2015

# Rural Subwatershed Analysis Protocol

## PART 1-TARGETING

CREATED BY THE CHISAGO SOIL & WATER CONSERVATION DISTRICT

# 1 CONTENTS

# 2 Protocol Development

Urban Subwatershed Retrofit Assessments (SRAs) have been an important tool for many organizations to help identify and rank the top priority Best Management Practices (BMPs) in urban areas. A standardized protocol was developed for completing SRAs. There was interest in completing a similar targeting and prioritizing analysis for rural areas. Due to major differences in the landscape and water movements in urban and rural areas, the urban SRA protocol is not sufficient in assessing rural areas. Therefore, this document outlines a protocol for Rural Subwatershed Analysis.

# 3 Top 50P! Project

Washington Conservation District developed the Fixing the Top 50 Rural Nonpoint Phosphorus Sources Project (Top50P!). This project is a focused effort to identify, implement, and assess prioritized phosphorus reduction practices in rural areas. The original project was developed for directly contributing tributary areas to Lake St. Croix.

The Top50P! Project protocol was outlined in a document produced by Washington Conservation District titled Rural Subwatershed Analysis Protocol. *The same protocol, along with any changes, additions, or enhancements to the original protocol, is included in this document*. Therefore, it should not be necessary to have the original Top50P! protocol document to conduct a rural subwatershed analysis.

# 4 ASSUMPTIONS OF THIS DOCUMENT

This is a technical document with specific instructions in how to perform the rural subwatershed analysis protocol. This document is intended for persons who are familiar with advanced GIS operation. The following is a list of assumptions of this document:

- The reader is fluent in the operation of GIS. These instructions are written using ArcMap 10.1.
- The reader has the Spatial Analyst Tools extension (requires a separate license). If you are on a USDA server, the USDA holds a license so the extension should be available to you.
- **Grids used in this protocol are 1 meter size.** If using a different grid size, substitute the grid size throughout the process whenever the instructions say to use 1 as the output cell size.
- In the prompt boxes, if these instructions do not indicate an input into a certain box, the default was used.
- NRCS's Engineering Tools are used to delineate watersheds and create stream networks.
- Display adjustments of the outputs are not discussed here. The user can adjust the display of the output to best suit their specific needs.
- The reader has access to RUSLE2 software.
- The reader has access to the BWSR Pollution Reduction Calculator.

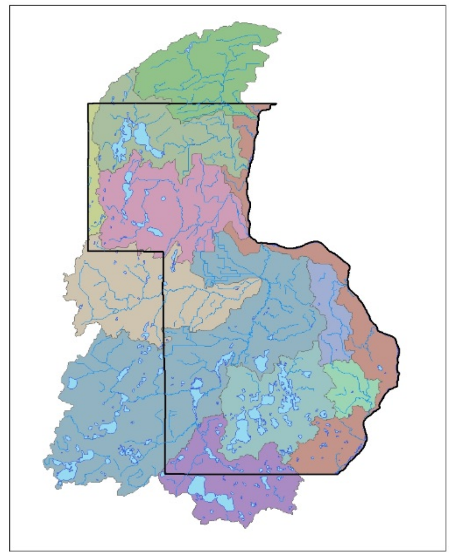

*Figure 1 Chisago County Boundary and Watersheds*

# 5 WHEN TO SKIP PART 1

This protocol is divided into two parts because many users may be able to skip part one and start with part 2. Part one discusses how to target a subwatershed or catchment within a larger watershed. The results of part one guide the user in choosing which subwatershed(s) or catchment(s) to focus grant funding and technical staff time on in order to achieve the greatest potential pollution reduction.

In many cases, the specific subwatershed or catchment is already determined for the user, often by what grant funding is available. For example, a grant may require that funds are spent only within a certain small watershed or within a certain subwatershed of a larger watershed. In this case, the user can skip part one and start the assessment process at part 2.

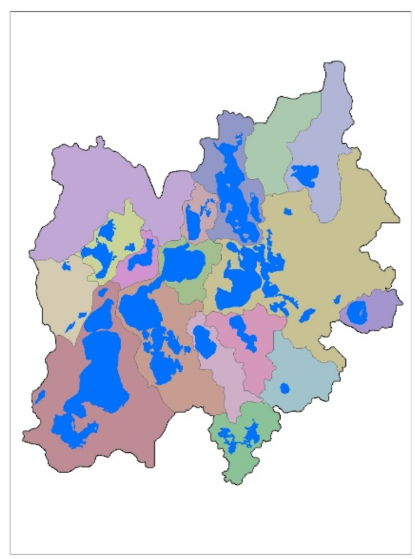

*Figure 2 Chain of Lakes Watershed with DNR Catchments*

# 6 TARGETING

Targeting helps narrow the working area to focus on a smaller scale. For many organizations, the largest scale may be the County boundary or the watershed scale. Figure 1 shows the Chisago County outline and the watersheds within the county boundaries. The targeting protocol can be used at this scale to determine which of the watersheds should be the highest priority for grant funding and water quality projects.

Similarly, targeting may be used within a watershed to determine the subwatershed(s) of highest priority. The DNR Catchments layer can be used as a subwatershed delineation layer (Figure 2). Figure 3 shows the Chisago Lakes Chain of Lakes watershed and the subwatersheds within it. These subwatersheds were produced from a SWAT model.

The scale at which a project should be targeted is usually determined on a project-by-project basis and is often guided by available funding. For example, if a watershed district funds a rural subwatershed analysis, the targeting will focus on which catchments or subwatersheds within the watershed should be the highest priority.

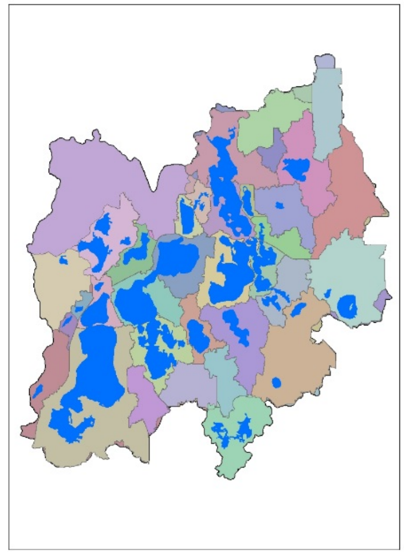

*Figure 3 Chain of Lakes Watershed with SWAT Subwatersheds*

Using the following targeting protocol on a scale smaller than the catchment or subwatershed scale (by field, for example) has been tried, but does not seem to be as useful as the prioritizing protocol described in Part 2-Prioritizing.

## 6.1 Getting Started

### 6.1.1 Choose Targeting Scale

The first step is to decide what scale the targeting protocol will be used on. Is the goal of the project to determine the highest priority watersheds in a county, or the highest priority subwatershed within a certain watershed? In many cases, this will be determined by funding.

### 6.1.2 Build GIS Project

Start gathering the necessary layers in a new GIS project. Table 1. Required GIS Layers for ProtocolTable 1 lists layers that were used and sources for obtaining the GIS data.

*Table 1. Required GIS Layers for Protocol*

| GIS Layer | Source | Notes |
|---|---|---|
| **Aerial photography** | FSA | High resolution images are essential. Import as many different years as are available |
| **Watersheds** | USDA | HUC |
| **Subwatersheds or Catchments** | DNR | SWAT model or DNR Catchments |
| **Lakes and Streams** | DNR | |
| **Digital Elevation Model** | LiDAR | 1 meter |
| **Soils** | SSURGO-USDA database | Available on the USDA server or can be downloaded online |
| **Land Cover** | DNR-MLCCS | This is not land use. ***It may be best to create your own layer (see instructions in Appendix A -*** *Land Cover Layer* ***).*** |
| **Wetlands** | NWI | Use both the original NWI and the 2013 NWI update |
| **Contours** | LiDAR | 1 foot contours are best |

### 6.1.3 Turn on Spatial Analyst Extension

The Spatial Analyst Extension is essential to this protocol. It requires a separate license. To turn the extension on, click under the Customize tab and click Extensions from the drop down menu. A prompt box will appear with the available extensions. Make sure that the Spatial Analyst box is checked.

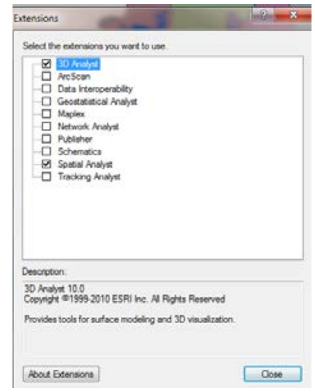


*Figure 4. Extensions Prompt Box*

## 6.2 RUSLE Analysis

The Revised Universal Soil Loss Equation (RUSLE) is an empirical model used to predict soil erosion potential. RUSLE is usually calculated using the software program. For this protocol, the equation will be built into the GIS project and calculated cell-by-cell.

The RUSLE equation is shown below:

A = R * K * L * S * C * P

A = Average annual soil loss potential in tons/acre/year
R = Rainfall-runoff erosivity factor
K = Soil erodibility factor
L = Slope length factor
S = Slope steepness factor
C = Cover management factor
P = Conservation practice factor

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Raster Creation
**Create Constant Raster**

### 6.2.1 Create R Factor Raster

The R Factor is the runoff erosivity factor. It is a constant in the equation that is determined by county. An NRCS employee in the project area should be able to provide the appropriate number. In Chisago County, this number is 130.

- Create a constant raster with the value of the R factor (130 in Chisago County).
- In the Environments Tab of the prompt box, expand the Output Coordinates and Processing Extent menus. Under each, open the drop down menu and select "Same as layer (Watershed Border Shapefile)". This will keep the raster output to the same size as your watershed.
- Change the output cell size to 1 (even if it says 1 already).

