

Module 5b: City Wide Applications of WinSLAMM using the Batch Processor and Decision Analyses

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City-Wide WinSLAMM Application

Purpose:

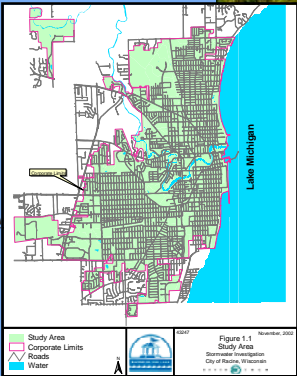
- ☛ Establish “Base” or “No Controls” Urban Pollution Loads
- ☛ Analyze the Effect of Existing Stormwater Controls on the “Base” Load
- ☛ Identify High Priority Areas to Focus Management
- ☛ Determine Cost Effective Stormwater Control Practices

City-Wide WinSLAMM Application

Example: Racine, WI

Challenge:

- ☛ Population: 81,800
- ☛ City Area: 16 square mile
- ☛ Outfalls: 97
- ☛ Subbasins: 245



City-Wide WinSLAMM Application

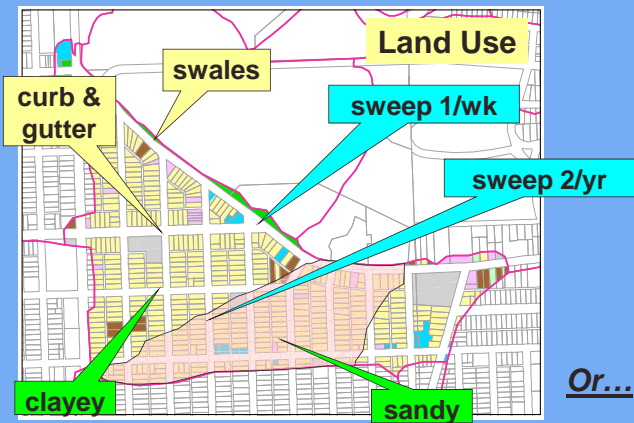
Example: Racine, WI

Choice #1:

- ☛ Create a “*.dat” file for each of the 245 subbasins

Example of one subbasin:

City-Wide WinSLAMM Application



City-Wide WinSLAMM Application

- Choice #2:**
Create Unit Area Loading Database with 4 variables:
1. Land use (26 combinations of LU & roof connections)
 2. Soils (2)
 3. Drainage Type (2)
 4. Management Practices (15 combinations)
- 1,560 Potential Combinations**

Conducting Pollution Loading Analysis on Entire City – Racine, WI

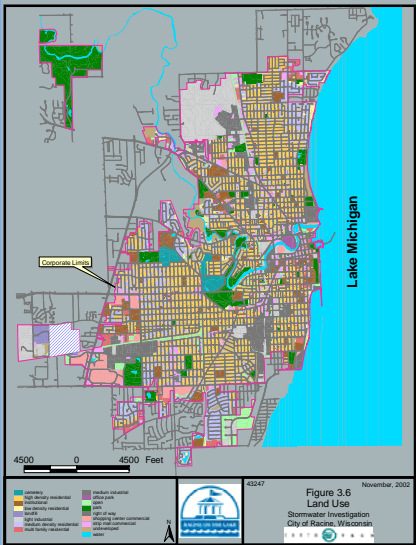
Unit area loading database

File	Runoff	SS	DS	TS	Part_Ph	Diss_Ph
AAG01	944319	8,659	4,824	13,483	26.8	16.7
AAG02	944319	8,402	4,681	13,083	26.2	16.3
AAG03	944319	8,501	4,736	13,237	26.5	16.5
AAG04	944319	8,595	4,788	13,384	26.7	16.6
AAG05	944319	8,654	4,821	13,475	26.8	16.7
AAG06	944319	6,290	3,504	9,794	19.8	12.3
AAG07	944319	6,290	3,504	9,794	19.8	12.3
AAG08	944319	6,114	3,406	9,520	19.4	12.1
AAG09	944319	6,114	3,406	9,520	19.4	12.1
AAG10	944319	6,179	3,442	9,620	19.6	12.2
AAG11	944319	6,179	3,442	9,620	19.6	12.2
AAG12	944319	6,244	3,479	9,723	19.7	12.3
AAG13	944319	5,439	3,030	8,469	17.9	11.1
AAG14	944319	6,284	3,501	9,785	19.8	12.3
AAG15	944319	6,284	3,501	9,785	19.8	12.3
AAW01	328200	1,644	916	2,560	5.7	3.6

750

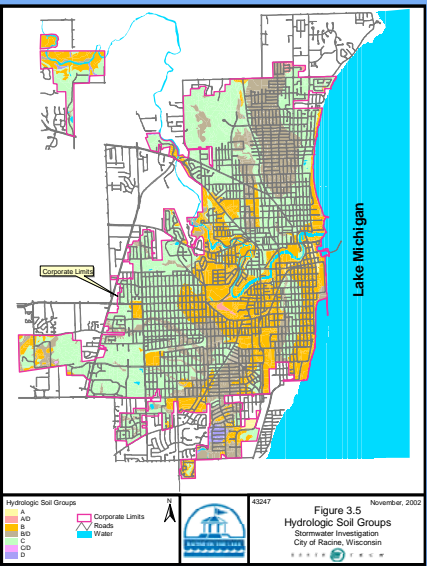
Racine GIS Example

Land Use Coverage

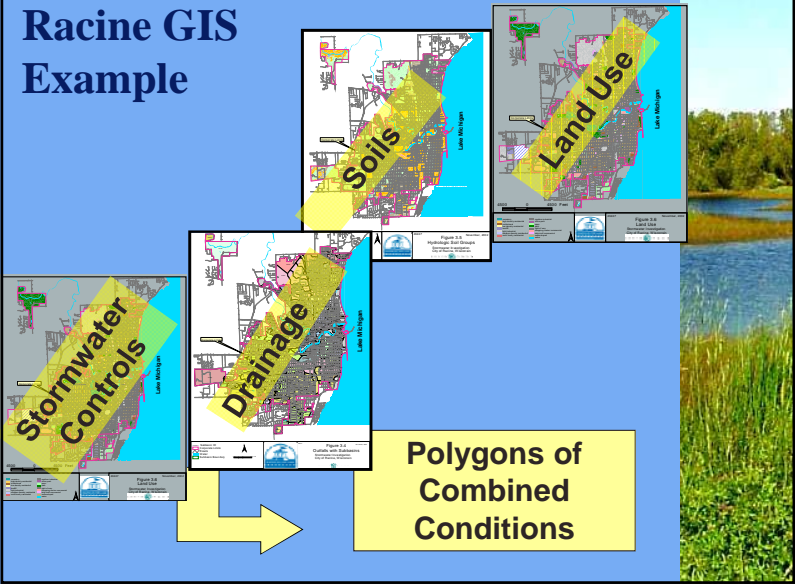


Racine GIS Example

Soils
Coverage
(Hydrologic Groups)

