EXHIBIT VIII.C.17.a.Attachment "A"

STORM WATER PRACTICE FEASIBILITY STUDY REPORT

ALCO/MAXON REDEVELOPMENT

City of Schenectady

County of Schenectady

State of New York

PREPARED BY:

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July 29, 2013
Revised February 14, 2014
Revised February 19, 2014
Revised June 11, 2014

INTRODUCTION

The applicant for approval of this project and the applicant for approval of the plan under GP#0-10-001 ALCO Maxon Holdings, LLC having its office at 695 Rotterdam Industrial Park, Schenectady, NY 12306. Their phone number is (315) 76-5610.

The proposed project is known as ALCO Redevelopment. A revised Phase 1 Plan has been developed and other uses are as currently contemplated for the site including a potential casino. The total plan considered and consists of the following components:

Residential Opportunities in 260 Dwelling units (Apartments and/or Condos) for employees on the site (Offices, Hotel or Retail uses) or in the City of Schenectady, Village of Scotia or the Town of Glenville all within walking, bicycle distance or accessible public transportation.

Offices, Hotel and Retail Employment. This site is proposed to include in excess of 170,000 SF of retail space, 30,000 SF of supermarket, 60,000 SF of office space and a 124 room hotel. Included within the retail uses are a banquet house and uses to provide for visitors, residents and individuals travelling on the Mohawk.

The two contemplated phases have the following components which are consistent with the uses evaluated by the Draft Environmental Impact Statement.

Description	Phase 1	Phase 2	Total
Hotel	124 Rooms	-	124 Rooms
Supermarket	30,000 SF	-	30,000 SF
Other Retail/Office	30.000 SF	150,000	180,000
Retail Below Apts.	50,000	-	50,000
Sub Total Retail/Office	110,000	150,000	260,000
Apartments	184	51	235
Condominiums	25	-	25
Total Housing	209	-	260

Based upon a proposed casino/hotel construction, an alternative development scenario has been considered. The changes in the total site development on the site is as shown below

Description	**Uses as per Above**	**Alternative Proposal Totals**
Residential	**50 Townhouses** **50 Condos** **100 Apartments**	**0 Townhouses** **70 Condos** **304 Apartments**
Hotel	**124 Rooms**	**124 Rooms**
Commercial (General Office)	**450,000 sq. ft.**	**60,000 sq. ft.**
Retail (including Restaurant)	**75,000 sq. ft**	**130,000 sq. ft.**
Casino Banquet Facility	**-**	**450 seat**
Supermarket	**-**	**0 sq. ft.**
Casino/Gaming Facility	**-**	**150,000 sq. ft**
Hotel	**-**	**150 rooms**
Light Industrial	**-**	**72,000 sq. ft.**

Creating Public Access to Waterfront through use of Harbor, Boat Docking Facilities in the Mohawk River, Walkways, Parking Facilities, Sitting Areas, amphitheater, Pedestrian access and connection point to the Mohawk Hudson Hike-Bike Trail.

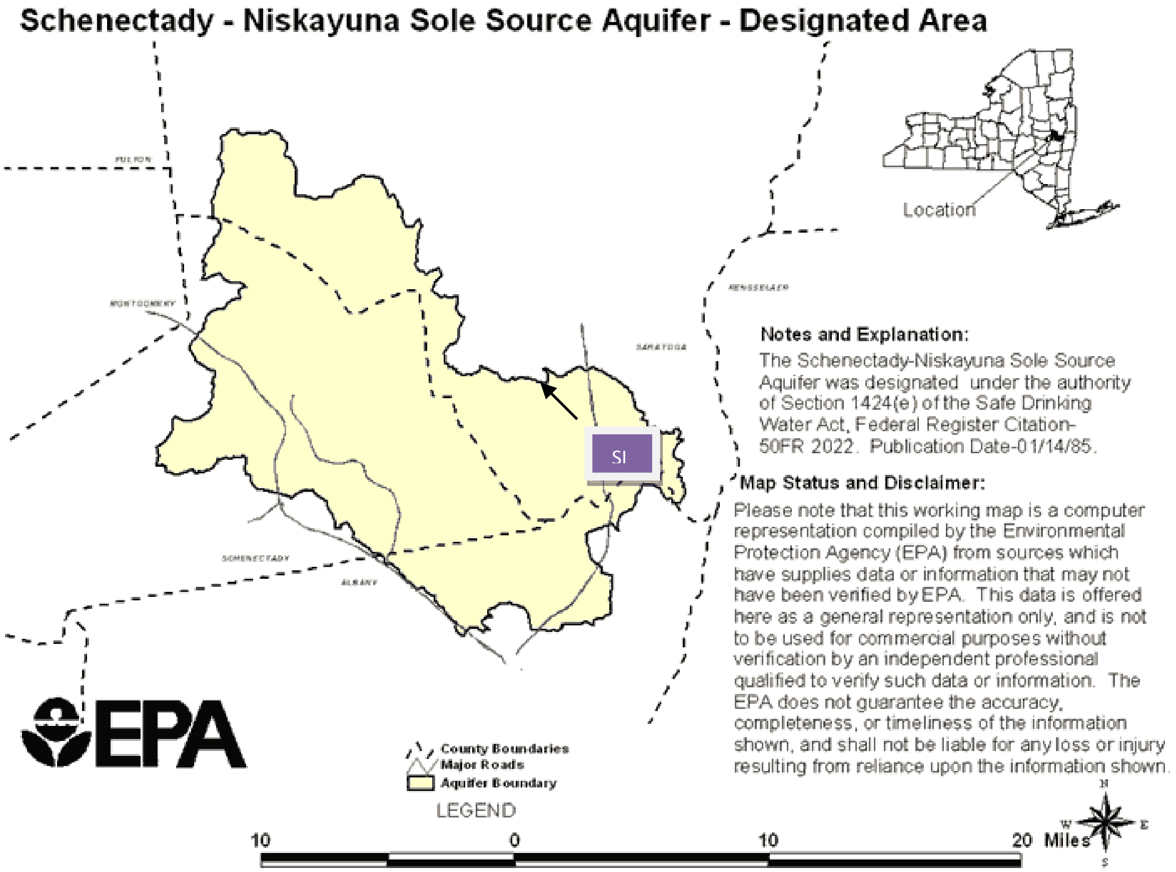
Providing street trees, shrubs and plantings in an urban streetscape.

Assisting in Flood Control by widening the Mohawk River, stabilizing the banks and creating a new harbor.

EXISTING SOILS

The existing soils are primarily remnants of the former development and testing has indicated that there are contaminants in the soil making the use of infiltration methods inadvisable under SPDES GP#0-010-001.

The Schenectady-Niskayuna Sole Source Aquifer impacts many areas within the City of Schenectady. The area of this project is inside of the sole source aquifer as shown on the map below. Sole Source Aquifers require special consideration for infiltration systems and infiltration through contaminated soils is not permitted.


Schenectady - Niskayuna Sole Source Aquifer - Designated Area

Notes and Explanation:

The Schenectady-Niskayuna Sole Source Aquifer was designated under the authority of Section 1424(e) of the Safe Drinking Water Act, Federal Register Citation-50FR 2022. Publication Date-01/14/85.

Map Status and Disclaimer:

Please note that this working map is a computer representation compiled by the Environmental Protection Agency (EPA) from sources which have supplies data or information that may not have been verified by EPA. This data is offered here as a general representation only, and is not to be used for commercial purposes without verification by an independent professional qualified to verify such data or information. The EPA does not guarantee the accuracy, completeness, or timeliness of the information shown, and shall not be liable for any loss or injury resulting from reliance upon the information shown.

Schenectady Niskayuna Sole Source Aquifer

EXISTING DRAINAGE

Existing site drainage runs generally from the east to the west and is tributary to the Mohawk River which forms the west boundary of the site. The discharge from the site is through a system of catch basins connected to a series of culverts which discharge directly to the Mohawk River, a fifth order or higher stream course. Also there are three storm sewers and the College Creek which traverse portions of the site. All of these with the exception of College Creek will be abandoned or relocated.

PROPOSED DRAINAGE SYSTEM

This site is a Redevelopment site. Therefore the following exceptions to the use of infiltration practices apply:

From Section 3.2 of the New York State Stormwater Management Design Manual (Emphasis added)

Exceptions to Meeting the Runoff Reduction Volume (RRv) Criteria:

Although encouraged, meeting the RRv criteria is not required for redevelopment projects that meet the "Application Criteria" in Section 9.3.1 of this manual.

Meeting the RRv criteria is required for projects over karst geology. However, the use of large infiltration basins must be avoided. A geotechnical assessment is recommended for infiltration and recharge at small scales.

For projects that meet the "hotspot" criteria in Chapter 4 of this manual, designers shall use noninfiltration type practices to meet the RRv criteria. [1]

From Section 4.3 of the New York State Stormwater Management Design Manual (Emphasis added)

Designers must be selective with the design of infiltration on sites with karst geology, shallow bedrock and soils, and **hotspot land uses**. Projects located over karst geology must provide runoff reduction by techniques that do not involve large infiltration basins and deep, concentrated recharge to the ground. A geotechnical assessment is recommended for infiltration and recharge at small scales. **For projects identified as "hotspot" runoff reduction cannot be provided by infiltration, unless an enhanced treatment that addresses the pollutants of concern is provided**.[2]

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[1] New York State Stormwater Management Design Manual, August, 2010, NYSDEC, Section 3.2, Page 3-3

[2] Ibid., Section 4.3, Page 4.6

The following is from Section 9.3.1 (emphasis added to indicate the rationale for use of this design):

> This Chapter applies when specific physical constraints are present at a site that will disturb existing impervious area and then reconstruct that area as either pervious or impervious surface. Where site specific circumstances do not allow proper sizing and installation of the management practices contained in this Manual, a SWPPP must clearly identify and document the design difficulties that meet redevelopment application criteria and provide documented justification for the use of proposed alternative approaches presented in this chapter. To make such determination, the following criteria must be met:
>
> **(1) An existing impervious area is disturbed and then reconstructed as either a pervious or impervious surface**, and
>
> (2) There is inadequate space for controlling stormwater runoff from the reconstructed area, or
>
> **(3) The physical constraints of the site do not allow meeting the required elements of the standard practices**.[3]

The existing impervious areas of the site will be disturbed and reconstructed as either buildings, roadways, parking areas or green space. The final plan will increase pervious area of the site from less than 5% to between 30 and 45%.

The Vortechs System or similar technology will be utilized. This system is included by reference in the Alternative stormwater practices in the NYSSWDM. The table listed below is from the State of New Jersey Department of Environmental Protection Certification Letter.[4]

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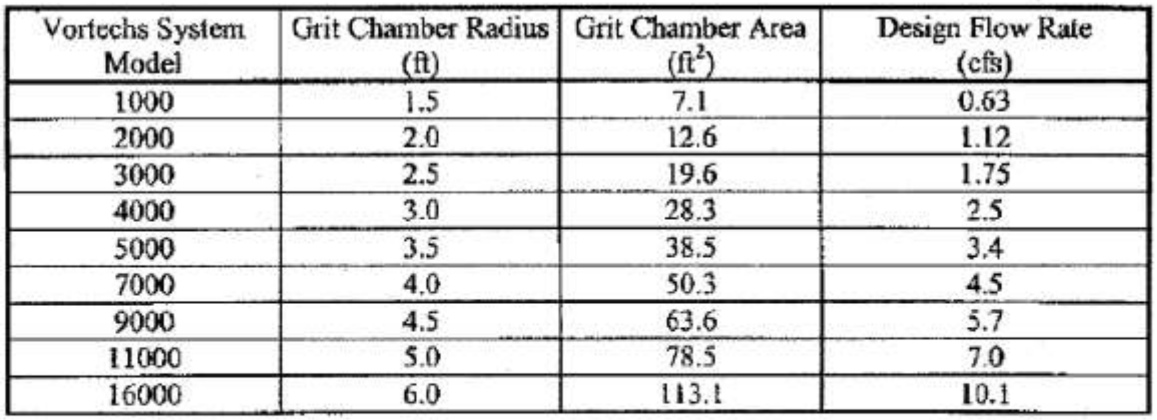
[3] Ibid, Section 9.3.1, Page 9-5

[4] Letter from State of New Jersey Department of Environmental Protection, August 31, 2011, see Appendix 3

Table 1



Vortechs System Model	Grit Chamber Radius (ft)	Grit Chamber Area (ft^2)	Design Flow Rate (cfs)
1000	1.5	7.1	0.63
2000	2.0	12.6	1.12
3000	2.5	19.6	1.75
4000	3.0	28.3	2.5
5000	3.5	38.5	3.4
7000	4.0	50.3	4.5
9000	4.5	63.6	5.7
11000	5.0	78.5	7.0
16000	6.0	113.1	10.1

[5]

Literature on the use of Hydrodynamic Separators is included in Appendix 1.

The proposed drainage storm water system will include at least four separate hydrodynamic separators (Models 9000, 11000 or 16000) which will include diversion and bypass capabilities. The treated volume will exceed 25% of the WQv The overflow from the system for flows exceeding the 25% of WQv storm will discharge to the east end of the harbor without any further detention. This is permitted because the Mohawk River is a fifth order or higher stream course. Also the 36 inch storm sewer to be relocated will be combined with drainage from the proposed road which will traverse the site and will discharge to the Mohawk River at the southerly limit of the site. This will be dedicated to the City of Schenectady.

The drainage from the proposed road will also be treated by two hydrodynamic separators. One will treat the roadway area south of College Creek and one will treat the area of the public roadway north of the College Creek. The one treating the area of the pavement south of the College Creek will be maintained by the City of Schenectady and will discharge to the

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[5] New Jersey Department of Environmental Protection, August 31, 2011 letter See Appendix 4

relocated drainage pipe near the southern end of the site. The one treating the area of the pavement north of the College Creek will be maintained by the City of Schenectady and will discharge to the end of the harbor.

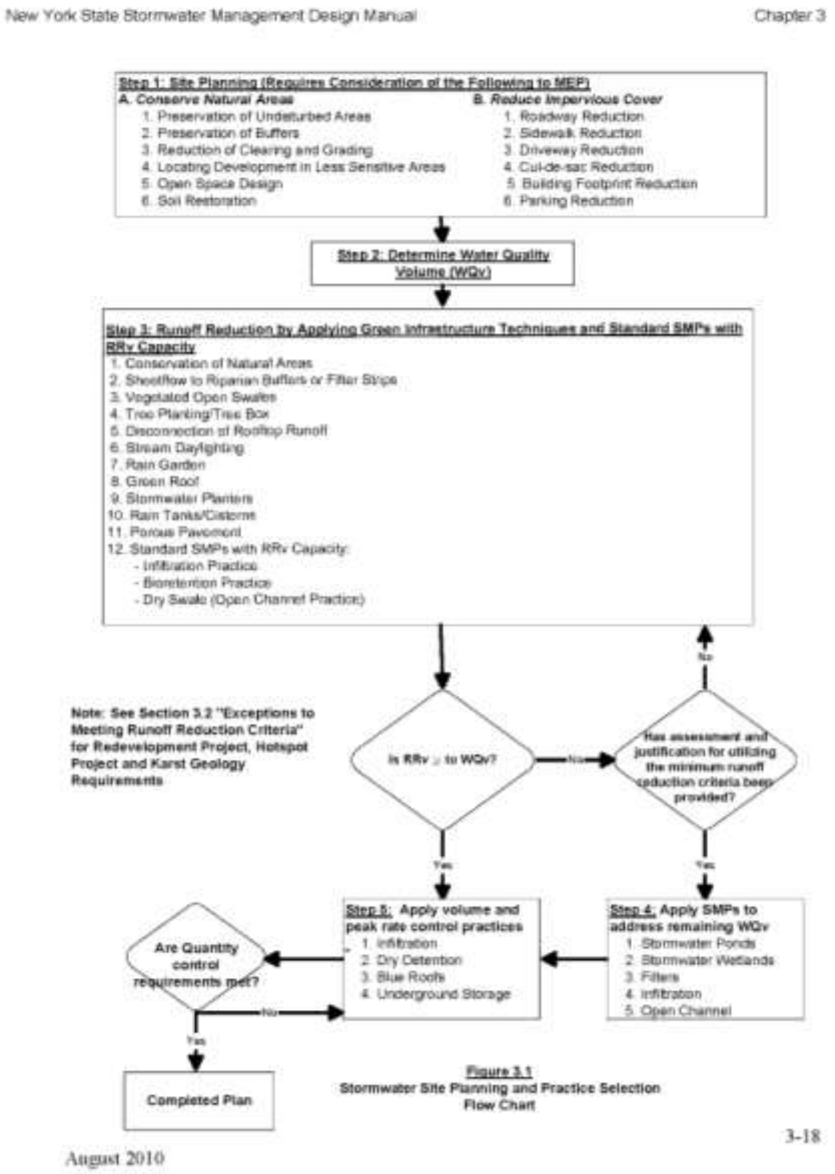
Roof drainage and parking lot drainage as well as drainage from the private extension of the road in the Phase 1 will be treated hydrodynamic separators. These will be collected into a privately maintained system which will also discharge into the end of the harbor. In addition a privately maintained storm sewer collection system and treatment system will serve the Phase 2 area or the casino development area. This drainage of this area will also be treated by a hydrodynamic separator. The discharge from these two pipes will provide for flushing the harbor during major storm events.

SITE ANALYSIS

The preparer of this study has examined the site and believes that it is not suitable to employ infiltration methods comprising most of the green infrastructure practices. This site is a Redevelopment Site. Existing structures and infrastructures either have been or will be demolished. The direct discharge remains to the Mohawk River, a fifth order or higher stream course. All utilities with the exception of the College Creek traversing the site will be abandoned or replaced with new utilities. The only steep grades on site are the banks of the Mohawk River. The area designated for installation of the hydrodynamic separators is not impacted by high groundwater levels. They will be protected from inundation during flood tide conditions through the use of flood gates on the discharge pipes.

COMPLIANCE WITH GREEN INFRASTRUCTURE REQUIREMENTS UNDER SPDES GP#0-10-001

Under SPDES GP#0-10-001, the SWPPP must comply with the latest revision of the New York State Stormwater Design Manual (hereinafter NYSSWDM), last revised August, 2010. This includes consideration of the "Five Step Process" which is shown below:



New York State Stormwater Management Design Manual Chapter 3

Step 1: Site Planning (Requires Consideration of the Following to MEP)

A. Conserve Natural Areas
1. Preservation of Undisturbed Areas
2. Preservation of Buffers
3. Reduction of Clearing and Grading
4. Locating Development in Less Sensitive Areas
5. Open Space Design
6. Soil Restoration

B. Reduce Impervious Cover
1. Roadway Reduction
2. Sidewalk Reduction
3. Driveway Reduction
4. Cul-de-sac Reduction
5. Building Footprint Reduction
6. Parking Reduction

Step 2: Determine Water Quality Volume (WQv)

Step 3: Runoff Reduction by Applying Green Infrastructure Techniques and Standard SMPs with RRv Capacity
1. Conservation of Natural Areas
2. Sheetflow to Riparian Buffers or Filter Strips
3. Vegetated Open Swales
4. Tree Planting/Tree Box
5. Disconnection of Rooftop Runoff
6. Stream Daylighting
7. Rain Garden
8. Green Roof
9. Stormwater Planters
10. Rain Tanks/Cisterns
11. Porous Pavement
12. Standard SMPs with RRv Capacity:
    - Infiltration Practice
    - Bioretention Practice
    - Dry Swale (Open Channel Practice)

Note: See Section 3.2 "Exceptions to Meeting Runoff Reduction Criteria" for Redevelopment Project, Hotspot Project and Karst Geology Requirements

Is RRv ≥ to WQv?

Has assessment and justification for utilizing the minimum runoff reduction criteria been provided?

Step 4: Apply SMPs to address remaining WQv
1. Stormwater Ponds
2. Stormwater Wetlands
3. Filters
4. Infiltration
5. Open Channel

Step 5: Apply volume and peak rate control practices
1. Infiltration
2. Dry Detention
3. Blue Roofs
4. Underground Storage

Are Quantity control requirements met?

Completed Plan

Figure 3.1
Stormwater Site Planning and Practice Selection Flow Chart

August 2010 3-18

Five Step Process

COMPLIANCE WITH FIVE STEP PROCESS

STEP 1 – SITE PLANNING

The following steps were considered and implemented where reasonable:

A. CONSERVE NATURAL AREAS

1. Preservation of Undisturbed Areas

   There were no undisturbed areas on this site.

2. Preservation of Buffers

   There are no buffers on this site.

3. Reduction of Clearing and Grading

   This site has been entirely cleared. Grading is largely limited to areas where construction will take place.

4. Locating Development in Less Sensitive Area

   This project is not located in a sensitive area

5. Open Space Design

   This plan retains approximately 55% as green space or harbor.

6. Soil Restoration

   Soil restoration using de-compaction techniques is not recommended due to the presence of contaminated soils.

B. REDUCE IMPERVIOUS COVER

1. Roadway Reduction

   This development utilizes the minimum paving width required for to provide access.

2. Sidewalk Reduction

   This development utilizes the minimum sidewalks consistent with the pedestrian accessibility goals of the project.

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3. Driveways Reduction

   The driveways are arranged as shared driveways to reduce the area devoted to driveways.

4. Building Footprint Reduction

   The building footprint has been reduced to the minimum required by utilizing multi-story design on all buildings.

5. Parking Reduction

   This development reduces impervious parking paving by placing parking beneath buildings wherever possible. This development provides the minimum number of surface parking spaces thought to meet the needs of the Applicant. The total parking area will be adjusted based upon actual tenants needs.

STEP 2 – WATER QUALITY VOLUME

Water Quality Volume (WQ_v) is computed based upon the following formula:[6]

$$WQ_v = \frac{(P)\ (R_v)\ (A)}{12}$$

Where WQ_v = water quality volume (acre-feet)

P = 90% rainfall event[7]

R_v = 0.05 + 0.009 I, where I is percent impervious cover

A = site area in acres

The Water Quality Volume (WQ_v) is computed for the the subject site without mitigation of utilizing porous pavement is 2.172 acre-feet. The required

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[6] ***New York State Stormwater Management Design Manual***, New York State Department of Environmental Conservation, Albany, New York, August, 2010, Page 4-2

[7] **Ibid.**, Page 4-2, Figure 4.1

treatment of 25% of WQv is 0.543 acre-feet or 23,657 cubic feet. See computation in Appendix 2.

STEP 3 – MINIMUM RUNOFF REDUCTION VOLUME

Minimum Runoff Reduction Volume (RR_v) is computed based upon the following formula:[8]

$$RR_v = \frac{(P)\,(R_v)\,(Ai)}{12}$$

Where RR_v = runoff reduction volume (acre-feet)
P = 90% rainfall event[9]
R_v = 0.95
AiC = site impervious area in acres
S = Hydrologic Soil Group Specific Reduction Factor (0.30 for Class C)
Ai = (AiC) (S)

The Minimum Runoff Reduction Volume (RR_v) is computed in Appendix #2 for the tributary areas as 0.184 acre-feet for subject site.

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[8] **Ibid.**, Page 4-6
[9] **Ibid.**, Page 4-6

UTILIZATION OF GREEN INFRASTRUCTURE TECHNIQUES

As a redevelopment site with hotspot characteristics, this site is exempt from minimum RRV requirements, however the Applicant will use flow through planters with drainage captured and transmitted to the storm drainage system to the maximum extent possible. As direct tributary area to the Mohawk River, a sixth order stream course, Channel Protection Volume (Cp_v), Overbank Flood Protection Control Criteria (Q_p) and Extreme Flood Control Criteria (Q_f) need not be met,

CONCLUSION:

The drainage concept as presented herein is, in the engineer's opinion, feasible.

STATE OF NEW YORK
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LICENSED PROFESSIONAL ENGINEER & LAND SURVEYOR

Prepared by:

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APPENDIX 1

VORTECHS SYSTEM

United States
Environmental Protection
Agency

Office of Water
Washington, D.C.

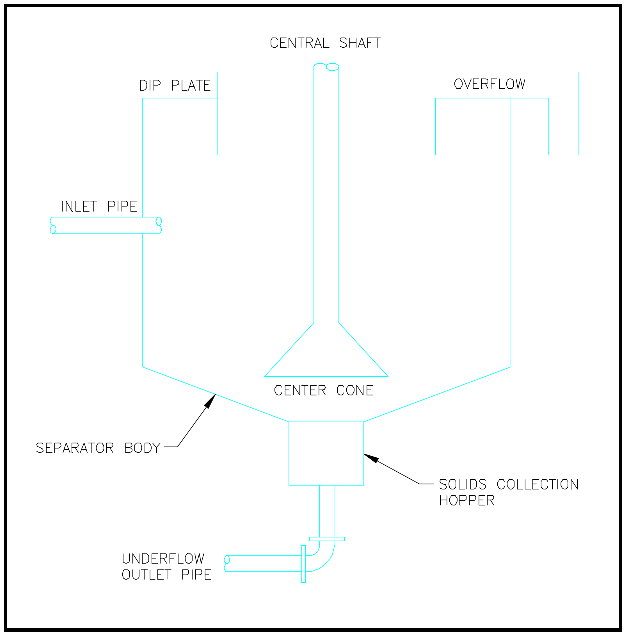
EPA 832-F-99-017
September 1999

Storm Water Technology Fact Sheet

Hydrodynamic Separators

DESCRIPTION

Hydrodynamic separators are flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely used in storm water treatment. No outside power source is required, because the energy of the flowing water allows the sediments to efficiently separate. Depending on the type of unit, this separation may be by means of swirl action or indirect filtration. A generalized schematic of a unit is shown in Figure 1. Variations of this unit have been designed to meet specific needs.



Source: Fenner and Tyack, 1997.

FIGURE 1 GENERALIZED HYDRODYNAMIC SEPARATOR

Hydrodynamic separators are most effective where the materials to be removed from runoff are heavy particulates - which can be settled - or floatables - which can be captured, rather than solids with poor settleability or dissolved pollutants.

In addition to the standard units, some vendors offer supplemental features to reduce the velocity of the flow entering the system. This increases the efficiency of the unit by allowing more sediments to settle out.

APPLICABILITY

This technology may be used by itself or in conjunction with other storm water BMPs as part of an overall storm water control strategy. Hydrodynamic separators come in a wide size range and some are small enough to fit in conventional manholes. This makes hydrodynamic separators ideal for areas where land availability is limited. Also, because they can be placed in almost any specific location in a system, hydrodynamic separators are ideal for use in potential storm water "hotspots"--areas such as near gas stations, where higher concentrations of pollutants are more likely to occur.

The need for hydrodynamic separators is growing as a result of decreasing land availability for the installation of storm water BMPs. This fact sheet discusses hydrodynamic separator systems from four vendors. Although there are many hydrodynamic separation systems available, these four address the major types.

They are the following:

- Continuous Deflective Separation (CDS).

- Downstream Defender™.
- Stormceptor®.
- Vortechs™.

Continuous Deflective Separation (CDS)

CDS' hydrodynamic separator technology is suitable for gross pollutant removal. The system utilizes the natural motion of water to separate and trap sediments by indirect filtration. As the storm water flows through the system, a very fine screen deflects the pollutants, which are captured in a litter sump in the center of the system. Floatables are retained separately. This non-blocking separation technique is the only technology covered in this fact sheet that does not rely on secondary flow currents induced by vortex action.

The processing capacities of CDS units vary from 3 to 300 cubic feet per second (cfs), depending on the application. Precast modules are available for flows up to 62 cfs, while higher flow processing requires cast-in-place construction. Every unit requires a detailed hydraulic analysis before it is installed to ensure that it achieves optimum solids separation. The cost per unit (including installation) ranges from $2,300 to $7,200 per cfs capacity, depending on site-specific conditions and does not include any required maintenance.

Maintenance of the CDS technology is site-specific but the manufacturer recommends that the unit be checked after every runoff event for the first 30 days after installation. During this initial installation period the unit should be visually inspected and the amount of deposition should be measured, to give the operator an idea of the expected rate of sediment deposition. Deposition can be measured with a calibrated "dip stick". After this initial operation period, CDS Technologies recommends that the unit should be inspected at least once every thirty days during the wet season. During these inspections, the floatables should be removed and the sump cleaned out (if it is more than 85 percent full). It is also recommended that the unit be pumped out and the screen inspected for damage at least once per year.

A recently completed study by UCLA for CDS Technologies evaluating the effectiveness of four different sorbent materials in removing used motor oil at concentrations typically found in storm water runoff. They applied the sorbents in a CDS unit separation chamber and reported captures of 80-90 percent. The test found that polypropylene or co-polymer sorbents to be the most effective in the capture of the used motor oil.

