# 2014

# Final Project Report

for Identifying
Priority Management Zones
for Best Management
Practice Implementation in
Impaired Watersheds

KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING

BARR

STEARNS COUNTY SOIL & WATER SWCD CONSERVATION DISTRICT

Minnesota Department of Agriculture

CLEAN WATER LAND & LEGACY AMENDMENT

In 2007, the Minnesota Legislature passed the Clean Water Legacy Act (MN Statute 114D). The Minnesota Department of Agriculture (MDA) received an appropriation for the 2008-2009 Fiscal Years for research on impaired waters in agricultural watersheds. This document has been prepared in partial fulfillment of the Minnesota Department of Agriculture research grant entitled Identifying Priority Management Zones (PMZs) for Best Management Practice (BMP) Implementation in Impaired Watersheds. This grant was issued March 7, 2011.

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## Abbreviations and Symbols

| | |
|---|---|
| AOI | Area of Interest |
| BEHI | Bank Erosion Hazard Index |
| BMP | Best Management Practice |
| BWSR | [Minnesota] Board of Water and Soil Resources |
| CEAP | Conservation Effects Assessment Project |
| CIR | Color Infrared |
| CP | Conservation Practice |
| CSA | Critical Source Area |
| CTI | Compound Topographic Index |
| DEM | Digital Elevation Model |
| EBI | Environmental Benefits Index |
| ESRI | Environmental Systems Research Institute |
| FSA | Farm Service Agency |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| HSPF | Hydrologic Simulation Program-Fortran |
| HUC | Hydrologic Unit Code |
| LiDAR | Light Detection and Ranging |
| MDA | Minnesota Department of Agriculture |
| MDNR | Minnesota Department of Natural Resources |
| MN | Minnesota |
| MAWQCP | MN Agricultural Water Quality Certification Program |
| MNGeo | Minnesota Geospatial Information Office |
| MPCA | Minnesota Pollution Control Agency |
| MRBI | Mississippi River Basin Initiative |
| NAIP | National Aerial Imagery Program |

| | |
|---|---|
| NLCD | National Land Cover Database |
| NRCS | National Resource Conservation Service |
| P-Index | MN Phosphorus Index |
| PMZ | Priority Management Zone |
| Rapid P-Index | MN Rapid Phosphorus Index |
| RUSLE2 | Revised Universal Soil Loss Equation, Version 2 |
| SDP | Sediment Delivery Potential |
| SPI | Stream Power Index |
| SSURGO | Soil Survey Geographic Database |
| SWAT | Soil and Water Assessment Tool |
| TMDL | Total Maximum Daily Load |
| TN-99 | Technical Note 99 |
| USDA | United States Department of Agriculture |
| USLE | Universal Soil Loss Equation |

# Project Overview

## Background and Project Need

Topographic, hydrologic, and agronomic factors often combine to make some nonpoint sources contribute a disproportionate amount of pollutants such as sediments and nutrients to nearby surface waters resulting in an inordinate impact on the beneficial use of the water resources. Government conservation programs often have limited funding and landowner participation is voluntary, which may not result in enrolling the most critical lands. Therefore, methods or strategies to identify these priority areas are necessary to efficiently and proactively target the available resources for Best Management Practice (BMP) implementation.

Critical Source Areas (CSAs) are defined as portions of the landscape that combine high pollutant loading with a high propensity to deliver runoff to surface waters. These areas have a higher likelihood of conveying more pollutants to surface waters than other portions of the landscape. Priority Management Zones (PMZs) are regions of the watershed targeted for conservation practices that address disproportionate or large pollutant loads.

Most of the available literature regarding CSA evaluations confirms that a small fraction of the agricultural landscape can have a disproportionately large impact on downstream water quality (Pionke et al., 2000; Gburek et al., 2000; Yang and Weersink, 2004; White et al., 2009; Winchell et al., 2011 and Meals et al., 2012). White et al. (2009) reported that just 5% of the land area yielded 50% of the sediment load and 34% of the phosphorus load in Oklahoma watersheds. Pollutant loads from these agricultural CSAs were more than four times greater than the average load from agricultural areas within the watershed. In a large Vermont river basin, about 74% of the annual nonpoint source phosphorus load was estimated to come from just 10% of the land area (Winchell et al. 2011). In the Minnesota portion of the Cedar River watershed, Soil and Water Assessment Tool (SWAT) modeling showed that approximately 30% of the sediment load was coming from 5% of the watershed area (Barr, 2014) after accounting for the effects of streambank erosion.

United States Department of Agriculture's (USDA) Conservation Effects Assessment Project (CEAP) resulted in several lessons learned about identifying a watershed's critical source areas (Meals et al., 2012). Most of the land treatment in the CEAP projects had already been implemented under previous voluntary programs and not deliberately targeted to CSAs. In the Little Bear River, 13% of the watershed was characterized as CSAs. Twenty-six percent of the CSAs had existing conservation practices, but 75% of the watershed practices were applied to areas with low potential for pollutant load. In the Cheney Lake Watershed only 22% of implemented conservation practices were located in CSAs.

The approaches used to identify CSAs in the CEAP watersheds varied from watershed modeling, including export coefficients, the SWAT model, Generalized Watershed Loading Function (GWLF) and Universal Soil Loss Equations (USLE and Revised Universal Soil Loss Equation, Version 2 [RUSLE2]), as well as soil moisture and curve number modeling, monitoring data and topographic indices (Meals et al., 2012). Just a few of these projects used a combination of approaches to identify CSAs.

Minnesota Board of Water & Soil Resource's (BWSR) Environmental Benefits Index (EBI) spatially shows relative risk for soil erosion based on terrain attributes and soil characteristics, accounts for proximity to surface waters and accounts for habitat quality. As a result, the EBI represents a good tool, especially for planning-level, watershed-scale analysis. The limitations of the EBI are that the terrain attributes are based on 30-meter digital elevation model topography, so it does not make use of light detection and ranging (LiDAR) data, which makes it more difficult to distinguish pourpoints (locations where upland areas discharge to riparian areas) and the relative water quality risk.

Most of the available tools or models used for CSA identification utilize some portion of the USLE (Wischmeier and Smith, 1960). The USLE is a multiplicative equation using the formula A =R x K x LS x C x P where:

- A = potential long term average annual soil loss in tons/acre/year
- R = rainfall and runoff erosivity factor
- K = soil erodibility factor
- LS = slope length-gradient factor
- C = crop/vegetation and cover management factor
- P = support practice factor

The K and LS factors are typically calculated based on National Resource Conservation Service (NRCS) spatial and tabular Soil Survey Geographic (SSURGO) Database soils data. The R factor does not typically vary significantly for most watershed studies and the C and P factors require site-specific data or are assumed to be the same for planning purposes. It is important to note that, while the USLE approach represents a good approximation of sheet and rill erosion and the potential for loss of particulate nutrients, it is typically subject to the following limitations:

- Downstream pollutant delivery can differ significantly depending on flow accumulation, proximity to surface waters and hydraulic connectivity with the drainage network
- Soil loss can differ significantly depending on the shape of the slope or compound slopes of the tributary area(s)
- Nutrient loss variations due to nutrient and crop management practices are not accounted for (except through the use of some watershed models)
- Pollutant load generation and delivery will differ significantly depending on drainage water management and/or variable hydrologic source areas
- Other methods should be used to accurately quantify the relative magnitude of gully and channel erosion

Comprehensive hydrologic and water quality models like the SWAT and Hydrological Simulation Program-Fortran (HSPF) models can be effective for identifying CSAs because they incorporate landcover, topography, soil characteristics, rainfall, and land cover management, all of which influence the mobilization and transport of sediment and nutrients. The primary limitation of watershed-scale modeling efforts are that they do not typically contain the spatial detail and/or physical processes necessary to account for gully erosion and the potential delivery mechanisms to simulate transport from upland to riparian areas in the system. As a result, researchers are recognizing the need to combine the beneficial aspects of watershed modeling with Geographic Information System (GIS) terrain analysis to better identify and prioritize CSAs.

## Project Objectives

Three main factors contribute to the identification of CSAs: the magnitude of pollutant sources, the transport potential and the risk for erosion. Depending on the pollutant and receiving water, some combination of these three factors can be used for prioritization and targeting of CSAs. PMZs, in turn, can be characterized by three areas of emphasis: source reduction, interception treatment, and in-channel assimilative capacity. New tools and technology make it possible to target conservation practices to areas of the landscape where they are needed most. With the increasing availability of LiDAR data for Minnesota, there is greater potential for rapid landscape assessments that help identify CSAs and PMZs.

The primary goals and objectives for this project involve the development of a process that:

- Provides a scalable, streamlined approach that combines GIS terrain and spatial analysis techniques with targeted site visits for pinpointing vulnerable lands where conservation implementation and funding will provide the most beneficial water quality improvements
- Provides repeatable and measurable methods for ranking vulnerable sites during funding applications
- Is flexible and allows for increasing complexity from the integration of other sources of data (modeling, soils, land cover, pourpoint stability, phosphorus indices, etc.) with terrain attributes to enhance decision-making
- Quickly and efficiently analyzes large watershed areas and quantifies manageable number of high potential sites in a target area
- Facilitates the development of watershed restoration and protection strategies
- Supports funding requirements that implementation projects be:
    - Prioritized
    - Targeted
    - Measurable
- Assists with initiating conversations with agricultural producers that provides visual communication regarding potential conservation activities will visualize the issues and potential solutions.

## Report Organization

This report is intended to be an operation handbook or manual that provides combined guidance for watershed practitioners to use in identifying and prioritizing CSAs and delineating PMZs for optimum placement of conservation measures based on source magnitude, hydrologic connectivity and delivery mechanisms/erosion potential.

The methodology described here-in is organized into the following sections to demonstrate how high-resolution GIS analysis and field verification can be integrated with other sources of data to direct practitioners to those sites with the greatest potential for sediment and nutrient movement across the landscape:

1. **Digital Terrain Analysis—**this section is intended to deliver the information in a manner that even novice GIS users and technicians can readily apply when developing and verifying an in-depth/accurate map of the CSAs in their focus watershed. The mapping allows watershed practitioners to quickly and efficiently identify the specific locations and landowners that warrant site visits and field validation.
2. **Field Assessment—**a suite of field evaluation tools are provided to guide the assessment of the cropland and streams/ditches/conveyances in your project area to evaluate the importance of the site's potential for source reductions, interception treatment practices and improving channel stability or erosion control.
3. **Case Studies—**summaries of desktop analyses, including integration of modeling/monitoring/indices, site evaluation protocols and decision-support guidance are also provided to enable practitioners to further target and prioritize candidate areas for implementation of conservation practices in multiple regions of the state.

# Digital Terrain Analysis

# Digital Terrain Analysis

## Overview

This section provides digital terrain analysis methods and procedures for identifying CSA predictions. It is intended to be used in conjunction with the protocols described in the Field Assessment section. Digital terrain analysis is the preferred method for locating CSA's due to its efficiency and high-quality, readily accessible input data. It has been the focus of several recent studies in Minnesota with overall accuracies ranging from 78-88% (see Appendix section A.1 for details). This section discusses the feasibility of using GIS analysis to inform field assessments. For this project, GIS software is used to perform a terrain analysis, which employs elevation data to characterize the physical features of the landscape. Terrain analysis can be used to identify locations with a high potential for erosion and pollutant runoff. These identified source areas can then be assessed for further evaluation. Additional spatial analyses can also be incorporated, including source proximity to a water body and soil erosion risk factors. Terrain analysis and other spatial analyses do not eliminate the need for field assessments. However, they can reduce the amount of time spent in the field and enhance data collection efforts by enabling technicians to select potentially sensitive sites.

It is important to note that many of the sites identified as sensitive by the GIS analysis may already have appropriate management and operation. Thus, these tools also provide an important opportunity to recognize producer accomplishments and track program progress necessary for supporting basin management and Total Maximum Daily Load (TMDL) efforts.

The steps described in this section require the use of Environmental Systems Research Institute's (ESRI) ArcGIS computer software with Spatial Analyst extension installed. The basic version (ArcView license) is sufficient for the methods described herein. This methodology is also designed to accommodate users of either ArcGIS versions 9.0 to 9.3.1 or 10.0 to 10.2 – the former will be referred to as 9.x and later as 10.x from here on. Other GIS-based software programs that are able to process large raster datasets and calculate logical map algebra should work for terrain analysis processing but will not be covered in this section.

The terrain analysis process involves combining primary attributes to form secondary attributes. The core primary attributes used for this terrain analysis include flow direction, flow accumulation, and slope. Secondary attributes include Stream Power Index (SPI) and Compound Topographic Index (CTI).

SPI is calculated as the product and CTI the quotient of the natural log of both slope and flow accumulation.

$$\mathbf{SPI} = \ell n(FA * \beta)$$

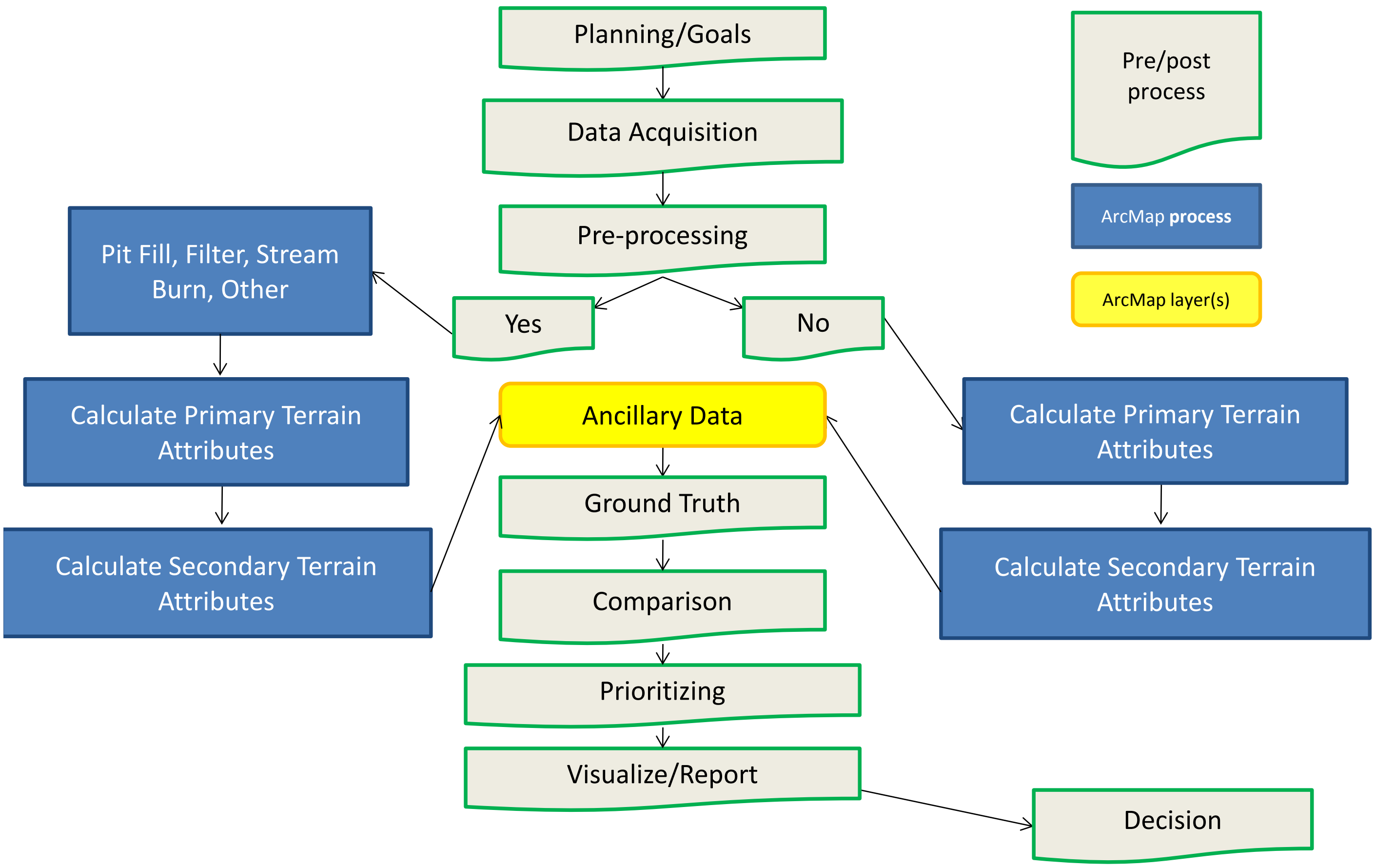
$$\mathbf{CTI} = \ell n(FA / \beta)$$

Where FA represents flow accumulation and β slope

High SPI values displayed in GIS represent areas on the landscape where high slopes and flow accumulations exist and thus areas where flows can concentrate with erosive potential. For this reason, SPI is very useful for determining potential CSA locations. Conversely, CTI can show areas on a landscape that pond and store water, and is therefore useful for locating potential wetland locations. The plan and profile curvature terrain attributes can also be used to identify upland sinkhole locations, and to aid in ravine identification (see Appendix A.2).

The digital terrain analysis core process can be visualized using the following flow chart:

**Digital Terrain Analysis Flow Chart**




Digital terrain analysis flow chart

Digital terrain analysis begins with a planning process where project goals are established and an appropriate scale for assessment is defined. The spatial scale will determine the amount of data acquisition necessary to address project goals. The attributes created may or may not require pre-processing. This again is at the discretion of the user's project goals. The attributes are either primary or secondary in nature, depending on whether they derive directly from elevation data or a secondary product. The attributes, when combined with relevant ancillary data, should provide enough information to locate and prioritize potential CSAs. Ground-truthing is an important step necessary to relate mapping to planned goals. The objective of ground-truthing is to determine best-fit threshold values for a given Area of Interest (AOI) by comparing digital terrain attributes to real-world conditions. When thresholds have been established, CSAs can then be located and prioritized using a combination of primary attributes, secondary attributes, and ancillary data. CSA validation is used to determine accuracy of predictions and reveal the existence of commission and omission errors. This step is fundamental to the user learning process since locating potential CSAs digitally is an adaptive process and validation provides opportunities to improve visualization and prediction techniques. Evaluation of site conditions should accompany field validation. The PMZ Field Assessment section was developed to assist in site evaluations, and to direct efforts and track results when visiting priority sites in the field. The final step is to make decisions regarding how to address field-verified CSAs. This may involve contacting and working with land owners, determining which BMPs are most suited for the agroecoregion, and/or securing conservation practice funds for BMP implementation, among others.

## Procedure

### Data acquisition

For the primary attribute calculations that define terrain analysis, only a raster DEM is required, but ancillary data will be necessary to create CSA predictions – all of which are available at the Minnesota 'data deli' website: http://deli.dnr.state.mn.us/ unless otherwise noted.

