August 14, 2009

WinSLAMM, the Source Loading and Management Model

WinSLAMM, the Source Loading and Management Model was developed starting in the mid-1970's as part of early EPA street cleaning and receiving water projects in San Jose (Pitt 1979) and Coyote Creek (CA) (Pitt and Bozeman 1983). The primary purpose of the model is to identify sources of urban stormwater pollutants and to evaluate the efficiency of control practices. During the mid 1980s, the model was expanded to include more management options beyond street cleaning, including wet detention ponds, infiltration and grass swales. The Nationwide Urban Runoff Program (NURP) projects (EPA 1983) provided a large data set for the model, especially, Alameda Co. CA (Pitt and Shawley 1983); Bellevue, WA (Pitt and Bissonnette 1983); and Milwaukee, WI (Bannerman, et al 1983). Research funded by the Ontario Ministry of the Environment (Ottawa) (Pitt 1987) and the Toronto Area Watershed Management Strategy study in the Humber River (Pitt and McLean 1986) also provided much information on bacteria sources in urban areas. During the mid-1980s, the model started to be used by the Wisconsin Department of Natural Resources (WDNR) in their Priority Watershed Program (Pitt 1986). The first Windows version of the model was developed in 1995 and the current version is 9.3.0, released in April 2008. The model is continuously being updated based on user needs and new research (recent and current support from Stormwater Management Authority of Jefferson County, AL; the TVA, Economic Development group; WDNR; the USGS; and Imbrium). The next version currently being developed will include drag and drop watershed elements and more complete routing options.

Over the years, WinSLAMM has been extensively revised and expanded and now includes a wide range of capabilities. The following lists several important model features:

- The model can evaluate a long-series of rain events. One to five years of typical rains are used, but several decades of rains can be evaluated
- The model is based on actual field data. For example, street dirt accumulation and washoff equations and direct runoff from paved surfaces are based on many thousands of measurements from actual rain events
- The effects of compacted urban soils are considered
- Uncertainties of many modeling parameters are represented by built-in Monte Carlo components
- Costs of control practices can be directly calculated and considered in model runs
- Runoff flow-duration probability distributions and associated receiving water biological conditions are calculated based on site conditions and the control measures being used
- The model can be interfaced with several other models for more detailed drainage system and receiving water evaluations.

Prior descriptions of WinSLAMM have been presented during the Engineering Foundation and in the Urban Water Modeling Conference series, and in other publications (Pitt 1986; 1997; 1999; Pitt and Voorhees 2002 for example). The model web site (http://www.winslamm.com/) also contains further model descriptions and references.

Applications of WinSLAMM include:

- Permit Compliance – Municipal Pollutant Loadings and Discharge Reductions
- Evaluate Alternative Stormwater Controls
    - City-wide

- Watershed
- Site Development

- Identify critical drainage areas
    - Identify critical land uses
    - Identify critical source areas
    - Assist with cost-sharing
    - Identify the most cost-effective stormwater control and development scenarios

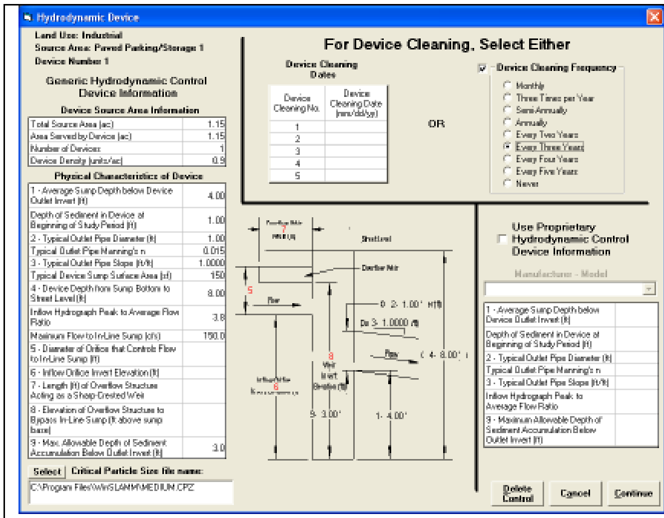
WinSLAMM is an urban stormwater model (it does not directly address agricultural areas, natural areas, etc.). It is designed to be an effective multi-scale model (individual lots to whole communities), and can calculate annual or seasonal pollutant loads. It evaluates individual or multiple stormwater control scenarios (source area, land use, drainage, outfalls), as shown highlighted in the following table:

WinSLAMM Treatment Practice Options by Source Area

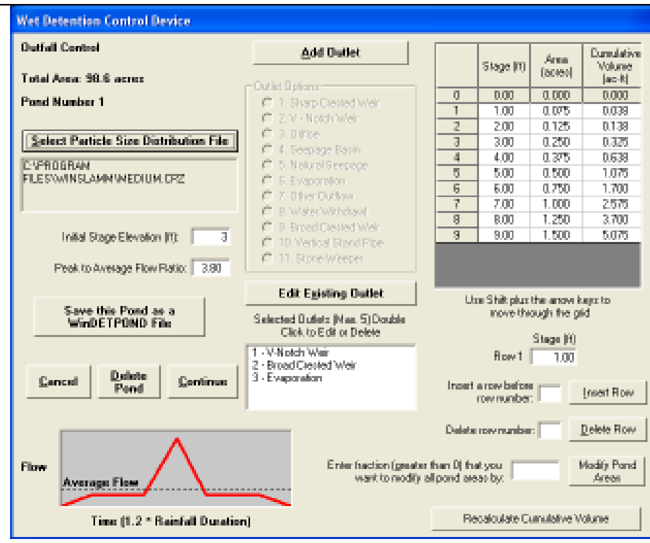
	Hydro-dynamic Device	Wet Detention	Street Cleaning	Biofiltration/ Rain Gardens	Porous Pavement	Rain Barrels/ Tanks	Grass Swales	Catch-basin Cleaning	Drainage Dis-connection
Roof	■	■		■		■			■
Paved Parking/Storage	■	■		■	■	■			■
Unpaved Parking/Storage	■	■		■		■			■
Playgrounds	■	■		■	■	■			■
Driveways		■		■	■	■			■
Sidewalks/Walks		■		■	■	■			■
Streets/Alleys			■	■		■			
Undeveloped Areas	■	■		■		■			
Small Landscaped Areas	■	■		■		■			
Other Pervious Areas	■	■		■		■			
Other Impervious Areas	■	■		■	■	■			■
Freeway Lanes/Shoulders	■	■							
Large Turf Areas	■	■							
Large Landscaped Areas	■	■							
Land Uses				■		■	■		
Drainage System	■			■	■	■	■	■	
Outfall		■		■		■			

The effectiveness of the control practices are calculated based on the size and other attributes of the devices, the source area or outfall location characteristics, and the calculated runoff characteristics. The model does a complete mass balance and routing of water volume and particulate mass, considering the combined effects of all controls. Hydraulic and particle size routing occurs for each device individually, although serial effects of multiple devices are being expanded for these parameters in an upcoming version. The effects of the sedimentation controls are calculated using modified Puls hydraulic routing with surface overflow rate particulate routing. The performance of wet ponds have been verified by extensively monitoring several ponds (WI DNR and USGS, with documentation at: http://unix.eng.ua.edu/~rpitt/SLAMMDETPOND/WinDetpond/WinDETPOND%20user%20guide%20and%20documentation.pdf). The infiltration and biofiltration devices use a combination of hydraulic routing with infiltration and evaporation losses, plus any pumped withdrawals. Evapotranspiration losses are being added to the devices in the next model update. Underdrain filtering in biofilters is based on extensive tests of media filtration. Grass swale performance is calculated based on extensive laboratory and outdoor testing of particulate trapping of shallow flowing water and infiltration losses (Kirby 2005; Johnson, et al. 2003; Nara and Pitt 2005). Porous pavement performance is calculated based on infiltration losses and clogging effects. Street cleaning and catchbasin benefits are based on extensive EPA research, and newer updated research that has examined modern street cleaning equipment. Hydrodynamic devices are based on the basic sedimentation processes, but have been verified by tests conducted by the USGS and the DNR, plus continued tests at the University of Alabama. The following figure shows some example screen shots used to enter information for some of the controls.