Downstream Defender

The Downstream Defender, manufactured by H.I.L. Technology, Inc., regulates both the quality and quantity of storm water runoff. The Downstream Defender is designed to capture settleable solids, floatables, and oil and grease. It utilizes a sloping base, a dip plate and internal components to aid in pollutant removal. As water flows through the unit, hydrodynamic forces cause solids to begin settling out. A unique feature of this unit is its sloping base (see Figure 1), which is joined to a benching skirt at a 30-degree angle. This feature helps solids to settle out of the water column. The unit's dip plate encourages solids separation and aids in the capture of floatables and oil and grease. All settled solids are stored in a collection facility, while flow is discharged through an outlet pipe. H.I.L. Technology reports that this resulting discharge is 90 percent free of the particles greater than 150 microns that originally entered the system.

The Downstream Defender comes in predesigned standard manhole size, typically ranging from 4 to 10 feet in diameter. These units have achieved 90 percent removal for flows from 0.75 cfs to 13 cfs. To meet specific performance criteria, or for larger flow applications, units may be custom designed up to 40 feet in diameter. (These are not able to fit in conventional manholes.) The approximate capital and installation costs, range from $10,000 to $35,000 per pre-cast unit.

Inspecting the Downstream Defender periodically (once a month) over the first year of operation will aid in determining the rate of sediment and floatables accumulation. A probe (or dipstick) may be used to help determine the sediment depth in the collection facility. (With this inspection information a maintenance schedule may be established.) A sump vac (commercial or municipally-owned) may be used to remove captured floatables and solids. With proper upkeep, H.I.L. Technology reports the Downstream Defender will treat storm water for more than 30 years.

Stormceptor

Stormceptor Corporation is based in Canada and has licensed manufacturers throughout Canada and the United States. Stormceptor is designed to trap and retain a variety of non-point source pollutants, using a by-pass chamber and treatment chamber. Stormceptor reports that it is capable of removing 50 to 80 percent of the total sediment load when used properly.

Stormceptor units are available in prefabricated sizes up to 12 feet in diameter by 6 to 8 feet deep. Customized units are also available for limited spaces. Stormceptor recommends its units for the following areas:

- Redevelopment projects of more than 2,500 square feet where there was no previous storm water management (even if the existing impervious area is merely being replaced).
- Projects that result in doubling the impervious area.
- Projects that disturb at least half of the existing site.

The cost of the Stormceptor unit is based on the costs of two important system elements:

- A treatment chamber and by-pass insert.
- Access way and fittings.

Typically, the cost for installation of a unit for a one acre drainage area is $9,000. This cost will vary depending on site-specific conditions. Stormceptor units range from 900 to 7,200 gallons and cost between $7,600 and $33,560. Cleaning costs depend on several factors, including the size of the installed unit and travel costs for the cleaning crew. Cleaning usually takes place once per year and costs approximately $1,000 per structure.

Vacuum trucks are used to clean out the Stormceptor unit. Although annual maintenance is recommended, maintenance frequency will be based on site-specific conditions. The need for maintenance is indicated by sediment depth; typically, when the unit is filled to within one foot of capacity, it should be cleaned. Visual inspections may also be performed and are especially recommended for units that may capture petroleum-based pollutants. The visual inspection is accomplished by removing the manhole cover and using a dipstick to determine the petroleum or oil accumulation in the unit.

If the Stormceptor unit is not maintained properly, approximately 15 percent of its total sediment capacity will be reduced each year.

Vortechs

The Vortechs™ storm water treatment system, manufactured by Vortechnics™ of Portland, Maine, has been available since 1988. Like the other hydrodynamic separators, Vortechs removes floating pollutants and settleable solids from surface runoff. This system combines swirl-concentrator and flow-control technologies to separate solids from the flow. Constructed of precast concrete, Vortechs uses four structures to optimize storm water treatment through its system. These are:

- *Baffle wall*: Situated permanently below the water line, this structure helps to contain floating pollutants during high flows and during clean outs.
- *Circular grit chamber*: This structure aids in directing the influent into a vortex path. The vortex action encourages sediment to be caught in the swirling flow path and to settle out later, when the storm event is complete.
- *Flow control chamber*: This device helps keep pollutants trapped by reducing the forces that encourage resuspension and washout. This chamber also helps to

eliminate turbulence within the system.

- *Oil chamber*: This structure helps to contain floatables.

Vortechnics manufactures nine standard-sized units. These range from 9 feet by 3 feet to 18 feet by 12 feet. The unit sizes depend on the estimated runoff volume to be treated. For specific applications, dimensions of the runoff area are used to customize the unit. Vortechnics reports that Vortechs systems are able to treat runoff flows ranging from 1.6 cfs to 25 cfs. The cost for these units ranges from $10,000 to $40,000, not including shipment or installation.

As with other hydrodynamic separator systems, maintenance of the Vortechs system is site-specific. Frequent inspections (once a month) are recommended during the first year and whenever there may be heavy contaminant loadings: after winter sandings, soil disturbances, fuel spills, or sometimes, intense rain or wind.

The Vortechs unit requires cleaning only when the system has nearly reached capacity. This occurs when the sediment reaches within one foot of the inlet pipe. The depth may be gauged by measuring the sediment in the grit chamber with a rod or dipstick. To clean out the system, the manhole cover above the grit chamber is lifted and the sediment is removed using as vacuum truck. Following sediment removal, the manhole cover is replaced securely to ensure that runoff does not leak into the unit.

Hydrodynamic separators are most effective where the separation of heavy particulate or floatable from wet weather runoff is required. (The typical concentrations of heavy particulate and floatable pollutants found in storm water are shown in Table 1.) They are designed to remove settleable solids and capture floatables; however, suspended solids are not effectively removed. Most units are small (depending on the flow entering needing to be treated) and may be able to fit into pre-existing manholes. For this reason, this technology is particularly well suited to locations where there is limited land available.

TABLE 1 CONCENTRATION OF POLLUTANTS IN STORM WATER

Pollutant	Concentration
TSS	100 mg/L
Total P	0.33 mg/L
TKN	1.50 mg/L
Total Cu	34 µg/L
Total Pb	144 µg/L
Total Zn	160 µg L

Source: U.S. EPA, 1995.

The units designed for hydrodynamic separators are generally prefabricated in set sizes up to twelve feet in diameter, but they may be customized for a specific site if needed. Some structures are available in concrete or fiberglass. (Fiberglass is recommended for areas of potential hazardous material spills.) These materials are both suitable for retrofit applications.

Hydrodynamic separators are also good for potential storm water "hotspots" or sites that fall under industrial NPDES storm water requirements. "Hotspots" are areas such as gas stations, where a higher concentration of pollutants is more likely to be found.

ADVANTAGES AND DISADVANTAGES

The use of hydrodynamic separators as wet weather treatment options may be limited by the variability of net solids removal. While some data suggest excellent removal rates, these rates often depend on site-specific conditions, as well as other contributing factors. Pollutants such as nutrients, which adhere to fine particulates or are dissolved, will not be significantly removed by the unit.

Site constraints, including the availability of suitable land, appropriate soil depth, and stable soil to support the unit structurally, may also limit the applicability of the hydrodynamic separator. The slope of the site or collection system may necessitate the use of an underground unit, which can result in an extensive excavation.

Observable improvements in waterways are often attributable to the use of hydrodynamic separators. This is due to the reduction of sediments, floatables, and oil and grease in the flow out of the unit. These positive impacts are only achievable when proper design and O&M of the unit are implemented.

PERFORMANCE

Hydrodynamic separators are designed primarily for removing floatable and gritty materials; they may have difficulty removing the less-settleable solids generally found in storm water. The reported removal rates of sediments, floatables, and oil and grease differ depending on the vendor. Proper design and maintenance also affect the unit's performance.

OPERATION AND MAINTENANCE

Hydrodynamic separators do not have any moving parts, and are consequently not maintenance intensive. However, maintaining the system properly is very important in ensuring that it is operating as efficiently as possible. Proper maintenance involves frequent inspections throughout the first year of installation. The unit is full when the sediment level comes within one foot of the unit's top. This is recognized through experience or the use of a "dip stick" or rod for measuring the sediment depth. When the unit has reached capacity, it must be cleaned out. This may be performed with a sump vac or vacuum truck, depending on which unit is used. In general, hydrodynamic separators require a minimal amount of maintenance, but lack of attention will lower their overall efficiency.

COSTS

The capital costs for hydrodynamic separators depend on site-specific conditions. These costs are based on several factors including the amount of runoff (in cfs) required to be treated, the amount of land available, and any other treatment technologies that are presently being used. Capitol costs can range from $2,300 to $40,000 per pre-cast unit. Units which are site-specifically designed, typically cost more and the price is based on the individual site.

Total costs for hydrodynamic separators often include predesign costs, capital costs, and operation and maintenance (O&M) costs. Again, these costs are site-specific. The predesign costs depend upon the complexity of the intended site. O&M costs vary based on the company contracted to clean out the unit, and may depend on travel distances and cleaning frequency. These costs generally are low (maximum of $1,000 a year) and vary from year to year.

The individual unit prices are discussed in the current status section previously mentioned. This covers a more in depth price range of the various systems.

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OWM MTB
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MUNICIPAL TECHNOLOGY BRANCH

CONTECH® STORMWATER SOLUTIONS INC.

Vortechs® Guide

Operation, Design, Performance and Maintenance

Vortechs®

Vortechs®

The Vortechs system is a high-performance hydrodynamic separator that effectively removes finer sediment (e.g. 50-microns (μm), oil, and floating and sinking debris. The swirl concentration operation and flow controls work together to minimize turbulence and provide stable storage of captured pollutants. Precast models can treat peak design flows up to 30-cfs (850-L/s); cast-in-place models handle even greater flows. A typical system is sized to provide a specific removal efficiency of a predefined particle size distribution (PSD).

Operation Overview

Stormwater enters the swirl chamber inducing a gentle swirling flow pattern and enhancing gravitational separation. Sinking pollutants stay in the swirl chamber while floatables are stopped at the baffle wall. Vortechs systems are usually sized to efficiently treat the frequently occurring runoff events and are primarily controlled by the low flow control orifice. This orifice effectively reduces inflow velocity and turbulence by inducing a slight backwater that is appropriate to the site.

During larger storms, the water level rises above the low flow control orifice and begins to flow through the high flow control. Any layer of floating pollutants is elevated above the invert of the Floatables Baffle Wall, preventing release. Swirling action increases in relation to the storm intensity, while sediment pile remains stable. When the storm drain is flowing at peak capacity, the water surface in the system approaches the top of the high flow control. The Vortechs system will be sized large enough so that previously captured pollutants are retained in the system, even during these infrequent events.

As a storm subsides, treated runoff decants out of the Vortechs system at a controlled rate, restoring the water level to a dry-weather level equal to the invert of the inlet pipe. The low water level facilitates easier inspection and cleaning, and significantly reduces maintenance costs by reducing pump-out volume.

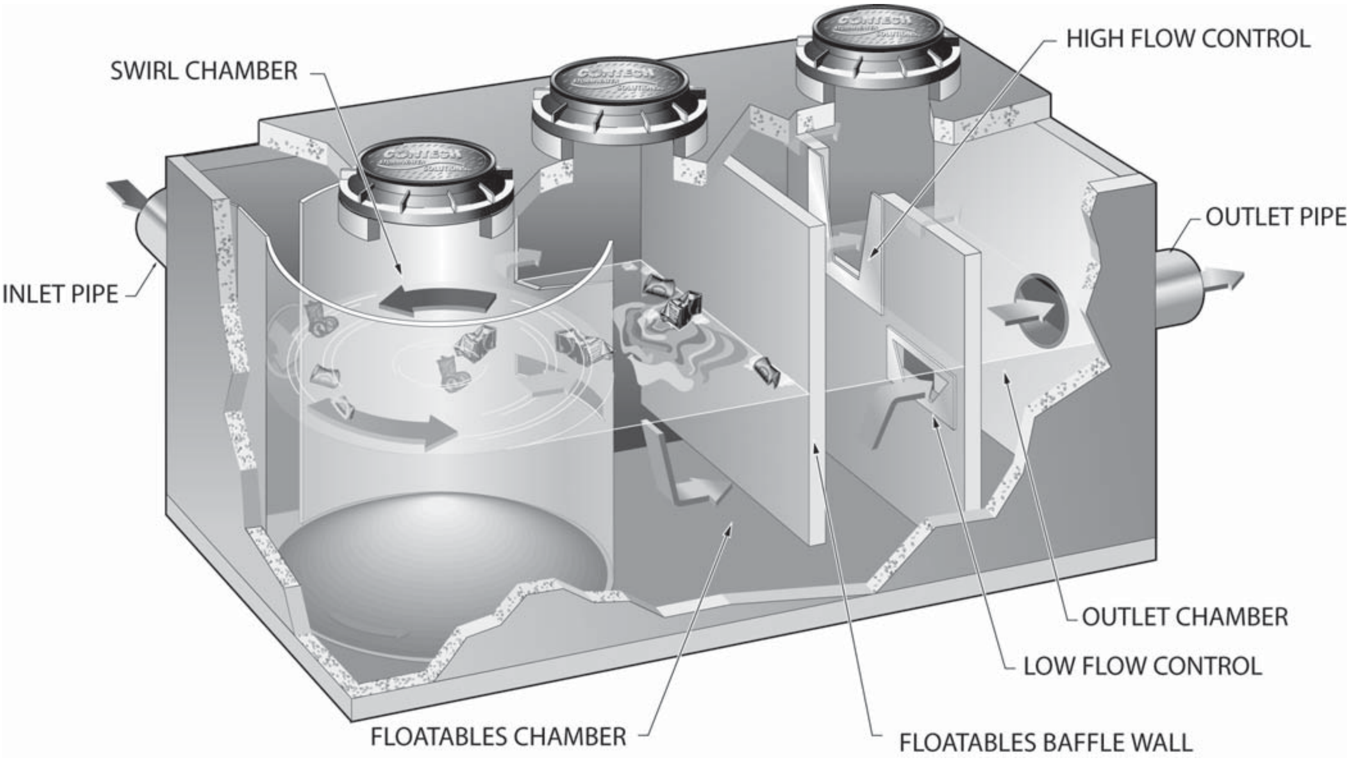
Design Basics

Each Vortechs system is custom designed based on site size, site runoff coefficient, regional precipitation intensity distribution, and anticipated pollutant characteristics. There are two primary methods of sizing a Vortechs system. The first is to determine which model size provides the desired removal efficiency at a given flow for a defined particle size or PSD. The second and more in depth method is the summation of Rational Rainfall Method™ which uses a summation process described below in detail and is used when a specific removal efficiency of the net annual sediment load is required.

Typically Vortechs systems are designed to achieve an 80% annual solids load reduction based on lab generated performance curves for either 50-μm particles, or a particle gradation found in typical urban runoff (see performance section of this manual for more information).

The Rational Rainfall Method™

Differences in local climate, topography and scale make every site hydraulically unique. It is important to take these factors into consideration when estimating the long-term performance of any stormwater treatment system. The Rational Rainfall Method combines site-specific information with laboratory generated performance data, and local historical precipitation records to estimate removal efficiencies as accurately as possible.



Short duration rain gauge records from across the United States and Canada were analyzed to determine the percent of the total annual rainfall that fell at a range of intensities. US stations' depths were totaled every 15 minutes or hourly and recorded in 0.01-inch increments. Depths were recorded hourly with 1-mm resolution at Canadian stations. One trend was consistent at all sites; the vast majority of precipitation fell at low intensities and high intensity storms contributed relatively little to the total annual depth.

These intensities, along with the total drainage area and runoff coefficient for each specific site, are translated into flow rates using the Rational Rainfall Method. Since most sites are relatively small and highly impervious, the Rational Rainfall Method is appropriate. Based on the runoff flow rates calculated for each intensity, operating rates within a proposed Vortechs system are determined. Performance efficiency curve determined from full scale laboratory tests on defined sediment PSDs is applied to calculate solids removal efficiency. The relative removal efficiency at each operating rate is added to produce a net annual pollutant removal efficiency estimate.

Once a system size is established, the internal elements of the system are designed based on information provided by the site engineer. Flow control sizes and shapes, sump depth, oil spill storage capacity, sediment storage volume and inlet and outlet orientation are determined for each system. In addition, bypass weir calculations are made for off-line systems.

Flow Control Calculations

Low Flow Control

The low flow control, or orifice, is typically sized to submerge the inlet pipe when the Vortechs system is operating at 20% of its treatment capacity. The orifice is typically a Cippoletti shaped aperture defined by its flat crest and sides which incline outwardly at a slope of 1 horizontal to 4 vertical.

$$Q_{orfice} = C_d \bullet A \bullet \sqrt{2gh}$$

Where:

$Q_{orifice}$ = flow through orifice, cfs (L/s)

C_d = orifice coefficient of discharge = 0.56 (based on lab tests)

A = orifice flow area, ft^2 (m^2) (calculated by orifice geometry)

h = design head, ft (m) (equal to the inlet pipe diameter)

g = acceleration due to gravity (32.2-ft/s^2 (9.81-m/s^2)

The minimum orifice crest length is 3-in (76-mm) and the minimum orifice height is 4-in (102-mm). If flow must be restricted beyond what can be provided by this size aperture, a Fluidic-Amp™ HydroBrake flow control will be used. The HydroBrake allows the minimum flow constriction to remain at 3-in (76-mm) or greater while further reducing flow due to its unique throttling action.

High Flow Control

The high flow control, or weir, is sized to pass the peak system capacity minus the peak orifice flow when the water surface elevation is at the top of the weir. This flow control is also a Cippoletti type weir.

The weir flow control is sized by solving for the crest length and head in the following equation:

$$Q_{weir} = C_d \bullet L \bullet (h)^{3/2}$$

Where:

Q_{weir} = flow through weir, cfs (L/s)

C_d = Cippoletti weir coefficient = 3.37 (based on lab testing)

h = available head, ft (m) (height of weir)

L = design weir crest length, ft (m)

Bypass Calculations

In most all cases, pollutant removal goals can be met without treating peak flow rates and it is most feasible to use a smaller Vortechs system configured with an external bypass. In such cases, a bypass design is recommended by CONTECH Stormwater Solutions for each off-line system. To calculate the bypass capacity, first subtract the system's treatment capacity from the peak conveyance capacity of the collection system (minimum of 10-year recurrence interval). The result is the flow rate that must be bypassed to avoid surcharging the Vortechs system. Then use the following arrangement of the Francis formula to calculate the depth of flow over the bypass weir.

$$H = (Q_{bypass} /(C_d \bullet L))^{2/3}$$

Where:

H = depth of flow over bypass weir crest, ft (m)

Q_{bypass} = required bypass flow, cfs (L/s)

C_d = discharge coefficient = 3.3 for rectangular weir

L = length of bypass weir crest, ft

The bypass weir crest elevation is then calculated to be the elevation at the top of the Cippoletti weir minus the depth of flow.

Hydraulic Capacity

In the event that the peak design flow from the site is exceeded, it is important that the Vortechs system is not a constriction to runoff leaving the site. Therefore, each system is designed with enough hydraulic capacity to pass the 100-year flow rate. It is important to note that at operating rates above 100-gpm/ft^2 (68-Lps/m^2) of the swirl chamber area (peak treatment capacity), captured pollutants may be lost.

When the system is operating at peak hydraulic capacity, water will be flowing through the gap over the top of the flow control wall as well as the orifice and the weir.

Performance

Full Scale Laboratory Test Results

Laboratory testing was conducted on a full scale Vortechs model 2000. The 150-μm curve demonstrates the results of tests using particles that passed through a 60-mesh sieve and were retained on a 100-mesh sieve. The 50-μm curve is based on tests of particles passing through a 200-mesh sieve and retained on a 400-mesh sieve (38-μm). A gradation with an average particle size (d50) of 80-μm, containing particles ranging from 38–500-μm in diameter was used to represent typical stormwater solids. (Table 1)

Particle Size Distribution (μm)	Percentage of Sample Make-Up
<63	42%
63 - 75	4%
75 - 100	9%
100 - 150	7%
150 - 250	11%
>250	27%

Table 1: Particle gradation of typical urban runoff used for efficiency curve

As shown, the Vortechs system maintains positive total suspended solids (TSS), defined by the tested gradations, removal efficiencies over the full range of operating rates. This allows the system to effectively treat all runoff from large, infrequent design storms, as well as runoff from more frequent low-intensity storms.

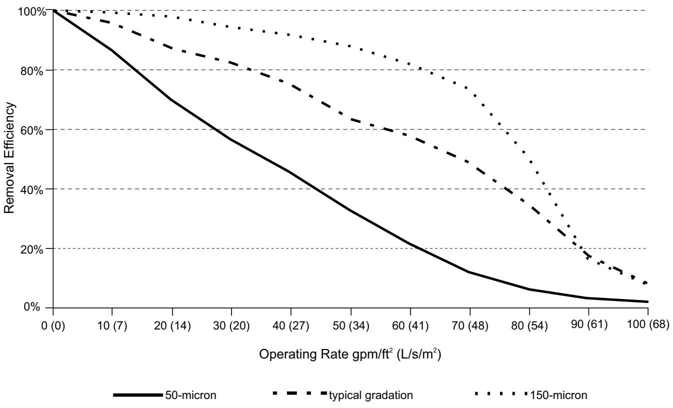


Figure 1: Vortechs model 2000 Removal Efficiencies

Typical Vortechs systems are designed to treat peak flows from 1.6-cfs (45-L/s) up to 30-cfs (850-L/s) online without the need for bypass. However, external bypasses can be configured to convey peak flows around the system if treatment capacity is exceeded. The system can also be configured to direct low flows from the last chamber of the system to polishing treatment when more stringent water quality standards are imposed. In all configurations, high removal efficiencies are achieved during the lower intensity storms, which constitute the majority of annual rainfall volume.

Full report available at www.contechstormwater.com.

Laboratory Testing

Full reports available at www.contechstormwater.com

Technical Bulletin 1: Removal Efficiencies for Selected Particle Gradations

Technical Bulletin 2: Particle Distribution of Sediments and the Effect on Heavy Metal Removal

Technical Bulletin 3: Sizing for Net Annual Sediment Removal

Technical Bulletin 3a: Determining Bypass Weir Elevation for Off-Line Systems

Technical Bulletin 4: Modeling Long Term Load Reduction: The Rational Rainfall Method

Technical Bulletin 5: Oil Removal Efficiency

Field Monitoring

Following are brief summaries of the field tests completed to date.

Full reports available at www.contechstormwater.com

DeLorme Mapping Company

Yarmouth, ME

CONTECH Stormwater Solutions

Prior to this premier field test of the Vortechs system, CONTECH developed an extensive body of laboratory data to document total suspended solids (TSS) removal efficiency. CONTECH performed this field study in order to compare the performance predicted using laboratory data to the performance of a correctly sized system in the field.

The study site was the headquarters of DeLorme Mapping in Yarmouth, Maine. The building, driveway, parking lot and ancillary facilities were constructed in 1996. A Vortechs model 11000 was installed to treat runoff from the 300-space, 4-acre (1.62-ha) parking lot.

Testing Period	May 1999 to Dec 1999
# of Storms Sampled	20
Mean Influent Concentration	328-mg/L
Mean Effluent Concentration	60-mg/L
Removal Efficiency	82%

The main purpose of the DeLorme study was to verify that the sizing methodology developed from our full-scale laboratory testing was valid and an accurate means of predicting field performance. The results of the study confirmed our sizing methodology.

Village Marine Drainage

Lake George, NY

New York State Department of Environmental Conservation, Division of Water

The New York State DEC used funds obtained in a Section 319 grant to initiate a study of the effectiveness of the Vortechs system to remove sediment and other pollutants transported by stormwater to Lake George, Lake George Village, New York. "Since the 1970s, when there was a rapid increase in the rate and concentration of development along the southwestern shores of Lake George, we have been concerned about the impact of stormwater discharges into the lake," said Tracy West, co-author of the study.

Testing Period	Feb 2000 to Dec 2000
# of Storms Sampled	13
Mean Influent Concentration	801-mg/L
Mean Effluent Concentration	105-mg/L
Removal Efficiency	88%

The study concluded that the Village and Town of Lake George should consider installing additional Vortechs systems in areas where sedimentation and erosion have been identified as non-point source pollution problems.

Harding Township Rest Area
Harding Township, NJ
RTP Environmental Associates

This third party evaluation was performed under a U.S. Environmental Protection Agency grant, administered by the New Jersey Department of Environmental Protection. A. Roger Greenway, principal of RTP Environmental Associates, Inc., conducted the study in conjunction with Thonet Associates, which assisted with data analysis and helped develop best management practices (BMP) recommendations.

The Vortechs model 4000 was sized to handle a 100-year storm from the 3 acre (1.21 ha) paved parking area at the Harding Rest Stop, located off the northbound lane of I-287 in Harding Township, New Jersey.

Testing Period	May 1999 to Nov 2000
# of Storms Sampled	5
Mean Influent Concentration (TSS)	493-mg/L
Mean Effluent Concentration (TSS)	35-mg/L
Removal Efficiency (TSS)	93%
Mean Influent Concentration (TPH)	16-mg/L
Mean Effluent Concentration (TPH)	5-mg/L
Removal Efficiency (TPH)	67%

The study concluded that truck rest stops and similar parking areas would benefit from installing stormwater treatment systems to mitigate the water quality impacts associated with stormwater runoff from these sites.

Timothy Edwards Middle School
South Windsor, CT
UCONN Department of Civil & Environmental Engineering

This study of the Vortechs system was published as a thesis by Susan Mary Board, as part of the requirements for a Master of Science degree from the University of Connecticut. Her objective was to determine how well the Vortechs system retained pollutants from parking lot runoff, including total suspended solids (TSS), nutrients, metals, and petroleum hydrocarbons.

A Vortechs model 5000 was installed in 1998 to treat runoff from the 82-space parking lot of Timothy Edwards Middle School. The entire watershed was approximately 2 acres (0.81 ha), and was 80% impervious.

Testing Period	Jul 2000 to Apr 2001
# of Storms Sampled	weekly composite samples taken
Mean Influent Concentration	324-mg/L
Mean Effluent Concentration	73-mg/L
Removal Efficiency	77%

Additionally, the Vortechs system was particularly effective in removing zinc (85%), lead (46%), copper (56%), phosphorus (67%) and nitrate (54%).

The study concluded that the Vortechs system significantly reduced effluent concentrations of many pollutants in stormwater runoff.

Maintenance

The Vortechs system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. The rate at which the system collects pollutants will depend more heavily on site activities than the size of the unit, e.g., unstable soils or heavy winter sanding will cause the swirl chamber to fill more quickly but regular sweeping will slow accumulation.

Inspection

Inspection is the key to effective maintenance and is easily performed. Pollutant deposition and transport may vary from year to year and regular inspections will help ensure that the system is cleaned out at the appropriate time. Inspections should be performed twice per year (i.e. spring and fall) however more frequent inspections may be necessary in equipment washdown areas and in climates where winter sanding operations may lead to rapid accumulations. It is useful and often required as part of a permit to keep a record of each inspection. A simple inspection and maintenance log form for doing so is provided on the following page, and is also available on contechstormwater.com.

The Vortechs system should be cleaned when inspection reveals that the sediment depth has accumulated to within 12 to 18 inches (300 to 450 mm) of the dry-weather water surface elevation. 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. Note: To avoid underestimating the volume of sediment in the chamber, the measuring device must be carefully lowered to the top of the sediment pile. Finer, silty particles at the top of the pile typically offer less resistance to the end of the rod than larger particles toward the bottom of the pile.

Cleaning

Cleaning of the Vortechs system should be done during dry weather conditions when no flow is entering the system. Clean-out of the Vortechs system with a vacuum truck is generally the most effective and convenient method of excavating pollutants from the system. If such a truck is not available, a “clamshell” grab may be used, but it is difficult to remove all accumulated pollutants using a “clamshell”.

In installations where the risk of petroleum spills is small, liquid contaminants may not accumulate as quickly as sediment. However, an oil or gasoline spill should be cleaned out immediately. Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use adsorbent pads to solidify the oil since these pads are usually much easier to remove from the unit individually and less expensive to dispose of than the oil/water emulsion that may be created by vacuuming the oily layer. Floating trash can be netted out if you wish to separate it from the other pollutants.

Cleaning of a Vortechs system is typically done by inserting a vacuum hose into the swirl chamber and evacuating this chamber of water and pollutants. As water is evacuated, the water level outside of the swirl chamber will drop to a level roughly equal to the crest of the lower aperture of the swirl chamber. The water outside the swirl chamber should remain near this level throughout pumping as the bottom and sides of the swirl chamber are sealed to the tank floor and walls. This “water lock” feature prevents water from migrating into the swirl chamber, exposing the bottom of the baffle wall and creating excess pump-out volume. Floating pollutants will decant into the swirl chamber as the water level is drawn down. This allows most floating material to be withdrawn from the same access point above the swirl chamber. Floating material that does not decant into the swirl chamber during draw down should be skimmed from the baffle chamber. If maintenance is not performed as recommended, sediment may accumulate outside the swirl chamber. If this is the case, it may be necessary to pump out other chambers. It is advisable to check for sediment accumulation in all chambers during inspection and maintenance.

