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

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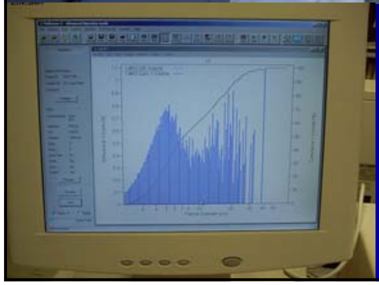
Aesthetic (Floatables) and Gross Solids Characteristics of Stormwater

- 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.

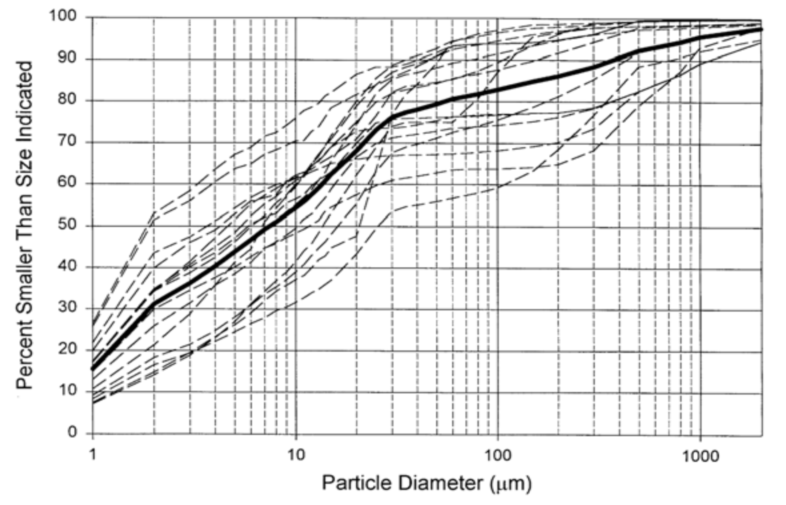
Stirred and Settled Sample, Showing Settleable Solids (Madison high-efficiency street cleaning tests)

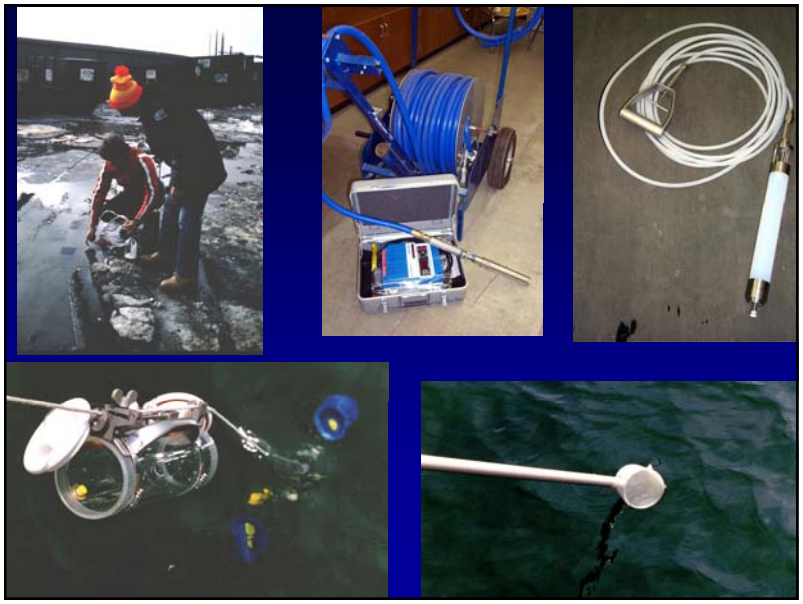


Coulter Counter Multi-Sizer 3 used to measure particle size distribution of solids up to several hundred micrometers. Larger particles (up to several mm) are quantified using sieves.

Particle Size Analyses Using Cascading Sieves

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





Many stormwater monitoring configurations used over the years

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

Bed load compromises about 4% of Madison area total solids discharges.

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

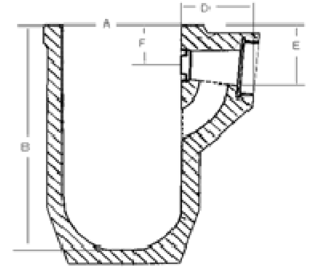
Research Results

- 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

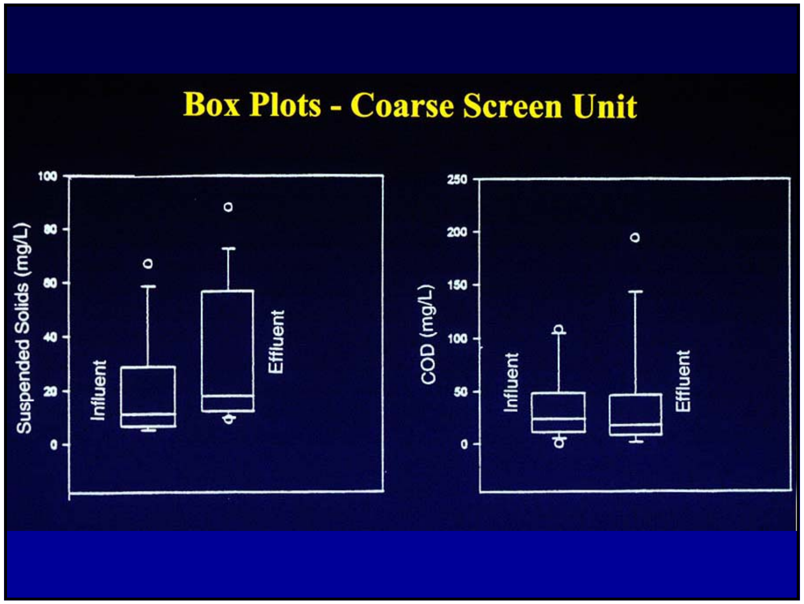


Small British “Gully pot” inlet for combined sewers

Drain Inserts

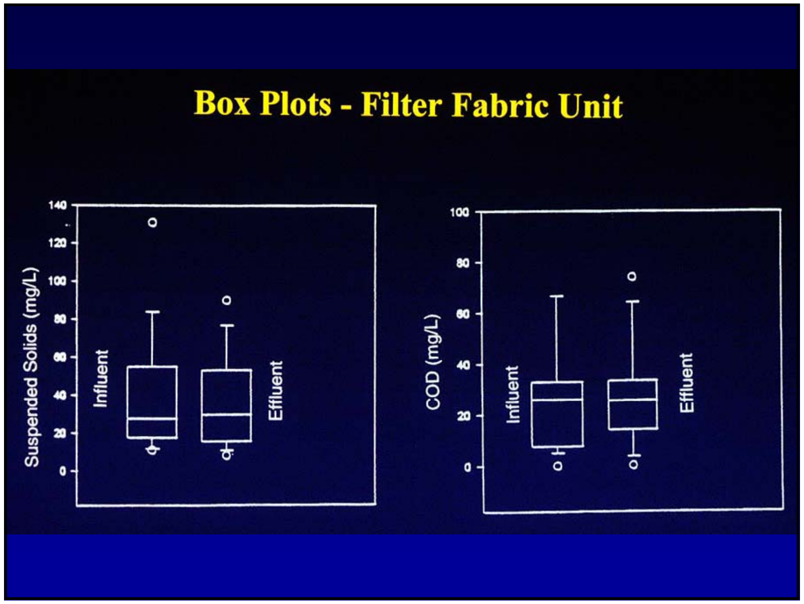
Caltrans, San Diego and Los Angeles, California

Coarse Screen Tested at Ocean County, NJ

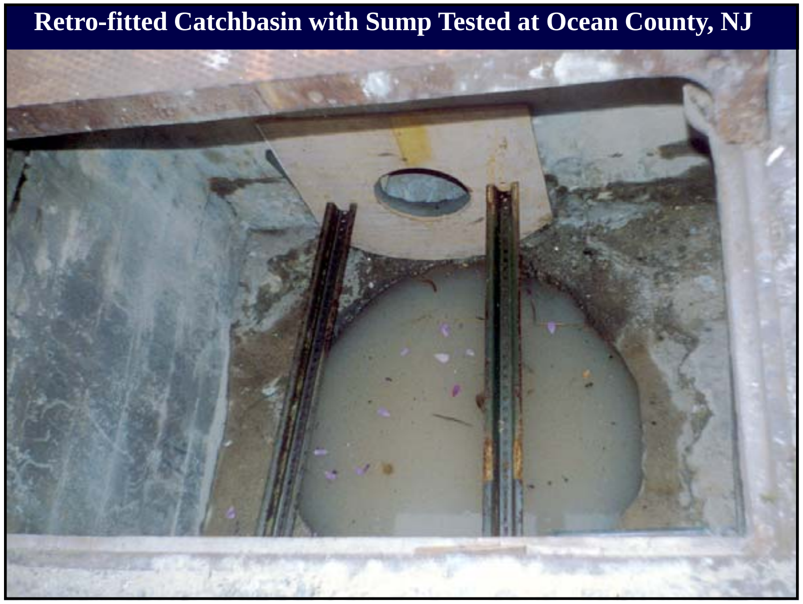


Box Plots - Coarse Screen Unit

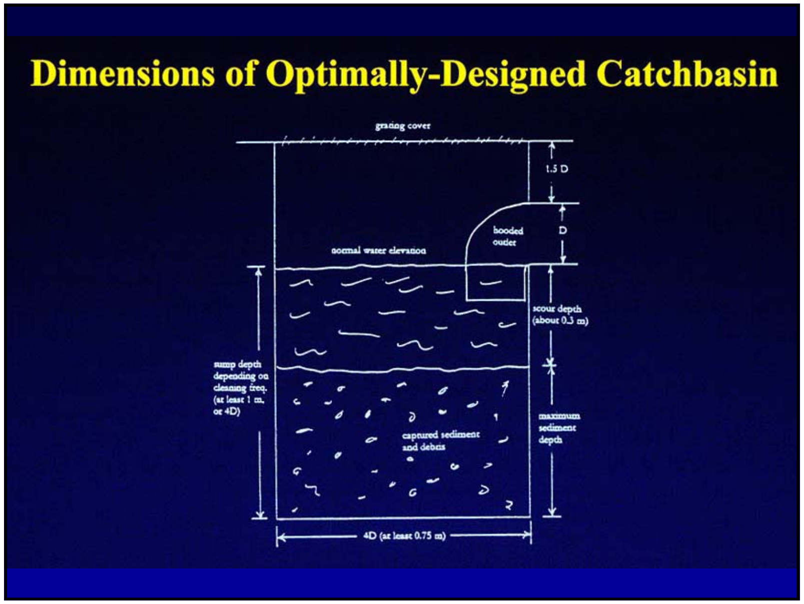
Filter Fabric Inlet Insert Tested at Ocean County, NJ



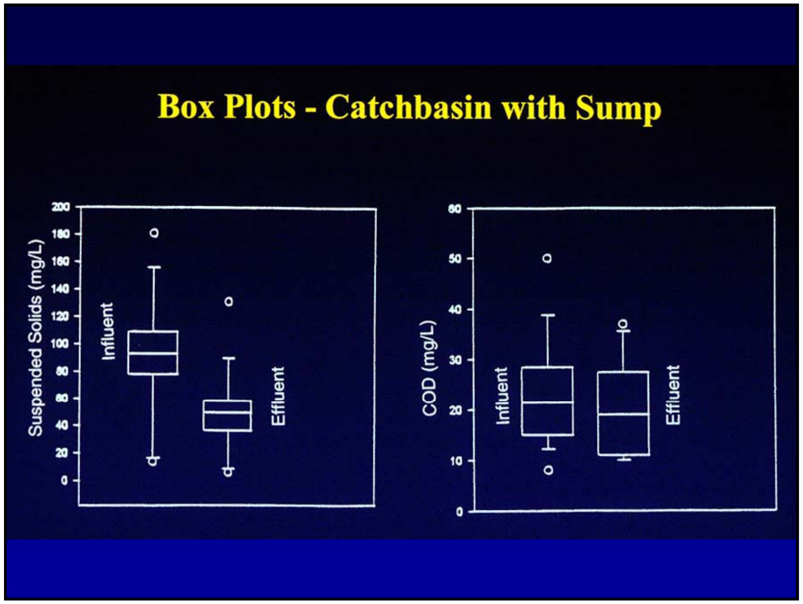
Box Plots - Filter Fabric Unit



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

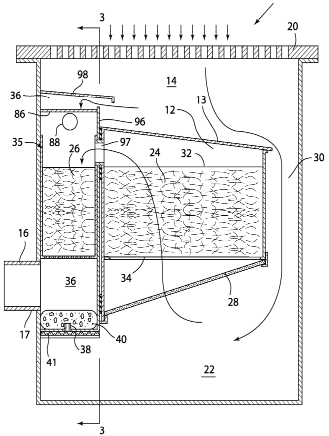


FIG. 1

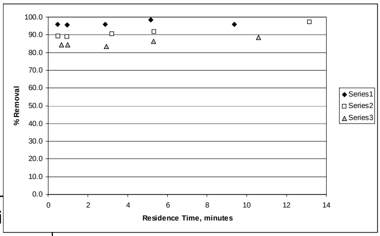
Upflow Filter™ patented

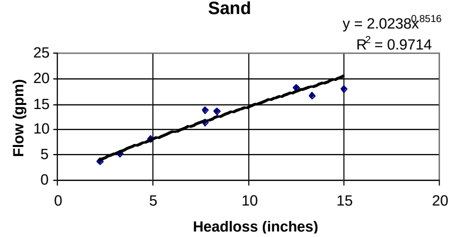
Main features of the MCTT can be used in smaller units.

