

# SLAMM EXERCISE

## The Use of GIS to Support Operation of the Source Loading and Management Model (SLAMM) for Analysis of Urban Non-Point Source Pollution

Dan Rodman

David Hart

Brea Lemke

*University of Wisconsin-Madison*

*Email: dahart@wisc.edu*

### **Objective**

Examine the use of ArcView desktop GIS to support operation of the Source Loading and Management Model (SLAMM) for planning and management of nonpoint source pollution in urban areas.

### **Software Needed**

- ArcView version 3.x from Environmental Systems Research Institute (ESRI). Retail price \$1195. (<http://www.esri.com/software/arcview/index.html>). Additional training available for ArcView 3.x (<http://www.lic.wisc.edu/training/>).

*Note: This exercise was written using ArcView 3.3. There may be minor differences noted between software versions.*

- WinSLAMM from PV and Associates. Retail price \$200. (<http://www.winslamm.com>). Additional training is available for SLAMM (on a rotating basis at the UW) (<http://epdweb.engr.wisc.edu/>).

*Note: This exercise was written using WinSLAMM 8.5. There may be minor differences noted between software versions.*

### **Background**

According to the EPA, “runoff from urban areas is the leading source of impairments to surveyed estuaries and the third largest source of water quality impairments to surveyed lakes. In addition, population and development trends indicate that by 2010 more than half of the Nation will live in coastal towns and cities. Runoff from these rapidly growing urban areas will continue to degrade coastal waters (1). High levels of pollution prevented people from swimming safely at coastal beaches on more than 12,000 occasions from 1988 through 1994, and the latest National Water Quality Inventory reports that one-third of surveyed estuaries (areas near the coast where seawater and freshwater mixing occurs) are damaged (2).”

Hydrologic models for non-point source (NPS) pollution are important tools for analyzing the relation among land use, pollutants generated by those uses, and mitigation measures to reduce pollution. Models are useful not only for estimating current NPS pollution, but predicting future levels based on changing land use and mitigation measures.

Geographic Information Systems (GIS) are able to store and analyze large amounts of spatial data, such as the land use, soil type and even topographical information required by NPS pollution models. Currently, the most common use of GIS with NPS pollution models is as a data preparation tool, as opposed to using GIS itself to perform the modeling (3). In this exercise, GIS will be used to provide a summary table of total land areas having a given land use and soil type. This information will serve as input into the SLAMM NPS pollution model.

### **References**

1. EPA, 1997. NonPoint Source Pointers - Managing Urban Runoff. EPA Office of Water, document EPA841-F-96-004G (<http://www.epa.gov/owow/nps/facts/point7.htm>)
2. EPA, 1997. NonPoint Source Pointers - Protecting Coastal Waters from Nonpoint Source Pollution. EPA Office of Water, document EPA841-F-96-004E (<http://www.epa.gov/owow/nps/facts/point5.htm>)
3. Maidment, David R. (1993) GIS and Hydrologic Modeling. *Environmental Modeling with GIS* (Chapter 14). Ed. by Goodchild, M.F., Parks, B.O. and Steyaert, L.T. Oxford University Press, New York.

### **SLAMM Overview** (taken from the abstract in the SLAMM documentation)

The Source Loading and Management Model (SLAMM) was originally developed to better understand the relationships between sources of urban runoff pollutants and runoff quality. It has been continually expanded since the late 1970s and now includes a wide variety of source area and outfall control practices (infiltration practices, wet detention ponds, porous pavement, street cleaning, catchbasin cleaning, and grass swales). SLAMM is strongly based on actual field observations, with minimal reliance on theoretical processes that have not been adequately documented or confirmed in the field. SLAMM is mostly used as a planning tool, to better understand sources of urban runoff pollutants and their control.

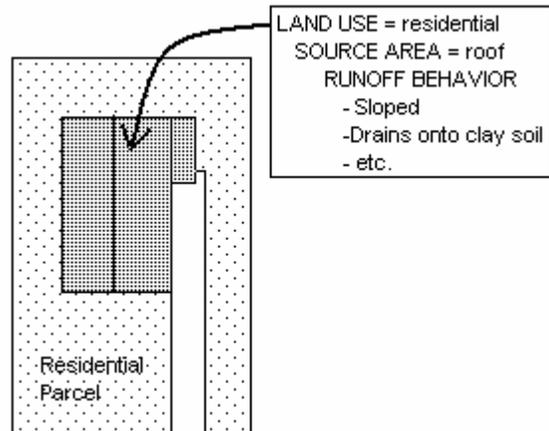
Special emphasis has been placed on small storm hydrology and particulate washoff in SLAMM. Many currently available urban runoff models have their roots in drainage design where the emphasis is with very large and rare rains. In contrast, stormwater quality problems are mostly associated with common and relatively small rains. The assumptions and simplifications that are legitimately used with drainage design models are not appropriate for water quality models. SLAMM therefore incorporates unique process descriptions to more accurately predict the sources of runoff pollutants and flows for the storms of most interest in stormwater quality analyses. However, SLAMM can be effectively used in conjunction with drainage design models in order to incorporate the mutual benefits of water quality controls on peak flow rates.

SLAMM has been used in many areas of North America and has been shown to accurately predict stormwater flows and pollutant characteristics for a broad range of rains, development characteristics, and control practices. As with all stormwater models, SLAMM needs to be accurately calibrated and then tested (verified) as part of any local stormwater management effort.

## Basic Concept of SLAMM Calculations

SLAMM divides land up into 6 broad land use classes (residential, institutional, commercial, industrial, open, and freeways). Within each class of land use, the land area is further classified into 14 “source areas” (such as turf, roofs, parking, playgrounds, freeways...). Source areas are further classified according to their runoff behavior (for example, whether roofs are flat or pitched, and whether they drain directly to the drainage system or drain onto sandy or clayey soils).

For each of these land use / source area / runoff behavior combinations, its total land area is determined. A set of coefficients for water runoff, particulate solids loadings and pollutant loadings are determined for it as well. The creators of SLAMM have done extensive testing in various cities to derive the coefficients that we will use (hence the empirical, or observation-based, nature of SLAMM).



For each of these runoff-unique land types, SLAMM makes the basic calculations shown in the table (presented conceptually, not exactly). Computed volumes and mass loadings are summed to give values for an entire watershed or sewershed.

SLAMM also models related phenomena, such as the effect of runoff mitigation measures (e.g., detention ponds), and the statistical uncertainty in pollutant concentrations derived from different land use & source areas. We will not examine those capabilities.

See Appendix A at the end of this handout for a more detailed description of the SLAMM parameter files.

### Concept of SLAMM Calculations

Rainfall Volume x Runoff Coefficient = Water Runoff Volume

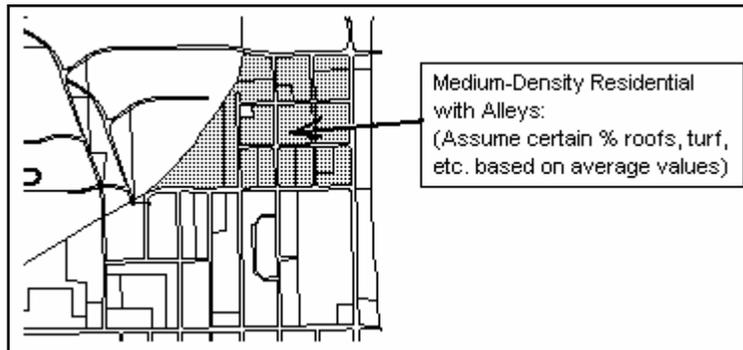
Water Runoff Volume x Particulate Solids Concentration = Particulate Solids Loading\* (in pounds)

Water Runoff Volume (or Particulate Solids Loading) x Pollutant Probability Distribution = Pollutant Loading

\* An additional Particulate Residue Reduction factor reduces the amount of particulate solid ultimately leaving the drainage system, to take into account particulate settling in the drainage system.

## Role of GIS in Preparing SLAMM Data

SLAMM assumes there is very detailed land information. Interpreted literally, the entire watershed could be quantified roof by roof, parking lot by parking lot, etc.



To simplify, typical distributions of SLAMM land uses, source areas and runoff behaviors have been established for approximately twenty general land use categories. This information is compiled in SLAMM Standard Land Use (SLU) files.

Thus, our task with GIS is not to quantify the area of every roof and parking lot. Rather, we will quantify the area of each *general* land use class (and its soil characteristics – clayey or sandy) within a sewershed. These general land use categories and soil data will then be associated with SLAMM “Standard Land Use” data files.

## Spatial Data Requirements

### Required Data

**Land Use:** Land use codes must be related to the Standard Land Use categories defined in SLAMM.

**Sewersheds:** Sewersheds define the study boundaries. They can be created from analysis of topography (such as a digital elevation model) and the storm sewer network.

### Optional Data

**Soils:** The sandy or clayey characteristic of soils is considered in SLAMM to affect runoff coefficients. In this exercise, it is assumed that all soils are clayey, because most urban soils are well-compacted and have low infiltration rates. If actual soils data were included in the analysis, the county-level SSURGO soils data would be most appropriate to match the high spatial detail of the land use data.

