Small Storm Hydrology
The Integration of Water Quality and Drainage Design Objectives

Modeling Flow and Pollutant Sources
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Urban Stormwater Hydrology History
- Early focus of urban stormwater was on storm sewer and flood control design using the Rational Method and TR-55 (both single event, design storm methods).
- The Curve Number procedure was developed in the 1950s by the (then) SCS as a simple tool for estimating volumes generated by large storm events in agricultural areas, converted to urban uses in mid 1970s (TR55 in SCS 1976). Data based on many decades of observations of large storms in urban areas, at Corps of Engineers monitoring locations. Data available from the Rainfall-Runoff database report prepared by the Univ. of Florida for the EPA.
- Water quality focus results form Public Law 92-500, the Clean Water Act, 1972. Stormwater quality research started in the late 1960s, with a few earlier interesting studies. Big push with Nationwide Urban Runoff Program (NURP) in late 70s and early 80s. Most still rely on earlier drainage design approaches.

Importance of Site Hydrology in the Design of Stormwater Controls
- Design of stormwater management programs requires knowledge of site hydrology
- Understanding of flows (variations for different storm conditions, sources of flows from within the drainage area, and quality of those flows), are needed for effective design of source area and outfall controls.

Many stormwater monitoring configurations used over the years
The following equation can be used to calculate the actual NRCS curve number (CN) from observed rainfall depth (P) and runoff depth (Q), both expressed in inches:

$$CN = \frac{1000}{[10+5P+10Q-10(Q^2+1.25QP)^{1/2}]}$$

The following plots use rainfall and runoff data from the EPA’s NURP projects in the early 1980s (EPA 1983), and from the EPA’s rainfall-runoff-quality data base (Huber, et al. 1982).
Knowing the Runoff Volume is the Key to Estimating Pollutant Mass

- There is usually a simple relationship between rain depth and runoff depth.
- Changes in rain depth affect the relative contributions of runoff and pollutant mass discharges:
  - Directly connected impervious areas contribute most of the flows during relatively small rains
  - Disturbed urban soils may dominate during larger rains
Source Characteristics of Stormwater Pollutants

- Quality of sheetflows vary for different areas.
- Need to track pollutants from sources and examine controls that affect these sources, the transport system, and outfall.

Street dirt washoff and runoff test plot, Toronto

Runoff response curve for typical residential street, Toronto

Ponding during very intense rain in area having sandy soils.
**Disturbed Urban Soils during Land Development**

Road shoulder soil compaction due to parked cars along road.

Soil modifications can result in greatly enhanced infiltration in marginal soils.

Direct measurements of turf runoff for different soil conditions.
### WI DNR Double-Ring Infiltrometer Test Results (in/hr), Oconomowoc (mostly A and B soils)

<table>
<thead>
<tr>
<th>Initial Rate</th>
<th>Final Rate</th>
<th>Range of Observed Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>15</td>
<td>11 to 25</td>
</tr>
<tr>
<td>22</td>
<td>17</td>
<td>17 to 24</td>
</tr>
<tr>
<td>14.7</td>
<td>9.4</td>
<td>9.4 to 17</td>
</tr>
<tr>
<td>5.8</td>
<td>9.4</td>
<td>0.2 to 9.4</td>
</tr>
<tr>
<td>5.7</td>
<td>9.4</td>
<td>5.1 to 9.6</td>
</tr>
<tr>
<td>4.7</td>
<td>3.6</td>
<td>3.1 to 6.3</td>
</tr>
<tr>
<td>4.1</td>
<td>6.8</td>
<td>2.9 to 6.8</td>
</tr>
<tr>
<td>3.1</td>
<td>3.3</td>
<td>2.4 to 3.8</td>
</tr>
<tr>
<td>2.6</td>
<td>2.5</td>
<td>1.6 to 2.6</td>
</tr>
<tr>
<td>0.3</td>
<td>0.1</td>
<td>0 to 0.3</td>
</tr>
<tr>
<td>0.3</td>
<td>1.7</td>
<td>0.3 to 3.2</td>
</tr>
<tr>
<td>0.2</td>
<td>0</td>
<td>0 to 0.2</td>
</tr>
<tr>
<td>0</td>
<td>0.6</td>
<td>0 to 0.6</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>all 0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>all 0</td>
</tr>
</tbody>
</table>

### Infiltration Rates in Disturbed Urban Soils (AL tests)

- **Sandy Soils**
- **Clayey Soils**

Recent research has shown that the infiltration rates of urban soils are strongly influenced by compaction, probably more than by moisture saturation.