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

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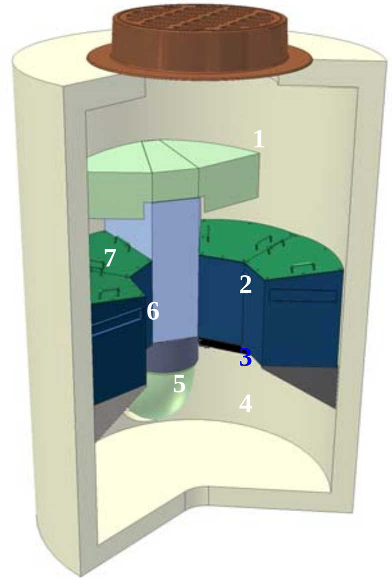
UpFlow Filter™ New Concept

Components:

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

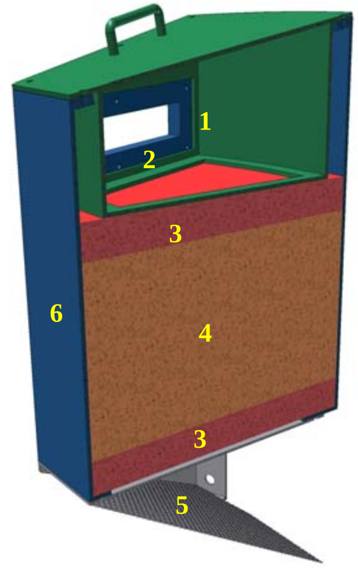
Hydro International

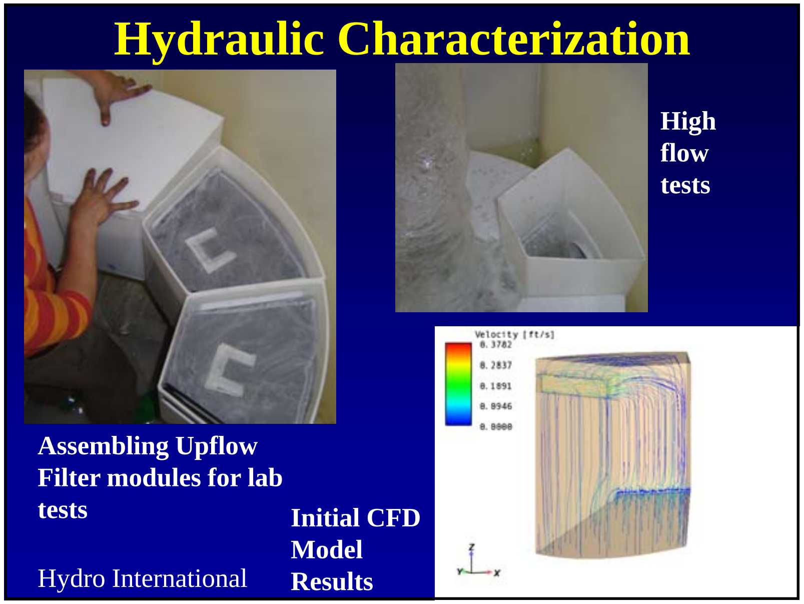


Upflow Filter Components

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

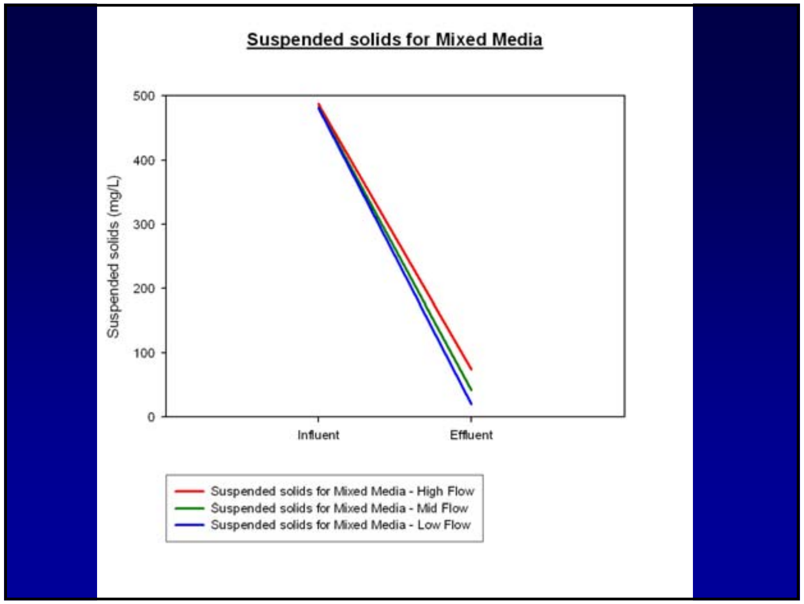
High flow tests

Assembling Upflow Filter modules for lab tests

Hydro International

Initial CFD Model Results

EPA-funded SBIR2 Field Test Setup, Tuscaloosa, AL



Suspended solids for Mixed Media

Scour in Stormwater Catchbasin Devices – Experimental Results from a Physical Model

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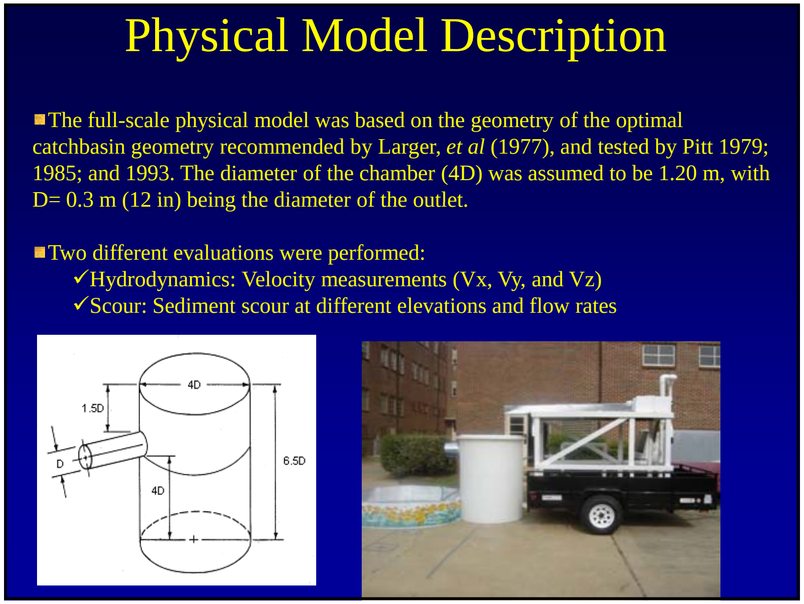
Stormwater and Urban Water Systems Modeling

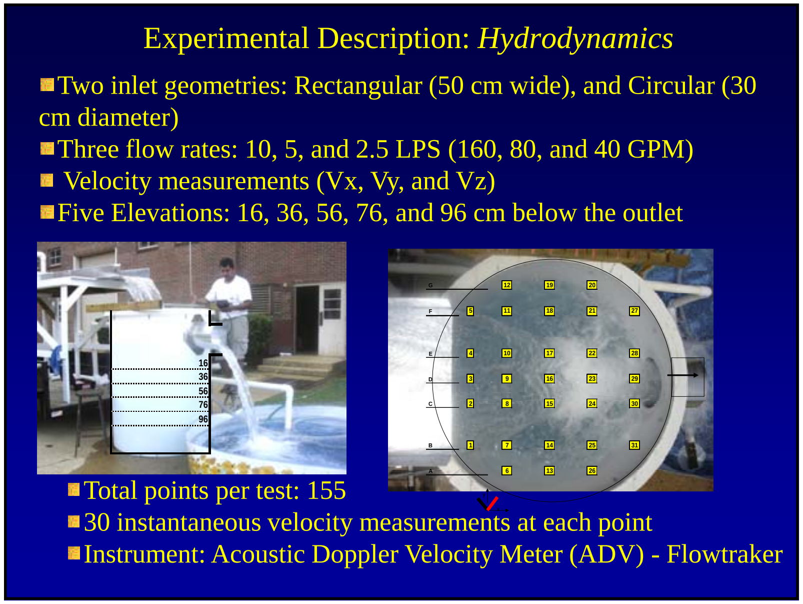
February 21–22, 2008
Toronto, Canada



Physical Model Description

- The full-scale physical model was based on the geometry of the optimal catchbasin geometry recommended by Larger, *et al* (1977), and tested by Pitt 1979; 1985; and 1993. The diameter of the chamber (4D) was assumed to be 1.20 m, with D= 0.3 m (12 in) being the diameter of the outlet.

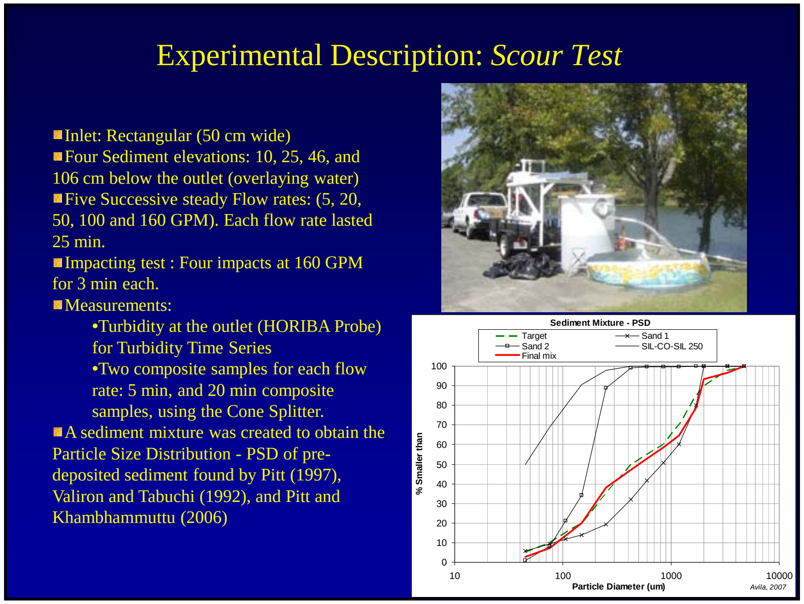
- Two different evaluations were performed:
  - ✓Hydrodynamics: Velocity measurements (Vx, Vy, and Vz)
  - ✓Scour: Sediment scour at different elevations and flow rates



Experimental Description: *Hydrodynamics*

- Two inlet geometries: Rectangular (50 cm wide), and Circular (30 cm diameter)
- Three flow rates: 10, 5, and 2.5 LPS (160, 80, and 40 GPM)
- Velocity measurements (Vx, Vy, and Vz)
- Five Elevations: 16, 36, 56, 76, and 96 cm below the outlet

- Total points per test: 155
- 30 instantaneous velocity measurements at each point
- Instrument: Acoustic Doppler Velocity Meter (ADV) - Flowtraker



Experimental Description: *Scour Test*

- Inlet: Rectangular (50 cm wide)
- Four Sediment elevations: 10, 25, 46, and 106 cm below the outlet (overlaying water)
- Five Successive steady Flow rates: (5, 20, 50, 100 and 160 GPM). Each flow rate lasted 25 min.
- Impacting test : Four impacts at 160 GPM for 3 min each.
- Measurements:
  - •Turbidity at the outlet (HORIBA Probe) for Turbidity Time Series
  - •Two composite samples for each flow rate: 5 min, and 20 min composite samples, using the Cone Splitter.
- A sediment mixture was created to obtain the Particle Size Distribution - PSD of pre-deposited sediment found by Pitt (1997), Valiron and Tabuchi (1992), and Pitt and Khambhammuttu (2006)

