Rural Subwatershed Analysis Protocol

PART 2-PRIORITIZING

CREATED BY THE CHISAGO SOIL & WATER CONSERVATION DISTRICT

Version 2.0 March 2022

1 CONTENTS

Version 2.0 March 2022

Version 2.0 March 2022

Version 2.0 March 2022

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 developed by the Chisago Soil and Water Conservation District (SWCD) for Rural Subwatershed Assessment (Rural SWA).

The original protocol was developed in 2015. An updated protocol was completed in 2022. The update is for ArcGIS version 10.7, which has some different prompts and graphics than ArcGIS 10.1 (which is what the original protocol used).

This is PART 2 of a 2-part document. Part 1: Targeting describes the protocol for targeting the subwatershed or catchment of highest priority. Part 2: Prioritizing describes prioritizing and identifying specific projects within the targeted subwatershed or catchment.

3 TOP 50P! PROJECT

In 2014, the Washington Conservation District developed the Fixing the Top 50 Rural Nonpoint Phosphorus Sources Project (Top50P!). This project was 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 Assessment.

This protocol is a step-by-step guide for completing a Rural Subwatershed Assessment as developed by the Chisago Soil and Water Conservation District (SWCD). It uses Top50P! as a starting base and adds detailed instruction, updated values, and some additional practices that may be included in an assessment.

4 ASSUMPTIONS OF THIS DOCUMENT

This is a technical document with specific instructions on how to perform a Rural Subwatershed Assessment. 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 10.7.
- The reader has access to NRCS's Engineering Tools, which are used to delineate watersheds and create stream networks.
- 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.
- 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 and basic knowledge to use RUSLE2 software.
- The reader is using the 2021 updated version of the BWSR Water Erosion Pollution Reduction Estimator.

If the user does not meet the assumptions above, resources for learning are available for some things in several attached Appendices. These will be referred to when appropriate in the protocol.

5 USING THIS DOCUMENT

This document has been created using a consistent theme throughout. Important information or explanatory text follows each whole number section.

5.1 SUB SECTIONS

Sub Sections may be found using a progressive numbering system, such as Section 1, Sub Section 1.1, Sub Sub Section 1.1.1 and so on.

5.2 PHYSICAL ACTION

When instructions require the user to complete a physical action, a solid black circle bullet (●) will precede the text. The user should complete all instructions on one bullet before moving on to the next bullet.

5.3 FIGURES AND TABLES

Figures and Tables are provided to help the user visually match the instructions in the protocol to what they see in the actual ArcMap or calculator programs. The figures in the update (2022) show graphics from ArcMap 10.7. If you are using a different version of ArcMap the graphics may be different but generally should have the same/similar options.

5.4 HELPFUL HINTS

Helpful Hint grey boxes will appear periodically and are meant to draw attention to an issue the user may commonly encounter, how to work through quirks in the program that may not be obvious, where to find more information or further detail on something in one of the instructions, or other helpful hints.

Helpful Hint: when frustrated, do the chicken dance.

5.5 SUGGESTED FILE NAMES

Suggested file names for the outputs of each step are provided (***SUGGESTED FILE NAME: WATERSHED_RFACTOR)***. The user should insert the name of his or her own assessment watershed in place of ***WATERSHED*** in each suggested file name. It's not required that you follow this naming convention. It is intended to create a naming system that can help someone who has questions or is getting help from someone to work through an issue so that both people can be sure they are talking about the same file(s), or so that a person can go back through the protocol and match a file to an exact step if need be.

Rarely, the file names shown in figures in this protocol may be different than the suggested filename; this is commonly due to a character limit in ArcMap and are a shortened version of the suggested filename.

5.6 HYPERLINKS

When other sections of the protocol are referenced, they are linked to the section using a hyperlink and will appear in blue text and be underlined. For example, see Section 5.6 – Hyperlinks. External hyperlinks wils be underlined in green.

5.7 APPENDICES

Several appendices are located at the end of the document and are referred to throughout the protocol.

5.7.1   Appendix A: GIS Basics
➢ Section 16.1-Create a New Shapefile
➢ Section 16.2-Clipping Shapefiles and Rasters

5.7.2   Appendix B: Desktop Scouting
➢ Section 17.1-Desktop Scouting Examples

5.7.3   Appendix C: Attribute Tables
➢ Section 18.1-Attribute Tables
➢ Section 18.2-Templates for Manual Recording

5.7.4   Appendix D: NRCS Engineering Toolbox
• Section 19.1-NRCS Engineering Tools-Watershed Delineation

5.7.5   Appendix E: Troubleshooting
• Section 20.1-Troubleshooting
• Section 20.2-Prioritizing

5.7.6   Appendix F: Resources
• Section 21-Appendix F: Resources

5.7.7   Appendix G: Archived Instructions
• Section 22.1-Wetland Restoration

6 YELLOW PEALS RIVER SCENARIO

For the purpose of this protocol, a fictional scenario has been created and will be used throughout the document to provide examples. When the scenario is mentioned during the protocol, it will be in different text font (see below).

6.1 BANANAS SWCD

The Bananas Soil and Water Conservation District (SWCD) office has been awarded several grants for the upcoming season. The boss has delegated the management of each grant to a separate staff member and expects a Rural Subwatershed Assessment to be completed for each grant area.

In Part 1: Targeting, we met the SWCD Technician George who is working through the full subwatershed assessment process (Part 1: Targeting and Part 2: Prioritizing) for a grant awarded for the Yellow Peals River Sub Watershed. His coworker Chuck Els is also working on an assessment-his for Curious Catchment, but Chuck Els was able to start with Part 2: Prioritizing of the assessment protocol. Their boss, The Man With the Yellow Hat, has all the confidence that his two employees will produce excellent reports with priority practices identified. The SWCD office works closely with their Natural Resource Conservation Service (NRCS) partner, Mona Key, who is also excited to see the outcome of the Rural SWAs.

7 PRIORITIZING

Now that the area of highest potential soil erosion and phosphorus loading has been targeted, prioritizing can be done on a smaller scale within the targeted subwatershed or catchment. The goal of prioritization is to locate potential soil erosion or other resource concern areas at a field level, to suggest options for BMPs that could be used to correct the issue, and to assign a ranking that would identify the projects that are the most efficient pollution reduction for the cost.

Different BMPs vary widely in the costs for design, implementation, and maintenance, as well as how much value they provide to water quality in the terms of total phosphorus load reduction to surface waters. This protocol uses a cost/pound of phosphorus determination to compare projects, enabling the user to identify the projects that have the best ratio. Presumably, these projects are the best place to spend money to make the most impact on improving water quality and reducing soil erosion. This protocol does not, and cannot, take into account the local variables that go into the decision making on which projects to design and fund. Those factors may lead to different conclusions than the straight best cost per pound value. This must be accounted for at a local level.

The protocol can be used to prioritize projects by lowest cost per pound of phosphorus reduction, but it can also be useful as an outreach tool or to prioritize by a different goal (such as the most phosphorus reduction). For example, a Rural SWA may be completed primarily to prioritize based on cost per pound of phosphorus, but there may be another funding source dedicated to installing a specific practice, such as filter strips. The protocol provides an easy way to look up where there are potential filter strip projects in the targeted area. These can even be ranked among themselves for best cost per pound of phosphorus reduction. Some users also use the protocol to rank projects by the amount of phosphorus reduction with the intent to fix the biggest "polluters".

7.1 STRUCTURAL BMPS VERSUS MANAGEMENT BMPS

There are two categories of BMPs considered for this protocol (Table 1). Structural BMPs are those that are usually a one-time installation project, often involving construction or earthwork. These BMPs are usually very expensive, but they also tend to have large pollution reduction value and have long life spans.

Table 1. Structural Versus Management BMPs

Structural BMPs	Management BMPs
Water and Sediment Control Basin	Residue and Tillage Management
Grassed Waterway	Cover Crops
Lined Waterway or Outlet	Integrated Pest Management
Diversion	Nutrient Management
Grade stabilization Structure	Conservation Crop Rotation
Waste Facility	Soil Health Management
Wetland Restoration	Prescribed Grazing
Filter Strips	Pasture or Hay Planting

Version 2.0 March 2022

Management BMPs are practices that are implemented on a more continuous basis, and often change the way the producer operates. These practices have associated costs annually, or on a regular basis. They also often require an up-front investment to convert from one management type to another. These factors make it difficult to compare the two types of BMPs. This assessment attempts to determine cost per pound of potential phosphorus removal/prevention as a means to compare the vast range of possible BMPs.

It is widely accepted that the most efficient BMPs for protecting and improving water quality are management practices that can be applied across the entire landscape, thus making a bigger impact than spot practices. Therefore, this protocol assumes that management practices are always going to be the best option, but we acknowledge that in real world conservation, management BMPs are not always easily accepted. Structural practices are often more popular because they have an immediate impact and don't require major changes to the way a producer operates. The cost per pound of phosphorus comparison that results from completing a Rural SWA may be a new tool that can be used in the field to support the value of management BMPs when presenting options to a landowner.

7.2 MONKEY CATCHMENT

George will be diving deeper into two regions that he identified in Part 1: Targeting. He's called them Banana 1 and Banana 2 (Figure 1). He plans to run through Part 2: Prioritizing for Banana 1 first to get the hang of the process. Besides, Chuck Els should be an expert helper since he's already working on this part!
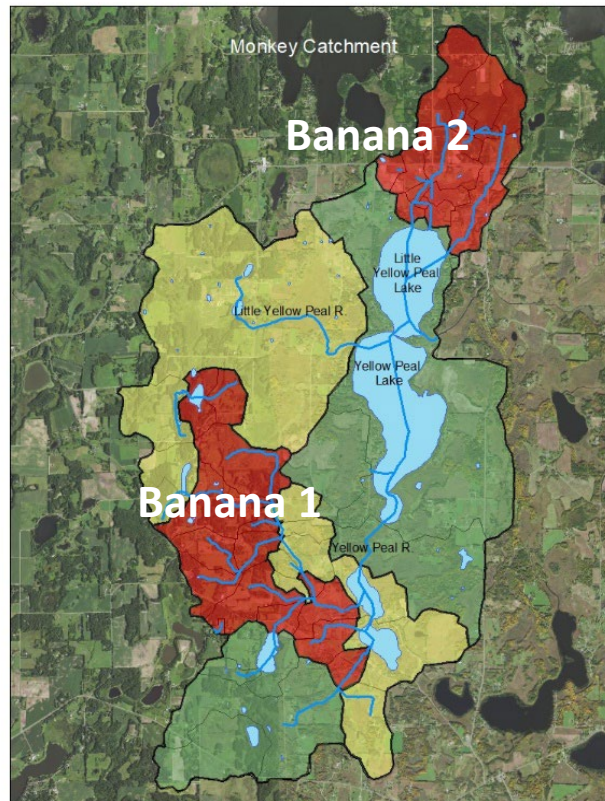
Figure 1. Monkey Catchment Regions Ranked

Version 2.0 March 2022

8   WHEN TO SKIP PART 1

This protocol is divided into two parts because some users may be able to skip Part 1: Targeting and start with Part 2: Prioritizing. The assessment area may already be defined; for example, the assessment area may be set by a grant or other funding source, watershed district boundaries, or another reason that the user has already narrowed their assessment area to a small enough scale where Part 1: Targeting will not be useful.

8.1   YELLOW PEALS RIVER

Lucky duck Chuck was able to skip Part 1: Targeting because the grant he is working on is focused on Curious Catchment only. This is a small catchment and already at a small enough scale that Chuck Els doesn't need to do further targeting. Poor George's grant was for the whole Yellow Peals River Sub Watershed, which was too large of an area to effectively prioritize projects across. Therefore, he needed to first do Part 1: Targeting to locate the regions he could do more focused work on.

9   GETTING STARTED

9.1   SETTING THE RULES

Before starting the desktop assessment, it is helpful to set some rules so that a consistent approach is followed throughout the process.   The rules described in this document reflect what was set by the Chisago SWCD during the Rural Subwatershed Assessment process. It is okay to change these rules to better suit your specific project.

*Helpful Hint: throughout this document, there will be many instances where the user may prefer to use different values, different scales, different BMPs, etc. What is listed in this document is what was used by the Chisago SWCD, but individual users may have different needs or goals from their Rural SWA. This is completely acceptable and even encouraged so that the user can get the best product for their needs. The bottom line is: **BE CONSISTENT**. If you change something from the protocol, make sure you keep that change throughout the process.*

9.1.1   Level of Assessment

There are a range of potential erosion issues and BMP locations on the landscape. The severity and importance vary. Some are large issues (major gullies) while some are small (shallow erosion on agricultural fields). When performing the desktop scouting, every potential problem regardless of size can be marked, or a threshold can be set. For example, small erosion seen in agricultural fields can be marked or left unmarked. These small areas are less likely to be high priority in the end and therefore may clutter the final report. On the other hand, they could become a larger problem in the future. By identifying them, they are in the report for future investigation. Similarly, some wetlands drain through another wetland. Will these wetlands be included as possible restoration sites or will they be left out in favor of wetlands that drain directly into lakes or rivers?

Decide what scale of marking to use in the desktop scouting step based on your specific needs. You might understand this better when you've started actually marking locations and can weigh the difference in work at the different scales. The most important thing is to be consistent with whatever level you use.

George thinks he should mark all the potential erosion problems he sees. He'll also mark feedlots/pastures and areas that could obviously use a filter strip or buffer.

9.1.2   Current Land Cover

Land cover can change annually, especially on agricultural fields. For this assessment, potential erosion issues that were located on hay fields or in herbaceous areas were marked and included in the final report. The concentrated flow path may not be causing any erosion while the field is in hay, but what if the field is converted to an annual row crop? If the potential issue is marked, it will be in the assessment and ranked so that if it is converted, it can be addressed. This will be mentioned again in the modeling section, but all agricultural fields will be modeled as if the current land cover is an annual row crop (corn or soybeans). This is done to reflect an accurate ranking among other fields if the hay field is converted. A note is made in the project profile that the current cover at the time of the report is hay so that the reader knows the site is a potential problem only if and when the land cover changes.

9.1.3   Terminology

During desktop scouting, different levels of erosion will be evident. There are many terms used throughout the conservation world for erosion (sometimes interchangeably), including "ravine", "sheet and rill", and "gully". Likewise, the terms "ditch" and "surface water" can have different meanings to different people. Table 2 (next page) defines what terms were used in this protocol and their definitions.

Table 2. Definitions

Term	Definition
Gully	A large, perennial erosion problem that is not located in an agricultural field. These are often located on the <u>edge</u> of the field.
Concentrated Flow Path	A path where water congregates and runs, often causing erosion. <u>In agricultural fields, these are farmed through</u>. These can also be located in hay fields, pastures, and grasslands where they are not causing erosion large enough to be called a gully.
Ditch	An excavated waterway that is <u>not farmed through</u>. Usually at least 1 foot deep or more. If the farmer goes around it, it is a ditch. If they go through it, it is a concentrated flow path.
Surface Water	Perennial streams, intermittent streams, or ditches that connect directly to streams or lakes; wetlands with perennial surface water that contribute to a stream or lake; and lakes.

10 BUILD GIS PROJECT

If you completed Part 1: Targeting, you will already have done parts of this section and you can skip down to Section 10.2. For those who are starting at Part 2: Prioritizing, you will want to build your GIS project before moving forward. Follow instructions beginning in Section 10.1.

10.1 CREATE PROJECT FOLDER

- Create a new folder to store the ArcMap project and the files that will be created during the protocol.

Helful Hint: ArcMap requires file names with no spaces and has a character limit so it's best to create a short name. Underscores can be used in place of spaces. If your project is buried down several layers of folders, you'll need an even shorter name. If possible, create your folder directly on the drive to give yourself the most character space to work with later on.

SUGGESTED FOLDER NAME: WATERSHED_SWA

Each employee at the Bananas SWCD has their own folder on the shared drive. George names his folder Yellow_Peal_SWA. He has a nice short file path of S:\George\Yellow_Peal_SWA.

10.2 CREATE ARCMAP PROJECT

- Open a new ArcMap project. You may be able to start with a Template of your area that already contains some of the required layer files. Save the new project to the location you just created in Section 10.1.

SUGGESTED FILENAME: WATERSHED_SWA

10.3 CREATE BOUNDARY SHAPEFILE

- Create a new polygon shapefile of the boundary of the Sub Watershed (or Catchment) that you are going to assess. See Appendix A: Section 16.1 – Create A New Shapefile for instructions to create a new shapefile and use the Trace tool.

SUGGESTED FILENAME: WATERSHED_BOUNDARY

George creates a new polygon shapefile and uses the Trace Tool to create his boundary layer. He names his new polygon Yellow_Peal_ Boundary.

10.3.1 Clip Shapefiles to Boundary

It will greatly reduce processing time if you are only running tools on the area you are working in. Clipping your base shapefiles at the beginning is recommended. For instructions on clipping, see Appendix A: Section 16.2 – Clipping Shapefiles and Rasters.

Version 2.0 March 2022

10.4 MINNESOTA NATURAL RESOURCE ATLAS

The Natural Resource Research Institute created the Minnesota Natural Resource Atlas (https://mnatlas.org/), which will be a very valuable tool for completing a Rural SWA. The interactive GIS site combines information from many different sources into one location. Sometimes all you need to do is see what's on the layer and not necessarily need it to be in your GIS project. Other times, it may be necessary to transfer the data into your project. Table 3 lists some of the layers from the MN Atlas that will be useful. In most cases, the data can be downloaded from MN Atlas and imported into the ArcMap project you created for this protocol.

Helpful Hint: alternate sources for obtaining some of these layers is available in Appendix F: Section 21 - Resources.

Table 3. MN Atlas Useful Shapefiles

Category	Layer Name	Source
Agriculture	Feedlots	MN Pollution Control Agency
	Fertilizer (Manure)-Nitrogen-2021	University of MN
	Fertilizer (Manure)-Phosphorus-2021	University of MN
Boundaries	Watersheds-DNR Level 7	MN DNR
	Watersheds-DNR Level 9	MN DNR
	Watersheds-USGS HUC 10	USGS
	Watersheds-USGS HUC 12	USGS
Climate	Precipitation: Annual 1981-2010	MN Climatology Working Group (MN DNR)
Environment	EB-Soil Erosion Risk	MN BWSR, Natural Resources Research Institute
	EB-Water Quality Risk	MN BWSR, Natural Resources Research Institute
Geology & Topography	Topography-Digital Elevation Model (3M)	MN DNR (LiDAR)
	Topography-Hillshade (1M)	MN DNR (LiDAR)
	Pollution Sensitivity-Near Surface Materials	MN DNR
Imagery & Land Cover	Various	Various
Water	Rivers & Streams	DNR
	Water Buffers-Basins	DNR
	Water Buffers-Watercourses and Public Ditches	DNR
	Wetlands-NWI-Circular 39	MN DNR
	Wetlands-NWI-Cowardin	MN DNR
	Wetlands-Restorable Index	National Research Institute, MN DNR

10.5 GATHERING SHAPEFILES

Start gathering the necessary layers in the ArcMap project created in Section 10.2 – Create ArcMap Project, either from MN Atlas or other sources.   Table 3 (previous page) lists layers that will be needed or are helpful to complete the assessment. At a minimum, you will need a Digital Elevation Model (DEM) at a scale of 1 meter if possible, aerial photography, and wetlands to complete this protocol.

A hillshade layer, a clipped DEM, a depth grid layer, and contours will be created using the NRCS Engineering Toolbox. A DEM is required to complete this.

> *Helpful Hint: clipping layers to your watershed boundary will be help your ArcMap project load more quickly. See Appendix A: Section 16.2 for instructions on clipping shapefiles and rasters.*

10.6 WATERSHED DELINEATION TOOLS

For instructions on using the NRCS Engineering Toolbox, see Appendix D: Section 19. The tools will create a clipped DEM, hillshade, depth grid, and contours layers that will be automatically added to the Table of Contents in your ArcMap project. These layers will be valuable throughout the modeling process.

- Run the first two steps of the NRCS Watershed Delineation tools (Define Area of Interest and Create Stream Network) using the clipped assessment area boundary.

The staff at the Bananas SWCD work closely with their NRCS partners and therefore have access to many of the layers needed for the assessment already loaded on the server. They also have the NRCS Engineering Toolbox loaded into ArcMap for them, thanks to the help from Mona Key at the NRCS office.

