Module 4a: Catchbasins, Inserts, and Hydrodynamic Devices for the Control of Gross Solids and Conventional Stormwater Pollutants

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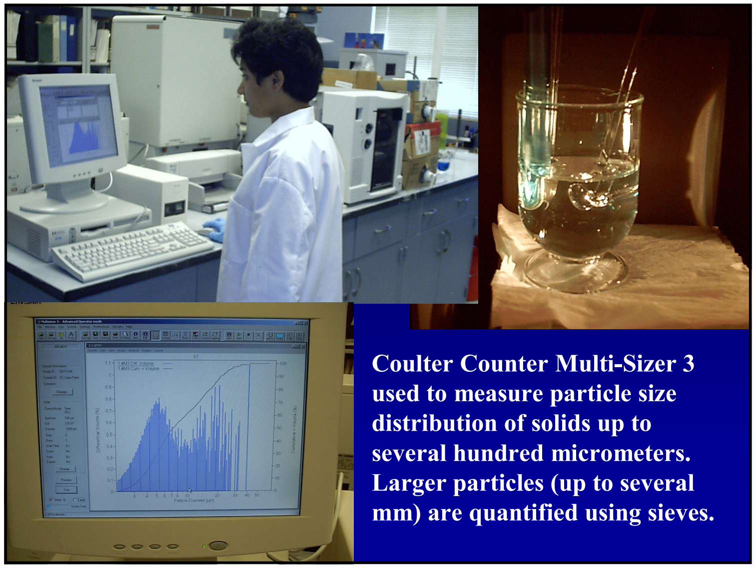
Aesthetic (Floatables) and Gross Solids Characteristics of Stormwater

- Many communities are struggling with aesthetic degradation of urban waterways
- Litter from the landscape contributes to shoreline contamination
- Gross solids/bedload material, although a small portion of stormwater total solids loads, contributes to clogging of sewerage

Gross floatables currently most important wet weather flow pollutant in many urban areas.

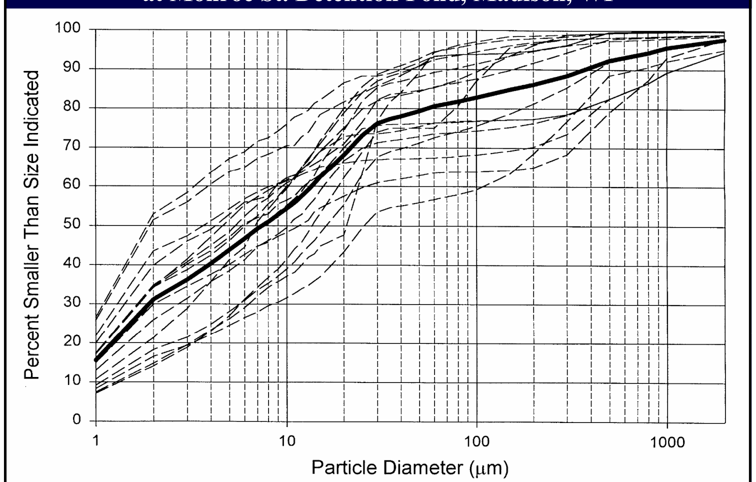
Stirred and Settled Sample, Showing Settleable Solids (Madison high-efficiency street cleaning tests)

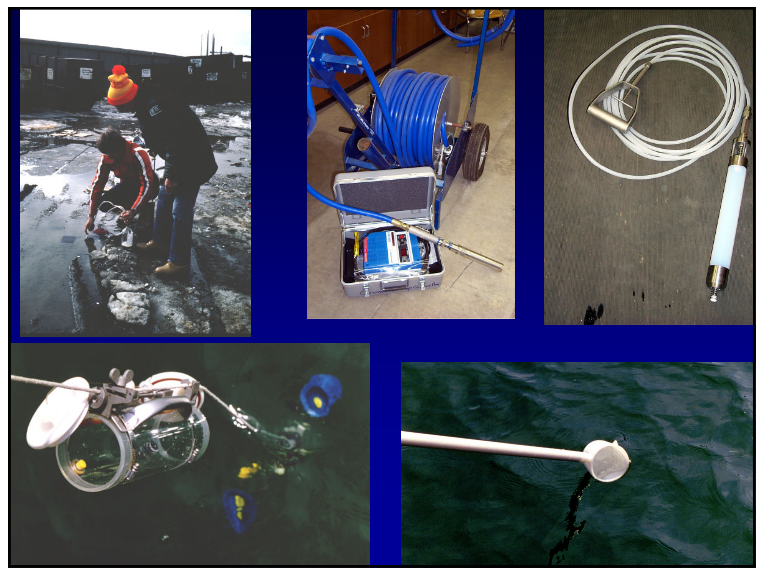


Coulter Counter Multi-Sizer 3 used to measure particle size distribution of solids up to several hundred micrometers. Larger particles (up to several mm) are quantified using sieves.

Particle Size Analyses Using Cascading Sieves

Measured Particle Sizes, Including Bed Load Component, at Monroe St. Detention Pond, Madison, WI



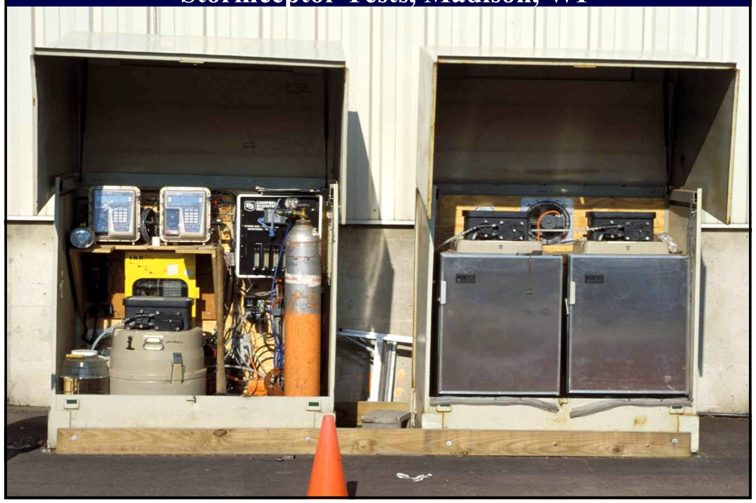


Loss of Large Particulates in Sampling Lines (100 cm/sec sample line velocity)

Percentage loss of particulates	Critical settling rate (cm/sec)	Size range (1.5 to 2.5 sp. gr.)
100	100	8,000 – 25,000
50	50	3,000 – 10,000
25	25	1,500 – 3,000
10	10	350 – 900
1	1	100 – 200

Problem isn't sample line velocity, but location of intake; need bedload sampler

USGS and WI DNR Monitoring Facility for Stormceptor Tests, Madison, WI



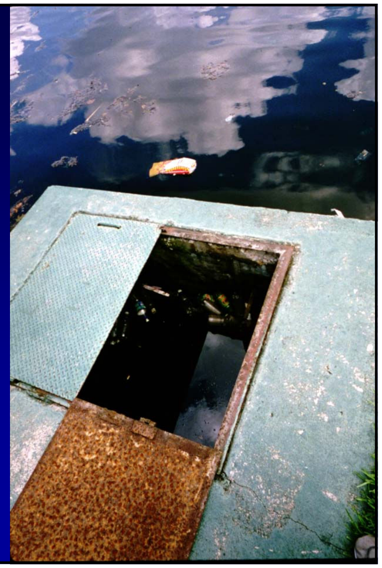
Results of Verification Monitoring of Stormceptor (Madison, WI)

Sampled solids load in (plus material not sampled by automatic sampler)	1623 +131 = 1754 kg
Sampled solids load out	1218 kg
Trapped by difference	405 kg (25% removal)
Actual trapped total sediment	536 kg (33% actual removal)
Fraction total solids not captured by automatic samplers	7.5%

Trash screening, along with alum injection, Orlando, FL

EquiFlow pump back system (Fresh Creek Technologies), Brooklyn, NY

Netting TrashTrap (Fresh Creek Technologies), Brooklyn, NY



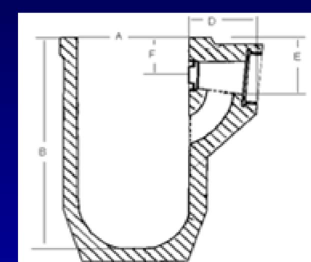
Research Results

- A New Jersey study (Pitt, 1999) found average removal rates of 32% for suspended solids using catchbasins with a suitable sump.
- Pitt & Shawley (1982) found cleaning catchbasin twice per year reduced total residue yields between 10% and 25%.
- Pitt (1985) found sediment in catchbasins were the largest particles washed from streets.