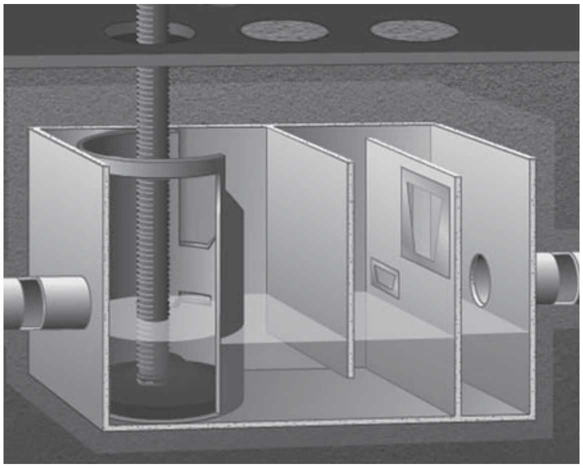
These maintenance recommendations apply to all Vortechs systems with the following exceptions:

1. It is strongly recommended that when cleaning systems larger than the Model 16000 the baffle chamber be drawn down to depth of three feet prior to beginning clean-out of the swirl chamber. Drawing down this chamber prior to the swirl chamber reduces adverse structural forces pushing upstream on the swirl chamber once that chamber is empty.
2. Entry into a Vortechs system is generally not required as cleaning can be done from the ground surface. However, if manned entry into a system is required the entire system should be evacuated of water prior to entry regardless of the system size.

Manhole covers should be securely seated following cleaning activities to prevent leakage of runoff into the system from above and also to ensure proper safety precautions. If anyone physically enters the unit, Confined Space Entry procedures need to be followed.

Disposal of all material removed from the Vortechs system should be done in accordance with local regulations. In many locations, disposal of evacuated sediments may be handled in the same manner as disposal of sediments removed from catch basins or deep sump manholes. Check your local regulations for specific requirements on disposal.

For assistance with maintaining your Vortechs system, contact us regarding the CONTECH Maintenance Compliance Certification Program.



Vortechs Inspection & Maintenance Log

Vortech Model: ______________________ Location: ______________________

Date	Water depth to sediment[1]	Floatable Layer Thickness[2]	Describe Maintenance Performed	Maintenance Personnel	Comments

1. The water depth to sediment is determined by taking two measurements with a stadia rod: one measurement from the manhole opening to the top of the sediment pile and the other from the manhole opening to the water surface. If the difference between these measurements is less than eighteen inches the system should be cleaned out. **Note: To avoid underestimating the volume of sediment in the chamber, the measuring device must be carefully lowered to the top of the sediment pile.**
2. For optimum performance, the system should be cleaned out when the floating hydrocarbon layer accumulates to an appreciable thickness. In the event of an oil spill, the system should be cleaned immediately.

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Support

- Drawings and specifications are available at www.contechstormwater.com.
- Site-specific design support is available from our engineers.

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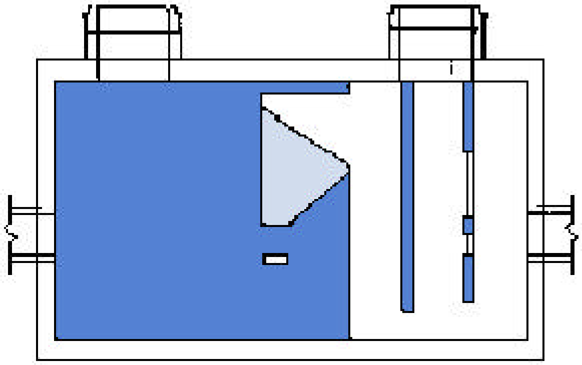
vx_manual 03/08 3M

FINAL REPORT

A Study of the Effectiveness of a Vortechs™ Stormwater Treatment System for Removal of Total Suspended Solids and Other Pollutants in the Marine Village Watershed, Village of Lake George, New York



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A Study of the Effectiveness of a Vortechs™ Stormwater Treatment System for Removal of Total Suspended Solids and Other Pollutants in the Marine Village Watershed, Village of Lake George, New York

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January 2001

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Section II. Background

Disclaimer

This report has been reviewed by the Division of Water, New York State Department of Environmental Conservation, and the New York State Soil and Water Conservation Committee and approved for publication. This approval does not signify that the contents necessarily reflect the views and policies of the Department and committee, nor does it mention of trade names or commercial products constitute endorsement or recommendation for use.

Abstract

Aerial photographs indicate that a significant increase in the size of stream deltas in Lake George has occurred over the past 50 years, an increase that greatly exceeds the normal rate of geologic and hydrologic processes. The 1983 National Urban Runoff Program (NURP) concluded that Lake George would be directly affected by the rapid rate of commercial and residential development along its shorelines, resulting in water quality decline. In an effort to reduce in-Lake sedimentation, a Vortechs™ Stormwater Treatment System was installed in a 3.78-hectare subcatchment in the Village of Lake George in 1997. The Vortechs™ System is a concrete, underground structure comprised of three chambers – an initial grit chamber that concentrates and deposits sediments, an oil chamber and baffle wall that traps floatables, and a flow control chamber. The current study evaluates the effectiveness of the Vortechs™ System in removing sediment and other pollutants from stormwater runoff. The pollutants requiring evaluation under the SPDES General Permit 93-06 include total suspended solids, total phosphorus, total nitrogen and biological oxygen demand. In addition, specific conductance and fecal coliform bacteria are being monitored. Samples collected from the inflow and outflow of the Vortechs™ System during different types of events are compared. The purpose of this study is to define, more specifically, the Vortechs™ System's performance and efficiency in removing different pollutants over a range of different types of storm events.

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Acknowledgements

The authors would like to acknowledge the following individuals – without their support, this project would not have started or been completed.

Mayor Robert M. Blais and the Village of Lake George Trustees for their foresight, stewardship and considerable effort in implementing a stormwater management plan for the Marine Village watershed. These same individuals were instrumental in getting the monitoring station installed near the Lake George Junior-Senior High School and the Village continues to pay for the electric power that operates the station.

Robert Bombard from the New York State Department of Environmental Conservation directed the installation of monitoring equipment at the site and provided upkeep at the station, lab assistance, and guidance.

From the Warren County Soil and Water Conservation District, Jim Lieberum conducted the site survey for elevations, Dave Wick provided administrative assistance, and Rhonda Jarvis was responsible for the study's bookkeeping.

Larry Eichler, Eric Howe, and Jeff Bartkowski from the Darrin Fresh Water Institute provided prompt lab services over the duration of the project.

Tom Wardell, Lake George Park Commission, assisted with the site survey and the installation of monitoring equipment.

Vaikko Allen, an Environmental Scientist for Vortechnics, Inc., provided technical assistance with the study design and rating curve information for the Model 11000 Vortechs™ System installed at Canada Street.

Alexandra Rhodes of C.T. Male Associates, P.C. provided site plan drawings prepared for the installation of the Vortechs™ System.

The administration of the Lake George Junior-Senior High School allowed the station and its equipment to be installed on the property.

Reggie Burlingame, Superintendent of the Village of Lake George Sanitation Department, and his staff provided time and effort with the regular cleanouts of the Vortechs™ System and also allowed access to the Village Wastewater Treatment facility so that inoculums for the biological oxygen demand (BOD) testing could be collected.

Finally, the Lake George Association provided use of the CatchVac to the Village of Lake George to clean the Vortechs™ System.

SECTION I. INTRODUCTION

Lake George is the largest body of water located entirely in the Adirondack Park in New York State. Historically, it is known as the “Queen of American Lakes” for its crystal clear waters and inherent natural beauty, and the Lake has been a tourist attraction since the late 1800’s. The construction of the Adirondack Northway, Interstate 87, in the 1960’s greatly facilitated travel to the region, and as a result, there was a surge in tourism and recreation in the Lake George region during the early 1970’s. The extreme rate and concentration of development along the southwestern shores of Lake George, particularly in Lake George Village, has led to many environmental problems, including high sedimentation rates from streams. As the tourism industry rapidly grew, so did concern for the health of Lake George water quality.

Initiated in 1977, the five-year National Urban Runoff Program (NURP) demonstrated that stormwater discharges from land surfaces contain various pollutants and loading rates depending on land use and climatological factors. Lake George, located in Warren County, New York, was one of the original sites selected for this study (Sutherland et al. 1983). As a result of the NURP Program and other studies, the National Pollutant Discharge Elimination System (NPDES) program was initiated at the national level and delegated to most individual states.

On 1 August 1993, the New York State Department of Environmental Conservation (NYSDEC) issued General Permit GP-93-06 for storm water discharges from construction activities. GP-93-06 requires the preparation of a Storm Water Pollution Prevention Plan that addresses three areas of concern: erosion control during construction, increased volume and rate of runoff after construction, and increased pollutant load and wash off due to the proposed land use changes. The permit requires an applicant to evaluate the impacts of total phosphorus (TP), total nitrogen (TN), biological oxygen demand (BOD), total suspended solids (TSS), and potential thermal changes to receiving water bodies. The results of this evaluation lead to designed mitigation practices to reduce the increased load to acceptable levels.

Environmental concern about non-point sources of pollution and the regulation of these discharges has led to a rapid increase in the number and types of products and systems that are marketed to reduce the impacts from developed areas on water quality. The Vortechs™ Stormwater Treatment System is one of many devices available. In 1997, two separate Vortechs™ Systems were installed in the Village of Lake George as part of a comprehensive stormwater management design that was prepared for a highly urbanized watershed (Marine Village) that drains directly to Lake George.

There are no known independent studies in the northeastern region of the United States that demonstrate the effectiveness of the Vortechs™ System in mitigating the pollutant concerns noted in the SPDES permit system. The manufacturer’s literature does discuss the ability of the units to remove sediment over certain ranges of flow as a result of studies conducted in the lab, but similar studies have not been conducted in the field. As in the case of Lake George, many of these units have been installed in urbanized settings to retrofit a site for water quality improvements. However, specific water quality performance evaluation over a range of pollutants is lacking.

During 1998, the NYSDEC Division of Water was awarded a grant from Section 319 (Non-point Source Implementation) funds to evaluate the Vortechs™ System installed adjacent to Canada Street in the Marine Village Watershed. The Warren County Soil and Water Conservation District (WCSWCD) administered the study through a contract with the NYS Department of Agriculture and Markets. The period of the contract for the Study was from 1 April 1999 through 15 May 2000. Due to delays, however, the contract was not executed until August 1999 and sampling did not start until February 2000. The period of the contract was extended until 31 December 2000 so that the sampling objectives of the project could be accomplished.

A monitoring program was established to determine the effectiveness of the Vortechs™ System in removing sediment and other pollutants from stormwater runoff. The pollutants requiring evaluation under the SPDES GP-93-06 include TSS, TP, TN and BOD. In addition, specific conductance (SpC) and fecal coliform bacteria (FC) were monitored. Samples were collected from the inflow and outflow of the Vortechs™ System during different types of events, analyzed for the pollutants identified above, and then compared to each other.

SECTION II. BACKGROUND

Description of Previous Studies in the Marine Village Watershed

The Marine Village watershed was studied intensively in the early 1980's during the Lake George Urban Runoff Study (Sutherland et al., 1983) and again in the early 1990's as part of a Section 314 (Clean Water Act) Phase 2 Implementation Project (Sutherland, 1999) and a Stormwater Retrofitting Project (Hyatt et al., 1995). Results from these studies clearly show that this watershed is a significant contributor of pollutants to Lake George. Of seven watersheds studied during these investigations, Marine Village ranked 3rd or higher based on the total load per unit area of primary runoff pollutants, including total Kjeldahl nitrogen, total phosphorus, lead, chloride, and suspended sediment, to Lake George. The table below summarizes baseflow concentrations, the total load and the load per unit area of major pollutants in the average springtime runoff from the Marine Village watershed. These data are compared with the forested and undeveloped segment of Prospect Mountain Brook west of Interstate 87.

Table 1. Baseflow concentrations, load, and load per unit area of major pollutants in the average springtime runoff from the Marine Village watershed.

	Pollutants				
	TKN	TSS	Cl	Pb	TOTP
Marine Village					
Baseflow	0.23 mg/L	4 mg/L	82 mg/L	7 ìg/L	14 ìg/L
Load	70 kg	31,049 kg	13,155 kg	4,505 g	10,875 g
Load/unit area	28.34 kg/ha	12570.45 kg/ha	5325.91 kg/ha	1823.88 g/ha	4402.83 g/ha
Undeveloped*					
Baseflow	0.11 mg/L	1 mg/L	2 mg/L	5 ìg/L	3 ìg/L
Load	35 kg	2,002 kg	76 kg	127 g	2,839 g
Load/unit area	14.17 kg/ha	810.53 kg/ha	30.77 kg/ha	51.42 g/ha	1149.39 g/ha

* Prospect Mountain Brook west of Interstate 87 used as undeveloped watershed for comparison

Description of Stormwater Management in the Marine Village Watershed

The Village of Lake George retained C.T. Male Associates, P.C. during 1989 to investigate stormwater flooding and pollution within the Marine Village watershed. In 1990, following this investigation, a report entitled *Marine Village Subbasin Stormwater Management Design Report* presented four major components for stormwater management in the Marine Village watershed. Two management structures identified in the report were grit separators to treat street runoff before it enters the main watershed conveyance pipe west of the Lake. Unfortunately, when the report was issued, funding was not available for implementation of the stormwater management recommendations.

In 1993, the Village of Lake George was awarded an Intermodal Surface Transportation Efficiency Act (ISTEA) Program grant from the New York State Department of Transportation (NYSDOT). Funds from the grant were used to implement several components of the Marine Village watershed stormwater runoff management plan. The Vortechs™ System was chosen as the grit separation device to treat stormwater runoff from major transportation corridors in the watershed. Two Vortechs™ Systems were purchased and installed during 1997; one unit adjacent to Ottawa Street, and the other unit adjacent to Canada Street (Route 9).

Description of the Vortechs™ Stormwater Treatment System

The Vortechs™ System is a large capacity, precast concrete structure installed below grade to receive surface runoff. The chambered design of the System combines swirl-concentrator and flow-control technologies to eliminate turbulence. A brief description of the Vortechs™ System features and operation is as follows (also refer to Figure 1):

- Grit chamber (#1) – the swirling motion created by the tangential inlet directs settleable solids towards the center of the chamber. Sediment is caught in the swirling flow path and settles back onto the pile after the storm event is over.
- Oil chamber (#2) and baffle wall – the center baffle traps floatables in the oil chamber.
- Flow control chamber (#3) – the weir and orifice flow controls a) raise level and volume in the System as flow rate increases, and b) gradually drain the System as flow rate subsides.

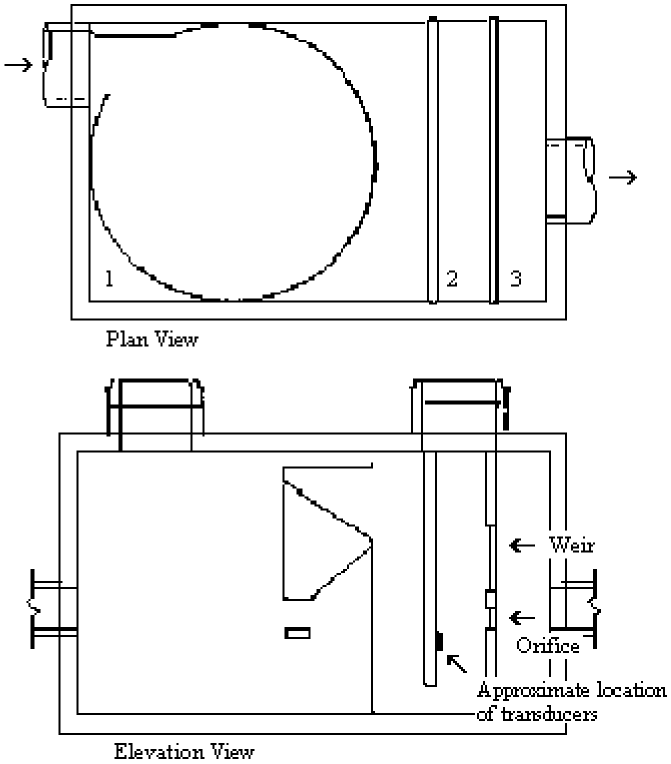
According to the manufacturer’s literature, the System is designed to provide 80% TSS removal on a net annual basis.

SECTION III. DESCRIPTION OF THE AREA

Marine Village Watershed

The Marine Village watershed is located on the west side of Lake George near the south end of the Lake and has a surface area of 95.55 hectares (0.96 km^2). About one-half (47 percent) of the watershed is located west of Interstate 87 (Figure 2) and is almost totally forested (Hyatt et al., 1995). The portion of the watershed east of Interstate 87 is about 85 percent developed (urbanized) and has an impervious area of 12.42 ha. Road and highway surfaces, primarily Canada and Ottawa Streets and Interstate 87, cover 6.39 ha in this watershed and comprise about 50 percent of the total impervious area.

Figure 1. Schematic of the Vortechs™ Stormwater Treatment System.



A natural channel conveys runoff from the forested portion of the watershed west of Interstate 87 (Figure 2). This channel has no baseflow during the late summer and early fall of dry years. Flow from the western watershed is directed under Interstate 87 via paved channels and culverts with some detention occurring in a structure that was installed recently between the northbound exit # 22 ramp and the northbound travel lane of Interstate 87. Flow from the Interstate 87 area is directed eastward through culverts that drain the berm of an abandoned railroad right-of-way. Below this point, flow is conveyed in an open swale to the developed portions of the watershed near Jogues Farm Road. Jogues Farm Pond is the only continuous source of flow in the Marine Village system. Once in the developed area, flow from the west combines with flows from the northwest (Jogues Farm Pond) and is carried via culverts directly to Lake George.

Study Area

The Canada Street Vortechs™ Stormwater Treatment System is located on the west side of Canada Street, on property occupied by the Lake George Junior-Senior High School (Figure 3). The main axis of the subwatershed extends in a north-south direction and includes a 670-meter section of Canada Street and adjacent properties that are primarily commercial and residential. The total surface area of the subwatershed draining to the Vortechs™ System is 3.78 hectares; Canada Street comprises 30 percent (1.21 ha) of this total area. Only 5 percent (0.19 ha) of the subwatershed is pervious surface.

The minimum surface elevation in the subwatershed, about 104 m, occurs at the Vortechs™ System site while the maximum elevation, 113 m, occurs at the northern extent of the drainage area, at the intersection of Canada Street and Lake Avenue. The surface elevation along the southern boundary of the subwatershed, south of Amherst Street and west to Ottawa Street, is about 108 m.

The Vortechs™ System installed at the Canada Street site is a Model 11000. Some of the specifications of the Model 11000 are listed below.

Grit Chamber Diameter/Area (m/m²)	Peak Design Flow (m^3/s)	Sediment Storage (m³)	Oil storage (m³)	Approximate Size, L x W (m)
3.1/7.34	0.496	4.21	6.81	4.88 x 3.05

The inlet/outlet configuration of the Vortechs™ System is shown in Figure 1. The side inlet optimizes grit chamber swirling action and is the preferred configuration.

Surface runoff in the subwatershed is collected in a series of drop inlets and culverts along Canada Street and adjacent areas. Subsurface runoff approaching the Vortechs™ System from the north and south is diverted to an interceptor chamber and then routed to the System through a 61 cm HDPE culvert. Runoff leaves the System through a 61 cm HDPE and is discharged to a culvert that carries runoff from the remainder of the Marine Village Watershed.

SECTION IV. METHODOLOGY

A monitoring station established at the site of the Marine Village Storm Sewer in the early 1980's (Lake George NURP Study) and then re-established in 1991 (Lake George Stormwater Management Feasibility Study and Section 319 Monitoring) was used to house the instrumentation for the current study. The station is located adjacent to the Lake George Junior-Senior High School, on the west side of Canada Street, and consists of an insulated fiberglass shelter (Kenco Plastics Company) that has AC power, lighting, and heat. The shelter, 1.37 m wide x 0.76 m deep x 2.13 m high, is situated on a wooden platform about 11 m from the northeast corner of the Vortechs™ System.

Instrumentation

The following equipment was installed at the monitoring station for the Vortechs™ System study:

- A Telog Instruments Inc. Model WLS-2109e Level Tracker equipped with an 1830 series Druck 5.0 psi submersible transducer (strain gauge differential pressure type) with 50 mV output.
- A Keller Psi 5.0 psi submersible transducer (strain gauge differential pressure type) with 4-20 mA output.
- Two Manning Environmental, Inc. 4901 Portable Vacuum Priority Contaminant™ Samplers that collect stormwater runoff samples based either on time or level.

Figure 4 is a schematic diagram of the equipment setup at the monitoring station and the Vortechs™ System. The Druck and Keller Psi submersible transducers were mounted next to each other on the wall of the Vortechs™ System between the Grit Chamber (#1) and the Oil Chamber (#2), facing the wall of the Flow Control Chamber (#3) that contains the weir and orifice (see Figures 1 and 4).

Figure 2. Map of the Marine Village Watershed

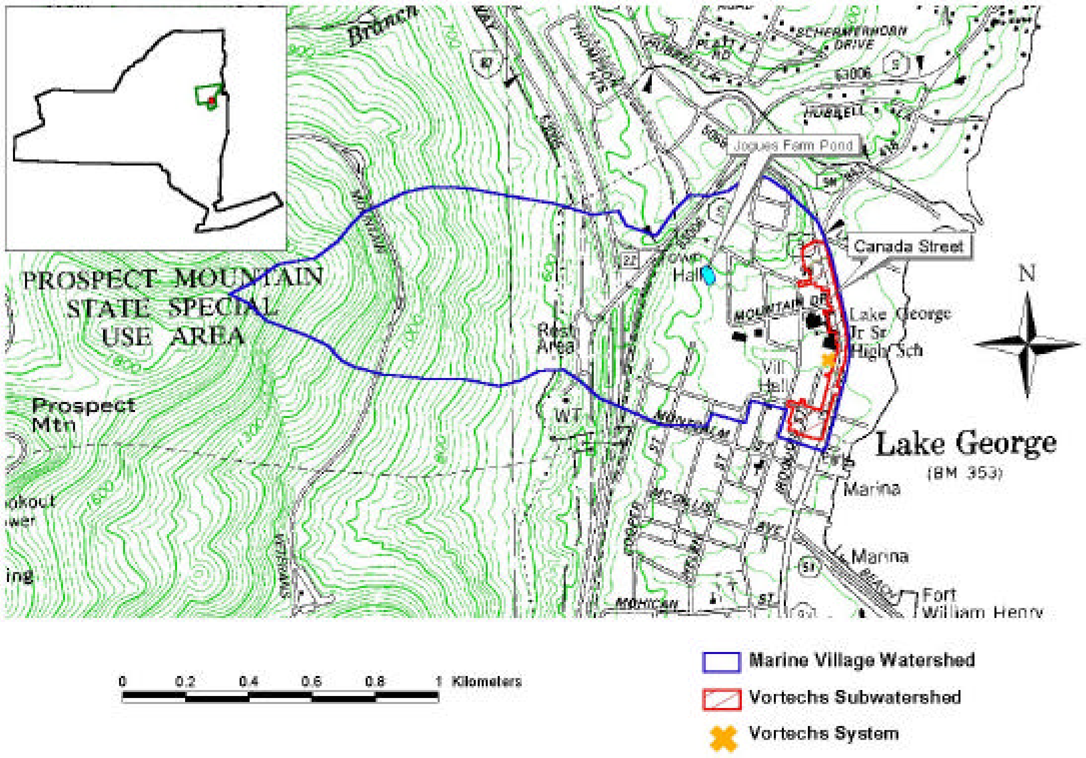
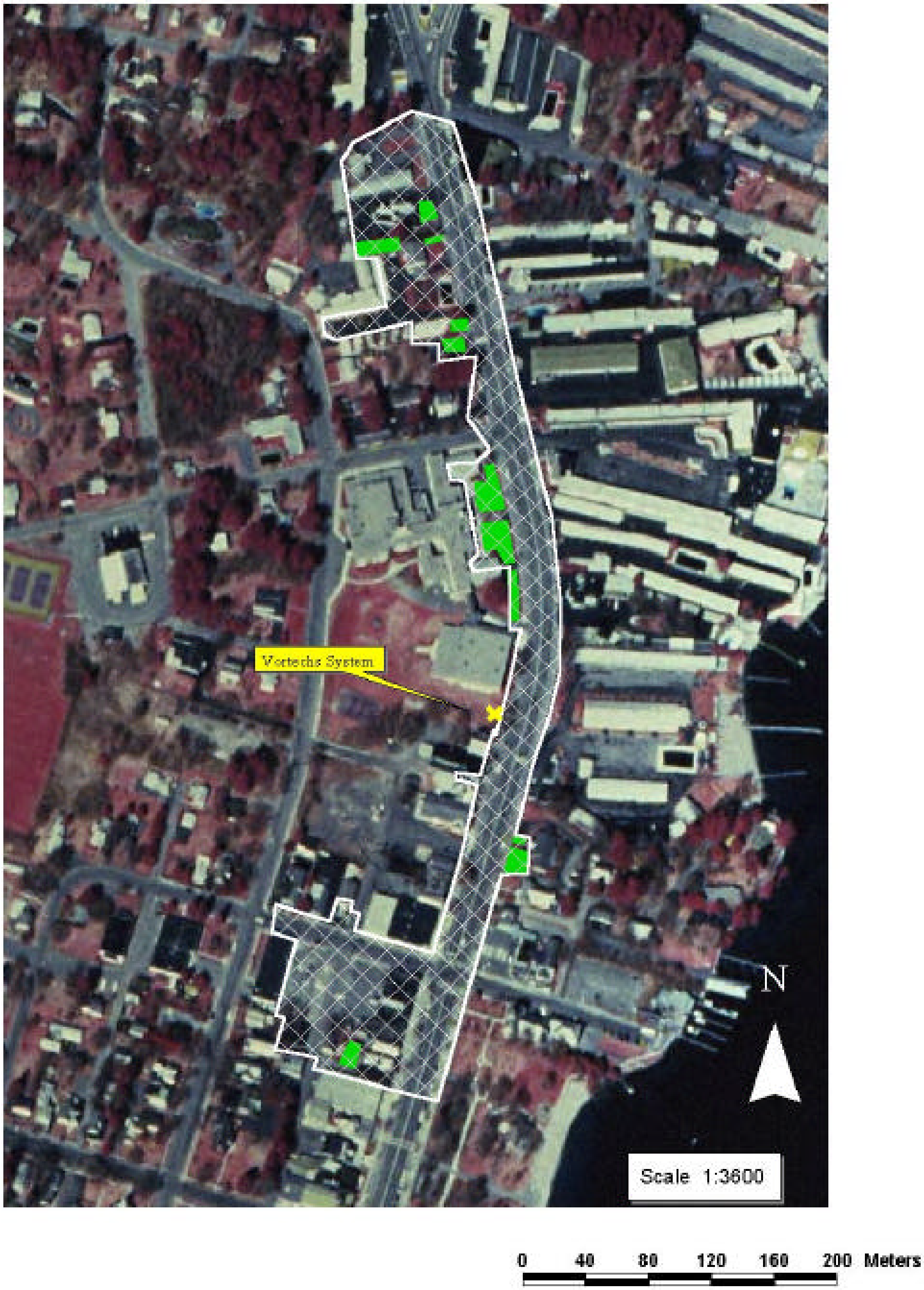
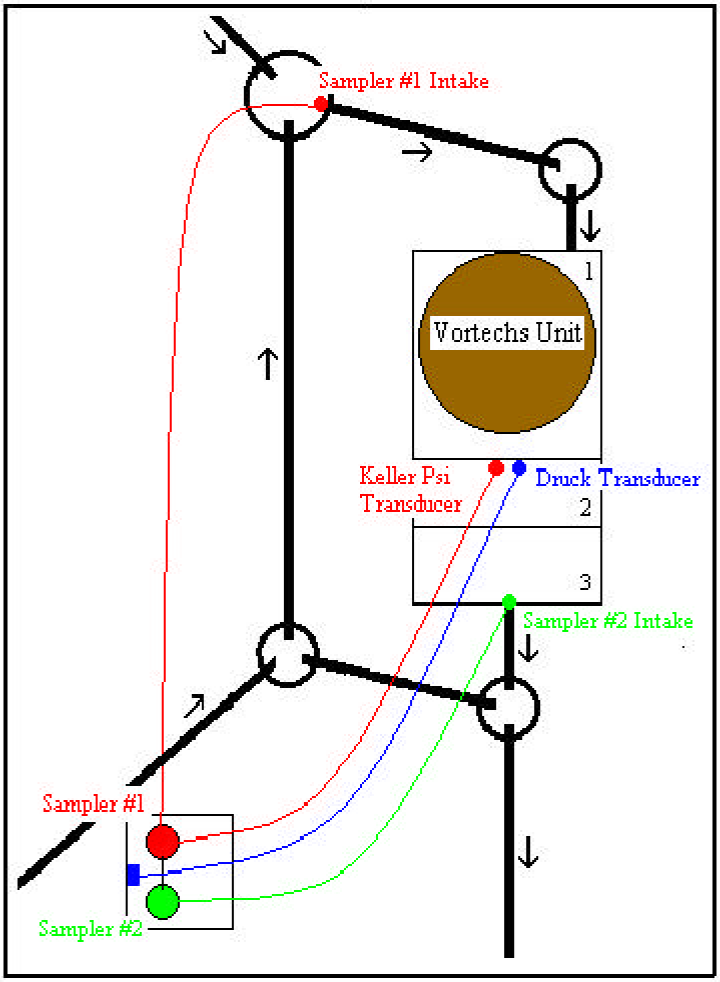


Figure 3. Canada Street Vortechs™ System Subcatchment



White hatch – subcatchment area = 3.78 hectares
Green blocks – pervious areas = 0.19 hectares

Figure 4. Schematic of the Vortechs™ System with instrumentation installed for the study



The transducer wires exit the Vortechs™ System through the sidewall and run underground, enclosed in PVC conduit, to the shelter. The Druck transducer was wired to the WLS-2109e recorder (Level Tracker) installed in the shelter. The recorder was programmed to process the input signal from the transducer, as percentage of the full-scale reading (3.59 meters), once each minute. At the end of a five-minute interval, the recorder averages the previous five values, and stores this value. The recorder was scaled to save data continuously at five-minute intervals for readout in feet.

