FINAL REPORT

Stormwater Management Practices (Closed Drainage) Study
(C - 01 - 74)

Laboratory Simulation and Field Studies

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DISCLAIMER

EXECUTIVE SUMMARY

STORMWATER MANAGEMENT PRACTICES (CLOSED DRAINAGE) STUDY LABORATORY SIMULATION AND FIELD STUDIES

December 2007

Non-Point Source Pollution (NPS), unlike pollution from industrial and sewage treatment system plants, comes from many diffuse sources. It is caused by the movement of rainfall or snowmelt that becomes contaminated, carrying pollutants (trash, metals, aromatic hydrocarbon, fecal matter and suspended solids) to receiving waters. NPS pollution represents the main cause of the contamination of many rivers, streams and other water bodies and became a concern in the United States resulting in the passage of the *Federal Water Pollution Control Act* (FWPCA) Amendments in 1987, which prohibits the discharge of stormwater unless authorized by a *National Pollutant Discharge Elimination System* (NPDES) permit. The NPDES was implemented initially with the promulgation of the *Phase I* and subsequently with the promulgation of *Phase II*.

A Catch Basin Insert (CBI) is a device for reducing stormwater pollution from runoff without requiring any land. NYS DOT (New York State Department of Transportation) has funded this project to evaluate the performance and effectiveness of six commercially-available CBIs: 1) Atlantic Construction Fabric's Siltsack®, 2) Hydro Compliance Management's Hydro-Kleen™, 3) KriStar's FloGard® +PLUS, 4) AbTech's Ultra-Urban® Filter, 5) Stream Guard™ Catch Basin Insert for Oil & Grease, and 6) Stream Guard™ Passive Skimmer.

This document reports the results of both the laboratory and the field studies. The laboratory study focused on evaluating pollutant-removal efficiencies of the 6 selected CBIs. A simulator, composed of a stilling chamber, a spillway with a street-like surface, and a catch basin was constructed at the Polytechnic University laboratory. The CBI removal efficiency of five water quality parameters (TSS – Total suspended solids, TN – Total Nitrogen, TP – Total Phosphorus, TPH – Total Petroleum Hydrocarbons, and BOD_5 – Biochemical Oxygen Demand) was measured at three flow rates (50, 150 and 300 L/min) and three contamination concentrations (low, median and high). We also screened the same 6 CBIs for potential FCB removal and found none. The field study examined the same 6 CBIs under field conditions during 4 seasons and notes ease of CBI installation, maintenance concerns, and performance. The field study also examined the performance of two structural oil/grit separators by way of sample collection and analysis during storm events.

Overall, in the laboratory simulator, the best performing insert was the Stream Guard™ Insert for Oil and Grease. It consistently was one of the top performing inserts in every parameter except TP, in which it demonstrated minimal removal. Additionally, at the price of $69.00 per insert, it is an affordable choice. The AbTech Ultra-Urban® Filter with Smart Sponge® was also a strong candidate among the CBIs. It performed extremely well in the removal of TP, TSS/VSS, and BOD_5. However, it is considerably more expensive at $690.00 per insert and requires substantially more space for storage than the next best performer.

Accepted stormwater management practices should be capable of 80% TSS removal and 40% TP removal. None of the CBIs achieved an average removal of 40% for TP in our simulator tests. Only the Stream Guard™ Insert for Oil and Grease was capable of 80% TSS removal. The simulator test results suggest that CBIs work best as pretreatment or in conjunction with other stormwater structural practices.

The other part of this study evaluates the pollutant removal efficiencies of two existing stormwater treatment systems: V2b1™ and Vortechs®. These systems were installed at Hauppauge and Bay Shore in Long Island (NY), respectively. In both locations, two autosamplers were installed to collect the influent and effluent samples during rainfall events for twelve months. The samples collected were analyzed to evaluate the pollutant removal performance of these systems. The measured parameters that will be used to determine the system efficiency were: conductivity, pH, TKN, TP, TPH, BOD_5, TSS and FCB. The operation and maintenance (O&M) considerations, capital cost, and estimated O&M costs are also considered in this report. The field study also monitored 6 CBIs (the same 6 CBI studied in the laboratory simulator) installed in parking lots and rest areas in

Westchester County (NY) for one year for installation characteristics, durability and maintenance, as well as whether the insert can be conveniently, safely, and economically installed and maintained.

The amount and quality of the debris captured by each CBI was also measured. With regard to CBI field observations, it was found that each CBI posed different concerns and a simple summary here is not appropriate. The appropriate sections of this document should be reviewed for helpful insight regarding CBI selection. Overall, key issues regarding CBIs were related to the proper selection of device for existing conditions and maintenance issues. For example, some of the CBIs are deep units that should not be used in shallow catch basins, as they will block the flow from neighboring catch basins. Thus, selecting a specific CBI might include consideration of a maintenance program for leaf and sediment removal from the CBI.

Maintenance also proved to be a serious concern regarding the performance of the two stormwater treatment systems. Both units have comparable economic costs (installation, O&M, etc.), making performance the critical difference between the two units. While the analytical results of influent and effluent samples reported in this document indicate better removal performance for the Vortechs® unit over the V2b1™, it should be noted that neither unit was properly maintained and that likely had a significant effect on performance. The installer of the V2b1™ unit observed that if it was not serviced since installation in 2001, it would have accumulated 2.5 times the maximum storage capacity and obstructed the normal flow pattern and in turn putting the unit in continuous by-pass mode and exporting pollutants.

Statement on Implementation – The results of this study may be presented at meetings of regulatory agencies and resource organizations. This Final Report will be posted on NYSDOT's Environmental Science Bureau Research webpage. Although not a direct result of this study, NYSDOT has a New Product Evaluation Committee that can provide a qualitative evaluation of water quality practices, has begun revising its specification for Stormwater Treatment Systems, and is developing an Approved Materials List for appropriate products.

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LIST OF ACRONYMS

ABS	Absorption
ACF	Atlantic Construction Fabric
BMP	Best Management Practices
BOD5	5-Day Biochemical Oxygen Demand
CBI	Catch Basin Insert
CRWR	Center for Research in Water Resources
CSO	Combined Sewer Overflows
CWA	Clean Water Act
CWC	Catskill Watershed Corporation
CWP	Center for Watershed Protection
CZARA	Coastal Zone Act Reauthorization Amendments
DEC	Department of Environmental Conservation
DEP	Department of Environmental Protection
DI	Deionized (water)
DO	Dissolved Oxygen
DOH	Department of Health
DOT	Department of Transportation
ECL	Environmental Conservation Law
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FW	Formula Weight
GF/C	Glass Fiber/ Carbon
IR	Infra Red
ISTEA	Intermodal Surface Transportation Efficiency Act
L	Liter
MCL	Maximum Contaminant Levels
mg	Milli-Gram
mg/L	Milli- Gram per Liter
mg-N/L	Milli-Gram Nitrogen per Liter
mg-P/L	Milli-Gram Phosphorus per Liter
min	Minutes
mL	Milli-Liter
MOA	Memorandum of Agreement
MS4	Municipal Separate Storm Sewer Systems
mV	Milli-Volts
MW	Molecular Weight

NEP	National Estuary Program
NJ	New Jersey
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NURP	National Urban Runoff Program (EPA, 1983)
NYC	New York City
NYS	New York State
OSTDS	On-Site Sewage Treatment and Disposal Systems
PAH	Polycyclic Aromatic Hydrocarbons
PL	Public Law
ppm	Parts Per Million
SAR	Surface to Area Ratio
SDWA	Safe Drinking Water Act
SEQR	State Environmental Quality Review Act
SMP	Stormwater Management Practice
SPDES	State Pollutant Discharge Elimination System
SWRPC	Southeastern Wisconsin Regional Planning Commission
THM	Trihalomethane
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids
WWTP	Waste Water Treatment Plants

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Chapter 1 — Introduction

It is commonly known that stormwater runoff picks up pollutants from the ground along the path it takes to reach a body of water. These pollutants are known as nonpoint source pollutants, since they have no specific origin. Distinct from point sources, which enter the environment at well-defined locations and at continuous discharges, nonpoint source pollutants usually find their way into the surface or groundwater in sudden surges, often in large quantities, and are associated with rainfall, thunderstorms, or snowmelts (*Liban, 1998*). According to the EPA and NOAA, nonpoint source pollution has become the largest single factor preventing the attainment of water quality standards nationwide (*EPA, 1996*). Common forms of nonpoint source pollutants are dirt and dust, antifreeze, engine oil, pesticides, fertilizer, pet wastes, and trash, such as cigarette butts, paper cups, and other litter. These contaminants are carried to lakes, rivers, streams, and oceans. The effects of these pollutants have drastically increased with the rate of urbanization.

Urban development has had a significant influence on the quality of local streams and has changed the hydrology of the area developed. For example, urban development removes trees and vegetation that intercepts rainfall, and levels off the natural depressions that temporarily pond and detain runoff. The spongy humus layer of the ground that absorbs rainfall is typically removed, eroded, or severely compacted. It no longer can prevent rainfall from being rapidly converted into stormwater runoff. The increase in impervious areas such as rooftops, roads, parking lots, and driveways prevent rainfall from being soaked into the ground and increases the volume of runoff produced. These impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown from adjacent areas, and thereby, become non-point source pollutants in rain runoff (*Maryland Dept. of the Env.*).

The quantity and type of pollutant contained in nonpoint sources depends on the level and type of human activity (*e.g.*, land use), the intensity and duration of the precipitation, and the time between storms. The combination of the randomness of rainfall with the varying levels of human activity makes controlling nonpoint sources relatively difficult. In urban areas, the large percentage of pavement reduces the opportunity for stormwater to filter into the ground, causing even relatively small storms (a few tenths of an inch) to create significant runoff (*National Academies Press, 1993*).

Additionally, runoff from impervious surfaces may increase temperature in receiving waters, adversely affecting aquatic organisms that require cold and cool water conditions (e.g., trout). Data suggest that increasing development can increase stream temperatures between five and twelve degrees Fahrenheit, and that the increase is related to the level of impervious cover in the drainage area (*Galli, 1991*). Thermal impacts are a serious concern in trout waters, where cold temperatures are critical to species survival (*CWP, 2003*).

1.1. Effects and Sources of Pollutants

Contaminants from runoff pollution include sediment, oils and grease, heavy metals, debris, road salts, fertilizers, pesticides, and herbicides. These pollutants have various detrimental effects on the waters they pollute, as well as the soil, vegetation, animals, and microorganisms it meets.

Trash and debris, in considerable amounts, are washed through the storm drain networks. They accumulate in natural waterways and detract from their beauty. Depending on the type of trash, this material may also lead to increased organic matter, which can cause premature aging or eutrophication, or toxic contaminants in water bodies (*CWP, 2003; EPA, 1995*).

Sediment (suspended solids) is produced when soil particles are eroded from stream banks and construction sites or when particles deposited on impervious areas are washed off and transported to surface waters. Sediment prevents sunlight from reaching aquatic plants, clogs fish gills, chokes other organisms, and can smother fish spawning and nursery areas. In addition, the reflected energy from light reflecting off of suspended sediment can increase water temperatures (*CWP, 2003; Kundell and Rasmussen, 1995*). Other pollutants adhere to sediment, such as heavy metals, pesticides, and nutrients. These pollutants further degrade water quality (*EPA, 1995*).

Oils and grease leak onto road surfaces from cars or trucks, spilled at fueling stations, and discarded directly onto pavement or into sewers instead of being recycled. Oil and grease contain a wide variety of hydrocarbon compounds, which can be toxic at low concentrations to aquatic life (*Maryland Dept. of the Env.*).

Organic matter, washed from impervious surfaces during storms, can present a problem in slower moving downstream waters. In addition, organic carbon is formed indirectly from algal growth within systems with high nutrient loads. As organic matter decomposes, it can deplete dissolved oxygen in lakes and tidal waters. Declining levels of oxygen in the water can have an adverse impact on aquatic life. An additional concern is the formation of Trihalomethane (THM), a carcinogenic disinfection by-product, due to the mixing of chlorine with water high in organic carbon. This is of particular importance in unfiltered water supplies, such as the New York City Reservoir System (*CWP, 2003*).

Heavy metal contaminants originate from some natural sources such as minerals in rocks, vegetation, sand, and salt. They also come from car and truck exhaust, worn tires, and engine parts, weathered paint and rust. Heavy metals are toxic to aquatic life and can potentially contaminate ground water. Routinely, cadmium, copper, lead, and zinc are found in stormwater runoff (*EPA, 1995; Maryland Dept. of the Env.*). Heavy metals in highway runoff generally undergo physical, chemical, and biological transformations as they reach adjacent ecosystems. Sometimes, they are taken up by plants or animals, or adsorbed on clay particles. Other times, they settle to bottom sediments, or re-dissolve back into solution. Particulate fractions settling to the bottom surface of receiving waters may develop into sediments after several years of continuous deposition. These sediments may or may not leach metals depending on the condition and sensitivity of the receiving water. For example, chloride and acetate (from deicing chemicals) trigger the movement of metals that would otherwise remain in soil–ion exchange sites usually found in the first 20cm of the soil columns in sediments (*FHWA, 1999*).

Road salts can be a major pollutant in both urban and rural areas. Snow runoff containing salt can produce high sodium and chloride concentrations in ponds, lakes, and bays. They can cause unnecessary fish kills and changes to the water chemistry (*EPA, 1995*).

Fertilizers, pesticides, and herbicides, from agricultural areas, forestry activities, and neighborhood lawns, if applied excessively, can be carried away by runoff. Pesticides and herbicides can be harmful to human and aquatic life. Nutrients found in fertilizers, such as phosphorus and nitrogen, contribute to algal blooms and excessive plant growth and can lead to eutrophication. Algal growth can block sunlight from reaching underwater grasses and depletes oxygen in bottom waters. Nutrient enrichment can also drive up the pH levels in water through increased photosynthetic activity (*FHWA, 1999*). Urban runoff has been identified as a key and controllable source of nutrients (*EPA, 1995; Maryland Dept. of the Env.*). Nitrogen has contributed to hypoxia in the Long Island Sound and is a key pollutant of concern in the New York Harbor and the Peconic Estuary. Phosphorus in runoff has impacted the quality of a number of New York natural lakes, including the Finger Lakes and Lake Champlain, which are susceptible to eutrophication from phosphorus loading (*CWP, 2003*).

Bacteria levels in stormwater runoff routinely exceed public health standards for water contact recreation. Some stormwater sources include waste from pets and urban wildlife. Other sources in developed land include sanitary and combined sewer overflows (CSOs), wastewater, and illicit connections to the storm drain system. CSOs harbor all the pollutants found in municipal wastewater, including pathogenic microorganisms, trash, and unpleasant odors, and may carry objectionable debris such as medical waste that has been found on east coast beaches in recent years (*National Academies Press, 1993*). Bacteria is a leading contaminant in many of New York's waters, and has led to shellfish bed closures in the New York Bight Area, on Long Island, and in the Hudson-Raritan Estuary (*CWP, 2003*).

1.2. Best Management Practices

Any management practice which is designed to prevent or reduce contaminants in stormwater qualifies as a Best Management Practice (BMP). The adverse effect of runoff water quality can be minimized through structural or non-structural best management practices (BMPs) or through a combination of both. *Structural BMPs* operate by physically trapping runoff until contaminants settle out or are filtered through the underlying soils. The basic mechanisms for constituent removal are gravity settling, infiltration of soluble nutrients through soil or filters, or biological and chemical processes. *Non-structural BMPs*, on the other hand, are source control practices such as street sweeping, public education program, land use planning, vegetated buffer areas, and fertilizer application controls. They are used to reduce the initial concentration and accumulation of contaminants in runoff. Non-structural BMPs may reduce the need for costly structural controls. Structural BMPs can be thought of as largely corrective measures to address existing and anticipated water quality problems (*FHWA, 1999*).

It is recommended that one take into account the expected amount of runoff, type and amount of contaminants, availability of land, and physical characteristics of the site, when trying to select the appropriate BMP. Some BMPs can operate effectively regardless of weather conditions while others can't. Structural BMPs are not always suitable for areas where land space is limited, as in urban settings, while non-structural BMPs can be implemented just about anywhere, even where space is a constraint (*FHWA, 1999*).

1.3. Project Goals

The project goals were to study the performance of two specific types of BMP devices currently available, but are not yet included in the NYS Stormwater Management Design Manual as standard practices:

1. Catch Basin Inserts

- Siltsack®
- Stream Guard™ Catch Basin Insert
- FloGard® +PLUS Filter
- Hydro-Kleen™ Filtration System
- Ultra-Urban® Filter
- Stream Guard™ Passive Skimmer

2. Stormwater Treatment Systems
    - Vortechs® System
    - V2b1™ System

The project involved both laboratory and field studies. In the laboratory, a simulator was used to measure the pollutant removal efficiency of the six CBIs listed above. The field studies focused on both the manufactured systems and the catch basin inserts.

The field studies of two installed manufactured systems, a Vortechs® and a V2b1™ unit, measured the removal efficiency for the following six parameters:

1. Total Suspended Solids (TSS)
2. Total Petroleum Hydrocarbon (TPH)
3. 5-days Biochemical Oxygen Demand (BOD_5)
4. Total Kjeldahl Nitrogen (TKN)
5. Total Phosphorus (TP)
6. Fecal Coliform Bacteria (FCB) (limited batch testing)

In addition, the maintenance and overall performance of the two manufactured systems were evaluated in this one study.

The field study also evaluated the installation characteristics, durability, cost effectiveness and maintenance/replacement requirements of the six catch basin inserts mentioned above, over one year of monitoring time. The devices were not tested for the removal efficiency of any pollutants, but periodically the litter accumulated into the insert, were removed and brought to the laboratory for drying, separation, and weighing, respectively.

Chapter 2 - Catch Basin Inserts

A catch basin insert (CBI) is a device that is placed directly inside of an existing catch basin to remove pollutants from stormwater. Treatment of stormwater flows occurs as the water passes through the structure into the catch basin (*Connecticut DEP, 2004*). The main removal mechanisms utilized in the design of the inserts are screening, sedimentation, and absorption (Edwards *et al*., 2004).

Most inserts consist of a structure, such as a tray, a basket, or a bag that typically contains a pollutant removal medium (filter media) and a method for suspending the structure in the catch basin (straps, hooks, frames, etc.). Although filter media is commonly used, basket-type inserts constructed of wire mesh and fabric bag-type inserts are also used without filter media for removing gross particles (trash and debris). Although inserts have the potential to remove total suspended solids, organics, and metals, the removal capabilities depend on the pollutant loading characteristics of the stormwater and the choice of filter medium. Since these devices are limited by the size of the catch basin, there is a relatively short contact time between the stormwater and the media for pollutant removal and little storage area for the material that is removed. Consequently, frequent maintenance is typically required to avoid clogging of the insert and there is the possibility of re-suspension of filtered pollutants.

Catch basin inserts are most successful at removing large particles and debris for pretreatment. They offer a flexible means of retrofitting an existing system and are easy to install. Catch basin inserts also offer the benefit of having low land requirements (*Tetra Tech, 2002*).

2.1. Limitations

Due to their small volumes, catch basin inserts have very limited retention times and require frequent cleaning or replacement to be effective. Since they require frequent inspection and maintenance, it is recommended that they be used where a full time maintenance person is on-site. Catch basin inserts do not provide peak flow attenuation, runoff volume reduction, or groundwater recharge. They are susceptible to clogging that can aggravate flooding. Appropriate testing of the sediment and materials collected in the insert should be conducted to determine the proper methods of handling and disposing of the insert and its contents. Another disadvantage to the implementation of CBIs is the limited availability of peer-reviewed performance data (*Connecticut DEP*, *2004*).

2.2. Case Studies

Lau *et al*.(2001) performed a series of tests using bench and full scale device under both laboratory and field conditions to evaluate their ability to remove trash and debris, suspended solids and oil and grease in stormwater. Four locations were selected and sampled during 14 storm events of the 1997-98 wet season of Santa Monica, California (which was an El Niño year and rainfall was at least 200% greater than normal). Two prototype designs were tested. The first consisted of OARS absorbent placed in metal boxes with open tops and screened bottoms. The second insert prototype used polypropylene cloth as an absorption/ filtration media supported by a geotextile for stabilizing solids. The OARS insert device had removal efficiencies that ranged from 46% to 91% for oil and grease and 78% to 99% for TSS (averaging 91%). The polypropylene insert device had removal efficiencies ranging from 49% to 86% for oil and grease and 95% to 98% for TSS (averaging 96%). Observations during storms showed that they do not create flooding problems, even when they are clogged. Laboratory testing showed that free oil and grease could be removed by a variety of absorbents in simple flow through contactors. Emulsified oil can generally not be removed. Laboratory tests showed that particles can be removed down to 100um, and field tests showed that much smaller particles could also be trapped. Laboratory testing also demonstrated that absorbents could remove dissolved PAHs with efficiencies ranging from 16% to 88%.

Edwards *et al*., (2004) evaluated four different inserts for removal of suspended solids and petroleum hydrocarbons by using a pilot scale catch basin and synthetic stormwater. The insert manufacturers were AbTech Industries, Aqua Shield, Inc., Geotechnical Marine Corporation and PacTec, Inc. At a flow of approximately 200 gal/ min and pollutant concentrations of 225mg/L for TSS and 31mg/l for TPH, the filters were able to remove 11% to 42% of TSS and 10% to 19% of TPH. The TSS removal efficiency of the AbTech and Geotechnical Marine inserts remained unchanged over the series of tests. However, over the ten tests conducted, the TSS removal efficiency of the Aqua Shield insert declined from 14% to 1% and the PacTec insert declined from 55% to 5%. None of the inserts experienced a decline in TPH removal. In addition, the inserts were placed at operating transportation facilities and monitored for operational problems. Two general operational problems of catch basin inserts were discovered during the testing: 1) the potential for plugging if the inserts are overloaded with sediment, and 2) the potential for debris to dry between storms and flush out in a subsequent storm. It was observed that the Geotechnical Marine insert could become plugged when sediment fills the bottom of the insert. It was also the only insert that held water between storms, which can become a mosquito– breeding site. However, with regard to sediment removal, the two best inserts were AbTech and Geotechnical Marine inserts.

2.3. Maintenance

Maintenance of an insert is fairly simple, provided the inlet grate can be lifted by manpower and that power equipment is available for vacuuming the accumulated sediment and debris from the insert. Due to their small volumes, catch basin inserts have very limited retention times and require frequent cleaning or replacement to be effective. Since they require frequent inspection and maintenance, it is recommended that they be used where a full time maintenance person is on-site (*Connecticut DEP, 2004*). This report contains details from a 1-year field study that includes observations on the maintenance of 6 selected CBIs.

2.4. Device Descriptions–CBIs

The following descriptions of the six catch basin inserts tested were obtained from their manufacturers (brochures, technical drawings, websites, etc.), EPA website and other company publications or advertisements.

2.4.1. Atlantic Construction Fabric's Siltsack®

Siltsack® is a sediment control device, made of a permeable geotextile, used to prevent silt and sediment from entering a drainage system by catching the silt and sediment while allowing water to pass through freely. It can be used as a primary or secondary sediment control device to prevent failure of a drainage system due to clogging. It must be maintained on a regular basis to function properly. Siltsack® is available in both high-flow and regular flow sizes (*ACF Environmental, 2004*).

Routine inspection of Siltsack's collected sediment level is important to prevent "ponding" around storm drains. Inspection of each Siltsack® should occur after every major rain event.

If there have been no major events, Siltsack® should be inspected every 2-3 weeks. The yellow restraint cord (see Figure 1) should be visible at all times. If the cord is covered with sediment, the Siltsack® should be emptied (*ACF Environmental, 2004*).

The cost of Siltsack® inserts differs depending on size and flow (regular or high flow). The 2'x2', regular flow filter (item # SILT02X02) costs $54.00/ filter. The 2'x 4', regular flow filter (item # SILT02X04) costs $57.00/ filter. The 2'x 2', high flow filter (Item # SSECX0202) costs $65.00/ filter. The 2'x 4', high flow filter (item # SSECX0402) costs $70.00/ filter.

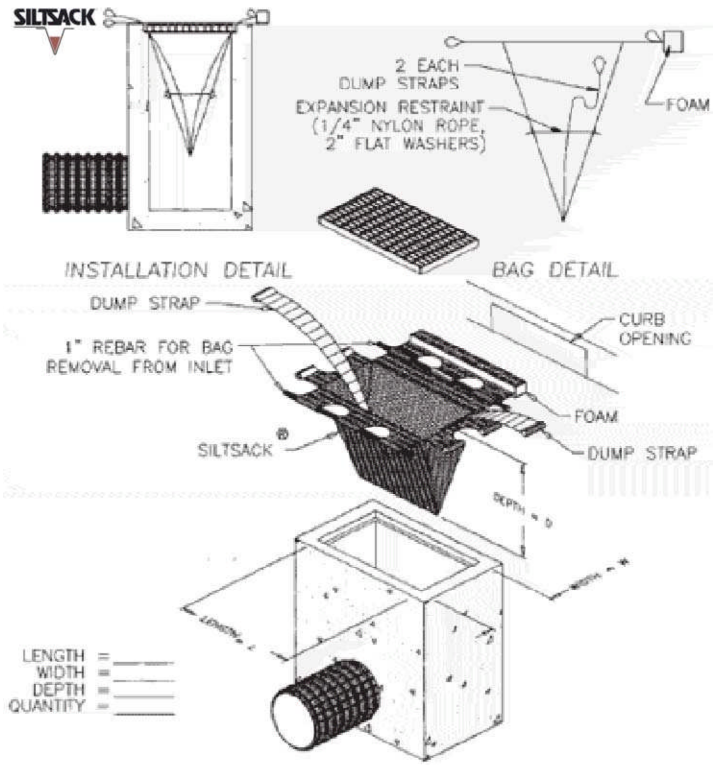

Figure 1: Siltsack® Technical Drawings.

2.4.2. Stream Guard™ Catch Basin Insert for Oil and Grease (#3021)

Stream Guard™ Insert for Oil and Grease was designed specifically to remove oil and grease from stormwater, though it is also effective in removing sediments and debris. It is equipped with oil encapsulating absorbent polymer. Unlike other absorbents, Bowhead Manufacturing Company maintains that the Stream Guard™ polymer media will not deteriorate or release absorbed hydrocarbons. Therefore, spent inserts can usually be disposed of as a municipal solid waste (*Bowhead Manufacturing Company, 2004*).

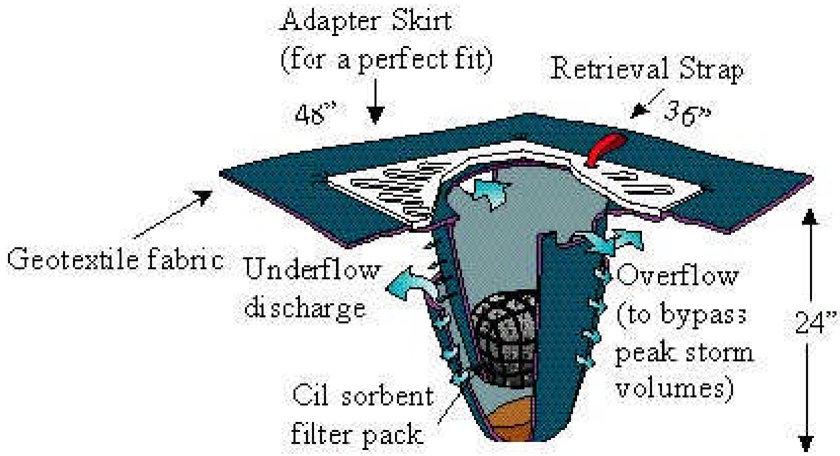

Figure 2: Stream Guard™ Catch Basin Insert for Oil & Grease.

As contaminated water flows through the insert, the geotextile fabric absorbs oil and retains sediment. Once contaminants have accumulated, the body of the unit fills with water and sediment collects at the bottom of the insert. In this mode, the body of the insert fills with water, providing detention for the gravity settling of sediment, which is captured in the bottom of the insert. The unit becomes an oil/water separator (see Figure 2) with continuous absorption of hydrocarbons, which accumulate at the surface (*Bowhead Manufacturing Company, 2004*).

The insert's universal skirt adapter allows it to be installed in minutes in any size catch basins up to 30" x 40". It is ideal for gas stations, vehicle maintenance areas, and fuel transfer stations, where small, frequent hydrocarbon spills are common. The filter can absorb up to ½ gallon of oil. Maintenance may be required at 3- to 6-month intervals where moderate levels of hydrocarbons and sediments are encountered. The total water flow rate through the insert when new is in excess of 500 gpm. The bypass rate is approximately 700 gpm (*Bowhead Manufacturing Company, 2004*). The unit cost of this filter is $69.00. Ten packs of the filter retail for $650.00 ($65.00/filter).

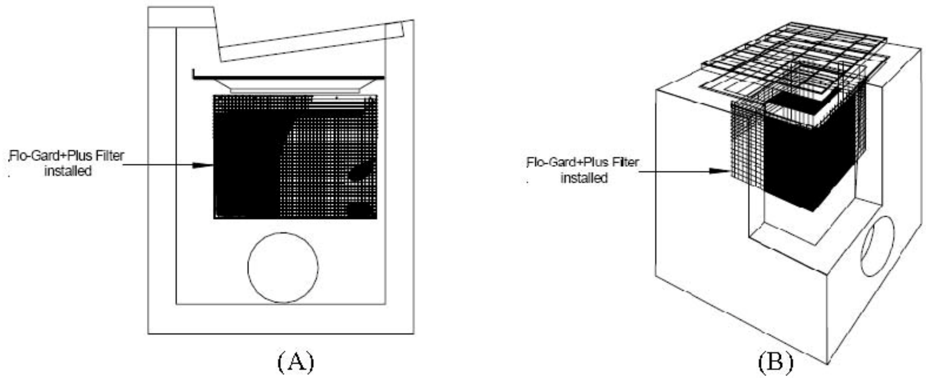

Figure 3: FloGard® + PLUS (A) side view and (B) 3D rendition.

2.4.3. KriStar's FloGard® +PLUS Catch Basin Insert

FloGard® +PLUS is a multipurpose catch basin insert designed to capture sediment, debris, trash & oils/grease from low (first flush) flows. A (dual) high-flow bypass allows flows to bypass the device while retaining sediment and larger floatables (debris & trash) and allows sustained maximum design flows under extreme weather conditions. FloGard® +PLUS inserts are available in sizes to fit most industry-standard drainage inlets (flat grated, combination, curb and round inlets). FloGard® +PLUS catch basin inserts are recommended by KriStar Enterprises for areas subject to silt and debris as well as low to moderate levels of petroleum hydrocarbon (oils and grease). Examples of such areas are vehicle parking lots, aircraft ramps, truck and bus storage yards, corporation yards, subdivision streets and public streets (*KriStar, 2005b*).

FloGard® +PLUS filter inserts are supplied with Fossil Rock filter medium for the effective removal and retention of oil and grease as well as other non-soluble pollutants normally found in stormwater runoff (Figure 3). Fossil Rock filter medium is supplied in easy to install "clip in" pouches, simplifying replacement and reducing maintenance costs. The unique filter medium pouch design offers effective "flow-through" filtration during lower flows and "skimmer" filtration for continued effective removal of remaining floatable (free) oils during higher flows. Fossil Rock filter medium pouches allows for the separation of oil and grease from the collected solids (sediment, debris), simplifying and reducing the cost of disposal. Fossil Rock is non-hazardous, non-biodegradable and non-leaching, allowing for disposal at most land fills (*KriStar, 2005b*).

KriStar Enterprises states that, based on independent field and lab studies conducted in Auckland and Honolulu, the FloGard® +PLUS Filter should provide 80% removal of total suspended solids (TSS) from treated flow with a particle size distribution consistent with typical urban street deposited sediments. The filter should capture at least 70% of oil and grease and 40% of total phosphorus (TP) associated with organic debris–fraction of particle. The unit should provide for isolation of trapped pollutants, including debris, sediments, and floatable trash and hydrocarbons, from bypass flow such that re-suspension and loss of pollutants is minimized during peak flow events (*KriStar, 2004*). The cost of one insert and frame unit is $602.00.

2.4.4. Hydro Compliance Management, Inc. – Hydro-Kleen™

According to the manufacturers of Hydro-Kleen™, the patented, dual-media Hydro-Kleen™ Filtration System is a cost-effective Stormwater compliance technology for use with stormwater catch basins and drains (Figure 4). It traps hydrocarbons, metals, sediments, and other contaminants contained in stormwater and other surface runoff. They are designed to trap contaminants contained in the "first flush" from storm events, while providing overflow protection and preventing flooding or ponding during high flows (*ACF Environmental, 2004*).

The multimedia filtration system contains design features that filter out hydrocarbons and other contaminants. The Hydro-Kleen™ filters up to ½ inches of rain per hour in a properly designed drain and diverts high flows to bypass outlets.

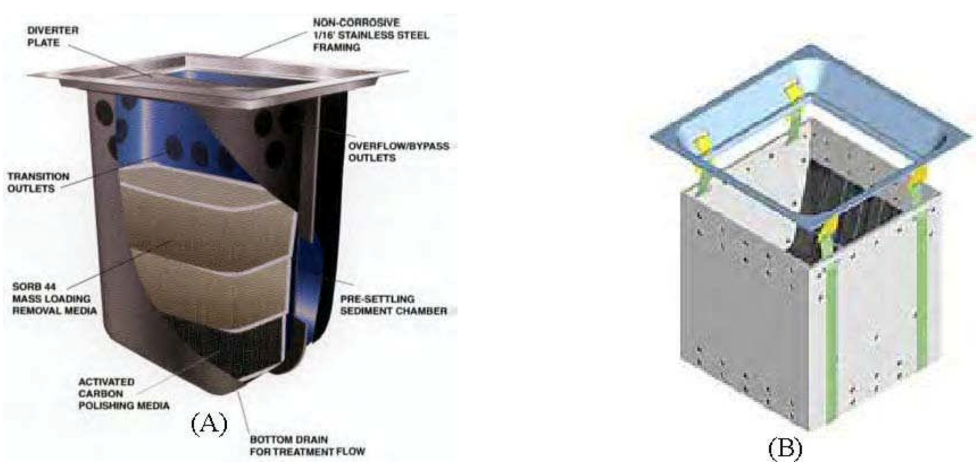

Figure 4: Catch Basin Inserts (A) Hydro-Kleen™ and (B) Ultra-Urban® Filter.

2.4.5. AbTech's Ultra-Urban® Filter (DI2020-N)

According to AbTech Industries, the Ultra-Urban® Filter with the AbTech Smart Sponge® is an innovative low-cost BMP designed to help meet NPDES requirements with easy installation, effective filtration, and moderate maintenance. The Ultra-Urban® Filter captures oil, grease, trash, and sediment from stormwater runoff before it enters the storm drain system. The Ultra-Urban® Filter is ideal for municipal, industrial, and construction applications for reducing Nonpoint Source Pollution (*EPA, 2004a; AbTech, 2005*).

The Ultra-Urban® Filter is designed for use in storm drains that experience oil and grease pollution accompanied by sediment and debris. Trash and sediment accumulate in the internal basket while the filtration media captures oil and grease (see Figure 4). Field tests have proven that the proprietary OARS Smart Sponge® filtration media will remove up to 80% of the oil and grease in stormwater runoff. Oil is bonded within the Smart Sponge®, eliminating the possibilities of leaching back into the environment (*EPA, 2004a; AbTech, 2005*). The cost of one filter unit is $690.00.

2.4.6. Stream Guard™ Passive Skimmer (#3018)

The Stream Guard™ Passive Skimmer, containing 3 pounds of hydrocarbon-absorbing polymer, is designed to float in the sump of ordinary catch basins, oil/water separators, or other stormwater vault configurations. Uniquely, the oleophilic Stream Guard™ polymer media will not deteriorate or release absorbed hydrocarbons, like other common adsorbents. This innovative polymer absorbent is contained in a screen pillow that allows for long-term exposure to oil-contaminated water, unlike fabric-covered products that rapidly become coated with oil and sediment, preventing further adsorption in stormwater applications (*EPA, 2004b; Bowhead Manufacturing Company, 2004*).

Bowhead Manufacturing Company states in its brochure that the Passive Skimmer is particularly effective in capturing hydrocarbons that otherwise accumulate at the surface of sumps, and then discharge suddenly during the peak flow of a rainfall storm event. Unlike catch basin filters that attempt to filter oil from sediment-containing stormwater, the Passive Skimmer is not affected by sediment and will not clog. The Passive Skimmer will not impede the flow of water through the stormwater collection system. This technology may be installed in virtually any sump, catch basin, or oil/water separator.

Spent Skimmers can be disposed of by municipal incineration for energy recovery, or handled as municipal solid waste if approved by the local solid waste disposal authority (*EPA, 2004b; Bowhead Manufacturing Company, 2004*).

The Stream Guard™ Passive Skimmer was developed for use in catch basins, oil/water separators and sumps where the object is to continuously capture hydrocarbon sheen as well as being able to absorb up to 2 gallons of spilled fuel or oil (*USEPA, 2004; Bowhead Manufacturing Company, 2004*). A 2-pack of the Passive Skimmers costs $120.00 ($60.00/filter) and a 5 pack costs $299.00 ($59.80/ filter) (*Bowhead Manufacturing Company, 2004*).

2.5. Laboratory (Simulator) Tests

2.5.1. Methodology and Equipment

The laboratory study focused on evaluating pollutant-removal efficiencies of 6 selected CBIs. A simulator, composed of a stilling chamber, a spillway with a street-like surface, and a catch basin was constructed at the Polytechnic University laboratory. Five water quality parameters were monitored using the simulator to determine the removal efficiency of the inserts: total suspended solids and volatile suspended solids (TSS/VSS), total nitrogen (TN), total phosphorus (TP), total petroleum hydrocarbons (TPH), and biochemical oxygen demand (BOD_5). Each of these contaminants was used at three contamination concentrations (low, median and high). In addition, testing was performed at three flow rates (50, 150 and 300 L/min). The contaminant levels and the flow rates were determined using data from the NURP Report (*EPA, 1983*). Furthermore, limited (batch) tests were performed to determine potential FCB removal by each of the CBIs. Before testing, these plans were discussed and agreed upon with the NYS DOT. This section includes detailed information of: 1) the construction of the simulator; 2) outline of the simulator testing protocol used; 3) methods of chemical analysis for both laboratory simulator samples and field samples, and; 4) a listing of material and equipment.

Six catch basin inserts were tested in the simulator: Atlantic Construction Fabric's (*ACF*) Siltsack, Hydro Compliance Management Hydro-Kleen™, KriStar's FloGard® +PLUS, AbTech's Ultra-Urban® Filter (DI2020-N), Stream Guard™ Catch Basin Insert for Oil and Grease (#3021) and Stream Guard™ Passive Skimmer (#3018). They were all fitted to the catch basin chamber and tested under similar conditions.

2.5.1.1. Simulator

Construction

The simulator was comprised of three main parts: the stilling chamber, spillway, and catch basin. It was constructed using plywood and 2"x 4" and 2"x 2" wood studs. The stilling chamber, spillway, and catch basin were all sealed using Thompson's water seal and waterproof paint. Then, the spillway floor was coated with cement and pebbles to simulate the surface of a road. The only difficulty that occurred was leaking from the stilling chamber, which occurred due to the large volume of water and consequently the pressure exerted on the walls of this chamber. A sketch of the simulator is in Appendix A.

2.5.1.2. Parts of the Simulator

The simulator (*i.e.*, the pilot-scale laboratory setup used to simulate roadside catch basins) was comprised of various parts that are further detailed below. In order to supply the flow rates up to 300 L/min, a separate water supply was required. Laboratory simulator tests were delayed about 1 month until a new water supply pipe was installed from the street main.

Stilling Chamber

The stilling chamber was a 3-foot by 3-foot chamber containing three baffles used to reduce the turbulence of the incoming flow of water before it reaches the spillway. This chamber contained only tap water with no contaminants.

Figure 5: Simulator photographs: a) spillway view from stilling chamber (no baffles), b) cement–lined spillway view from catch basin, c) baffle setup in stilling chamber.

Spillway

The spillway was the 7-foot long by 2-foot wide channel used to connect the stilling chamber to the catch basin. The spillway has a slight incline to encourage flow to the catch basin. The floor of the spillway was coated with cement and pebbles to simulate the surface of the road. All contaminants were added at the beginning of the spillway to ensure through mixing of contaminant before the filter. Preliminary dye tests confirmed adequate mixing was achieved.

Catch Basin

The catch basin was a 3-foot-by-3-foot chamber located at the end of the spillway. All catch basin inserts were fitted to this chamber for testing. On the wall located opposite the spillway entrance to the catch basin was a window used to collect sample water expelled from the inserts.

Contamination Tank & Pump Setup

The contamination tank was a 52-liter tank used to hold a concentrated synthetic pollutant solution. The contamination tank was connected to the spillway with a pump that had a multiple point dispersion glass tube to release pollutant into the spillway.

Constant Head Device

A constant head device (Figure 6) was used to dispense oil into the spillway at a constant flow from a singular point. It was constructed from fiberglass parts and metal fittings.

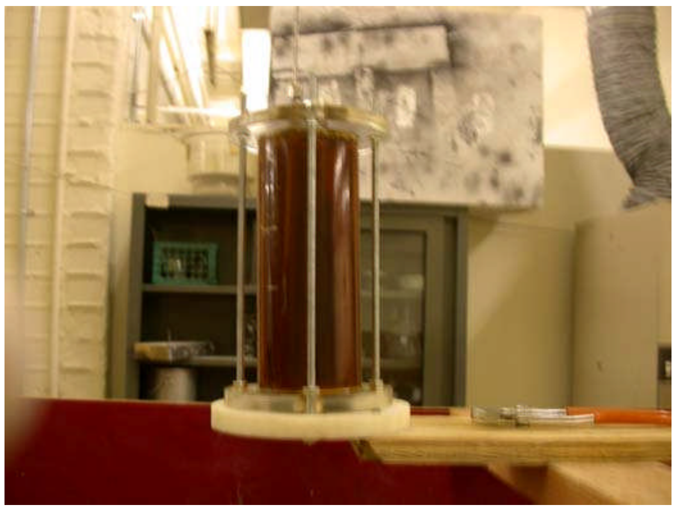

Figure 6: Constant Head Device full of motor oil.

2.5.1.3. Testing Preparation Procedure

Simulator Preparation and Procedure

Prior to initiating a test run, several steps were taken to ensure that the simulator was clean of contaminants. Foremost, a new filter was used for every test run. For the Hydro-Kleen™ and Passive Skimmer filters, the additional steps of removing collected sediment from the stilling compartments, washing of the frame with a light solution of soap, followed by washing with acid and then flushing the system for an hour with water (at flow rates ranging from 400 to 500 liters per minute) to remove contaminants from previous tests. Finally, the flow rate was regulated to the desired flow rate and allowed to stabilize for thirty minutes prior to a test run.

FCB Batch Tests

Before any simulator testing of the 6 CBIs, batch tests were performed to measure potential FCB sorption by the CBI material. The reasoning for the batch tests was two-fold: testing for FCB removal using the simulator would require verification after each run to ensure that the simulator was clean and would require substantial preparation time between the runs, and; FCB analyses of the samples generated by each simulator run would require approximately 600 test tubes, that in turn require cleaning and autoclaving. The time required to perform simulator tests that included FCB would be substantial, and the potential for FCB removal was unlikely. Hence, batch tests were performed using material from each CBI to measure FCB sorption and determine if the potential existed prior to conducting simulator tests that incorporated FCB. None of the CBIs exhibited a measurable sorption of FCB and no simulator tests were conducted using FCB.

TSS Preparation

Before testing, sand particles were sieved and then recombined to produce an evenly divided mixture, by mass of sand, with US standard meshes of 10, 20, 40, 50, 80, 100, 200, 325, 400. The recombined mixture was divided into smaller portions to be spread evenly at timed intervals during the test run.

Figure 7: Portioned out sediment for a simulation test.

Contaminant Solution Preparation

The desired amount of the contaminants needed to run each test was calculated *a priori* and example calculations can be found in Appendix D. Before testing, each chemical was weighed and dissolved completely (except for the conditions of "medium flow, high concentration" and "high flow, high concentration") in water. The chemical tank was washed with acid and rinsed before being used. All the chemicals that make up the synthetic pollutant mixture were then mixed and diluted to 52 liters in the pollutant tank. After the test, the remaining synthetic solution was analyzed to confirm the concentration entering the system.

Constant Head Device Preparation

Each testing condition required a unique configuration of the constant head device to obtain the desired flow rate of oil into the system. Prior to testing the pipes were re–adjusted to the proper configuration, and filled with motor oil. The constant head device was weighed before and after the test to obtain the mass of the oil dispensed.

2.5.1.4. Sampling Procedures

Sample Identification

During every test run, nine water samples were collected. These samples were labeled with a code that consisted of an abbreviation of the filter brand name, test run number, sample number, code for test conditions of flow rate and concentration and the date of the test so that they can be easily identified and distinguished. (Key to labeling code is provided in the Appendix C.) The sample numbers were 00, 1 to 6, composite and tank.

Sampling Procedures

Sample 00 contained water from the stilling chamber and represented the initial conditions of the water before any pollutants were added. Samples 1 to 6 contained water collected every ten minutes from the output of the CBI being tested. The composite sample contained a composite water sample made by collecting 500 ml of influent from the spillway before it entered the CBI every ten minutes and mixing them together to form a 3 liter sample. The composite sample represented the average incoming conditions to the CBI. This was tested in practice runs before actual testing on any insert was conducted. The tank sample was taken from the pollutant tank. It represents the pollutant concentrations being added to the spillway and was used to check that the estimated incoming conditions were at the desired levels.

Sample Preservation and Testing Schedule

All samples were initially collected in three-liter plastic bottles. After a test run was completed, samples were promptly divided, preserved and refrigerated. Each sample was divided into smaller samples for TP, TN, and BOD and preserved using sulfuric acid. A 125 ml sample for TP and a 250 ml sample for TN were separated into plastic bottles, preserved with sulfuric acid, and frozen. A 500 ml sample was preserved for BOD with sulfuric acid and refrigerated for testing the next day. The remainder of the sample was preserved in the 3-liter bottle using a hydrochloric acid for testing TSS, TPH and for retesting should the need arise. Analysis of a round of samples was usually completed within a week.

2.5.1.5. Contaminant Levels

Determination of Contaminant Concentration Levels

Five simulated basic contaminants, total suspended solids and volatile suspended solids (TSS/VSS), total nitrogen (TN), total phosphorus (TP), 5-day biochemical oxygen demand (BOD_5) and total petroleum hydrocarbon (TPH), were released in solution by pump at controlled rates to produce the desired concentration levels. Using the statistical data available from the 1983 National Urban Run-off Program (NURP) study conducted by the USEPA (*EPA, 1983*) (median, mean, 90th percentile, and coefficient of variance values) and the TPH data found in the Federal Highway Administration document, "*FHWA Environmental Technology Brief: Is Highway Runoff a Serious Problem?*" (range of average value of TPH) values for high, median, and low concentrations of pollutants were determined (*FHWA, 1999*).

NURP data was used to determine the high, median, and low concentration levels for TSS, TN, TP, and BOD_5 (and FCB, although not used in the simulator runs). The 90th percentile established the high concentration, while the 10th percentile was set as the low concentration level. The median concentration level was given by the NURP data. The 90th and 10th percentiles were determined using the following formula:

$$\frac{x_\alpha}{median} = \exp\left(z_\alpha \sqrt{\ln\left(1 + (CV)^2\right)} \right)$$

where X_α = expected values of 90^{th} or 10^{th} percentiles

$Z_\alpha = \pm 1.2817$ can be used to find the 90^{th} (1.2817) and 10^{th} percentiles (-1.2817);

CV = Coefficient of Variance

The Federal Highway Administration document gave a range of average values for runoff contaminants. The range for aromatic hydrocarbons (12.7-37 mg/L) was used to establish the TPH concentration levels.

These values were used to target desired conditions from low to high concentration levels and tested at variable flow rates (50, 150, 300 L/min) to test the inserts removal efficiencies, as well as, whether the inserts failed or overflowed under extreme conditions. The flow rates used for the simulator runs were also selected using statistical data from NURP study (EPA, 1983). Note that the NURP study reports data for both warm and cold weather. (All concentration calculations can found in Appendix D.)

2.5.1.6. Chemical Analyses

The methods used to analyze TSS/VSS, TP, TN, FCB, and BOD_5 were taken from *Standard Methods for the Examination of Water and Wastewater*, 20^{th} edition (*APHA, 1998*). TPH was analyzed using the EPA Standard Method (EPA 418.1/413.2 Freon Method) provided by Buck Scientific. All the methods and modifications used are paraphrased below.

Total Suspended Solids (TSS) & Volatile Suspended Solids (VSS)

Standard Methods: 2540 D. Total Suspended Solids Dried at 103-105 ºC

An aluminum dish and glass fiber filters were placed in a furnace to dry for 20 minutes at 550°C to prepare filters for use in testing. Before weighing, filters were placed in a desiccator to cool devoid of any moisture. The filters were weighed using an analytical balance and that value was recorded.

First, the sample was shaken vigorously to obtain a uniform distribution. Then, a volume ranging from 200-1000 ml (depending on turbidity) was poured over a filter; afterwards the filter was placed on the vacuum apparatus. The vacuum was turned on until all the water of the sample was removed.

Subsequently, the filter was removed from the vacuum apparatus and transferred back to the aluminum dish. The aluminum dish with the filter was then dried in the oven at 105°C for 1 hour. After being removed from the oven, the dish and filter was cooled in a desiccator and then the filter was weighed on the analytical balance. Finally, the Total Suspended Solids was calculated using the equation provided below.

$$\text{mg total suspended solids/L} = \frac{(A - B) \times 1000}{sample\ Volume, mL}$$

where A = weight of filter + dried residue (mg), and

B = weight of filter (mg).

Standard Methods: 2540 E. Fixed and Volatile Solids Ignited at 550 ºC

After weighting the aluminum dish and filter for TSS, they were placed in furnace at 550° C for 15 to 20 minutes for ignition to occur. Then the dish and filter are removed from the furnace and cooled in a desiccator to balance the temperature and the filter was subsequently weighed in the analytical balance as before. VSS was calculated using the following equation:

$$\text{volatile suspended solids (mg/L)} = \frac{(A - C) \times 1000}{sample\ Volume, mL}$$

where A = weight of filter + dried residue (mg), and

C = weight of filter + dried residue after 550° C (mg).

Total Reactive Phosphorus (TP)

Standard Methods: 4500-P C. Vanadomolybdophosphoric Acid Colorimetric Method

Since the same chemical used in making the standard curve (anhydrous KH_2PO_4) was also used in the synthetic pollutant mixture, a direct colorimetric method was used to analyze the samples. Phosphates that respond to colorimetric tests without preliminary hydrolysis or oxidative digestion of the sample are termed "*reactive phosphorus*," therefore the results found using this method are known as the Total Reactive Phosphorus. All measurements were performed in triplicate from each specimen collected and the average reported.

All glassware was washed with HCl solution and rinsed with distilled water before being used. After use, the glassware was washed again and placed in an HCl solution acid wash. The glassware was exclusively used for phosphorus testing.

A Spectronic® Genesys 2 Spectrophotometer set at 420 nm was used to analyze the absorption of the samples.

All TP samples were preserved by adding H_2SO_4 acid until the pH was less than 2, and then the samples were frozen until analysis.

The standard phosphorus solution was prepared as stated in *Standard Methods*. A standard curve was prepared using concentrations of 0 mg-P/L (blank), 0.1 mg-P/L, 0.5 mg-P/L, 1.0 mg-P/L, and 10.0 mg-P/L. The absorption of each was plotted to compare to the unknown values to estimate their concentration. These standards were made anew with every set of samples tested.

The samples and the standards were prepared for analysis in the exact same way, as follows: First, 35 ml of the sample was placed in a 50 ml volumetric flask. Then, 10 ml of vanadate – molybdate reagent was added. Next, the solution was diluted with deionized water to the mark (50 mL), shaken, and allowed to set for about 10 minutes. Afterwards, the measurements of the absorbance of the samples versus a blank were taken at a wavelength of 420 nm. These readings were compared to the standard curve to obtain the concentration of phosphorus. The result from Sample 00 was subtracted from the values of the other samples, in order to subtract the TP of the water incoming from the tap.

Samples that demonstrated high turbidity due to sediment in the water were either shaken until the particles dissolved or filtered using glass carbon filters (usually only for the high flow, high concentration levels).

Total Nitrogen (TN)
Standard Methods: 4500-NH3 B. Preliminary Distillation Step &
4500-NH3 D. Ammonia – Selective Electrode Method

Since the same chemical used in making the standard curve (anhydrous NH_4Cl) was also used in the synthetic pollutant mixture, a direct application of the ammonia-selective electrode method was used to analyze the samples. This method required no digestion of the standard; therefore, the samples were not digested as well. However, distillation of the samples ensured purity from turbidity or other interference. Duplicates were analyzed and averaged. Note that the field samples were analyzed for Total Kjeldahl Nitrogen (TKN) and the procedure for analysis (described in Chapter 3 of this document) included digestion.

All glassware was washed with HCl solution and rinsed with distilled water before being used. After use, the glassware were washed again and placed in an HCl solution acid wash. The glassware was exclusively used for nitrogen testing.

All TN samples were preserved by adding H_2SO_4 acid until pH was less than 2, and then the samples were frozen until analysis.

The standard ammonium chloride solution was prepared as stated in *Standard Methods* using the stock solution. A standard curve was prepared using concentrations of 0.1 mg-N/L, 0.5 mg-N/L, 1.0 mg-N/L, 10.0 mg-N/L and 100.0 mg-N/L and plotting the absorption of each.

The Fisher Scientific Distillation Unit (model 2100) was used to distill TN samples before any measurements were made. 50 mL of H_2SO_4 were put into an Erlenmeyer flask to collect the distillate. After defrosting and shaking, 200 mL of sample were added into a 500 mL test tube; and 25 ml of borate buffer reagent was added to the test tube. The pH should exceed 9.5, if not, 1mL of NaOH, 10N, was added. Then, the sample was distilled for 5 minutes. The Erlenmeyer flask containing the distillate was then diluted to 200 mL in a volumetric flask with distilled water. 100 mL of the solution from the previous step was placed in a beaker on a magnetic stirrer, the NH_3 electrode was immersed into it, and next 1 mL of 10 N NaOH solution was added. When the reading stabilized, the value was recorded. The reading was then compared to the standard curve to obtain the concentration of ammonia.

Biochemical Oxygen Demand (BOD_5)

Standard Methods: 5210 B 5-Day BOD Test

Wheaton 300 ml BOD Bottles with penny stopper caps were used to conduct BOD tests on samples. These bottles were washed with an HCl solution and rinsed with distilled water to ensure cleanliness.

HACH BOD Nutrient Buffer Pillows were diluted in 4 liters of deionized (DI) water to make the dilution water used in BOD testing. Polyseed, BOD Seed Inoculum, was used to inoculate BOD samples. The Polyseed was prepared by adding the contents of the capsule to 150 mL of dilution water and mixing this solution with a magnetic stirrer until used. Both the dilution water and the Polyseed Inoculum were prepared fresh for every test.

In this experiment, there were three BOD concentration levels tested: low (4.9 mg/L), median (9 mg/L), and high (19 mg/L). The volume of the sample used in the BOD test was dependent on the concentration. For low concentration, 300 mL of sample was used, for median concentration, 100 mL of sample was used, and for high concentration, 50 to 75 mL of the sample was used.

The BOD bottles were prepared by taking a volume of the sample (as specified above) and adding dilution water in the BOD glass bottle until the final volume reached 300 ml. Then, the YSI 5100 Dissolved Oxygen Meter and YSI 5010 BOD Probe were used to measure the dissolved oxygen (DO) of the BOD samples. This data was recorded. A blank consisting of 300mL of dilution water was also prepared and added with each test. The sample bottles and blank were then inoculated with 1mL of Polyseed, and covered with a glass cap and paraffin to prevent the escape and entering of air. Every sample bottle spent 5 days at 20° C in the incubator. On the fifth day, DO5 values of the sample bottles were measured.

There are two testing criteria that must be met by all BOD samples after 5-day incubation: (1) there must be a DO uptake of at least 2 mg/L and (2) a residual DO of at least 1 mg/L. If the criteria were met then the following equation was used to obtain the BOD value:

$$BOD_5, mg/L = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

where D1 = DO of diluted sample immediately after preparation, mg/L

D2 = DO of diluted sample after 5 days incubation at 20º C, mg/L

P = decimal volumetric fraction of sample used

B1 = DO of seed control before incubation, mg/L

B2 = DO of seed control after incubation, mg/L

f = (volume of seed in diluted sample) / (volume of seed in seed control)

Total Petroleum Hydrocarbon (TPH)

EPA Method: EPA 418.1 / 413.2 Freon Method

Buck Scientific Model 404 IR Total Hydrocarbon Analyzer was used to measure the concentration of TPH in the water samples. Prior to analysis, the Total Hydrocarbon Analyzer was warmed up for 30 - 45 minutes. Afterward, TPH Sealed Standards, provided by Buck Scientific, containing standards of 0 ppm, 11 ppm, 50 ppm, and 244 ppm, were used to calibrate the Total Hydrocarbon Analyzer.

All TPH samples were preserved by adding HCl acid until the pH was less than 2, and then they were refrigerated at 4ºC until tested.

The separatory funnel and quartz cells used in this test were cleaned using Chronic - Sulfuric Acid (sulfuric acid and chromium trioxide) for cleaning glassware and rinsed with tap and then DI water.

After removal from the refrigeration unit, the sample was shaken and 200 ml of sample water was transferred into a separatory funnel. 10 ml of hydrochloric acid was added to the sample in the separatory funnel followed by 50 ml Freon-113 solvent. Then, the separatory funnel was stoppered and shaken vigorously for 1-2 minutes. The stopcock on the separatory funnel was opened to vent pressure frequently. Then, the separatory funnel was placed back on a ring stand; the stopper was removed, and allowed the Freon-113 to settle to the bottom of the funnel. The stopcock was subsequently opened to drain the Freon-113 extraction into a clean 50 ml beaker. This solvent extraction represents an 8-x concentration of the oil from the original sample. The solvent extract was poured from the beaker into a clean quartz cell and placed into the cell holder of IR spectrophotometer. The reading was then recorded. The IR spectrophotometer was recalibrated after every nine readings or approximately every hour.

Fecal Coliform Bacteria (FCB)

The Most Probable Number (MPN) method is a statistical, multi-step assay consisting of presumptive, confirmed and completed phases. Serial dilutions of a specimen are inoculated into broth media (lauryl tryptose) that are incubated and then examined for the presence of gas. A score is assigned to the number of gas-positive tubes (indicating the fermentation of lactose). The positive are then used in the next 2 phases of the assay and the combinations of positive results are used to consult statistical tables that estimate the number of organisms present, or MPN.

A broth of lauryl tryptose is prepared by mixing 35.6 g of lauryl tryptose with one liter of water and gently stirring under heat. The pH is measured to ensure a value between 6.6 to

7 after sterilization. Sterilization is performed by placing an inverted vial into a larger test tube. Lauryl tryptose broth is poured into the tube to cover the smaller vial (about 25 tubes are prepared in this manner per FCB test) and are then placed into the sterilizer at 120-150 °C for 2 hours.

Brilliant green lactose bile broth is prepared by mixing 40 g of brilliant green lactose with 1 liter of water, and stirring under heat to dissolve. The pH of the broth should be between 7 to 7.4 after sterilization. A group of 25 tubes are prepared and sterilize in the same manner as for the lauryl tryptose broth.

After preparing the broth solutions, a series of dilutions are prepared of the sample using 10, 1, 0.1, 0.01 and 0.001 ml of the sample within the fermentation test tubes containing lauryl tryptose broth and incubated at 35°C for 48 ± 3 hours.
The presence of gas in smaller tubes is recorded. Presence of gas indicates a positive for fecal coliform. If a whole group of tubes are negative, they can all be sterilized and discarded. If any tube within a group of five is positive, then all five tubes will be further analyzed in the next 2 phases.

Further analysis is performed by using a sterile loop to transfer 1 or more loopfuls of the specimens to fermentation tubes containing brilliant green lactose broth, being sure to sterilize the loop before using it for a different tube. The fermentation tubes are incubated again at 35°C for 48 ± 3 hours.

Visually examine and record the presence of gas in smaller tube. Presence of gas indicates a positive for fecal coliform and those tubes (only) can move on for further analysis. The postitive tubes are visually analyzed and used to calculate the MPN/100 mL for the specimen using a statistical table. Tubes that are negative can be sterilized and discarded. After recording data, all tubes must be sterilized and discarded.

2.5.1.7. Equipment, Chemicals and Materials

Glassware

Beakers

Beakers of various volumes (50 ml, 100 ml, 150 ml, 250 ml, 600 ml, and 1000 ml), furnished by Pyrex and Kimax, were used for various lab tests.

Graduated Cylinders

Graduated Cylinders of various volumes (25 ml, 100 ml, 250 ml, 500 ml, and 1000 ml), furnished by Pyrex, were used for various lab measurements of samples and chemicals.

BOD Bottles

300 ml Wheaton BOD Bottles with penny stopper caps were used to conduct BOD tests on samples.

Volumetric Flasks

Volumetric Flasks of various volumes (50 ml, 100 ml, 200 ml, 250 ml, 500 ml, 1000 ml and 2000 ml), furnished by Pyrex, were used for preparation of standard curve and chemical solutions, as well as specific sample preparation for TN and TP analysis.

Separatory Funnels

Separatory Funnels of 500 ml and 1000 ml, supplied by Pyrex and Kimax, were used for TPH analysis.

Pipettes

Pipettes of various volumes (1 ml, 5 ml, 10 ml and 25 ml), furnished by Kimax, were used for various lab tests.

Quartz Cell

BUCK I.R. Quartz Cell, 10 mm (for ranges of 10 to 500 ppm TPH), provided by BUCK Scientific, used to measure TPH samples.

TPH Sealed Standards

TPH Sealed Standards, provided by Buck Scientific, E. Norwalk, CT, containing standards of 0 ppm, 11 ppm, 50 ppm, and 244 ppm, were used to calibrate the Total Hydrocarbon Analyzer prior to TPH testing.

Meters and Probes

BOD_5

The YSI 5100 Dissolved Oxygen Meter and YSI 5010 BOD Probe were used to measure the DO of BOD samples.

TP

Spectronic® Genesys 2 Spectrophotometer, from Sepectronic Instruments, was used to measure the light absorption of TP samples.

TPH

Buck Scientific Model 404 IR Total Hydrocarbon Analyzer was used to measure the concentration of TPH in water samples.

TN/pH

Accumet® Research AR25 Dual Channel pH/ Ion Meter, furnished by Fisher Scientific, was used with Orion 3512 ammonia probe to measure changes in mV readings to correlate TN concentrations. Likewise, the Accumet meter was used with Orion915606 pH probe to measure pH.

Miscellaneous Laboratory Equipment

Distillation Unit

2100 Fisher Scientific Distillation Unit was used to distill TN samples before any measurements were made.

Glass Fiber Filters

Whatman Glass Microfibre filters GF/C circles 47 mm were used to perform TSS analysis.

Vacuum

GE Motors AC Motors Thermally Protected 6180GDX Non Reversible 1/3 Hp vacuum was used to apply suction to the glass fiber filters during TSS analysis.

DI Water

Barnstead ROpure Infinity™ Reverse Osmosis Water System in series with Barnstead NANOpure Infinity™ Ultrapure Water System was used to supply de-ionized water for analysis.

Scales

Denver Instruments Co. XE Series Model 300 and Mettler Toledo PG5002-S scales were used to measure chemical reagents, glass fiber filters, sand, etc. throughout the project.

Sample Bottles

Nalgene HDPE bottles of 125 ml, 250 ml, and 1000 ml were used to store samples. Aero Housewares Food Storage 3 qt. canisters, from Areo Plastics Inc., Leominster, MA, were used to store samples.

Incubator

Revco Incubator set at 20°C was used for BOD testing.

Oven

Fisher Scientific Isotemp Oven was used for TSS testing and drying glassware.

Furnace

Thermolyne- Dubuque III was used for VSS testing of samples.

Stirrer

Cimarec® 2 Thermolyne magnetic stirrer was used to mix samples during certain tests.

ParaFilm

ParaFilm, provided by Pechiney Plastic Packaging, Menashe, WI, was used during various tests.

Pollutant Tank Pump

Master Flex variable speed pump, from Cole-Parmer Instruments Co. and Manufactured by Barnant Co, Barrington, IL, was used to pump the synthetic pollutant solution into the spillway.

Flow Meter

Bürket Easy Flow Flow Meter was used to measure the incoming water flow.

Pollutant Tank Stirrer

T-Line Laboratory Stirrer with Bodine motor, from Talboys Engineering Corp, Emerson, NJ, was used to constantly mix the synthetic pollutant solution in the pollutant tank.

Sand

The sand mixture used to simulate sediment on the spillway, provided by Lansco Colors, Montvale, New Jersey, comprised of SC2-5 Min-U-Sil 40, SC2-2 Silica 611, SC2-6 Silica 622, SC3-8 Sil-Co-Sil 75, SC3-3 Sand Mesh 40, and SC3-15 F35 Sand.

Chemical Reagents

Freon

1,1,2 Trichloro – 1,2,2- Trifluroethane [CCl_2FCClF_2] Certified Standard (FW =187.38), supplied by ChemNet of Sarasota, Florida, was used in TPH analysis.

Hydrochloric Acid

Hydrochloric Acid [HCl] ACS Reagent Grade, supplied by Pharmco Products Inc. of Brookfield, CT, was used to preserve samples and in acid washes and bathes for TN and TP glassware.

Cleaning Solution

Chronic - Sulfuric Acid [sulfuric acid and chromium trioxide] for cleaning glassware, furnished by Fisher Scientific, was used to clean glassware and quartz cells.

Sulfuric Acid

Sulfuric acid, NF/FCC Grade, provided by Fisher Scientific, was used for preservation of samples and TN distillation.

BOD Buffer Pillows

BOD Nutrient Buffer Pillows, supplied by HACH Company, Loveland, CO, was used in 4 liters of water to make the dilution water used in BOD testing.

BOD Seed

Polyseed, BOD Seed Inoculum, furnished by Inter Lab, The Woodlands, TX, was used to inoculate BOD samples.

Sodium Hydroxide

Sodium Hydroxide [NaOH], Reagent ACS, pellets 97+% (MW = 40), provided by Acros Organics, was used to neutralize pH in BOD samples and during TN testing.

Potassium Phosphate

Potassium Phosphate [H_2KO_4P], monobasic (MW=136.09), provided by Acros Organics, was used in TP testing.

Glutamic Acid

L(+)-Glutamic Acid [$C_5H_9NO_4$], 99% (MW = 147.13), provided by Acros Organics, was used during BOD testing.

Glucose

D(+)-Glucose [$C_6H_{12}O_6$], Reagent ACS, anhydrous (FW = 180.16), provided by Acros Organics, was used during BOD testing.

Ammonium Chloride

Ammonium Chloride [NH_4Cl], USP/ FCC grade (FW = 53.49), provided by Fisher Scientific, was used during TN testing.

Ammonium Vanadate

Ammonium Meta Vanadate [NH_4VO_3], Purified Grade (FW = 116.98), provided by Fisher Scientific, was used during TP testing.

Ammonium Molybdate

Ammonium Molybdate [$(NH_4)_6Mo_7O_{24}*4H_2O$], Certified ACS (FW = 1235.86), provided by Fisher Scientific, was used during TP testing.

Sodium Borate

Sodium Borate [$Na_2B_4O_7*10H_2O$], certified ACS powder (FW = 381.37), provided by Fisher Scientific, was used during TN testing.

Motor Oil

Castrol GTX Drive Hard [SAE 10W-30] Motor Oil, from Castrol North American Inc., Wayne, NJ, was used during TPH testing.

2.5.2. Laboratory Results

The minimum criteria used for a BMP was taken from the *New York State Stormwater Management Design Manual* (CWP, 2003), which states that acceptable stormwater management practices (SMPs) should be capable of 80% TSS removal and 40% TP removal. Although not typically considered acceptable stand–alone BMPs, the following results of the CBIs laboratory simulator tests were considered for compliance with the NYS minimum requirement. Note that none of the CBIs were tested in the laboratory simulator for FCB removal because the FCB batch tests results showed no sorption of FCB for all of the CBIs.

Siltsack®

TN **-** The Total Nitrogen output concentration was approximately equal to or less than the input for all concentration levels. The output for runs using a low concentration input, regardless of flow rate, demonstrated the greatest removal efficiency, averaging 42.3%. The overall average removal efficiency for all testing conditions was 29.3%, with a range from - 42.2% to 68%. If the one negative result is considered an error and ignored, the overall average removal efficiency is 38.2% with a range from 17.0% to 68.1%. Overall, the total nitrogen removal efficiency declines as the nitrogen concentration level increases. This result appears counter-intuitive, however, the removal mechanism is not likely due to nitrogen sorption onto the CBI material but rather, nitrogen sorption onto TSS that are saturated at lower nitrogen levels. Thus, as the influx of nitrogen is increased and the sorption sites onto TSS become saturated, the nitrogen removal efficiency diminishes. Also, note (see TSS results below) that TSS removal efficiency declined with higher TSS levels, which corroborates the hypothesis that the nitrogen removal mechanism is sorption onto TSS.

TP - The Siltsack® removal efficiency for phosphorus regardless of flow rate or concentration level was minimal to none. The overall average removal efficiency was - 17.1%, with a range from - 90% to 13.5%. This situation was possibly due to some pooling of water when the Siltsack® had collected much sediment or the flow rate was so great that ponding occurred within the CBI, which caused some pollutant loading. At high and medium flow rates, the effluent concentration was greater than the influent. At the low concentration levels, the insert demonstrated some removal of phosphorus. The Siltsack® clearly worked best at low flow rates for TP removal.

TSS - The Siltsack's overall average removal efficiency for suspended solids in all situations was 49.6% with a range from 24.1% to 69.6%. As a general rule, the lower the concentration level the greater the removal efficiency. However, as the flow rate increased the removal efficiency decreased. The best performance was achieved at medium flow rate (150 L/min) for all concentration levels.

TPH – The Siltsack® CBI contained no absorbent, however it still demonstrated some removal of the motor oil added. The overall average removal efficiency was 54.8%, with a range from 3.33% to 87.3%. As a general rule, the lower the concentration and flow rate the better the removal performance. This removal is likely due to the adsorption of the motor oil onto the geotextile fabric of the CBI. This can cause two major problems:

1. Since the possibility of the CBI re-releasing the oil exists, it cannot be disposed of in a landfill. Special arrangements will have to be made with a waste disposal facility, which can add to the maintenance costs.
2. Any storm that follows, consequently, can also trigger the re-release of oil from the fabric.

BOD_5 - The Siltsack's overall average removal efficiency of BOD_5 for all situations was 29.8% with a range of 3.8% to 59.3%. Lower incoming concentration levels generally demonstrated better removal efficiency. However, no discernable pattern could reliably be observed from the data. It is likely that the decrease in BOD is a direct result of the insert (in Siltsack® as well as the other inserts tested) removing nutrients, which attach to the sediment added, from the influent.

Observations – The Siltsack® CBI, during testing of the extreme condition of high flow, high concentration overflowed 20 minutes into testing. Forty minutes into the test, the insert was almost completely clogged and water only trickled from the underside and sides of the insert.

Regarding operation and maintenance, this insert was easy to install, remove, and required little space for storage.