- DEM – A DEM contains one elevation value (as measured above Mean Sea Level) in each pixel, or cell, of data. Ideally, LiDAR elevation data should be used in terrain analysis for its high spatial resolution and accuracy characteristics. LiDAR data are available for the entire State of Minnesota, downloadable at the county level from either of the two links below:
  ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/
  ftp://lidar.dnr.state.mn.us/
  LiDAR data from the above sources provide DEM's in both 1 and 3 meter resolutions. Digital terrain analyses are best processed using a 3 meter DEM to minimize processing times and file sizes while maintaining a high level of elevation detail (Galzki, et al., 2011).
  - *Note:* When downloading LiDAR data, an ftp client such as FileZilla should be used due to large file sizes associated with LiDAR geodatabases. LiDAR datasets for some counties exceed 5 gigabytes and can be computationally inefficient to acquire and process. In some cases, it may be necessary to use lower resolution DEM data. 30m DEM data is still readily available throughout the state, though it should be noted that this will considerably reduce the ability to accurately predict CSA locations (Srinivasan et al., 2009).
- Surface waters – Current stream data containing both perennial and intermittent networks along with lake/wetland layers will be necessary to determine hydrologic connection to secondary attributes.
- Watershed catchments – Watershed data at various spatial scales. These are typically ordered from the number of digits in a hydrologic unit code (HUC) – from 2 digits representing regional watersheds to 12 digits representing subwatersheds. These layers are also convenient for use as an output extent when creating a clipped raster subset (see DEM clipping on page 18).
- Cities and political boundaries – Political boundary and populated area data can be useful for spatial orientation, locating areas of interest, and improving map presentation.
- Land cover/land use – The most current National Land Cover Database (NLCD) raster layer, available from the USDA Geospatial Data Gateway: http://datagateway.nrcs.usda.gov/
- Environmental Benefits Index – The EBI layer integrates soil erosion risk, water quality risk and habitat quality factors to determine the relative conservation value of a parcel of land. It can be useful for locating regions with high erosion risk. The Soil Erosion Risk portion of the EBI can also be used alone to aid with CSA placement. The EBI and its individual layers are available at a 30m resolution for most of the State of Minnesota here:
  http://www.bwsr.state.mn.us/ecological_ranking/
- NRCS GIS Engineering tools – The freeware python-based toolset is compatible with ArcGIS 9.3 and 10.x, allowing for seamless integration and familiar, user friendly interfaces identical to default ArcGIS Arctools. The NRCS tools include processes for hydro-conditioning, watershed delineation, conservation planning and more. Direct download link:
  ftp://ftp.lmic.state.mn.us/pub/data/elevation/lidar/tools/NRCS_engineering/NRCS_GIS_ENGINEERING_TOOLS_ver1.1.7.zip

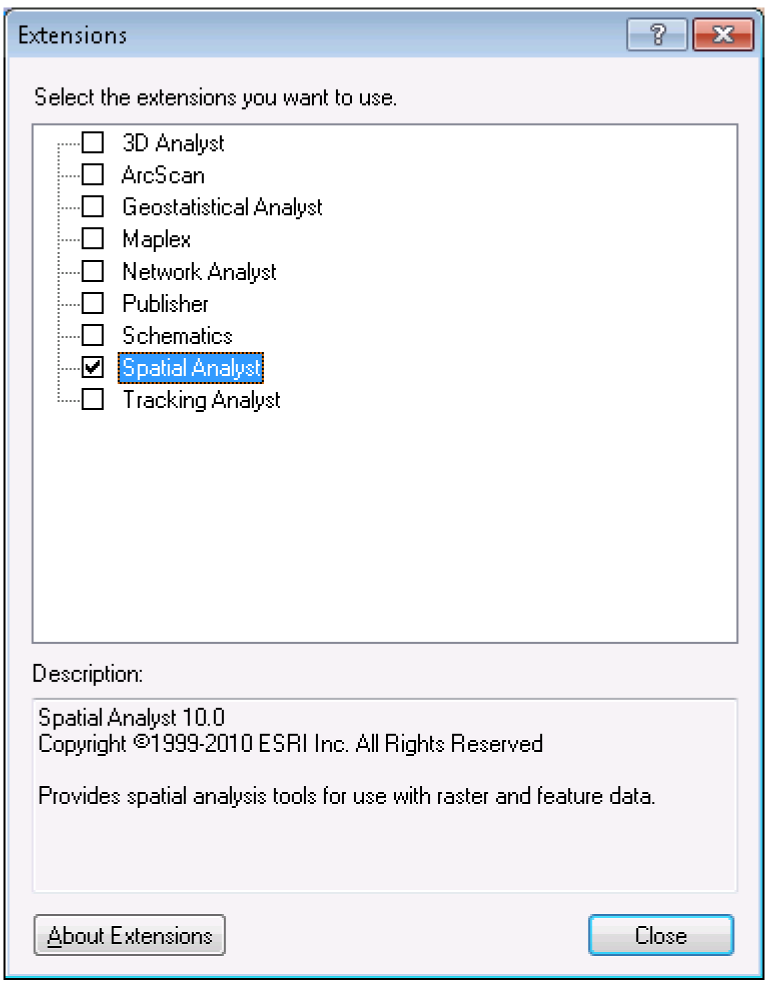
- High resolution aerial orthophotos – Orthorectified and georeferenced photos should be used to ensure correct alignment with surface features. Color or Color Infrared (CIR) photos with at least 5 meter resolution are preferred with leaf-off periods (spring or fall) being ideal. Recently acquired Farm Service Agency (FSA) National Aerial Imagery Program (NAIP) digital photos from Spring, Summer, and Fall throughout Minnesota are readily available at: http://www.mngeo.state.mn.us/chouse/airphoto/
  ArcGIS software users can connect to the Minnesota Geospatial Information Office's (MNGeo) web map service through a GIS server. This will negate the need to download any photos. Instructions for connection are here: http://www.mngeo.state.mn.us/chouse/wms/how_to_use_wms.html
  1. Open ArcMap and click on 'Add Data'
  2. Look in the Catalog, and click on 'GIS Servers'
  3. Highlight 'Add WMS Server' so that it appears in the Name window, and hit 'Add'. An 'Add WMS Server' window will pop up.
  4. To bring up the Imagery server, type '**http://geoint.lmic.state.mn.us/cgi-bin/wms?**'(without quotes) in the URL window. You can click on the 'Layers' button to see a list of the layers available under the wms. Click 'OK'.
  5. To bring up the Scanned DRG server, type '**http://geoint.lmic.state.mn.us/cgi-bin/wmsz?**' (without quotes) in the URL window. You can hit the 'Get Layers' button to see a list of the layers available under the wms. Click 'OK'.
  6. Now when you look under 'GIS Servers' you have two new entries: 'LMIC WMS server (aerial photography) on geoint.lmic.state.mn.us' and 'LMIC WMS server (quad sheet drgs) on geoint.lmic.state.mn.us'
  7. Still in the 'Add Data' window under 'GIS Servers', highlight one of the services listed under #6 to bring it into the 'Name' window, then click on 'Add'. The service, with all of its layers, has now been added to your ArcMap project.
- Other – Other useful information could range from regional data such as soils (SSURGO data), Highly Erodible Lands, feedlot, culvert, and point source locations to field specific information such as individual landowner nutrient application rates, existing conservation practice locations and conditions, artificial drainage size and placement, etc.

## Pre-process DEM

Digital Elevation Models can benefit from pre-processing before terrain analysis is conducted. The amount of pre-processing required may depend on the user's local knowledge of their AOI and its characteristics, and the resolution and quality of the original DEM. A semi-automated utility for both creating AOIs and hydrologically conditioning DEMs will be presented here. Alternatively, advanced GIS users may find it advantageous to create their own Python scripts and/or ModelBuilder flow paths within ArcGIS to semi-automate pre-process and terrain attribute calculations to decrease processing times and ensure consistent outputs.

- Activate Spatial Analyst Extension
  This initial step is necessary for certain Arctool processes to run. ArcGIS will remember your selection and automatically activate selected extensions every time the program is run.

  1. From the **Tools** menu (ArcMap 9.x) or **Customize** menu (10.x), select **Extensions…** and check-on the **Spatial Analyst** extension.




  2. Click Close.

- <u>Hydrologic Conditioning</u>

Hydrologic conditioning (HC) is the process of modifying a DEM to change flow routing and drainage. The most common practice of HC is to remove "digital dams" that block the hypothetical flow of water typically associated with road crossings and other obstructions. One method of removing digital dams is to "burn" the stream through the obstruction to force flow downstream.

HC can be a time consuming process, thus it is important to consider whether your project goals would benefit from the operation, and if so, how much correction is needed and at what scale. For instance, some projects may only warrant burning the largest culverts along high order streams while others may require burning tile lines at the field scale.

Some points to consider:

- HC will only change terrain analysis attributes in close proximity to the digital dams removed.
- HC is most useful when combined with pit filling – if pit filling is not necessary or suitable in your AOI, HC will provide minimal terrain analysis benefits. However, if pit filling is to be used, hydro-conditioned DEMs will tend to produce more accurate terrain attributes within filled depressions. For instance, when filling all sinks in a DEM, HC can improve flow routing by unblocking large depression areas that would otherwise fill with hypothetical water to force flow over obstructions. The Stream Power Index signatures in those unblocked depressions will be more representative of actual overland flow when sinks have been filled.

The left image shows an example of how water ponds (in blue) behind road crossings when using a non-conditioned DEM. There are culverts present at both crossings (circled in yellow), though the DEM does not recognize culverts and sees the road as an obstruction – known as a digital dam. Ideally all DEM's used for SPI creation should be hydrologically corrected, though the process can be time consuming and small culverts may not show up in aerial photography making field verification necessary.

ArcGIS includes tools that can be used to hydrologically condition DEMs, such as **Topo to Raster** (Vaughn 2012). Several 2$^{nd}$ party applications also exist with HC capabilities. The NRCS GIS Engineering toolset introduced in the Data Acquisition section (page 9) is one such utility recommended for its ability to burn streams through a semi-automated process of digitizing culverts. The user must input culverts either by importing a polyline shapefile or by manually digitizing their locations.

See the Data Acquisition section (page 9) for the NRCS tools zip file download link. Once the file is downloaded to your computer, follow the readme instructions to install the software:

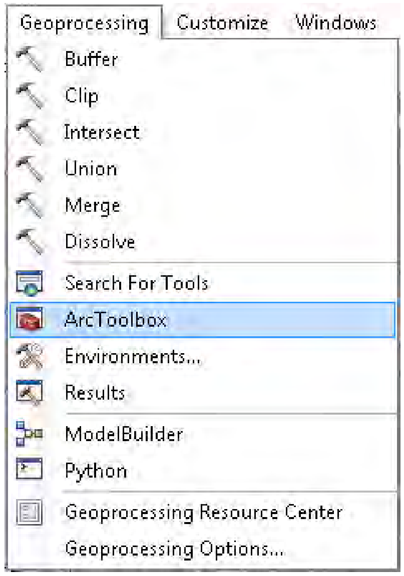
[from the version1.1.7_ReadMe.txt]

```
Installing the tools:
--------------------
No special or admin privileges are required, simply unzip the zip file
to a local directory.
An "NRCS_GIS_ENGINEERING_TOOLS" folder will be created in specified
location. Within the NRCS_GIS_ENGINEERING_TOOLS folder there will be
an "NRCS Engineering Tools.tbx" toolbox file and a "SUPPORT" folder.
The support folder contains the necessary scripts, files, and
symbology layers, and must always reside in the same directory as the
toolbox.

Adding to ArcMAP:
----------------
Enable the ArcToolbox window (if necessary), right click, and select
"Add Toolbox".
Browse to the location where the files were unzipped, then the
"NRCS_GIS_ENGINEERING_TOOLS" Folder within, and click once to select
or highlight the NRCS Engineering Tools Toolbox, then click the "Open"
button in the bottom right hand corner of the dialog box.

ArcMap Settings:
---------------
Make sure that the Spatial and 3D Analyst extensions are enabled by
going to the Customize > Extensions Menu (ArcGIS10) or the Tools >
Extensions Menu (ArcGIS 9.3). 9.3 Users should also go to the Tools >
Options Menu, click on the Geoprocessing Tab, and make sure that both
"Overwrite the outputs of Geoprocessing Operations" and "Add Results
of geoprocessing operations" options are selected. "Results are
temporary by default" should also be UN-CHECKED.
---------------
END
```

When properly setup in ArcMap, the NRCS tools should resemble the following image in your ArcToolbox:

The following section will guide users on area of interst and hydrologic conditioning DEM pre-processing using the NRCS GIS Engineering Tools. For manual AOI raster clipping, see Appendix section A.3.

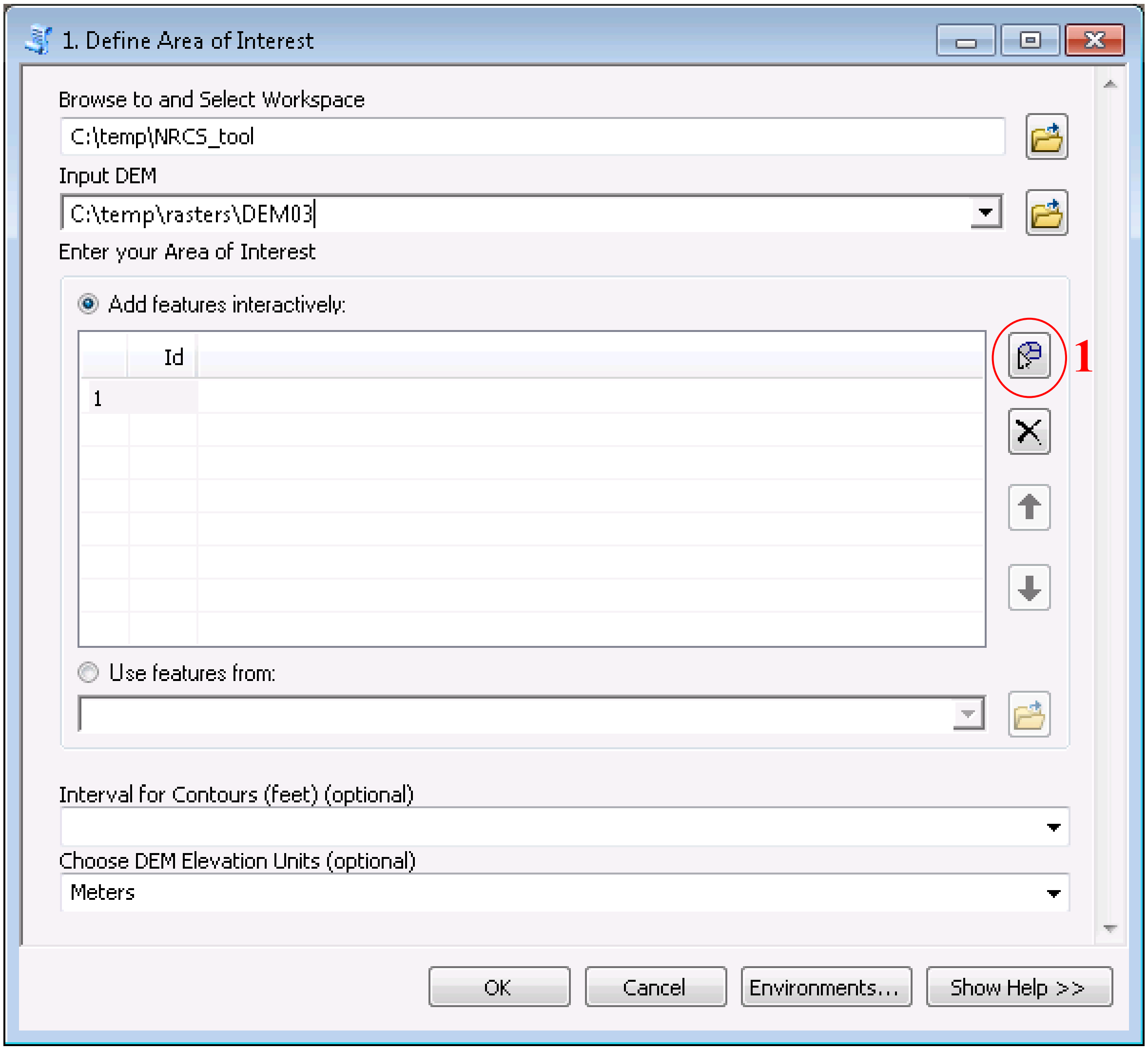
1. Launch **ArcToolbox** by clicking the toolbar  icon (9.x) or **ArcToolbox** in the **Geoprocessing** menu (10.x).




2. Expand the **NRCS Engineering Tools**, then expand the **Watershed Tools** toolset, followed by the **Watershed Delineation** toolset. Double-click the **Define Area of Interest** tool to start it. Minnesota LiDAR data acquired at the county level can contain very large file sizes. It is therefore important to minimize the spatial area to be processed to reduce output files sizes and increase processing times. The **Define Area of Interest** tool creates a subset of a raster dataset and will be used for this purpose.

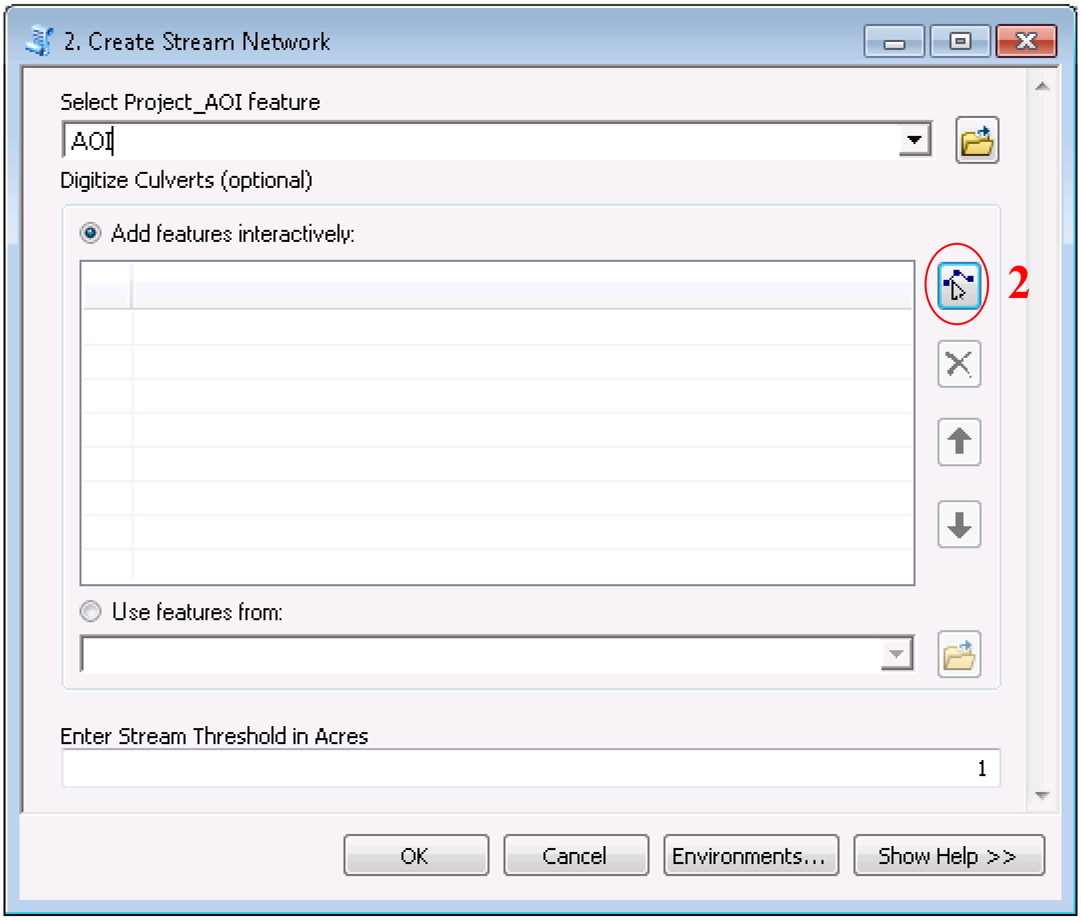
   *Note:* There are several additional ways to find this (or any) tool in ArcToolBox:

   - Select the **Index** tab at the bottom of ArcToolbox and scroll through the list to find **Clip** (Data Management) (9.x).
   - Select the **Search** tab at the bottom and type in 'fill' to find any tools with fill in their titles (9.x).
   - From the **Geoprocessing** menu, choose **Search For Tools** (10.x).