The Keller Psi transducer was wired to a Manning 4901 sampler equipped with a controller that can accept input from an external device, such as a transducer, that outputs a 4-20mA signal representing water level in the System. This optional analog input allowed the sampler to be used in *09 mode to initiate stormwater runoff sampling during the rising and falling water levels of storm events in the Vortechs™ System.

The intake for the Manning sampler equipped with the Keller transducer (Sampler #1) is located in the runoff interceptor chamber, where the culverts carrying stormwater from Canada Street converge (Figure 4). The intake for the other sampler (Sampler #2) was located in the Flow Control Chamber (#3) of the Vortechs™ System, just below the invert level of the outlet pipe. The sampler hoses were buried below grade in PVC conduit and wrapped with heat tape and pipe insulation to keep the lines from freezing in cold weather.

Prior to an event, the samplers were programmed for collection based on the anticipated intensity and duration of the event. Sampler #1 was set either for 'Flow Mode' or 'Time

Mode', and was connected to Sampler #2 via a contact closure connection. Sampler #1 collected a sample when the signal for a preset level was received from the transducer or a preset time interval had elapsed. A contact closure output from Sampler #1 signaled completion of each sampling sequence from the System inflow and activated collection of a sample from the System outflow by Sampler #2. In this way, corresponding inflow and outflow samples were collected from the Vortechs™ System during storm events.

Sampler #1 was equipped with a controller that had data logging capability and would record the specific time that discrete stormwater runoff samples were collected during an event. This information could be downloaded from the sampler to a PC in ASCII format using a HyperTerminal link.

Stage Discharge Relationships

The stage discharge curve for the Canada Street Vortechs™ System was received through personal communication with Vortechnics, Inc. personnel. The sensors of the Druck and Keller Psi transducers were mounted about 78 cm above the floor of the Vortechs™ System on the baffle, and about 6 cm below the crest of the orifice (Figure 1). Knowing the elevation relationship between the transducer sensors and the crest of the orifice, flow calculations could be computed for the System by subtracting 0.06 m from the level, in m, recorded by the Level Tracker. The flow equations are shown in Appendix 1.

Sample Methodology

Stormwater runoff samples were collected from the inflow and outflow of the Vortechs™ System along the entire duration of a hydrologic event. Refer to Appendix 2, Marine Village Vortechs™ System Storm Hydrographs, for the sampling start/stop times in relation to the precipitation start/stop times. The frequency of sample collection during each event was determined by the anticipated duration and intensity of the event runoff.

Personnel would visit the monitoring station every 12-24 hours during an event to check equipment, change sampler bases (and bottles) as required, download sample collection information from the Manning sampler and collect water level information from the Vortechs™ System recorder. The stormwater runoff samples were transported to the Darrin Fresh Water Institute (Rensselaer Polytechnic Institute) Field Station in Bolton Landing, NY (~ 16 kilometers north of the study site) for processing.

Water level information collected from the Vortechs™ System recorder was exported as an event hydrograph. The 'Inflow' and 'Outflow' samples were plotted along the hydrograph according to the date and time of collection. Samples were selected from different portions of the event hydrograph for processing. The total number of samples selected for processing was based upon the duration and intensity of each runoff event.

Stormwater runoff samples were processed as discrete samples for TP, TN, TSS, BOD, and FC bacteria. A summary of the processing, preservation, sample volume, storage containers, and holding times for the parameters is listed in Table 2.

Table 2. Summary of processing, preservation, sample volume, storage containers and holding times for study parameters.

Parameter	Processing	Preservation	Volume (mL)	Container	Holding Time
Total phosphorus	raw sample	freeze	100 mL	125 mL PE	28 days
Total soluble phosphorus	filter sample	freeze	100 mL	125 mL PE	28 days
Total nitrogen	raw sample	freeze	100 mL	125 mL PE	28 days
Total soluble nitrogen	filter sample	freeze	100 mL	125 mL PE	28 days
Total suspended solids	raw sample	cool to 4ºC	500-1000 mL	1000 mL PE	7 days
Biological Oxygen Demand	raw sample	cool to 4ºC	1000 mL	1000 mL PE	48 hours
Fecal coliform bacteria	raw sample	cool to 4ºC	100 mL	125 mL PE	6 hours
Chloride	filter sample	cool to 4ºC	50 mL	50 mL PE	28 days

PE = polyethylene

Specific conductance (as µS/cm at 25º C) was analyzed on all samples selected for TP, TN and TSS analysis.

Almost all sample analyses were performed at the Darrin Fresh Water Institute (DFWI) field station. Table 3 is a summary of the analytical procedures for parameters included in this study. Samples processed for TP and TN were stored frozen until analysis, while the FC bacteria samples were processed immediately and incubated within the 6-hour holding time. TSS samples generally were run on the same day as collection.

The BOD samples either were 1) processed and incubated at the field lab immediately following collection or 2) shipped on ice (4°C) overnight to the NYS Department of Health, Wadsworth Center for Laboratories and Research in Albany, NY for processing and incubation within the 48-hour holding time. The results of the two different procedures used to assess BOD were determined to be comparable.

Table 3. Summary of analytical procedures utilized in the Vortechs™ System study.

Parameter	**Method**
Total Phosphorus	Colorimetric – Persulfate Oxidation (SM 4500-P)
Total soluble phosphorus	Colorimetric – Persulfate Oxidation, w/filtration (SM 4500-P)
Total Nitrogen	Colorimetric – Persulfate Oxidation (SM 4500-N)
Total soluble nitrogen	Colorimetric – Persulfate Oxidation, w/filtration (SM 4500-N)
Total Suspended Solids	Total Suspended Solids Dried at 103-105º C (SM 2540 D)
Fecal Coliform Bacteria	Membrane Filtration (SM 9222 D)
Biological Oxygen Demand	NYSDOH Lab - 5-day BOD test (SM 5210 B)
	Field Lab – 5-day BOD test (BOD Trak™ Instrument, Hach® Company) (Appendix 3)
Chloride	Ion Chromatography (EPA Method 300)
Specific Conductance	Instrumental (SM 2510 B)

Precipitation monitoring

Wetfall and frozen precipitation that occurred during the study were monitored at the Cedar Lane Atmospheric Deposition Station. The station is located in the Lake George Beach and Battlefield State Park, Town of Lake George, about 1.5 km from the site of the Canada Street Vortechs™ System. Precipitation data at the station are collected with a Qualimetrics, Inc. Model 6021A tipping bucket rain-snow gauge that tips once for each 0.0254 centimeters of wetfall. The gauge is equipped with heaters to allow the accurate measurement of frozen precipitation. The tipping mechanism in the gauge is associated with a mercury-reed switch that sends a signal to a Telog Instruments, Inc. Model R-2107 event recorder for each tip that occurs. The event recorder provides a continuous record of precipitation at the Cedar Lane station and is programmed to summarize and store the information at 5-minute intervals.

Visual Land Survey

A survey of the Vortechs™ System subcatchment was conducted on 13 and 16 October 2000. A sample survey sheet is shown in Appendix 4. Village of Lake George tax map information was used to determine property boundaries and approximate building dimensions on each lot. Based on the survey and aerial photography of the subwatershed, the impervious and pervious area draining to the Vortechs™ System was determined.

Pollutant Loading Calculations

The total discharge (in m^3) for each event was calculated by summing the individual instantaneous five-minute values for discharge through the System. Pollutant loadings were calculated by the method used by Longabucco and Rafferty (1998). Discrete chemistry data for TSS, TP and TN were linearly interpolated to produce concentrations at five-minute intervals for each storm. These values were multiplied by the instantaneous discharge and summed to produce the event mass loading for each constituent. If there were discharges at the end of an event and no chemistry sample for a constituent, the last chemistry value was used to estimate the five-minute concentrations for the “tail” of the event. This assumption affected the calculations for TP and TN for two events (03/28/00 and 04/3/00).

SECTION V. RESULTS AND DISCUSSION

Total Suspended Solids

Figure 5 shows the TSS event mean concentration values of the inflow versus the outflow for the various storm events sampled during the study. Figure 6 shows the TSS percent removal for each storm event. Appendix 5 lists the TSS values in mg/L at the specific date and time they were collected. Event mean concentration data for TSS, TP, and TN (inflow and outflow) are presented in Appendix 6.

The chemical loading graphs for TSS in Appendix 7 show that the inflow had a greater amount of TSS than the outflow, indicating removal of TSS in all storm events except one (the 03/25/00 event). Furthermore, all of the storms with removal had at least a 50 percent removal rate with many of the storms having removals of well over 80 percent (Figure 6 and Table 4).

Figure 5. Event Mean Concentration for TSS.

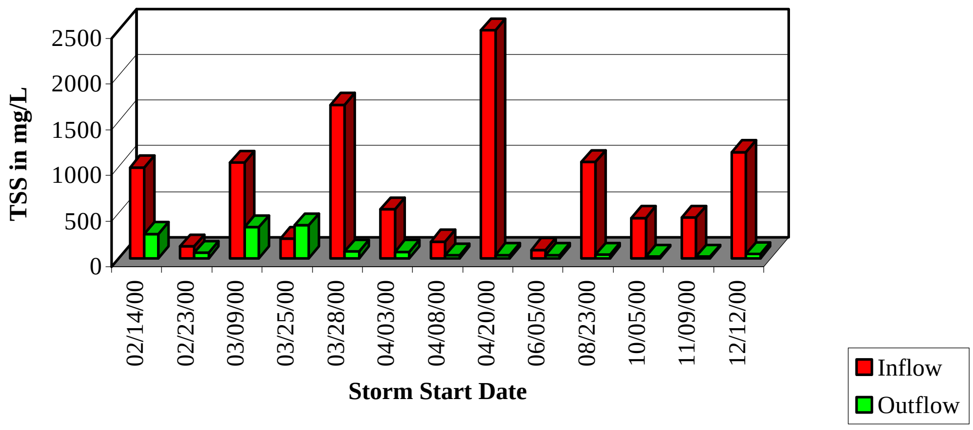


Figure 6. Percent Removal of TSS.

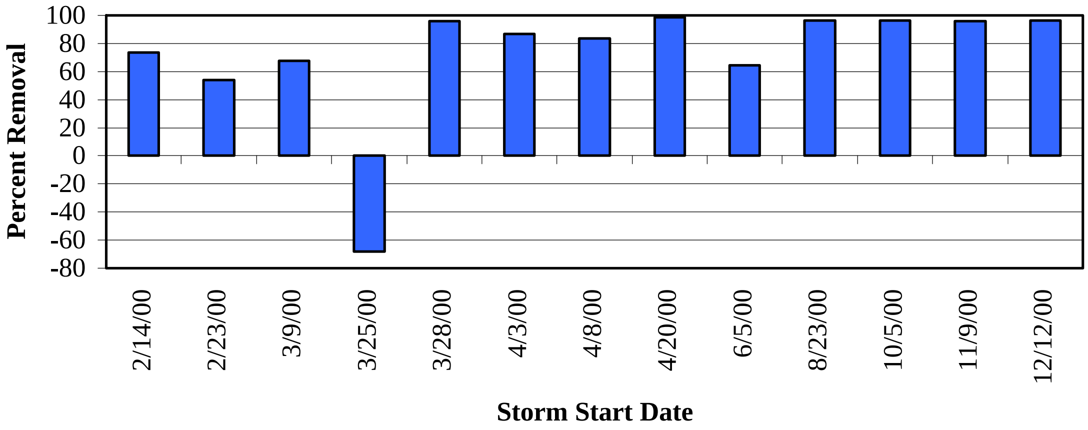


Table 4. Percent removal of TSS, TP and TN from Vortechs™ System during the study.

	Percent Removal		
Storm Start Date	TSS	TP	TN
02/14/00	73.35	11.56	-9.13
02/23/00	53.99	25.02	9.88
03/09/00	67.51	11.30	22.30
03/25/00	-68.03		
03/28/00	95.73	5.05	30.19
04/03/00	86.89	-26.94	20.07
04/08/00	83.54		
04/20/00	98.58		
06/05/00	64.46		
08/23/00	96.46	-118.95	-52.48
10/05/00	96.23	2.85	-113.64
11/09/00	96.10	5.70	18.95
12/12/00	96.13	3.30	-6.47

The 03/25/00 storm event was low intensity and short duration. The total rainfall for the storm was 0.10 cm in a 40-minute period (Table 5). This is the only storm sampled where the TSS loading for the outflow was greater than that of the inflow.

Table 5. Summary of runoff events that were sampled during the study.

Event Summary							Vortechs™ Summary
Start Day	Start Time	Stop Day	Stop Time	Duration (minutes)	Depth (centimeters)	Mean (cm/hr)	Event Volume Thru Unit (meters^3)
02/13/00	2225	02/14/00	1345	920	3.51	0.23	1192.54
02/24/00	1340	02/25/00	1740	1680	0.84	0.03	285.17
02/27/00	2335	02/28/00	0720	465	0.99	0.13	337.02
02/28/00	1355	02/28/00	1400	5	0.03	0.00	8.64
03/01/00	1855	03/01/00	2230	215	0.08	0.03	25.93
							*4209.41
03/09/00	1115	03/09/00	2245	690	0.53	0.05	181.47
03/11/00	0755	03/12/00	1610	1935	2.39	0.08	812.31
03/25/00	2015	03/25/00	2055	40	0.10	0.00	34.56
03/27/00	2330	03/28/00	1505	935	2.95	0.18	1002.42
04/03/00	0850	04/03/00	1425	335	0.51	0.10	172.83
04/03/00	2145	04/04/00	1420	995	3.58	0.23	1218.46
04/08/00	1910	04/09/00	1750	1360	1.83	0.08	622.19
04/20/00	2010	04/21/00	1630	1220	2.21	0.10	751.82
06/05/00	2000	06/06/00	2355	1675	5.51	0.20	1780.86
08/23/00	1045	08/23/00	1650	365	1.85	0.30	599.09
10/05/00	1440	10/06/00	0910	1110	2.90	0.15	935.57
11/09/00	2240	11/10/00	1640	1080	2.41	0.13	779.64
12/11/00	2155	12/12/00	0945	710	1.78	0.15	**604.91

* 3552.65 m^3 = volume due to snowmelt and 656.76 m^3 = volume precipitation

** volume based on ground being frozen

Thirteen events were sampled from 02/14/00 to 12/11/00 and represent 38.5 cm of runoff. Since this subwatershed is approximately 95% impervious area and the average annual precipitation in the Lake George region is just over 100 cm/yr, about 40% of the annual runoff was sampled during this study. By subtracting the inflow and outflow TSS loads, it was determined that the System removed 7.2 metric tons of suspended solids during the 304-day study period. Using a bulk density of 2 g/cm^3, this is equivalent to 3.6 m^3, or just below the System's rated storage capacity of 4.2 m^3. This would indicate that the System probably should be cleaned twice per year.

Total Phosphorus and Total Nitrogen

Figure 7 shows the TP event mean concentration values of the Vortechs™ System inflow versus the outflow. Figure 8 shows the percent removal of TP for each storm event that was sampled. Appendix 5 lists the phosphorus values in ìg/L at the specific date and time they were collected.

Figure 7. Event Mean Concentration for TP.

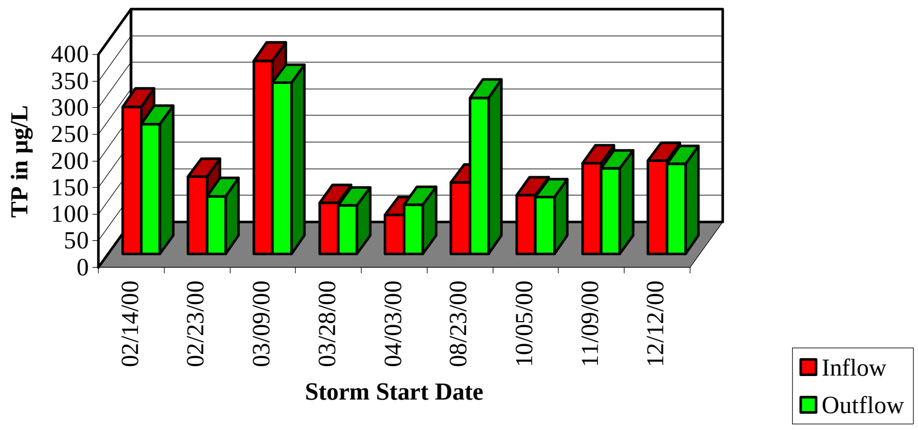
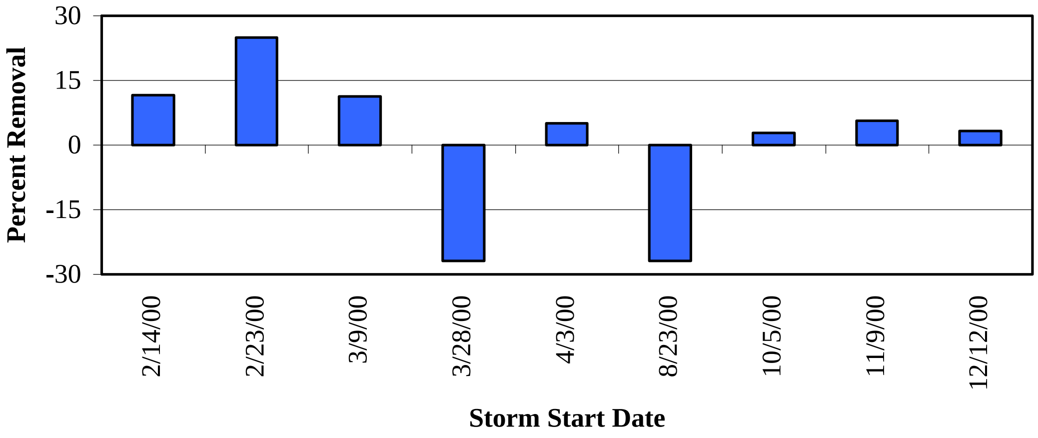


Figure 8. Percent Removal of TP.



Total phosphorus values from the DFWI Offshore Chemistry Program indicate that the mean level of phosphorus in Lake George at the Lake George Village station for the period 1996-1999 was 6.2 ìg/L. The phosphorus levels of stormwater in the Vortechs™ System are significantly higher, ranging from a low of 37 ìg/L to a high of 2229 ìg/L.

Figure 9 shows the TN event mean concentration values of the Vortechs™ System inflow versus the outflow. Figure 10 shows the percent removal of TN for each storm event that was sampled. Appendix 5 lists the nitrogen values in mg/L at the specific date and time that they were collected.

Total nitrogen values from the DFWI Offshore Chemistry Program, 1996-1999, indicate that the mean nitrogen level at the Lake George Village station for the three-year period was 0.20 mg/L. The nitrogen levels of stormwater that leaves the Vortechs™ System range from a low of 0.0 mg/L to a high of 56.8 mg/L.

Figure 9. Event Mean Concentration for TN.

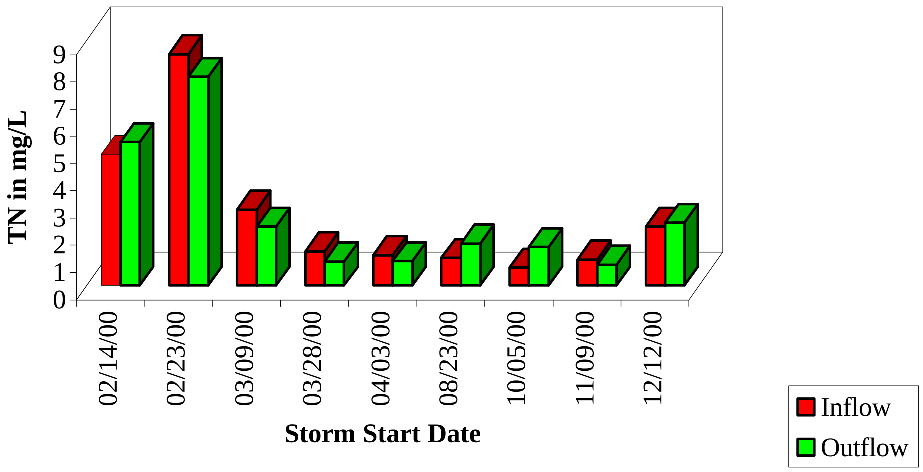
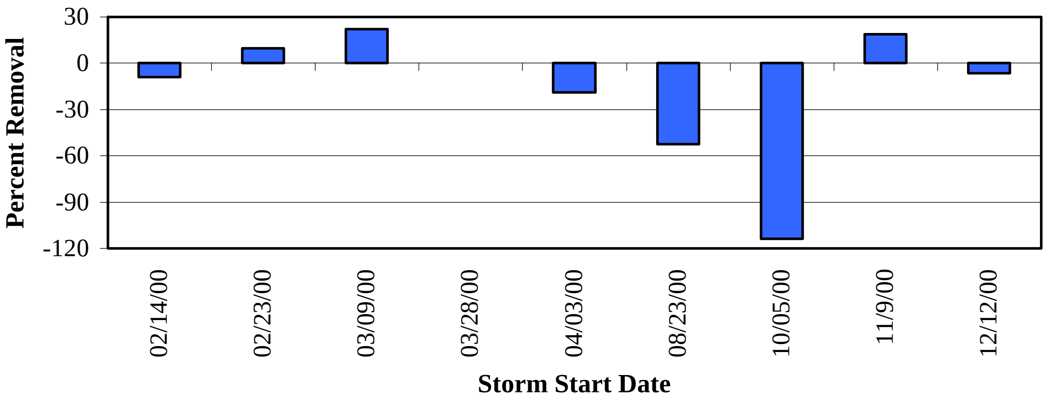
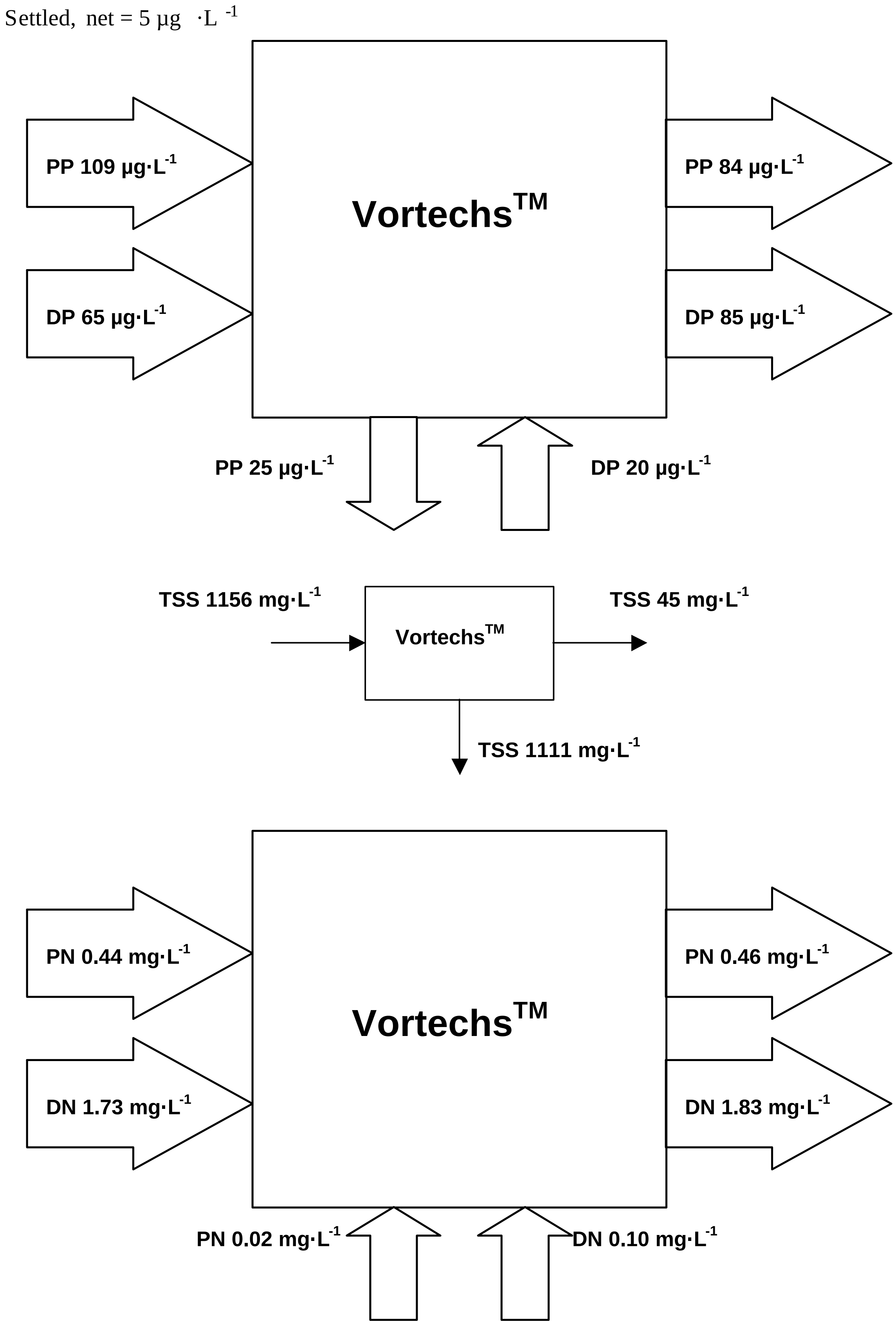


Figure 10. Percent Removal of TN.



On 12/11/00, a five-hour runoff event occurred that produced 503 m^3 (resulting from a 1.3 cm rainfall) of runoff. During this storm eleven samples were analyzed for total suspended sediment and seven for nitrogen and phosphorus. Filtered samples were also analyzed for nitrogen and phosphorus. Although the Vortechs™ System removed 96.1% of the TSS, it removed only 23% of the particulate phosphorus, which corresponds to a removal of 3.3% for total phosphorus. The System did not remove either total or particulate nitrogen. Figure 11 summarizes the flow-weighted concentrations for TSS and the forms of nitrogen and phosphorus for the 12/11/00 event. The reason that the System removes very little phosphorus and no nitrogen is because removals are confined to sand-sized (minus #200 sieve) particles that are low in nitrogen and phosphorus. For example, the TSS removed by the System (Coarse Particulate Phosphorus, CPP) has a phosphorus content of only 0.002%, while the outflow TSS has a phosphorus level (Fine Particulate Phosphorus, FPP) of 0.188%, or almost 100 times greater. Since the System does not remove particulate nitrogen, it is not possible to do a similar calculation, but the nitrogen level in the outflow TSS is 1.089%. In summary, at least for the one event sampled during the 2000 field season, it is clear that the sand-sized material removed by the System has very low levels of both nitrogen and phosphorus and hence overall nutrient removal is also small. The fine-grained material and the dissolved fraction that pass through the System contain almost all of the nitrogen and phosphorus. These observations need to be confirmed by additional sampling during 2001.

Figure 11. A summary of the flow-weighted concentrations for TSS and the forms of nitrogen and phosphorus for the 12/11/00 event.