Goals of Storm Drainage Inlet Devices

- Does not cause flooding when clogged with debris
- Does not force stormwater through the captured material
- Does not have adverse hydraulic head loss properties
- Maximizes pollutant reductions
- Requires inexpensive and infrequent maintenance

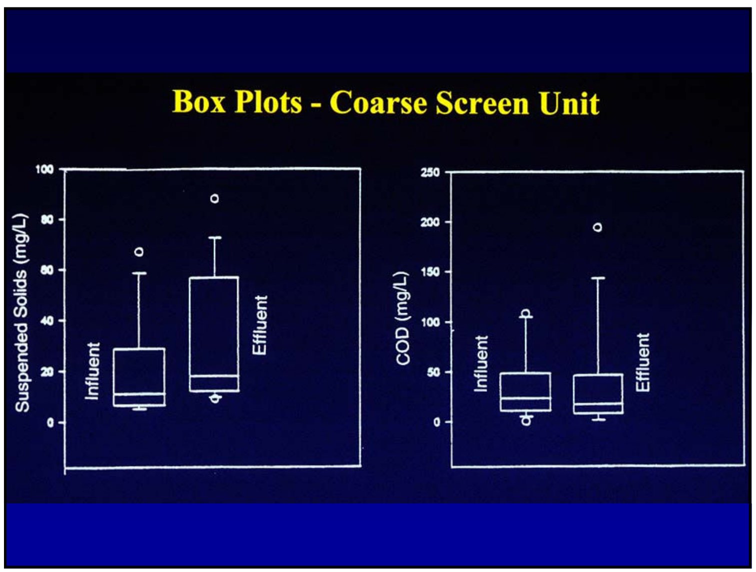
Typical German Inlet Strainer Basket



Small British "Gully pot" inlet for combined sewers

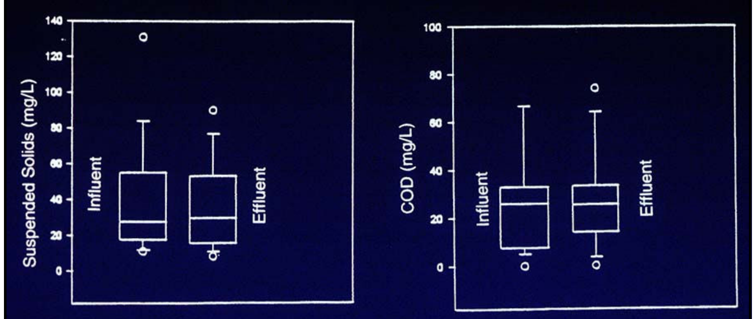

Drain Inserts
Caltrans, San Diego and Los Angeles, California


Coarse Screen Tested at Ocean County, NJ


Box Plots - Coarse Screen Unit
Suspended Solids (mg/L)
100
80
60
40
20
0
Influent
Effluent
COD (mg/L)
250
200
150
100
50
0
Influent
Effluent

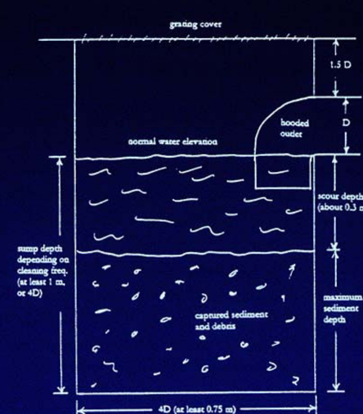

Filter Fabric Inlet Insert Tested at Ocean County, NJ

Box Plots - Filter Fabric Unit

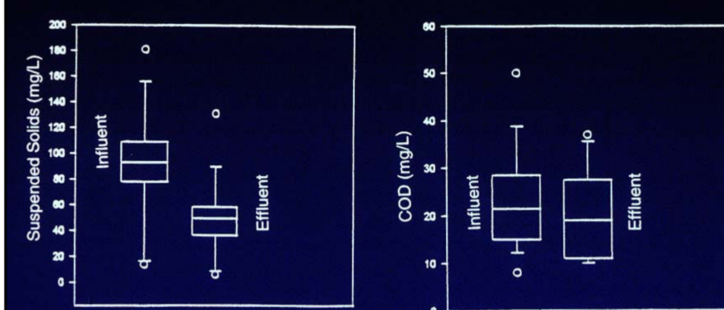


Retro-fitted Catchbasin with Sump Tested at Ocean County, NJ

Dimensions of Optimally-Designed Catchbasin



Box Plots - Catchbasin with Sump



Pollutant Accumulations in 200+ Bellevue, WA, Residential/Commercial Area Catchbasins (kg/ha/yr) (Pitt 1985)

Total Solids	COD	TKN	TP	Lead	Zinc
100 – 147	7.5 – 37	0.07 – 0.17	0.07 – 0.25	0.07 – 0.49	0.02 – 0.10

Baseflow total solids discharge: 110 kg/ha/yr
Stormwater: 210 kg/ha/yr

Velocity and shear stress for different slopes and depths (2 ft pipe)

Depth/ Diameter ratio	Velocity (ft/sec) 0.1% slope	Shear stress (lb/ft^2) 0.1% slope	Velocity (ft/sec) 2% slope	Shear stress (lb/ft^2) 2% slope
0.1	0.91	0.0081	4.1	0.16
0.5	2.3	0.031	10	0.62
1.0	2.3	0.031	10	0.62

Pipes having small slopes allow large particles to settle and form permanent deposits, while pipes with large slopes will likely have moving beds of larger material.

Velocity (ft/sec)	Fluid Shear Stress (lb/ft^2)	Example conditions for 10 ft rough concrete pipe (full-flowing pumped system) (recent EPA wet-weather group report)
1.2	0.0056	Severe deposition
2.0	0.015	Mild to moderate deposition
3.5	0.038	None to slight erosion top layer
4.0	0.059	Slight to mild erosion of consolidated beds (2-5%)
5.9	0.13	Moderate erosion of consolidated beds (15-25%)
7.9	0.24	Substantial erosion (35-50%)

Upflow filter insert for catchbasins

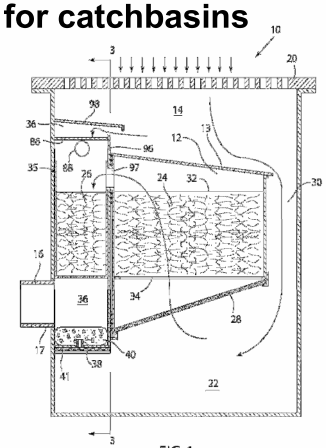


FIG. 1

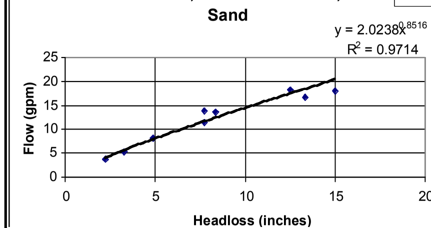
Upflow Filter™ patented

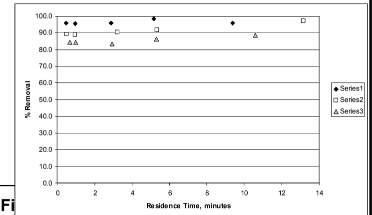
Main features of the MCTT can be used in smaller units.