3. **Browse to and Select Workspace:** Choose your workspace folder where outputs will be stored. Select a destination directory without spaces and choose a name for the folder based on your project or area of interest
4. **Input DEM:** Your DEM, preferably a 3m LiDAR elevation dataset.
5. **Enter your Area of Interest:** Click the **Add feature** icon (#1 circled red in above image), then minimize the **Define Area of interest** window. The cursor should be a cross icon. The add feature tool works as a polygon editor, with each click creating a new vertex. The sketch is finished by double clicking to connect the first and last sketch vertices. Optionally, the **Use features from** field can be used with a compatible raster or vector file fitting you AOI
6. **Interval for Contours (feet) (optional):** Select desired contour foot contours. If left blank, no contours will be created
7. **Choose DEM Elevation Units (optional):** User preference
8. Click OK to run tool script. Several new layers will be added to your map

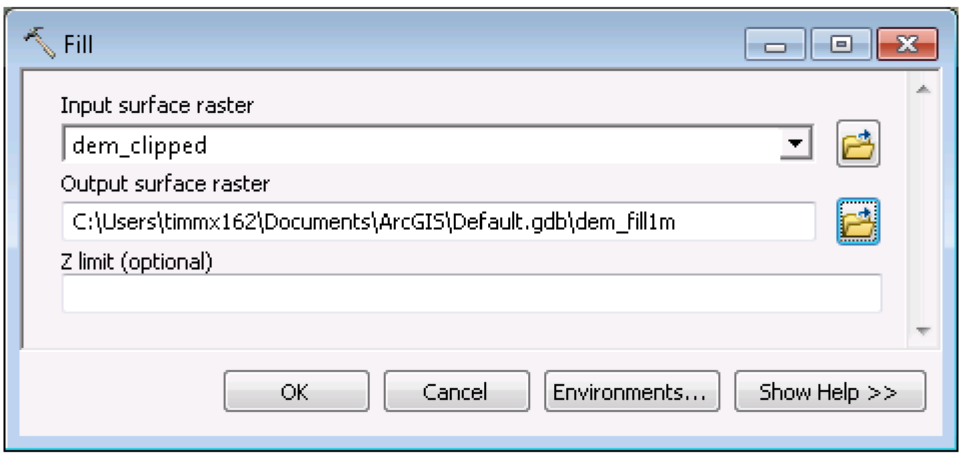
1. Open **NRCS Engineering Tools > Watershed Tools > Watershed Delineation > Create Stream Network**
   The **Create Stream Network** tool serves multiple purposes: it creates a stream network, it is used to burn culvert locations, and it creates a hydro-conditioned DEM all within the AOI established in the previous **Define Area of Interest** tool.




2. **Select Project_AOI feature:** Select the AOI that was created by the previous **Define Area of Interest** tool
3. **Digitize Culverts (optional):** Click the Add feature icon (#2 circled in red above) then minimize the current window. The add feature function works as a line sketch tool. Use the function to make a line that represents a culvert at any obvious or known locations where a culvert exists. The **DepthGrid** layer created by the previous tool **Define Area of Interest** can aid in showing where water backs up at impoundments such as road crossings (following figure). Culverts are likely to exist at these locations. Create as many digitized culverts as necessary to ensure an accurate stream network representation

4. **Enter Stream Threshold in Acres:** This value is the minimum contributing area required to form a stream. The default value of 1 is adequate in most situations and will form stream headwaters near catchment boundaries
5. Click OK to run tool script. Several new layers will be added to your map.
   - *Note:* The hydro-conditioned DEM will be created and called **hydroDEM** but will NOT be automatically added to your map. It is located in an auto-created file geodatabase within the workspace you selected in the first **Define Area of Interest** tool.

- <u>Pit & Sink Filling</u>
  Along with hydro-conditioning, pit filling should also be considered before terrain attribute calculations are made. This procedure fills depressions with hypothetical water flow and forces drainage to the lowest possible outlet. These depressions can vary considerably in scale from an isolated single cell to hundreds of contiguous cells covering well over a thousand acres. The pit-filling process may not be appropriate for all areas, especially where water is held and evaporated in depressions or where extensive tile drainage exists. It is, however, a more conservative approach than using a non-filled DEM because it tends to err on the side of overestimating flows (Galzki, et al. 2011) – SPI signatures created from pit filled DEMs are more analogous to saturation excess runoff flow paths produced from large storm events than unsaturated flows. For SPI creation, users may generally find filling pits most suitable for steep-sloping landscapes and less suitable for low relief areas, though it is highly advisable to experiment with various pit fill Z limits, including a "fill all" run and a run with no pit filling. This will allow comparisons to be made among the SPI layers and help determine which best represents the landscape.
  For CTI layer creation, a 'fill all' routine should be used to accurately depict surface water storage.
  1. Open **ArcToolbox > Spatial Analyst Tools > Hydrology > Fill**

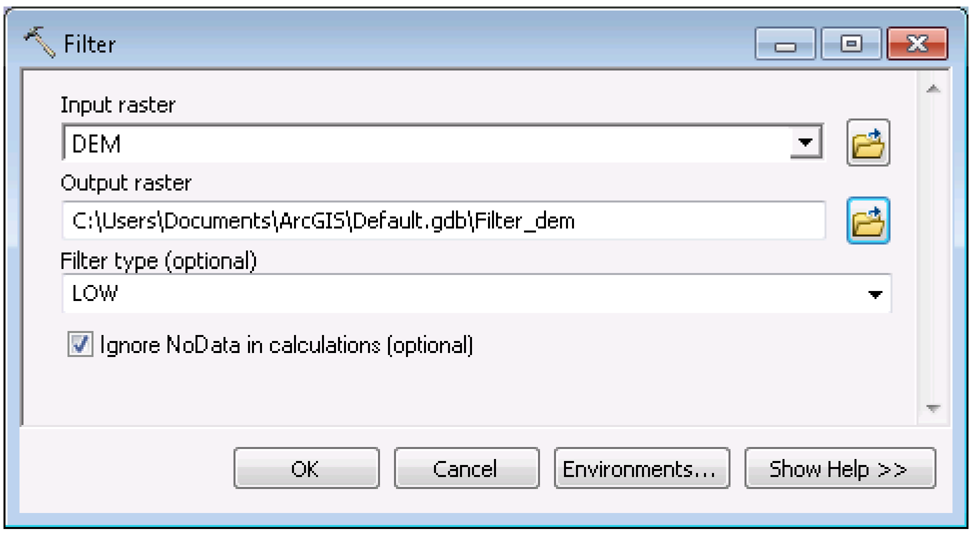



  2. **Input surface raster**: Your DEM. If you used the NRCS Engineering tools previously, your **Input surface raster** will be **hydroDEM** for you hydro-conditioned DEM, or [**Your workspace folder name]_DEM** for your non-hydro-conditioned DEM. If you manually created a clipped subset of your original DEM, your **Input surface raster** will be the 'dem_clip' layer. To fill the tool fields, select layers from the drop-down, drag the layer to the blank field, or browse to the desired layer by clicking on the folder icon left of field.
  3. **Output surface raster**: Browse to output workspace and name using it something you can remember, e.g. 'dem_fill'. It may be useful to add the unit amount used to fill the DEM so that users can identify each layer's Z limit when calculating multiple filled DEMs; e.g. 'dem_fill1m' or 'dem_fillall'
  4. **Z limit**: The maximum elevation difference between a sink and its pour point to be filled. Units will be the same as the DEM's Z (vertical) axis, typically meters.
     *Note*: The default, which is achieved by leaving the Z limit field blank, will fill all sinks regardless of depth
  5. Click OK to run. The output surface raster is added to your map as a new layer

- Filter

  At times, LiDAR data expressed in fine-resolution DEMs can contain either errors or spurious features which impede flow analysis and/or other terrain analysis, though these anomalies are becoming a non-issue with advancing technology in LiDAR acquisition along with improved quality control and assurance deliverables. The filter tool employs a low pass filter using a 3x3 moving window to "smooth" the raster and create a more contiguous dataset. Caution should be used when filtering, as it essentially 'dumbs down' the data by averaging out extreme outliers. Similar to pit filling, it is recommended to run terrain analysis with both filtered and non-filtered processes and determine which outputs best suit the terrain. The filter tool is typically run after pit filling.

1. **ArcToolbox > Spatial Analyst Tools > Neighborhood > Filter**.



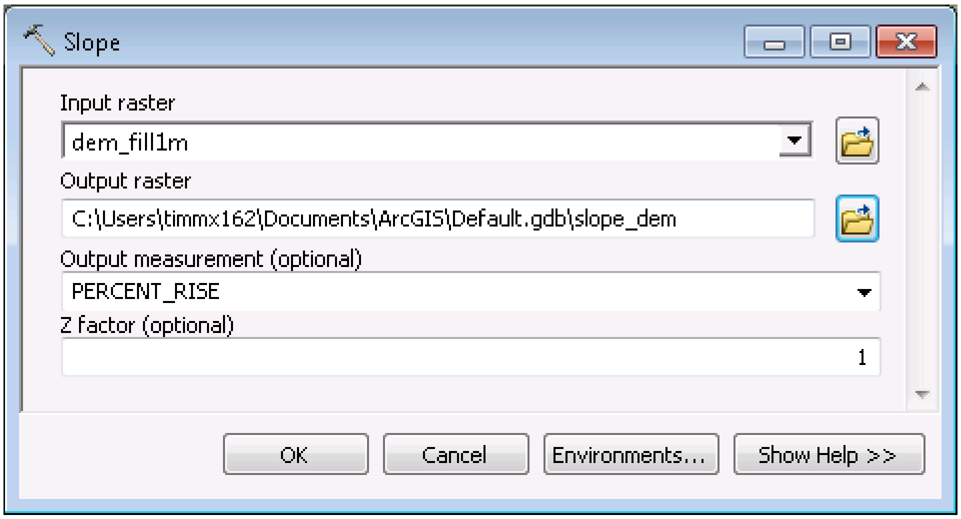

2. **Input raster**: Your DEM. If pit filling was previously used, your **Input raster** will be 'dem_fill'. If pit filling was not used, but clipping was, your **Input raster** will be 'dem_clipped'. If NRCS tools were used, the **Input Raster** will be **hydroDEM** or [**Your workspace folder name]_DEM**
3. **Output raster**: Browse to output workspace and name it, e.g. 'dem_filter'.
4. **Filter type (optional):** the enhancement to be performed in the filter analysis.
   - *Note*: The default is "LOW" which is required to do the smoothing we seek.
5. Click OK to run.
6. The output raster is added to your map as a new layer.

## Calculate primary attributes

Primary attributes are derived directly from the DEM. The slope, flow direction, and flow accumulation primary attributes will be used to calculate secondary attributes. Many of the other primary attributes created here will be used to visualize landscape surfaces and terrain attributes.

- Slope

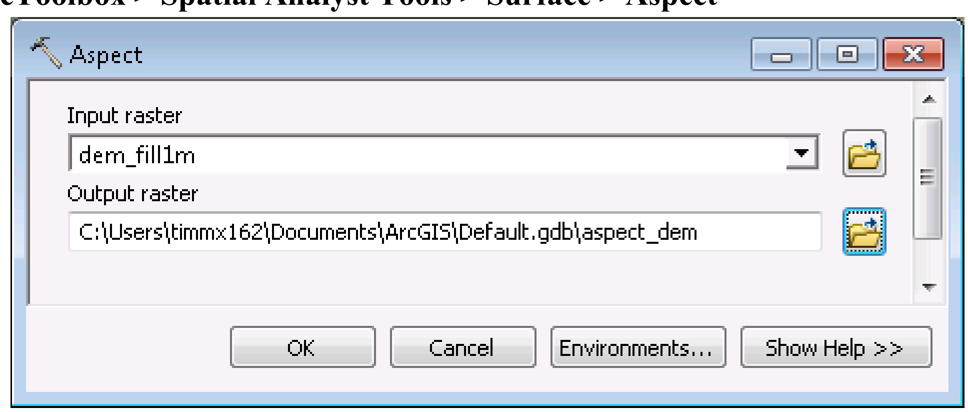
1. **ArcToolbox > Spatial Analyst Tools > Surface > Slope**




2. **Input Raster**: Your DEM. If pre-processing was used, this should be the final DEM created, such as 'dem_fill' or 'dem_filter'.
3. **Output raster**: Browse to output workspace and name output layer 'slope_dem'.
4. **Output measurement (optional):** Select 'PERCENT_RISE'
   - *Note:* It is important for the rest of the analysis that you select PERCENT_RISE, even though the data will look the same.
5. **Z factor (optional):** For DEMs with vertical (Z) units in meters, type 1, or else leave as default
6. Click OK to run. The output raster is added to your map as a new layer.

- Aspect

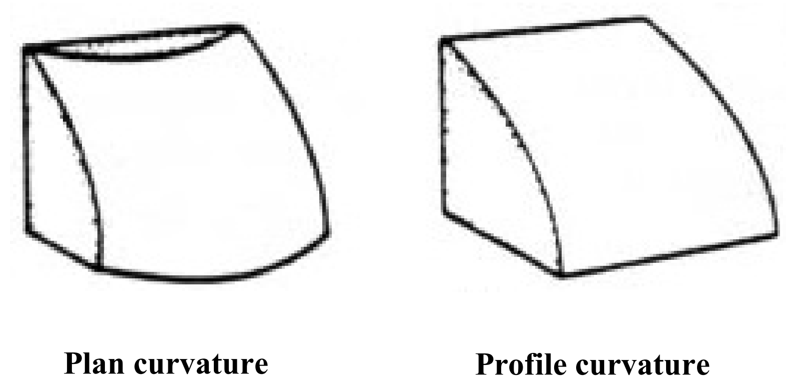
1. **ArcToolbox > Spatial Analyst Tools > Surface > Aspect**




2. **Input Raster**: Your DEM. If pre-processing was used, this should be the final DEM calculated, such as 'dem_fill' or 'dem_filter'.
3. **Output raster**: Browse to output workspace and name output layer 'aspect_dem'.
4. Click OK to run. The output raster is added to your map as a new layer.

- <u>Plan & Profile Curvature</u>

Plan curvature is measured perpendicular to the direction of descent and describes converging/diverging flow. It is well suited for describing soil water content and characteristics. Profile curvature is measured in the direction of maximum descent or aspect direction. It is a measure of flow acceleration and suited for erosion/deposition rate and geomorphology visualization.



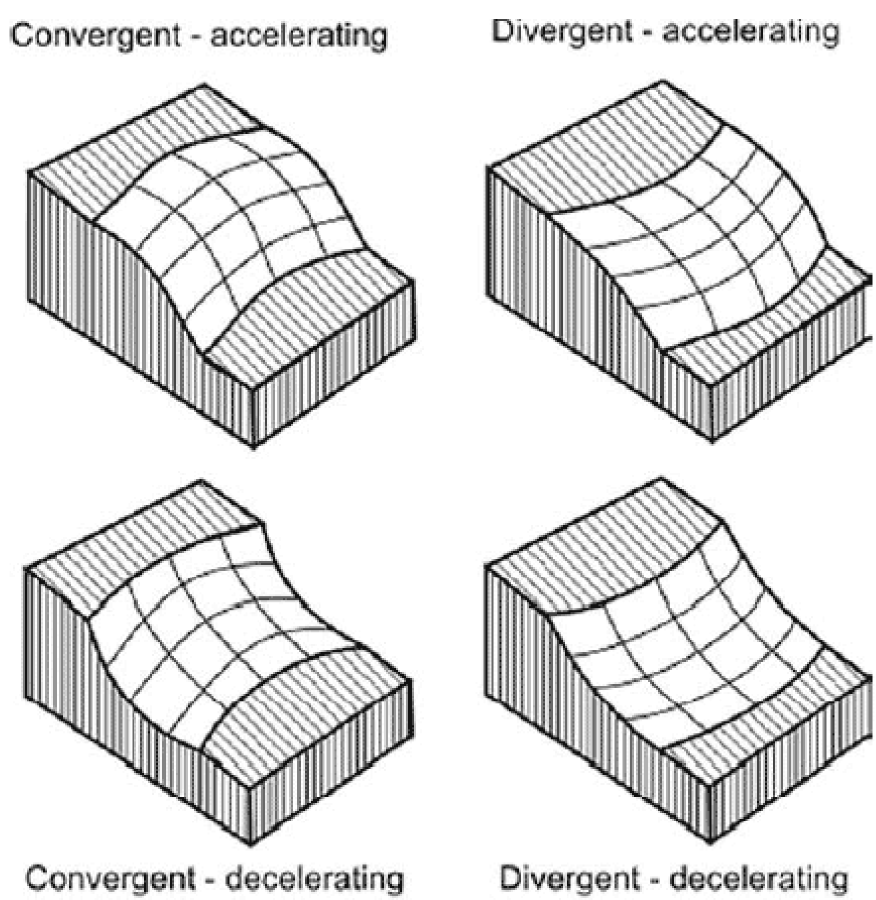
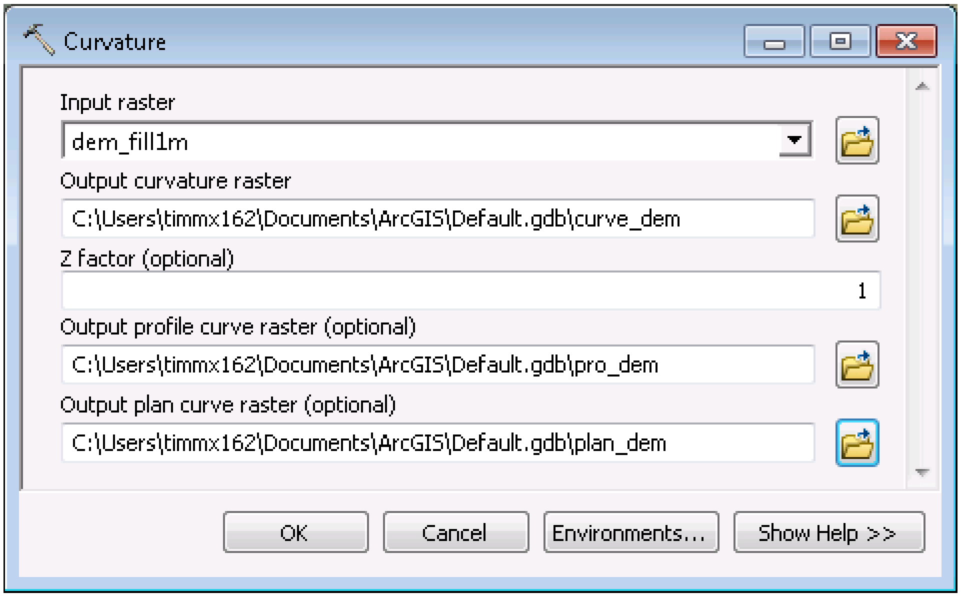




Image courtesy of Transport Scotland (Harrison et al., 2008)

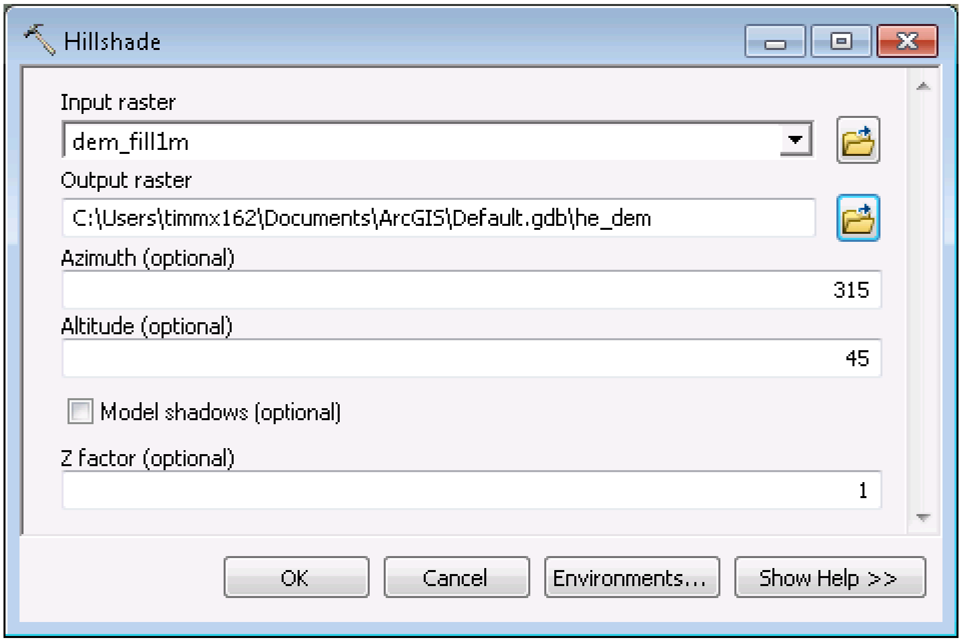
1. **ArcToolbox > Spatial Analyst Tools > Surface > Curvature**




2. **Input Raster**: Your DEM. If pre-processing was used, this should be the final DEM calculated, such as 'dem_fill' or 'dem_filter'.
3. **Output curvature raster**: Browse to output workspace and name output layer 'curve_dem'.
4. **Output profile curve raster**: Browse to output workspace and name layer as 'pro_dem'.
5. **Output plan curve raster**: Browse to output workspace and name layer as 'plan_dem'.
6. Click OK to run. The 3 output rasters are added to the map as new layers.