Sutherland et al. (1983) developed an equation that compared areal unit phosphorus loading (gP/ha/day) to percent land development in selected Lake George Urban Runoff Study (NURP) catchments. If the equation were applied to a theoretical Lake George catchment that was 100 percent developed (equivalent to 25 percent impervious area for the NURP catchments), the areal unit phosphorus loading rate would be 0.959 gP/ha/day. Since the Vortechs™ System subwatershed is approximately 95% impervious area, using a straight multiplier, one could estimate the areal unit phosphorus loading rate as 3.800 gP/ha/day. With a subwatershed area of 3.78 ha, the annual NURP TP load to the Vortechs™ System would be 5,243 g TP/yr. The events that were sampled for TP represented about 38.5 cm, or about one third of the annual runoff. The annual TP load to the Vortechs™ System, based on the events that were sampled, is 6,005 g TP/yr, which is similar to the NURP number.

In May 1998, the Vortechs™ System was cleaned and samples of sediment in the unit were analyzed for TP, TN, metals and grain size (Table 6). About 90 percent of the material was sand-sized, with equal amounts of larger (gravel) and smaller (silt and clay) particles. The material was 0.02 percent P and 0.16 percent N. Stormwater samples collected from the entire Marine Village watershed (which includes less developed upland areas) from 1991-1993 exhibited TP/TSS and TN/TSS ratios of 0.15 percent and 0.16 percent, respectively. These results indicate that the material trapped in the Vortechs™ System appears to be similar in nitrogen content but depleted in phosphorus content when compared to stormwater samples from the entire watershed.

Table 6. Results of Vortechs™ System Sediment Chemistry Evaluation

Sample	Matrix	Date	Dry Wt (grams)	Volume (mL)	TP (mg/Kg)	TN (mg/Kg)	Ca (mg/Kg)	Mg (mg/Kg)	Na (mg/Kg)	K (mg/Kg)	Pb (mg/Kg)
V1A	sediment	5/1/98	1.166	50		580.6	20798	7504	223	169	7
V1B	sediment	5/1/98	1.1292	50			26567	11114	522	228	40
V2A	sediment	5/1/98	1.0698	50	204.6	2616	6637	4674	939	362	87
V2B	sediment	5/1/98	1.17	50			4188	4444	1030	361	62
				average	**205**	**1598**	**14548**	**6934**	**679**	**280**	**49**
				fraction	0.0002	0.0016	0.01455	0.00693	0.00068	0.00028	0.000049

Sample	Matrix	Date	Dry Wt (grams)	Volume (mL)	Fe (mg/Kg)	Cu (mg/Kg)	Mn (mg/Kg)	Zn (mg/Kg)	LOI (mg/Kg)	LOI (%)
V1A	sediment	5/1/98	1.166	50	227	3	44	6	10000	1.0%
V1B	sediment	5/1/98	1.1292	50	7527	18	161	58		
V2A	sediment	5/1/98	1.0698	50	8460	332	432	457	380000	38.0%
V2B	sediment	5/1/98	1.17	50	9658	397	523	567		
				average	**6468**	**188**	**290**	**272**	**195000**	**19.5%**
				fraction	0.00647	0.00019	0.00029	0.00027	0.195	

Fecal Coliform

Appendix 5 presents the FC data in CFU/100mL. Due to the difficulty of proper sampling procedures, very few samples were analyzed for FC. The levels of FC for contact recreation, set by the NYSDEC (NYSCR&R, Title 6, Chapter X, Parts 700-706), require that a five-sample geometric mean be 400/100mL per sample, or less. In February 2000, FC results ranged from less than 10 to a high of 90/100mL. In August and October 2000 the FC numbers rose to a low of 60/100mL and a high of 100,000/100mL. Several of the higher values violate the standard stated above. It is expected that the fecal coliform levels are lower in the winter and colder months and higher in the summer and warmer months.

Biological Oxygen Demand

The BOD values in mg/L are listed in Appendix 5. The BOD values for inflow and outflow are comparable. For the seven samples taken, the inflow averaged 24 mg/L and the outflow averaged 16 mg/L. There does not seem to be a significant removal rate.

Conductivity

Appendix 5 shows the Vortechs™ System conductivity values in ìS. Table 7 shows a comparison of Marine Village conductivity data collected in 1992 to Vortechs™ System conductivity data collected in 2000.

The conductivity levels in the samples from the Vortechs™ System vary greatly from conductivity results for the entire Marine Village watershed. Because the Vortechs™ System subwatershed is 95 percent impervious, the conductivity values are expected to be higher than those of the 95.55 ha Marine Village watershed (which is 47 percent forested), especially in the winter months when salting and sanding take place. Both data sets in Table 7 clearly show that there are seasonal variations in conductivity levels. The Vortechs™ System results indicate that there are significant seasonal variations in conductivity levels and that the average levels are significantly higher than those of the entire Marine Village watershed.

Table 7. Average conductance values for the Marine Village watershed and Vortechs™ System subwatershed.

	Conductivity in μS		
	Annual average	Winter average	Summer average
Marine Village (1992 data)	230	522	144
Vortechs™ (2000 data)			
Inflow	2569	3571	95
Outflow	2751	3916	268

DFWI water chemistry data (1996) show that the summer mean chloride concentration in Lake George has risen 33 percent over a 12-year period, from 6.71 mg/L for the period 1981-1984, to 7.55 mg/L for the period 1985-1989, to 8.94 mg/L for the period 1990-1993. Although chloride was not one of the parameters included in this study, it was added to the list of analytes for the 12/11/00 storm event. The chloride event mean concentrations for the Vortechs™ System inflow and outflow were 1224.97 mg/L and 1093.08 mg/L, respectively, for the single runoff event. These data emphasize the dramatic impact of human influence on the water quality of Lake George and corroborate the DFWI data that increased chloride concentrations are the result of road and highway deicing practices.

Sediment Sieve Analysis

Sediment samples were collected from the Vortechs™ System in 1998 and 2000 during the cleanout procedure. These 18-kg samples were transported to Parrot-Wolff Labs in East Syracuse, New York, where grain size, distribution analysis and tests for organic content were carried out. Based upon these analyses, the two samples were very close in character. The grain size distribution analysis shows that the samples are predominantly sand (Appendix 8). The Vortechs™ System did capture fine material (minus #200 sieve) to the degree that 5.2 percent finer by weight of the 1998 sample and 3.3 percent of the 2000 sample were realized. The organic content for the two samples also were very close. The

1998 sample contained 2.2 percent organic content while the 2000 sample contained 2.8 percent.

Since the watershed contributing to this unit is 95 percent impervious, the fact that well over 50 percent of the sediment is medium to fine sand is consistent with what would be expected in this location.

SECTION VI. CONCLUSIONS AND RECOMMENDATIONS

The subwatershed that drains to the Canada Street Vortechs™ Stormwater Treatment System has a surface area of 3.78 ha and is 95 percent impervious. The Vortechs™ System was evaluated in this study by comparing inflow samples to outflow samples and calculating pollutant loadings for TSS, TP, and TN. Conductivity was measured for samples that were collected and analyzed for TSS. Very few samples were analyzed for FC and BOD because of restrictive sampling procedures and holding times, respectively.

The evaluation of the Vortechs™ System through the comparison of the inflow to the outflow shows that the System removes at least 60 percent of total suspended solids from stormwater for individual storms under most flow conditions. The TSS removal efficiency for the entire study period was calculated to be 88 percent, exceeding the manufacturer’s estimated annual removal efficiency (80 percent).

About 3.6 m^3 of sediment was removed from the Vortechs™ System in June 2000, an amount just below the rated storage capacity of 4.2 m^3, indicating that the clean out of the System probably should be increased from once to twice a year. Sediment sieve analysis indicates that the majority of sediment trapped in the System is sand-sized particles. The System also captured fine material (minus #200 sieve), an average of 4.25 percent finer by weight. Less than 3 percent of the total sediment from the sieve analysis was organic.

Estimates from this study show that the Vortechs™ System removes some coarse particulate nutrients (phosphorus and nitrogen). However, the bulk of the phosphorus and nitrogen in stormwater runoff is in fine particulate and dissolved forms and passes through the System. A more complete data set is necessary to verify this finding and additional data will be collected during 2001.

Conductivity levels in the Vortechs™ System vary seasonally as a result of salt compounds being applied to roads and highways during winter deicing practices. Although chloride was not one of the analytes included in the present study, chloride concentrations were measured during a December 2000 runoff event and demonstrate the high loading of this substance to the Lake from a single developed catchment. These data corroborate the DFWI data (1996) that show a significant increase in annual average summer chloride values in Lake George during 12 years of water chemistry monitoring.

In spite of the small number of samples analyzed during the study, it is apparent that the FC levels vary with the seasons of the year, tending to be lower in colder months and higher in warmer months. BOD levels were low, indicating low organic content in material entering the Vortechs™ System.

The following recommendations are offered as a result of the present study:

1. The Canada Street Vortechs™ System should be cleaned at least two times each year to maintain its high sediment removal efficiency. By adhering to this frequency of cleanouts, it will be possible to greatly reduce the amount of total suspended solids that enter Lake George from this subcatchment. The load of other pollutants will be greatly reduced by a regular cleanout schedule (e.g. Pb [adsorbed to sediment] and Ca [dissolved in water that will be removed during cleanout]). One of the cleanouts should occur during mid-winter to maximize sediment removal efficiency during the period of high and (usually) sustained runoff during spring snowmelt. The mid-winter cleanout will reduce the load of dissolved pollutants, such as Ca and Cl, which enter the Lake as a result of winter deicing practices.

2. The Village and Town of Lake George should consider installing additional Vortechs™ Stormwater Treatment Systems in locations adjacent to the Lake where sedimentation and erosion have been identified as non-point source pollution problems. Potential watersheds for these installations include Prospect Mountain Brook, West Brook and English Brook and areas where there is drainage directly from impervious surfaces to Lake George (e.g. Beach Road along the south end of the Lake). The installation of these units and regular maintenance would greatly reduce the annual load of sediment and other pollutants that currently enter Lake George.

3. The Village of Lake George should retain the services of an engineering consultant to investigate the possibility of retrofitting the Canada Street Vortechs™ System with some structure or device (BMP) to remove the fine particulate and dissolved forms of phosphorus and nitrogen that are bypassing the System and entering Lake George.

4. Due to the highly sensitive situation involving highway corridors adjacent to the shoreline within the Village and Town of Lake George and the impact of stormwater runoff from these areas on water quality of the Lake, the New York State Department of Transportation and local highway departments should consider using a road salt substitute during winter de-icing practices to reduce the loading of Ca and Cl.

5. The Darrin Fresh Water Institute should summarize and analyze Lake George water chemistry data for the entire period 1980-2000 to determine whether there has been a significant increase in calcium concentrations since the previous analysis was conducted (1996). This information is particularly important in view of the potential calcium loading to Lake George from stormwater runoff during and after winter de-icing practices and the recent discovery of zebra mussels (*Dreissena polymorpha*) in the Lake George ecosystem.

SECTION VII. REFERENCES

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Sutherland, J. W., J. A. Bloomfield, and J. M., Swart. 1983. Lake George Urban Runoff Study Final Report. NYSDEC. 84 pp. + app.

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Appendix 1

Vortechs^{TM} System flow equations

The equation for flow through the orifice is:

$$\mathbf{Q = C_d\, A \sqrt{2\, gh}}$$

where Q = flow rate (cfs)
C_d = coefficient of discharge (=0.58)
A = area of orifice (ft^2)
g = acceleration due to gravity
h = head measured from the center of the orifice to the water level elevation

The equation for flow through the weir is:

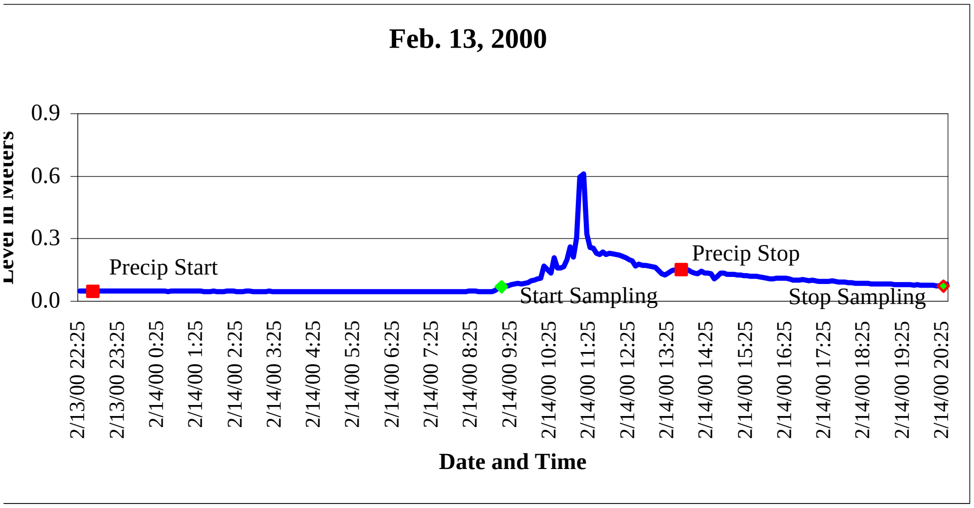
$$\mathbf{Q = C_d\, L\, (h)^{3/2}}$$

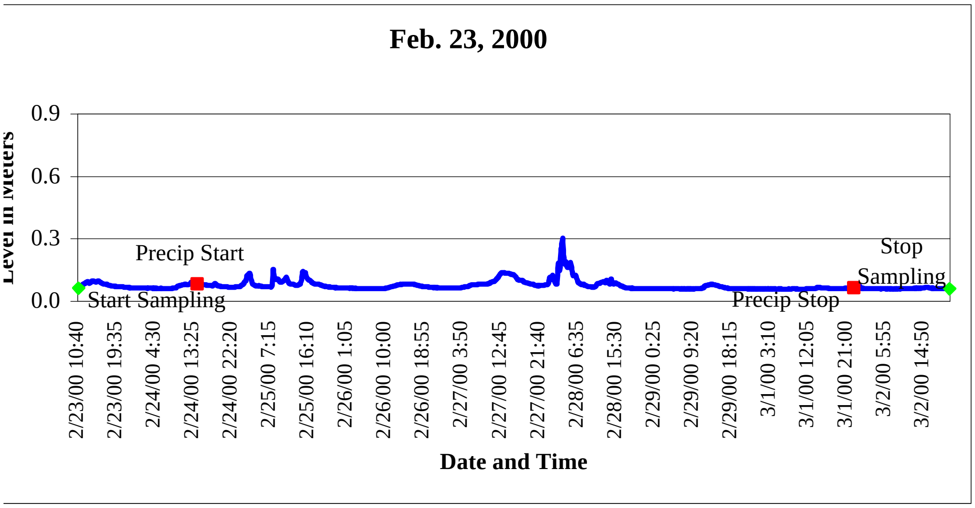
where Q = flow rate (cfs)
C = coefficient of discharge
L = length of weir crest
h = head measured from the crest of the weir to the water level elevation

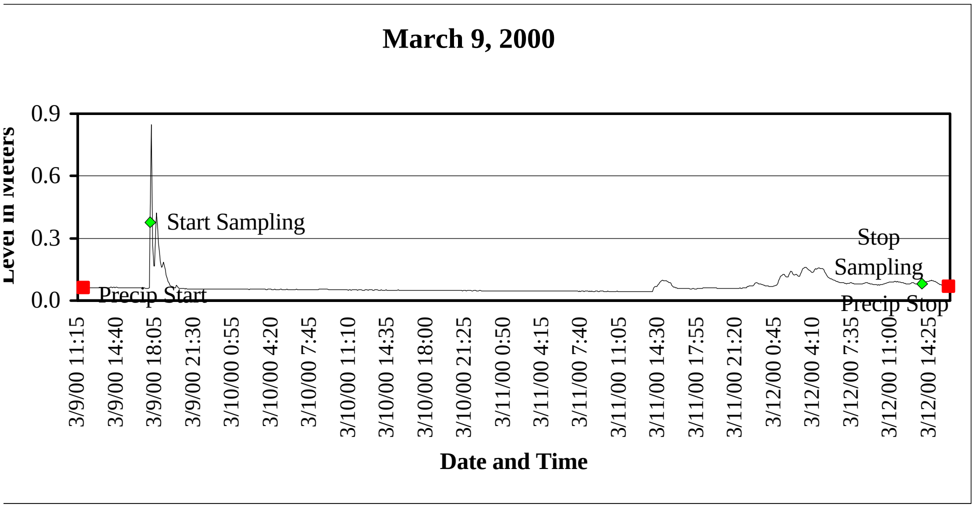
Appendix 2

Storm hydrographs showing precipitation start/stop times in relation to sampling start/stop times

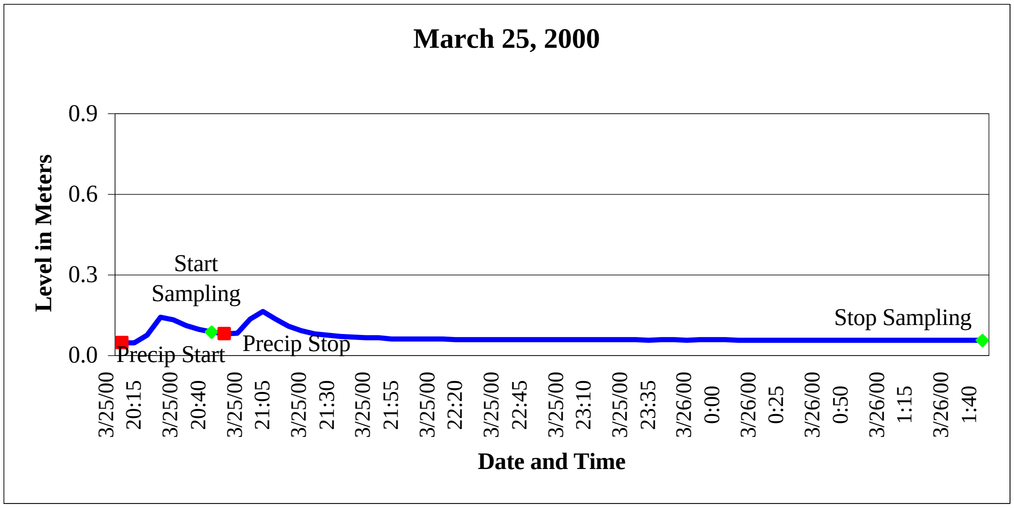
Marine Village Vortechs^{TM} System Hydrographs

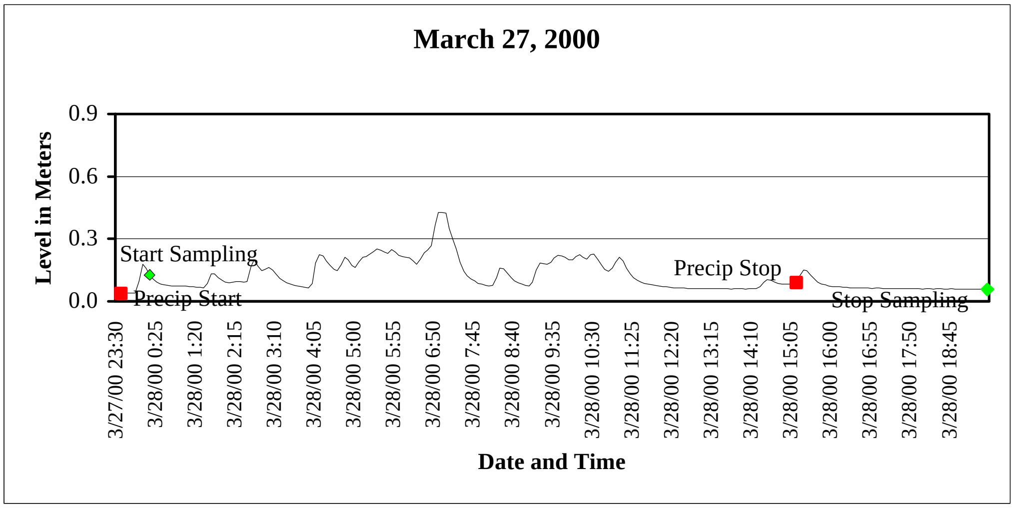


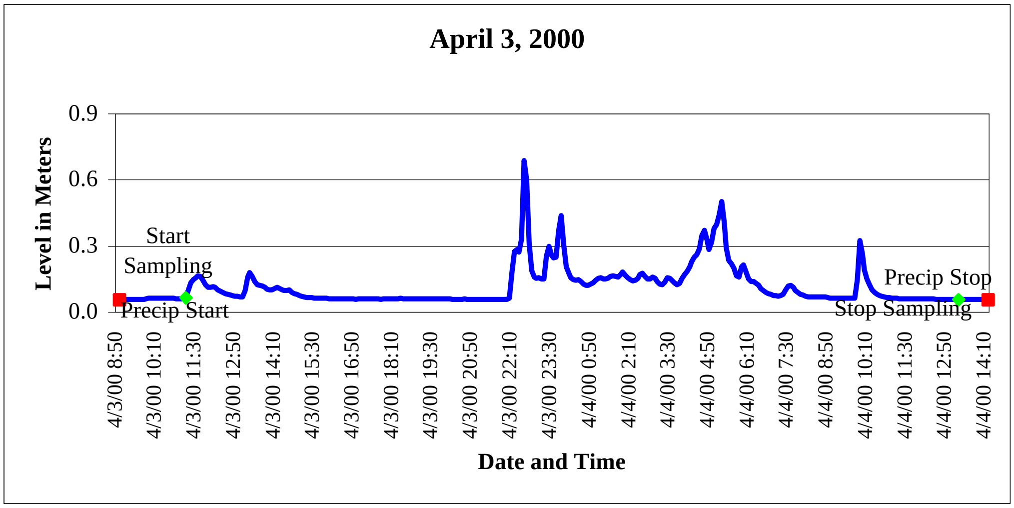




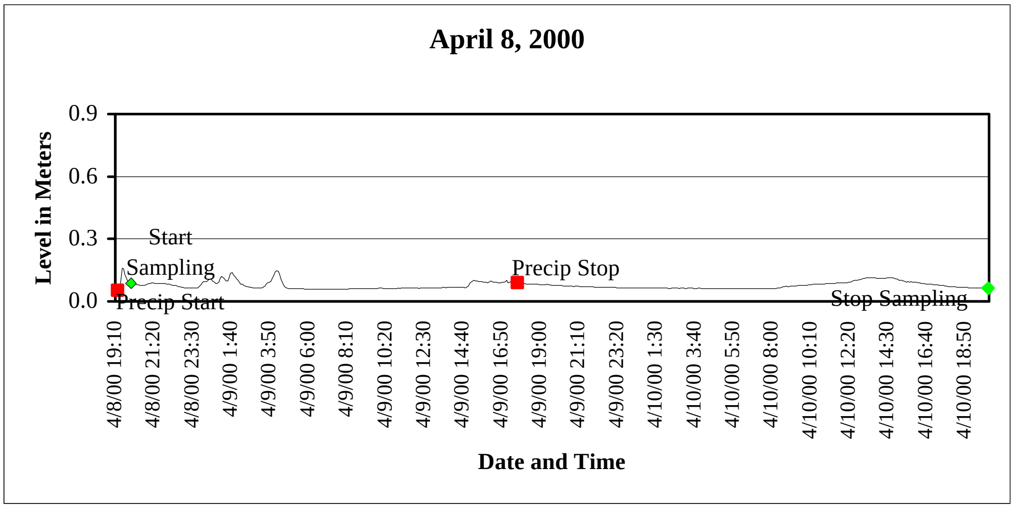
Marine Village Vortechs^{TM} System Hydrographs

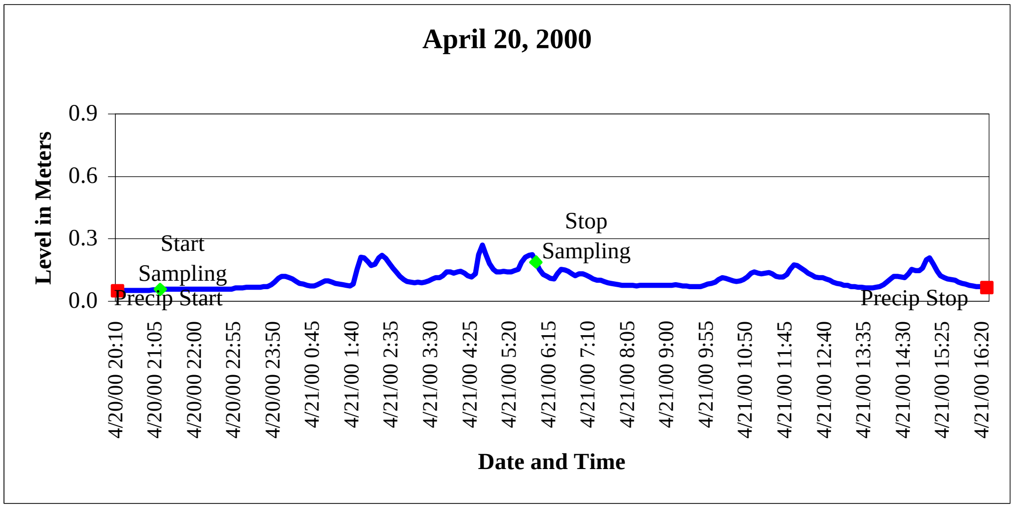


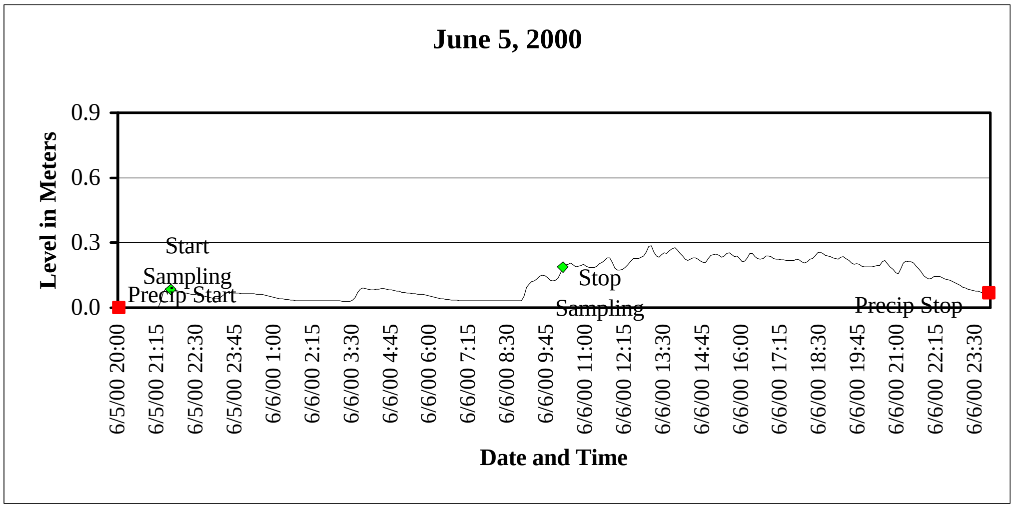




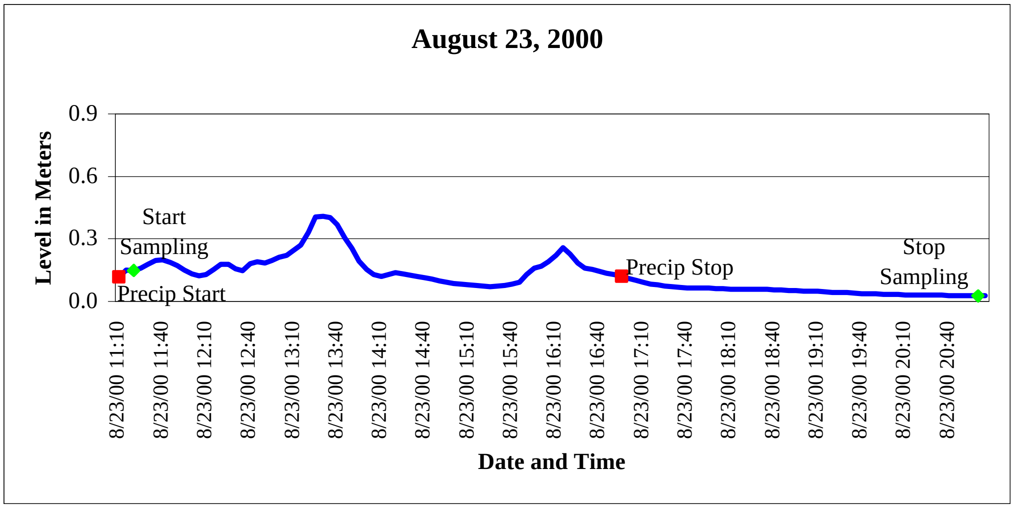
Marine Village Vortechs^{TM} System Hydrographs