The Upflow Filter™ uses sedimentation (22), gross solids and floatables screening (28), moderate to fine solids capture (34 and 24), and sorption/ion exchange of targeted pollutants (24 and 26).

Successful flow tests using prototype unit and mixed media as part of EPA SBIR phase 1 project. Phase 2 tests are being currently conducted, including ETV.

15 to 20 gpm/ft² obtained for most media tested





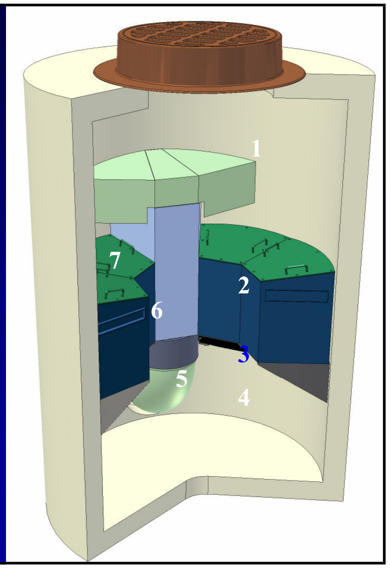
80 to 90% removal of dissolved zinc using sand/peat upflow filtration

UpFlow Filter™ New Concept

Components:

1. Access Port
2. Filter Module Cap
3. Filter Module
4. Module Support
5. Coarse Screen
6. Outlet Module
7. Floatables Baffle/Bypass

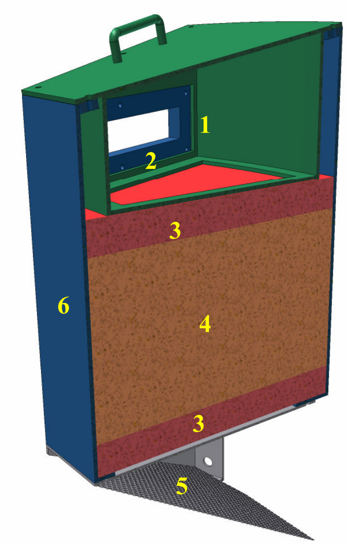
Hydro International



Upflow Filter Components

1. Module Cap/Media Restraint and Upper Flow Collection Chamber
2. Conveyance Slot
3. Flow-distributing Media
4. Filter Media
5. Coarse Screen
6. Filter Module

Hydro International

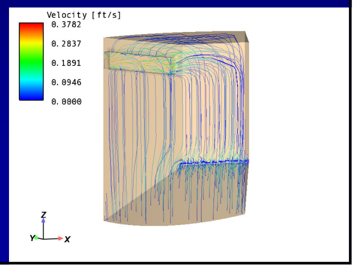


Hydraulic Characterization

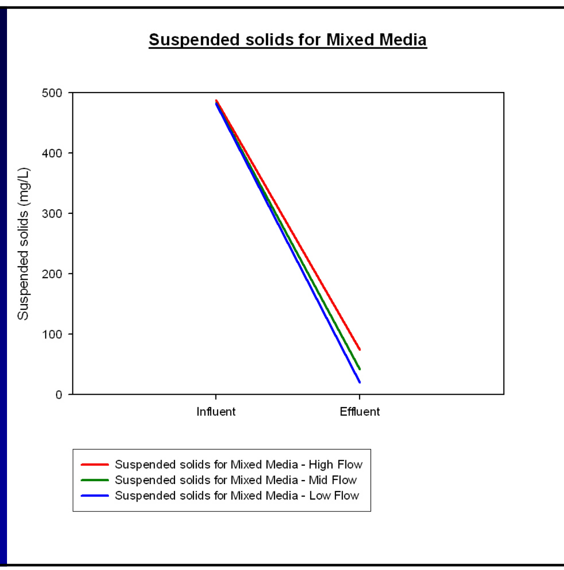
Assembling Upflow Filter modules for lab tests

Hydro International

High flow tests



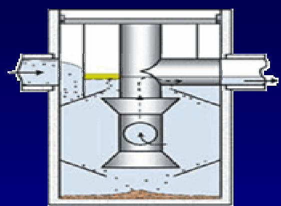
Initial CFD Model Results

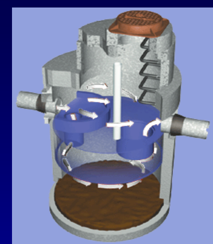


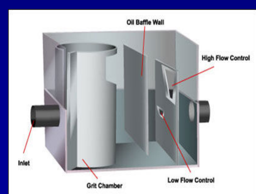
Preliminary Look at WinSLAMM as Method for Sizing Proprietary Settling Devices

Roger Bannerman (WI DNR)
Judy Horwatich (USGS)
Jim Bachhuber (Earth Tech)
September 19 – 22, 2005

Examples of Proprietary BMPs Using Settling for Treatment


Downstream Defender


Stormceptor

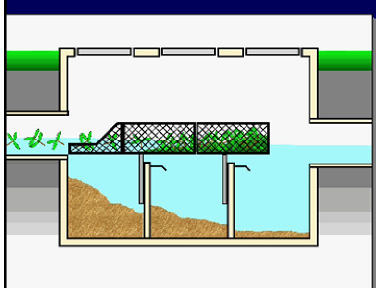


Vortechs

Proprietary Devices Using a Unit Process of Settling

- Benefits
  - Underground
  - Easy to Install
  - Easy Maintenance
  - Claims of High Performance
- Costs
  - Installation Cost Biggest Variable
  - Installation + Capitol Cost Range from $15,000 to 50,000 per Acre of Imperviousness

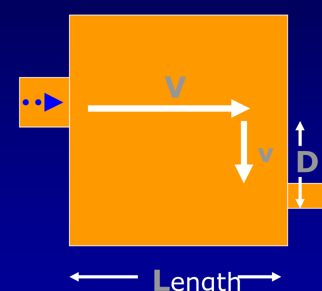
Why Not Use Methods for Designing Detention Ponds to Develop a Sizing Criteria for Proprietary Treatment Practices – Both Rely on Settling


Suntree


Detention Pond

Critical Velocities and Detention Pond Dimensions

Path of particle is the vector sum of the water velocity (V) in the pond and the particle settling velocity (v).

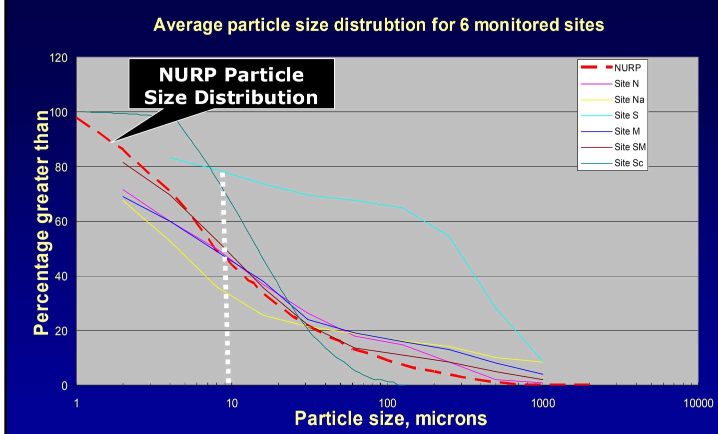


Upflow Velocity

- In an ideal sedimentation pond, particles having settling velocities greater than the upflow velocity will be removed.
- Design pond to make v as small as practical.
- Only increasing the surface area or decreasing system discharge rate will increase removal rates.

$$v = \frac{Q}{A}$$

v = Upflow Velocity = critical settling velocity
Q = Pond Outflow Rate
A = Pond Surface Area



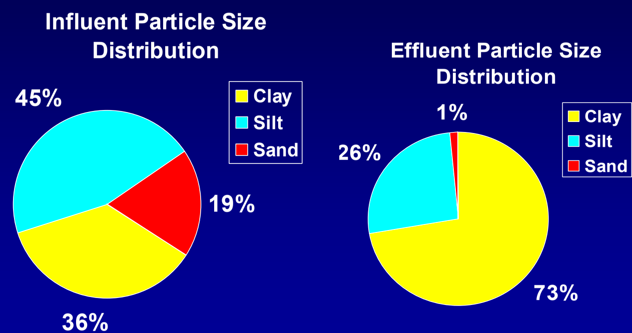
Variables in Sizing Treatment Practice

- Influent hydrograph
- Particle Size Distribution
- Influent Pollutant Load
- Upflow Velocity
- Scour Calculation
- Short-circuiting Calculation
- Land Use

Needs for Continuous Simulation Model

- Changing Q means changing v; create flow weighted critical velocity.
- Flexibility to use different inputs eg. Particle size distribution, rainfall, etc.
- Account for short-circuiting.
- More flexibility in selection of outlet structures.