Experimental Description: *Scour Test*

Installation of blocks to set the false bottom

Measuring of depth below the outlet

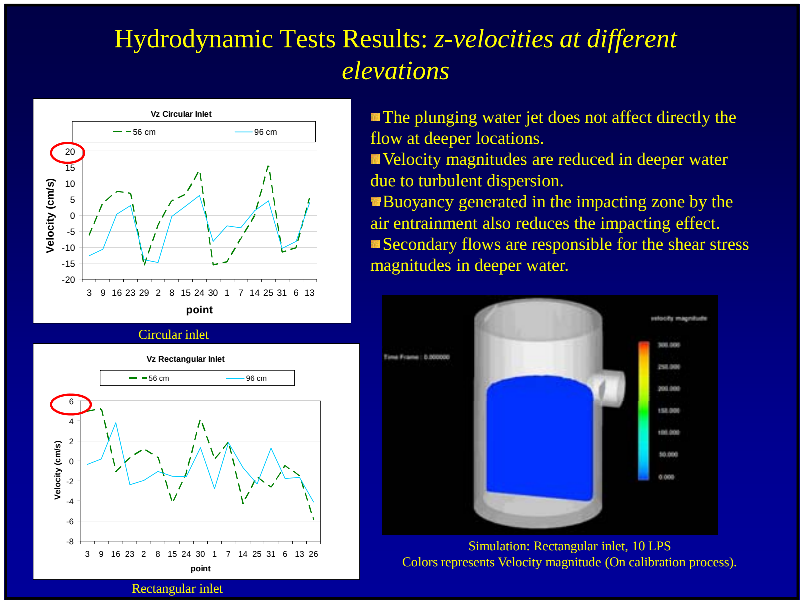
Cone Splitter and Sample Bottles

False bottom sealed on the border

Performing scour test

Sediment bed after test

Leveling of sediment bed: 20 cm thick



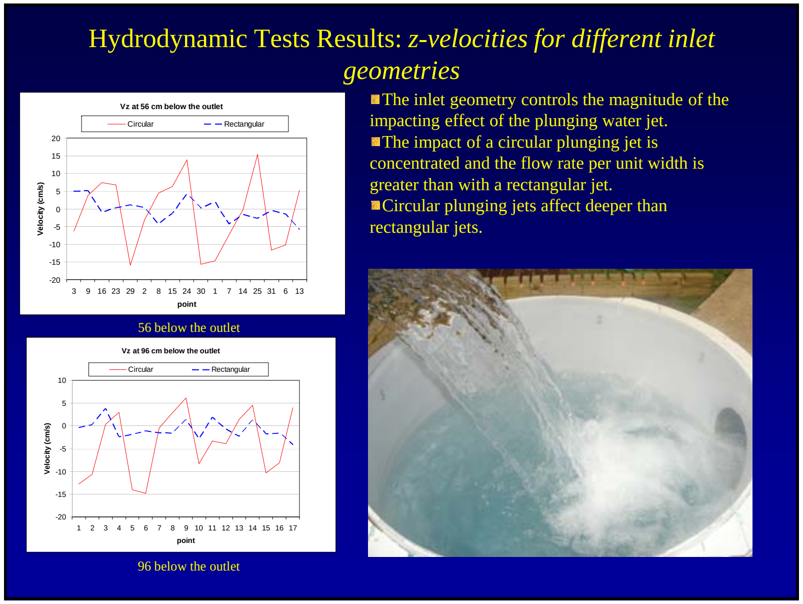
Hydrodynamic Tests Results: *z-velocities at different elevations*

- The plunging water jet does not affect directly the flow at deeper locations.
- Velocity magnitudes are reduced in deeper water due to turbulent dispersion.
- Buoyancy generated in the impacting zone by the air entrainment also reduces the impacting effect.
- Secondary flows are responsible for the shear stress magnitudes in deeper water.

Circular inlet

Rectangular inlet

Simulation: Rectangular inlet, 10 LPS
Colors represents Velocity magnitude (On calibration process).

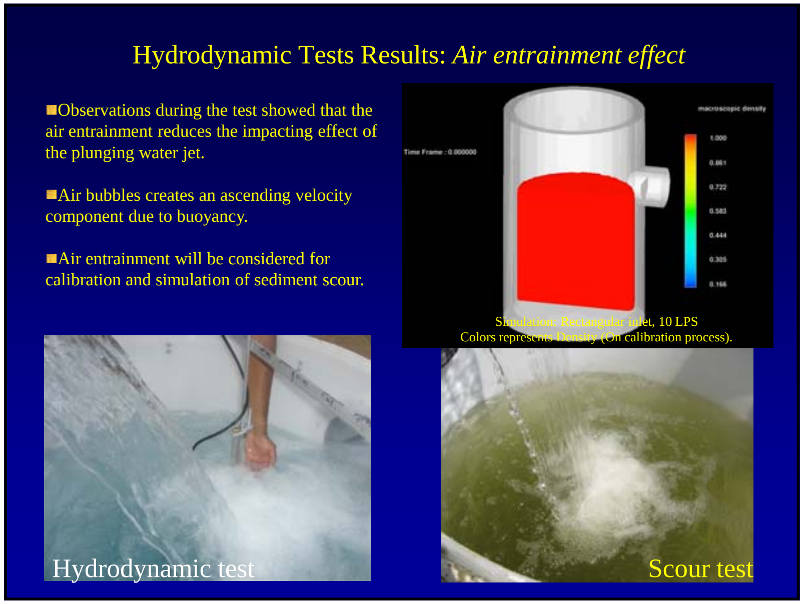


Hydrodynamic Tests Results: *z-velocities for different inlet geometries*

- The inlet geometry controls the magnitude of the impacting effect of the plunging water jet.
- The impact of a circular plunging jet is concentrated and the flow rate per unit width is greater than with a rectangular jet.
- Circular plunging jets affect deeper than rectangular jets.

56 below the outlet

96 below the outlet



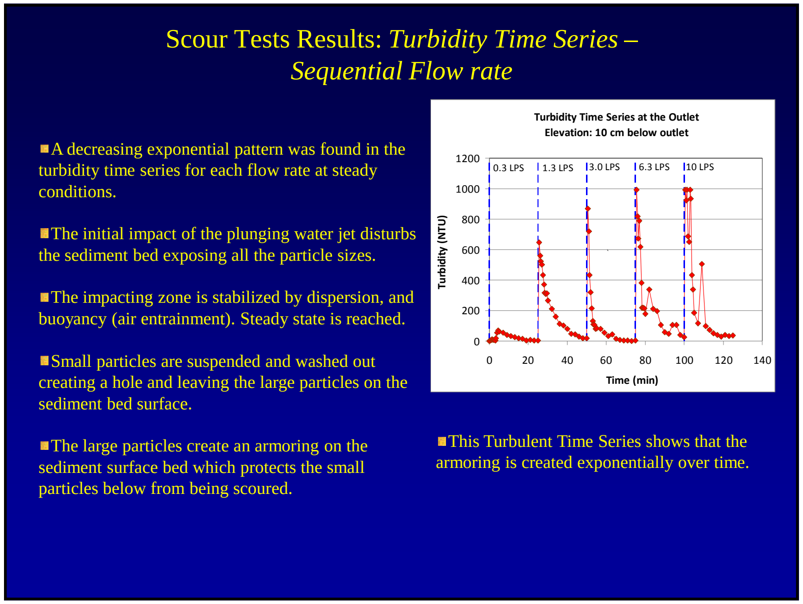
Hydrodynamic Tests Results: *Air entrainment effect*

- Observations during the test showed that the air entrainment reduces the impacting effect of the plunging water jet.
- Air bubbles creates an ascending velocity component due to buoyancy.
- Air entrainment will be considered for calibration and simulation of sediment scour.

Simulation: Rectangular inlet, 10 LPS
Colors represents Density (On calibration process).

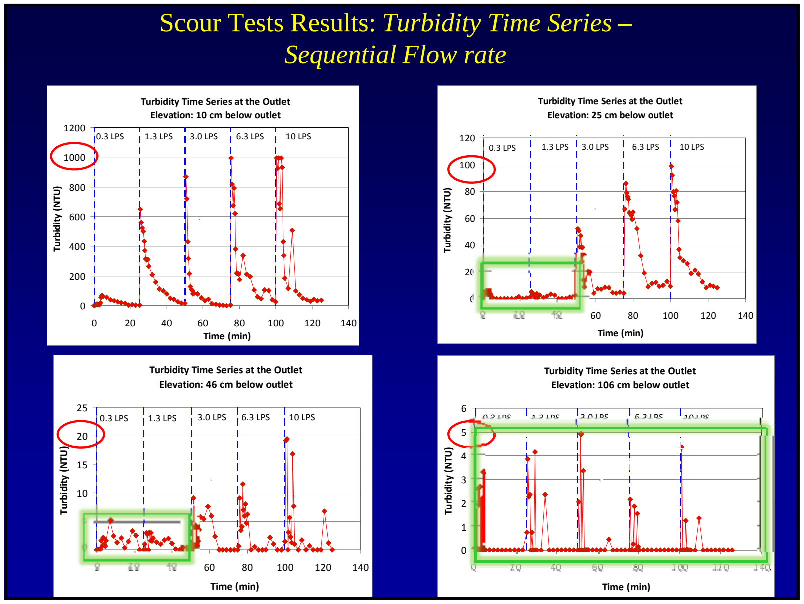
Hydrodynamic test

Scour test



Scour Tests Results: *Turbidity Time Series – Sequential Flow rate*

- A decreasing exponential pattern was found in the turbidity time series for each flow rate at steady conditions.
- The initial impact of the plunging water jet disturbs the sediment bed exposing all the particle sizes.
- The impacting zone is stabilized by dispersion, and buoyancy (air entrainment). Steady state is reached.
- Small particles are suspended and washed out creating a hole and leaving the large particles on the sediment bed surface.
- The large particles create an armoring on the sediment surface bed which protects the small particles below from being scoured.
- This Turbulent Time Series shows that the armoring is created exponentially over time.



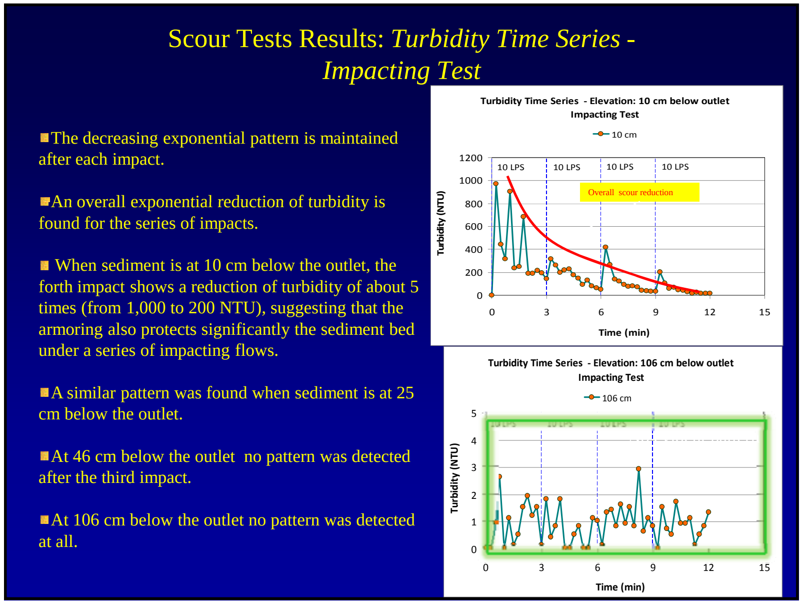
Scour Tests Results: *Turbidity Time Series – Sequential Flow rate*

Turbidity Time Series at the Outlet Elevation: 10 cm below outlet

Turbidity Time Series at the Outlet Elevation: 25 cm below outlet

Turbidity Time Series at the Outlet Elevation: 46 cm below outlet

Turbidity Time Series at the Outlet Elevation: 106 cm below outlet

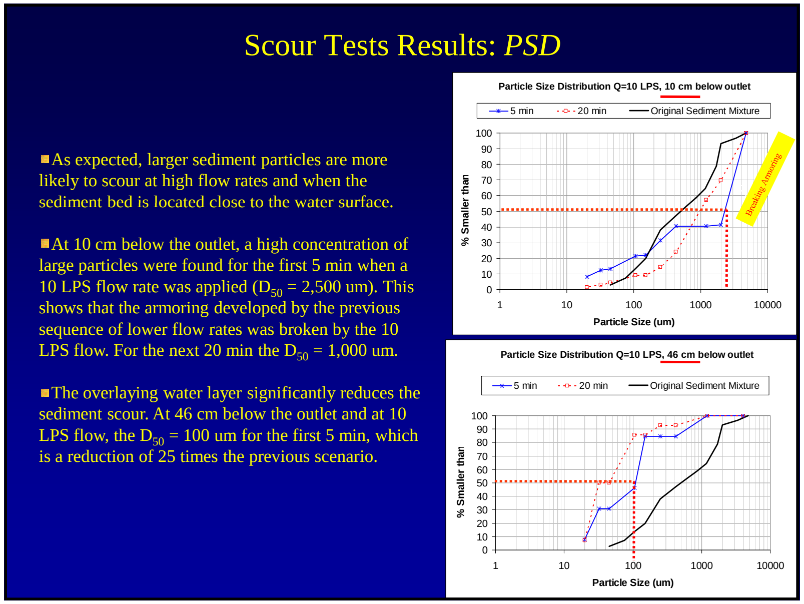


Scour Tests Results: *Turbidity Time Series - Impacting Test*

- The decreasing exponential pattern is maintained after each impact.
- An overall exponential reduction of turbidity is found for the series of impacts.
- When sediment is at 10 cm below the outlet, the forth impact shows a reduction of turbidity of about 5 times (from 1,000 to 200 NTU), suggesting that the armoring also protects significantly the sediment bed under a series of impacting flows.
- A similar pattern was found when sediment is at 25 cm below the outlet.
- At 46 cm below the outlet no pattern was detected after the third impact.
- At 106 cm below the outlet no pattern was detected at all.