However, in the SLAMM data structure, soils are an inherent characteristic in each source area (for example, if a roof source type is not connected directly to the drainage system, then a sandy or clayey soil type, along with other runoff characteristics, must be specified for that roof type). It does not appear easy to change the soil type of source areas through some batch process.

**Planimetric Features (building outlines, sidewalks, driveways...):** This could theoretically be used to quantify source area statistics (such as what percentage of residential land use is roofs), either for original measurement or verification of existing SLAMM Standard Land Use files. However, the runoff behavior of these source areas, such as roof slope and connection to drainage system, could not be determined from most planimetric feature data.

### Original Data Sets for This Exercise

FILE NAME	FORMAT	DESCRIPTION
Malu.shp	Polygon shapefile	Marquette land use
Maswbnd.shp	Polygon Shapefile	Marquette Sewersheds
Lu2slammcode.dbf	Dbase table	A table relating each Marquette land use code to a single-letter SLAMM land use code
Roadfactor-mimals12.dbf	Dbase table	Road area factor per Marquette land use code within sewershed MIMALS12

### Data Sets Created through This Exercise

FILE NAME	FORMAT	DESCRIPTION
Maluswb.shp	Polygon shapefile	Merged land use and sewersheds
Mimalu12-landuse.dbf	Dbase table	Total land area for each land use within MIMALS12 sewershed (SLAMM land use codes, road factors and land area per soil type are added)
Mimalu12.dbf	Dbase table	Mimalu12-landuse table, exported & purged of unneeded fields.
Mimalu12.txt	Text file	ASCII-format text file from Mimalu12.dbf
mimalu12.pla	Text file	Mimalu12.txt, with SLAMM file extension "pla"

### Spatial Reference System for Marquette, Michigan Data:

Coordinate Units: U.S. Survey Feet (1 meter = 3.2808333333 U. S. Survey Feet)

Datum: NAD27 (Clarke 1866 Ellipsoid)

Projection: State Plane, Michigan (old) West Zone

Projection Parameters:

Transverse Mercator

Central Meridian: exactly 88d45'00" West (-88.75 degrees)

Reference Latitude: exactly 41d30'00" North (41.5 degrees)

Scale Factor: 0.9999090909

False Easting: exactly 500,000 U.S. Survey Feet (152400.3048 meters)

False Northing: exactly 0

### Summary of Procedures:

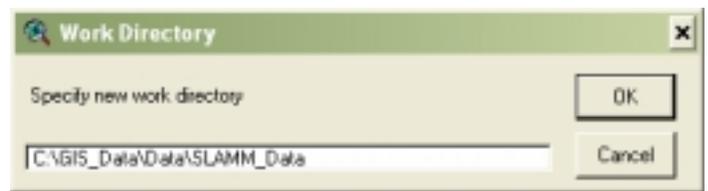
- I. Merge Land Use and Sewershed Themes
- II. Create Land Use Statistics for a Sewershed
- III. Reformat Land Use Statistics for Use in SLAMM
- IV. Create or Obtain Appropriate SLAMM Parameter Files (ran, ppd, prr, rsv, psc, cpz)
- V. Modify Standard Land Use Files in SLAMM for Needed Land Use Categories
- VI. Run SLAMM Batch Editor to Estimate Pollutant Loadings
- VII. Display Output in GIS

# **I. Merge Land Use and Sewershed Themes**

## **A. Initiate ArcView and Load Spatial Data**

- 1) Start the ArcView 3.x program.
- 2) If the “Welcome to ArcView GIS” window appears, select “Create a new project, with a new View”. If this window does not appear, from ArcView’s project menu highlight “VIEWS” and click the “New” button.
- 3) Activate (click on) the view window, “View1”.
- 4) From “View1”’s main menu, select “View” then “Add Theme” from the pull-down menu.
- 5) Add the following themes: MALU.SHP (land use) and MASWBND.SHP (sewersheds).
- 6) Set distance units. To do this, from the “View” menu select “Properties”. In the new window, set the Map Units and Distance Units to “Feet”. In this window, also change the name of the View from “View 1” to “View: Land Use & Sewersheds”. Click “OK”.

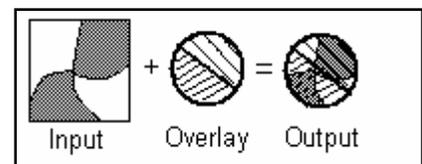
- 7) Set the working directory. From the “File” menu select “Set Working Directory”. In the new window set the working directory to the folder where you copied the SLAMM Exercise files. In doing so, all new files will be saved there by default. Click “OK”.



- 8) In the view window, turn on the two themes. This can be done by clicking on the small box by each of the theme’s names, thus adding a check mark.
- 9) If one theme is not visible, it does not have the highest viewing priority on the hierarchy of layers. Layers that are on the top of the legend have the highest viewing priority, and are in essence, placed on top of the other layers. If there are elements in the layer that have solid fill, they will cover the layers that are lower in the legend hierarchy. To see a theme on top of other themes, left click (and hold down) on the layer’s name, then drag the layer to the top of the list of layers.

## **B. Merge Land Use and Sewershed Themes**

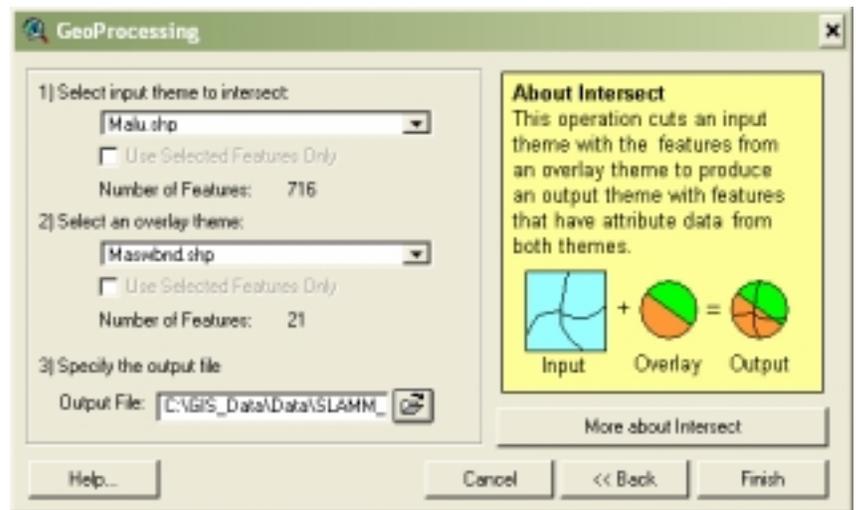
In modeling, it is useful to determine the total area of each type of land use within each sewershed. To perform this analysis, the two datasets are overlaid using a spatial “intersection.” The result is a single theme whose polygons contain both land use and sewershed attributes from the original themes.



- 1) From the “File” menu, select “Extensions”. In the new window, under “Available Extensions”, scroll down to “Geoprocessing” and check it; click “OK”.

2) From the “View” menu, select “Geoprocessing Wizard”. In the window that appears, enter the following parameters:

- Select “Intersect Two Themes”;  
Click the “Next” button.
- Specify the Input Theme as  
“Malu.shp”.
- Select the Overlay Theme as  
“Maswbnd.shp”.
- Specify the Output File as  
“Maluswb.shp”.
- Click the “Finish” button to  
execute the intersection command.  
The processing may take a few  
minutes.



3) Save the ArcView project as “Marqslamm.apr”, by using the “Save As” command from the “File” menu.

### **C. Update Polygon Areas in the Attribute Table**

ArcView’s Intersection command correctly splits polygons, but it does not update polygon areas or perimeters in the attribute table. Instead, the area and perimeter numbers, from the two original datasets, are simply copied as if they were nominal attributes like land use or sewershed names. Quantifying land area is critical for runoff computations in the SLAMM model, so the area values must be corrected.

- 1) In the window, “View: Land Use & Sewersheds”, turn on and activate the new theme (Maluswb.shp). To activate it, click on its name so that a highlighted box appears around the whole name (in addition to the check in the small box that turns the theme on).
- 2) From the “Theme” menu, select “Table”. The attribute table for the active shapefile (maluswb.shp) will appear.