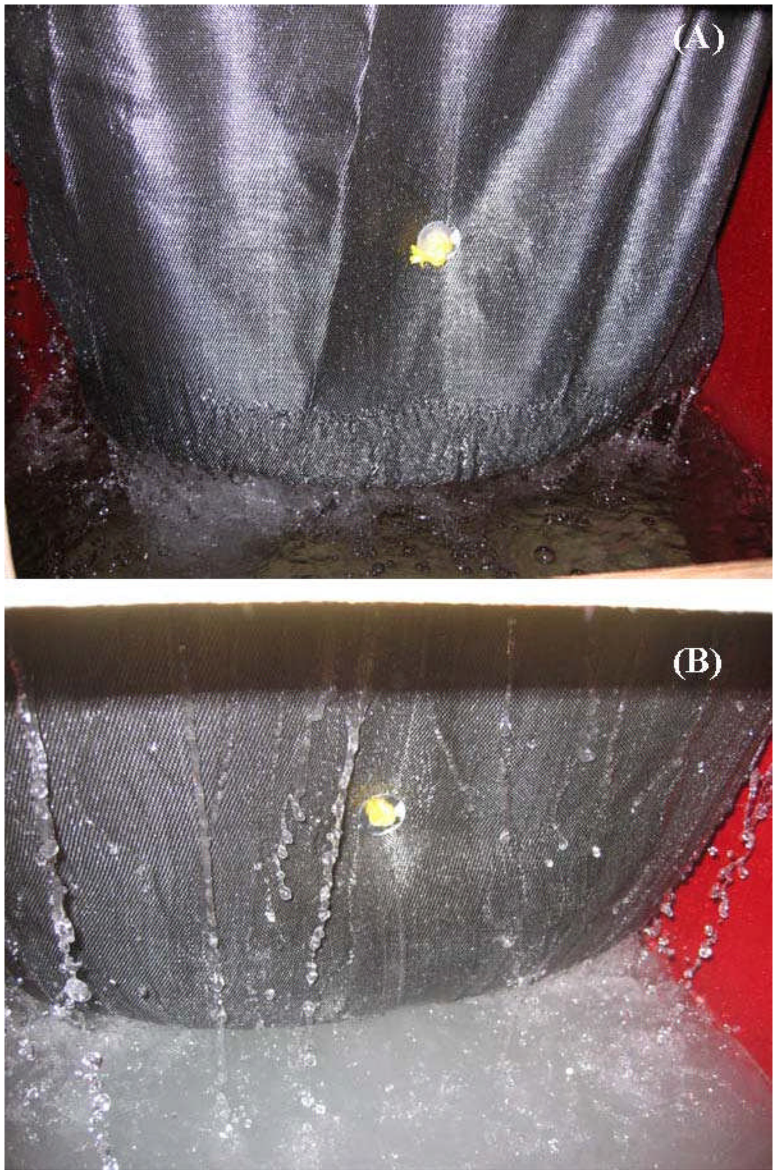

Figure 8: Siltsack® insert tested with (A) clean water and (B) high flow, high concentration testing conditions.

Stream Guard™ Catch Basin Insert for Oil and Grease

TN - All the total nitrogen effluent concentrations from the Stream Guard™ insert showed a notable decrease in nitrogen from that of the influent, notwithstanding flow rate or concentration level. Generally, the higher the flow rate the lower the removal efficiency. The overall average removal efficiency was 50.5% with a range of 40.8% to 75.4%. The Stream Guard™ insert worked well under all conditions for the removal of nitrogen.

TP - The Stream Guard™ insert generally performed better with higher flow rates and low concentrations for phosphorus removal. However, the removal of phosphorus was still minimal. The overall average removal efficiency was 4.6%, with a range from – 20.2% to 18.6%. The highest removal efficiency of 18.6% was achieved under the conditions of high flow rate and high concentration.

TSS - The Stream Guard™ insert consistently performed well in all situations for suspended solid removal. The overall average removal efficiency was 80.0% with a range of 69.9% to 85.5%. On the whole, the insert performed best at low flow rates and low to median concentration levels for the removal of suspended solids.

TPH - The Stream Guard™ insert functioned best at low concentration levels for removal of petroleum hydrocarbons, regardless of flow rate. The overall average removal efficiency was 64.7% with a range of 34.2% to 84.5%. Like the Silt Sack insert, some of the motor oil was adsorbed onto the fabric of the Stream Guard insert.

BOD_5 - The Stream Guard's overall average removal efficiency of BOD_5 for all situations was 41.9% with a range from 34.3% to 61.2%. In general, the lower the flow rate the better the removal efficiency.

Observations -In general, the Stream Guard™ CBI overflowed during high flow rates and high concentrations. During the test for high flow rate, low concentration, the filter overflowed in 60 minutes (towards the end of the last sampling round). During the high flow rate, median concentration test, the insert overflowed in 40 minutes. In 30 minutes, the insert overflowed during the medium flow rate, high concentration test. During testing of the extreme condition of high flow and high concentration, the insert overflowed 20 minutes into testing. All overflows exited the insert through the overflow openings designed for the CBI. These overflows can probably be attributed to the sediment clogging the pores of the geotextile fabric of the insert and the large volume of water flow entering the CBI. In addition, the volume of the bag of the insert was much less than that of the Silt Sack insert. Similar to the Silt Sack, the Stream Guard™ insert was easy to install, remove and store.

Figure 9: Stream Guard™ tested with high flow, high concentration levels.

FloGard® +PLUS

TN - The total nitrogen effluent concentrations from the FloGard® +PLUS insert always showed a decrease from that of the influent, notwithstanding flow rate or concentration level. Generally, the lower the concentration and flow rate the better the performance of the insert. The best removal occurred during the testing of the condition of low flow rate and low concentration. The overall average removal efficiency was 29.4% with a range from 18.3% to 51.9%.

TP -The FloGard® +PLUS insert performed best at low flow rates and median to high concentration levels. The overall average removal efficiency for all conditions was 24.9% with a range from 1.5% to 49.5%.

TSS - The insert performed best at low flow rates and concentration. The higher the flow rate or concentration level the more sediment would escape the filter. In performing TSS analysis, the observation was made that larger grains of sand/sediment were visible in the results than other CBI's tested. The overall average removal efficiency for all conditions was 26.6% with a range from - 34.2% to 81.8%. The negative results can be attributed to the fact that during these tests there was an observed overflow of the CBI being tested, meaning that the incoming water may have bypassed the CBI and exited without being treated by the mesh screening and absorbent. It was also observed that the mesh or pore size of the FloGard® +PLUS inserts were larger than the previously mentioned inserts and probably why it allowed more sediment to pass through.

TPH -The FloGard® +PLUS insert obtained higher removal efficiency at lower concentration levels. As the concentration level increased, the insert's removal efficiency decreased. The overall average removal efficiency for all conditions was 68.8% with a range from 53% to 86.1%. Lower removal efficiencies were observed during high concentration levels.

BOD_5 - The FloGard® +PLUS removal efficiency for BOD, regardless of flow rate or concentration level, was minimal to none and sometimes the effluent levels were greater than that of the influent. The overall average removal efficiency for all conditions was 15.8% with a range from - 56.3% to 55.8%. FloGard® +PLUS obtained best results at high concentration levels. It is believed that more nutrients were available in the effluent since more sediment (to which the nutrients attach) of varying particle sizes could pass through the insert without being captured.

Observations - In general, the FloGard® +PLUS CBI overflowed during high flow rates and high concentrations. Overflow was observed during the following test conditions:

high flow and median concentration; medium flow and high concentration; and high flow and high concentration. For the high flow, median concentration test condition, within 20 minutes the insert had a slight overflow. During the medium flow, high concentration test, with in 20 minutes the filter begins to overflow over the top of the frame. After 40 minutes, most of the water has overflowed over the insert's absorbent pillow, which was floating near the top of the frame, and oil and sand begins to attach onto the outside of the frame. After 30 minutes of the high flow rate, high concentration test, the insert was completely overflowing.

The FloGard® +PLUS insert consisted of a frame and a four-walled absorbent pillow liner. The metal frame has plastic netting onto which the absorbent pillow was attached with hooks, one for each corner. The installation, removal and replacement of the absorbent pillow were very difficult due to the difficulty of attaching the hooks to the netting.

Hydro-Kleen™

TN - The Hydro-Kleen™ insert performed best with low concentration levels. As the concentration level increased the insert's removal efficiency decreased. The overall average removal efficiency for all conditions was 8.3% with a range from - 29.3% to 87%. The negative results can probably be attributed to the pooling of water in this insert's sediment settling chamber. The highest removal efficiency of 87% was obtained during the high flow, low concentration test.

TP - The Hydro-Kleen™ insert's removal efficiency for phosphorus, regardless of flow rate or concentration level, was minimal. The overall average removal efficiency for all conditions was 17.6% with a range from 6.2% to 31.4%. This insert performed best at low concentration levels.

TSS - As the concentration level or the flow rate increased, so did the removal efficiency. The best results for removal efficiency were obtained during the testing of medium flow, high concentration (84.6%) and high flow, high concentration conditions (82.1%). The overall average removal efficiency for all conditions was 48.8% with a range from 4.8% to 84.6%. (TSS overall averages are reported ignoring the negative result as human error.)

TPH - For the Hydro-Kleen™ insert, as the influent's TPH concentration level increased, the removal efficiency for TPH decreased. This insert worked best at low flow rates for TPH removal. The overall average removal efficiency for all conditions was 76.1% with a range from 55.8% to 91.2%.

BOD_5 - The Hydro-Kleen™ insert yielded the best result under the conditions of low flow rate, low concentration, which was 69% removal efficiency. The removal efficiency decreased as the concentration level and flow rate increased. The overall average removal efficiency for all conditions was 3.1% with a range from - 62.1% to 69%.

Observations - In general, it was observed that the Hydro-Kleen™ insert would overflow during high flow rates (300 L/min). Within 10 minutes of the high flow, low concentration; medium flow, median concentration; high flow, median concentration; and high flow, high concentration tests, the insert overflowed due to its inability to handle high flow rates. A test on a clean filter with no contaminants added at the high flow rate of 300 L/min demonstrated that it would overflow.

The Hydro-Kleen™ insert is a dual chambered CBI with a metal frame. The first chamber collects water so that sediment settles out due to gravity. When the chamber fills with water, it spills over the central barrier into the second chamber, which contains two absorbent pillows and one activated carbon filter media pillow. The first chamber can sometimes become clogged and pool water in it indefinitely. If this water was to pool in the summer months, it could become a mosquito breeding ground, and in the winter, it could freeze, limiting the detention time in this chamber and its removal of sediment.

The installation, removal and replacement of the absorbent pillows were very difficult due to the depth of the chambers. It would be advantageous, if the pillows had some kind of band that could be hooked for easier removal and installation of the pillows.

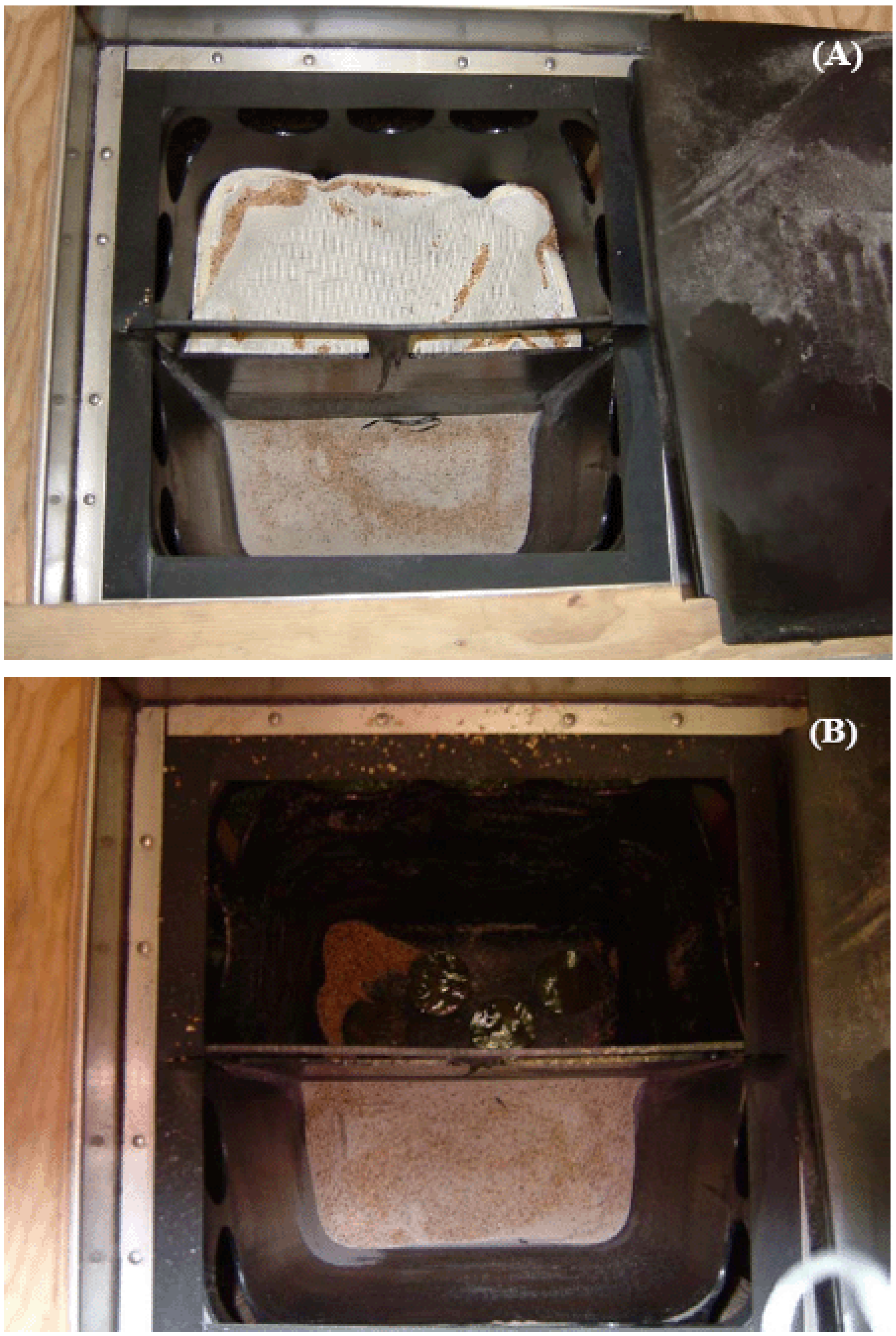

Figure10: Hydro-Kleen™ insert (A) after testing medium flow, high concentration (fully drained). Hydro-Kleen™ insert (B) with the pillows removed (water did not drain out of first chamber).

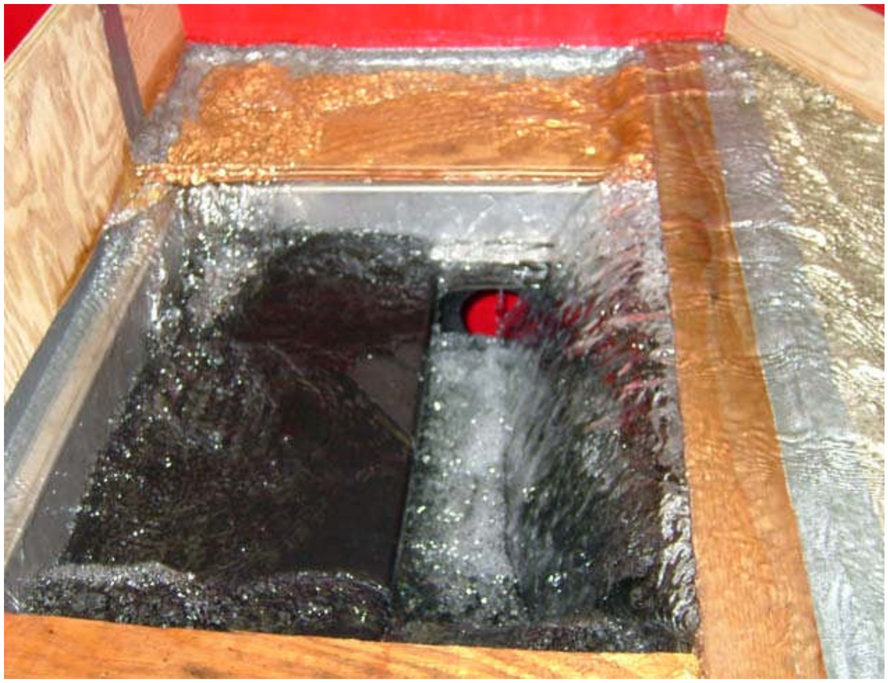

Figure 11: Hydro-Kleen™ insert tested with flow rate of 300 liters per minute.

AbTech Ultra-Urban® Filter (DI2020-N)

TN -The Ultra-Urban® insert achieved its best results at higher concentration levels and lower flow rates. The overall average removal efficiency for all conditions was 22.7% with a range from - 24.2% to 50.6%.

TP – Ultra-Urban's overall average removal efficiency for all conditions was 37.8% with a range from 6.1% to 84.0%. Ultra-Urban® preformed best at low concentration levels. Its removal efficiency decreased at high flow rates.

TSS – Ultra-Urban's removal efficiency increased as the sediment concentration levels became higher. This may be the result of having more large-grained sediment to fill in the pore holes or gaps between the absorbent materials, which would then allow for finer sediment to be captured. This suggests that as time would elapse and more sediment was retained that the insert would become more effective at capturing sediment. The overall average removal efficiency for all conditions was 63.0% with a range from - 4.9% to 95.6%.

TPH - The Ultra-Urban's removal efficiency of the motor oil increased as the concentration levels increased. Low flow rates (50 L/min) also enhanced the function of the insert. The overall average removal efficiency for all testing conditions was 36.7% with a range from - 31.5% to 93.7%. The best results were achieved under the testing conditions of low flow rate, low concentration (93.8%).

BOD_5 - This insert preformed better at low concentration levels. As the testing condition of flow rate increased, the removal efficiency decreased. The overall average removal efficiency for all testing conditions was 29.5% with a range from - 5.7% to 68.4%.

Observations -The Ultra-Urban® insert, regardless of flow rate tested (50 L/min to 300 L/min) or pollutant concentration level, never overflowed. This insert was reasonably easily to install, remove and replace. However, it can become quite heavy due to its capture of oil and sediment. It also requires space for storage since each insert has a hard box structure.

Figure 12: Ultra-Urban® insert (top and bottom) tested with clean water, flow rate of 150 l/min.

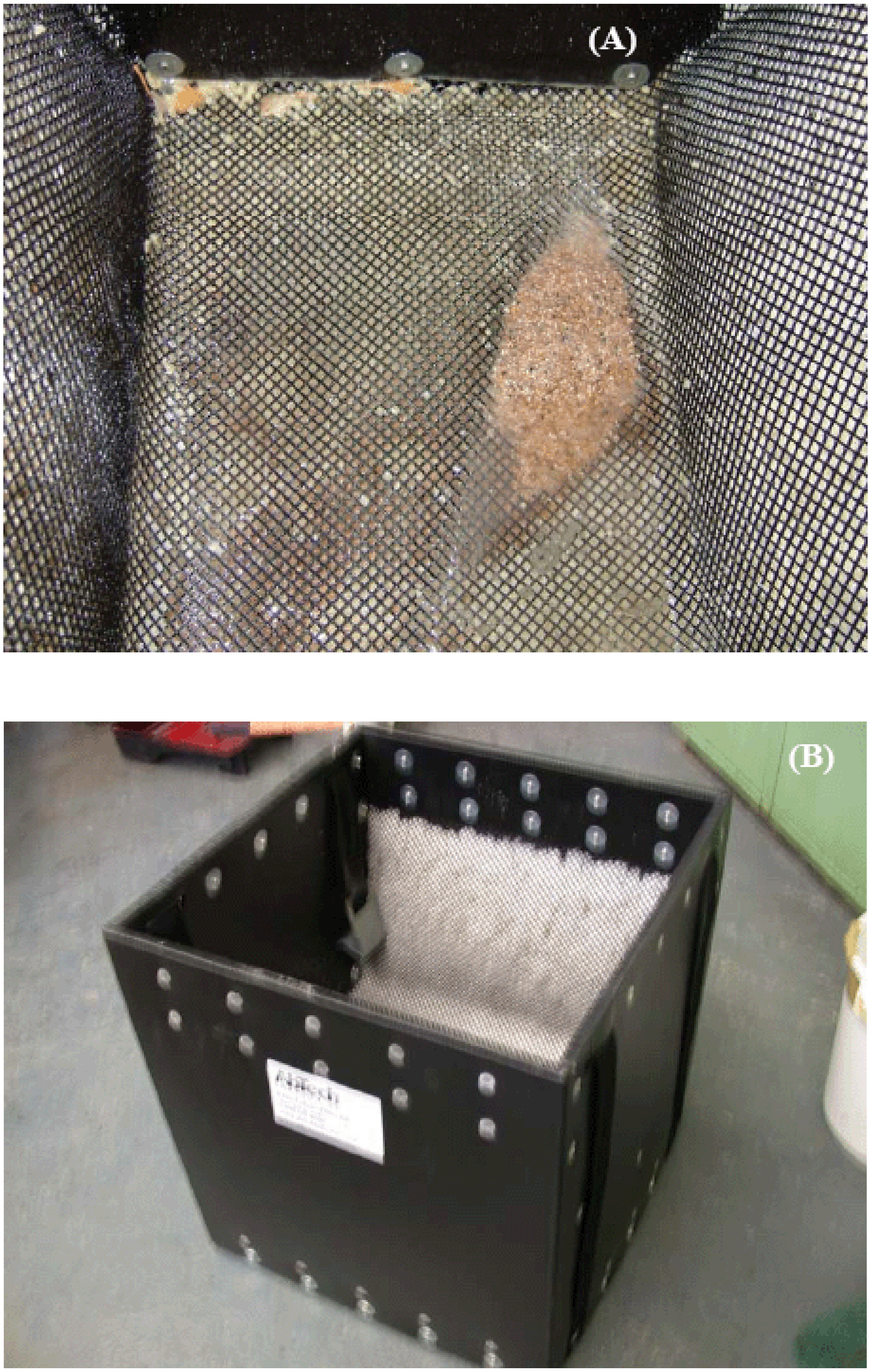

Figure 13: Ultra-Urban® insert (A) used insert and (B) unused insert.

Stream Guard™ Passive Skimmer

Note: The removal of pollutants other than Total Petroleum Hydrocarbons was a function of the catch basins in which the Passive Skimmer was set. Although the test results are presented in this report, it should be noted that similar results may have been derived without the Passive Skimmer in place.

TN - The removal efficiency was highest when the concentration levels were low. As the flow rate increased so did the removal efficiency for nitrogen. The overall average removal efficiency for all testing conditions was 31.7% with a range from 1.0% to 48.6%. However, the absorbent pillow was not designed to remove any nutrient. TN removal is likely due to retention onto sediment, which was removed by the container that acted like a catch basin in the simulator setup (see TSS results below).

TP - The removal efficiency was highest when the concentration levels were low. As the concentration level increased, the removal efficiency decreased. The overall average removal efficiency for all testing conditions was 36.3% with a range from - 3.0% to 76.4%. Since this insert was not designed to remove phosphorus, it is believed that the removal of phosphorus is likely due to the phosphorus adhering to the sediment that was retained at the bottom of the container acting as the catch basin (see TSS results below).

TSS – The Passive Skimmer is designed to float within the sump of a catch basin. It is not designed to retain or capture sediment in anyway. In the simulator, the Passive Skimmer was placed within a plastic container, which had an outlet 7 inches from the bottom and resembled a catch basin that may be found in the field. This set-up was based on typical catch basins, which may have a space up to 12 inches from the floor to the storm lead (*SWRPC, 1991*). The outlet, being located above the floor of the catch basin has the effect of allowing the heavier sediment to settle out due to gravity, which is reflected in the results. The overall average removal efficiency for all testing conditions was 65.1% with a range from 28.7% to 90.3%. It is interesting to include these results for comparison with the CBIs that are designed to capture sediment, as a means of comparing results with a ‘do nothing’ alternative. During testing, it was observed that the skimmer would float into the outlet/ storm lead.

TPH **-** The Passive Skimmer worked best under median concentration levels and lower flow rates. The overall average removal efficiency for all testing conditions was 39.7% with a range from - 24.9% to 89.7%. Ignoring the negative result, the overall average removal efficiency for all testing conditions was 57.4% with a range from 22.0% to 89.7%.

It was observed that during testing of median to high concentration levels of the motor oil pollutant, a film of oil and sediment (scum) would appear on the surface of the water in the container acting as the catch basin. This was most pronounced during high concentration testing as huge puddles of oil and fine sediment formed of the water’s surface.

BOD_5 – The overall average removal efficiency for all testing conditions was 42.6% with a range from 27.3% to 58.4% (BOD_5 overall averages are reported ignoring the negative result as human error). No correlation between BOD_5 removal and concentration level or flow rate was noted. Since the Passive Skimmer was designed to only remove oil or grease, <u>the low BOD outlet concentrations might be due to chemicals bonding to sediment, which was retained in the catch basin</u>.

Observations **-** The Passive Skimmer is a pillow full of an absorbent polymer attached to two floating booms. The skimmer can be attached to the catch basin through the connector hardware and line. It was observed that this line would easily become loosened from the connector after being installed. During simulator testing, it was also observed that the skimmer would float into the outlet/ storm lead (which was smaller diameter than the typical field counterpart) using medium and high flow rates. It is possible that this weak connection line coupled with medium to high flow rates could cause the skimmer to become loose and float out into the sewer system.

The installation, removal, and replacement of the skimmers were very easy due to the connector line, which could be easily reeled in or thrown into the catch basin.

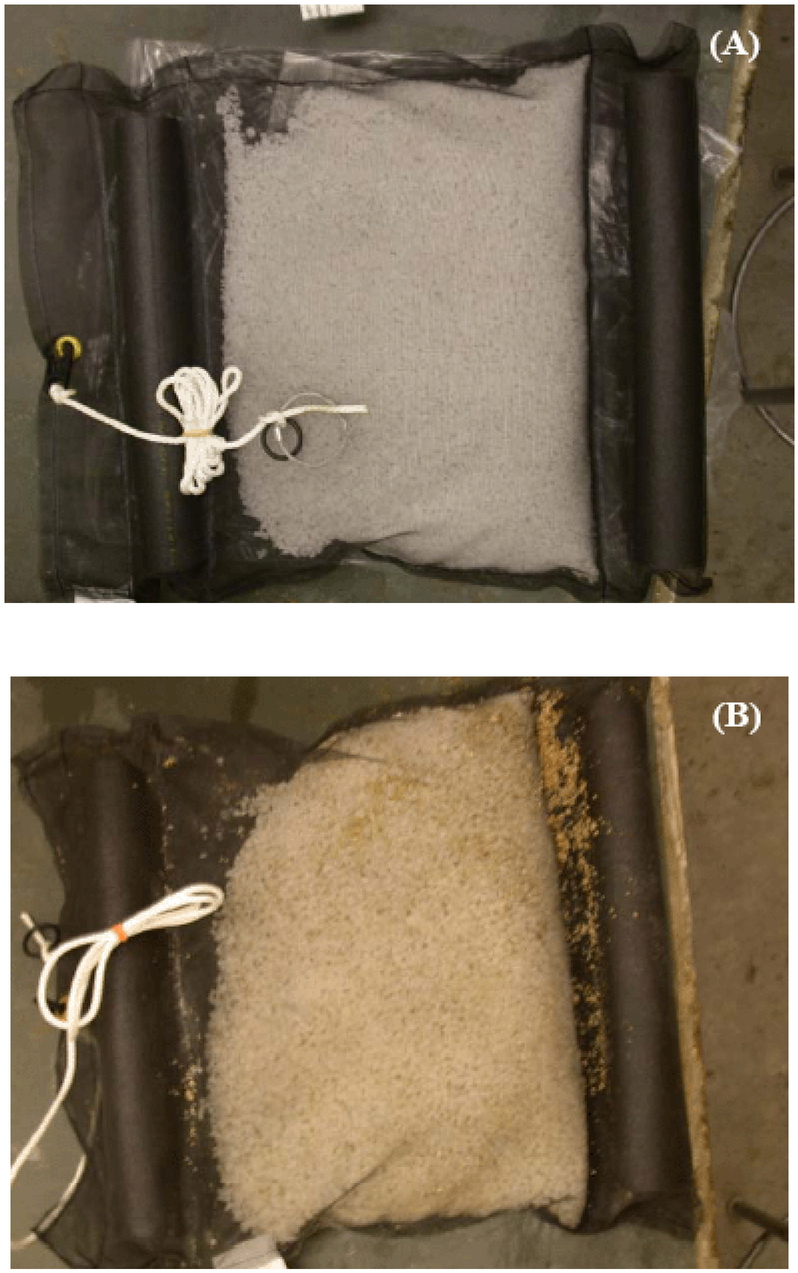

Figure 14: Passive Skimmer: (A) unused and (B) used with medium flow, high concentration.

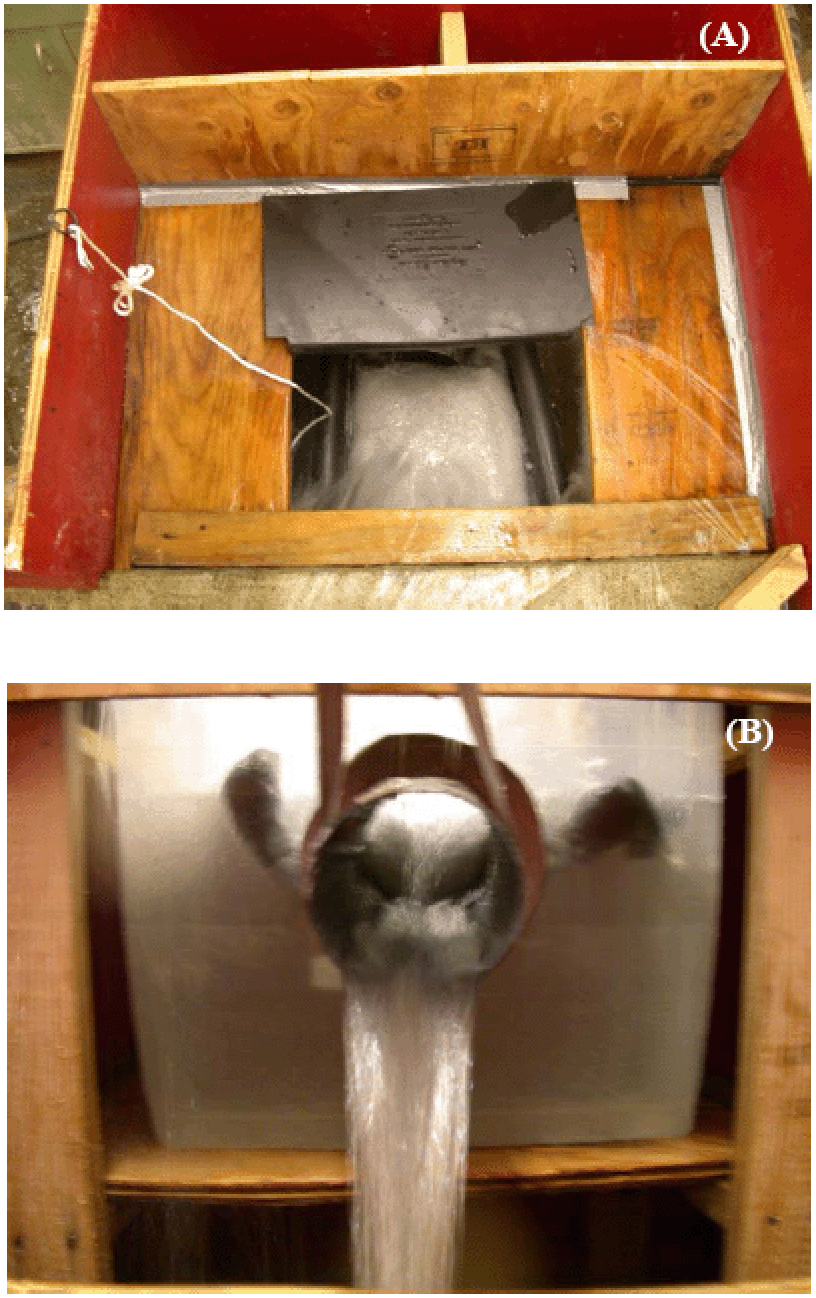

Figure 15: Passive Skimmer at 150 liters per minute: (A) view from above and (B) side of simulator.

Figure 16: Passive Skimmer during high flow rate, high concentration test after 40 minutes.

Figure 17: The catch basin with the Passive Skimmer removed after the test.

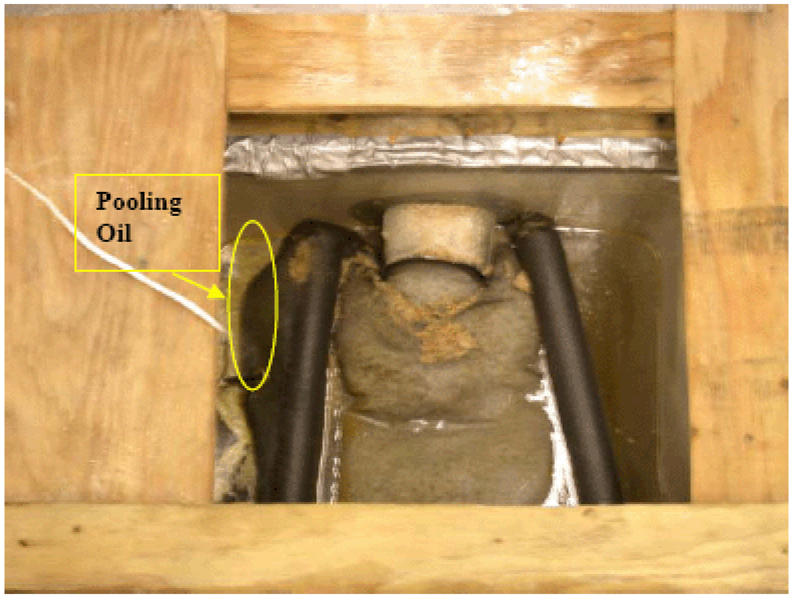

Figure 18: The Passive Skimmer in the catch basin with pooling oil.

2.5.3. Laboratory Testing Summary

TP

Overall, most of the inserts had little effect on the removal of phosphorus from the influent. The best results were observed during the testing of the Ultra-Urban® Filter and the Passive Skimmer, with removal efficiency of 37.8% and 41.2%, respectively. However, the Passive Skimmer insert is not designed to remove phosphorus and it is believed that the removal may be due to the phosphorus adhering to the sediment that was retained at the bottom of the container that was acting as the catch basin or from the retention of influent in this container. This result is interesting and seems to suggest that a catch basin alone could remove trapped phosphorus as sediment settles within the sump of a typical CB. The sediment in this set up had prolonged exposure to the influent and therefore could "capture" more phosphorus to its surfaces. However, it should also be considered that, in the field, this sediment can also release adsorbed phosphorus during subsequent storms or become swept from the CBI sump during heavy storms. The least favorable insert for phosphorus removal was the Siltsack, which was expected since this CBI was designed only to retain sediment. These results rule out these CBI's from being considered an acceptable stormwater management practice, since none surpassed the 40% TP removal criteria.

TSS

Every CBI performed well in suspended solids removal, with all CBI's obtaining overall average removal efficiencies above 45%. The best CBI's were the Stream Guard™ and the Ultra-Urban® inserts, which obtained average removal efficiencies of 80.0% and 71.5% respectively. It should be noted that the FloGard® +PLUS CBI overflowed during several testing conditions, which affected its ability to remove sediment. However, the FloGard® +PLUS insert worked well at lower flow rates, where overflows were not an issue.

TN

In a side-by-side comparison of total nitrogen removal, the results varied greatly. The best insert was the Stream Guard™ with an overall average of 50.5% removal of nitrogen. This filter also had the least fluctuation between testing conditions for nitrogen. The Siltsack® insert, which is a bag designed to remove sediment, also did well, with an average removal of 38.2%. The Hydro-Kleen™ insert performed the least favorable in removal of nitrogen with an overall average removal efficiency of 8.3%.

TPH

All the CBI's were able to remove greater than 36% (overall average removal efficiency) of the motor oil added into the influent. The best performing filters were Hydro-Kleen™, FloGard® +PLUS, and Stream Guard™, with overall average removal efficiencies of 76.1%, 68.8%, and 64.7% respectively. It should be noted that the FloGard® +PLUS overflowed during higher flow rates. This only affected its removal efficiency when coupled with high concentration levels. Ultra-Urban® performed the least favorable with a removal efficiency of 36%. The Passive Skimmer, which was solely designed to remove oil from the surface of the water, had a removal efficiency of 57.4%.

The Siltsack® CBI contained no absorbent, however it still demonstrated some removal of the motor oil added. The overall average removal efficiency was 54.8%. This removal could be due to the absorption of the motor oil onto the geotextile fabric of the CBI. This can cause two major problems:

1. Since the possibility of the CBI re-releasing the oil exists, it cannot be disposed of in a landfill. Special arrangements will have to be made with a waste disposal facility, which can add to the maintenance costs.

2. Any storm that follows, consequently, can become contaminated with oil that is released from the fabric.

BOD_5

The results varied greatly from one testing condition to the next. The best inserts were the Stream Guard™ (42% removal efficiency), Siltsack (29.8% removal efficiency), and AbTech's Ultra-Urban® Filter (29.8% removal efficiency).

2.5.4. Laboratory Study Conclusions

Overall, the best performing filter was the Stream Guard® Insert for Oil and Grease. It consistently was one of the top performing inserts in every parameter tested except TP, in which it demonstrated minimal removal. This CBI also was easy to remove, replace, and store in small areas. Additionally, at the price of $69.00 per insert, the Stream Guard™ Insert for Oil and Grease is an affordable choice.

The AbTech Ultra-Urban® Filter with Smart Sponge® was also a strong candidate among the CBIs. It performed extremely well in the removal of TP, TSS, and BOD_5. It removed TPH well at low flow rates. The Ultra-Urban® insert, regardless of flow rate tested (50 L/min to 300 L/min), never overflowed. This insert was reasonably easily to install, remove and replace. However, it can become quite heavy due to its capture of oil and sediment. This CBI is more expensive ($690.00 per insert) and does require significant space for storage.

Acceptable stormwater management practices (SMPs) should be capable of 80% TSS removal and 40% TP removal. The simulator results were considered with these criteria in mind to see if any of the CBIs could be considered as an acceptable "stand alone" SMP.

The laboratory simulator results corroborate the NYS Stormwater Management Design Manual (CWP, 2003), which does not consider the use of a CBI to be an acceptable SMP. None of the catch basin inserts achieved an overall average removal of 40% for TP. Their removal of TP varied greatly from test to test suggesting that they are unreliable for the removal of this pollutant. Only the Stream Guard™ Insert for Oil and Grease was capable of 80% TSS removal consistently. In conclusion, the results suggest that catch basin inserts are probably best put to use as a device for pre-treatment or in conjunction with other stormwater structural practices.

2.6. Field Studies

2.6.1. Methodology

This part of the project consists of qualitatively monitoring catch basin inserts for maintenance, durability, ease of installation and cost effectiveness, based upon monthly field inspection with photographic reports. Samples and data collected in the field were stored, analyzed and evaluated at the laboratory at Polytechnic University.

In the first part of this section, installation details are reported, with descriptions of each site and the strategies adopted for the field monitoring.

In the second part of this section, the major test apparatii and analytical instruments are described, including sample storage details and procedures used to analyze field samples. A definition of the analyzed parameters and their effect on the environment are also reported.

2.6.2. Field Monitoring

This part of the project consisted of installing Catch Basin Inserts (CBIs) in the field and monitoring through four seasons, over 12 months. The sites were inspected every month, examining each CBI, removing the grating, and checking the condition of each CBI. To track the CBI performance, photographs and careful observations were taken, under different weather conditions and length of service. During each inspection, the following information was recorded:

- Condition of area around the inlet, e.g., accumulation of debris, oil, dirt, etc.
- Structural integrity of the CBI, i.e., needs any repair or replacement.
- Condition of the sorbent material, if applicable.
- Extent of sediment trapped in the filter.

If damage to the CBI was noted, it was replaced with a new one and taken to the laboratory for further inspection. Also, if the sorbent material was saturated with oil, the device was replaced. If the accumulated sediment was more than the 50% of the filter's capacity, the filter was removed, cleaned, and the sediment was collected. Any sediment collected after a clean–out of the filter or after a replacement was brought to the laboratory for gravimetric analysis.

Catch Basin Inserts (CBIs) were installed at locations in Westchester County, NY, following the manufacturers' installation guidelines, as described below:

Ultra-Urban® Filter

The filter was installed in the Goldens Bridge Metro North station parking lot on Route 138 (Goldens Bridge Road), just west of I-684 (Figure 19 & Figure 20). It is a drop–in device that does not require any special labor for the installation, but does require two people to lift and install. The CBI is supported by a stainless steel frame, furnished by the manufacturer and custom made because of the dimension of the catch basin. Two filters were placed next to each other to cover the inlet area of the catch basin, as shown in Figure 21.

FloGard® +PLUS

This CBI was also installed in the Goldens Bridge Metro North station parking lot on Route 138, just west of I-684 (Figure 19 & Figure 20), into a different catch basin. The device was frame mounted and because of the special dimensions of the catch basin, two filters were installed next to each other, in order to cover the catch basin inlet area (Figure 22). This is also a drop–in device and, once the grate was removed, no special labor was required for the installation. Two people are needed to lift the CBI.

Hydro-Kleen®

This filter was also installed in the Goldens Bridge Metro North station parking lot on Route 138, just west of I-684 (Figure 19 & Figure 20), into a 3rd catch basin. After the grate was lifted, the device was installed following the manufacturer guidelines, placing the sedimentation chamber next to the curb. The sedimentation chamber allows sediment to settle out of the runoff before passing through the filter media chamber. Three layers of media where used to fill the filter chamber: two layers of oil sorbent material at the top and one layer of activated carbon at the bottom. Because of the catch basin dimensions, two devices were necessary to cover the catch basin area (see Figure 23).

Stream Guard™ Catch Basin Insert for Oil and Grease

This filter was located in the parking lot of the I-684 north bound rest area between Exits 8 and 9 (Figure 24). It is a fabric bag that can fit almost any inlet shape or size because of its fabric adapter "skirt" (see Figure 25). The installation of this unit did not require any custom made frame. Once the grate was removed, the CBI skirt was laid over the opening and the grating replaced. To facilitate the removal of the filter, two metal sticks where used to hang and hold it while the grate was removed. Two people are needed to lift the grating.

Stream Guard™ Passive Skimmer

This device was also located in the I-684 north bound rest area between Exits 8 and 9 (Figure 24), but in the truck parking lot. The device is made of a mesh fabric and has the shape of a pillow stuffed with sorbent beads. No special attention was needed for the installation of this filter, as it is designed to float in the sump of any ordinary catch basin. The only recommendation was to anchor the pillow to the catch basin vault using the attached rope and ring, as shown in Figure 26 to avoid loss of the filter through the discharge pipe.

Siltsack®

The filter was installed in the rest area of I-684 South, between Exits 5 and 4, in a catch basin at the end of the parking lot, as shown in Figure 27. The device is a polypropylene sack that fits into the catch basin and no special frame is required. It was necessary to remove the grate, mount the filter inside and hold the lifting loops outside of the catch basin frame, and replace the grate to hold the filter (see Figure 28). The installation process required three people, to hold the filter in place while replacing the grate. Special attention was required during the maintenance inspections, such as when lifting the filter, because it was very heavy when full of sediment.

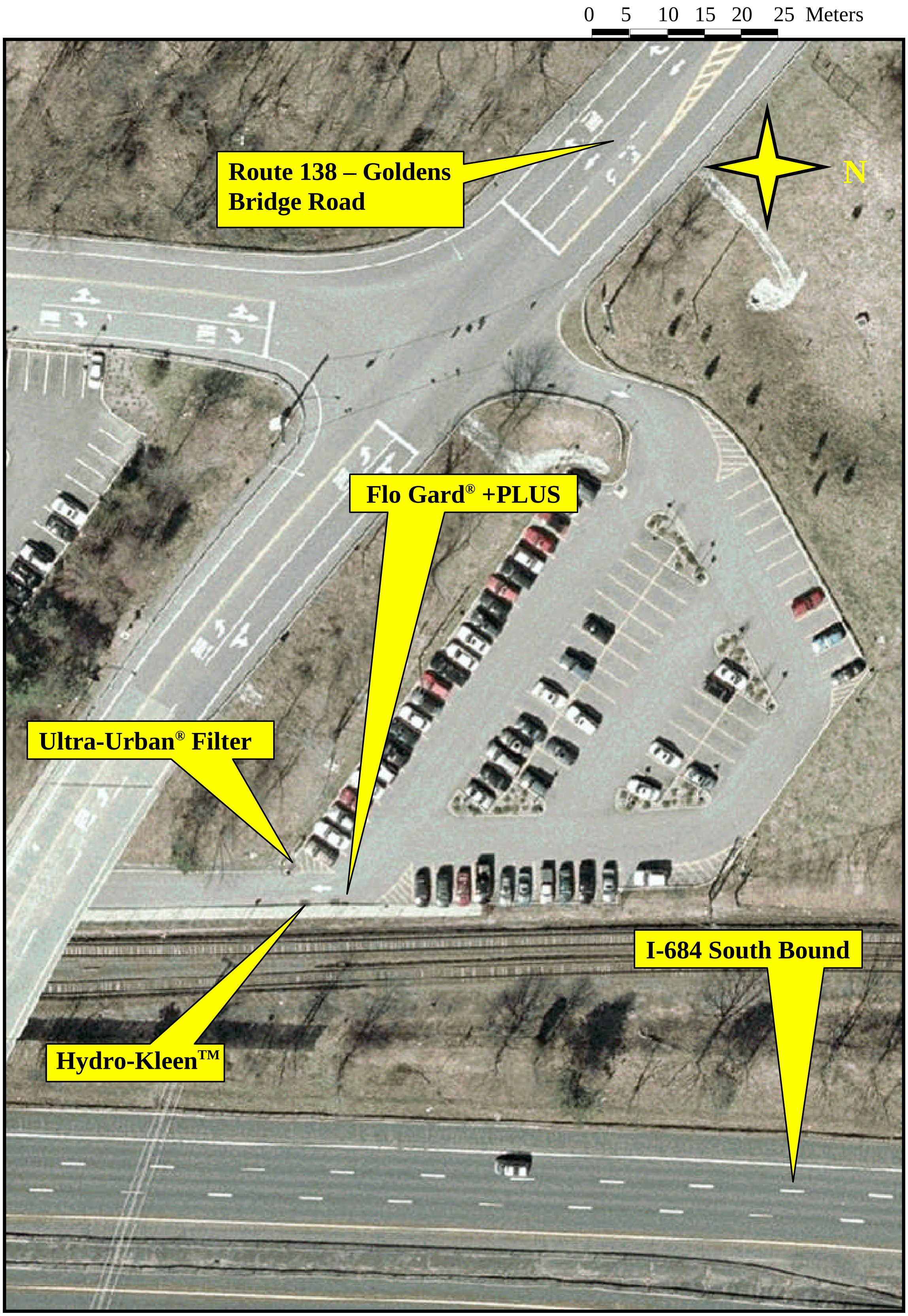

Figure 19: Goldens Bridge Metro North Station Parking Lot

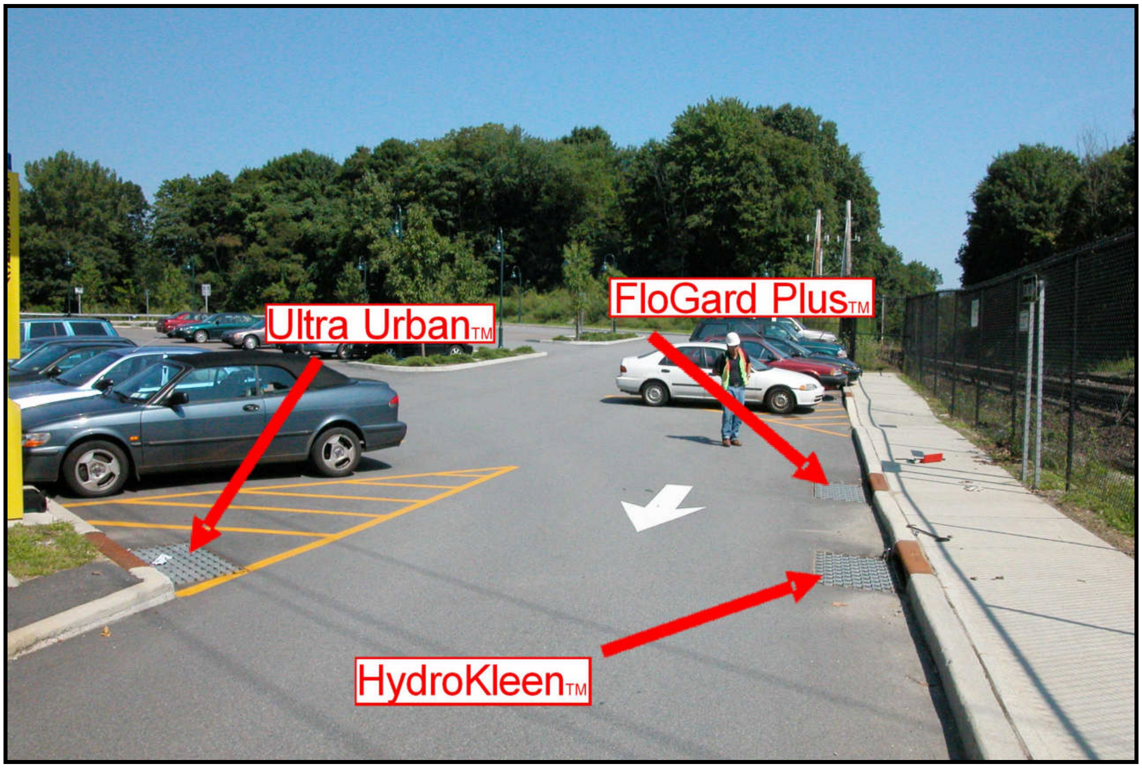

Figure 20: Catch basins locations, Goldens Bridge Metro North Station Parking Lot.

Figure 21: Ultra-Urban® Filter installation details.

Figure 22: FloGard® +PLUS Filter installation details

Figure 23: Hydro-Kleen® Filter installation details.

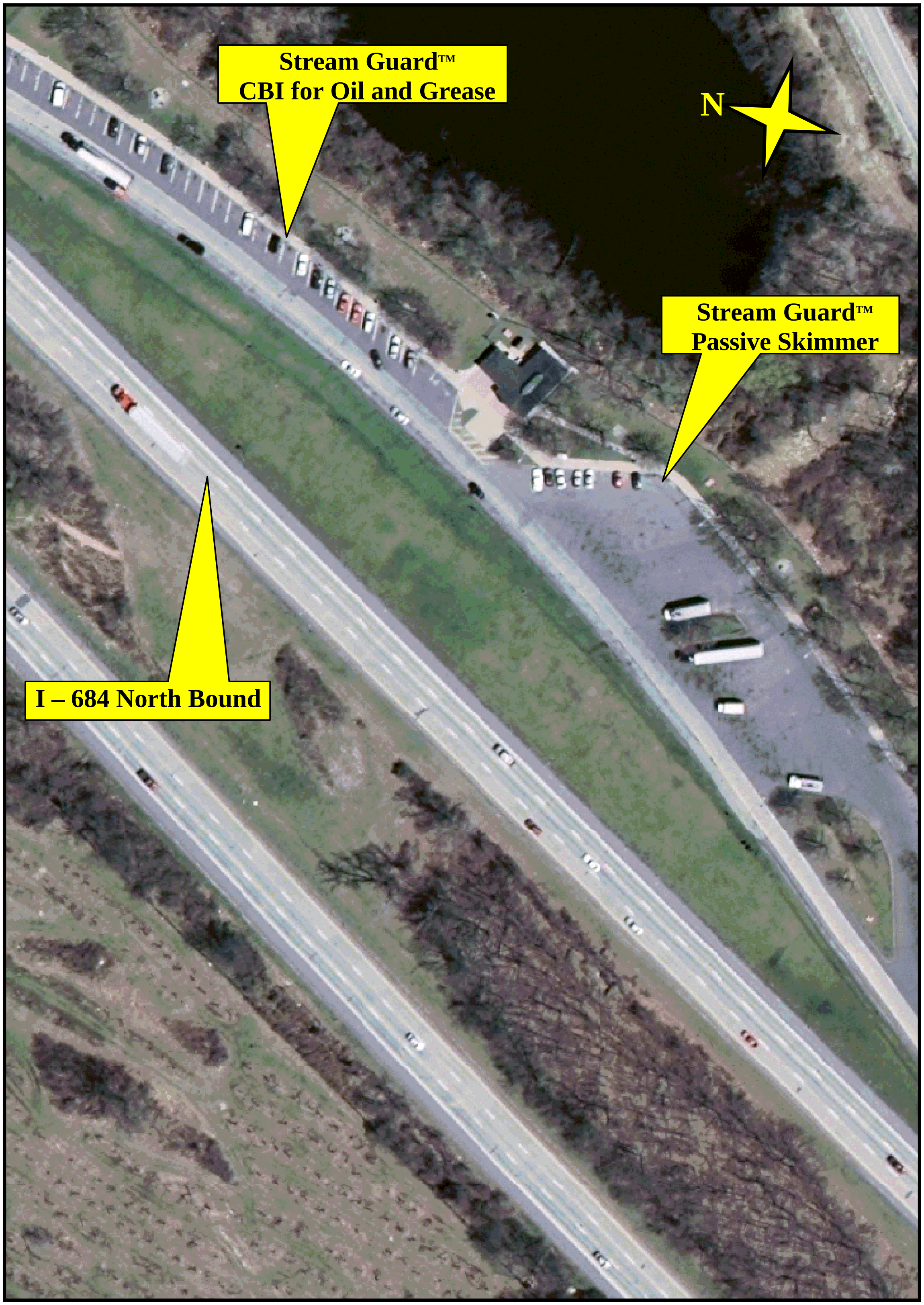

Figure 24: I-684 North Bound Rest Area – between Exits 8 and 9

0 10 20 30 40 50 Meters

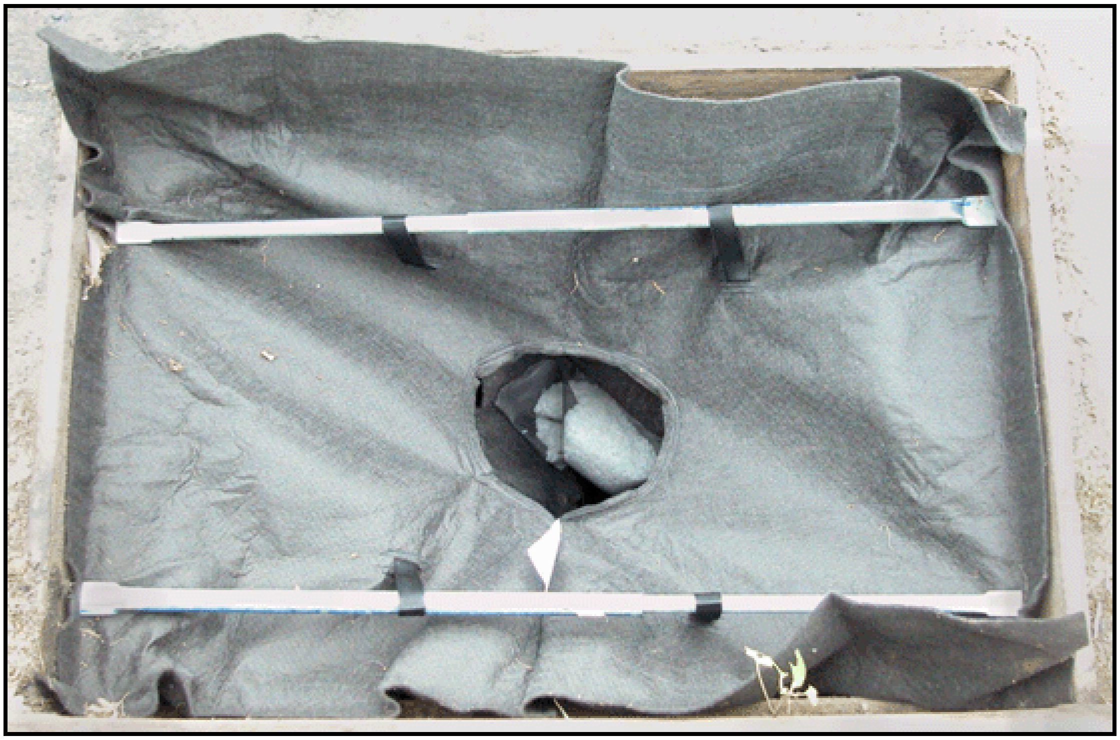

Figure 25: Stream Guard™ catch basin insert installation details

Figure 26: Stream Guard™ Passive Skimmer installation details.

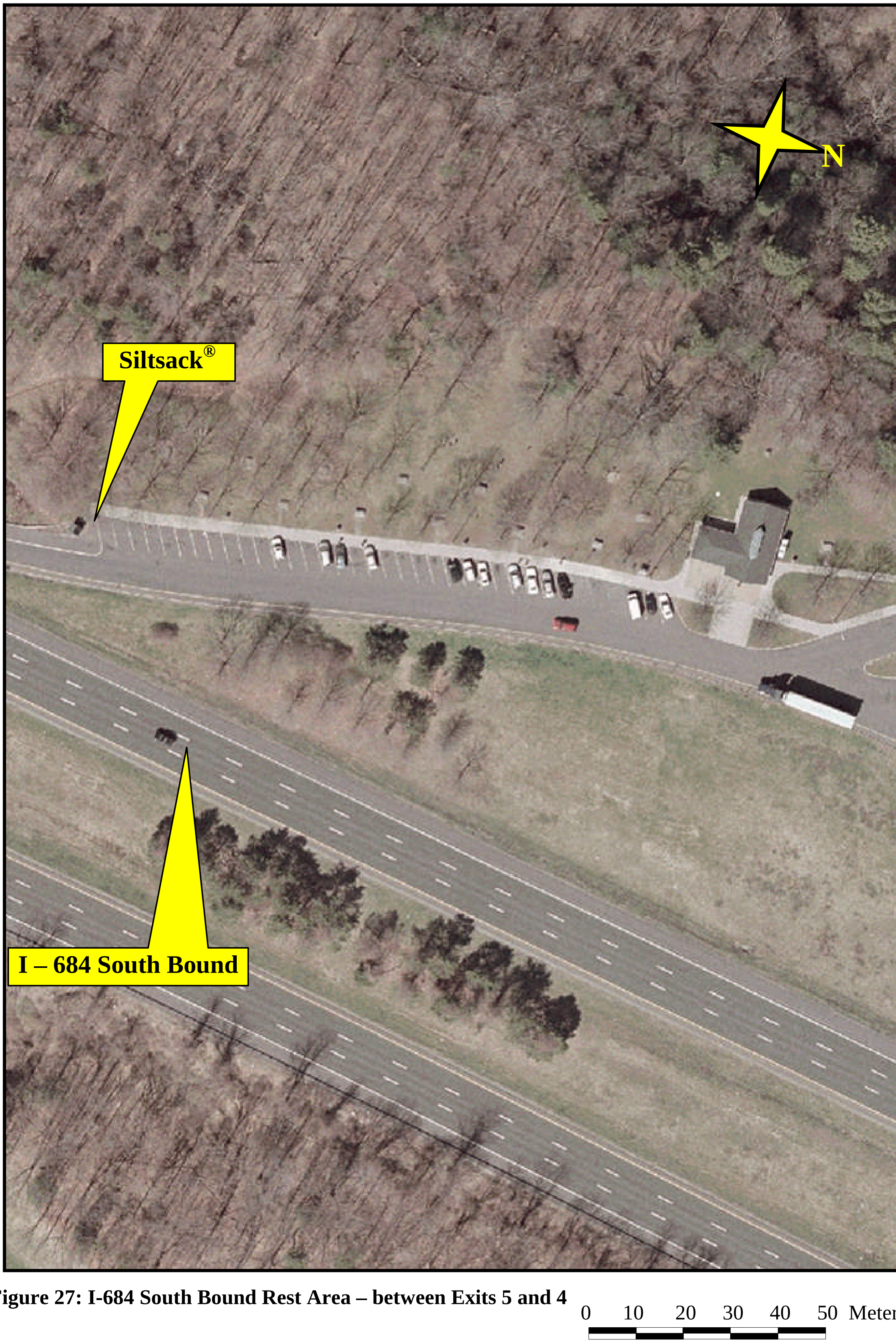

Figure 27: I-684 South Bound Rest Area – between Exits 5 and 4

Figure 28: Siltsack® installation detail.

2.6.3. Litter Analysis

Samples collected in the Westchester area from the catch basin inserts were carried to the laboratory for drying, separation, and weighing. The litter was first dried for one or two days in the oven at 35-40ºC to assure separation of gravel and other solid particles from leaves. After this first step, the leaves were separated from gravel particles and sediments with the use of a shaker and by hand. All the leaf litter was weighed and data were recorded. The next step was to dry the gravel and sediment at 105ºC for 24 hours and then sort them using two US standard meshes (N.10 & N. 20) into three groupings: greater than 2 mm, between 2– 0.85 mm and less than 0.85 mm. Finally, these three groupings were weighed and data were recorded.

2.6.4. Field Study Results

CBIs were monitored in the field for a period of over one year and the following Table 1 shows the details of the field inspection for each device: installation date, number of replacements, days of operation, cleanup and removal date. CBIs were inspected every month and, when required, they were cleaned and the collected sediments were brought to the laboratory for separation and weighing. In the laboratory, after drying, samples were separated into four main categories. Table 2 summarizes all the field inspections and sample collections for each CBI, including sampling date and the amount of sediment, for each category of sediments, including the total weight collected from each inspection.

Table 1: Field study summary of the Catch Basin Inserts

CBI Name	Date	Notes	Monitoring Time [Days]	Replacements
Silt Sack®	7/31/2003 12/18/2003 8/9/2004	Installed Cleaned Removed	 140 235	0
Total Monitored Days = 375				
Stream Guard™ CBI	5/3/2003 6/10/2003 9/18/2003 10/10/2003 11/12/2003 3/10/2004 7/1/2004	Installed Replaced Removed Installed Replaced Replaced Removed	 38 100 33 119 113	3
Total Monitored Days = 403				
FloGard® +PLUS	8/19/2003 12/18/2003 4/13/2004 8/9/2004	Installed Cleaned Replaced Removed	 121 117 118	1
Total Monitored Days = 356				

Table 1: Field study summary of the Catch Basin Inserts (continued)

CBI Name	Date	Notes	Monitoring Time [Days]	Replacements
Hydro-Kleen™	2/20/2004 7/1/2004 10/22/2004 5/6/2005	Installed Cleaned Replaced(1) Removed	 132 113 309(2)	1
Total Monitored Days = 441				
Ultra-Urban®	5/3/2003 6/10/2003 7/15/2003 12/18/2003 8/9/2004	Installed Cleaned Cleaned Cleaned Removed	 38 35 156 235	0
Total Monitored Days = 464				
Passive Skimmer™	6/10/2003 12/18/2003 1/22/2004 2/4/2004 7/1/2004	Installed Replaced Removed Installed Removed	 191 35 147	2
Total Monitored Days =373				

(1) Only the media were replaced but the first chamber (sedimentation) was not cleaned because there was not enough sediment to be collected.

(2) The counting of these days starts from the inspection of 07/01/2004 since no sediment was collected on 10/22/2004.

Table 2: Summary of CBI sediment collection

CBI Type	Sampling Date	Other(*)	Sediments sizes			
			Smaller Than mesh N.20 (< 0.850 mm)	mesh N.20 (0.850 mm – 2 mm)	larger than mesh N. 10 (> 2 mm)	Total Weight
		[kg]	[kg]	[kg]	[kg]	[kg]
Siltsack®	12/18/2003	6.28	19.28	11.90	3.14	40.60
	08/09/2004	9.12	19.40	18.24	6.36	53.12
						Total collected sediments = 93.72
Stream Guard™ CBI	06/10/2003	0.09	0.69	0.41	0.42	1.61
	09/18/2003	0.05	0.83	0.60	1.39	2.87
	11/12/2003	0.53	0.26	0.07	0.03	0.89
	03/10/2004	1.20	1.32	0.46	0.26	3.24
	07/01/2004	0.85	1.15	0.37	0.28	2.65
						Total collected sediments = 11.26
FloGard® +PLUS	12/18/2003	0.76	3.82	3.92	1.58	10.08
	04/13/2004	1.20	7.86	4.02	1.20	14.28
	08/09/2004	1.02	9.46	3.26	1.46	15.38
						Total collected sediments = 39.74
Hydro-Kleen™	07/01/2004	0.32	4.56	4.24	2.70	11.82
	05/06/2005	9.38	3.44	10.80	7.90	31.52
						Total collected sediments = 43.34
Ultra-Urban® Filter	06/10/2003	0.07	0.59	0.31	0.20	1.17
	07/17/2003	0.05	0.33	0.12	0.13	0.63
	12/18/2003	2.46	1.58	0.96	0.36	5.36
	08/09/2004	5.04	8.06	20.10	10.34	43.54
						Total collected sediments = 50.70

(*) "Other" was not gravel, but consisted mostly of leaves, plastics, cigarettes, etc.

2.6.5. Field Study Summary

Table 3 summarizes the performance of the CBIs during the entire period, reporting on number of filter replacements, days of service (lifetime), the amount of sediment captured, and the average amount of sediments captured per day of operation. All six filters were studied for more than one year, covering 4 seasons. Five of the six devices were observed to remove sediment and oil from stormwater, although certain units were more effective than others. The Stream Guard™ Passive Skimmer is not designed to remove sediment and, therefore, only removed hydrocarbons from stormwater.

Table 3: Summary of the CBIs field study

CBI	No. of Replacements (during monitoring time)	Monitoring Time [day]	Sediment Captured [kg]	Sediment Captured / Day [kg/day]
Siltsack®	0	375	93.72	0.25
Stream Guard™ CBI	3	403	11.26	0.03
FloGard® +PLUS	1	356	39.74	0.11
Hydro-Kleen™	1	441	43.34	0.10
Ultra-Urban® Filter	0	464	50.70	0.11
Passive Skimmer™	2	373	---	---

As shown in Table 3, the Ultra-Urban® filter, FloGard® +PLUS and Hydro-Kleen™ removed nearly the same amount of sediment per day. It is likely that they had very similar influent loading of sediment, also, since they were installed near each other at the end of the same parking lot. The Hydro-Kleen™ may have removed a slightly lower amount because it was located after the FloGard® +PLUS filter, along the same curb (see Figure 20).

The Siltsack® Filter trapped the largest amount of sediment and the highest rate of sediment captured per day, most likely due to the filter's location. As shown in Figure 27 and Figure 29, the filter was installed in a catch basin located at the end of the curb in a parking lot that borders a picnic area. During the storm events, sediments were eroded from the picnic area, traveled to the sidewalk and curb nearby the catch basin where the Siltsack® filter was installed (see Figure 30).

Figure 29: Siltsack® filter installation site

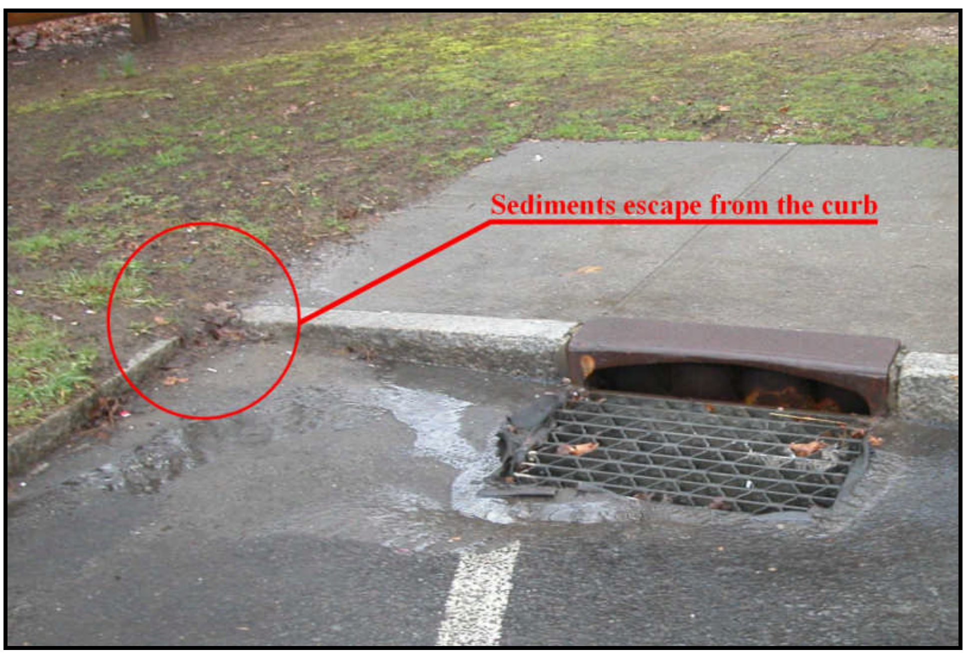

Figure 30: Siltsack® - Sediments were eroded from the nearby picnic area

The Stream Guard™ filter collected the least amount of sediment, apparently due to the slope of the parking lot in the installed area. In fact, the other filters were located in a parking lot with a slope that facilitated sediment transport to the catch basins.

The Stream Guard™ filter location had a very small slope and resulting in a slower runoff velocity and, consequently, a lower concentration of sediments transported in the runoff to the catch basin. Although all six devices were found to remove oil from the runoff, only five were designed to absorb it. Five filters were manufactured with hydrocarbon–absorbing polymers that are reported to remove oil from the stormwater runoff and trap it without leaching. During the field inspections and monitoring the color of the sorbent material that became darker after every storm event, it was noticed that all five filters removed oil. However, no analytical data are available to evaluate the oil removal efficiency of each device, since no analytical tests were performed for this part of the study. The Siltsack® filter is the only filter that was not furnished with oil sorbent material, however, after few months of operation, sediments accumulated on the bottom of the filter and trapped some oil from the runoff. While not measured for the field study, the capability to hold a large quantity of sediments will likely result in a significant oil removal efficiency by the Siltsack® filter.

Table 3 also shows how often each filter was replaced during the study period. The Ultra-Urban® Filter and Siltsack® were the only two filters that were never replaced. At the end of the monitoring period, the Ultra-Urban® Filter still appeared capable of sediment and oil removal, no damage to the filter was noted, and the sorbent material was not completely oil– saturated. Therefore, the Ultra-Urban® Filter was capable to operate longer than 464 days without any replacement. The Siltsack® filter, on the other hand, had a tear on the side of the sack (Figure 31) after 375 days of operation (at the end of the monitoring time), and would need to be replaced if longer operation was required.

Figure 31: Siltsack® - Hole in the geotextile fabric

The FloGard® +PLUS filter was replaced once during the monitoring period because of a loss of sorbent material due to a hole in the mesh (see Figure 32 & Figure 33). In fact, it was noted that the mesh holding the sorbent material was weak and easily torn. At the end of the monitoring study, 118 days since the last replacement, the sorbent material was not completely saturated and appeared capable of continued use.

The Hydro-Kleen™ filtration system was also replaced once during the monitoring period, after verifying the sorbent material was saturated with oil, 132 days after installation. Only the pillows that hold the sorbent material and the activated carbon were replaced. The filter was removed 309 days after the last replacement and it was again found completely oil– saturated. It is possible that the sorbent reached saturation prior to removal.

Figure 32: FloGard® +PLUS - Loose absorbent material

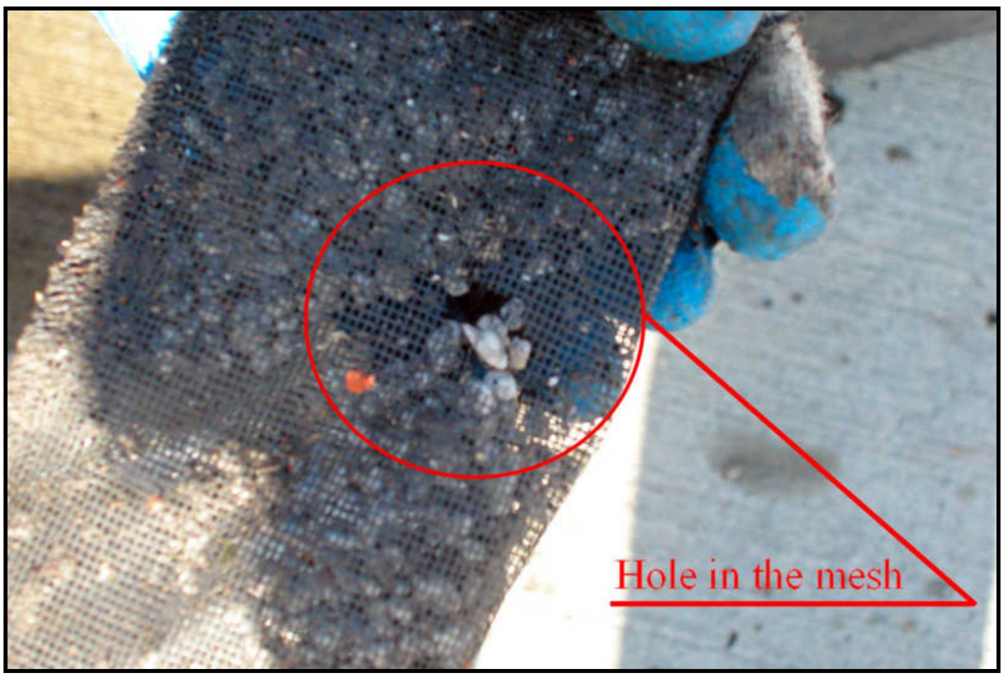

Figure 33: FloGard® +PLUS – Hole in the mesh that holds the absorbent material

The Stream Guard™ filter was replaced three times during the study period. The filter was replaced because of damage to the geotextile fabric all three times, and not because the sorbent was oil–saturated. Figure 34 shows the holes in the filter fabric. It appeared that these holes were caused from lit cigarettes that people would throw into the catch basin and, during dry weather, these cigarettes would have the time to make a hole through the fabric. It was determined that a lit cigarette would require about three seconds to make a hole through the fabric (see Figure 35).