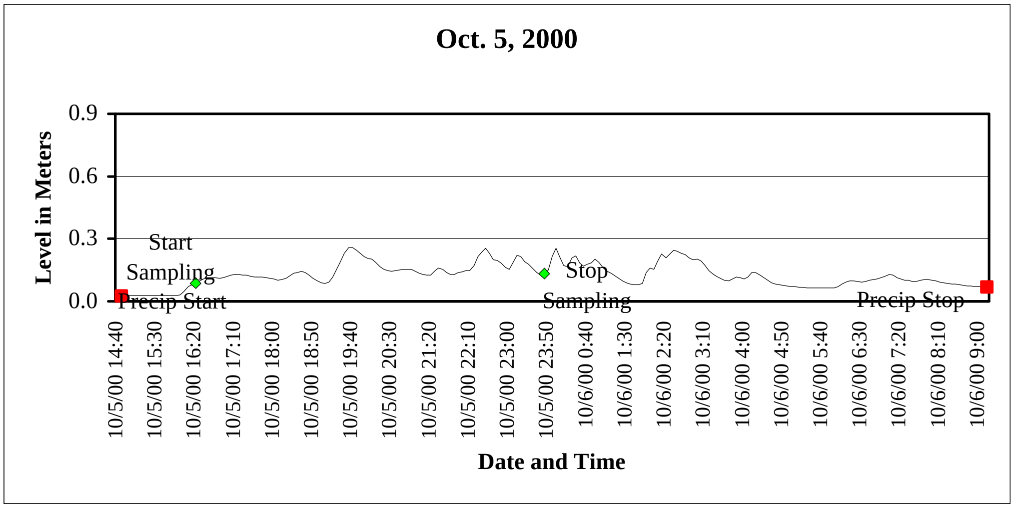


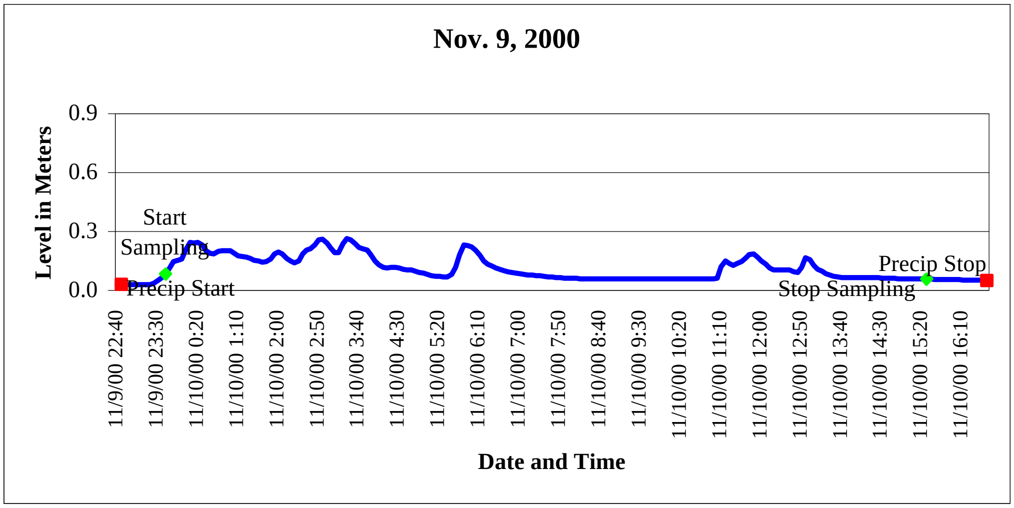




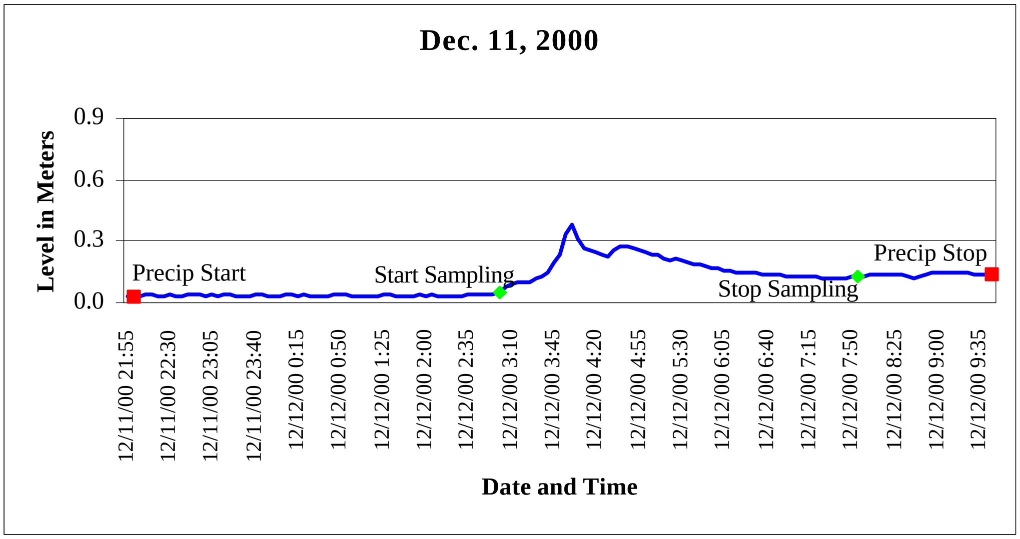
Marine Village Vortechs^{TM} System Hydrographs







Marine Village Vortechs^{TM} System Hydrographs



Appendix 5

Marine Village Subcatchment Survey Sheet

Marine Village Subcatchment Survey

Name of Surveyors	
Date	

Lot #			
Tax Map #			
Land Use Type			
Town	Village of Lake George		
Street Address			
Commercial Address			
Lot Dimensions			

Structures	1	2	3	4
Building Type				
Dimensions (ft x ft)				
Gutters (ft)				
Drains to…				

Other Impervious Areas					
Area Type					
Dimensions (ft x ft)					
Drains to…					
Material					

Lawn Dimension (ft x ft)					
% Bare Ground					
% Shrubs, Gardens, Etc.					

Comments:

Appendix 6

Marine Village Vortechs ^{TM} System Inflow and Outflow Data for conductivity, TP, TN, TSS, FC, and BOD

Vortechs^{TM} System Inflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
2/14/00 9:00	VTI 00-01	0.36	202	7.0	186.89	28500		<10*		
2/14/00 9:30	VTI 00-02	0.47	260	6.5	266.47	22500		<10*		
2/14/00 10:00	VTI 00-03	0.53	339	5.0	352.60	15600		<10*		
2/14/00 10:30	VTI 00-04	0.88	388	5.6	558.72	12400		10*		
2/14/00 11:00	VTI 00-05	0.89	439	8.4	1231.30	11000		<10*		
2/14/00 11:30	VTI 00-06	1.03	318	4.4	3785.20	9900		<10*		
2/14/00 12:00		0.94			1153.95	7600				
2/14/00 13:00		0.74			434.19	9600				
2/14/00 14:00	VTI 00-07	0.66	133	3.5	523.91	8470		<10*		
2/14/00 15:30		0.59			163.97	16720				
2/14/00 16:30	VTI 00-08	0.55	276	4.5	227.29	11920		30*		
2/14/00 18:30		0.48			73.00	14130				
2/14/00 20:30	VTI 00-09	0.43	207	4.5	58.32	12570		90*		
2/23/00 10:40		0.39			48.82	13940				
2/23/00 12:40		0.50			204.10	7260				
2/23/00 15:40		0.51			114.87	5200				
2/23/00 18:40		0.43			59.00	6730				
2/24/00 4:40		0.39			25.71	6610				
2/24/00 11:20		0.46			90.36	4110				
2/24/00 14:20		0.47			159.23	6200				
2/24/00 16:20		0.45			102.31	4970				
2/24/00 18:20		0.48			282.96	4890				
2/24/00 20:20	VTI 00-14	0.42	172	3.8	68.81	3800				
2/25/00 0:20		0.42			41.18	3260				
2/25/00 1:20	VTI 00-16	0.51	205	6.6	125.93	2060				
2/25/00 2:20	VTI 00-17	0.64	265	4.3	349.83	1060				
2/25/00 3:20	VTI 00-18	0.46	165	3.7	140.18	1010				
2/25/00 4:20		0.43			57.17	1390				
2/25/00 7:20	VTI 00-20	0.42	114	3.4	11.70	1740				
2/25/00 8:20	VTI 00-21	0.56	244	4.5	148.57	1090				
2/25/00 12:20	VTI 00-22	0.46	140	56.8	55.77	3040				
2/25/00 15:20	VTI 00-23	0.65	225	13.3	53.82	1061				
2/25/00 18:20		0.47			92.12	1206				
2/25/00 21:20	VTI 00-25	0.41	105	37.5	59.69	1572				
2/26/00 6:20	VTI 00-26	0.39	50	43.5	11.74	1942				
2/26/00 12:20		0.44			45.24	1403				
2/26/00 15:20	VTI 00-28	0.46	163	18.3	68.84	1190				
2/26/00 18:20		0.43			37.08	1090				
2/26/00 21:20		0.41			24.38	1114				
2/27/00 6:20	VTI 00-30	0.45	94	16.5	33.85	893				
2/27/00 9:20		0.46			38.41	788				
2/27/00 13:20	VTI 00-31	0.65	227	1.3	219.56	530				
2/27/00 16:20		0.57			83.33	492				
2/27/00 19:20	VTI 00-33	0.48	96	2.8	36.79	511				
2/27/00 22:20	VTI 00-34	0.44	795	0.2	19.55	558				
2/28/00 1:20		0.50			69.85	549				
2/28/00 4:20	VTI 00-36	0.73	126	0.5	965.23	179				
2/28/00 7:20		0.46	5748		325.54	220				

Vortechs$^{\text{TM}}$ System Inflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
BLANK	VTI 00-38		<1	<0.05						
2/28/00 10:45	VTI 00-39	0.42	78	0.2	147.81	352				
2/28/00 12:45	VTI 00-40	0.50	152	0.2	126.46	277				
2/28/00 14:45		0.48			96.42	424				
2/28/00 16:45		0.43			59.38	333				
2/28/00 18:45		0.40			22.54	351				
2/28/00 20:45	VTI 00-41	0.39	99	5.5	22.96	404				
2/29/00 8:50		0.39			7.78	555				
2/29/00 12:50	VTI 00-42	0.44	164	0.9	58.74	427				
2/29/00 14:50		0.44			51.50	298				
2/29/00 16:50		0.40			31.84	296				
2/29/00 18:50		0.39			22.94	334				
2/29/00 22:50		0.39			15.78	357				
3/1/00 4:55		0.38			12.02	374				
3/1/00 12:50	VTI 00-44	0.39	64	2.8	11.30	532				
3/1/00 14:50		0.41			37.11	455				
3/1/00 16:50	VTI 00-45	0.39	132	0.0	26.21	365				
3/1/00 20:50		0.40			18.31	430				
3/1/00 22:50	VTI 00-46	0.46	258	28.0	138.99	1573				
3/2/00 0:50	VTI 00-47	0.39	164	21.8	68.70	1470				
3/2/00 2:50		0.39			40.95	1402				
3/2/00 4:50	VTI 00-48	0.39	109	22.8	34.15	1361				
3/2/00 8:50		0.38			28.87	1334				
3/2/00 12:50		0.40			20.58	1156				
3/2/00 14:50		0.40			21.10	747				
3/2/00 16:50		0.40			42.29	437				
3/2/00 18:50		0.39			30.98	386				
3/2/00 20:55	VTI 00-49	0.39	170	0.7	24.04	387				
3/9/00 17:40	VTI 00-50	2.97	1976	7.3	4160.85	312				
3/9/00 17:45	VTI 00-51	2.06	1911	4.4	2586.87	233				
3/9/00 17:50	VTI 00-52	1.08	428	3.4	1701.54	221				
3/9/00 17:55	VTI 00-53	0.74	918	2.7	1753.13	209				
3/9/00 18:05	VTI 00-54	1.36	1068	2.7	4903.03	225				
3/10/00 0:05	VTI 00-55	0.38	338	2.4	2063.43	203				
3/10/00 6:05	VTI 00-56	0.37	137	2.6	345.77	230				
3/11/00 14:45	VTI 00-57	0.51	291	6.1	221.52	12160				
3/11/00 15:45	VTI 00-58	0.42	326	4.1	152.50	8220				
3/11/00 17:45		0.38	8783		61.28	6210				
3/11/00 21:45	VTI 00-59	0.39	n/a	1.8	36.58	11010				
3/11/00 22:45	VTI 00-60	0.43	105	2.5	60.94	18280				
3/11/00 23:45		0.44			72.80	22400				
3/12/00 1:45	VTI 00-61	0.57	129	1.2	92.44	9570				
3/12/00 2:45		0.59			45.70	6900				
3/12/00 3:45	VTI 00-62	0.68	86	1.5	71.43	3810				
3/12/00 4:45	VTI 00-63	0.70	72	0.4	301.37	1910				
3/12/00 5:45	VTI 00-64	0.54	67	1.7	417.61	2700				
3/12/00 6:45		0.48			178.90	5680				
3/12/00 9:45	VTI 00-65	0.45	69	1.2	59.55	7630				

Vortechs™ System Inflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
3/12/00 11:45	VTI 00-66	0.49	84	1.2	63.75	3160				
3/12/00 13:45	VTI 00-67	0.46	57	0.8	62.17	1450				
BLANK	VTI 00-68		2	<0.05						
3/25/00 20:50		0.48	669		382.50	6650				
3/25/00 21:50		0.41			238.75	3300				
3/26/00 1:50		0.38			55.00	2910				
3/28/00 0:08	VTI 00-69	0.72	572	6.6	1111.09	851				
3/28/00 0:18	VTI 00-70	0.55	382	3.8	628.92	99				
3/28/00 1:30	VTI 00-71	0.40	125	2.9	57.72	1179				
3/28/00 1:45	VTI 00-72	0.63	185	2.8	1241.85	415				
3/28/00 2:30	VTI 00-73	0.51	167	2.7	536.56	365				
3/28/00 2:40	VTI 00-74	0.85	201	3.0	1587.66	223				
3/28/00 3:30	VTI 00-75	0.46	93.9	2.4	795.09	196				
3/28/00 4:08	VTI 00-76	0.93	260	2.0	1175.08	150				
3/28/00 4:20	VTI 00-77	0.83	148	1.6	8947.81	132				
3/28/00 4:45	VTI 00-78	0.89	89	1.1	4163.23	88				
3/28/00 5:10	VTI 00-79	0.89	68	0.9	2889.70	58				
BLANK	VTI 00-80		<1	<0.05						
3/28/00 11:10		0.83	2290.9		468.78	56				
3/28/00 11:35		0.50			217.44	79				
3/28/00 14:05		0.39			20.86	156				
3/28/00 14:30		0.54			86.42	263				
3/28/00 14:55		0.46			84.76	226				
3/28/00 15:20		0.69			178.89	162				
3/28/00 15:45		0.47			91.48	131				
3/28/00 16:35		0.40			38.05	165				
3/28/00 19:35		0.38			29.24	196				
4/3/00 11:20	VTI 00-81	0.63	378	2.3	176.67	241				
4/3/00 11:25	VTI 00-82	0.68	356	2.3	361.88	185				
4/3/00 12:00	VTI 00-83	0.56	126	1.2	148.28	102				
4/3/00 13:20	VTI 00-84	0.78	138	1.3	537.78	99				
4/3/00 13:50	VTI 00-85	0.56	81	0.8	178.28	84				
4/3/00 15:50	VTI 00-86	0.40	62	1.1	72.36	115				
4/3/00 20:25		0.38	1141		27.01	179				
4/3/00 22:20		1.13			5022.20	69				
4/3/00 22:40		2.17			1385.68	43				
4/3/00 23:00		0.70			587.93	39				
4/3/00 23:30		1.04			1403.37	33				
4/3/00 23:50		1.63			827.98	28				
4/4/00 0:05		0.77			483.37	31				
4/4/00 0:30		0.65			110.96	43				
4/4/00 8:15		0.42			37.07	75				
4/4/00 10:15		0.60			48.40	57				
4/4/00 10:45		0.42			28.22	64				
4/4/00 11:15		0.39			13.21	77				
4/4/00 14:15		0.38			16.52	93				
4/8/00 19:50		0.51			47.73	162				
4/9/00 0:20		0.53			28.64	83				

Vortechs^{TM} System Inflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
4/9/00 7:45		0.38			10.58	37				
4/9/00 15:20		0.52			139.26	20100				
4/9/00 22:45		0.41			820.00	12700				
4/10/00 10:05		0.45			60.12	8880				
4/10/00 12:05		0.49			38.29	6680				
4/10/00 14:05		0.56			100.85	5580				
4/10/00 16:05		0.50			65.19	4120				
4/10/00 20:05		0.40			11.49	3520				
4/20/00 21:00		0.37			67.86	737				
4/20/00 23:00		0.40			25.31	504				
4/21/00 0:00		0.59			99.25	205				
4/21/00 1:00		0.52			28.64	158				
4/21/00 2:00		0.76			11526.13	115				
4/21/00 2:30		0.72			7062.22	57				
4/21/00 3:00		0.49			2310.12	73				
4/21/00 4:30		0.93			398.16	61				
4/21/00 5:30		0.81			391.10	59				
4/21/00 6:30		6.05			119.02	55				
6/5/00 20:10					*1251.43*	*339*				
6/5/00 21:40	VTI 00-87	0.47	238	4.1	66.88	185				
6/5/00 23:10		0.33			30.39	169				
6/6/00 0:40		0.39			22.68	156				
6/6/00 3:40		0.43			20.53	145				
6/6/00 8:55		0.30			26.84	143				
6/6/00 10:25		0.85			292.28	71				
8/23/00 11:10	VTI 00-93	0.58	1229	8.9	3254.31	307				
8/23/00 11:45	VTI 00-90/94	0.81	729	3.7	1310.53	123	58	800?		
8/23/00 12:45		0.82			1270.24	69				
8/23/00 13:40	VTI 00-91/95	1.40	94	0.8	527.92	28	9	60?		
8/23/00 14:10		0.59			146.38	37				
8/23/00 15:40	VTI 00-92/96	0.46	69	1.2	26.08	75	11	1000?		
8/23/00 16:10		0.92			12427.75	54				
8/23/00 16:40		0.67			3155.19	45				
8/23/00 18:05		0.39			446.91	66				
8/23/00 21:05	VTI 00-97	0.28	46	0.7	9.27	75	12	7900		
10/5/00 16:15	VTI 00-98	0.45	297	0.7	87.50	310	54	25200		
10/5/00 18:15		0.56			22.96	71				
10/5/00 19:50	VTI 00-99	0.95	96	0.8	78.23	32	17	29100		
10/5/00 20:50		0.70			396.10	34				
10/5/00 22:15		0.76			1363.78	35				
10/5/00 23:50	VTI 00-100	0.69	43	0.4	120.58	29	5	100000		
11/9/00 23:45	VTI 00-101	0.57	505	5.9	160.29	244				
11/10/00 0:20	VTI 00-102	1	304	2.1	287.91	78				
11/10/00 1:30	VTI 00-103	0.7	201	0.9	193.38	49				
11/10/00 2:40		0.89			1257.44	35				
11/10/00 3:50	VTI 00-104	0.87	115	0.4	935.51	28				

Vortechs^{TM} System Inflow

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11/10/00 4:25		0.58			172.52	35				
11/10/00 5:35	VTI 00-105	0.46	134	0.7	27.67	62				
11/10/00 6:10	VTI 00-106	0.78	115	0.6	72.27	35				
11/10/00 7:20		0.44			11.55	47				
11/10/00 9:05	VTI 00-107	0.39	159	0.8	4.92	75				
BLANK	VTI 00-108		<1	<0.05						
11/10/00 12:20	VTI 00-109	0.53	91	0.4	356.81	56				
11/10/00 15:20	VTI 00-110	0.38	165	0.6	18.73	65				
12/12/00 3:00	VTI 00-111		259	4.7	251.90	15480			63	3.5
12/12/00 3:30	VTI 00-112		353	4.3	292.35	9400			20	2.7
12/12/00 4:00	VTI 00-113		162	2.7	2297.74	6180			41	2.0
12/12/00 4:30	VTI 00-114		189	2.0	3706.93	3060			55	1.6
12/12/00 5:00					332.20	1720				
12/12/00 5:30					171.36	1260				
12/12/00 6:00	VTI 00-115		127	1.6	145.41	1060			70	1.4
12/12/00 6:30					72.80	1000				
12/12/00 7:00					36.52	900				
12/12/00 7:30	VTI 00-116		154	1.8	36.36	920			130	1.7
12/12/00 8:00	VTI 00-117		192	2.1	80.73	1790			129	1.7
BLANK	VTI 00-118		6	lt 0.05					lt 1.0	lt 0.5

Results marked with a "*" were tested outside of the six hour holding time and are not certifiable as per DFWI.

Fecal Coliform results marked with a "?" refers to a count with high background.

Vortechs^{TM} System Outflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
2/14/00 9:00	VTO 00-01	0.36	41	6.85	23.94	30600		<10*		
2/14/00 9:30	VTO 00-02	0.47	39	7.69	21.79	30400		<10*		
2/14/00 10:00	VTO 00-03	0.53	120	8.08	121.64	26600		<10*		
2/14/00 10:30	VTO 00-04	0.88	392	7.79	483.17			10*		
2/14/00 11:00	VTO 00-05	0.89	490	6.56	775.85	11500		30*		
2/14/00 11:30	VTO 00-06	1.03	284	4.54	396.90	9600		10*		
2/14/00 12:00		0.94			188.73	7800				
2/14/00 13:00		0.74			136.76	9000				
2/14/00 14:00	VTO 00-07	0.66	176	3.81	147.50	8500		<10*		
2/14/00 15:30		0.59			140.00	15700				
2/14/00 16:30	VTO 00-08	0.55	188	4.99	132.00	12600		30*		
2/14/00 18:30		0.48			81.41	14300				
2/14/00 20:30	VTO 00-09	0.43	48	7.35	28.03	29500		<10*		
2/23/00 10:40		0.39			80.66	13610				
2/23/00 12:40		0.50			182.39	8910				
2/23/00 15:40		0.51			125.54	5640				
2/23/00 18:40		0.43			72.61	6540				
2/24/00 4:40		0.39			36.09	6570				
2/24/00 11:20		0.46			94.24	4710				
2/24/00 14:20		0.47			104.14	4750				
2/24/00 16:20		0.45			118.36	5800				
2/24/00 18:20		0.48			89.25	4700				
2/24/00 20:20	VTO 00-14	0.42	227	5.72	149.20	4600				
2/25/00 0:20		0.42			54.94	3770				
2/25/00 1:20	VTO 00-16	0.51	156	4.99	73.33	3280				
2/25/00 2:20	VTO 00-17	0.64	278	5.33	202.50	1800				
2/25/00 3:20	VTO 00-18	0.46	167	15.75	108.72	1080				
2/25/00 4:20		0.43			68.96	1080				
2/25/00 7:20	VTO 00-20	0.42	107	33.75	25.66	1540				
2/25/00 8:20	VTO 00-21	0.56	280	19.25	24.00	1510				
2/25/00 12:20	VTO 00-22	0.46	144	3.23	80.65	2700				
2/25/00 15:20	VTO 00-23	0.65	212	17.25	164.15	1264				
2/25/00 18:20		0.47			48.03	1126				
2/25/00 21:20	VTO 00-25	0.41	89	23.75	31.50	1309				
2/26/00 6:20	VTO 00-26	0.39	73	26.75	21.77	1496				
2/26/00 12:20		0.44			21.22	1501				
2/26/00 15:20	VTO 00-28	0.46	78	37.25	20.26	1660				
2/26/00 18:20		0.43			59.55	1289				
2/26/00 21:20		0.41			49.04	1109				
2/27/00 6:20	VTO 00-30	0.45	96	1.8	27.31	1150				
2/27/00 9:20		0.46			23.77	1100				
2/27/00 13:20	VTO 00-31	0.65	78	9.5	27.95	865				
2/27/00 16:20		0.57			121.07	975				
2/27/00 19:20	VTO 00-33	0.48	133	4.25	72.43	595				
2/27/00 22:20	VTO 00-34	0.44	91	1.24	33.42	556				
2/28/00 1:20		0.50			24.83	582				
2/28/00 4:20	VTO 00-36	0.73	130	5.75	64.18	686				
2/28/00 7:20		0.46			50.86	214				

Vortechs^{TM} System Outflow										
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BLANK	VTO 00-38		<1	<0.05						
2/28/00 10:45	VTO 00-39	0.42	69.4	0.8	26.67	279				
2/28/00 12:45	VTO 00-40	0.50	151	0.54	48.83	307				
2/28/00 14:45		0.48			88.64	436				
2/28/00 16:45		0.43			69.10	409				
2/28/00 18:45		0.40			57.19	379				
2/28/00 20:45	VTO 00-41	0.39	161	0.78	55.20	373				
2/29/00 8:50		0.39			44.40	379				
2/29/00 12:50	VTO 00-42	0.44	145	2.25	36.55	397				
2/29/00 14:50		0.44			51.57	394				
2/29/00 16:50		0.40			46.67	349				
2/29/00 18:50		0.39			42.68	343				
2/29/00 22:50		0.39			38.86	343				
3/1/00 4:55		0.38			36.83	348				
3/1/00 12:50	VTO 00-44	0.39	145	0.3	33.76					
3/1/00 14:50		0.41			29.67					
3/1/00 16:50	VTO 00-45	0.39	114	0.3	29.28					
3/1/00 20:50		0.40			25.60					
3/1/00 22:50	VTO 00-46	0.46	121	0.3	24.00					
3/2/00 0:50	VTO 00-47	0.39	132	4.75	37.72	645				
3/2/00 2:50		0.39			36.80	682				
3/2/00 4:50	VTO 00-48	0.39	121	6.75	36.47	697				
3/2/00 8:50		0.38			35.49	694				
3/2/00 12:50		0.40			35.69	700				
3/2/00 14:50		0.40			35.54	729				
3/2/00 16:50		0.40			40.94	858				
3/2/00 18:50		0.39			35.34	945				
3/2/00 20:55	VTO 00-49	0.39	113	10.25	36.83	937				
3/3/00 1:35					*33.26*	*935*				
3/3/00 4:55					*32.64*	*932*				
3/3/00 ?					*33.15*	*940*				
3/9/00 17:40	VTO 00-50	2.97	1837	5.8	3397.16	454				
3/9/00 17:45	VTO 00-51	2.06	2229	4.5	2367.43	296				
3/9/00 17:50	VTO 00-52	1.08	1566	6.3	1571.13	263				
3/9/00 17:55	VTO 00-53	0.74	1459	4.9	1214.29	251				
3/9/00 18:05	VTO 00-54	1.36	828	4.6	955.94	238				
3/10/00 0:05	VTO 00-55	0.38	165	1.6	116.49	128				
3/10/00 6:05	VTO 00-56	0.37	119	1	57.30	122				
3/11/00 14:45	VTO 00-57	0.51	110	1.2	30.29	868				
3/11/00 15:45	VTO 00-58	0.42	264	3.9	104.32	11180				
3/11/00 17:45		0.38			101.97	11500				
3/11/00 21:45	VTO 00-59	0.39	206	2.8	91.59	10670				
3/11/00 22:45	VTO 00-60	0.43	185	3.1	81.29	10230				
3/11/00 23:45		0.44			100.46	15430				
3/12/00 1:45	VTO 00-61	0.57	139	1.9	152.65	12390				
3/12/00 2:45		0.59			61.16	9090				
3/12/00 3:45	VTO 00-62	0.68	108	0.4	52.62	3950				