Turbidity Time Series - Elevation: 10 cm below outlet Impacting Test

Turbidity Time Series - Elevation: 106 cm below outlet Impacting Test

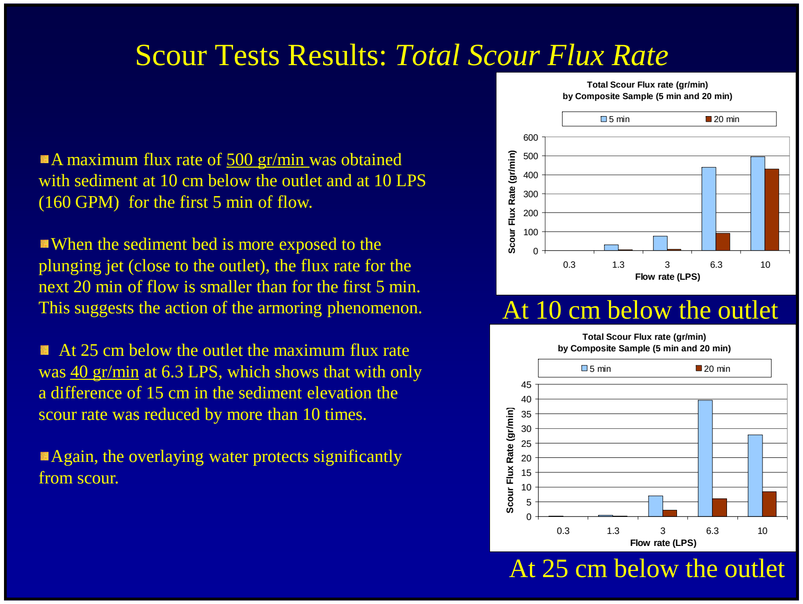


Scour Tests Results: *PSD*

- As expected, larger sediment particles are more likely to scour at high flow rates and when the sediment bed is located close to the water surface.
- At 10 cm below the outlet, a high concentration of large particles were found for the first 5 min when a 10 LPS flow rate was applied (D_{50} = 2,500 um). This shows that the armoring developed by the previous sequence of lower flow rates was broken by the 10 LPS flow. For the next 20 min the D_{50} = 1,000 um.
- The overlaying water layer significantly reduces the sediment scour. At 46 cm below the outlet and at 10 LPS flow, the D_{50} = 100 um for the first 5 min, which is a reduction of 25 times the previous scenario.

Particle Size Distribution Q=10 LPS, 10 cm below outlet

Particle Size Distribution Q=10 LPS, 46 cm below outlet



Scour Tests Results: *Total Scour Flux Rate*

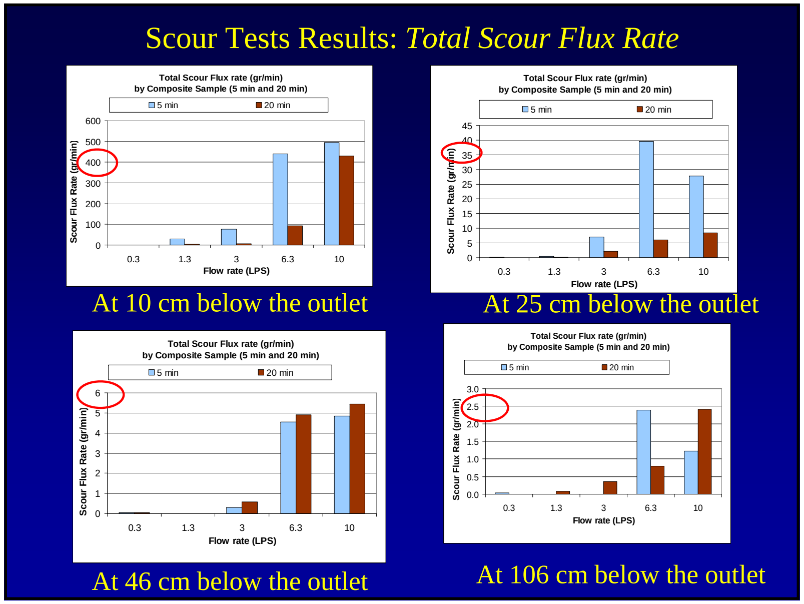
- A maximum flux rate of 500 gr/min was obtained with sediment at 10 cm below the outlet and at 10 LPS (160 GPM) for the first 5 min of flow.
- When the sediment bed is more exposed to the plunging jet (close to the outlet), the flux rate for the next 20 min of flow is smaller than for the first 5 min. This suggests the action of the armoring phenomenon.
- At 25 cm below the outlet the maximum flux rate was 40 gr/min at 6.3 LPS, which shows that with only a difference of 15 cm in the sediment elevation the scour rate was reduced by more than 10 times.
- Again, the overlaying water protects significantly from scour.

Total Scour Flux rate (gr/min) by Composite Sample (5 min and 20 min)

At 10 cm below the outlet

Total Scour Flux rate (gr/min) by Composite Sample (5 min and 20 min)

At 25 cm below the outlet



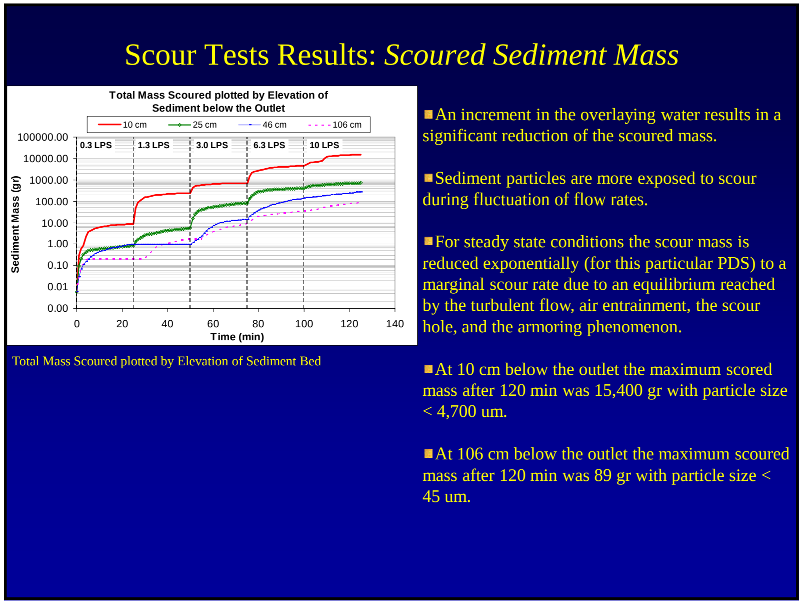
Scour Tests Results: *Total Scour Flux Rate*

At 10 cm below the outlet

At 25 cm below the outlet

At 46 cm below the outlet

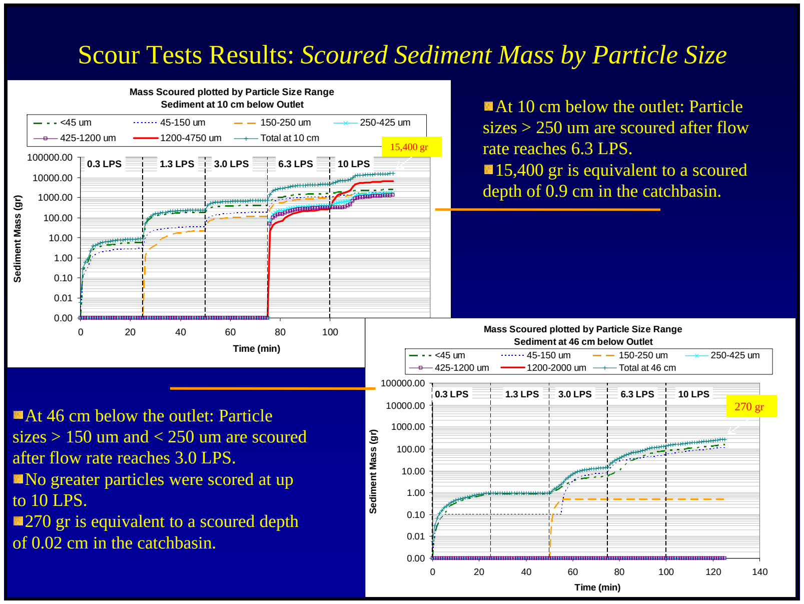
At 106 cm below the outlet



Scour Tests Results: *Scoured Sediment Mass*

Total Mass Scoured plotted by Elevation of Sediment Bed

- An increment in the overlaying water results in a significant reduction of the scoured mass.
- Sediment particles are more exposed to scour during fluctuation of flow rates.
- For steady state conditions the scour mass is reduced exponentially (for this particular PDS) to a marginal scour rate due to an equilibrium reached by the turbulent flow, air entrainment, the scour hole, and the armoring phenomenon.
- At 10 cm below the outlet the maximum scored mass after 120 min was 15,400 gr with particle size < 4,700 um.
- At 106 cm below the outlet the maximum scoured mass after 120 min was 89 gr with particle size < 45 um.



Scour Tests Results: *Scoured Sediment Mass by Particle Size*

- At 10 cm below the outlet: Particle sizes > 250 um are scoured after flow rate reaches 6.3 LPS.
- 15,400 gr is equivalent to a scoured depth of 0.9 cm in the catchbasin.

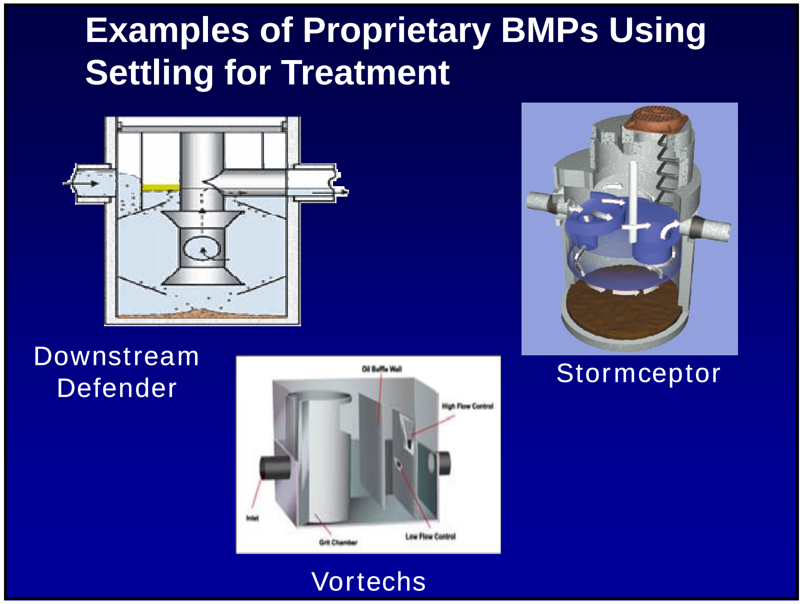
- At 46 cm below the outlet: Particle sizes > 150 um and < 250 um are scoured after flow rate reaches 3.0 LPS.
- No greater particles were scored at up to 10 LPS.
- 270 gr is equivalent to a scoured depth of 0.02 cm in the catchbasin.

Conclusions

- The scour potential in a catchbasin sump depends directly on the inlet geometry. Circular inlets are more erosive than rectangular inlets.
- Velocity magnitudes are reduced in deeper water due to turbulent dispersion and buoyancy (air entrainment). Secondary flows are responsible for the shear stress magnitudes in deeper water.
- A decreasing exponential pattern was found in the Turbidity Time Series, which suggest that the scour mass trend to decrease exponentially under steady flow conditions.
- Fluctuating flow rates have more impact on the scour production. However, the decreasing exponential trend is maintained for successive flow rate fluctuations of equal magnitude.
- The overlaying water has a significant reduction of sediment scour. The particle sizes scoured at 10 cm below the outlet (D_{50} = 1,000) is reduced by 25 times if the sediment bed is located at 25 cm below the outlet (D_{50} = 100) .
- The same effect is detected with the flux rate, in which a magnitude of 500 gr/min was found for 10 LPS and sediment at 10 cm below the outlet, while at the same flow rate but at 25 cm below the outlet the flux rate was 40 gr/min.
- The total mass scoured at 10 cm below the outlet was 15,400 gr equivalent to about a depth of 0.9 cm of material, while at 46 cm below the outlet the scoured mass was 270 gr, equivalent to 0.02 cm of material in the catchbasin.