- <u>Hillshade</u>
  The hillshade tool creates a shaded relief layer from a surface raster by considering the illumination source angle and shadows. The resulting hillshade raster creates a pseudo 3D display of topography.

1. **ArcToolbox > Spatial Analyst Tools > Surface > Hillshade**

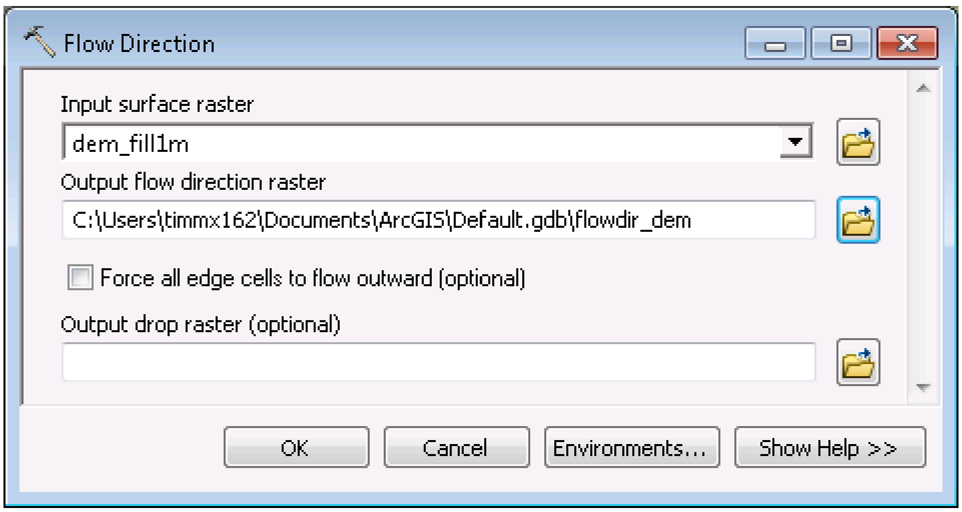



2. **Input Raster**: Your DEM. If pre-processing was used, this should be the final DEM calculated, such as 'dem_fill' or 'dem_filter'.
3. **Output raster**: Browse to output workspace and name output layer 'hs_dem'.
4. Accept defaults for **Azimuth** and **Altitude**
   - *Note:* You can try checking on **Model Shadows**, it can be helpful in visualization, but in some cases it may make little difference.
5. **Z factor (optional):** For DEMs with vertical (Z) units in meters, enter 1, or else leave as default
6. Click OK to run. The output raster is added to your map as a new layer.

- Flow Direction

ArcMap's Flow Direction tool uses a calculation method called the 'D8' algorithm. This method is well suited to the identification of individual channels, channel networks and basin boundaries making it suitable for terrain analysis CSA identification. However, it is based on two simplifying assumptions that do not capture the geometry of divergent flow over hillslopes. The two simplifications are the use of 8 discrete flow angles, and each pixel has a single flow direction (Rivix, 2008). Due to these factors, the 'D-Infinite' algorithm was created to overcome D8 limitations and therefore provide an increased potential to improve terrain analysis results. Several software programs exist with dedicated DEM processing offering both D8 and D-Infinite calculations (e.g. TauDEM, RichDEM, RiverTools, etc.). The D8 method imbedded in the Flow Direction ArcTool is used in this section, though users are encouraged to process DEMs with the D-Infinite method Flow Direction calculation if available.

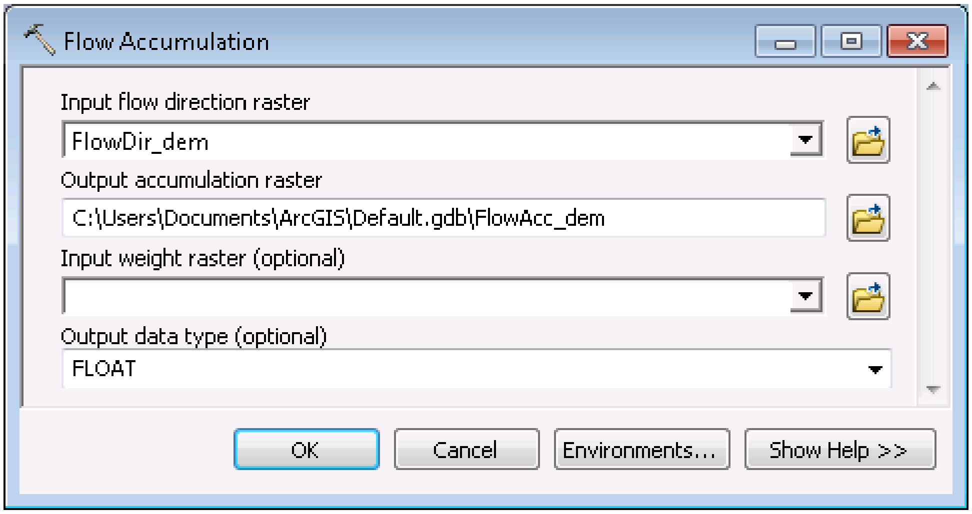
1. **ArcToolbox > Spatial Analyst Tools > Hydrology > Flow Direction**




2. **Input Raster**: Your DEM. If pre-processing was used, this should be the final DEM calculated, such as 'dem_fill' or 'dem_filter'.
3. **Output flow direction raster**: Browse to output workspace and name output layer 'flowdir_dem'.
4. Click OK to run. The output raster is added to your map as a new layer.

- Flow Accumulation

1. **ArcToolbox > Spatial Analyst Tools > Hydrology > Flow Accumulation**

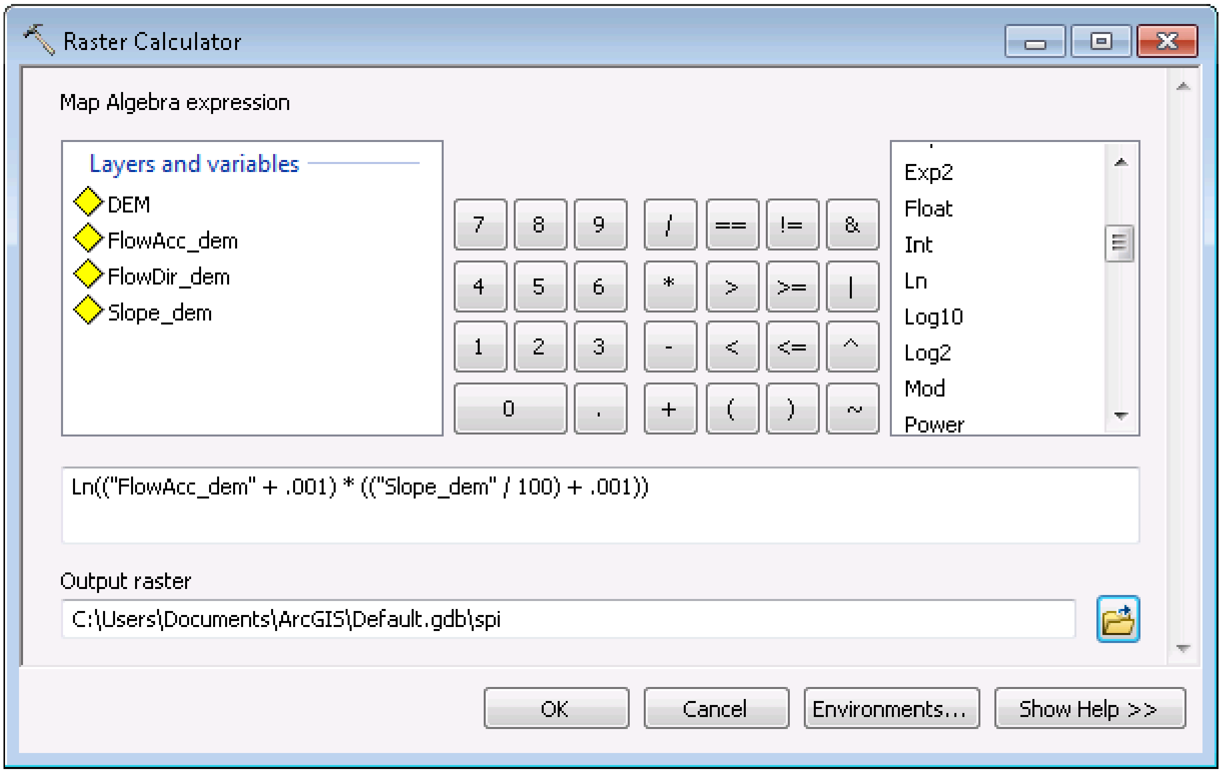



2. For **Input Flow Direction Raster**, use the output of Flow Direction from earlier step. If you kept the suggested name, it will be 'flowdir_dem'.
3. **Output accumulation raster**: Browse to output workspace and name output layer 'flowacc_dem'.
4. Accept defaults for other parameters.
5. Click OK to run. The output raster is added to your map as a new layer.

### Calculate secondary attributes

- SPI

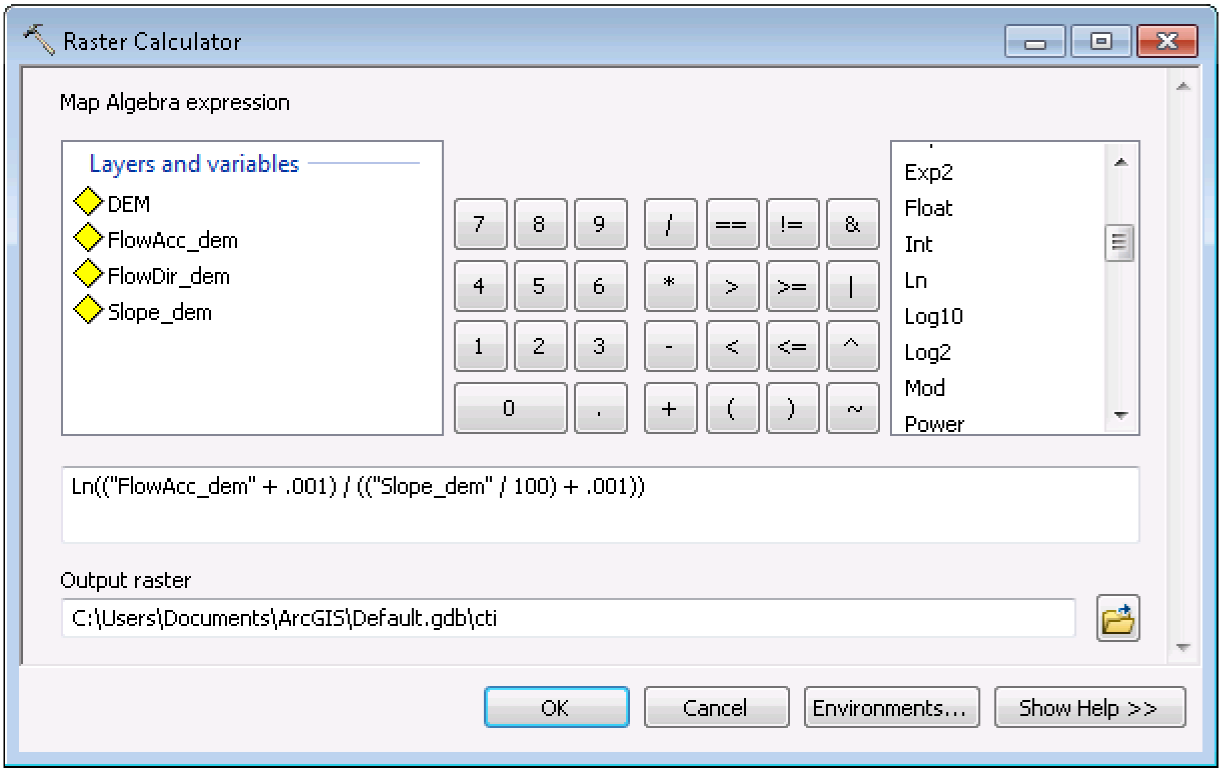
1. Launch the **Raster Calculator** by clicking on **Spatial Analyst Tools > Map Algebra > Raster Calculator**




2. Enter formula so the Map Algebra expression looks exactly as follows: **Ln(("flowacc_dem" + 0.001) * (("slope_dem" / 100) + 0.001))**
   - *Note:* The spaces between operators are required for proper calculation
3. **Output raster**: Browse to output workspace and name output layer 'spi'.
4. Click OK to run calculation.

- <u>Compound Topographic Index (CTI)</u>

1. Launch the **Raster Calculator** by clicking on **Spatial Analyst Tools > Map Algebra > Raster Calculator**



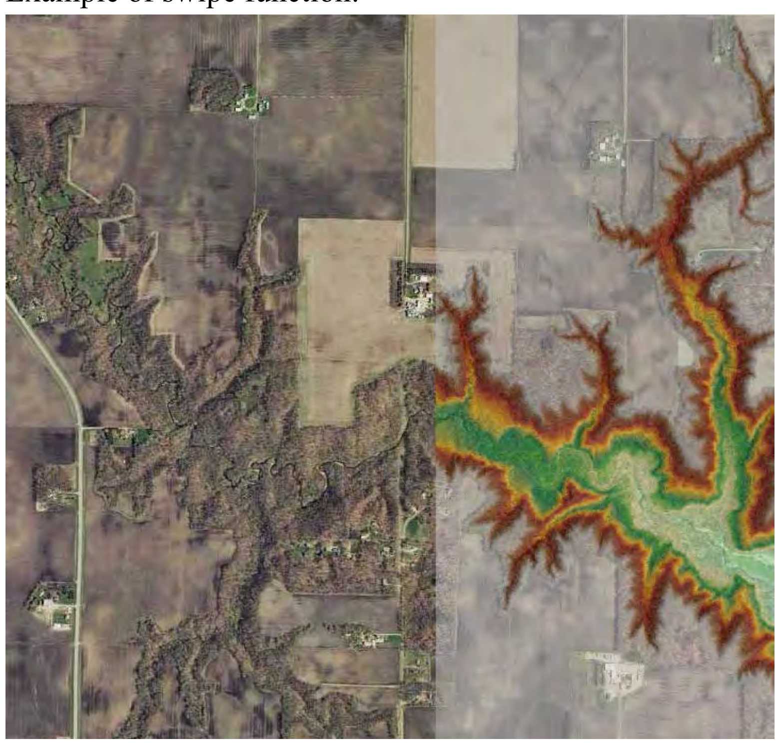

2. Enter formula so the Map Algebra expression looks exactly like: **Ln(("flowacc_dem" + 0.001) / (("slope_dem" / 100) + 0.001))**
   - *Note:* The formula above is the same as the SPI formula with the only difference being the division between Flow Accumulation and Slope.
3. **Output raster**: Browse to output workspace and name output layer 'cti'.
4. Click OK to run calculation.

## Visualizing terrain attributes

- <u>Terrain Attribute Comparison</u> – Often, the best way to understand differences in terrain attribute calculations is to view each layer in conjunction with one another. By paying careful attention to a specific portion of the landscape, one can overlay each of the terrain attributes to gain a better understanding of the relationships between each attribute.
- <u>Aerial Photo Comparison</u> - Utilizing aerial photography is a great way to better understand your landscape, and it may be possible to validate some of the largest features in your area of interest with aerial photos alone. While ground-truthing is the most effective way to determine the accuracy of terrain attribute-based predictions of CSAs, this is not always possible – especially on privately-owned land. Furthermore, photos when used with flow accumulation and its associated secondary terrain attributes, often help in assessing whether or not further hydrologic conditioning is required for the task at hand.
- <u>Swipe function</u>
    1. To display the **Effects** toolbar, right-click anywhere in the toolbar and select Effects.
    2. Select the Swipe Tool to "wipe" a layer using a horizontal or vertical line across the screen.


    3. Make sure the layer you want to "swipe" is shown in the "Layer:" box.
    4. Click on the map and drag to swipe *(do not release mouse button; the mouse must be depressed to get the swipe effect).*

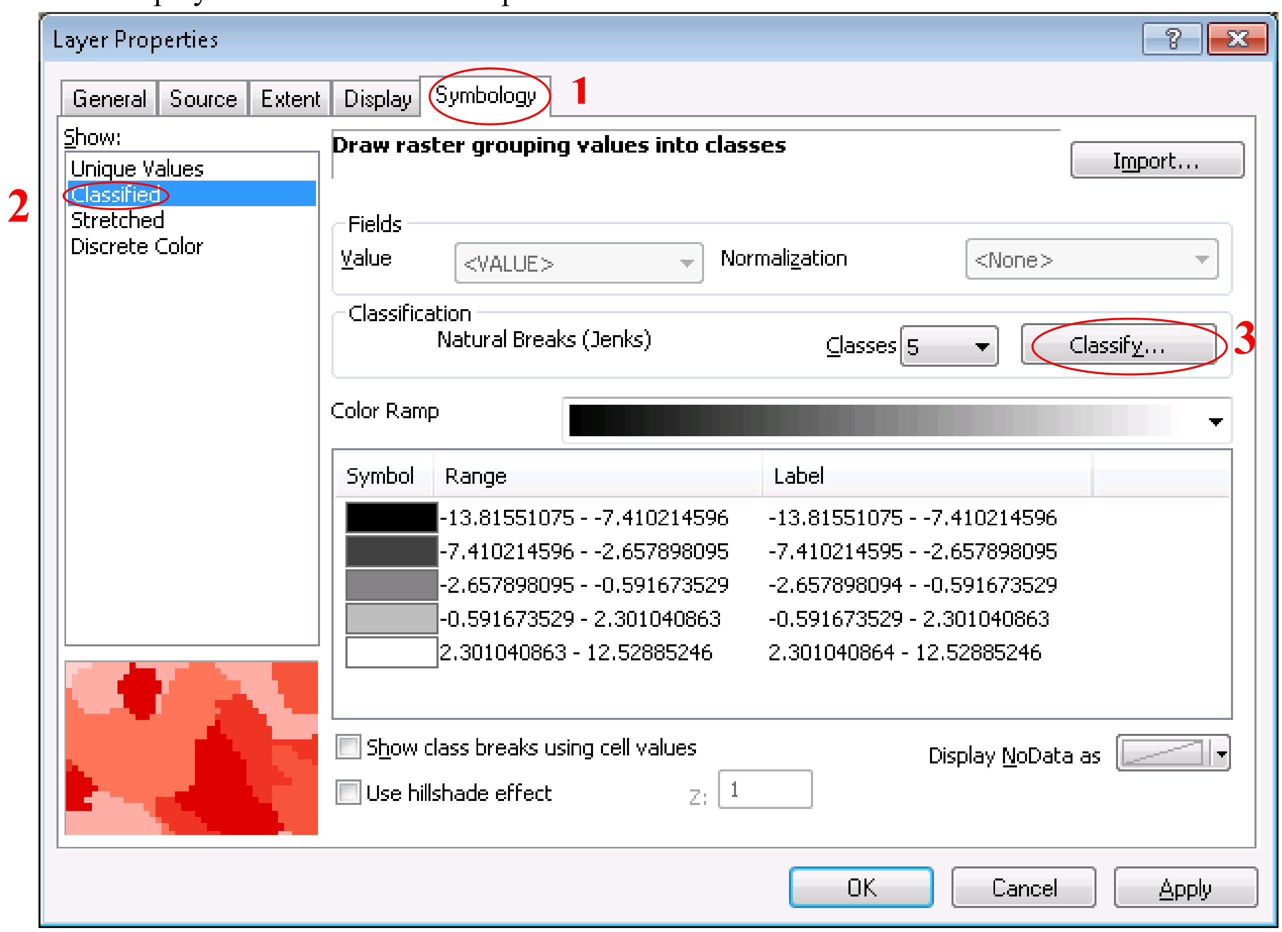
Example of swipe function:



- <u>Symbology for Terrain Attributes</u>

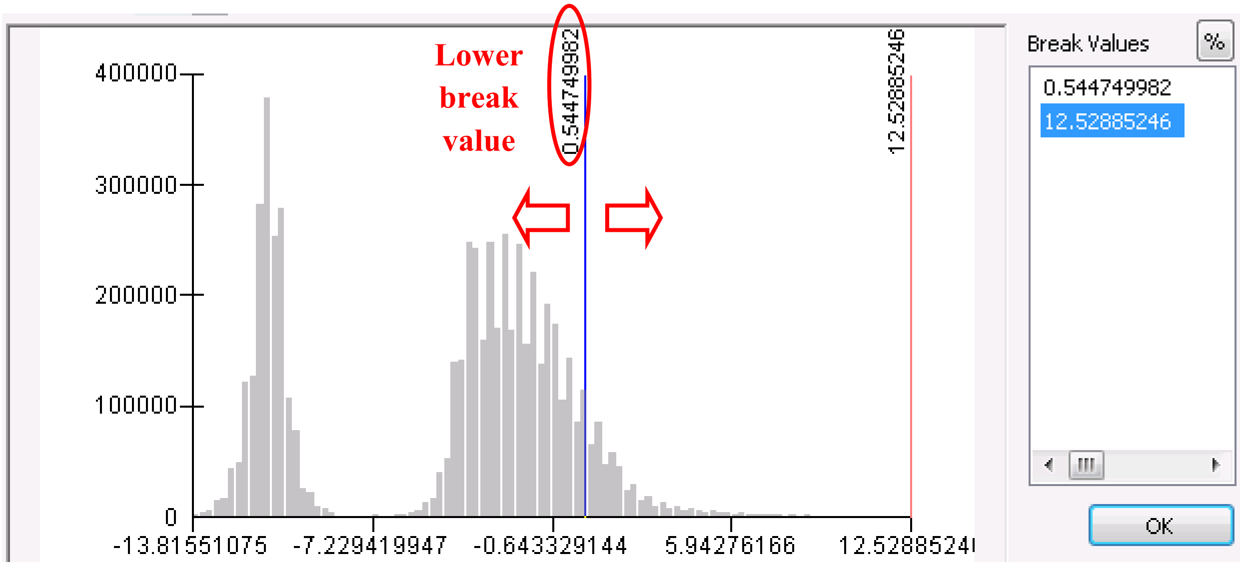
  Often this is a matter of personal preference, but there are a few tips/tricks in display used for specific terrain attributes:
  1. Slope - Colormap variations
  2. Flow Accumulation - Visualize upslope contributing area as if it were a watershed boundary.
  3. CTI – Blue/water – display highest values darkest
  4. SPI – Brown/sediment - display highest values darkest
- <u>SPI/CTI visualization</u> – Once calculated, the SPI and CTI layers are not very informative without first removing a majority of the cells that have low erosion (SPI) or ponding (CTI) risk. The layer histograms can be used to estimate a threshold for these unwanted values for quick display changes. More precise methods for determining how many cells to remove from the layers are discussed in the **Determining thresholds** section on page 36.

  To modify the original SPI and/or CTI layers to display percentile values:
  1. Double click on the layer in the Table of Contents window in ArcMap to open the layer's Properties menu.
  2. In Layer Properties, open the Symbology tab (**1**). On the right side under 'Show' click on 'Classified' (**2**) and in the classification box click 'Classify…' (**3**). The Classification window will open. At this point users can experiment with several different classification methods, classes, and threshold values. Keep in mind that any changes made here in Layer Property Symbology will not modify the data in anyway; it will only change the way the data is displayed in the active ArcMap data frame.



- The Classes pull down menu allows for the user to select the number of class breaks to be calculated using the user defined classification method. Using class breaks between 1 and 10 should be appropriate for displays.
- With the classification method, there is no right or wrong method to use, though the Quantile and Natural Breaks (Jenks) classification methods often match well with signature gradients. ESRI provides the following descriptions for each classification method from their ArcGIS Help Resource Center:
  - Equal interval divides the range of attribute values into equal-sized sub-ranges. This allows you to specify the number of intervals, and ArcGIS will automatically determine the class breaks based on the value range.
  - Defined interval allows you to specify an interval size used to define a series of classes with the same value range.
  - With Quantile classification, each class contains an equal number of features. A quantile classification is well suited to linearly distributed data. Quantile assigns the same number of data values to each class. There are no empty classes or classes with too few or too many values.
  - Natural Breaks (Jenks) classes are based on natural groupings inherent in the data. Class breaks are identified that best group similar values and that maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big differences in the data values.
  - The Geometrical Interval classification scheme creates class breaks based on class intervals that have a geometrical series. The geometric coefficient in this classifier can change once (to its inverse) to optimize the class ranges. The algorithm creates geometric intervals by minimizing the sum of squares of the number of elements in each class. This ensures that each class range has approximately the same number of values with each class and that the change between intervals is fairly consistent.
  - The Standard deviation classification method shows you how much a feature's attribute value varies from the mean. Class breaks are created with equal value ranges that are a proportion of the standard deviation—usually at intervals of 1, ½, ⅓, or ¼ standard deviations using mean values and the standard deviations from the mean.
- The Data Exclusion option can be used to exclude all data below or above any user determined threshold value.

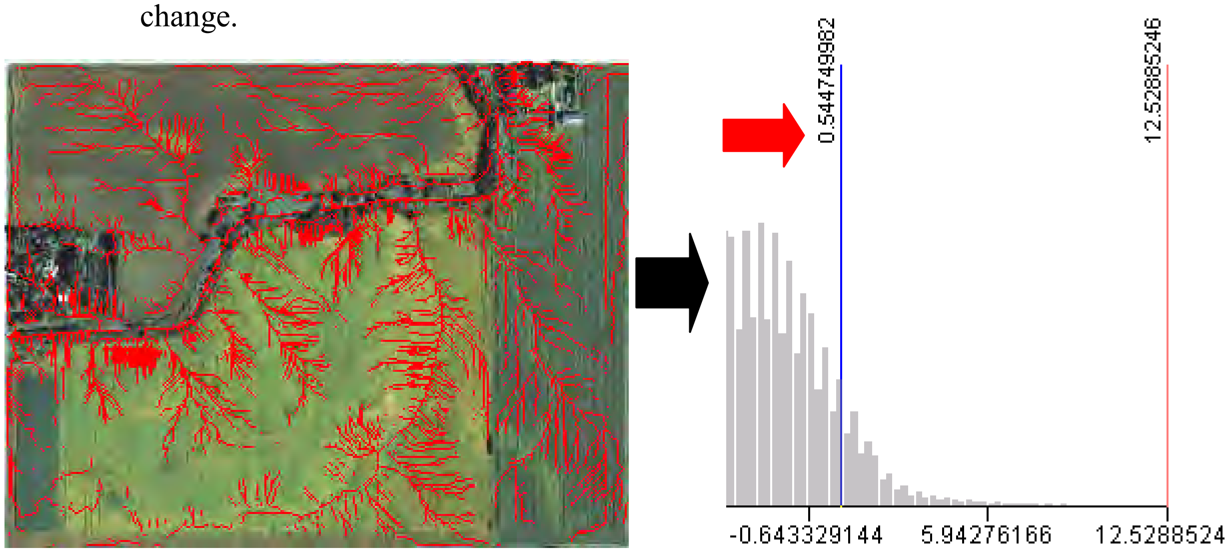
3. The simplest method for display is to use two classes to represent all signatures over a certain threshold. This threshold value is at the users' discretion, though quantitative methods for calculating statistical thresholds are presented in the **Determining thresholds** section on page 36.
   - For the simple method described here, set Classes to '2' and Classification Method to 'Manual' in that order. Two values will display in the Break Values column on right (see following figure). For this initial step, click and drag the lower break line to the approximate location shown in regards to the background histogram, or place it at the break value of ~2. This can be easily fine-tuned later. Click OK.



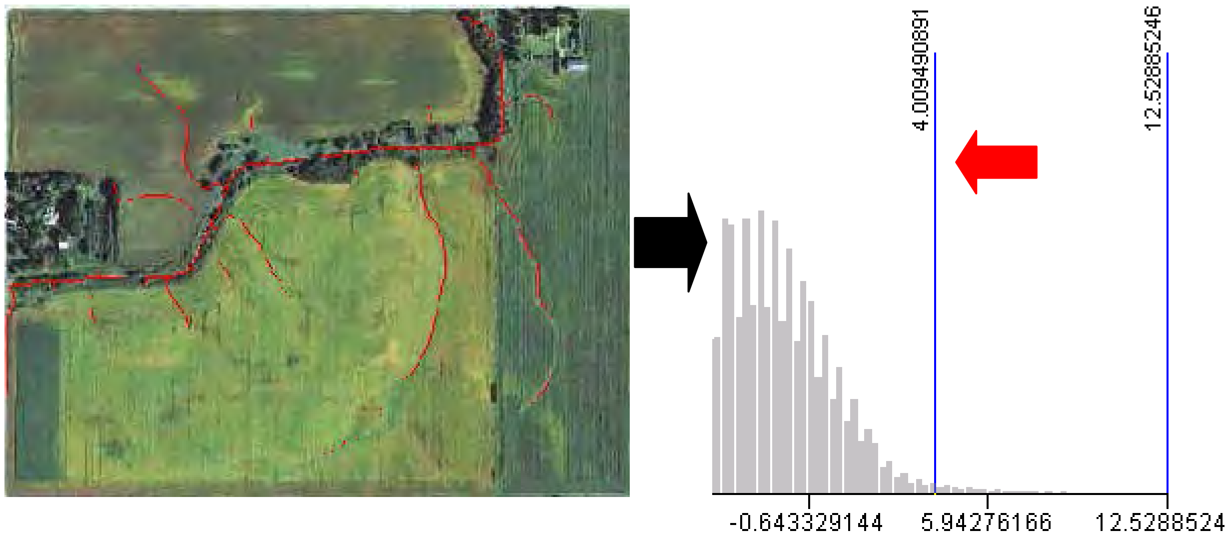

- Back in the Symbology window, there will be two class symbols displayed – one black and one white – with the ranges associated with each to their right. The black symbol by default will contain all values below the threshold we chose, and the white contains the values above. Double-click the white rectangle symbol and a color palette will appear. Click any color you prefer that is highly visible, such as 'Mars Red'. Double-click the black rectangle and choose "No Color" at the top of the palette window. If the layer is active, you can click 'Apply' the see the changes behind the Layer Properties window instantly, otherwise click 'OK'.
- Users will likely want to tweak the threshold value used to best represent the surface flow paths (SPI) or ponding (CTI) in their area of interest.
  - If the SPI signatures look too crowded or dense (example 1 below), the threshold values should be increased incrementally by clicking and dragging the vertical break line in the classification window until display results are satisfactory and vice versa for sparse SPI populations (example 2).

    *Note:* The symbol colors will need to be changed again after each classification change.

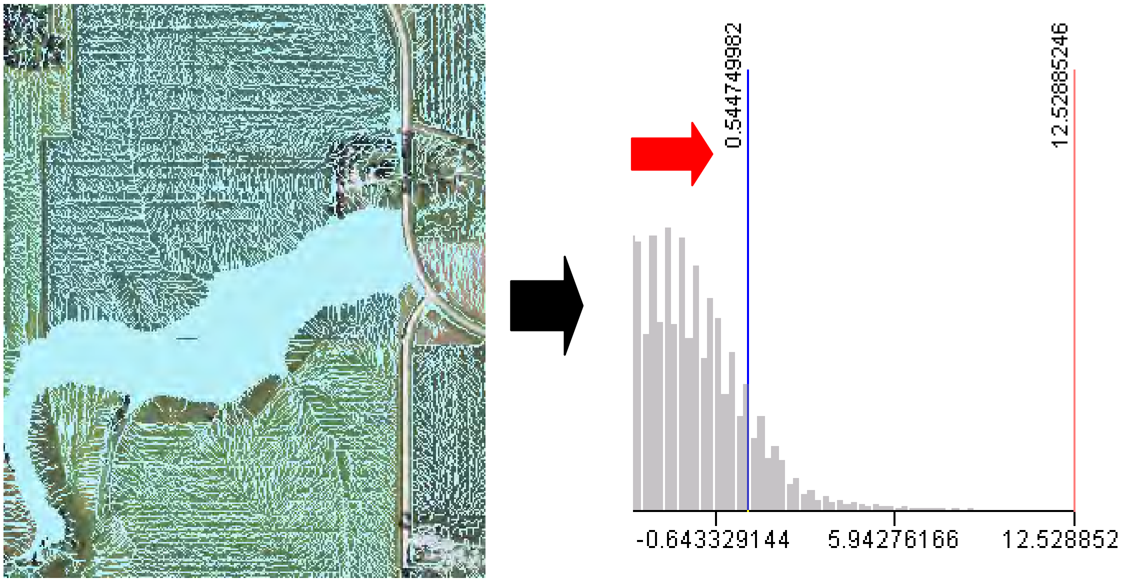
**Ex. 1**

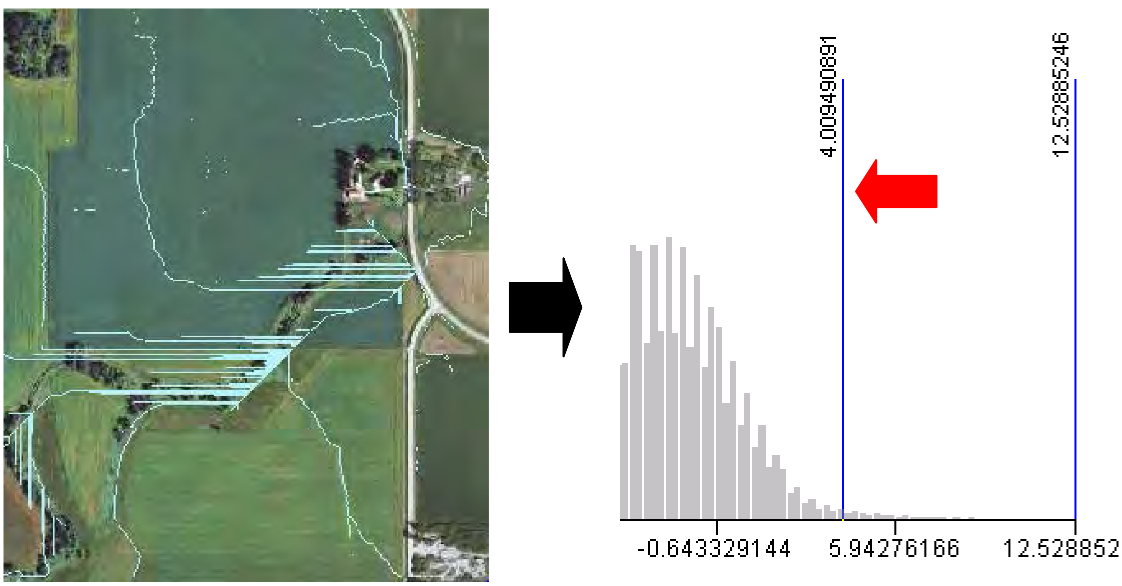


**Ex. 2**

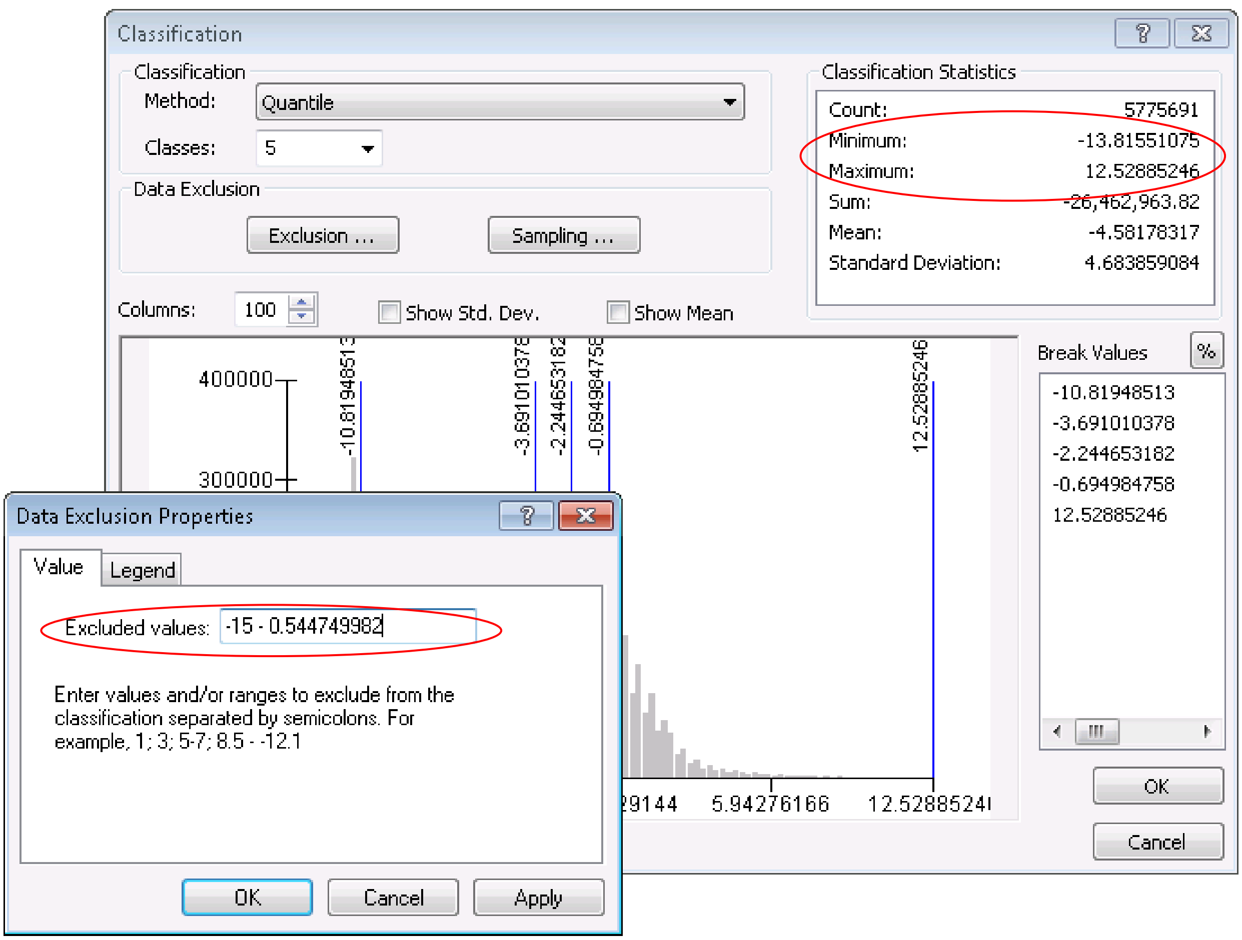


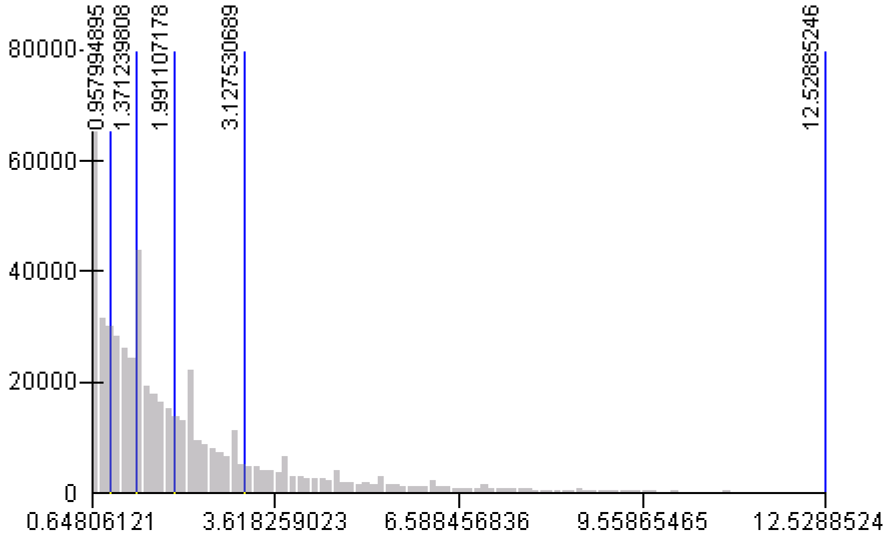
- Treat the CTI layer using the same technique described in the previous step. A proper CTI threshold should display areas of impounded water if pit filling was used during DEM pre-processing.