Vortechs^{TM} System Outflow

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3/12/00 4:45	VTO 00-63	0.70	74	1.6	39.84	2210				
3/12/00 5:45	VTO 00-64	0.54	77	1.7	44.66	2470				
3/12/00 6:45		0.48			27.44	2760				
3/12/00 9:45	VTO 00-65	0.45	64	1.4	33.77	8410				
3/12/00 11:45	VTO 00-66	0.49	79	0.4	53.80	4090				
3/12/00 13:45	VTO 00-67	0.46	182	3.6	52.84	2110				
BLANK	VTO 00-68		1.3	0.1						
3/25/00 20:50		0.48			621.96	8600				
3/25/00 21:50		0.41			337.78	4430				
3/26/00 1:50		0.38			204.51	4040				
3/28/00 0:08	VTO 00-69	0.72	552	4.9	303.73	4000				
3/28/00 0:18	VTO 00-70	0.55	348	4.9	351.32	2260				
3/28/00 1:30	VTO 00-71	0.40	147	2.8	154.87	1597				
3/28/00 1:45	VTO 00-72	0.63	194	3.6	132.50	1585				
3/28/00 2:30	VTO 00-73	0.51	389	2.9	87.57	885				
3/28/00 2:40	VTO 00-74	0.85	392	2.7	151.03	818				
3/28/00 3:30	VTO 00-75	0.46	223	2.4	47.95	583				
3/28/00 4:08	VTO 00-76	0.93	128	2.1	71.48	578				
3/28/00 4:20	VTO 00-77	0.83	196	1.4	157.03	698				
3/28/00 4:45	VTO 00-78	0.89	126	1.1	97.95	525				
3/28/00 5:10	VTO 00-79	0.89	46	0.4	56.88	367				
BLANK	VTO 00-80		12	<0.05						
3/28/00 11:10		0.83			48.80	70				
3/28/00 11:35		0.50			44.11	74				
3/28/00 14:05		0.39			26.78	88				
3/28/00 14:30		0.54			25.76	98				
3/28/00 14:55		0.46			39.54	189				
3/28/00 15:20		0.69			57.88	273				
3/28/00 15:45		0.47			76.31	226				
3/28/00 16:35		0.40			66.55	211				
3/28/00 19:35		0.38			58.68	211				
4/3/00 11:20	VTO 00-81	0.63	87	1.9	32.22	376				
4/3/00 11:25	VTO 00-82	0.68	122	2.2	59.68	527				
4/3/00 12:00	VTO 00-83	0.56	172	2.4	91.30	244				
4/3/00 13:20	VTO 00-84	0.78	136	1.3	64.41	166				
4/3/00 13:50	VTO 00-85	0.56	108	1.2	60.68	107				
4/3/00 15:50	VTO 00-86	0.40	87	0.8	41.21	111				
4/3/00 20:25		0.38			35.77	112				
4/3/00 22:20		1.13			30.83	113				
4/3/00 22:40		2.17			188.64	74				
4/3/00 23:00		0.70			343.37	45				
4/3/00 23:30		1.04			168.37	42				
4/3/00 23:50		1.63			156.74	43				
4/4/00 0:05		0.77			131.18	38				
4/4/00 0:30		0.65			53.70	34				
4/4/00 8:15		0.42			22.47	73				
4/4/00 10:15		0.60			47.20	50				
4/4/00 10:45		0.42			35.16	54				
4/4/00 11:15		0.39			32.17	54				

Vortechs$^{\text{TM}}$ System Outflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
4/4/00 14:15		0.38			24.18	55				
4/8/00 19:50		0.51			76.63	224				
4/9/00 0:20		0.53			20.56	148				
4/9/00 7:45		0.38			5.76	43				
4/9/00 15:20		0.52			16.41	3440				
4/9/00 22:45		0.41			22.90	16600				
4/10/00 10:05		0.45			51.08	8580				
4/10/00 12:05		0.49			43.56	6710				
4/10/00 14:05		0.56			47.91	5170				
4/10/00 16:05		0.50			39.89	4350				
4/10/00 20:05		0.40			24.07	4040				
4/20/00 21:00		0.37			19.69	205				
4/20/00 23:00		0.40			14.38	208				
4/21/00 0:00		0.59			14.38	208				
4/21/00 1:00		0.52			34.95	410				
4/21/00 2:00		0.76			28.02	317				
4/21/00 2:30		0.72			18.84	285				
4/21/00 3:00		0.49			148.46	492				
4/21/00 4:30		0.93			35.44	109				
4/21/00 5:30		0.81			13.80	82				
4/21/00 6:30		6.05			26.70	71				
6/5/00 21:40	VTO 00-87	0.47	254	3.6	38.72	888				
6/5/00 23:10		0.33			36.44	571				
6/6/00 0:40		0.39			29.29	379				
6/6/00 3:40		0.43			29.09	338				
6/6/00 8:55		0.30			16.94	201				
6/6/00 10:25		0.85			48.37	236				
8/23/00 11:10	VTO 00-93	0.58	39.8	0.4	5.82	151				
8/23/00 11:45	VTO 00-90/94	0.81	884	1.2	80.63	129	57	1600?		
8/23/00 12:45		0.82			40.43	92				
8/23/00 13:40	VTO 00-91/95	1.40	152	2.6	38.07	74	21	17100?		
8/23/00 14:10		0.59			39.86	68				
8/23/00 15:40	VTO 00-92/96	0.46	169	0.7	54.59	30	3	1200?		
8/23/00 16:10		0.92			19.78	30				
8/23/00 16:40		0.67			13.08	42				
8/23/00 18:05		0.39			10.76	47				
8/23/00 21:05	VTO 00-97	0.28	37	0.5	9.17	48	10	7200		
10/5/00 16:15	VTO 00-98	0.45	230	5.7	2.42	4900	4	23500		
10/5/00 18:15		0.56			17.72	285				
10/5/00 19:50	VTO 00-99	0.95	105	0.8	42.89	62	8	8600		
10/5/00 20:50		0.70			8.86	39				
10/5/00 22:15		0.76			6.85	40				
10/5/00 23:50	VTO 00-100	0.69	50	0.4	4.22	29	6	9100		
11/9/00 23:45	VTO 00-101	0.57	228	1.0	13.20	179				
11/10/00 0:20	VTO 00-102	1	295	2	44.79	80				
11/10/00 1:30	VTO 00-103	0.7	223	1	8.20	50				

Vortechs™ System Outflow

DATE + TIME	ACCESSION NUMBER	LEVEL IN FEET	TP (µg/L)	TN (mg/L)	TSS (mg/L)	COND µS/cm	BOD (mg/L)	FC #/100mL	TFP (µg/L)	TSN (mg/L)
11/10/00 2:40		0.89			10.88	36				
11/10/00 3:50	VTO 00-104	0.87	99	0.4	5.92	27				
11/10/00 4:25		0.58			3.50	31				
11/10/00 5:35	VTO 00-105	0.46	120	0.3	3.40	38				
11/10/00 6:10	VTO 00-106	0.78	106	0.5	7.92	33				
11/10/00 7:20		0.44			4.30	39				
11/10/00 9:05	VTO 00-107	0.39	126	0.4	3.68	42				
BLANK	VTO 00-108		<1	<0.05						
11/10/00 12:20	VTO 00-109	0.53	117	0.5	36.79	72				
11/10/00 15:20	VTO 00-110	0.38	158	0.8	36.33	78				
12/12/00 3:00	VTO 00-111		74	1.3	7.78	2110			24	1.5
12/12/00 3:30	VTO 00-112		295	3.3	85.08	8690			131	2.4
12/12/00 4:00	VTO 00-113		158	3.1	89.29	6380			60	2.2
12/12/00 4:30	VTO 00-114		175	2.7	57.64	3300			62	1.8
12/12/00 5:00					26.67	1900				
12/12/00 5:30					20.33	1370				
12/12/00 6:00	VTO 00-115		134	1.6	16.72	1170			100	1.7
12/12/00 6:30					20.57	1100				
12/12/00 7:00					18.79	1040				
12/12/00 7:30	VTO 00-116		171	1.5	27.83	990			122	1.6
12/12/00 8:00	VTO 00-117		255	1.9	46.29	1440			124	1.3
BLANK			6	lt 0.05					lt 1.0	lt 0.5

Results marked with a "*" were tested outside of the six hour holding time and are not certifiable as per DFWI.

Fecal Coliform results marked with a "?" refers to a count with high background.

Appendix 7

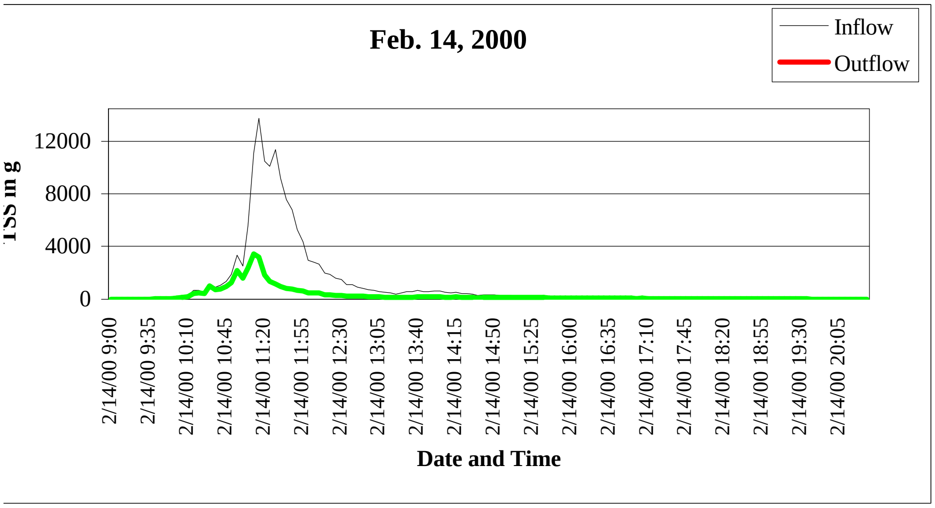
Event Mean Concentration data for TP, TN, and TSS

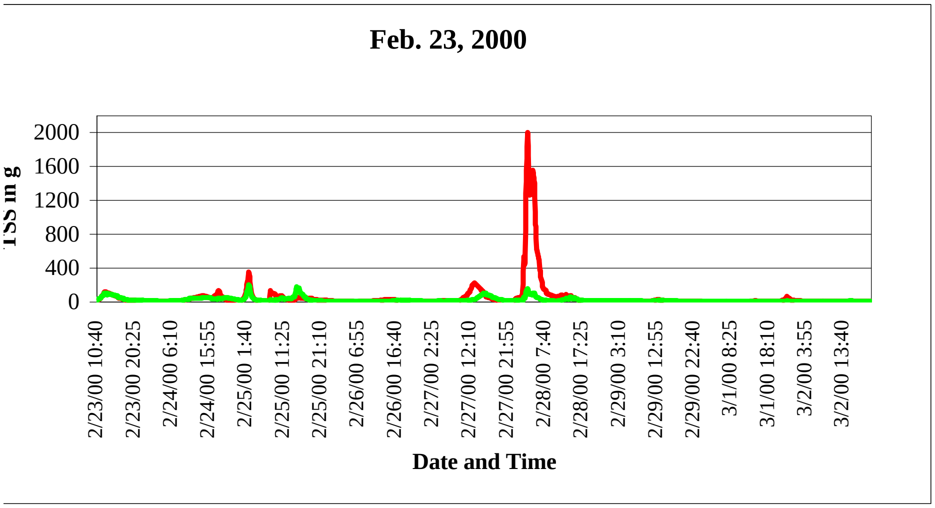
	Event Mean Concentrations			Event Mean Concentrations		
	Inflow			Outflow		
Storm Start Date	TP in µg/L	TN in mg/L	TSS in mg/L	TP in µg/L	TN in mg/L	TSS in mg/L
02/14/00	276.04	4.82	987.48	244.13	5.26	263.18
02/23/00	144.43	8.50	128.73	108.30	7.66	59.23
03/09/00	362.62	2.78	1040.04	321.66	2.16	337.87
03/25/00			213.73			359.14
03/28/00	95.19	1.25	1673.57	90.38	0.88	71.39
04/03/00	72.42	1.12	535.16	91.94	0.90	70.14
04/08/00			180.81			29.76
04/20/00			2491.55			35.41
06/05/00			89.99			31.98
08/23/00	133.82	1.01	1047.02	293.00	1.54	37.08
10/05/00	109.64	0.66	439.45	106.51	1.41	16.57
11/09/00	169.86	0.95	445.19	160.17	0.77	17.36
12/12/00	174.53	2.16	1156.16	168.76	2.30	44.72

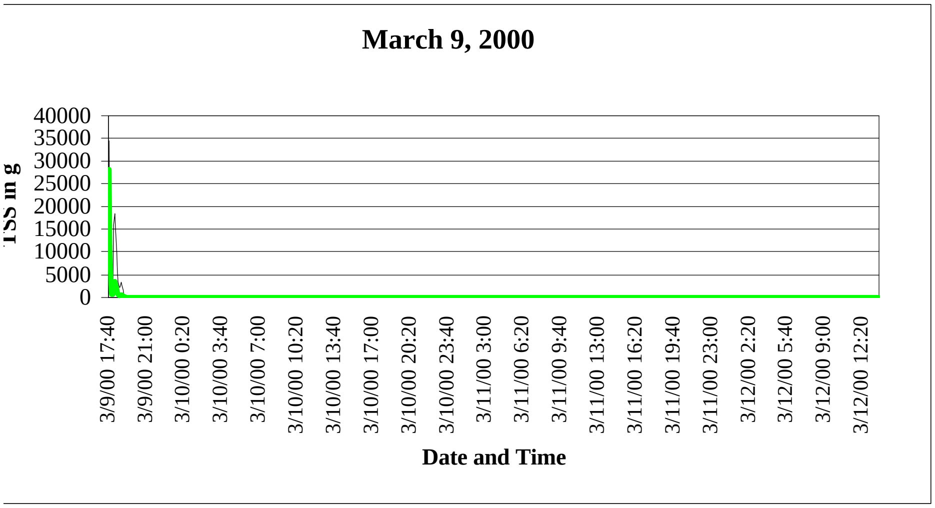
Appendix 8

Total Suspended Solids Chemical Loading Graphs for each storm sampled

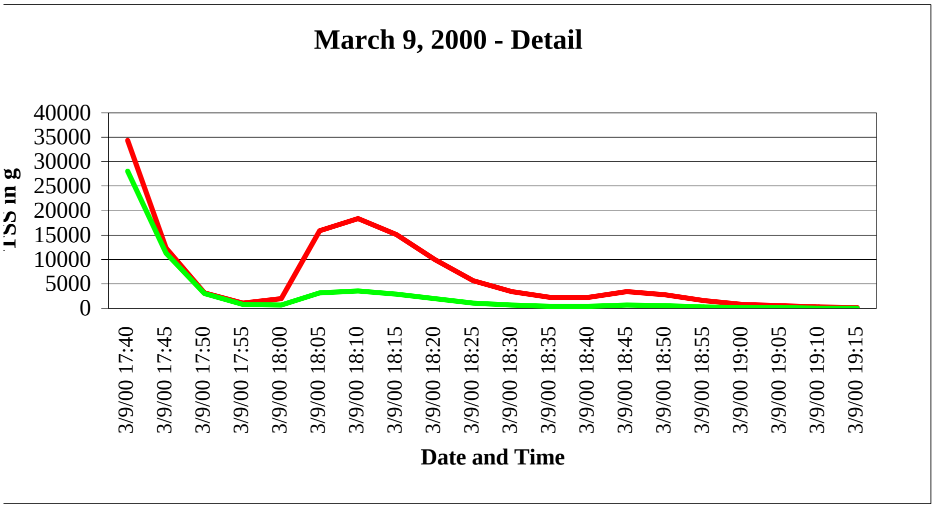
Total Suspended Solids Chemical Loading

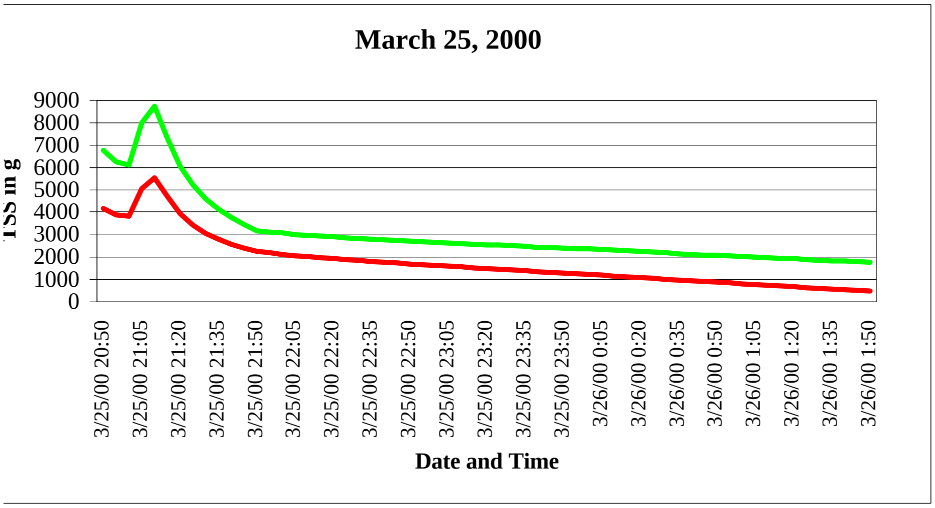


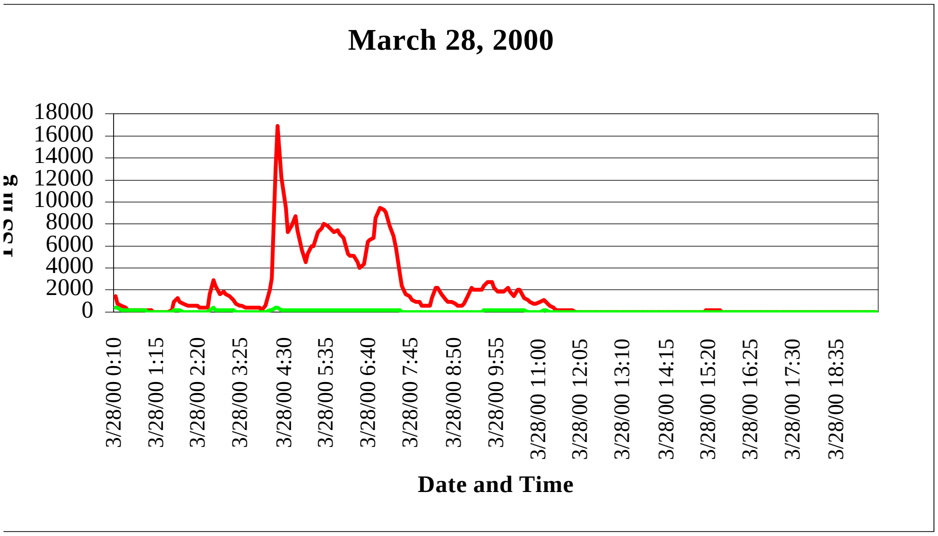




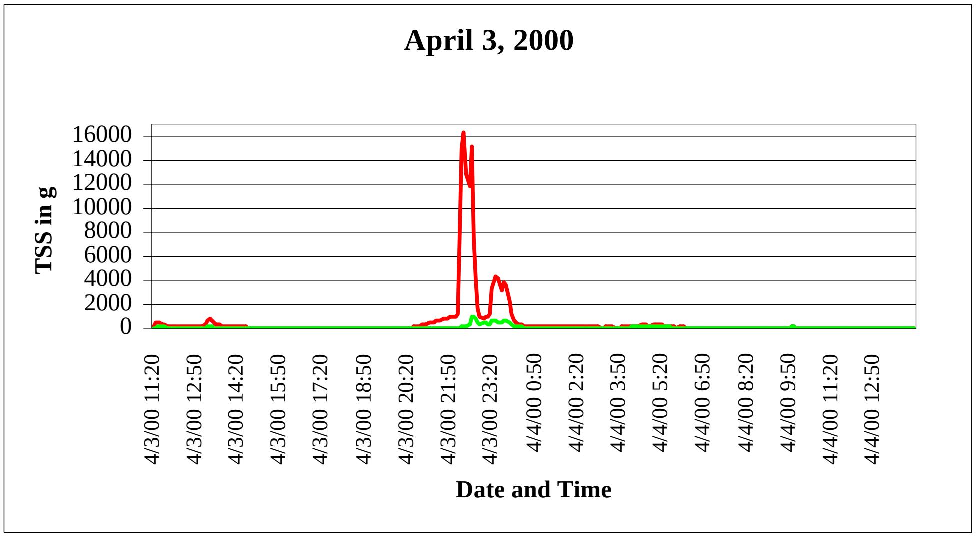
Total Suspended Solids Chemical Loading

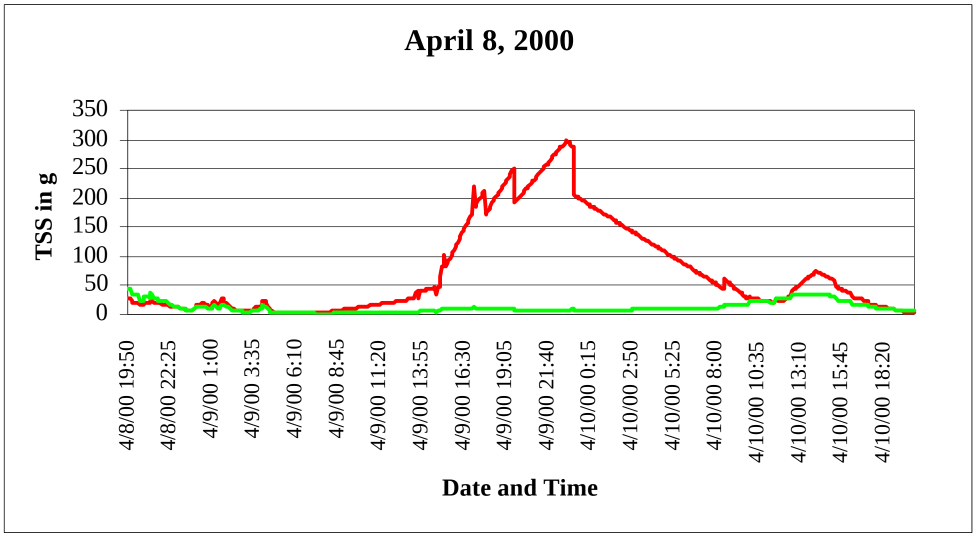


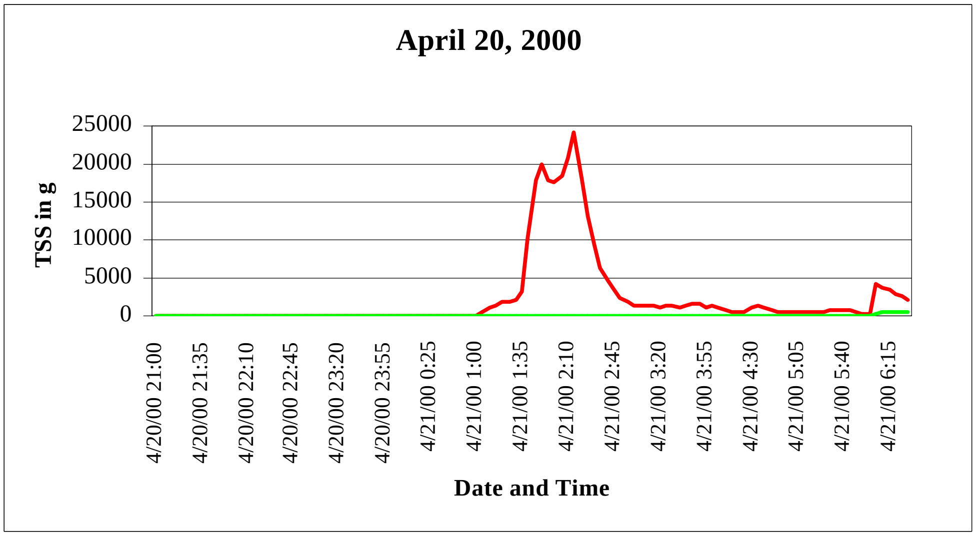




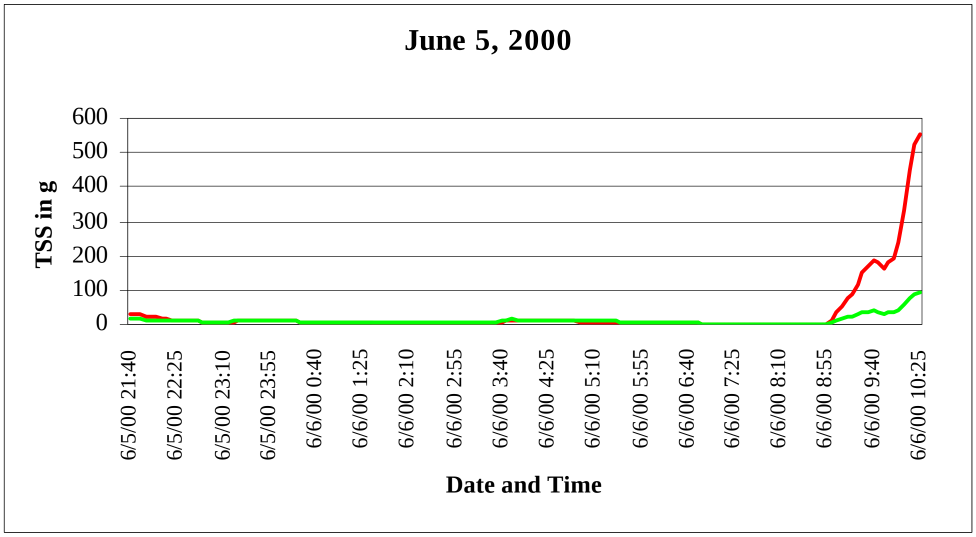
Total Suspended Solids Chemical Loading



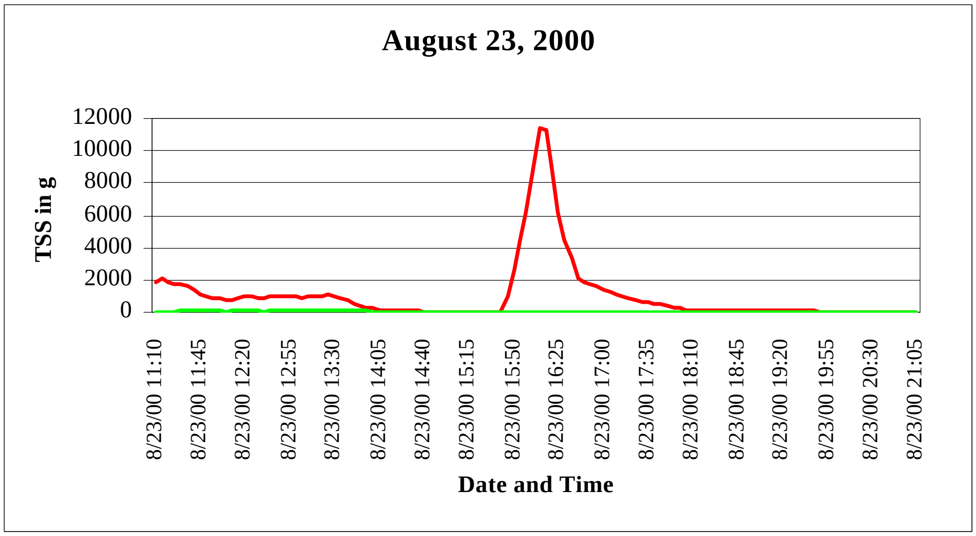




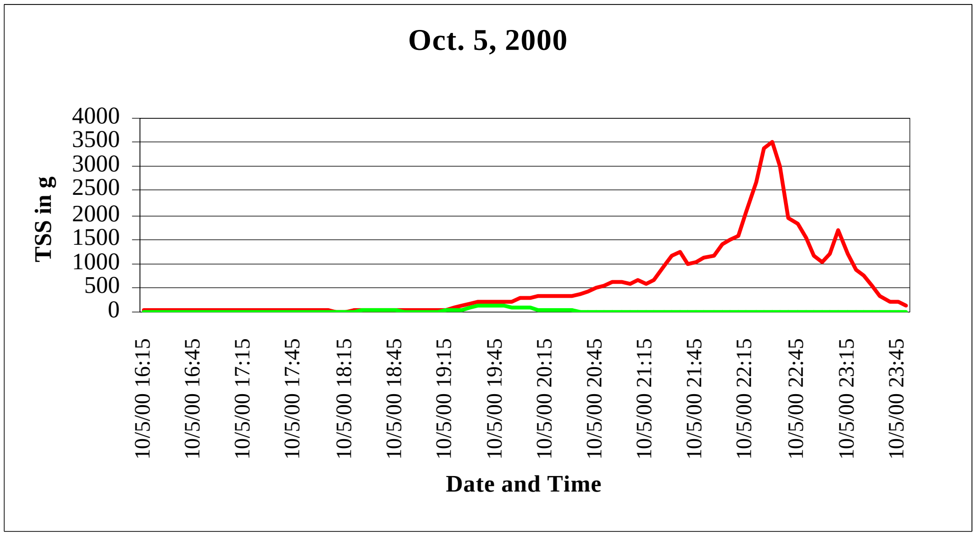
Total Suspended Solids Chemical Loading



June 5, 2000

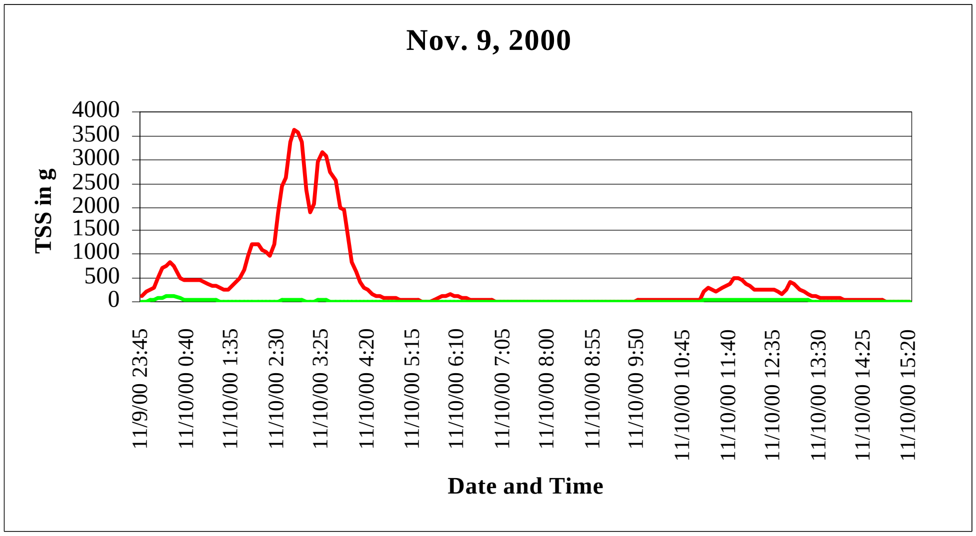


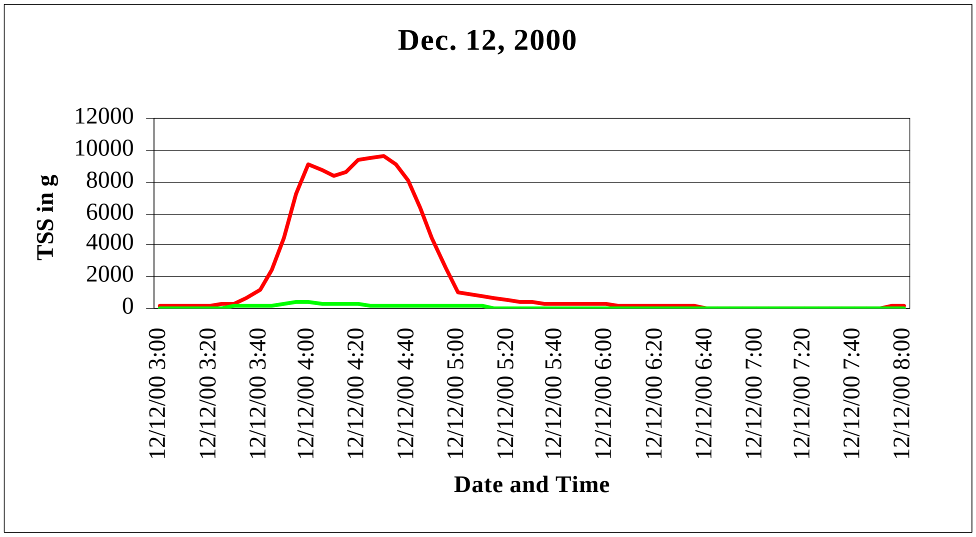
August 23, 2000



Oct. 5, 2000

Total Suspended Solids Chemical Loading





Appendix 9

Grain size distribution graph from Vortechs^{TM} Systems cleanouts in 1998 and 2000

SCS-ENG-353A
Rev. 11-71

LABORATORY NO.