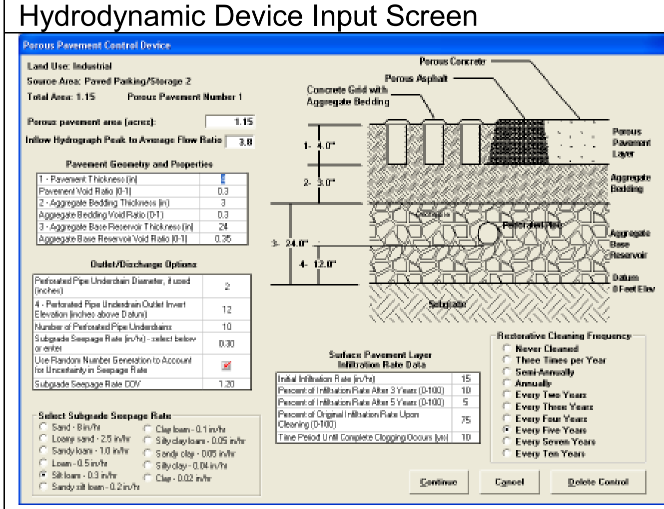
Example Control Practice Input Screens for WinSLAMM



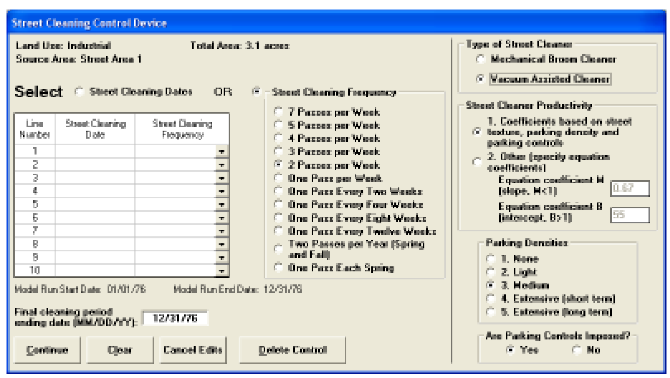
Hydrodynamic Device Input Screen



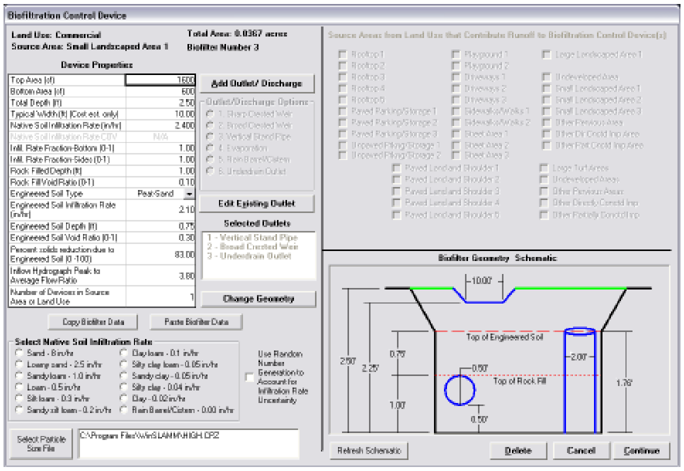
Main Wet Detention Pond Input Screen



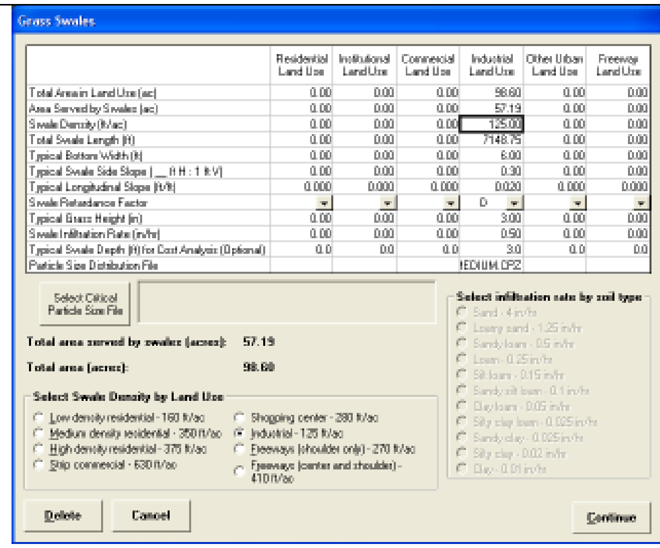
Porous Pavement Input Screen



Street Cleaning Input Screen



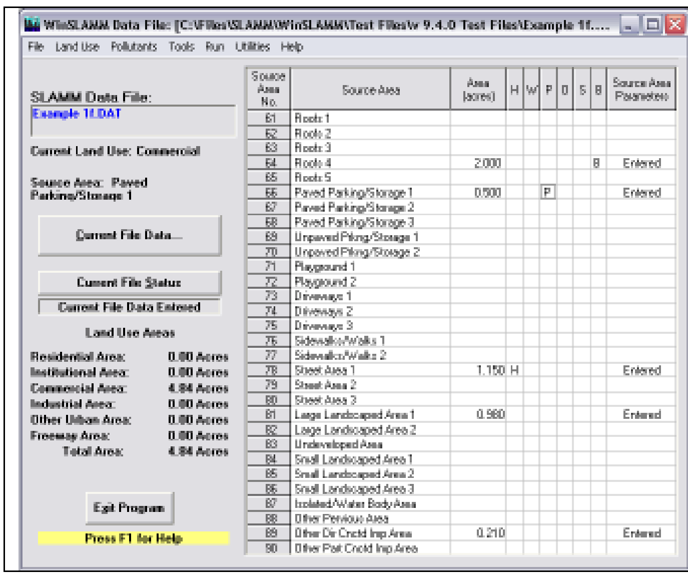
Biofilter Input

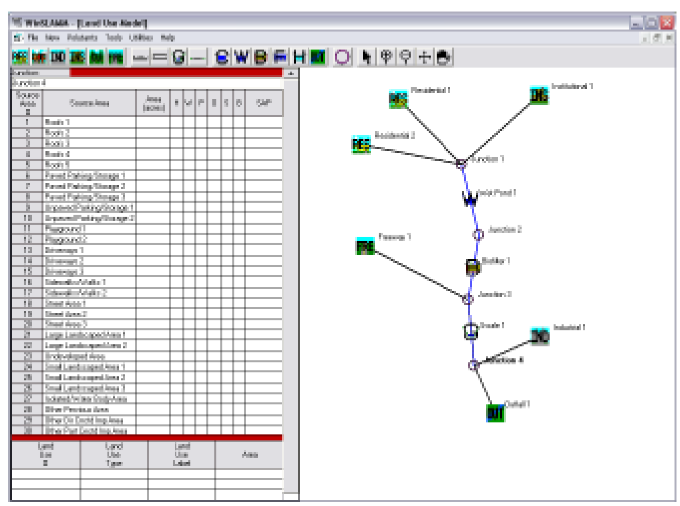


Grass Swale Input Screen

Each land use is described by characterizing elements for each source area within the land use, including source area and land use controls. Outfall and drainage system controls are described using the drop down menus. A new drag and drop interface is currently being developed that will allow greater efficiency and flexibility for control placement, and for