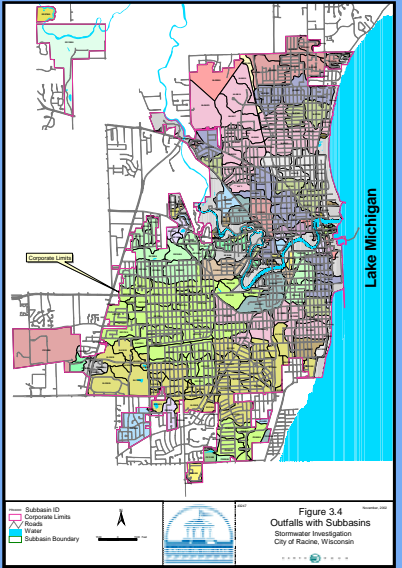


Racine GIS Example

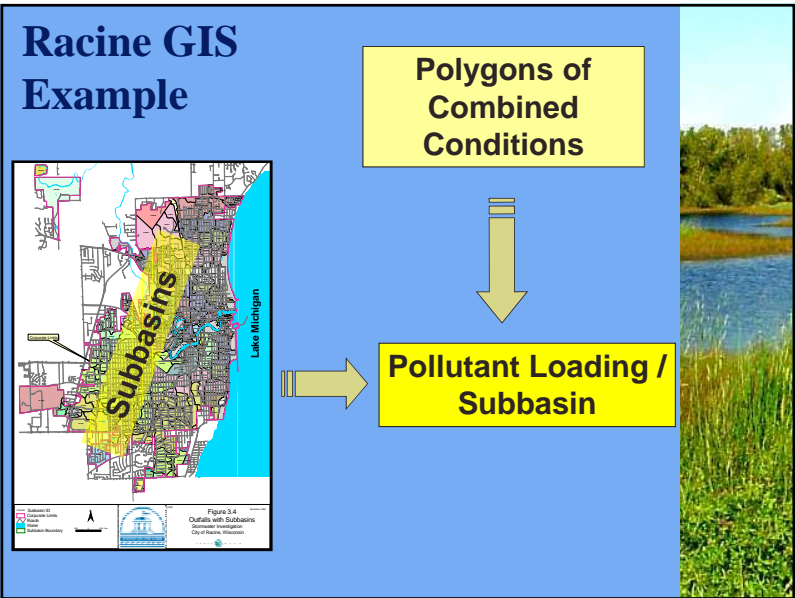


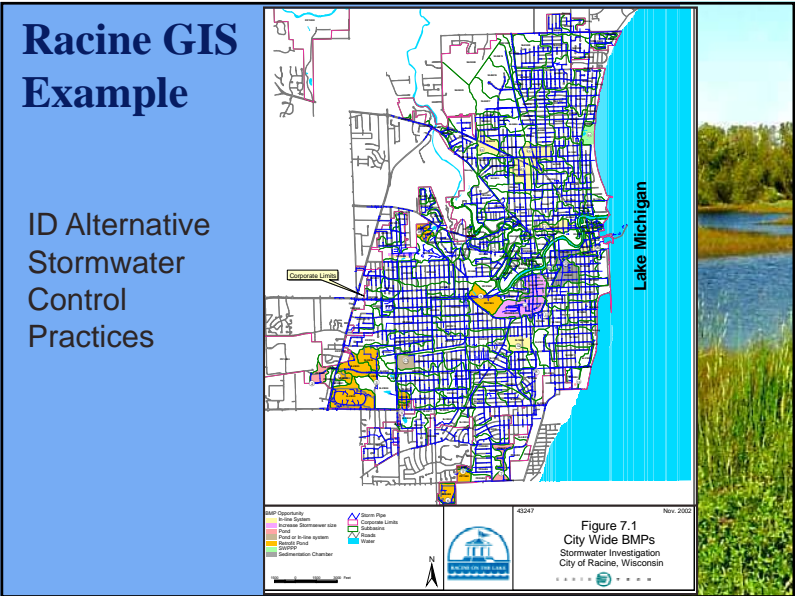
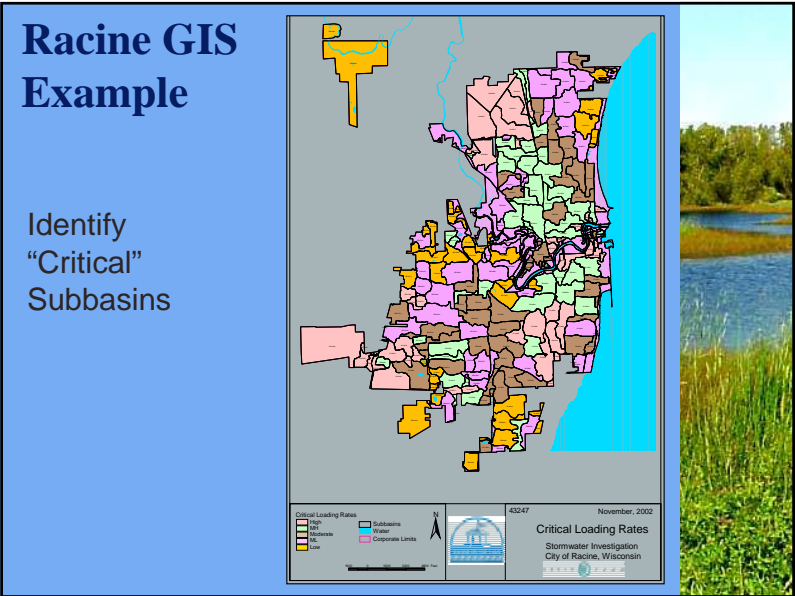
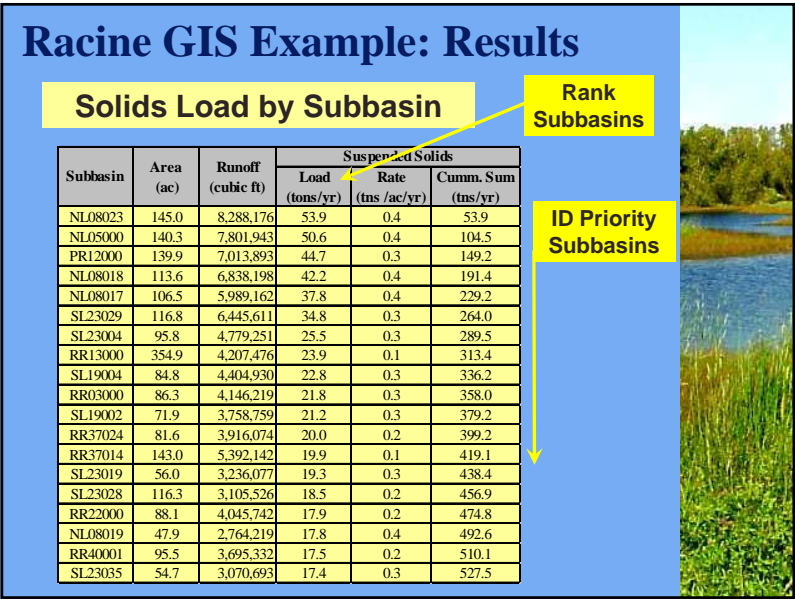
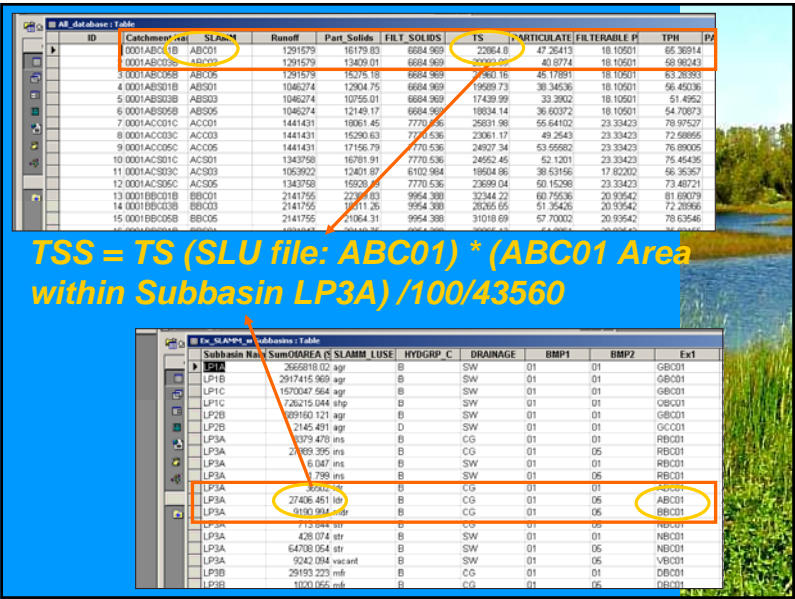
Racine GIS Example