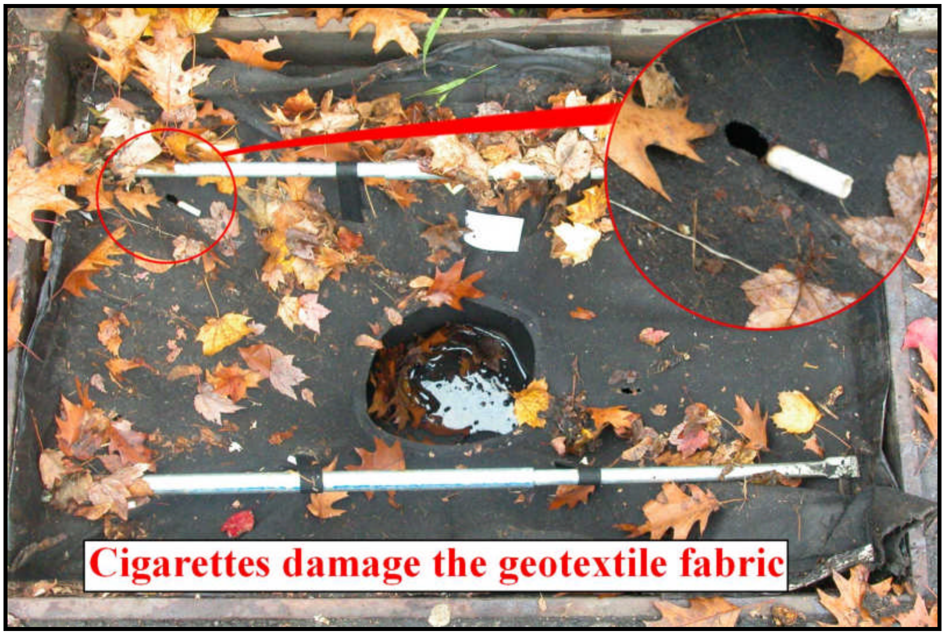

Figure34: Stream Guard™ filter, holes in the fabric caused by lit cigarettes

Figure 35: Stream Guard™ – Test performed with a lit cigarette on the fabric

The Passive Skimmer™, like the Stream Guard™ and the FloGard® +PLUS filter, was replaced because of damage to the filter during normal operation and not because sorbent material became oil saturated.

Figure 36: Passive Skimmer™, slit in the mesh with loss of absorbent material

Figure 37: Passive Skimmer™, missing the ring that allows the tying of the filter

As shown in the Figure 36, the mesh holding the absorbent material is very weak and easily torn. Furthermore, the device was replaced early in the study because the entire filter was lost. The rope that secured the floating pillow disconnected (see Figure 37) and the pillow was carried away during the first storm event. The second Passive Skimmer^{TM} was replaced because a hole in the mesh of the pillow was observed. After the last replacement, the third filter remained in operation for 147 days, at which time it was nearly oil-saturated.

The removal of the sediment from the chambers of the devices is suggested with the use of a vacuum truck, which is the most effective and convenient method. Manhole openings provide access to both the sediment and floatable chambers. To remove oil, grease, and other hydrocarbons, it may be preferable to use adsorbent pads since they are likely to be less expensive to dispose of than the oil/water emulsion that may be created by vacuuming the oily layer (*Vortechnics, 2006*).

2.6.6. Operation & Maintenance

During this study, monthly inspections were performed in order to assess the maintenance requirements of these devices for a long–term use in a parking lot environment. The maintenance intervals of the devices and the difficulty in conducting maintenance vary seasonally, being more difficult during the fall and the winter seasons when inspection or replacement would likely require snow or leaf removal from the catch basin grates. Figure 38 is a picture of a catch basin during the fall season. It shows a large quantity of leaves collected at the entrance of the catch basin, affecting the operation of the catch basin. When a large portion of these leaves falls into the filter installed inside, they affect the performance of the CBI. Therefore, during the fall season, if trees are present in the drainage area, a CBI inspection once every two weeks is suggested, and an increase of the street sweeping activity in the drainage area.

Figure 38: Catch basin covered with leaves during the fall season

During the winter season, problems were encountered with the inspection and eventual cleanout or replacement of the device, related to the snow accumulated on top of the grate and inside of the CBI. As shown in Figure 39, the large amount of snow complicated the inspection of the CBI that required shoveling of the snow that was covering the catch basin. The snow inside the CBI would increase the weight of the system, complicating the lifting during cleanout or replacement of the filter.

Figure 39: Snow accumulated on lid of the catch basin

It is important to note that the maintenance schedule should be customized depending on the location where the devices are installed and on the amount of pollutants generated from the drainage area. The operation and maintenance procedures of each studied CBI are reported in the following sections.

Siltsack®: The Siltsack® filter is a permeable geotextile bag held within a catch basin between the grating and the rim of the catch basin (see Figure 40). This configuration has two main advantages. First, it allows the filter to fit in a variety of catch basins without the need to be customized. Second is the small volume that it occupies during transportation since it can be folded. Both advantages make the device very practical for the operator that would have to install or replace large quantities of filters. Another relevant aspect of this device is that it does not contain any sorbent material and this makes its disposal easier, since no special procedures are required. While disposal costs of collected sediment is likely a similar concern for all CBIs that capture TSS, replacing a filter or filter media that contains sorbent material will add to the disposal cost.

Figure 40: Installation of the Siltsack® filter

The installation and replacement processes were difficult on the initial attempt, but become easier with experience. During installation, the edges of the filter need to be held outside of the catch basin, while at least two operators lift the grate and lower it straight (downward) on the rim of the catch basin. A difficulty that was noticed during filter clean–out was the weight of the sediments inside the filter, which made it heavy to lift. There is always the potential for the geotextile to tear during removal, and that the accumulated sediment could fall back into the catch basin.

The device, during the entire period of evaluation, performed very well, removing primarily sediments and required very little maintenance.

Stream Guard™ Catch Basin Insert for Oil and Grease: The Stream Guard™ filter is a polypropylene geotextile basket that, like the Siltsack® filter, is held within the catch basin between the grate and the rim of the catch basin (Figure 41).

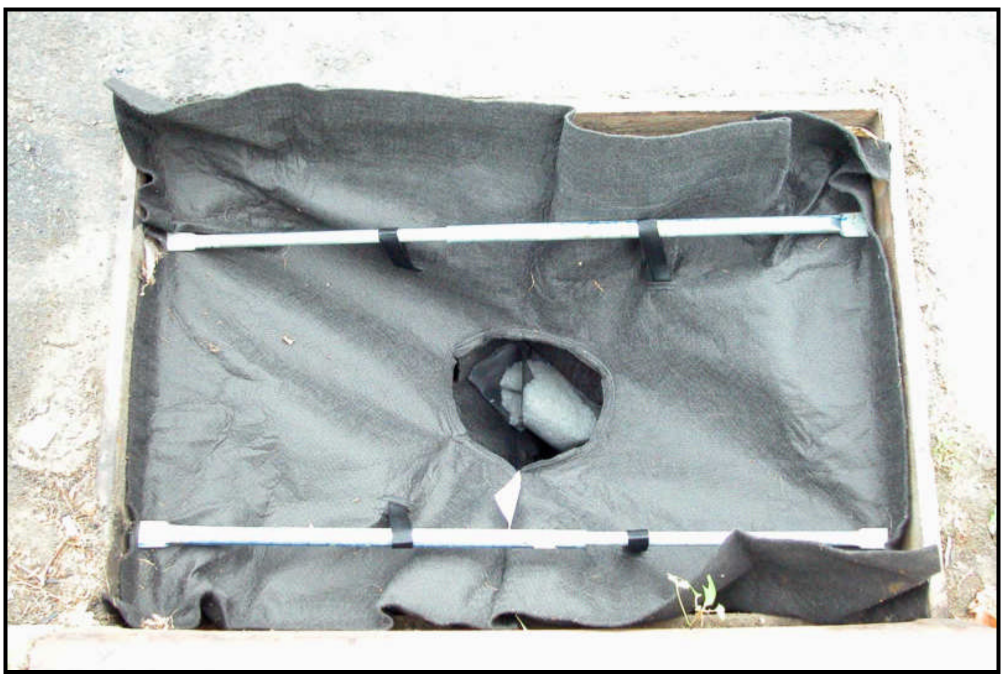

Figure 41: Stream Guard™ filter installation

Similarly, this device presents the same two advantages - it fits into a variety of catch basins without requiring customizing, and it can be folded, making the device easy to transport. Installation and replacement of the filter are similar to the Siltsack®, but they differ in that this device can not accumulate large quantity of sediment and that makes it easier to lift out of the catch basin when performing routine maintenance cleanout or replacement. On the other hand, due to its lower capacity, the device will require more frequent maintenance. During operation, it was noted that the device collected sediments and oils, and appeared to also remove floatable pollutants from the stormwater runoff. The main problem that was observed on this device is that the fabric material is very weak and easy to break, increasing the potential for releasing its contents into the catch basin. Holes were found in the fabric, caused by lit cigarettes, especially during dry weather conditions (see Figure 34). The small diameter of the basket leads to clogging of the filter, particularly during the fall season when a large quantity of leaves accumulated at the bottom of the filter and resulted in standing water so that subsequent runoff by–passed through the overflow holes (see Figure 42).

Figure 42: Stream Guard™ filter clogged due to the leaves.

FloGard® +PLUS: The FloGard® +PLUS is a frame–mounted filter that has to be custom–sized for each site. Also, in this case, two filters were needed to fit the catch basin. The filter is easy to install and the filter pouches are replaceable. However, the snap hooks that hold the pouches are not easy to unsnap. This device also needs to be lifted during the cleanout or replacement. Each filter, however, can be removed separately, making the lifting easier. In the event of snow accumulation within the filter, lifting of the device is more complicated, and replacement of the pouches is very difficult unless the snow is first removed from the filter. Also, the depth of the filter obstructed the piping that connects with other catch basins, thereby impeding sediment and litter coming from previous catch basins.

Figure 43: FloGard® +PLUS Filter operation

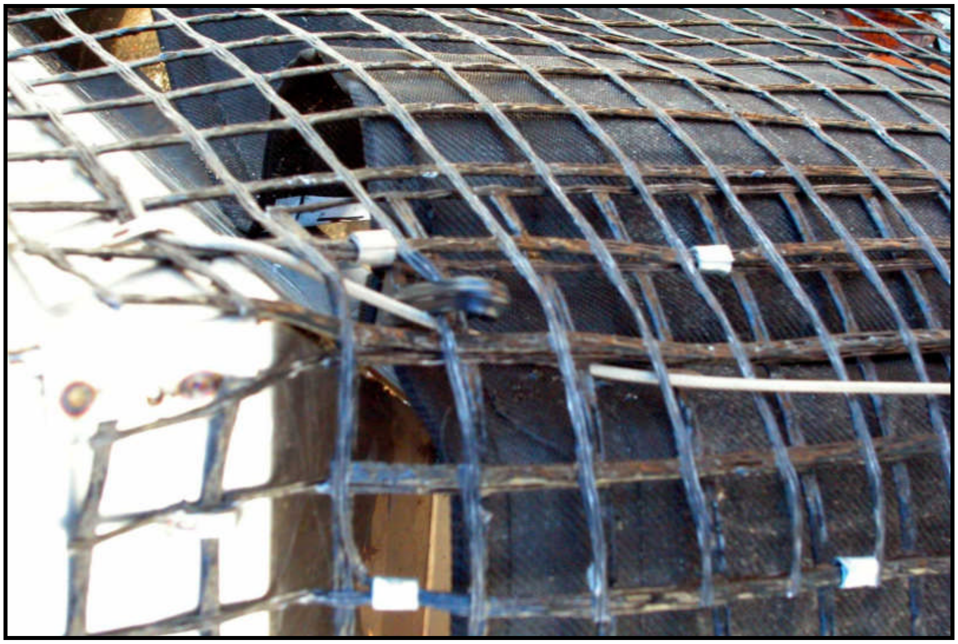

Figure 44: FloGard® +PLUS, snap hook that holds the replacement pouch

Figure 45: Snow covering the FloGard® +PLUS Filter

Figure 46: FloGard® +PLUS is deep and can obstruct connecting drainage piping

The filter appeared to collect oil and sediment for the entire study period, but on one occasion the sorbent material was released due to a tear in the mesh and replacement of the pouch was required (see Figure 32 and Figure 33). It was noted that this mesh holding the sorbent material is too weak and can be easily torn by the litter. If it is replaced with a stronger mesh material, it can be expected that very little maintenance would be required throughout one year.

Hydro-Kleen™: The Hydro-Kleen™ is a multimedia filtration system (hydrophobic cellulose and activated carbon are used as filtration media) with a preliminary chamber for sedimentation and with overflow by–pass protection. The device was easily installed after its dimensions were customized from the manufacturer. Two filters were mounted on the same frame, next to each other, in order to cover the catch basin area (Figure 47).

Figure 47: Hydro-Kleen™ operation

The replacement of the filtration media of the Hydro-Kleen™ system proved to be very easy, since no lifting of the structure is required and the filtration pillows are simply layered in the chamber, next to pre–settling chamber, where no sediment is present. The cleanout of the sedimentation chamber was not easy to perform due to standing water that was always retained within the preliminary (sedimentation) chamber. Also, during dry weather, it was complicated to scoop out the sediment from the chamber and the use of a vacuum cleaner is suggested. The design of the system does not allow high flow rates to be treated, as high flow will tend to by–pass the filter since the level of the overflow by–pass outlets is very close to the level of the standing water in the first sedimentation chamber, as shown in Figure 47 and Figure 48. Also, because of the shape and the size of the device, it caused a partial obstruction of the drainage pipe (see Figure 49).

Figure 48: Hydro-Kleen^{TM}, the overflow by–pass is close to the standing water level

The sedimentation chamber did not appear capable enough, under the parking lot conditions where the device was installed during this study, to handle the flow and floatables. Particularly during the fall season, the device was easily clogged with a large quantity of leaves, thereby increasing the likelihood for the runoff to by–pass, and would require frequent leaf removal from the chamber (see Figure 48 & Figure 50).

During the period of evaluation, the device was observed to remove sediments and oils from the runoff (observed within the device chambers) and the change in color of the sorbent material. However, since no runoff samples were collected and analyzed, it was impossible to evaluate the removal of other pollutants (organics, metals, etc.) through the activated carbon filter from this field study.

Figure 49: Catch basin where the Hydro Kleen® was installed

Figure 50: Hydro-Kleen™ is easily clogged with leaves

Ultra-Urban® Filter (DI2020-N): The Ultra-Urban® is a high–strength, corrugated plastic device with the shape of a box (Figure 51). It was easily mounted inside the catch basin, supported by a custom–size frame, and the installation of two filters was necessary to fit the dimension of the catch basin.

Figure 51: Operation of the Ultra-Urban® Filter

Due to the fact that there were two filters installed on the same frame, lifting the filter from inside the catch basin was not easy due to its weight, especially during the snow season (see Figure 52). Installation and replacement of a large number of these devices at the same time is difficult due to the rigid construction, large shape and volume that require a large truck for the transportation. Another problem related to its shape and size, as shown in Figure 53, is that the filter obstructed the drainage pipe that connects to the previous catch basin, holding back a lot of leaf litter, sediment, and floatables within the pipe, outside of the filter.

Figure 52: Ultra-Urban® Filter during snow season was heavy to lift

Figure 53: The Ultra-Urban® obstructed the drainage pipe

Figure 54: Catch basin where the Ultra-Urban® Filter was installed

During operation, the CBI performed well, removing sediments and oil for the entire evaluation period, remaining unsaturated at the end of it and requiring very little maintenance. The device exhibited high capability of operation with low and high flow rates and the presence of sorbent material on three sides of the box appears to facilitate the absorption of hydrocarbons from the runoff. The mesh that holds the sorbent material appeared to remain very strong and durable during the observation period.

Stream Guard™ Passive Skimmer: The Passive Skimmer is a floatable device in the shape of a pillow, filled with hydrocarbon–absorbing polymers. Its simple configuration made this device very easy to install, maintain, and replace, since no specific expertise or procedures were required (see Figure 55). The only problem that was noticed during the evaluation period was related to the mesh that holds the sorbent material—it is very weak and easy to tear. On one occasion, after rubbing on the bottom of the catch basin, a tear in the mesh resulted in loss of sorbent material (see Figure 36). On another occasion, the mesh tore where the string used to tie-off the filter was connected, again resulting in a loss of all the filter material (see Figure 37).

Figure 55: Stream Guard™ Passive Skimmer installation

During operation, it can be determined that the device removes oil because the sorbent material darkens, but because of its floating configuration, it is difficult to determine the ability of the skimmer to absorb all of the floating oil within the catch basin.

2.6.7. Capital and O&M Costs

The economy associated with implementing BMPs, related to the capital and O&M cost, is an important consideration of stormwater management programs. Below, the costs are reported for each device evaluated in this study, including average installation and O&M costs. The cost of each unit varies with the model size of the device, while installation and O&M costs depend on the site characteristics and may vary from site to site. Costs of the units, including supports and installation were all provided from the manufacturers and are based on the year 2006. Hydro-Kleen™ is the only device for which costs are unknown, as the manufacturer did not reply to requests for this information.

Siltsack®

The Siltsack® filter is a permeable geotextile bag that can fit a variety of catch basins. The cost of each unit ranges from $54 to $70, depending on the size (*AFC Environmental, 2006*). The specific device used in this study was a 2'x2' size with a price of $65 (*AFC Environmental, 2006*). In the current study, the device was never replaced during the entire year of operation, so in this case the total cost for the device in one year is $65. The annual labor costs for maintenance are assumed to be the same of the other devices, $480 for the monthly inspection and $320 for the quarterly cleanout, for a total of $800. The first installation and replacement of the devices are assumed to be performed within the one hour of labor considered for the quarterly cleanout.

Stream Guard™ Catch Basin Insert for Oil and Grease

The Stream Guard™ catch basin insert is non–woven, polypropylene geotextile fabric filter bag that can fit a variety of catch basins. The cost of each unit is of $65 (*Bowhead Manufacturing Company, 2006*) and considering that, on average, this device needs to be replaced every three months, in one year the total cost for the devices will be of $260. Replacement should be performed during the quarterly scheduled inspection; therefore, no additional labor costs need to be considered. Similarly, the annual labor maintenance costs can be assumed to be $800.

FloGard® +PLUS

The FloGard® +PLUS evaluated in this study was the 24-inch size. The device is frame mounted and its cost is $602 (*KriStar, 2006*), which includes the frame cost ($545) and the first filter pouch ($57). Because of the size of the catch basin, it was necessary to install two devices into the same catch basin and, thus, the total initial cost for the devices is $1204. The cost of the replacement pouches is $57 each (*KriStar, 2006*). Therefore, over a one year operation, the replacement of the filters would cost an additional $114 based on these observations. The annual labor costs for maintenance are assumed to be the same as the previously discussed filter, $800, for the monthly inspections and quarterly cleanouts that are required. The first installation and replacement of the devices are assumed to be performed within the one hour of labor considered for the quarterly cleanout.

Hydro-Kleen™

The Hydro-Kleen™ system is a multimedia filtration device with a preliminary chamber for sedimentation. No costs were provided from the manufacturer during the evaluation period. Therefore, the only additional costs are related to the labor for the maintenance of the unit. The unit requires a replacement of the filtration media on average every six months. The labor required for the maintenance of the unit is half–hour every month for the inspection, and one hour every three months for the cleanout. Therefore the total maintenance cost during one year of operation is $800.

Ultra-Urban® Filter (DI2020-N)

The Ultra-Urban® filtration system evaluated in this study was Model # DI2020-N-TD with Smart Sponge®. Two devices were mounted into the same catch basin. The cost of one unit is of $550 (*AbTech, 2006*) and the cost of the double collar used to hold two devices within the catch basin is $575 (*AbTech, 2006*). The device never needed replacement during the entire year of the evaluation period. Therefore, the total cost for the devices during the first year of operation is $1675. Monthly inspections are assumed to take one half–hour, and cleanout of the device, required once every three months, should take about one hour. Based on an average wage of $80 per hour for a two–person crew equipped with a van, the annual maintenance cost will be $480 for the monthly inspections and $320 for the quarterly cleanout for a total of $800. The first installation and subsequent replacement of the devices should be completed within the one hour of labor considered for the quarterly cleanout.

Stream Guard™ Passive Skimmer

The Stream Guard™ Passive Skimmer, also called "Pillow", is a device designed to remove only floating hydrocarbons. The cost of the each unit is of $60 each (*Bowhead Manufacturing Company, 2006*) and considering a replacement every 3 months, the total annual cost for the devices is $240. Annual labor costs for maintenance are not estimated considering that the device does not require cleanout, and the replacement consists just of tying the device at the lid of the catch basin and no additional time is needed. It is assumed that the replacement could be done during the half hour of labor considered for the monthly inspection. Thus, the annual maintenance costs will be calculated based on 12 monthly inspections at $40 each, for a total cost of $480 per year.

2.6.8. Costs Summary

Table 4 summarizes the costs detailed above related to the catch basin inserts monitored in this study.

Table 4: Cost summary for the Catch Basin Inserts

Device	Structure Cost	Filtration Media Cost	Approximate Media Replacement Interval(1)	Annual Cost for Filtration Media	Annual Maintenance Cost
Siltsack®	n/a	$65	12 months	$65	$800
Stream Guard™	n/a	$65	3 months	$260	$800
FloGard® +PLUS	$1090(4)	$57	12 months	$114(3)	$800
Hydro-Kleen™	---	---	6 months	---	$800
Ultra-Urban®	$575(2)	$550	36 months	$366(3)	$800
Passive Skimmer™	n/a	$60	3 months	$240	$480

** Costs do not reflect any manufacturer discount. Unit costs do not include delivery and sales tax.

(1) The replacement interval depends on the conditions of the site were the device is installed.

(2) The cost is related to a frame that supports two devices.

(3) Two devices were mounted into the same catch basin and replacements are doubled.

(4) Each device is frame mounted. Therefore two frames were needed for this catch basin.

2.6.9. Field Study Conclusions

The field observations are that CBI filter selection should be guided by site conditions and the purpose of the installation. For example, in terms of durability, the most effective device was the Ultra-Urban® Filter that has a high capacity for holding sediment and was not oil–saturated after one year of operation, and showed no signs of structure damage or wear and tear. All the other devices, except for the Siltsack®, were replaced during the monitoring time: the FloGard® +PLUS and the Hydro-Kleen™ were replaced once, the Passive Skimmer twice and the Stream Guard™ three times.

On the other hand, in terms of annual cost for filtration media, the lowest cost was the Siltsack® at $65 per year, while the cost of the Ultra-Urban® was $366, the FloGard® +PLUS was $114, the Passive Skimmer was $240, and the Stream Guard™ was $260. However, the Siltsack® is not furnished with an oil–absorbing media and the installation of this device is suggested in sites where only the collection of sediment is needed. This CBI had an ability to remove oil from runoff as a result of the accumulated sediment, not by design.

In terms of Operation & Maintenance, all the devices were relatively easy to operate and maintain and they should all, with the exception of the Passive Skimmer, have comparable annual maintenance cost (approximately $800 per year) relative to the labor of a two person crew equipped with a van. The annual maintenance cost of the Stream Guard® Passive Skimmer was estimated about $480 per year. A significant difference will be noted in terms of storage for the devices, as the Hydro-Kleen™, Ultra-Urban® and FloGard® +PLUS require significantly more space, while the Siltsack®, the Stream Guard™, and the Stream Guard™ passive skimmer can be stored with much less space requirement.

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Chapter 3 — Stormwater Treatment Systems

3.1. Device Descriptions

Stormwater treatment systems provide primary treatment of stormwater flows using physical processes of gravitational separation of floating and settling materials. These devices rely on the differences between the densities of the pollutants (such as oil and grit) and water. In these units, stormwater is forced to flow in certain patterns and/or at certain velocities that promote the separation between the pollutants and water. Some stormwater treatment systems are equipped with filters to improve the performance. However, clogging of filters is a common problem encountered for these devices.

3.1.1. Vortechs® Unit

This unit is manufactured by CONTECH® Stormwater Solutions, Inc. (formerly Vortechnics, Inc.) Stormwater flows into the unit tangential to a grit chamber, which promotes a gentle swirling motion. As polluted water circles within the grit chamber, pollutants migrate toward the center of the chamber where the velocities are lowest and sediments are prone to settle. Stormwater exits the grit chamber through two apertures on the perimeter of the chamber and moves into a second chamber with a baffle wall having an opening on the bottom allowing only water to exit. The baffle separates oil and grease, which float on the water due to their relatively low specific gravity.

The grit chamber is a cylindrical aluminum structure with two apertures at two different elevations that ensure proper flow at different storm intensities. The main aperture is designed with a varied opening to regulate the flow rate between the two chambers while storm intensity and height of water inside the grit chamber fluctuate. As shown in Figure 56, the outlet flow is regulated through an orifice for the lower flow control and a weir for the high flow control. The apertures are designed specifically for the site hydraulics and are Cippoletti–shaped (see “high flow control” and “low flow control” in Figure 56).

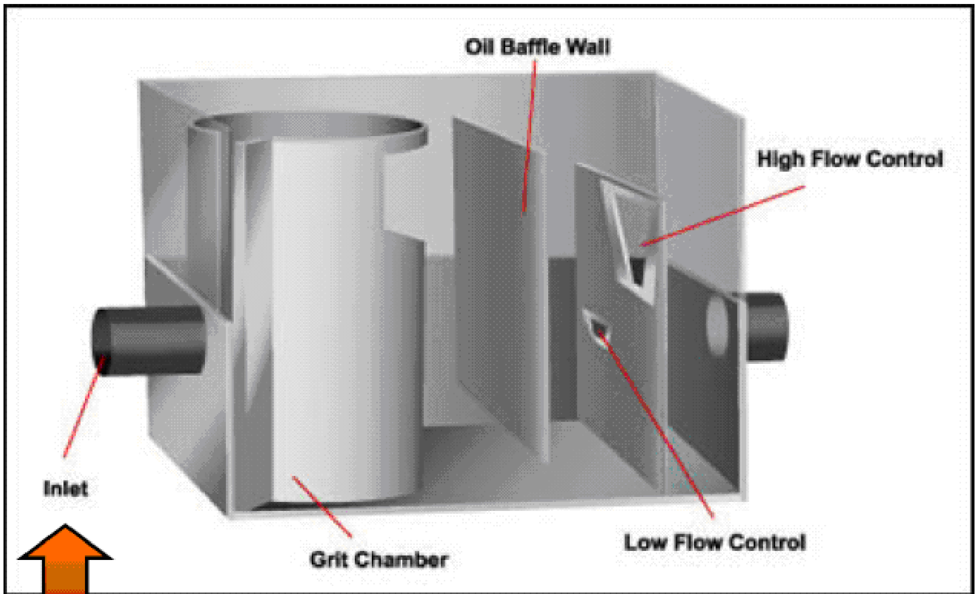
Over time, a conical pile containing sediment and associated pollutants tend to accumulate in the center of the unit, while floating debris and oil and grease form a floating layer trapped in front of the baffle wall. These pollutants must be removed periodically.

The accumulation of pollutants can easily be observed and removed through access manholes over each chamber.

3.1.2. V2b1™ Unit

The V2b1™ is manufactured by the Environment 21, LLC. and is composed of two cylindrical chambers. Similar to the Vortechs® unit described above, stormwater enters the first chamber tangentially, assuming a swirling motion that facilitates the sedimentation of settable material. Storm water from the grit chamber is centrally withdrawn using a Coriolus pipe, and the water enters a second chamber where oil and floating debris are trapped by a baffle wall. An optional storm pipe can be installed to provide additional conveyance for high flow. An underflow opening in the bottom of the baffle wall directs flow to the system outlet pipe.

As shown in Figure 56, both chambers are precast concrete cylindrical structures and, over time, the accumulated sediments can be removed through the manholes above each chamber.



DESIGN NOTES
Model: 3000
Swirl chamber diameter: 5 ft
Design storm return interval: 10 yr
Design storm flow rate: 4.50 ft^3/sec
Location: RTE. 27A – Bay Shore, NY

DESIGN NOTES
Model #: 11
Swirl chamber diameter: 8 ft
Design storm return interval: 10 yr
Design storm flow rate: 10.89 ft^3/sec
Location: RTE. 347 – Suffolk County, NY

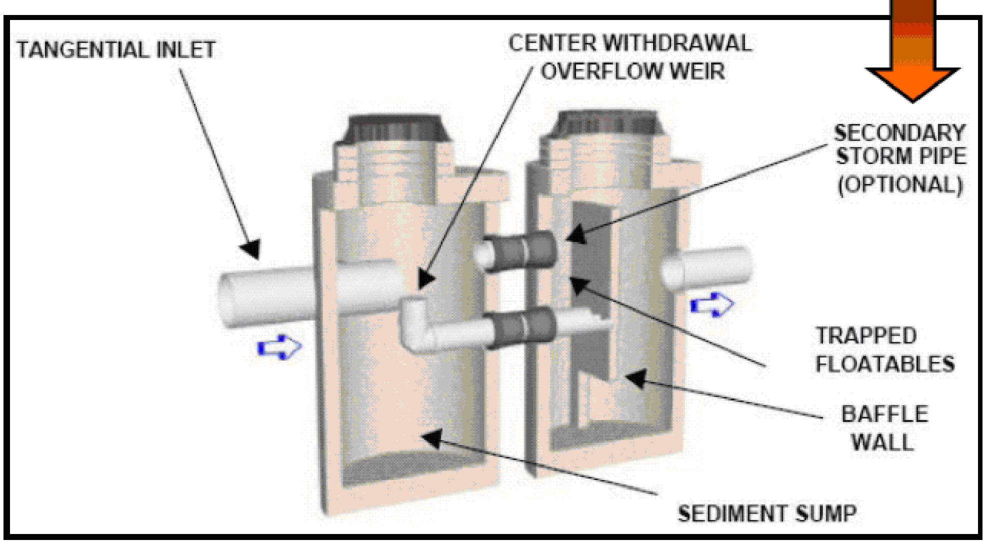


Figure 56: Stormwater Treatment Systems A) Vortechs® and B) V2b1™

3.2. Field Study

3.2.1. Methodology

Stormwater treatment systems were analytically tested at the field scale for removal of certain parameters and relative cost effectiveness. Samples and data collected in the field were stored, analyzed and evaluated at the laboratory at Polytechnic University.

In the first section, the locations are described where two full-scale stormwater treatment units were instrumented with sample collection devices and a sampling protocol adopted to collect runoff samples during storm events. Samples were collected simultaneously from a location immediately before, and immediately following the treatment units.

In the second section, the major test apparatii and analytical instruments are described, including sample storage details and procedures used to analyze field samples.

3.2.1.1. Locations

Vortechs® and V2b1™ units were both installed at locations in Long Island, NY, by the NYS Department of Transportation and instrumented for this field study. The Vortechs® unit is located on the east bound Route 27A in Bay Shore at the entrance to a parking lot for a shopping center, while the V2b1™ is located on the west bound Route 347 in Hauppauge, Suffolk County, just west of Route 111. A sampling station was installed for each location of the stormwater units, and since both stormwater treatment systems have a very similar design and operation procedure, the same sampling system was used to collect runoff at both locations.

3.2.1.2. Instrumentation

Two custom–built wooden storage boxes were used to house all the instruments utilized in the sampling systems for the study. After inspection of the site, the two storage boxes were built in the lab with plywood and were waterproof painted to protect the wood from weather damages. The storage boxes were sized to house two autosampler machines and all the tools used in the field later during sampling collection setup. The boxes were then brought to the field and secured to the ground with 2x4–inch studs and locked with chains and padlocks.

Figure 57: Storage box in Hauppauge – V2b1™ System

Figure 58: Storage box in Bayshore – Vortechs® System

The two boxes were not provided with line power, so it was necessary to supply the power for the sampling devices with rechargeable, high-capacity batteries that would ensure the operation of the autosamplers for the entire duration of the storm event. The major apparatii used for the field investigation, including their function, model number and manufacturer, are listed in Table 5, and are briefly described as follows:

- Autosampler machine is a programmable device, designed to collect samples through a specified preset protocol defined by the operator. This instrument accepts a variety of composite and multiple bottle kits, from a twenty-four, 350 mL bottles, to a single bottle of 20.8L volume. It uses a peristaltic pump that delivers samples at the EPA-recommended velocity of 2 ft/sec and it operates within 26 feet (head height) with 99 feet of suction line. The suction line is the tubing from the sampling point to the pump intake. The sampler accepts a series of modules that offer a number of options: liquid level actuator, rain gauge, flow meter, sensors for parameter control (such as pH, temperature, etc.) and modem for remote control. Finally, the sampler stores values in memory that can be easily retrieved by a computer. Figure 59 is a photograph of the ISCO Model 6712 sampler machine used in the study.

Figure 59: The ISCO Model 6712 Autosampler

- A liquid level actuator is used in conjunction with an autosampler to begin a sampling routine when the liquid level reaches a predetermined height. The type used in the study is an ISCO Model 1640 that consists of a control box assembly connected to the end of a 22 ft. coaxial cable, as shown in Figure 60.

Figure 60: The ISCO model 1640 Liquid Level Actuator

The control box allows the user to choose between "Latch" mode and "Toggle/Reset" mode. When set to LATCH, the 1640 will actuate the sampler when the liquid level rises to the stainless steel ring on the probe assembly and the sampler will remain actuated even if the liquid level recedes. With the Liquid Level Actuator set to TOGGLE/RESET, the liquid level actuator sampler takes samples only while the liquid is touching the probe assembly. When the liquid level rises to the probe assembly, the 1640 actuates the sampler. The sampler will continue taking samples only as long as the liquid touches the probe. If the liquid level recedes, the sampler will be inhibited until the liquid level again rises to the probe assembly. The TOGGLE/RESET switch selection is also used to reset the Liquid Level Actuator when it is used in LATCH mode.

- The Rain Gauge is an instrument for measuring rainfall. The rain gauge is an ISCO Model 674 (see Figure 61) mounted on three thumb screws with a bubble level inside a steel cylinder. It has an eight-inch opening on top to collect rain that falls through a screen into a funnel. From the funnel, rain collects in one side of a two-chambered plastic bucket mounted on pivots.

Figure 61: ISCO 674 rain gauge

When rain fills the chamber, the bucket tips, draining the water and exposing the other chamber to fill. When that chamber fills, the bucket tips back and the process begin again. Each time the bucket tips, the rain gauge measures 0.01 inch of rain. When connected to the autosampler machine, the rain gauge enables the autosampler to store rainfall data in memory and can also trigger the autosampler to begin the sampling procedure when the rain reaches a pre–set value.

- Lead-Acid batteries, ISCO Model 946 (see Figure 62), are rechargeable, high-capacity power for the ISCO autosampler machines that provide an output of 12V DC and are environmental sealed and maintenance free.
- ISCO Model 965 AC charger (see Figure 62) was used to recharge the ISCO Model 946 batteries. It is able to work with the input line power of 120V & 240V and charge up to five batteries at one time. It is provided with a switch that allows users to choose to charge either Nickel-Cadmium or Lead-Acid batteries.

Figure 62: Model 946 Lead-Acid battery and Model 965 charger

- Flowlink® software is a Microsoft Windows® application that allows the user to monitor instruments manufactured from ISCO, Inc., retrieve data from installed instruments, generate and manipulate statistical information from the site data, edit site data and finally present data graphically. The version used in the current study was Flowlink® 4.

Table 5: Field Apparatii

Instruments	Function	Model No.	Manufacturer
Autosampler	Collect Samples	6712	ISCO, Inc. Los Angeles, CA
Liquid Level Actuator	Determine Liquid Level	1640	ISCO, Inc. Los Angeles, CA
Rain Gauge	Measure Rain intensity	674	ISCO, Inc. Los Angeles, CA
Lead-Acid Batteries	Power Source	946	ISCO, Inc. Los Angeles, CA
Charger	Charge Batteries	965	ISCO, Inc. Los Angeles, CA
Software	Retrieve Data	Ver. 4	ISCO, Inc. Los Angeles, CA

3.2.1.3. Installation of the Sampling System

The sampling station for each site consisted of two autosampler devices with 24 sample bottles of 1 liter volume each. One autosampler was installed to collect samples from the inlet chamber of the stormwater treatment systems and the second device was installed to collect samples from the outlet chamber. The two autosamplers were connected together and synchronized to start sampling simultaneously, in order to be able to compare the concentration of pollutants from the inlet and the outlet flow.

Figure 63 shows a schematic diagram of the equipment setup at the monitoring station of the stormwater treatment system. The liquid level detector and the rain gauge were both connected to the main autosampler that recorded the data.

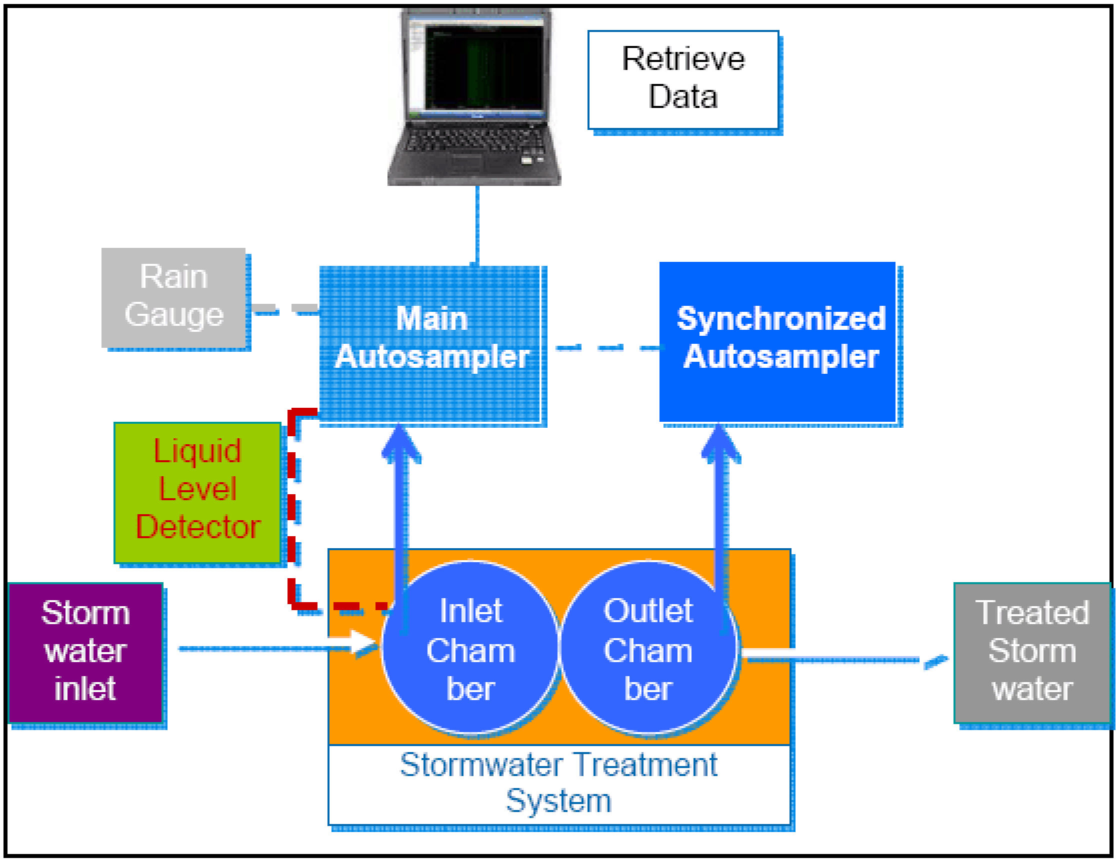


Figure 63: Schematic diagram of the sampling equipment setup.

To accommodate differences between the two locations of the stormwater treatment systems, some details of the sampling system installations were slightly different.

Vortechs® System– Bayshore

As shown in Figure 64, the storage box was located near the shoulder area adjacent to Awixa Creek. The liquid level detector was mounted only into the inlet chamber of the Vortechs® System while the suction lines were mounted in each chamber of the unit. At the end of each suction line, a ⅜-inch stainless steel low flow strainer was mounted that helped to prevent solids from clogging the suction line. The liquid level detector and the suction lines were hung in the unit chambers from a steel rod mounted to the concrete wall of the unit and allowed the height of both the sensor and the suction line to be adjusted in the chamber before the storm event, so that the end was as close to the center of the chamber as possible. The wire of the sensor and the suction lines exit through a hole made in the concrete wall of the Vortechs® unit and then run, enclosed in a PVC conduit, to the monitoring station. Because the Vortechs® unit is installed at the entrance to a parking lot, the PVC conduit was installed below the ground surface from the Vortechs® System toward the creek. The NYSDOT was needed to help trench the asphalt parking lot to install the PVC conduit. For the part of PVC conduit running above ground, insulation was necessary to prevent the water from freezing within the suction line during cold weather. Figure 65 shows the different phases and details of the excavation of the trench and the installation of the liquid level detector and the suction lines.

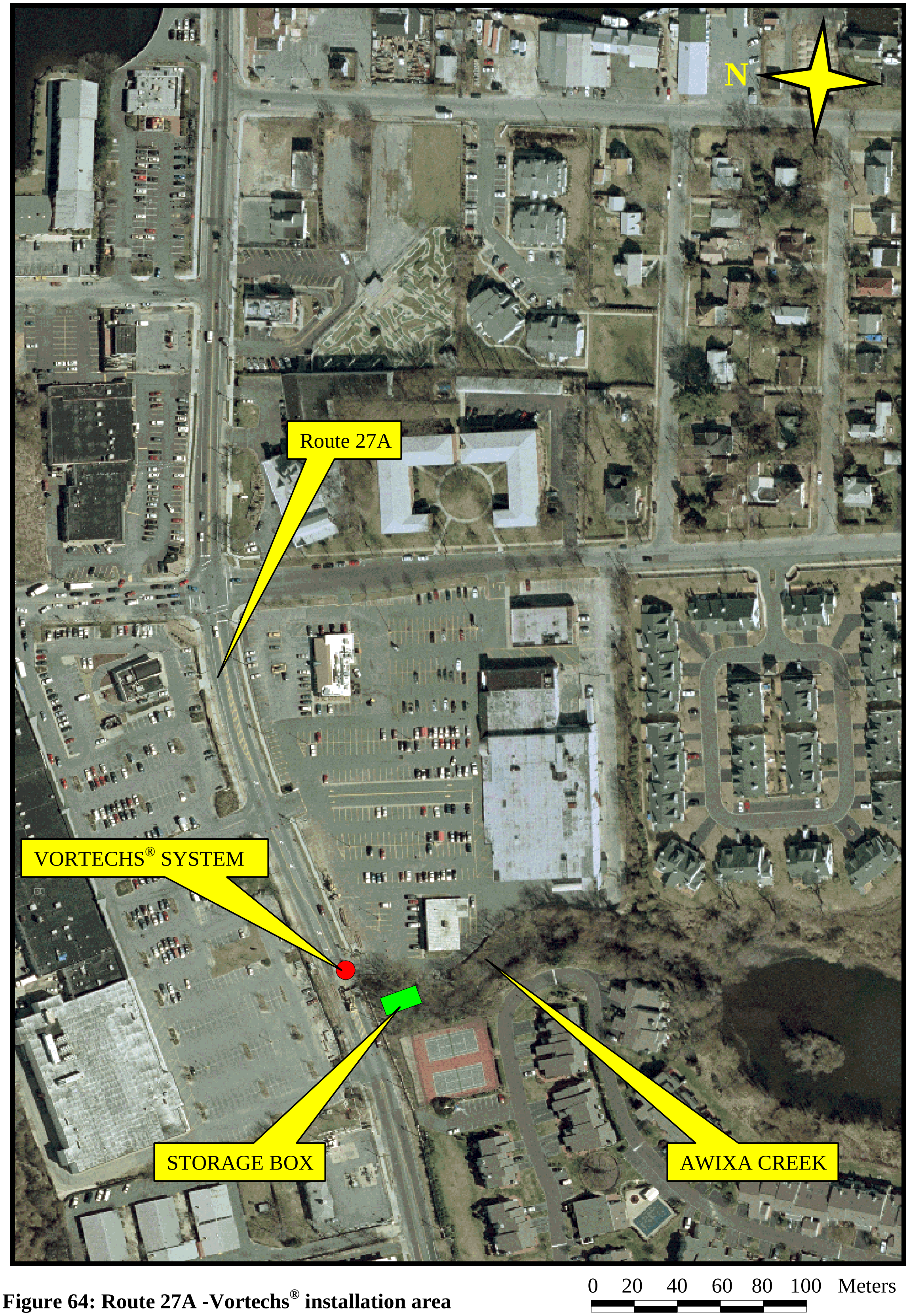


Figure 64: Route 27A -Vortechs® installation area

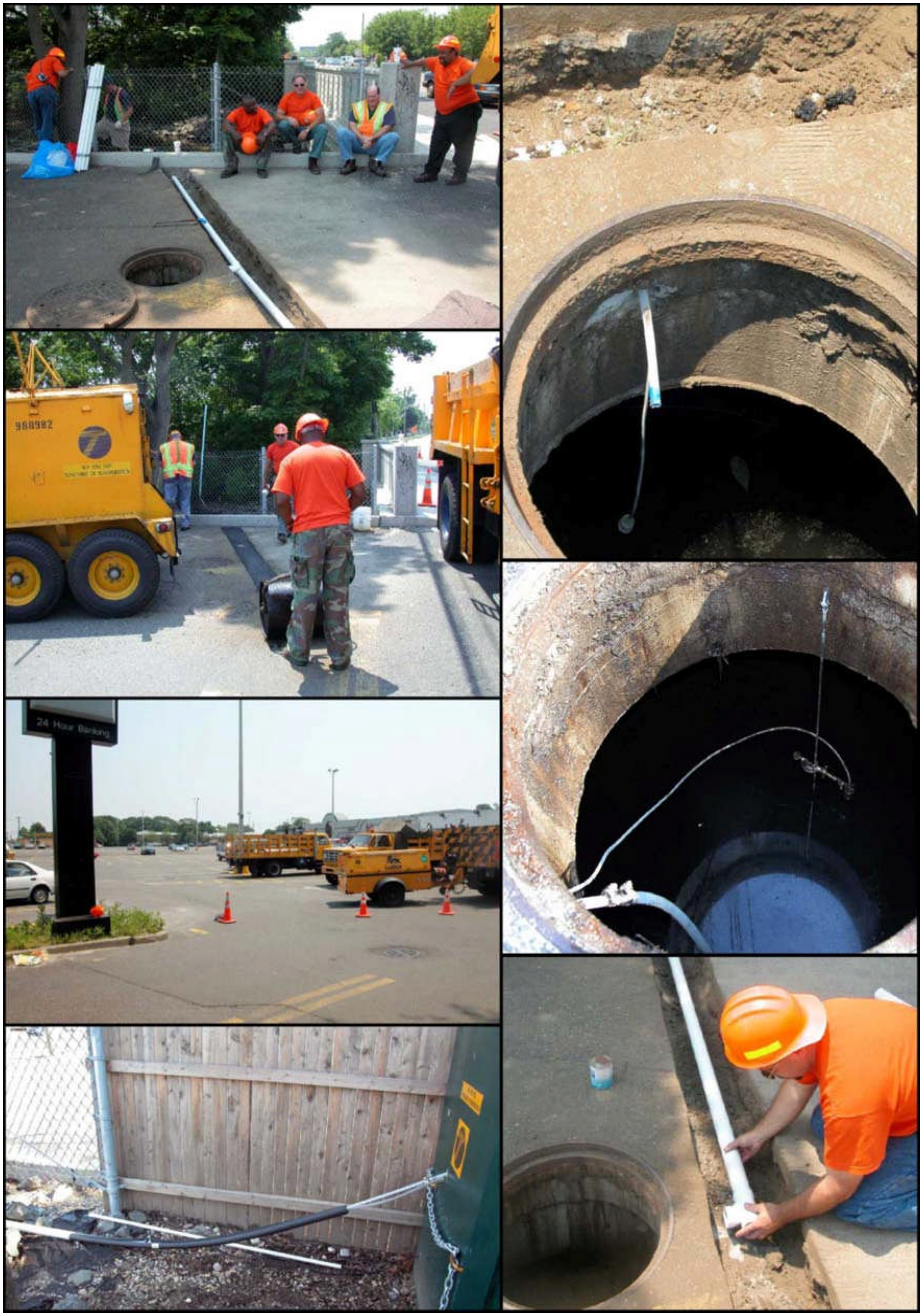


Figure 65: Vortechs® - Suction line and liquid level detector installation

As shown in Figure 66, the rain gauge device was placed in the middle of the nearby Awixa Creek supported on a PVC pipe that was anchored on the headwall of the culvert. The location of the rain gauge was chosen following the manufacturer suggestions to place the device in the vicinity of a group of trees of uniform height, since it would assure an accurate catch by acting as a windbreak while not interfering with the catch. In addition, this location was chosen to prevent possible vandalism and other harmful occurrences. The rain gauge wire runs to the storage box partly enclosed in a PVC conduit and partly submerged into the river. The device was connected to the autosampler machine, which was programmed to record input signal once each minute.

Figure 66: Vortechs® Sampling System – Rain Gauge

V2b1™ System – Hauppauge

The V2b1™ stormwater treatment system was located on the shoulder of the west side of Route 347 in Hauppauge. The storage box for the monitoring system, in this case, was placed near the unit on the shoulder of the highway and beyond the guiderail, as shown in Figure 67 and Figure 68. The suction lines and the liquid level detector were installed inside of the unit chambers in a similar manner used for the Vortechs® system. A ⅜-inch stainless steel, low–flow strainer was mounted at the end of each suction line to prevent solids from clogging the hoses. The wire from the liquid level detector and the hoses exit the chamber through the holes on the manhole cover and run along the guiderail, insulated and enclosed in a PVC pipe (Figure 68) to protect them from possible vandalism and to prevent freezing in the cold weather. The rain gauge was placed above the storage box, and protected with a wooden case around the sides. The manufacturer guidelines were followed to ensure the correct installation of all devices.

The main autosampler was programmed according to the sampling protocol and was triggered by both the rain intensity and the water level into the stormwater unit. When triggered, before starting collecting samples, it would send a signal, "event mark", to the synchronized autosampler that began sampling from the other chamber of the stormwater unit. The synchronized autosampler was connected to the main autosampler through the liquid level detector connection port, using a "Y" shaped wire that split the connection port on the main autosampler. The synchronized autosampler was programmed to start collecting samples after an "event mark" and to stop at the end of each sample.

Figure 67: Route 347, V2b1™ installation area.

Figure 68: V2b1™ – Sampling system installation

3.2.1.4. Sampling Protocol

The stormwater program consisted of two parts: "PART A" was intended to collect the samples from the "first flush" of the storm event, where six samples were collected in the first twenty-five minutes of the event; "PART B" was programmed with longer time spacings to capture samples from the entire event. In this second part of the stormwater program, eighteen samples were collected in six hours, so that the entire program covered a total of six hours and 25 minutes of the rain event (plus one minute between each part). The stormwater program was triggered when both the rain intensity would reach the 0.05 in/hr and the water level in the treatment device chamber reached the liquid level detector connected to the autosampler.

Based on the weather forecast, prior to a storm event, the samplers were charged and stationed at the site, calibrated according to manufacturer specifications, and programmed to collect samples. Personnel would visit the monitoring station during the event to ensure that the collector started and at the end of the event to retrieve the data from the autosampler using a laptop with the Flowlink® software and bring the collected samples to the Polytechnic University laboratory (Brooklyn, NY) for analysis. An example of the sampling reports downloaded from the ISCO autosampler using the Flowlink® software are shown here (below) for the main and synchronized autosampler. The program settings are reported in the first part of the printout and all the sampling details follow (sample number, starting and ending time and date, pump revolutions, etc.). The printout from the main autosampler has an additional table reporting the rain intensities related to each sampling time. The use of the Flowlink® software also allowed personnel to retrieve the rain data for every minute of the event, and to analyze and present them as a hyetograph.

Main autosampler from Vortechs® System

SAMPLER ID# 3227444541 14:29 31-MAR-04
Hardware: A0 Software: 2.01
********* PROGRAM SETTINGS **********

PROGRAM NAME:
"VORTECHS "
SITE DESCRIPTION:
"BAY SHORE "

UNITS SELECTED:
LENGTH: ft
----

1 MINUTE
DATA INTERVAL

24, 1000 ml BTLS
25 ft SUCTION LINE
AUTO SUCTION HEAD
0 RINSES, 0 RETRIES

TWO-PART PROGRAM
BOTTLE ASSIGNMENTS:
1 - 6 TO 'A'
7 - 24 TO 'B'

'A' PACING:
TIME, EVERY
0 HOURS, 5 MINUTES

'A' DISTRIBUTION:
SEQUENTIAL

'A' VOLUME:
1000 ml SAMPLES

'A' ENABLE:
RAIN >0.05"/ 1:00

'A' ENABLE:
ONCE ENABLED,
STAY ENABLED
NO SAMPLE AT ENABLE

'A' ENABLE:
0 MINUTE DELAY TO
START OF SAMPLING

'A' ENABLE:
0 PAUSE & RESUMES

'B' PACING:
TIME, EVERY
0 HOURS, 20 MINUTES

'B' DISTRIBUTION:
SEQUENTIAL

'B' VOLUME:
1000 ml SAMPLES

'B' ENABLE:
WHEN 'A' IS DONE
AND
RAIN >0.05"/ 1:00

'B' ENABLE:
ONCE ENABLED,
STAY ENABLED
NO SAMPLE AT ENABLE

'B' ENABLE:
0 MINUTE DELAY TO
START OF SAMPLING

'B' ENABLE:
0 PAUSE & RESUMES

NO DELAY TO START

LIQUID DETECT ON
QUICK VIEW/CHANGE

TAKE MEASUREMENTS
EVERY 1 MINUTES

DUAL SAMPLER OFF
BTL FULL DETECT OFF
TIMED BACKLIGHT

PULSED EVENT MARK
AT INITIAL PURGE

PUMP COUNTS FOR
EACH PURGE CYCLE:
200 PRE-SAMPLE
AUTO POST-SAMPLE

NO PERIODIC
SERIAL OUTPUT

INTERROGATOR
CONNECTOR
POWER ALWAYS ON

----
inch TIP
RAIN GAUGE

NO SDI-12 SONDE
AUTO SDI-12 SCAN OFF

I/O1= NONE
I/O2= NONE
I/O3= NONE
----
0 ANALOG OUTPUTS

Program Started at 11:54 FR 26-MAR-04
PART 'A' Nominal Sample Volume = 1000 ml
PART 'B' Nominal Sample Volume = 1000 ml
COUNT TO
SAMPLE BOTTLE TIME SOURCE ERROR
LIQUID

11:54 'A' DISABLED
11:54 'B' DISABLED
11:58 MANUAL PAUSE
12:00 MANUAL RESUME
------------- SA 27-MAR-04 -------------
15:07 MANUAL PAUSE
15:08 MANUAL RESUME
------------- WE 31-MAR-04 ------------
06:35 'A' ENABLED
1,1 1 06:40 'A' T 1024
1,1 2 06:45 'A' T 968
1,1 3 06:50 'A' T 968
1,1 4 06:55 'A' T 976
1,1 5 07:00 'A' T 978
1,1 6 07:05 'A' T 980
07:05 'A' DONE 31-MAR
07:06 'B' ENABLED
1,1 7 07:26 'B' T 972
1,1 8 07:46 'B' T 972
1,1 9 08:06 'B' T 974
1,1 10 08:26 'B' T 972
1,1 11 08:46 'B' T 970
1,1 12 09:06 'B' T 974
1,1 13 09:26 'B' T 972
1,1 14 09:46 'B' T 974
1,1 15 10:06 'B' T 974
1,1 16 10:26 'B' T 966
1,1 17 10:46 'B' T 968
1,1 18 11:06 'B' T 968
1,1 19 11:26 'B' T 974
1,1 20 11:46 'B' T 968
1,1 21 12:06 'B' T 974
1,1 22 12:26 'B' T 974
1,1 23 12:46 'B' T 974
1,1 24 13:06 'B' T 974
13:06 'B' DONE 31-MAR
13:07 PGM DONE 31-MAR
SOURCE T ==> TIME

SAMPLER ID# 3227444541 14:29 31-MAR-04
Hardware: A0 Software: 2.01
******* SAMPLING RESULTS ********
SITE: BAY SHORE
PROGRAM: VORTECHS
SAMPLER ID# 3227444541 14:29 31-MAR-04
Hardware: A0 Software: 2.01
MODULE: NONE
********* COMBINED RESULTS *********
SITE: BAY SHORE
PROGRAM: VORTECHS
Program Started at 11:54 FR 26-MAR-04
PART 'A' Nominal Sample Volume = 1000 ml
PART 'B' Nominal Sample Volume = 1000 ml

MODULE: NONE

SAMPLER ID# 3227444541 14:30 31-MAR-04
Hardware: A0 Software: 2.01
********* COMBINED RESULTS *********
SITE: BAY SHORE
PROGRAM: VORTECHS
Program Started at 11:54 FR 26-MAR-04
PART 'A' Nominal Sample Volume = 1000 ml
PART 'B' Nominal Sample Volume = 1000 ml
FR-TEMP
SAMPLE BOTTLE TIME C

NO FR-TEMPERATURE

SAMPLER ID# 3227444541 14:30 31-MAR-04
Hardware: A0 Software: 2.01
*********** COMBINED RESULTS ***********
SITE: BAY SHORE
PROGRAM: VORTECHS
Program Started at 11:54 FR 26-MAR-04
PART 'A' Nominal Sample Volume = 1000 ml
PART 'B' Nominal Sample Volume = 1000 ml
TOTAL
RAIN
SAMPLE BOTTLE TIME in

------------- WE 31-MAR-04 ------

1,1	1	06:40	0.30
1,1	2	06:45	0.30
1,1	3	06:50	0.31
1,1	4	06:55	0.31
1,1	5	07:00	0.32
1,1	6	07:05	0.32
1,1	7	07:26	0.34
1,1	8	07:46	0.36
1,1	9	08:06	0.38
1,1	10	08:26	0.40
1,1	11	08:46	0.42
1,1	12	09:06	0.45
1,1	13	09:26	0.47
1,1	14	09:46	0.49
1,1	15	10:06	0.50
1,1	16	10:26	0.52
1,1	17	10:46	0.53
1,1	18	11:06	0.55
1,1	19	11:26	0.56
1,1	20	11:46	0.57
1,1	21	12:06	0.58
1,1	22	12:26	0.59
1,1	23	12:46	0.60
1,1	24	13:06	0.61

SAMPLER ID# 3227444541 14:30 31-MAR-04
Hardware: A0 Software: 2.01
SDI-12 DATA
*********** COMBINED RESULTS ***********
SITE: BAY SHORE
PROGRAM: VORTECHS
Program Started at 11:54 FR 26-MAR-04
PART 'A' Nominal Sample Volume = 1000 ml
PART 'B' Nominal Sample Volume = 1000 ml

NO SDI-12 SONDE

Synchronized autosampler report from V2b1™ System:

SAMPLER ID# 3293770935 16:18 31-MAR-04
Hardware: A0 Software: 2.01
*********** PROGRAM SETTINGS ***********

PROGRAM NAME:
"V2B1-1"
SITE DESCRIPTION:
"HAUPPAUGE"

UNITS SELECTED:
LENGTH: ft

24, 1000 ml BTLS
27 ft SUCTION LINE
9 ft SUCTION HEAD

ONE-PART PROGRAM

PACING:
FLOW, EVERY
1 PULSES
NO SAMPLE AT START

DISTRIBUTION:
SEQUENTIAL

VOLUME:

1000 ml SAMPLES

ENABLE:

NONE PROGRAMMED

ENABLE:
REPEATABLE ENABLE
NO SAMPLE AT DISABLE
NO SAMPLE AT ENABLE

ENABLE:
COUNTDOWN IS STOPPED
WHILE DISABLED

ENABLE:
0 PAUSE & RESUMES

NO DELAY TO START

LIQUID DETECT OFF

QUICK VIEW/CHANGE

TAKE MEASUREMENTS
EVERY 1 MINUTE

DUAL SAMPLER OFF
BTL FULL DETECT OFF
TIMED BACKLIGHT

PULSED EVENT MARK
AT INITIAL PURGE

PUMP COUNTS FOR
EACH PURGE CYCLE:
200 PRE-SAMPLE
AUTO POST-SAMPLE

NO PERIODIC
SERIAL OUTPUT

INTERROGATOR
CONNECTOR
POWER ALWAYS ON

NO RAIN GAUGE

NO SDI-12 SONDE

AUTO SDI-12 SCAN OFF

I/O1= NONE
I/O2= NONE
I/O3= NONE
----
0 ANALOG OUTPUTS

SAMPLER ID# 3293770935 16:18 31-MAR-04
Hardware: A0 Software: 2.01

*********** SAMPLING RESULTS ***********
SITE: HAUPPAUGE1 PROGRAM: V2B1-1
Program Started at 14:27 MO 22-MAR-04
Nominal Sample Volume = 1000 ml
COUNT
TO

14:27 PGM ENABLED
------------- FR 26-MAR-04 -------------
10:46 MANUAL PAUSE
10:49 MANUAL RESUME
------------- WE 31-MAR-04 ------------

SAMPLE	BOTTLE	TIME	SOURCE ERROR	LIQUID
1,1	1	02:32	F	0
1,1	2	02:36	F	0
1,1	3	02:41	F	0
1,1	4	02:46	F	0
1,1	5	02:51	F	0
1,1	6	02:56	F	0
1,1	7	03:18	F	0
1,1	8	03:38	F	0
1,1	9	03:58	F	0
1,1	10	04:18	F	0
1,1	11	04:38	F	0
1,1	12	04:58	F	0
1,1	13	05:18	F	0
1,1	14	05:38	F	0
1,1	15	05:58	F	0
1,1	16	06:18	F	0
1,1	17	06:38	F	0
1,1	18	06:58	F	0
1,1	19	07:18	F	0
1,1	20	07:38	F	0
1,1	21	07:58	F	0
1,1	22	08:18	F	0
1,1	23	08:38	F	0
1,1	24	08:58	F	0

08:59 PGM DONE 31-MAR

SOURCE F ==> FLOW

3.2.2. Laboratory Analyses

3.2.2.1. Instrumentation

The major apparatii and analytical instruments used for laboratory analyses of samples collected in the field, including the measured parameters, model number and manufacturer, can be found in the Chemical Analyses section.

3.2.2.2. Field Sample Preservation

After collection in the field, samples from the Stormwater Treatment Systems in Long Island were preserved on ice and carried to Polytechnic University laboratory in Brooklyn where all the analyses where performed. Because of the limited volume of runoff (one liter) available for analyses and the high number of tests that were required, not all the tests were performed on each of the 24 samples. Figure 69 and Table 6 explains how each sample bottle was assigned a letter and how the samples were divided per test. Once the samples were received in the laboratory, they were portioned and preserved in smaller polyethylene or glass bottles with either sulfuric or hydrochloric acid, as prescribed in the Standard Method and depending upon the analyses to be performed on the sample. The samples were stored in the refrigerator at +4ºC. BOD_5 and FCB tests were performed within 6 hours from the end of the sampling collection.

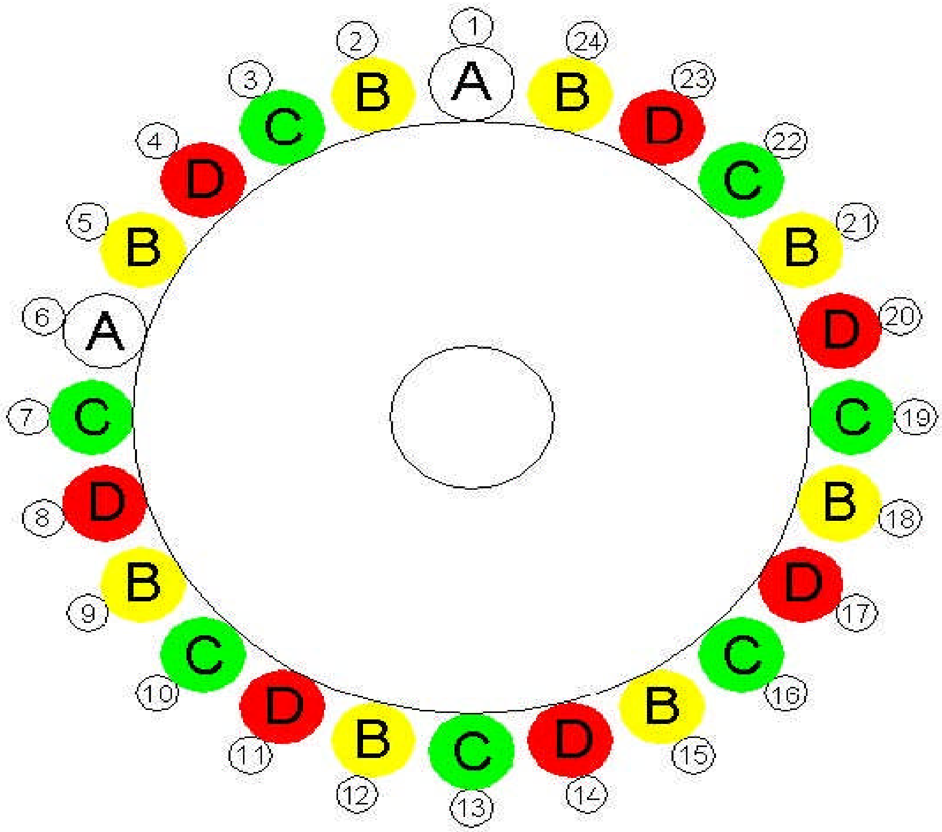


Figure 69: Sample distribution per autosampler collection.

Table 6: Associated analyses per sample type

Sample Type	Number of Samples	Test Performed for Each Sample					
		TSS	TPH	TKN	TP	FCB	BOD_5
A	**2**	X	X	X	X		
B	**8**	X	X			X	X
C	**7**	X	X	X			
D	**7**	X	X		X		
Total Sample	**24**	**24**	**24**	**9**	**9**	**8**	**8**

The analyses on the runoff samples were performed following the EPA & Standard Method procedures. Table 7 lists the procedures used for each parameter analyzed in this study and the chemical reagent used in each test.

Table 7: Analyses procedures and reagents

Test	Chemicals Name	Step used in the test	Reagent Name	Grade	Manufacturer
TKN	Digestion Reagent	Digestion SM 4500-N_{org}-B	K_2SO_4	---	ACROS Organic, NJ
			$CuSO_4$	98%	ACROS Organic, NJ
	Sodium Hydroxide – Sodium Thiosulfate Reagent	Distillation SM 4500-N_{org}-B	NaOH	97%	ACROS Organic, NJ
			$Na_2S_2O_3 \cdot 5H_2O$	99.6%	Fisher Scientific
	Sodium Hydroxide 10N	Ammonia Selective Electrode SM 4500-N_{org}-D	NaOH	97%	ACROS Organic, NJ
	Ammonia Chloride Solution	Calibration Solution - Ammonia Selective Electrode SM 4500-N_{org}-D	NH_4Cl		Fisher Scientific
TP	Ammonium Persulfate	Digestion SM 4500-P-B	$(NH_4)_2S_2O_8$	98%	ACROS Organic, NJ
	Sulfuric Acid Solution		H_2SO_4	NF/FCC	Fisher Scientific
	Hydrochloric Acid	Colorimetric Method SM 4500-P-C	HCl	ACS	Pharmco Products, CT
	Vanadate – Molybdate Reagent		$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	82.1%	Fisher Scientific
			NH_4VO_3	Purified Grade	Fisher Scientific

Table 7: Analyses procedures and reagents (continued)

Test	Chemicals Name	Step used in the test	Reagent Name	Grade	Manufacturer
	Standard Phosphate Solution	Calibration Solution - Colorimetric Method SM 4500-P-C	K_2PO_4	99%	ACROS Organic, NJ
BOD_5	Micro-biological population	Sample Preparation SM 5210-B	Polyseed	---	Interlab, TX
	Dilution Water		BOD Nutrient Buffer Pillows	---	Hach Company, CO
FCB	Selective agent to inhibit non-coliform organism	Presumptive Phase SM 9221-B	Lauryl Tryptose Broth	---	Remel, KS
	Selective Agent for coliform organism	Confirmed Phase SM 9221-B	Brilliant Green Bile Broth	---	Remel, KS
TSS	Aluminum weighing dishes	Sample Preparation SM 2540-D	Disposal Aluminum Dish 63mL	---	Fisher Scientific
	Filter		Glass Fiber Filter Disk GF/C 47mm φ	---	Whatman Inc., NJ
TPH	Hydrochloric Acid	Sample Preparation EPA 418.1/413.2 Freon Method	HCl	ACS	Pharmco Products, CT
	Non-absorbing solvent		Freon	99.9%	Chemnet, FL

Calculations

The discrete concentration data, from the samples collected at the Stormwater Treatment Systems sites, were analyzed to obtain the removal efficiencies of the devices. The following explains the calculation methodology adopted to achieve the results:

Single Event Mean concentration: is the arithmetic average of the concentrations values, measured during a single storm event.

Overall Mean Concentration: is the arithmetic average of the concentrations values measured on every sample collected during the entire study, throughout all the events that were monitored.

The same procedure was also followed for the Median, Standard Deviation, Max Value and Minimum Value: the results that refer to a single event were calculated using the data from the single event, while the overall values were obtained using data collected during all the storm events that were sampled.

Single Event Removal Efficiency:

(Inflow Concentration – Outflow Concentration) / Inflow Concentration

Where: *Inflow Concentration* is the Single Event Inflow Mean Concentration of the specific Parameter, and,

Outflow Concentration is the Single Event Outflow Mean Concentration of the specific parameter.

The **Overall Removal Efficiency** was calculated using the same method as above, with the difference being that the concentrations used were the Inflow & Outflow Overall Mean.

3.2.3. Field Study Results

Vortechs®

Table 8 presents data for the 6 storms studied at the Vortechs® site, reporting details regarding the storms and the sampling collections.

Table 8: Runoff events sampled during the study of the Vortechs® unit

Storm Event Details						Sampling Details	
Starting date	Starting time	Ending Time	Duration [min]	Depth [in]	Intensity [in/hr]	Starting Time	Ending Time
03/31/2004	1:58AM	2:01PM	724	0.49	0.04	6:40AM	1:06PM
05/24/2004	7:44AM	8:28AM	45	0.18	0.24	7:50AM	2:16PM(1)
09/18/2004	8:11AM	12:44PM	274	0.40	0.09	10:02AM	4:28PM(1)
12/06/2004	1:16PM	7:55PM	400	0.33	0.05	1:53PM	8:19PM(1)
02/10/2004	12:35AM	12:34PM	720	0.14	0.01	7:48AM	2:14PM(1)
04/23/2005	9:35AM	5:30PM	476	1.06	0.13	10:13AM	4:39PM

(1) The sampling collection ended after the event.

In two right columns of Table 8, note that every sampling cycle has duration of 386 minutes, which is the sum of “PART A” (6 samples every 5 minutes for a total of 25 minutes) and “PART B” (18 samples every 20 minutes for a total of 360 minutes) of the sampling protocol, plus 1 minute between each part. Also, note that the rain intensity shown in Table 8 was calculated by dividing the total rain during the event by the total duration of the event.

Table 9 shows the analyses that were performed on each sample collection. A human error was made in preparation for the collection of samples on 12/06/2004 (acid was accidentally added to the samples intended for BOD analysis). In order to characterize the BOD removal for 4 seasons, a final storm event on 04/23/2005 was sampled to perform only the BOD_5 test.

Table 9: Analysis performed on samples collected for the Vortechs® System.