*Helpful Hint: Click the box for output cell size and type 1, even if there is already a 1 there. If you do not, it will sometimes revert to an output cell size of 60.*

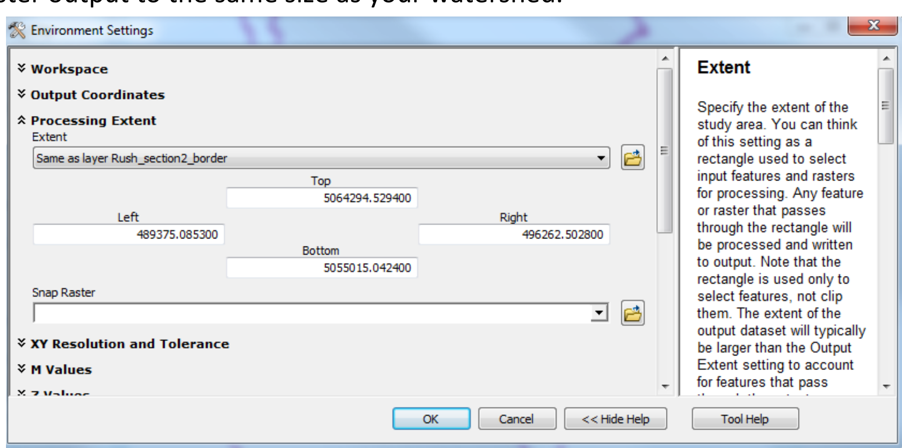


*Figure 5. Environmental Settings Prompt Box*

***SUGGESTED FILE NAME: WATERSHED_RFACTOR***

### 6.2.2 Create K Factor Raster

The K Factor is the soil erodibility factor. This can be found in a soil survey book (for Chisago County, it is listed in Table 15 Physical and Chemical Properties of the Soils). One way to digitize this information is to edit the Attribute Table of the soils layer. **(Skip to the next paragraph to see if the second method is available for you to use).**

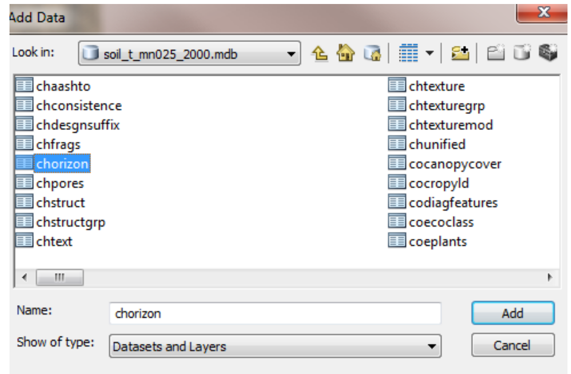


*Figure 6. Add chorizon and component tables*

- Right click on the soils layer and select Open Attribute Table.
- In the Attribute Table, click on the first icon that has a drop down menu and select Add Field.
- In the Add Field prompt box, type in a name. For Type, select Float. Leave the Precision and Scale boxes at default. The new column should be added at the end of the table.
- Start editing the soils shapefile by right clicking on the shapefile in the Table of Contents and select Edit Features, then Start Editing.
- Make sure that the Template for the soils layer is selected in the Create Features pane.
- Switch to the Attribute Table and you should now be able to manually input the K Factor from the soil survey into the table for each soil type.

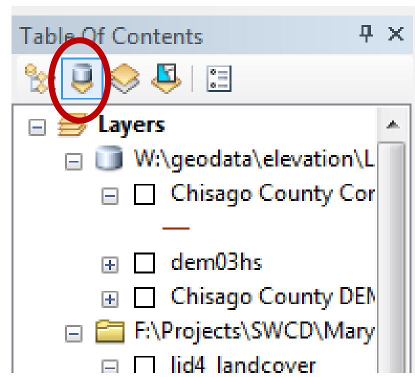


*Figure 7 Table of Contents List by Source*

There is another option for getting the K Factor into the Attribute Table. The required information may already be loaded on the USDA server in Access databases.

- To check if this method is available, in ArcMap open the Add Data tool and navigate to the location of the soils geodatabase (Figure 6). Double click on the geodatabase to open it. You may need to select the "Tabular" folder. If there is a list of many tables, look for the "chorizon" and "component" tables. If these are both present, this method should work.
- Add the "chorizon" and "component" tables to the project. These are tables and will not be visible in the Table of Contents. To view them, switch to the Table of Contents List By Source (the second icon from the left hand side in the icon menu in the Table of Contents pane. See Figure 7). There is no need to view them except to ensure that they were successfully imported into the project.
- Right click on the soils layer, scroll down to Joins and Relates, and click on Joins. A prompt box should open.
- In the "What do you want to join to this layer?" drop down menu, select "Join attributes from a table".

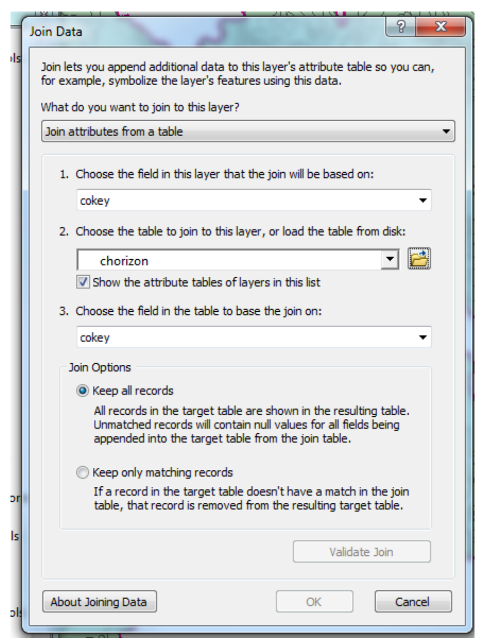


*Figure 8. Join chorizon table*

- In box 1, “Choose the field in this layer that the join will be based on”, select “mukey”.
- In box 2, “Choose the table to join to this layer, or load the table from disk”, select “component”.
- In box 3, “Choose the field in the bable to base the join on”, select “mukey”.
- Push OK.
- Again, right click on the soil layer in the Table of Contents and open the Join Data prompt box.
- In the “What do you want to join to this layer?” drop down menu, select “Join attributes from a table”.
- In box 1, “Choose the field in this layer that the join will be based on”, select “cokey”.
- In box 2, “Choose the table to join to this layer, or load the table from disk”, select “chorizon”.
- In box 3, “Choose the field in the table to base the join on”, select “cokey”.
- Push OK.
- To check if the process was completed correctly, open the attribute table for the soil layer. There will be many fields in the table. Scroll over to locate the kkfact field. It will be towards the end of the table.

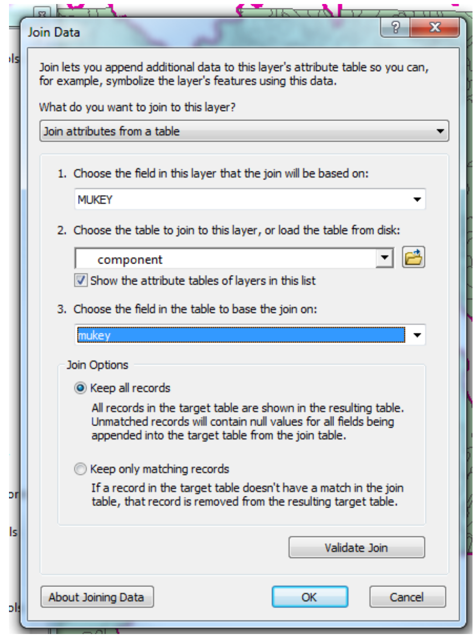


*Figure 9. Join component table*

The soil attribute table should now have a K Factor number assigned to each soil type. Next, a raster will be created with this information.

**Tool Path**
ArcToolbox
Conversion Tools
To Raster
**Feature to Raster**

- Open the Feature to Raster tool prompt box.
- The Input Feature is the soil shapefile that has the K Factor attribute in the table.
- In the Field box, select “kffact”.
- The output cell size should be 1.

***SUGGESTED FILENAME: WATERSHED_KFACTOR***

*Helpful Hint: Example outputs are shown in Appendix B - Example Targeting Outputs of this document.*

### 6.2.3 Create LS Factor Raster

This is a combination of the L Factor (Slope Length) and the S Factor (Slope Steepness). Creating this raster takes several steps and has several intermediate output rasters.

**Tool Path**
ArcToolbox
Data Management Tools
Raster
Raster Processing
**Clip**

- Clip the DEM file to the watershed boundary.

***SUGGESTED FILENAME: WATERSHED_CLIP***

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Hydrology
**Fill**

- Fill the DEM.

***SUGGESTED FILENAME: WATERSHED_FILL***

- Create a flow direction grid based on the filled DEM. The output cell size should be 1.

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Hydrology
**Flow Direction**

***SUGGESTED FILENAME: WATERSHED_FLOWDIR***

- Create a flow accumulation grid based on the flow direction grid. The output cell size should be 1.

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Hydrology
**Flow Accumulation**

***SUGGESTED FILENAME: WATERSHED_FLOWACC***

- Create a slope grid based on the filled DEM. The output cell size should be 1.

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Surface
**Slope**

***SUGGESTED FILENAME: WATERSHED_SLOPE***

- Open Raster Calculator.
- Input the following into the Raster Calculator.

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Map Algebra
**Raster Calculator**

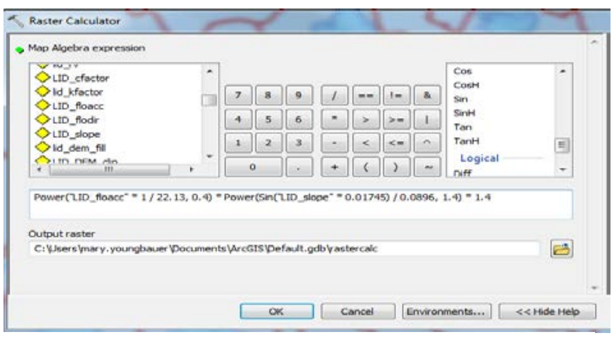

*Figure 10. Raster Calculator*

Power(“Watershed_flowacc” * 1 / 22.13, 0.4) * Power(Sin(“Watershed_slope” * 0.01745) / 0.0896, 1.4) * 1.4

***SUGGESTED FILENAME: WATERSHED_LS***

*Helpful Hint: When using the Raster Calculator, **space and capitalization do matter**.*
*Use the buttons instead of typing into the box whenever possible.*

- Condition the LS grid that was just created to equalize outliers. This step is required because RUSLE is not as accurate at calculating long slopes, gullies, or stream bank erosion. The Flow Accumulation grid gives extremely high values in these areas and needs to be corrected. Per the NRCS LS Factor chart, the LS grid values over 20 were changed to equal 20.
- Open the Raster Calculator.
- Input the following into the Raster Calculator.

Con(“Watershed_LS” > 20, 20)

***SUGGESTED FILENAME: WATERSHED_LS_CON***

- Check the output raster. Most pixels should read “No Data” when using the Identify Tool. The pixels that were originally higher than 20 (generally located around streams, gullies, and extreme slopes) should all read 20.
- Create Position Raster next. Open Raster Calculator.
- Input the following into the Raster Calculator.

Con(“Watershed_LS” > 20, 2, Con(“Watershed_LS” <= 20, 1))

***SUGGESTED FILENAME: WATERSHED_LS_POS***

- Check the output raster. There should only be two values, either 1 or 2.
- Create the Pick Raster. Open the Raster Calculator.
- Input the following into the Raster Calculator.

