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

Robert Pitt
Department of Civil and Environmental Engineering
The University of Alabama
Tuscaloosa, AL 35487

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.

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)

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

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

Bed load compromises about 4% of Madison area total solids discharges.
**Results of Verification Monitoring of Stormceptor (Madison, WI)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampled solids load in (plus material not sampled by automatic sampler)</td>
<td>1623 +131 = 1754 kg</td>
</tr>
<tr>
<td>Sampled solids load out</td>
<td>1218 kg</td>
</tr>
<tr>
<td>Trapped by difference</td>
<td>405 kg (25% removal)</td>
</tr>
<tr>
<td>Actual trapped total sediment</td>
<td>536 kg (33% actual removal)</td>
</tr>
<tr>
<td>Fraction total solids not captured by automatic samplers</td>
<td>7.5%</td>
</tr>
</tbody>
</table>

**Trash screening, along with alum injection, Orlando, FL**

**EquiFlow pump back system (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

Filter Fabric Inlet Insert Tested at Ocean County, NJ

Box Plots - Coarse Screen Unit
Retro-fitted Catchbasin with Sump Tested at Ocean County, NJ

Box Plots - Catchbasin with Sump

Box Plots - Filter Fabric Unit

Dimensions of Optimally-Designed Catchbasin
Pollutant Accumulations in 200+ Bellevue, WA, Residential/Commercial Area Catchbasins (kg/ha/yr) (Pitt 1985)

<table>
<thead>
<tr>
<th>Total Solids</th>
<th>COD</th>
<th>TKN</th>
<th>TP</th>
<th>Lead</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 – 147</td>
<td>7.5 – 37</td>
<td>0.07 – 0.17</td>
<td>0.07 – 0.25</td>
<td>0.07 – 0.49</td>
<td>0.02 – 0.10</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Depth/ Diameter ratio</th>
<th>Velocity (ft/sec) 0.1% slope</th>
<th>Shear stress (lb/ft²) 0.1% slope</th>
<th>Velocity (ft/sec) 2% slope</th>
<th>Shear stress (lb/ft²) 2% slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.91</td>
<td>0.0081</td>
<td>4.1</td>
<td>0.16</td>
</tr>
<tr>
<td>0.5</td>
<td>2.3</td>
<td>0.031</td>
<td>10</td>
<td>0.62</td>
</tr>
<tr>
<td>1.0</td>
<td>2.3</td>
<td>0.031</td>
<td>10</td>
<td>0.62</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Velocity (ft/sec)</th>
<th>Fluid Shear Stress (lb/ft²)</th>
<th>Example conditions for 10 ft rough concrete pipe (full-flowing pumped system) (recent EPA wet-weather group report)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>0.0056</td>
<td>Severe deposition</td>
</tr>
<tr>
<td>2.0</td>
<td>0.015</td>
<td>Mild to moderate deposition</td>
</tr>
<tr>
<td>3.5</td>
<td>0.038</td>
<td>None to slight erosion top layer</td>
</tr>
<tr>
<td>4.0</td>
<td>0.059</td>
<td>Slight to mild erosion of consolidated beds (2-5%)</td>
</tr>
<tr>
<td>5.9</td>
<td>0.13</td>
<td>Moderate erosion of consolidated beds (15-25%)</td>
</tr>
<tr>
<td>7.9</td>
<td>0.24</td>
<td>Substantial erosion (35-50%)</td>
</tr>
</tbody>
</table>
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
Hydraulic Characterization

Assembling Upflow Filter modules for lab tests
Initial CFD Model Results

Hydro International

High flow tests

EPA-funded SBIR2 Field Test Setup, Tuscaloosa, AL

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

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

- 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 + Capital 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

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.

\[
\frac{Q}{A} = v
\]