Starting Date	Parameter Analyzed							
	TKN	TP	BOD_5	FCB	TSS	TPH	pH	Cond.
03/31/2004	X	X		X	X		X	X
05/24/2004	X	X	X		X	X	X	X
09/18/2004	X	X	X	X	X	X	X	X
12/06/2004	X	X		X	X	X	X	X
02/10/2004	X	X	X	X	X	X	X	X
04/23/2005			X					

Hyetographs of the storm events are shown for each storm event that include the total rain during the event and indicate the beginning and the end of the sampling cycle. For each storm event, the "Field Test Summary" tables (Table 10, 12, 14, 16, 18 and 20) report mean concentration, median concentration, standard deviation, max and minimum concentration of the results of the analysis on the samples from the inlet and the outlet chamber of the device, for each parameter studied in this project. The last column of the table shows the removal efficiency for each parameter calculated by comparing the inlet and outlet values. The "Field Testing Data" tables (Table 11, 13, 15, 17, 19 and 21) show the sampling time and the results of the analysis on each sample collected in the inlet and outlet chamber for each parameter studied in the project.

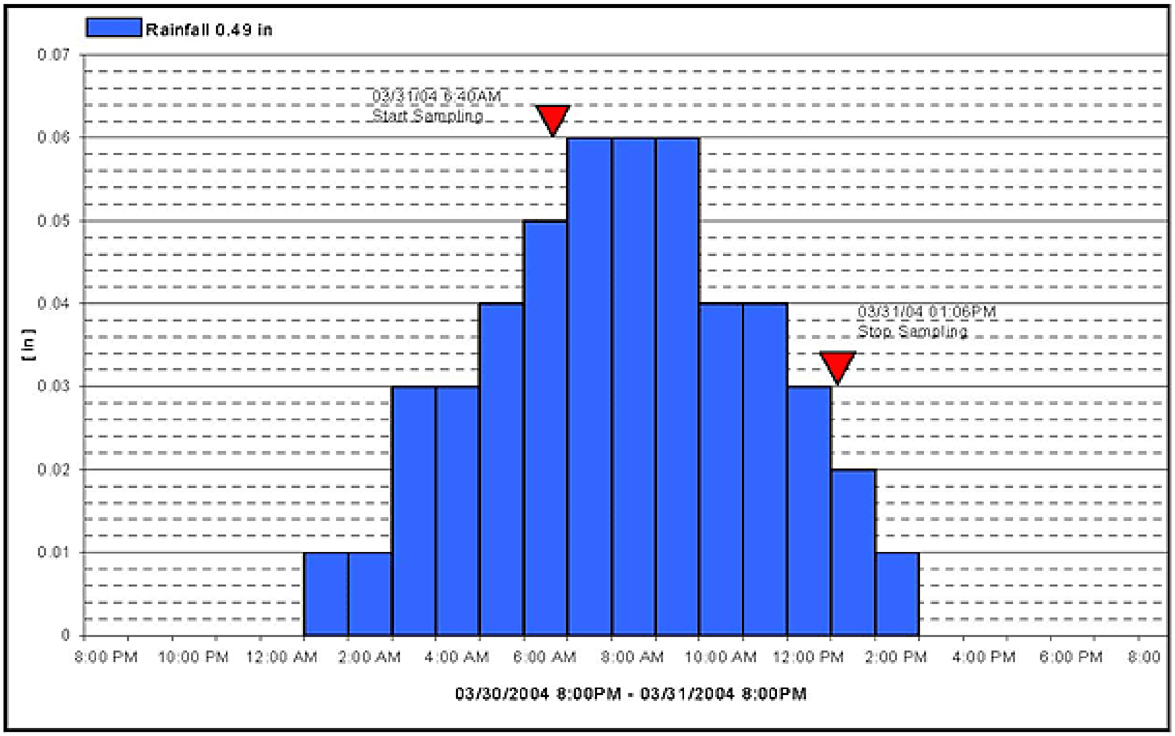


Figure 70: Bay Shore Vortechs® System Hyetograph – March 31, 2004

Table 10: Field Testing summary, Vortechs® System, event March 31, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	72.92	70.00	35.93	190.00	10.00	45.62%
	O	39.65	33.33	24.15	100.00	10.00	
VSS [mg/L]	I	28.75	20.00	16.77	80.00	10.00	38.16%
	O	17.78	15.00	9.61	40.00	5.00	
TKN [mg/L]	I	1.18	1.11	0.48	2.3	0.57	34.79%
	O	0.77	0.79	0.11	0.93	0.63	
TP [mg/L]	I	0.98	0.84	0.48	2.07	0.54	-6.16%
	O	1.04	0.90	0.33	1.69	0.69	
FCB [MPN/100mL]	I	10212	4250	11373	28000	1700	5.14%
	O	9687	11000	6731	22000	2200	

[2] comparing mean inlet and outlet values

Table 11: Field testing data, Vortechs® System Inlet, event March 31, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-I-A-1	6:40 AM	130.00	60.00		2.30	1.12		
BS-I-B-2	6:45 AM	100.00	40.00					3500
BS-I-C-3	6:50 AM	110.00	40.00		0.97			
BS-I-D-4	6:55 AM	80.00	10.00			2.07		
BS-I-B-5	7:00 AM	40.00	20.00					11000
BS-I-A-6	7:05 AM	70.00	40.00		1.20	0.84		
BS-I-C-7	7:26 AM	100.00	40.00		1.11			
BS-I-D-8	7:46 AM	80.00	20.00			1.25		
BS-I-B-9	8:06 AM	80.00	20.00					28000
BS-I-C10	8:26 AM	60.00	20.00		1.29			
BS-I-D-11	8:46 AM	50.00	40.00			1.07		
BS-I-B-12	9:06 AM	190.00	80.00					5000
BS-I-C-13	9:26 AM	70.00	20.00		1.34			
BS-I-D-14	9:46 AM	70.00	40.00			0.66		
BS-I-B-15	10:06AM	70.00	20.00					28000
BS-I-C-16	10:26AM	50.00	30.00		1.08			
BS-I-D-17	10:46AM	60.00	30.00			0.54		
BS-I-B-18	11:06AM	40.00	20.00					2800
BS-I-C-19	11:26AM	80.00	20.00		0.79			
BS-I-D-20	11:46AM	70.00	10.00			0.66		
BS-I-B-21	12:06 PM	40.00	20.00					1700
BS-I-C-22	12:26 PM	10.00	10.00		0.57			
BS-I-D-23	12:46 PM	50.00	30.00			0.57		
BS-I-B-24	1:06 PM	50.00	10.00					1700

Table 11: Field testing data, Vortechs® System Outlet, event March 31, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-O-A-1	6:40 AM	50.00	30.00		0.75	0.69		
BS-O-B-2	6:45 AM	60.00	30.00					2800
BS-O-C-3	6:50 AM	100.00	40.00		0.79			
BS-O-D-4	6:55 AM	50.00	20.00			1.69		
BS-O-B-5	7:00 AM	70.00	30.00					22000
BS-O-A-6	7:05 AM	33.33	26.67		0.83	1.07		
BS-O-C-7	7:26 AM	46.67	20.00		0.90			
BS-O-D-8	7:46 AM	33.33	20.00			0.75		
BS-O-B-9	8:06 AM	73.33	20.00					11000
BS-O-C10	8:26 AM	40.00	10.00		0.93			
BS-O-D-11	8:46 AM	85.00	25.00			0.90		
BS-O-B-12	9:06 AM	55.00	30.00					11000
BS-O-C-13	9:26 AM	35.00	15.00		0.79			
BS-O-D-14	9:46 AM	30.00	15.00			0.81		
BS-O-B-15	10:06 AM	20.00	5.00					2200
BS-O-C-16	10:26 AM	25.00	10.00		0.67			
BS-O-D-17	10:46 AM	25.00	15.00			0.87		
BS-O-B-18	11:06 AM	25.00	15.00					3500
BS-O-C-19	11:26 AM	20.00	5.00		0.63			
BS-O-D-20	11:46 AM	20.00	10.00			1.39		
BS-O-B-21	12:06 PM	15.00	5.00					11000
BS-O-C-22	12:26 PM	20.00	10.00		0.66			
BS-O-D-23	12:46 PM	10.00	10.00			1.16		
BS-O-B-24	1:06 PM	10.00	10.00					14000

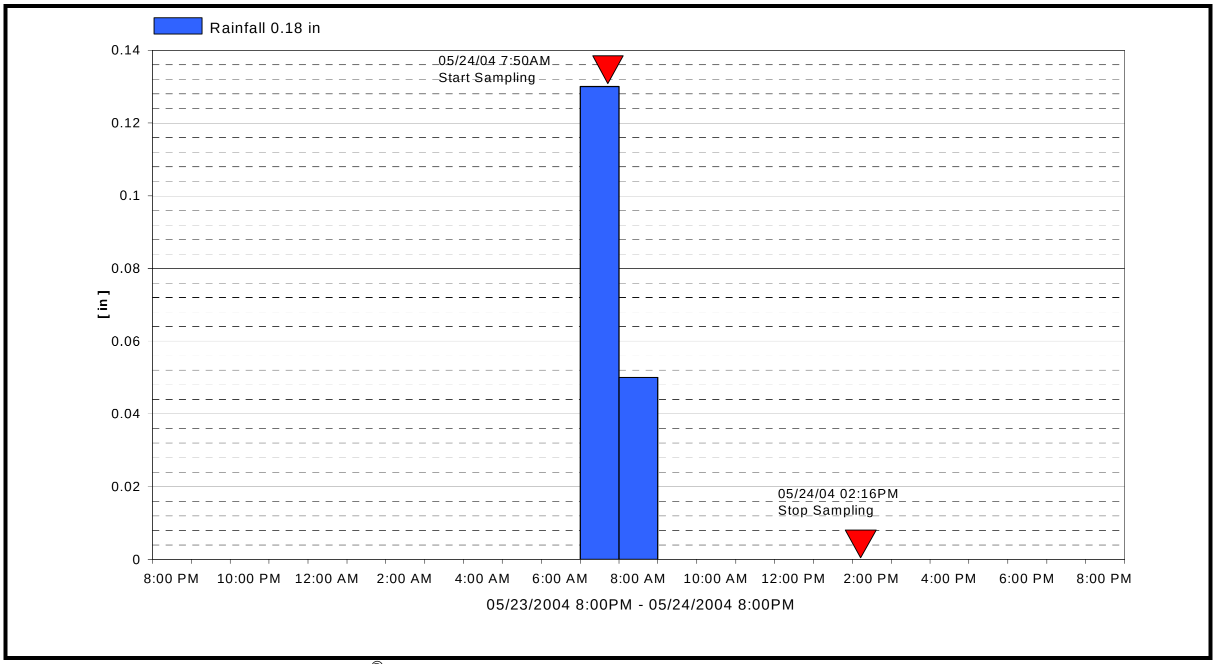


Figure 71: Bay Shore Vortechs® System Hyetograph – May 24, 2004

Table 12: Field testing summary, event May 24, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	31.72	30.67	16.48	73.33	2.00	**-57.45%**
	O	49.94	16.67	73.87	293.00	4.00	
VSS [mg/L]	I	17.30	15.50	9.00	40.00	0.00	**-29.46%**
	O	22.40	8.57	29.59	106.67	0.00	
TPH [ppm]	I	2.51	1.77	1.89	7.56	1.10	**56.14%**
	O	1.10	1.06	0.53	2.52	0.25	
TKN [mg/L]	I	3.25	3.12	0.58	4.09	2.37	**68.89%**
	O	1.01	0.90	0.52	2.18	0.54	
TP [mg/L]	I	0.88	0.85	0.10	1.02	0.70	**30.75%**
	O	0.61	0.61	0.17	1.00	0.43	
BOD_5 [mg/L-O_2]	I	12.14	11.85	1.97	16.56	9.96	**26.36%**
	O	8.94	8.51	3.64	14.76	4.83	

[2] comparing mean inlet and outlet values

Table 13: Field testing data, Vortechs® System Inlet, event May 24, 2004.

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-I-A-1	7:50AM	73.30	40.00	7.23	4.09	1.02	10.80	
BS-I-B-2	7:55AM	60.00	26.70	5.84				
BS-I-C-3	8:00AM	2.00	0.000	7.56	3.72			
BS-I-D-4	8:05AM	36.00	20.00	5.11		0.91		
BS-I-B-5	8:10AM	40.00	20.00	2.40			16.56	
BS-I-A-6	8:15AM	36.00	12.00	2.85	3.80	0.855		
BS-I-C-7	8:36AM	36.00	16.00	1.81	3.63			
BS-I-D-8	8:56AM	40.00	35.00	1.39		1.01		
BS-I-B-9	9:16AM	40.00	25.00	1.10			12.60	
BS-I-C10	9:36AM	10.00	10.00	1.16	2.93			
BS-I-D-11	9:56AM	8.00	8.00	1.61		0.70		
BS-I-B-12	10:16AM	26.70	20.00	1.54			11.28	
BS-I-C-13	10:36AM	24.00	16.00	2.05	3.12			
BS-I-D-14	10:56AM	20.00	10.00	1.80		0.83		
BS-I-B-15	11:16AM	33.30	13.30	1.83			12.18	
BS-I-C-16	11:36AM	25.00	15.00	1.54	2.65			
BS-I-D-17	11:56AM	22.90	14.30	2.62		0.85		
BS-I-B-18	12:16PM	50.00	25.00	1.36			9.96	
BS-I-C-19	12:36PM	20.00	16.00	1.42	2.37			
BS-I-D-20	12:56PM	28.00	8.00	1.78		0.95		
BS-I-B-21	1:16PM	50.00	15.00	1.76			12.00	
BS-I-C-22	1:36PM	23.30	13.30	1.66	2.97			
BS-I-D-23	1:56 PM	16.70	10.00	1.47		0.83		
BS-I-B-24	2:16 PM	40.00	26.70	1.30			11.70	

Table 13: Field testing data, Vortechs® System Outlet, event May 24, 2004.

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-O-A-1	7:50AM	180.0	96.00	2.52	2.18	1.00	8.49	
BS-O-B-2	7:55AM	293.3	106.70	0.86				
BS-O-C-3	8:00AM	192.0	72.00	1.95	1.42			
BS-O-D-4	8:05AM	116.7	36.70	1.80		0.68		
BS-O-B-5	8:10AM	85.00	40.00	0.94			12.90	
BS-O-A-6	8:15AM	53.30	33.30	1.06	0.90	0.51		
BS-O-C-7	8:36AM	45.70	20.00	1.45	1.04			
BS-O-D-8	8:56AM	36.70	33.30	1.16		0.62		
BS-O-B-9	9:16AM	28.00	12.00	0.38			14.76	
BS-O-C10	9:36AM	16.70	13.30	1.36	0.93			
BS-O-D-11	9:56AM	17.10	8.60	0.95		0.70		
BS-O-B-12	10:16AM	16.70	6.70	0.25			10.77	
BS-O-C-13	10:36AM	13.30	6.70	1.58	0.89			
BS-O-D-14	10:56AM	14.30	8.60	1.29		0.61		
BS-O-B-15	11:16AM	16.70	3.30	0.69			8.52	
BS-O-C-16	11:36AM	12.00	2.00	0.80	0.66			
BS-O-D-17	11:56AM	10.00	10.00	1.05		0.47		
BS-O-B-18	12:16PM	10.00	7.50	0.76			6.18	
BS-O-C-19	12:36PM	6.00	0.00	0.85	0.55			
BS-O-D-20	12:56PM	7.50	5.00	1.06		0.48		
BS-O-B-21	1:16PM	10.00	7.50	0.41			5.04	
BS-O-C-22	1:36PM	4.00	2.00	1.09	0.54			
BS-O-D-23	1:56 PM	6.00	4.00	1.60		0.43		
BS-O-B-24	2:16 PM	7.50	2.50	0.54			4.83	

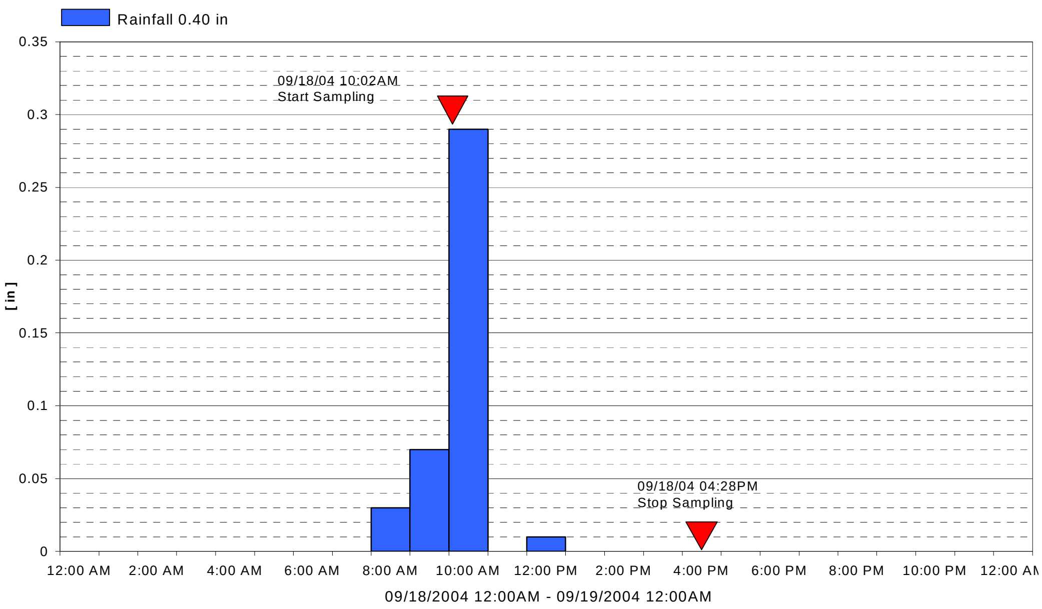


Figure 72: Bay Shore Vortechs® System Hyetograph – September 18, 2004

Table 14: Field testing summary, event September 18, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	55.40	42.00	46.66	212.33	6.67	**55.00%**
	O	24.93	16.07	17.83	60.00	6.67	
VSS [mg/L]	I	28.65	22.00	21.79	93.33	6.67	**79.59%**
	O	5.85	5.00	5.89	22.22	0.00	
TPH [ppm]	I	0.66	0.58	0.51	2.05	0.00	**-22.72%**
	O	0.80	0.40	1.14	4.29	0.00	
TKN [mg/L]	I	1.62	1.09	1.17	3.25	0.23	**53.25%**
	O	0.76	0.53	0.36	1.39	0.41	
TP [mg/L]	I	1.20	1.09	0.42	2.10	0.69	**34.18%**
	O	0.79	0.84	0.21	1.09	0.53	
BOD_5 [mg/L-O_2]	I	5.94	4.12	4.67	16.17	2.31	**58.09%**
	O	2.49	1.72	1.99	6.84	0.74	
FCB [MPN/100mL]	I	168750	135000	105212	350000	50000	**22.96%**
	O	130000	130000	51547	220000	50000	

[2] comparing mean inlet and outlet values

Table 15: Field testing data, Vortechs® System Inlet, event September 18, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-I-A-1	10:02 AM	145.00	75.00	2.05	2.61	1.09		
BS-I-B-2	10:07 AM	213.30	93.30	1.21			16.17	350000
BS-I-C-3	10:12 AM	115.00	70.00	1.28	2.47			
BS-I-D-4	10:17 AM	45.00	35.00	0.96		1.53		
BS-I-B-5	10:22 AM	93.30	26.70	0.96			9.54	220000
BS-I-A-6	10:27 AM	75.00	40.00	0.93	3.25	2.10		
BS-I-C-7	10:48 AM	60.00	30.00	0.59	2.87			
BS-I-D-8	11:08 AM	48.00	24.00	1.63		1.41		
BS-I-B-9	11:28 AM	65.00	30.00	0.78			4.38	50000
BS-I-C10	11:48 AM	26.70	16.70	0.38	0.23			
BS-I-D-11	12:08 PM	30.00	13.30	0.79		1.09		
BS-I-B-12	12:28 PM	60.00	28.00	0.00			3.86	130000
BS-I-C-13	12:48 PM	36.00	24.00	0.46	0.40			
BS-I-D-14	1:08 PM	28.00	16.00	0.30		0.93		
BS-I-B-15	1:28 PM	44.00	20.00	0.59			2.31	70000
BS-I-C-16	1:48 PM	40.00	20.00	0.48	0.55			
BS-I-D-17	2:08 PM	44.00	36.00	0.35		0.95		
BS-I-B-18	2:28 PM	40.00	20.00	0.00			3.45	280000
BS-I-C-19	2:48 PM	20.00	14.30	0.36	1.09			
BS-I-D-20	3:08 PM	13.30	6.70	0.58		0.69		
BS-I-B-21	3:28 PM	36.00	16.00	0.35			4.44	140000
BS-I-C-22	3:48 PM	13.30	10.00	0.64	1.08			
BS-I-D-23	4:08 PM	6.70	6.70	0.10		1.06		
BS-I-B-24	4:28 PM	32.00	16.00	0.00			3.38	110000

Table 15: Field testing data, Vortechs® System Outlet, event September 18, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-O-A-1	10:02 AM	44.00	0.00	2.61	1.39	0.88		
BS-O-B-2	10:07 AM	44.00	0.00	4.29			6.84	130000
BS-O-C-3	10:12 AM	60.00	0.00	3.01	1.21			
BS-O-D-4	10:17 AM	52.00	0.00	2.53		1.09		
BS-O-B-5	10:22 AM	60.00	0.00	0.84			3.71	80000
BS-O-A-6	10:27 AM	36.70	0.00	1.31	0.67	0.59		
BS-O-C-7	10:48 AM	48.00	0.00	0.43	1.05			
BS-O-D-8	11:08 AM	36.70	0.00	0.60		0.80		
BS-O-B-9	11:28 AM	28.00	16.00	0.61			2.72	130000
BS-O-C10	11:48 AM	15.00	10.00	0.35	0.52			
BS-O-D-11	12:08 PM	11.40	8.60	0.62		0.84		
BS-O-B-12	12:28 PM	17.10	11.40	0.43			1.34	220000
BS-O-C-13	12:48 PM	14.30	5.70	0.00	0.53			
BS-O-D-14	1:08 PM	12.00	4.00	0.01		0.85		
BS-O-B-15	1:28 PM	13.30	13.30	0.38			1.77	170000
BS-O-C-16	1:48 PM	6.70	3.30	0.00	0.53			
BS-O-D-17	2:08 PM	10.00	5.00	0.15		0.53		
BS-O-B-18	2:28 PM	22.20	22.20	0.60			1.67	130000
BS-O-C-19	2:48 PM	8.00	4.00	0.00	0.49			
BS-O-D-20	3:08 PM	8.00	8.00	0.14		0.53		
BS-O-B-21	3:28 PM	12.00	8.00	0.00			1.16	50000
BS-O-C-22	3:48 PM	7.50	5.00	0.00	0.41			
BS-O-D-23	4:08 PM	11.40	5.70	0.19		1.05		
BS-O-B-24	4:28 PM	20.00	10.00	0.22			0.74	130000

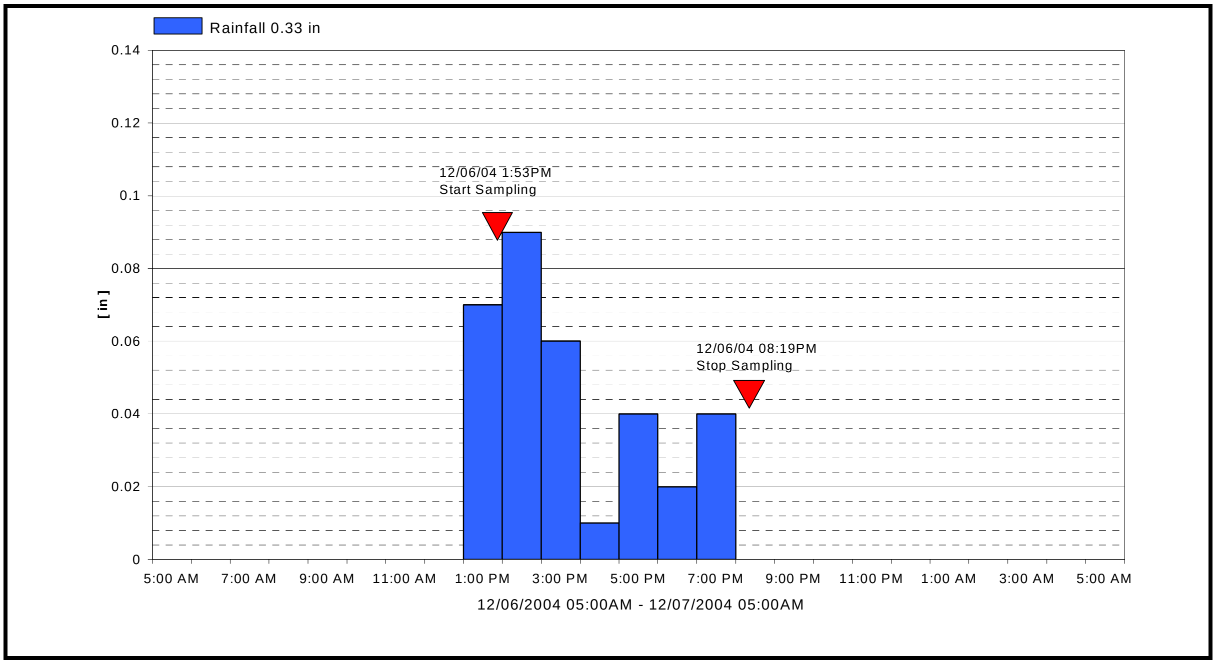


Figure 73: Bay Shore Vortechs® System Hyetograph – December 06, 2004

Table 16: Field testing summary, event December 06, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	9.64	10.71	3.62	15.00	0.00	**-23.20%**
	O	11.88	12.00	5.25	24.00	2.86	
VSS [mg/L]	I	6.46	8.00	2.89	12.00	0.00	**-16.82%**
	O	7.54	8.00	3.29	16.00	2.86	
TPH [ppm]	I	1.65	1.74	0.66	2.66	0.48	**20.59%**
	O	1.31	1.58	0.75	2.49	0.14	
TKN [mg/L]	I	1.29	1.13	0.62	2.36	0.63	**4.37%**
	O	1.23	1.14	0.58	2.06	0.51	
TP [mg/L]	I	0.25	0.23	0.12	0.47	0.12	**14.46%**
	O	0.22	0.23	0.06	0.30	0.12	
FCB [MPN/100mL]	I	12800	10000	11123	30000	1700	**75.29%**
	O	3163	2250	2701	9000	700	

[2] comparing mean inlet and outlet values

Table 17: Field testing data, Vortechs® System Inlet, event December 06, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-I-A-1	1:53 PM	8.00	8.00	0.48	0.75	0.48		
BS-I-B-2	1:58 PM	15.00	5.00	0.64				1700
BS-I-C-3	2:03 PM	10.00	10.00	0.76	1.01			
BS-I-D-4	2:08 PM	12.00	12.00	0.84		0.25		
BS-I-B-5	2:13 PM	12.00	8.00	0.54				3000
BS-I-A-6	2:18 PM	8.00	4.00	0.80	0.63	0.41		
BS-I-C-7	2:39 PM	12.00	8.00	1.49	1.13			
BS-I-D-8	2:59 PM	8.00	8.00	1.56		0.22		
BS-I-B-9	3:19 PM	0.00	0.00	2.32				22000
BS-I-C10	3:39 PM	12.00	4.00	2.64	2.36			
BS-I-D-11	3:59 PM	12.00	8.00	2.65		0.23		
BS-I-B-12	4:19 PM	0.00	0.00	1.64				1700
BS-I-C-13	4:39 PM	12.00	8.00	2.66	2.21			
BS-I-D-14	4:59 PM	8.00	4.00	1.86		0.26		
BS-I-B-15	5:19 PM	12.50	9.40	2.03				24000
BS-I-C-16	5:39 PM	8.00	8.00	2.04	1.38			
BS-I-D-17	5:59 PM	8.00	8.00	2.06		0.19		
BS-I-B-18	6:19 PM	11.40	5.70	1.95				30000
BS-I-C-19	6:39 PM	12.00	8.00	2.11	1.25			
BS-I-D-20	6:59 PM	12.00	8.00	1.84		0.13		
BS-I-B-21	7:19 PM	9.80	6.60	1.76				9000
BS-I-C-22	7:39 PM	8.00	4.00	1.71	0.85			
BS-I-D-23	7:59 PM	8.00	4.00	1.64		0.12		
BS-I-B-24	8:19 PM	12.70	6.30	1.63				11000

Table 17: Field testing data, Vortechs® System Outlet, event December 06, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-O-A-1	1:53 PM	5.70	5.70	0.19	1.14	0.12		
BS-O-B-2	1:58 PM	10.00	5.00	0.22				1400
BS-O-C-3	2:03 PM	7.50	5.00	0.15	0.51			
BS-O-D-4	2:08 PM	2.90	2.90	0.38		0.23		
BS-O-B-5	2:13 PM	5.70	2.90	0.45				2800
BS-O-A-6	2:18 PM	5.70	5.70	0.14	0.52	0.23		
BS-O-C-7	2:39 PM	13.30	13.30	0.49	0.67			
BS-O-D-8	2:59 PM	20.00	12.00	0.67		0.30		
BS-O-B-9	3:19 PM	16.00	8.00	1.33				1700
BS-O-C10	3:39 PM	16.00	12.00	1.77	1.60			
BS-O-D-11	3:59 PM	24.00	16.00	2.49		0.30		
BS-O-B-12	4:19 PM	16.00	8.00	1.92				1700
BS-O-C-13	4:39 PM	12.00	8.00	2.07	2.06			
BS-O-D-14	4:59 PM	20.00	8.00	1.97		0.24		
BS-O-B-15	5:19 PM	14.30	8.60	1.58				700
BS-O-C-16	5:39 PM	16.00	8.00	1.84	1.88			
BS-O-D-17	5:59 PM	12.00	8.00	1.91		0.21		
BS-O-B-18	6:19 PM	12.00	8.00	1.65				3000
BS-O-C-19	6:39 PM	8.00	8.00	2.09	1.54			
BS-O-D-20	6:59 PM	8.00	8.00	1.93		0.19		
BS-O-B-21	7:19 PM	12.00	4.00	1.45				5000
BS-O-C-22	7:39 PM	8.00	4.00	1.57	1.14			
BS-O-D-23	7:59 PM	12.00	8.00	1.71		0.15		
BS-O-B-24	8:19 PM	8.00	4.00	1.53				9000

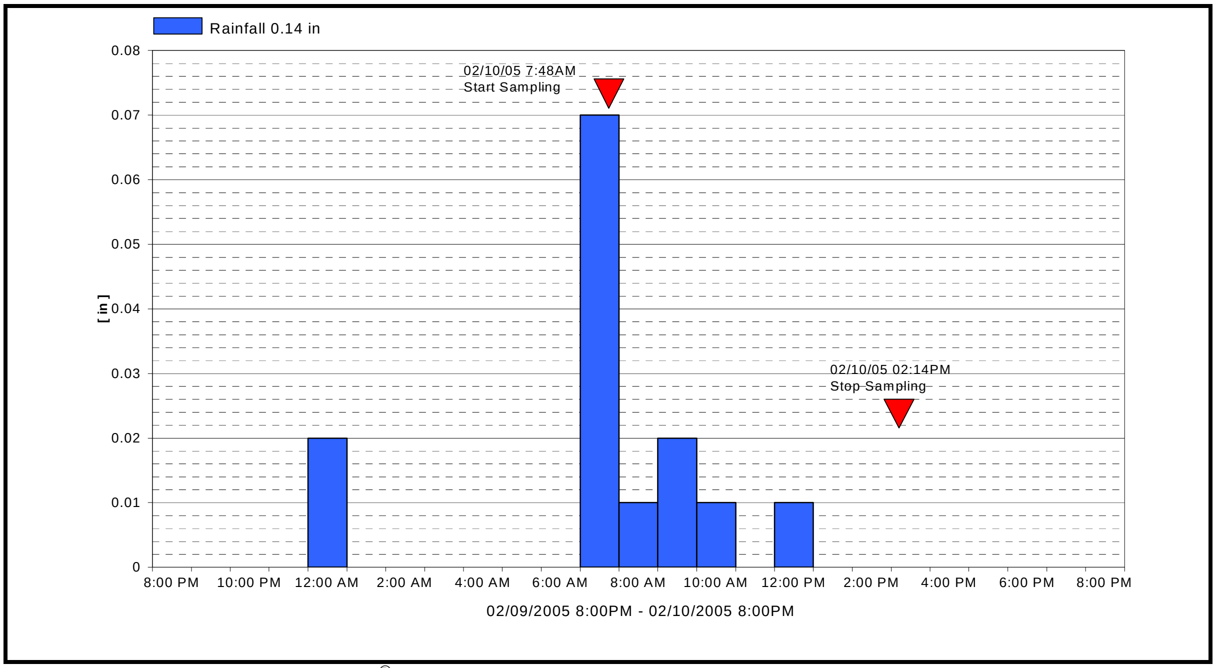


Figure 74: Bay Shore Vortechs® System Hyetograph – February 10, 2005

Table 18: Field testing summary, event February 10, 2005.

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	156.29	160.00	26.09	200.00	76.00	**77.34%**
	O	35.42	26.00	29.22	93.33	3.33	
VSS [mg/L]	I	67.47	70.00	10.99	80.00	36.00	**70.42%**
	O	19.96	18.00	11.45	46.67	2.86	
TPH [ppm]	I	11.84	12.11	2.59	18.47	5.67	**78.00%**
	O	2.60	1.84	1.75	6.71	0.73	
TKN [mg/L]	I	2.30	2.31	0.41	2.85	1.78	**-8.69%**
	O	2.50	2.64	0.42	2.99	1.69	
TP [mg/L]	I	1.20	1.24	0.25	1.54	0.71	**49.10%**
	O	0.61	0.58	0.37	1.51	0.23	
BOD_5 [mg/L-O_2]	I	19.29	19.62	2.55	22.44	15.24	**65.11%**
	O	6.73	7.08	2.94	10.88	2.32	
FCB [MPN/100mL]	I	9963	9000	8061	24000	1700	**74.62%**
	O	2529	1400	3550	11000	230	

[2] comparing mean inlet and outlet values

Table 19: Field testing data, Vortechs® System Inlet, event February 10, 2005

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-I-A-1	7:48 AM	76.00	36.00	15.40	1.80	1.45		
BS-I-B-2	7:53 AM	105.00	50.00	5.67			15.96	17000
BS-I-C-3	7:58 AM	120.00	53.30	12.22	2.74			
BS-I-D-4	8:03 AM	140.00	70.00	12.79		1.29		
BS-I-B-5	8:08 AM	170.00	70.00	10.87			21.96	24000
BS-I-A-6	8:13 AM	170.00	80.00	12.73	2.85	0.71		
BS-I-C-7	8:34 AM	150.00	70.00	12.00	2.47			
BS-I-D-8	8:54 AM	170.00	70.00	13.01		1.54		
BS-I-B-9	9:14 AM	180.00	70.00	13.08			22.44	3000
BS-I-C10	9:34 AM	160.00	80.00	10.54	2.69			
BS-I-D-11	9:54 AM	150.00	70.00	14.22		1.02		
BS-I-B-12	10:14 AM	180.00	80.00	9.51			19.32	3000
BS-I-C-13	10:34 AM	160.00	80.00	12.55	1.78			
BS-I-D-14	10:54 AM	180.00	70.00	9.26		1.38		
BS-I-B-15	11:14 AM	200.00	70.00	11.13			19.44	1700
BS-I-C-16	11:34 AM	160.00	70.00	9.22	2.31			
BS-I-D-17	11:54 AM	170.00	80.00	12.47		1.10		
BS-I-B-18	12:14 PM	170.00	60.00	9.73			19.80	5000
BS-I-C-19	12:34 PM	150.00	70.00	11.97	2.00			
BS-I-D-20	12:54 PM	150.00	50.00	14.25		1.09		
BS-I-B-21	1:14 PM	170.00	60.00	11.90			15.24	13000
BS-I-C-22	1:34 PM	160.00	70.00	13.07	2.06			
BS-I-D-23	1:54 PM	150.00	70.00	18.47		1.24		
BS-I-B-24	2:14 PM	160.00	70.00	8.03			20.16	13000

Table 19: Field testing data, Vortechs® System Outlet, event February 10, 2005

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
BS-O-A-1	7:48 AM	5.70	2.90	0.87	2.16	0.23		
BS-O-B-2	7:53 AM	28.00	8.00	0.96			3.68	230
BS-O-C-3	7:58 AM	11.40	8.60	0.73	1.69			
BS-O-D-4	8:03 AM	3.30	13.30	0.93		0.33		
BS-O-B-5	8:08 AM	24.00	8.00	0.84			2.32	700
BS-O-A-6	8:13 AM	6.70	10.00	1.23	2.30	0.41		
BS-O-C-7	8:34 AM	5.70	8.60	1.90	2.32			
BS-O-D-8	8:54 AM	12.00	16.00	1.01		0.45		
BS-O-B-9	9:14 AM	17.10	14.30	1.36			6.36	1400
BS-O-C10	9:34 AM	20.00	20.00	1.54	2.64			
BS-O-D-11	9:54 AM	12.00	8.00	1.61		0.59		
BS-O-B-12	10:14 AM	40.00	12.00	1.77			5.10	300
BS-O-C-13	10:34 AM	20.00	20.00	1.31	2.82			
BS-O-D-14	10:54 AM	32.00	24.00	2.26		0.70		
BS-O-B-15	11:14 AM	56.00	24.00	2.69			7.80	1400
BS-O-C-16	11:34 AM	36.00	28.00	3.58	2.67			
BS-O-D-17	11:54 AM	44.00	28.00	3.35		0.58		
BS-O-B-18	12:14 PM	72.00	28.00	4.01			7.90	2200
BS-O-C-19	12:34 PM	8.00	16.00	4.34	2.92			
BS-O-D-20	12:54 PM	56.00	28.00	5.16		0.71		
BS-O-B-21	1:14 PM	93.30	40.00	4.98			10.88	11000
BS-O-C-22	1:34 PM	66.70	33.30	4.16	2.99			
BS-O-D-23	1:54 PM	86.70	46.70	6.71		1.51		
BS-O-B-24	2:14 PM	93.30	33.30	5.17			9.80	3000

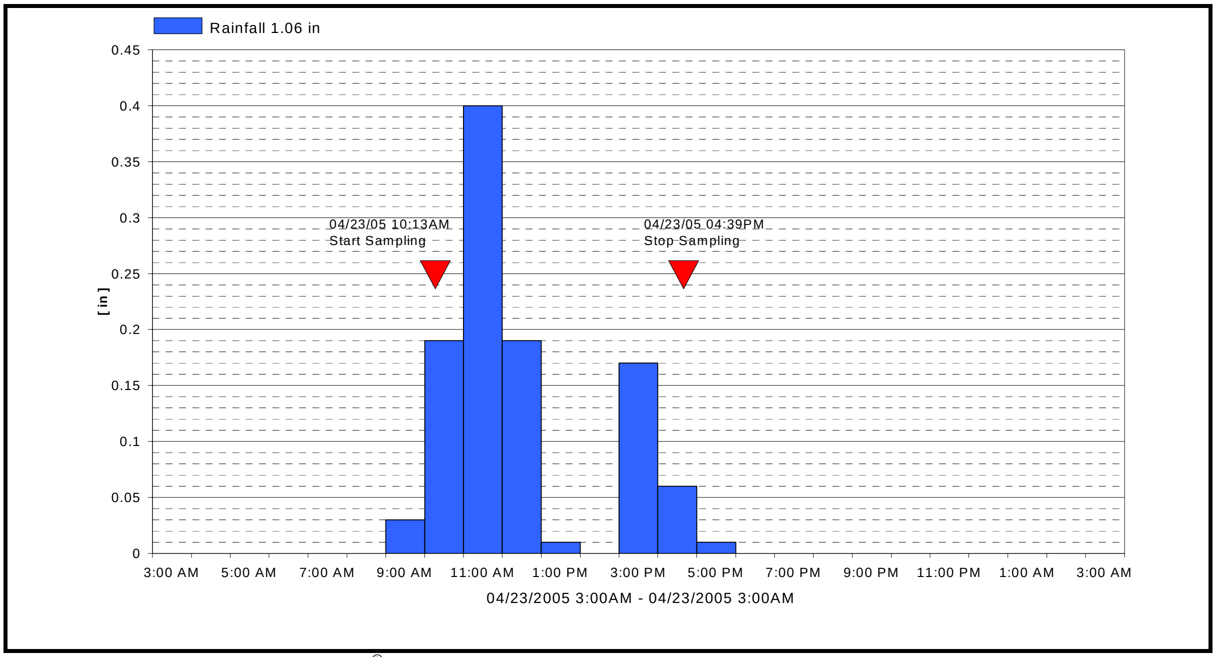


Figure 75: Bay Shore Vortechs® System Hyetograph – April 23, 2005

Table 20: Field testing summary, event April 23, 2005.

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
BOD_5 [mg/L-O_2]	I	11.61	9.58	4.70	19.56	6.84	**20.87%**
	O	9.19	8.61	2.07	13.32	6.90	

[2] comparing mean inlet and outlet values

Table 21: Field testing data, Vortechs® System, event April 23, 2005

Sample Code	Sampling Time	BOD_5 Inlet [mg/L-O2]	BOD_5 Outlet [mg/L-O_2]
BS-B-2	7:53 AM	19.56	7.28
BS-B-5	8:08 AM	17.88	13.32
BS-B-9	9:14 AM	12.54	10.80
BS-B-12	10:14 AM	7.94	8.50
BS-B-15	11:14 AM	9.62	8.72
BS-B-18	12:14 PM	9.54	9.52
BS-B-21	1:14 PM	8.96	6.90
BS-B-24	2:14 PM	6.84	8.46

Table 22 reports the pH and Table 23 reports the Conductivity of samples for each storm event collected at the Bay Shore Vortechs® system. Table 24 summarizes the overall concentrations and removal efficiencies of each parameter studied in all storm events for the Vortechs® system.

Table 22: Bay Shore Vortechs® System Inflow and Outflow, data for pH.

Sample Code	pH of the Events				
	03/31/2004	05/24/2004	09/18/2004	12/06/2004	02/10/2005
BS-I-B-2	6.91	6.94	6.12	6.38	7.13
BS-I-B-5	6.83	6.72	5.98	6.41	6.96
BS-I-B-9	6.80	6.65	6.04	6.48	6.91
BS-I-B-12	6.94	6.59	6.00	6.34	7.03
BS-I-B-15	6.69	6.65	5.95	6.38	7.09
BS-I-B-18	6.84	6.49	6.01	6.44	7.07
BS-I-B-21	6.95	6.55	5.94	6.37	7.05
BS-I-B-24	6.95	6.48	5.99	6.40	7.04
BS-O-B-2	6.95	6.14	6.18	6.75	6.44
BS-O-B-5	6.93	6.17	5.98	6.87	6.55
BS-O-B-9	6.84	6.13	6.28	6.51	6.44
BS-O-B-12	6.94	6.15	6.24	6.49	6.52
BS-O-B-15	6.53	6.30	6.35	6.42	6.58
BS-O-B-18	7.11	6.40	6.50	6.31	6.62
BS-O-B-21	6.97	6.49	6.40	6.31	6.62
BS-O-B-24	6.78	6.36	6.38	6.26	6.65

Table 23: Bay Shore Vortechs® System Inflow and Outflow, data for conductivity.

Sample Code	Conductivity of the Events [kΩ·cm]				
	03/31/2004	05/24/2004	09/18/2004	12/06/2004	02/10/2005
BS-I-B-2	2.85	2.38	10.62	8.55	0.21
BS-I-B-5	2.62	2.65	6.06	8.07	0.18
BS-I-B-9	2.56	2.83	9.50	8.23	0.22
BS-I-B-12	3.23	2.90	9.37	11.25	0.27
BS-I-B-15	4.26	2.85	10.93	12.15	0.31
BS-I-B-18	5.17	3.14	10.16	15.40	0.36
BS-I-B-21	5.32	3.11	10.23	16.26	0.40
BS-I-B-24	6.13	3.07	11.30	18.01	0.42
BS-O-B-2	8.76	8.29	9.23	5.06	0.11
BS-O-B-5	6.85	8.54	31.85	5.93	0.11
BS-O-B-9	8.05	6.63	10.38	7.64	0.11
BS-O-B-12	10.11	6.64	10.27	8.97	0.12
BS-O-B-15	10.81	5.43	8.03	10.42	0.12
BS-O-B-18	10.25	4.95	7.55	11.72	0.12
BS-O-B-21	9.33	4.84	7.40	13.05	0.14
BS-O-B-24	7.59	4.58	7.77	14.47	0.14

Table 24: Field testing summary for the Vortechs® System

Parameter		N. of Samples	Mean Concentr.	Median Concentr.	Standard Deviation	Max Concentr.	Min Concentr.	Removal Efficiency[2]
TSS [mg/L]	I	120	65.19	42.00	58.40	213.33	0.00	**50.36%**
	O	120	32.36	17.14	39.62	293.33	2.86	
VSS [mg/L]	I	120	29.73	20.00	24.80	93.33	0.00	**50.53%**
	O	120	14.71	9.29	16.33	106.67	0.00	
TPH [ppm]	I	96	4.16	1.77	4.79	18.47	0.00	**65.05%**
	O	96	1.46	1.13	1.32	6.71	0.00	
TKN [mg/L]	I	45	1.93	2.00	1.03	4.09	0.23	**34.95%**
	O	45	1.25	0.93	0.77	2.99	0.41	
TP [mg/L]	I	45	0.90	0.93	0.46	2.10	0.12	**27.67%**
	O	45	0.65	0.61	0.36	1.69	0.12	
BOD_5 [$mg/L-O_2$]	I	32	12.24	11.85	5.95	22.44	2.31	**44.17%**
	O	32	6.84	7.09	3.78	14.76	0.74	
FCB [MPN/100mL]	I	32	50431	13000	85963	350000	1700	**27.93%**
	O	32	36345	4250	60340	220000	230	

[2] comparing mean inlet and outlet values

V2b1™

Table 25 presents the events studied at the V2b1™ site. Details regarding the storms and the sampling collections are reported. Table 26 summarizes the analyses performed on the samples collected for each storm event for evaluation of the performance of the V2b1™ system. Hyetographs of the storm events are shown for each storm event that include the total rain during the event and indicate the beginning and the end of the sampling cycle. For each storm event, the "Field Test Summary" tables (Table 27, 29, 31, 33, and 35) report mean concentration, median concentration, standard deviation, max and minimum concentration of the results of the analysis on the samples from the inlet and the outlet chamber of the device, for each parameter studied in this project. The last column of the table shows the removal efficiency for each parameter calculated by comparing the inlet and outlet values. The "Field Testing Data" tables (Table 28, 30, 32, 34, and 36) show the sampling time and the results of the analysis on each sample collected in the inlet and outlet chamber for each parameter studied in the project.

Table 25: Runoff events sampled during the study of the V2b1™ System

Event Details						Sampling Details	
Starting date	Starting time	Ending Time	Duration [min]	Depth [in]	Mean [in/hr]	Starting Time	Ending Time
03/31/2004	1:24AM	12:53PM	690	1.31	0.11	3:30AM	9:56AM
05/16/2004	12:17AM	1:39AM	83	0.15	0.11	12:33AM	7:00AM(1)
09/08/2004	12:02AM	3:50PM	949	3.37	0.21	4:44AM	11:10AM
11/12/2004	9:13AM	8:25AM(*)	1393	1.15	0.05	8:06PM	2:33AM(*)
03/28/2005	11:28PM(**)	7:02PM	1167	1.56	0.08	9:44AM	4:10PM

(*) Next Day; (**) Previous Day;

(1) The sampling collection ended after the event.

Table 26: Analysis conducted on samples collected from the V2b1™ System.

Starting date	Parameter Analyzed							
	TKN	TP	BOD_5	FCB	TSS	TPH	pH	Cond.
03/31/2004	X		X	X			X	X
05/16/2004	X	X		X	X	X	X	X
09/08/2004	X	X	X	X	X	X	X	X
11/12/2004	X	X	X	X	X	X	X	X
03/28/2005	X	X	X		X	X	X	X

Table 27: Field testing summary, V2b1™ System, event March 31, 2004.

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TKN [mg/L]	I	0.57	0.49	0.21	0.88	0.23	**-21.53%**
	O	0.69	0.57	0.26	1.14	0.37	
BOD_5 [mg/L-O_2]	I	9.56	9.08	1.10	11.31	8.56	**24.65%**
	O	7.21	6.50	2.35	11.91	5.04	
FCB [MPN/100mL]	I	921	850	516	1700	220	**-106.51%**
	O	1903	875	2670	8000	50	

[2] comparing mean inlet and outlet values

Table 28: Field testing data, V2b1™ System Inlet, event March 31, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-I-A-1	3:30 AM				0.88			
HG-I-B-2	3:35 AM						10.77	1400
HG-I-C-3	3:40 AM				0.66			
HG-I-D-4	3:45 AM							
HG-I-B-5	3:50 AM						10.43	350
HG-I-A-6	3:55 AM				0.49			
HG-I-C-7	4:16 AM				0.85			
HG-I-D-8	4:36 AM							
HG-I-B-9	4:56 AM						9.26	220
HG-I-C10	5:16 AM				0.46			
HG-I-D-11	5:36 AM							
HG-I-B-12	5:56 AM						8.61	1300
HG-I-C-13	6:16 AM				0.23			
HG-I-D-14	6:36 AM							
HG-I-B-15	6:56 AM						11.31	900
HG-I-C-16	7:16 AM				0.44			
HG-I-D-17	7:36 AM							
HG-I-B-18	7:56 AM						8.66	1700
HG-I-C-19	8:16 AM				0.68			
HG-I-D-20	8:36 AM							
HG-I-B-21	8:56 AM						8.91	800
HG-I-C-22	9:16 AM				0.41			
HG-I-D-23	9:36 AM							
HG-I-B-24	9:56 AM						8.56	700

Table 28: Field testing data, V2b1™ System Outlet, event March 31, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-O-A-1	3:30 AM				0.99			
HG-O-B-2	3:35 AM						11.91	280
HG-O-C-3	3:40 AM				0.80			
HG-O-D-4	3:45 AM							
HG-O-B-5	3:50 AM						7.61	2800
HG-O-A-6	3:55 AM				0.55			
HG-O-C-7	4:16 AM				1.14			
HG-O-D-8	4:36 AM							
HG-O-B-9	4:56 AM						6.63	350
HG-O-C10	5:16 AM				0.52			
HG-O-D-11	5:36 AM							
HG-O-B-12	5:56 AM						9.24	8000
HG-O-C-13	6:16 AM				0.48			
HG-O-D-14	6:36 AM							
HG-O-B-15	6:56 AM						5.12	2200
HG-O-C-16	7:16 AM				0.37			
HG-O-D-17	7:36 AM							
HG-O-B-18	7:56 AM						6.38	1400
HG-O-C-19	8:16 AM				0.57			
HG-O-D-20	8:36 AM							
HG-O-B-21	8:56 AM						5.04	50
HG-O-C-22	9:16 AM				0.78			
HG-O-D-23	9:36 AM							
HG-O-B-24	9:56 AM						5.73	140

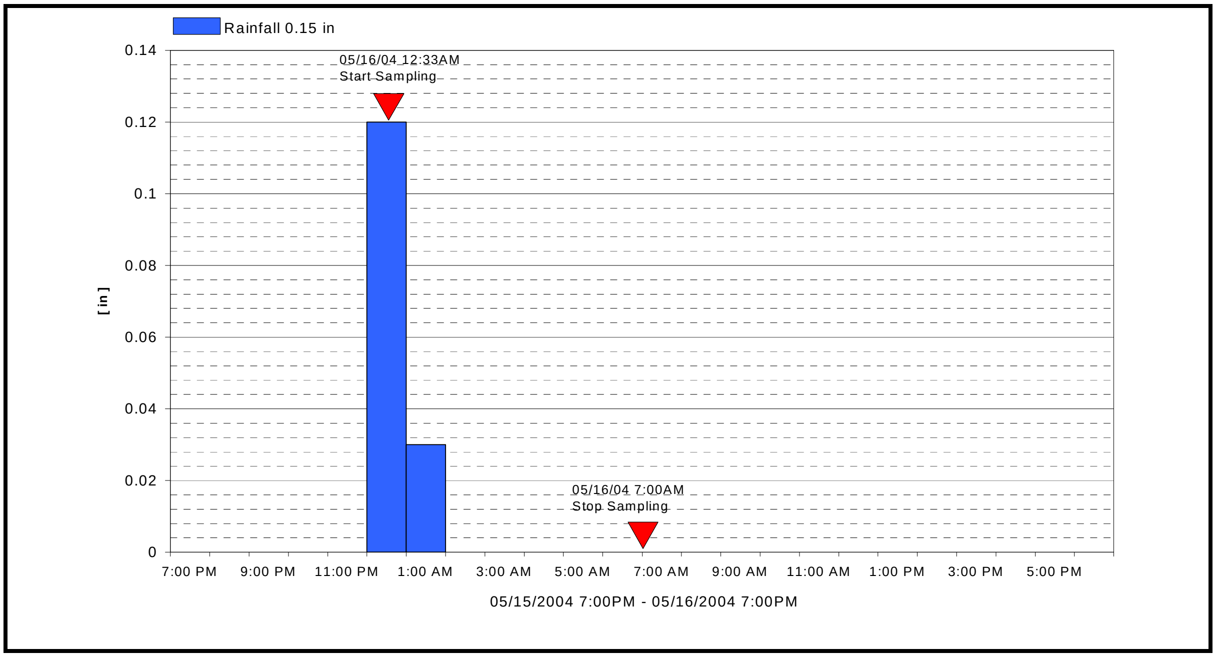


Figure 76: Hauppauge V2b1™ System Hyetograph – May 16, 2004

Table 29: Field testing summary, V2b1™ System, event May 16, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	40.43	30.00	28.12	108.00	11.43	**-7.43%**
	O	43.43	38.00	23.45	93.33	16.00	
VSS [mg/L]	I	19.94	15.50	13.87	53.33	4.00	**-5.30%**
	O	21.00	20.00	11.80	40.00	4.00	
TPH [ppm]	I	1.87	1.75	0.71	3.66	0.89	**26.60%**
	O	1.37	1.29	0.42	2.28	0.79	
TKN [mg/L]	I	2.56	2.42	0.26	2.90	2.27	**16.22%**
	O	2.14	2.00	0.40	2.99	1.77	
TP [mg/L]	I	0.52	0.44	0.25	1.05	0.19	**0.00%**
	O	0.52	0.45	0.19	0.82	0.33	
FCB [MPN/100mL]	I	40250	39000	25235	90000	13000	**39.19%**
	O	24475	22000	13398	50000	2800	

[2] comparing mean inlet and outlet values

Table 30: Field testing data, V2b1™ System Inlet, event May 16, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-I-A-1	12:33 AM	108.00	48.00	3.66	2.90	1.05		
HG-I-B-2	12:38 AM	106.70	53.30	2.72				90000
HG-I-C-3	12:43 AM	26.70	16.70	2.90	2.80			
HG-I-D-4	12:48 AM	80.00	40.00	2.25		0.44		
HG-I-B-5	12:53 AM	93.30	46.70	2.20				17000
HG-I-A-6	12:58 AM	17.10	8.60	3.05	2.81	0.68		
HG-I-C-7	1:20 AM	32.00	16.00	2.15	2.80			
HG-I-D-8	1:40 AM	44.00	20.00	1.94		0.66		
HG-I-B-9	2:00 AM	60.00	33.30	1.59				24000
HG-I-C10	2:20 AM	40.00	16.00	2.00	2.42			
HG-I-D-11	2:40 AM	40.00	24.00	1.44		0.57		
HG-I-B-12	3:00 AM	35.00	15.00	0.94				13000
HG-I-C-13	3:20 AM	20.00	8.00	2.23	2.40			
HG-I-D-14	3:40 AM	32.00	20.00	1.66		0.33		
HG-I-B-15	4:00 AM	26.70	13.30	1.04				50000
HG-I-C-16	4:20 AM	26.70	10.00	1.50	2.32			
HG-I-D-17	4:40 AM	32.00	12.00	2.16		0.19		
HG-I-B-18	5:00 AM	26.70	13.30	1.10	2.27			50000
HG-I-C-19	5:20 AM	11.40	5.70	1.59				
HG-I-D-20	5:40 AM	28.00	16.00	1.65		0.37		
HG-I-B-21	6:00 AM	20.00	13.30	1.05				50000
HG-I-C-22	6:20 AM	24.00	12.00	1.84	2.30			
HG-I-D-23	6:40 AM	20.00	4.00	1.38		0.42		
HG-I-B-24	7:00 AM	20.00	13.30	0.89				28000

Table 30: Field testing data, V2b1™ System Outlet, event May 16, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-O-A-1	12:33 AM	80.00	40.00	2.28	2.36	0.45		
HG-O-B-2	12:38 AM	93.30	40.00	1.89				50000
HG-O-C-3	12:43 AM	75.00	35.00	1.70	2.44			
HG-O-D-4	12:48 AM	68.00	28.00	1.70		0.76		
HG-O-B-5	12:53 AM	80.00	40.00	1.76				30000
HG-O-A-6	12:58 AM	70.00	35.00	2.05	2.99	0.63		
HG-O-C-7	1:20 AM	56.00	28.00	1.75	2.20			
HG-O-D-8	1:40 AM	40.00	12.00	1.33		0.61		
HG-O-B-9	2:00 AM	46.70	20.00	1.64				22000
HG-O-C10	2:20 AM	32.00	8.00	1.70	1.86			
HG-O-D-11	2:40 AM	36.00	20.00	1.48		0.41		
HG-O-B-12	3:00 AM	40.00	20.00	1.25				30000
HG-O-C-13	3:20 AM	32.00	16.00	1.18	2.00			
HG-O-D-14	3:40 AM	24.00	4.00	1.54		0.82		
HG-O-B-15	4:00 AM	46.70	33.30	1.22				22000
HG-O-C-16	4:20 AM	24.00	12.00	1.03	1.80			
HG-O-D-17	4:40 AM	20.00	12.00	0.81		0.33		
HG-O-B-18	5:00 AM	33.30	26.70	0.79				17000
HG-O-C-19	5:20 AM	20.00	10.00	0.85	1.77			
HG-O-D-20	5:40 AM	16.00	8.00	1.08		0.35		
HG-O-B-21	6:00 AM	53.30	26.70	1.08				2800
HG-O-C-22	6:20 AM	20.00	8.00	0.88	1.86			
HG-O-D-23	6:40 AM	16.00	8.00	1.03		0.33		
HG-O-B-24	7:00 AM	20.00	13.30	0.99				22000

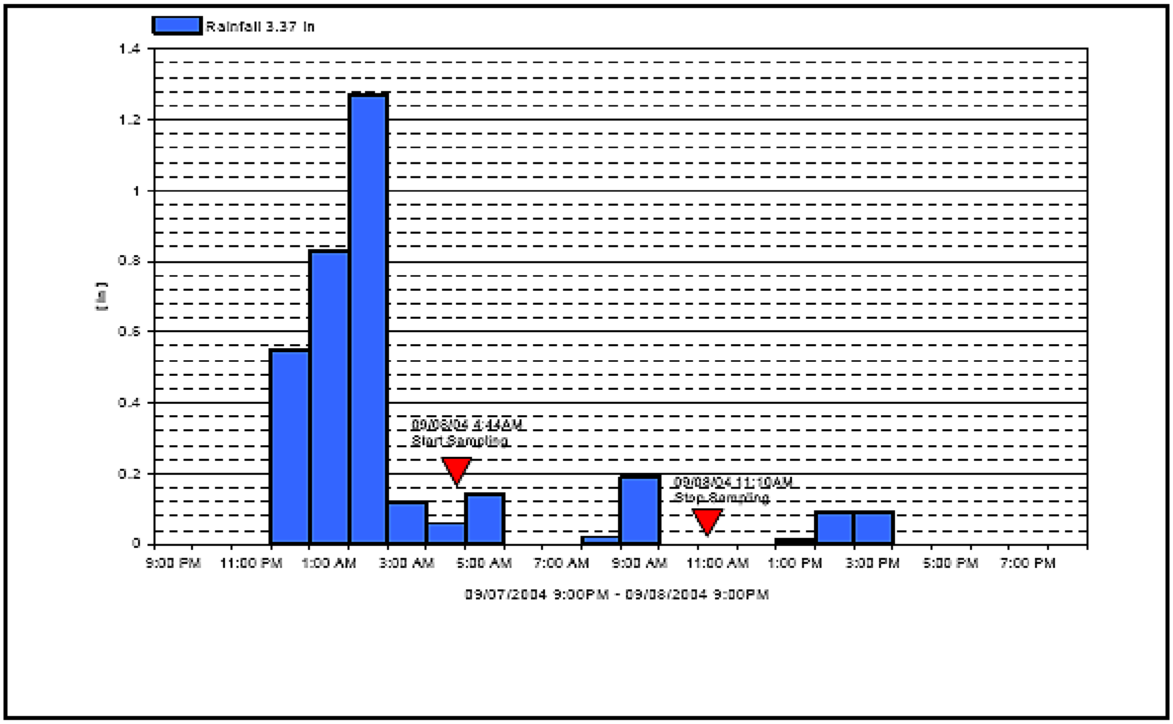


Figure 77: Hauppauge V2b1™ System Hyetograph – September 8, 2004

Table 31: Field testing summary, V2b1™ System, event September 8, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	11.30	11.00	6.15	28.00	3.33	**-61.69%**
	O	18.26	20.00	5.18	29.17	6.67	
VSS [mg/L]	I	6.95	8.00	4.01	16.00	0.00	**-24.30%**
	O	8.64	6.91	4.97	20.00	0.00	
TPH [ppm]	I	1.33	1.27	0.43	2.36	0.73	**49.76%**
	O	0.67	0.68	0.14	0.98	0.38	
TKN [mg/L]	I	0.60	0.65	0.14	0.72	0.26	**28.38%**
	O	0.43	0.38	0.17	0.77	0.24	
TP [mg/L]	I	0.20	0.15	0.10	0.46	0.12	**-82.04%**
	O	0.37	0.34	0.07	0.49	0.29	
BOD_5 [mg/L-O_2]	I	3.99	3.90	0.29	4.50	3.72	**2.48%**
	O	3.89	3.87	0.15	4.10	3.70	
FCB [MPN/100mL]	I	106000	80000	84597	300000	28000	**16.39%**
	O	88625	26000	105692	280000	13000	

[2] comparing mean inlet and outlet values

Table 32: Field testing data, V2b1™ System Inlet, event September 8, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-I-A-1	4:44 AM	3.30	0.00	0.81	0.67	0.12		
HG-I-B-2	4:49 AM	8.00	4.00	0.79			3.80	80000
HG-I-C-3	4:54 AM	4.00	4.00	1.05	0.55			
HG-I-D-4	4:59 AM	5.00	0.00	0.94		0.15		
HG-I-B-5	5:04 AM	4.00	4.00	0.80			3.76	300000
HG-I-A-6	5:09 AM	8.00	8.00	0.73	0.26	0.13		
HG-I-C-7	5:30 AM	12.00	4.00	1.59	0.65			
HG-I-D-8	5:50 AM	8.00	8.00	1.36		0.15		
HG-I-B-9	6:10 AM	12.00	8.00	1.16			3.72	130000
HG-I-C10	6:30 AM	8.00	4.00	1.31	0.58			
HG-I-D-11	6:50 AM	8.00	4.00	1.33		0.24		
HG-I-B-12	7:10 AM	12.00	4.00	1.28			4.00	80000
HG-I-C-13	7:30 AM	4.00	4.00	1.26	0.69			
HG-I-D-14	7:50 AM	12.00	8.00	1.66		0.15		
HG-I-B-15	8:10 AM	12.00	8.00	1.03			4.08	28000
HG-I-C-16	8:30 AM	8.00	4.00	1.09	0.63			
HG-I-D-17	8:50 AM	10.00	10.00	1.26		0.19		
HG-I-B-18	9:10 AM	17.10	11.40	1.15			3.73	110000
HG-I-C-19	9:30 AM	28.00	16.00	2.36	0.72			
HG-I-D-20	9:50 AM	20.00	12.00	2.09		0.24		
HG-I-B-21	10:10 AM	17.10	11.40	1.64			4.50	70000
HG-I-C-22	10:30 AM	17.10	8.60	1.81	0.69			
HG-I-D-23	10:50 AM	13.30	10.00	1.90		0.46		
HG-I-B-24	11:10 AM	20.00	11.40	1.50			4.28	50000

Table 32: Field testing data, V2b1™ System Outlet, event September 8, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-O-A-1	4:44 AM	20.00	15.00	0.60	0.37	0.36		
HG-O-B-2	4:49 AM	24.00	12.00	0.43			4.10	280000
HG-O-C-3	4:54 AM	20.00	13.30	0.59	0.24			
HG-O-D-4	4:59 AM	20.00	13.30	0.68		0.49		
HG-O-B-5	5:04 AM	29.20	8.30	0.38			3.79	13000
HG-O-A-6	5:09 AM	20.00	13.30	0.68	0.38	0.32		
HG-O-C-7	5:30 AM	26.70	13.30	0.73	0.41			
HG-O-D-8	5:50 AM	13.30	13.30	0.73		0.29		
HG-O-B-9	6:10 AM	18.20	4.50	0.68			3.70	110000
HG-O-C10	6:30 AM	13.30	20.00	0.73	0.34			
HG-O-D-11	6:50 AM	25.00	5.00	0.77		0.47		
HG-O-B-12	7:10 AM	17.90	7.10	0.89			3.77	17000
HG-O-C-13	7:30 AM	6.70	0.00	0.61	0.28			
HG-O-D-14	7:50 AM	13.30	6.70	0.81		0.40		
HG-O-B-15	8:10 AM	16.00	4.00	0.75			3.75	17000
HG-O-C-16	8:30 AM	13.30	6.70	0.53	0.45			
HG-O-D-17	8:50 AM	20.00	6.70	0.98		0.34		
HG-O-B-18	9:10 AM	13.00	8.70	0.63			3.95	30000
HG-O-C-19	9:30 AM	20.00	6.70	0.73	0.77			
HG-O-D-20	9:50 AM	13.30	6.70	0.84		0.30		
HG-O-B-21	10:10 AM	20.00	5.00	0.66			3.96	22000
HG-O-C-22	10:30 AM	13.30	0.00	0.55	0.66			
HG-O-D-23	10:50 AM	20.00	13.30	0.47		0.34		
HG-O-B-24	11:10 AM	21.70	4.30	0.61			4.07	220000

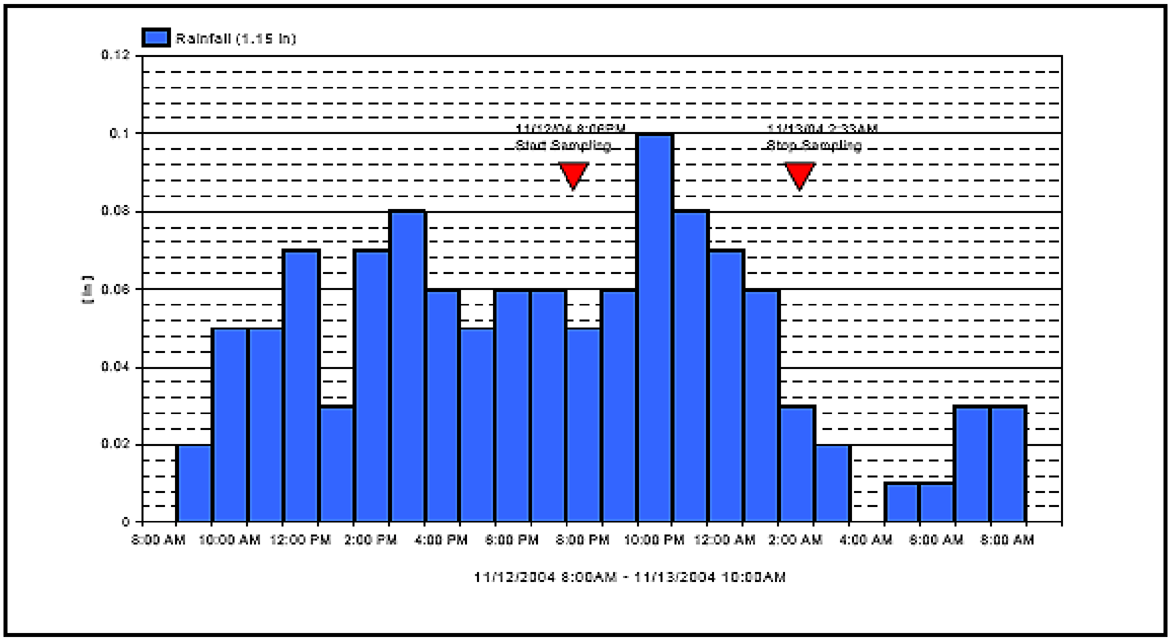


Figure 78: Hauppauge V2b1™ System Hyetograph – November 12, 2004

Table 33: Field testing summary, V2b1™ System, event November 12, 2004

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	5.18	5.00	3.09	13.33	0.00	**13.64%**
	O	4.47	3.33	2.89	13.33	0.00	
VSS [mg/L]	I	4.74	5.00	2.28	8.57	0.00	**8.03%**
	O	4.36	3.33	2.38	8.00	0.00	
TPH [ppm]	I	1.11	1.06	0.41	1.91	0.55	**28.95%**
	O	0.79	0.71	0.45	1.64	0.22	
TKN [mg/L]	I	1.59	1.58	0.90	3.51	0.65	**40.45%**
	O	0.95	0.88	0.15	1.13	0.73	
TP [mg/L]	I	0.17	0.18	0.04	0.21	0.10	**44.51%**
	O	0.09	0.08	0.05	0.22	0.05	
BOD_5 [mg/L-O_2]	I	5.48	5.31	2.49	10.43	2.67	**21.58%**
	O	4.30	3.88	1.37	6.47	3.05	
FCB [MPN/100mL]	I	1383	850	1618	5000	230	**-23.06%**
	O	1701	900	1691	5000	210	

[2] comparing mean inlet and outlet values

Table 34: Field testing data, V2b1™ System Inlet, event November 12, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-I-A-1	8:06 PM	6.7	6.7	1.58	3.51	0.21		
HG-I-B-2	8:11 PM	5.0	5.0	1.12			10.43	5000
HG-I-C-3	8:16 PM	6.7	6.7	1.68	1.90			
HG-I-D-4	8:21 PM	6.7	6.7	1.84		0.18		
HG-I-B-5	8:26 PM	5.0	5.0	0.85			6.13	1300
HG-I-A-6	8:31 PM	6.7	6.7	1.74	2.12	0.10		
HG-I-C-7	8:53 PM	3.3	3.3	1.91	1.88			
HG-I-D-8	9:13 PM	0.0	3.3	1.54		0.21		
HG-I-B-9	9:33 PM	3.3	3.3	1.13			5.04	300
HG-I-C10	9:53 PM	6.7	6.7	1.19	1.58			
HG-I-D-11	10:13 PM	0.0	6.7	1.31		0.17		
HG-I-B-12	10:33 PM	6.7	6.7	0.98			5.58	2300
HG-I-C-13	10:53 PM	13.3	3.3	1.11	0.98			
HG-I-D-14	11:13 PM	10.0	6.7	1.09		0.19		
HG-I-B-15	11:33 PM	10.0	6.7	0.96			3.83	230
HG-I-C-16	11:53 PM	6.7	6.7	1.04	0.80			
HG-I-D-17	12:13 AM	3.3	3.3	0.75		0.20		
HG-I-B-18	12:33 AM	3.3	3.3	0.72			7.02	800
HG-I-C-19	12:53 AM	3.3	0.0	0.78	0.65			
HG-I-D-20	1:13 AM	3.3	0.0	0.55		0.12		
HG-I-B-21	1:33 AM	2.9	2.9	0.63			2.67	900
HG-I-C-22	1:53 AM	5.7	2.9	0.55	0.87			
HG-I-D-23	2:13 AM	2.9	8.6	0.96		0.14		
HG-I-B-24	2:33 AM	2.9	2.9	0.65			3.16	230

Table 34: Field testing data, V2b1™ System Outlet, event November 12, 2004

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-O-A-1	8:06 PM	4.0	8.0	1.61	1.12	0.22		
HG-O-B-2	8:11 PM	3.3	3.3	0.96			6.47	5000
HG-O-C-3	8:16 PM	13.3	6.7	1.64	0.84			
HG-O-D-4	8:21 PM	6.7	6.7	1.46		0.11		
HG-O-B-5	8:26 PM	3.3	3.3	1.06			6.21	2800
HG-O-A-6	8:31 PM	6.7	6.7	1.60	1.13	0.11		
HG-O-C-7	8:53 PM	10.0	6.7	1.10	1.13			
HG-O-D-8	9:13 PM	3.3	6.7	1.03		0.08		
HG-O-B-9	9:33 PM	3.3	0.0	0.37			3.07	1300
HG-O-C10	9:53 PM	3.3	3.3	0.95	0.85			
HG-O-D-11	10:13 PM	3.3	3.3	0.94		0.05		
HG-O-B-12	10:33 PM	3.3	3.3	0.74			3.05	500
HG-O-C-13	10:53 PM	10.0	6.7	0.83	0.88			
HG-O-D-14	11:13 PM	3.3	0.0	0.39		0.10		
HG-O-B-15	11:33 PM	3.3	3.3	0.46			4.59	500
HG-O-C-16	11:53 PM	3.3	6.7	0.55	0.73			
HG-O-D-17	12:13 AM	0.0	3.3	0.35		0.05		
HG-O-B-18	12:33 AM	3.3	0.0	0.32			3.23	500
HG-O-C-19	12:53 AM	3.3	6.7	0.60	0.97			
HG-O-D-20	1:13 AM	3.3	3.3	0.35		0.08		
HG-O-B-21	1:33 AM	3.3	3.3	0.22			3.82	210
HG-O-C-22	1:53 AM	3.3	3.3	0.69	0.88			
HG-O-D-23	2:13 AM	3.3	6.7	0.50		0.05		
HG-O-B-24	2:33 AM	3.3	3.3	0.22			3.93	2800

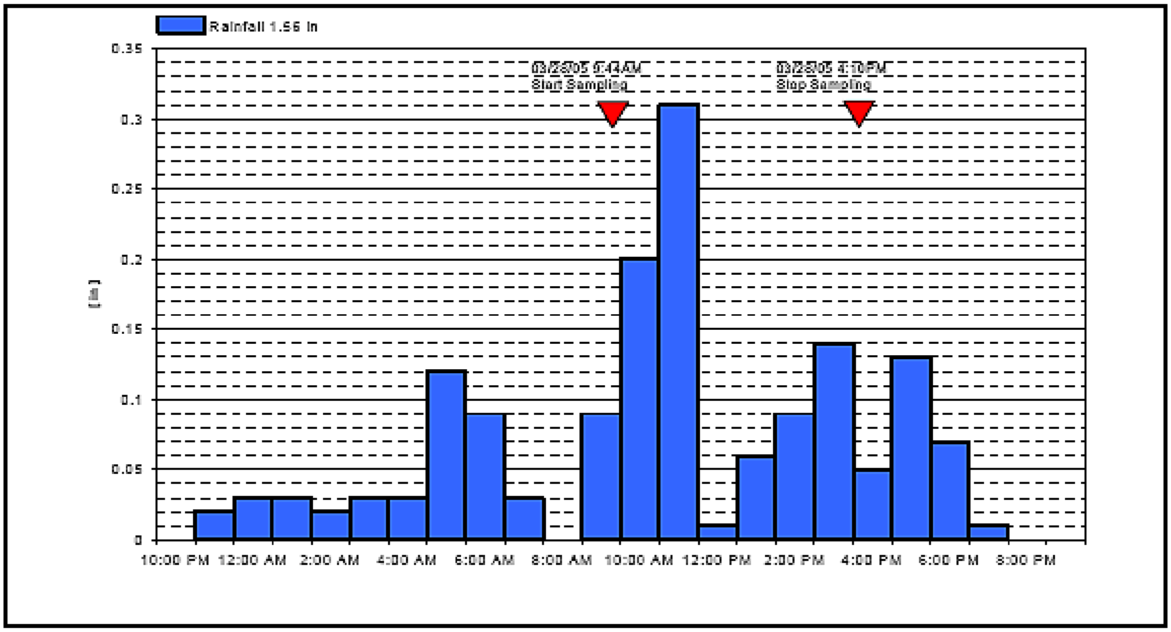


Figure 79: Hauppauge V2b1™ System Hyetograph – March 28, 2005

Table 35: Field testing summary, V2b1™ System, event March 28, 2005

Parameter		Mean	Median Value	Standard Deviation	Max	Min	Removal Efficiency[2]
TSS [mg/L]	I	137.57	105.00	92.02	355.00	40.00	-22.51%
	O	168.54	112.50	116.56	465.00	75.00	
VSS [mg/L]	I	47.18	40.00	22.63	105.00	20.00	-8.64%
	O	51.25	40.00	30.97	130.00	25.00	
TPH [ppm]	I	5.75	5.13	2.78	12.69	2.47	16.21%
	O	4.81	4.38	2.62	10.56	1.67	
TKN [mg/L]	I	0.47	0.46	0.19	0.70	0.17	41.24%
	O	0.28	0.26	0.04	0.34	0.22	
TP [mg/L]	I	0.38	0.39	0.14	0.63	0.23	1.23%
	O	0.38	0.35	0.09	0.57	0.29	
BOD_5 [mg/L-O_2]	I	9.08	9.27	2.83	14.46	5.12	-30.93%
	O	11.89	10.13	4.25	18.60	6.50	

[2] comparing mean inlet and outlet values

Table 36: Field testing data, V2b1™ System Inlet, event March 28, 2005

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-I-A-1	9:44 AM	95.0	40.0	5.03	0.17	0.24		
HG-I-B-2	9:49 AM	115.0	35.0	5.11			9.99	
HG-I-C-3	9:54 AM	165.0	65.0	8.09	0.29			
HG-I-D-4	9:59 AM	130.0	45.0	7.55		0.42		
HG-I-B-5	10:04 AM	120.0	40.0	7.50			8.58	
HG-I-A-6	10:09 AM	40.0	20.0	7.39	0.36	0.46		
HG-I-C-7	10:30 AM	75.0	40.0	6.87	0.46			
HG-I-D-8	10:50 AM	195.0	65.0	7.04		0.63		
HG-I-B-9	11:10 AM	355.0	105.0	12.69			6.74	
HG-I-C10	11:30 AM	345.0	100.0	12.04	0.33			
HG-I-D-11	11:50 AM	325.0	85.0	7.29		0.49		
HG-I-B-12	12:10 PM	235.0	60.0	7.24			14.46	
HG-I-C-13	12:30 PM	130.0	40.0	6.48	0.63			
HG-I-D-14	12:50 PM	100.0	45.0	5.16		0.39		
HG-I-B-15	1:10 PM	66.7	22.2	3.89			9.95	
HG-I-C-16	1:30 PM	85.0	30.0	4.16	0.70			
HG-I-D-17	1:50 PM	75.0	35.0	3.87		0.34		
HG-I-B-18	2:10 PM	70.0	35.0	3.26			7.50	
HG-I-C-19	2:30 PM	70.0	40.0	3.03	0.70			
HG-I-D-20	2:50 PM	65.0	30.0	2.54		0.23		
HG-I-B-21	3:10 PM	190.0	55.0	2.47			5.12	
HG-I-C-22	3:30 PM	110.0	40.0	2.80	0.56			
HG-I-D-23	3:50 PM	80.0	35.0	3.62		0.26		
HG-I-B-24	4:10 PM	65.0	25.0	2.76			10.30	

Table 36: Field testing data, V2b1™ System Outlet, event March 28, 2005

Sample Code	Sampling Time	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
		[mg/L]	[mg/L]	[ppm]	[mg/L]	[mg/L]	[mg/L]	MPN/100 mL
HG-O-A-1	9:44 AM	85.0	30.0	6.10	0.24	0.29		
HG-O-B-2	9:49 AM	115.0	40.0	5.34			10.19	
HG-O-C-3	9:54 AM	140.0	50.0	5.71	0.26			
HG-O-D-4	9:59 AM	110.0	40.0	7.67		0.35		
HG-O-B-5	10:04 AM	165.0	55.0	7.31			12.11	
HG-O-A-6	10:09 AM	120.0	40.0	6.68	0.24	0.32		
HG-O-C-7	10:30 AM	90.0	25.0	3.62	0.22			
HG-O-D-8	10:50 AM	365.0	100.0	7.29		0.44		
HG-O-B-9	11:10 AM	465.0	130.0	10.56			6.50	
HG-O-C10	11:30 AM	425.0	125.0	8.36	0.34			
HG-O-D-11	11:50 AM	340.0	85.0	8.64		0.57		
HG-O-B-12	12:10 PM	290.0	85.0	6.48			9.95	
HG-O-C-13	12:30 PM	195.0	60.0	3.47	0.30			
HG-O-D-14	12:50 PM	155.0	50.0	3.16		0.46		
HG-O-B-15	1:10 PM	145.0	35.0	2.84			18.60	
HG-O-C-16	1:30 PM	110.0	40.0	2.19	0.31			
HG-O-D-17	1:50 PM	100.0	35.0	1.88		0.33		
HG-O-B-18	2:10 PM	105.0	30.0	1.83			18.00	
HG-O-C-19	2:30 PM	85.0	35.0	1.91	0.31			
HG-O-D-20	2:50 PM	75.0	25.0	1.67		0.29		
HG-O-B-21	3:10 PM	90.0	25.0	5.13			9.70	
HG-O-C-22	3:30 PM	100.0	35.0	3.13	0.25			
HG-O-D-23	3:50 PM	80.0	25.0	2.61		0.37		
HG-O-B-24	4:10 PM	95.0	30.0	1.94			10.06	

Data for pH and Conductivity of the Hauppauge V2b1™ system are reported below in Table 37 and Table 38, respectively. Table 39 summarizes the overall concentrations and removal efficiencies of each parameter studied in all storm events for the V2b1™ system.