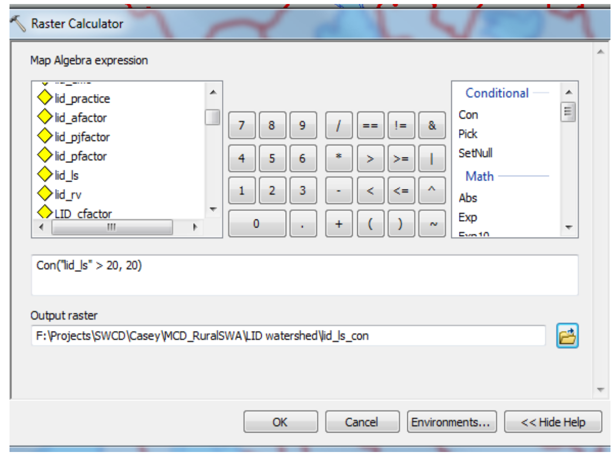


*Figure 11. LS Conditioning*

Pick(“Watershed_LS_POS”, [“Watershed_LS”, “Watershed_LS_CON”])

***SUGGESTED FILENAME: WATERSHED_LS_FACTOR***

- Check the output raster. No values should exceed 20. This is the raster that will be used in the RUSLE calculation as the LS Factor.

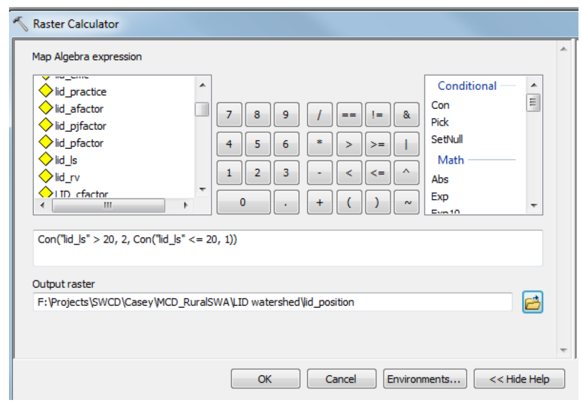


*Figure 12. LS Position Raster*

### 6.2.4 Create C Factor Raster

The C Factor represents the land cover management (NOT land use). A good land cover shapefile will be used as cover management for this project. If a good land cover layer does not exist for the watershed, it may be easiest to create one. **See Appendix A - Land Cover Layer** for more information on determining what makes a good land cover layer and how to create one.

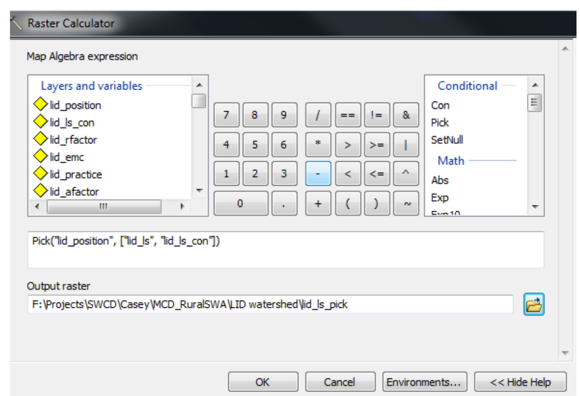


*Figure 13. LS Pick Raster*

- Create a dBASE table with assigned C factor, RV factor, and EMC factor for each cover type in your cover type file. **See Appendix C - Determining C Factor, RV Factor, and EMC Factor Values** on how to find these factors. If a new land cover layer was created using the instructions in Appendix A - **Land Cover Layer**, use Table 2 for the appropriate values.

**Tool Path**
ArcCatalog
Right Click on folder
New
**dBASE Table**

*Table 2. Cover Type Values for R, RV, EMC Factors*

| Cover Type | C Factor | RV Factor | EMC Factor |
|---|---|---|---|
| **Open Water** | 0 | 0 | 0 |
| **Corn or Beans** | 0.2 | 0.5 | 1.486 |
| **Hay** | 0.02 | 0.45 | 0.3 |
| **Pasture** | 0.02 | 0.45 | 0.856 |
| **Wooded Wetland** | 0.003 | 0.4 | 0.051 |
| **Wetland** | 0.003 | 0.45 | 0.29 |
| **Forest** | 0.003 | 0.4 | 0.051 |
| **Herbaceous** | 0.02 | 0.45 | 0.29 |
| **Barren** | 0.45 | 0.5 | 0.8 |
| **Developed Low Intensity** | 0.15 | 0.3 | 0.5 |
| **Developed Medium Intensity** | 0.26 | 0.4 | 0.8 |

- Once created, the new dBASE table will show up in the Table of Contents List By Source view. Open the new dBASE table.
- Before turning editing on, add the appropriate columns to the table (C Factor, RV Factor, and EMC Factor).
- Start editing by right clicking on the dBASE table, scroll down to Edit Features, and select Start Editing. Populate the table with the values from Table 2. Save edits and stop editing.
- Join the cover type shapefile with the new dBASE table. Use the cover type as the linking column between the tables.
- Create a raster using Feature to Raster. The Input Feature is the land cover file. The Field is C Factor. Change the output cell size to 1.

**Tool Path**
ArcToolbox
Conversion Tools
To Raster
**From Feature**

***SUGGESTED FILENAME: WATERSHED_CFACTOR***

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Raster Creation
**Create Constant Raster**

### 6.2.5 Create P Factor Raster

The P Factor is the conservation practice factor. For this calculation, the P Factor will be a constant across the watershed. This will assume that the conservation practices are the same across the watershed (no conservation).

- Create a constant raster with the value of 1. Change the output cell size to 1.
- In the environments tab, set the output coordinates and the processing extent to the watershed border.
- Because there is also a P Factor in the Simple Method calculation, but it is not the same value, it is best to name this output something other than P Factor.

***SUGGESTED FILENAME: WATERSHED_PRACTICE***

### 6.2.6 Create RUSLE Calculation Raster

This step runs the actual calculation of all the rasters that were just created. The output will be a value that represents the potential soil loss for each pixel in tons per acre per year.

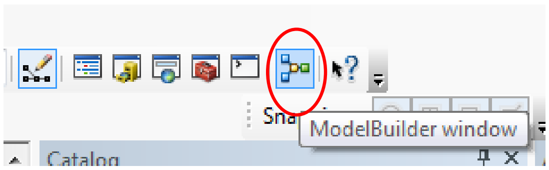


*Figure 1. Model Builder Icon*

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Math
**Times**

- Open ModelBuilder in ArcMap.
- Open ArcToolbox. Drag Times from ArcToolbox into the blank white model space. A new white "Times" box and an "Output Raster" oval should appear (Figure 15. Insert Times Function).
- Double click on the "Times" Box. A prompt box will appear.
- Input the appropriate rasters until the model looks like Figure 16.

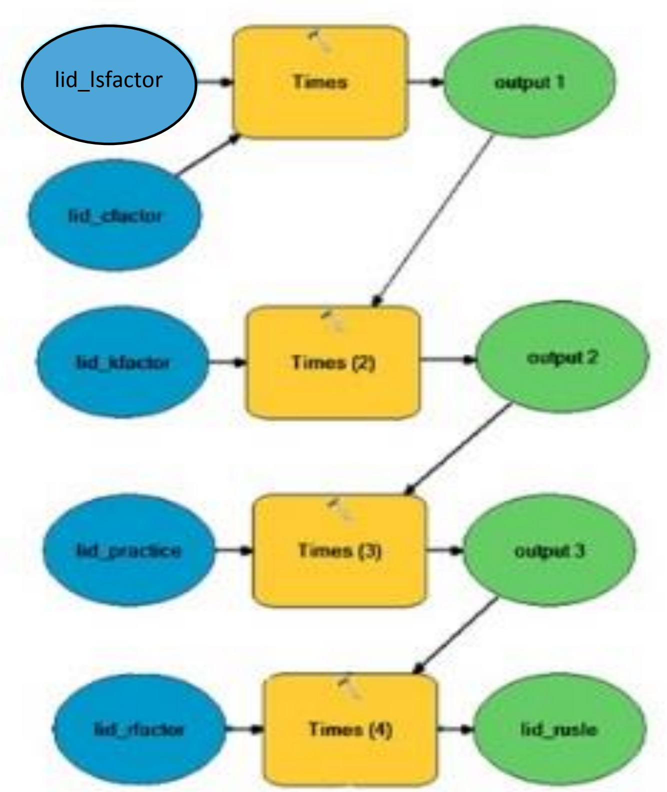


*Figure 3. RUSLE Model*

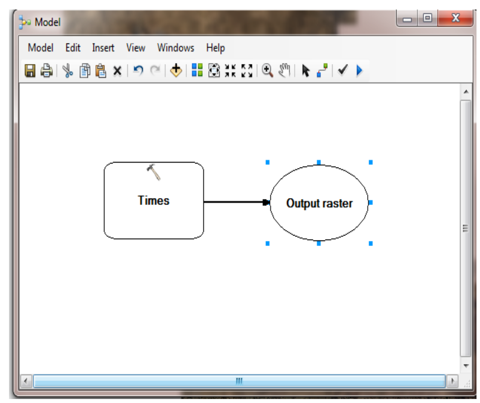


*Figure 2. Insert Times Function*

***SUGGESTED FILENAME: WATERSHED_RUSLE***

*Helpful Hint: There is no need to save the output rasters for Output 1, 2, and 3 as a special name. Be sure to save the final output to the same location as the other rasters created for the other factors and name it appropriately.*

- Right click on the green bubble that was created last (Watershed_RUSLE). Select "Add to Display".
- Run the Model. The new raster should appear in the Table of Contents.

#### 6.2.7 Delivery Ratio

This step is included in the Top50P! protocol, but may not be required in all watersheds. The delivery ratio is a score assigned to each subwatershed or catchment to denote if it is a contributing or non-contributing subwatershed or catchment to a certain body of water. The Top50P! protocol assigned a score of 0 for non-contributing subwatersheds, a score of 0.5 to subwatersheds that contribute but pass through some sort of treatment, and a score of 1 for contributing subwatersheds. For the rural subwatershed assessments done in Chisago, this step was not used because all subwatersheds were determined to be contributing.

- Open the Attribute Table for the shapefile with the subwatersheds or catchments.
- Add a column titled "Del Ratio" to the Attribute Table.
- Start editing. Assign the appropriate number (0, 0.5, or 1) to each subwatershed or catchment.
- Save edits and stop editing.
- Create a raster using the Feature to Raster tool. The Input Feature is the subwatershed or catchment layer. The Field is "Del Ratio". Change the output cell size to 1.