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

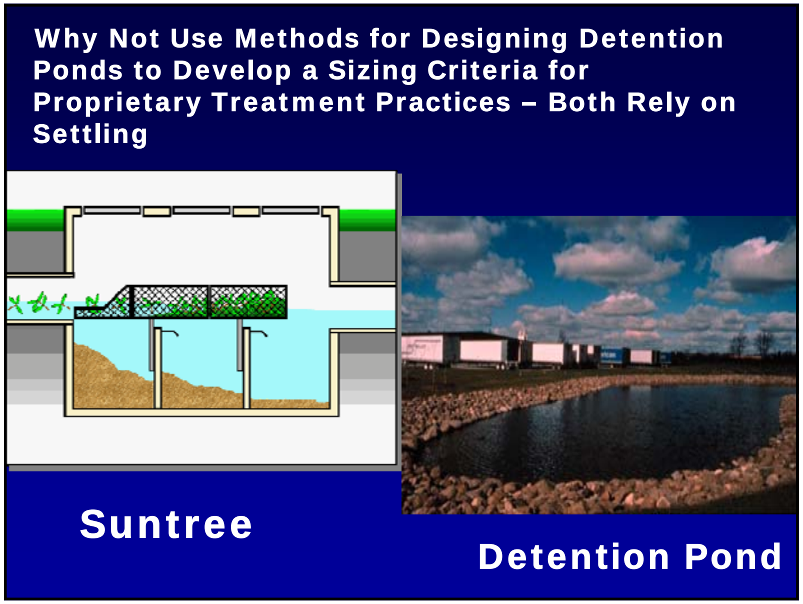
Downstream Defender

Stormceptor

Vortechs

Proprietary Devices Using a Unit Process of Settling

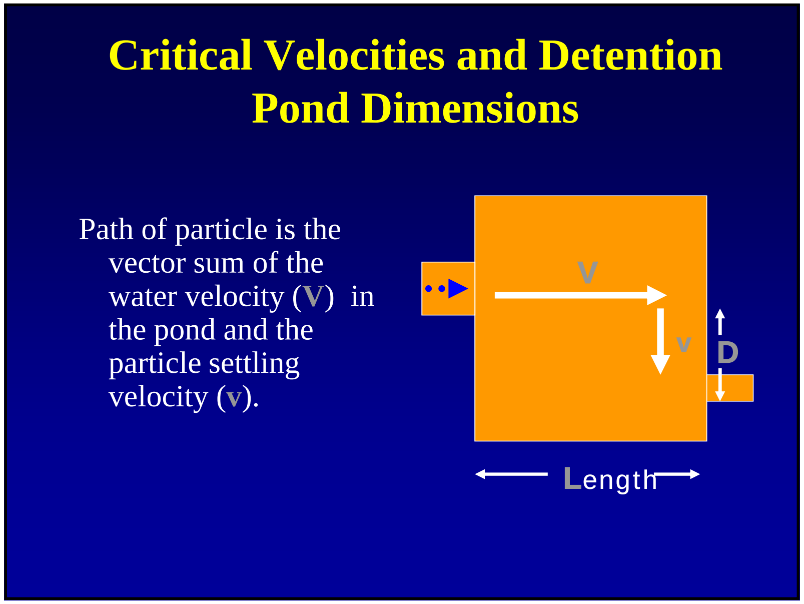
- Benefits
  - Underground
  - Easy to Install
  - Easy Maintenance
  - Claims of High Performance
- Costs
  - Installation Cost Biggest Variable
  - Installation + Capitol Cost Range from $15,000 to 50,000 per Acre of Imperviousness



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

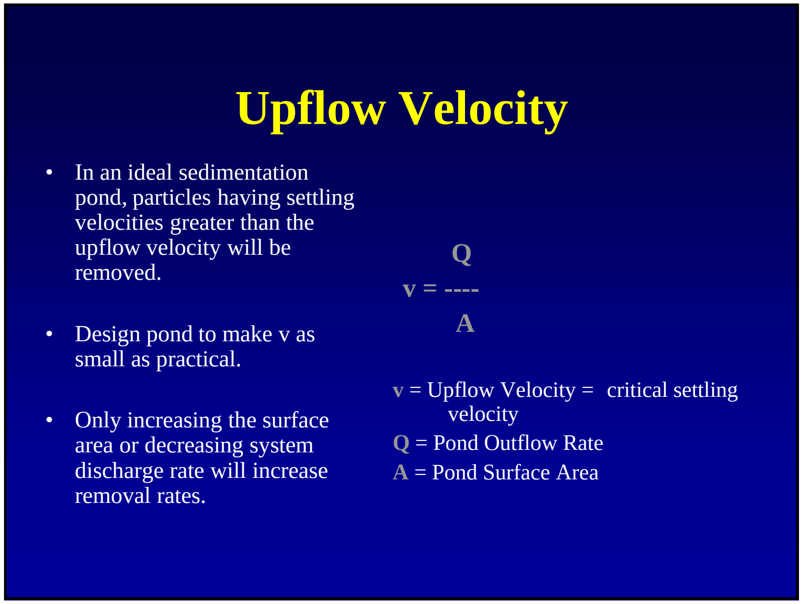
Suntree

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).

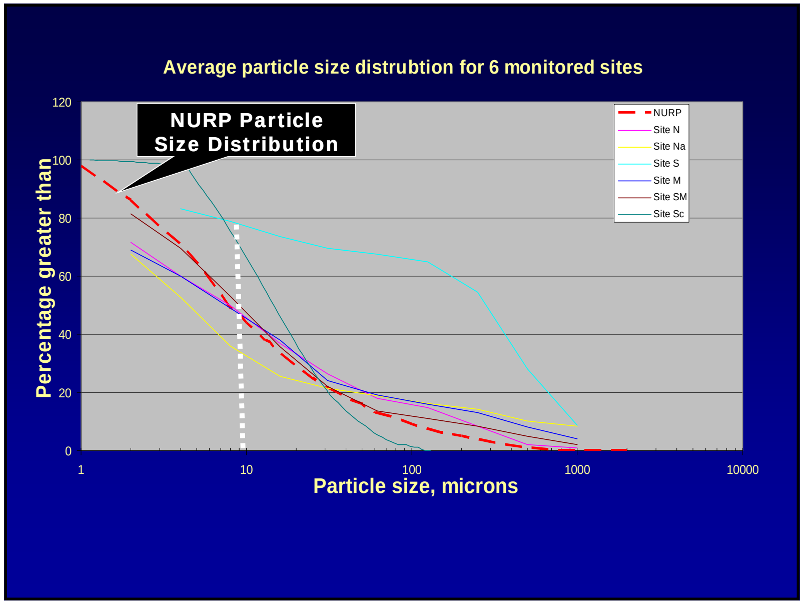


Upflow Velocity

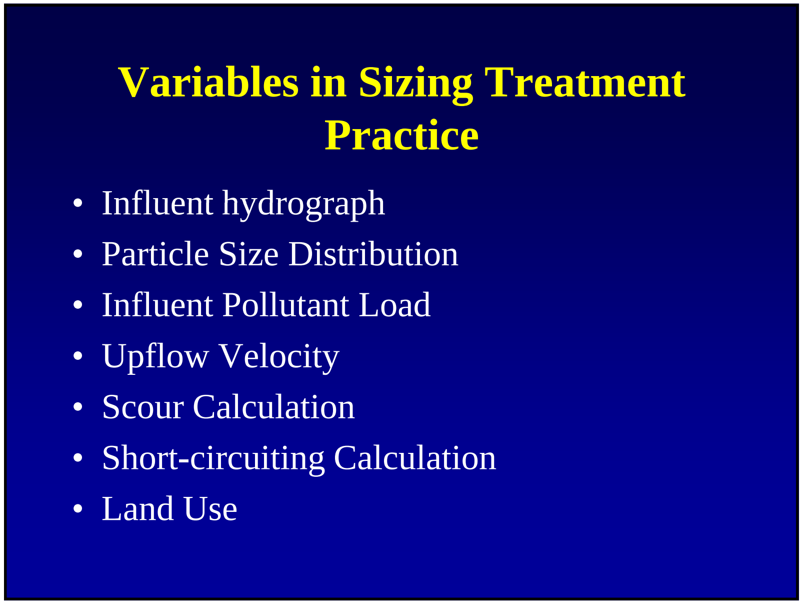
- In an ideal sedimentation pond, particles having settling velocities greater than the upflow velocity will be removed.
- Design pond to make v as small as practical.
- Only increasing the surface area or decreasing system discharge rate will increase removal rates.

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

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



Average particle size distrubtion for 6 monitored sites



Variables in Sizing Treatment Practice

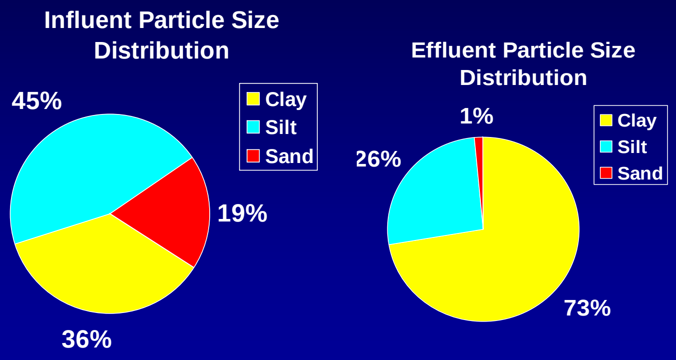
- Influent hydrograph
- Particle Size Distribution
- Influent Pollutant Load
- Upflow Velocity
- Scour Calculation
- Short-circuiting Calculation
- Land Use

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

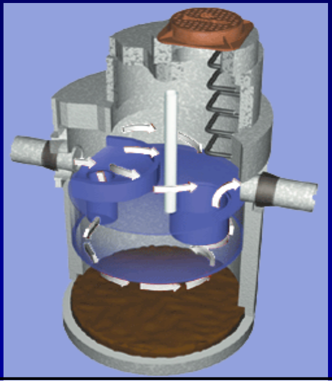
Example of Proprietary Device Monitoring

