has been conducted
V2B1									No field studies have been done
CDS	Walker, 1999	70	Mixed	15	Multiple grabs	Not in report	Not in report	Not in report	CDS model had 4700 um screen that was not effective at influent TSS<75 mg/L.
StormFilter	Stormwater 1994	92	Arterial & residential	15	Flow wt composites	0.17 to 1.47	5 to 24	Meets criteria	Study was of a flat bed system, not the cartridge.
	Lief, 1998	43	Roadway	10	Flow wt composites	Not in report	Not in report	Not in report	Study was of a flat bed system, not the cartridge. Efficiency is just the filter; excludes pretreat unit.

Table 8. Summary Evaluation of Products (continued)

Product	Data Source/ Reference	TSS Removal %	Land Use	No. of Storms	Sample Type	Storm Depth Range (inches)	Storm Duration Range (hours)	Storm Intensity Range (in/hour)	Comments
Envirodrain									No field studies have been done
Fossil filter	Ambient, 1997	0	Street	1	Composites	Not in report	Not in report	Not in report	Influent TSS was only 9 mg/L.
	Larry Walker, 1998	18	Mall	2	Flow wt. composites	0.04 to 0.40	2 to 7	0.02 to 0.06	
Hydro-Kleen									No field studies have been done
UltraUrban Filter									One field study did not include TSS test
StormTreat	Horsely, 1995	99	Parking lot	5	Single influent grab, multiple effluent grabs	Not in report	Not in report	Not in report	Only one study has been conducted.

Jensen Interceptor

This system is essentially a wet vault, where sedimentation is the dominant pollutant removal mechanism. This type of device, therefore, should be able to provide the desired level of performance, if it is sized and configured properly. Using the manufacturer's sizing guidelines, this device is generally designed to achieve only coarse pollutant removal.

Of the two studies of this product reported by the manufacturer, the Piner (1994) study did not provide sufficient data to draw any conclusions. The study by Kinnetic Laboratories (1996) provided data from six storm events, but the influent TSS concentrations may have been influenced by upstream construction activities during one or more storm events. Further, the study authors reported that "bypasses of the interceptor were common during most storm events". To account for the untreated bypass flow, the overall TSS removal efficiency was adjusted from 63 to 50 percent. The relatively low observed removal efficiency (compared to the public domain control measures) and the high frequency of bypassing suggests that this device may be undersized.

An issue with the use of wet vaults is their inability to remove dissolved pollutants; further, Kinnetic (1996) found that dissolved cadmium increased significantly between the influent and the effluent. Dissolved zinc increased in five of the six storms sampled, although the differences between the influent and effluent were not found to be statistically significant. The increase in concentrations of dissolved metals may be due to release of soluble metal species under anaerobic conditions in the pooled water. This hypothesis should be studied further.

The reported studies do not meet the established criteria (see Appendix A) in terms of sampling and documentation protocols.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol.
2. Insufficient number of sites studied with proper protocol.
3. Sizing criteria questionable.

Teichert Interceptor

The above observations for the Jensen Interceptor are applicable to the Teichert Interceptor.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.
3. Sizing criteria questionable

BaySaver

Only one field study has been conducted and only three storms were sampled. Further, two of the storms were extremely small.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

Stormceptor

The manufacturer has conducted several other field studies not listed in Table 3. However, the sampling was limited to a few grab samples during each event, and therefore are not reported in Table 3. The minimum criteria are nearly met (four studies, but meeting the 10 storm criterion at only one site). However, performance is highly variable as indicated in Table 3. Two observations of significant note: in the study by Greb et al. (1998) in which 45 storms were sampled, the aggregate removal efficiency for TSS over the 45 storms was only 26%, as reported in Table 3. However, the study has been criticized by Stormceptor because it was found that salt from a salted sand pile (used for road deicing) was entering the Stormceptor, causing a dense layer of water in the lower half of the device. It therefore could be argued that this caused the low efficiency. However, at least 14 storm events occurred prior to the outset of the dense lower layer and for these 14 events the overall TSS removal efficiency was still only about 35%.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Inadequate performance