**Tool Path**
ArcToolbox
Conversion Tools
To Raster
**From Feature**

***SUGGESTED FILENAME: WATERSHED_DELRATIO***

- Open Raster Calculator and input the following formula:

"Watershed_RUSLE" * "Watershed_Delratio"

***SUGGESTED FILENAME: WATERSHED_RUSLE_DR***

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Map Algebra
**Raster Calculator**

### 6.3 Simple Method Analysis

The Simple Method is another method for estimating stormwater runoff pollutant loads. The output is a measurement of phosphorus in pounds per year. The simplest form of the equation is listed below:

L = 0.226 * R * C * A

L = Annual load in pounds per year
R = Annual runoff in inches
C = Pollutant concentration in mg/l
A = Area in acres
0.226 is a unit conversion factor

To get a value for R, an equation is needed. It is listed below:

R = P * Pj * Rv

R = Annual runoff in inches
P = Annual rainfall in inches
Pj = Fraction of annual rainfall events that produce runoff (often 0.9)
Rv = Runoff coefficient

For this document, the formula for calculating the simple method has been adjusted to reflect the necessary calculations for R. The equation is listed below:

L = P * Pj * Rv * EMC * A * 0.226

L = Annual load in pounds per year
P = Annual rainfall in inches
Pj = Fraction of annual rainfall events that produce runoff (0.9)
Rv = Runoff coefficient
EMC = Event Mean Concentration in mg/l (C in original equation)

A = Area in acres
0.226 is a unit conversion factor

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Raster Creation
**Create Constant Raster**

### 6.3.1 Create P Factor Raster

This is **NOT** the same P Factor as the one in the RUSLE equation from above. In this equation, the P Factor is the annual rainfall in inches received in your watershed. For Chisago County, this is 30. This will be a constant raster.

- Create constant raster. Change the output cell size to 1.
- Click the environments tab and set the Output Coordinates and the Processing extent to the same as the watershed boundary file.

***SUGGESTED FILENAME: WATERSHED_PFACTOR***

### 6.3.2 Create Pj Factor Raster

This raster will also be a constant raster. The value is 0.9.

- Create constant raster. The output data type should be Float. Change the output cell size to 1.
- Click the environments tab and set the Output Coordinates and the Processing extent to the same as the watershed boundary file.

***SUGGESTED FILENAME: WATERSHED_PJFACTOR***

### 6.3.3 Create Rv Factor Raster

The Rv Factor is based on the land cover. The necessary information was added to the Attribute Table of the land cover file during the instructions for the RUSLE equation. If those steps were not completed, go back to Section 6.2.4.

- Open the Feature to Raster Tool.
- The Input Feature is the land cover shapefile that the new dBASE table was joined to in Section 6.2.4.
- The Field is Rv Factor.
- Change the output cell size to 1.

***SUGGESTED FILENAME: WATERSHED_RVFACTOR***

**Tool Path**
ArcToolbox
Conversion Tools
To Raster
**Feature to Raster**

#### 6.3.4 Create EMC Factor Raster

The EMC factor is also based on land cover. The necessary information was added to the Attribute Table of the land cover file in Section 4.2.4.

- Open the Feature to Raster Tool.
- The Input Feature is the land cover shapefile that the new dBASE table was joined to in Section 6.2.4.
- The Field is EMC Factor.
- Change the output cell size to 1.

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Raster Creation
**Create Constant Raster**

***SUGGESTED FILENAME: WATERSHED_EMCFACTOR***

#### 6.3.5 Create A Factor Raster

The A Factor is the portion of an acre that is found within a 1 meter by 1 meter cell area. To determine the number, divide the square meters (1 * 1 = 1) by the number of square meters in an acres (4046.86). This equals 0.0002471, which is the constant used in this protocol.

*Helpful Hint: If the cell size of your project is not 1 meter, compute this constant for your cell size. For example, 10 x 10 meter would be 100/4046.86.*

- Create a constant raster with the value of 0.0002471.
- Change the output cell size to 1.
- The output data type must be Float.
- Click the environments tab to set the Output Coordinates and Processing Extent to the same as the watershed border file.

***SUGGESTED FILENAME: WATERSHED_AFACTOR***

#### 6.3.6 Create Simple Method Calculation Raster

This step runs the actual calculation of all the rasters that were just created for the Simple Method. The output will be a value that represents the phosphorus loading for each pixel in pounds per year.

- Open ModelBuilder in ArcMap.
- Open ArcToolbox. Drag Times from ArcToolbox to the white open space in the ModelBuilder window. A "Times" box and an "Output Raster" oval should appear.
- Double click on the "Times" box to open the prompt box.
- Continue to build the model so it looks like Figure 17.
- For the last blue oval, input the number 0.226 instead of selecting a file. This is the unit conversion factor.
- Save the last output to the folder where the other rasters have been saved. Rename this file to something appropriate.
- Right click on this green bubble and select "Add to Display".
- Run the model.

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Math
**Times**

***SUGGESTED FILENAME: WATERSHED_SIMPLE***

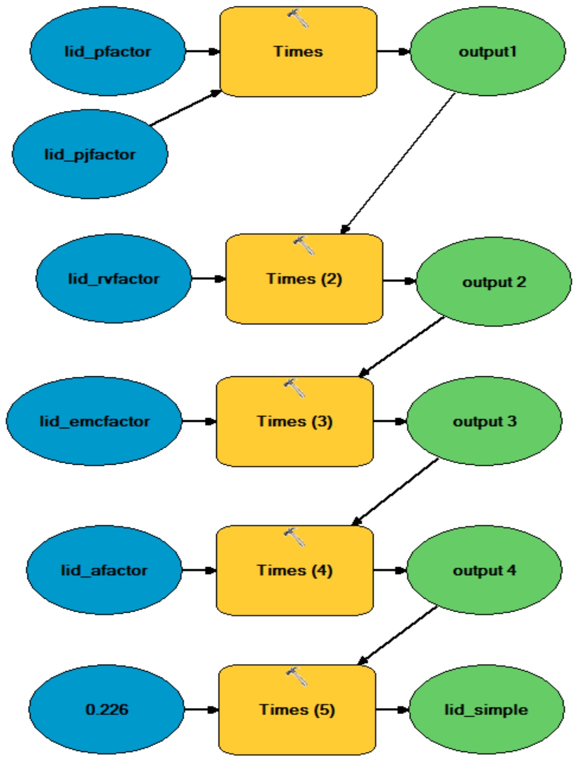


*Figure 17. Simple Method Model*

### 6.3.7 Delivery Ratio

Again, this step is included in the Top50P! protocol, but may not be required in all watersheds. The delivery ratio is a score assigned to each subwatershed or catchment to denote if it is a contributing or non-contributing subwatershed or catchment to a certain body of water. The Top50P! protocol assigned a score of 0 for non-contributing subwatersheds, a score of 0.5 to subwatersheds that contribute but pass through some sort of treatment, and a score of 1 for contributing subwatersheds. For the rural subwatershed assessments done in Chisago, this step was not used because all subwatersheds were determined to be contributing.

If the delivery ratio was included in the calculation for the RUSLE raster, follow this step to include it for the Simple Method raster as well. If the delivery ratio was not used before, skip this step.

- The raster "Watershed_Delratio" was already created in Section 6.2.7.
- Open Raster Calculator and input the following formula:

"Watershed_Simple" * "Watershed_Delratio"

***SUGGESTED FILENAME: WATERSHED_SIMPLE_DR***

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Map Algebra
**Raster Calculator**

## 6.4 Combine RUSLE and Simple Method Rasters

To incorporate both sets of data that was just produced through the RUSLE and Simple Method calculations, the two raster outputs need to be combined. However, they have greatly different values. To account for this discrepancy, the rasters need to be normalized so they represent an equal weight in the final output raster.

To provide equal weighting, the largest RUSLE value (or the largest RUSLE value from Watershed_RUSLE_DR if a delivery ratio was used) is divided by the largest Simple Method value (or Watershed_Simple_DR). Find these values by opening the Attribute Table for each raster. Sort the field that has the value and find the largest value.

In the project completed by Chisago County, the largest RUSLE value was 7020 and the largest Simple Method value was 0.0011203. To get the conversion factor, divide 7020 by 0.0011203.

Largest RUSLE Value (7020) / Largest Simple Method Value (0.0011203) =
6,266,178.70 (Conversion Factor)

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Map Algebra
**Raster Calculator**

- Apply the conversion factor to the Simple Method raster and add to the RUSLE raster (or to the Watershed_Simple_DR raster and Watershed_RUSLE_DR if delivery ratio was included).
- Open Raster Calculator.
- Input the following formula into the Raster Calculator:

("Watershed_Simple" * conversion factor) + "Watershed_RUSLE"

If delivery ratio was used: ("Watershed_Simple_DR" * conversion factor) + "Watershed_RUSLE_DR"

***SUGGESTED FILENAME: WATERSHED_FINAL***

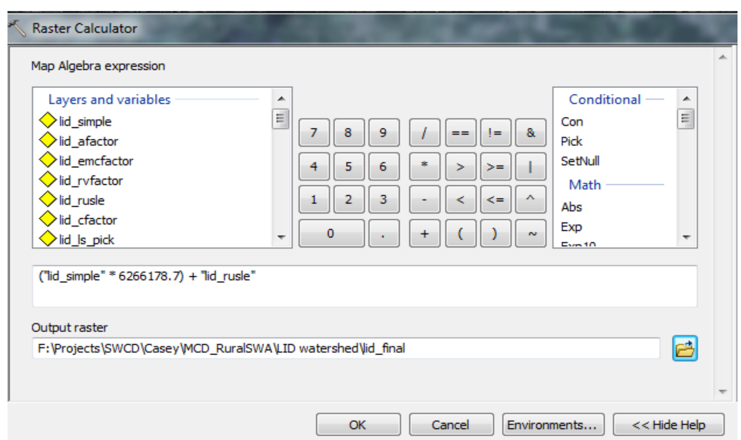


*Figure 18. Raster Calculator for Final Raster Creation*

## 6.5 Adding Stream Weighting

This step was not included in the Top50P! protocol. Adding a weighting factor to areas next to streams and ditches was added as a way to incorporate the distance to surface water into the equation. Distance to surface water is not accounted for in either the RUSLE or Simple Method formulas. This step is optional. This step is also flexible, depending on how important the distance to surface water is in the overall project.

There are a few things to consider when giving weight to stream-adjacent areas. Should all streams and ditches be included in the weighting, or only the perennial streams? What distance from a stream should be given additional weight? These questions can have a variety of answers and should be decided on a project-by-project basis. For the rural subwatershed assessments in Chisago County, all streams identified by the DNR and all ditches (identified by the GIS user) were included and a distance of 100 feet on either side of a stream or ditch was considered high priority.