### Infiltration Measurements for Noncompacted, Sandy Soils (Pitt, *et al*. 1999)

- **Recent research has shown that the infiltration rates of urban soils are strongly influenced by compaction, probably more than by moisture saturation.**

<table>
<thead>
<tr>
<th>Number of tests</th>
<th>Average infiltration rate (in/hr)</th>
<th>COV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncompact sandy soils</td>
<td>36</td>
<td>13</td>
</tr>
<tr>
<td>Compacted sandy soils</td>
<td>39</td>
<td>1.4</td>
</tr>
<tr>
<td>Noncompact and dry clayey soils</td>
<td>18</td>
<td>9.8</td>
</tr>
<tr>
<td>All other clayey soils (compacted and dry, plus all wetter conditions)</td>
<td>60</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Natural forces and management attempts to increase infiltration in compacted soils. Nature much better at this than we are.
Download WinSLAMM version 9.4
http://www.winslamm.com/

Installing the program

NEW INSTALL
   - Place the WinSLAMM CD in your CD Drive
   - On your CD drive, go to the ÏWinSLAMMÓ Folder
   - Double-click on the ÏSETUP.EXEÓ file
   - The program will install just like any other Windows program
   - We recommend that you use the default folder settings when you install the program

PV & Associates LLC

SLAMM for Windows
Source Loading and Management Model
Version 9.3

Copyright 1996-2003 Robert Pitt and John Vosechek

Disk contents and file structure

- Executable program (WinSLAMM.exe)
- Miscellaneous System Files
- Parameter and Cost Files
- Help File (WinSLAMM.HLP)
- Documentation
- WinSLAMMFile Summary.doc
- Pond Sizing and Cation Exchange Spreadsheets
- Rain Files
- Example File and Standard Land Use Folders
- Update Folder
- WinSLAMMLog.txt
- Users Guides
Tab 4 Ŧ Small storm hydrology
Outline

• Main Screen
• Current File Data
• Toolbar Selections
  - File
  - Pollutants
  - Tools
  - Utilities
  - Help
  - Land Use
  - Run
• Land Use
  - Land Uses
  - Control Practices
• Output

To Enter the Program
Main Menu Window without a .DAT File

To make source area data, select the Land Use name area and select the desired Land Use.

Main Menu Window with a .DAT File

Main Menu Window with a .DAT File

To Review Current File Data

Select the "Edit" Buttons to Enter or Change values

Tab 4 ñ Small storm hydrology
Parameter Files and Drainage System Data

Input Data Printout

Output Options

Tab 4: Small storm hydrology

To Review Current File Data

Status

File Version Number: 9.3

Input Data Printout

Output Format Options

1. Square Areas by Land Use for Each Rain - Complete Printout
2. Source Area Totals and Outfall Summaries
3. Outfall Data Only for Each Rain
4. Outfall Summaries Only
5. One Line per Event Runoff and Flow Summary
6. Continuous Hydrograph With 6 Minute Time Increments
7. Continuous Hydrograph With 15 Minute Time Increments
8. Continuous Hydrograph With 60 Minute Time Increments
9. Water Balance Summary of All Detention Ponds
10. Save Outfall Runoff and Particular Loading for WATEPORD Analysis
11. Some Model Output for Input into CE QUAL-HV1
Tab 4 – Small storm hydrology

Pollutants

- Particulate
- Dissolved
- Total

- Sulfate
- Phosphorus
- Nitrate
- TC
- Cd
- Fecal Coliform Bacteria
- Chromium
- Copper
- Zinc
- Cadmium (pp/L)
- Pyrene
- Other 3
- Other 4
- Other 5
- Other 6

The pollutants listed above are in the file C:\VProgram Files\SWING\AMMVEG\1201.PDF.
Select a pollutant to evaluate.