11 DESKTOP SCOUTING

The goal of this step is to locate as many potential issues or BMP sites as possible using GIS before going out into the field. Although it takes some time, the best method known to the Chisago SWCD is to simply scan around the subwatershed or catchment using ArcGIS looking for these locations.

11.1 MANAGEMENT PRACTICES AND COVER CROPS

Management practices such as tillage and residue management, nutrient management, soil health building, and integrated pest management are not included in the Desktop Scouting portion of this protocol. They are included in the modeling section and the final report. The reason they are not included here is because they are blanket practices-they would be options for all fields and there is no need for scouting to determine locations.

11.2 MARK POTENTIAL EROSION ISSUES AND POLLUTANT SOURCES

While scanning around the watershed, use aerial photos and the layers created from the NRCS Watershed Delineation Tools in Section 10.6. Be sure to switch back and forth between all the layers to get a complete picture of the site. Some things are obvious on one layer but invisible on another. For example, you may not notice a ditch on an aerial photo, but it sticks out on the hillshade layer.

Table 4 on the next page shows what problems to look for and mark during this step. There may be additional categories that should be added to this table, depending on the subwatershed being analyzed. The exact category or BMP is not critical or identified in this step; this step simply marks where there may be a problem.

Table 4. Potential Issues to Mark during Scouting

Category	Description
Gully	A large erosion issue, often having been active for 100 years or more. Best located using contours and/or hillshade layers. Mark the head of the gully.
Concentrated Flow Path	Areas where water concentrates and flows, causing erosion. Erosion can vary from minor to severe. Mark these locations regardless of current land cover because land cover can change, especially in agricultural fields. Use as many layers as possible to pick these out.
Ditches and Streams	Mark the areas that need a filter strip. Any agricultural field that is worked to within 50 feet of a ditch or stream should be marked. Best identified from contours and hillshade. The DNR Rivers and Streams layer and the MN Buffer Program layer may also be helpful.
Pastured or Drained/Altered Wetlands	Any pastured areas that include or are directly adjacent to a wetland or surface water should be marked. Locating pastures is easiest by reviewing aerial photos, looking for fences, bare soils, and short vegetation. Using the NWI layer helps determine if there is a wetland, but mark the location even if it isn't identified on the NWI but obvious wetlands can be seen on the aerial. The NWI also usually includes a modifier marking wetlands that are drained or altered.
Animal Operations	Feedlots are critical to mark. Some subwatersheds don't have many feedlots but do have other large animal operations that cause pollution concerns. Mark these. The Minnesota Pollution Control Agency keeps a Feedlot layer.
Stream bank/Shoreline Erosion	Use the contours and hillshade along streams and lakes to look for any areas with very steep slopes. Bank slumping can sometimes be seen on contours.

Helpful Hint: See Appendix B: Section 17 for examples of what these categories look like in GIS.

- Create a new shapefile to mark potential BMP locations. A point shapefile works well.

    Helpful Hint: If you do not know how to create a new shapefile, see Appendix A: Section 16.1 for step-by-step instructions.

- Start editing. Put a point where a possible issue or the need for a BMP is evident (Figure 2).

Helpful Hint: This is where the decision of what scale to mark potential projects comes in.

- Save edits and stop editing.

Figure 2. Potential Issues Marked During Desktop Scouting

SUGGESTED FILENAME: WATERSHED_SCOUTING

George starts in the region designated Banana 1 (Figure 3). Now that he's actually marking points of potential projects, he realizes there are a lot more dots on his map than is practical. Before he gets too far, he decides to reduce his scale of what he will mark to only larger, more perennial or substantial issues. He ends up marking 36 potential project locations (not including his steep slopes and wetland restorations). Chuck Els was much more ambitious (or crazy?) and marked everything he saw; he had over 130 dots.

Figure 3. Banana 1 Region for Desktop Scouting

11.3 IDENTIFY STEEP SLOPES

It is easiest to manipulate the display settings on a slope raster to show only the areas that have slopes in excess of 6%. Any slopes over 6% are considered very likely to have sheet and rill erosion and would benefit the most from having permanent vegetation planted.

Helpful Hint: if you completed Part 1: Targeting, you created a slope raster. However, this raster was in Degrees and the raster needed for this step should be Percent Rise so you'll need to follow instructions to create a new slope raster.

- In ArcMap, open the Slope tool in ArcToolbox, Spatial Analyst Tools, Surface, Slope (Figure 4).
- The input raster is a clipped DEM raster. For output raster, select the file location created in Section 10.1.

SUGGESTED FILENAME: WATERSHED_SLOPE

- In the output measurement dropdown menu, choose PERCENT RISE.
- If the Output measurement is not already, select PLANAR.
- Select OK.
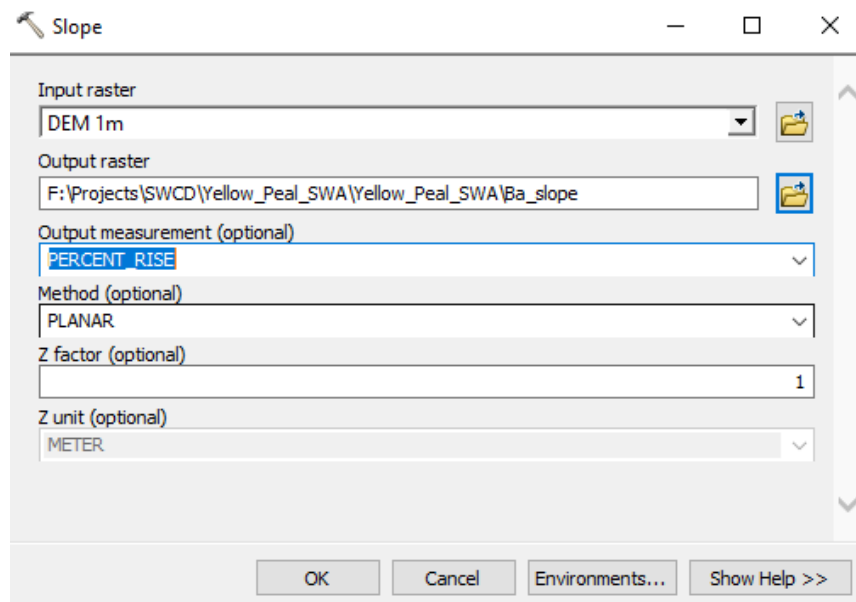
Figure 4. Slope Raster

Version 2.0 March 2022

- A new raster should be created in the Table of Contents.
- Right click on this layer and select properties. Open the Symbology tab (Figure 5). By default, the Classified option should be selected in the left-hand box. If it's not, select Classified.
- In the Classification section, choose 2 in the Classes drop-down menu.
- Then click on Classify. In the Break Values box on the righthand side, adjust the two classes so that they break at 6%. There should be two values in the box. Click on the first one and type in 6. The second one can remain as is.

Figure 5. Slope Layer Properties

- Click Ok to return to the Properties box. There should now be 2 boxes showing with a range of 0-6 and 6-the highest slope value you have (Figure 5). Change the color of the class 0-6 to show no color. Select OK.
- The slope raster should now only show slopes over 6% (Figure 6).
- Create a new polygon shapefile.
- Begin editing.
- Scan the agricultural fields within the subwatershed or catchment.
- Draw a polygon around the fields (or portions of fields) with more than 33% of the total field having slopes over 6% (Figure 7, next page).

Figure 6. Slopes greater than 6%

Helpful Hint: turn on the Land Cover polygon shapefile created in Part 1: Targeting; use the Trace tool to maintain the same boundaries for your new steep slope shapefile as those in the Land Cover layer.

- Save edits and stop editing.

SUGGESTED FILENAME: WATERSHED_PERMVEG

George marks 8 fields (or parts of fields) that he determines would benefit from being converted to permanent vegetation due to steep slopes.

11.4 POTENTIALLY RESTORABLE WETLANDS

This section has changed significantly from the original version of the Rural SWA Protocol. New tools have been developed that better suit the needs of a subwatershed assessment. For the updated 2022 protocol, the Wetland Restoration Effectiveness Tool (http://bbe.umn.edu/wret) is used to estimate nitrogen, phosphorus, and carbon reduction potentials for wetland restoration projects.

Many wetlands have been manipulated by ditching and draining. Restoring the hydrology to these wetlands may provide nutrient and sediment removal from stormwater runoff. Due to the large number of small wetlands, modeling each one is not practical. Only wetlands over 2 acres in size were included in the modeling process.

Figure 7. Steep Slope Fields
Green=steep slopes; Black=fields with corn, beans, or hay

Many wetland restorations are not possible or not feasible for a variety of reasons (number of landowners involved, location of wetland, watershed to wetland ratio). These factors were not considered during this assessment, but will likely have a major impact on real-world wetland restoration projects. This protocol uses the Wetland Restoration Effectiveness Tool to determine potential pollution reduction values, which can then be used to determine cost per pound of nutrient removal and allow the user to compare wetland restoration to other potential BMPs in terms of cost effectiveness.

- Create a new polygon shapefile.

SUGGESTED FILENAME: WATERSHED_WETLAND RESTO

- Turn on the NWI or another wetland shapefile that you want to use.
- Manipulate the display settings so that only wetlands over 2 acres are shown (Figure 8, next page).
- Begin editing the new shapefile.
- Use the Trace tool to copy the outline of wetlands. Skip wetlands that are clearly manmade (like someone's back yard pond) if it is not part of a larger, natural wetland complex.

Version 2.0 March 2022

- Open the Attribute Table. Under the ID column, number or otherwise identify your wetlands. If this column is not in the table by default, you will need to stop editing, add a field to the table, and start editing again to fill in the table.
- Save edits and stop editing.

George ends up with 15 wetlands that are over 2 acres in Banana 1 region.

11.5 FIELD REVIEW

Once all potential erosion and nutrient loading issues are marked in the GIS project, field verification should be conducted. Print maps that display the marked locations and drive around the subwatershed. Note the location, number, and type of animals in the subwatershed. Verify or discount as many of the marked potential issues as possible. It is not practical to meet with every landowner to verify marked potential issues that cannot be verified from the road. Make notations on the maps to confirm or remove the marked potential issues.

Figure 8. Wetlands over 2 Acres

The protocol for the Top50P! project has much more in-depth instructions for field review, including templates to fill out for each issue that is reviewed during the field verification. For the Chisago Rural Subwatershed Assessment, these templates were not used and field review was not as in-depth.

Version 2.0 March 2022

12 BMP IDENTIFICATION

This step takes the desktop scouting and field verification information and translates it into a series of specific BMP shapefiles. Table 5 lists the potential erosion issues and pollutant sources that were marked and located during the previous steps and indicates what BMP should be prescribed, as well as what type of new shapefile to create for each. Display settings are included as a suggestion, but you can use whatever display you want to.

Table 5. Shapefiles for BMP Identification

Erosion Issue/Pollutant Source	BMP	Shapefile Type	Display
Gully	Gully stabilization	Line	Green, dotted, drawn along length of gully
Concentrated Flow Path-Plowed through	Grassed waterway	Line	Yellow, dashed, drawn along length of concentrated flow path
	Water and sediment control basin	Point	Red, placed at location for WASCOB
Concentrated Flow Path-Edge of field gully	Water and sediment control basin	Point	Red, placed at edge of field and head of gully
Ditch or stream-within 50 feet of active agricultural field	Filter Strip	Line	Green, solid, drawn along location where filter strip is needed
Animal Operation	Various	Polygon	Yellow outline, drawn around feetlot or animal operation
Pastured Wetland	Various	Polygon	Purple outline, drawn around pasture
Steep Slopes*	Permanent Vegetation	Polygon	Turquoise outline, drawn around portion of field to be converted to permanent vegetation
Ditched/Drained Wetland*	Wetland Restoration	Polygon	Purple outline, drawn around wetland
Streambank/Shoreline Erosion	Various	Line	Dark blue, solid, drawn along the portion of the bank that is eroding

*The shapefiles for these categories were already created in the desktop scouting sections 11.3 and 11.4.

- Create new shapefiles for each of the BMPs you plan to model or rank.

SUGGESTED FILENAMES: WATERSHED_(CHOOSE ONE:WASCOB, WATERWAY, GULLY, FILTERSTRIP, ANIMALOP, PASTURE, BANKEROSION)

George starts making shapefiles in preparation for determining BMPs, but he doesn't remember seeing any shoreline or streambank erosion. He decides not to make that shapefile unless he finds an area he marked and forgot about.

The Top50P! protocol instructs users to also document wind erosion, land application of manure, bluffs, and low-density residential development. There are certainly other potential issues that may be relevant in a subwatershed or catchment. There is flexibility for choosing those potential BMPs to include in the rural subwatershed assessment for each individual report.

Helpful Hint: When deciding which BMPs to include in the report, consider the ability to model potential pollution reduction values and if these values can be ranked against other BMPs.

- Turn on the Watershed_Scouting layer. Use this layer and the notes from the field verification to guide you around the subwatershed or catchment.
- Determine what BMP should be used at each of the potential erosion issues and pollutant sources. Make the appropriate mark in the appropriate shapefile until all of the original marks have been allocated to a shapefile or discounted as not being an issue. For personnel familiar with installing grassed waterways and water and sediment control basins, use your professional judgment to mark the BMP that would be best suited to the location.

Helpful Hint: If you are not familiar with how the determination is made between a grassed waterway and a water and sediment control basin, don't spend too much time debating. Set a protocol for yourself and follow it. For example, any concentrated flow paths that have a 6 foot elevation change over 100 feet should be marked as a WASCOB.

George ends up with new shapefiles for gully (3), WASCOB (17), filter strip (19), and animal operations (4). He found a few more spots he missed that he decided to include as a potential project while he was going through the dots. He lumped his pastures in with the animal operations because they were all directly adjacent to each other. He didn't come across any spots where he thought a grassed waterway should be used so he didn't end up using the shapefile he created for that. He was right about not having any shoreline erosion too; phew!

13 MODELING

Two models were used to complete the modeling for structural practices in this protocol. These two models were also used for some of the management BMPs, including conservation crop rotation, cover crops, and residue and tillage management. The two models are the Revised Soil Loss Erosion (RUSLE2) model (Figure 9) and the BWSR Water Erosion Pollution Reduction Estimator model (Figure 10, next page).
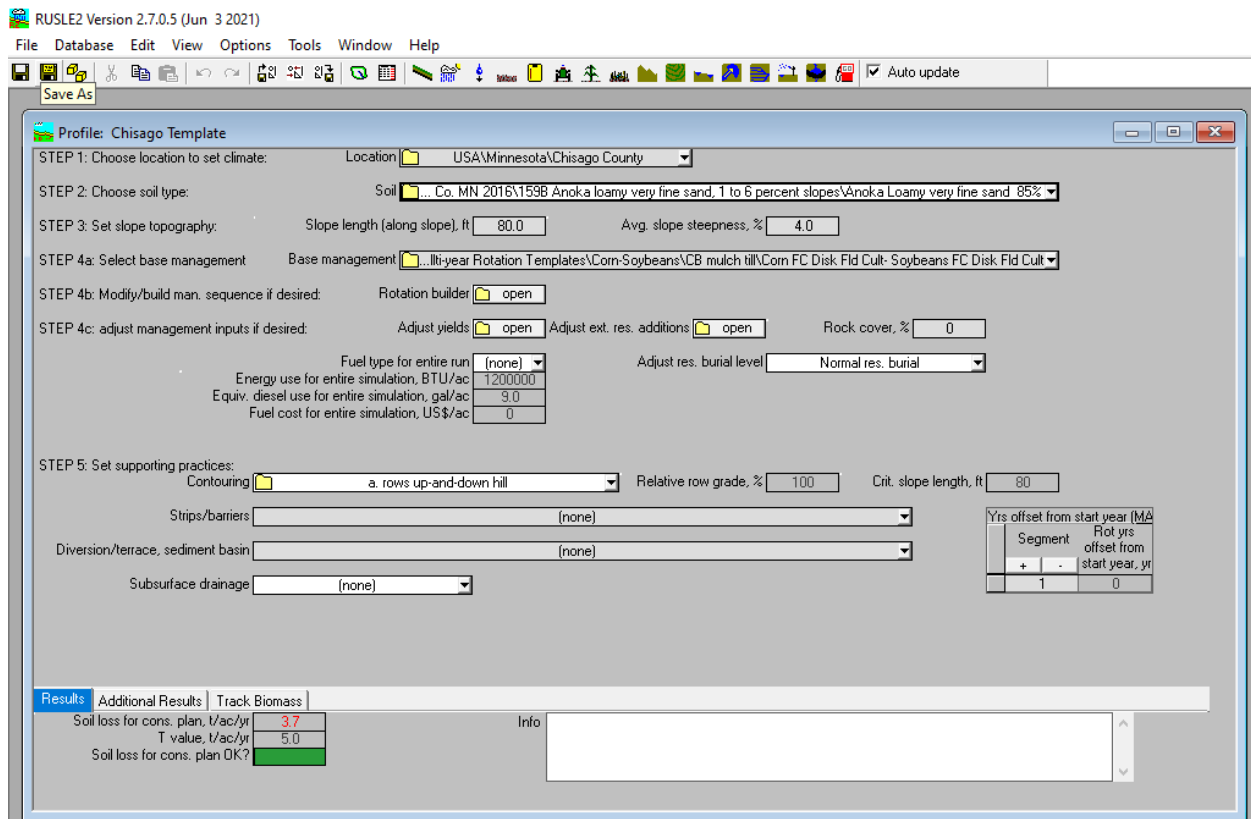
Figure 9. RUSLE2 model

Version 2.0 March 2022

Sheet & Rill Erosion Control Estimator Version 2.1

SLB$_{PA}$	SEDB0pa (T/A/Y)	Filter Strip present	SEDBpa
Soil Loss Before per acre 1.5	= SLB$_{PA}$*SDR 0.46	before installation	=FS*SEDB0pa 0.46
(T/Ac/yr)	sed before/ acre	Y/N	(T/A/Y)
		N	

SEDR
= (SEDBpa-SEDApa)*CA   **7.99**
Sediment Reduction   (T/yr)

SLA$_{PA}$	SEDA0pa (T/A/Y)		SEDApa
Soil Loss After per acre 0.5	= SLA$_{PA}$*SDR 0.15	1	=FS*SEDA0pa 0.15
(T/Ac/yr)	sed after /acre	Filter	(T/A/Y)
		Strip
D		Factor
distance to surface water 300	SDR 0.31		
(feet)			

PBpa		1	0.72
Pbefore/acre 0.72		2	0.00
(lbs/A/yr)		3	0.00
		4	0.00

SLRpa
Soil Loss Reduction per acre   1.00
= SLBpa- SLApa (T/Ac/yr)

PApa		1	0.30
P after/acre 0.30		2	0.00
(lbs/A/yr)		3	0.00
		4	0.00

SLR = (SLRpa)(Ac)
Soil Loss Reduction (T/yr)   40.00

SOIL = sand (1), silt (2), clay(3), peat(4)   1

PR
= (PBpa - PApa)*C   **11.03**
P reduction (lbs/yr)

AC = units applied (acres)   40

CA = contributing acres (acres)   26

☐	= input
☐	= calculated value
☐	= result

ENTER THIS DATA ON eLINK INDICATORS TAB

SEDIMENT (TSS) T/yr:	7.99
SOIL (estimated savings) T/yr:	40.00
PHOSPHORUS (est. reduction) lbs/yr	11.03

Figure 10. BWSR Water Erosion Pollution Reduction Estimator

13.1 RUSLE2 MODEL
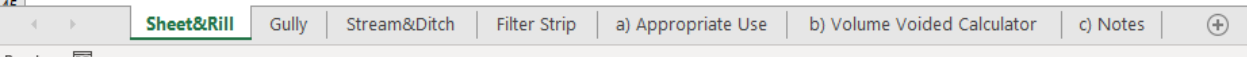
The Revised Universal Soil Loss Equation (RUSLE2) is an empirical model used to predict soil movement *within a field* and can be used to estimate erosion potential. See Appendix F: Section 21 for resources on downloading RUSLE2 and detailed instructions on using the program. This protocol will indicate what values to put into the model so the user should not need to know the program in great detail.