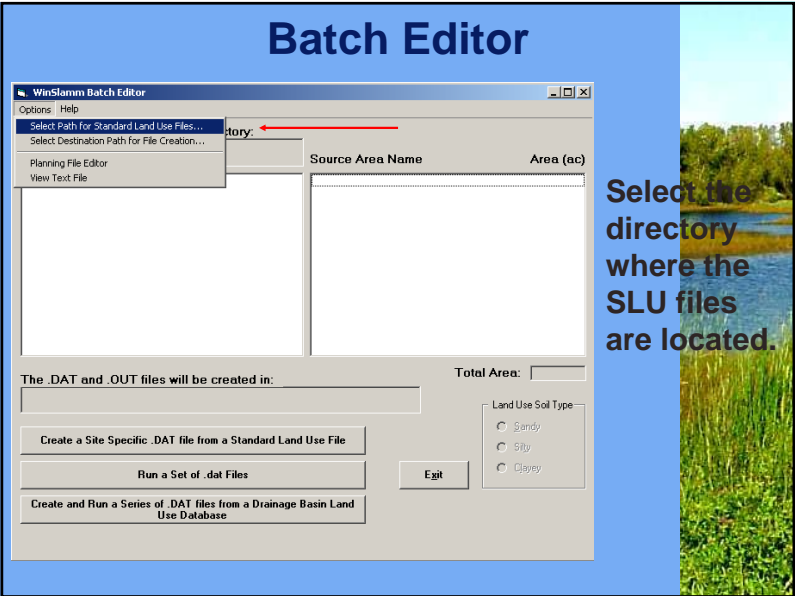
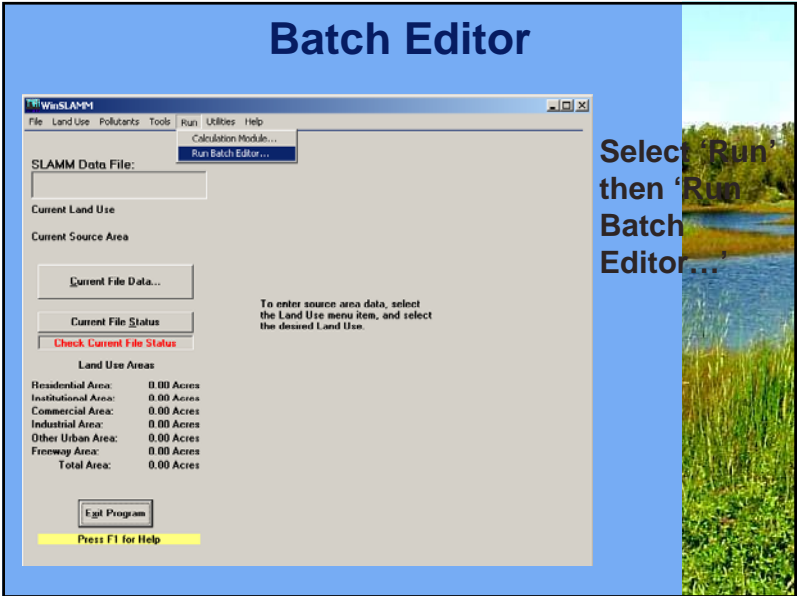
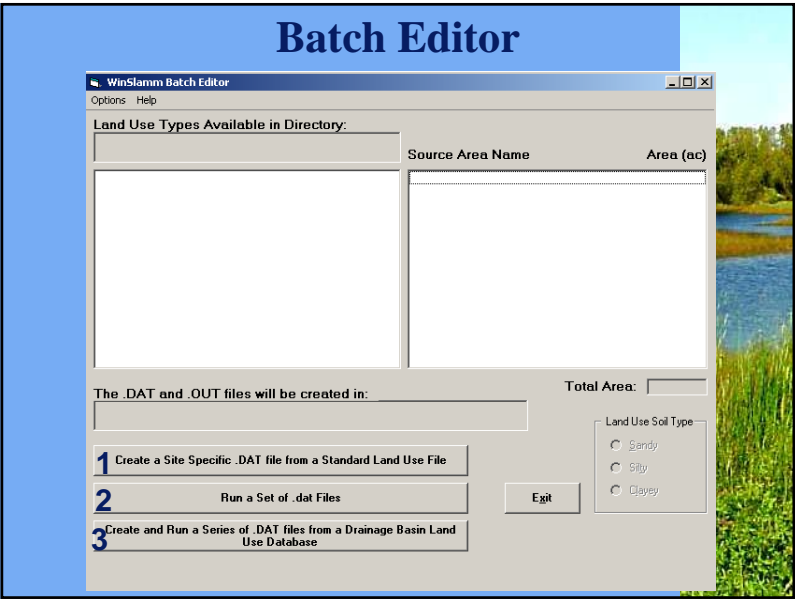
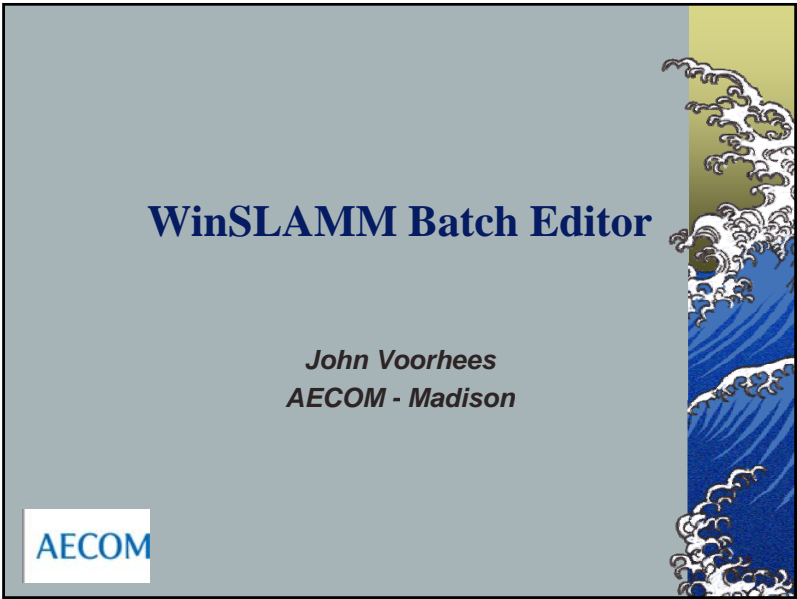
Drainage
Areas &
Subbasins



Racine GIS Example







Batch Editor

The screenshot shows the WinSLAMM Batch Editor interface. A callout box titled "View Clayey Soil Standard Land Use Files" points to the "Clayey" radio button in the "Land Use Soil Type" section, which is highlighted with a red box. The "Land Use Types Available in Directory" list on the left includes various categories like Cemetery, Commercial, High Density Residential, and Industrial. The "Source Area Name" and "Area (ac)" columns are visible but empty.

Batch Editor

The screenshot shows the WinSLAMM Batch Editor interface. A callout box titled "View Sandy Soil Standard Land Use Files" points to the "Sandy" radio button in the "Land Use Soil Type" section, which is highlighted with a red box. The "Land Use Types Available in Directory" list on the left is the same as in the previous image. The "Source Area Name" and "Area (ac)" columns are visible but empty.

Batch Editor

The screenshot shows the WinSLAMM Batch Editor interface. A callout box titled "Double-Click on Standard Land Use File to see Source Area Names and Areas in this Pane" points to the "High Density Residential, with curb" entry in the "Land Use Types Available in Directory" list, which is highlighted with a red box. The "Source Area Name" and "Area (ac)" columns are visible but empty.

Batch Editor

The screenshot shows the WinSLAMM Batch Editor interface. A callout box titled "View Source Area Name and Area (acres)" points to a table of source area names and areas, which is highlighted with a red box. The table lists various source areas and their corresponding areas in acres.

Source Area Name	Area (ac)
Roofs 1	10.90
Roofs 2	11.10
Driveways 1	14.10
Sidewalks/Walks 1	2.00
Sidewalks/Walks 2	2.00
Street Area 1	4.50
Street Area 2	9.00
Small Landscaped Area 1	41.00
Isolated Area	0.10
Other Pervious Area	5.90

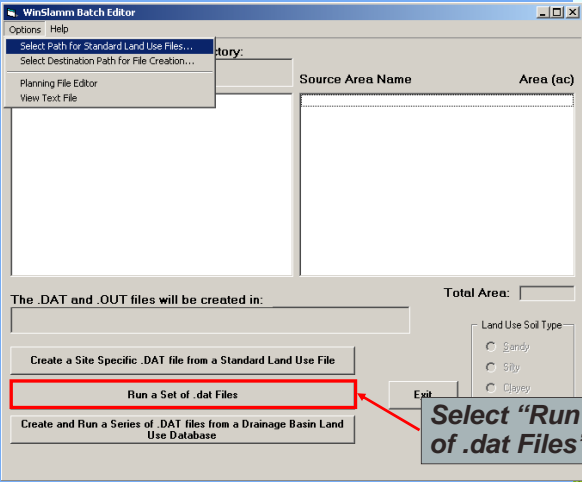
Function 2

Run a Set of .dat files

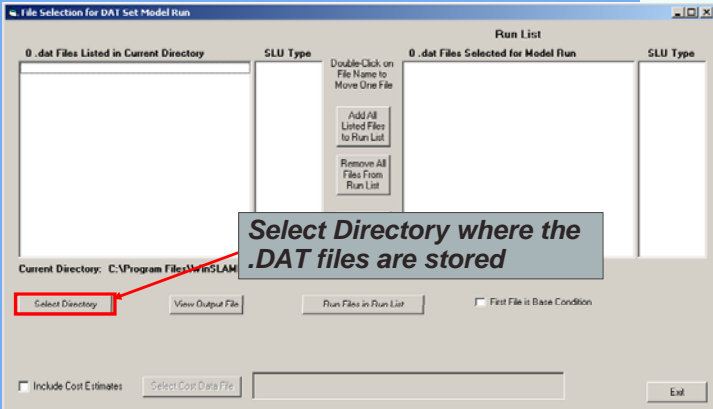
Function 2 - Running a Set of .dat Files

- ☛ *Run a Series of WinSLAMM Data Files at One Time*
- ☛ *View and Analyze the Results in Spreadsheet*
- ☛ *Compare Files with Control Practices to a Base Conditions File*
- ☛ *Analysis Cost Data*

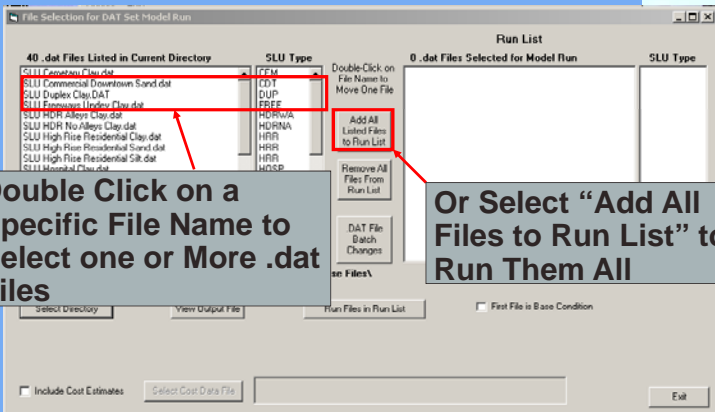
Function 2 - Running a Set of .dat Files