Downstream Defender

No field studies have been conducted. Performance evaluation is limited to a laboratory study in which sediment was added to potable water.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

Vortechs

Only one study has been conducted. Although the observed performance is promising, the study does not meet the 10 storm requirement.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

V2B1

No field studies have been conducted. Performance evaluation is limited to a laboratory study in which sediment was added to potable water.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

CDS

As previously indicated, CDS needs to offer a screen with much smaller openings. CDS is currently experimenting with a 1200 micron screen. CDS has conducted many studies but these have focused on the removal of gross solids. Only the study cited in Table 8 focused on the removal of pollutants, specifically TSS, phosphorus and nitrogen. Evaluation of 15 storms found that about 70% of the TSS was removed over all storms monitored. However, the CDS model, which employed a 4700 micron screen, was relatively ineffective at reducing the TSS when the influent concentration was less than 75 mg/L. Given the relatively mild storms occurring in Sacramento, and the relationship between TSS concentration and runoff rate, it is possible that for Sacramento, the TSS concentration of untreated stormwater will be frequently less than 75 mg/L.

Recommendation: Not acceptable.

Deficiencies:

1. Inadequate performance

StormFilter

Two studies are reported in Table 8, both of which meet the criteria, although not all of the rainfall information is available. Figure 6 presents a plot of the data from the two studies. The data from Stormwater Management (1994) shows satisfactory performance. The data points from Leif (1998) fall to the right side of the Line of Comparative Performance[®]. However, Leif (1998) evaluated the performance of only the filter unit, that is, the influent sample was taken at the entrance of the filter rather than the vault in which the filter was placed. Hence, the pretreatment efficiency of the forebay was not included. Taking this aspect into consideration, it is likely the data points would have fallen to the left of the comparative performance line.

A more significant consideration is that the two cited studies are of the flat bed system, rather than the cartridge system, which is now used. It therefore may not be appropriate to apply the findings from flat bed systems to the cartridge system as the unit flow rates (gpm/ft² of filter surface) may differ. The flat bed systems have 18" of media where as the thickness of media in the cartridge systems is only 7 to 9".

Stormwater Management, Inc has conducted several studies of the cartridge system, with several types of media: leaf compost, perlite, and either of these two media with a fabric. However, only grab samples, typically only one of the influent and one of the effluent, have been taken during these studies. While the two comprehensive studies have been of the flat-bed type system rather than the current cartridge system, the performance and studies are satisfactory.