$v = \text{Upflow Velocity} = \text{critical settling velocity}$

$Q = \text{Pond Outflow Rate}$

$A = \text{Pond Surface Area}$

---

**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

**Influent Particle Size Distribution**
- 45% Clay
- 19% Silt
- 36% Sand

**Effluent Particle Size Distribution**
- 26% Clay
- 1% Silt
- 73% Sand

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

Inlet Sample Point

Outlet Sample Point

Vortechs

Milwaukee, WI. Test Site: I 794
### Vortechs Monitoring Site

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

### Stormceptor vs. Vortechs System

<table>
<thead>
<tr>
<th></th>
<th>Stormceptor</th>
<th>Vortechs System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measured</td>
<td>Estimated</td>
</tr>
<tr>
<td>Water Volume, cubic feet</td>
<td>85,600</td>
<td>73,893</td>
</tr>
<tr>
<td>TSS Load, lbs.</td>
<td>939</td>
<td>814</td>
</tr>
</tbody>
</table>
TSS Load Reduction Results Used for Model Comparison

- **TSS Loads, Kg.**

<table>
<thead>
<tr>
<th>Type of Load</th>
<th>Influent</th>
<th>Effluent</th>
<th>% TSS Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vortechs (18 events, no bypass)</td>
<td>63</td>
<td>51</td>
<td>19%</td>
</tr>
<tr>
<td>Stormceptor (15 events, bypass)</td>
<td>939</td>
<td>895</td>
<td>5%</td>
</tr>
</tbody>
</table>

**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.

TSS Reduction as a Function of Peak Discharge for the Stormceptor (includes both treated & bypass water)

>1.1cfs = bypass flow

**Model Input**

- Total Basin Area: 0 acres
- 1. Area served by catchbasins (acres): [Input]
- 2a. Catchbasin density (cib/acre): [Input]
- 2b. Number of Catchbasins: [Input]
- 3. Average tank depth below catchbasin outlet invert (ft): [Input]
- 4. Depth of sump in catchbasin tank at beginning of study period (ft): [Input]
- 5. Typical outlet pipe diameter (ft): [Input]
- 6. Typical outlet pipe slope (x): [Input]

**Catchbasin Cleaning Data**

<table>
<thead>
<tr>
<th>Cleaning Frequency</th>
<th>Capture Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly</td>
<td>80%</td>
</tr>
<tr>
<td>Three Times per Year</td>
<td>70%</td>
</tr>
<tr>
<td>Semi Annually</td>
<td>60%</td>
</tr>
<tr>
<td>Annually</td>
<td>50%</td>
</tr>
<tr>
<td>Every Two Years</td>
<td>40%</td>
</tr>
<tr>
<td>Every Three Years</td>
<td>30%</td>
</tr>
<tr>
<td>Every Four Years</td>
<td>20%</td>
</tr>
<tr>
<td>Every Five Years</td>
<td>10%</td>
</tr>
</tbody>
</table>
Particle size distribution for warm weather events at the Stormceptor site

Particle-size data used in WINSLAMM

Ideal Particle Size Trapped for Different Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Percent Greater Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential (Monroe)</td>
<td>20 Percent: 50</td>
</tr>
<tr>
<td></td>
<td>40 Percent: 13</td>
</tr>
<tr>
<td></td>
<td>80 Percent: 1</td>
</tr>
<tr>
<td>Freeway (Riverwalk)</td>
<td>20 Percent: 150</td>
</tr>
<tr>
<td></td>
<td>40 Percent: 12</td>
</tr>
<tr>
<td></td>
<td>80 Percent: 1</td>
</tr>
<tr>
<td>Parking Lot (St. Marys)</td>
<td>20 Percent: 31</td>
</tr>
<tr>
<td></td>
<td>40 Percent: 12</td>
</tr>
<tr>
<td></td>
<td>80 Percent: 2</td>
</tr>
<tr>
<td>NURP</td>
<td>20 Percent: 35</td>
</tr>
<tr>
<td></td>
<td>40 Percent: 12</td>
</tr>
<tr>
<td></td>
<td>80 Percent: 3</td>
</tr>
</tbody>
</table>
Particle size distribution for summer events at Stormceptor site

Comparison of Measured and Modeled TSS Reductions

<table>
<thead>
<tr>
<th>Stormceptor</th>
<th>Measured TSS Reductions</th>
<th>SLAMM / DETPOND Estimates with Measured PSD and Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stormceptor</td>
<td>5%</td>
<td>12%</td>
</tr>
<tr>
<td>Vortechs</td>
<td>19%</td>
<td>19%</td>
</tr>
</tbody>
</table>

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.
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?