Table 37: Hauppauge V2b1™ System Inflow and Outflow, data for pH.

Sample Code	pH of the Events				
	03/31/2004	05/16/2004	09/08/2004	11/12/2004	03/28/2005
HG-I-B-2	6.74	6.16	6.26	5.72	6.42
HG-I-B-5	6.51	6.33	6.36	5.88	6.49
HG-I-B-9	6.68	6.31	6.30	6.12	6.51
HG-I-B-12	6.55	6.20	6.25	5.99	6.54
HG-I-B-15	6.65	6.52	6.36	6.10	6.58
HG-I-B-18	6.82	6.22	6.39	6.05	6.42
HG-I-B-21	6.81	6.23	6.44	6.07	6.41
HG-I-B-24	6.62	6.30	6.55	6.09	6.42
HG-O-B-2	6.23	6.42	6.53	5.91	6.45
HG-O-B-5	6.28	6.53	6.70	6.09	6.50
HG-O-B-9	6.36	6.40	6.69	6.21	6.46
HG-O-B-12	6.29	6.51	6.57	5.97	6.35
HG-O-B-15	6.32	6.45	6.57	6.30	6.26
HG-O-B-18	6.50	6.65	6.70	6.19	6.22
HG-O-B-21	6.50	6.52	6.63	5.99	6.50
HG-O-B-24	6.49	6.67	6.54	6.03	6.08

Table 38: Hauppauge V2b1™ System Inflow and Outflow, data for conductivity.

Sample Code	Conductivity of the Events [kΩ·cm]				
	03/31/2004	05/16/2004	09/08/2004	11/12/2004	03/28/2005
HG-I-B-2	1.76	4.59	9.25	30.08	0.24
HG-I-B-5	2.71	4.88	8.35	32.40	0.53
HG-I-B-9	3.12	4.94	10.12	35.81	0.36
HG-I-B-12	2.96	5.77	9.37	42.35	0.41
HG-I-B-15	1.73	5.70	10.28	52.70	0.27
HG-I-B-18	1.06	5.14	10.36	50.63	0.23
HG-I-B-21	0.81	5.15	10.93	48.92	0.25
HG-I-B-24	0.59	5.24	11.34	44.20	0.24
HG-O-B-2	1.15	4.34	8.64	30.20	0.25
HG-O-B-5	1.73	4.90	10.42	29.53	0.32
HG-O-B-9	2.16	4.68	9.53	32.33	0.95
HG-O-B-12	2.07	6.53	9.47	37.46	0.52
HG-O-B-15	0.77	4.49	8.86	51.10	0.13
HG-O-B-18	0.67	4.37	8.50	52.24	0.12
HG-O-B-21	0.62	4.38	7.93	48.12	0.56
HG-O-B-24	0.58	4.42	8.12	46.60	0.12

Table 39: Field testing summary for the V2b1™ System

Parameter		N. of Samples	Mean Concentr.	Median Concentr.	Standard Deviation	Max Concentr.	Min Concentr.	Removal Efficiency[2]
TSS [mg/L]	I	96	48.62	20.00	71.40	355.00	0.00	-20.69%
	O	96	58.68	20.00	87.71	465.00	0.00	
VSS [mg/L]	I	96	19.70	10.71	21.54	105.00	0.00	-8.17%
	O	96	21.31	12.00	24.76	130.00	0.00	
TPH [ppm]	I	96	2.51	1.62	2.38	12.69	0.55	23.98%
	O	96	1.91	1.03	2.16	10.56	0.22	
TKN [mg/L]	I	45	1.16	0.69	0.92	3.51	0.17	22.47%
	O	45	0.90	0.73	0.71	2.99	0.22	
TP [mg/L]	I	36	0.32	0.24	0.21	1.05	0.10	-6.57%
	O	36	0.34	0.34	0.19	0.82	0.05	
BOD_5 [mg/L-O_2]	I	32	7.03	6.88	3.04	14.46	2.67	2.95%
	O	32	6.82	5.42	4.03	18.60	3.05	
FCB [MPN/100mL]	I	32	37138	9000	60457	300000	220	21.44%
	O	32	29175	6500	62207	280000	50	

[2] comparing mean inlet and outlet value

3.2.4. Field Study Summary

Table 40 summarizes the overall removal efficiency of all the parameters analyzed in this study for the Vortechs® and the V2b1™ systems. It represents the average removal efficiency of the devices, measured over the entire 1-year (4 seasons) study period. The overall percent removal is obtained from the overall inflow and outflow mean concentrations (reported in Table 24 and Table 39). The performance of the devices with respect to each parameter is discussed separately below with respect to metrics. It must be emphasized however, that the visual observations indicate that maintenance also proved to be a serious concern regarding the performance of the two treatment systems. While the analytical results of influent and effluent samples reported in this document could be used to compute performance metrics, neither unit was properly maintained and that likely had a significant effect on performance. The installer of the V2b1™ unit observed that if it was not serviced since installation in 2001, it would have accumulated 2.5 times the maximum storage capacity and obstructed the normal flow pattern and in turn putting the unit in continuous by-pass mode and exporting pollutants.

Table 40: Summary of Overall Removal Efficiency for the Vortechs® & V2b1™

Storage Date	Percent Removal						
	TSS	**VSS**	**TPH**	**TKN**	**TP**	**BOD_5**	**FCB**
Vortechs®							
3/31/04	45.62	38.16	---	34.79	-6.16	---	5.14
5/24/04	-54.45	-29.46	56.14	68.89	30.75	26.36	---
9/18/04	55.00	79.59	-22.72	53.25	34.18	58.09	22.96
12/06/04	-23.20	-16.82	20.59	4.37	14.46		75.29
2/10/05	77.34	70.42	78.00	-8.69	49.10	65.11	74.62
4/28/05	---	---	---	---	---	20.87	---
Overall Percent Removal	**50.36**	**50.53**	**65.05**	**34.95**	**27.67**	**44.17**	**27.93**

Table 40: Summary of Overall Removal Efficiency for the Vortechs® & V2b1™ (continued)

Storm Date	Percent Removal						
	TSS	VSS	TPH	TKN	TP	BOD_5	FCB
V2b1™							
3/31/04	---	---	---	-21.53	---	24.65	-106.51
5/16/04	-7.43	-5.30	26.60	16.22	0.31	---	39.19
9/8/04	-61.69	-24.30	49.76	28.34	-82.04	2.48	16.39
11/12/04	13.64	8.03	28.95	40.45	44.51	21.58	-23.06
3/28/05	-22.51	-8.64	16.21	41.24	1.23	-30.93	---
Overall Percent Removal	**-20.69**	**-8.17**	**23.98**	**22.47**	**-6.57**	**2.95**	**21.44**

Total Suspended Solids

Figure 80 and Figure 81 shows the mean concentration, inflow and outflow, for each storm event sampled at the Vortechs® and at the V2b1™ sites, respectively. As shown in Figure 81, at the V2b1™ system site, the outflow concentration was higher than the inlet in almost all the events that were sampled. The only storm event for the V2b1 ™ system, where the inflow mean concentration was higher than the outflow, is the event on November 12, 2004. However, the outflow concentration was stable and very low, and was probably due to the fact that the sampling collection during the storm event didn't start at the beginning of the storm (when the rain intensity reached the sampling protocol value of 0.05 in/hr, which was between 12:00PM and 1:00PM), but it started after almost eight hours, missing the "first flush" and a big part of the storm, due to a technical problem with the sampling machine. Figure 82 shows the TSS percent removal for the Vortechs® versus the V2b1 ™ systems. All the graphs show higher removal efficiency for the Vortechs® system.

The Vortechs® system results (Figure 82) show two storm events with negative removal efficiency and are explained as follows: May 24, 2004 was a high intensity (0.24 inches/hour) and short duration event, with 0.18 inches total rainfall in 45 minutes, which caused a high sediment loading of a short duration, overloading and affecting the performance of the device. The sediment accumulated from prior events was washed out by the high intensity storm. During the storm event on December 06, 2004 the TSS inflow concentration was very low, with the maximum inflow value of 15 mg/L. Low TSS concentrations are not removed effectively with this device, which has better performance with high TSS inflow concentration. The overall TSS removal efficiency for the Vortechs® system was 50.36% compared with the V2b1™ system that had a removal efficiency of -20.69%, which means that the V2b1™ device would release sediments during the storm events. The typical runoff TSS concentration published in the National Urban Runoff Program (EPA, 1983) is 54.5 mg/L (Smullen and Cave, 1998), while average TSS concentrations measured at the inlet of the Vortechs® is 65.19 and at the inlet of the V2b1™ is 48.62 mg/L. The TSS Concentrations measured at the outlets of the Vortechs® and V2b1™ sites are 32.36 mg/L and 58.68 mg/L, respectively. The TSS concentration history is reported for each event in Appendix E and Appendix F for the Vortechs® and V2b1 ™ systems, respectively.

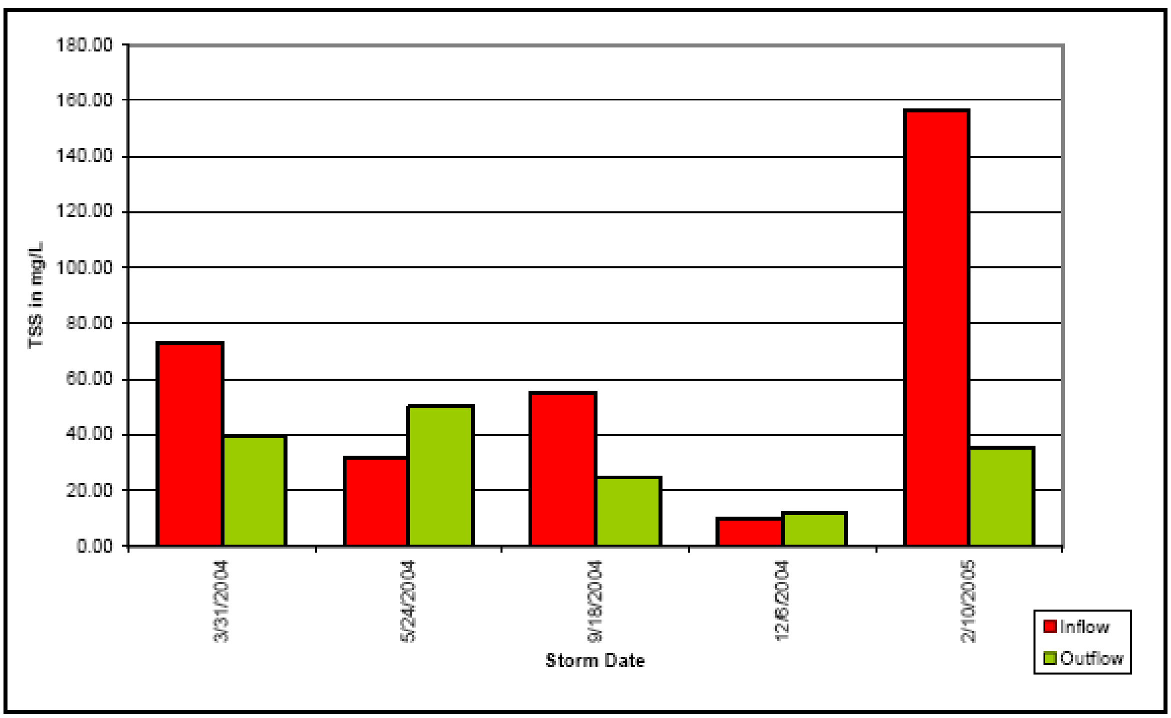


Figure 80: Mean TSS Concentration for each storm event at the Vortechs®

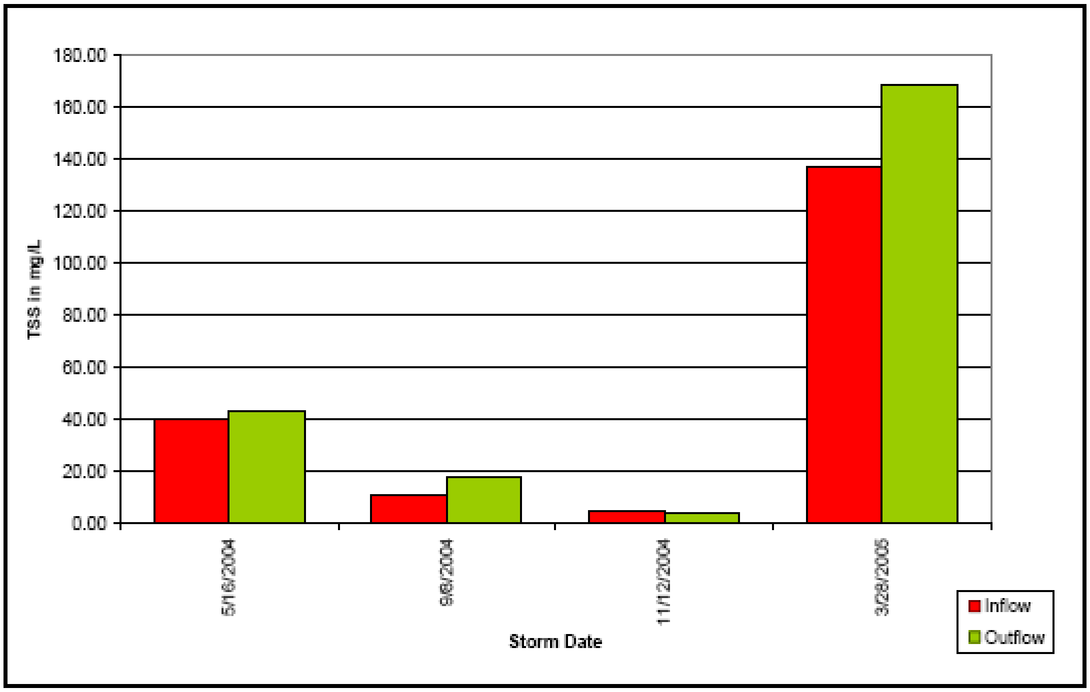


Figure 81: Mean TSS Concentration for each storm event at the V2b1™

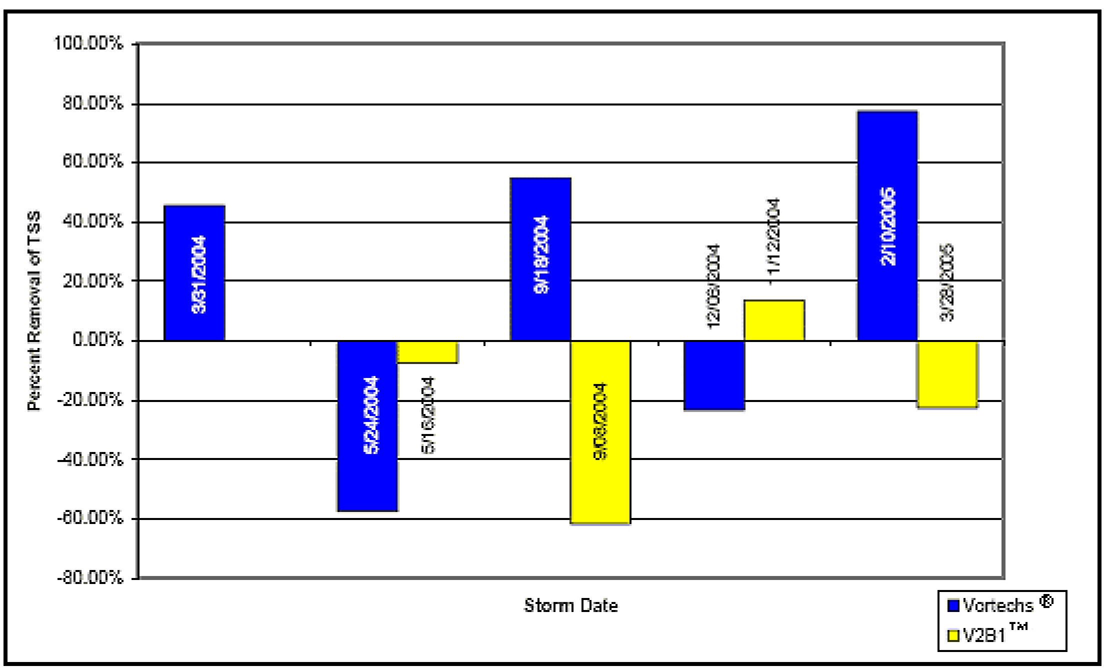


Figure 82: Percent TSS Removal of Vortechs® vs. V2b1™ Systems

Total Petroleum Hydrocarbon

Figure 83 and Figure 84 show mean inflow and outflow TPH concentration for each storm event sampled at the Vortechs® and the V2b1™ systems. Figure 85 shows the TPH removal of the Vortechs® compared with the V2b1™ system. More detailed graphs of TPH concentration history for each storm event are reported in Appendix G and Appendix H for the Vortechs® and the V2b1™ system, respectively.

The Vortechs® system results show one storm event with negative removal efficiency for the event on September 18, 2004 where inflow TPH concentration was very low (average value of 0.66 ppm). All other storm events resulted in a positive TPH removal efficiency with similar performance for the first three events for both devices. The last storm event resulted in significant TPH removal of the Vortechs® system, indicating that better performance occurs with higher inflow concentration.

Also, overall removal efficiency is higher for the Vortechs® system (65.05%) than the V2b1™ system (23.98%) with regard to TPH. The typical runoff concentration published in the NURP is 3.5 mg/L (Rabanal and Grizzard, 1995), while the average TPH concentrations measured at the inlet of the Vortechs® is 4.16 ppm and at the inlet of the V2b1™ is 2.51 ppm. The TPH concentrations measured at the outlets of the Vortechs® and V2b1™ sites are 1.46 ppm and 1.91 ppm, respectively.

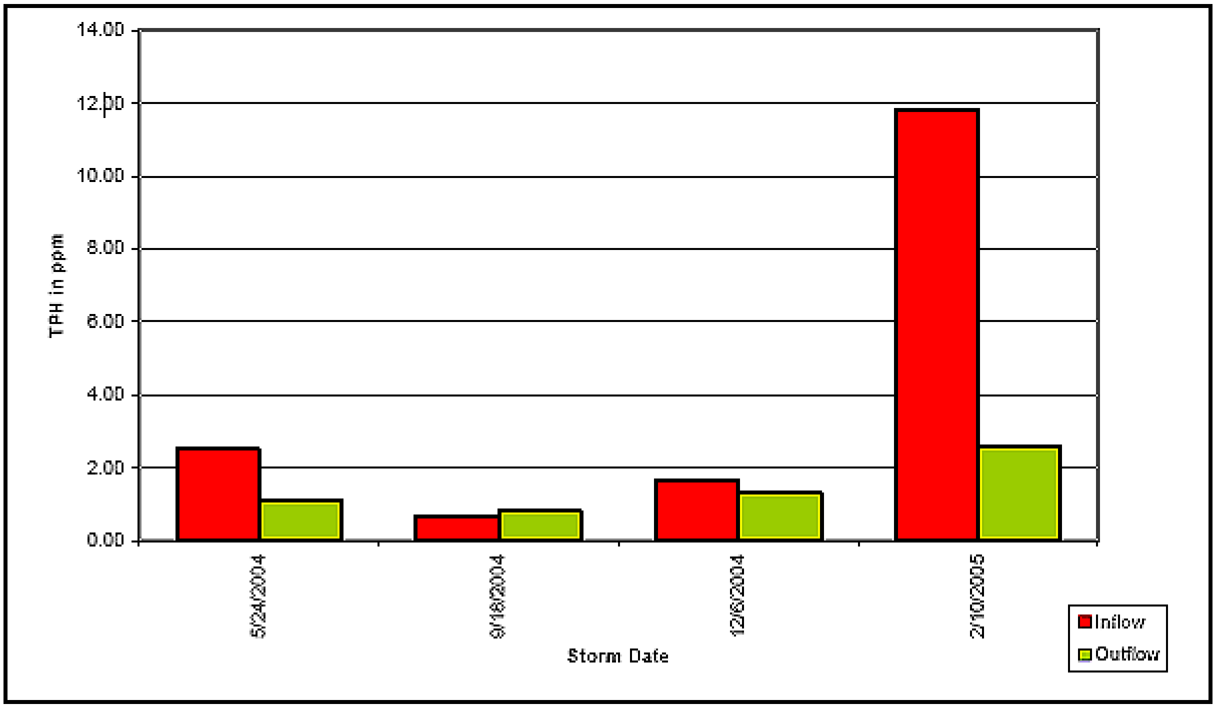


Figure 83: Mean TPH Concentration for each storm event at the Vortechs®

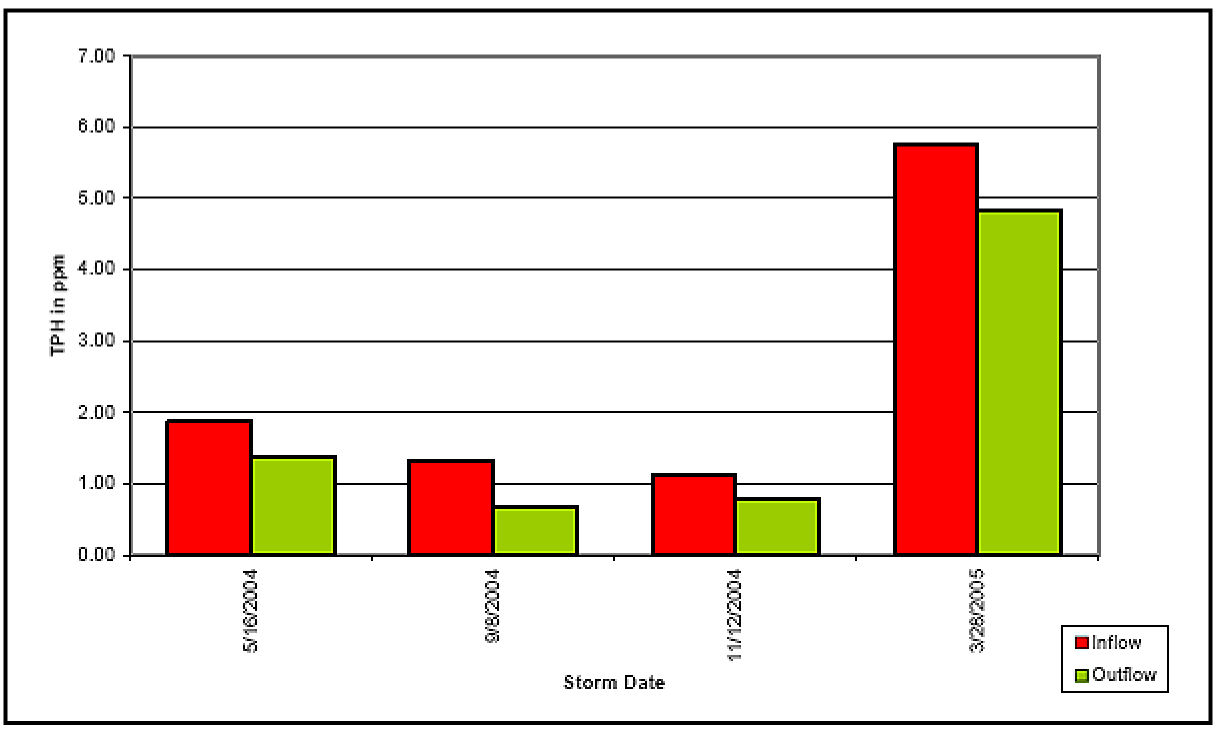


Figure 84: Mean TPH Concentration for each storm event at the V2b1™

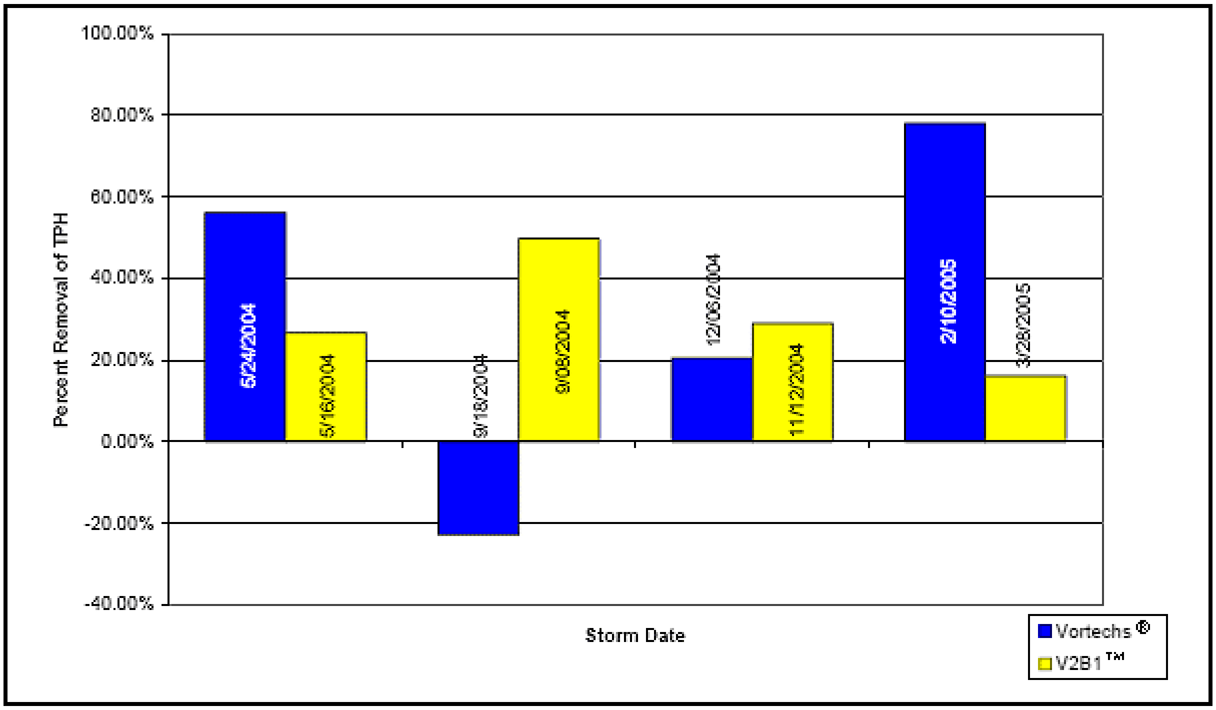


Figure 85: Percent TPH Removal of Vortechs® vs. V2b1™ Systems

Total Kjeldahl Nitrogen

Figure 86 and Figure 87 show the mean TKN concentration, inflow and outflow, for each storm event sampled at the Vortechs® and the V2b1™ systems, respectively. Figure 88 shows the percent removal of TKN for Vortechs® versus V2b1™, for each storm event. (Appendix I and Appendix J report the TKN concentration history of each storm event for the Vortechs® and the V2b1™ systems)

These two devices rely on physical separation of pollutants from runoff and are not specifically designed to remove dissolved pollutants such as nitrogen or phosphorus.

However, Figure 86 and Figure 87 show that both devices removed some TKN in nearly all the events. The Vortechs® system removed the highest percentage of influent TKN, about 34.95%, compared to the V2b1™ system that removed 22.47%. The typical TKN concentration reported in the NURP is 1.47 mg/L (*Smullen and Cave*, 1998), while the overall TKN average concentrations at the inlet of the Vortechs® is 1.93 mg/L and at the inlet of the V2b1™ is 1.16 mg/L. The TKN concentrations measured at the outlets of the Vortechs® and V2b1™ sites are 1.25 mg/L and 0.90 mg/L, respectively.

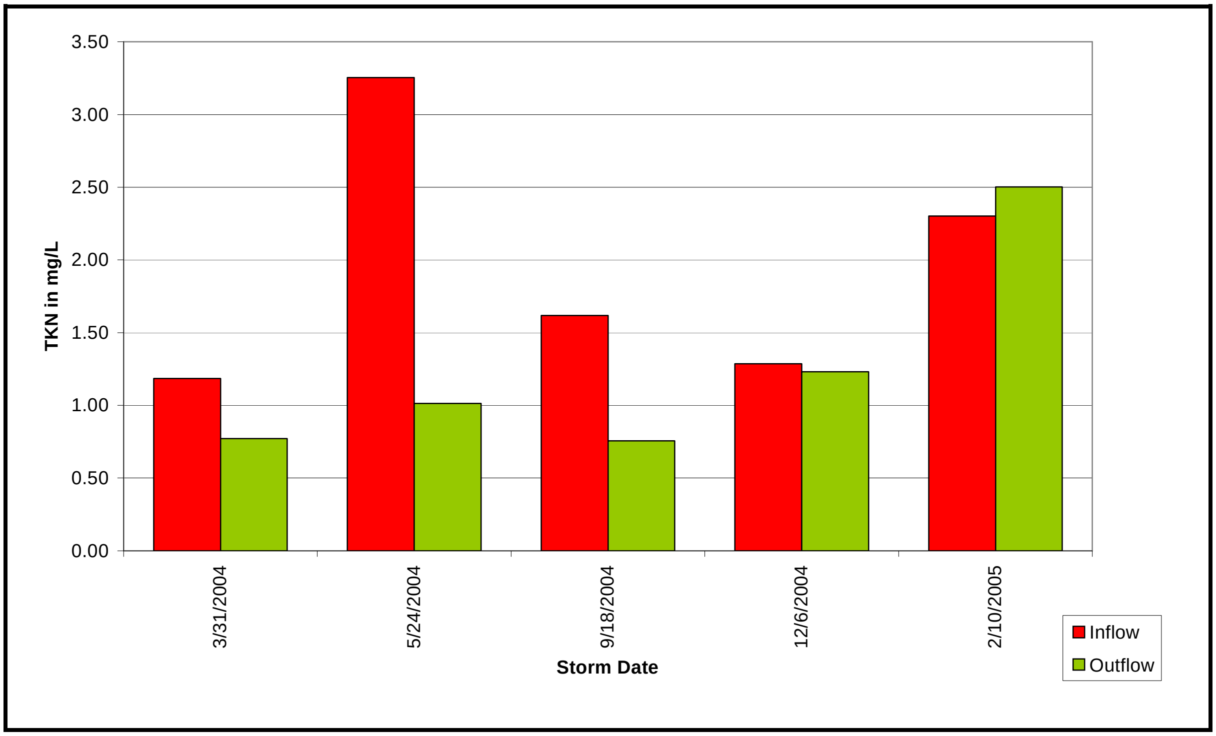


Figure 86: Mean TKN Concentration for each storm event at the Vortechs®

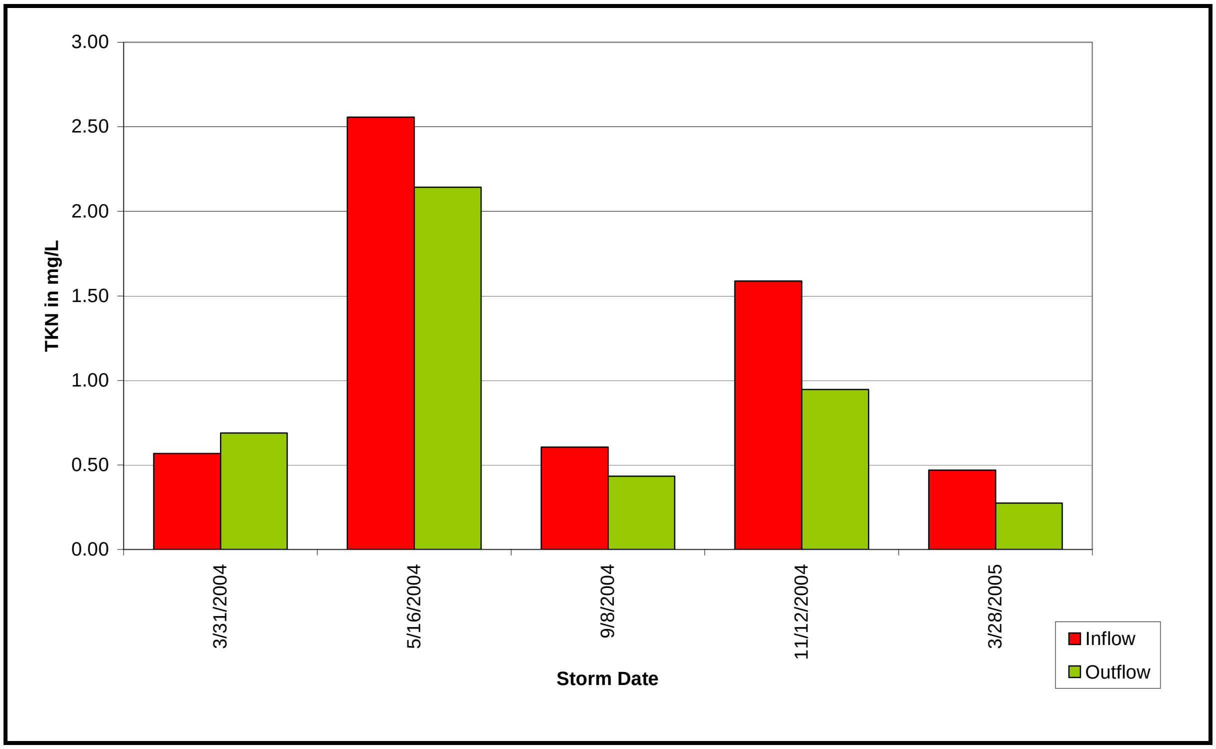


Figure 87: Mean TKN Concentration for each storm event at the V2b1™

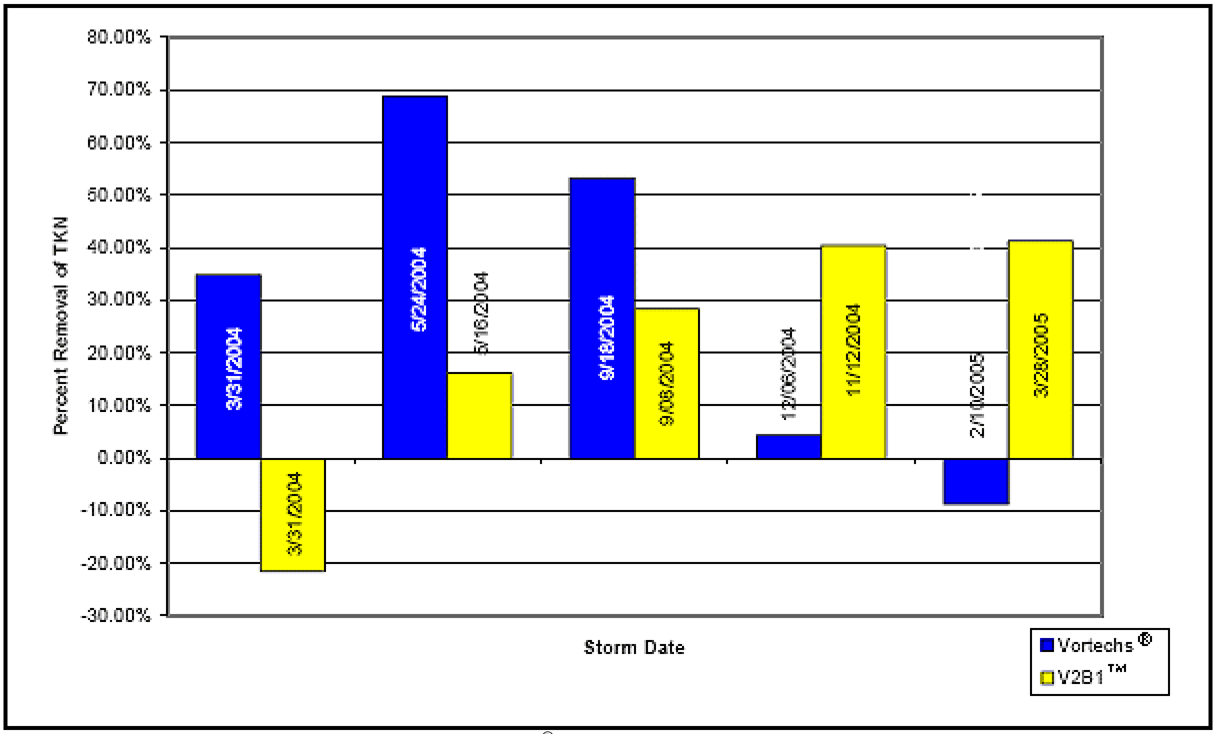


Figure 88: Percent TKN Removal of Vortechs® vs. V2b1™ Systems

Total Phosphorus

Phosphorus is a pollutant that is likely removed indirectly by these two systems, as has shown to be the case for nitrogen. Figure 89 and Figure 90 show the mean TP concentration in the inflow and outflow for each storm event for the Vortechs® and the V2b1™ system, respectively. Figure 91 shows the TP removal efficiency of the Vortechs® system compared with the V2b1™ (TP concentration history for each storm event are in Appendix K and Appendix L for the Vortechs® and the V2b1™ system, respectively).

Note that, for both devices, phosphorus concentration at the inlet and outlet chambers are nearly identical, indicating a very low TP removal efficiency of both devices. Hence, Figure 89 and 90 show a negative or zero percent removal storm events for both systems. Comparing the average concentrations of both systems, the Vortechs® resulted in a higher TP removal, about 27.67% , compared to -6.57% for the V2b1™. The typical TP concentration reported in the NURP is 0.26 mg/L (*Smullen and Cave*, 1998), while the overall average TP concentrations at the inlet of the Vortechs® is 0.90 mg/L and at the inlet of the V2b1™ is 0.32 mg/L. The TP concentrations measured at the outlets of the Vortechs® and V2b1™ sites are 0.65 mg/L and 0.34 mg/L, respectively.

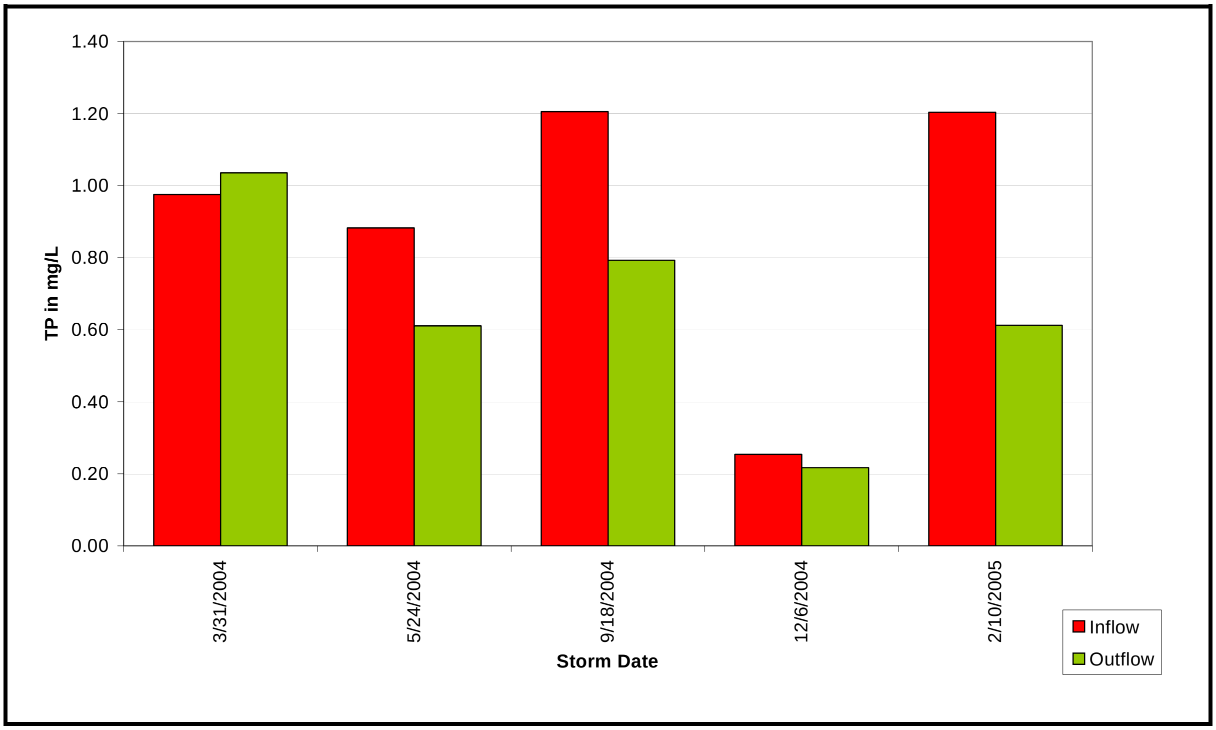


Figure 89: Mean TP Concentration for each storm event at the Vortechs®

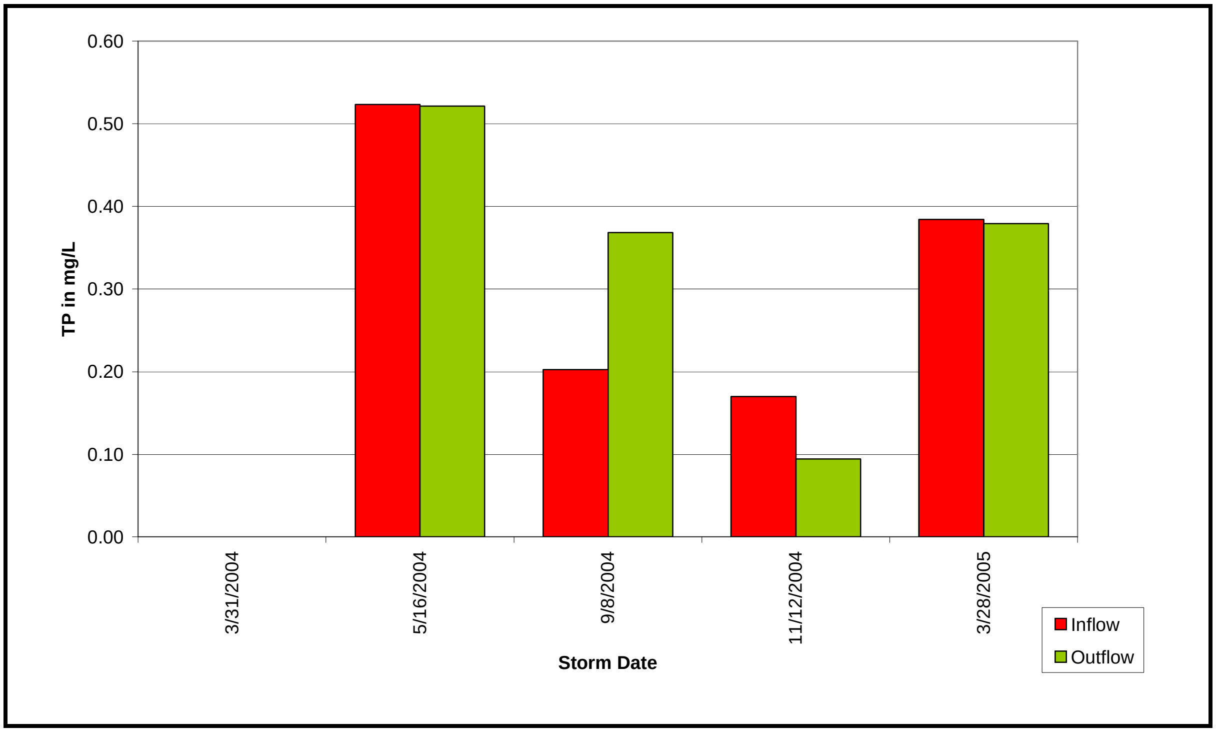


Figure 90: Mean TP Concentration for each storm event at the V2b1™

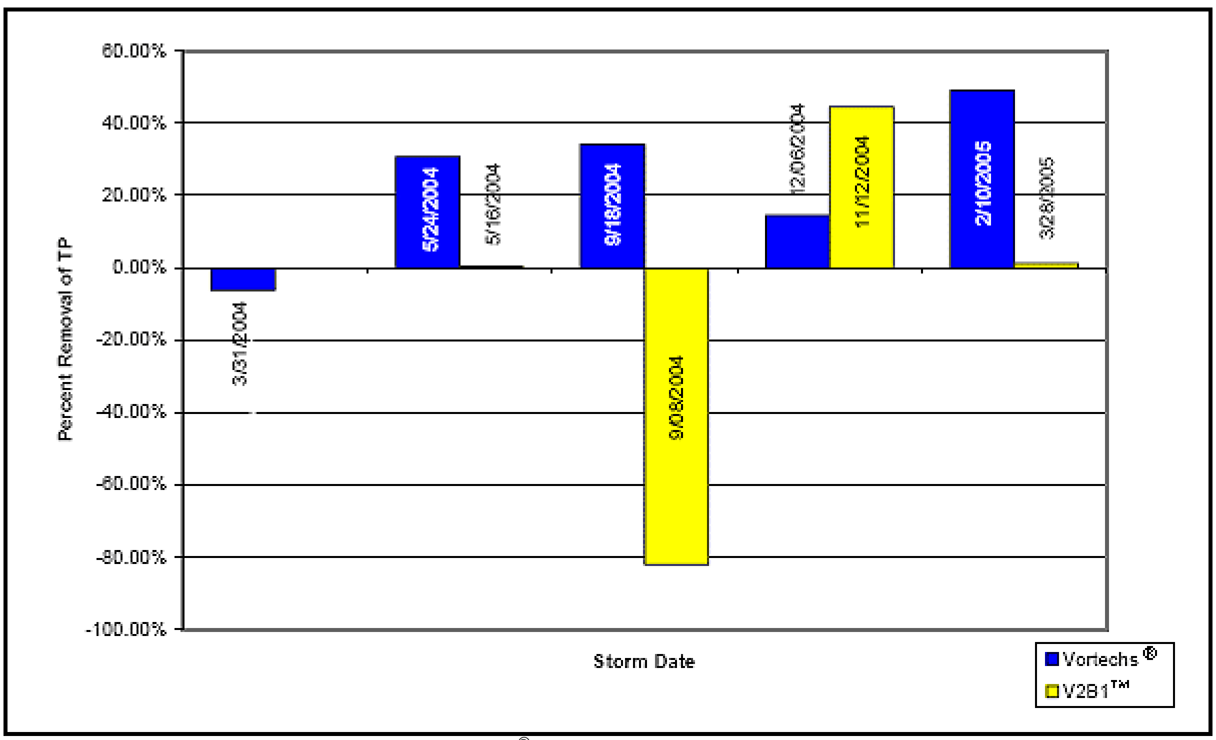


Figure 91: Percent TP Removal of Vortechs® vs. V2b1™ Systems

5-Day Biochemical Oxygen Demand (BOD_5)

Figure 92 and Figure 93 report the mean BOD_5 concentration of the inflow and outflow for each storm event sampled for the Vortechs® and the V2b1™ systems, respectively. The figures show the percent removal of BOD_5 of the Vortechs® compared with the V2b1™ for each storm event (Appendix M and Appendix N include BOD_5 concentration history of each storm event for the Vortechs® and the V2b1™ systems, respectively). In Figure 92, the outflow concentration for the Vortechs® system was lower than the inflow, resulting in positive removal efficiency for every event sampled. For the V2b1™ system, Figure 93 shows one event (March 28, 2005) where the outflow concentration was higher than the inflow. The average removal efficiency for all the events studied was 44.17% for the Vortechs® system and 2.95% for the V2b1™ system. The typical BOD_5 concentration reported on the NURP is 11.50 mg/L (*Smullen and Cave*, 1998), while the overall BOD_5 average concentrations of the outflow at the Vortechs® and V2b1™ sites are 6.84 mg/L and 6.82 mg/L, respectively. The two devices present a similar average concentration in the outlet chamber, while a higher inflow concentration is noted at the Vortechs® system (12.24 mg/l) compared with the V2b1™ is (7.03 mg/L).

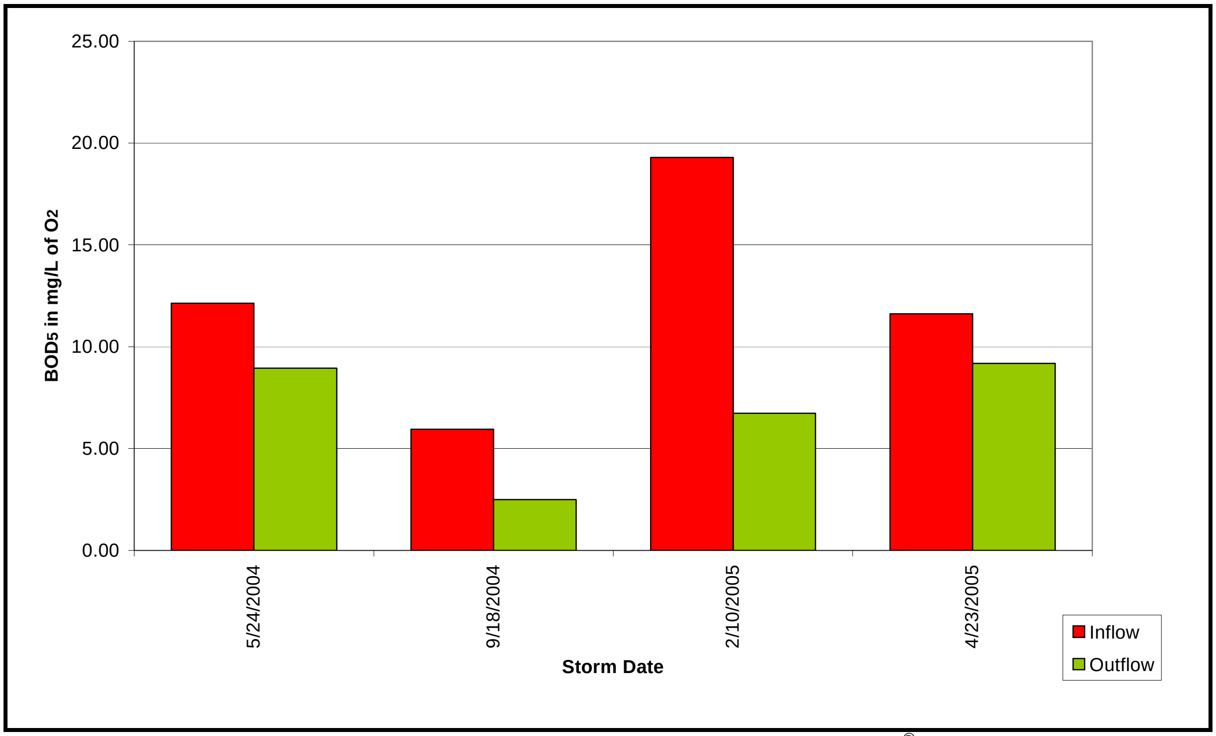


Figure 92: Mean Concentration of BOD_5 for each storm event at the Vortechs®

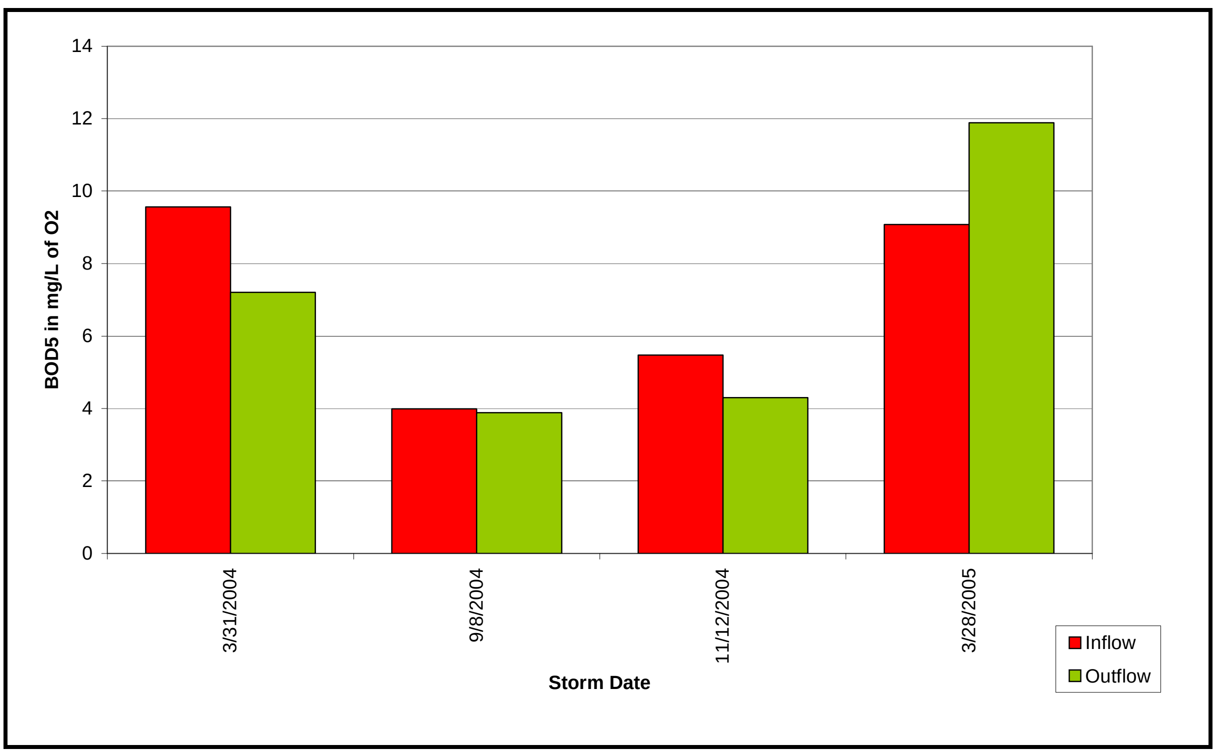


Figure 93: Mean Concentration of BOD_5 for each storm event at the V2b1™

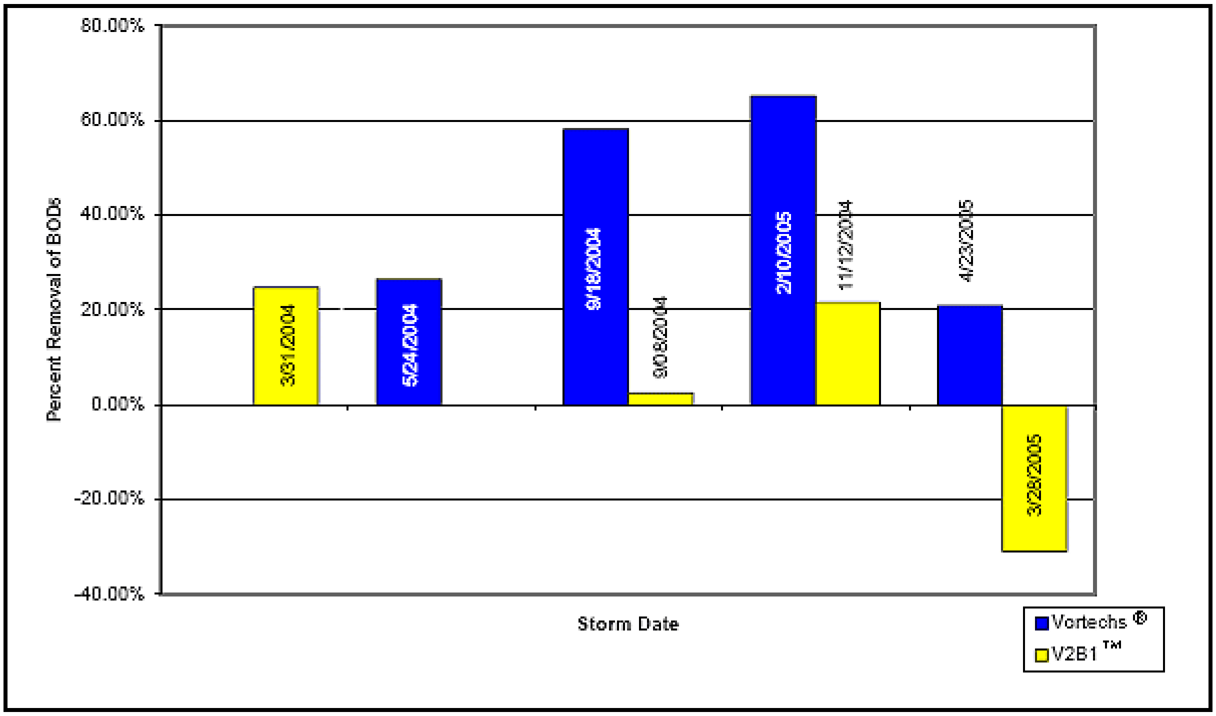


Figure 94: Percent Removal of BOD_5 of Vortechs® vs. V2b1™ Systems

Fecal Coliform Bacteria

Figure 95 and Figure 96 show the average FCB concentration of the inflow and outflow for each storm event sampled at the Vortechs® and the V2b1™ systems, respectively. From both graphs, note that the inflow FCB concentration during the storm events sampled in September 2004 was above 100,000 MPN/100 mL for the both systems. This is likely due to the fact that FCB are organisms and their growth is facilitated with the warm weather.

Figure 97 compares the average FCB removed by the Vortechs® with the V2b1™ system for each storm event. The V2b1™ system results show negative removal efficiency for two storm events (March 31 and November 12) due to the very low inflow concentration that characterized these two events. The inflow FCB concentrations for these two events, was 921 MPN/100 mL (March 31), and 1383 MPN/100 mL (November 12), both much lower than the typical concentration reported in the NURP. The Vortechs® system had positive removal efficiency for all four storm events, with inflow concentrations for three of the four events within the range of the typical concentration reported in the NURP. The typical

FCB concentration reported in the NURP is 15,000 col/100 mL (Schueler, 1999), while the overall FCB average concentrations of the outflow at the Vortechs® and V2b1™ sites are 36,345 MPN/100 mL and 29,175 MPN/100 mL, respectively. Both devices exhibited similar performance, with an average removal efficiency of 27.93% for the Vortechs® system and 21.44% for the V2b1™ system (Appendix O and Appendix P include concentration history of FCB for each storm event for the two systems).

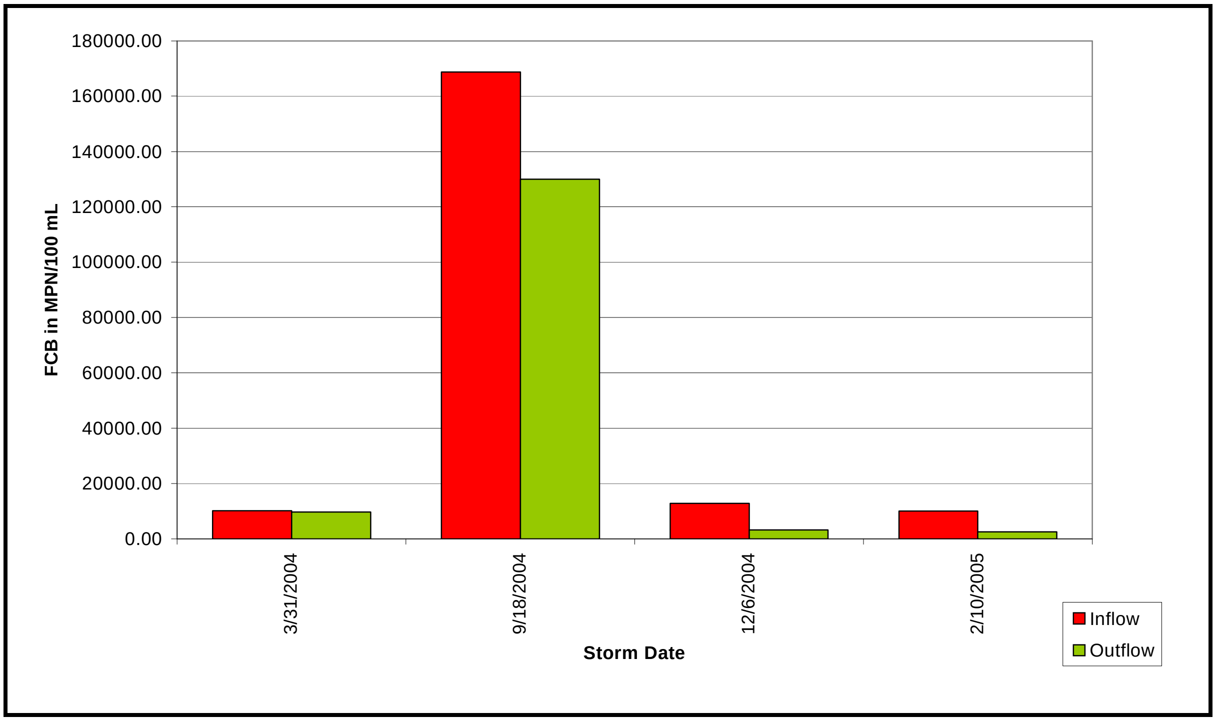


Figure 95: Mean FCB Concentration for each storm event at the Vortechs®

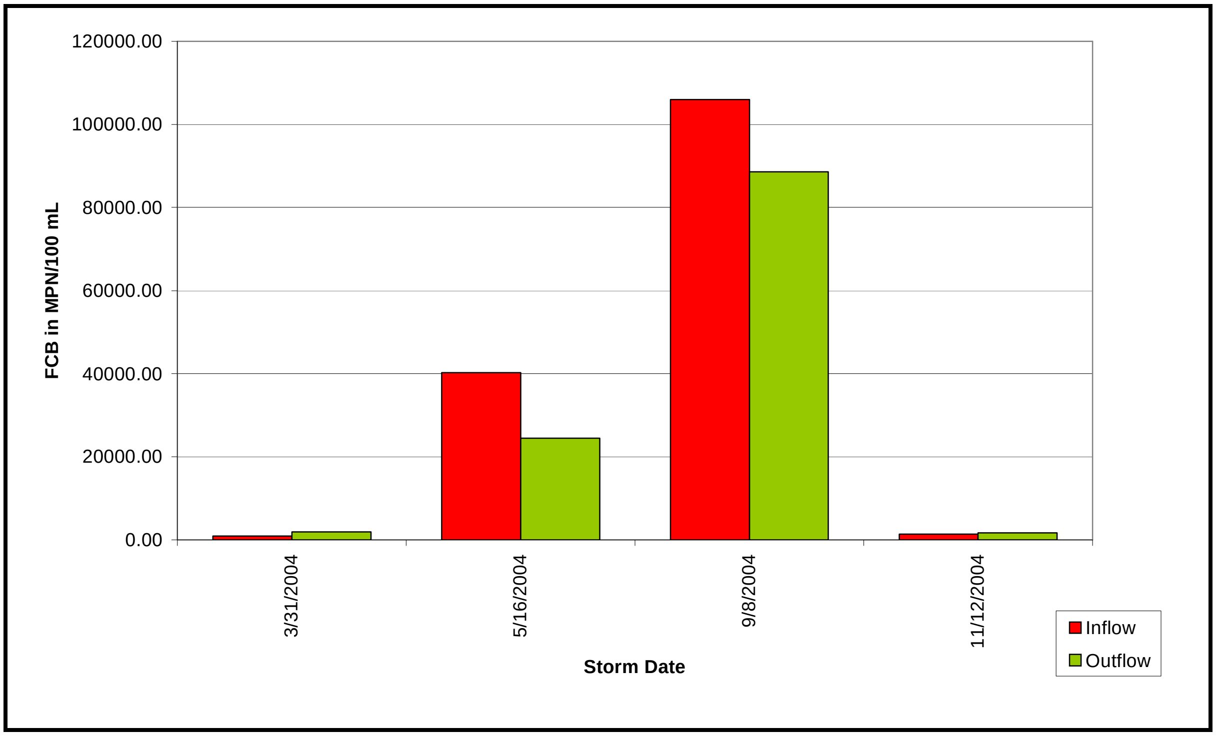


Figure 96: Mean FCB Concentration for each storm event at the V2b1™

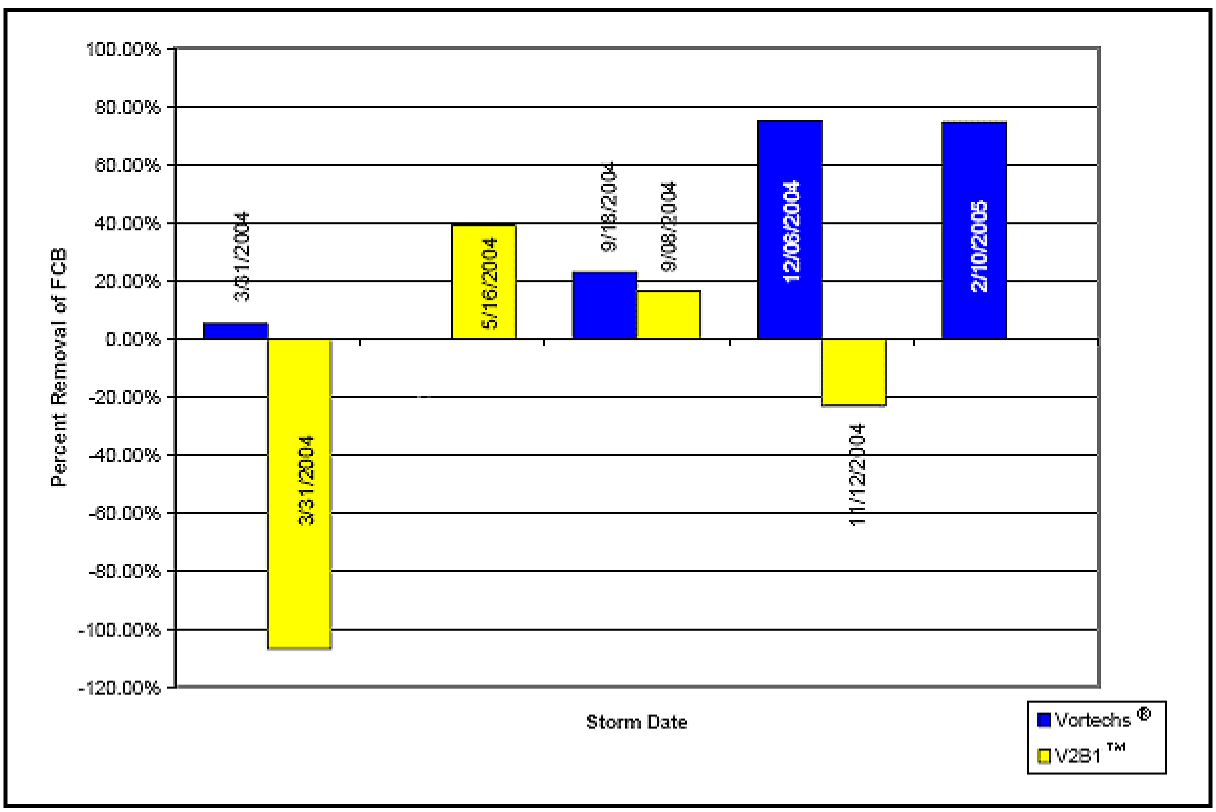


Figure 97: Percent FCB Removal of Vortechs® vs. V2b1™ Systems

3.2.5. Operation & Maintenance

An important consideration of these BMPs is the maintenance required to ensure the effective operation of the devices. If BMPs are not properly maintained, pollutants removed during one storm may become re–suspended during another storm and may pollute receiving waters (*EPA, 1999a*). In addition, while improper maintenance decreases the efficiency of BMPs, correct maintenance might consist of frequent inspections and high cost labor and equipment, making a device economically impractical. An effective maintenance plan for proper operation of BMPs should consist of that maintenance that gives the highest efficiency and performance at the lowest cost. Again, it must be noted that neither the V2b1™ nor the Vortechs® unit were cleaned-out during the period of the study.