Influent and Effluent Particle Size Distributions for Monroe St. Pond



Models Using Upflow Velocity – Authors Robert Pitt and John Voorhees

Source Load and Management Model (SLAMM)

Developed to assist cities in evaluating the benefits of alternative stormwater treatment practices for both runoff quality and quantity in existing and developing urban areas.

DETPOND

Developed to predict how much particulate solids a wet detention pond will be removed from urban runoff. Most features of DETPOND are in SLAMM.

Criteria for Testing Validity of Using SLAMM

- 1. "Treatment Efficiency Range"
  - 0 to 20 Percent = Low
  - 20 to 40 Percent = Medium Low
  - 40 to 60 percent = Medium
  - 60 to 80 percent = Medium High
  - 80 to 100 percent = High
- 2. Closer than 10 percentage points

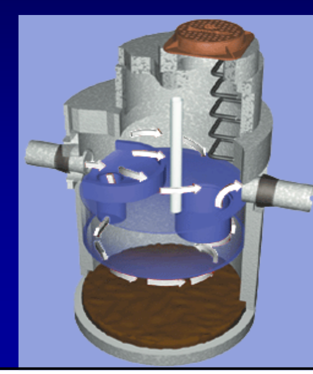
Example of Proprietary Device Monitoring

Rob Waschbusch – USGS

1996 to 1997

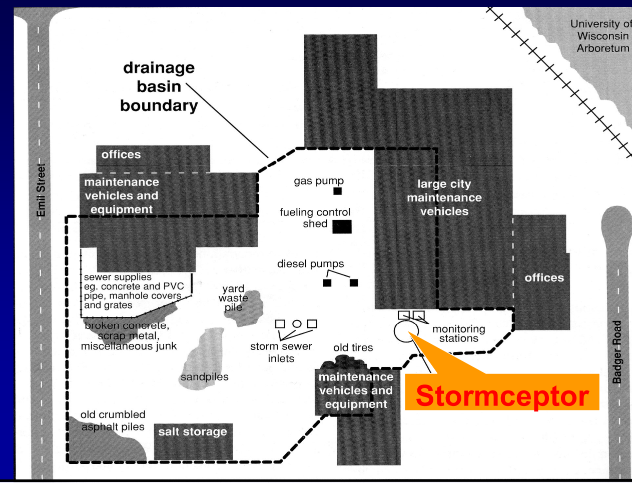
Sponsors – City of Madison and WDNR

Stormceptor



Site Conditions – Maintenance Yard

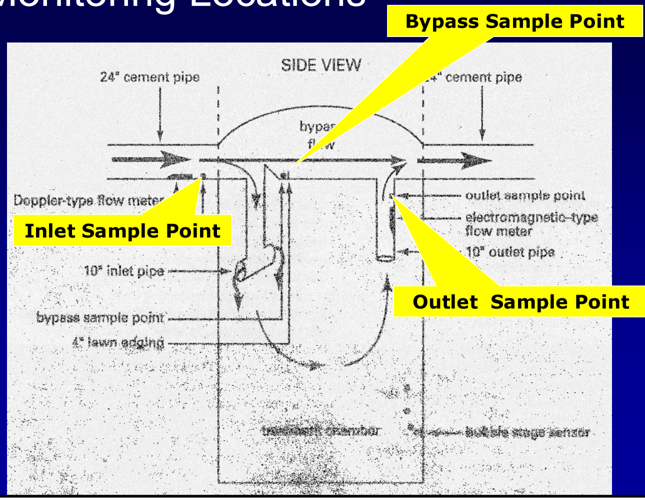
Site Conditions

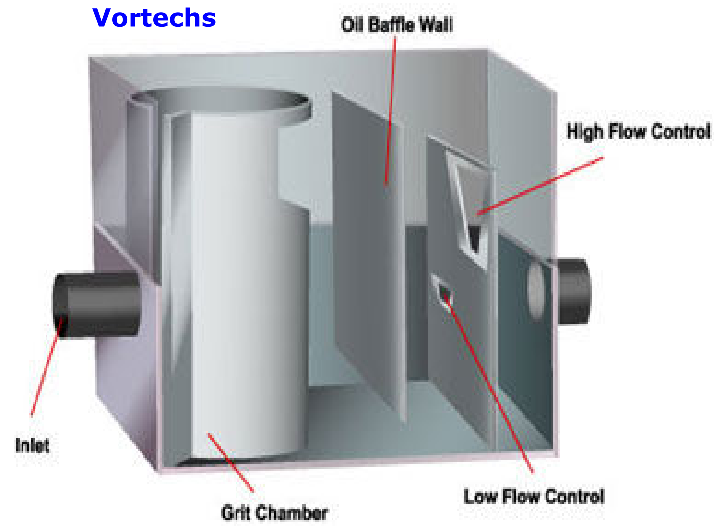


Manufacturer Sizing Guidelines Claimed 80% Removal of Total Suspended Solids for the Site.

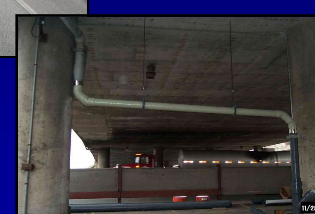
Stormceptor Monitoring Equipment – Sampled 45 Runoff Events

Monitoring Locations

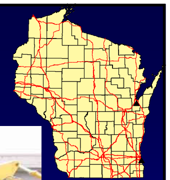




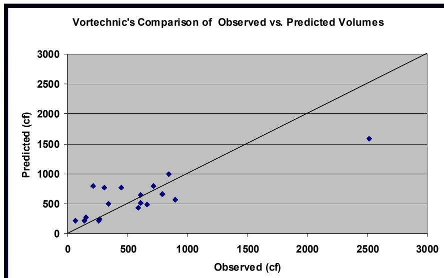
Milwaukee,WI. Test Site: I 794



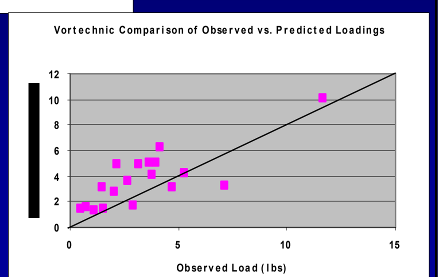
Vortechs Monitoring Site



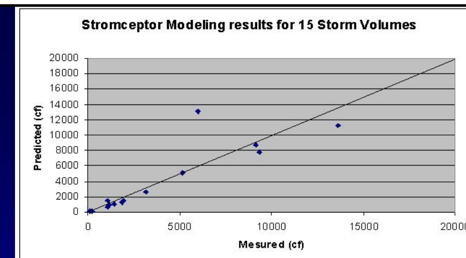
	Stormceptor			Vortechs System		
	Measured	Estimated	Percent Difference	Measured	Estimated	Percent Difference
Water Volume, cubic feet	85,600	73,893	14	10,466	10,633	- 2
TSS Load, lbs.	939	814	13	63	68	- 8