MATERIALS TESTING REPORT	**U. S. DEPARTMENT of AGRICULTURE SOIL CONSERVATION SERVICE**	**SOIL CLASSIFICATION**

PROJECT and STATE: VORTECHS STUDY - LAKE GEORGE VILLAGE
SAMPLE LOCATION: CANADA STREET
FIELD SAMPLE NO.: AS SHOWN
DEPTH: CHAMBER
GEOLOGIC ORIGIN: STORM WATER WASH OFF
TYPE OF SAMPLE:
TESTED AT: PARROTT-WOLFF
APPROVED BY:
DATE: AS SHOWN
SYMBOL:
DESCRIPTION:

GRAIN SIZE DISTRIBUTION

C_u

C_c

D_{max}

D_{85}

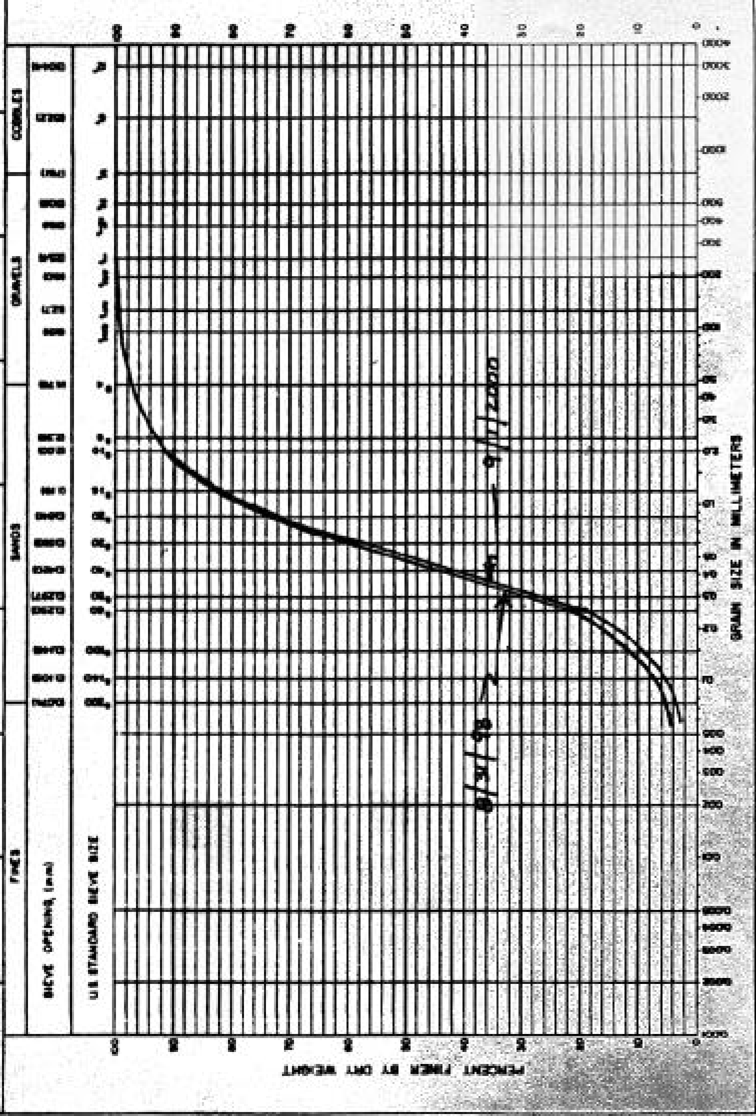
D_{60}

D_{50}

D_{30}

D_{15}

D_{10}



UNDISTURBED CONDITION
MOISTURE %
DRY UNIT WEIGHT g/cc pcf

SHRINKAGE LIMIT %

SOLUBLE SALTS %

ATTERBERG LIMITS
NATURAL MOISTURE: LL PI
AIR DRY: LL PI
OVEN DRY: LL PI

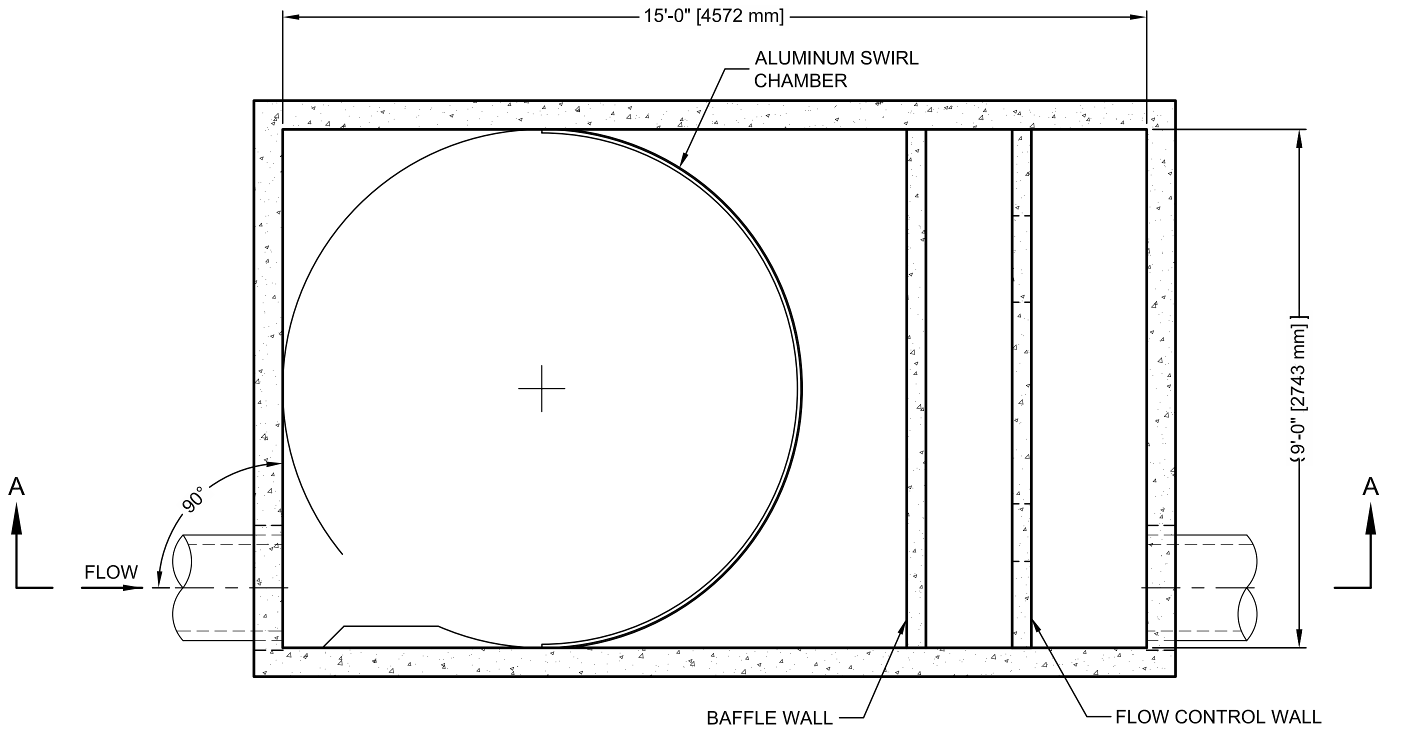
SPECIFIC GRAVITY (G_s)
(-) #4
(+) #4

REMARKS

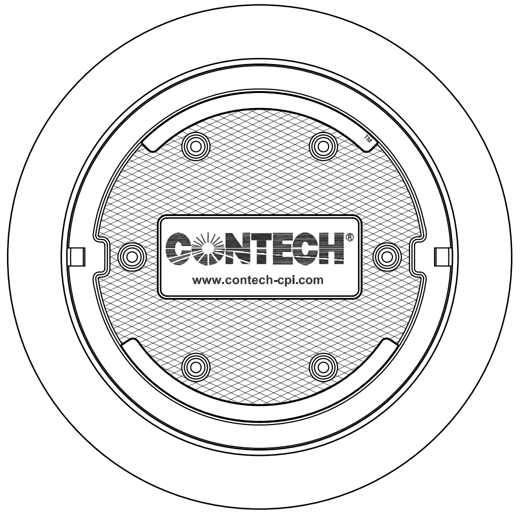
VORTECHS 9000 DESIGN NOTES

VORTECHS 9000 RATED TREATMENT CAPACITY IS 14 CFS, OR PER LOCAL REGULATIONS. IF THE SITE CONDITIONS EXCEED RATED TREATMENT CAPACITY, AN UPSTREAM BYPASS STRUCTURE IS REQUIRED.

THE STANDARD INLET/OUTLET CONFIGURATION IS SHOWN. FOR OTHER CONFIGURATION OPTIONS , PLEASE CONTACT YOUR CONTECH REPRESENTATIVE. www.contechES.com



SECTION B-B



FRAME AND COVER

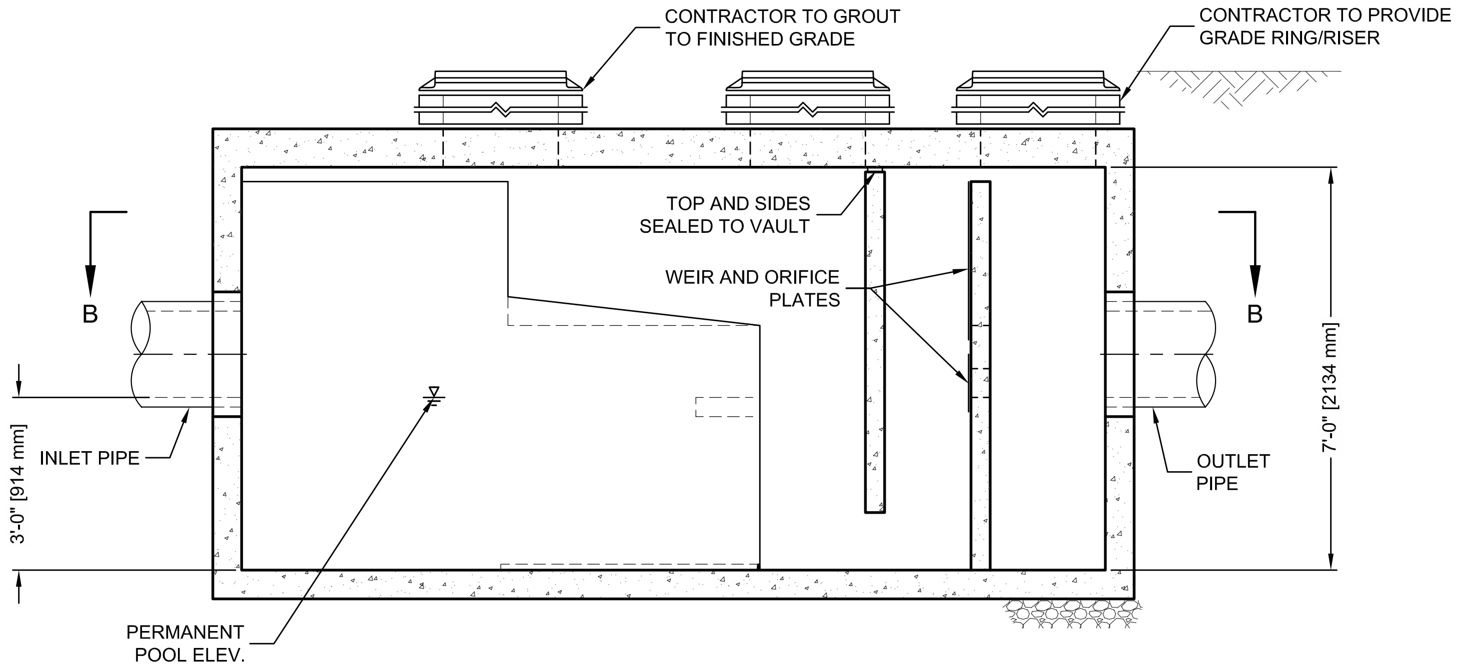
(DIAMETER VARIES)

N.T.S.

SITE SPECIFIC DATA REQUIREMENTS

STRUCTURE ID			*
WATER QUALITY FLOW RATE (CFS)			*
PEAK FLOW RATE (CFS)			*
RETURN PERIOD OF PEAK FLOW (YRS)			*
PIPE DATA:	I.E.	MATERIAL	DIAMETER
INLET PIPE 1	*	*	*
INLET PIPE 2	*	*	*
OUTLET PIPE	*	*	*
RIM ELEVATION			*
ANTI-FLOTATION BALLAST		WIDTH	HEIGHT
		*	*
NOTES/SPECIAL REQUIREMENTS:			

* PER ENGINEER OF RECORD



SECTION A-A

GENERAL NOTES

1. CONTECH TO PROVIDE ALL MATERIALS UNLESS NOTED OTHERWISE.
2. DIMENSIONS MARKED WITH ( ) ARE REFERENCE DIMENSIONS. ACTUAL DIMENSIONS MAY VARY.
3. FOR FABRICATION DRAWINGS WITH DETAILED STRUCTURE DIMENSIONS AND WEIGHT, PLEASE CONTACT YOUR CONTECH REPRESENTATIVE. www.contechES.com
4. VORTECHS WATER QUALITY STRUCTURE SHALL BE IN ACCORDANCE WITH ALL DESIGN DATA AND INFORMATION CONTAINED IN THIS DRAWING.
5. STRUCTURE SHALL MEET AASHTO HS20 AND CASTINGS SHALL MEET AASHTO M306 LOAD RATING, ASSUMING GROUNDWATER ELEVATION AT, OR BELOW, THE OUTLET PIPE INVERT ELEVATION. ENGINEER OF RECORD TO CONFIRM ACTUAL GROUNDWATER ELEVATION.
6. INLET PIPE(S) MUST BE PERPEDICULAR TO THE VAULT AND AT THE CORNER TO INTRODUCE THE FLOW TANGENTIALLY TO THE SWIRL CHAMBER. DUAL INLETS NOT TO HAVE OPPOSING TANGENTIAL FLOW DIRECTIONS.
7. OUTLET PIPE(S) MUST BE DOWN STREAM OF THE FLOW CONTROL BAFFLE AND MAY BE LOCATED ON THE SIDE OR END OF THE VAULT. THE FLOW CONTROL WALL MAY BE TURNED TO ACCOMODATE OUTLET PIPE KNOCKOUTS ON THE SIDE OF THE VAULT.

INSTALLATION NOTES

A. ANY SUB-BASE, BACKFILL DEPTH, AND/OR ANTI-FLOTATION PROVISIONS ARE SITE-SPECIFIC DESIGN CONSIDERATIONS AND SHALL BE SPECIFIED BY ENGINEER OF RECORD.
B. CONTRACTOR TO PROVIDE EQUIPMENT WITH SUFFICIENT LIFTING AND REACH CAPACITY TO LIFT AND SET THE VORTECHS STRUCTURE (LIFTING CLUTCHES PROVIDED).
C. CONTRACTOR TO INSTALL JOINT SEALANT BETWEEN ALL STRUCTURE SECTIONS AND ASSEMBLE STRUCTURE.
D. CONTRACTOR TO PROVIDE, INSTALL, AND GROUT PIPES. MATCH PIPE INVERTS WITH ELEVATIONS SHOWN.
E. CONTRACTOR TO TAKE APPROPRIATE MEASURES TO ASSURE UNIT IS WATER TIGHT, HOLDING WATER TO FLOWLINE INVERT MINIMUM. IT IS SUGGESTED THAT ALL JOINTS BELOW PIPE INVERTS ARE GROUTED.

Vortechs®

THIS PRODUCT MAY BE PROTECTED BY THE FOLLOWING U.S. PATENT: 5,759,415; RELATED FOREIGN PATENTS.

CONTECH®
ENGINEERED SOLUTIONS LLC
www.contechES.com
9025 Centre Pointe Dr., Suite 400, West Chester, OH 45069
800-338-1122 513-645-7000 513-645-7993 FAX

VORTECHS 9000
STANDARD DETAIL

C:\USERS\FISHERS\DESKTOP\LOGO UPDATE\VORTECHS DIM UPDATE\VX-9000-DTL.DWG 8/28/2012 11:03 AM

APPENDIX 2

WQv Calculations

COMPUTATION OF WATER QUALITY VOLUME (WQ$_v$)

Impervious Area (Acres)	25.88	
I (Impervious Cover)	46.61%	
Rv = 0.05+0.009I	0.47	Minimum Rv = 0.20
P	1	
A (site area in acres)	55.52	
WQ$_v$ (1A)= [(P)(R$_v$)(A)]/12 (in acre-feet)	2.172	

TREATMENT IN REDEVELOPMENT AREA	
Required Treatment Volume (25% of WQv) in ac-ft	0.543
Required Treatment Volume (25% of WQv) in CF	23657

COMPUTATION OF MIN. RUNOFF REDUCTION VOLUME (RR$_v$) OF TOTAL SITE

Aic - Total Impervious Area -(Acres)	25.88	
I (Impervious Cover)	46.61%	
Rv = 0.95	0.95	Rv = 0.95
P	1	
A (site area in acres)	55.52	

S (Hydrologic Group Specific Reduction Factor)	0.30	Hydrologic Class C Soil
Ai (Impervious cover targeted for runoff reduction)	7.76	Aic * S
RR$_v$ = [(P)(R$_v$)(*Ai*)]/12 (in acre-feet)	0.184	

APPENDIX 3

Certification Letter

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
401-02B
Bureau of Nonpoint Pollution Control
Division of Water Quality
Post Office Box 420
Trenton, New Jersey 08625-0420
609-633-7021 Fax: 609-777-0432
http://www.state.nj.us/dep/dwq/bnpc_home.htm

BOB MARTIN
Commissioner

August 31, 2011

Derek Berg
200 Enterprise Drive
Scarborough, ME 04074

Re: MTD Field Test Certification for the Vortechs Stormwater Treatment System by CONTECH Construction Products, Inc.

Effective Date: September 1, 2011
Expiration Date: December 1, 2016
TSS Removal Rate: 50%

Dear Mr. Berg:

The Stormwater Management Rules at N.J.A.C. 7:8 allow the use of manufactured treatment devices (MTDs) for compliance with the design and performance standards provided that the pollutant removal rates have been verified by New Jersey Corporation for Advanced Technology, NJCAT, and certified by the New Jersey Department of Environmental Protection (NJDEP).

The certification process was revised through the "Transition for Manufactured Treatment Devices," dated July 15, 2011. NJDEP has determined that Vortechs Stormwater Treatment System by CONTECH Construction Products, Inc. is consistent with the criteria under *B. Manufactured Treatment Devices with Final Certifications*. Therefore, **NJDEP certifies the use of the Vortechs Stormwater Treatment System by CONTECH Construction Products, Inc. with a 50% TSS removal rate, provided that the project design is consistent with the following conditions:**

1. The model selected for the project design must be sized in accordance with Table 1 and based on the peak flow of the New Jersey Water Quality Design Storm as specified in N.J.A.C. 7:8-5.

2. The Vortechs Stormwater Treatment System can only be used off-line. Any flow above the New Jersey Water Quality Design Storm must utilize an external bypass around the system.

3. A hydrodynamic separator, such as the Vortechs Stormwater Treatment System, cannot be used in series with another hydrodynamic separator to achieve an enhanced removal rate for total suspended solids (TSS) removal under N.J.A.C. 7:8-5.5.
4. The maintenance plan for the sites using this device shall incorporate at a minimum, the maintenance requirements for the Vortechs Stormwater Treatment System, attached.

Table 1

Vortechs System Model	Grit Chamber Radius (ft)	Grit Chamber Area (ft^2)	Design Flow Rate (cfs)
1000	1.5	7.1	0.63
2000	2.0	12.6	1.12
3000	2.5	19.6	1.75
4000	3.0	28.3	2.5
5000	3.5	38.5	3.4
7000	4.0	50.3	4.5
9000	4.5	63.6	5.7
11000	5.0	78.5	7.0
16000	6.0	113.1	10.1

In addition to the attached, any project with a Stormwater BMP subject to the Stormwater Management Rules, N.J.A.C. 7:8, must include a detailed maintenance plan. The detailed maintenance plan must include all of the items identified in Stormwater Management Rules, N.J.A.C. 7:8-5.8. Such items include, but are not limited to, the list of inspection and maintenance equipment and tools, specific corrective and preventative maintenance tasks, indication of problems in the system, and training of maintenance personnel. Additional information can be found in Chapter 8: Maintenance of the New Jersey Stormwater Best Management Manual.

NJDEP anticipates proposing further adjustments to this process through the readoption of the Stormwater Management Rules. Additional information regarding the implementation of the Stormwater Management Rules N.J.A.C. 7:8 are available at www.njstormwater.org. If you have any questions regarding the above information, please contact Ms. Sandra Blick of my office at (609) 633-7021.

Sincerely,

Ed Frankel, P.P., Acting Bureau Chief
Bureau of Nonpoint Pollution Control

C: Richard S. Magee, NJCAT
Chron file

Vortechs® Maintenance

The Vortechs system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. The rate at which the system collects pollutants will depend more heavily on site activities than the size of the unit, e.g., unstable soils or heavy winter sanding will cause the swirl chamber to fill more quickly but regular sweeping will slow accumulation.

Inspection

Inspection is the key to effective maintenance and is easily performed. Pollutant deposition and transport may vary from year to year and regular inspections will help ensure that the system is cleaned out at the appropriate time. Inspections should be performed twice per year (i.e. spring and fall) however more frequent inspections may be necessary in equipment washdown areas and in climates where winter sanding operations may lead to rapid accumulations. It is useful and often required as part of a permit to keep a record of each inspection. A simple inspection and maintenance log form for doing so is provided on the following page, and is also available on contechstormwater.com.

The Vortechs system should be cleaned when inspection reveals that the sediment depth has accumulated to within 12 to 18 inches (300 to 450 mm) of the dry-weather water surface elevation. 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. Note: To avoid underestimating the volume of sediment in the chamber, the measuring device must be carefully lowered to the top of the sediment pile. Finer, silty particles at the top of the pile typically offer less resistance to the end of the rod than larger particles toward the bottom of the pile.

Cleaning

Cleaning of the Vortechs system should be done during dry weather conditions when no flow is entering the system. Clean-out of the Vortechs system with a vacuum truck is generally the most effective and convenient method of excavating pollutants from the system. If such a truck is not available, a "clamshell" grab may be used, but it is difficult to remove all accumulated pollutants using a "clamshell".

In installations where the risk of petroleum spills is small, liquid contaminants may not accumulate as quickly as sediment. However, an oil or gasoline spill should be cleaned out immediately. Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use adsorbent pads to solidify the oil since these pads are usually much easier to remove from the unit individually and less expensive to dispose of than the oil/water emulsion that may be created by vacuuming the oily layer. Floating trash can be netted out if you wish to separate it from the other pollutants.

Cleaning of a Vortechs system is typically done by inserting a vacuum hose into the swirl chamber and evacuating this chamber of water and pollutants. As water is evacuated, the water level outside of the swirl chamber will drop to a level roughly equal to the crest of the lower aperture of the swirl chamber. The water outside the swirl chamber should remain near this level throughout pumping as the bottom and sides of the swirl chamber are sealed to the tank floor and walls. This "water lock" feature prevents water from migrating into the swirl chamber, exposing the bottom of the baffle wall and creating excess pump-out volume. Floating pollutants will decant into the swirl chamber as the water level is drawn down. This allows most floating material to be withdrawn from the same access point above the swirl chamber. Floating material that does not decant into the swirl chamber during draw down should be skimmed from the baffle chamber. If maintenance is not performed as recommended, sediment may accumulate outside the swirl chamber. If this is the case, it may be necessary to pump out other chambers. It is advisable to check for sediment accumulation in all chambers during inspection and maintenance.

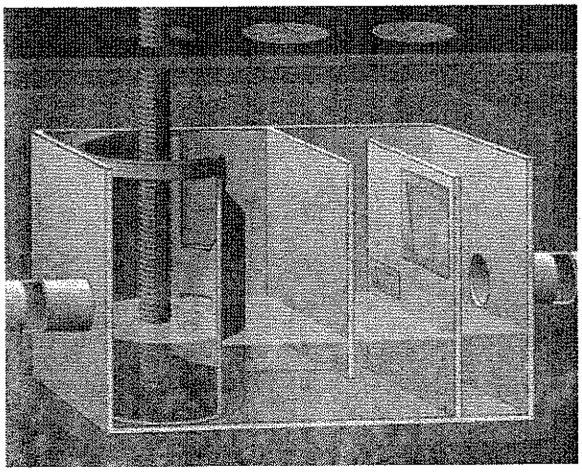
These maintenance recommendations apply to all Vortechs systems with the following exceptions:

1. It is strongly recommended that when cleaning systems larger than the Model 16000 the baffle chamber be drawn down to depth of three feet prior to beginning clean-out of the swirl chamber. Drawing down this chamber prior to the swirl chamber reduces adverse structural forces pushing upstream on the swirl chamber once that chamber is empty.
2. Entry into a Vortechs system is generally not required as cleaning can be done from the ground surface. However, if manned entry into a system is required the entire system should be evacuated of water prior to entry regardless of the system size.

Manhole covers should be securely seated following cleaning activities to prevent leakage of runoff into the system from above and also to ensure proper safety precautions. If anyone physically enters the unit, Confined Space Entry procedures need to be followed.

Disposal of all material removed from the Vortechs system should be done in accordance with local regulations. In many locations, disposal of evacuated sediments may be handled in the same manner as disposal of sediments removed from catch basins or deep sump manholes. Check your local regulations for specific requirements on disposal.

For assistance with maintaining your Vortechs system, contact us regarding the CONTECH Maintenance Compliance Certification Program.



Vortechs Inspection & Maintenance Log

Vortech Model: ______________________ Location: ______________________

Date	Water depth to sediment[1]	Floatable Layer Thickness[2]	Describe Maintenance Performed	Maintenance Personnel	Comments

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1. The water depth to sediment is determined by taking two measurements with a stadia rod: one measurement from the manhole opening to the top of the sediment pile and the other from the manhole opening to the water surface. If the difference between these measurements is less than eighteen inches the system should be cleaned out. Note: To avoid underestimating the volume of sediment in the chamber, the measuring device must be carefully lowered to the top of the sediment pile.

2. For optimum performance, the system should be cleaned out when the floating hydrocarbon layer accumulates to an appreciable thickness. In the event of an oil spill, the system should be cleaned immediately.