Select All  
Clear All  
Continue

Tools

- Combine .dat Files
- Access Cost Data
- Access Detailed Output Options

Control Practice Cost Data

- Cost Index Data
- Summary Data
- Detailed Output Options
- Default Model Options
- File Update Options

Detailed Output Options

- Wet Detention Pond
- Storm Sewage Detailed Output File
- Outfall Discharge Hydrograph
- Detailed Output File
- Voltage Balance Summary of All Ponds
- Flow Stage-Volume Data
- Flow Diameter Curve Data

Default Model Options

- Suppress Control Practice Review Warning Messages
- Suppress No Street Cleaning with Catchbasin Cleaning Warning Messages
- Save "Save File Output Call" Messages .RST
- Turn "Save Detailed Runoff and Particulate Loading for Wind/ET-PTRAS Analysis" Output Option On

File Update Options

- Suppress All Detailed Output Options
- Save .RST File

Tools
Tab 4 – Small storm hydrology

Utilities

Parameter File Editors

Street Delivery Parameter File

Critical Particle Size Parameter File

Runoff Coefficient Parameter File
Tab 4 Small storm hydrology

![Rainfall Parameter File](image1)

![Particular Solids Concentration Parameter File](image2)

![Particulate Resin Reduction Parameter File](image3)

![Pollutant Parameter File](image4)
Tab 4 – Small storm hydrology

Help

Land Use

Source Area Parameters: Double-click to change or review

Source Area Numbers: Stipments by 30 for each Land Use

Different Source Areas and Source Area Parameters from Other Land Uses
Source Area Parameters

- Land Use: Residential
- Source Area: 2.86 acres
- Roof: Flat Roof
- Is the Source Area: Directly Connected or Draining to a Directly Connected Area
- Soil Type: Sandy
- Building Density: Low
- Alley present: No

Freeway Source Area Parameters

- Current Land Use: Freeway
- Current Source Area: Panhandle 5th Area 1
- Freeway Drainage System:
  - Grass Swales
  - Curb and Gutter, Valleys, or Sealed Swales in poor condition or very flat
  - Curb and Gutter, Valleys, or Sealed Swales in fair condition
- Freeway Length (in ft): 4,000
- Average Daily Traffic (Vehicles/day): 1,000
- Initial Freeway Dist Loading (lbs/cum-ft-m)
  - Use value calculated by program based upon average daily traffic and freeway length
  - Specify value: 25.25

Pre-Development Areas and Curve Numbers (CN)

- Total Area: 100.00

Street Source Area Parameters

- Current Land Use: Residential
- Current Source Area: Street Area 1
- Total Area: 3.92 acres
- Street Drainage System:
  - Directly Connected or Draining to a Directly Connected Area
- Street Texture:
  - 1. Smooth
  - 2. Intermediate
  - 3. Rough
  - 4. Very Rough (including soil and screens)
- Street Dist Accumulation:
  - 1. Use value calculated by program based upon land use and street texture
  - 2. Enter accumulation equation coefficients
- Equation Form: \( y = mx + b \)
  - where \( m \) = Accumulation Rate
  - \( y \) = Loading (lbs/cum-ft-m)
  - \( x \) = Time (hr)
- Initial Street Dist Loading (lbs/cum-ft-m)
  - Use value calculated by program based upon land use and street texture
  - Specify value: 25.40
- Initial Street Dist Loading at End of Winter Season (lbs/cum-ft-m)
Tab 4: Small storm hydrology
Warning Messages

Potential Control Practice Conflicts

1. Street Cleaning and Catchbasin control practices are not allowed in the same drainage basin.
2. Wet Detention/Ponds, Street Cleaning, Catchbasins and non-irrigating Barriers in Source Areas or Control Areas, and Solid Flow Control practices such as Wet Detention/Ponds and Infiltration Basins may be redundant.
3. Non-irrigating Source Areas control practices such as Barriers that do not indicate Wet Detention/Ponds should not be combined with other such practices at the source area level.
4. Street Cleaning is not allowed with Grass Swales unless the street system that drains to the controls is catch and gutter system.
5. The model assumes that any combinations of hydrodynamic devices are in parallel and not in series. If they are connected in the field in series, the model will probably not perform as well as the actual results indicate.