Rob Waschbusch – USGS

1996 to 1997

Sponsors – City of Madison and WDNR

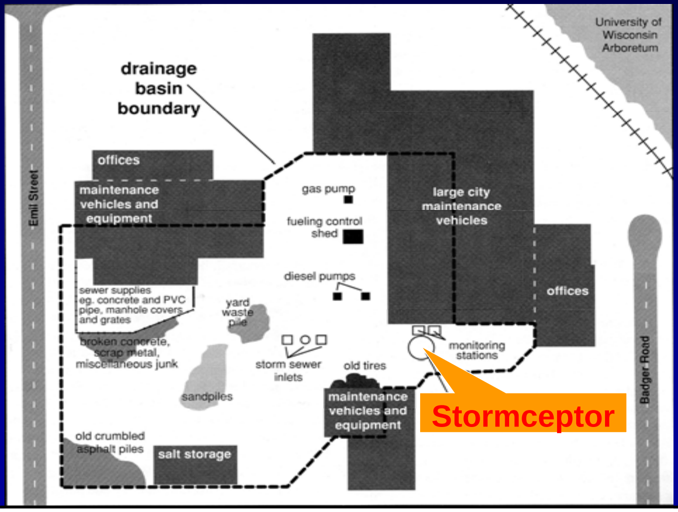
Stormceptor



Site Conditions – Maintenance Yard

4.3 Acres with 100% Connected Imperviousness

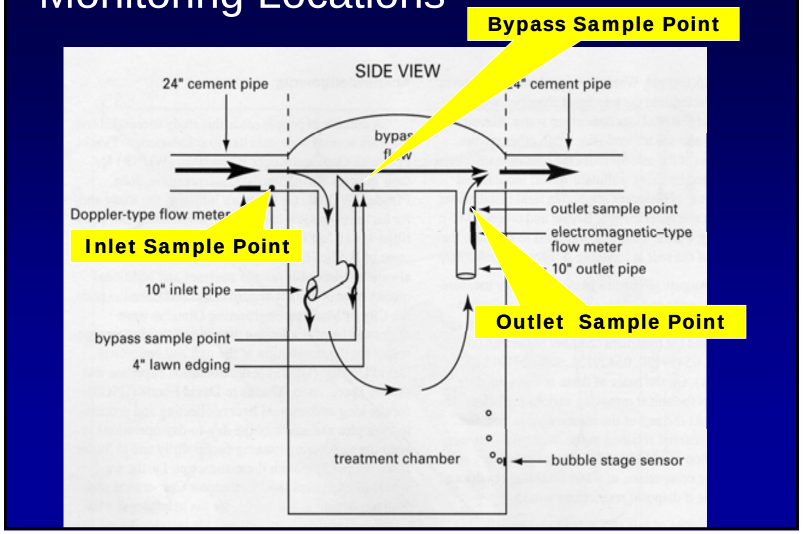
Site Conditions



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

Stormceptor Monitoring Equipment – Sampled 45 Runoff Events

Monitoring Locations

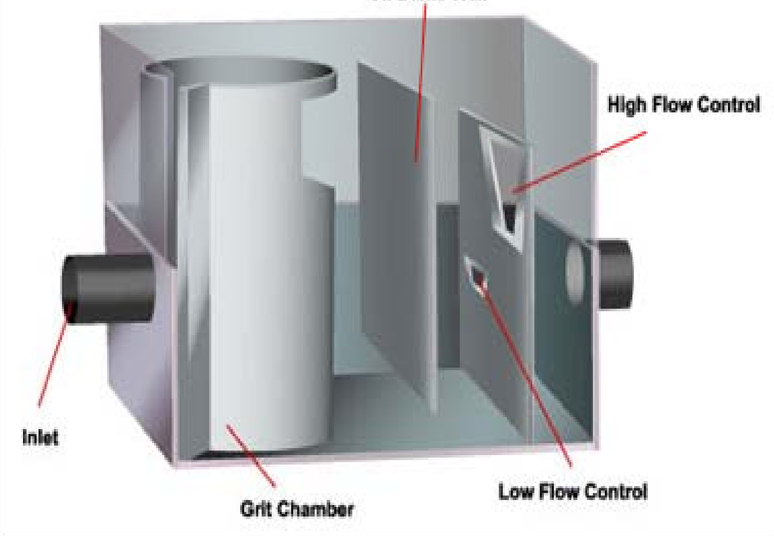


Bypass Sample Point

Inlet Sample Point

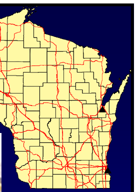
Outlet Sample Point

Vortechs

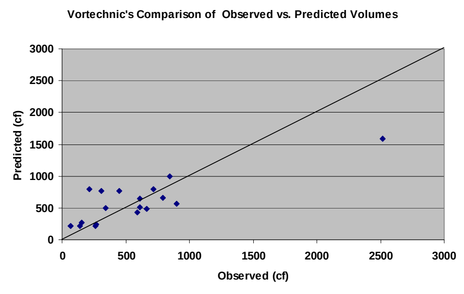


Milwaukee,WI. Test Site: I 794

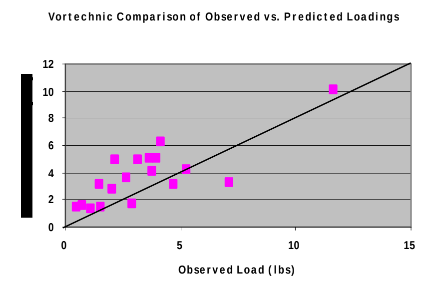
Vortechs Monitoring Site

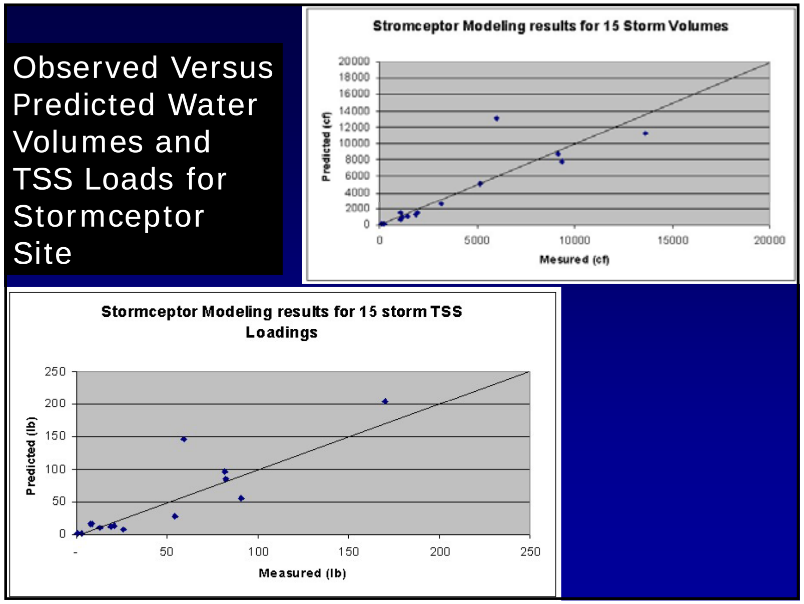


	Stormceptor			*Vortechs System*		
	Measured	**Estimated**	**Percent Difference**	**Measured**	**Estimated**	**Percent Difference**
Water Volume, cubic feet	85,600	73,893	14	10,466	10,633	- 2
TSS Load, lbs.	939	814	13	63	68	- 8



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

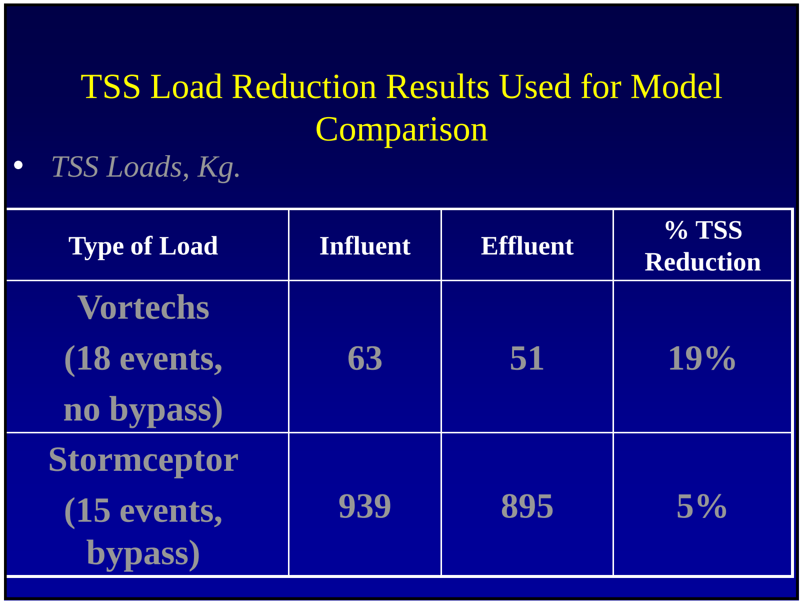




Observed Versus Predicted Water Volumes and TSS Loads for Stormceptor Site

Stromceptor Modeling results for 15 Storm Volumes

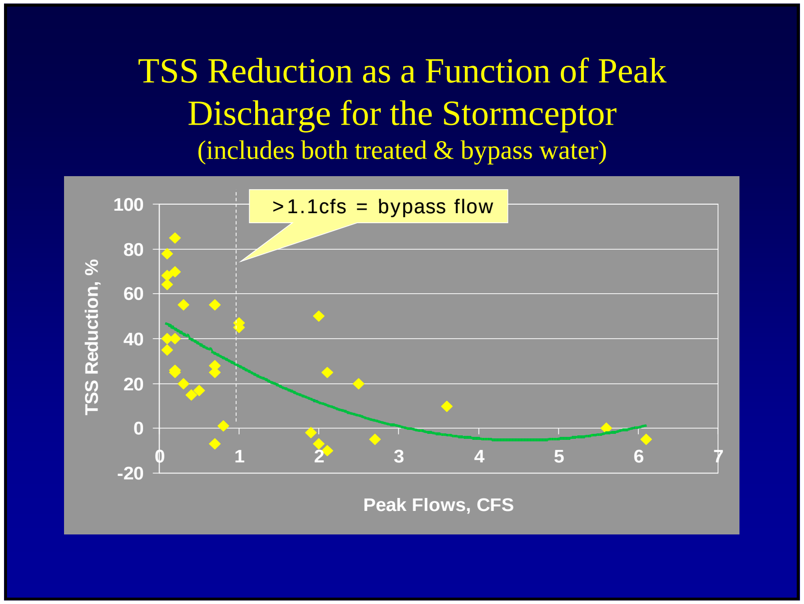
Stormceptor Modeling results for 15 storm TSS Loadings



TSS Load Reduction Results Used for Model Comparison

- *TSS Loads, Kg.*

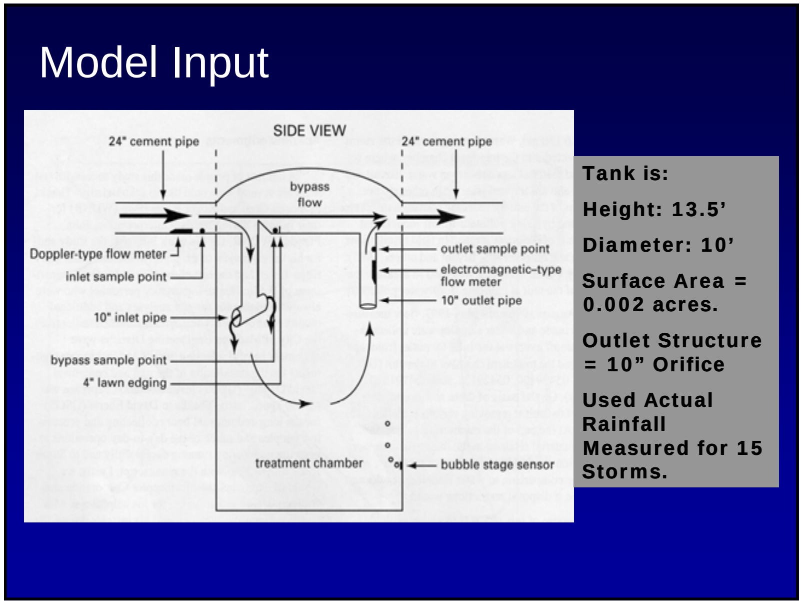
Type of Load	Influent	Effluent	% TSS Reduction
Vortechs (18 events, no bypass)	63	51	19%
Stormceptor (15 events, bypass)	939	895	5%



TSS Reduction as a Function of Peak Discharge for the Stormceptor

(includes both treated & bypass water)

>1.1cfs = bypass flow



Model Input

Tank is:

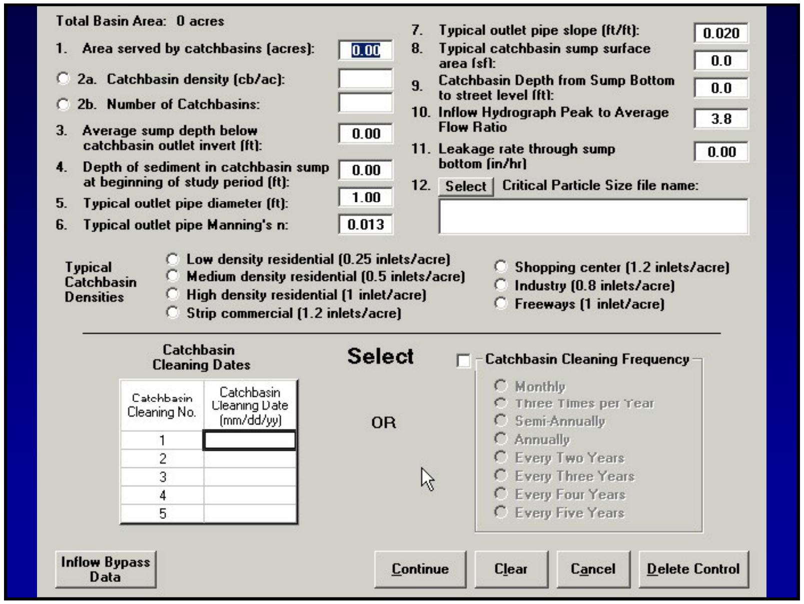
Height: 13.5’

Diameter: 10’

Surface Area = 0.002 acres.

Outlet Structure = 10” Orifice

Used Actual Rainfall Measured for 15 Storms.


Total Basin Area: 0 acres

1. Area served by catchbasins (acres): 0.00
○ 2a. Catchbasin density (cb/ac):
○ 2b. Number of Catchbasins:
3. Average sump depth below catchbasin outlet invert (ft): 0.00
4. Depth of sediment in catchbasin sump at beginning of study period (ft): 0.00
5. Typical outlet pipe diameter (ft): 1.00
6. Typical outlet pipe Manning's n: 0.013
7. Typical outlet pipe slope (ft/ft): 0.020
8. Typical catchbasin sump surface area (sf): 0.0
9. Catchbasin Depth from Sump Bottom to street level (ft): 0.0
10. Inflow Hydrograph Peak to Average Flow Ratio 3.8
11. Leakage rate through sump bottom (in/hr) 0.00
12. Select Critical Particle Size file name:

Typical Catchbasin Densities
○ Low density residential (0.25 inlets/acre)
○ Medium density residential (0.5 inlets/acre)
○ High density residential (1 inlet/acre)
○ Strip commercial (1.2 inlets/acre)
○ Shopping center (1.2 inlets/acre)
○ Industry (0.8 inlets/acre)
○ Freeways (1 inlet/acre)

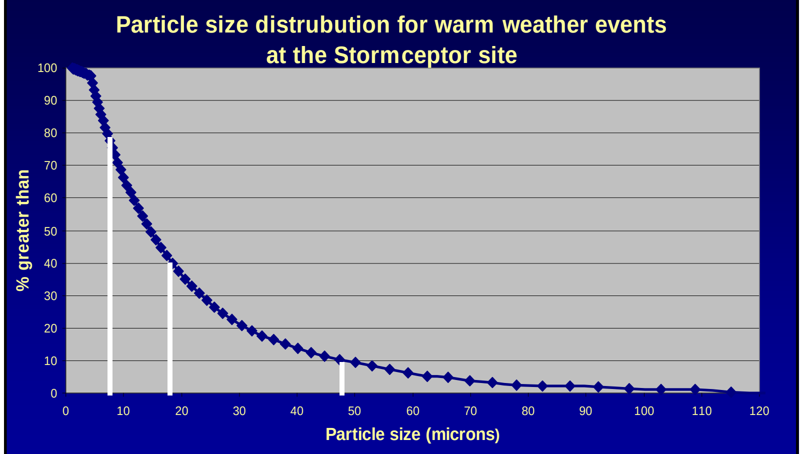
Catchbasin Cleaning Dates

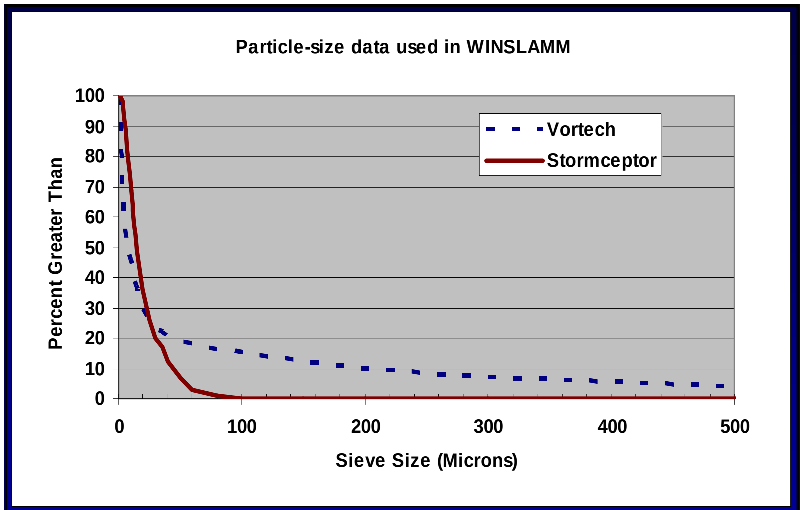
Catchbasin Cleaning No.	Catchbasin Cleaning Date (mm/dd/yy)
1	
2	
3	
4	
5	