*Helpful Hint: Some ditch information may be available from the County or potentially within the LiDAR geodatabase (for some areas only). It is also fairly easy to create a new shapefile and manually identify ditches. They are easily seen on aerial photos or by using the hillshade.*

**Tool Path**
Geoprocessing Menu
Buffer

- Open the Buffer Tool.
- The Input Feature should be the stream and ditch layer.
- This output (Figure 19) will be a template for creating a raster in the next steps.
- Create a new shapefile (see Appendix D - Creating a New Shapefile for instructions). Copy the watershed boundary into the new shapefile. Begin editing the new shapefile.

*Figure 19. Stream Weighting Buffer*

***SUGGESTED FILENAME: WATERSHED_BUFFER***

- Use the Trace tool to trace around the outside of the stream buffer within the watershed boundary to create distinct polygons ("buffered" and "non-buffered"). The "buffer area" around the streams and ditches should be one polygon. "Non-buffer areas" should be a separate polygon(s).

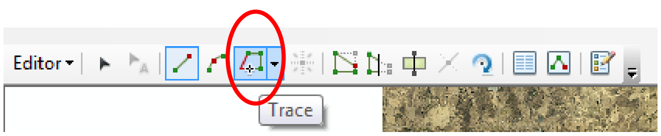


*Figure 20. Trace Tool*

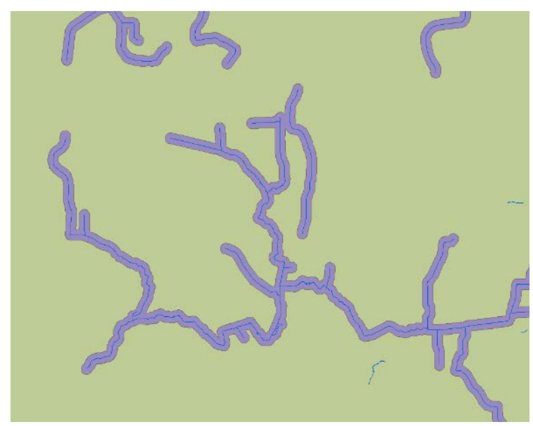

*Figure 21. Stream Weight Raster*

- Stop editing. Add a column to the Attribute Table called "Value".
- Begin editing. In the Attribute Table, give a value of 1 to all the polygons that are not within the stream buffer area (do not use zero because this value will be used in an equation in the next step and a zero is not valid). Give a weighting value to the polygons that are within the buffer area. For the Chisago County rural subwatershed assessment, a value of 200 was used. Stop editing.

*Helpful Hint: Consider the range of values that exist in the Final Raster. Choose a stream weight value somewhere within this range, depending on how much weight you want to place on the distance to surface water. The higher the value, the more weight those stream buffer areas will have and the higher priority they will show in the final output.*

- Create a raster using the weighting just assigned. Open the Feature to Raster prompt box.
- The Input Feature is the buffer shapefile that was just created.
- The Field is the field in the Attribute Table that gives the weighting to the buffer areas. There should only be two values (1 or 200 for Chisago).
- Choose the location for the output raster.

**Tool Path**
ArcToolbox
Conversion Tools
To Raster
**Feature to Raster**

***SUGGESTED FILENAME: WATERSHED_SWEIGHT***

- The stream weighting then needs to be applied to the whole subwatershed or catchment. Open Raster Calculator.
- Input the following into the Raster Calculator:

("Watershed_Final" * "Watershed_Sweight")

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Map Algebra
**Raster Calculator**

***SUGGESTED FILENAME:WATERSHED_FINAL_WEIGHTED***

## 6.6 Apply Zonal Statistics to Final Raster

The output raster named Watershed_Final (or Watershed_Weighted if stream weighting was used) will display a range of values. This value is the equally-weighted combination of the RUSLE and Simple Method equations. The value is unit-less. The highest values are the areas where there is the most potential for soil loss and phosphorus loading. The lowest values are the areas where there is the least potential for soil loss and phosphorus loading. The display likely looks similar to the land cover shapefile. It is easy to pick out fields that are of high value.

The goal of this targeting process was to determine the subwatershed or catchment to focus BMP work in. The final raster in itself highlights a patchwork of high priority areas, but does not translate this into which subwatersheds or catchments should be at the top of the priority list. To do this, the Zonal Statistics Tool is needed.

- Open the Zonal Statistics prompt box.
- The Input Raster is the shapefile with the subwatershed or catchments within the larger watershed.
- The Zone Field should be a unique identifier (for example, ID).

*Helpful Hint: It may be useful to edit the Attribute Table of the subwatershed or catchment layer to include a column that has a unique identifier for each subwatershed or catchment. It could be a number or the name of the subwatershed or catchment.*

**Tool Path**
ArcToolbox
Spatial Analyst Tools
Zonal
**Zonal Statistics**

- The Input Value Raster is the Watershed_Final (or Watershed_Weighted) raster that was created.

***SUGGESTED FILENAME: WATERSHED_ZONAL***

The Zonal Statistics output should assign a value to each of the subwatershed or catchments. Compare Figure 22 and Figure 23 to see how Zonal Statistics takes the Final Raster and uses it to assign a value to the larger subwatershed or catchment. This is the priority ranking that should dictate where to begin working first.

Use the property display options of the raster to visually rank the subwatersheds or catchments from highest to lowest value. Right click on the Watershed_Zonal raster in the Table of Contents. Select Properties. Click the Symbology tab. In the left hand column, select Unique Values. Click yes if there is a pop-up box. Change the color scheme to a color ramp and select ok.

Rasters can be difficult to transfer to other projects. It is recommended that you create a shapefile of the zonal statistics raster.

- To do so, open the Raster to Polygon tool.
- The input raster is the Watershed_Zonal raster.
- The optional Field box should not need to be filled in.
- In the Output polygon Features box, select the folder location for storing the new shapefile. Click ok.

*If the shapefile does not come out showing the same ranking as the raster did (consider the actual values of each polygon, not just the way it is displayed), try to re-run the tool. This time, in the Optional Field box, select the field that has the raster value (there should only be two options, FID and one other-choose the other one).*

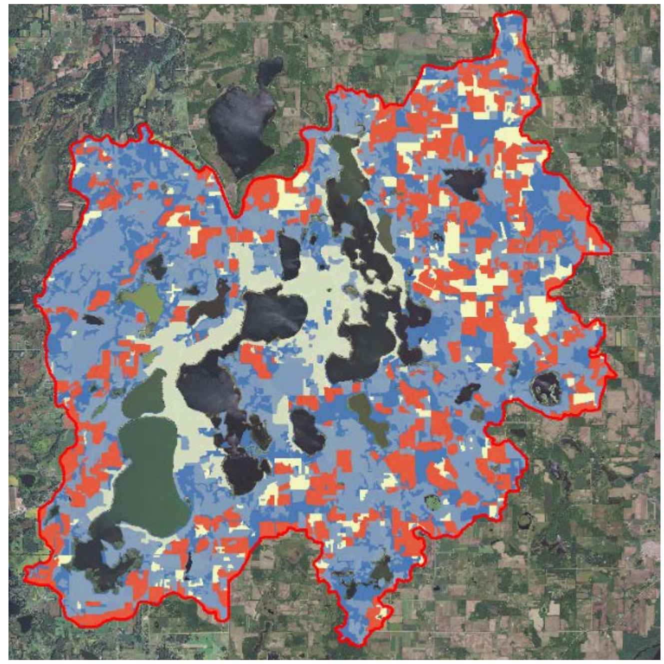

*Figure 22 Example Final Raster*

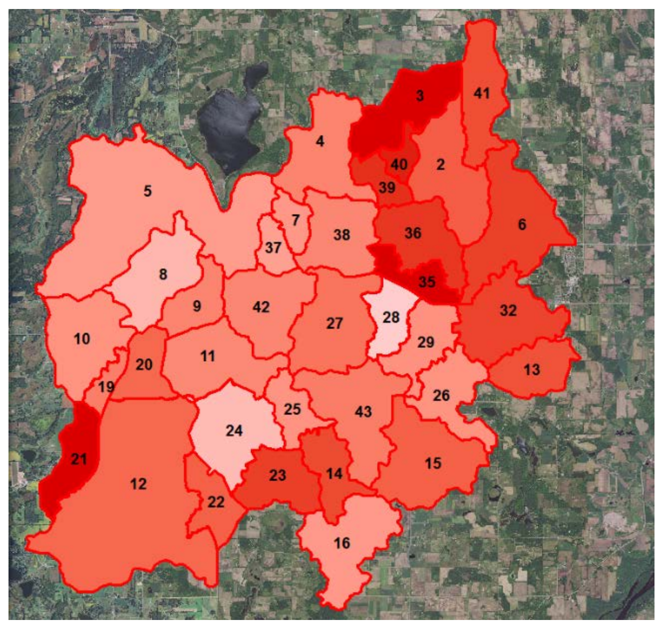


*Figure 23 Example Zonal Statistics by Subwatershed or Catchment*

**Tool Path**
ArcToolbox
Conversion Tools
From Raster
**To Polygon**

It may be useful to lump together some subwatersheds or catchments into a larger area for the next part of this process. Lump together subwatersheds or catchments of similar ranking. For Chisago County, the SWAT catchments within the Chisago Lakes Chain of Lakes watershed were ranked (Figure 24) and then lumped into larger "levels" (Figure 25). The highest priority section (Level 1 in Figure 25) was the first section to be analyzed in depth following the next steps of this protocol.

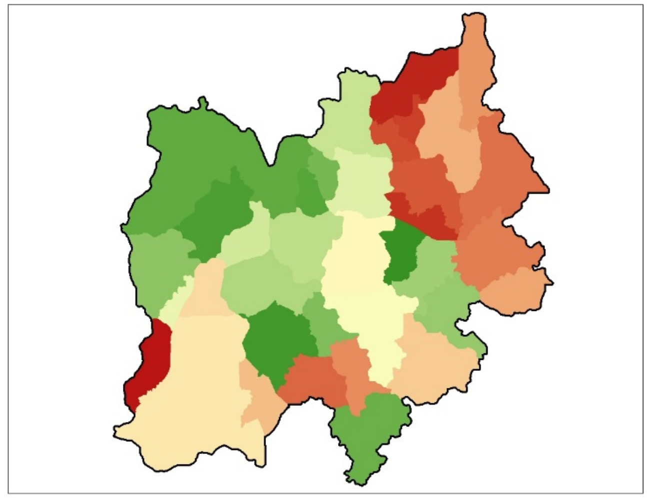

*Figure 24 Target Catchments within the Chisago Lakes Chain of Lakes Watershed*

# 7 Part 2: Prioritizing

This concludes the Targeting portion of the rural subwatershed assessment protocol. To continue, start Part 2: Prioritizing. The prioritizing portion will guide you through individual BMP identification, modeling, ranking, and final reporting.