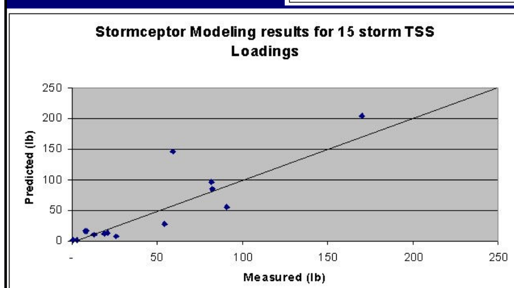


Observed Versus Predicted Water Volumes and TSS Loads for the Vortechs Site



Observed Versus Predicted Water Volumes and TSS Loads for Stormceptor Site





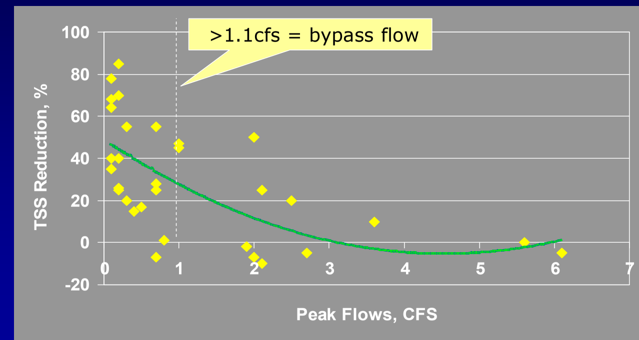
TSS Load Reduction Results Used for Model Comparison

- *TSS Loads, Kg.*

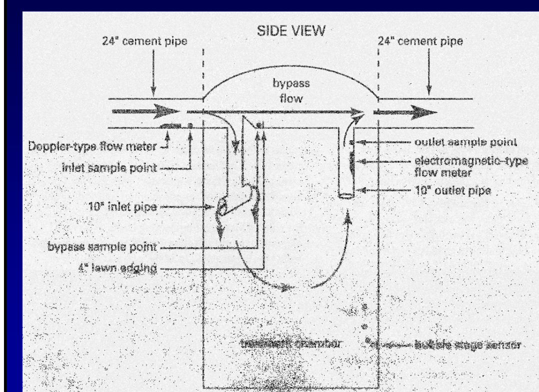
Type of Load	Influent	Effluent	% TSS Reduction
Vortechs (18 events, no bypass)	63	51	19%
Stormceptor (15 events, bypass)	939	895	5%

TSS Reduction as a Function of Peak Discharge for the Stormceptor

(includes both treated & bypass water)



Model Input



Tank is:

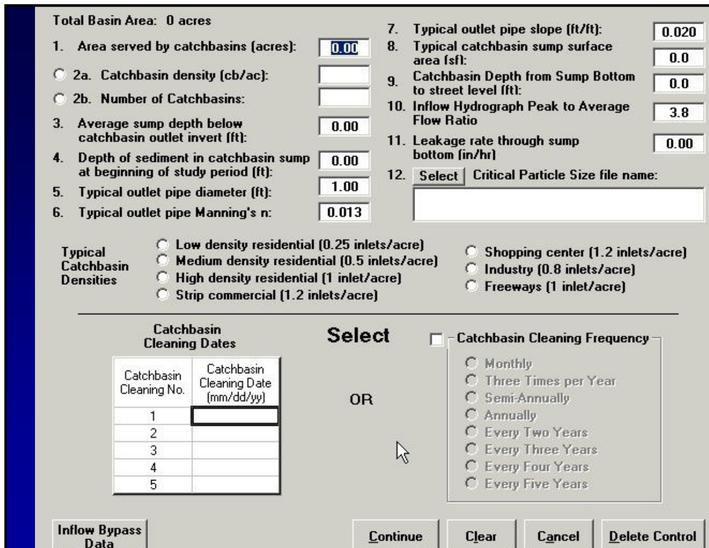
Height: 13.5'

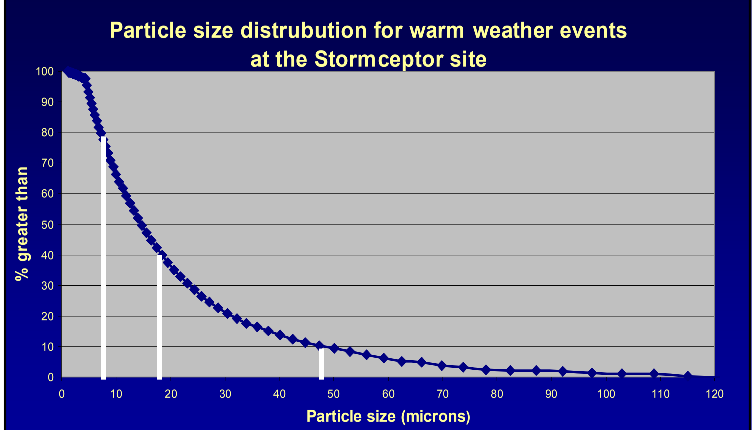
Diameter: 10'

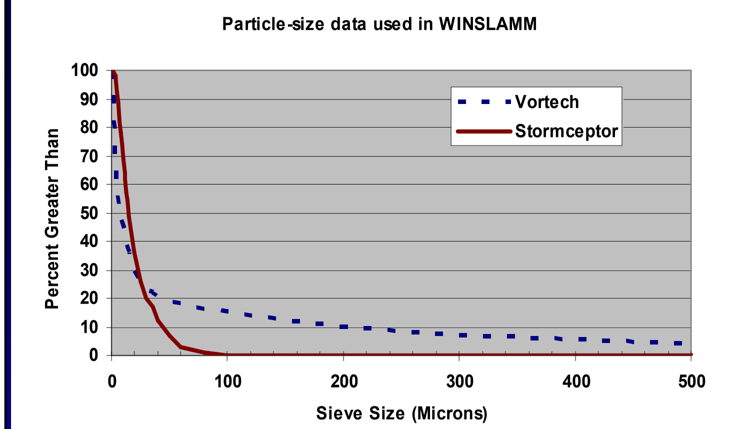
Surface Area = 0.002 acres.

Outlet Structure = 10" Orifice

Used Actual Rainfall Measured for 15 Storms.