Helpful Hint: The soil moving within a field is not always a direct correlation for soil loss from the field; some soil may settle in depressions within the field and is, therefore, not actually lost from the field. The user should study the watershed to see if soil is actually moving off the field when using RUSLE2 as an estimate of soil loss potential.

13.2 BWSR Water Erosion Pollution Reduction Estimator

The BWSR Water Erosion Pollution Reduction Estimator is available for free download from the BWSR website (http://www.bwsr.state.mn.us/water-quality-tools-and-model). If you downloaded a version of this spreadsheet before October 2021, download the newer version from the website. There is also an instruction document available for download in the same location.

The spreadsheet has five calculator tabs: sheet and rill, gully, stream and ditch, filter strip, and volume voided calculator. The sheet and rill and filter strip tabs require inputs from RUSLE2 to calculate potential pollution reduction. Figure 11, from the Estimator spreadsheet, shows BMPs that can be modeled using the estimator.

| Sheet&Rill | Gully | Stream&Ditch | Filter Strip | a) Appropriate Use | b) Volume Voided Calculator | c) Notes | ⊕ |

Practice Name	Practice Code	Applicable BWSR Estimator	Practice Life Expectancy (years)
Conservation Cover	327	Sheet and Rill	10
Conservation Crop Rotation	328	Sheet and Rill	3 to 5
Contour Buffer Strips	332	Sheet and Rill	10
Contour Farming	330	Sheet and Rill	10
Cover Crop	340	Sheet and Rill	1 to 3
Erosion Control	148M	Sheet and Rill, Filter Strip, Gully, Stream and Ditch	10
Filter Strip	393	Filter Strip	10
Grade Stabilization Structure	410	Gully	10
Grassed Waterway and Swales	412	Gully	10
Lined Waterway or Outlet	468	Gully	10
Riparian Forest Buffer	391	Stream and Ditch	
Riparian Herbaceous Cover	390	Filter Strip, Stream and Ditch	10
Sediment Basin	350	Gully	10
Stream Channel Stabilization	584	Stream and Ditch	20
Streambank and Shoreland Protection	580	Stream and Ditch	20
Strip-cropping	585	Sheet and Rill	1 to 3

Figure 11. Applicable BWSR Estimator for BMPs

Version 2.0 March 2022

13.3 MODELING RULES

There are several inputs into the various calculators that have a consistent value during all calculations. Make the decision for each of the following rules and stick with that throughout the modeling process. If you change an input part way through the assessment, the output potential pollution reduction values you get will not be comparable to the values of other projects of the same BMP.

13.3.1 Base Management Practice

In the RUSLE2 model, a base management practice must be chosen (Figure 12). Virtually any combination of management practices can be used. Choose a management regime that is common to the area being assessed. For example, in Chisago County most of the farmers conduct fall tillage and plant a corn/soybean rotation.

Therefore, the management chosen was "Corn FC Disk Fld Cult- Soybeans FC Disk Fld Cult" (located under CMZ 04, Multi-year Rotation Templates, Corn-Soybeans, CB mulch till).
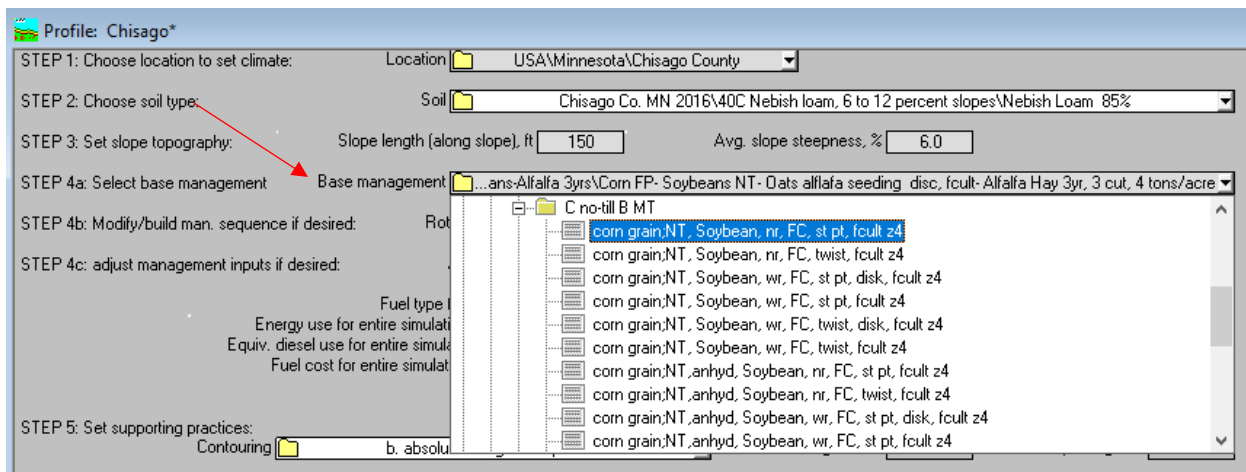
Figure 12. Base Management Menu

Helpful Hint: Double click on the yellow folder icon next to Base Management to get more information. This allows the user to manipulate the base management to precisely match a specific regime if desired.

13.3.2 Permanent Vegetation Management Practice

When determining the reduction in soil loss achieved by converting a field in annual row crop production to permanent vegetation, a "permanent vegetation" base management will be used. Choose one that represents a stable vegetation base.

For Chisago, the management chosen was "Established Alfalfa, Year 4" (located under CMZ 04, Single Year/Single Crop Templates, Forages, Alfalfa late summer direct seed).

Version 2.0 March 2022

13.3.3 Management BMPs

For the management BMPs including reduced tillage/no till and cover crops, you will run two scenarios similar to Section 13.3.2 (with and without the management activity). The management that was used for the modeling is:

Cover Crops:

CMZ04, Multi-year Rotation Templates, Cover Crops rotations, corn grain; NT, Sdisk fcult rye cover, Soybean; 18 in row, NT z4.

Residue and Tillage Management:

CMZ04, Multi-year Rotation Templates, Corn-Soybeans, CB NT, corn grain; NT Soybean, nr NT single disk openers Z4.

Conservation Crop Rotation:

CMZ04, Multi-year Rotation Templates, Corn-Soybeans-Alfalfa 3 yrs, corn FP-Soybeans NT-Oats alfalfa seeding disc, fcult-Alfalfa Hay 3 yr, 3 cut, 4 tons/acre.

13.3.4 Contouring

In the RUSLE2 model, one of the inputs is called "Contouring". This refers to the direction of the ridges left by operations that disturb the soil, such as tillage. The direction of the ridges affects how water runs off the field. Water is able to pool in ridges that run across the slope; the water will overflow the ridge when the space behind the ridge is full. In contrast, rows that run up and down the slope do not affect water because the water runs straight down the space between the ridges. There are a variety of settings in between that can be chosen as well.

For the Chisago Rural Subwatershed Assessment, an absolute row grade was chosen from the drop-down menu that would result in the Relative Row Grade % being as close to 50% as possible (Figure 13).

Figure 13. Contouring in RUSLE

Helpful Hint: In RUSLE, the user can right click on any of the inputs and select Help. The help box provides information on what the input is and how to determine it.

Version 2.0 March 2022

13.3.5   Number of Years

In the BWSR Water Erosion Pollution Reduction Estimator spreadsheet, on the Gully tab, one of the inputs is Number of Years (Figure 14). This value greatly effects the output value. For concentrated flow paths that are farmed through every year, use the value of 1 year. In some cases there are concentrated flow paths in the field that are farmed around, but are not major gullies. These were modeled using 30 years. For large edge-of-field or other perennial gullies, use 100 years (about the beginning of the "farming age").

13.3.6   Gully Channelization

In the BWSR Water Erosion Pollution Reduction Estimator spreadsheet, on the Gully tab, one of the inputs asks if the gully is channelized, non-channelized, or landlocked (Figure 14). According to the instructions, a

Figure 14. Number of Years and Gully Channelization

value of 1 should be used if the gully is channelized and outlets directly into a surface water. If the gully fans out before reaching surface water, use a value of 2 for non-channelized. The landlocked option was not used.

Version 2.0 March 2022

13.4 BMP MODELING

The challenge of ranking potential projects is finding a way to be able to compare different BMPs with pollutant reduction numbers derived from different modeling systems against one another. In many cases, it may not be possible.

It will be up to the user how many different BMPs to include in the ranking list. All of the BMPs that have a cost per pound of phosphorus determined could be ranked together. Practices that do not have a cost per pound of phosphorus reduction should be listed amongst themselves and not included with the ranking.

Helpful Hint: Large gully stabilization projects that are not water and sediment control basins were listed separately because of the huge potential pollution reduction values produced by modeling, which put these projects to the top of the ranking list if included with the other structural BMPs. The Chisago SWCD felt that they are just not able to be compared with other structural BMPs with any confidence so they should be ranked amongst themselves.

13.4.1 Filter Strips

The BWSR Water Erosion Pollution Reduction Estimator spreadsheet is used for modeling filter strips. RUSLE2 is needed to determine certain inputs.

- Open the Filter Strip tab in the BWSR Water Erosion Pollution Reduction Estimator (Figure 15, next page).
- In ArcMap, open the Attribute Table for the filter strip shapefile (right click on the layer and click Open Attribute Table).
- At a minimum, add 4 columns to the Attribute Table, named according to Table 6. In the open Attribute Table, click on the first icon with a drop-down menu and select Add Field. **This can only be done when the shapefile is not being edited**.
- For additional columns that may be added, see Appendix C: Section 18.1.2.

Table 6. Attribute Table Columns

Column Name	Type	Length/Precision
FS_ID	Text	50
TP	Float	Scale 2, Precision 5
TSS	Float	Scale 2, Precision 5
Sediment	Float	Scale 2, Precision 5

*Helpful Hint: It is important to record the inputs to each model. Some people find it helpful to include columns for all the modeling inputs in the Attribute Table in ArcMap. The benefit to this is that all the model inputs are saved in case there is a need to review the model. However, it is time-consuming to input all of the data for every attribute, especially if you have to switch back and forth between screens. See Appendix C: Section 18.1 for additional columns that **could** be included in the Attribute Table to record all necessary model input data. Also available in Appendix C: Section 18.2 are templates that can be printed out and manually filled in with the model input data. This may be easier than trying to do it on the computer.*

Version 2.0 March 2022
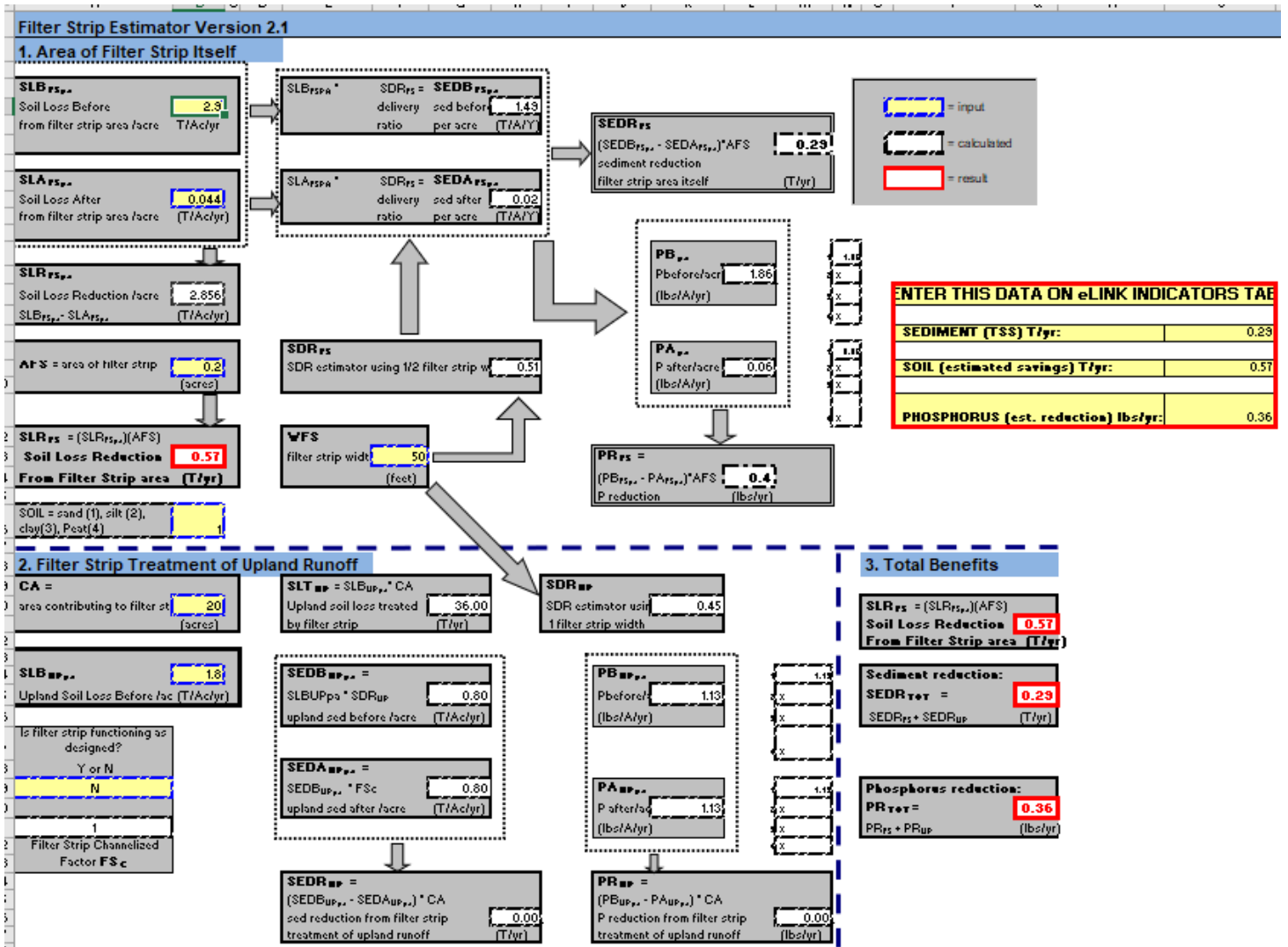
Figure 15. Filter Strip Tab

- When all of the desired columns have been added to the Attribute Table, start editing the shapefile. Right click on the layer and select Edit Features, then Start Editing. You will need to make sure you have the correct Template selected in the Editing Window for Create Features.
- Open RUSLE2 program. Open a new profile.

> *Helpful Hint: If you are not familiar with running RUSLE, use the Simple Template. Click on Options, Template, Load and select the NRCS Simple Template for your area.*

- Location: Should be set to your county already.
- Soil: Choose the most dominant soil type for the area of the filter strip itself (the 50 feet adjacent to the stream or ditch).

First, the soil loss within the filter strip itself (the 50 feet adjacent to the stream or ditch) will be determined. For this protocol, it is assumed the filter strip area is currently under agricultural production.

Version 2.0 March 2022

- Slope Length: 50 (the width of the filter strip used for this protocol).
- Avg. Slope Steepness: In ArcMap, measure the difference in contours within the area of the filter strip itself (the 50 feet adjacent to the stream or ditch).
- Base Management: Choose the base management that was chosen for the subwatershed or catchment area (Section 13.3.1). Use this regardless of what the current land cover is.
- Contouring: From the drop-down Contouring menu, select an absolute row grade that makes Relative Row Grade = 50% (Section 13.3.4).
- The model will automatically re-calculate after each input is changed. Wait for it to finish calculating. The box at the bottom labeled "Soil loss for cons. Plan" is the tons per acre per year of potential soil loss. Input this number into the BWSR Pollution Reduction Estimator first box (SLB_FS).

Next, the soil loss of the filter strip area itself will be determined assuming it is now planted as a filter strip, not managed as an agricultural crop area.

- Return to RUSLE. Using the same profile that was used in the previous step, add a filter strip in the Strips/Barriers drop down menu. Select Filter Strip, Actual Width, 50-Ft Cool Season Grass Filter Strip (Figure 16).
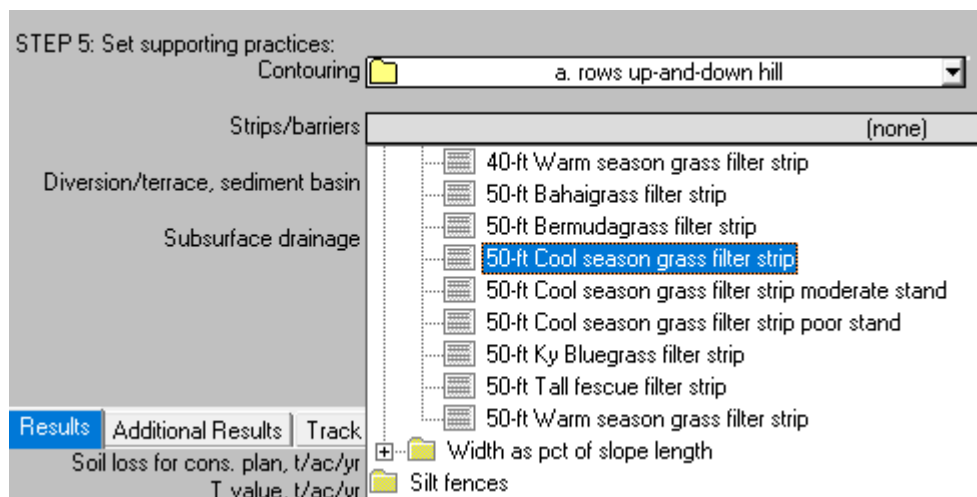
Figure 16. Strips/Barriers

- Wait for the model to recalculate. Input the number into the BWSR Pollution Reduction Estimator second box (SLA_FS).
- In the BWSR Water Erosion Pollution Reduction Estimator, input the area of the filter strip into the AFS box. To calculate the area of the filter strip, measure the length of the proposed filter strip in ArcMap. Multiply the length by 50 (for a 50 foot wide filter strip). Then divide by 43,560 to convert to acres. Input this number into the spreadsheet AFS box.
- Next, in the BWSR spreadsheet, input the SOIL box with the appropriate number based on the type of soil. Input 1 for sand, 2 for silt, 3 for clay, or 4 for peat.
- The default setting of the WFS (filter strip width) box should be 50. Change it to 50 if this is not the default.

Next, calculations will be made for the watershed that is contributing to the filter strip. For the protocol, it is assumed that the watershed area is being managed for annual agricultural crop production.

- Use the NRCS Engineering Toolbox-Watershed Delineation Create Watershed tool to measure the watershed area (See Appendix D – Section 19.1- NRCS Engineering Tools-Watershed Delineation for instructions).
- In the BWSR spreadsheet, input the watershed area of the filter strip into the CA Box.
- Return to RUSLE. Close the profile that is open. Do not save. Open a new profile.

Helpful Hint: It is important to close the RUSLE profile and open a new one after the step where the filter strip has been added. If you remove the filter strip and try to run a new calculation in the same profile, the calculation is often wrong.

- Location: Should be set to your county by default.
- Soil: Choose the most dominant soil type of the watershed area.
- Slope Length: Find the area of the watershed with the steepest slope. Measure from the top of the hill to the area where it flattens out. Use this length for the Slope Length.
- Ave. Slope Steepness: Use the value given as an output of the Watershed Delineation Tool.
- Base Management: Choose the base management that was chosen in Section 13.3.1. Use this regardless of what the current land cover is.
- Contouring: From the drop-down Contouring menu, select an absolute row grade that makes Relative Row Grade = 50% (Section 13.3.4).
- Wait for the model to recalculate. Input the value into the BWSR Water Erosion Pollution Reduction Estimator in the SLB box under 2. Filter Strip Treatment of Upland Runoff.
- Always select Y for "Is the filter strip functioning as designed?"
- The outputs in the yellow box (Sediment, Soil, and Phosphorus) should now be accurate for the filter strip modeled. Record these values in the Attribute Table or on the paper template for Filter Strips.
- Repeat process with the next filter strip.