using multiple land use source areas. The following figures show a screen from the most current version (v 9.40) and from the interface under development.

WinSLAMM Version 9.40 Source Area Screen and Version 10 Interface (Under Development)





The calculated outputs from WinSLAMM are organized in several tiers. The first output the model shows is a summary table with the results of the most commonly analyzed pollutants (runoff volume and particulate solids). The data in the summary table includes the following information:

Runoff Volume (ft^3, percent reduction; and R_v, runoff coefficient) and Particulate Solids (lbs and mg/L) for:

- Source area total without controls
- Total before drainage system
- Total after drainage system
- Total after outfall controls

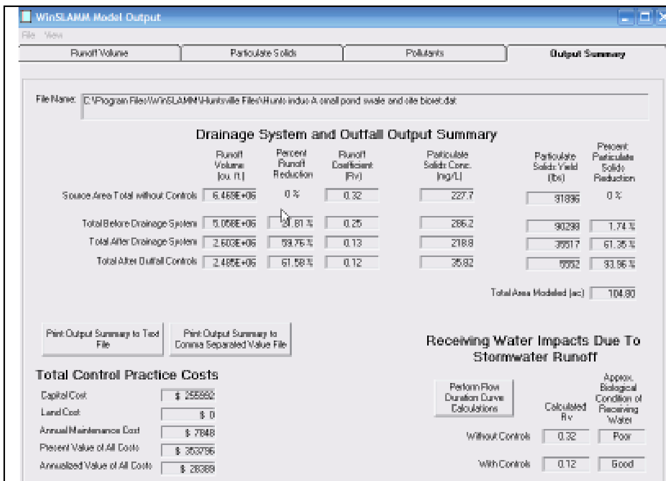
Total control practice costs:

- Capital costs
- Land cost
- Annual maintenance cost
- Present value of all costs
- Annualized value of all costs

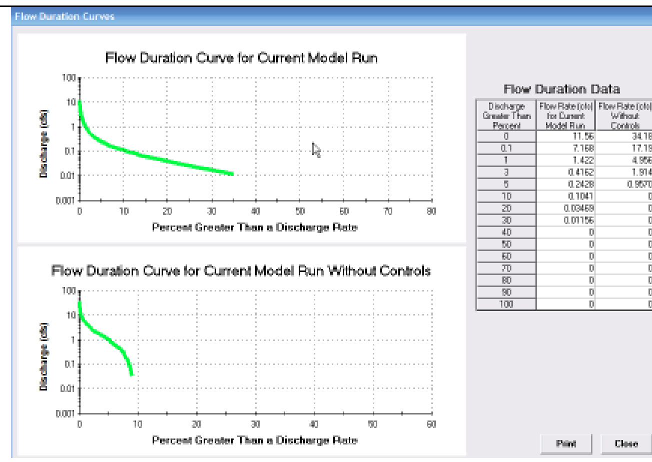
Receiving water impacts due to stormwater runoff:

- Calculated R_v with and without controls
- Approximate biological condition of receiving water (good, fair, or poor)
- Flow duration curves (probabilities of flow rates for current model run with and without controls)

The flow duration curves are included on an optional second page, as shown on the following figure.



Summary Table with Detailed Output Tabs (need updated picture, attached)

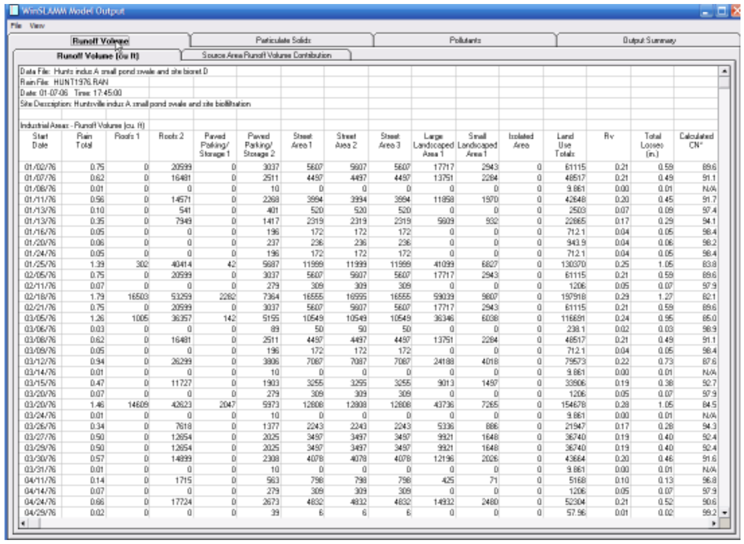


Flow-Duration Summary Output Option

The tabs along the top of the summary table display additional results for runoff volume (ft^3), particulate solids (lbs and mg/L), and the analyzed pollutants (lbs and mg/L). Results are shown:

- By source area for each rain event
- Land use total
- Summary for all rains
- Total for land use and for each event
- Outfall summary, before and after drainage system and before and after outfall controls
- R_v (runoff volume only)
- Total losses (runoff volume only)
- Calculated CN (runoff volume only)

An example of the detailed data for runoff volume is shown in the following figure.