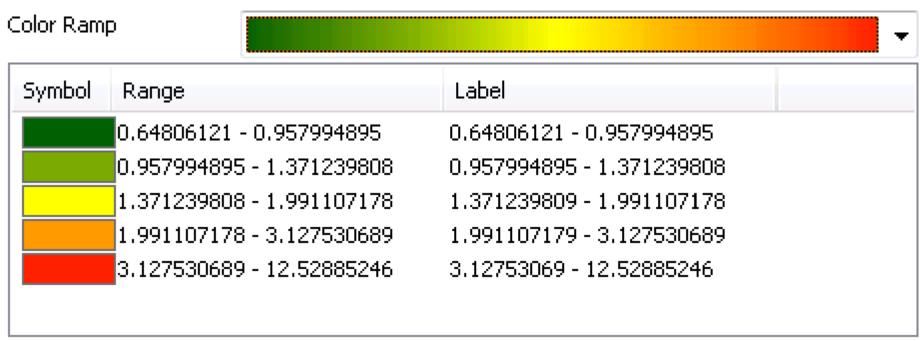



- Often it is preferable to display SPI and CTI signatures with color gradients that represent high and low values within the same signature. For this purpose we can use the classification window with more than two classes.
  - ➢ Under Classification Method, choose 'Quantile' or 'Natural Breaks (Jenks)' and Classes between 5 and 10 (user preference).
  - ➢ We will use the Data Exclusion option to remove all values below a threshold. In the Classification window's Data Exclusion box, click "Exclusion…"
    Under the Value tab, type your desired data exclusion range in the blank. For instance, to exclude all values below a threshold value of 2, and a minimum value range of -14, you would enter "-14 - 2" (without quotes). The minimum or maximum value used can be below or above the true value respectively to ensure full exclusion of data in the desired range.
    *Note:* The range will be displayed in the underlying Classification window in the upper right, as Minimum and Maximum
  - ➢ Click on the Apply button to see the changes in the underlying window's histogram to ensure it matches your exclusion range. If the results are satisfactory, click OK on both windows to return to the Layer Properties window.






- In the layer properties window, you can set your preferred color ramp for pixel display by clicking on the Color Ramp pull down. It may be best to match the highest values with the darkest colors and lowest values with lightest.




| Symbol | Range | Label |
|---|---|---|
| | 0.64806121 - 0.957994895 | 0.64806121 - 0.957994895 |
| | 0.957994895 - 1.371239808 | 0.957994895 - 1.371239808 |
| | 1.371239808 - 1.991107178 | 1.371239809 - 1.991107178 |
| | 1.991107178 - 3.127530689 | 1.991107179 - 3.127530689 |
| | 3.127530689 - 12.52885246 | 3.12753069 - 12.52885246 |

- As with the two class display approach, you may find that the exclusion range used allows too many or too few signatures for display. The method for correction is to change the threshold value in the data exclusion range. If the signatures are too crowded, increase the threshold value closer to your maximum value, and vice versa.

## Determining thresholds

The SPI and CTI raster layers are most useful when displayed at a certain percentage of values above a threshold. The threshold depends mainly on local topography and overall slopes, and there is often a range of percentile values that will represent surface features sufficiently. Common thresholds are typically between the top 15% of values for flat areas to the top 1% of values for high relief areas.

Using estimation to visualize thresholds was previously described. This section will detail several methods for calculating exact percentile values from raster layers. Though not a necessary step for locating potential CSAs, the percent of SPI or CTI values displayed should be known to ensure consistency among users, or if following SOPs and/or publishing results. Methods for creating exportable SPI/CTI raster files with permanently-set thresholds will also be explained in this section.

When determining thresholds, the user must consider the spatial extent of the area being processed, as software has limited abilities to process large data sizes. For instance, if using Microsoft Excel, the maximum records affect ability to input LiDAR data:

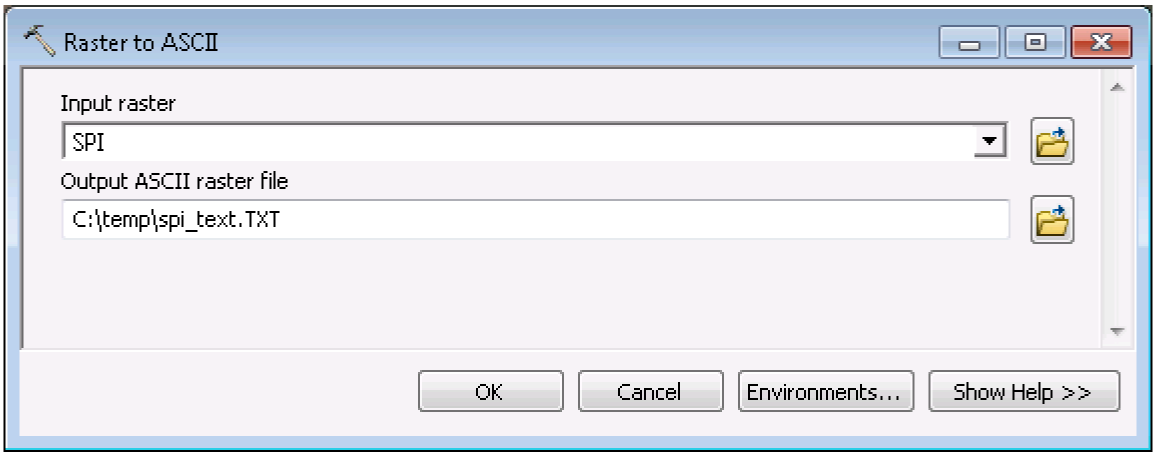
Excel 2003 max records - 65,569
Excel 2007 max records - 1,048,575
Statistical Packages – Many around 10 million

If Excel maximum records become an issue, users may circumvent those limitations by creating random samples from the SPI raster at a 95% or better confidence interval. There are also many statistical software packages that can readily compute percentiles from large datasets, such as the free to use R program (CRAN, http://www.r-project.org/). Since those programs often have a learning curve for even basic functioning, using a more familiar program such as Microsoft Excel may be preferable. This section focuses on using Excel for threshold calculations. A full explanation on using the R statistical software package for percentile calculations is presented in the appendix (see appendix section A.4).

**Calculating thresholds using Excel:**

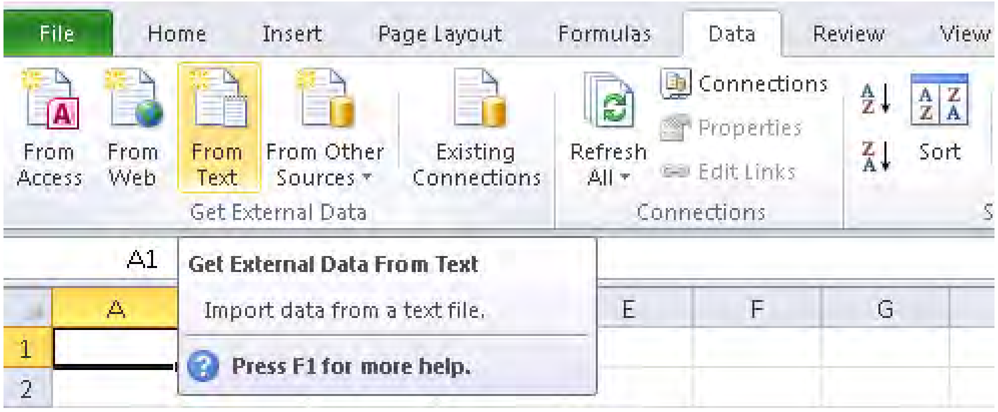
When using Excel, first consider data size. Using 3m LiDAR derived attributes from an AOI of 2,332 acres or more will contain too many records to be contained in a single Excel 2007 sheet. As mentioned previously, there are ways to circumvent these limitations. Two methods for using Excel to calculate thresholds will be described in detail. One will use an exported text file (also known as ASCII file) from ArcMap to be opened directly in Excel, while the other method will first use a random sample from stream power index values to be opened in Excel.

- Raster to ASCII method
  1. Launch the **Raster to ASCII** tool by clicking on **Conversion Tools > From Raster > Raster to ASCII** in **ArcToolbox**

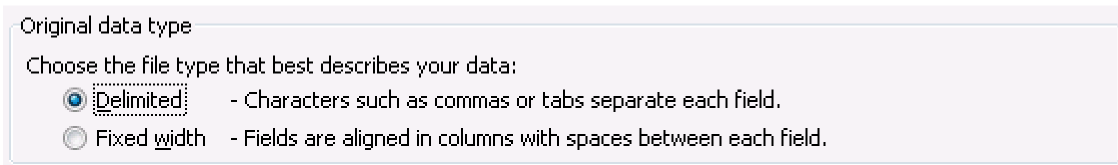



     a. **Input raster**: Your SPI raster layer.
     b. **Output ASCII raster file**: Any folder location of your choosing. Name the file 'spi_text'
     c. Click OK to run.
        - *Note:* If the output text file exceeds 250mb, users should consider proceeding with other percentile calculation methods described in this section.

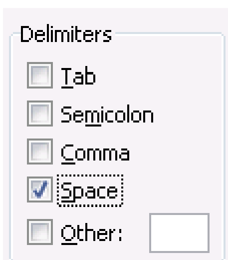
  2. Open Microsoft Excel with a blank workbook.
  3. In Excel 2007/2010, choose the **Data** tab, and click on **From Text** from the **Get External Data** group (pictured below).
     In Excel 2003 and earlier, navigate to the **Data** pull down menu and choose > **Import External Data > Import Data…**



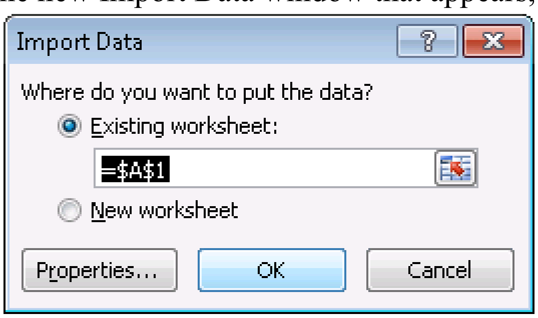

4. Browse to the saved ‘spi_text’ file created previously and click Import. The Text Import Wizard will open.
5. In the step 1 of 3 window, click the “Delimited” radio button and click Next.



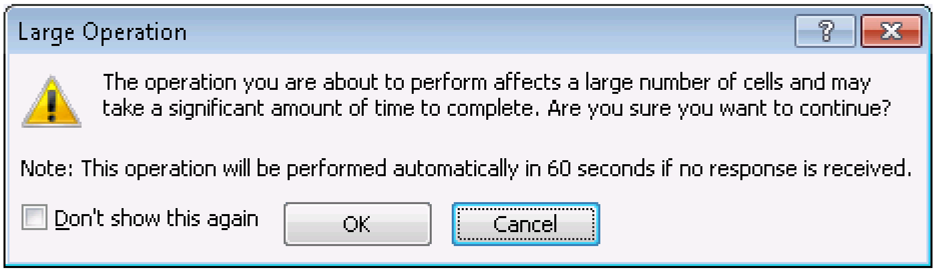

6. In step 2 of 3, under the Delimiters checkbox fields, un-select Tab, check the Space box and click Next.

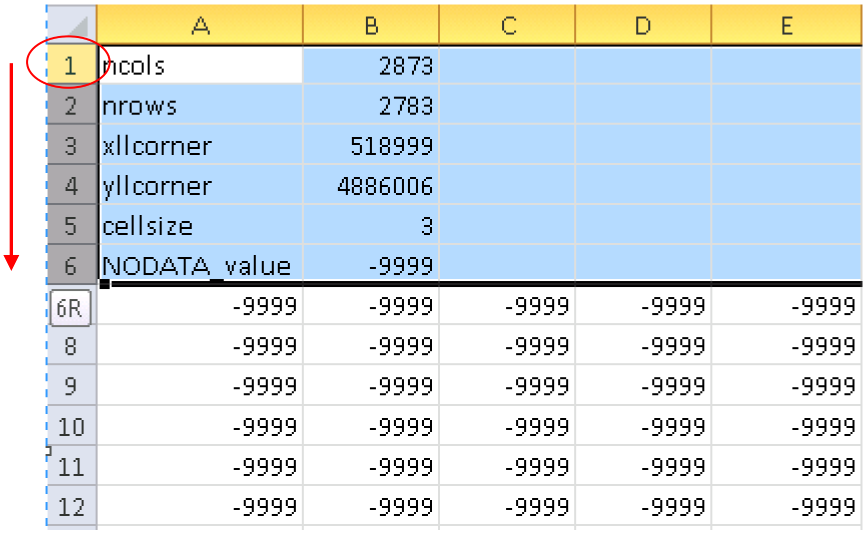



7. In step 3 of 3, leave the fields at default and click Finish.
8. In the new Import Data window that appears, click OK.

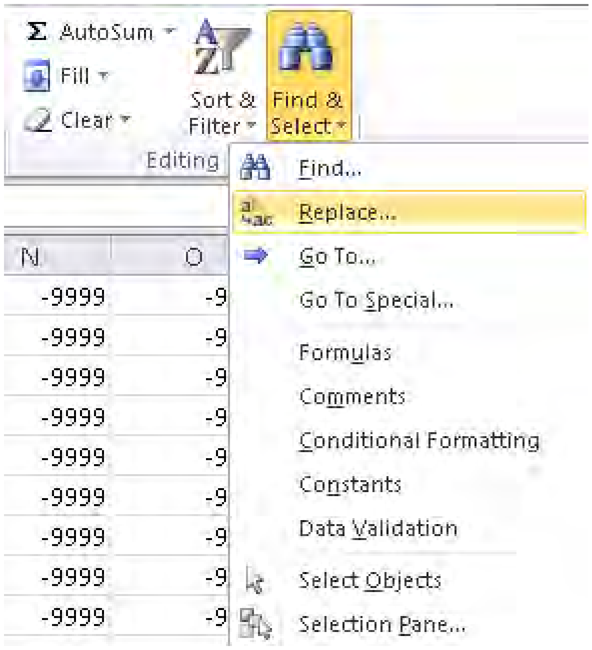



9. The data from the text file is added to your current worksheet.
10. Notice that the first 6 rows of the sheet are populated with data properties. These should be deleted. Move your cursor over the 1st row header until the pointer turns into a right pointing arrow ➡ then click and drag down to the 6th row (fig. 2). Once the cells are highlighted, right click anywhere in the blue highlighted section and choose delete. Once the header cells are deleted, click any cell in the sheet to unselect the highlighted rows.
    - *Note:* If the following ‘Large Operation’ warning box appears, click OK.

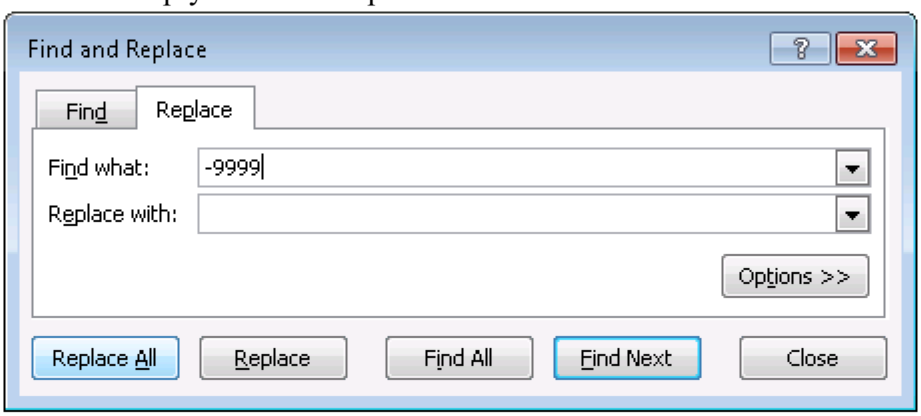



11. Many of the cells will contain a value of -9999 which is ArcMap's default NoData value. All cells containing that value will need to be removed as they will affect the percentile calculation. The Find and Replace editing tool in Excel can be used for this purpose.
    In Excel 2007/2010, from the Home tab, find the editing group (far right) and click on the 'Find & Select' button and choose 'Replace…' (pictured below). The 'Find and Replace' dialog box will open.
    Excel 2003 users should click the Edit pull down menu, then choose 'Find…' Select the 'Replace' tab after the tool opens.
    - *Note:* The Find and Replace function can be quickly brought up by typing Crtl+F in all Excel versions.

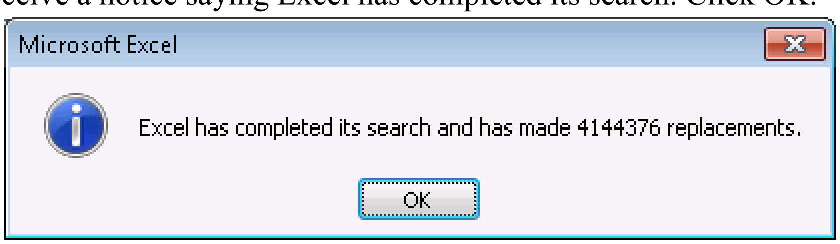



12. In the Find and Replace dialog box, type '-9999' into the 'Find what' field, and leave the 'Replace with' field empty. This will replace all -9999 NoData cells with a blank cell.




13. Click 'Replace All' to run the operation.
    - *Note:* During this operation, Excel may become unresponsive. This is normal, and the replace function may take several minutes to complete depending on data size.

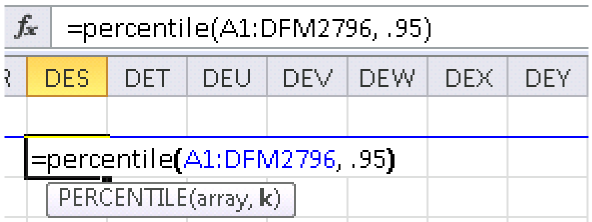
14. You should receive a notice saying Excel has completed its search. Click OK.




15. To calculate percentiles from the data, we will use the built-in Percentile function. The data range will first need to be determined. The easiest way is to click the first cell in the upper-

right-most corner of the sheet (A1) and type Ctrl+Shift+End. All active cells in the worksheet will be highlighted. Make note of the row and column header extents, e.g. 'A1 to DFM2796' as they will be used for the percentile array.