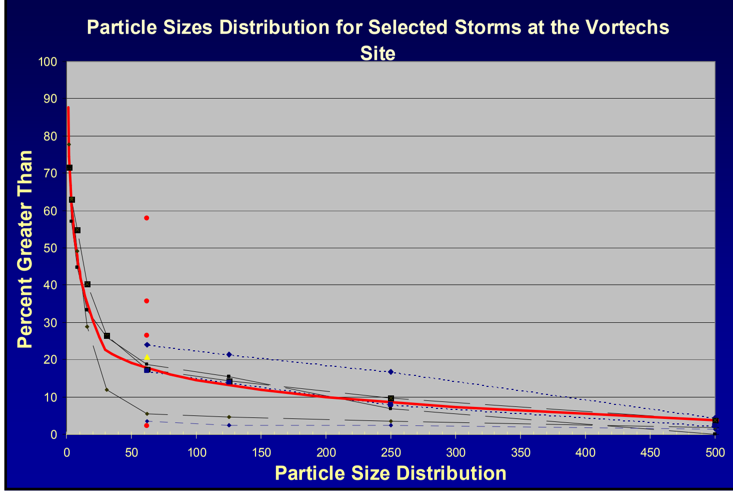


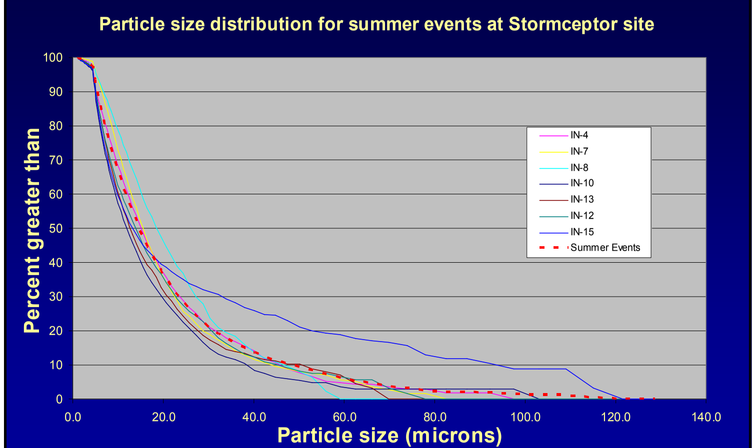




Ideal Particle Size Trapped for Different Sites

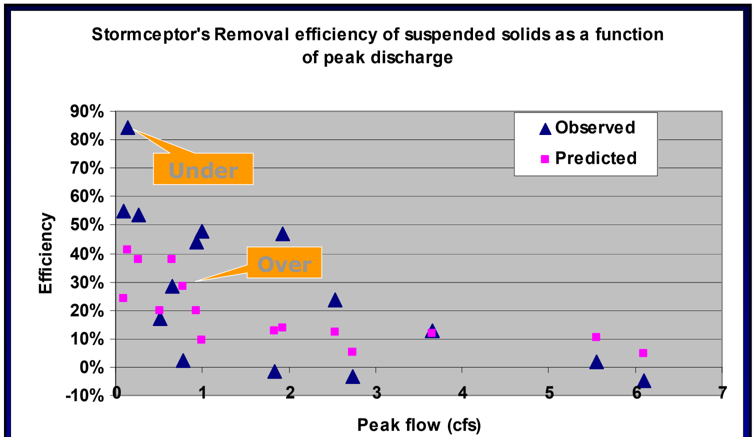
	Percent Greater Than		
Site	**20 Percent**	**40 Percent**	**80 Percent**
Residential (Monroe)	50	13	1
Freeway (Riverwalk)	150	12	1
Parking Lot (St. Marys)	31	12	2
NURP	35	12	3



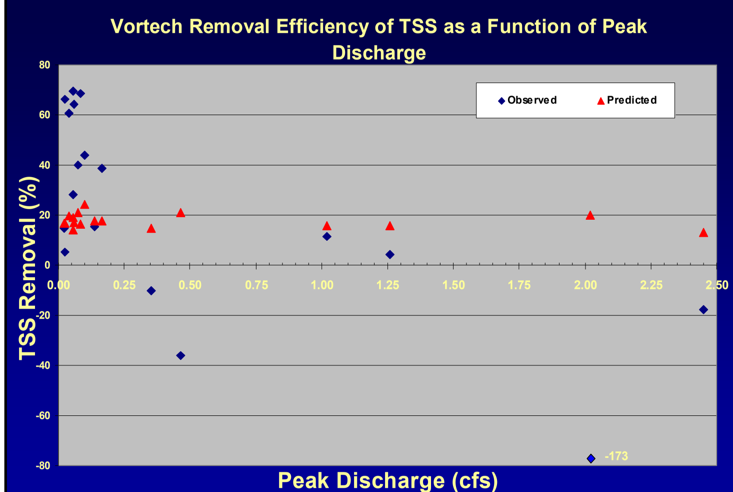


Comparison of Measured and Modeled TSS Reductions

	Measured TSS Reductions	SLAMM / DETPOND Estimates with *Measured PSD and Rainfall*
Stormceptor	5%	12%
Vortechs	19%	19%



1. Good agreement (+- 10%) for ½ half of events.
2. Particle size range of 35 microns = 35% change in percent control.

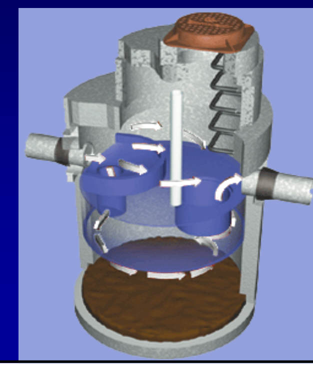


Factors Affecting Difference Between Observed and Predicted Percent Reductions for Individual Storms

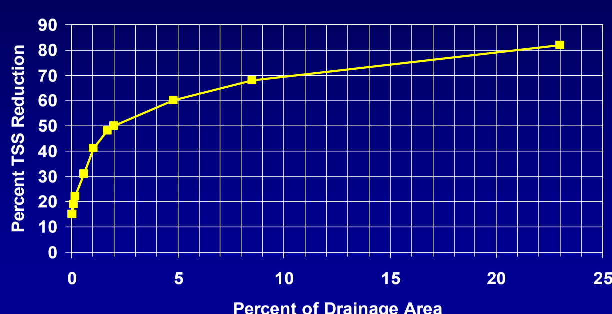
- Scour – SLAMM needs to predict scour using velocity, type of sediment, and depth of sediment
- Particle Size Distribution – Individual event particle size not practical, but SLAMM will accept
- Bypass - SLAMM does, but needs higher concentration (Concentrations x 1.7)
- Short Circuiting – Appears to have small effect.

How Big Do We Have to Make Stormceptor to Achieve TSS Performance Standards at Maintenance Yard?

Stormceptor



TSS Reductions for Stormceptor using DETPOND (Madison Rain81 and NURP PSD)



Size of Stormceptor for Selected TSS Reductions (Madison Rain81 and NURP PSD)

Percent TSS Reduction	Diameter of Tank, Feet	Tank as a Percent of Drainage Area
15	10	0.05%
20	18	0.14%
40	50	1.05%
80	235	23%

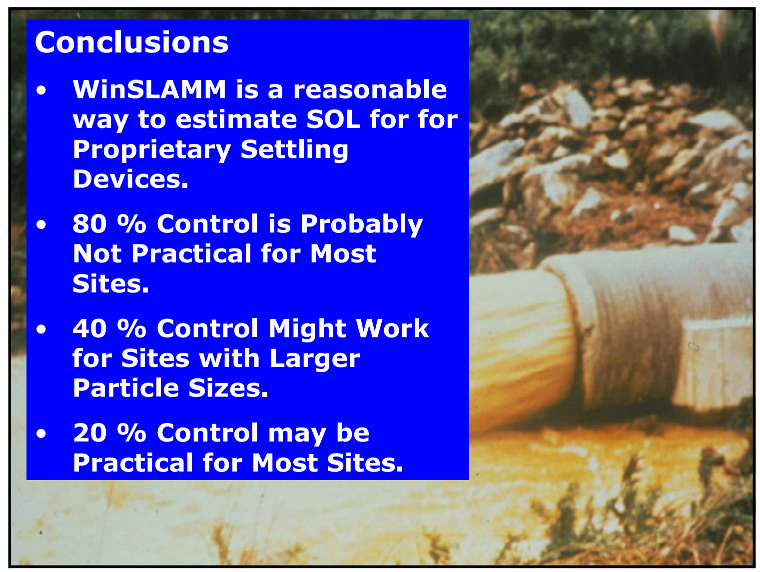
Number of 10’ Diameter Stormceptors to Achieve TSS Reduction on a 4.3 acre Site

Percent TSS Reduction	Number of Stormceptors for 4.3 acre Site
10%	1
20%	3
40%	20

Why Does Stormceptor Require Such a Large Surface Area (A) To Achieve Performance Standards?