Practices that are marked with a red X indicate that there may be potential problems or conflicts with the combinations of control practices in the site. This either from a performance point of view or with a Regulatory Agency. Review the practices, and if appropriate either consult with your Regulatory Agency or modify the site to remove the potential problems.

To prevent the messages from appearing, from the Main Menu go to “Edit/Options...” and check the Suppress Control Practice Warning Messages box.

Output

Runoff Volume Tab

The runoff volume is listed for each event, for each source area.

The model also calculates the land use runoff coefficient (RV), the total losses, and the SCS Curve Number for each event.

Runoff Volume Tab

Source Areas

The runoff volume is listed for each event, for each source area.
The runoff statistics are summarized for each source area below the event-by-event list.

### Runoff Volume Source Area Percent Contribution Summary

<table>
<thead>
<tr>
<th>Source Area</th>
<th>Percent Contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>45.6</td>
</tr>
<tr>
<td>Rural</td>
<td>34.2</td>
</tr>
<tr>
<td>Wetlands</td>
<td>20.2</td>
</tr>
</tbody>
</table>

#### Additional Output – Runoff coefficient (Rv)

- Total losses
- SCS Curve Number

#### With an Outfall Detention Pond - Peak Reduction Factor

- Pond Flushing Ratio
- Outlet structure failure

The model also summarizes the output for the total area, before and after the drainage system, and at the outfall.
Tab 4: Small storm hydrology

Particulate Solids Concentration Tab
Source Areas

<table>
<thead>
<tr>
<th>Source Areas</th>
<th>Concentration</th>
<th>Tab</th>
<th>Total Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Particulate Solids Concentration Tab
Outfall

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Particulate Solids in the drainage system and at the outfall, by rainfall event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Particulate Solids Yield Tab
Source Areas

<table>
<thead>
<tr>
<th>Source Areas</th>
<th>Particulate Solids Yield Summary at the outfall also includes the Flow-weighted Minimum Particle Size (microns) controlled by the outfall pond, if there was one.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Particulate Solids Yield Tab
Outfall

<table>
<thead>
<tr>
<th>Particulate Solids yield has the same output format.</th>
</tr>
</thead>
</table>
The model also calculates the percentage contribution of particulate solids from each source area for each land use.

Particulate Solids Yield Source Area Percent Contribution Summary

Output option 5 is a summary of the outlet results, by event, along with a number of statistics for each parameter.
**WinSLAMM Parameter Files for Alabama**
(based on regional model calibration and verification)

- **Particle Solids Concentrations:**
  - ABHAM_PSC_CALIB_June07.psc

- **Pollutant Probability Distributions:**
  - ABHAM_PPD_CALIB_June07.ppd

- **Drainage System Solids Delivery:**
  - ABHAM_DELIVERY.BHAM.prr

- **Cost Analysis File:**
  - ABham Cost Data.csv

- **Runoff Coefficient File:**
  - AB Runoff.rsv

- **Street Particulate Delivery Files (by land use):**
  - AB Street_BHAM RES.std
  - AB Street_BHAM INST and OTHER URBAN.std
  - AB Street_BHAM COM and IND.std
  - AB Freeway_BHAM.std

**Example Land Development Conditions for a Residential Area**

- **WinSLAMM Data File:** C:\Program Files\WinSLAMM\Mynew world.dat

- **Current Land Use:** Residential
- **Source Areas:**
  - Residential Areas: 100.00 Acres
    - Institutional Areas: 0.00 Acres
    - Commercial Areas: 0.00 Acres
    - Other Urban Areas: 0.00 Acres
    - Foreway Areas: 0.00 Acres
  - Total Area: 100.00 Acres

- **Change output format options** under “file” to option 1 Source Areas by Land Use for Each Rain.
After running the model, select detailed model output:

You can then plot the data in Excel (after copying output to file and then importing the data into Excel) and label the most significant sources. Look for which source areas are most important for different rain ranges of most interest. Can also do for other pollutants contained in the *.ppd file, but start with runoff volume and solids.