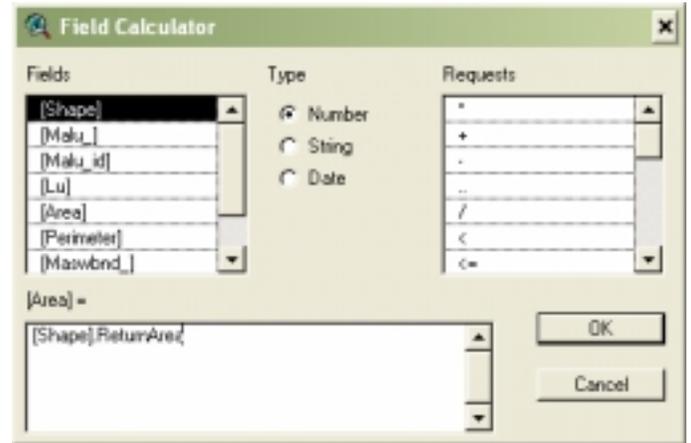
*Examine the area and perimeter values in the MALUSWB attribute table. There are two sets of area and perimeter values – one from each of the land use and sewershed themes. Notice that many records (polygons) share the exact same area and perimeter values. These are not the recalculated areas and perimeters of the intersected polygons; rather, they are the original areas and perimeters of the pre-intersection polygons.*

- 3) With the table window active, from the “Table” menu select “Start Editing”.
- 4) Delete the first area and perimeter fields. To do this, select the left-most “area” field by clicking on its gray header box; from the “Edit” menu select “Delete Field”; click “Yes” to confirm the command. Now, select the left-most “perimeter” field by clicking in its gray header box. Again from the “Edit” menu select “Delete Field”. Click “Yes” to confirm the deletion.

5) Clear the current selection, to make sure no records are selected. From the “Edit” menu select “Select None”. This process is done to assure that the subsequent command applies to all records, not just the selected records.

6) In the attribute table, select the remaining “Area” field (click on the field’s title); from the “Field” menu select “Calculate”. In the calculation screen that appears, enter the following parameters:

- In the [Area] = box, type “[Shape].ReturnArea”
- Click “OK”.



7) Again in the attribute table, select the remaining “Perimeter” field; from the “Field” menu select “Calculate”. Enter the following parameters in the Field Calculator screen:

- In the [Area] = box, type “[Shape].ReturnLength”
- Click “OK”.

8) From the “Table” menu, select “Stop Editing”, thus saving all edits.



9) From the “File” menu, select “Save Project”.

## II. Create Land Use Statistics for a Sewershed

### A. Relate SLAMM Land Use Codes to Existing Land Use Codes

For each land use class, SLAMM references a Standard Land Use (SLU) file which describes the distribution of source areas and runoff behavior. SLAMM requires a single letter code as a reference to the SLUs. The “translation” from existing land use codes into single-letter SLAMMCODE is accomplished with a separate table defining the relation between the two code systems. This translation table is appended, or “joined”, in ArcView terminology, to the land use summary table previously generated. The table below lists the relations.

It is important to note that this particular Marquette land use classification system was designed to match the Standard Land Use files utilized by SLAMM. In a study area where existing land use classification might not match SLAMM SLU categories, there are two options: 1) relate land use to the most similar SLU; or 2) create new SLUs with source area distributions which represent the local land use classes.

*NOTE: Due to the single-letter that relates land use classes to SLU files, SLAMM is limited to 26 different Standard Land Use files (codes A to Z) for a single run. If an existing land use classification system has more than 26 classes, not every class could be associated with a unique SLU.*

In subsequent steps of this exercise, a table of total area per land use type will be derived. It is important to translate to SLAMM land use codes *before* computing the area totals because SLAMM doesn't handle more than one record (line of data) per land use for a sewershed. For example, cemeteries and parks are both to be coded as SLAMMCODE "H", because they have similar characteristics. If the land use data was not translated to SLAMM codes before producing the total area table, there would be a record in the table for both CEM and PARK. After translating CEM and PARK to "H", there would be two records for land use "H". Thus, SLAMM would give incorrect results as it would only process the last record.

<b>Standard Land Use Classes and Codes</b>		
<i>"LU" Land Use Code</i>	<i>SLAMMCODE</i>	<i>Land Use Description</i>
CDT	S	Commercial Downtown
CEM	K	Cemetery *
CST	F	Commercial Strip *
FREE	G	Freeway
HOSP	U	Hospital *
HRNA	M	High Density Residential (no Alley) *
HRWA	N	High Density Residential (with Alley)
LI	O	Light Industrial
LR	C	Low Density Residential *
MF	D	Multi-Family Residential *
MI	E	Medium Industrial *
MISC	J	Miscellaneous *
MOBR	P	Mobile Homes
MRNA	A	Medium Density Residential (no Alley) *
MRWA	B	Medium Density Residential (with Alley)
OP	T	Office Park
OSUD	I	Open Space *
PARK	H	Park *
SC	R	Shopping Center
SCH	Q	School *

*(Classes with an astrix\* are used in this exercise)*

In this step we will join the land use code translation table (lu2slammcode.dbf) to the land use theme:

- 1) Open the project window; from the "Window" menu select "Marqslamm.apr". In the project window, select the "Tables" icon and press the "Add" button. Navigate to the "lu2slammcode.dbf" file and click "OK".
- 2) In the attribute table of the newly added database file, select the "Lu" field by clicking on its gray header bar.
- 3) Now open (and activate) the "maluswb" table. Use the "Window" pull-down menu to return to "View: Land Use & Sewersheds". Make sure the "maluswb" theme is active and



click on the “Open Theme Table” button. While in the attribute table of “maluswb”, select the “Lu” field by clicking on its gray header bar.

- 4) To bring the two tables together, from the “Table” menu, select “Join”.
- 5) Examine the “Attributes of maluswb.shp” table; notice that there are no SLAMM codes for roads or water. This is because there is an absence of those land use codes in the “lu2slammcode” table. This issue will be looked at later in the exercise.

*NOTE: In this relation between tables, the first table selected (lu2slammcode.dbf) is joined to the latter table selected (mimal2-landuse.dbf) using the “key” field (Lu). It is important to understand which table will be used as the output table for the “join” as a mistake may result in a loss of records in the database. It is always the table from which the “Join” command is prompted that will serve as the output table, or the table to which the other tabular information will be added. The loss of data may occur (depending on database organization) if there is more than one “Lu” code associated with one SLAMM code. A comparison of total area (see Section II, Part C) would verify whether this type of omission had occurred.*

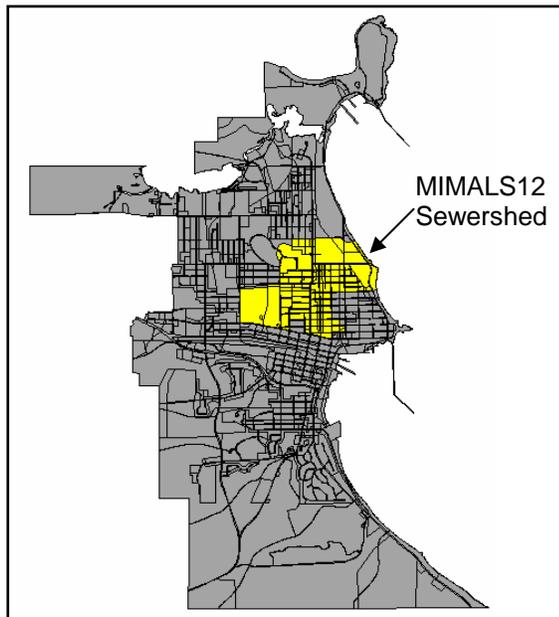
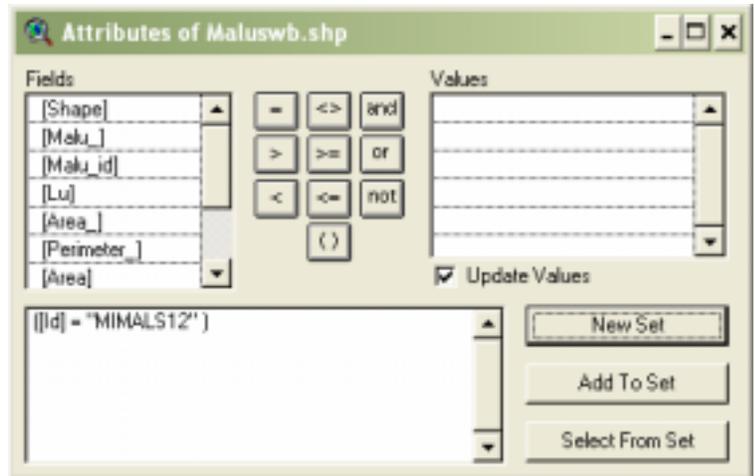
**B. Select Polygons from One Sewershed (MIMALS12)**

This analysis will be limited to the MIMALS12 sewershed. Therefore, the polygons within that sewershed will be selected and summarized in a separate table.



- 1) With the attribute table for “Maluswb.shp” still active, from the “Table” menu select “Query” or click on the “Query Builder” icon.

- 2) In the Query Builder dialog box, build the expression ([Id] = "MIMALS12") and select the “New Set” button. Close the Query Builder window.



- 3) Open the View window (View: Land Use & Sewersheds) and look at the “Maluswb.shp” theme (remember that this theme is the intersected land use and sewersheds records). The polygons that pertain to the selected records should appear in yellow. These selected records depict the area in the MIMALS12 sewershed.