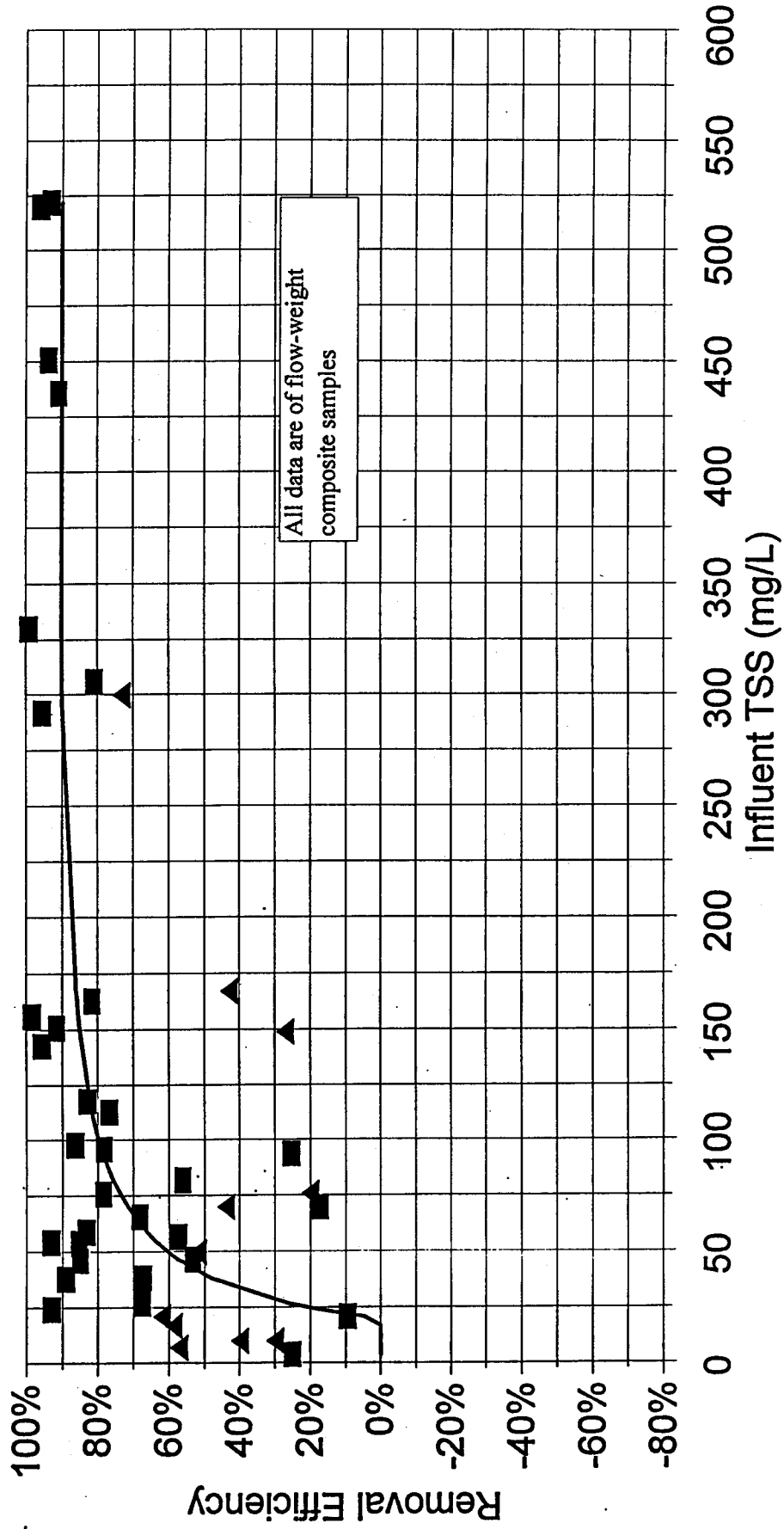
Recommendation: Conditionally acceptable.

Deficiencies:

1. Insufficient number of sites studied with proper protocol using cartridge system

FIGURE 6 STORMFILTER

TSS Removal - Flatbed System



May 4

■ 185th St. prototype ▲ Leif study

Envirodrain

No field studies of performance have been conducted.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

Fossil Filter

Two studies have been conducted that included consideration of the removal of TSS. With one study the removal efficiency was 0%. However, the influent TSS was only 9 mg/L and therefore further reduction would not be expected. Regardless, only one storm was sampled.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

Hydro-Kleen

No field studies of performance have been conducted.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

UltraUrban Filter

An extensive field study carried out in Santa Monica demonstrated that the filter removes litter and sediment from stormwater. However, as the influent and effluent were not sampled it is not possible to calculate efficiency. The manufacturer has conducted laboratory tests to evaluate the performance with respect to the removal of petroleum. However, the artificial stormwater that was created for the tests was not representative because sediment was not included in the stormwater. This is important because motor and diesel oil sorbs to sediment. The removal efficiency with regard to sediments is therefore important to

evaluate, whether in a laboratory or field test, even if the pollutant of interest is petroleum products.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.

StormTreat

Only one field study has been conducted. Further, in this field study only one grab sample was taken of the influent during each storm. Thus, efficiency cannot be properly determined. However, effluent concentrations of TSS and other pollutants were very low, indicating high efficiencies are achievable with this system. The TSS concentration in the effluent was typically less than 3 mg/L, with a high of 11.9 mg/L. It is important to note that StormTreat gradually treats the water for several days after the storm has passed. Hence, to use StormTreat, a detention system must also be included to retain the specified volume of water that is to be treated. This need suggests that before approving or conditionally approving this product, the manufacturer should be required to provide a sizing procedure specific to the climatic conditions of California.