Select

OR

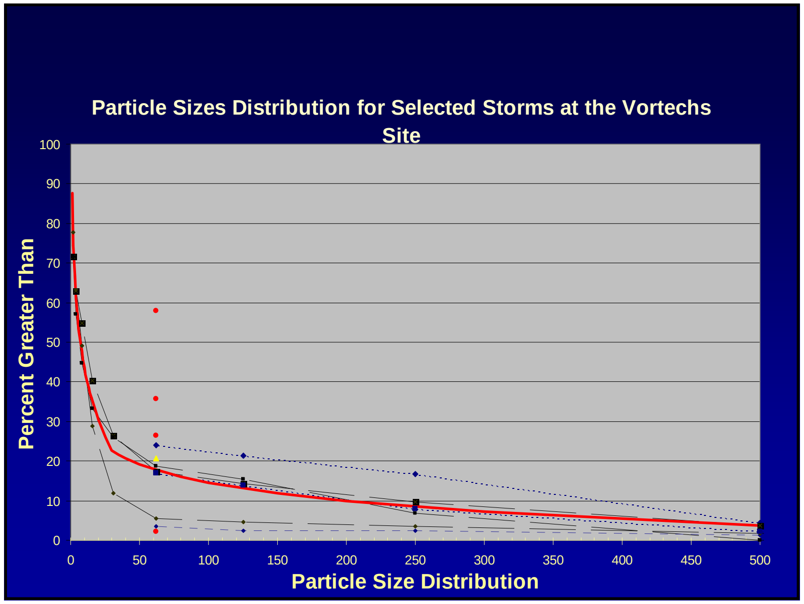
☐ Catchbasin Cleaning Frequency
○ Monthly
○ Three Times per Year
○ Semi-Annually
○ Annually
○ Every Two Years
○ Every Three Years
○ Every Four Years
○ Every Five Years


Particle size distrubution for warm weather events at the Stormceptor site

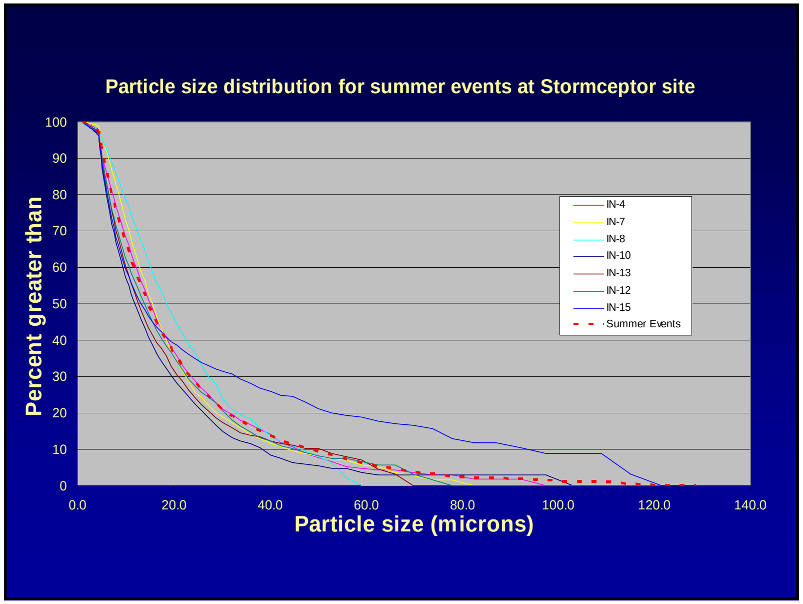

Particle-size data used in WINSLAMM

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



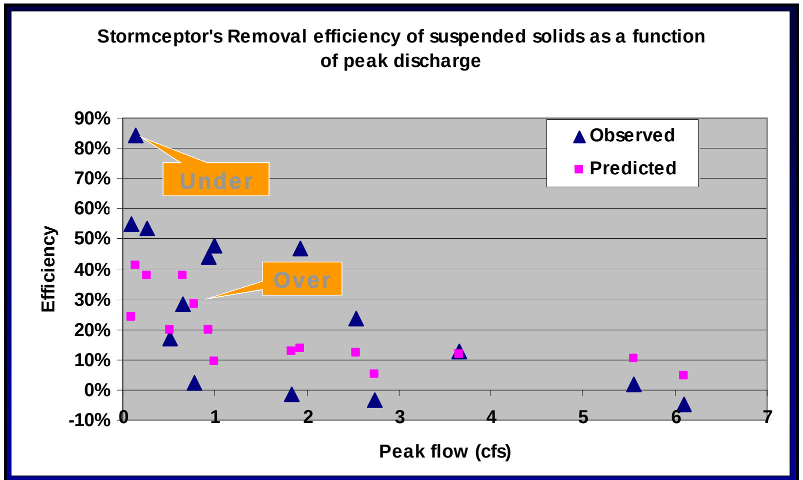
Particle Sizes Distribution for Selected Storms at the Vortechs Site



Particle size distribution for summer events at Stormceptor site

Comparison of Measured and Modeled TSS Reductions

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

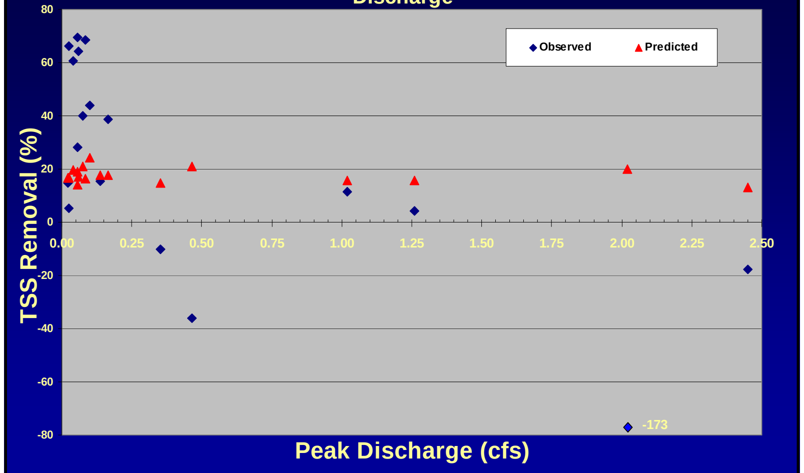


Stormceptor's Removal efficiency of suspended solids as a function of peak discharge

1. Good agreement (+- 10%) for ½ half of events.

2. Particle size range of 35 microns = 35% change in percent control.

Vortech Removal Efficiency of TSS as a Function of Peak Discharge

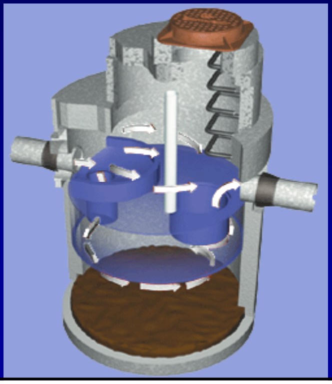


Factors Affecting Difference Between Observed and Predicted Percent Reductions for Individual Storms

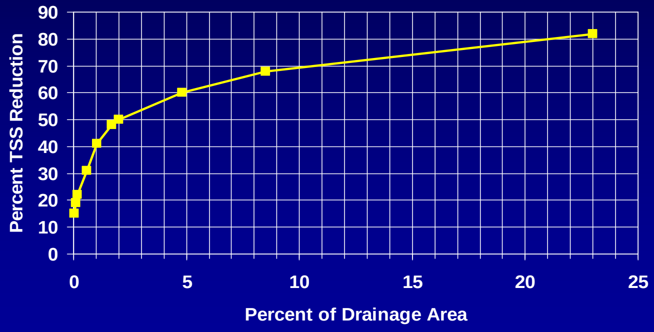
- Scour – SLAMM needs to predict scour using velocity, type of sediment, and depth of sediment
- Particle Size Distribution – Individual event particle size not practical, but SLAMM will accept
- Bypass - SLAMM does, but needs higher concentration (Concentrations x 1.7)
- Short Circuiting – Appears to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

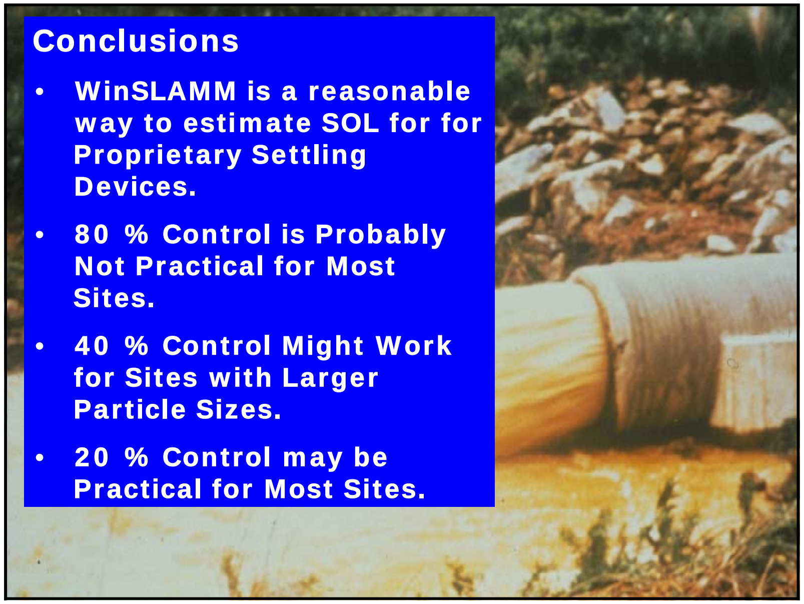
Detention Pond Needs to be 2.4% of the Drainage Area to Achieve 80% Control of TSS at Stormceptor Site.

Monroe St. Detention Pond

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)

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

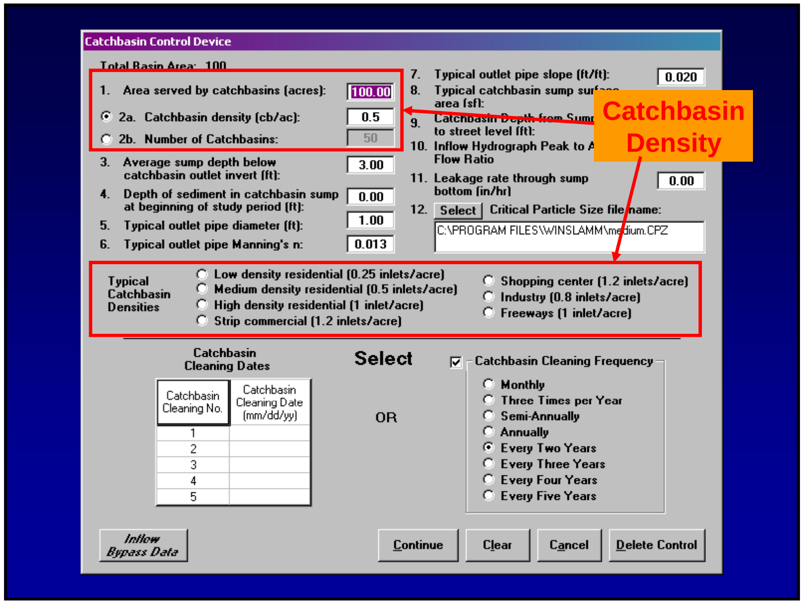


Conclusions

- WinSLAMM is a reasonable way to estimate SOL for for Proprietary Settling Devices.
- 80 % Control is Probably Not Practical for Most Sites.
- 40 % Control Might Work for Sites with Larger Particle Sizes.
- 20 % Control may be Practical for Most Sites.