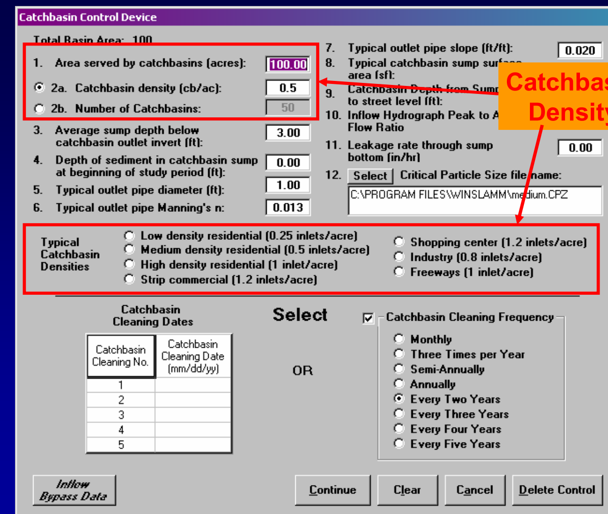
- Typically, these devices do not have sufficient active storage
- Active storage is needed to allow for a small enough outlet structure (smaller Q)

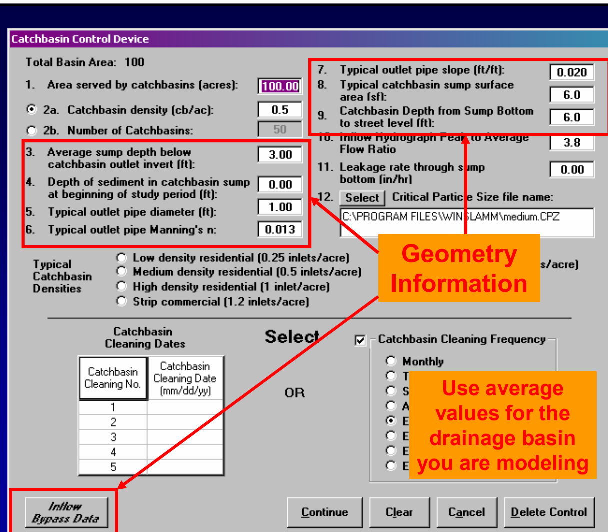
$$V = \frac{Q}{A}$$



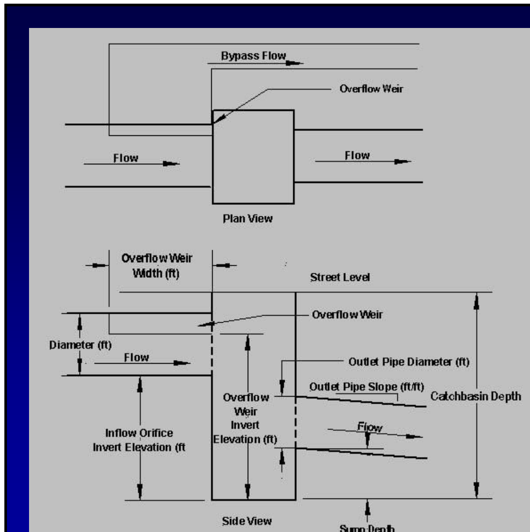
Information Needed to Model Catchbasins and Hydrodynamic Devices

1. Catchbasin Density
2. Catchbasin Geometry
3. Flow and Particle Size Data
4. Catchbasin Cleaning Information
5. Outlet Controls
6. Bypass Information for Hydrodynamic Device





Inflow Bypass Data

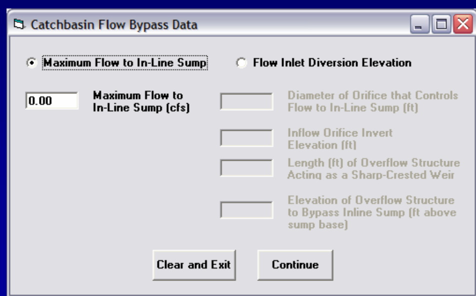


Hydrodynamic Devices Only

Inflow Bypass Data

Two Options – Either User-defined Maximum Flow, or . . .

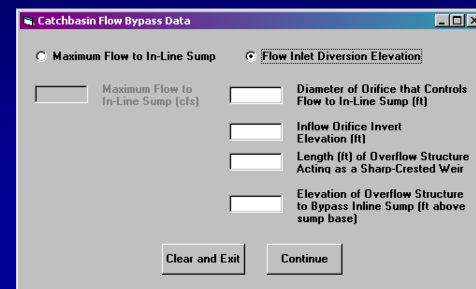
Hydrodynamic Devices Only

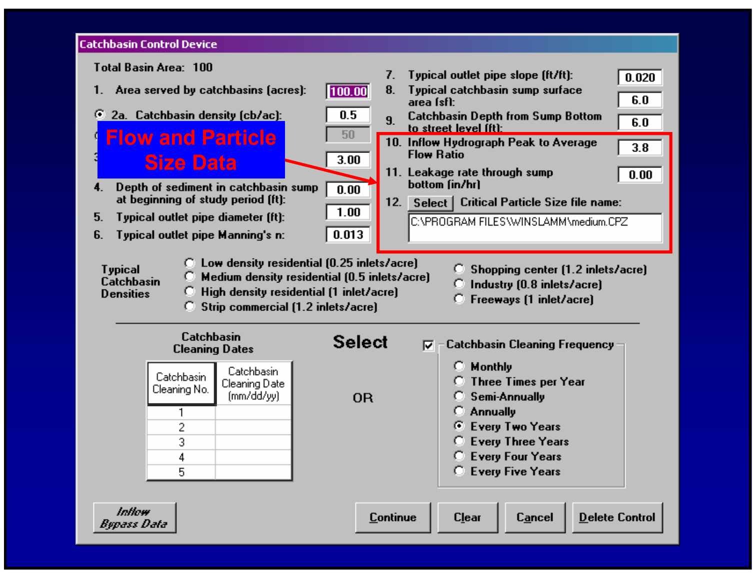


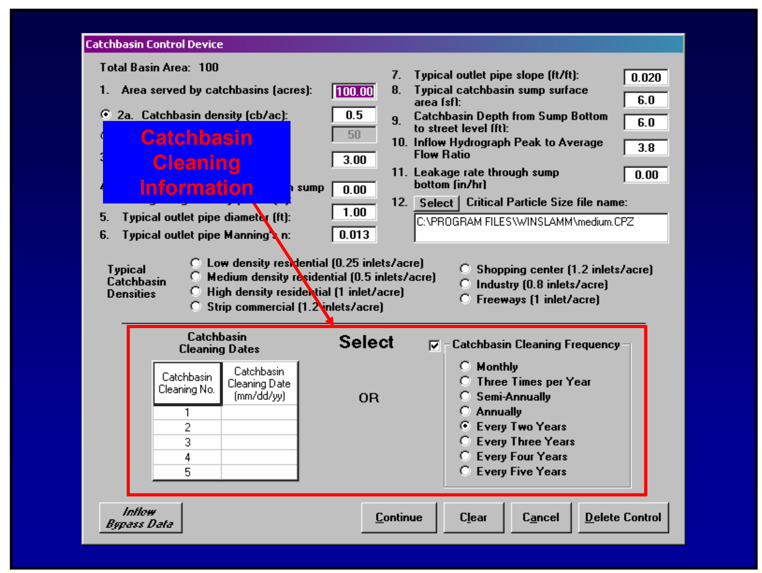
Inflow Bypass Data

Defined Flow Diversion Geometry

Hydrodynamic Devices Only

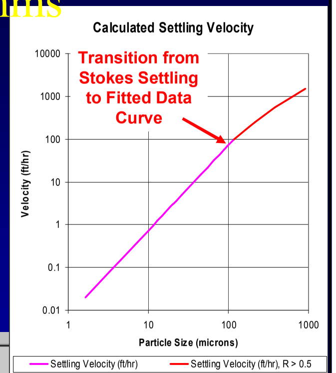


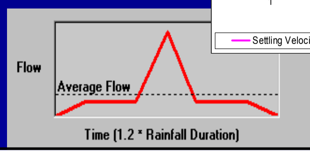




Catchbasin Performance Algorithms

- Particulate removal based upon particle size
- Settling modeled as a detention basin assuming:
  - Vertical sides
  - No storage
- Flow rate calculated using Complex Triangular Hydrograph