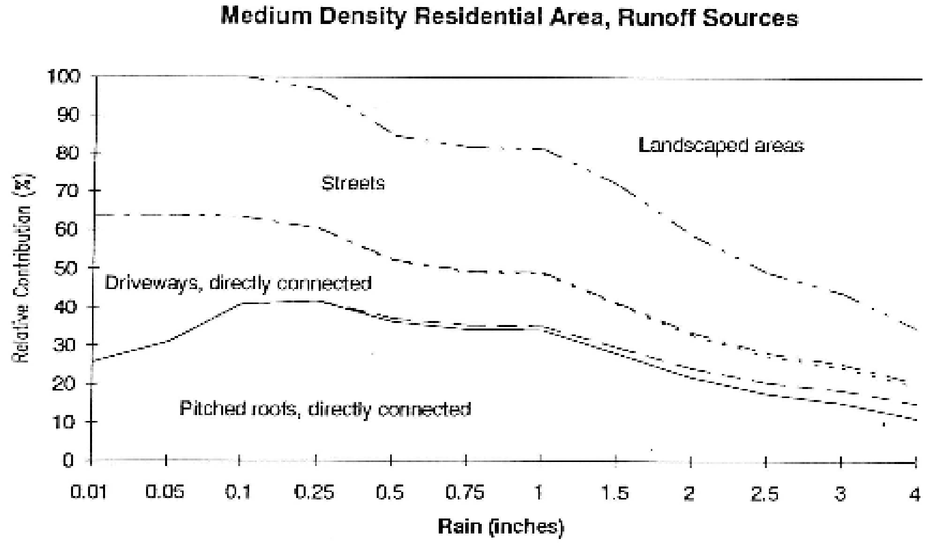
Start Date	Rain Total	Roofs 1	Roofs 2	Paved Parking/ Storage 1	Paved Parking/ Storage 2	Street Area 1	Street Area 2	Street Area 3	Large Landscaped Area 1	Small Landscaped Area 1	Isolated Area	Land Use Totals	Rv	Total Losses (in.)	Calculated CN*
01/02/76	0.75	0	20599	0	3037	5607	5607	5607	17717	2943	0	61115	0.21	0.59	89.6
01/07/76	0.62	0	16481	0	2511	4497	4497	4497	13751	2284	0	48517	0.21	0.49	91.1
01/08/76	0.01	0	0	0	10	0	0	0	0	0	0	9.861	0.00	0.01	N/A
01/11/76	0.56	0	14571	0	2268	3994	3994	3994	11858	1970	0	42648	0.20	0.45	91.7
01/13/76	0.10	0	541	0	401	520	520	520	0	0	0	2503	0.07	0.09	97.4
01/13/76	0.35	0	7949	0	1417	2319	2319	2319	5609	932	0	22865	0.17	0.29	94.1
01/16/76	0.05	0	0	0	196	172	172	172	0	0	0	712.1	0.04	0.05	98.4
01/20/76	0.06	0	0	0	237	236	236	236	0	0	0	943.9	0.04	0.06	98.2
01/24/76	0.05	0	0	0	196	172	172	172	0	0	0	712.1	0.04	0.05	98.4
01/25/76	1.39	302	40414	42	5687	11999	11999	11999	41099	6827	0	130370	0.25	1.05	83.8
02/05/76	0.75	0	20599	0	3037	5607	5607	5607	17717	2943	0	61115	0.21	0.59	89.6
02/11/76	0.07	0	0	0	279	309	309	309	0	0	0	1206	0.05	0.07	97.9
02/18/76	1.79	16503	53259	2282	7364	16555	16555	16555	59039	9807	0	197918	0.29	1.27	82.1
02/21/76	0.75	0	20599	0	3037	5607	5607	5607	17717	2943	0	61115	0.21	0.59	89.6
03/05/76	1.26	1005	36357	142	5155	10549	10549	10549	36346	6038	0	116691	0.24	0.95	85.0
03/06/76	0.03	0	0	0	89	50	50	50	0	0	0	238.1	0.02	0.03	98.9
03/08/76	0.62	0	16481	0	2511	4497	4497	4497	13751	2284	0	48517	0.21	0.49	91.1
03/09/76	0.05	0	0	0	196	172	172	172	0	0	0	712.1	0.04	0.05	98.4
03/12/76	0.94	0	26299	0	3806	7087	7087	7087	24188	4018	0	79573	0.22	0.73	87.6
03/14/76	0.01	0	0	0	10	0	0	0	0	0	0	9.861	0.00	0.01	N/A
03/15/76	0.47	0	11727	0	1903	3255	3255	3255	9013	1497	0	33906	0.19	0.38	92.7
03/20/76	0.07	0	0	0	279	309	309	309	0	0	0	1206	0.05	0.07	97.9
03/20/76	1.46	14609	42623	2047	5973	12808	12808	12808	43736	7265	0	154678	0.28	1.05	84.5
03/24/76	0.01	0	0	0	10	0	0	0	0	0	0	9.861	0.00	0.01	N/A
03/26/76	0.34	0	7618	0	1377	2243	2243	2243	5336	886	0	21947	0.17	0.28	94.3
03/27/76	0.50	0	12654	0	2025	3497	3497	3497	9921	1648	0	36740	0.19	0.40	92.4
03/29/76	0.50	0	12654	0	2025	3497	3497	3497	9921	1648	0	36740	0.19	0.40	92.4
03/30/76	0.57	0	14899	0	2308	4078	4078	4078	12196	2026	0	43664	0.20	0.46	91.6
03/31/76	0.01	0	0	0	10	0	0	0	0	0	0	9.861	0.00	0.01	N/A
04/11/76	0.14	0	1715	0	563	798	798	798	425	71	0	5168	0.10	0.13	96.8
04/14/76	0.07	0	0	0	279	309	309	309	0	0	0	1206	0.05	0.07	97.9
04/24/76	0.66	0	17724	0	2673	4832	4832	4832	14932	2480	0	52304	0.21	0.52	90.6
04/29/76	0.02	0	0	0	39	6	6	6	0	0	0	57.96	0.01	0.02	99.2