### C. Aggregate Polygon Areas by Land Use

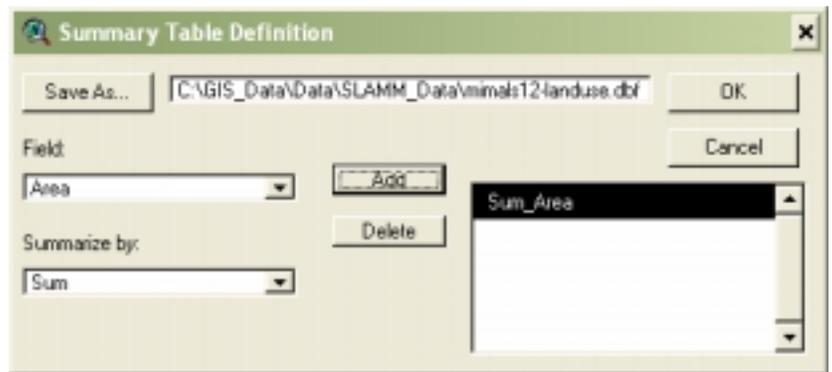
SLAMM only requires the total area of each hydrologically-distinct land use within the sewershed. It does not require information about the spatial distribution of those land uses. Therefore, a new table will be generated with the aggregated area per land use within the selected sewershed.

- 1) Activate the “Attributes of Maluswb” table. Either click on the “Open Theme Table” icon in the View, or from the “Window” menu select “Attributes of Maluswb.shp”.
- 2) Make sure that the previously selected records are still selected (in yellow). Activate the “SLAMMCODE” field (click on the gray box at the top of its column).

*NOTE: If you accidentally clicked within the table so that only one or a few records are selected, you will have to repeat the selection process above with the Query Builder. If all the features of the MIMALS12 sewershed are not select, the area aggregation will not include the desired records (polygons) in the analysis.*

- 3) From the “Field” menu, select “Summarize”. In the “Summary Table Definition” window, enter the following parameters:

- Specify output file as “mimals12-landuse.dbf”
- Field: “AREA”
- Summarize by: “SUM”
- Click on the “Add” button so that the command “SUM\_AREA” appears in the box on right.
- Click “OK” to create the summary table.



Slammcode	Count	Sum_Area
A	72	7619264.9110
C	1	18284.4380
D	2	29303.4000
E	1	905927.2810
F	24	1356719.7000
H	2	3222927.3280
I	2	46926.4000
J	1	669375.0630
K	1	1680956.2980
M	13	1206840.1020
Q	12	5421081.7210
U	3	576965.5940
	3	2702891.7380

The resulting summary table should be identical to the table shown here. The count represents the number of polygons in sewershed MIMALS12 with that land use code.

*NOTE: The last record in the table has no SLAMMCODE. This is the total area of land uses (roads and water) for which there was no SLAMMCODE. SLAMM does not consider roads and water as separate land uses, so this is not a problem.*

### **D. Data Consistency Check: Total Land Area**

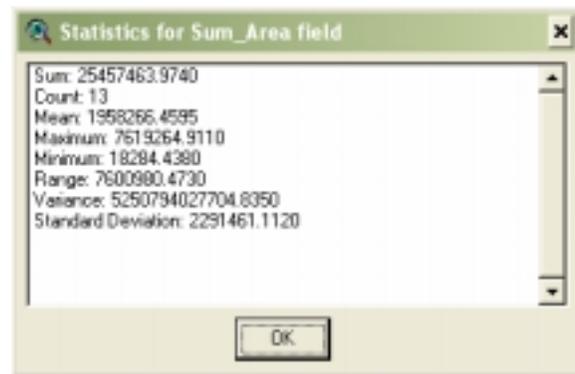
In this step, verify that the total land area in the summarized table equals the total area of the sewershed.

1) Open the new table (mimals12-landuse.dbf), if not already open.

2) In the table, activate the “Sum\_Area” field by clicking on the gray box at the top of its column.

3) From the “Field” menu select “Statistics”.

4) Write down the sum, which is the total land area. Close the statistics window by clicking “OK”.



5) Open the view window and activate the sewershed theme “Maluswb.shp” (click on its name so that it appears raised).



6) From the menu line, select the “Identify” button. Click on the MIMALS12 sewershed; compare the area to the sum from the table.

*In previous runs, the total area from the summarized table was 25,457,464 square feet, while the area of sewershed MIMALS12 was 25,457,704 square feet. The difference (240 square feet) was only 0.001% of the MIMALS12 sewershed area – an insignificant difference probably attributable to slight edge mismatches where there was no land cover information inside the sewershed.*

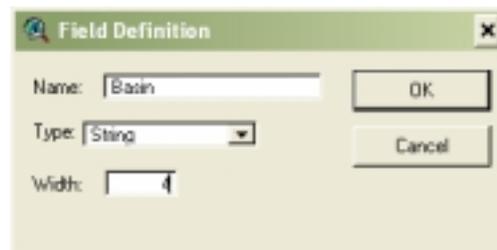
## **III. Reformat Land Use Statistics for Use in SLAMM**

### **A. Add a Field for Sewershed Name to the Summarized Land Use Table**

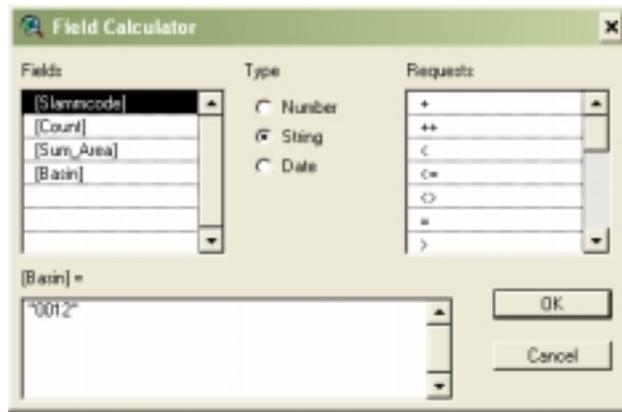
1) With the new “mimals12-landuse.dbf” table open, select “Start Editing” from the “Table” menu.

2) From the “Edit” menu select “Add Field”. In the “Field Definition” box, enter the following:

- Name: “Basin”
- Type: “String”
- Width: “4”
- Click “OK” to continue.



3) From the “Field” menu select “Calculate”.



- 4) In the window titled “[Basin] =”, enter “0012” (include the quotations, because the BASIN field is a character string, not a numeric value).

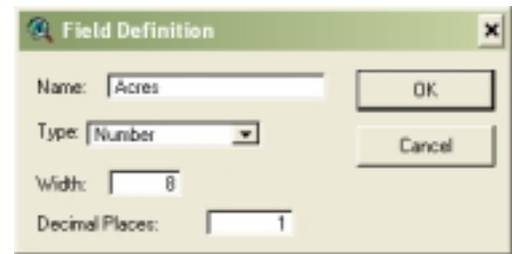
Click “OK”.

- 5) Examine the table; all records in the Basin field should equal 0012.

*NOTE: This exercise deals only with the sewershed MIMALS12. If all sewersheds were to be studied, it would be much more efficient to produce a single land use summary table. This is more complicated, however. In the “Maluswb” theme table, a unique identifier for each sewershed / SLAMMCODE combination would be needed (for example, a new item in the “Maluswb” table = Sewershed name + SLAMMCODE, which would have values such as MIMALS12A, MIMALS12B, etc.). The entire table (not just records from a selected sewershed) would be summarized using the unique identifier field. The items ID (sewershed ID), SLAMMCODE and SUM\_AREA would need to be included in the generated summary table.*

### **B. Convert Area from Square Feet to Acres**

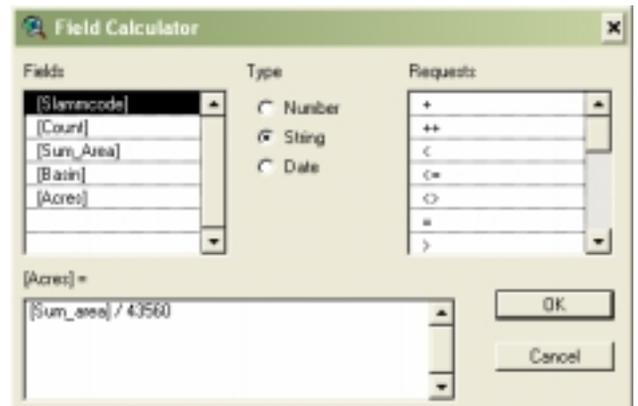
- 1) Activate the “mimals12-landuse.dbf” table.
- 2) From the “Edit” menu select “Add Field”. If the “Add Field” option is blocked, select “Start Editing” again from the “Table” menu.
- 3) In the “Field Definition” window, enter the following parameters:
  - Name: “Acres”
  - Type: “Number”
  - Width: “8”
  - Decimal Places: “1” (*NOTE: Historically, SLAMM has not handled more than one decimal place!*)
  - Click “OK” to continue.



- 4) From the “Field” menu select “Calculate” or click on the “Calculate” button.

- 5) In the “Field Calculator” window enter the following equation: [acres] = “[Sum\_area] / 43560”. This is the conversion from square feet to acres. Click “OK”.

- 6) Save the edits to the attribute table. From the “Table” menu, select “Stop Editing” and confirm the process.