The two stormwater treatment systems studied in this project have very similar maintenance requirements (primarily inspection and cleanout) that are easy to be performed, except for exceptional situations when special equipment is needed.

Vortechs® and V2b1™ manufacturers suggest on–going quarterly inspections of the grit chamber for accumulated contaminants. Adherence to a program of scheduled device inspection is very important, especially during the first year of installation of the device when pollutant loading rates are still unknown. The inspection schedule can be modified in subsequent years according to experience (*Environment21, 2006*).

Both manufacturers suggest that their device be cleaned when inspection reveals the sediment depth has accumulated to within six inches of dry weather water level. This determination can be made by taking two measurements with a stadia rod or similar measuring device; one measurement from the manhole opening to the top of the sediment pile and the other from the manhole opening to the water surface (*Vortechnics, 2006*).

The removal of the sediment from the chambers of the devices is suggested with the use of a vacuum truck, which is the most effective and convenient method. Manhole openings provide access to both the sediment and floatable chambers. To remove oil, grease, and other hydrocarbons, it may be preferable to use adsorbent pads since they are likely to be less expensive to dispose of than the oil/water emulsion that may be created by vacuuming the oily layer (*Vortechnics, 2006*).

3.2.6. Capital and O&M Costs

Vortechs® System

The Vortechs® System evaluated in the current study was a Model # 3000. The cost of the unit is of $16,000, including delivery to the site (*Vortechnics, 2006*). The cost for the installation is on average about 30% of the unit cost (*Vortechnics, 2006*), which would be $4,800 in this case. Considering an average wage of $80 per hour (direct cost only) for a two person crew with one van, in the first year of operation, the quarterly inspection of the device will cost $320, assuming that one hour of time will be adequate to perform each inspection, including traveling to the site. The yearly cleanout with a vacuum truck will cost around $1,500.

V2B1™ System

The V2b1™ System studied was a Model # 11. The cost of the unit is about $15,400, including delivery to the site (*Environment21, 2006*). The installation cost is also about 30% of the unit cost (*Environment21, 2006*), which would be $4,620 in this case. The costs for the quarterly inspections and the yearly cleanout of the device are calculated with the same considerations as for the Vortechnics unit. Therefore, the maintenance in the first year of operation of the device and the cleanout will cost $320 and $1,500, respectively, or about the same as the Vortechs® unit.

3.2.7. Cost Summary

Table 41 summarizes the costs detailed above related to the stormwater treatment systems monitored in this study.

Table 41: Cost summary for the Stormwater Treatment Systems

Device	Unit Cost	Installation Cost	Annual Maintenance Cost
Vortechs®	$16,000(1)	$4,800(2)	$1,820(3)
V2B1™	$15,400(1)	$4,620(2)	$1,820(3)

** Costs do not reflect any manufacturer discount. Unit costs do not include sales tax.
(1) Unit cost includes delivery to the site.
(2) Typically about 30% of the unit cost.
(3) Maintenance cost includes the quarterly inspections and the annual cleanout.

3.2.8. Conclusions

Two Stormwater Treatment Systems were instrumented and monitored in the field for one year to evaluate their effectiveness at contaminant removal. The Vortechs® and the V2b1™ were both installed by the NYS Department of Transportation at locations in Long Island, NY and instrumented for this field study. They were evaluated by comparison of the inflow and the outflow concentrations, in order to determine their removal efficiency for six parameters: TSS/VSS, TPH, TKN, TP, BOD_5 and FCB. Samples were collected at each site during five storm events and lab analyses were performed at the Polytechnic University laboratory, in Brooklyn, NY, following the Standard Method and EPA Procedures. Also, the costs for installation and maintenance were studied.

The evaluation of the Vortechs® showed that the system removes on average 50% of the TSS, which is lower than the manufacturer's estimated annual removal efficiency (80%). In addition, the study showed that the system is capable of removing on average 65% of TPH, 35% of the TKN, 30% of TP and FCB and 45% of the BOD_5. Finally, the system presented positive removal efficiency for all the parameters that were analyzed in this study. The V2b1™ system evaluation, on the other hand, resulted in very low removal efficiency on average, and occasionally resulted in negative values for some parameters.

The average TSS removal efficiency was -20% (the manufacturer's estimated annual removal efficiency is 80%), and was only found to remove TSS effectively during one storm event. With respect to the other parameters, the V2b1™ removed on average 24% of TPH, 22% of TKN, -6% of TP, 3% of BOD_5 and 21% of FCB.

In terms of costs, the two devices are very similar, both having an average unit cost of $16,000, plus an installation cost about the 30% of the unit cost, and a maintenance cost less than $2,000 per year. Considering that both units have comparable costs, the most effective stormwater treatment systems was the Vortechs® system, in view of the fact that it was more efficient in TSS removal. It should be noted again, however, that no maintenance was performed prior to or during the period the performance of two treatment systems was monitored, and it was suspected that this factor had a significant effect on performance.

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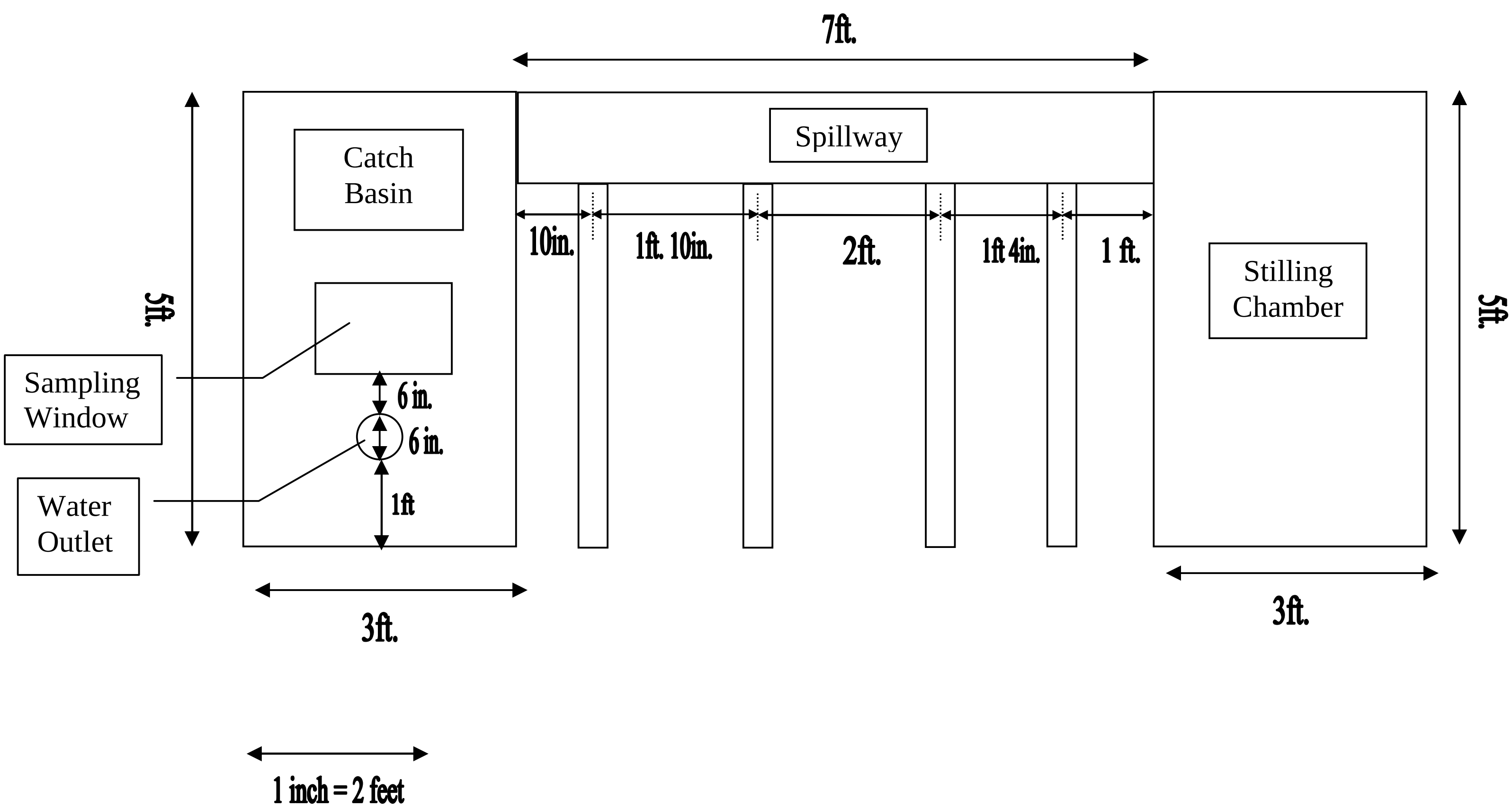
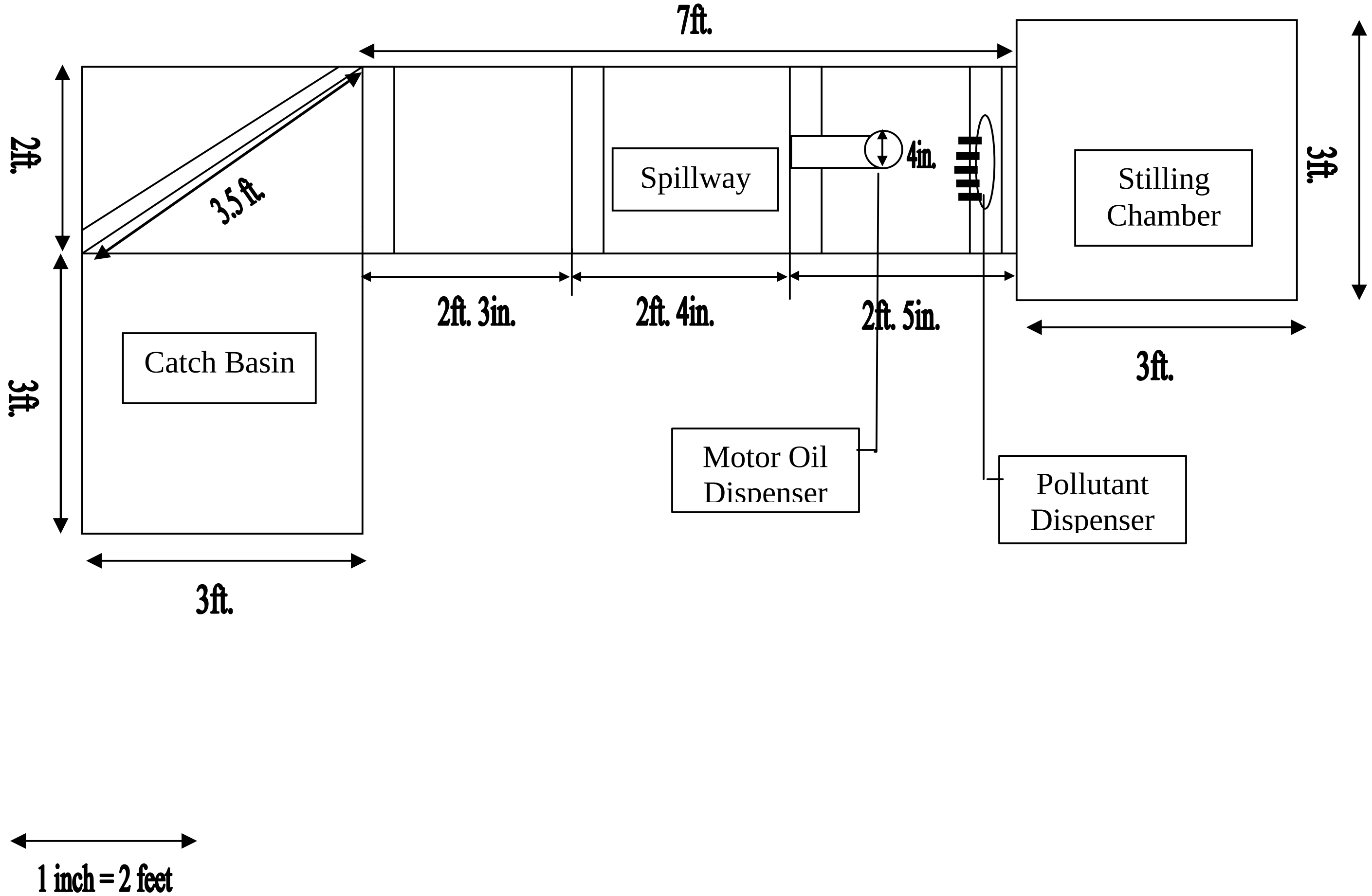
Appendix A: Simulator Drawings

Simulator - Side View



Simulator - Top View



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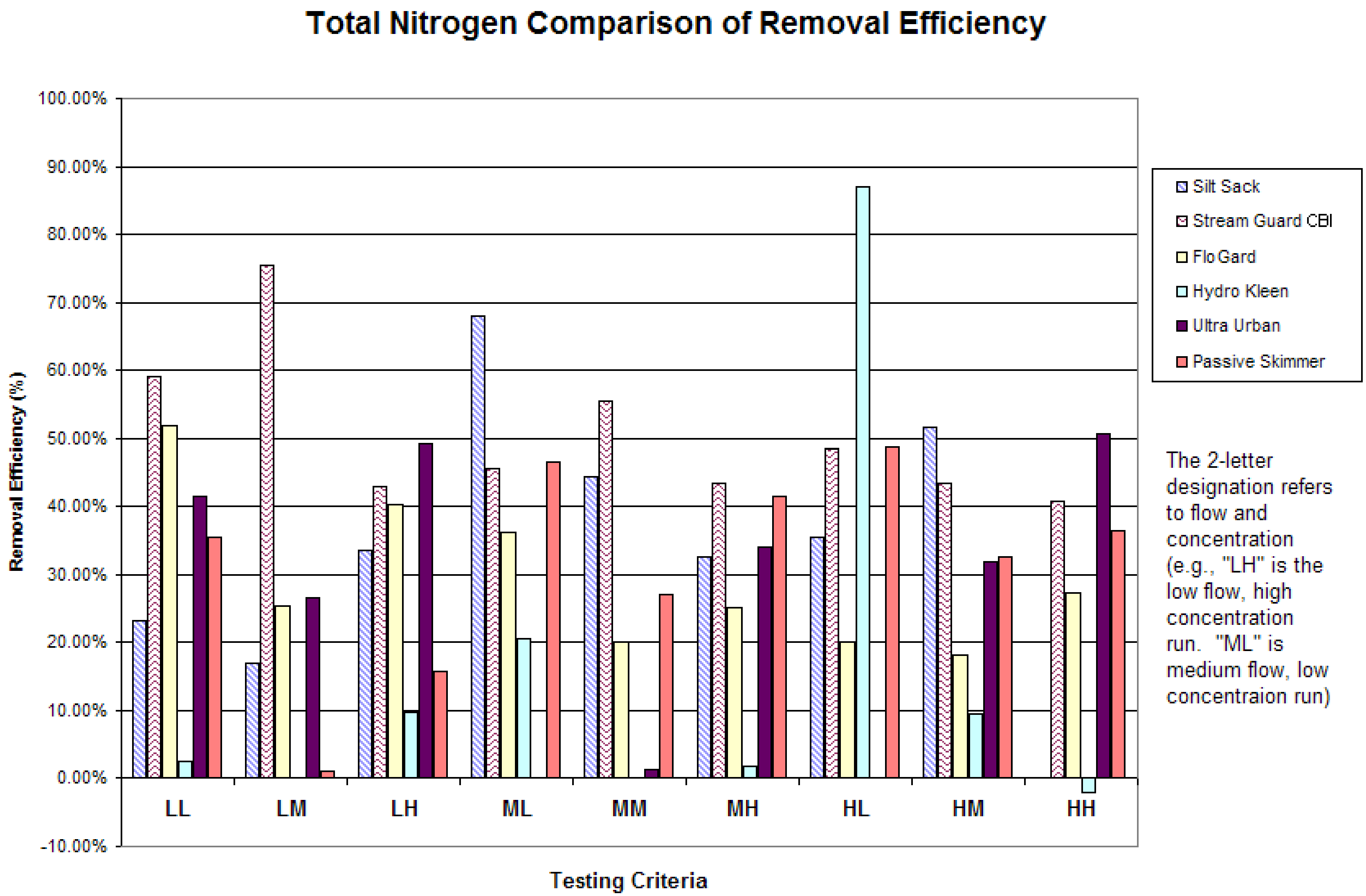
Appendix B: Catch Basin Inserts – Comparison Graphs



Total Nitrogen Comparison of Removal Efficiency
Removal Efficiency (%)
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
-10.00%
LL
LM
LH
ML
MM
MH
HL
HM
HH
Testing Criteria
Silt Sack
Stream Guard CBI
Flo Gard
Hydro Kleen
Ultra Urban
Passive Skimmer
The 2-letter designation refers to flow and concentration (e.g., "LH" is the low flow, high concentration run. "ML" is medium flow, low concentraion run)

Total Nitrogen (excluding negative results)

Removal Efficiencies

Testing Criteria	Siltsack	Stream Guard	Flow Guard	Hydro-Kleen	Ultra-Urban	Passive Skimmer
LL	23.28%	59.11%	51.89%	2.63%	41.51%	35.45%
LM	17.03%	75.43%	25.35%		26.64%	1.03%
LH	33.65%	42.91%	40.29%	9.69%	49.31%	15.70%
ML	68.05%	45.52%	36.11%	20.68%		46.66%
MM	44.38%	55.57%	20.20%		1.42%	27.01%
MH	32.48%	43.49%	25.22%	1.73%	33.95%	41.53%
HL	35.54%	48.58%	20.01%	86.97%		48.62%
HM	51.50%	43.49%	18.27%	9.40%	31.96%	32.66%
HH		40.79%	27.30%		50.61%	36.51%
Average :	**38.24%**	**50.54%**	**29.40%**	**18.43%**	**33.63%**	**31.69%**
Standard Deviation:	**16.20%**	**11.18%**	**11.21%**	**31.12%**	**16.76%**	**15.26%**

Low Conc Ave SS	42.29%	Low Flow Ave.	24.65%
Med Conc Ave SS	37.64%	Med Flow Ave	48.31%
High Conc Ave SS	33.07%	High Flow Ave.	43.52%

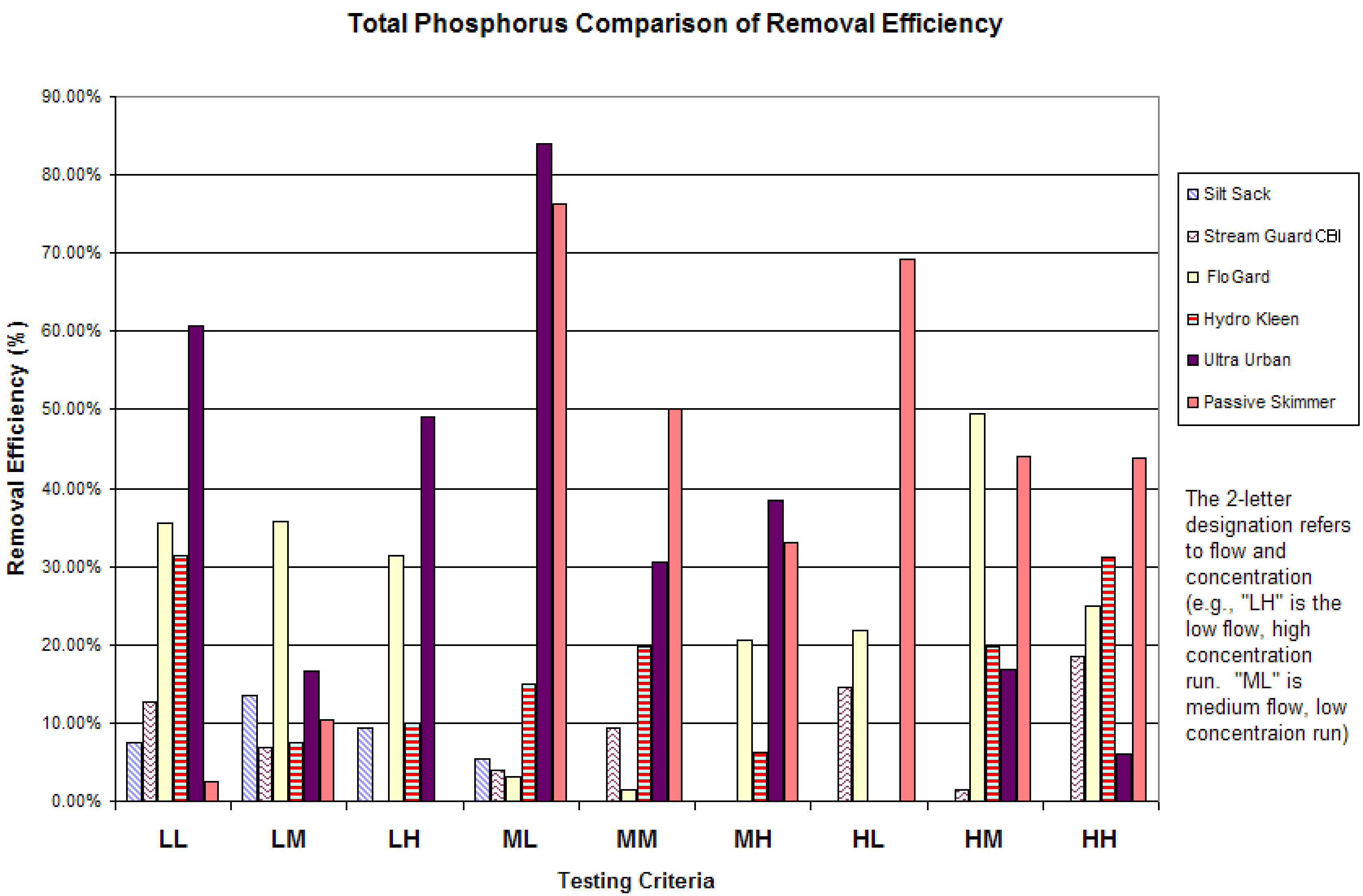
Low Conc Ave SG	51.07%	Low Flow Ave.	59.15%
Med Conc Ave SG	58.16%	Med Flow Ave	48.19%
High Conc Ave SG	42.40%	High Flow Ave.	44.29%

Low Conc Ave FG	36.01%	Low Flow Ave.	39.18%
Med Conc Ave FG	21.27%	Med Flow Ave	27.18%
High Conc Ave FG	30.94%	High Flow Ave.	21.86%

Low Conc Ave HK	36.76%	Low Flow Ave.	6.16%
Med Conc Ave HK	9.40%	Med Flow Ave	11.20%
High Conc Ave HK	3.12%	High Flow Ave.	31.44%

Low Conc Ave UU	41.51%	Low Flow Ave.	39.15%
Med Conc Ave UU	20.01%	Med Flow Ave	17.69%
High Conc Ave UU	44.62%	High Flow Ave.	41.28%

Low Conc Ave PS	43.58%	Low Flow Ave.	17.40%
Med Conc Ave PS	20.23%	Med Flow Ave	38.40%
High Conc Ave PS	31.25%	High Flow Ave.	39.26%


Total Phosphorus Comparison of Removal Efficiency
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Removal Efficiency (%)
LL
LM
LH
ML
MM
MH
HL
HM
HH
Testing Criteria
Silt Sack
Stream Guard CBI
Flo Gard
Hydro Kleen
Ultra Urban
Passive Skimmer
The 2-letter designation refers to flow and concentration (e.g., "LH" is the low flow, high concentration run. "ML" is medium flow, low concentraion run)

Total Phosphorus (excluding negative results)

Removal Efficiencies

Testing Criteria	Siltsack	Stream Guard	Flow Guard	Hydro-Kleen	Ultra-Urban	Passive Skimmer
LL	7.53%	12.63%	35.49%	31.42%	60.69%	2.52%
LM	13.54%	6.94%	35.70%	7.58%	16.59%	10.36%
LH	9.26%		31.39%	9.99%	48.95%	
ML	5.38%	3.85%	3.10%	14.97%	84.00%	76.37%
MM		9.26%	1.54%	19.72%	30.55%	50.17%
MH			20.57%	6.23%	38.52%	33.02%
HL		14.47%	21.81%			69.19%
HM		1.43%	49.54%	19.79%	16.85%	43.99%
HH		18.57%	24.95%	31.18%	6.13%	43.87%
Average :	**8.93%**	**9.59%**	**24.90%**	**17.61%**	**37.78%**	**41.18%**
Standard Deviation:	**3.46%**	**6.06%**	**15.52%**	**9.85%**	**25.99%**	**25.72%**

Low Conc Ave SS	6.45%	Low Flow Ave.	10.11%
Med Conc Ave SS	13.54%	Med Flow Ave	5.38%
High Conc Ave SS	9.26%	High Flow Ave.	No Data

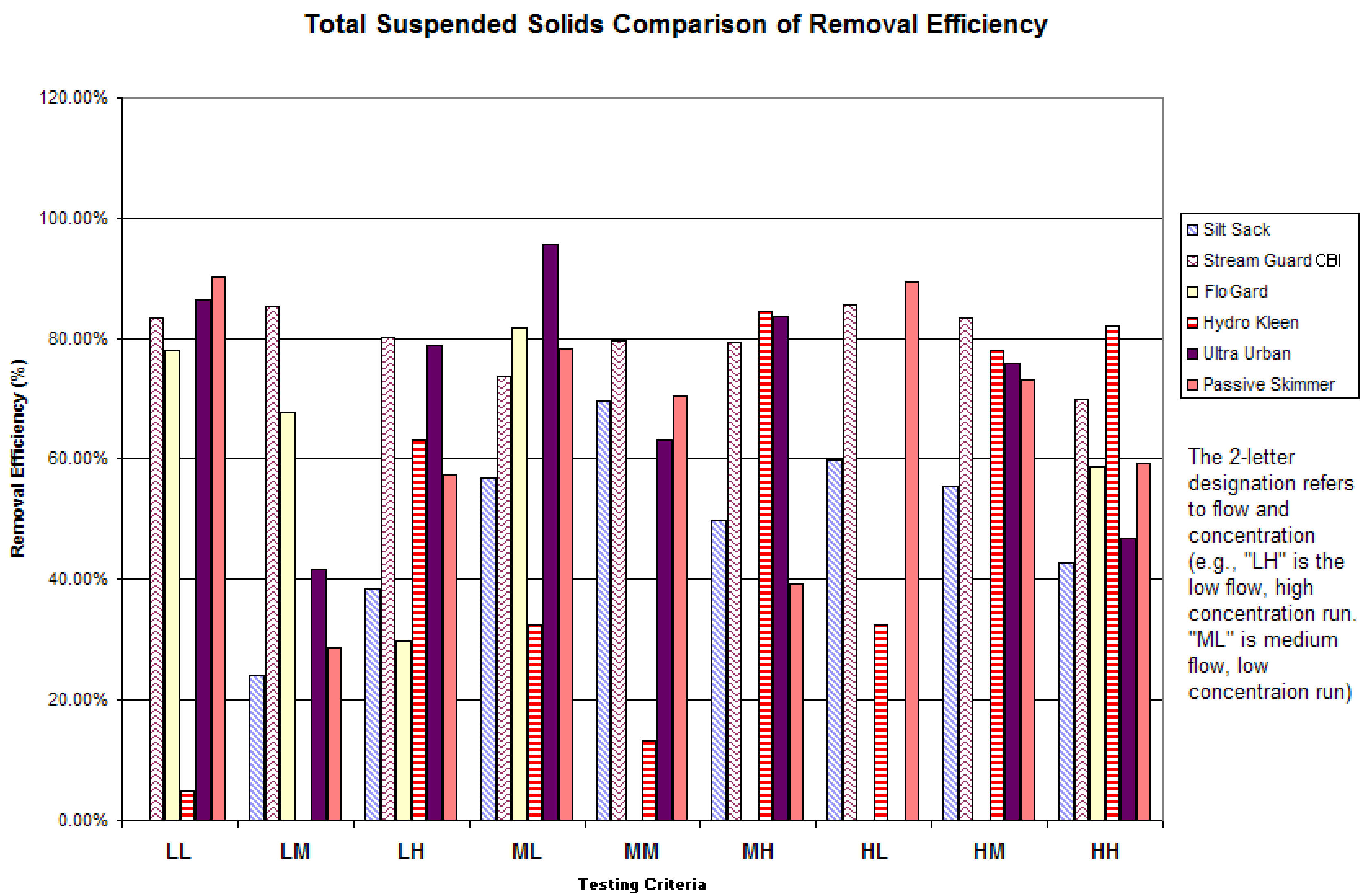
Low Conc Ave SG	10.32%	Low Flow Ave.	9.79%
Med Conc Ave SG	5.88%	Med Flow Ave	6.55%
High Conc Ave SG	18.57%	High Flow Ave.	11.49%

Low Conc Ave FG	20.13%	Low Flow Ave.	34.19%
Med Conc Ave FG	28.93%	Med Flow Ave	8.40%
High Conc Ave FG	25.64%	High Flow Ave.	32.10%

Low Conc Ave HK	23.20%	Low Flow Ave.	16.33%
Med Conc Ave HK	15.70%	Med Flow Ave	13.64%
High Conc Ave HK	15.80%	High Flow Ave.	25.48%

Low Conc Ave UU	72.34%	Low Flow Ave.	42.08%
Med Conc Ave UU	21.33%	Med Flow Ave	51.02%
High Conc Ave UU	31.20%	High Flow Ave.	11.49%

Low Conc Ave PS	49.36%	Low Flow Ave.	6.44%
Med Conc Ave PS	34.84%	Med Flow Ave	53.18%
High Conc Ave PS	38.44%	High Flow Ave.	52.35%



The 2-letter designation refers to flow and concentration (e.g., "LH" is the low flow, high concentration run. "ML" is medium flow, low concentraion run)

Total Suspended Solids (excluding negative results)

Removal Efficiencies

Testing Criteria	Siltsack	Stream Guard	Flow Guard	Hydro-Kleen	Ultra-Urban	Passive Skimmer
LL		83.33%	78.02%	4.76%	86.41%	90.28%
LM	24.14%	85.24%	67.75%		41.67%	28.70%
LH	38.54%	80.05%	29.69%	63.01%	78.83%	57.55%
ML	56.86%	73.64%	81.79%	32.54%	95.61%	78.29%
MM	69.58%	79.53%		13.22%	63.23%	70.44%
MH	49.90%	79.39%		84.58%	83.73%	39.23%
HL	59.74%	85.50%		32.54%		89.36%
HM	55.60%	83.39%		77.98%	75.84%	73.11%
HH	42.70%	69.93%	58.75%	82.10%	46.89%	59.24%
Average :	**49.63%**	**80.00%**	**63.20%**	**48.84%**	**71.52%**	**65.13%**
Standard Deviation:	**14.19%**	**5.28%**	**20.79%**	**32.02%**	**19.23%**	**21.14%**

Low Conc Ave SS	58.30%	Low Flow Ave.	31.34%
Med Conc Ave SS	49.77%	Med Flow Ave	58.78%
High Conc Ave SS	43.71%	High Flow Ave.	52.68%

Low Conc Ave SG	80.82%	Low Flow Ave.	82.88%
Med Conc Ave SG	82.72%	Med Flow Ave	77.52%
High Conc Ave SG	76.46%	High Flow Ave.	79.61%

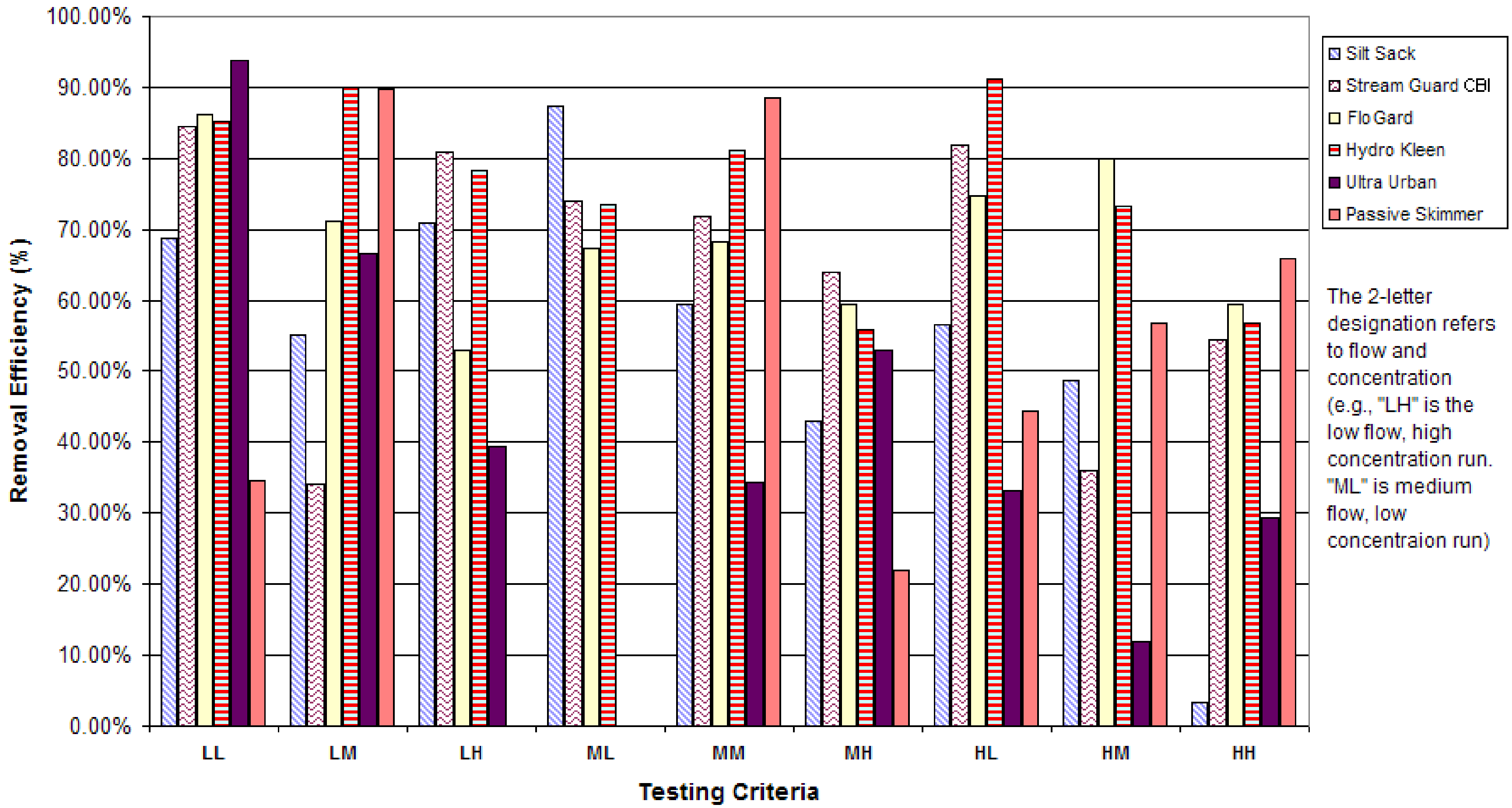
Low Conc Ave FG	79.91%	Low Flow Ave.	58.49%
Med Conc Ave FG	67.75%	Med Flow Ave	81.79%
High Conc Ave FG	44.22%	High Flow Ave.	58.75%

Low Conc Ave HK	23.28%	Low Flow Ave.	33.89%
Med Conc Ave HK	45.60%	Med Flow Ave	43.45%
High Conc Ave HK	76.56%	High Flow Ave.	64.21%

Low Conc Ave UU	91.01%	Low Flow Ave.	68.97%
Med Conc Ave UU	60.24%	Med Flow Ave	80.86%
High Conc Ave UU	69.81%	High Flow Ave.	61.36%

Low Conc Ave PS	85.98%	Low Flow Ave.	58.84%
Med Conc Ave PS	57.42%	Med Flow Ave	62.65%
High Conc Ave PS	52.01%	High Flow Ave.	73.90%

Total Petroleum Hydrocarbon Comparison of Removal Efficiencies



The 2-letter designation refers to flow and concentration (e.g., "LH" is the low flow, high concentration run. "ML" is medium flow, low concentraion run)

Total Petroleum Hydrocarbon (excluding negative results)

Removal Efficiencies

Testing Criteria	Siltsack	Stream Guard	Flow Guard	Hydro-Kleen	Ultra-Urban	Passive Skimmer
LL	68.85%	84.52%	86.06%	85.12%	93.77%	34.59%
LM	55.24%	34.18%	71.04%	89.92%	66.69%	89.71%
LH	70.98%	80.95%	53.00%	78.21%	39.35%	
ML	87.27%	74.02%	67.32%	73.44%		
MM	59.45%	71.88%	68.18%	81.14%	34.46%	88.50%
MH	42.97%	63.95%	59.51%	55.81%	52.87%	22.00%
HL	56.61%	81.93%	74.66%	91.16%	33.27%	44.34%
HM	48.74%	35.97%	79.88%	73.24%	11.97%	56.77%
HH	3.33%	54.48%	59.37%	56.73%	29.47%	65.92%
Average :	**54.83%**	**64.66%**	**68.78%**	**76.09%**	**45.23%**	**57.40%**
Standard Deviation:	**23.36%**	**19.22%**	**10.53%**	**12.90%**	**25.42%**	**25.91%**

Low Conc Ave SS	70.91%	Low Flow Ave.	65.02%
Med Conc Ave SS	54.48%	Med Flow Ave	63.23%
High Conc Ave SS	39.09%	High Flow Ave.	36.23%

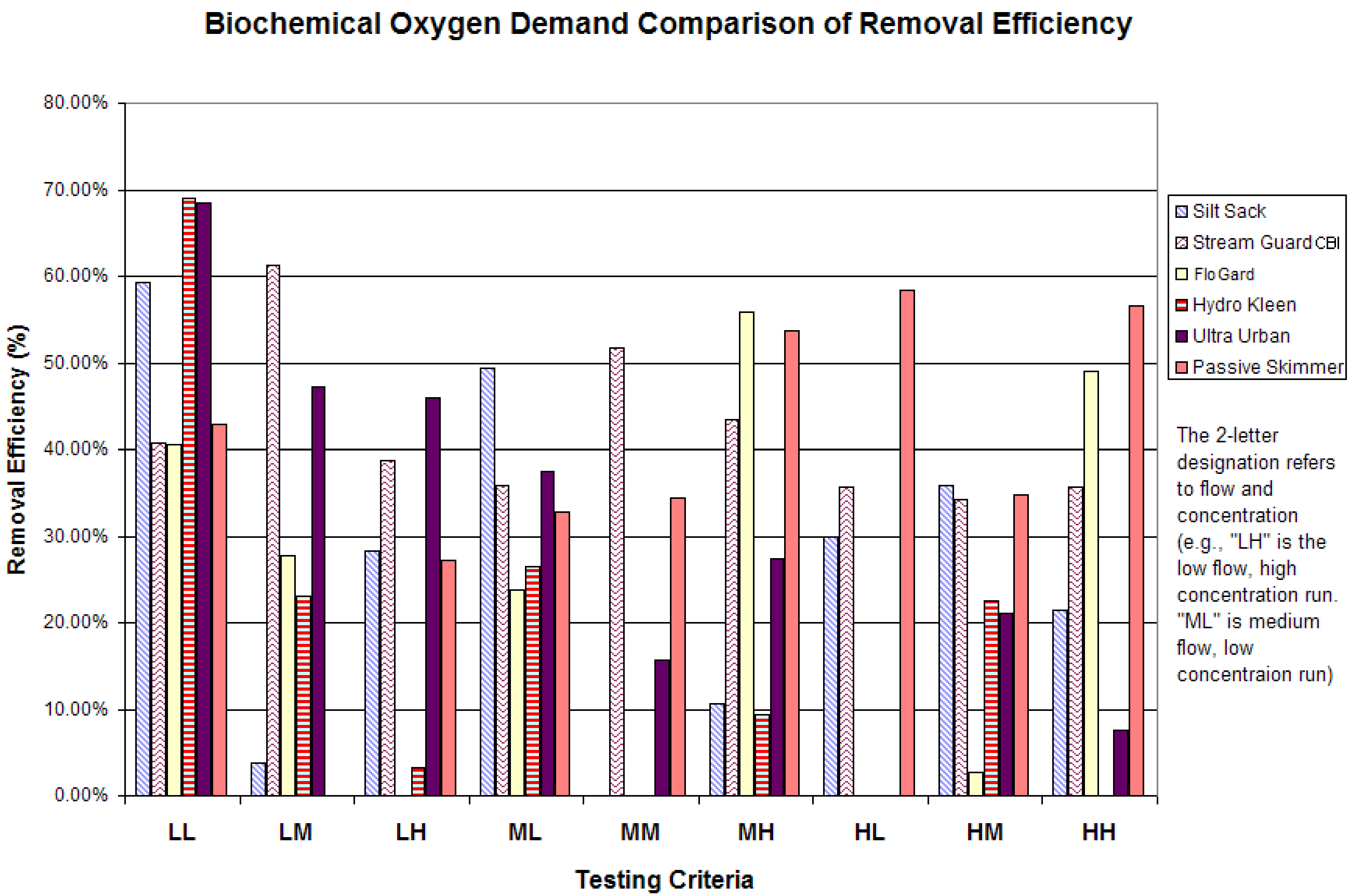
Low Conc Ave SG	80.16%	Low Flow Ave.	66.55%
Med Conc Ave SG	47.35%	Med Flow Ave	69.95%
High Conc Ave SG	66.46%	High Flow Ave.	57.46%

Low Conc Ave FG	76.01%	Low Flow Ave.	70.03%
Med Conc Ave FG	73.03%	Med Flow Ave	65.00%
High Conc Ave FG	57.29%	High Flow Ave.	71.30%

Low Conc Ave HK	83.24%	Low Flow Ave.	84.42%
Med Conc Ave HK	81.43%	Med Flow Ave	70.13%
High Conc Ave HK	63.58%	High Flow Ave.	73.71%

Low Conc Ave UU	63.52%	Low Flow Ave.	66.60%
Med Conc Ave UU	37.70%	Med Flow Ave	43.66%
High Conc Ave UU	40.56%	High Flow Ave.	24.90%

Low Conc Ave PS	39.47%	Low Flow Ave.	62.15%
Med Conc Ave PS	78.33%	Med Flow Ave	55.25%
High Conc Ave PS	43.96%	High Flow Ave.	55.67%



Biochemical Oxygen Demand Comparison of Removal Efficiency
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Removal Efficiency (%)
LL
LM
LH
ML
MM
MH
HL
HM
HH
Testing Criteria
Silt Sack
Stream Guard CBI
Flo Gard
Hydro Kleen
Ultra Urban
Passive Skimmer
The 2-letter designation refers to flow and concentration (e.g., "LH" is the low flow, high concentration run. "ML" is medium flow, low concentraion run)

Biochemical Oxygen Demand (excluding negative results)

Removal Efficiencies

Testing Criteria	Siltsack	Stream Guard	Flow Guard	Hydro-Kleen	Ultra-Urban	Passive Skimmer
LL	59.31%	40.77%	40.56%	68.97%	68.44%	42.79%
LM	3.83%	61.18%	27.69%	22.99%	47.19%	
LH	28.22%	38.67%		3.22%	46.03%	27.28%
ML	49.35%	35.81%	23.75%	26.56%	37.40%	32.76%
MM	NA	51.79%			15.71%	34.33%
MH	10.59%	43.34%	55.83%	9.29%	27.34%	53.76%
HL	29.93%	35.75%				58.38%
HM	35.86%	34.30%	2.64%	22.54%	21.01%	34.77%
HH	21.48%	35.60%	49.10%		7.60%	56.55%
Average :	**29.82%**	**41.91%**	**33.26%**	**25.59%**	**33.84%**	**42.58%**
Standard Deviation:	**18.54%**	**9.05%**	**19.35%**	**23.09%**	**19.86%**	**12.13%**

Low Conc Ave SS	46.19%	Low Flow Ave.	30.45%
Med Conc Ave SS	19.85%	Med Flow Ave	29.97%
High Conc Ave SS	20.10%	High Flow Ave.	29.09%

Low Conc Ave SG	37.45%	Low Flow Ave.	46.87%
Med Conc Ave SG	49.09%	Med Flow Ave	43.65%
High Conc Ave SG	39.20%	High Flow Ave.	35.22%

Low Conc Ave FG	32.16%	Low Flow Ave.	34.13%
Med Conc Ave FG	15.17%	Med Flow Ave	39.79%
High Conc Ave FG	52.47%	High Flow Ave.	25.87%

Low Conc Ave HK	47.77%	Low Flow Ave.	31.73%
Med Conc Ave HK	22.76%	Med Flow Ave	17.92%
High Conc Ave HK	6.25%	High Flow Ave.	22.54%

Low Conc Ave UU	52.92%	Low Flow Ave.	53.89%
Med Conc Ave UU	27.97%	Med Flow Ave	26.82%
High Conc Ave UU	26.99%	High Flow Ave.	14.31%

Low Conc Ave PS	44.65%	Low Flow Ave.	35.04%
Med Conc Ave PS	34.55%	Med Flow Ave	40.28%
High Conc Ave PS	45.86%	High Flow Ave.	49.90%

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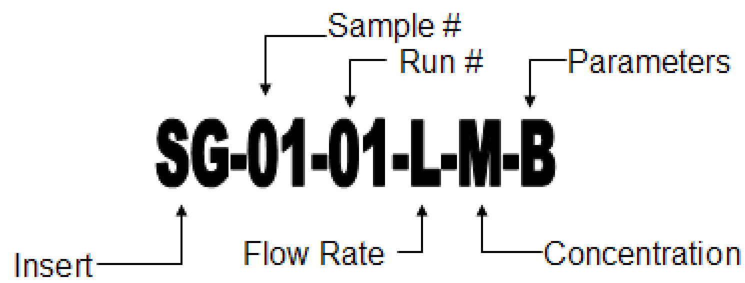
Appendix C: Sampling Code Legend

Sample Code Legend



Legend:

Insert
SG - Stream Guard
PS - Passive Skimmer
UU - Ultra Urban
SS - Silt Sack
FG - Flow Guard
HK - Hydro Kleen

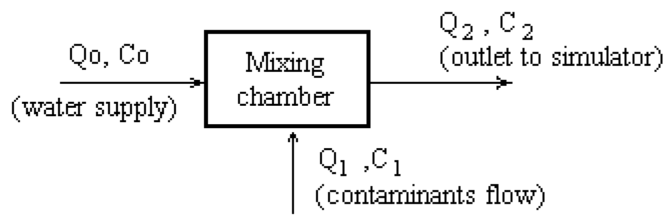
Flow Rate/ Concentration
H – High
M – Medium/Median
L - Low

Parameters
N – Normal (TKN, TP, TPH, BOD,TSS)
B – Bacterial (FCB)

Appendix D: Contaminant Calculations & Testing Breakdown

Concentration Calculation & Testing Breakdown

Q_1 (l/hr) =	52
Q_1 (l/min) =	0.87
C_0 =	0
Q_2=	$Qo + Q_1$
C_1=	$(Q_2{*}C_2)/Q_1$



(C_1 is calculated to deliver the desired test concentration, C_2)

Medium Median

Constituent	**Flow Rate (Qo) l/min**	**Conc. of Constituent (C_2) mg/l**	**Conc. Of Pump Tank (C_1) mg/l**	**g/l**	**Mass g/hr**	
TSS	**150**	**100**	**17407.69**	**17.41**	**905.20**	
BOD	**150**	9				
TP	**150**	0.33	57.45	0.06	13.11	**KH_2PO_4**
TKN	**150**	1.5	261.12	0.26	51.88	**NH_4Cl**
TPH	**150**	25	4351.92	4.35	274.64	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**150**	210000	1.400E+07		67.50	

Medium Low

Constituent	**Flow Rate (Qo) l/min**	**Conc. of Constituent (C_2) mg/l**	**Conc. Of Pump Tank (C_1) mg/l**	**g/l**	**Mass g/hr**	
TSS	**150**	**34.4**	**5988.25**	**5.99**	**311.39**	
BOD	**150**	4.9				
TP	**150**	0.18	31.33	0.03	7.15	**KH_2PO_4**
TKN	**150**	0.82	142.74	0.14	28.36	**NH_4Cl**
TPH	**150**	12.7	2210.78	2.21	139.52	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**150**	85240	1.400E+07		27.40	

Medium High

Constituent	Flow Rate (Qo) l/min	Conc. of Constituent (C_2) mg/l	Conc. Of Pump Tank (C_1) mg/l	g/l	Mass g/hr	
TSS	**150**	**547.5**	**95307.12**	**95.31**	**4955.97**	
BOD	**150**	19				
TP	**150**	0.885	154.06	0.15	35.17	**KH_2PO_4**
TKN	**150**	4.18	727.64	0.73	144.57	**NH_4Cl**
TPH	**150**	37	6440.85	6.44	406.46	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**150**	517000	1.400E+07		166.18	

Low Median

Constituent	Flow Rate (Qo) l/min	Conc. of Constituent (C_2) mg/l	Conc. Of Pump Tank (C_1) mg/l	g/l	Mass g/hr	
TSS	**50**	**100**	**5869.23**	**5.87**	**305.20**	
BOD	**50**	9				
TP	**50**	0.33	19.37	0.02	4.42	**KH_2PO_4**
TKN	**50**	1.5	88.04	0.09	17.49	**NH_4Cl**
TPH	**50**	25	1467.31	1.47	92.60	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**50**	210000	1.400E+07		22.50	

Low Low

Constituent	Flow Rate (Qo) l/min	Conc. of Constituent (C_2) mg/l	Conc. Of Pump Tank (C_1) mg/l	g/l	Mass g/hr	
TSS	**50**	**34.4**	**2019.02**	**2.02**	**104.99**	
BOD	**50**	4.9				
TP	**50**	0.18	10.56	0.01	2.41	**KH_2PO_4**
TKN	**50**	0.82	48.13	0.05	9.56	**NH_4Cl**
TPH	**50**	12.7	745.39	0.75	47.04	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**50**	85240	1.400E+07		9.13	

Notes:

*High concentration is based on an average of the 90% values from NURP
*TP Low and Median concentrations will be run with just tap water since the tap contains on average 0.7mg/l
*FCB Spring value $1.4x10^7$

	Low	High				
Constituent	**Flow Rate (Qo) l/min**	**Conc. of Constituent (C_2) mg/l**	**Conc. Of Pump Tank (C_1) mg/l**	**g/l**	**Mass g/hr**	
TSS	**50**	547.5	**32134.04**	**32.13**	**1670.97**	
BOD	**50**	19				
TP	**50**	0.885	51.94	0.05	11.86	**KH_2PO_4**
TKN	**50**	4.18	245.33	0.25	48.74	**NH_4Cl**
TPH	**50**	37	2171.62	2.17	137.04	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**50**	517000	1.400E+07		55.39	

	High	Median				
Constituent	**Flow Rate (Qo) l/min**	**Conc. of Constituent (C_2) mg/l**	**Conc. Of Pump Tank (C_1) mg/l**	**g/l**	**Mass g/hr**	
TSS	**300**	**100**	**34715.38**	**34.72**	**1805.20**	
BOD	**300**	9				
TP	**300**	0.33	114.56	0.11	26.15	**KH_2PO_4**
TKN	**300**	1.5	520.73	0.52	103.46	**NH_4Cl**
TPH	**300**	25	8678.85	8.68	547.69	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**300**	210000	1.400E+07		135.00	

	High	Low				
Constituent	**Flow Rate (Qo) l/min**	**Conc. of Constituent (C_2) mg/l**	**Conc. Of Pump Tank (C_1) mg/l**	**g/l**	**Mass g/hr**	
TSS	**300**	**34.4**	**11942.09**	**11.94**	**620.99**	
BOD	**300**	4.9				
TP	**300**	0.18	62.49	0.06	14.26	**KH_2PO_4**
TKN	**300**	0.82	284.67	0.28	56.56	**NH_4Cl**
TPH	**300**	12.7	4408.85	4.41	278.23	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**300**	85240	1.400E+07		54.80	

	High	High				
Constituent	**Flow Rate (Qo) l/min**	**Conc. of Constituent (C_2) mg/l**	**Conc. Of Pump Tank (C_1) mg/l**	**g/l**	**Mass g/hr**	
TSS	**300**	**547.5**	**190066.73**	**190.07**	**9883.47**	
BOD	**300**	19				
TP	**300**	0.885	307.23	0.31	70.13	**KH_2PO_4**
TKN	**300**	4.18	1451.10	1.45	288.30	**NH_4Cl**
TPH	**300**	37	12844.69	12.84	810.59	**Oil**
	Flow	**Bacteria/ L**	**Bacteria/ L in Sludge (estimate)**		**Volume (L)**	
FCB	**300**	517000	1.400E+07		332.36	

Concentration Values

Formula from page 5-6 of NURP Report (EPA, 1983)

Z for 90% = 1.282
Z for 1σ = 1
Z for 10% = -1.282

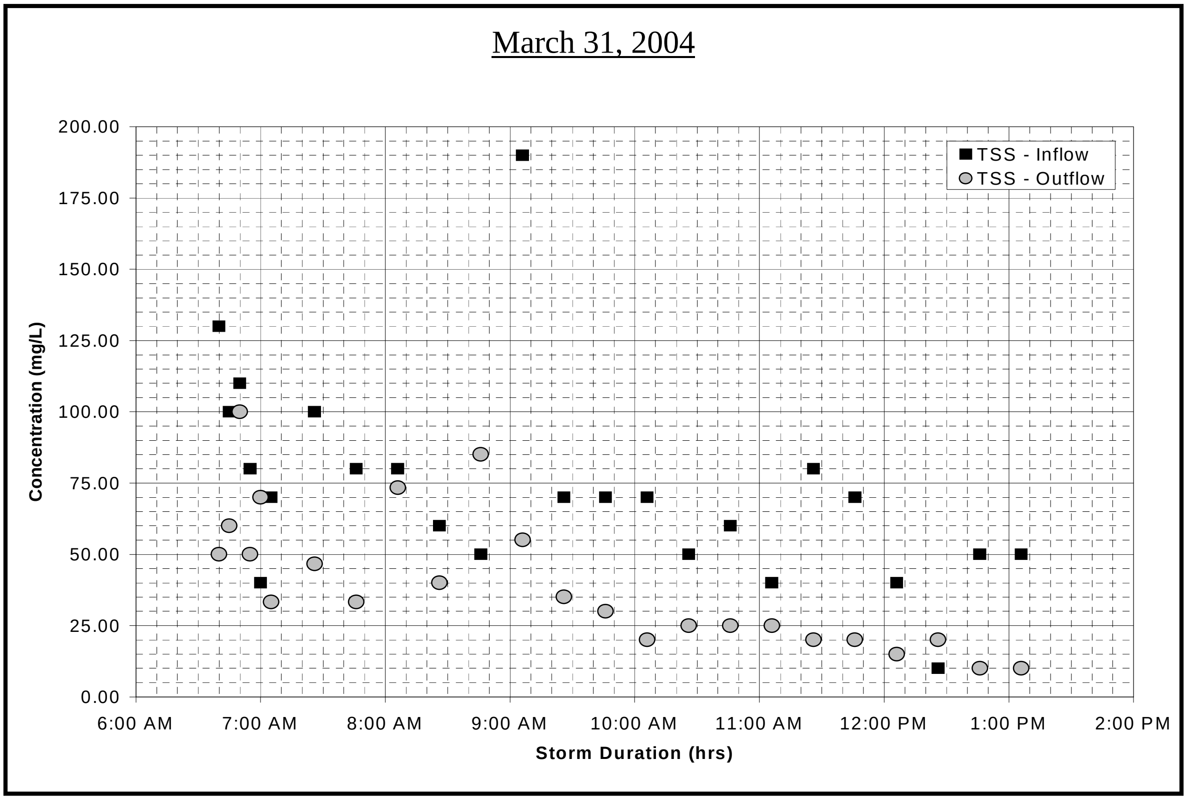
From Table 6-17 Of NURP Data					Calculated	
Constituent	**Coeff. of Var. Range**		**Median**	**90%**	**10% Range**	
TSS (mg/l)	1	2	100	300	34.39239	19.66378
BOD (mg/l)	0.5	1	9	15	4.911761	3.095315
TP (mg/l)	0.5	1	0.33	0.7	0.180098	0.113495
TKN (mg/l)	0.5	1	1.5	3.3	0.818627	0.515886

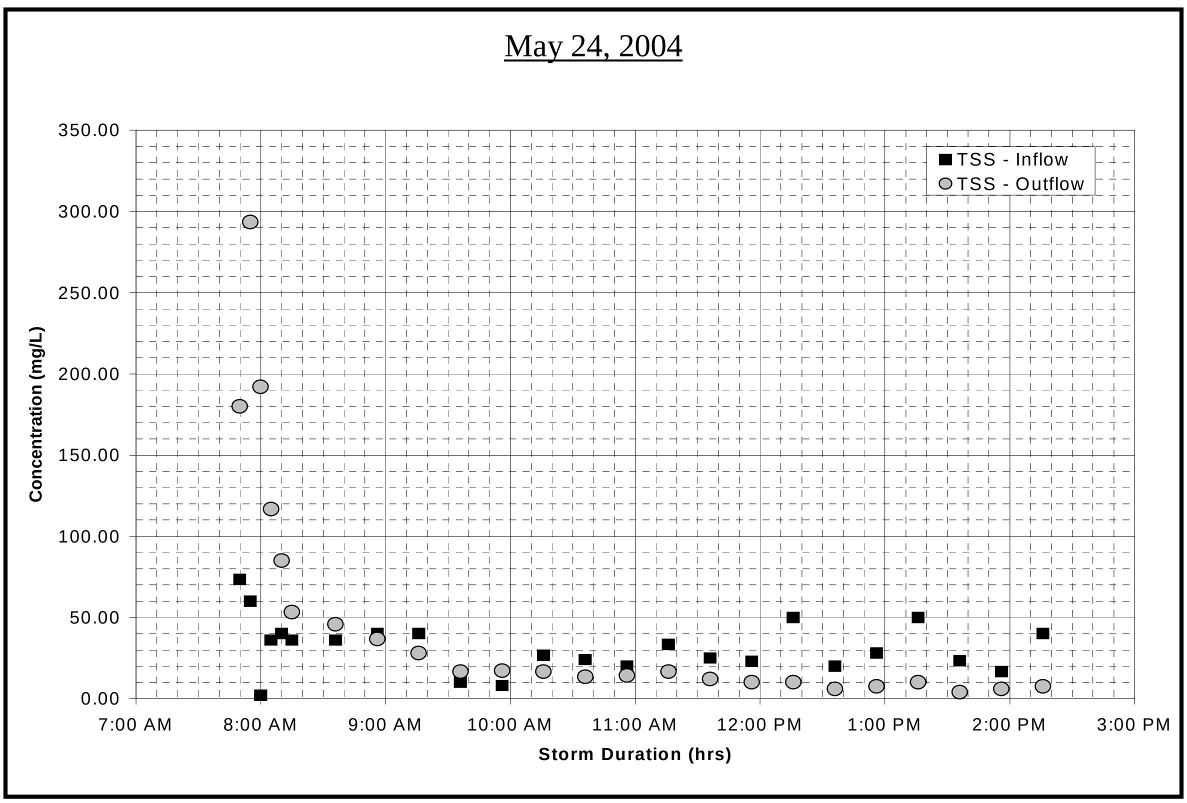
From Table 6-24 Of NURP Data					Calculated		
Constituent	**Mean Range**		**90% Range**		**10% Range**		**Ave of 90%**
TSS (mg/l)	141	224	424	671	34.39239	19.66378	547.5
BOD (mg/l)	10	13	17	21	4.911761	3.095315	19
TP (mg/l)	0.37	0.47	0.78	0.99	0.180098	0.113495	0.885
TKN (mg/l)	1.68	2.12	3.69	4.67	0.818627	0.515886	4.18

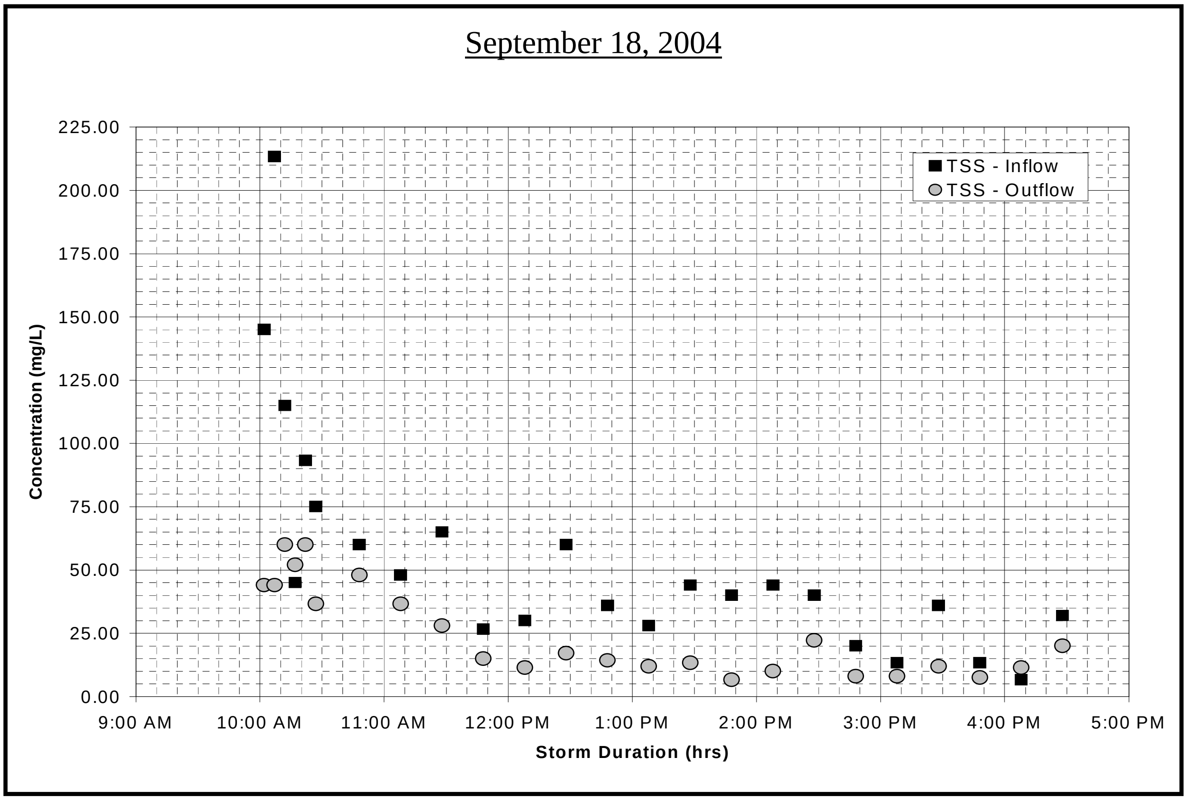
From Table 6-18 Of NURP Data Fecal Coliform	1000/100 ml				
Weather Condition	**Coeff. of Variance**	**Median**	**Mean**	**90%**	**10%**
Warm	0.8	21	26.89312	51.7390	8.5235
Cold	0.7	1	1.220656	2.2469	0.4451

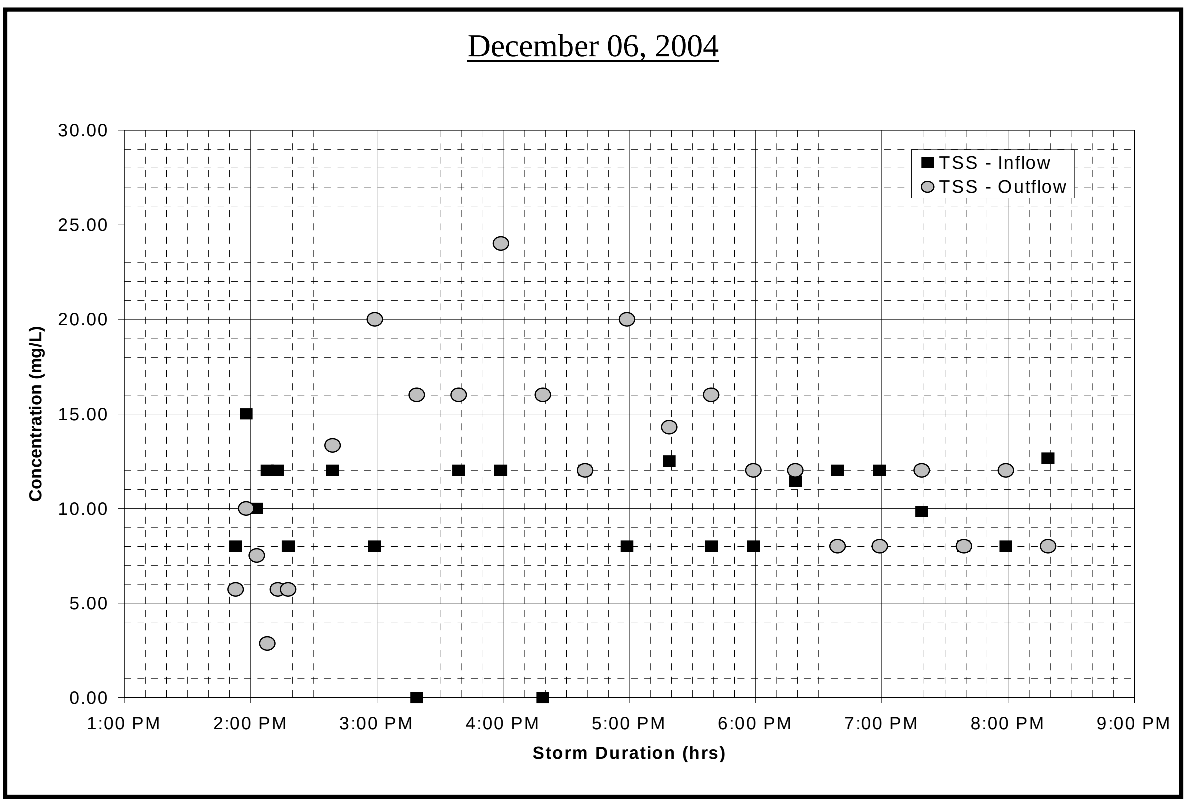
TPH Range from FHWA	Median	High	Low
12.7 - 37	24.85	37	12.7

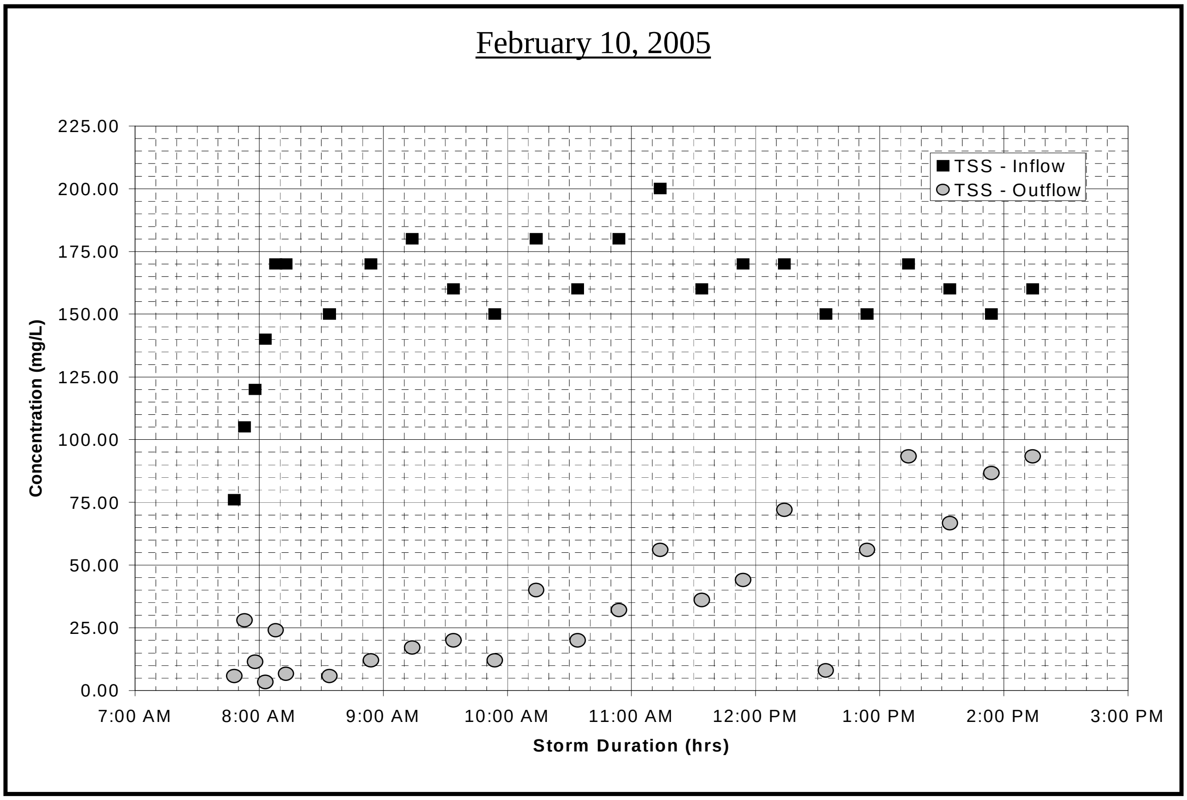
Appendix E: TSS Loading, All Events, Vortechs® Unit