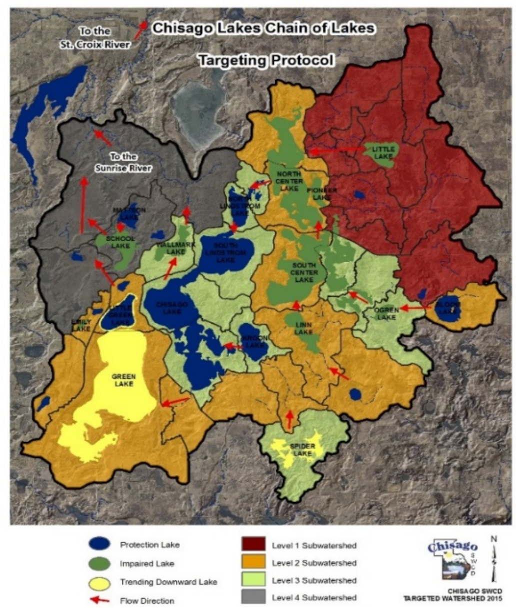


*Figure 25 Lumping of Like Catchments*

# Appendix A

## 8 LAND COVER LAYER

There are a few considerations to take into account when deciding if an existing land cover layer will work for a project, or if a new layer should be created. Some existing layers are actually depicting “land use” rather than “land cover”. This would indicate what is being done on the land, or how it is being used (farming, pasture, residential) versus recording the vegetation that is on the land (row crop, oak forest, wetland).

In some areas of Minnesota, the Minnesota Land Cover Classification System has been used to map and digitally record land cover. The value of this layer for this project depends highly on the quality of the data in the project area. The mapping was completed by many different mappers at different levels of detail. The way the polygons were mapped may not meet the needs of this project.

One of the possible outcomes of the rural subwatershed analysis protocol is a profile page with a specific identified field and the suggested BMPs shown. This page can be taken with to meet with a landowner and used to explain why that landowner has been targeted. If this is the goal, the land cover layer should be built to delineate fields by landowner or operator.

### 8.1 CREATING A NEW LAND COVER LAYER

For the purposes of this protocol, the following land covers were used to create a new shapefile.

- Open Water
- Corn or Beans
- Hay
- Pasture
- Wooded Wetland
- Wetland
- Forest
- Herbaceous
- Barren
- Developed Low Intensity
- Developed High Intensity

*Helpful Hint: When creating the new polygon, use the Trace tool on the Editor toolbar to trace the outline of the watershed. Then use the cut tool to break the large polygon into smaller polygons. This eliminates the need to go through the topology process.*

When delineating a field, it is recommended to separate fields by annual row crop cover (corn or beans usually) or permanent vegetation cover (usually hay). While this can change, fields are often in hay for several years in a row or permanently. Making this distinction helps to determine if a field is a high priority in the final report.

It is also suggested to delineate fields by land owner. For example if a large contiguous field is owned by more than one person, it is suggested that the field be split into smaller polygons where the ownership changes. This is helpful for making a project profile that shows one landowner’s field only, rather than also showing the neighboring property.

# Appendix B

## 9 Example Targeting Outputs

The following are examples of what the output rasters should look like after completing the RUSLE and Simple Method operations. Please note that the colors may be different. The coloration is a reflection of the display only and can be changed by right clicking on the layer in the Table of Contents, selecting Properties, opening the Symbology tab, and changing the settings. If the settings need to be a certain way to display correctly for any of the steps in this document, instructions will be given. Otherwise, the display is the default.

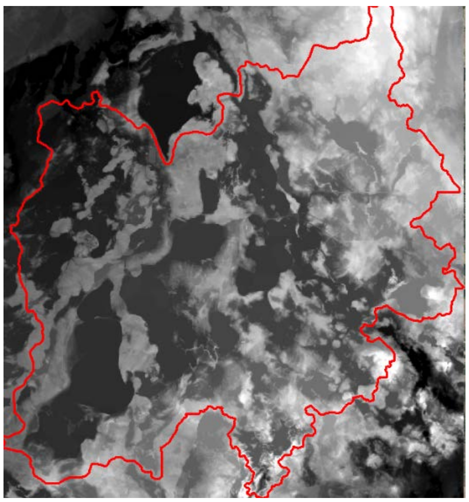

*Figure 26. Digital Elevation Model*

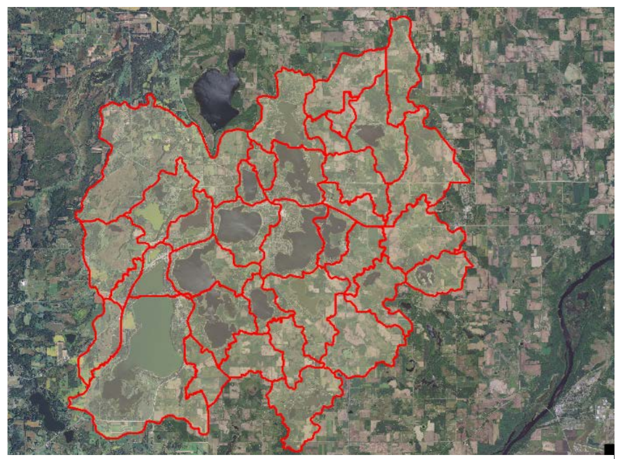

*Figure 27. Watershed and Subwatershed or Catchment Delineation*

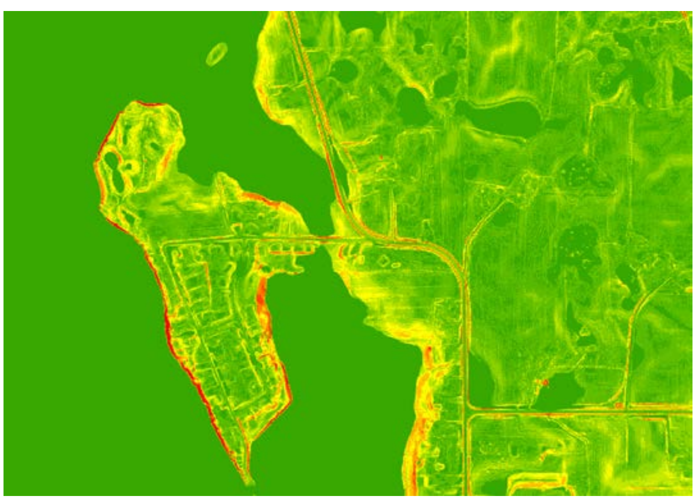

*Figure 28. Slope Grid Zoomed In*

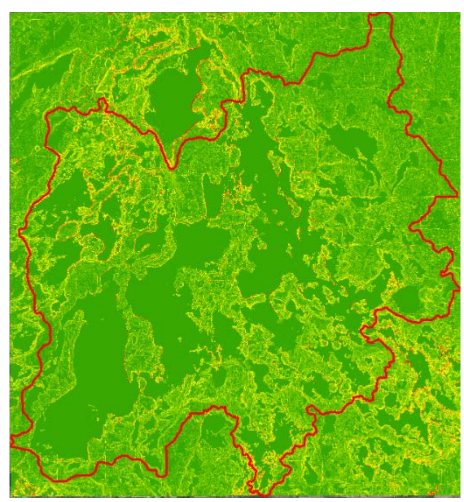

*Figure 29. Slope Grid*

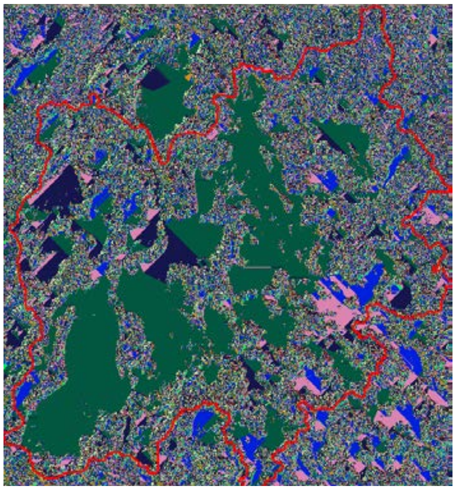

*Figure 30. Flow Direction Raster*

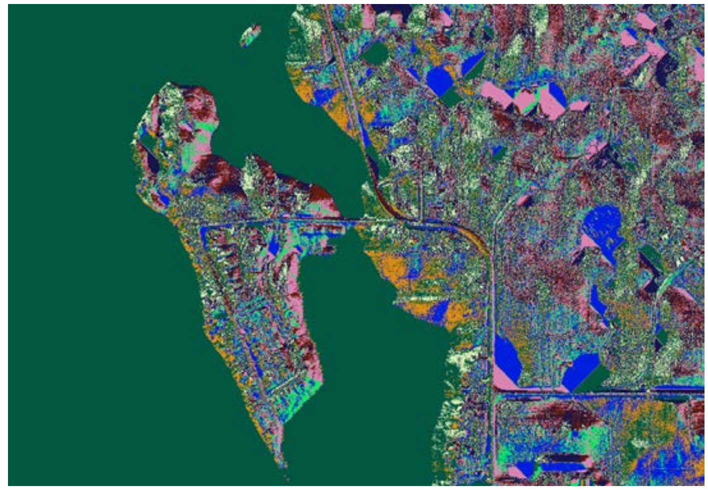

*Figure 31. Flow Direction Raster Zoomed In*

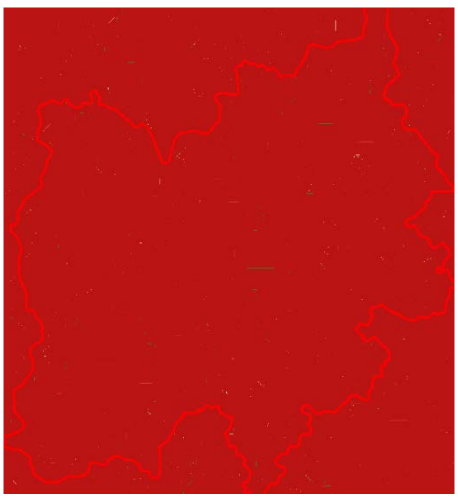

*Figure 32. Flow Direction Raster*

*Helpful Hint: The Flow direction Raster will appear to be all the same color at first glance. This is due to a few locations have extremely high values, which are highlighted a different color. The majority of the values are low and show up as the same color. Zoom in to find some of the different colored pixels to make sure the raster processed correctly.*