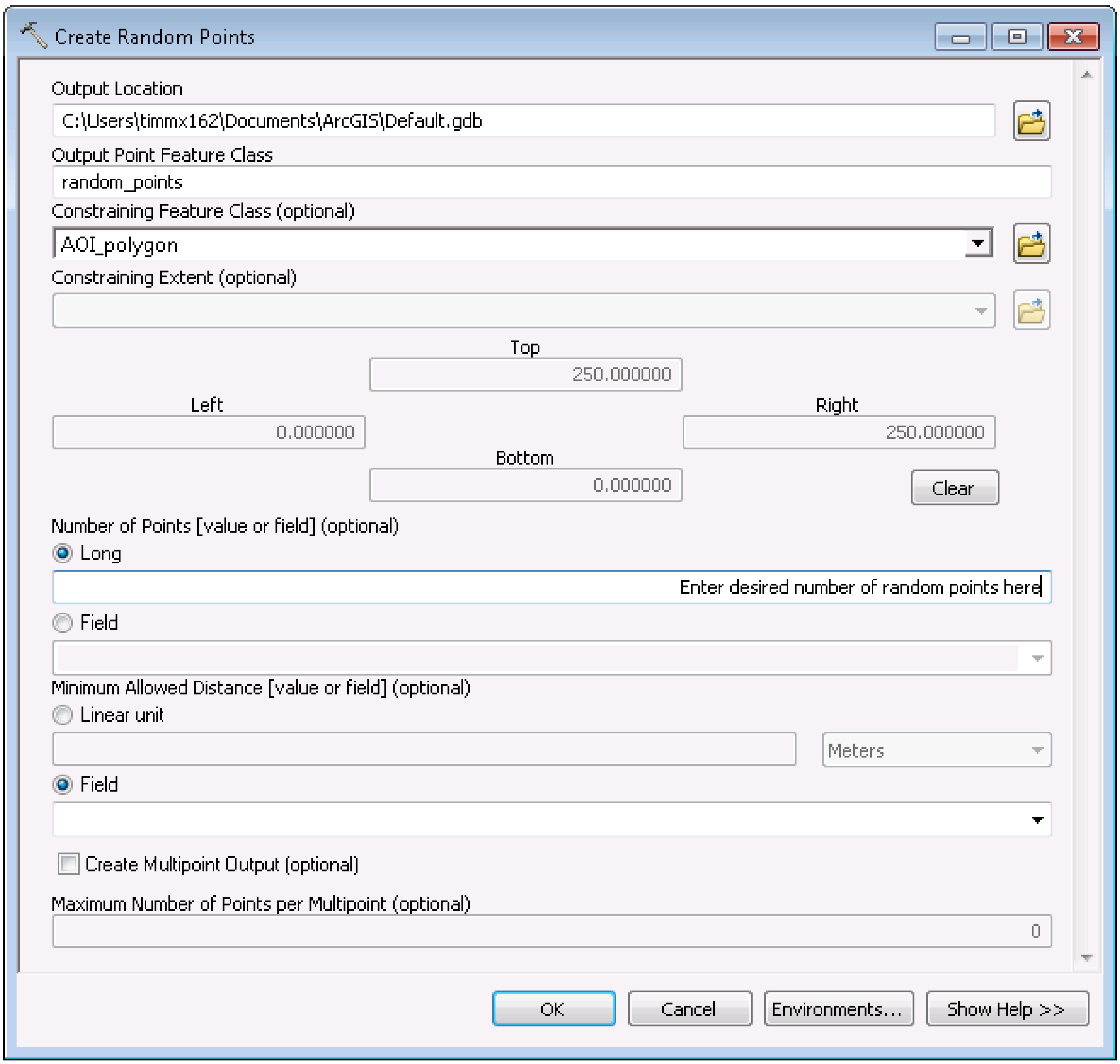
16. Click a blank cell anywhere below the highlighted cells, and type '=percentile(' (without quotes) and the percentile function will become active with format (**array,** k).
17. For **array**, type in your data range from the previous step as the array using the format 'top left cell:lower right cell' e.g. 'A1:DEF200' then type a comma.




18. For the k parameter, enter your percentile value, such as .95 for the 95th percentile threshold value. Finish the function by ending with a closing parentheses and hit enter. The function will calculate the threshold of acceptance value from your original range of SPI or CTI values.

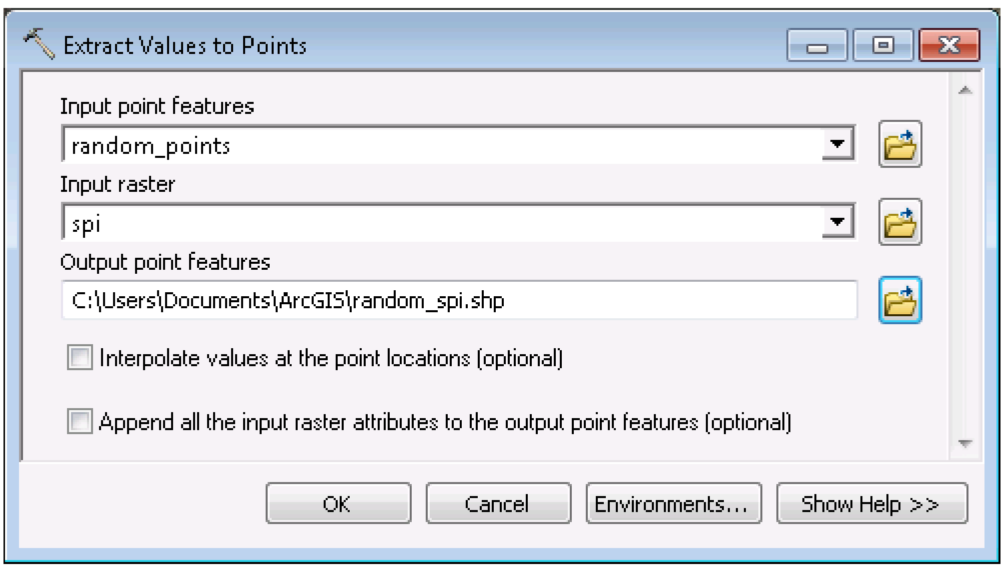
- Random point method

  1. In ArcGIS 9.x, Open **ArcToolbox > Data Management Tools > Feature Class > Tools > Create Random Points**
     In ArcGIS 10.x, Open **ArcToolbox > Data Management Tools > Feature Class > Create Random Points**
     - *Note:* The Spatial Analyst or 3D Analyst extension is required to use Create Random Points with both ArcView and ArcEditor licenses.



a. **Output Location**: Choose a geodatabase workspace as the output location. The Random Point tool requires an existing geodatabase, either file or personal, for output compatibility. Folders will not be accepted by this tool.
b. **Output Point Feature Class**: Name the output file 'random_points'
c. **Constraining Feature Class (optional)**: This is the boundary of your SPI and/or CTI layer(s). It must be vector format (shapefile, coverage, or feature class). It is often easiest to use the same **Output Extent** vector layer when clipping the original DEM to your area of interest. If clipping was not used, a polygon can be created around your SPI layer for use as the **Constraining Feature Class**.
d. **Number of Points [value or field] (optional)**: Click the radio button next to **Long**, and use the blank to input the desired number of random points. Users should create enough sample points from the population size to ensure at least a 95% confidence interval with a 1% margin of error. Table 1 can be used to this purpose.
   - *Note:* For determining population size of your SPI raster, see appendix section A.5.
e. Leave the rest of the fields as default and click OK to run. The output feature class is added to your map as a new layer.

2. Open **ArcToolbox > Spatial Analyst Tools > Extraction > Extract Values to Points**



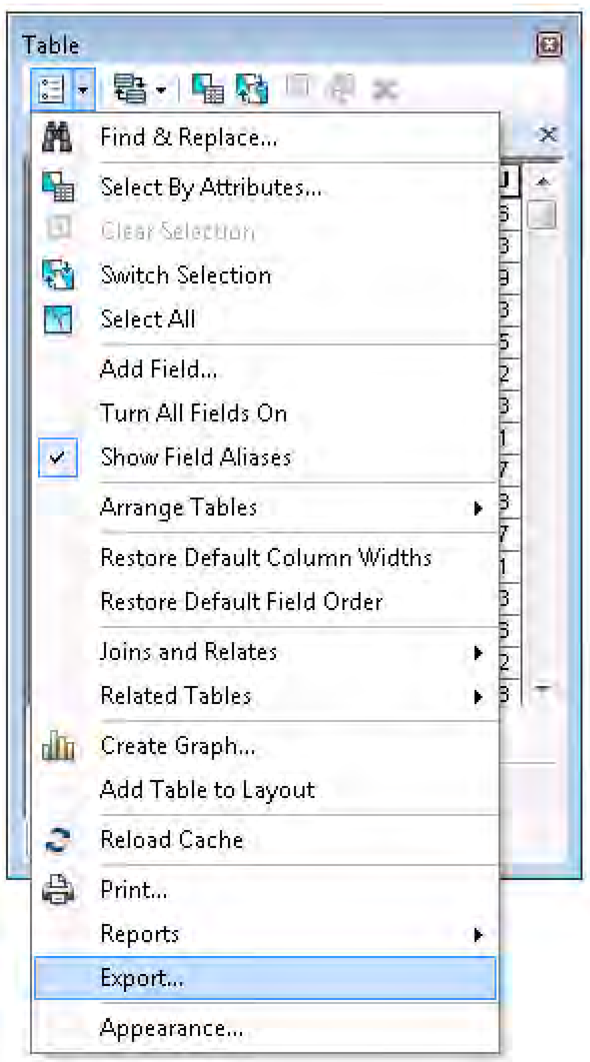

a. **Input point features**: Your 'random_points' layer created in previous step.
b. **Input raster**: Your SPI or CTI raster layer.
c. **Output point features**: Browse to output workspace and name output layer 'random_spi'
d. Click OK to run. The output shapefile is added to your map as a new layer.

**Table 1**

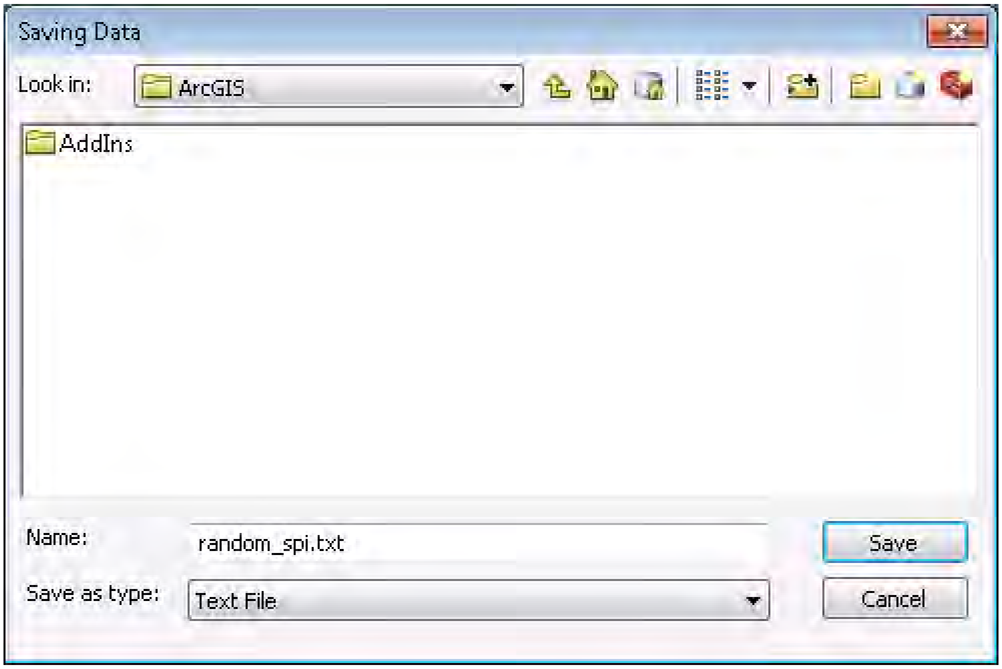
**Required Sample Size†**

| Population Size | Confidence = 95% Margin of Error 5.0% | 3.5% | 2.5% | 1.0% | Confidence = 99% Margin of Error 5.0% | 3.5% | 2.5% | 1.0% |
|---|---|---|---|---|---|---|---|---|
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 20 | 19 | 20 | 20 | 20 | 19 | 20 | 20 | 20 |
| 30 | 28 | 29 | 29 | 30 | 29 | 29 | 30 | 30 |
| 50 | 44 | 47 | 48 | 50 | 47 | 48 | 49 | 50 |
| 75 | 63 | 69 | 72 | 74 | 67 | 71 | 73 | 75 |
| 100 | 80 | 89 | 94 | 99 | 87 | 93 | 96 | 99 |
| 150 | 108 | 126 | 137 | 148 | 122 | 135 | 142 | 149 |
| 200 | 132 | 160 | 177 | 196 | 154 | 174 | 186 | 198 |
| 250 | 152 | 190 | 215 | 244 | 182 | 211 | 229 | 246 |
| 300 | 169 | 217 | 251 | 291 | 207 | 246 | 270 | 295 |
| 400 | 196 | 265 | 318 | 384 | 250 | 309 | 348 | 391 |
| 500 | 217 | 306 | 377 | 475 | 285 | 365 | 421 | 485 |
| 600 | 234 | 340 | 432 | 565 | 315 | 416 | 490 | 579 |
| 700 | 248 | 370 | 481 | 653 | 341 | 462 | 554 | 672 |
| 800 | 260 | 396 | 526 | 739 | 363 | 503 | 615 | 763 |
| 1,000 | 278 | 440 | 606 | 906 | 399 | 575 | 727 | 943 |
| 1,200 | 291 | 474 | 674 | 1067 | 427 | 636 | 827 | 1119 |
| 1,500 | 306 | 515 | 759 | 1297 | 460 | 712 | 959 | 1376 |
| 2,000 | 322 | 563 | 869 | 1655 | 498 | 808 | 1141 | 1785 |
| 2,500 | 333 | 597 | 952 | 1984 | 524 | 879 | 1288 | 2173 |
| 3,500 | 346 | 641 | 1068 | 2565 | 558 | 977 | 1510 | 2890 |
| 5,000 | 357 | 678 | 1176 | 3288 | 586 | 1066 | 1734 | 3842 |
| 7,500 | 365 | 710 | 1275 | 4211 | 610 | 1147 | 1960 | 5165 |
| 10,000 | 370 | 727 | 1332 | 4899 | 622 | 1193 | 2098 | 6239 |
| 25,000 | 378 | 760 | 1448 | 6939 | 646 | 1285 | 2399 | 9972 |
| 50,000 | 381 | 772 | 1491 | 8056 | 655 | 1318 | 2520 | 12455 |
| 75,000 | 382 | 776 | 1506 | 8514 | 658 | 1330 | 2563 | 13583 |
| 100,000 | 383 | 778 | 1513 | 8762 | 659 | 1336 | 2585 | 14227 |
| 250,000 | 384 | 782 | 1527 | 9248 | 662 | 1347 | 2626 | 15555 |
| 500,000 | 384 | 783 | 1532 | 9423 | 663 | 1350 | 2640 | 16055 |
| 1,000,000 | 384 | 783 | 1534 | 9512 | 663 | 1352 | 2647 | 16317 |
| 2,500,000 | 384 | 784 | 1536 | 9567 | 663 | 1353 | 2651 | 16478 |
| 10,000,000 | 384 | 784 | 1536 | 9594 | 663 | 1354 | 2653 | 16560 |
| 100,000,000 | 384 | 784 | 1537 | 9603 | 663 | 1354 | 2654 | 16584 |
| 300,000,000 | 384 | 784 | 1537 | 9603 | 663 | 1354 | 2654 | 16586 |

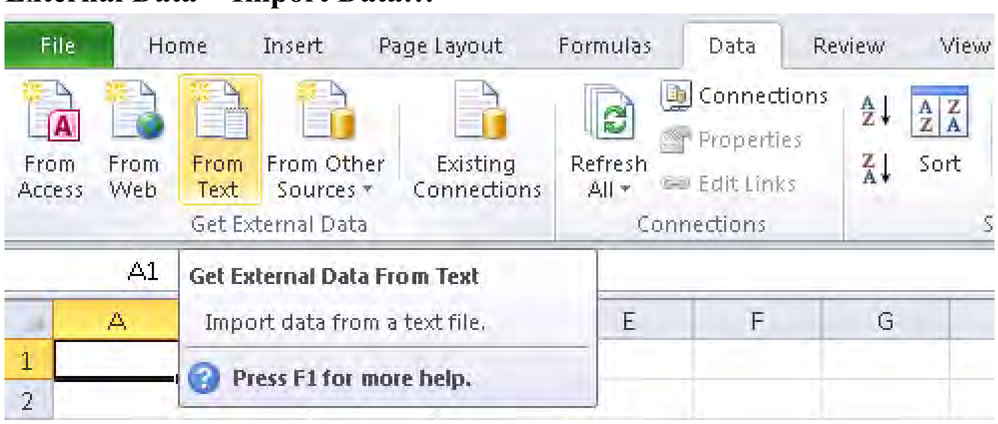
3. Microsoft Excel cannot open the .dbf file format so the 'random_points' shapefile's table will need to be exported as a text (ASCII) file.
   a. Right click on the new 'random_spi' layer in the table on contents window, and choose 'Open Attribute Table'
   b. Click the upper left pull down menu button (table options) and choose the 'Export…' option.



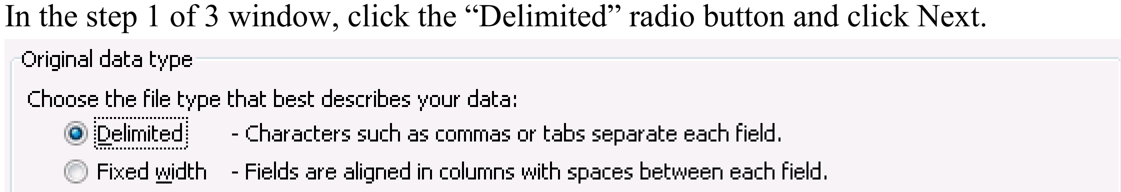

   c. In the Export Data window, click on the browse button  to the right of the 'Output table' field.
   d. Save the file in a folder (not a geodatabase), naming it spi_points.txt or cti_points.txt. Make sure to save the file as **Text File** under the 'Save as type' pull down and click Save (fig. 3).
   e. Back in the Export Data window, make sure 'All Records' is selected in the Export pull down, and click OK.
   f. When the process has completed, you can select No when prompted to add to the current map.



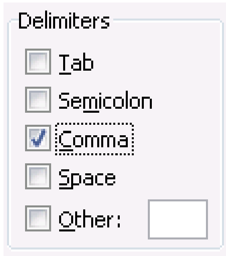

4. Open Microsoft Excel with a blank workbook.
   a. In Excel 2007/2010, choose the **Data** tab, and click on **From Text** from the **Get External Data** group (pictured below).
   In Excel 2003 and earlier, navigate to the **Data** pull down menu and choose > **Import External Data > Import Data…**




   b. Browse to the saved text file created in the steps above and click Import and the Text Import Wizard will open.
   c. In the step 1 of 3 window, click the "Delimited" radio button and click Next.

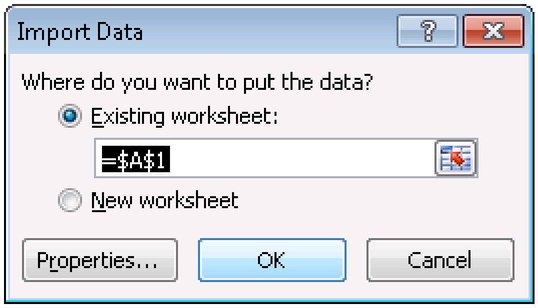


d. In step 2 of 3, under the Delimiters checkbox fields, un-select Tab, and check the Comma box and click Next.




e. In step 3 of 3, leave the fields at default and click Finish.

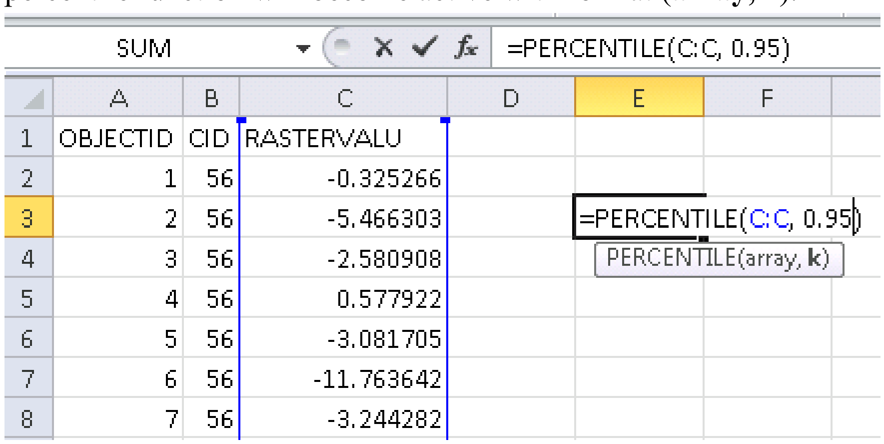
f. In the new Import Data window that appears, click OK.




g. The data from the text file is added to your current worksheet.