Version 2.0 March 2022

13.4.2 Water and Sediment Control Basins, Grassed Waterways, and Gullies

The BWSR Water Erosion Pollution Reduction Estimator is used to model the erosion formed in concentrated flow paths that could be corrected by a water and sediment control basin (WASCOB) or grassed waterway, or in large perennial gullies.
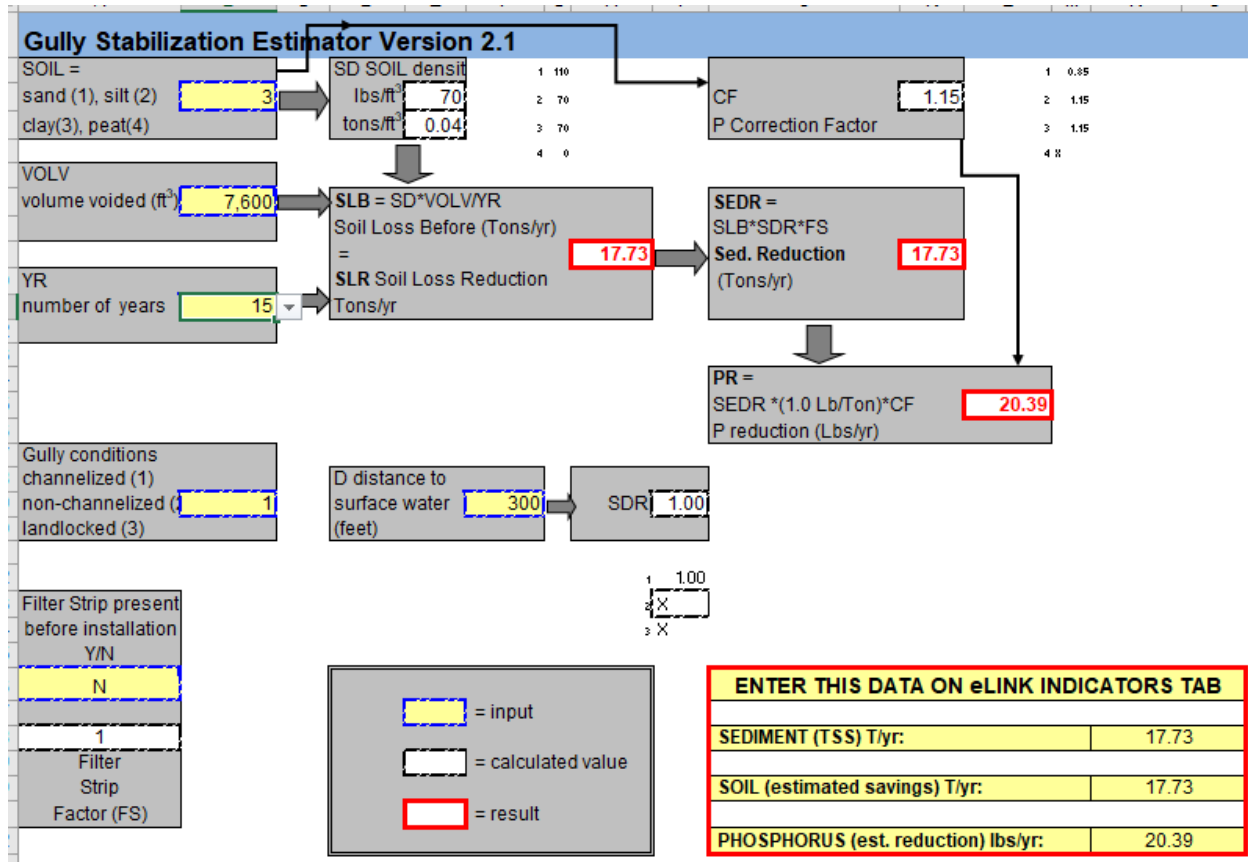
Figure 17. Gully Tab

- Open the Gully tab in the BWSR Water Erosion Pollution Reduction Estimator spreadsheet (Figure 17).
- In ArcMap, open the Attribute Table for the appropriate shapefile. Add the appropriate columns to the table. The minimum columns needed are listed in Section 13.4.1, Table 6. Additional optional columns are listed in Appendix C: Section 18.1.1.
- In the BWSR Water Erosion Pollution Reduction Estimator, choose the appropriate input for soil type in the first box. Input 1 for sand, 2 for silt, 3 for clay, or 4 for peat.
- Determine the volume voided using the Volume Voided Calculator tab in the BWSR Water Erosion Pollution Reduction Estimator.

For small, concentrated flow paths in agricultural fields that are plowed through every year, we assumed the top width and bottom width to be 1 foot each, with a 1 foot depth. To speed things up, for these concentrated flow paths, simply use the length of the concentrated flow path as the input for the VOLV box.

- Enter the Volume Voided into the VOLV box in the BWSR Water Erosion Pollution Reduction Estimator.

- Enter the number of years in the YR box. If the concentrated flow path is plowed through each year, enter 1. If the concentrated flow path or gully is in a field, but plowed around rather than through, enter 30. If the gully is off the field, enter 100. If different year values were chosen in Section 13.3.5, use those. Be consistent throughout.
- In the next box, choose either 1 (channelized) or 2 (non-channelized). See Section 13.3.6 for more information. We did not use landlocked for the Chisago rural subwatershed assessments.

Helpful Hint: A gully is channelized if it outlets directly into a surface water. A gully is non-channelized if it flattens out first, so sediment is deposited before it reaches a surface water.

- The Distance to surface water box should be used for all non-channelized gullies. This is the distance between where the gully fans out to the nearest surface water. The box does not need to be filled in for channelized gullies.
- At the bottom of the spreadsheet, there is a box to choose Y or N to indicate if a filter strip is present. Set this at N for all BMPs, regardless of if there is a filter strip or not. This helps compare BMPs equally across the map.
- The outputs in the yellow box (Sediment, Soil, and Phosphorus) should now be accurate for the BMP modeled. Record these inputs in the Attribute Table or on the paper template for the appropriate BMP type.
- Repeat process with the next BMP.

13.4.3 Permanent Vegetation Conversion

The BWSR Water Erosion Pollution Reduction Estimator was used for calculating the pollution reduction that can be achieved by converting a steeply sloped field (slopes over 6% covering at least 1/3 of the field) to permanent vegetation. All fields, regardless of current cover were modeled as if they were in annual row crop production.

- Open the BWSR Water Erosion Pollution Reduction Estimator spreadsheet to the Sheet and Rill tab (Figure 18, next page).
- In ArcMap, open the Attribute Table for the Permanent Vegetation shapefile. Add the appropriate columns (Section 13.4.1, Table 6). For additional columns that may be added, see Appendix C: Section 18.1.3.

In RUSLE, determine the Soil Loss Before value for the field (or portion of the field) that should be converted to permanent vegetation. Use the steepest area to take measurements.

- Open RUSLE2. Open a new profile.
- Location: This should be your county by default.
- Soil: Choose the most dominant soil on the field.
- Slope Length: Find the steepest location on the field. Measure from the top of the slope to the area where the slope flattens out. Input this number into the box.
- Avg. Slope Steepness: Use the value given as an output of the Watershed Delineation Tool.
- Base Management: Choose the base management that was set in Section 13.3.1. Use this regardless of what the actual land cover currently is.

Version 2.0 March 2022

Figure 18. Sheet and Rill Tab

- Contouring: From the drop-down Contouring menu, select an absolute row grade that makes Relative Row Grade = 50% (Section 13.3.4).
- Allow the model to finish calculating. Input the value into the BWSR Water Erosion Pollution Reduction Calculator in the Soil Loss Before box.

Next, calculate the erosion that would occur after the field was converted to permanent vegetation.
- Return to RUSLE. Change the base management to the management chosen for permanent vegetation in Section 13.3.2.
- Allow the model to re-calculate. Use this value for the Soil Loss After box in the BWSR Water Erosion Pollution Reduction Estimator.
- In the BWSR Spreadsheet, enter the distance from the bottom of the steep slope measured in the above steps to the nearest surface water in the box for D-distance to surface water.
- Enter the appropriate value for the dominant type of soil on the field. Choose 1 for sand, 2 for silt, 3 for clay, or 4 for peat.
- Leave the filter strip present box at a default of "n" for no.
- Enter the number of acres that should be converted to permanent vegetation in the AC (units applied) box. If you are only converting a portion of a field, only enter those acres.
- Then enter the watershed size in the CA (contributing acres) box. This can be calculated using the NRCS Engineering Toolbox-Watershed Delineation tool (Appendix D: Section 19.1).

Version 2.0 March 2022

- The outputs in the yellow box (Sediment, Soil, and Phosphorus) should now be accurate for the field that should be converted to permanent vegetation. Record these values in the Attribute Table or on the paper template for permanent vegetation conversion.
- Repeat process with the next field.

13.4.4 Wetland Restorations

This section has changed dramatically from the original version of the protocol. The old instructions have been archived as Appendix G: Section 22.1, but it is recommended to use the newest tools available. The Wetland Restoration Effectiveness Tool was used to identify and rank restorable wetlands in the assessment area.

- A shapefile of wetlands in the assessment area was created in Section 11.4. The NRCS Engineering Toolbox was used to create a Stream Network layer in Section 10.6.
- In ArcMap, use the NRCS Engineering Toolbox-Watershed Delineation-Create Watershed tool to delineate watersheds of the wetlands in the assessment area (Appendix D: Section 19.1.3).

Helpful Hint: for very large wetlands, or wetlands that are only partially within your assessment area, it may be desirable to divide the wetlands into segments and complete the model on each section.

The Wetland Restoration Effectiveness Tool will be used to determine nitrogen and phosphorus removal rates from individual wetlands. The cost per pound of nitrogen or phosphorus can then be determined using cost data from Table 8 in Section 13.5. Get this toolbox from https://bbe.umn.edu/wret.

- Open the spreadsheet to the Phosphorus tab (Figure 19).
- Enter the values in the User Inputs box.
- Find Wetland Acres using the Identify tool on your weltand layer.
- The Watershed Area can be calculated by running the Create Watershed step of the NRCS Engineering Toolbox – Watershed Delineation (see Appendix D: Section 19.1.3).

Site Name:	

User Inputs	Value
Wetland Area (Acres)	0.00
Watershed Area (Acres)	0.00
Mean Annual Runoff (Inches)	0.00
Annual Total Phosphorus Yield (lbs/acre)	0.00
Depth to Water Table - Wetland Depth (ft)	0.00
Sand Content (%)	0%
Soil Bulk Density (g/cm^3)	0.00
Soil Organic Matter Content (%)	0.00
pH	0.00

Toolbar Outputs	Value
Total Phosphorus Load (pounds)	0.00
Total Phosphorus Removal Rate (%)	#DIV/0!
Total Phosphorus Load Removed (pounds)	#DIV/0!
Particulate Phosphorus Removed (pounds)	#DIV/0!
Dissolved Phosphorus Removed (pounds)	#DIV/0!

Pounds	Kilograms

Figure 19. Wetland Restoration Toolbox-Phosphorus

Version 2.0 March 2022

- Mean Annual Runoff (Figure 21) and Annual Total Phophorus Yield (Figure 20) can be determined by the layers included in the toolbox. Both will likely be the same value for all fields in your assessment area.

Helpful Hint: for phosphorus, use the value 0.350 (per Table 1 in the Technical Memorandum for the Wetland Restoration Effectiveness Tool Development) since all of the fields we will be assessing will be considered "Agriculture".

George uses 7.5 inches for Mean Annual Runoff since the Monkey Catchment is about halfway between the lines for 7 and 8 inches. The Annual Total Phosphorus Yield is 0.350 for all fields.
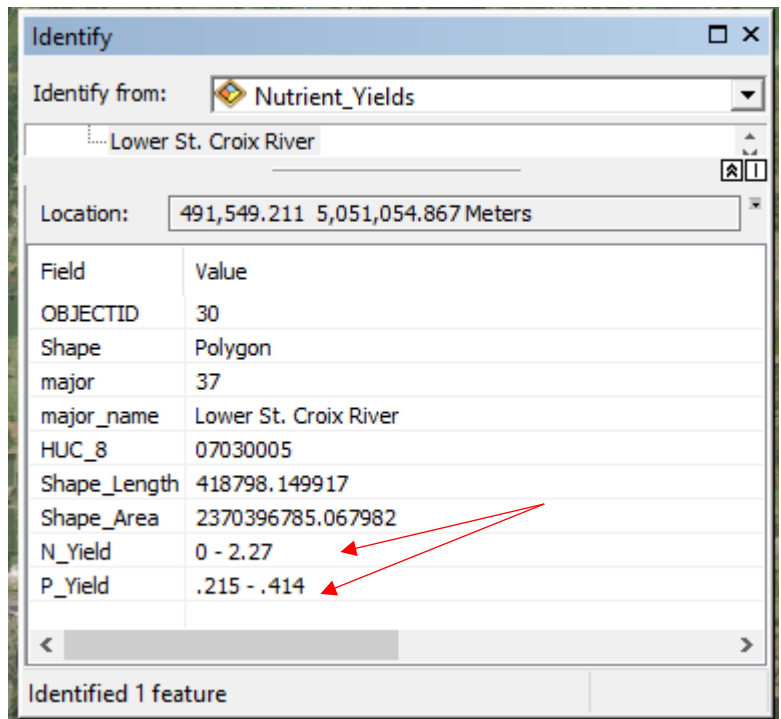
Figure 20. Nutrient Yield

- Use the Identify tool to determine Depth to Surface Water. This layer (WaterTableDepth) is included in the toolbox.
- Sand Content, Soil Bulk Density, Soil Organic Matter, and pH values can all be obtained from the SSURGO_Soil_Inputs layer included in the toolbox (Figure 22).
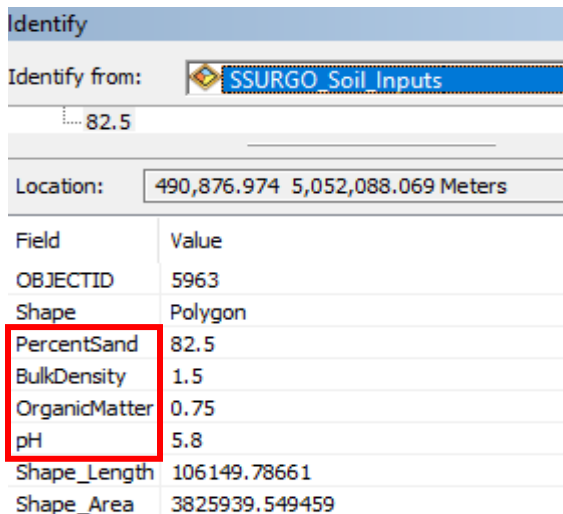
Figure 22. SSURGO Soil Inputs
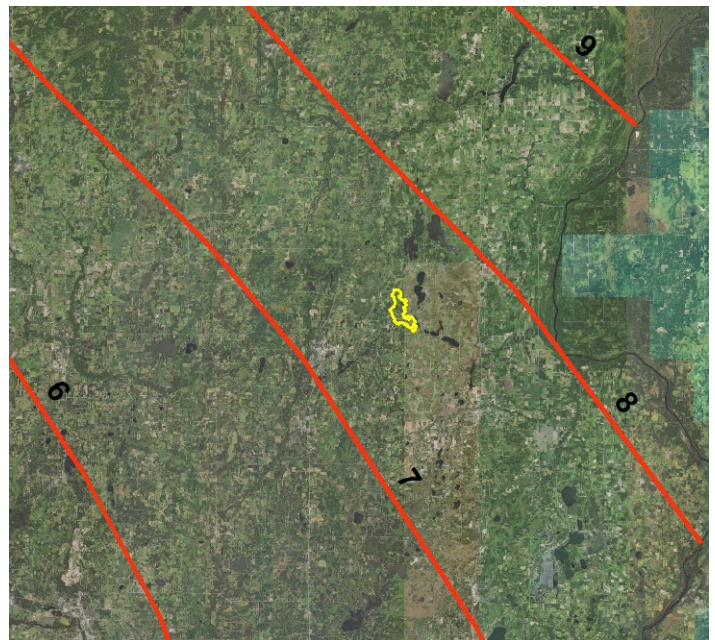
Figure 21. Mean Annual Runoff Layer

- Once all inputs are entered into the User Outputs box, the outputs will be automatically calculated in the Toolbar Outputs. Record these values in the Attribute Table.
- Repeat for all wetlands.

Next, determine the Total Nitrogen:

- Open the Nitrogen tab.
- Select a value in the range given when the Identify tool is used (Figure 20, previous page) and use it for all fields. For the Chisago Rural SWA, the highest value in the range was used as a "worst case scenario."

George uses 2.27 for the nitrogen yield. It's the upper end of the range (0–2.27) for his wetland.

- Once all inputs are entered into the User Outputs box, the outputs will be automatically calculated in the Toolbar Outputs. Record these values in the Attribute Table.
- Repeat for all wetlands.

If desired, enter the inputs required in the Carbon Tab to determine Total Organic Matter Mass, Total Carbon Storage in Tons, and Total Carbon Storage in Tons per Acre.

13.4.5   Animal Operations and Pastured Wetlands

No modeling was done for the animal operations or pastured wetlands for the Chisago Rural Subwatershed Assessment. Due to the in-depth nature of modeling any type of animal operation and the difficulty in fairly comparing pollution reduction efficiency with other BMPs, the Chisago SWCD felt this would be better left to a separate assessment. There are available models that can be used, such as MINNFarm. The tool and instructions are available from the University of Minnesota.

https://extension.umn.edu/livestock-operations/manure-management#runoff-risk-advisory-forecast-2289113

13.4.6   Stream Bank and Shoreline Erosion

No modeling was done for stream bank or shoreline erosion in the Chisago Rural Subwatershed Assessment. However, there is a Stream/Ditch tab in the BWSR Water Erosion Pollution Reduction Estimator designed to estimate the sediment (TSS), soil, and total phosphorus values for bank erosion in streams and ditches. The inputs needed for this model are the soil type (sand, silt, clay, or peat), the volume voided (see instructions in Section 13.4.2 for determining this number), and the number of years (use professional judgment to set "rules" for this input).

Version 2.0 March 2022

13.4.7 Management Practices

Management practices were not included in the mapping section of the protocol because of the widespread coverage of the practices. They can be applied to any field, so mapping is not valuable. However, there is some modeling that can be used to determine a potential pollution reduction value for implementing management practices on a field. The BWSR Water Erosion Pollution Reduction Calculator and RUSLE2 can be used to predict reductions in soil loss between different crop and management scenarios. Follow the instructions for modeling permanent vegetation (Section 13.4.3) and adjust the management practice you chose for different management practices in Section 13.3.3.

Not all management practices can be measured in terms of phosphorus reduction. For example, rotational grazing certainly reduces erosion and soil loss by keeping pasture forage healthy and not allowing livestock to create bare soil areas. There is not a good way to measure how much less erosion there will be in a scenario like this. Therefore, the management practices that are included in this protocol for cost per pound of phosphorus comparison are: residue and tillage management, cover crop, and conservation crop rotation (Table 7).

Table 7. Management BMP Scenarios

Management Practice	Scenario Before	Scenario After
Residue and Tillage Management	CMZ04, Multi-year Rotation Templates, Corn-Soybeans, CB Mulch till, Corn FC Disk Fld Cult-Soybeans FC Disk Fld Cult	CMZ04, Multi-year Rotation Templates, Corn-Soybeans, CB NT, corn grain; NT Soybean, nr NT single disk openers Z4.
Cover Crop		CMZ04, Multi-year Rotation Templates, Cover Crops rotations, corn grain; NT, Sdisk fcult rye cover, Soybean; 18 in row, NT z4.
Conservation Crop Rotation		CMZ04, Multi-year Rotation Templates, Corn-Soybeans-Alfalfa 3 yrs, corn FP-Soybeans NT-Oats alfalfa sseeding disc, fcult-Alfalfa Hay 3 yr, 3 cut, 4 tons/acre.

Version 2.0 March 2022

13.5 Determining Cost Per Pound of Total Phosphorus

Once all the BMPs have been modeled, the total cost of the BMP, an average annual cost, and the cost per pound of total phosphorus reduction can be determined. Table 8 is a template that can be used to combine all the BMPs that will be ranked against each other. For the Chisago SWCD report, the table was created in Excel.

Table 8. BMP Table

Rank	ID	BMP	Category	Amount	Unit	Cost/Unit	Total Cost	TP Reduction (pounds)	Cost/Pound TP	Life span	O&M Factor**	Ave. Annual Cost*

*Average Annual Cost is installation amortized over practice lifespan at 2.1%, plus O&M.