Recommendation: Not acceptable.

Deficiencies:

1. Insufficient number of storms studied with proper protocol
2. Insufficient number of sites studied with proper protocol.
3. Inadequate sizing procedure

Table 9. Summary of Product Recommendations

Product	Company	Date of Most Recent Study	Approval Recommendation	Follow-up Recommendation
Jensen Interceptor	Jensen Precast	1996	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol. Review sizing guidelines
Teichert Interceptor	Teichert Precast	none	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol. . Review sizing guidelines
BaySaver	BaySaver, Inc.	1998	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
Stormceptor	CSR Hydro Conduit	1998	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
Downstream Defender	H.I.L. Technology, Inc.	none	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
Vortechs	Vortechnics	1998	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
V2B1	Kistner Concrete		Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
CDS	CDS Technologies	1999	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol. Use smaller screen size
StormFilter	Stormwater Management	1998	Conditionally Acceptable	Studies at 1 site w/ 10 storms each. Follow recommended protocol w/ cartridge system
Envirodrain	Envirodrain	none	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
Fossil Filter	KriStar Enterprises	1998	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
HydroKleen	Weaver Manufacturing, LLC	none	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
Ultra-Urban Filter	Abtech Industries	none	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol
StormTreat	Storm Treat Systems, Inc.	1995	Not Acceptable	Studies at 2 sites w/ 10 storms each. Follow recommended protocol. Provide sizing procedure

CONCLUSIONS

This study has compiled the available performance data for 18 stormwater treatment control technologies (14 proprietary devices and four treatment technologies available within the public domain) and evaluated the potential of these controls to improve the quality of stormwater runoff from new developments in Sacramento, California. Cost data for the 14 proprietary devices were also compiled.

To be acceptable or conditionally acceptable by local stormwater agencies, a treatment technology should have demonstrated performance under conditions similar to those typically observed in the intended area of application. This means that adequate study data should be available to clearly demonstrate effective pollutant removals with the technology under typical Sacramento-area storm conditions, using influent quality representative of that typically found in runoff from Sacramento-area commercial and residential developments. Effective pollutant removal is considered equivalent to that provided by public domain controls – grassy swales and sand filters. The studies should be scientifically defensible and well-documented. A screening protocol was developed to evaluate whether adequate data had been produced for each of the devices studied.

The four public domain controls studied – grassy swales and three types of sand filters – have been documented to produce treatment effectiveness adequate to warrant continued recommendation for application in the Sacramento area. Furthermore, the demonstrated treatment performance of these technologies can be used as a relative measure against which to assess the acceptability of performance data from other (proprietary) treatment technologies.

Of the fourteen proprietary devices evaluated, none have adequate data at this time to recommend outright acceptance, using the screening protocol developed for this investigation. Only one device (StormFilter) is recommended as conditionally acceptable.

The inability to remove dissolved pollutants is a common problem with all of the products reviewed in this report with the possible exceptions of StormTreat and StormFilter.

RECOMMENDATIONS FOR FOLLOW-UP

1. Manufacturers of proprietary controls that are recommended as “not acceptable” at this time should be encouraged to conduct studies that can be used to demonstrate the effectiveness of their products for application in Sacramento-area new developments. A recommended data collection and documentation protocol is provided in Appendix A to this report. In general, studies that follow the recommended guidelines would be applicable to most of the western United States.
2. Product manufacturers capable of producing a report that meets the criteria for conditional acceptance should submit such reports. Conditional acceptance of a product should be determined on a case-by-case basis by the various Permittee agencies. It is further suggested that manufacturers must be required to produce a subsequent report that meets all the protocols listed in Appendix A. Failure to submit such a report in a timely manner would result in the product being removed from the “Conditionally Acceptable” list.
3. The manufacturers of the Jensen and Teichert Precast units should be encouraged to review their sizing guidelines and make corrections as needed to resolve any unnecessary treatment deficiencies.

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