March 31, 2004
200.00
175.00
150.00
125.00
100.00
75.00
50.00
25.00
0.00
Concentration (mg/L)
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
Storm Duration (hrs)
TSS - Inflow
TSS - Outflow

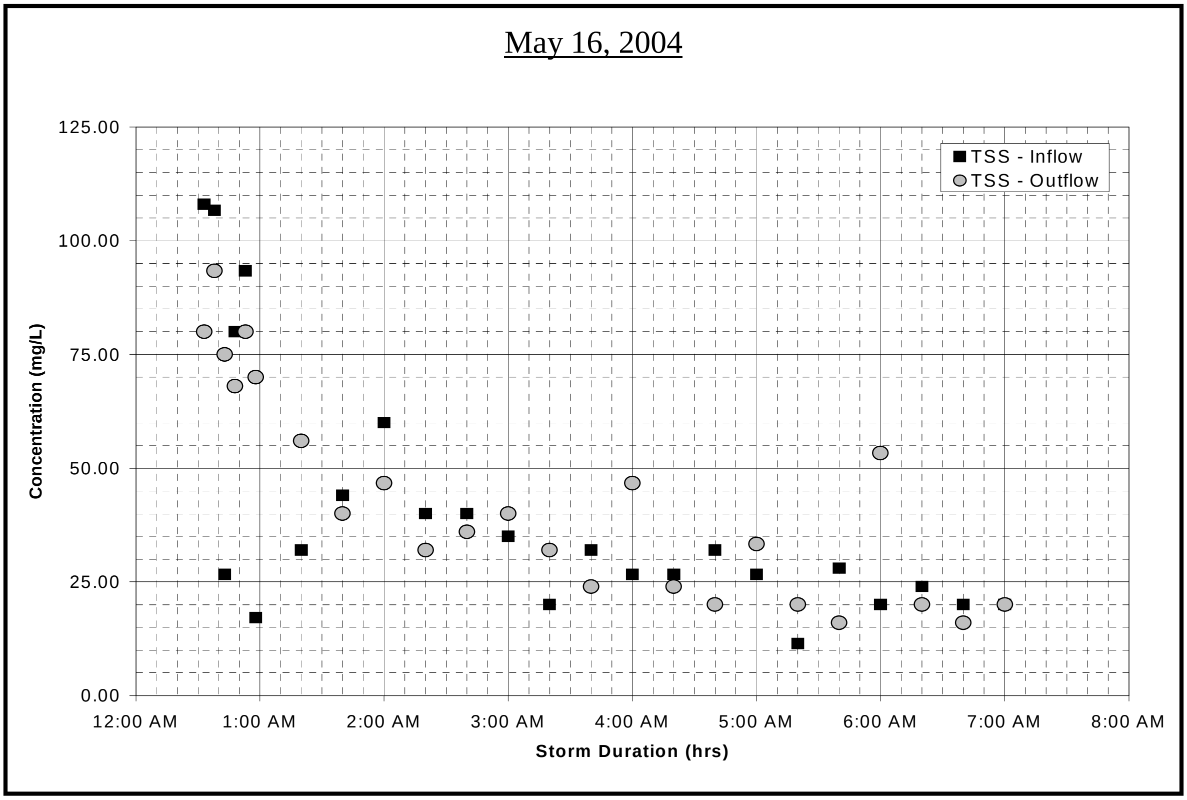

May 24, 2004
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Concentration (mg/L)
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)
TSS - Inflow
TSS - Outflow

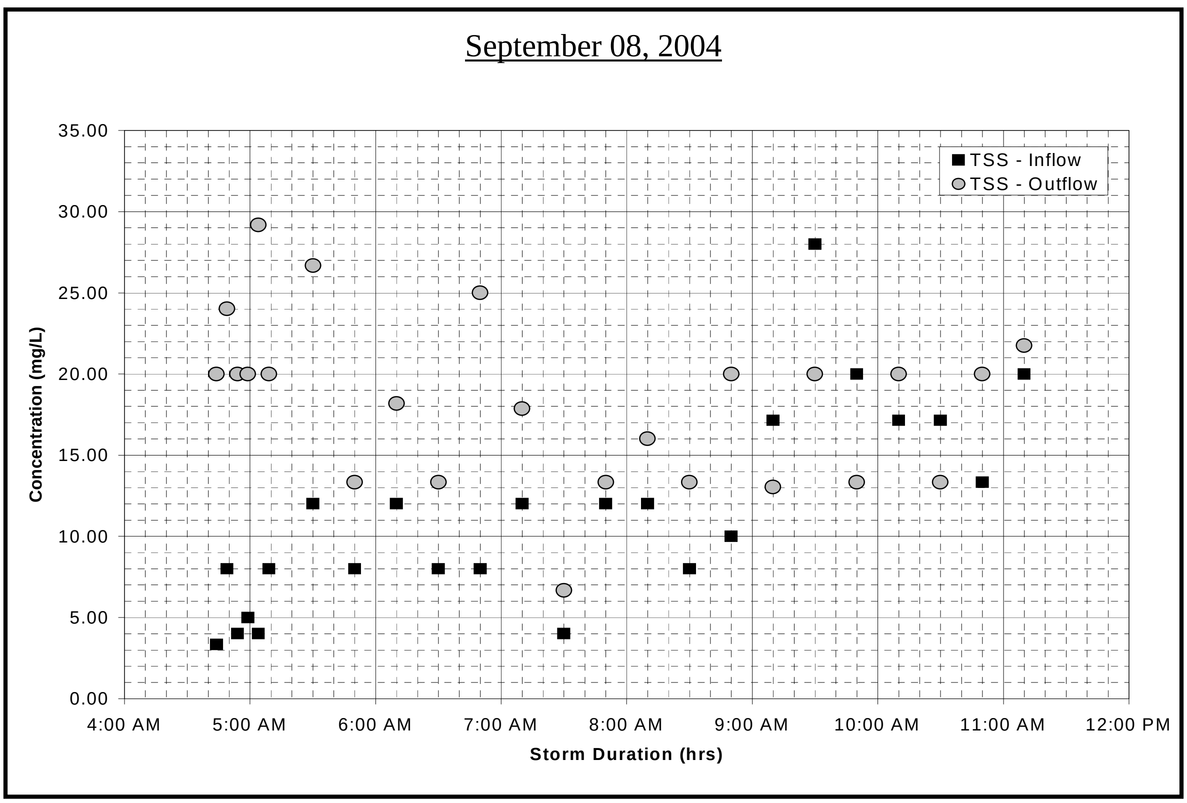

September 18, 2004
225.00
200.00
175.00
150.00
125.00
100.00
75.00
50.00
25.00
0.00
Concentration (mg/L)
TSS - Inflow
TSS - Outflow
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)

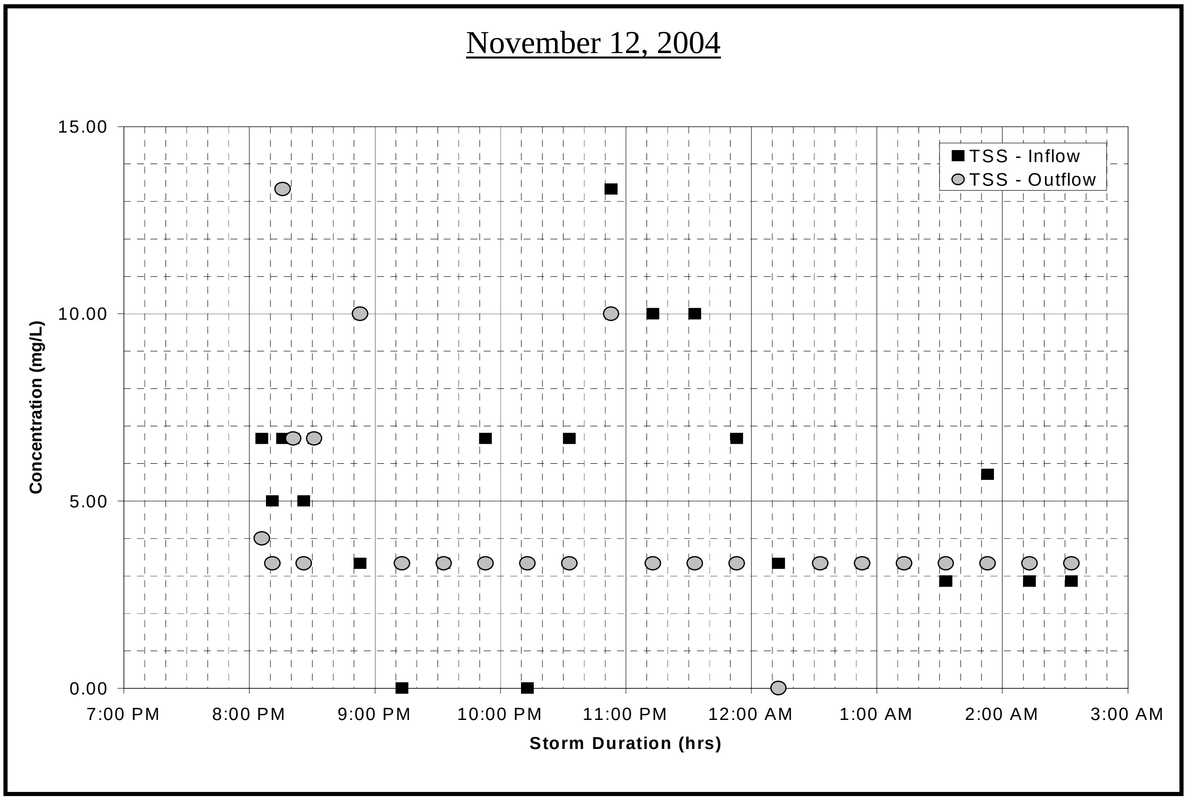

December 06, 2004
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Concentration (mg/L)
TSS - Inflow
TSS - Outflow
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
Storm Duration (hrs)

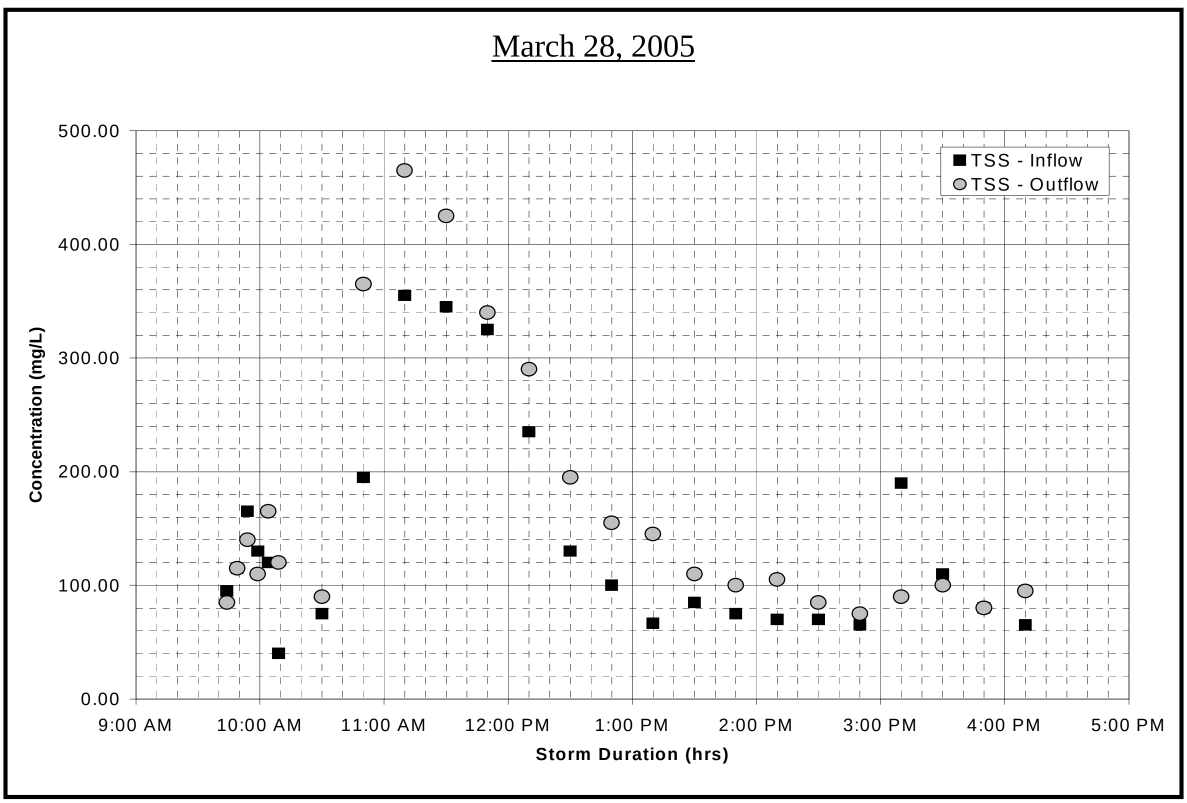

February 10, 2005
225.00
200.00
175.00
150.00
125.00
100.00
75.00
50.00
25.00
0.00
Concentration (mg/L)
TSS - Inflow
TSS - Outflow
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)

Appendix F: TSS Loading, All Events, V2B1™ Unit


May 16, 2004
125.00
100.00
75.00
50.00
25.00
0.00
Concentration (mg/L)
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
Storm Duration (hrs)
TSS - Inflow
TSS - Outflow


September 08, 2004
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Concentration (mg/L)
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
Storm Duration (hrs)
TSS - Inflow
TSS - Outflow


November 12, 2004
TSS - Inflow
TSS - Outflow
Concentration (mg/L)
15.00
10.00
5.00
0.00
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
1:00 AM
2:00 AM
3:00 AM
Storm Duration (hrs)


March 28, 2005
TSS - Inflow
TSS - Outflow
Concentration (mg/L)
500.00
400.00
300.00
200.00
100.00
0.00
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)

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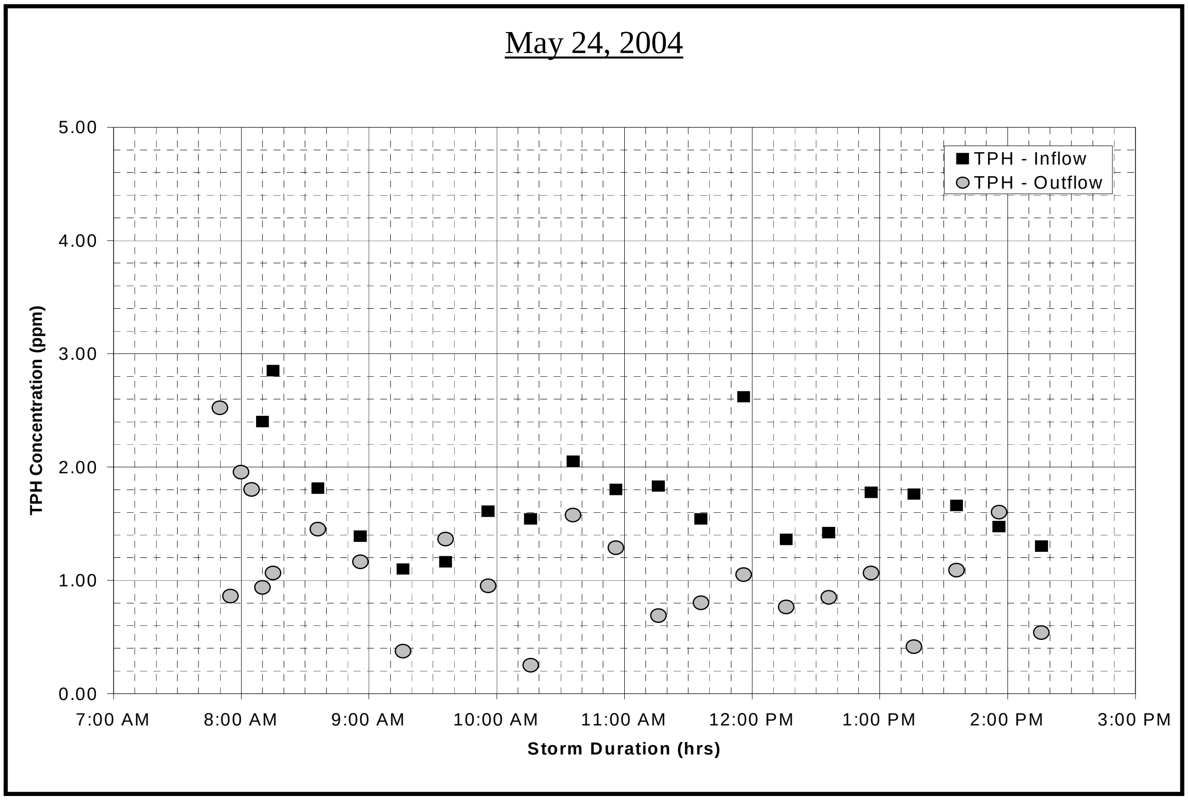
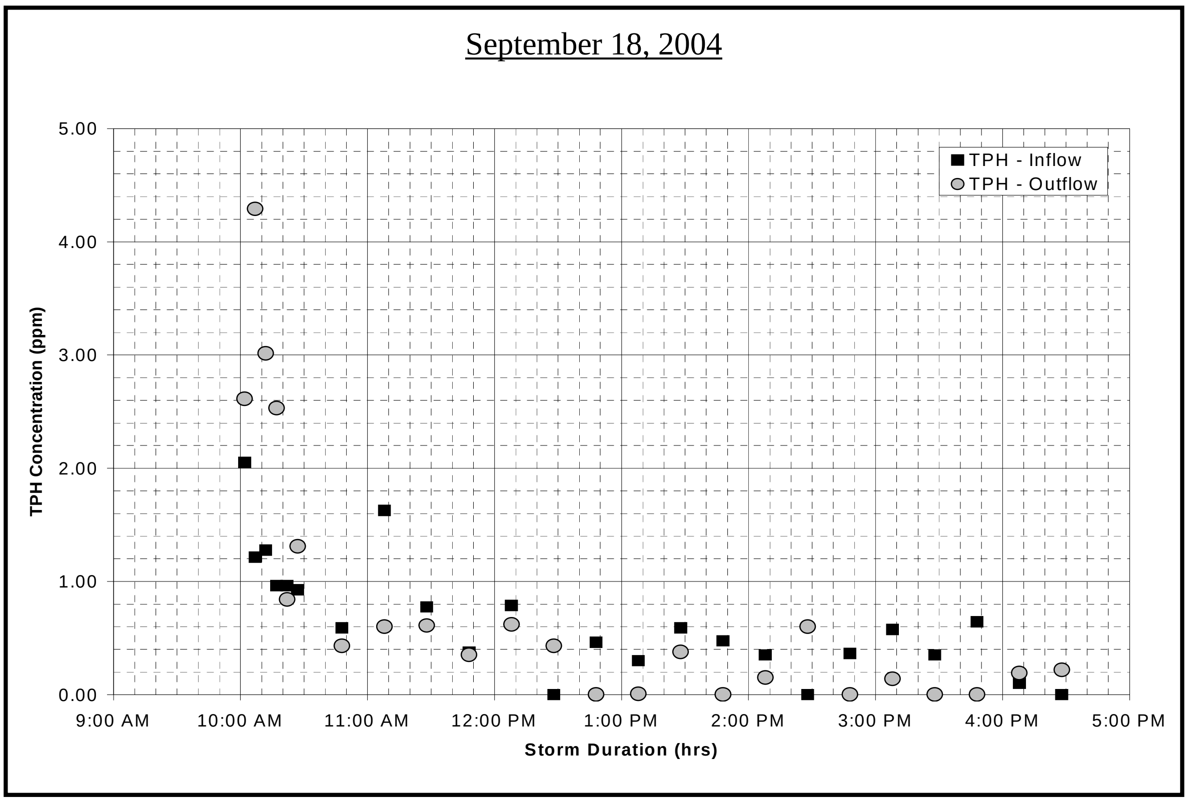
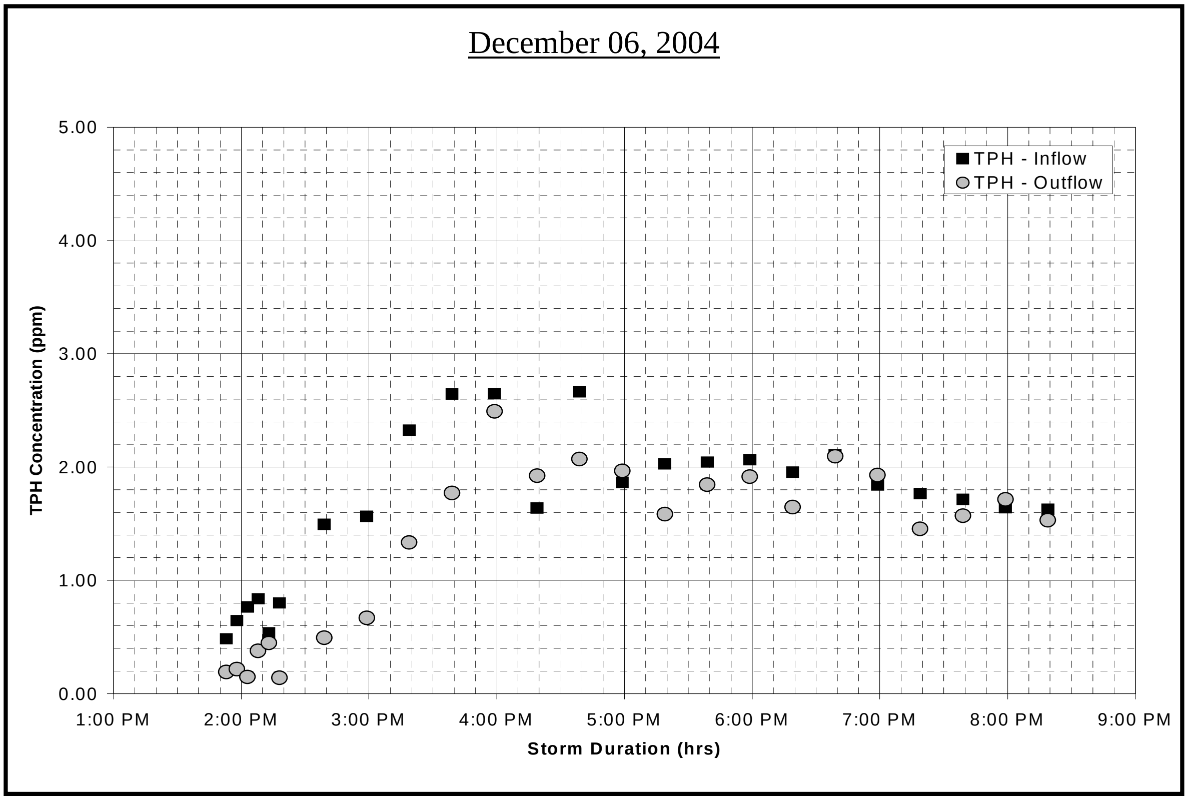
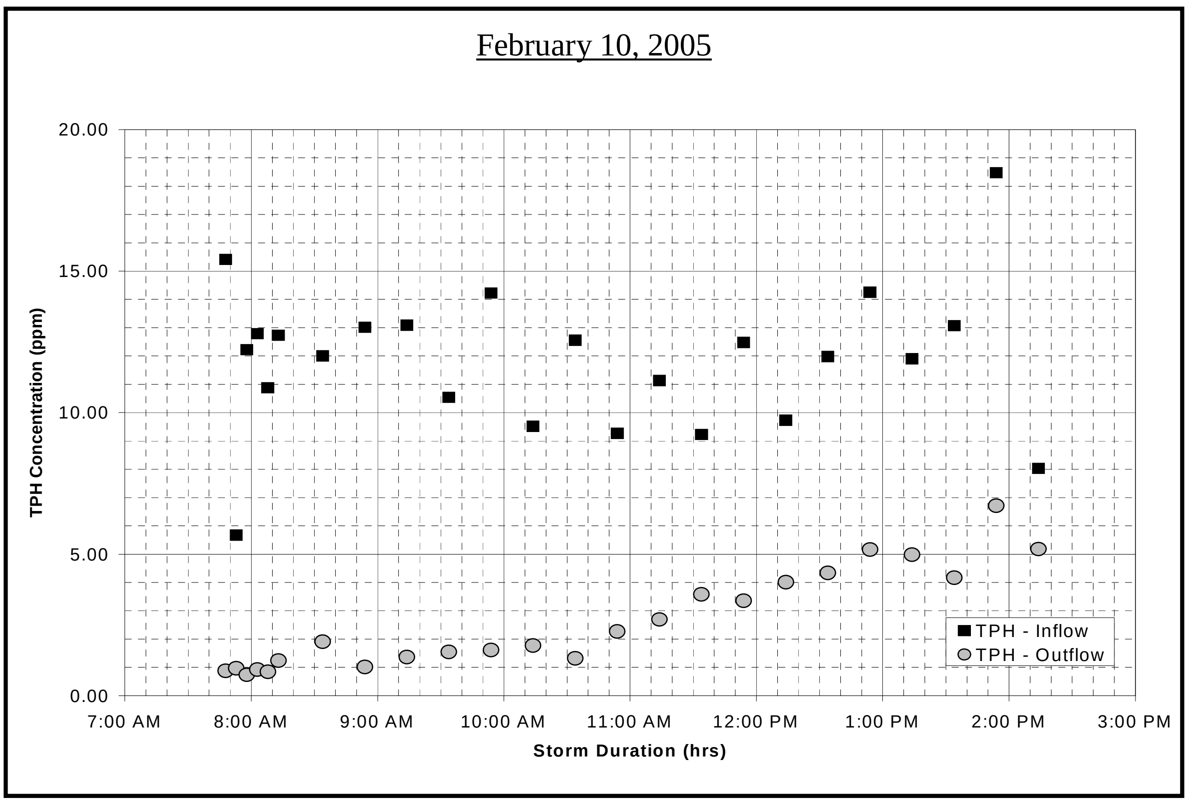
Appendix G: TPH Loading, All Events, Vortechs® Unit


May 24, 2004
5.00
4.00
3.00
2.00
1.00
0.00
TPH Concentration (ppm)
TPH - Inflow
TPH - Outflow
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)


September 18, 2004
5.00
4.00
3.00
2.00
1.00
0.00
TPH Concentration (ppm)
TPH - Inflow
TPH - Outflow
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)


December 06, 2004
TPH - Inflow
TPH - Outflow
TPH Concentration (ppm)
5.00
4.00
3.00
2.00
1.00
0.00
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
Storm Duration (hrs)


February 10, 2005
TPH - Inflow
TPH - Outflow
TPH Concentration (ppm)
20.00
15.00
10.00
5.00
0.00
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)

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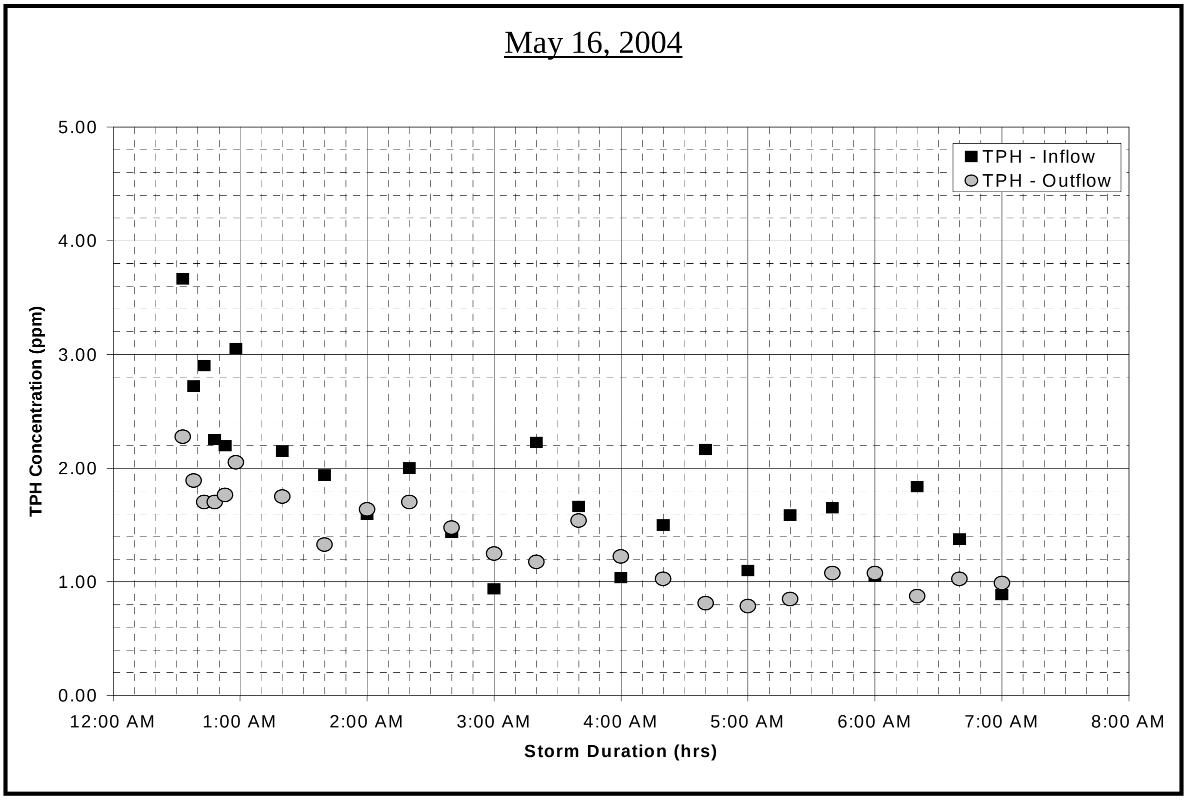
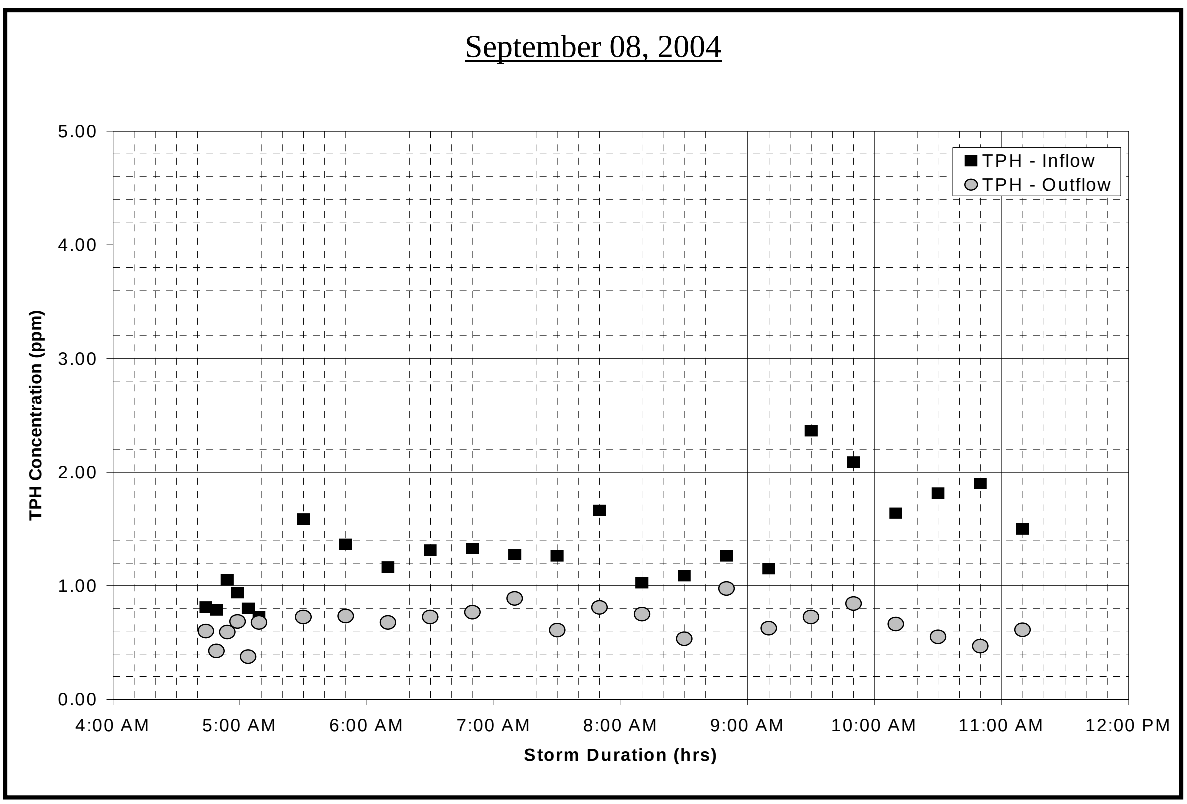
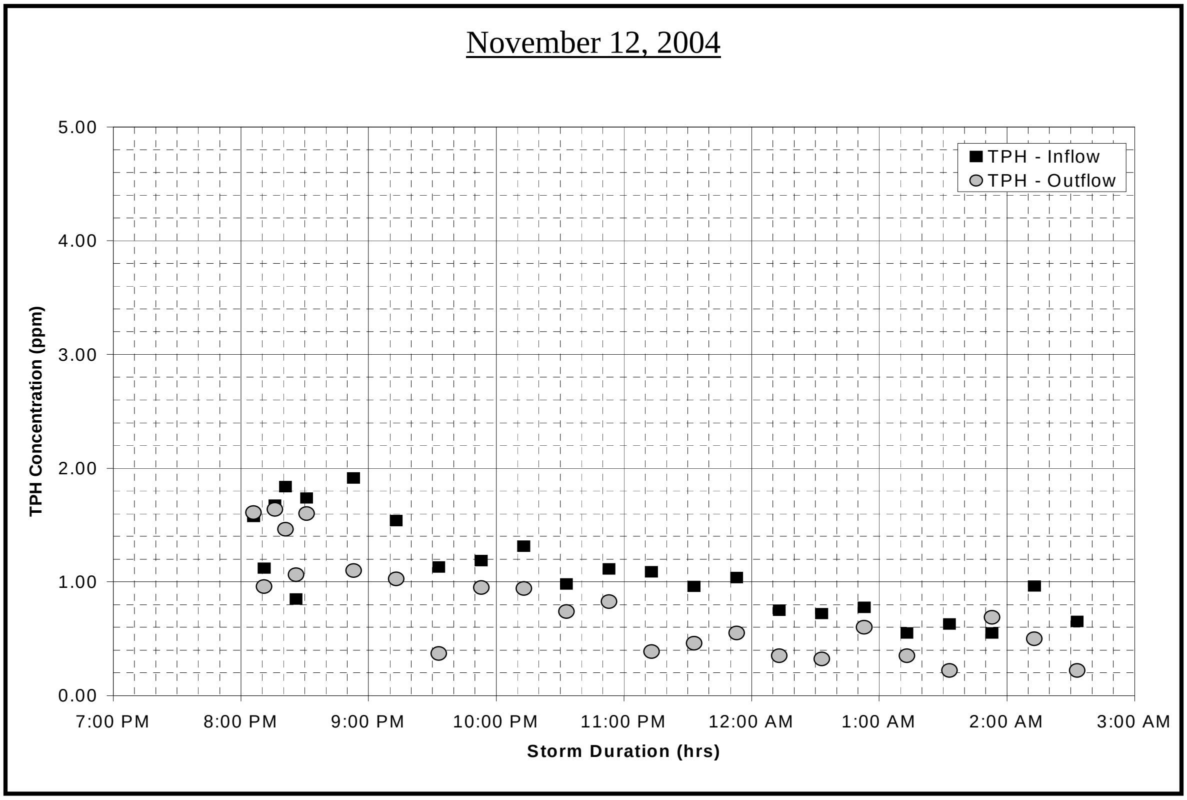
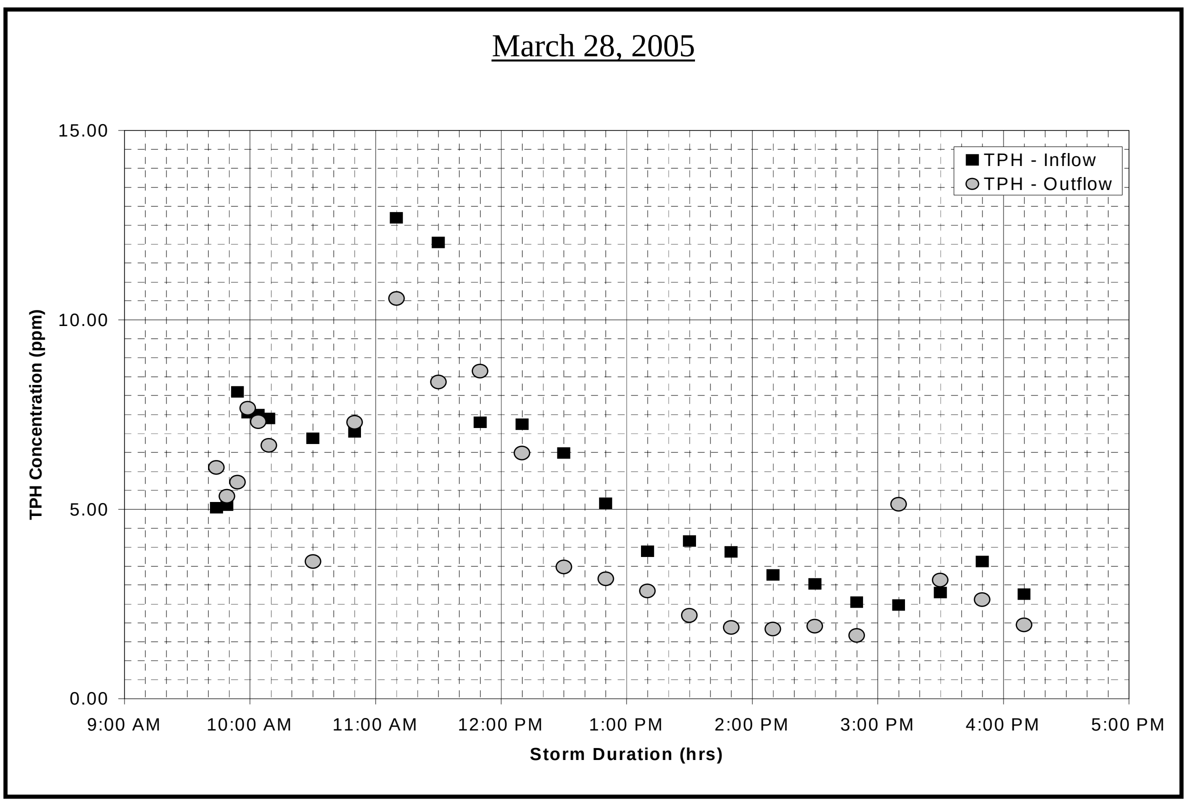
Appendix H: TPH Loading, All Events, V2B1™ Unit


May 16, 2004
5.00
4.00
3.00
2.00
1.00
0.00
TPH Concentration (ppm)
TPH - Inflow
TPH - Outflow
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
Storm Duration (hrs)


September 08, 2004
5.00
4.00
3.00
2.00
1.00
0.00
TPH Concentration (ppm)
TPH - Inflow
TPH - Outflow
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
Storm Duration (hrs)


November 12, 2004
TPH - Inflow
TPH - Outflow
TPH Concentration (ppm)
5.00
4.00
3.00
2.00
1.00
0.00
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
1:00 AM
2:00 AM
3:00 AM
Storm Duration (hrs)


March 28, 2005
TPH - Inflow
TPH - Outflow
TPH Concentration (ppm)
15.00
10.00
5.00
0.00
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)

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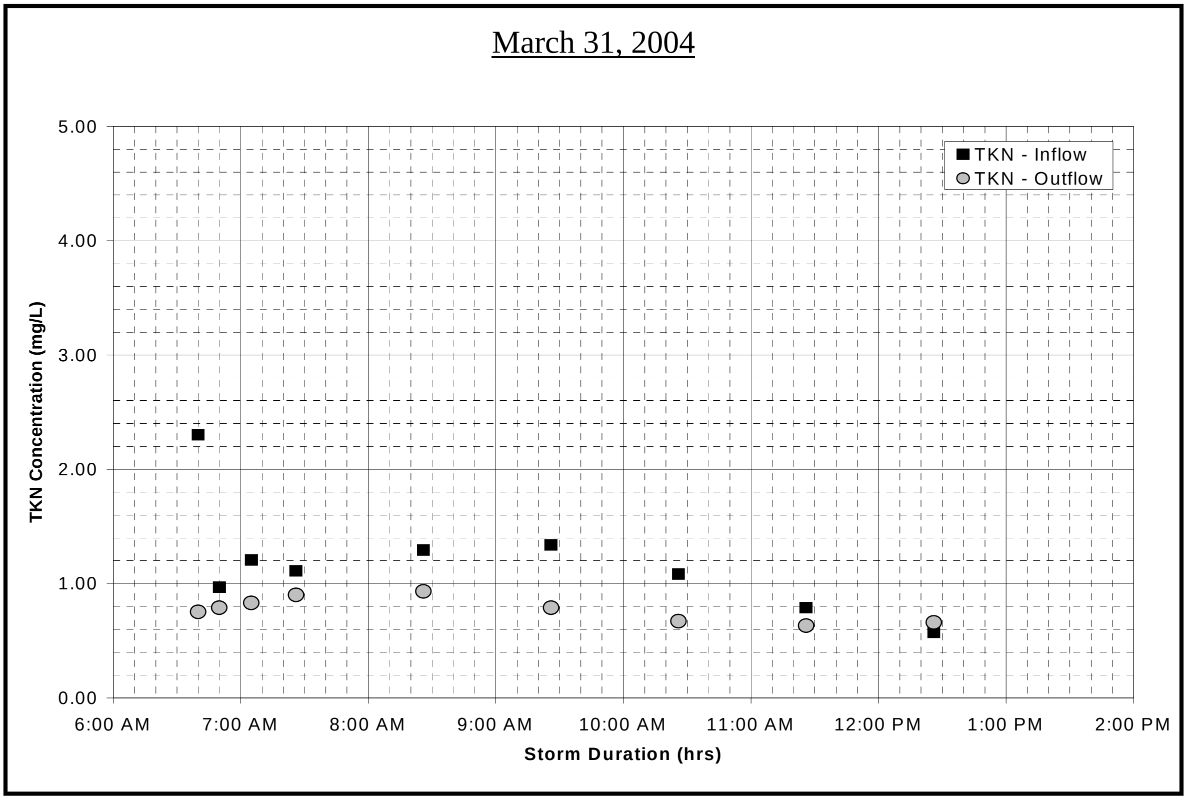
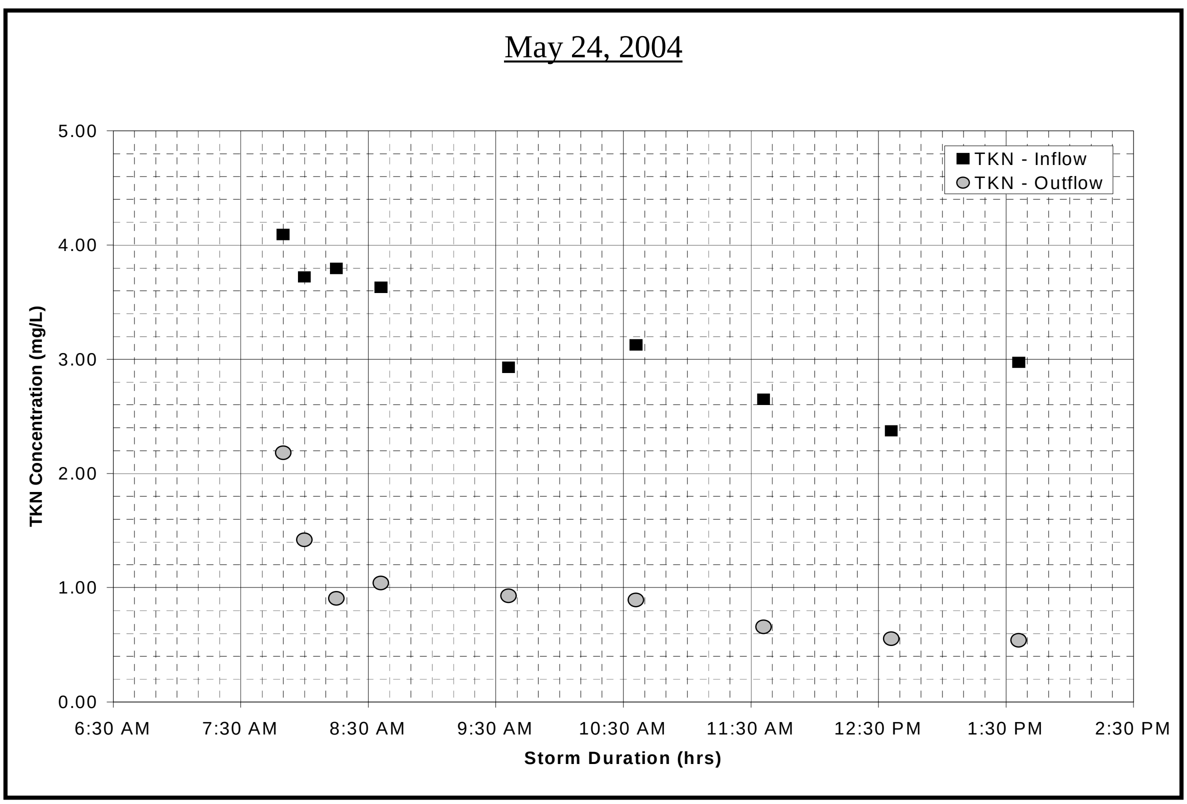
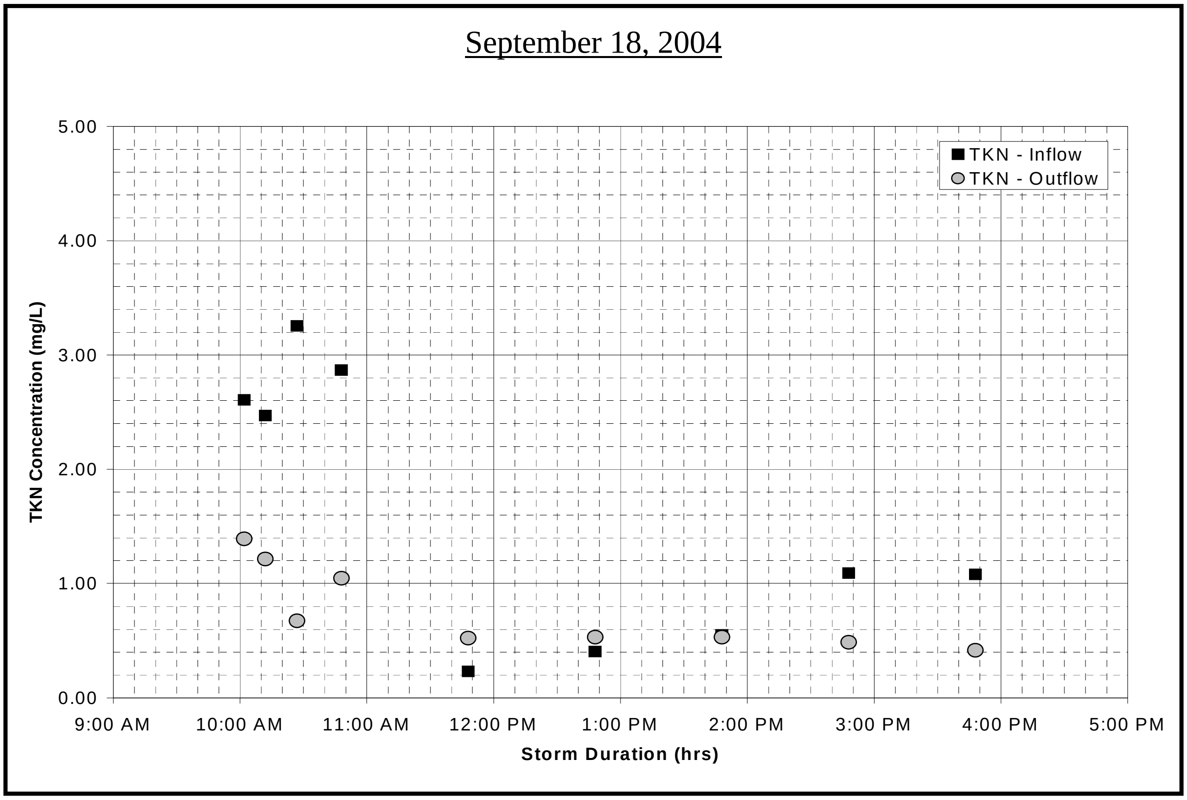
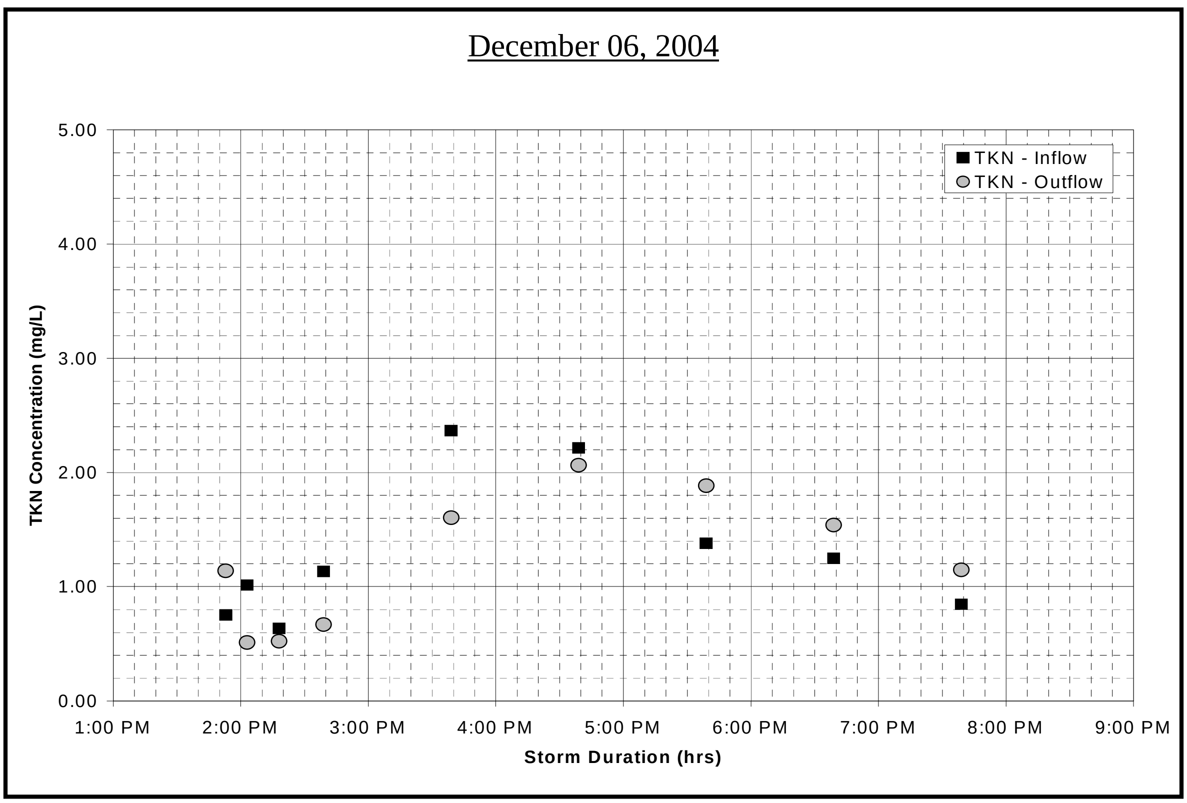
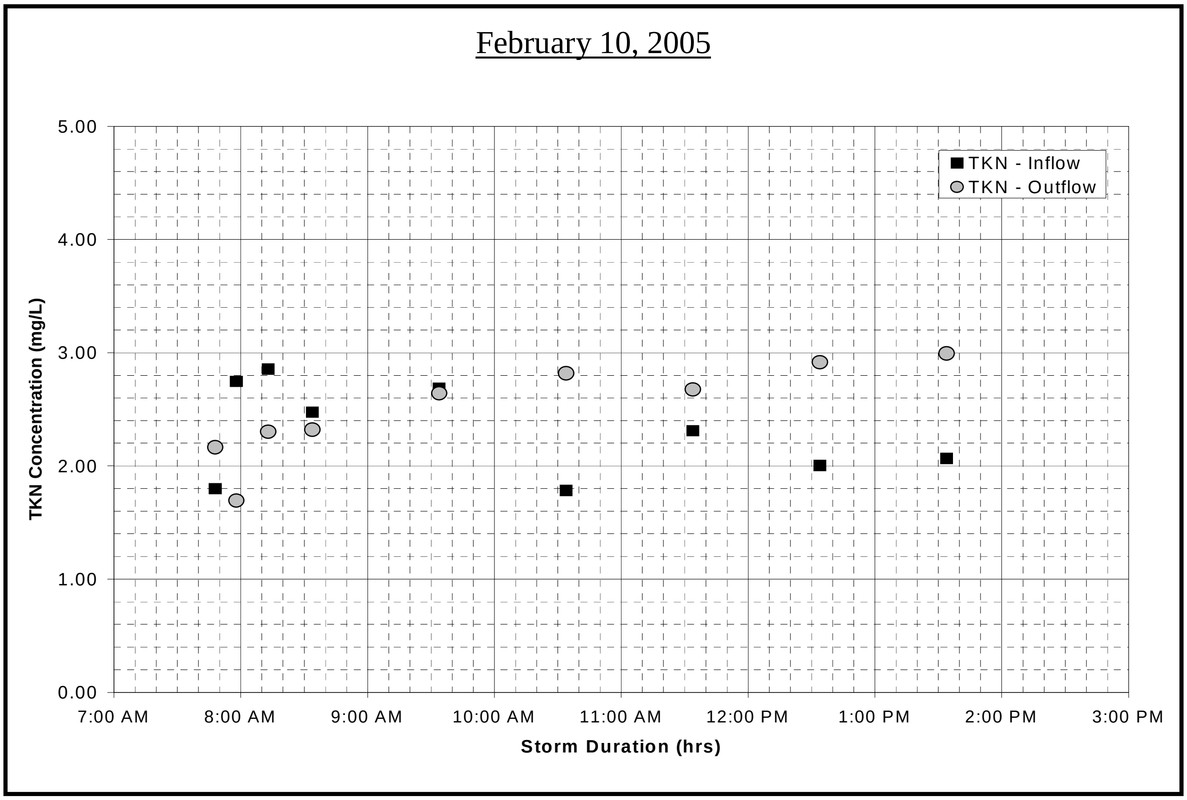
Appendix I: TKN Loading, All Events, Vortechs® Unit


March 31, 2004
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
Storm Duration (hrs)

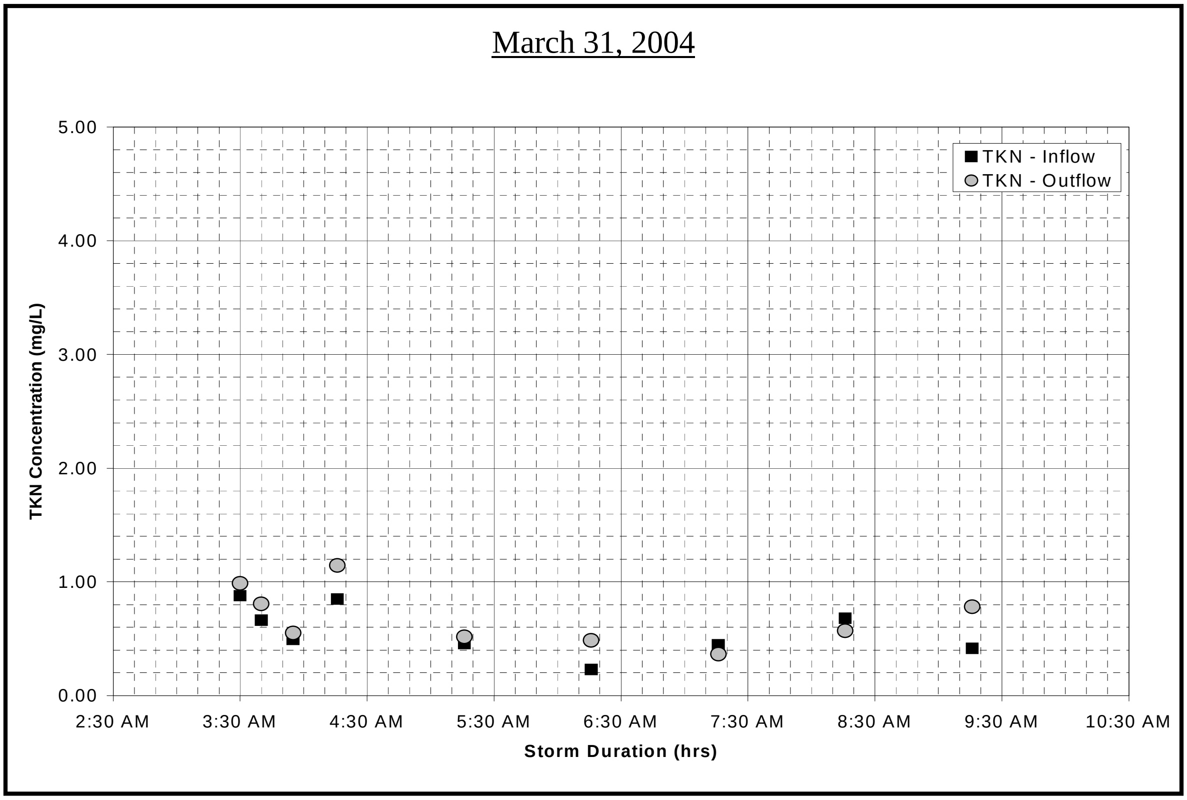

May 24, 2004
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
6:30 AM
7:30 AM
8:30 AM
9:30 AM
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
Storm Duration (hrs)

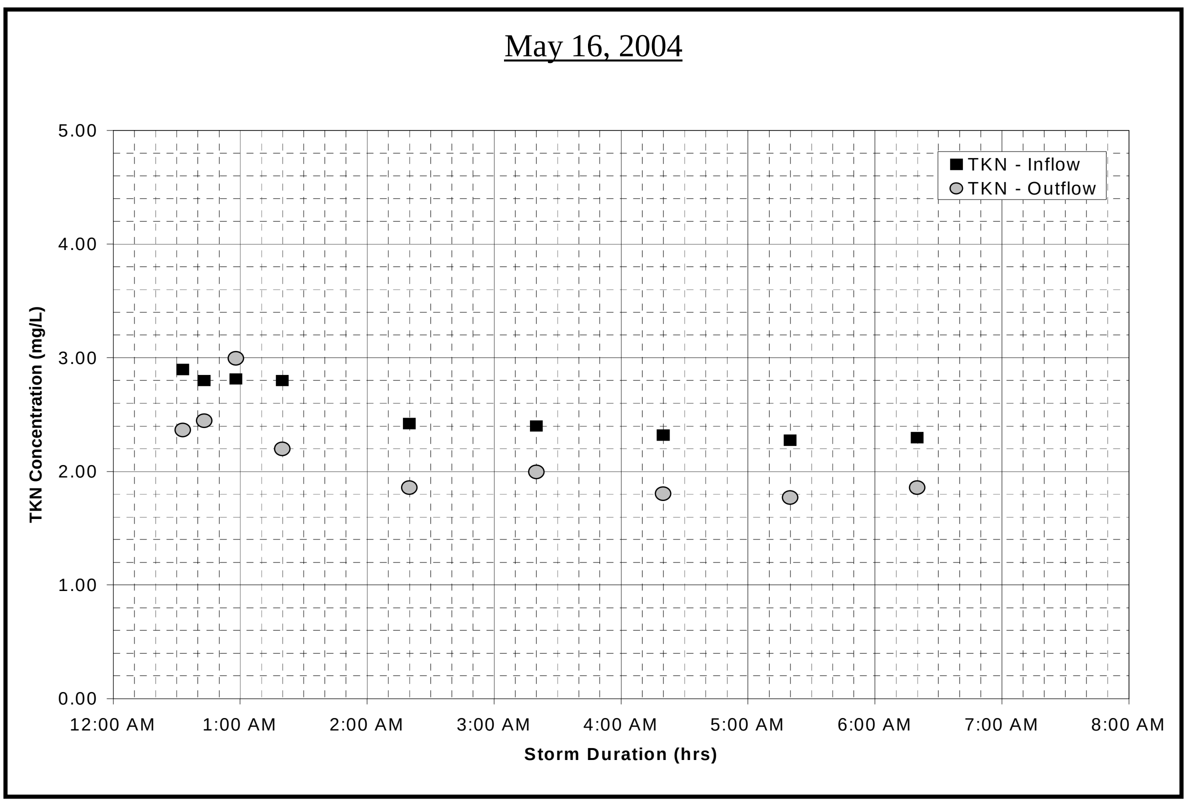

September 18, 2004
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)


December 06, 2004
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
Storm Duration (hrs)

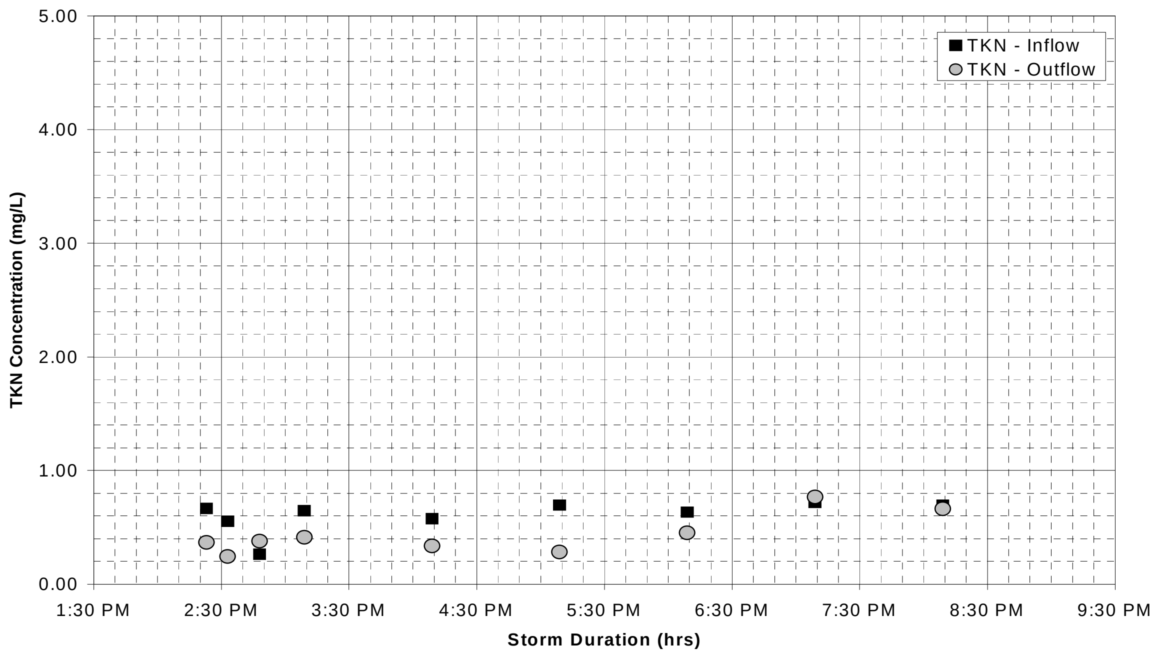

February 10, 2005
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)

Appendix J: TKN Loading, All Events, V2B1™ Unit

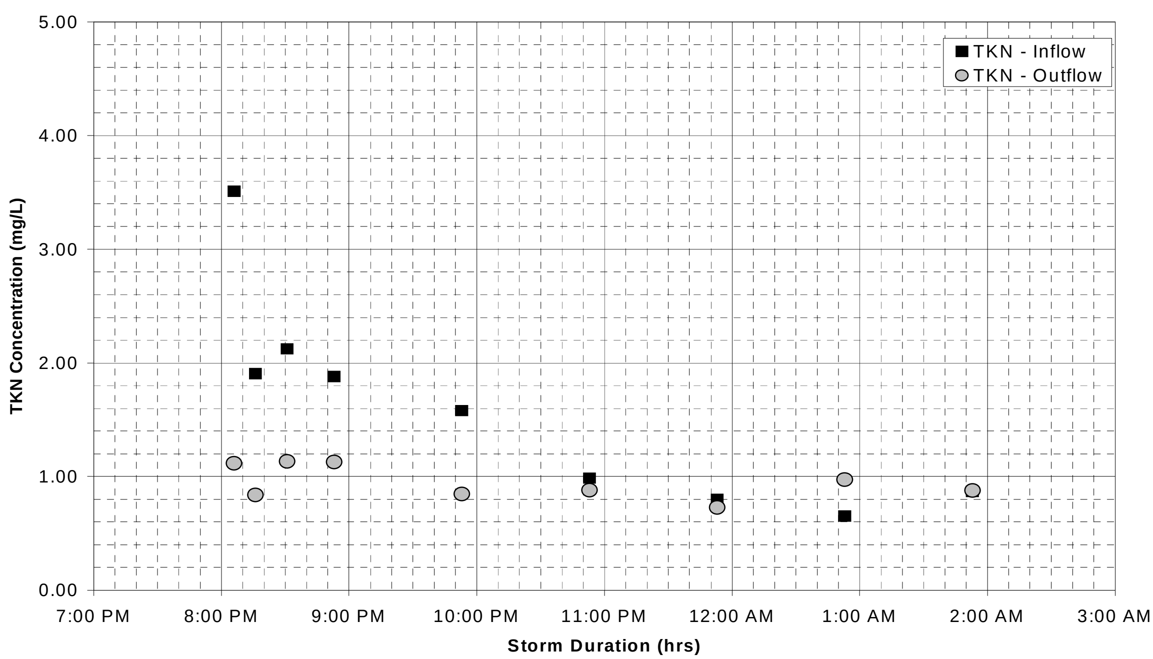

March 31, 2004
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
7:30 AM
8:30 AM
9:30 AM
10:30 AM
Storm Duration (hrs)

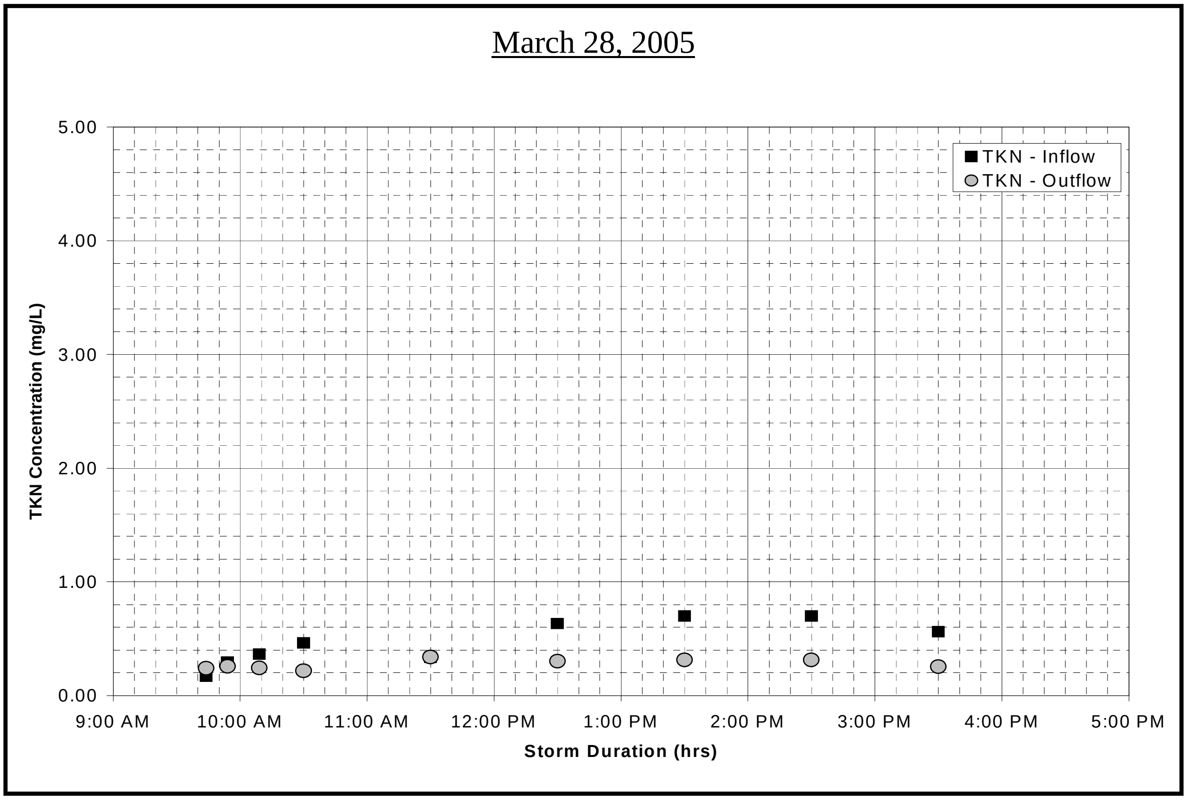

May 16, 2004
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
Storm Duration (hrs)