**Multiply the factor by the typical total cost to determine the estimated O&M

Helpful Hint: be sure to note the Typical Units in Tables 9 and 10 (next pages). Many of the dollar amounts given are not a straight 1:1. For example, a grassed waterway <200 acres in drainage area is $4,800 per 1,000 ft. This is important when calculating the total cost of each BMP. If you have a grassed waterway with 150 acres of drainage area that is 400 feet long, you need to convert your unit to match the one in the table. In this case, you would divide your unit value (400) by the typical unit value (1000) and then multiply that number by the typical total cost given in the table ($1,920).

If you plan to calculate the Average Annual Cost, you'll need to multiply the total cost as figured above by the O&M factor, add the value to the total cost, and then divide that by the lifespan. For example, our total cost for the grassed waterway came out to $1,920. To determine the O&M, multiply that by the O&M Factor (2%). Add this value ($38.40) to the total ($1,958.40). Divide by the lifespan (10 years) to determine the average annual cost ($195.84).

Version 2.0 March 2022

13.5.1 Structural BMPs

Use Table 9 to determine an approximate cost for installation and maintenance of each the structural BMPs that are modeled in this protocol. These values are from the Natural Resources Conservation Service (NRCS) Statewide Typical Practice Costs 2018.

Table 9 Structural BMPs

BMP	Category	Typical Total Cost (rounded)	Units	Typical Units	Estimated Average Cost per Unit	Life Span (yrs)	O&M Factor **	Ave. Annual Cost*
Grassed Waterway	<200 acres DA	$4,800		1,000	$5			$634
	200-600 acres	$6,100		1,200	$5			$804
	>600 acres	$15,700		1,500	$10	10	2%	$2,070
Grassed Waterway with Checks	<200 acres	$7,400	Ft	1,000	$7			$981
	200-600 acres	$10,400		1,200	$9			$1,380
	>600 acres	$26,000		1,500	$17			$3,430
Water and Sediment Control Basin (Grassed)	<4'	$2,600		400	$6			$375
	4-6'	$5,400		600	$9			$773
	6-8'	$9,400	Ft	600	$16	10	3%	$1,330
	8-10'	$14,100		600	$24			$2,010
	10-12'	$18,000		500	$36			$2,550
	12-15'	$13,000		250	$52			$1,850
Water and Sediment Control Basin (Farmed)	<4'	$5,500	Ft	450	$12	10	3%	$778
	4-6'	$9,400		600	$16			$1,330
Grade Stabilization Structure (Embankment Dam)	0-5 acres DA	$6,000			$6,021			$532
	5-10 acres	$8,000			$7,794			$705
	10-20 acres	$11,400			$11,363			$1,000
	20-40 acres	$18,500	Ea	1	$18,492	15	1%	$1,630
	40-70 acres	$30,200			$30,220			$2,670
	70-100 acres	$32,300			$32,276			$2,850
	100-200 acres	$35,700			$35,726			$3,160
	>200 acres	$42,600			$42,602			$3,770
Lined Waterway or Outlet	Turf Reinforced Matting	$3,600			$0.80			$642
	Rock Lined <= 6"	$18,800	Sq Ft	4,500	$4	15	10%	$3,360
	Rock Lined >6"	$30,000			$7			$5,360
	Concrete	$26,700			$6			$4,770
Diversion	Earthen	$1,500	Ft	500	$3	10	2%	$201
Filter Strip	Native species	$613	Ac	1	$613	10	2%	$81
	Introduced species	$597			$597			$79
Wetland Restoration	Ditch Plug	$623	Ea	1	$623			$55
	Tile Break	$606			$606			$54
	Sediment Removal and Plug	$22,000	Ac	15	$1,468	15	1%	$1,950
	Scrape 12"	$6,600		1	$6,622			$585
	Scrape 24"	$12,700			$12,749			$1,130

*Average Annual Cost is installation amortized over practice lifespan at 2.1%, plus O&M.

**Multiply the factor by the typical total cost to determine the estimated O&M

13.5.2 Management BMPs

Costs for management activities are listed in Table 10. These values are from the NRCS Statewide Typical Practice Costs 2018. It is important to remember that management practice costs and benefits are complex and unique to each situation. There is no one hard and fast cost for the practices, but these have been included to get an estimate that can be compared with structural BMPs.

Table 10. Management BMPs

BMP	Category	Typical Total Cost (rounded)	Units	Typical Units	Estimated Average Cost per Unit	Life Span (years)	O&M Factor **	Average Annual Cost*
Residue and Tillage Management	No till/Strip till	$2,100	Acre	100	$21	1	0%	$2,050
	With Herbicide	$4,500			$45			$4,460
Cover Crop	1 species	$3,400	Acre	40	$84	1	0%	$3,350
	Multiple species	$3,900			$98			$3,920
Nutrient Management	Basic	$339	Acre	40	$8	1	0%	$339
	Manure/Compost	$731			$18			$731
	Precision	$2,000			$50			$2,010
Integrated Pest Management	Basic	$666	Acre	40	$17	1	0%	$666
Conservation Crop Rotation	Basic	$1,301	Acre	100	$1,300	1	0%	$1,300
Pasture or Hay Planting	Cool Season	$5,600	Acre	30	$185	5	3%	$1,350
Waste Storage Facility	In ground <50K storage, earthen	$9,500	Cubic Foot	25,000	$.40	15	2%	$935
	In ground >50K storage, earthen	$47,200		168,000	$0.30			$4,630
	Concrete <25K storage, earthen	$96,500		13,237	$7			$9,500
	Concrete 25-100K storage, earthen	$206,600		73,952	$3			$20,300
	Concrete >100K storage, earthen	$387,900		175,034	$2			$38,240
	Dry Stack, Concrete	$50,800	Sq ft	4,000	$13			$5,000
	Buried Tank <5K storage	$26,800	Cubic Foot	3,600	$7			$2,630
	Buried Tank 5-15K storage	$27,600		9,420	$3			$2,720
	Buried Tank 15-25K storage	$45,200		20,000	$2			$4,450
	Buried Tank 25-50K storage	$51,200		28,000	$2			$5,040
	Buried Tank 50-75K storage	$98,500		62,000	$2			$9,700
	Buried Tank 75-110K storage	$130,400		92,500	$1			$12,830
	Buried Tank >110K storage	$199,000		152,600	$1			$19,520
Prescribed Grazing	Pasture Standard	$1,200	Acre	40	$31	1	0%	$1,230

*Average Annual Cost is installation amortized over practice lifespan at 2.1%, plus O&M.

**Multiply the factor by the typical total cost to determine the estimated O&M

13.6 RANKING

After completing all the modeling and cost estimation for the BMPs identified for the assessment, ranking of the highest priority projects can be completed. There are several ways to rank the projects. Three options will be discussed in this protocol.

13.6.1   Ranking by Lowest Cost per Pound of Total Phosphorus Reduction

In line with the Top50P! protocol, ranking can be done as a list of the top 50 (or another number that you choose) individual projects from a variety of BMPs ranked by cost per pound of phosphorus reduction. The cost per pound of phosphorus can be compared across different BMPs and different models because you have determined a common unit of comparison. Using the template in Table 8, you would sort the table by "Cost per pound TP".

13.6.2   Ranking by Total Phosphorus Reduction

Some users choose to rank projects by the total phosphorus reduction each project could achieve, regardless of cost. Since total phosphorus output values from different models cannot be reliably compared, a ranking list for the highest potential phosphorus reduction should be made for each of the BMPs that were modeled using the same calculator. For example, the identified water and sediment control basins could be listed together with gullies and grassed waterways since they all use the BWSR Water Erosion Pollution Reduction Estimator Gully tab for modeling. Wetland restorations would be ranked amongst other wetland restorations, and so on. Management BMPs could be ranked against each other because they are all modeled using the same process.

13.6.3   Ranking by Field

Another option is to combine all comparable BMPs that are on a single field, giving each field a cumulative phosphorus reduction value. For example, a field may have one water and sediment control basin, 2 grassed waterways, and a filter strip identified on it. The cumulative value for this field would be the sum value of all the BMPs' estimated phosphorus reduction. The fields would be ranked by their cumulative total phosphorus reduction values. This method is valuable for meeting with landowners and addressing all the issues on a certain field, rather than just picking one BMP to resolve.

In this method, the phosphorus values from different models still cannot be compared equally. Therefore, wetland restorations, animal operations, and pastured wetlands are still ranked individually by BMP type. Even though the management BMPs and permanent vegetation fields used the same models as structural BMPs, the reduction values could be totaled separately to show the difference between the benefits of installing structural versus management BMPs across a field. It is also optional to list gullies separately due to the large reduction numbers that can be associated with these projects.

To rank by field, you will need to assign each field a unique identifier. This may have been done in Part 1: Targeting when the Land Cover Class shapefile was edited or created. To group different BMPs under the same field ID, you will need to add a column to each of the BMP attribute tables and enter the Field ID to each BMP on a field.

13.6.4   Create Ranking Document

When the decision on which method to use for ranking is made, the actual ranking can take place. If you created the BMP table (Table 8 from Section 13.5), all you need to do is sort the table by your desired column.

Version 2.0 March 2022

14 FINAL REPORT

The prioritizing protocol has been completed. The final step is to put this data into a format that can be used by staff to locate projects and begin project development. An example of a Project Profile page is provided here (Figure 23, next page) and is based off of the template used in the Urban Subwatershed Retrofit Analysis protocol.

The basic requirements for the final report include:

- Executive summary
- BMP location map of all identified BMPs
- Prioritization list(s) (by field or by each BMP)
- Project Profiles
- Documentation of how the targeting and prioritization were conducted

Several Rural SWAs completed by the Chisago SWCD are available at https://chisagoswcd.org/assessments/.

14.1 PROJECT PROFILE TEMPLATE

Chisago Lakes Chain of Lakes Section 3 Watershed-Field 130*

Project Description

This is an agricultural field of about 11 acres. A large concentrated flow path with several branches drains from the field and into a drainage ditch. About half of this field has steep slopes.

BMP Recommendation

The portion of this field that has steep slopes should be converted to permanent vegetation, such as hay or native grasses. If this field continues to be farmed with annual row crops, water and sediment control basins should be installed to stabilize erosion within the concentrated flow paths.

Catchment Summary	
Field Acres	10.5
Current Cover	**Corn/Beans**
# of Landowners	1
Removed TP (Lb/yr)	**44**
Removed TSS (Ton/yr)	**42**
Estimated Cost	**$39,330.06**
Cost/Lb TP	**$894**
Model Inputs	
Soil Type	**169B;169C**
Slopes >6%	**Yes**

Practice	Removed TP (Lb/yr)	Removed TSS (Ton/yr)	Watershed Size (Acres)	Average Watershed Slope (%)	Distance to Surface Water (Feet)		Estimated Cost	Cost/Lb TP
WASCOB 1	20	20	2.2	4.1	22		$9,803.70	$490
WASCOB 2	3	3	0.8	4.1	22		$9,803.70	$3,268
WASCOB 3	7	7	0.6	4.5	22		$9,803.70	$1,401
WASCOB 4	2	2	0.6	7.8	93		$9,803.70	$4,902

Practice	Removed TP (Lb/yr)	Removed TSS (Ton/yr)	Watershed Size (Acres)	Average Watershed Slope (%)	Existing Filter Strip (Feet)	Area (Acres)	Estimated Cost	Cost/Lb TP
Filter Strip	12	10	6.1	9.0	20	0.17	$115.26	$10

Chisago Soil & Water Conservation District   24

Figure 23. Example Project Profile

14.2 PARTS OF THE PROJECT PROFILE

14.2.1 Heading

At the top of the page, the watershed, subwatershed, or catchment name should be provided. The individual field or BMP number (or other identifying marker) should be given.

In the example provided (Figure 23, previous page), an asterisk (*) is shown at the end of the heading. This is used to indicate the identified Project Profiles that are also listed on the Permanent Vegetation table or have management BMPs identified. These fields would most benefit by being converted to permanent vegetation or by implementing a management BMP. If that is not feasible, the Project Profile lists other BMPs that can be implemented.

14.2.2 Project Description

This is a short sentence or two about the field or project location. Some of the important things to include are the size of the field, the current land cover, observations about the history or probability of future management, and anything else that is important to the management of that location or field.

14.2.3 BMP Recommendation

In this section, a recommendation for one or several BMPs is given. These are the BMPs that are identified on the map that is shown in the Project Profile and that contribute to the cumulative potential total phosphorus reduction for the field. Only those BMPs that are included in that total phosphorus reduction for this field should be given. If the ranking is done by individual BMP, the Project Profile should only include that individual BMP. The other BMPs will have their own Project Profile in the next BMP section.

14.2.4 Catchment Summary Table

The catchment summary table has information about the field as a whole. The exact categories in the table are different for each BMP. Categories can be added or deleted, but stay consistent throughout the final report. Example tables are not given for BMPs that were not included in the Rural Subwatershed Assessments done by the Chisago SWCD.

Table 11. WASCOB, Grassed Waterway, Filter Strip Catchment Summary Table

Catchment Summary		
Field Acres		Acres of the field that the Project Profile represents
Current Cover		Land cover that is on the field at the time of the assessment
# of Landowners		Number of unique landowners that own a portion of the field
Removed TP (Lb/yr)		Cumulative total of all the BMPs on the field
Removed TSS (Ton/yr)		Cumulative total of all the BMPs on the field
Estimated Cost	$	Estimated cost of installing all the BMPs on the field
Cost/Lb TP	$	Cost per pound of installing all the BMPs on the field
Model Inputs		
Soil Type		List all the soil types that are present on the field
Slopes >6%		Yes or no-are there any slopes on the field over 6%

Table 12. Gully Catchment Summary Table

Catchment Summary		
Length (Feet)		Length of the gully
Depth (Feet)		Depth of the gully
Watershed Size (Acres)		Size of the watershed contributing to the gully
Soil Type		List of all soil types that are present along the gully
Distance to Surface Water (Feet)		Distance from the bottom of the gully to the nearest surface water
Removed TP (Lb/yr)		
Removed TSS (Ton/yr)		

Table 13. Wetland Restoration Catchment Summary Table

Catchment Summary		
Soil Type		List all soil types that are present in the wetland
NWI Wetland Code (Cowardin)		The NWI code given to the wetland. If the code is from the 2013 update, put (2013 update) after the code.
Wetland Type (Circular 39)		The wetland type of the wetland. If the code is from the 2013 update, put (2013 update) after the code.
Current Wetland Size	Acres	Size of the wetland as delineated by the NWI layer.
Watershed Size	Acres	Size of the watershed contributing to the wetland. If the wetland is in a chain of wetlands, cut off the wetland at the next upstream wetland's outlet.
Watershed to Wetland Ratio		Watershed: Wetland in reduced format
Received Water From		What other identified wetlands, or lakes/streams, contribute to this wetland?
Flows To		Where does the water from this wetland go next?
Dominant Watershed Land Use		List the top one or two most dominant land uses in the watershed.
Number of Landowners		The number of unique landowners that may be affected by a restoration.
Potential Total Phosphorus Reduction	Lbs/yr	

Table 14. Animal Operation Catchment Summary Table

Catchment Summary		
Animal Operation Acres		The size of the feedlot or animal operation.
#/Type Animal		Categories: 0-10, 11-100, 101-250, 250+
# of Landowners		The number of unique landowners that own a portion of the animal operation. Usually 1.
Soil Type		List all soils types that are present in the feedlot area.
Wetland Present		Are there NWI identified wetlands present?
Streams Present		Are there streams present in the animal operation area?
Ditching Present		Is there ditching into or out of the animal operation area?
Distance to Surface Water (Feet)		The distance from the edge of the animal operation area to the nearest surface water.

Table 15. Pastured Wetland Catchment Summary Table

Catchment Summary		
Pasture Acres		The size of the pasture.
#/Type Animal		Categories: 0-10, 11-100, 101-250, 250+
# of Landowners		The number of unique landowners that own a portion of the animal operation. Usually 1
Soil Type		List all soils types that are present in the feedlot area.
NWI Wetlands Present		Are there NWI identified wetlands present?
Streams Present		Are there streams present in the animal operation area?
Ditching Present		Is there ditching into or out of the animal operation area?

14.2.5 Map

Include a map that shows the extent of the field and the watershed(s) of the BMP(s). Use an aerial photograph for the background. Turn on the appropriate BMP layer(s) for the Project Profile being created. Label the field that is being described in the Project Profile and any other fields that are mentioned in the Project Description. If more than one BMP is shown on the map, label each so that they can be identified individually.

Helpful Hint: Use the Insert Legend tool to build a legend based on the layers being displayed on the map. In some cases, it may be easier to build your own legend rather than manipulate the display of the layers. For example, when there are multiple polygons in a shapefile (such as the watersheds of several different BMPs that cross field boundaries), but you don't want to display them all, they will still show up in the Legend.

Version 2.0 March 2022

14.2.6 Individual BMP Table

At the bottom of the Profile Page for each field, a second table (Figure 16, next page) is included that gives specific information for each individual BMP. This allows the reader to identify which BMPs are most crucial to achieving the reported pollution reduction values.

Table 16. Individual BMP Table

Practice	Removed TP (Lb/yr)	Removed TSS (Lb/yr)	Watershed Size (Acres)	Average Watershed Slope (%)	Distance to Surface Water (Feet)	Length (Feet)	Estimated Cost	Cost/Lb TP
GW 1								
Practice	Removed TP (Lb/yr)	Removed TSS (Lb/yr)	Watershed Size (Acres)	Average Watershed Slope (%)	Distance to Surface Water (Feet)		Estimated Cost	Cost/Lb TP
WASCOB 1								
Practice	Removed TP (Lb/yr)	Removed TSS (Lb/yr)	Watershed Size (Acres)	Existing Filter Strip (Feet)	Area (Acres)		Estimated Cost	Cost/Lb TP
Filter Strip								

15 FINAL NOTES

The protocol given here is simply what was done during the Rural Subwatershed Assessments completed in Chisago County. The Chisago SWCD staff had very few developed protocols to follow and had to create many of the steps and procedures used in this document. There are almost certainly better ways to complete some of these steps. Feedback and improvements are welcome.

The main thing to remember is to set your "rules" and stick to them during the modeling process. If you change certain inputs part way through the project, your results are no longer valid.

16 APPENDIX A: GIS BASICS

16.1 CREATE A NEW SHAPEFILE

The best way to create a new shapefile in your project is to use ArcCatalog. ArcMap should be open to the .mxd file created for this rural subwatershed assessment.

Figure 24. Arc Catalog

- Click on the ArcCatalog button to open ArcCatalog (Figure 24).
- In the Catalog window, navigate to the location of your ArcMap project mxd. file. If you haven't already, you may want to create a new folder to hold the project and the new shapefile(s) you are going to create.
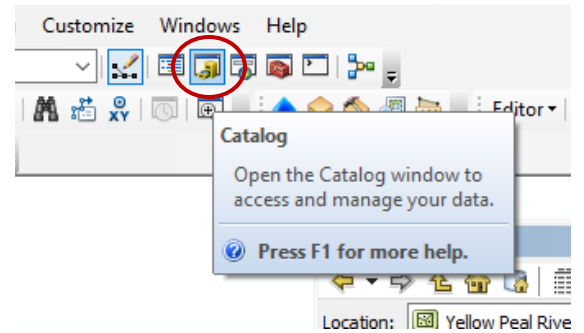
George had already created a new folder in Section 10.1.

- 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 25).
- Enter a name for your new shapefile.