Runoff volume detailed WinSLAMM output.

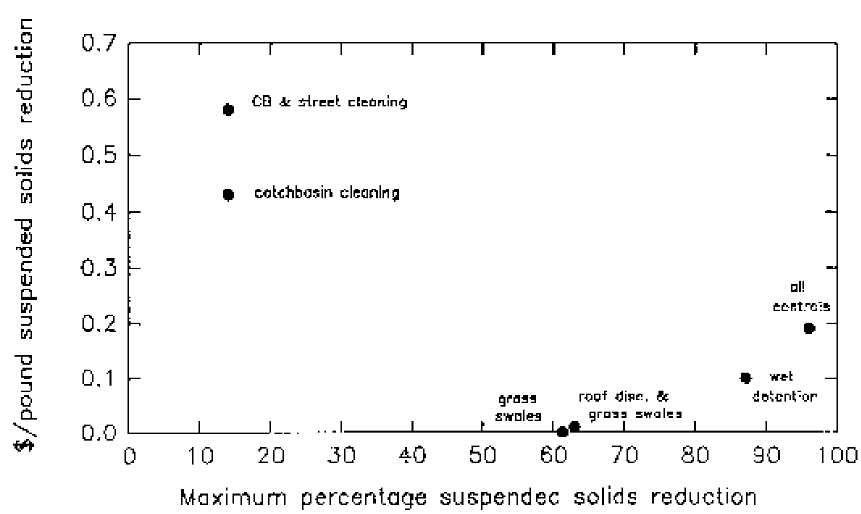
Another group of output options are "one-line per event" data sets. This data is saved in a *.csv file format that can be opened in a spreadsheet for viewing and further data manipulation. These files can also be examined by selecting the "utilities/view file/use notepad or use Windows view" pull down menu option from the main WinSLAMM page. The data presented in these files includes "One-Line per Event Runoff Details," with data for each event and statistical summaries for all events (number of events, total, equivalent annual total, minimum, maximum, average of all events, median, standard deviation, and coefficient of variation). The available data includes:

- Rain duration (hours)
- Rain interevent period (days)
- Runoff duration (hours)
- Rain depth (inches)
- Runoff volume (ft^3)
- R_v
- Average flow (cfs)
- Peak flow (cfs)
- Suspended solids (lbs and mg/L)

One of the main features of WinSLAMM is to identify the sources of pollutants for different rain conditions for a specific development. The following example plot shows how runoff volume originates from different sources in a medium density residential area for different categories of rains. This type of plot is very useful when determining the most likely effective locations for stormwater controls, or for changes in development characteristics.



A powerful feature of WinSLAMM is the batch processor that enables many control options to be quickly compared for an area. The batch processor can analyze runoff volume and pollutants and also combine unit cost data to evaluate the cost effectiveness of control options. The following plot of the cost-performance data for one study site shows the unit costs associated with preventing particulate solids from being discharged from an area.



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