7) Save the project.

### **C. Adjust Land Use Area Totals to Incorporate Road Areas**

The total road area is calculated from Marquette's land use data, but SLAMM does not treat roads as a separate land use. Instead, the standard land use files for SLAMM incorporate adjacent road area into each land use. To rectify this, either the SLAMM data format must be altered or an algorithm must be developed to incorporate road area into adjacent land uses.

The latter method, a "road folding" algorithm, was developed for the Lake Superior Non-Point project using the Arc Marco language (AML) in the Arc/Info GIS software. However, AMLs do not function in ArcView. A similar algorithm could be developed using ArcView's macro language, called a "script".

In the meantime, a lookup table will be used that contains the road folding factors for the sewershed MIMALS12. Otherwise the 61 acres of roads in the MIMALS12 sewershed would be unaccounted for, and runoff and pollutant loads would be underestimated.

In the following steps we will join the "roadfactor-mimals12.dbf" table to the "mimalu12-landuse.dbf" table, to relate the road area factors to each land use.

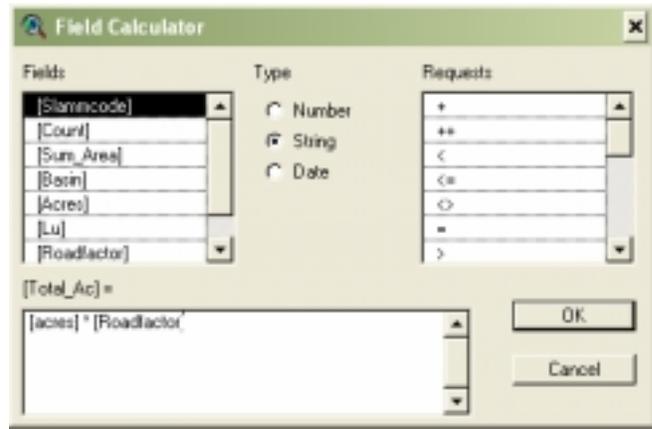
- 1) From the project window (Marqslamm.apr), select the "Tables" icon and press "Add". Navigate to the "roadfactor-mimals12.dbf" file and click "OK".
- 2) In the "roadfactor-mimals12.dbf" table, activate the "SLAMMCODE" field (click on its gray header bar).
- 3) Open and activate the "mimals12-landuse.dbf" table. In the attribute table, select the "SLAMMCODE" field (click on its gray header bar).
- 4) From the "Table" menu select "Join". Examine the "mimals12-landuse.dbf" table; it should have an additional field for the road factor.
- 5) Next we will determine the total area (including roads) per land use by multiplying the area per land use by the road factor.

From the "Table" menu, select "Start Editing".

- 6) In the "mimals12-landuse.dbf" table, select "Add Field" from the "Edit" menu. In the "Field Definition" window enter the following parameters:
  - o Name: "Total\_Ac"
  - o Type: "Number"
  - o Width: "8"
  - o Decimal Places: "1"
  - o Click "OK" to continue.
- 7) From the "Field" menu select "Calculate".

8) In the “Field Calculator” window, enter the following expression: [Total\_Ac] = [acres] \* [Roadfactor]

9) Click “OK”.



*NOTE: After applying this type of area conversion factor, total area from Total\_Ac could again be compared to the total sewershed area (excluding water) from the Maswbnd.shp theme, to make sure the total area was not significantly different. Previous checks gave a sum of Total\_Ac = 584.5 acres, compared to the Maswbnd.shp total for MIMALS12 of 25,457,704 square feet, or 584.43 acres (a 0.01% difference).*

10) Since SLAMM does not consider roads or water bodies as distinct land use categories, these records will be deleted from the table.

11) In the “mimals12-landuse.dbf” table, select (click on) the record which has no “SLAMMCODE” value. From the “Edit” menu select “Delete Records”.

12) From the “Table” menu, select “Stop Editing”. Choose “Yes” to save the edits.

#### **D. Add Fields for Soil Type (Sand or Clay)**

The SLAMM input file requires that for each land use, the soil type (sand or clay) be specified. In this exercise, all soils are assumed to behave like clay. Since urban soils are typically compacted for construction, even sandier soils tend to be less permeable and behave more like clay. Assuming all soils behave like clay gives a higher estimate of runoff and pollutant loading due to the lower water infiltration rate of clay soils.

If spatial soils data were intersected with the land use and sewershed theme, the land use summary file generated so far could further specify the relative proportion of sandy and clayey soils underneath each land use. For example, of a hypothetical 103 acres of park (code H), 90 acres could be specified on sandy soils and 13 acres on clayey soils in this city.

SLAMM, however, is not currently configured to allow different soil types for a given land use. For each land use (such as code “H” for parks), the SLAMM Standard Land Use file already has soil types assigned for each source area. For example, the Standard Land Use file for parks says that a park typically contains some playground source area which drains onto *sandy* soil. If the summary file we produce indicates that there are some parks on *clay* soils, this will conflict with the sandy soil reference, and SLAMM will not process the data.

So in summary, a GIS analysis could easily produce detailed information about which soils are actually underneath each land use in a study area, but SLAMM wouldn't consider the information because soil type is already coded into the Standard Land Use files. Instead, redundant data (reaffirming the soil type) must be included in the land use summary file.

### How Madison Handled Soils in SLAMM

The City of Madison, Wisconsin Engineering Department defined all soils as sand instead of clay. However, runoff coefficients (RSV file) for "sandy" soil were calibrated using actual rainfall and runoff measurements for the land use/source area combinations in Madison.

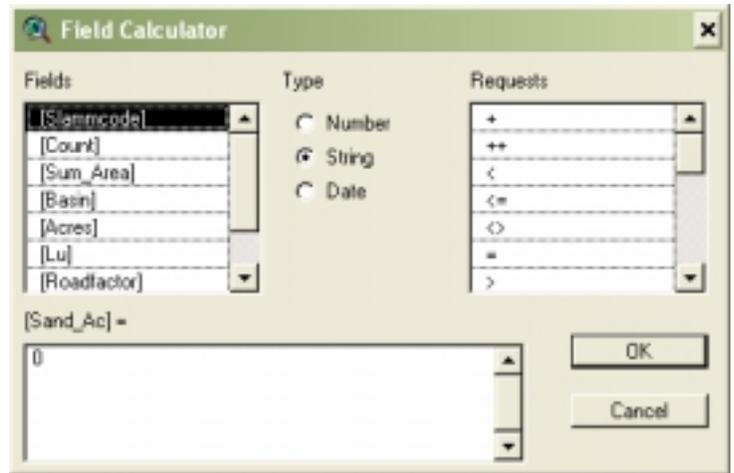
Thus Madison soils were not necessarily considered sandy. The "sand" classification assigned to Madison soil was just an identifier which linked land use/source area data to Madison-specific runoff coefficients. For more information, contact Greg Fries in Madison's Engineering Department.

- 1) Open the "mimals12-landuse.dbf" table. Choose to "Start Editing" from the "Table" menu. Select "Add Field" from the "Edit" menu. In the "Field Definition" window, enter the following parameters:

- o Name: "Sand\_Ac"
- o Type: "Number"
- o Width: "8"
- o Decimal Places: "1"
- o Click "OK" to continue.

- 2) In the table, activate the "Sand\_Ac" field (click on its gray header bar). From the "Field" menu select "Calculate".

- 3) In the "Field Calculator" window, enter the following equation "[Sand\_Ac] = 0" Click "OK". (No land area is sandy soil.)

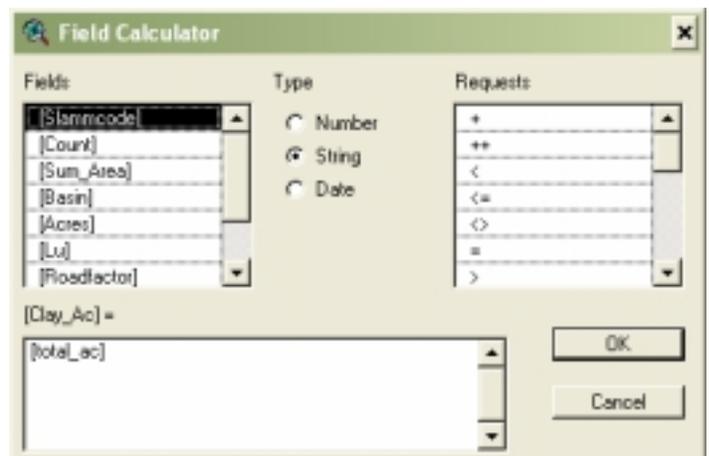


- 4) Again in the "mimals12-landuse.dbf" table, select "Add Field" from the "Edit" menu. Enter the following parameters:

- o Name: "Clay\_Ac"
- o Type: "Number"
- o Width: "8"
- o Decimal Places: "1"
- o Click "OK" to continue.

- 5) In the table, activate the "Clay\_Ac" field (click on its gray header bar). From the "Field" menu select "Calculate".