George names his Yellow_Peal_Boundary.
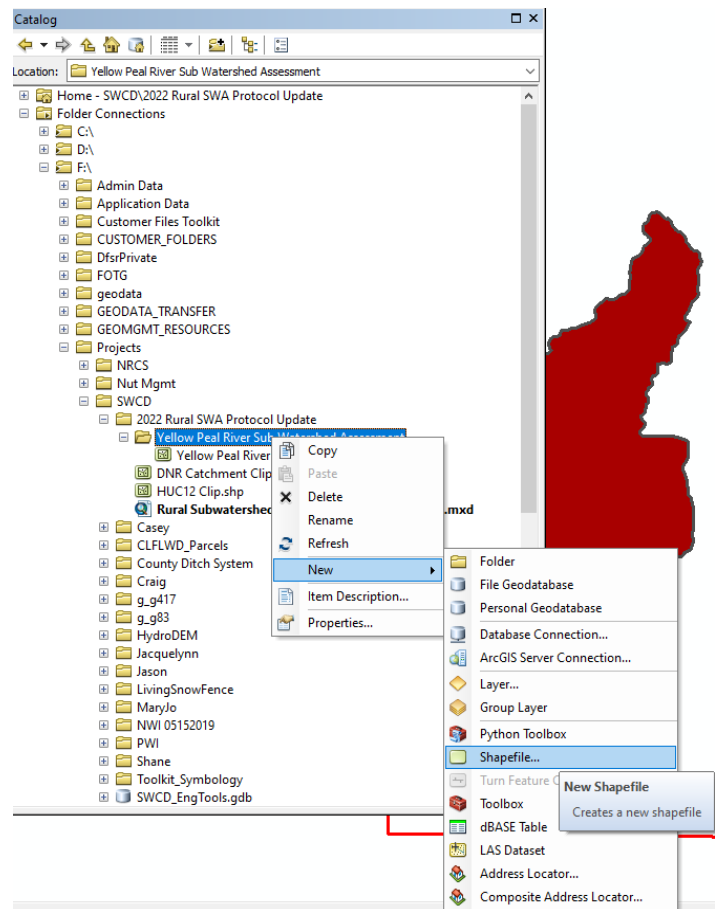
Figure 25. Create New Shapefile

Version 2.0 March 2022

- In the dropdown menu, choose Polygon.
- Click the Edit button to set the correct coordinate system for your project (Figure 26).
- Then click OK. The new shapefile should appear in the Table of Contents window.

George's assessment area is NAD 1983 UTM Zone 15N. He drills down to the correct coordinate system and selects it.
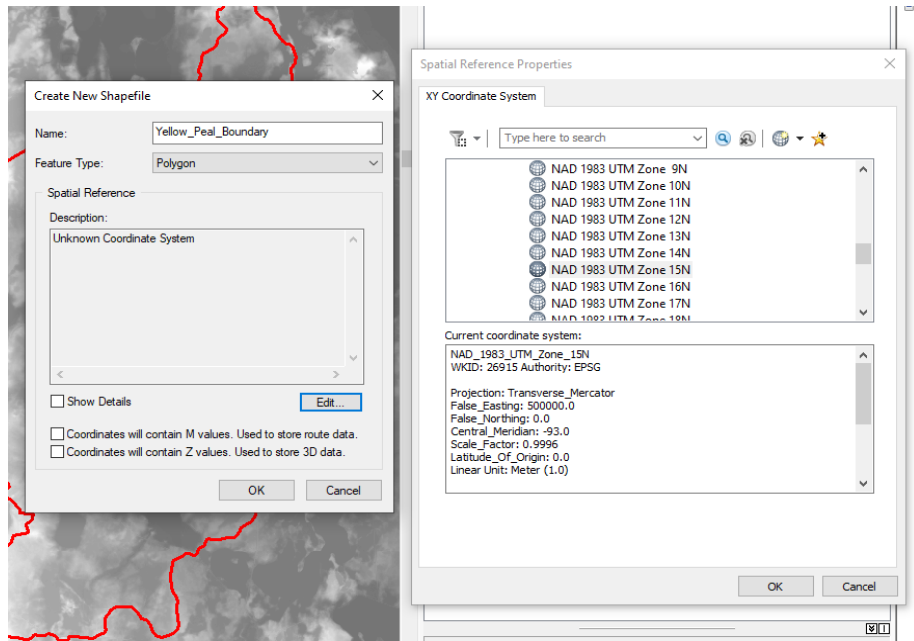
Figure 26. Create New Shapefile

- Right click on the new shapefile and select Start Editing (Figure 27).
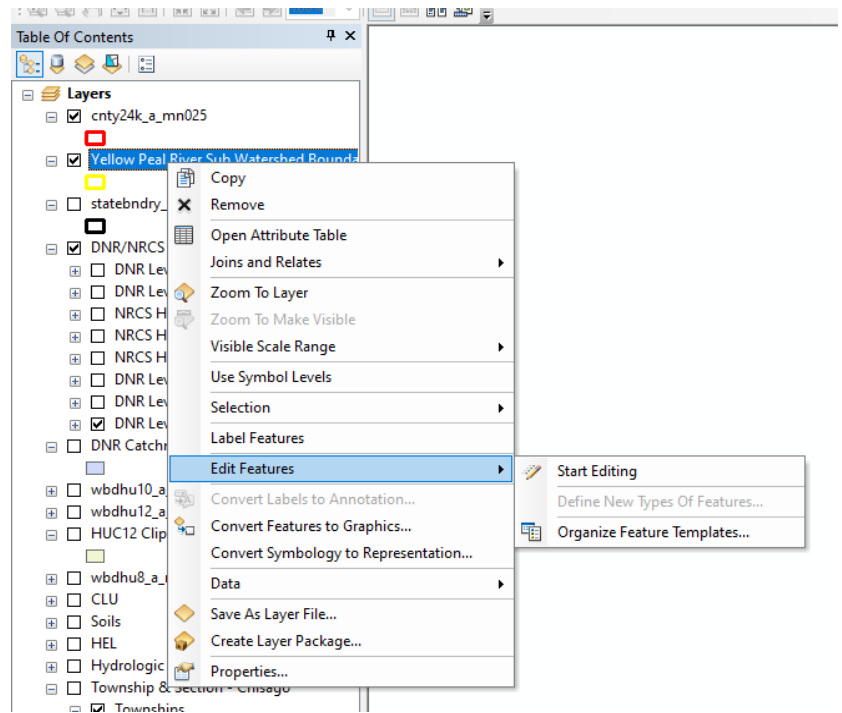
Figure 27. Start Editing New Shapefile

Version 2.0 March 2022

- Open the Editing Window. If you do not have an Editing Window open by default, select Editor on the Editor Toolbar to open a drop-down menu. Select Editing Windows and then Create Features (Figure 28).
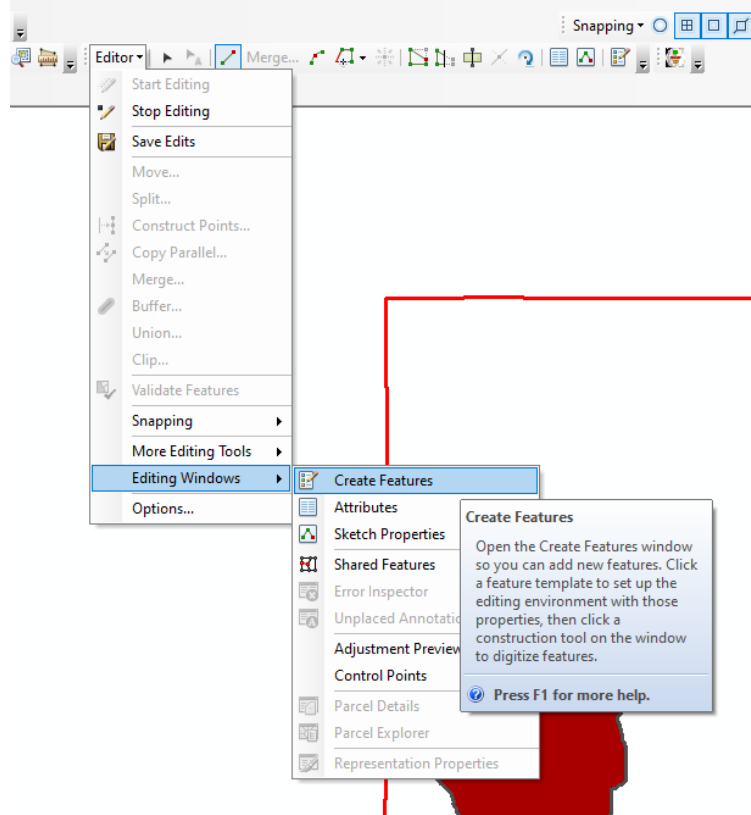
Figure 28. Open Editing Window

- In the Editing Window (Figure 29), select your boundary polygon in the top box.
- Below this should be a box labeled Construction Tools. Click on Polygon.

- Draw your watershed boundary. It is recommended you use the Trace Tool (Figure 30).

Figure 30. Trace Tool

Figure 29. Create Feature

Version 2.0 March 2022

- Once your polygon is complete, select Stop Editing from the Editor drop down menu (Figure 31).

George now has a polygon shapefile of the boundary of the Yellow Peal River Sub Watershed, which he will use frequently in the steps of the protocol (Figure 32).

Figure 31. Stop Editing
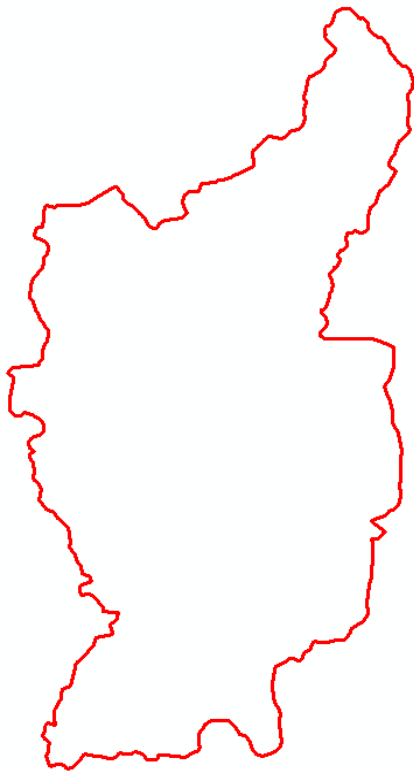
Figure 32. Yellow Peal River Sub Watershed Boundary

Version 2.0 March 2022
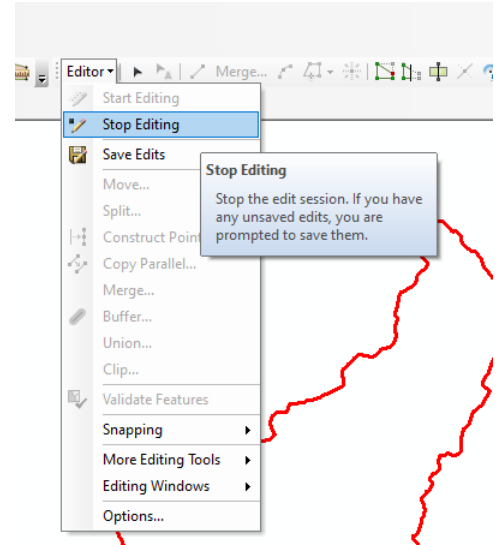
16.2 CLIPPING SHAPEFILES AND RASTERS

16.2.1 Clip Shapefiles to Boundary

It will greatly reduce processing time if you are only running tools on the area you are working in. Clipping your base shapefiles at the beginning is recommended.

- To clip polygon shapefiles, select Geoprocessing on the top ribbon, select Clip (Figure 33).
- Input Feature (Figure 34) will be the layer that you want to clip down to your assessment area.
- Clip feature is the watershed boundary shapefile.
- Select OK.
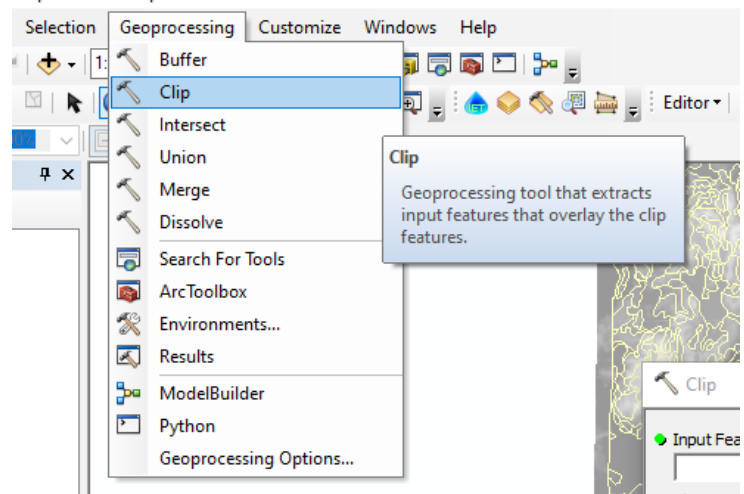
Figure 33. Clip tool
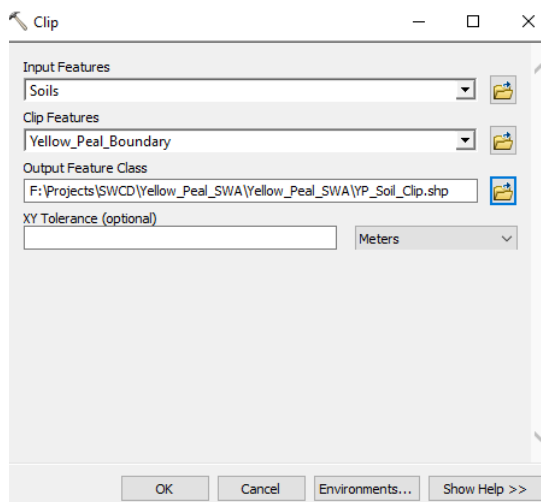
Figure 34. Clipping Shapefiles
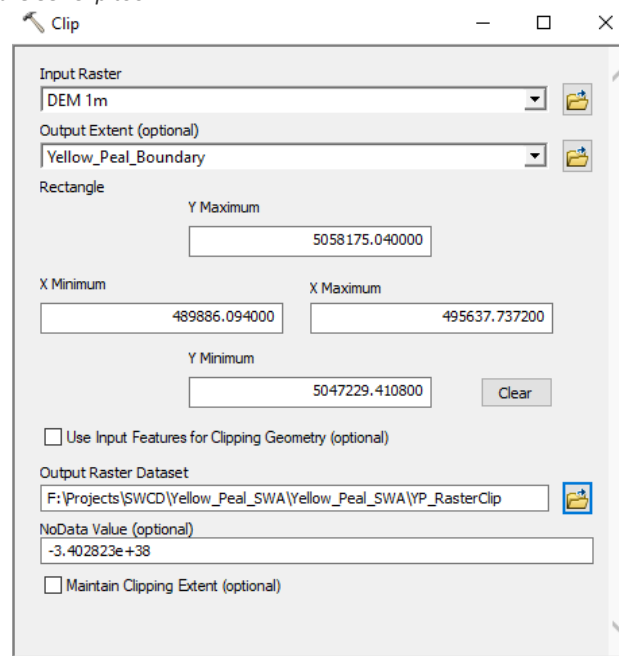
Figure 35. Clipping Rasters

16.2.2 Clipping Rasters

- Open the Clip tool from the Data Management Toolbox (Figure 35).
- Input Raster should be the DEM raster (1 Meter if available).
- Output Extent is the watershed boundary polygon.
- Output Raster Dataset will be the folder created for this project.
- Select OK.

Tool Path

ArcToolbox
Data Management Tools
Raster
Raster Processing
Clip

Version 2.0 March 2022
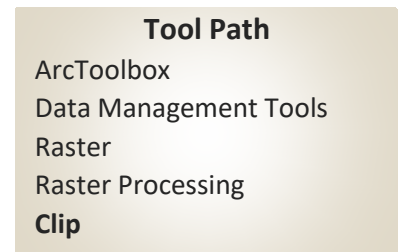
17 APPENDIX B: DESKTOP SCOUTING

17.1 DESKTOP SCOUTING EXAMPLES

The following are examples of what different potential issues can look like when scouting the aerial photos, hillshade, and contour layers. The series will show different views of the same location to prove how different views can provide different detection levels. Red arrows indicate features that should be marked as a potential problem.

> *Helpful Hint: Zoom in and out to view the layers at different scales. Certain things may show up at a finer scale that can't be seen when zoomed out.*

Figure 36. Aerial Photograph Only

Version 2.0 March 2022

Figure 37. Aerial Photograph Only

Figure 38. Hillshade Only

Version 2.0 March 2022
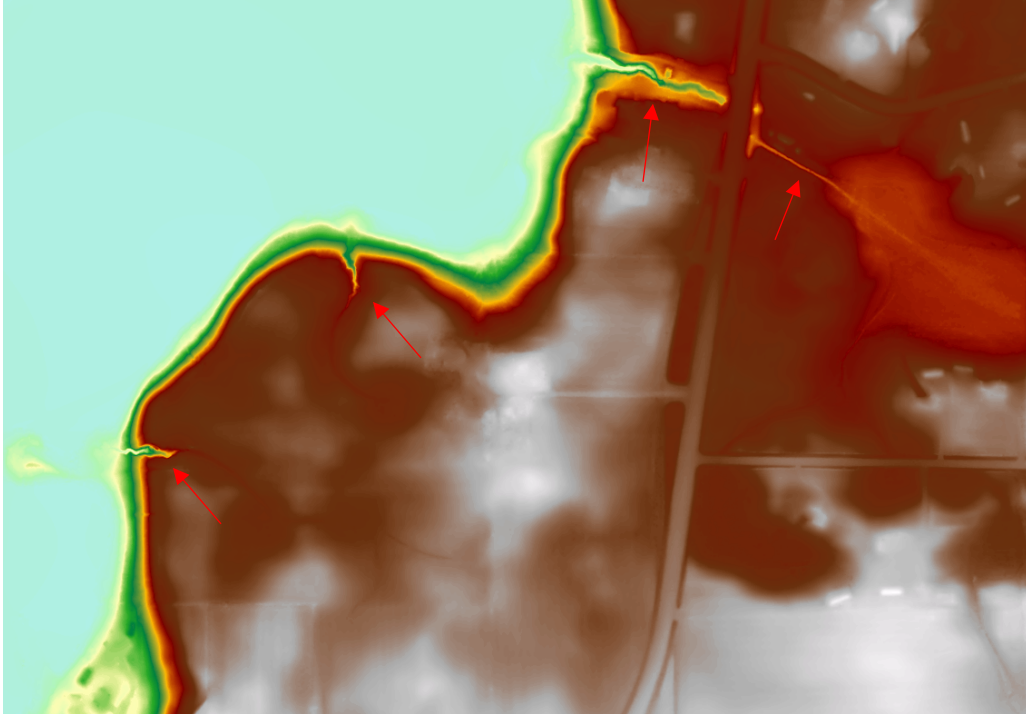
Figure 39. DEM Only
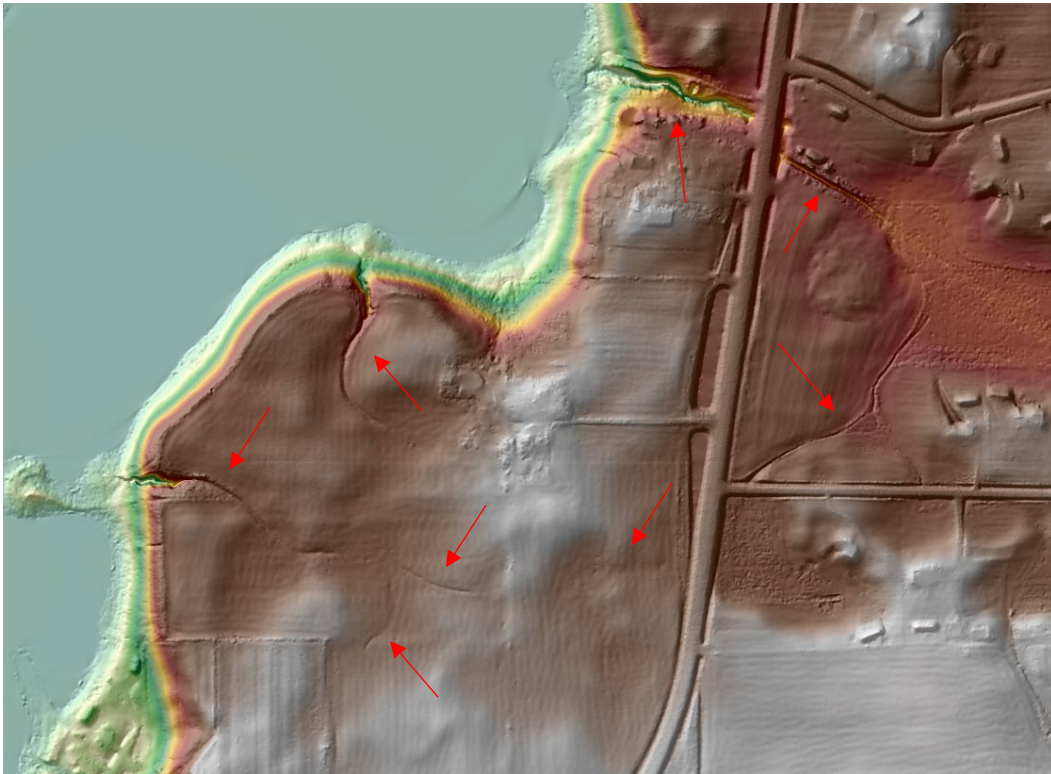
Figure 40. DEM and Hillshade

Version 2.0 March 2022

Figure 41. One-foot Contours

Figure 42. Zoom In on Contours

Helpful Hint: Concentrated flow paths often show up with "sharp" ends that point upstream.