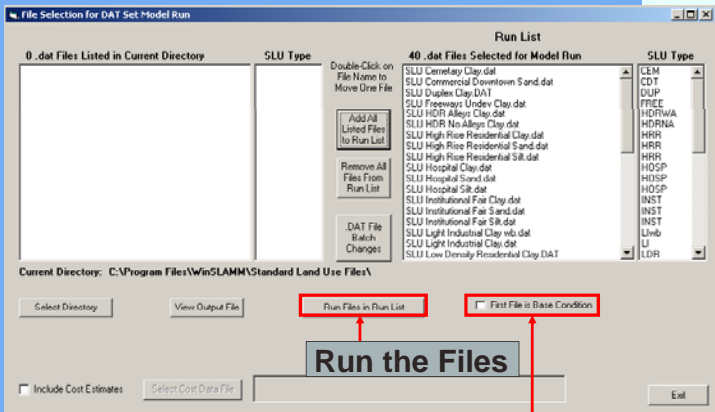
Function 2 - Running a Set of .dat Files



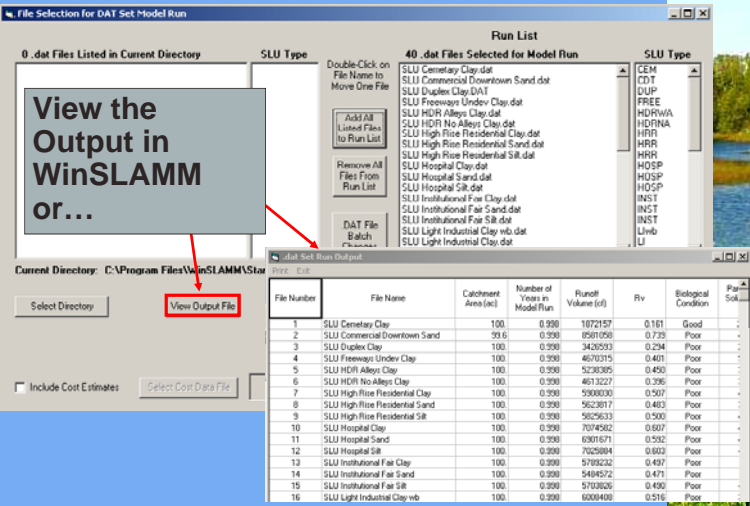
Function 2 - Running a Set of .dat Files



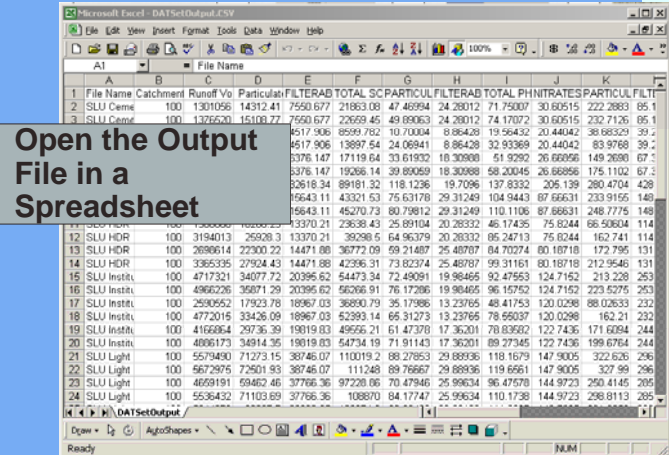
Function 2 - Running a Set of .dat Files



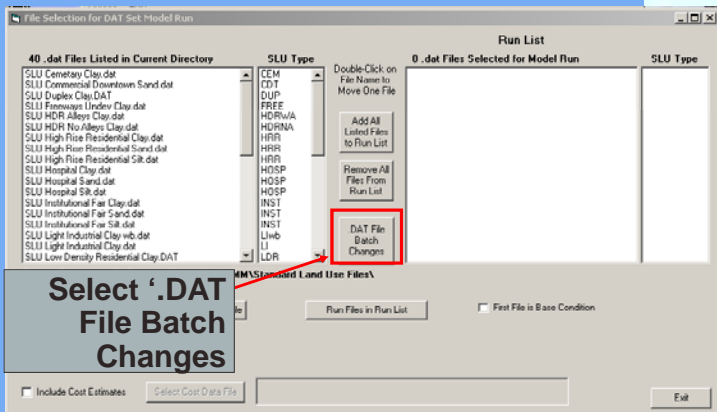
Function 2 - Running a Set of .dat Files



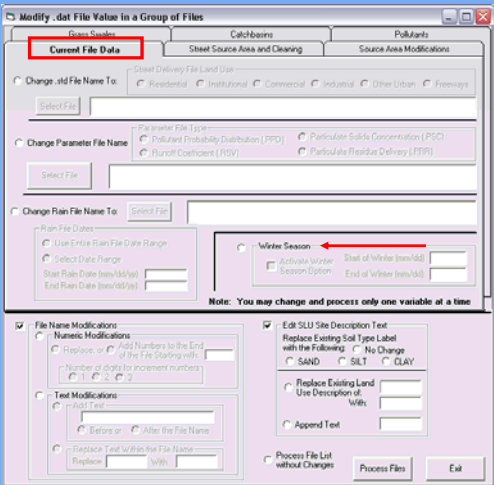
Function 2 - Running a Set of .dat Files



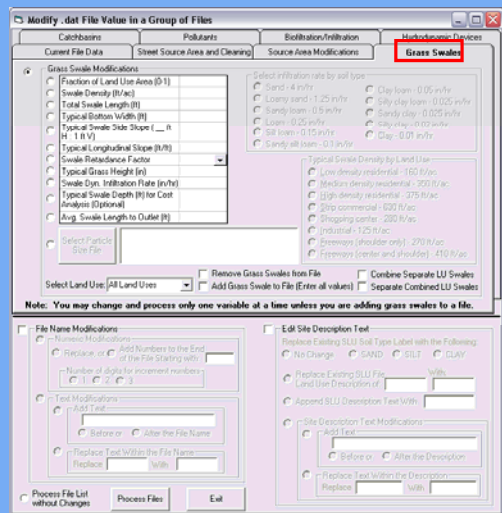
Function 2 - Modify a Set of .dat Files



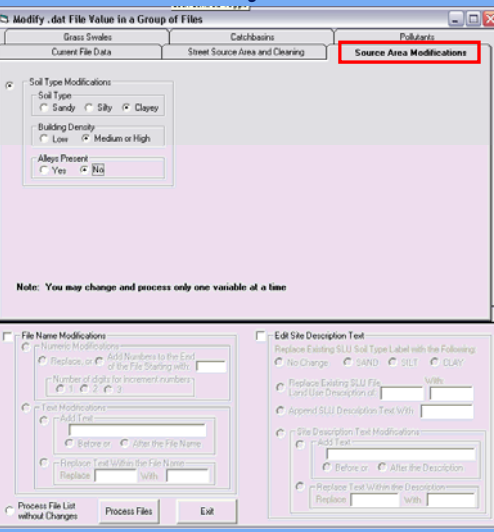
Function 2 - Modify a Set of .dat Files



Function 2 - Modify a Set of .dat Files



Function 2 - Modify a Set of .dat Files



Function 2 - Modify a Set of .dat Files

Modify .dat File Value in a Group of Files

Current File Data

Change .dat File Name To:

Change Parameter File Name:

Change Rain File Name To:

Rain File Dates

Use Entire Rain File Date Range

Select Date Range

Start Rain Date (mm/dd/yy):

End Rain Date (mm/dd/yy):

Winter Season

Activate Winter Season Option

Start of Winter (mm/dd):

End of Winter (mm/dd):

Note: You may change and process only one variable at a time

File Name Modifications

Numeric Modifications

Replace or Add Numbers to the End of the File Starting with:

Random all file extension numbers:

Test Modifications

Add Test:

Before or After the File Name:

Replace Test With the File Name:

Replace:

With:

Edit SLU Site Description Text

Replace Existing Soil Type Label with the Following:

SAND ☐ SILT ☐ CLAY ☐

Replace Existing Land Use Description of:

Append Test:

Process File List without Changes

Process Files

Exit

Using Decision Analyses to Select an Urban Runoff Control Program

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Earth Tech, Madison, WI

MCTT to treat parking lot runoff , Minocqua, WI

Stormwater Control Categories in the International Stormwater “BMP” Database:

Structural Controls: Non-Structural

- Detention ponds
 - Grass filter strips
 - Infiltration basins
 - Media filters
 - Porous pavement
 - Retention ponds
 - Percolation trenches/wells
 - Wetland basins
 - Wetland channels/swales
 - Hydrodynamic devices
- Education practice
 - Recycling practice
 - Maintenance practice
 - Source controls

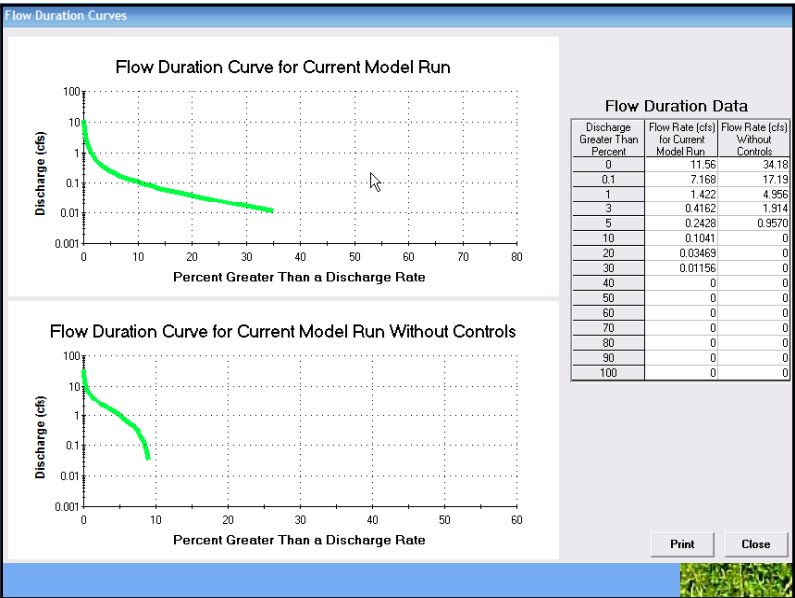
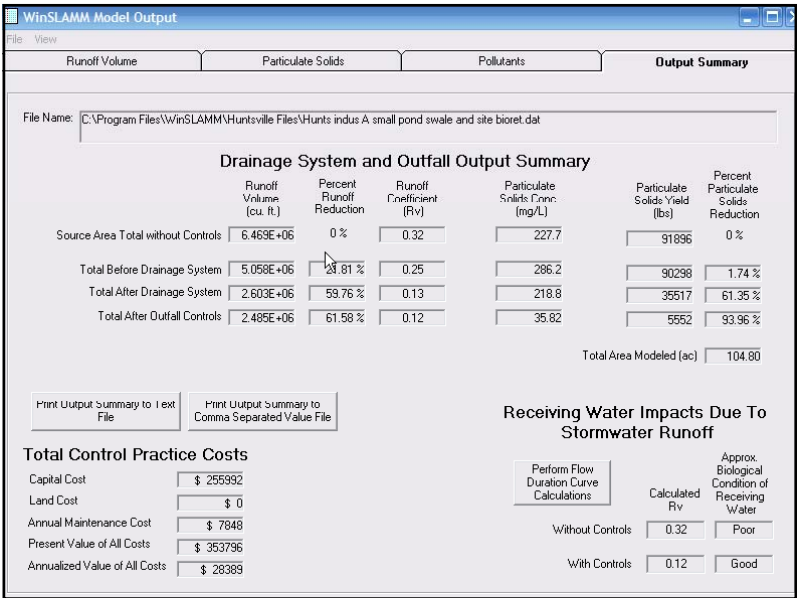
WinSLAMM Treatment Practices

	Infiltration Trenches	Biofiltration/Rain Gardens	Cisterns/ rain barrels	Wet detention pond	Grass Drainage Swale	Street Cleaning	Catch- basins	Porous Pavement	Drainage Discon- nection
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									
Drainage system									
Outfall									

Plus, we now have upflow filters and hydrodynamic devices, and are working on other media filters and combination controls

WinSLAMM Summary Data Outputs

- **Runoff Volume** (ft³, percent reduction; and Rv, runoff coefficient), 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



Detailed Data Outputs for Each Event

- Runoff Volume** (ft³), source area contributions, particulate solids (lbs and mg/L), pollutants (lbs and mg/L)
 - 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
 - Rv (runoff volume only)
 - total losses (runoff volume only)
 - calculated CN (runoff volume only)

Tab 17: City Wide Analysis

WinSLAMM Model Output																		
Runoff Volume			Particulate Solids					Pollutants			Output Summary							
Runoff Volume (cu ft)			Source Area Runoff Volume Contribution															
Data File: HUNT.index A small pond swale and site layout D																		
Run File: HUNT1976.RAN																		
Date: 01/07/06 Time: 17:45:00																		
Site Description: Huntville index A small pond swale and site layout D																		
Industrial Areas - Runoff Volume (cu ft)			Start Date	Run Total	Floors 1	Floors 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	Run	Total Losses (cu ft)	Calculated CN*
01/02/76	0.75	0	20599	0	3037	5607	5607	5607	17717	2943	0	61115	0.21	0.59	89.6			
01/03/76	0.82	0	16481	0	2511	4497	4497	4497	13751	2264	0	48817	0.21	0.48	91.1			
01/04/76	0.01	0	0	0	10	0	0	0	0	0	0	9.901	0.00	0.01	N/A			
01/11/76	0.56	0	14071	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	0.06	37.4			
01/13/76	0.35	0	7949	0	1417	2319	2319	2319	5609	932	0	22605	0.17	0.29	54.1			
01/16/76	0.05	0	0	0	196	172	172	172	0	0	0	712.1	0.04	0.05	58.4			
01/20/76	0.06	0	0	0	237	236	236	236	0	0	0	943.3	0.04	0.06	58.2			
01/24/76	0.05	0	0	0	196	172	172	172	0	0	0	712.1	0.04	0.05	58.4			
01/25/76	1.39	302	4014	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	57.9			
02/18/76	1.79	16503	53255	2262	7864	16055	16055	16055	59035	9607	0	187918	0.25	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	10543	10543	10543	36346	6038	0	116891	0.24	0.95	85.0			
03/06/76	0.03	0	0	0	49	50	50	50	0	0	0	238.1	0.02	0.03	58.9			
03/08/76	0.42	0	16481	0	2511	4497	4497	4497	13751	2264	0	48817	0.21	0.48	91.1			
03/09/76	0.05	0	0	0	196	172	172	172	0	0	0	712.1	0.04	0.05	58.4			
03/12/76	0.54	0	26259	0	3006	7087	7087	7087	24180	4018	0	77573	0.22	0.73	87.6			
03/14/76	0.07	0	0	0	10	0	0	0	0	0	0	9.901	0.00	0.01	N/A			
03/15/76	0.47	0	11727	0	1903	3255	3255	3255	9013	1497	0	33806	0.19	0.38	52.7			
03/20/76	0.07	0	0	0	279	309	309	309	0	0	0	1206	0.05	0.07	57.9			
03/20/76	1.45	14509	43523	2047	5573	12808	12808	12808	43736	7255	0	154578	0.28	1.05	84.5			
03/24/76	0.01	0	0	0	10	0	0	0	0	0	0	9.901	0.00	0.01	N/A			
03/26/76	0.34	0	7619	0	1377	2243	2243	2243	5336	886	0	21947	0.17	0.28	54.3			
03/27/76	0.50	0	12054	0	2025	3497	3497	3497	9621	1640	0	36740	0.19	0.40	52.4			
03/29/76	0.89	0	12054	0	2025	3497	3497	3497	9621	1640	0	36740	0.19	0.40	52.4			
03/30/76	0.57	0	14899	0	2200	4070	4070	4070	12196	2026	0	42664	0.20	0.46	59.6			
03/31/76	0.01	0	0	0	10	0	0	0	0	0	0	9.901	0.00	0.01	N/A			
04/11/76	0.14	0	1715	0	563	730	730	730	425	71	0	55168	0.10	0.13	36.8			
04/14/76	0.07	0	0	0	279	309	309	309	0	0	0	1206	0.05	0.07	57.9			
04/24/76	0.66	0	17724	0	3673	6832	6832	6832	14932	2480	0	52304	0.21	0.52	90.6			
04/28/76	0.02	0	0	0	39	6	6	6	0	0	0	57.96	0.01	0.02	59.2			

Additional Details Available for Each Event (with summaries)

rain duration (hours), rain interevent period (days), runoff duration (hours), rain depth

99	12/11/76	09:00	9,111.38	26.00	2.50	31.20	0.75	23,753	0.08
100	12/14/76	23:00	9,114.96	4.00	4.83	4.80	0.16	4,987	0.08
101	12/19/76	23:00	9,119.96	10.00	4.83	12.00	0.72	23,780	0.09
102	12/25/76	05:00	9,125.21	16.00	4.71	19.20	1.14	42,587	0.10
103	12/30/76	14:00	9,130.58	11.00	0.00	13.20	0.39	6,117	0.04