September 8, 2004

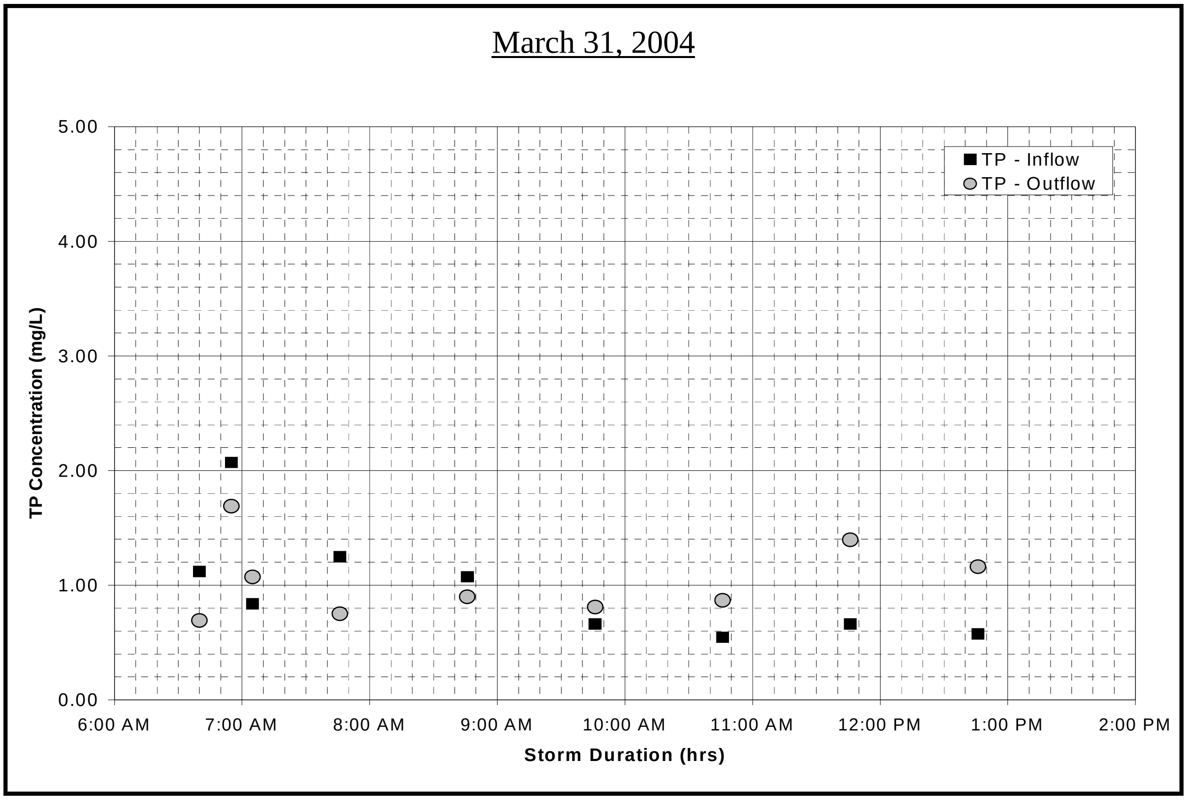


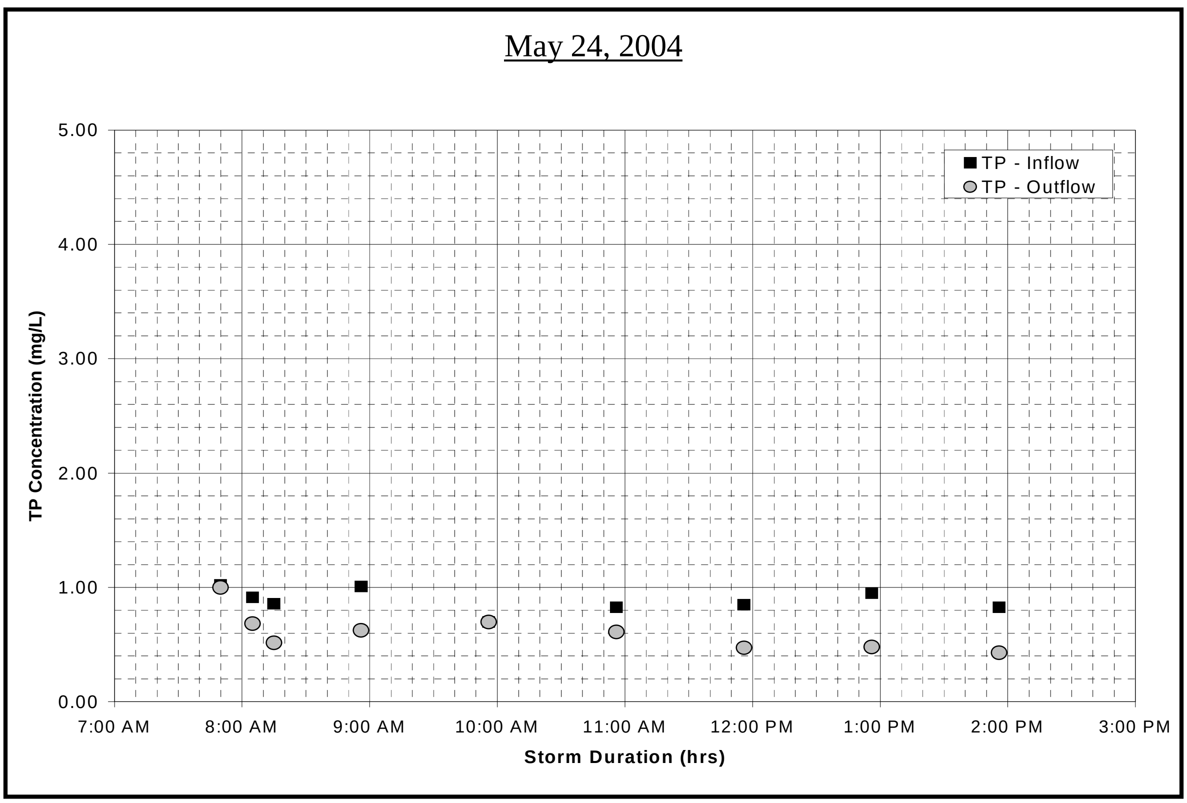
November 12, 2005

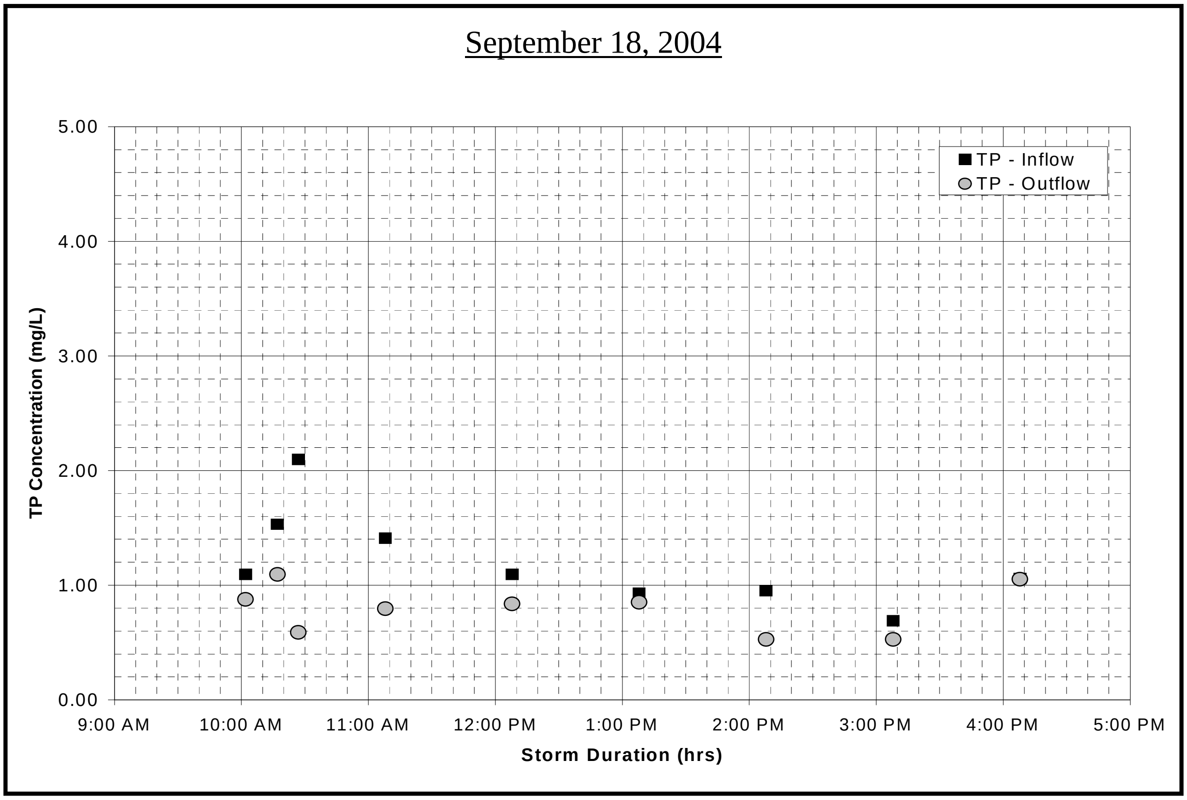


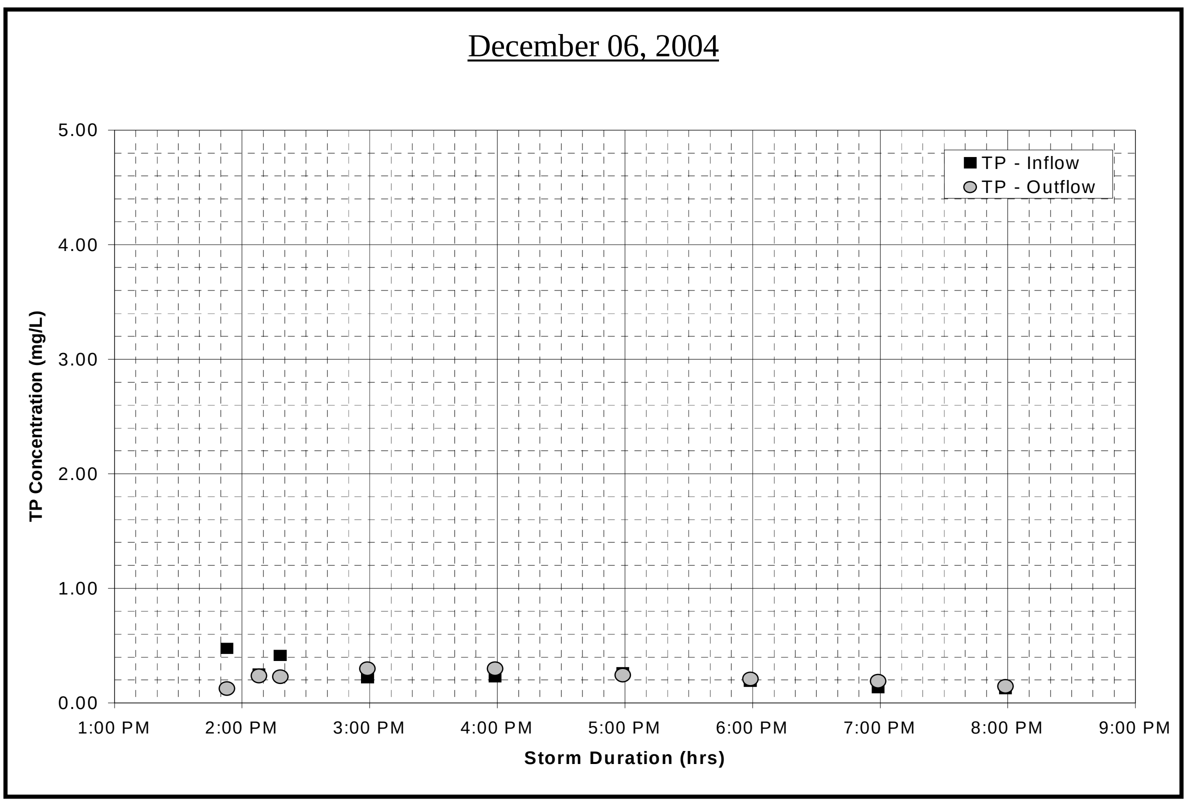

March 28, 2005
TKN - Inflow
TKN - Outflow
TKN Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)

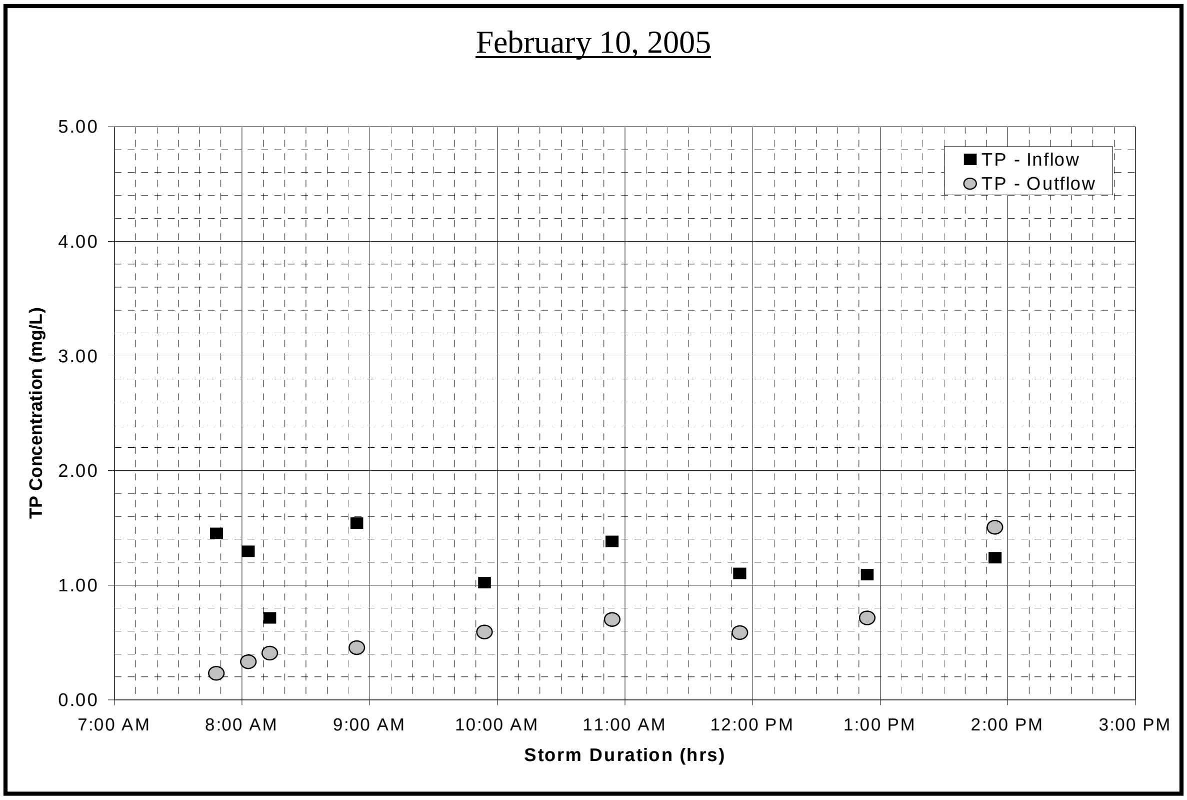
Appendix K: TP Loading, All Events, Vortechs® Unit


March 31, 2004
TP - Inflow
TP - Outflow
TP Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
Storm Duration (hrs)

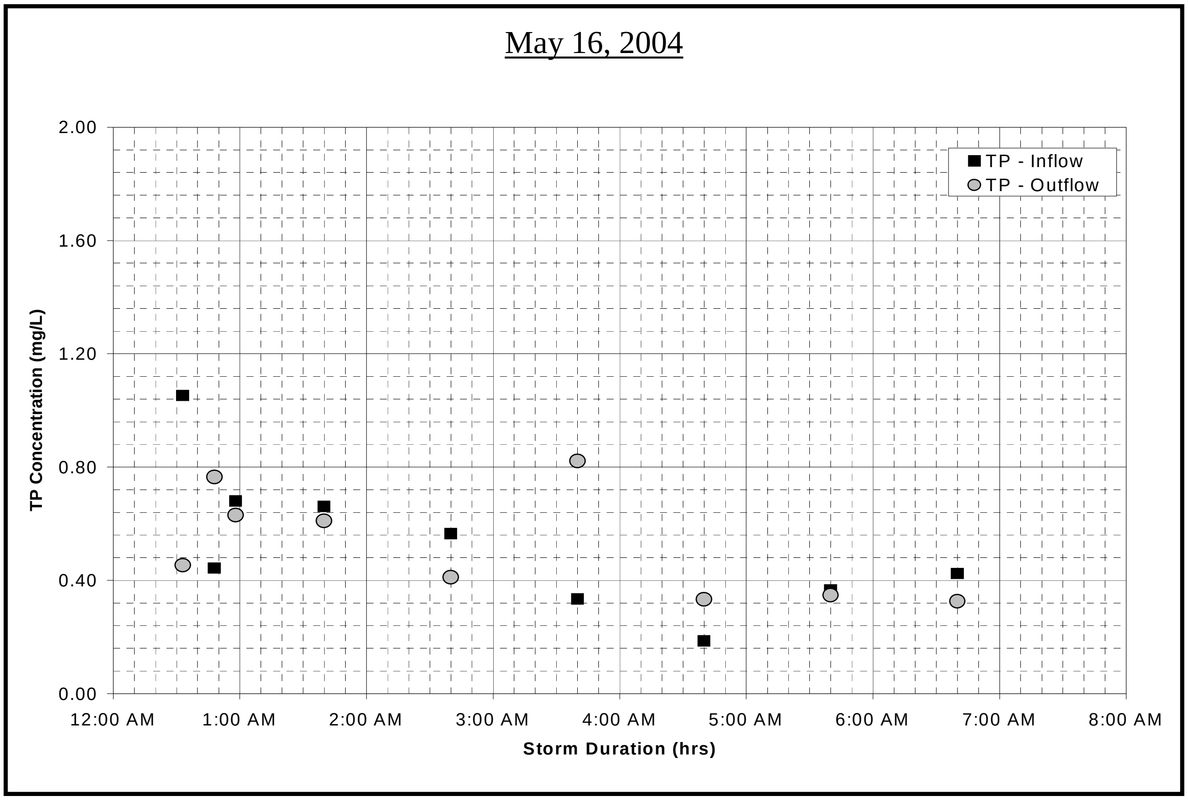

May 24, 2004
TP - Inflow
TP - Outflow
TP Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)

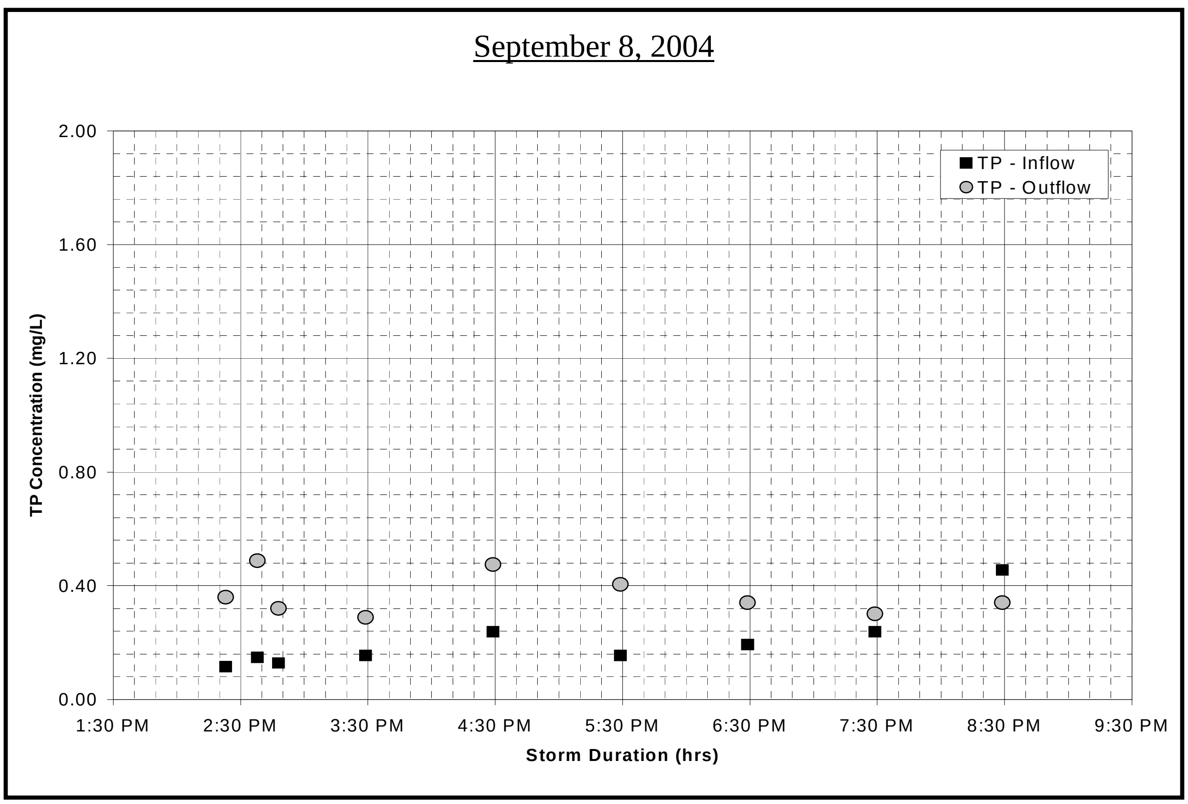

September 18, 2004
TP Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)
TP - Inflow
TP - Outflow

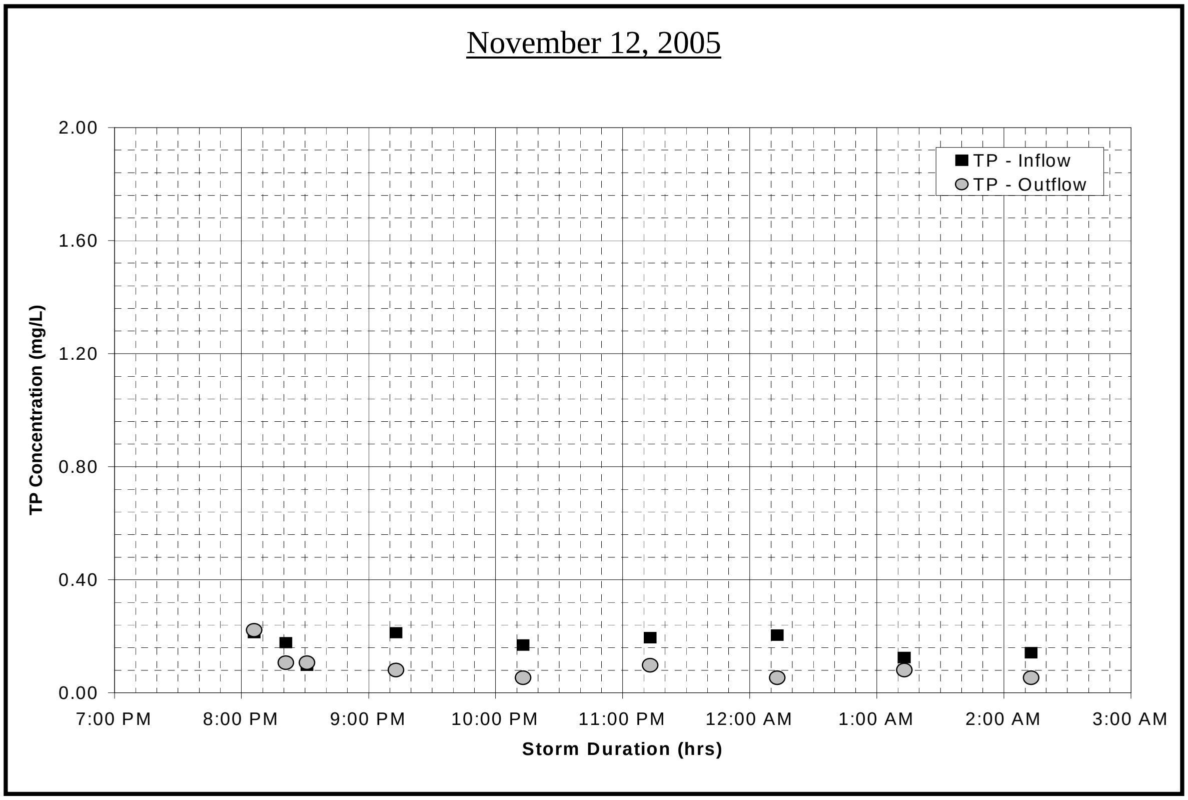

December 06, 2004
TP Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
Storm Duration (hrs)
TP - Inflow
TP - Outflow

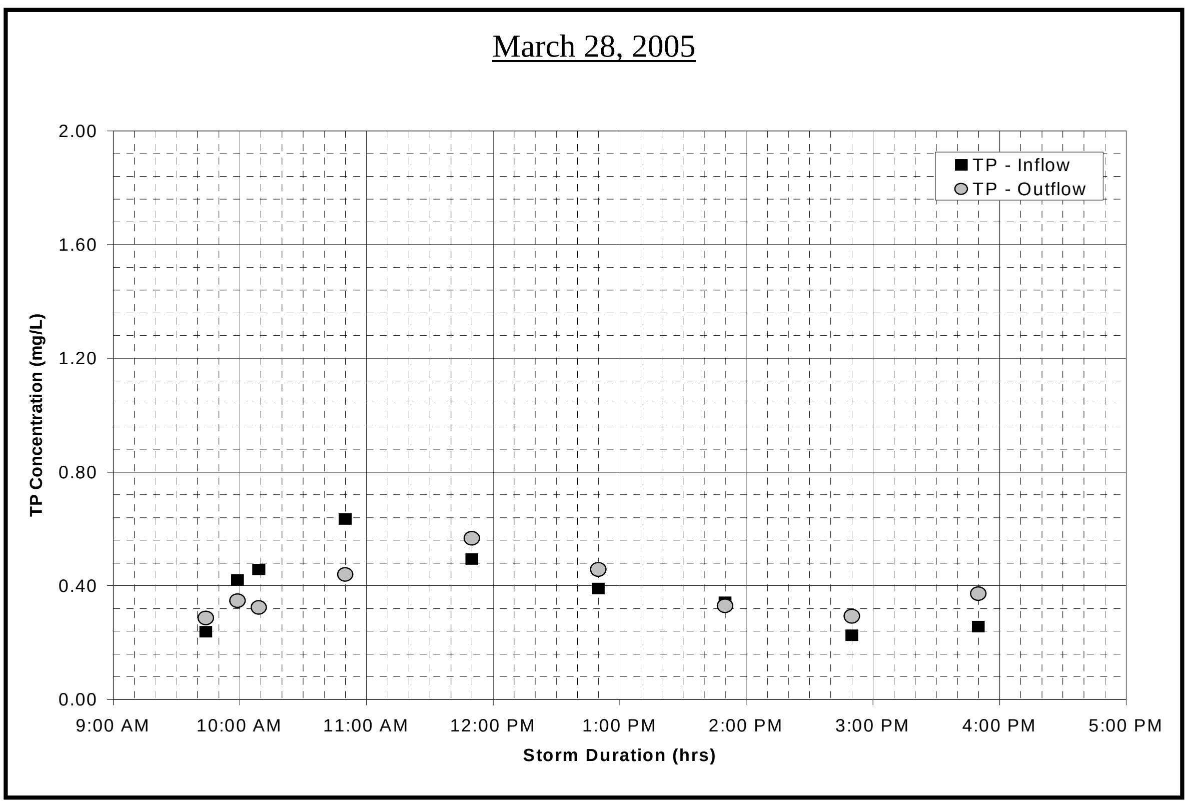

February 10, 2005
TP Concentration (mg/L)
5.00
4.00
3.00
2.00
1.00
0.00
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)
TP - Inflow
TP - Outflow

Appendix L: TP Loading, All Events, V2B1™ Unit


May 16, 2004
TP - Inflow
TP - Outflow
TP Concentration (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
Storm Duration (hrs)


September 8, 2004
TP - Inflow
TP - Outflow
TP Concentration (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
Storm Duration (hrs)


November 12, 2005
2.00
1.60
1.20
0.80
0.40
0.00
TP Concentration (mg/L)
TP - Inflow
TP - Outflow
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
1:00 AM
2:00 AM
3:00 AM
Storm Duration (hrs)


March 28, 2005
2.00
1.60
1.20
0.80
0.40
0.00
TP Concentration (mg/L)
TP - Inflow
TP - Outflow
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)

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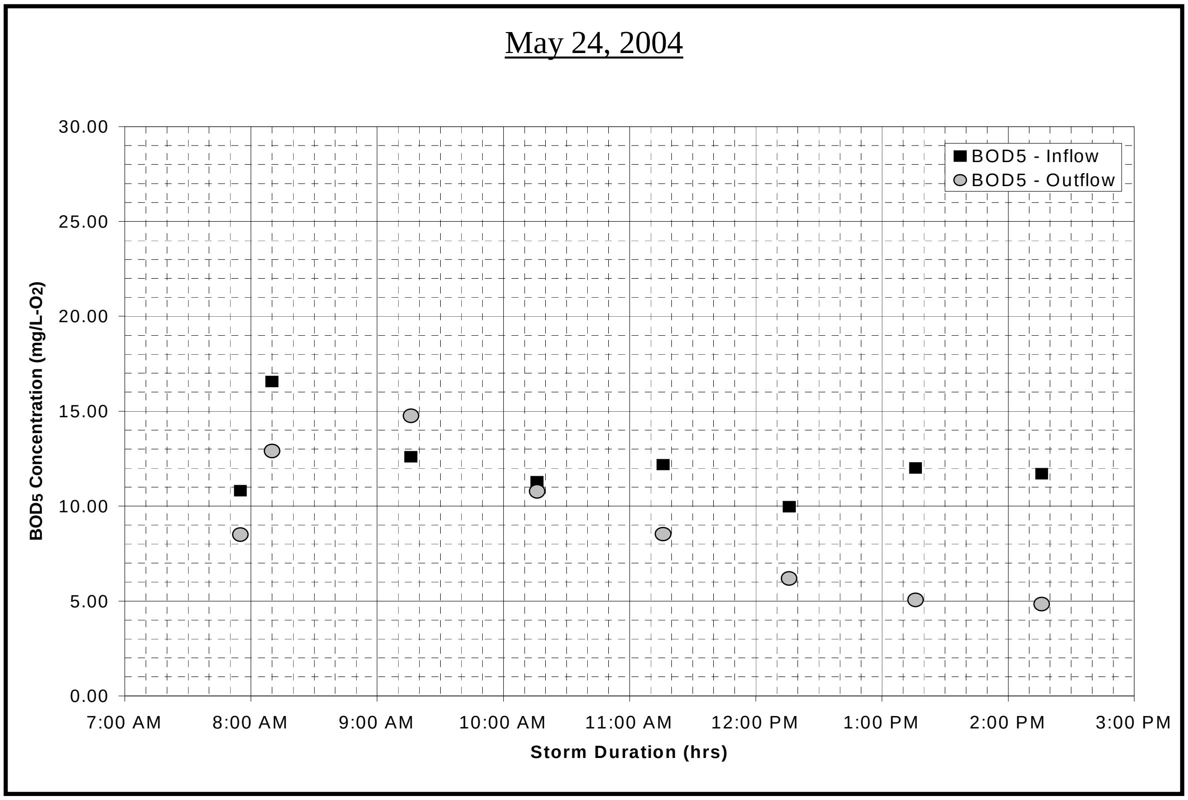
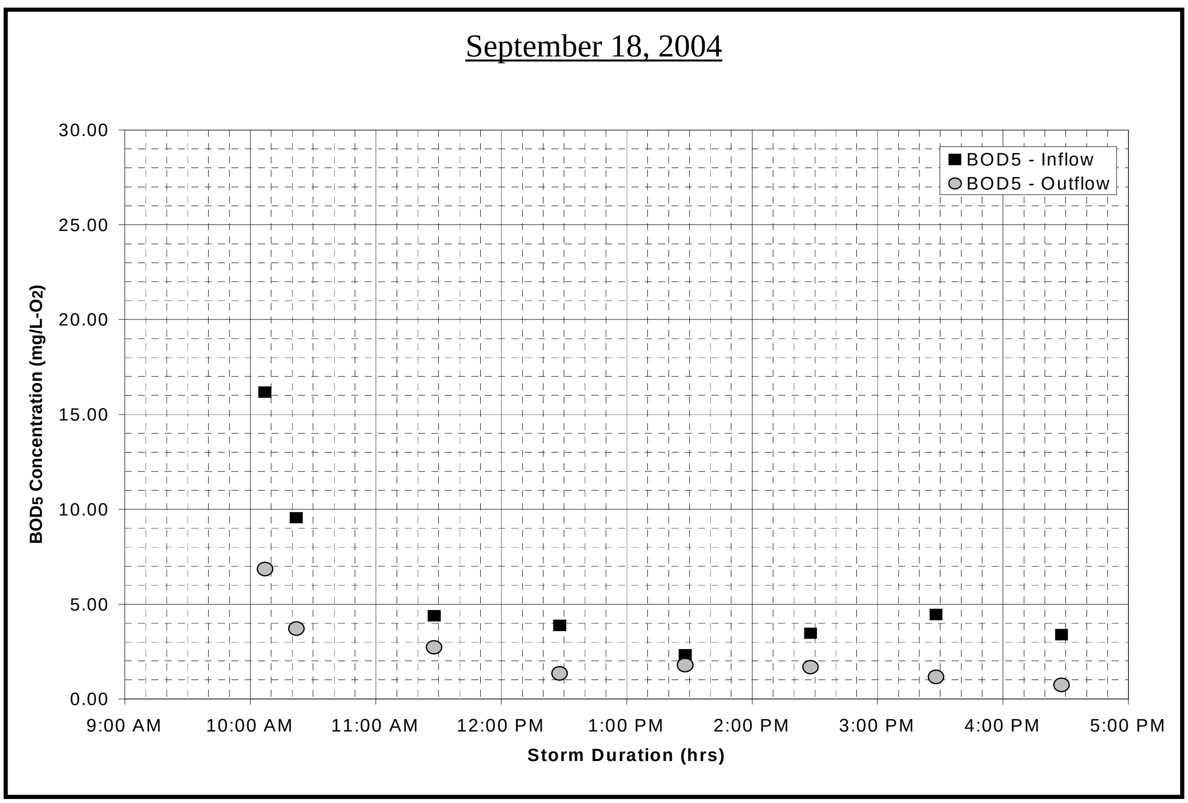
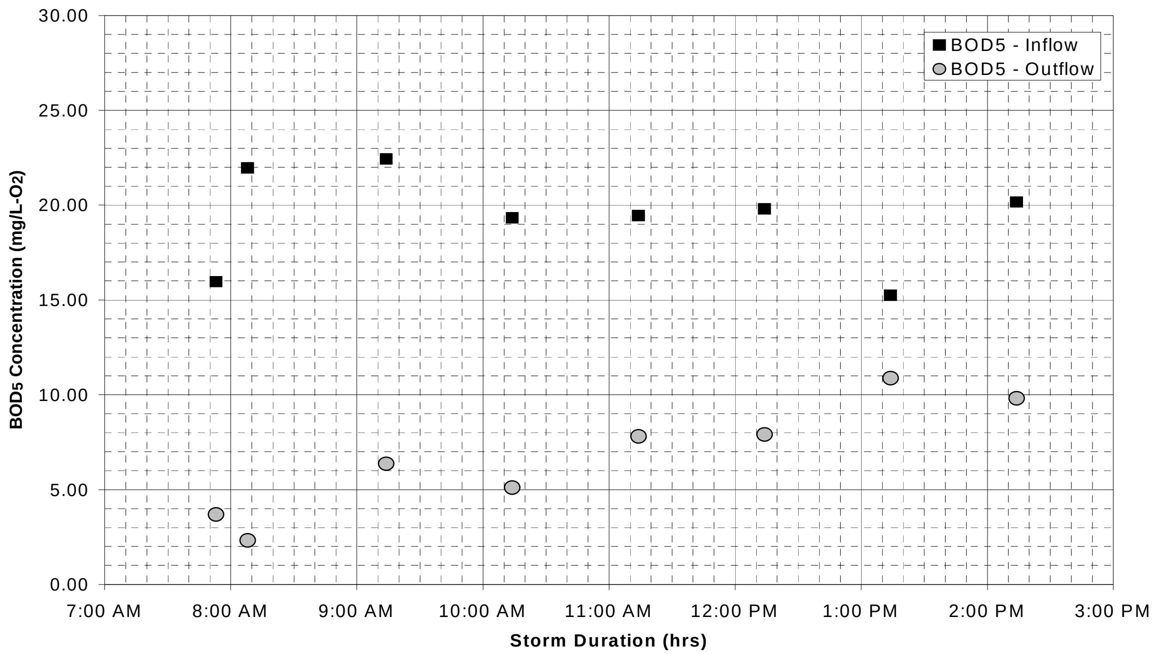
Appendix M: BOD_5 Loading, All Events, Vortechs® Unit

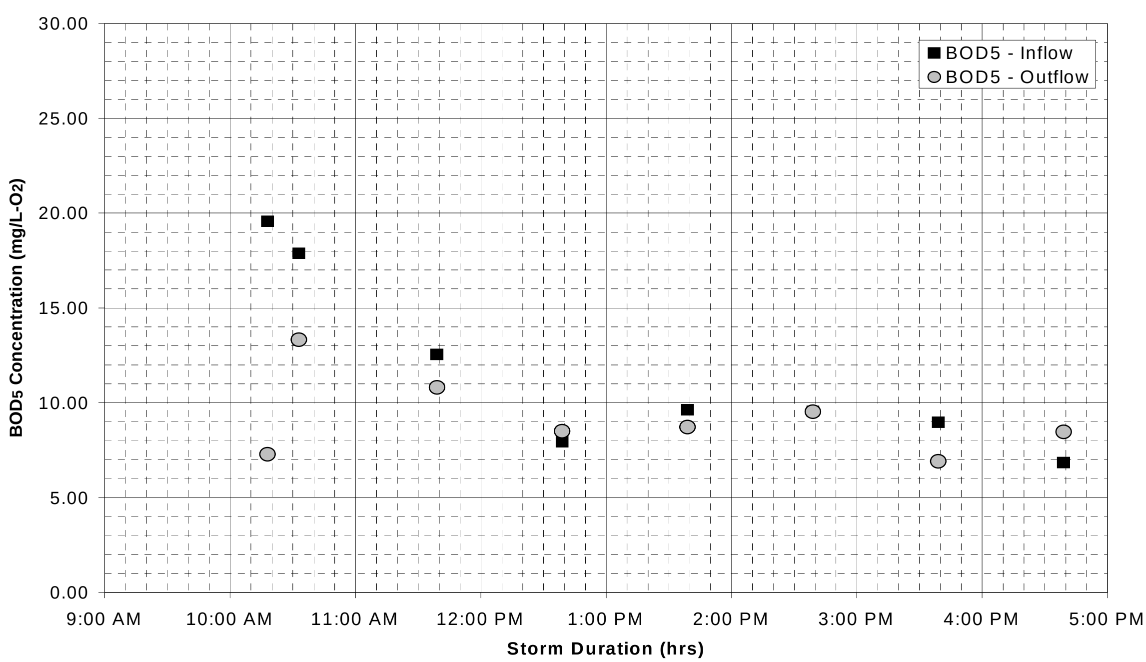

May 24, 2004
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD5 Concentration (mg/L-O2)
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)
BOD5 - Inflow
BOD5 - Outflow


September 18, 2004
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD5 Concentration (mg/L-O2)
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)
BOD5 - Inflow
BOD5 - Outflow

February 10, 2005



April 23, 2005



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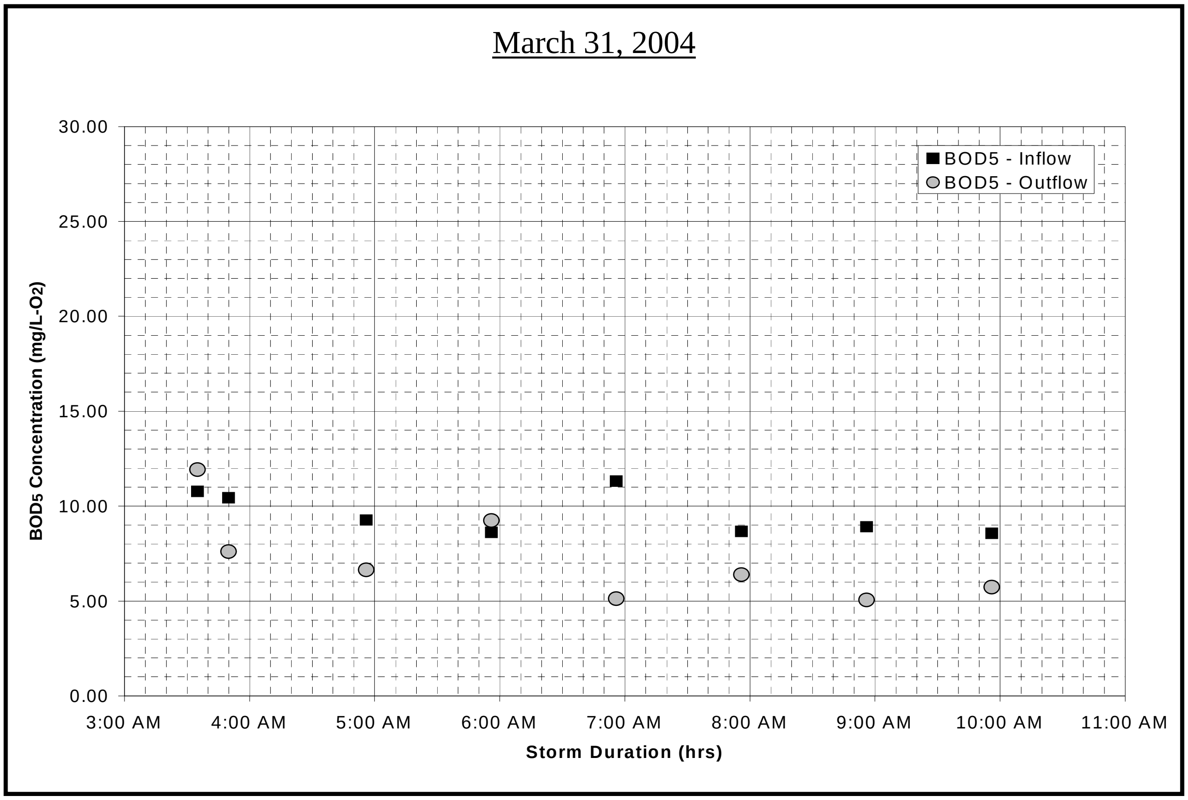
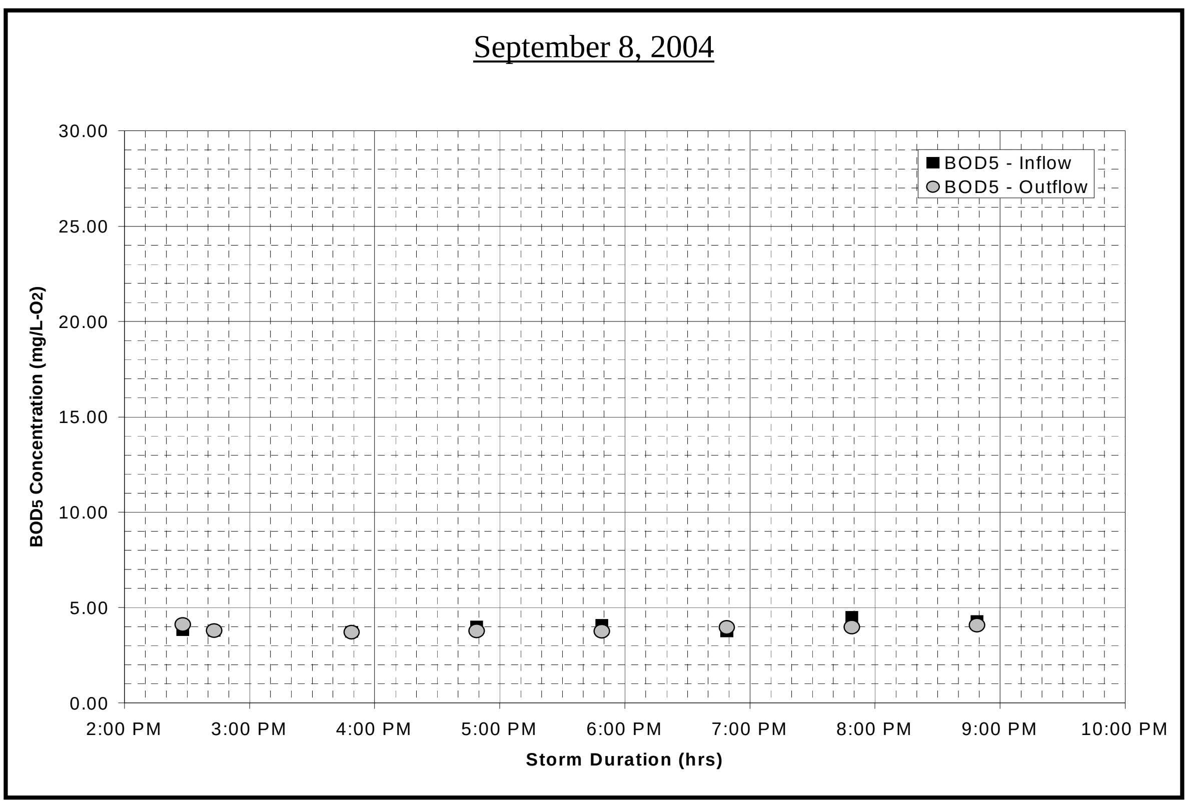
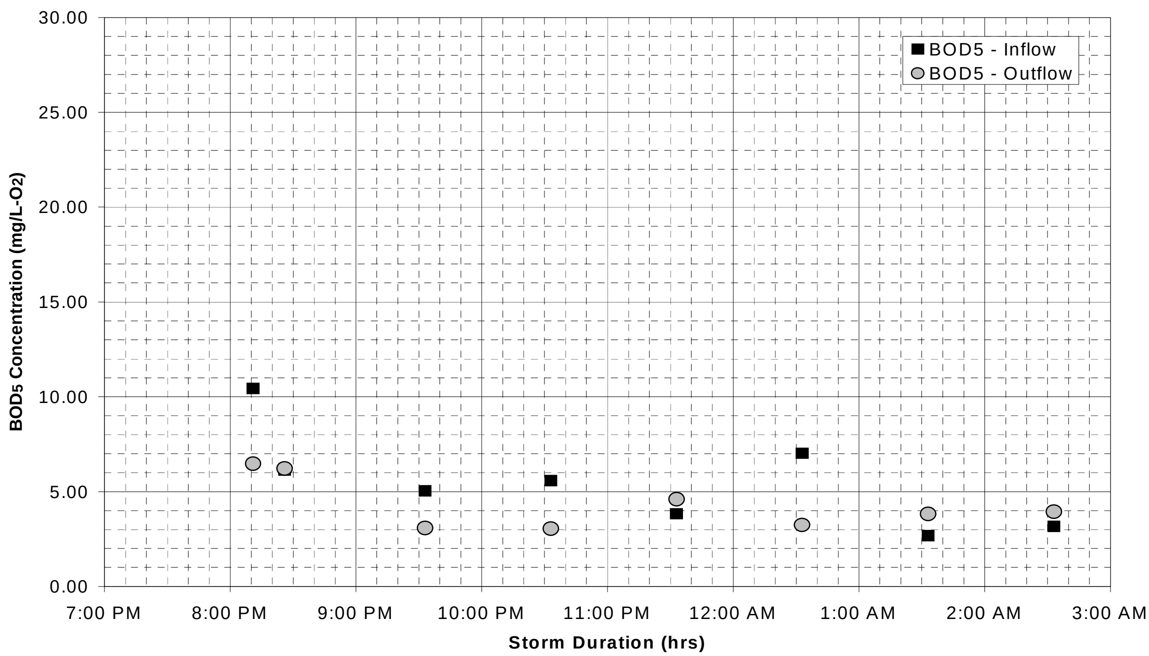
Appendix N: BOD_5 Loading, All Events, V2B1™ Unit

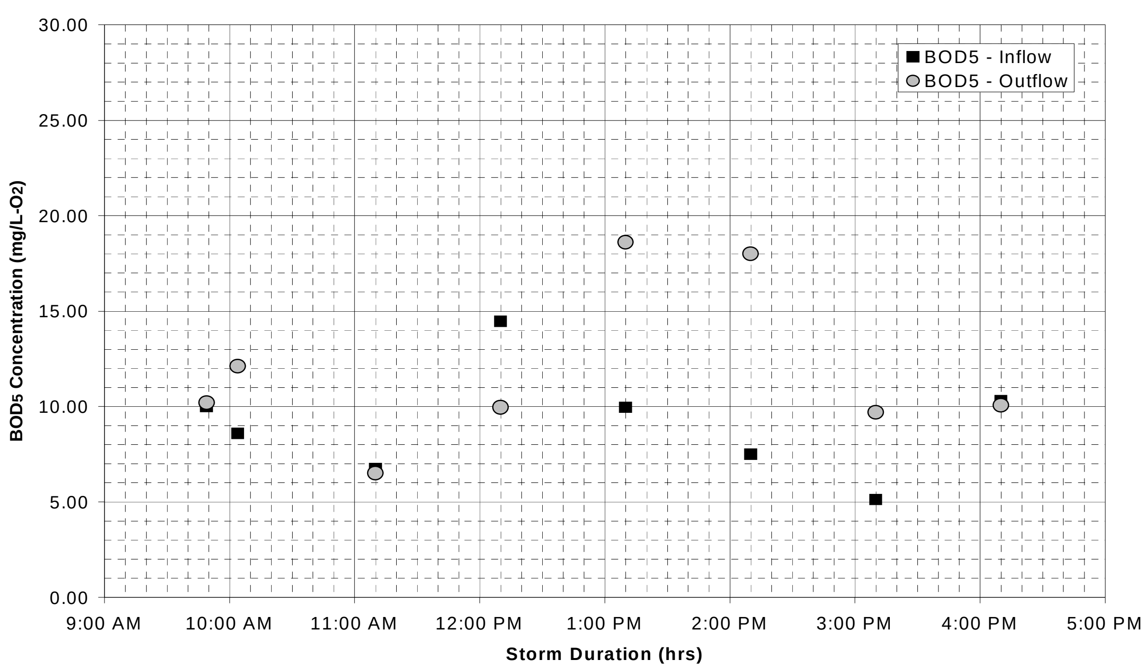

March 31, 2004
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD5 Concentration (mg/L-O2)
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
Storm Duration (hrs)
BOD5 - Inflow
BOD5 - Outflow


September 8, 2004
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD5 Concentration (mg/L-O2)
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
Storm Duration (hrs)
BOD5 - Inflow
BOD5 - Outflow

November 12, 2005



March 28, 2005



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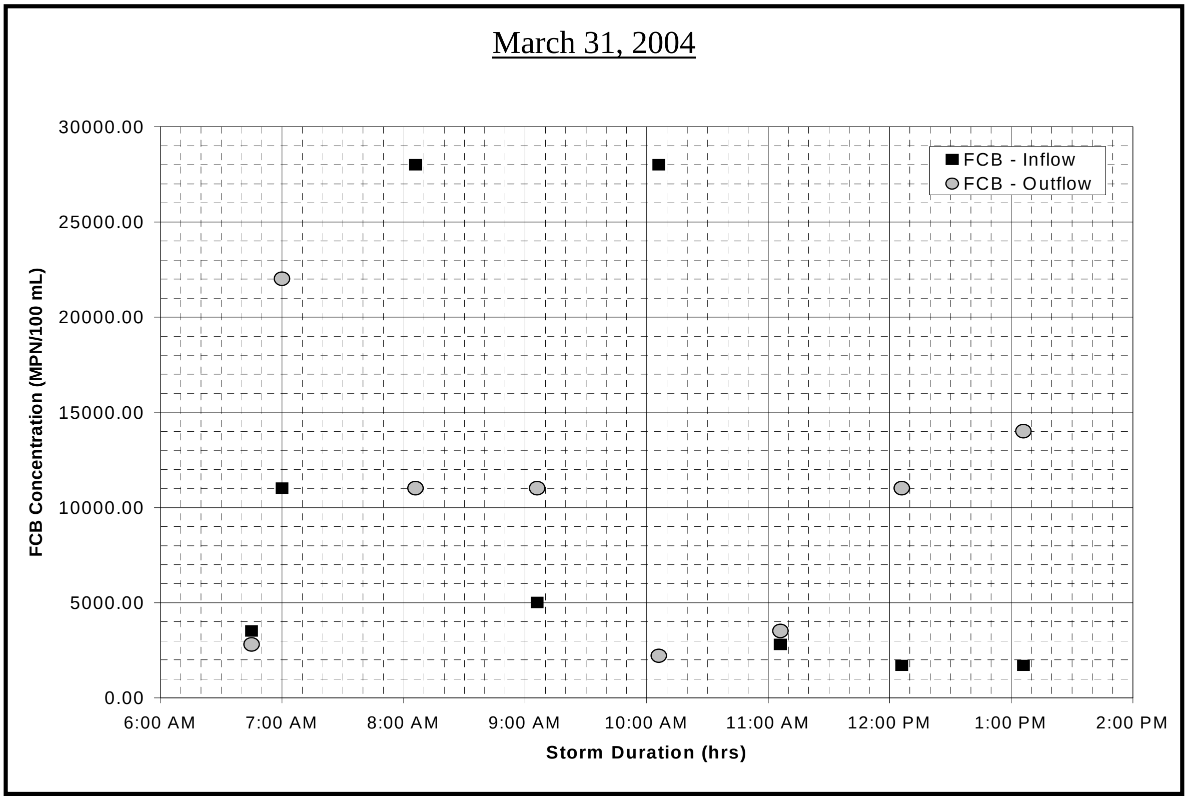
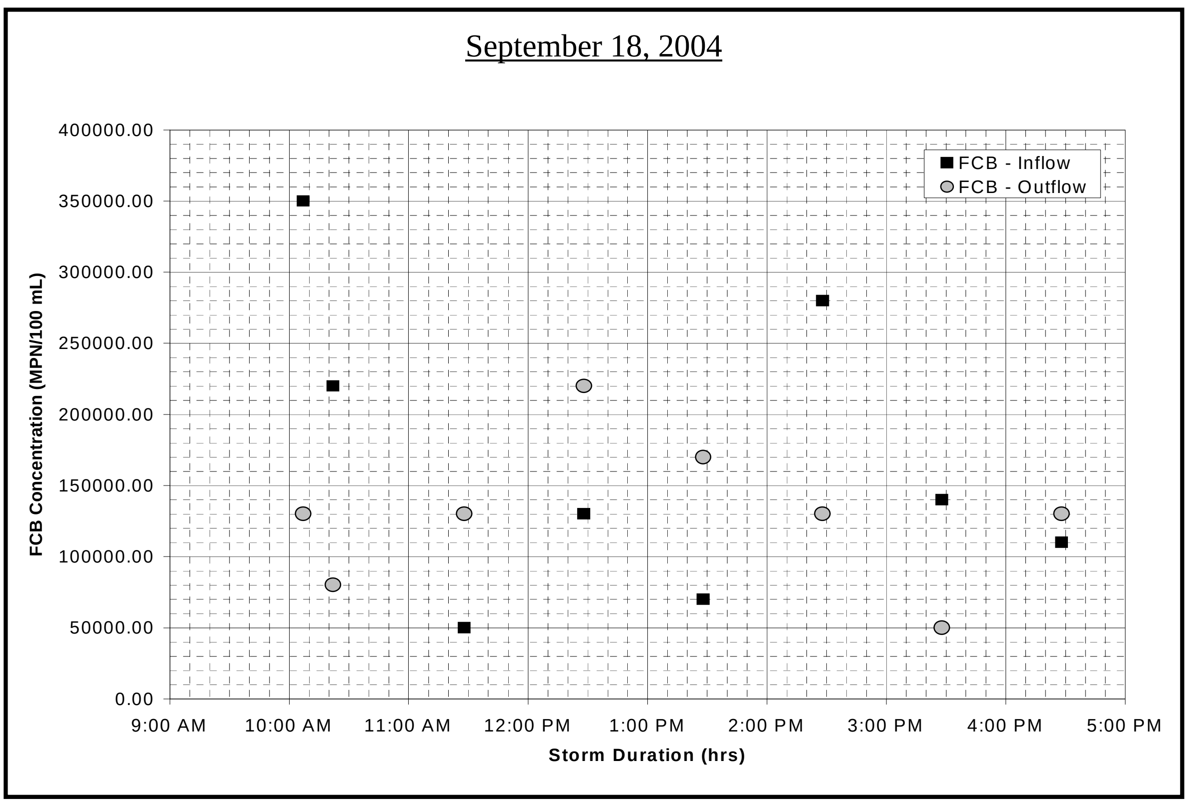
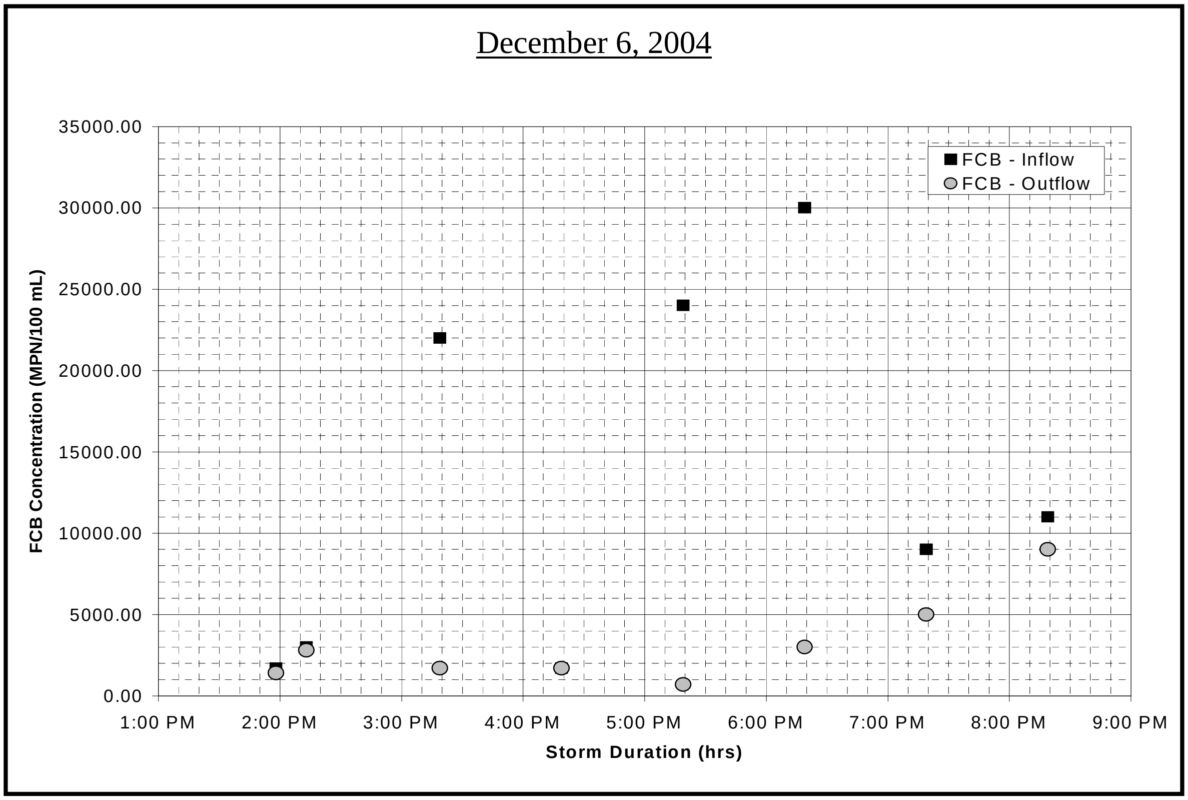
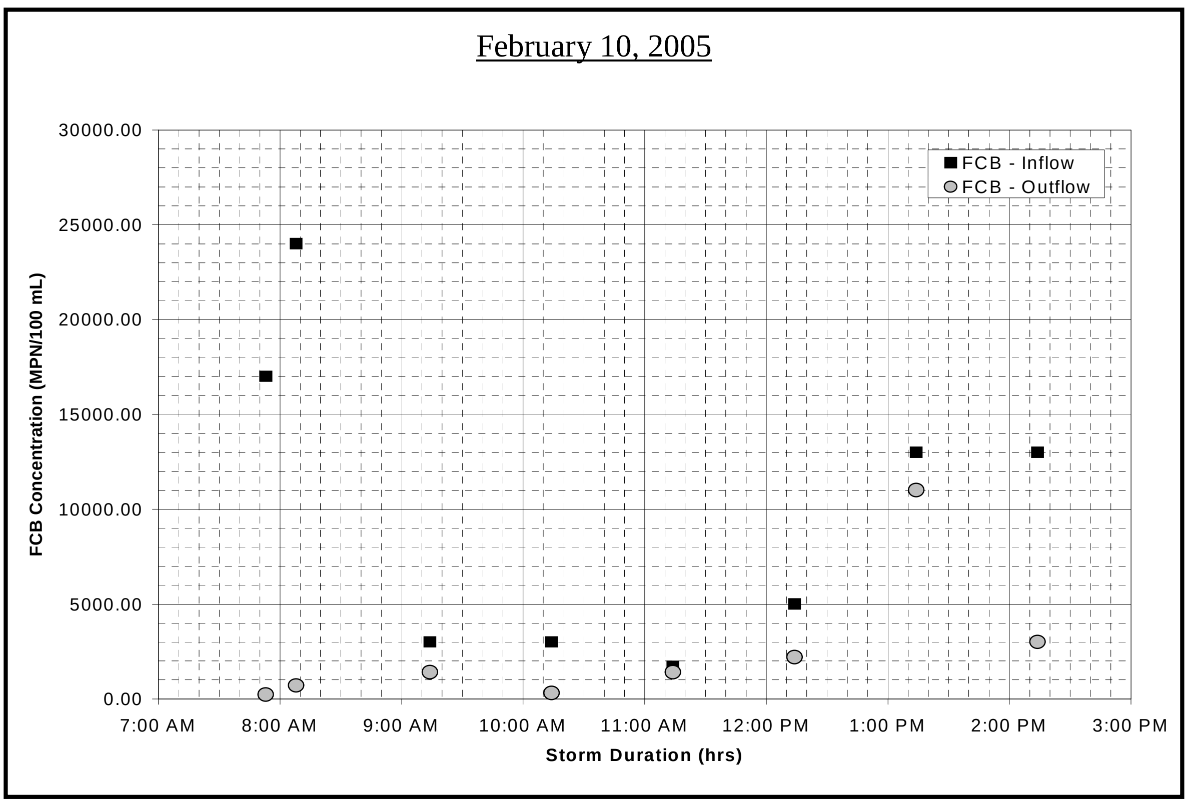
Appendix O: FCB Loading, All Events, Vortechs® Unit


March 31, 2004
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
FCB Concentration (MPN/100 mL)
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
Storm Duration (hrs)
FCB - Inflow
FCB - Outflow


September 18, 2004
400000.00
350000.00
300000.00
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
FCB Concentration (MPN/100 mL)
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
Storm Duration (hrs)
FCB - Inflow
FCB - Outflow



December 6, 2004
FCB - Inflow
FCB - Outflow
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
FCB Concentration (MPN/100 mL)
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
Storm Duration (hrs)



February 10, 2005
FCB - Inflow
FCB - Outflow
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
FCB Concentration (MPN/100 mL)
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
Storm Duration (hrs)

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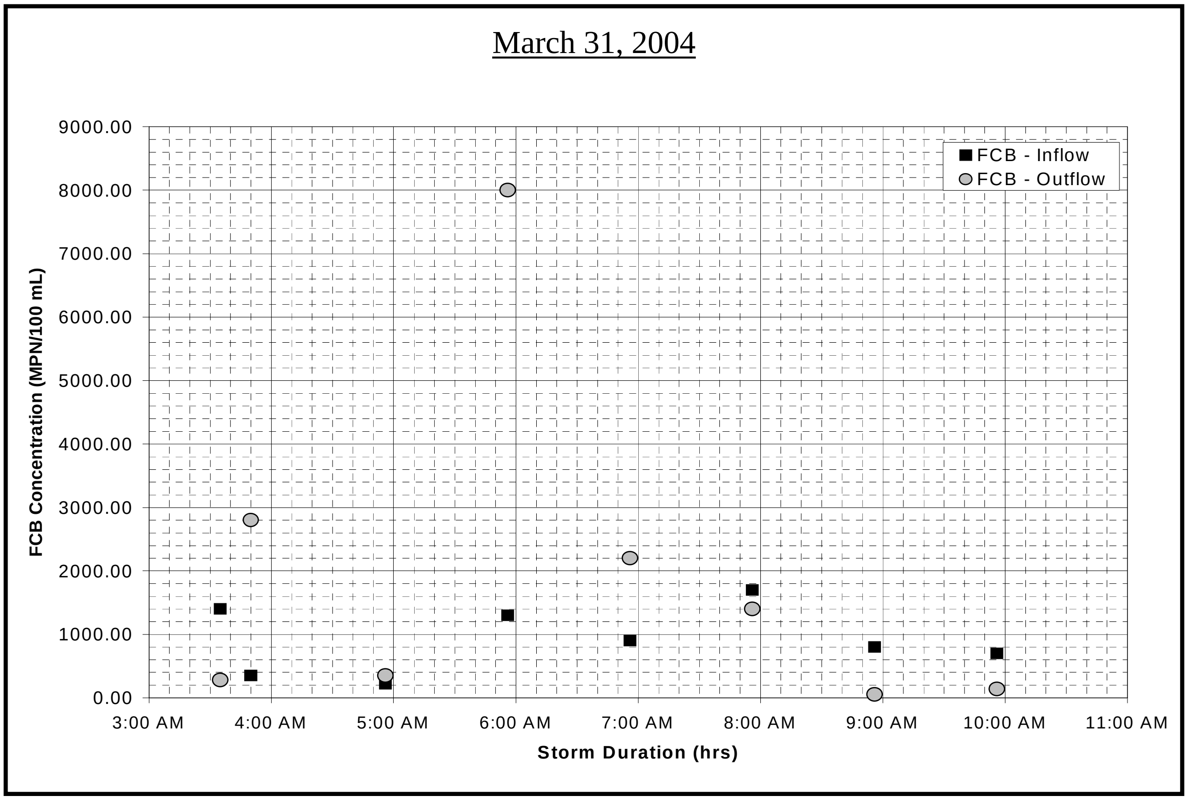
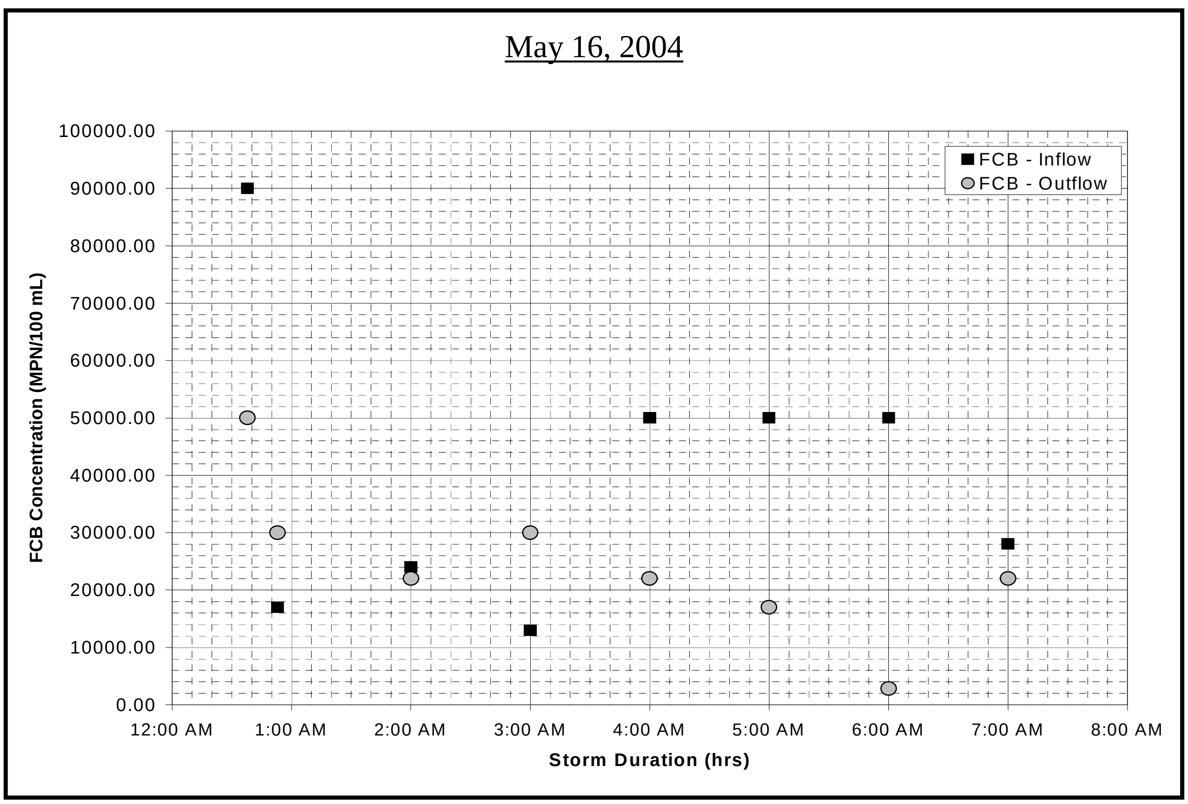
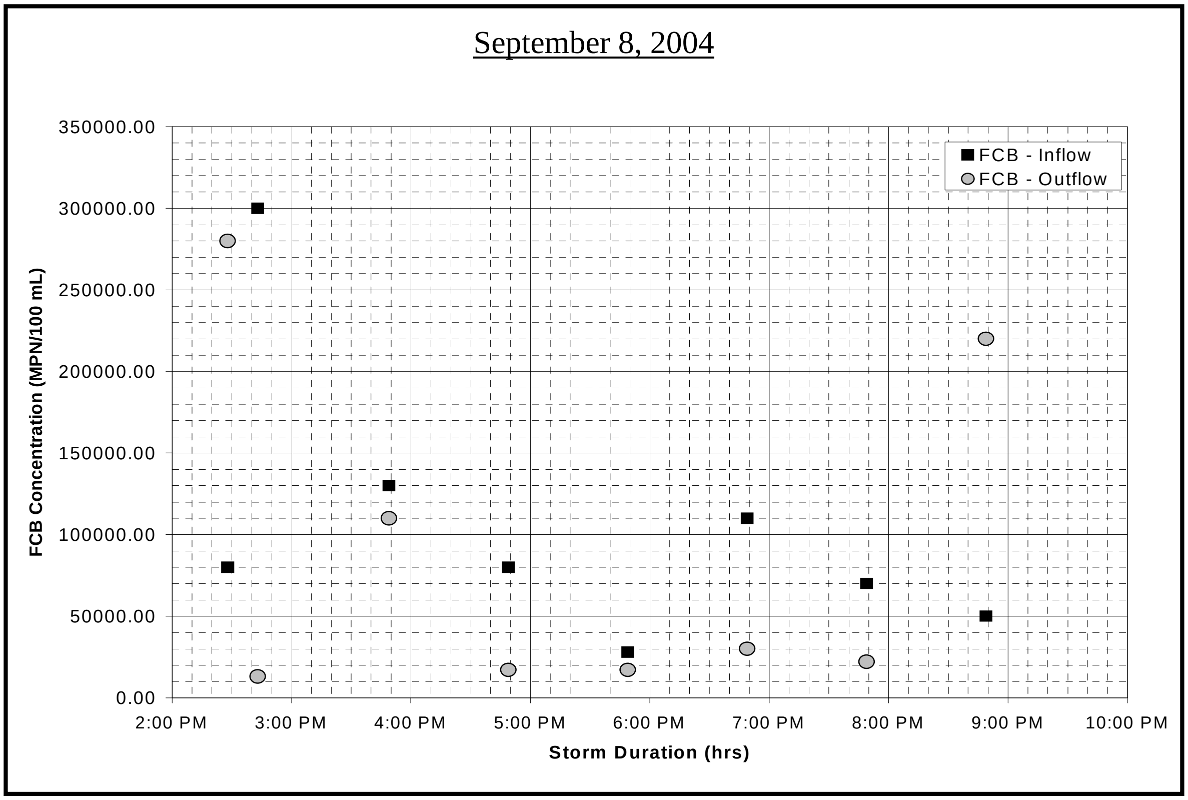
Appendix P: FCB Loading, All Events, V2B1™ Unit

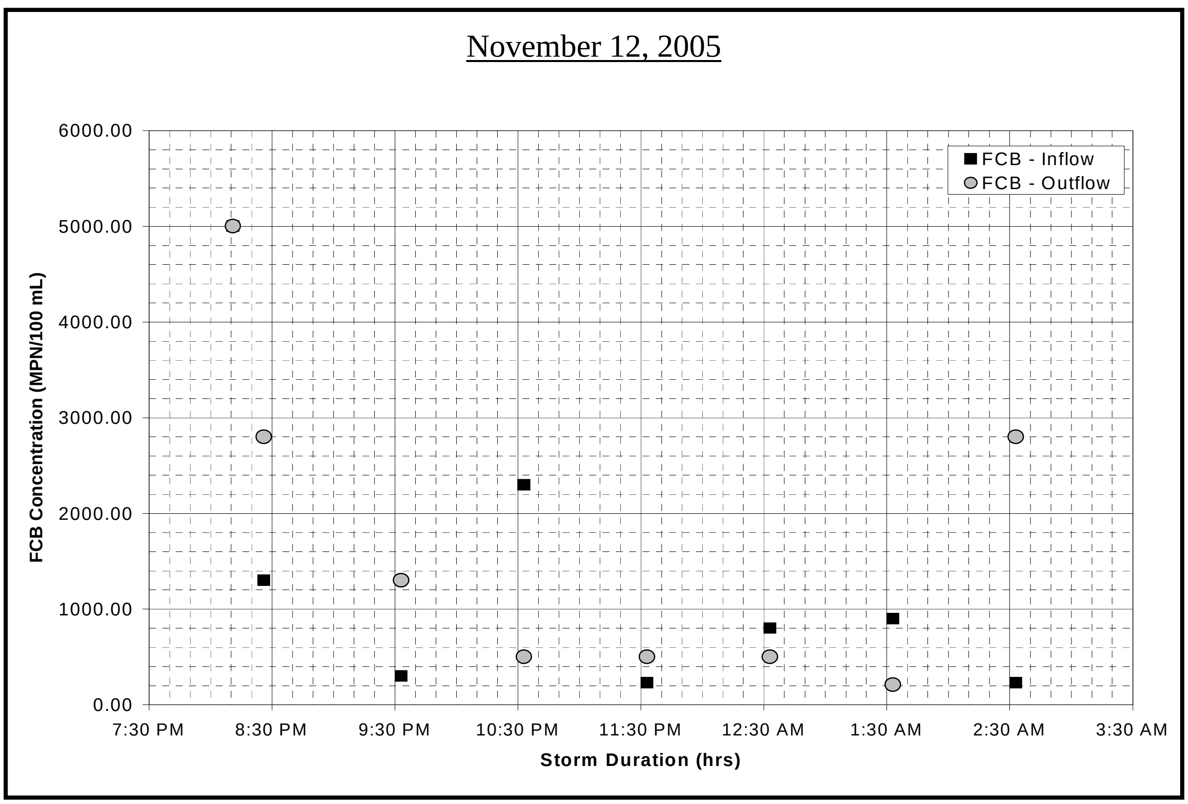


March 31, 2004
FCB - Inflow
FCB - Outflow
FCB Concentration (MPN/100 mL)
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
Storm Duration (hrs)



May 16, 2004
FCB - Inflow
FCB - Outflow
FCB Concentration (MPN/100 mL)
100000.00
90000.00
80000.00
70000.00
60000.00
50000.00
40000.00
30000.00
20000.00
10000.00
0.00
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
Storm Duration (hrs)


September 8, 2004
FCB - Inflow
FCB - Outflow
FCB Concentration (MPN/100 mL)
350000.00
300000.00
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
Storm Duration (hrs)


November 12, 2005
FCB - Inflow
FCB - Outflow
FCB Concentration (MPN/100 mL)
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
12:30 AM
1:30 AM
2:30 AM
3:30 AM
Storm Duration (hrs)