- 6) Enter the following equation "[Clay\_Ac] = [total\_ac]" in the "Field Calculator". Click



“OK”. (All soil is assumed to behave like clay.)

### **E. Save Changes and Export Table**

In order to permanently relate (join) the SLAMM code and road factor fields from the other tables, this table must be “exported” under a different name.

- 1) With the “mimals12-landuse.dbf” table active, from the “Table” menu select “Stop Editing”. Save all edits.
- 2) From the “File” menu select “Export”; in the “Export Table” window set the “Export Format” to “dBASE”. Click “OK”.
- 3) Save the file as “Mimals12.dbf”.
- 4) In the “mimals12-landuse.dbf” table “Stop Editing” from the “Table” menu, “Save Edits” and close the table.



- 5) Save the project.

### **F. Delete Unnecessary Fields from the Table**

In this step, we will delete unneeded data from the mimals12 database file.

- 1) Open the exported table (Mimals12.dbf). To do so, go to the project window (Marqslamm.apr); select the “Table” icon and press “Add”. Navigate to the “Mimals12.dbf” file and press “OK”.
- 2) With the table open, from the “Table” menu select “Start Editing”.
- 3) Select the “Count” field (click on its gray header bar); from the “Edit” menu select “Delete Field”. Click “Yes” to confirm the operation.
- 4) Repeat the process to delete the fields: “Sum\_Area”, “Acres”, “Lu” and “Roadfactor”.
- 5) Move “Basin” field to the first column, by clicking and holding on its grey header bar, and dragging it to the left of the “Slammcode” field.
- 6) From the “Table” menu select “Stop Editing”. Save the edits. The final table should look like the one shown here.

Basin	Slammcode	Total_ac	Sand_ac	Clay_ac
0012	A	208.3	0.0	208.3
0012	C	0.5	0.0	0.5
0012	D	0.9	0.0	0.9
0012	E	22.0	0.0	22.0
0012	F	37.6	0.0	37.6
0012	H	75.9	0.0	75.9
0012	I	1.2	0.0	1.2
0012	J	16.5	0.0	16.5
0012	K	39.7	0.0	39.7
0012	M	32.8	0.0	32.8
0012	Q	132.9	0.0	132.9
0012	U	15.1	0.0	15.1

### **G. Convert Final Table to SLAMM Format (ASCII Text File with “PLA” Extension)**

In this step, we will convert the mimals12 database file to a SLAMM .pla file, also called a “planning level sub-basin description file” specific to SLAMM.

- 1) With the “Mimals12.dbf” table active, from the “File” menu select “Export”. In the “Export Table” set “Export Format” to “Delimited Text”. Click “OK”.
- 2) Save the file as “mimalu12.txt”.
- 3) Close the “Mimals12.dbf” table.



4) Save the project.

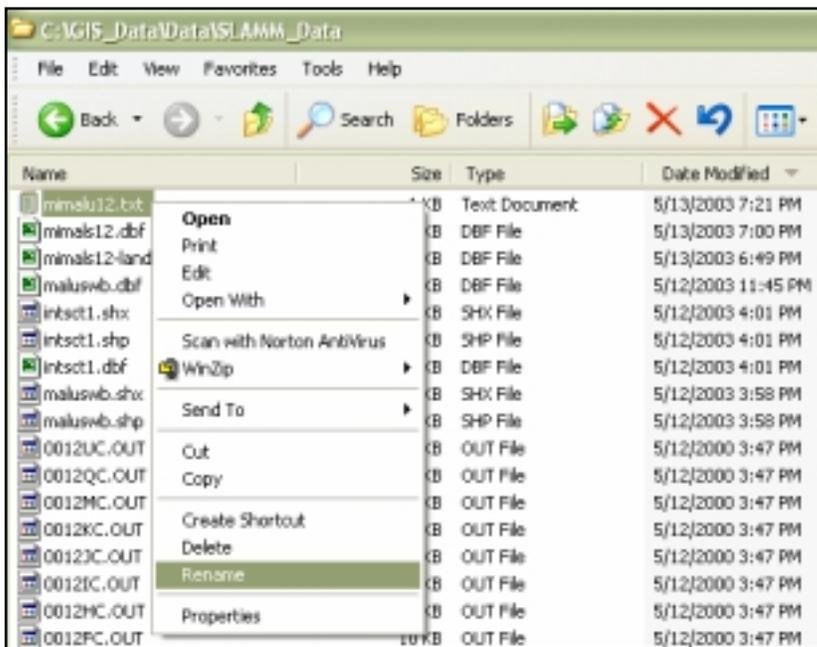
- 5) Minimize ArcView with the “\_” button.



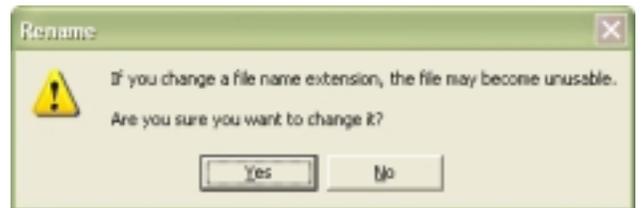
- 6) With a text editor (Notepad, for example), open the “mimalu12.txt” file. Delete the header information in the first line of the file.



- 7) Save the “mimalu12.txt” file and close the text editor.



- 8) Use the Windows Explorer to change the name of the file to “Mimalu12.pla”. Select “Yes” to change the name, if warned about changing the file extension.



## IV. Create or Obtain Appropriate SLAMM Parameter Files

Make sure the SLAMM Standard Land Use files (which specify the typical land use, source area and runoff behavior data for a given general land use) are in the working directory. See the table below for a list of files. (Note: The files needed are bolded.)

We will use existing parameter files for Marquette, Michigan. Verify that the files are also in the project directory: “Marq4.ppd”; “Marq.psc”; “Marq.prr”; “Marq.ran”; and “Marq.rsv”. These files must be in this specific directory because their location is coded into the header of each SLAMM Standard Land Use file.

*Note: since this exercise doesn't use the detention pond analysis module (DETPOND), a particulate size file (.CPZ extension) is not needed.*

## **V. Modify Standard Land Use Files in SLAMM for Needed Land Use Categories**

(This step has already been completed for this exercise.)

Our land use summary file (Mimalu12.pla) uses the SLAMMCODE to reference the relevant SLAMM Standard Land Use file (see table). If the Standard Land Use files do not have the appropriate SLAMMCODE in their Site Description line, SLAMM won't know which SLU file to associate with which SLAMMCODE land use. This has already been done for this exercise. See the SLAMM documentation for more information.

### **SLAMM Standard Land Use Files (Files in bold text are used in this exercise)**

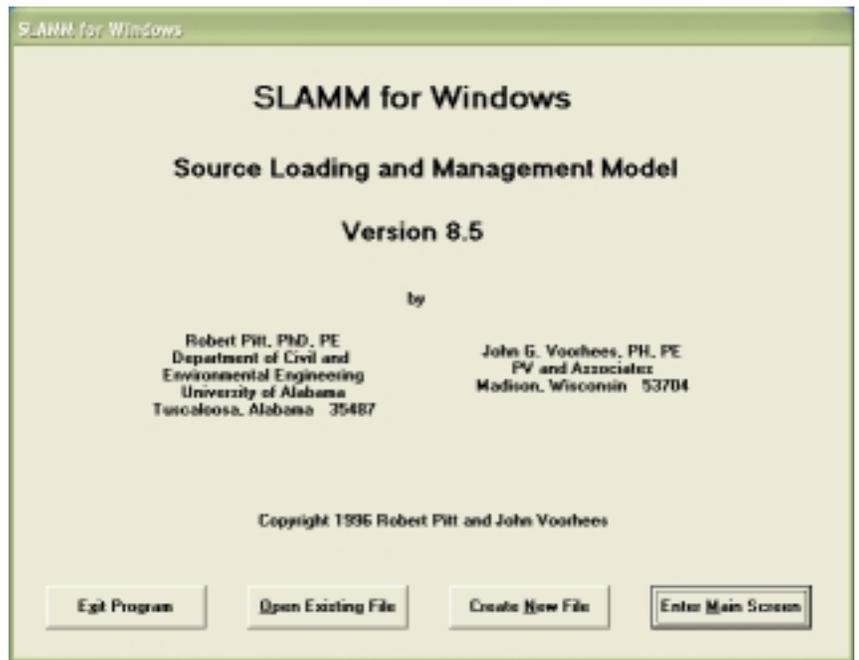
"LU" Land Use Code	SLAMMCODE	Land Use Description	SLU File Name
CDT	S	Commercial Downtown	SLUCDT.DAT
<b>CEM</b>	<b>K</b>	<b>Cemetery</b>	<b>SLUCEM.DAT</b>
<b>CST</b>	<b>F</b>	<b>Commercial Strip</b>	<b>SLUCST.DAT</b>
FREE	G	Freeway	SLUFREE.DAT
<b>HOSP</b>	<b>U</b>	<b>Hospital</b>	<b>SLUHOSP.DAT</b>
<b>HRNA</b>	<b>M</b>	<b>High Density Residential (no Alley)</b>	<b>SLUHRNA.DAT</b>
HRWA	N	High Density Residential (with Alley)	SLUHRWA.DAT
LI	O	Light Industrial	SLULI.DAT
<b>LR</b>	<b>C</b>	<b>Low Density Residential</b>	<b>SLULR.DAT</b>
<b>MF</b>	<b>D</b>	<b>Multi-Family Residential</b>	<b>SLUMF.DAT</b>
<b>MI</b>	<b>E</b>	<b>Medium Industrial</b>	<b>SLUML.DAT</b>
<b>MISC</b>	<b>J</b>	<b>Miscellaneous</b>	<b>SLUMISC.DAT</b>
MOBR	P	Mobile Homes	SLUMOBR.DAT
<b>MRNA</b>	<b>A</b>	<b>Medium Density Residential (no Alley)</b>	<b>SLUMRNA.DAT</b>
MRWA	B	Medium Density Residential (with Alley)	SLUMRWA.DAT
OP	T	Office Park	SLUOP.DAT
<b>OSUD</b>	<b>I</b>	<b>Open Space</b>	<b>SLUOSUD.DAT</b>
<b>PARK</b>	<b>H</b>	<b>Park</b>	<b>SLUPARK.DAT</b>
SC	R	Shopping Center	SLUSC.DAT
<b>SCH</b>	<b>Q</b>	<b>School</b>	<b>SLUSCH.DAT</b>