Summary Statistics

	Rain Duration (hrs)	Rain Interevent Period(days)	Runoff Duration (hrs)	Rain Depth (in)	Runoff Volume (cf)	R sub v
number of Events	102	102	102	102	102	
Total	733.0	332.7	865.2	33.36	2,485e+06	n/a
Equivalent Annual Total	737.4	334.7	870.4	33.68	2,500e+06	102
Minimum	1,000	0	1,200	1.000e+07	1.010e+05	1.045e+09
Maximum	39.00	12.67	39.60	3.700	360363	3.191
Average of All Events	7.117	3.231	8.482	0.3181	24363	0.1842
Median	5.000	2.250	6.000	0.3200	7098	0.07176
std. Deviation	6.701	1.302	8.060	0.6754	53229	0.4423
cov	0.9417	0.9912	0.9502	1.304	2.185	2.402

First Rain date: 01/02/76

Last Rain date: 12/30/76

Total Time Period (yrs): 0.9940639

0.08	0.28	6	8
0.01	0.04	0	0
0.05	0.37	6	9
0.09	0.72	13	39
0.06	0.11	2	1

Average

Flow (cfs)

102

n/a

Peak

Flow (cfs)

102

n/a

Suspended

Conc(mg/l)

102

n/a

Suspended

Solids Mass(lbs)

102

n/a

Pre-Develop.

Runoff Volume (cf)

102

n/a

Total

Events

102

n/a

Equivalent Annual total

Events

102

n/a

Minimum

Flow (cfs)

0.002144

4.657e-10

Maximum

Flow (cfs)

2.430

11.66

Average of All Events

Flow (cfs)

0.1347

0.6835

Median

Flow (cfs)

0.04082

0.1456

Std. Deviation

Flow (cfs)

0.3417

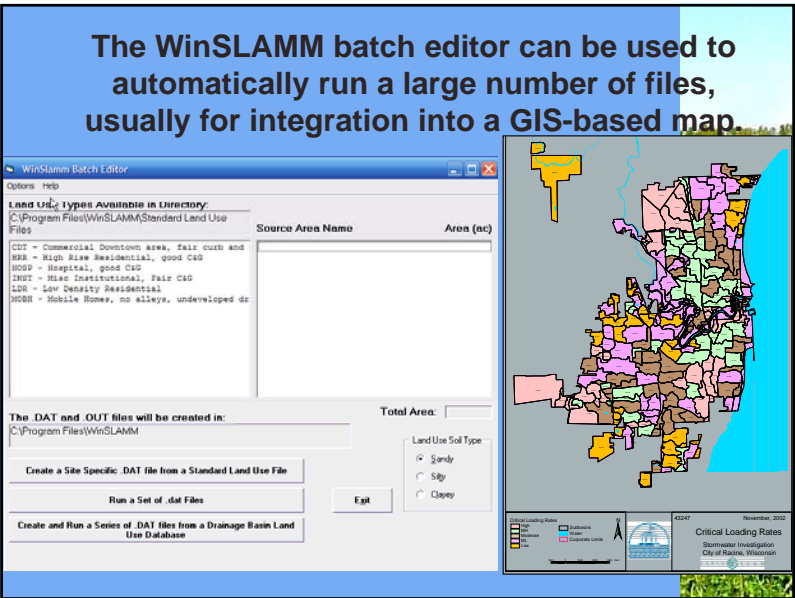
1.897

Cov

Flow (cfs)

2.537

2.775

The WinSLAMM batch editor can be used to automatically run a large number of files, usually for integration into a GIS-based map									
									

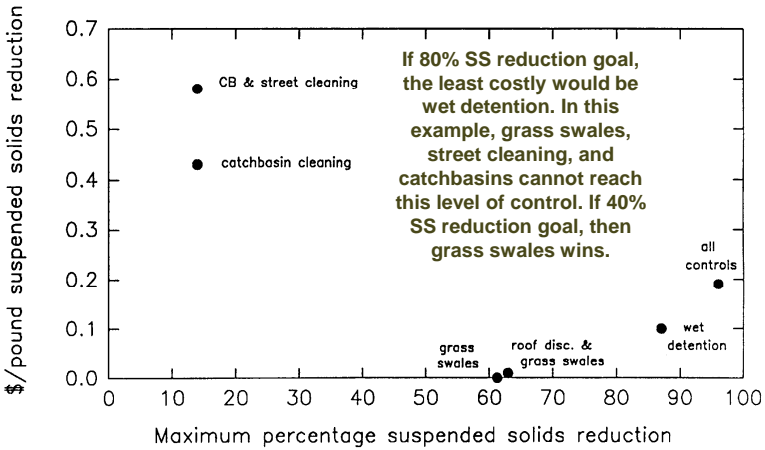
WinSLAMM can also calculate life-cycle costs and compare different control programs to obtain unit removal costs with the batch processor:									
File Name	Runoff Volume (cf)	Partic. Solids Yield (lbs)	Sub Basin Capital Cost	Sub Basin Land Cost	Sub Basin Maint. Cost	Sub Basin Total Annual Cost	Sub Basin Total Present Value Cost	% Part. Solids Reduc.	Cost per lb Sediment Reduced
Cost Example - Base Case No Controls	5246545	37413	0	0	0	0	0	0%	n/a
Cost Example - G	3136146	22341	119109	0	9100	18658	232515	40%	\$ 1.24
Cost Example - P 20 percent	4425257	30761	681686	0	3422	58122	724332	18%	\$ 8.74
Cost Example - P 50 percent	3193328	20784	1704215	0	8555	145306	1810829	44%	\$ 8.74

Decision Analysis

- ☛ *With so much data available, and so many options that can be analyzed, how does one select the “best” stormwater control program?*
- ☛ *The least costly that meets the objective?*



Possible, if only have one numeric standard:



If multiple goals, then possibly not as clear and need a more flexible approach. Consider the following example (a conservation design industrial park in

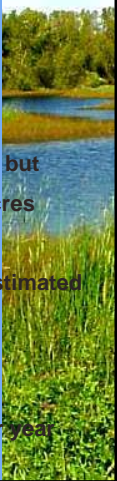


This site was divided into four subareas, one area has 13 industrial lots (about 2.6 acres each), plus a large undeveloped area (60.2 acres) and isolated sinkholes (4.6 acres). The developed area is divided into the following:

- Roofs plus paved parking: 20.7 acres
- Streets (1.27 curb-miles): 3.1 acres
- Small landscaped areas (B, or sandy-loam soils, but assumed silty soils due to compaction): 10.0 acres

Conventional drainage system costs (5% over 20 yrs) were estimated to be:

- Capital cost of project = \$296,400 (2005)
- Annual maintenance cost = \$2,960/year (2005)
- Annual cost of conventional drainage = \$26,850 per year



Biofilters to drain site runoff (paved parking and roofs) to regional swales:

- Top area: 4400 ft²
- Bottom area: 2000 ft²
- Depth: 2 ft
- Seepage rate: 2 in/hr
- Peak to average flow ratio: 3.8
- Typical width: 10 ft
- Number of biofilters: 13 (one per site)

Parking lot biofilter example, Portland, OR



WinSLAMM Input Screen for Biofilters

[illegible]

Regional swales to collect site runoff and direct to wet detention ponds:

- Length: 1653 ft
- infiltration rate in the swale:
1 in/hr
- swale bottom width: 50 ft
- 3H:1V side slopes
- longitudinal slope: 0.026 ft/ft
- Manning's n roughness coefficient:
0.024
- typical swale depth: 1 ft



WinSLAMM Input Screens for Grass Swales

Grass Swales

1. Swale infiltration rate (in/hr):

2. Swale density (ft/ac):

ENTER WETTED SWALE WIDTH (constant for all events)

3. Wetted swale width (ft):

OR

ENTER TYPICAL SWALE GEOMETRY (wetted swale width changes for each event based on expected flows)

Typical Swale Geometry

1. Typical Bottom Width (ft):

5. Typical Swale Side Slope (_ R H : 1 R V):

2. Typical Longitudinal Slope (ft/ft):

7. Swale Manning's n:

☐ Select swale density by land use

☐ Low density residential - 160 ft/ac
☐ Medium density residential - 350 ft/ac
☐ High density residential - 375 ft/ac
☐ Strip commercial - 630 ft/ac
☐ Shopping center - 280 ft/ac
☐ Industrial - 125 ft/ac
☐ Freeways (shoulder only) - 270 ft/ac
☐ Freeways (center and shoulder) - 410 ft/ac

☐ Select infiltration rate by soil type

☐ Sand - 4 in/hr
☐ Loamy sand - 1.25 in/hr
☐ Sandy loam - 0.5 in/hr
☐ Loam - 0.25 in/hr
☐ Silt loam - 0.15 in/hr
☐ Clay silt loam - 0.1 in/hr
☐ Clay loam - 0.05 in/hr
☐ Silty clay loam - 0.025 in/hr
☐ Sandy clay - 0.025 in/hr
☐ Silty clay - 0.02 in/hr
☐ Clay - 0.01 in/hr