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



Catchbasin Control Device

Total Basin Area: 100

1. Area served by catchbasins (acres): 100.00

● 2a. Catchbasin density (cb/ac): 0.5

○ 2b. Number of Catchbasins: 50

3. Average sump depth below catchbasin outlet invert (ft): 3.00

4. Depth of sediment in catchbasin sump at beginning of study period (ft): 0.00

5. Typical outlet pipe diameter (ft): 1.00

6. Typical outlet pipe Manning's n: 0.013

7. Typical outlet pipe slope (ft/ft): 0.020

8. Typical catchbasin sump sur area (sf):

9. Catchbasin Depth from Sump to street level (ft):

10. Inflow Hydrograph Peak to A Flow Ratio

11. Leakage rate through sump bottom (in/hr) 0.00

12. Select Critical Particle Size file name: C:\PROGRAM FILES\WINSLAMM\medium.CPZ

Typical Catchbasin Densities

○ Low density residential (0.25 inlets/acre)
○ Medium density residential (0.5 inlets/acre)
○ High density residential (1 inlet/acre)
○ Strip commercial (1.2 inlets/acre)
○ Shopping center (1.2 inlets/acre)
○ Industry (0.8 inlets/acre)
○ Freeways (1 inlet/acre)

Catchbasin Cleaning Dates

Catchbasin Cleaning No.	Catchbasin Cleaning Date (mm/dd/yy)
1	
2	
3	
4	
5	

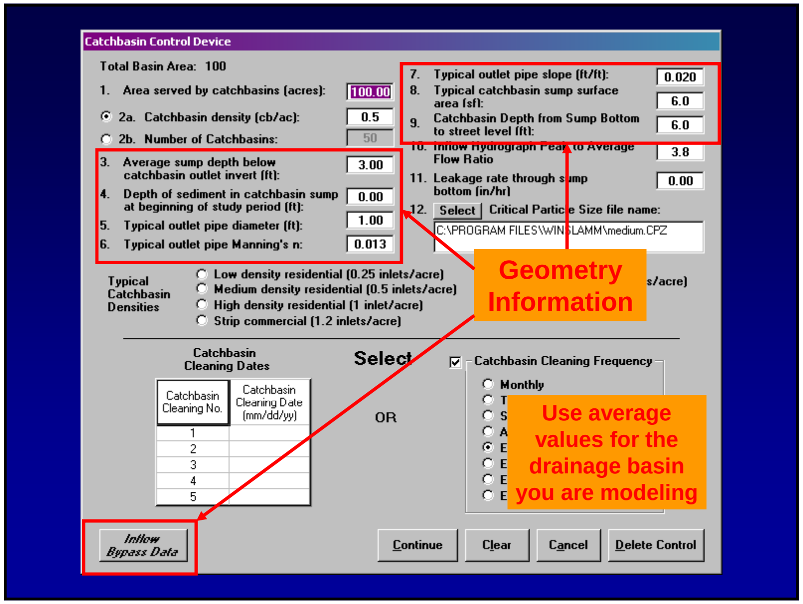
Select

OR

☑ Catchbasin Cleaning Frequency

○ Monthly
○ Three Times per Year
○ Semi-Annually
○ Annually
● Every Two Years
○ Every Three Years
○ Every Four Years
○ Every Five Years

Catchbasin Density



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Catchbasin Cleaning No.	Catchbasin Cleaning Date (mm/dd/yy)
1	
2	
3	
4	
5	

Select

OR

☑ Catchbasin Cleaning Frequency

○ Monthly
○ T
○ S
○ A
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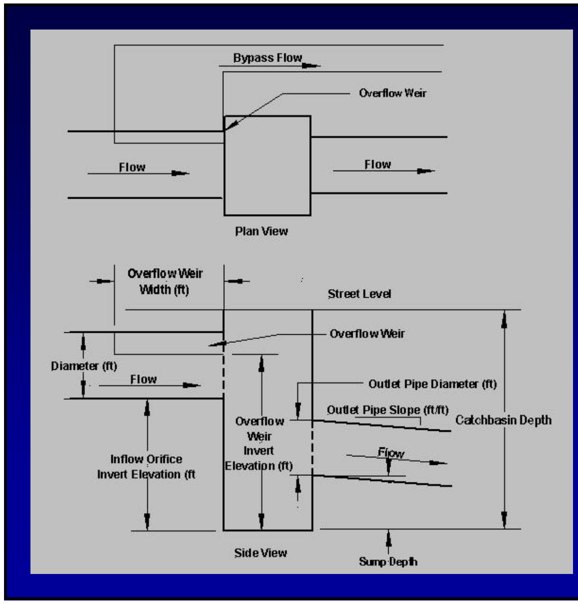
○ E
○ E
○ E

Geometry Information

Use average values for the drainage basin you are modeling



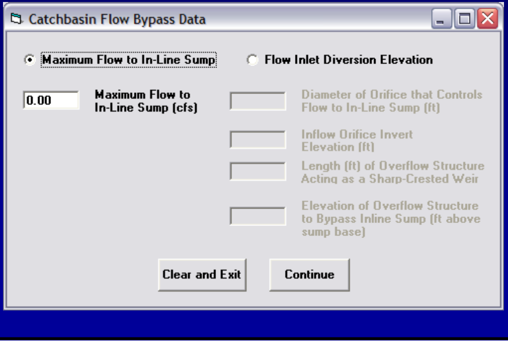
Inflow Bypass Data

Hydrodynamic Devices Only

Inflow Bypass Data

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

Hydrodynamic Devices Only



● Maximum Flow to In-Line Sump ○ Flow Inlet Diversion Elevation

0.00 Maximum Flow to In-Line Sump (cfs)

Diameter of Orifice that Controls Flow to In-Line Sump (ft)

Inflow Orifice Invert Elevation (ft)

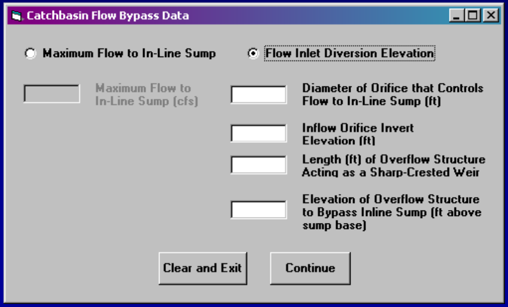
Length (ft) of Overflow Structure Acting as a Sharp-Crested Weir

Elevation of Overflow Structure to Bypass Inline Sump (ft above sump base)

Inflow Bypass Data

Defined Flow Diversion Geometry

Hydrodynamic Devices Only



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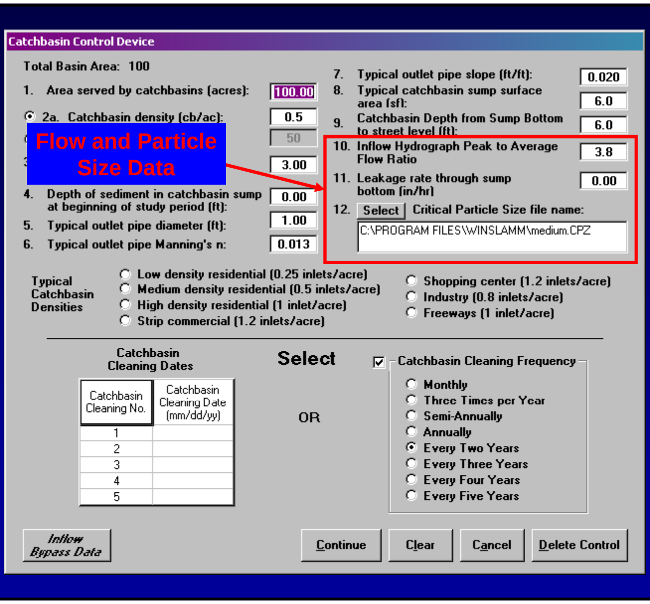

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12. Select Critical Particle Size file name: C:\PROGRAM FILES\WINSLAMM\medium.CPZ

Flow and Particle Size Data

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Catchbasin Cleaning Dates

Catchbasin Cleaning No.	Catchbasin Cleaning Date (mm/dd/yy)
1	
2	
3	
4	
5	

Select

OR

☑ Catchbasin Cleaning Frequency

- ○ Monthly
- ○ Three Times per Year
- ○ Semi-Annually
- ○ Annually
- ● Every Two Years
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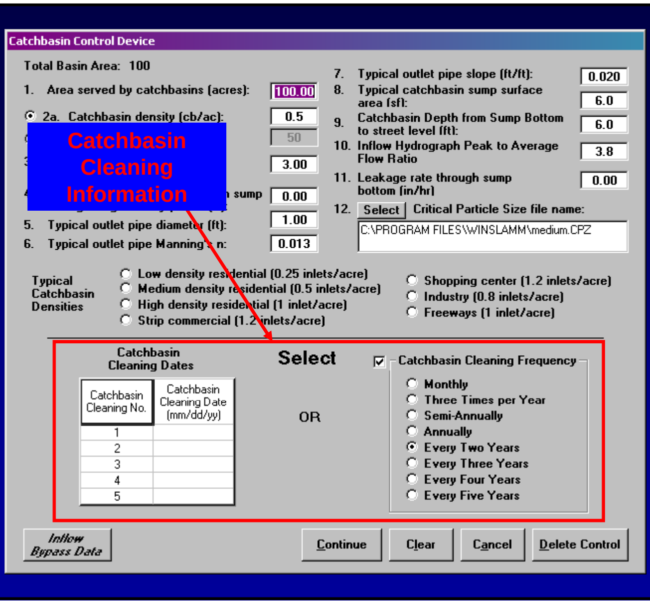

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50

3.00

sump 0.00

1.00

5. Typical outlet pipe diameter (ft):

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2	
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Select

OR

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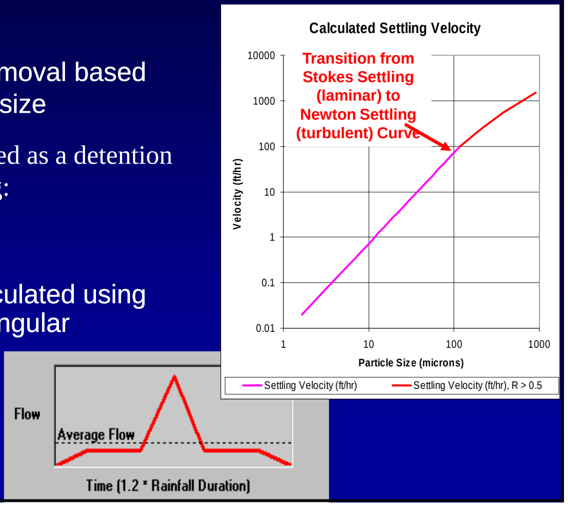
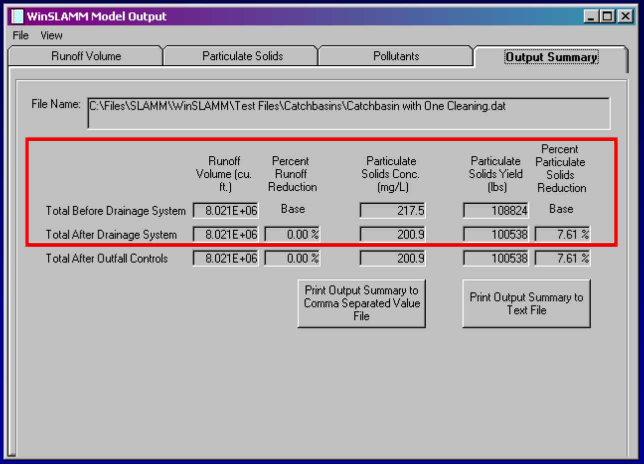
○ Semi-Annually
○ Annually
● Every Two Years
○ Every Three Years
○ Every Four Years
○ Every Five Years

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

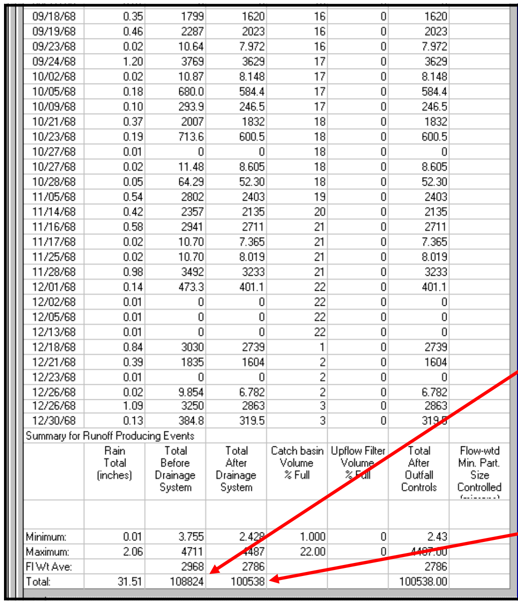


File Name: C:\Files\SLAMM\WinSLAMM\Test Files\Catchbasins\Catchbasin with One Cleaning.dat

	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 %

Catchbasin Cleaning Model Results

Drainage System Particulate Solids Yield



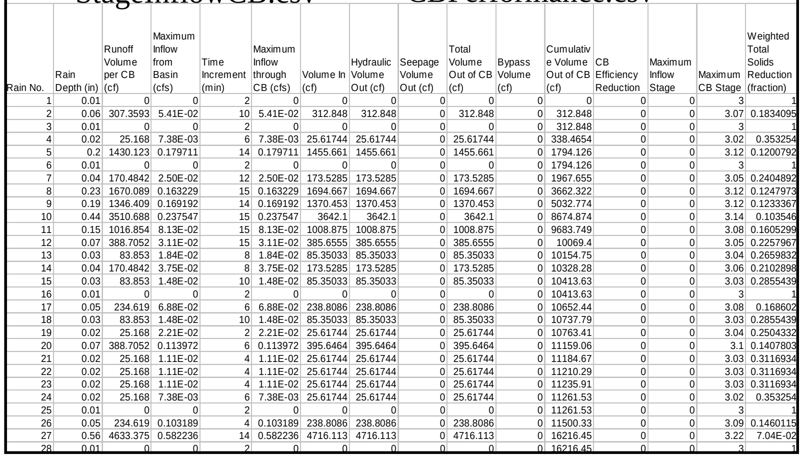
09/18/68	0.35	1799	1620	16	0	1620	
09/19/68	0.46	2287	2023	16	0	2023	
09/23/68	0.02	10.64	7.972	16	0	7.972	
09/24/68	1.20	3769	3629	17	0	3629	
10/02/68	0.02	10.87	8.148	17	0	8.148	
10/05/68	0.18	680.0	584.4	17	0	584.4	
10/09/68	0.10	293.9	246.5	17	0	246.5	
10/21/68	0.37	2007	1832	18	0	1832	
10/23/68	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	2.428	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