Version 2.0 March 2022

Figure 43. Identifying Pastures and Animal Operations

18 APPENDIX C: ATTRIBUTE TABLES

18.1 ATTRIBUTE TABLES

In the steps for modeling each BMP type, the minimum columns needed are listed (they are also included here). The additional columns listed here can be added to record the model input values and information that is needed for creating the Project Profiles.

***For explanation of inputs and sources, please refer back to the protocol guidance for each specific BMP.**particular*

18.1.1   Water and Sediment Control Basins, Grassed Waterways, and Gully

The model used for this BMP is the BWSR Water Erosion Pollution Reduction Estimator-Gully tab.

	Column Name	Description	Column Type	Length/ Scale	Precision	Unit	Source	Example Inputs
Project Profile	G_ID WASCOB_ID GWW_ID	Gully, WASCOB, or Grassed Waterway ID	Text	50			User assigned	GWW1, GWW2, etc.
	CC	Land Cover Class	Text	50			Part 1: Targeting Land Cover Class	Corn or Beans, Hay, Herbaceous, Pasture, Forest, Wooded Wetland, Wetland, Barren, Open Water, Developed High Intensity, Developed Low Intensity
	OWN	Number of landowners	Short Integer		5		County parcel data	1, 2, etc.
	Steep	Slopes over 6% present?	Text	5			Soil layer (C or higher letters = steep slopes)	Yes or No
	Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	169B
BWSR Water Erosion Pollution Reduction Estimator	SSCP	Sand, Silt, Clay, Peat	Short Integer		5		Soil layer	1 = Sand 2 = Silt 3 = Clay 4 = Peat
	VOLV	Volume Voided	Float	2	15	Ft^3	BWSR Volume Voided Calculator	7,600
	YR	Number of Years	Short Integer		5		User assigned (Section)	1 = plowed through 30 = plowed around 100 = gully
	COND	Gully condition	Short Integer		5		User assigned (Section)	1 = channelized 2 = non-channelized 3 = landlocked
	DSF	Distance to Surface Water	Short Integer		10	Feet	GIS measurement	300

Version 2.0 March 2022

	Column Name	Description	Column Type	Length/Scale	Precision	Unit	Source	Example Input
Outputs	TP	Total Phosphorus	Float	2	5	Lb/yr	BWSR	20.39
	TSS	Total Suspended Solids	Float	2	5	T/yr	BWSR	17.39
	S	Soil	Float	2	5	T/yr	BWSR	17.39

18.1.2 Filter Strip

The model used for this BMP is the BWSR Water Erosion Pollution Reduction Estimator-Filter Strip tab.
Inputs from RUSLE are required.

	Column Name	Description	Column Type	Length/ Scale	Precision	Unit	Source	Example Input
Project Profile	FS_ID	Filter Strip ID	Text	50			User assigned	FS1; FS2, etc
	CC	Land Cover Class	Text	50			Part 1: Targeting Land Cover Class	Corn or Beans, Hay, Herbaceous, Pasture, Forest, Wooded Wetland, Wetland, Barren, Open Water, Developed High Intensity, Developed Low Intensity
	OWN	Number of landowners	Short Integer		5		County parcel data	1, 2, etc.
	Steep	Slopes over 6% present?	Text	5			Soil layer (C or higher letters = steep slopes)	Yes or No
RUSLE2	Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	159B
	SL_FS	Slope Length of the filter strip itself	Short Integer		5	Feet	Constant	50.0
	SL_S	Slope Steepness	Float	2	5	%	GIS measurement	4.0
	BM1	Base Management with no FS	Text		100		User assigned (Section)	CMZ04/Multi-year Rotation Templates/Corn-Soybeans/CB Mulch till/Corn FC Disk Fld Cult-Soybeans FC Disk Fld Cult
	BM 2	Filter Strip Management	Text		100		User assigned (Section)	Filter Strip, Actual Width, 50-Ft Cool Season Grass Filter Strip.
	SL_FS2	Slope Length of the watershed	Short Integer		5	Feet	GIS measurement	80.2

	SL_S2	Slope Steepness of watershed	Float	2	5	%	NRCS Engineering Toolbox	4.2
BWSR Water Erosion Pollution Reduction Estimator	SLB_FS	Soil Loss Before of the filter strip itself	Float	2	10	T/Ac/yr	RUSLE	2.9
	SLA	Soil Loss After of the filter strip itself	Float	2	10	T/Ac/yr	RUSLE	0.044
	AFS	Area of filter strip to be installed	Float	2	5	Acres	(Length * 50) / 43,560	0.2
	SSCP	Sand, Silt, Clay, Peat	Short Integer		5		Soil layer	1 = Sand 2 = Silt 3 = Clay 4 = Peat
	CA	Contributing Area to filter strip	Float	2	5	Acres	NRCS Engineering Toolbox	20.0
	SLB_WS	Soil Loss Before of contributing area	Float	2	10	T/Ac/yr	RUSLE	1.8
Output	TP	Total Phosphorus	Float	2	5	Lb/yr	BWSR	0.36
	TSS	Total Suspended Solids	Float	2	5	T/yr	BWSR	0.29
	S	Soil	Float	2	5	T/yr	BWSR	0.36

Version 2.0 March 2022

18.1.3 Permanent Vegetation

The model used for this BMP is the BWSR Pollution Reduction Estimator-Sheet and Rill tab. Inputs from RUSLE are required.

	Column Name	Description	Column Type	Length/Scale	Precision	Unit	Source	Example Inputs
Project Profile	PV_ID	Permanent Vegetation ID	Text	50			User assigned	PV1, PV2, etc.
	CC	Land Cover Class	Text	50			Part 1: Targeting Land Cover Class	Corn or Beans, Hay, Herbaceous, Pasture, Forest, Wooded Wetland, Wetland, Barren, Open Water, Developed High Intensity, Developed Low Intensity
	OWN	Number of landowners	Short Integer		5		County parcel data	1, 2, etc.
RUSLE	Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	159B
	SL	Slope Length	Short Integer		5	Feet	GIS measurement	
	Slope	Average slope (%)	Float	2	5	%	NRCS Engineering Toolbox	
	BM1	Base Management before (farmed)	Text		100		User assigned (Section)	CMZ04/Multi-year Rotation Templates/Corn-Soybeans/CB Mulch till/Corn FC Disk Fld Cult-Soybeans FC Disk Fld Cult
	BM 2	Base Management after conversion to permanent vegetation	Text		100		User assigned (Section)	Established Alfalfa, Year 4
BWSR Water Erosion Pollution Reduction Estimator	SLB	Soil Loss Before	Float	2	10	T/Ac/yr	RUSLE	1.5
	SLA	Soil Loss After	Float	2	10	T/Ac/yr	RUSLE	0.5
	DSW	Distance to Surface Water	Short Integer		5	Feet	GIS measurement	300
	SSCP	Sand, Silt, Clay, Peat	Short Integer		5		Soil layer	1 = Sand 2 = Silt 3 = Clay 4 = Peat
	AC	Acres applied (portion of field that should be converted to permanent vegetation)	Float	2	5	Acres	GIS measurement	40
	CA	Contributing Acres (watershed size)	Float	2	5	Acres	NRCS Engineering Toolbox	16
Outputs	TP	Total Phosphorus	Float	2	5	Lb/yr	BWSR	11.03
	TSS	Total Suspended Solids	Float	2	5	T/yr	BWSR	7.99
	S	Soil	Float	2	5	T/yr	BWSR	10.0

Version 2.0 March 2022

18.1.4 Wetland Restoration

Potential wetland restorations were modeled using the Wetland Restoration Toolbar.

	Column Name	Description	Column Type	Length/ Scale	Precision	Unit	Source	Example Inputs
Project Profile	WR_ID	Wetland Restoration ID	Text	50			User assigned	WR1, WR2, etc.
	CC	Land Cover Class	Text	50			Part 1: Targeting Land Cover Class	Corn or Beans, Hay, Herbaceous, Pasture, Forest, Wooded Wetland, Wetland, Barren, Open Water, Developed High Intensity, Developed Low Intensity
	OWN	Number of landowners	Short Integer		5		County parcel data	1, 2, etc.
Total Phosphorus Inputs	WA	Wetland Area	Float	2	5	Acres	Clipped Wetland layer	4.5
	W_AREA	Watershed Area	Float	2	5	Acres	NRCS Engineering Toolbox	15.2
	MAR	Mean Annual Runoff	Float	2	5	Inches	Wetland Restoration Toolbox	31
	A_TP	Annual Total Phosphorus Yield	Float	2	5	Lbs/ acre	Wetland Restoration Toolbox	
	Dp_SW	Depth to Surface Water	Float	2	5	Ft	Wetland Restoration Toolbox	
	SAND	Sand Content	Short Integer	5		Percent		
	BD	Soil Bulk Density	Float	2	5	g/cm3		
	OMC	Soil Organic Matter Content	Float	2	5	Percent		
	pH	pH	Float	2	5			
Total Phosphorus Outputs	TP	Total Phosphorus Load	Float	2	5	Lbs	Wetland Restoration Toolbox	
	TP_RR	Total Phosphorus Removal Rate	Float	2	5	Percent	Wetland Restoration Toolbox	
	TP_Rem	Total Phosphorus Load Removed	Float	2	5	Lbs	Wetland Restoration Toolbox	
Total Nitrogen Inputs	A_N	Annual Total Nitrogen Yield	Float	2	5	Lbs/ acre		
	WW_RAT	Wetland to Watershed Ratio	Float	2	5	Percent	Wetland Restoration Toolbox	
	R_VOL	Runoff Volume	Float	2	5	m³	Wetland Restoration Toolbox	

Version 2.0 March 2022

	HLR	Hydraulic Loading Rate	Float	2	5	Meter	Wetland Restoration Toolbox	
Total Nitrogen Outputs	TN	Total Nitrogen Load	Float	2	5	Kg	Wetland Restoration Toolbox	
	TN_RR	Total Nitrogen Removal Rate	Float	2	5	%	Wetland Restoration Toolbox	
	TN_Rem	Total Nitrogen Load Removed	Float	2	5	Kg	Wetland Restoration Toolbox	
Carbon Outputs	TOMM	Total Organic Matter Mass	Float	2	5	Tons	Wetland Restoration Toolbox	
	TC	Total Carbon Storage (tons)	Float	2	5	Tons	Wetland Restoration Toolbox	
	TC_S	Total Carbon Storage (tons/acre)	Float	2	5	Tons/ acre	Wetland Restoration Toolbox	

18.1.5 Animal Operation and Pastures

Animal operations were not modeled in the Chisago rural subwatershed assessment. The inputs needed for modeling can be added to the chart if needed.

Column Name	Description	Column Type	Length/ Scale	Precision	Unit	Source	Example Inputs
AOP_ID	Animal Operation ID	Text	50			User assigned	AOP1, AOP2, etc
Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	169B
OWN	Number of Landowners	Short Integer		5		County parcel data	2
DSW	Distance to Surface Water	Float	2	5	Feet	GIS measurement	35.4
AO_Acre	Animal operation acres	Float	2	5	Acres	GIS measurement	456
ANIMAL	Number and type of animal	Text	50			Field verification	0-10, 11-100, 101-250, 250+ Dairy, Bovine, Horse, Unknown
WET	Wetlands Present?	Text	5			NWI	Yes or No
STREAM	Streams Present?	Text	5			DNR Streams Layer	Yes or No
DITCH	Ditching Present?	Text	5				Yes or No

18.1.6 Cover Crop, Conservation Crop Rotation, and Residue and Tillage Management

	Column Name	Description	Column Type	Length/ Scale	Precision	Unit	Source	Example Inputs
Project Profile	FLD_ID	Field ID	Text	50			User assigned	FLD1, FLDV2, etc.
	CC	Land Cover Class	Text	50			Land Cover Class shapefile	Corn or Beans, Hay, Herbaceous, Pasture, Forest, Wooded Wetland, Wetland, Barren, Open Water, Developed High Intensity, Developed Low Intensity
	ACRES	Field Acres	Float	2	5	Acres	Land Cover Class shapefile	10
RUSLE	Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	159B
	SL	Slope Length	Short Integer		5	Feet	GIS measurement	
	Slope	Average slope (%)	Float	2	5	%	NRCS Engineering Toolbox	
	BM1	Base Management before (farmed)	Text		100		User assigned (Section)	CMZ04/Multi-year Rotation Templates/Corn-Soybeans/CB Mulch till/Corn FC Disk Fld Cult-Soybeans FC Disk Fld Cult
	BM 2	Base Management with BMP	Text		100		User assigned (Section)	**Cover Crop:** CMZ04, Multi-year Rotation Templates, Cover Crops rotations, corn grain; NT, Sdisk fcult rye cover, Soybean; 18 in row, NT z4. **Tillage:** CMZ04, Multi-year Rotation Templates, Corn-Soybeans, CB NT, corn grain; NT Soybean, nr NT single disk openers Z4. **Crop Rotation:** CMZ04, Multi-year Rotation Templates, Corn-Soybeans-Alfalfa 3 yrs, corn FP-Soybeans NT-Oats alfalfa sseeding disc, fcult-Alfalfa Hay 3 yr, 3 cut, 4 tons/acre.
BWSR Water Erosion Pollution	SLB	Soil Loss Before	Float	2	10	T/Ac/yr	RUSLE	1.5
	SLA	Soil Loss After	Float	2	10	T/Ac/yr	RUSLE	0.5
	DSW	Distance to Surface Water	Short Integer		5	Feet	GIS measurement	300
	SSCP	Sand, Silt, Clay, Peat	Short Integer		5		Soil layer	1 = Sand 2 = Silt 3 = Clay 4 = Peat
	AC	Acres applied (Field Acres)	Float	2	5	Acres	Land Cover Class shapefile	40

Outputs	CA	Contributing Acres (Watershed Size)	Float	2	5	Acres	NRCS Engineering Toolbox	16
	TP	Total Phosphorus	Float	2	5	Lb/yr	BWSR	11.03
	TSS	Total Suspended Solids	Float	2	5	T/yr	BWSR	7.99
	S	Soil	Float	2	5	T/yr	BWSR	10.0

18.2 TEMPLATES FOR MANUAL RECORDING

On the following pages are blank templates that can be used to manually record modeling data inputs during the modeling process. This may be easier than switching back and forth between screens to enter data into the Attribute Table of the shapefiles in ArcMap. Use the tables above to reference what should be recorded in the templates.

Version 2.0 March 2022

Gully, Water and Sediment Control Basins, and Grassed Waterways

G_ID WASCOB_ID GWW_ID	CC	OWN	Steep	Soil	SSCP	VOLV	YR	COND	DSF	TP	TSS	S
Project Profile					BWSR Water Erosion Pollution Reduction Calculator					Outputs		

Version 2.0 March 2022

Filter Strip

Project Profile				RUSLE							BWSR Water Erosion Pollution Reduction Estimator						Outputs		
FS_ID	CC	OWN	Steep	Soil	SL_FS	SL_S	BM1		BM2	SL_FS2	SL_S2	SLB_FS	SLA	AFS	SSCP	CA	SLB_WS	TP	TSS	S

Permanent Vegetation

Project Profile			RUSLE					BWSR Water Erosion Pollution Reduction Estimator						Outputs		
PV_ID	CC	OWN	Soil	SL	Slope	BM1	BM2	SLB	SLA	DSW	SSCP	AC	CA	TP	TSS	S

Version 2.0 March 2022

Wetland Restoration

Project Profile			Total Phosphorus Inputs									Total Phosphorus Outputs			Total Nitrogen Input	Total Nitrogen Outputs						Carbon Outputs		
WR_ID	CC	OWN	WA	W_AREA	MAR	A_TP	Dp_SW	SAND	BD	OMC	pH	TP	TP_RR	TP_Rem	A-N	WW_RAT	R_VOL	HLR	TN	TN_RR	TN_Rem	TOMM	TC	TC_S

Cover Crops, Residue and Tillage Management, and Conservation Crop Rotation

Project Profile			RUSLE					BWSR Water Erosion Pollution Reduction Estimator						Outputs		
FLD_ID	CC	ACRES	Soil	SL	Slope	BM1	BM2	SLB	SLA	DSW	SSCP	AC	CA	TP	TSS	S

Version 2.0 March 2022

Animal Operation and Pastures

PROJECT PROFILE INPUTS								
AOP_ID	Soil	OWN	DSW	AO_Acre	ANIMAL	WET	STREAM	DITCH

Version 2.0 March 2022

19 APPENDIX D: NRCS ENGINEERING TOOLBOX

19.1 NRCS ENGINEERING TOOLS-WATERSHED DELINEATION

Several of the models used in this protocol to obtain potential pollution reduction values require the input of watershed size. Watershed size and average slope are also listed in the Project Profiles of several of the BMPs. The tools used to obtain the watershed size and average slope for the rural subwatershed assessments in Chisago County watershed are the delineation tools that are part of the NRCS Engineering Toolbox.

> *A step-by-step guide to using the NRCS Engineering Tools is also available through NRCS.*

The toolbox includes a 3-step process for delineating watersheds. You will need to add this toolbox to ArcToolbox.

19.1.1 Define AOI (Area of Interest)

This step is very simple and produces a series of very useful layers that are automatically added to the project in ArcMap.

- Browse to and Select Workspace: Click the folder icon and select a place to save the shapefiles that will be created (Figure 44).
- Input DEM: Open the drop-down menu and select a Digital Elevation Map (DEM) layer from the project. Only the eligible layers will show up in the menu.
- Enter your Area of Interest: Click the arrow top button (looks like an arrow pointing to a pie chart). On the map, draw a box around the area that you want to work in. Draw the box big enough that the entire watershed you are interested in will be included.
- Interval for Contours: Select 1.
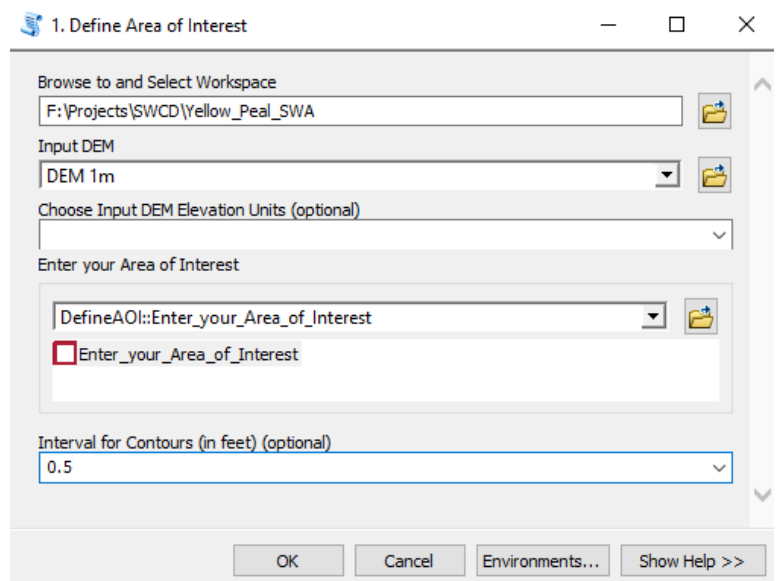- Original DEM Z Units: Leave at default setting.
- Push Ok.

Figure 44. Define Area of Interest

Version 2.0 March 2022

When complete, several new layers should be automatically added to your map and turned on. A 1-foot contour map (usually yellow lines) will show up on top (Figure 45). A red box that outlines the area of interest will appear.

Further down the list in the Table of Contents, a group of three new layers will appear. These are the Depth Grid (Figure 46), Hillshade (Figure 47), and DEM (Figure 47). The depth grid shows areas of pooling water. This can be helpful in determining where there may be digital dams due to culverts that are not represented on the DEM layer. The Hillshade shows the topography of the land in 3 dimensions. This layer is extremely helpful during the desktop scouting steps of this protocol. Finally, the DEM is displayed as a color ramp by default. It is helpful in visualizing the topography of the land, especially in conjunction with the hillshade layer.