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

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

<table>
<thead>
<tr>
<th>Percent TSS Reduction</th>
<th>Diameter of Tank, Feet</th>
<th>Tank as a Percent of Drainage Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>10</td>
<td>0.05%</td>
</tr>
<tr>
<td>20</td>
<td>18</td>
<td>0.14%</td>
</tr>
<tr>
<td>40</td>
<td>50</td>
<td>1.05%</td>
</tr>
<tr>
<td>80</td>
<td>235</td>
<td>23%</td>
</tr>
</tbody>
</table>
**Number of 10’ Diameter Stormceptors to Achieve TSS Reduction on a 4.3 acre Site**

<table>
<thead>
<tr>
<th>Percent TSS Reduction</th>
<th>Number of Stormceptors for 4.3 acre Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>1</td>
</tr>
<tr>
<td>20%</td>
<td>3</td>
</tr>
<tr>
<td>40%</td>
<td>20</td>
</tr>
</tbody>
</table>

**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).

**Conclusions**

- **WinSLAMM** is a reasonable way to estimate SOL 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 Density
- Geometry Information
- Use average values for the drainage basin you are modeling
- Inflow Bypass Data
- Hydrodynamic Devices Only
- Catchbasin Cleaning Frequency
- Months
- Bi-Monthly
- Quarterly
- Annually
- Every Two Years
- Every Three Years
- Every Four Years
- Catchbasin Cleaning Data
- Catchbasin Cleaning Frequency
- Catchbasin Cleaning Date
- Catchbasin Cleaning Duration
- Catchbasin Cleaning Completed Date
- Typical Catchbasin Information
- Low density residential (1.25 inlets/ac)
- Medium density residential (0.5 inlets/ac)
- High density residential (0.25 inlets/ac)
- Strip commercial (0.25 inlets/ac)
- Typical Outlet Pipe Diameter
- Typical Outlet Pipe Length
- Typical Outlet Pipe Manning's n
- Typical Catchbasin Information
- Low density residential (1.25 inlets/ac)
- Medium density residential (0.5 inlets/ac)
- High density residential (0.25 inlets/ac)
- Strip commercial (0.25 inlets/ac)
- Typical Outlet Pipe Diameter
- Typical Outlet Pipe Length
- Typical Outlet Pipe Manning's n

Flow Bypass Data

Catchbasin Cleaning Device

Catchbasin Density

Geometry Information

Use average values for the drainage basin you are modeling

Hydrodynamic Devices Only
Inflow Bypass Data

Two Options – Either

User-defined Maximum Flow, or . . .

Hydrodynamic Devices Only

Defined Flow Diversion Geometry

Hydrodynamic Devices Only

Catchbasin Cleaning Information
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

![Calculated Setting Velocity Diagram](image)

**Catchbasin Output**

<table>
<thead>
<tr>
<th>File Name</th>
<th>Particles</th>
<th>Pollutants</th>
<th>Output Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Drainage System</td>
<td>100/24</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Total After Drainage System</td>
<td>100/24</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Total After Control System</td>
<td>100/24</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Catchbasin Cleaning Model Results**

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

**Catchbasin Output Details**

- **Particulate Solids Yield**
- **Drainage System Particulate Solids Yield**
- **Before Drainage System Total**
- **After Drainage System Total**

**Additional Output**

- **Weighted Total Solids Reduction**