Drainage System

Enter the fraction of each type of drainage system serving the study area:

1. Grass Swales ☐ Enter swale data immediately

2. Undeveloped Roadside:

3. Curb and Gutters, Valleys, or Sealed Swales in poor condition or very flat

4. Curb and Gutters, Valleys, or Sealed Swales in fair condition

5. Curb and Gutters, Valleys, or Sealed Swales in good condition or very steep

Area served by swales (acres): 60.78

For Cost Analysis Only:

Typical Swale Depth (ft):

Typical Bottom Width (ft):

Delete

Cancel

Continue

The total must equal 1. Total: 1.000

Wet Detention Pond to Treat Runoff from

Pond Elevation (ft)	Full-Sized Pond Area (acres)
1	0.15
2	0.25
3	0.5
4	0.75
5	1.0 (normal pool elevation, and invert elevation of 30° v-notch weir)
6	1.5
7	2
8	2.5 (invert elevation of flood flow broad-crested weir). Normal maximum elevation during one and two year rains.
9	3.0 (approximate maximum pond elevation, or as determined based on flood flow analysis). Additional storage and emergency spillway may be needed to accommodate flows in excess of the design flood flow.

1:10 to 1:4 slope to normal high water level
1:4 to 1:1 slope
Routed aquatic plants on shelf
Flat shelf (at least 3' wide)
Normal water level range
Permanent pool depth (at least 3', preferably 6')
As steep as possible

Wet Detention Control Device

Outfall Control

Total Area: 104.9 acres

Pond Number 1

Select Particle Size Distribution File:
C:\PROGRAM FILES\WINSLAMM\MEDIUM.CPZ

Initial Stage Elevation (ft) 3

Peak to Average Flow Ratio 3.00

Edit Stage Area Data

Save this Pond as a WinDET POND File

Continue Delete Pond

Add Outlet

Outlet Options

- 1. Sharp Crested Weir
- 2. V - Notch Weir
- 3. Orifice
- 4. Seepage Basin
- 5. Natural Seepage
- 6. Evaporation
- 7. Other Outflow
- 8. Water Withdrawal
- 9. Broad Crested Weir
- 10. Vertical Stand Pipe

Selected Outlets (Max. 5)
Double Click to Edit or Delete

- 1 - V-Notch Weir
- 2 - Broad Crested Weir
- 3 - Evaporation

Flow

WinSLAMM Input Screens for Wet Detention Ponds

Stage Area Values

Pond Number 1

Stage (ft)	Area (acres)	Cumulative Volume (ac-ft)
0	0.00	0.000
1	1.00	0.075
2	2.00	0.125
3	3.00	0.250
4	4.00	0.375
5	5.00	0.500
6	6.00	0.750
7	7.00	1.000
8	8.00	1.250
9	9.00	1.500

Use Shift plus the arrow keys to move through the grid

Broad Crested Weir

Outfall

Pond Number 1

Outlet Number 2

1. Weir Crest Length (ft) 50

2. Weir Crest Width (ft) 3

3. Discharge Coefficient (English Units) 0

Default Discharge Coefficients

4. Height of Weir Opening (ft) 1

5. Height from Datum to Bottom of Weir Opening (ft) 8

Cancel Continue Delete

V-Notch Weir

Outfall

Pond Number 1

Outlet Number 1

Weir Angle

- 1. 22.5 degrees
- 2. 30 degrees
- 3. 45 degrees
- 4. 60 degrees
- 5. 90 degrees
- 6. 120 degrees

1. Height from bottom of weir opening (invert) to the top of the weir (ft) 4

2. Height from datum to bottom of weir opening (ft) 5

Cancel Continue Delete

Outlet Devices Available in WinSLAMM:

1. Sharp Crested Weirs
2. V-Notch Weir
3. Orifice
4. Seepage Basin
5. Natural Seepage
6. Evaporation
7. Other Outflow
8. Water Withdrawal
9. Broad Crested Weir
10. Vertical Stand Pipe

Batch Processor Data for Combinations of Above Controls							
Stormwater Treatment Option	Annual Total SW Treat. Cost (\$/yr)	Annual Addit. Drain. System Cost (\$/yr)	Total Annual Cost (\$/yr)	Land Needs for SW mgt (acres)	Runoff Volume (cf/yr)	Part. Solids Yield (lbs/yr)	Redu c. in SS Yield (%)
Base, No Controls	0	64,230	64,230	0	5,600,000	71,375	n/a
Option 1 Pond	19,134	64,230	83,364	4.5	5,507,000	10,192	86
Option 2 Reg. Swale	3,158	26,850	30,008	0	2,926,000	32,231	55
Option 3 Site Biofilter	32,330	37,380	69,710	0	2,705,000	68,890	1
Option 4 Small pond	10,209	64,230	74,439	2.3	5,557,000	19,552	73
Option 5 Pond and reg. swale	22,292	26,850	49,142	4.5	2,844,000	4,133	94
Option 6 Pond, swale, biofilter	54,622	0	54,622	4.5	1,203,000	2,183	97
Option 7 Small pond and swale	13,367	26,850	40,217	2.3	2,887,000	6,937	90
Option 8 Small pond, swale and biofilter	45,698	0	45,698	2.3	1,253,000	4,125	94

Additional Batch Processor Data (cont.)							
Stormwater Treatment Option	Part. Phos Yield (lbs/yr)	Volum. Runoff Coeff. (Rv) (est. bio. cond.)	% of time flow >1 cfs	% of time flow >10 cfs	SS conc. (mg/L)	Part. P conc. (mg/L)	Zn conc. (µg/L)
Base, No Controls	174	0.29 (poor)	4.5	0.3	204	0.50	359
Option 1 Pond	25	0.29 (poor)	4	0.05	30	0.073	128
Option 2 Reg. Swale	79	0.15 (fair)	2	0.1	178	0.43	390
Option 3 Site Biofilter	172	0.14 (fair)	2	0.2	408	1.0	696
Option 4 Small pond	41	0.29 (poor)	4	0.2	48	0.12	151
Option 5 Pond and reg. swale	10	0.15 (fair)	2	0	23	0.057	203
Option 6 Pond, swale, biofilter	5.5	0.06 (good)	0.5	0	29	0.073	386
Option 7 Small pond and swale	17	0.15 (fair)	2	0.05	39	0.095	220
Option 8 Small pond, swale and biofilter	10	0.07 (good)	0.8	0	53	0.13	390

Decision Analysis Approaches

1) Specific criteria or limits that must be met.

2) It is possible to simply filter out (remove) the options that do not meet all of the absolutely required criteria. If the options remaining are too few, or otherwise not very satisfying, continue to explore additional options. The above examples only considered combinations of 3 types of stormwater control devices, for example. There are many others that can also be explored. If the options that meet the absolute criteria look interesting and encouraging, then continue.

Control Options Meeting 80% SS Reduction Requirement, Ranked by Cost				
Stormwater Treatment Option	Total Annual Cost (\$/yr)	Reduction in SS Yield (%)	Meet 80% particulate solids reduction goal?	Rank based on annual cost
Option 1 Pond	83,364	86	Yes	5
Option 2 Regional Swale	30,008	55	No	n/a
Option 3 Site Biofilter	69,710	1	No	n/a
Option 4 Half-sized pond	74,439	73	No	n/a
Option 5 Pond and reg. swale	49,142	94	Yes	3
Option 6 Pond, reg. swale and biofilter	54,622	97	Yes	4
Option 7 Small pond and reg. swale	40,217	90	Yes	1
Option 8 Small pond, reg. swale and biofilter	45,698	94	Yes	2

2) Goals that are not absolute (based on methods developed by Keeney, R.L. and H. Raiffa. 1976. *Decision Analysis with Multiple Conflicting Objectives*. John Wiley & Sons. New York.)