19.1.2 Create Stream Network

The next step is to correct the DEM to break digital dams. These are most often located in places where there are culverts. The DEM shows the elevation of the road, which causes water to "pool" when in reality the water is able to move via the culvert. To correct the DEM, the digital dams must be broken, or "burned through". The second tool, Create Stream Network, does this automatically. The user must supply the placement of culverts.
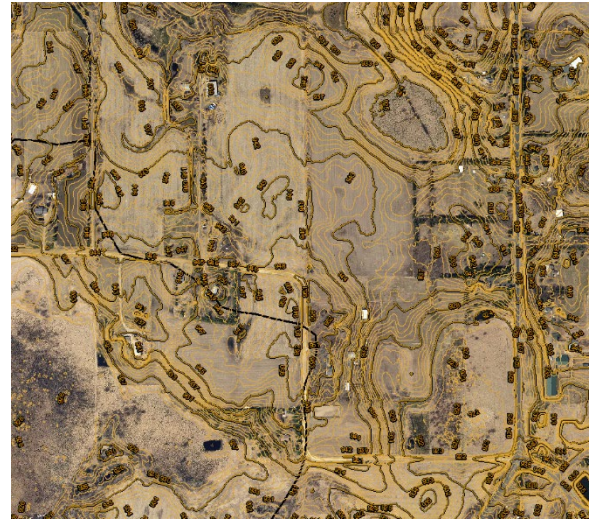
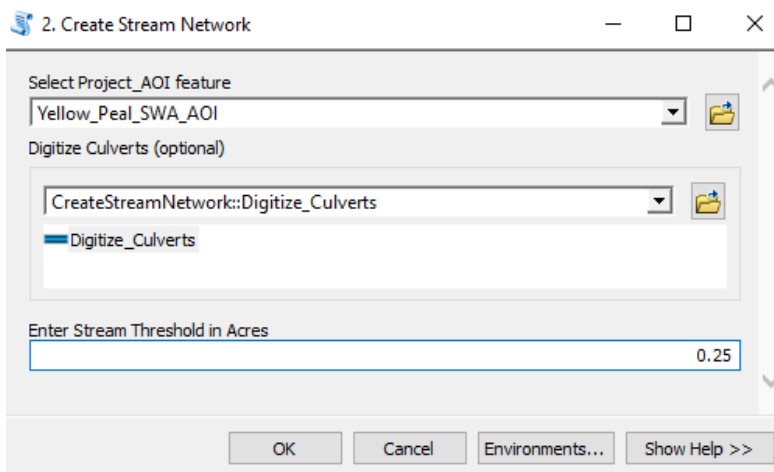*Figure 45. One-foot Contours*

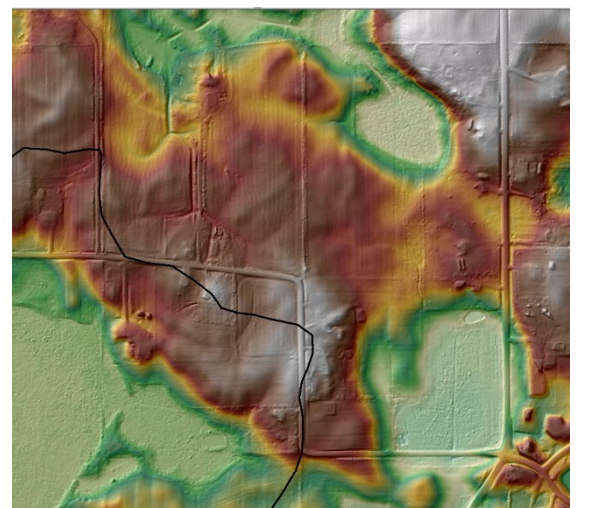*Figure 46. Depth Grid*

Figure 48. Create Stream Network

Figure 47. DEM with Hillshade

Version 2.0 March 2022

- Select Project AOI Feature: Open the drop-down menu and select the AOI that was created in the previous step (Figure 48).
- Digitize Culverts: This can be done manually using the "Add Features Interactively" box. Click the top button on the right that looks like an arrow with three dots connected by a line. Then in the map, draw a line where there is a culvert.
- Continue this process until all culverts have been added within the area of interest.
- If a culvert layer exists with the location of culverts already digitized, use this instead of manually marking them all. Click the circle next to Use Features From and then use the drop-down menu or the folder icon to select the culvert layer.

Figure 49. Stream Network

- Enter Stream Threshold in Acres: The default for this box is 1. You can choose the scale to use; 0.2 gives a detailed stream network. For large watersheds, use 0.5 or 1. On smaller watersheds, a smaller number is better.
- Click Ok.

A new shapefile called Streams should appear in the Table of Contents and be drawn in the map window. The blue lines represent where water runs (Figure 49).

Helpful Hint: Double check, especially if culverts were added, that the stream network makes sense. There have been instances where the streams drawn backwards (water running uphill instead of down). If the streams don't seem right, try using a different DEM in the first step.

19.1.3 Create Watershed
With the stream network turned on, the third step is to delineate watersheds for a specific "pour point". The watershed will delineate the area from which all the water drains to the pour point selected.

- Select AOI Stream Network Feature: Open the drop-down menu and select the stream network that was created in the last step (Figure 50).
- Digitize Outlets: Use the top button that looks like an arrow with three dots connected by a line. In the
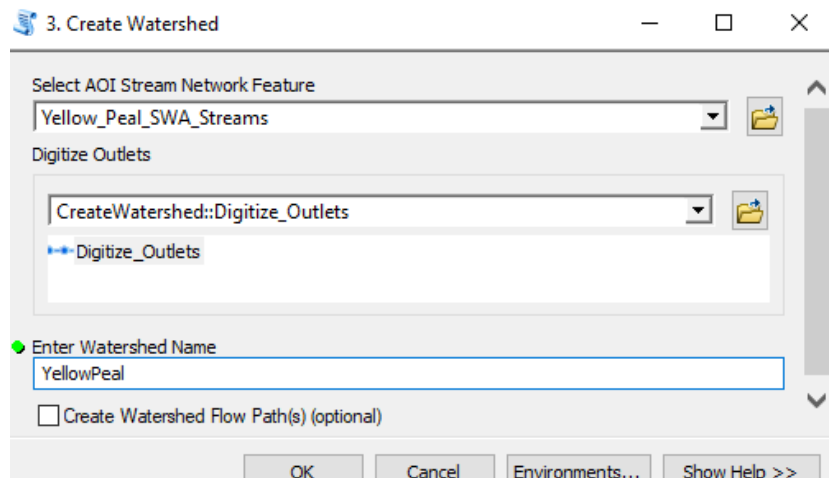

Figure 50. Create Watershed

Version 2.0 March 2022

map, draw a line across the stream network segment where the pour point is. The watershed will
be determined upstream of this point.

- Enter a watershed name. This is how the file will be saved.
- If desired, click the box at the bottom next to Create Watershed Flow Path.   This will create a line
  file that shows the longest flow path through the watershed to the pour point.
- Click Ok.

Two new shapefiles will appear in the Table of Contents list. The Outlet file will show the pour point and
the watershed file delineates the watershed of the pour point. By default, the watershed will be labeled
with the acres and average slope of the watershed (Figure 51).

All of the shapefiles created during the watershed delineation process, including the culverts layer, are
saved in a geodatabase. The location of the geodatabases was chosen in the first step, creating the Area
of Interest in the first box.

Figure 51. Watersheds and Outlets

20 APPENDIX E: TROUBLESHOOTING

20.1 TROUBLESHOOTING

There are numerous places where problems can occur. ArcMap, the NRCS Engineering Tools, and RUSLE2 all seem to have good days and bad days. They 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!

20.2 PRIORITIZING

During the desktop work for the prioritizing section, there can be frustrating errors that occur. Many of them seem related to the computer or the program just having a bad day rather than user error. If none of the suggestions below seem to help, re-start the program or come back another day and try again.

20.2.1 Adding Columns to Attribute Tables

For reasons unknown, you must NOT be editing in order to add a column to an attribute table, but you MUST be editing to fill in the table itself. So if you are editing and wish to add a column, stop editing, add the column, and then start editing again.

20.2.2 NRCS Engineering Tools

If you are using this toolbox, there are a few quirks to note. When choosing the "Workspace" in the step to Create AOI, there cannot be any spaces in the filename. An error message should pop up if you use a name with spaces. If you get other errors, or it says that the process failed, double check that you put the correct inputs into the boxes. If you are sure your inputs are correct and it still won't work, try re-starting or come back another day.

> *Using the C-drive as the location for the "Workspace" can help speed up the processing time of the tools.*

When creating the stream network, make sure you check the output. It has happened that the streams flow the wrong direction (uphill). Sometimes, this can be caused by the incorrect unit on the DEM. Check the DEM properties to see what units are listed (Meters or Feet). It is usually meters. If it is feet, you will need to change the unit in the prompt box for Creating the AOI. At the bottom of the box, there is a drop-down menu to choose units for the DEM. Usually, this should be left alone at the default. If you have a DEM in feet, choose Feet from the drop-down menu. This is rare.

If the DEM is in meters as usual, try using a different DEM if you have one. This sometimes corrects the streams.

The streams also sometimes come out as a series of parallel lines (often seen over lakes or flat wetlands). If you are trying to create a watershed in this area, it will most often fail or it will give a non-representative watershed. To remedy this, run through the watershed delineation steps again using a smaller AOI around the area that you need to re-define.

Version 2.0 March 2022

Many of the errors occur when trying to create a watershed. Sometimes, the watershed is actually created and can be found and imported from ArcCatalog. Always check there first before trying again. The reasons for watershed delineation errors vary. It seems like pour points that are drawn on the long, parallel lines described above often result in errors. Errors also seem more common when trying to draw multiple watersheds at once. Check ArcCatalog because some of the watersheds are often created. You can pinpoint which pour point caused the error to occur and try again.

Sometimes, the watershed would not work, no matter what was tried. Get creative. One technique is to delineate the watersheds on the streams around the one you want. It should leave a blank space where your watershed is and you can create a polygon that represents your watershed. Another option is to try a pour point further upstream of the pour point you really want. It may work to create a watershed that you can then edit to include the areas downstream.

21 APPENDIX F: RESOURCES

21.1 BWSR TECHNICAL RESOURCES: WATER QUALITY TOOLS AND MODELS
BWSR Pollution Reduction Calculator and instructions

➢ https://bwsr.state.mn.us/water-quality-tools-and-models

21.2 NRCS NATIONAL RUSLE2 DATABASE
➢ https://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm

21.3 NRCS ENGINEERING TOOLBOX
Instruction on using some of the tools in the NRCS Engineering Toolbox are included in Appendix D Section 21 of this document.

➢ https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/engineering/?cid=stelprdb1186070

21.4 MINNESOTA GEOSPATIAL COMMONS
A variety of data layers available for download. Includes data from the MN Department of Agriculture, MN Department of Natural Resources, MN Board of Water and Soil Resources, MN Pollution Control Agency, and many more.

➢ https://gisdata.mn.gov/
➢ Feedlots in MN
➢ DNR Hydrography Dataset (DNR Watersheds, All Water Features, Public Water Basins)

21.5 MN BUFFER PROTECTION MAP
An interactive map and data layer for the Minnesota Buffer Law.

➢ https://www.dnr.state.mn.us/buffers/index.html

21.6 MN ATLAS
The Natural Resource Research Institute created the Minnesota Natural Resource Atlas. The interactive GIS site combines information from many different sources into one location. In most cases, the data can be downloaded from MN Atlas and imported into the ArcMap project you created for this protocol.

➢ https://mnatlas.org/gis-tool/

21.7 MINNESOTA LAND COVER CLASSIFICATION SYSTEM (MLCCS)
Detailed information about the MLCCS layer.

➢ https://www.dnr.state.mn.us/mlccs/index.html

Version 2.0 March 2022

21.8 WEB SOIL SURVEY-SSURGO

See Section 9.3.2.2 of Part 1: Targeting for instructions on downloading soils data from Web Soil Survey.

➢ https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

21.9 RESTORABLE WETLAND PRIORITIZATION TOOL

An online interactive GIS tool that helps decision makers prioritize where to restore and protect wetlands. Created by the Natural Resource Research Institute and the Minnesota Pollution Control Agency with funding from the Clean Water Land & Legacy Amendment. A variety of layers, including Phosphorus Risk, Nitrogen Risk, Restorable Wetland Index, and Water Quality/Erosion Benefits are all useful for locating and ranking potential wetland restorations. Some data can be downloaded.

➢ http://mnwetlandrestore.org/map-tool/

21.10 WETLAND PRIORITIZATION TOOLBOX

A Zip file will contain several layers to be used in ArcMap. The tool itself is an Excel document.

➢ https://mnatlas.org/gis-tool/?id=k_0312

21.11 WETLAND RESTORATION EFFECTIVENESS TOOL

A tool to estimate the nutrient removal and carbon storage benefits of wetlands to prioritize conservation and restoration in the upper Midwest. This wetland-scale planning tool uses publicly available data on water quality, soil properties, and wetland-watershed relationships to estimate nitrogen removal, phosphorus removal, and carbon sequestration to maximize the benefits of wetland conservation and restoration.

➢ https://bbe.umn.edu/wret

22 APPENDIX G: ARCHIVED INSTRUCTIONS

22.1 WETLAND RESTORATION

There are two possible modeling methods for wetland restorations. Chose the model that best fits your subwatershed or catchment.

One model was modified from PONDNET by Bruce Wilson of EOR, Inc. The simplified model has inputs for land cover, watershed area, wetland size, and pond depth.

- Create the watershed shapefile for the potentially restorable wetland. Use NRCS Engineering Tools Watershed Delineation tool for this (instructions in Appendix D - NRCS Engineering Tools-Watershed Delineation). If the wetland you are working on is part of a chain of wetlands, the watershed may include other wetlands or even lakes. For the Chisago SWCD rural assessment, we used the outlet of the next upstream Type 1 or 2 wetland in the assessment or lake as the upstream limit of the watershed.
- Use the land cover shapefile in ArcMap to estimate the percentage of impervious, open (lawns, herbaceous, etc.), agricultural (pastures, fields), and other (forests) area in the watershed of a potentially restorable wetland.
- Input the total watershed area into the Watershed Area line, the percentages from above into the appropriate lines, and the area of the wetland into the pond surface area line. Leave the pond mean depth at 1.
- The potential phosphorus removal value is located under Pond Phosphorus Budgets, net sedimentation.

> *Helpful Hint: To get a copy of this estimator, contact the Chisago SWCD.*

The second modeling method uses the BWSR Wetlands Restoration Strategy Framework and the BWSR Pollution Reduction Estimator. Only those watersheds with a watershed to wetland ratio between 5:1 and 20:1 are included in the ranking. Therefore, the first step is to run the watershed size for each identified wetland. Use the NRCS Engineering Toolbox to do this (steps are outlined in Appendix D - NRCS Engineering Tools-Watershed Delineation).

- Open a new profile in RUSLE.
- Location: This should be set at your county by default.
- Soil: Choose the dominant soil of the watershed.
- Slope Length: Find the steepest slope located in the watershed. Measure from the top of the slope to the point where it begins to flatten out. Insert this number into the box.
- Avg. Slope Steepness: Determine the change in elevation from the top to the bottom of the slope measured in the previous step.
- Base Management: Choose the most suitable base management for the watershed. For non-agricultural watersheds, you may need to choose something as close to a permanent land cover as possible, such as long term alfalfa.
- Contouring: If the watershed is predominantly agricultural, choose "Relative row grade 50%". If the watershed is not agricultural, leave this at the default.

Version 2.0 March 2022

- Filter Strip: If there is a strip of vegetation between an agricultural field and the wetland, measure it and select the most appropriate option from the drop down list. If the watershed is not agricultural, leave this at the default setting.
- Let the model finish calculating.
- Insert the output from RUSLE into the BWSR Pollution Estimator Sheet and Rill Erosion tab in the Soil Loss Before box.
- Then calculate a 58% reduction in the Soil Loss Before value. Insert this into the Soil Loss After box. This is assuming that the wetland will capture 58% of the sediment coming into the wetland from the watershed.
- In the Distance to Surface Water box, enter 1.
- In the SOIL box, choose the most appropriate number to represent the soils of the watershed.
- AC is the acres applied. Enter the size of the wetland in acres.
- CA is the contributing acres. Enter the size of the watershed in acres.
- The outputs in the yellow box (Soil, Sediment, and Total Phosphorus) should now be accurate.

22.1.1   Wetland Restoration (USING BWSR POLLUTION REDUCTION ESTIMATOR)

The model used for this BMP was the BWSR Pollution Reduction Estimator-Sheet and Rill Tab.

Column Name	Description	Column Type	Length	Precision	Unit	Source	Optional Inputs	Input For
LC_ID	Land cover ID	Short Integer		5		Land cover shapefile ID column		PP (Project Profile)
TP	Total Phosphorus	Float		5	Lb/yr	BWSR Pollution Reduction Estimator		PP
TSS	Total Suspended Solids	Float		5	T/yr	BWSR Pollution Reduction Estimator		PP
S	Soil	Float		5	T/yr	BWSR Pollution Reduction Estimator		PP-optional
SLB	Soil Loss Before	Float		10	T/Ac/yr	RUSLE		Model
SLA	Soil Loss After	Float		10	T/Ac/yr	RUSLE		Model
SSCP	Sand, Silt, Clay, Peat	Text	5			Soil layer	1 = Sand 2 = Silt 3 = Clay 4 = Peat	Model
SL	Slope Length	Short Integer	5		Feet	Manual measurement		Model
Slope	Average slope (%)	Float		5	%	Change in elevation/Slope Length		Model
AC	Acres applied (portion of field that should be converted to permanent vegetation)	Float		5	Acres	Manual measurement		Model
CA	Contributing Acres	Float		5	Acres	Watershed delineation tool		Model

Version 2.0 March 2022

	(watershed size)							
DSW	Distance to Surface Water	Short Integer	5		Feet	Manual measurement		Model, PP
WET_AREA	Wetland area	Short Integer	5		Acres	Manual measurement		Model, PP
NWI	NWI Wetland Code	Text	10			NWI layer	Ex. PEM1Ad	PP
Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	Can have multiple soils listed	PP
TYPE	Wetland type	Short Integer	5			NWI layer	Ex. 1	PP
WWR	Watershed to Wetland Ratio	Text	10					PP
RWF	Receives water from	Text	20					PP
FLOW	Flows to	Text	20					PP
D_USE	Dominant watershed use	Text	20			Land cover file		PP
OWN	Number of Landowners	Short Integer	5			Parcel data		PP

22.1.2 Wetland Restoration (USING PONDNET MODEL)

The model used for this BMP was a modified version of PONDNET created by Bruce Wilson, EOR.

Column Name	Description	Column Type	Length	Precision	Unit	Source	Optional Inputs	Input For
LC_ID	Land cover ID	Short Integer		5		Land cover shapefile ID column		PP (Project Profile)
TP	Total Phosphorus	Float		5	Lb/yr	BWSR Pollution Reduction Estimator		PP
WS	Watershed Size	Float		5	Acres	Watershed delineation tool		Model, PP
IMP	Percent of watershed that is impervious	Short Integer	5		%	Manual measurement		Model
OPEN	Percent of watershed that is open	Short Integer	5		%	Manual measurement		Model
AG	Percent of watershed that is agricultural	Short Integer	5		%	Manual measurement		Model
OTHER	Percent of watershed that is not IMP, OPEN, or AG	Short Integer	5		%	Manual measurement		Model
DSW	Distance to Surface Water	Short Integer	5		Feet	Manual measurement		Model, PP
WET_AREA	Wetland area	Short Integer	5		Acres	Manual measurement		Model, PP

Version 2.0 March 2022

NWI	NWI Wetland Code	Text	10			NWI layer	Ex. PEM1Ad	PP
Soil	Numeric soil number (ie, 169B)	Text	20			Soil layer	Can have multiple soils listed	PP
TYPE	Wetland type	Short Integer	5			NWI layer	Ex. 1	PP
WWR	Watershed to Wetland Ratio	Text	10					PP
RWF	Receives water from	Text	20					PP
FLOW	Flows to	Text	20					PP
D_USE	Dominant watershed use	Text	20			Land cover file		PP
OWN	Number of Landowners	Short Integer	5			Parcel data		PP