Catchbasin Output

WinSLAMM Model Output

File View

Runoff Volume | Particulate Solids | Pollutants | Output Summary

File Name: C:\Files\SLAMM\WinSLAMM\Test Files\Catchbasins\Catchbasin with One Cleaning.dat

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total Before Drainage System	8.021E+06	Base	217.5	108824	Base
Total After Drainage System	8.021E+06	0.00 %	200.9	100538	7.61 %
Total After Outfall Controls	8.021E+06	0.00 %	200.9	100538	7.61 %

Print Output Summary to Comma Separated Value File

Print Output Summary to Text File

Catchbasin Cleaning Model Results

Drainage System Particulate Solids Yield

09/18/68	0.35	1799	1620	16	0	1620	
09/19/68	0.46	2287	2023	16	0	2023	
09/23/68	0.02	10.64	7.972	16	0	7.972	
09/24/68	1.20	3769	3629	17	0	3629	
10/02/68	0.02	10.87	8.148	17	0	8.148	
10/05/68	0.18	680.0	584.4	17	0	584.4	
10/09/68	0.10	293.9	246.5	17	0	246.5	
10/21/68	0.37	2007	1832	18	0	1832	
10/23/68	0.19	713.6	600.5	18	0	600.5	
10/27/68	0.01	0	0	18	0	0	
10/27/68	0.02	11.48	8.605	18	0	8.605	
10/28/68	0.05	64.29	52.30	18	0	52.30	
11/05/68	0.54	2802	2403	19	0	2403	
11/14/68	0.42	2357	2135	20	0	2135	
11/16/68	0.58	2941	2711	21	0	2711	
11/17/68	0.02	10.70	7.365	21	0	7.365	
11/25/68	0.02	10.70	8.019	21	0	8.019	
11/28/68	0.98	3492	3233	21	0	3233	
12/01/68	0.14	473.3	401.1	22	0	401.1	
12/02/68	0.01	0	0	22	0	0	
12/05/68	0.01	0	0	22	0	0	
12/13/68	0.01	0	0	22	0	0	
12/18/68	0.84	3030	2739	1	0	2739	
12/21/68	0.39	1835	1604	2	0	1604	
12/23/68	0.01	0	0	2	0	0	
12/26/68	0.02	9.854	6.782	2	0	6.782	
12/26/68	1.09	3250	2863	3	0	2863	
12/30/68	0.13	384.8	319.5	3	0	319.5	
Summary for Runoff Producing Events							
	Rain Total (inches)	Total Before Drainage System	Total After Drainage System	Catch basin Volume % Full	Upflow Filter Volume % Full	Total After Outfall Controls	Flow-wtd Min. Part. Size Controlled
Minimum:	0.01	3.755	2.429	1.000	0	2.43	
Maximum:	2.06	4711	4487	22.00	0	4487.00	
Fl Wt Ave:		2968	2786			2786	
Total:	31.51	108824	100538			100538.00	

Before Drainage System Total

After Drainage System Total

Additional Output

- StageOutflowCB.csv
- StageInflowCB.csv
- CBPerformanceByStep.csv
- CBPerformance.csv

Rain No.	Rain Depth (in)	Runoff Volume per CB (cf)	Maximum Inflow from Basin (cfs)	Time Increment (min)	Maximum Inflow through CB (cfs)	Volume In (cf)	Hydraulic Volume Out (cf)	Seepage Volume Out (cf)	Total Volume Out of CB (cf)	Bypass Volume (cf)	Cumulative Volume Out of CB (cf)	CB Efficiency Reduction	Maximum Inflow Stage	Maximum CB Stage	Weighted Total Solids Reduction (fraction)
1	0.01	0	0	2	0	0	0	0	0	0	0	0	0	3	1
2	0.06	307.3593	5.41E-02	10	5.41E-02	312.848	312.848	0	312.848	0	312.848	0	0	3.07	0.1834095
3	0.01	0	0	2	0	0	0	0	0	0	312.848	0	0	3	1
4	0.02	25.168	7.38E-03	6	7.38E-03	25.61744	25.61744	0	25.61744	0	338.4654	0	0	3.02	0.353254
5	0.2	1430.123	0.179711	14	0.179711	1455.661	1455.661	0	1455.661	0	1794.126	0	0	3.12	0.1200792
6	0.01	0	0	2	0	0	0	0	0	0	1794.126	0	0	3	1
7	0.04	170.4842	2.50E-02	12	2.50E-02	173.5285	173.5285	0	173.5285	0	1967.655	0	0	3.05	0.2404892
8	0.23	1670.089	0.163229	15	0.163229	1694.667	1694.667	0	1694.667	0	3662.322	0	0	3.12	0.1247973
9	0.19	1346.409	0.169192	14	0.169192	1370.453	1370.453	0	1370.453	0	5032.774	0	0	3.12	0.1233367
10	0.44	3510.688	0.237547	15	0.237547	3642.1	3642.1	0	3642.1	0	8674.874	0	0	3.14	0.103546
11	0.15	1016.854	8.13E-02	15	8.13E-02	1008.875	1008.875	0	1008.875	0	9683.749	0	0	3.08	0.1605299
12	0.07	388.7052	3.11E-02	15	3.11E-02	385.6555	385.6555	0	385.6555	0	10069.4	0	0	3.05	0.2257967
13	0.03	83.853	1.84E-02	8	1.84E-02	85.35033	85.35033	0	85.35033	0	10154.75	0	0	3.04	0.2659832
14	0.04	170.4842	3.75E-02	8	3.75E-02	173.5285	173.5285	0	173.5285	0	10328.28	0	0	3.06	0.2102898
15	0.03	83.853	1.48E-02	10	1.48E-02	85.35033	85.35033	0	85.35033	0	10413.63	0	0	3.03	0.2855439
16	0.01	0	0	2	0	0	0	0	0	0	10413.63	0	0	3	1
17	0.05	234.619	6.88E-02	6	6.88E-02	238.8086	238.8086	0	238.8086	0	10652.44	0	0	3.08	0.168602
18	0.03	83.853	1.48E-02	10	1.48E-02	85.35033	85.35033	0	85.35033	0	10737.79	0	0	3.03	0.2855439
19	0.02	25.168	2.21E-02	2	2.21E-02	25.61744	25.61744	0	25.61744	0	10763.41	0	0	3.04	0.2504332
20	0.07	388.7052	0.113972	6	0.113972	395.6464	395.6464	0	395.6464	0	11159.06	0	0	3.1	0.1407803
21	0.02	25.168	1.11E-02	4	1.11E-02	25.61744	25.61744	0	25.61744	0	11184.67	0	0	3.03	0.3116934
22	0.02	25.168	1.11E-02	4	1.11E-02	25.61744	25.61744	0	25.61744	0	11210.29	0	0	3.03	0.3116934
23	0.02	25.168	1.11E-02	4	1.11E-02	25.61744	25.61744	0	25.61744	0	11235.91	0	0	3.03	0.3116934
24	0.02	25.168	7.38E-03	6	7.38E-03	25.61744	25.61744	0	25.61744	0	11261.53	0	0	3.02	0.353254
25	0.01	0	0	2	0	0	0	0	0	0	11261.53	0	0	3	1
26	0.05	234.619	0.103189	4	0.103189	238.8086	238.8086	0	238.8086	0	11500.33	0	0	3.09	0.1460115
27	0.56	4633.375	0.582236	14	0.582236	4716.113	4716.113	0	4716.113	0	16216.45	0	0	3.22	7.04E-02
28	0.01	0	0	2	0	0	0	0	0	0	16216.45	0	0	3	1