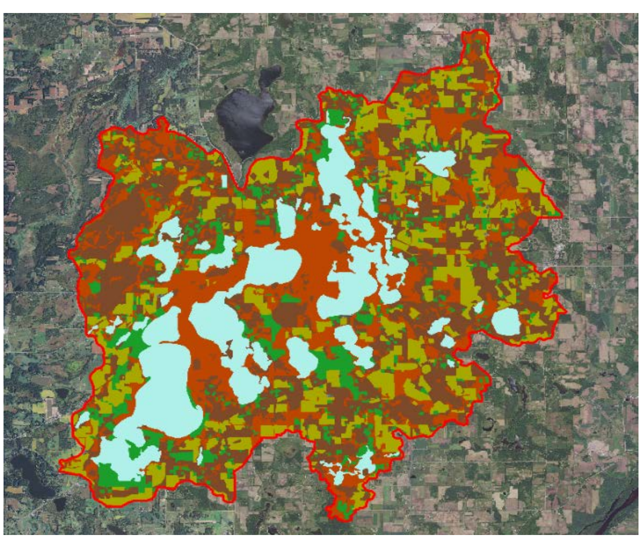

*Figure 33. RV Factor Raster*

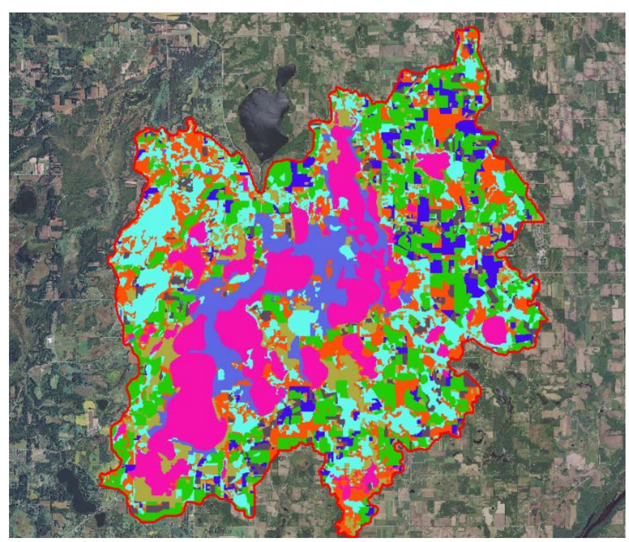

*Figure 34. EMC Value Raster*

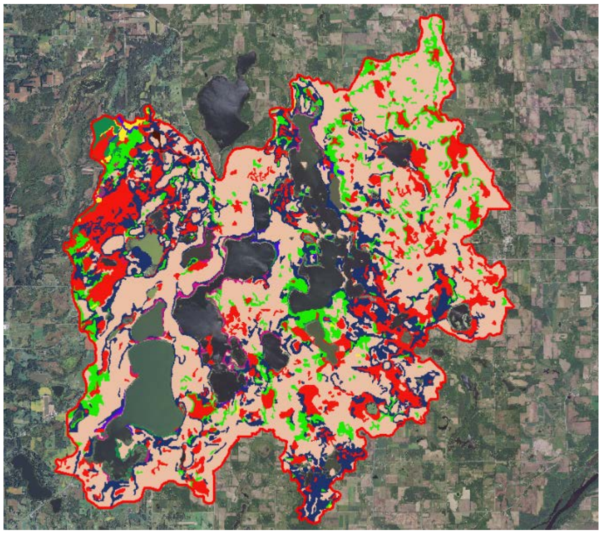

*Figure 35. K Factor Raster*

*Figure 36. Constant Raster*

*Helpful Hint: All of the constant rasters will look the same (P Factor, Practice Factor, R Factor, PJ Factor, A Factor).*

*Figure 37. LS Con Grid*

*Helpful Hint: This grid only shows the pixels with a value over 20. It may take some manipulation to see the pixels on your screen.*

*Helpful Hint: This grid will be mostly one color, with a few pixels of another color. The only values should be 1 or 2.*

*Figure 38. LS Position Grid*

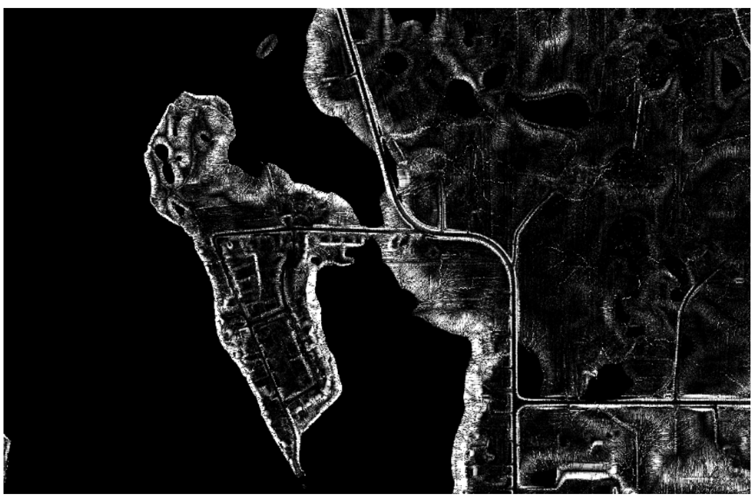

*Figure 39. LS Factor Pick Grid Zoomed In*

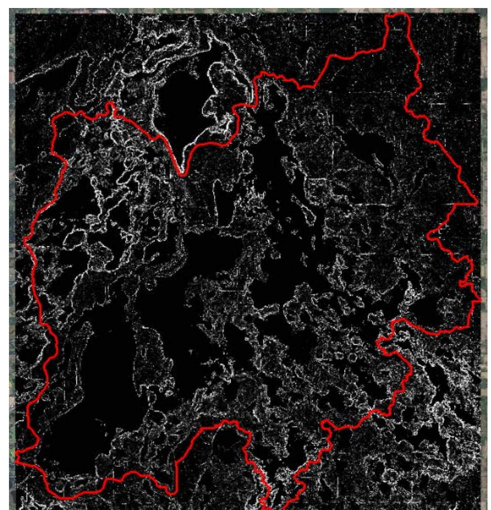

*Figure 40. LS Factor Pick Grid*

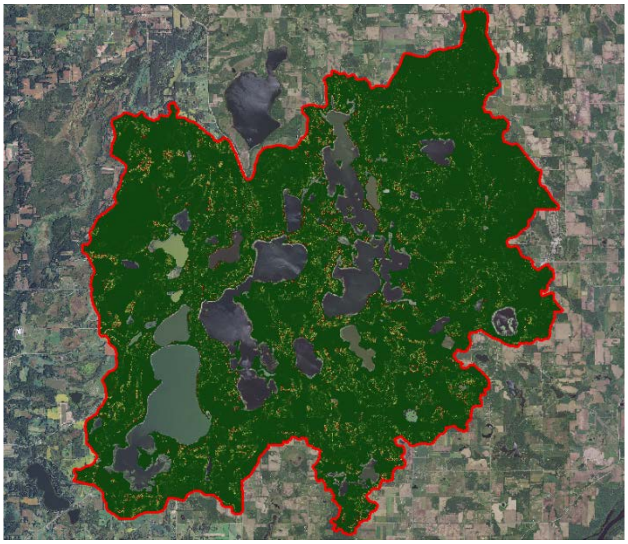

*Figure 41 RUSLE Raster*

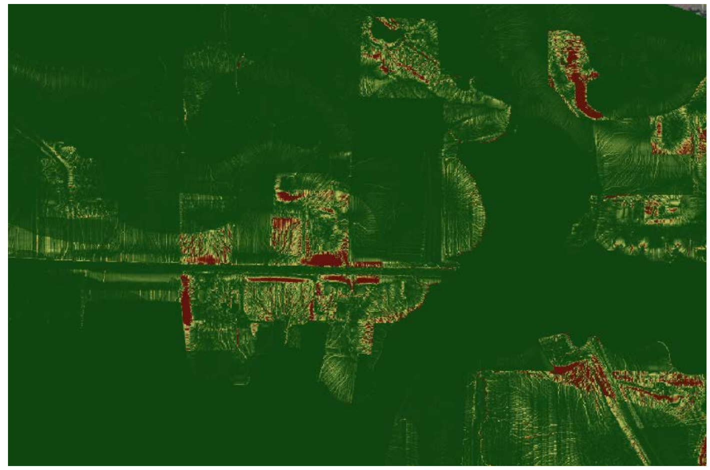

*Figure 42 RUSLE Raster Zoomed In*

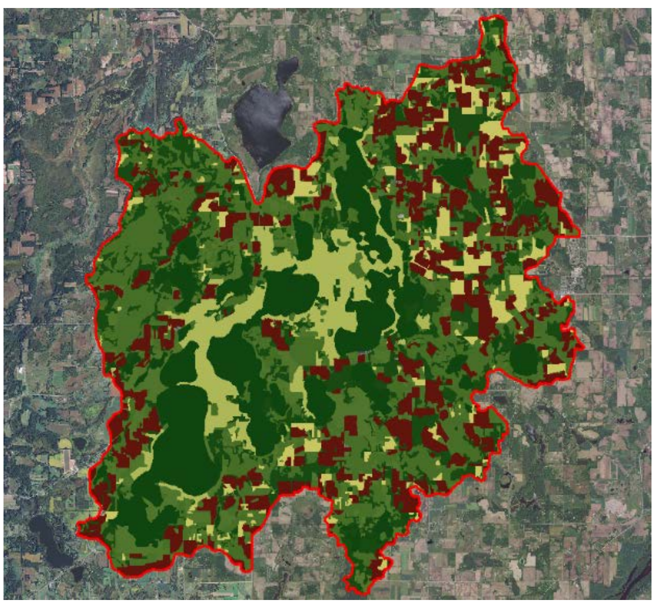

*Figure 43 Simple Method Raster*

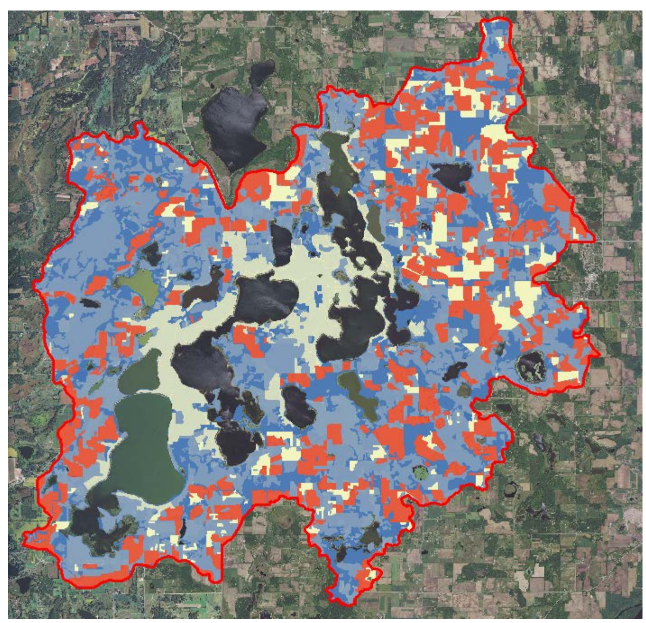

*Figure 44 Final Weighted Raster*

# Appendix C

## 10 Determining C Factor, RV Factor, and EMC Factor Values

During the development of this protocol, the C Factor, RV Factor, and EMC Factors were not included in any of the land cover layers available for Chisago County. A new land cover shapefile was created for this project (see Appendix A for instructions) and C Factor, RV Factor, and EMC Factors were assigned.