Utility curves and tradeoffs can be developed for the remaining attributes, after all the absolutely required goals are met. The above example includes attributes of several different types:

- costs

- land requirements

- runoff volume (volumes, habitat responses, and rates)

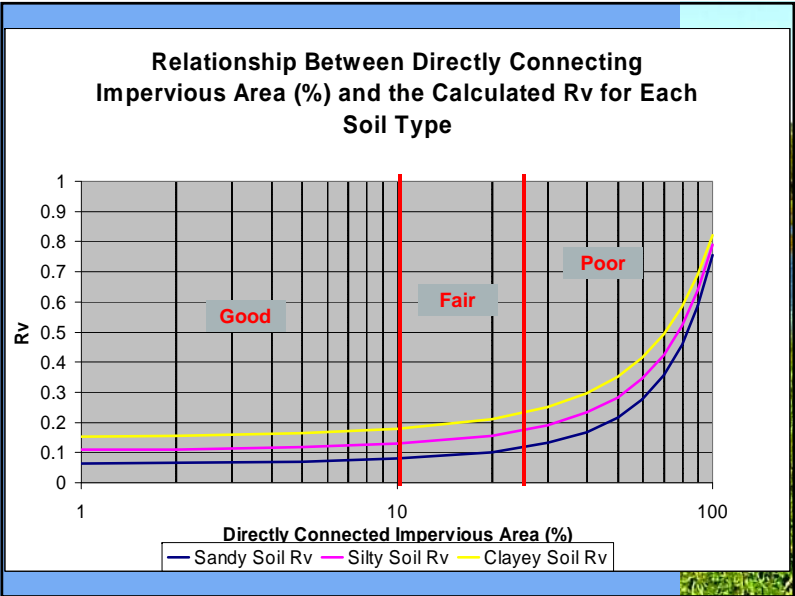
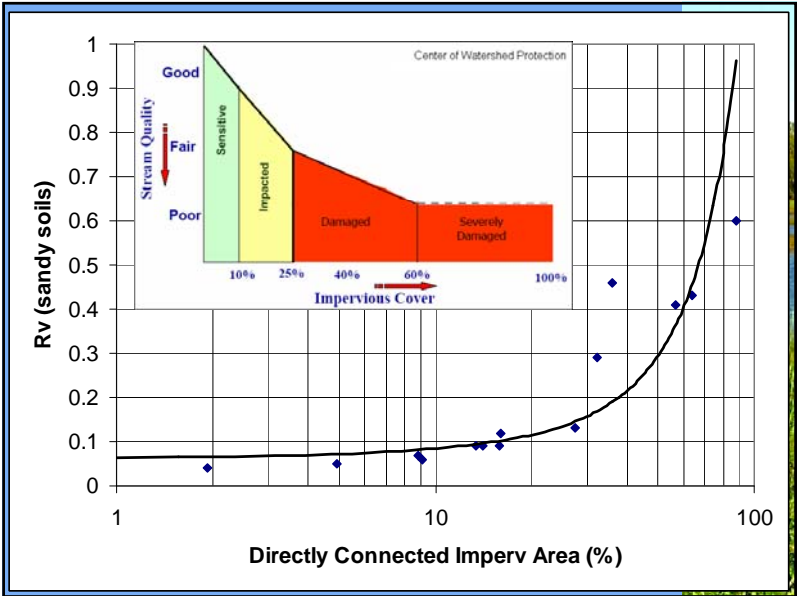
- particulate solids (reductions, yields and concentrations)

- particulate phosphorus (reductions, yields and concentrations)

- total zinc (reductions, yields and concentrations)

Attribute Value Ranges, plus Example Ranks and Trade-offs (ranks and trade-offs could vary for different interested parties)			
Attribute	Range of attribute value for acceptable options	Attribute ranks for selection (after absolute goals are met)	Trade-offs between remaining attributes
Total annual cost (\$/year)	\$40,217 to 83,364	2	0.20
Land needs (acres)	2.3 to 4.5 acres	5	0.08
Rv	0.06 to 0.29	1	0.30
% of time flow >1 cfs	0.5 to 4 %	7	0.05
% of time flow >10 cfs	0 to 0.05 %	3	0.18
Particulate solids yield (lbs/yr)	2,183 to 10,192 lbs/yr	6	0.07
Part. Phosphorus yield (lbs/yr)	5.5 to 25 lbs/yr	4	0.12
			Sum = 1.0

Utility Curves for Different Attributes (technically based, would not vary for different interested parties)		
• Volumetric runoff coefficient (Rv) as an indicator of habitat quality and aquatic biology stress:		
Attribute Value	Expected Habitat Condition	Utility Value
<0.1	Good	1.0
0.1 to 0.25	Fair	0.75
0.26 to 0.50	Poor	0.25
0.51 to 1.0	Really lousy	0



Example Utility Values for Other Attributes:

- Total annual cost: straight line, with \$83,364 = 0 and \$40,217 = 1.0.
- % of time flow >10 cfs Utility value
 - <0.05 1.0
 - 0.05 - 1 0.75
 - 1.1 – 2.5 0.25
 - >2.5 0



Example Utility Values for Other Attributes (cont):

- Part. Phosphorus yield (lbs/yr): straight line, with 25 lbs/yr = 0 and 5.5 lbs/yr = 1.0
- Land needs (acres): straight line, with 4.5 acres = 0 and 2.3 acres = 1.0
- Particulate solids yield (lbs/yr): straight line, with 10,192 lbs/yr = 0 and 2,183 lbs/yr = 1.0
- % of time flow >1 cfs Utility value
 - <1 1.0
 - 1 – 3 0.75
 - 3.1 – 10 0.25
 - >10 0

Attribute Values and Associated Utilities for Example

Stormwater Control Option	Total Annual Cost (\$/yr)	Cost utility	Land Needs for SW mgt (acres)	Land utility	Part. Solids Yield (lbs/yr)	Part. Solids utility	Part. Phos. Yield (lbs/yr)	Phos. utility
Tradeoff Value		0.20		0.08		0.07		0.12
Option 1 Pond	83,364	0	4.5	0	10,192	0	25	0
Option 5 Pond and reg. swale	49,142	0.79	4.5	0	4,133	0.76	10	0.77
Option 6 Pond, reg. swale and biofilter	54,622	0.67	4.5	0	2,183	1.0	5.5	1.0
Option 7 Small pond and reg. swale	40,217	1	2.3	1	6,937	0.41	17	0.41
Option 8 Small pond, reg. swale and biofilter	45,698	0.87	2.3	1	4,125	0.76	10	0.77

Attribute Values and Associated Utilities for Example (cont.)

Stormwater Control Option	Volumetric Runoff Coefficient (Rv)	Rv utility	% of time flow >1 cfs	Mod flow utility	% of time flow >10 cfs	High flow utility
Tradeoff Value		0.30		0.05		0.18
Option 1 Pond	0.29	0.25	4	0.25	0.05	0.75
Option 5 Pond and reg. swale	0.15	0.75	2	0.75	0	1.0
Option 6 Pond, reg. swale and biofilter	0.06	1.0	0.5	1.0	0	1.0
Option 7 Small pond and reg. swale	0.15	0.75	2	0.75	0.05	0.75
Option 8 Small pond, reg. swale and biofilter	0.07	1.0	0.8	1.0	0	1.0

Calculation of Factors for Each Option								
(Attribute Utility times Attribute Trade-off)								
Stormwater Control Option	Cost utility	Cost factor	Land utility	Land factor	Part. utility	Part. factor	Phos. utility	Phos factor
Tradeoff Value	0.20		0.08		0.07		0.12	
Option 1 Pond	0	0	0	0	0	0	0	0
Option 5 Pond and reg. swale	0.79	0.158	0	0	0.76	0.053	0.77	0.092
Option 6 Pond, reg. swale and biofilter	0.67	0.134	0	0	1.0	0.07	1.0	0.12
Option 7 Small pond and reg. swale	1	0.20	1	0.08	0.41	0.029	0.41	0.049
Option 8 Small pond, reg. swale and biofilter	0.87	0.174	1	0.08	0.76	0.053	0.77	0.092

Calculation of Factors for Each Option (cont.), Sum of Factors, and Overall Rank								
Stormwater Control Option	Rv utility	Rv factor	Mod flow utility	Mod flow factor	High flow utility	High flow factor	Sum of factors	Over-all Rank
Tradeoff Value	0.30		0.05		0.18			
Option 1 Pond	0.25	0.075	0.25	0.0125	0.75	0.135	0.2225	5
Option 5 Pond and reg. swale	0.75	0.225	0.75	0.0375	1.0	0.18	0.7455	4
Option 6 Pond, reg. swale and biofilter	1.0	0.30	1.0	0.05	1.0	0.18	0.8540	2
Option 7 Small pond and reg. swale	0.75	0.225	0.75	0.0375	0.75	0.135	0.7555	3
Option 8 Small pond, reg. swale and biofilter	1.0	0.30	1.0	0.05	1.0	0.18	0.9290	1

Conclusions

- ☂ *Calibrated and verified stormwater models can be used to develop a great deal of information concerning many different stormwater management options.*
- ☂ *Regulations and criteria also need to have different formats to acknowledge site specific problems and objectives.*
- ☂ *The use of clear and flexible decision analysis techniques, as outlined in this presentation, is therefore important when selecting the most appropriate stormwater control program for a site.*



Acknowledgements

The authors would like to acknowledge the support of the Tennessee Valley Authority (TVA), Economic Development Technical Services, and the Center for Economic Development and Resource Stewardship (CEDARS) of Nashville, TN, which has allowed us to develop extensions to WinSLAMM to enable the use of a decision analysis framework in evaluating alternative stormwater management options. The Stormwater Management Authority of Jefferson County, AL, is also acknowledged for their support that enabled the cost analyses to be added to WinSLAMM