## **VI. Run the SLAMM Batch Editor to Estimate Pollutant Loadings**

- 1) Start the SLAMM program.
  - Start → Programs → WinSLAMM → WinSLAMM
  - Or, run the file c:\Program Files\winslamm\winslamm.exe

- 2) A guiding screen will open for the program. Start this project by clicking “Enter Main Screen”.
- 3) From the SLAMM menu (at the top of the screen), select “Run”. From the pull-down menu select “Run Batch Editor”.

In the warning screen that appears, choose “Yes” to delete any data that has been entered in the WSLAMM Input Module.



- 4) In the Batch Editor menu, select “Options”. From the pull-down menu, choose “Select Path for Source Land Use Files”.

- 5) In the window that appears, navigate to the project directory that was set as the working directory in ArcView. This directory will contain the marqslamm.apr and associated files. Click “Ok”.

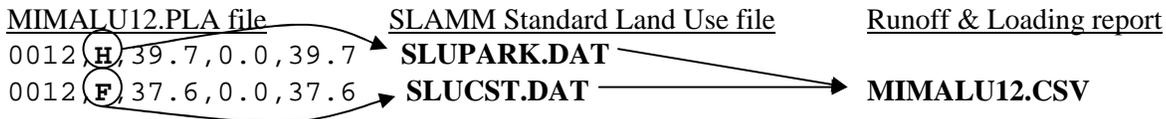
At this point, the Standard Land Use (SLU) files should appear in the right window of the Batch Editor.

If the files do not appear, select the “Land Use Soils Type” as “Silty” by placing a dot in front of the class.



In the Batch Editor, each record from our “Mimalu12.pla” file (called the “planning level sub-basin description file” in SLAMM) references a Standard Land Use (SLU) file. The Standard Land Use files are used to generate the runoff and loading values. Acreage in each SLU file is proportioned to equal the acreage from the record in the PLA file.

All of the adjusted SLU files are then run as a batch using the DOS SLAMM Calculations module. The output from the batch processor run is a comma separated value (CSV) file that summarizes, for all rain events in the model run, the total runoff, the particulate loading, and the selected pollutant loadings from SLU in the batch run.



*Note: The SLAMM Batch Editor is used here to process multiple land use areas (H,F,Q, etc.) within the same sewershed (0012). It can also be used to process single or multiple land use areas from different watersheds/sewersheds, using the same PLA file. In that case, statistics are totaled by sewershed in the CSV output file.*

- 6) In the Batch Editor window set the output directory. This is done by choosing “Select Destination Path for File Creation” from the “Options” pull down menu.

In the next window, navigate to the project directory (marqslamm) and select “Ok”.

- 7) In the Batch Editor window, select the bottom “Create” button to “Create a series of SLAMM.DAT files from a Land Use Database”.

- 8) Select the “Mimalu12.pla” file.



SLAMM should perform its final calculations and produce the comma-separated value (CSV) file. The format of this file includes a header that lists total runoff (c.f.), particulate solids (lbs), and the loadings for the selected pollutants. The total runoff, total particulate solids, and total pollutant loadings for each sub-basin are then listed. This file can be imported into a computer spreadsheet for further analysis.

**David- Here is where I have problems. WinSLAMM will not run for me. I keep getting the following error:**



## **VII. Display Output in GIS**

In addition to preparing input data for models, GIS is well suited for spatial analysis of model results. This is demonstrated using a previously generated SLAMM output file for all of the Marquette sewersheds (not just MIMALS12).

### **A. Modify SLAMM Output for Use in GIS**

Two main modifications must be made to the SLAMM output file so that it can be displayed in a GIS. These can be made in common spreadsheet or database software.

**Sewershed Key:** An item (column) must be added with the same sewershed name as in the spatial sewershed theme (in our case, MIMALS11, MIMALS12, etc.)

**Data Aggregation:** If it is desired to see a single runoff and loading total for each sewershed, multiple records (rows) for different land uses in the same sewershed must be aggregated into one. For example, the output file for this exercise would have 12 records for the sewershed MIMALS12 alone (one for each land use in that sewershed). Those 12 records would have to be summed into a single record for sewershed MIMALS12.

If it is desired to see the breakdown of runoff and loading *per land use* in a sewershed, then the table should not be aggregated. However, because such a table could have many records per sewershed, the method of relating the table to the sewershed theme is different ( a “link” instead of a “join” – explained below).

### **B. Relate SLAMM Output to Sewershed Polygons**

To display the SLAMM output spatially, each record must be assigned to a sewershed polygon.

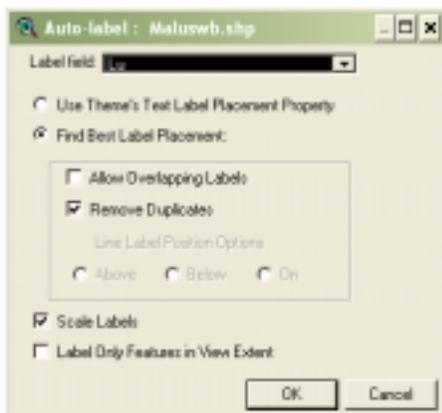
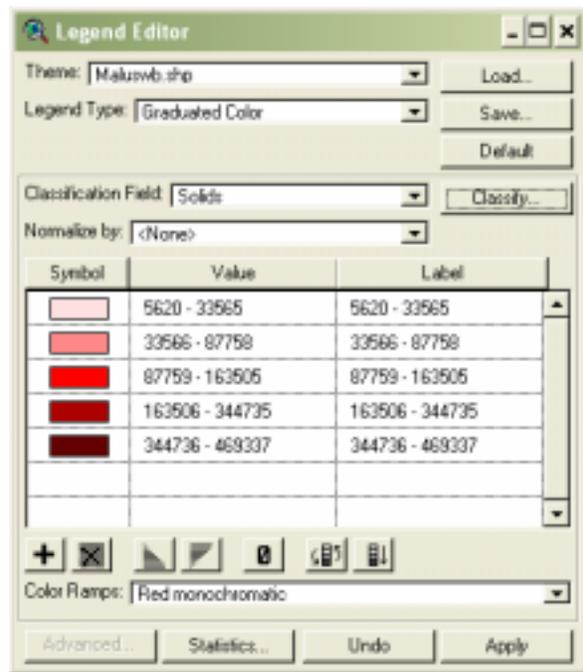
- 1) Restore the ArcView project.
- 2) From the “Window” menu, select “Marqslamm.apr”. In the project window that opens, select the “Tables” icon and press “ADD”. Navigate to the “Mimaloads.dbf” table and “OK” to add the table.
- 3) In the “Mimaloads.dbf” table, activate the “ID” field (click on its grey header bar).
- 4) Open the “View: Land Use & Sewersheds” window, from the “Window” command. Activate the sewershed theme “Maswbnd.shp” by clicking on its name in the legend. From the “Theme” menu, select “Table” to open the attribute table.
- 5) In the “Maswbnd.shp” table, activate the “ID” field (click on its grey header bar). (Be sure that no records are selected.)
- 6) From the “Table” menu, select “Join”.

*NOTE: If it is desired to see a breakdown of runoff or loadings per land use within a sewershed, a non-aggregated table of SLAMM output must be :linked" to the sewershed theme. In this case, there are many records (one per land use) in the SLAMM output table which are related to a single sewershed. Under a "link" relation (instead of the "join" used above), the sewershed polygons cannot be color coded using the SLAMM output data, as done below. However, if a sewershed polygon is selected in the sewershed theme, all associated records will automatically be selected in the SLAMM output table. These selected records can then be analyzed.*

### **C. Classify Sewershed Theme According to Runoff and Loading Values**

1) In the "View: Land Use & Sewersheds" window, turn on the sewershed theme "Maswbnd.shp". Open the Legend Editor by double clicking on the theme name.