### 10.1 C Factor

- Page 83 of the document found at http://mrbdc.mnsu/edu/sites/mrbdc/mnsu/edu/files/public/pub/midminn/reports/sevenmile/chr_all.pdf lists C Factors for a few of the land cover types included in the land cover file created for this project. The data at this site is for Minnesota. The following C Factor values were taken from this source.
- NRCS staff assigned the C factor for Corn and Beans.
- Professional judgment was used to assign the remaining C Factor values based on the most similar cover type.

*Table 3. C Factors Values*

| Cover Type | C Factor | Source Notes | Source |
|---|---|---|---|
| **Open Water** | 0 | Lakes and deeper wetlands | PDF document |
| **Corn and Beans** | 0.2 | After beans, 20% residue, fall mulch till | NRCS staff |
| **Hay** | 0.02 | Same as Herbaceous | Professional Judgment |
| **Pasture** | 0.02 | Same as Herbaceous | Professional Judgment |
| **Wooded Wetland** | 0.003 | Same as Forest | Professional Judgment |
| **Wetland** | 0.003 | Same as Forest | Professional Judgment |
| **Forest** | 0.003 | Deciduous forest | PDF document |
| **Herbaceous** | 0.02 | Grassland/CRP/Shrubs | PDF document |
| **Barren** | 0.45 | Exposed soil, sandbars, dunes | PDF document |
| **Developed Low Intensity** | 0.15 | Farmsteads and other rural development | PDF document |
| **Developed Medium Intensity** | 0.26 | Urban and industrial | PDF document |

### 10.2 RV Factor

- The RV Factor values were taken from the Minnesota DOT's runoff coefficients from the Drainage Manual (August 30, 2000), Chapter 3 Hydrology. Section 3.5.3 has a table with Runoff Coefficients for Rational Formula. Table 4 shows the RV Factor value that was chosen for each cover type for Chisago County. Each subwatershed or catchment may be different.

*Table 4. RV Factor Values*

| Cover Type | RV Factor | Source Notes |
|---|---|---|
| **Open Water** | 0 | |
| **Corn and Beans** | 0.5 | Rural; Below average infiltration rates; **Cultivated** |
| **Hay** | 0.45 | Rural; Below average infiltration rates; **Pasture** |
| **Pasture** | 0.45 | Rural; Below average infiltration rates; **Pasture** |
| **Wooded Wetland** | 0.4 | Rural; Below average infiltration rates; **Woodland** |
| **Wetland** | 0.45 | Rural; Below average infiltration rates; **Pasture** |
| **Forest** | 0.4 | Rural; Below average infiltration rates; **Woodland** |
| **Herbaceous** | 0.45 | Rural; Below average infiltration rates; **Pasture** |
| **Barren** | 0.5 | Rural; Below average infiltration rates; **Cultivated** |
| **Developed Low Intensity** | 0.3 | Residential; Single-family areas |
| **Developed Medium Intensity** | 0.4 | Residential; Multi-units; Detached |

## 10.3 EMC Factor

- The values for the EMC Factor were taken from the City of Savage's Non-degradation Report, Step 4.
- Remaining values were assigned using professional judgment based on the most similar cover type.

*Table 5. EMC Factor Values*

| Cover Type | EMC Factor | Source Notes | Source |
|---|---|---|---|
| **Open Water** | 0 | | Professional Judgment |
| **Corn and Beans** | 1.486 | Table 2b; Row Crops, Median | City of Savage |
| **Hay** | 0.3 | | Professional Judgment |
| **Pasture** | 0.856 | Table 2b; Pasture, Median | City of Savage |
| **Wooded Wetland** | 0.051 | Table 2c; Woods, Median | City of Savage |
| **Wetland** | 0.29 | Table 2c; Open Space, Median | City of Savage |
| **Forest** | 0.051 | Table 2c; Woods, Median | City of Savage |
| **Herbaceous** | 0.29 | Table 2c; Open Space, Median | City of Savage |
| **Barren** | 0.8 | | Professional Judgment |
| **Developed Low Intensity** | 0.5 | | Professional Judgment |
| **Developed Medium Intensity** | 0.8 | | Professional Judgment |

# Appendix D

## 11 Creating a New Shapefile

The best way to create a new shapefile in your project is to use ArcCatalog. ArcMap should be open to the project that requires a new shapefile.

- Click on the ArcCatalog button to open ArcCatalog.
- In the Catalog window, navigate to the location of the project that is currently open. You may want to create a new folder to hold the project and the new shapefile(s) you are going to create, if you don't already have one.
- In the Catalog, right click on the folder where you'd like to store the new shapefile. Select New and then Shapefile. A dialog box will open (Figure 46).
- Enter a name for your new shapefile.
- In the dropdown menu, choose between Point, Polyline, or Polygon.
- Click the Edit button to set the correct coordinate system for your project.
- Then click OK. The new shapefile should appear in the Table of Contents window.

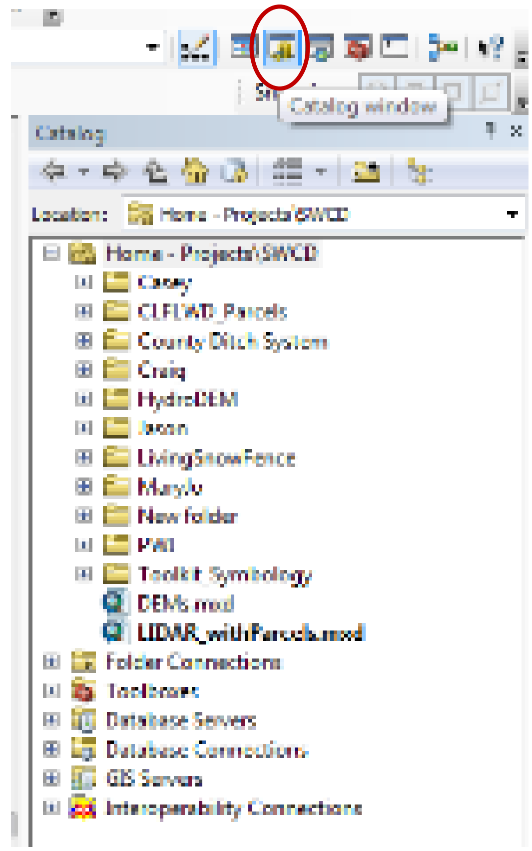


*Figure 45 ArcCatalog*

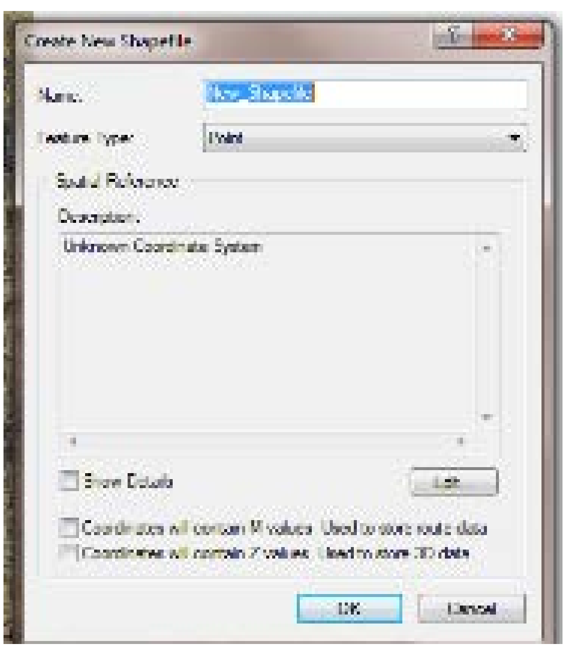


*Figure 46 New Shapefile*

# Appendix E

## 12 Troubleshooting

There are numerous places where problems can occur. ArcMap seems to have good days and bad days. The program and its tools are dependent on the inputs of the user and sometimes simply don't work for reasons unknown. This is why it is very important to check the outputs and make sure they seem logical. This section will list some areas that commonly caused problems during the development of this protocol. This by no means is a complete list. When a program simply isn't working, try closing and re-starting. If that doesn't work, try it another day. Sometimes, it works!

### 12.1 Targeting

During the targeting desktop work, many rasters are being created. It is important to check each one to make sure it seems correct. Compare the raster with the example output rasters in Appendix B.

#### 12.1.1 Raster Definition/Cell Size

The instructions in this document are all based on using a 1 meter x 1 meter DEM. If the rasters being created seem too rough or too fine, double check the cell size of the DEM you are using. It may be 10 meter by 10 meter, or 30 meter by 30 meter. If this is the case, you need to change the Output Cell Size to match your DEM in all of the steps.

To check the cell size, right click on the DEM layer and click Properties. Under the Source Tab, find the line that says Cell Size. It should say 1 (or 10, or 30). You can also use this to double check your output rasters for cell size. If they don't say 1, re-create the rasters and make sure that the Output Cell Size box says 1. For some reason, you may have to click in the box and type 1 even if there is already a 1 there because it seems to default to creating a raster with cell size of 60 if you don't.

#### 12.1.2 Raster Calculator

If you are getting errors when using the raster calculator, there is probably an error in the equation. The raster calculator is extremely sensitive and the equation must be exact for the calculation to work. Whenever possible, input the equation using the buttons at the top of the calculator. This puts the correct spacing in for you.

Some days the raster calculator just seems to not work. Try again another day.

#### 12.1.3 Raster Project

If the rasters you create are not projecting correctly (for example, they show up in some place far away from your project area), delete that raster and create a new one. In the prompt box, there is a tab labeled Environments. Click the tab to open another prompt box. Under Processing Extent, there is a drop down menu. There are many options listed. Choose the option that says "Same as…and then lists your watershed border shapefile". Do the same thing under the Output Coordinates menu. This should correct the projection issue. It seems like this is necessary in some tools but not others. Try creating the raster without manipulating the Environments first, but if the output raster doesn't project, then try this solution.