- 2) In the Legend Editor, set the following parameters:
- Legend Type = "Graduated Color"
  - Classification Field = "Solids" (total solids in pounds)
  - Press the "Classify" button; set the Number of Classes to "5"; press OK
  - Press the "Apply" button
  - Close the Legend Editor and return to the sewershed theme.



3) Next, add sewershed names for reference.

In the view window, activate "Maswbnd.shp" (click on its name in the legend so the entire name has a raised box around it).

From the "Theme" menu, select "Auto Label".

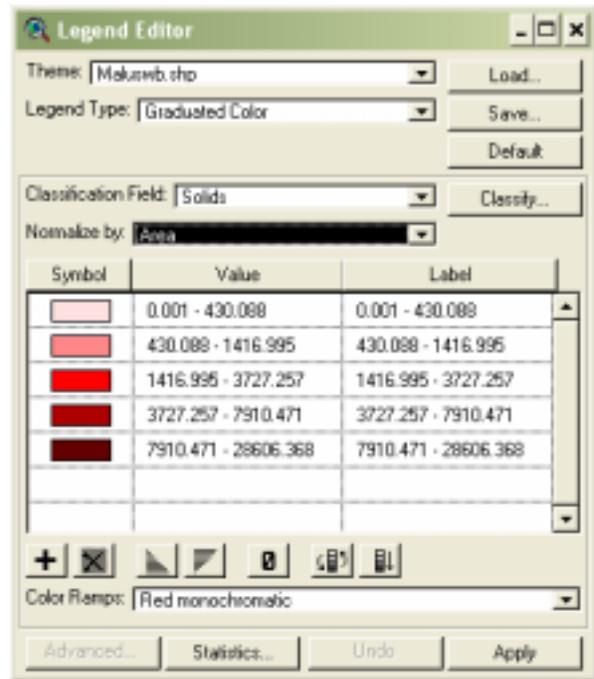
Select "OK" in the Auto Label window.

4) Next, re-classify the sewershed theme according to total solids divided by sewershed area.

Turn on the sewershed theme “Maswbnd.shp” (if not all ready). Double click on the theme name to open the Legend Editor.

In the Legend Editor, change the following parameters:

- Normalize by “Area” (solids divided by sewershed area = solids per area)
- Press the “Apply” button.
- Close the Legend Editor.

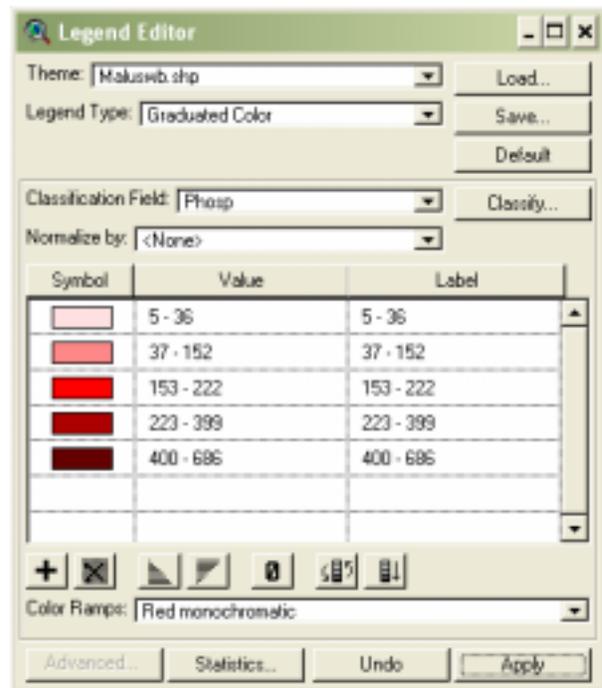


5) Re-classify the sewershed theme using pollutant loadings (phosphate):

Again, open the Legend Editor for the sewershed theme, “Maswbnd.shp”.

In the Legend Editor, set the following parameters:

- Legend Type = “Graduated Color”
- Classification Field = “Phosp”
- Normalize by “<None>”
- Press the “Classify” button. Set the Number of Classes to “5”; press “OK”.
- Press the “Apply” button.
- Close the Legend Editor to return to the sewershed theme.



6) Examine the distribution of different pollutant loadings (both in total pounds, and pounds per area using the Normalize option). You will likely see different distributions, because different land uses/source areas generate different pollutants.

## Conclusions/Issues

GIS can be used to easily and accurately total the land area within each sewershed having a given land use. Beyond that, however, runoff and sediment/pollutant loading calculations in SLAMM are dependent on parameters assigned to those land use classes. In particular, two key questions are:

1. Are the Standard Land Use files (e.g. SLUPARK.DAT for parks) a good enough estimate for the distribution of source area types and soils present in the study area? Remember that within the Standard Land Use files, source area/soil relationship cannot be changed merely by specifying a different soil type for a given land use in the PLA file.
2. Are the parameter files (ran, ppd, prr, rsv, psc, cpz) representative of the study area?

## Bugs in SLAMM Version 8.0 (as of December 12, 1999)

- **Batch Editor won't Produce Output Summary:** The final summary (CSV) is not produced. Intermediate files are produced. The Standard Land Use files, proportioned to actual acreage, but these are erased when the Batch Editor is closed.
- **Update Compatibility:** SLAMM Version 5 land use (DAT) files are not compatible with the version 8 program. Supposedly there is an import module to convert them, but this was not encountered by the authors.
- **ASCII-Format Text File Errors:** Sometimes SLAMM won't recognize the Planning agency land use (PLA) file or parameter files if they were saved using the Notepad program (even if saved as an ASCII-format text file). It is readable if saved by the DOA EDIT editor, but not if there is an extra carriage return at the end of the file. However, SLAMM has no problem reading the DAT files modified and saved using Notepad.

## Appendix A: Summary of SLAMM Parameters

### **Land Use Source Areas (\*.DAT file)**

The area (acreage) and runoff behavior of each type of "source area" within each land use class is compiled here. Areas are defined by the following criteria:

- Land use (6 classes: residential, institutional, commercial, industrial, open, and freeways)
- Source area within each land use (14 types, such as roofs, parking, playground, landscaped, streets...)
- Source area properties affecting runoff (for example: pitched or flat roof, direct or indirect connection to storm sewer, soil type, building density, presence of alleys, street texture)

*Note: in this exercise we are using GIS to compile only the acreage totals for each land use. We will use SLAMM's batch processing module, which accesses existing Standard Land Use files to compute expected source area distributions and runoff behavior within each general land use.*

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**Rain Events (\*.RAN file)**

Necessary rain information includes rain depths, durations, and interevent time periods. This information can be recorded from rainfall records or generated stochastically from rainfall statistics.

**Runoff Coefficients (\*.RSV file)**

Runoff coefficients, when multiplied by rain depths, land use source areas, and a conversion factor, determine the runoff volumes. RSV coefficients are a function of:

- Source area type (9 types, such as roof, pervious, impervious, streets)
- Rainfall depth (17 levels, from 1 to 125 mm)
- Drainage Efficiency Factor (3 levels for how directly runoff connects to storm sewer)

**Particulate Solids Concentration (\*.PSC file)**

Particulate solids concentration values, when multiplied by source area runoff volumes and a conversion factor, calculate particulate solids loadings (in pounds). PSC values are a function of:

- Land use (6 classes)
- Source area type (13 types)
- Rainfall depth (14 levels, from 1 to 80 mm)

**Pollutant Probability Distribution (\*.PPD file)**

Pollutant probability distribution values determine, when multiplied by either a source area runoff volume or source area particulate loading, the pollutant loading from a source area. These concentrations are ideally based on measurements specific to the study area. SLAMM calculates pollutant loadings for nine particulate and ten filterable pollutants. The user may define up to six other pollutants in both particulate and filterable forms. PPD values are a function of:

- Land use (6 classes)
- Source area type (14 types – PSC types, plus streets)

**Particulate Residue Reduction (\*.PRR file)**

This describes the fraction of total particulates that remains in the drainage system (curbs and gutters, grass swales, and storm drainage) after rain events end due to deposition. Residue reduction is a function of:

- Type of drainage system (grass swales; undeveloped roadside; curb & gutters, ‘valleys’, or sealed swales)
- Condition of curb and gutter (poor/flat, fair, or good/steep)
- Rainfall depth (14 levels, from 1 to 80 mm)

**Particle Size (\*.CPZ file – only for detention pond analysis)**

This information describes the size distribution of urban runoff particulates that enter a detention pond. Particle size determines the amount of settling in the pond, and how much particulate will continue as runoff.

**Stochastic Pollution Generation (optional Monte Carlo uncertainty simulation)**

To model uncertainty in pollutant concentrations, a stochastic number generator in the model generates lognormally distributed pollutant values. These values are based upon the pollutant mean and the pollutant coefficient of variation (COV) for the selected land uses and source areas.