5. Several columns may be currently displayed in the Excel worksheet – we are only interested in the column named RASTERVALU. We will now calculate the threshold value using the percentile function in Excel.

   a. Click on a blank cell in the sheet and type '=percentile(' (without quotes) and the percentile function will become active with format (**array,** k).




   b. For **array**, select all cells in the column named 'RASTERVALU' by clicking on the alphabetic character above that column, then type a comma.
      - *Note:* Including the cell with the text 'RASTERVALU' in the **array** will not affect the percentile calculation.

   c. For the k parameter, enter your percentile value such as .95 for the 95th percentile threshold value. Finish the function by ending with a closing parentheses and hit enter.

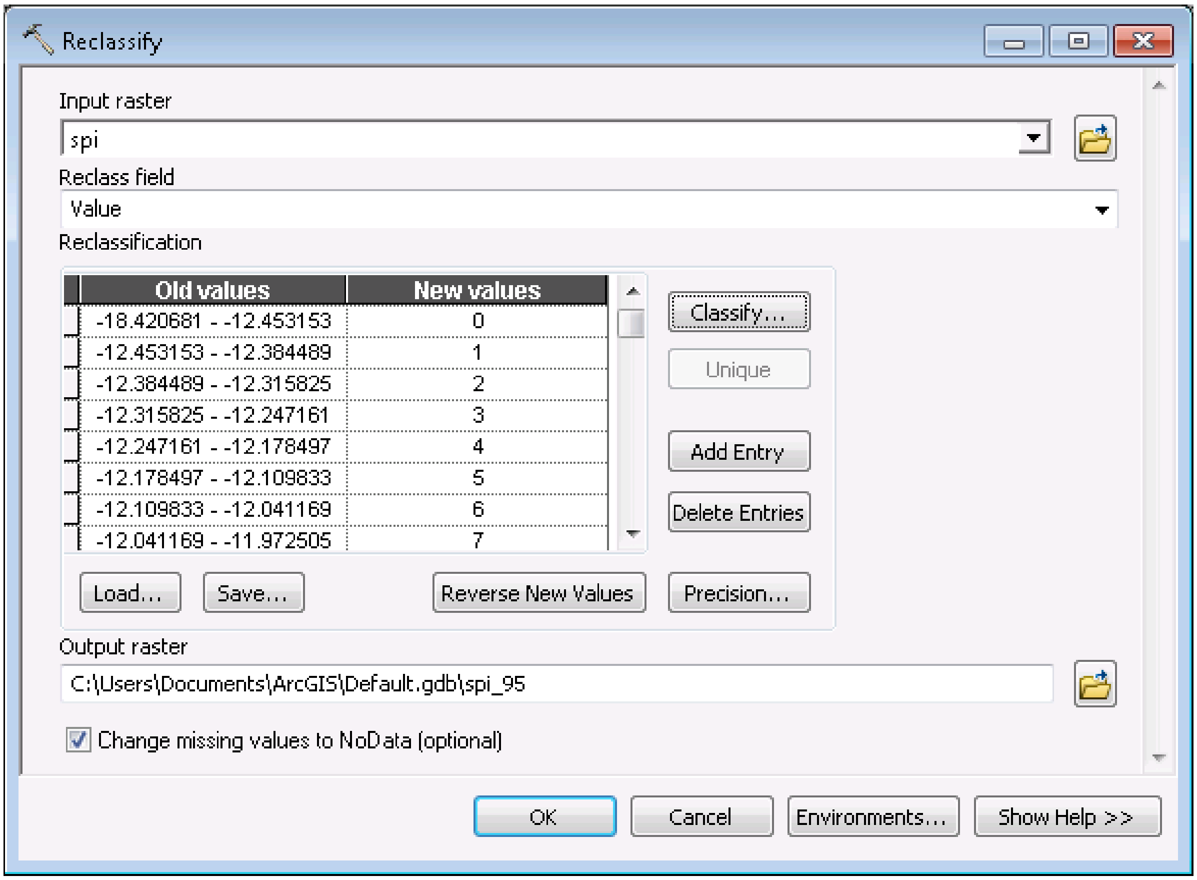
The function will calculate the threshold of acceptance value from your original range of SPI or CTI values.

## Rank secondary attributes

Once the percentile thresholds are known, they can be used with the SPI and CTI layers in ArcMap. The percentile values will be used to display all cell pixels above those thresholds. If additional display detail is desired, those cells can then be further ranked with color gradients using reclassification techniques. Refer to the **Visualize terrain attributes** ‘SPI visualization’ section on page 28 for detailed instructions on when to use those percentile thresholds.

Often, it is desirable to have multiple SPI layers each set to display different percentiles. For this purpose, separate SPI or CTI raster layers can be created each with permanently set percentile thresholds by using the **Reclassify** tool.

a. In ArcMap, open **ArcToolbox > Spatial Analyst Tools > Reclass > Reclassify**




b. **Input raster:** Your original SPI or CTI layer.

c. **Reclass field:** This should default to “Value”

d. The **Reclassification** is done using the same procedure as outlined previously and initiated by clicking the “Classify…” button.

   - *Note:* Make sure to use your desired threshold value in the data exclusion range.

e. **Output raster:** Browse to output workspace and name output layer spi or cti followed by the percentile threshold used, e.g. “spi_95”

f. Check the box next to **Change missing values to NoData (optional).**

g. Click OK to run. The output raster is added to your map as a new layer.

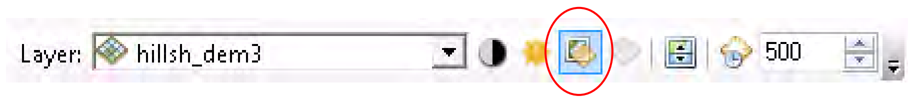
   - *Note:* You may have to enter Layer Properties and set the new SPI or CTI layer’s symbology to “Stretched” for a smooth display color gradient.

## Locate potential CSAs

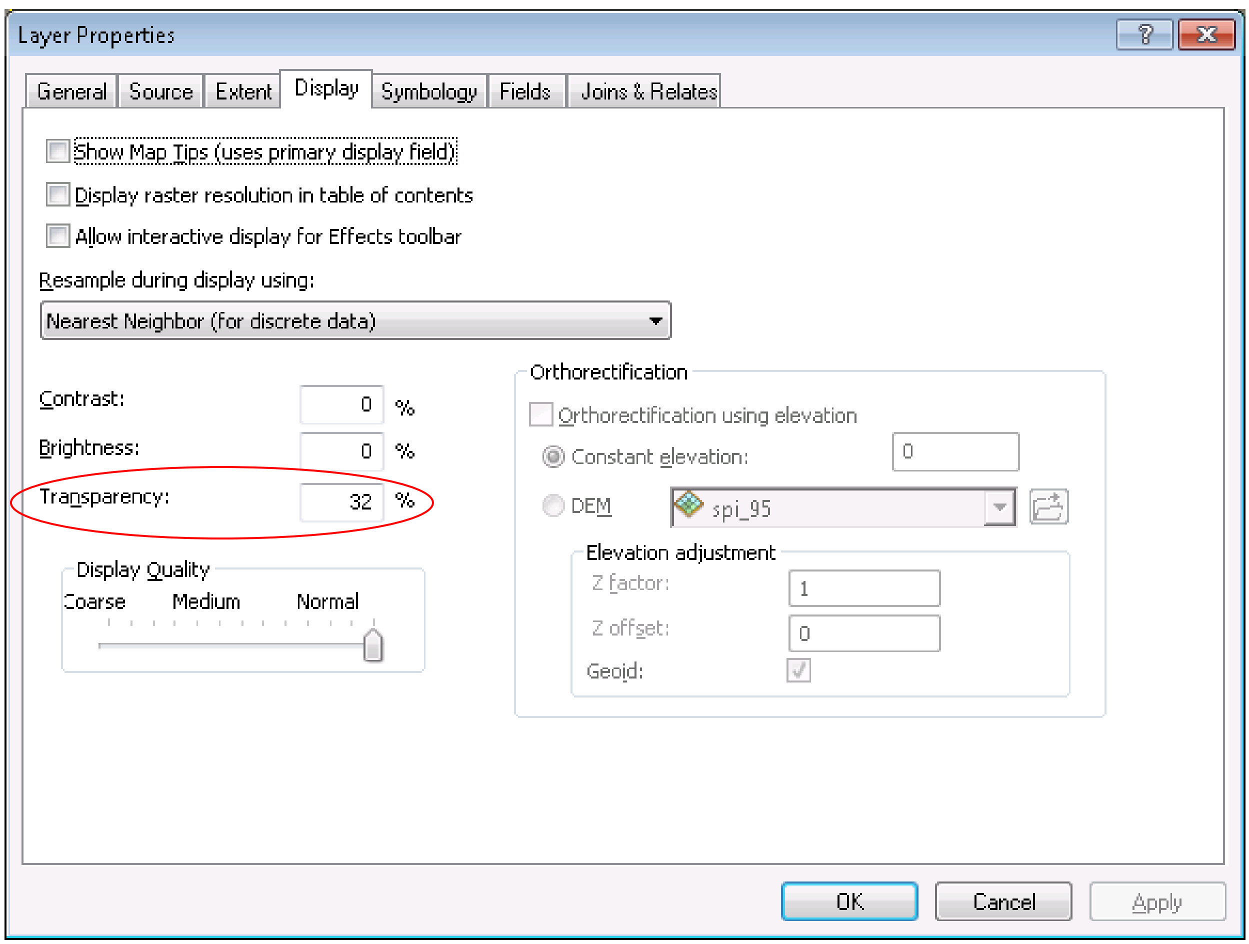
The data acquired earlier will now be used to assist in CSA placement.

1. Start a new ArcMap session with a blank map. Start populating your map with a base layer consisting of orthophoto(s) from the area of interest and the data layers collected in the Data Acquisition section. The layers in the table of contents should be generally organized so that orthophotos are on bottom, followed by raster layers, then polygon, polyline, and point vectors layers on top in that order.
   - *Note:* Some layers may benefit from using lowered display transparencies, such as the hillshade layer. This will allow base layers to still be visible. Layer transparency can be adjusted through the effects toolbar (**1**) or the layer properties display tab (**2**).

**1**




**2**

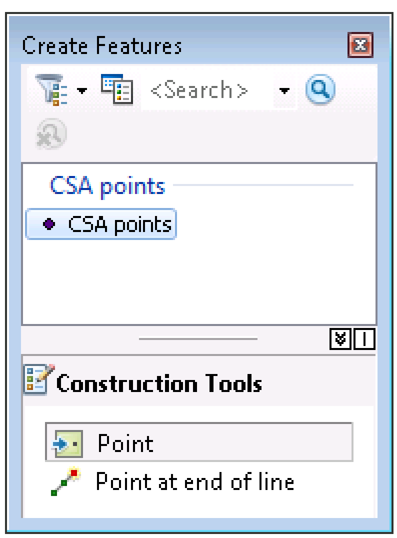



2. Create a new point shapefile or feature class to use for CSA placement.
   a. To create a new shapefile, open ArcCatalog either though ArcMap (version 10.x) or the separate ArcCatalog application.
   b. Browse to your preferred workspace folder or geodatabase using the catalog tree, right-click on your folder and select New, then “Shapefile…”, or right-click on your geodatabase and select New then “Feature Class…” The **Create New Shapefile** or **New Feature Class** window will open.

- **Create New Shapefile:** Choose a name for the shapefile, such as “CSA points”. Make sure ‘Feature Type’ is set to **Point**. You should set the spatial reference to match the spatial coordinate system used in your other data layers. For data acquired from many Minnesota government sources, including Minnesota Department of Natural Resources (MDNR) and MNGeo, the coordinate system used will often be “NAD 1983 UTM Zone 15N” but could differ, including UTM Zone 14N or 16N if using data from the far eastern or western parts of the state. Figure 1 shows Minnesota UTM zone grids, with zone numbers circled in red. An easy way to select the coordinate system is to use the Import option. From the **Create New Shapefile** window, click the ‘Edit…’ button in the Spatial Reference box. The Spatial Reference Properties window will open. Click the ‘Import…’ button. Browse to any vector of raster file currently being used in your active ArcMap session, select it and click Add. The coordinate system should be the North American Datum 1983 UTM system. Click OK. Back in the **Create New Shapefile** window, click OK and the new shapefile will be added to your chosen folder.
    - *Note:* When importing coordinate systems, some layers may not have spatial references set. ArcMap will still display those layers by automatically using the first coordinate system seen in the active data frame.
- <u>OR</u> create **New Feature Class:** Choose a Name and Alias for the new feature class. The Name must not have spaces – instead use underscores for spaces. The Alias can contain spaces. In the Type pull down menu, select ‘Point Features’. Click ‘Next >’. The second step involves choosing a coordinate system for the new Feature Class. Follow the steps from the **Create New Shapefile** process above using the ‘Import…’ button to select NAD 1983 UTM system. Click ‘Next >’ on the next three windows to create the new feature class.

c. Add the new shapefile or feature class to your active ArcMap session by either dragging the file from ArcCatalog onto the map, or using the Add Data button.

d. Before new points can be placed, an editing session must be started. Right click on the new shapefile or feature class point layer and choose ‘Edit Features’ then ‘Start Editing’. If a window appears with warnings, click Continue. You are now able to place new points on the map using the editing functions.



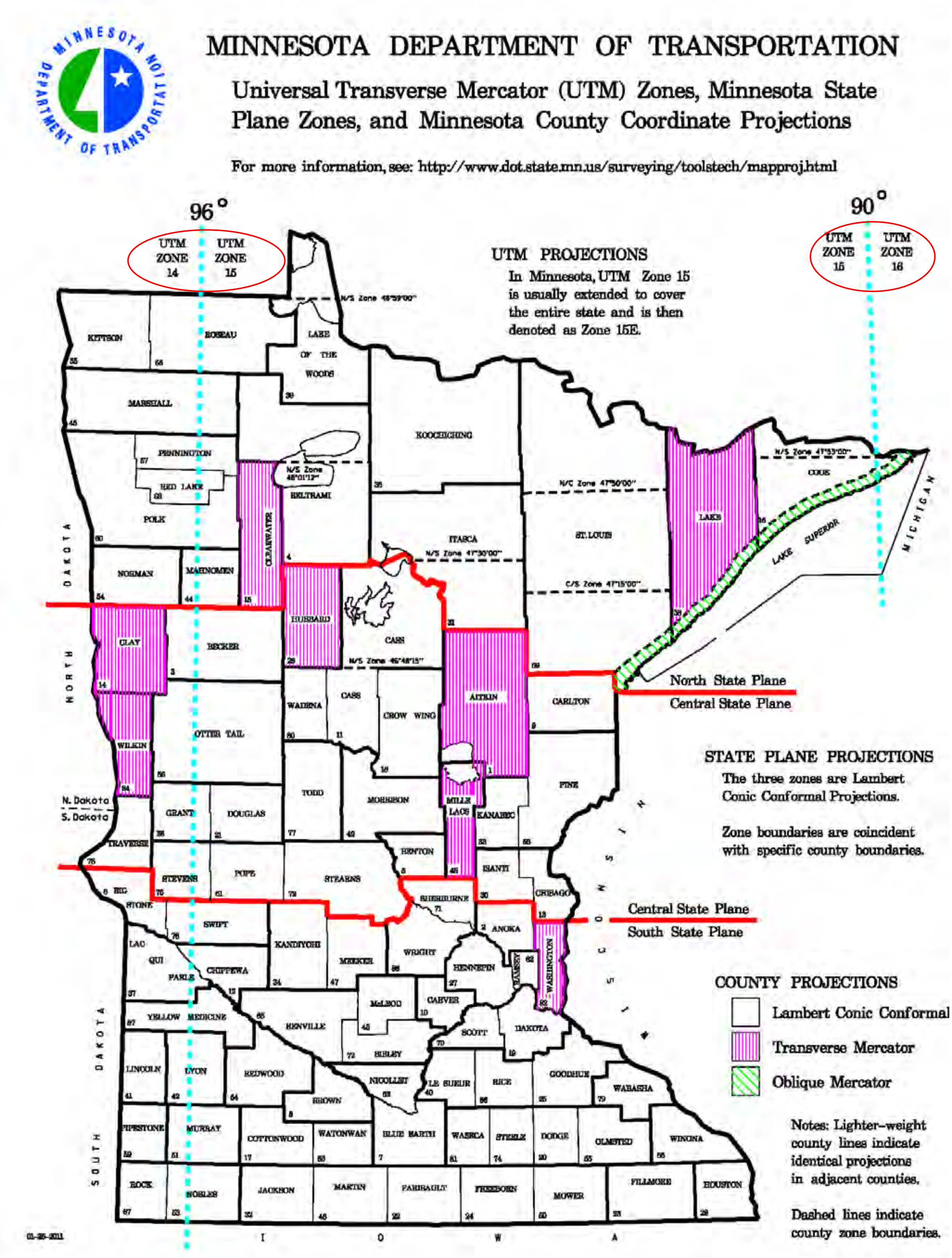

MINNESOTA DEPARTMENT OF TRANSPORTATION
Universal Transverse Mercator (UTM) Zones, Minnesota State Plane Zones, and Minnesota County Coordinate Projections
For more information, see: http://www.dot.state.mn.us/surveying/toolstech/mapproj.html
96°
UTM ZONE 14
UTM ZONE 15
90°
UTM ZONE 15
UTM ZONE 16
UTM PROJECTIONS
In Minnesota, UTM Zone 15 is usually extended to cover the entire state and is then denoted as Zone 15E.
North State Plane
Central State Plane
Central State Plane
South State Plane
STATE PLANE PROJECTIONS
The three zones are Lambert Conic Conformal Projections.
Zone boundaries are coincident with specific county boundaries.
COUNTY PROJECTIONS
Lambert Conic Conformal
Transverse Mercator
Oblique Mercator
Notes: Lighter-weight county lines indicate identical projections in adjacent counties.
Dashed lines indicate county zone boundaries.
NORTH DAKOTA
SOUTH DAKOTA
N. Dakota
S. Dakota
I O W A
WISCONSIN
MICHIGAN
LAKE SUPERIOR

**Figure 1**

## CSA Placement and Prioritization

CSAs are defined as portions of the landscape that combine high pollutant loading with a high propensity to deliver runoff to surface waters, either by an overland flow path or by sub-surface drainage. These areas have a higher likelihood of conveying more pollutants to surface waters than other portions of the landscape and thus coincide well with high SPI value characteristics. Features that could be associated with CSAs include culverts, drop structures, gullies, ravines, grassed waterways, bank slumping and erosion, in-stream vehicle/livestock crossings, tile drain outlets and side-inlets, exposed tile, and open intakes. CSA features can be placed anywhere on the landscape but users should focus targeting efforts to specific areas, depending on project goals.

A set of criteria were developed that facilitates systematic assessment of the factors involved in critical area identification. The ideal criteria incorporate the inherent characteristics associated with SPI, efficiency of the hydrologic system in pollutant transport, magnitude of the source, and type of pollutant into guidelines that can be applied throughout the watershed. Critical area criteria should be applied consistently throughout the project watershed. This ensures that the study area does not receive biased identification and also that landowners do not feel singled out or excluded from the selection process depending on whether areas of their land met the criteria or not (Line & Spooner, 1995).

Criteria for placement and prioritization of CSAs include:

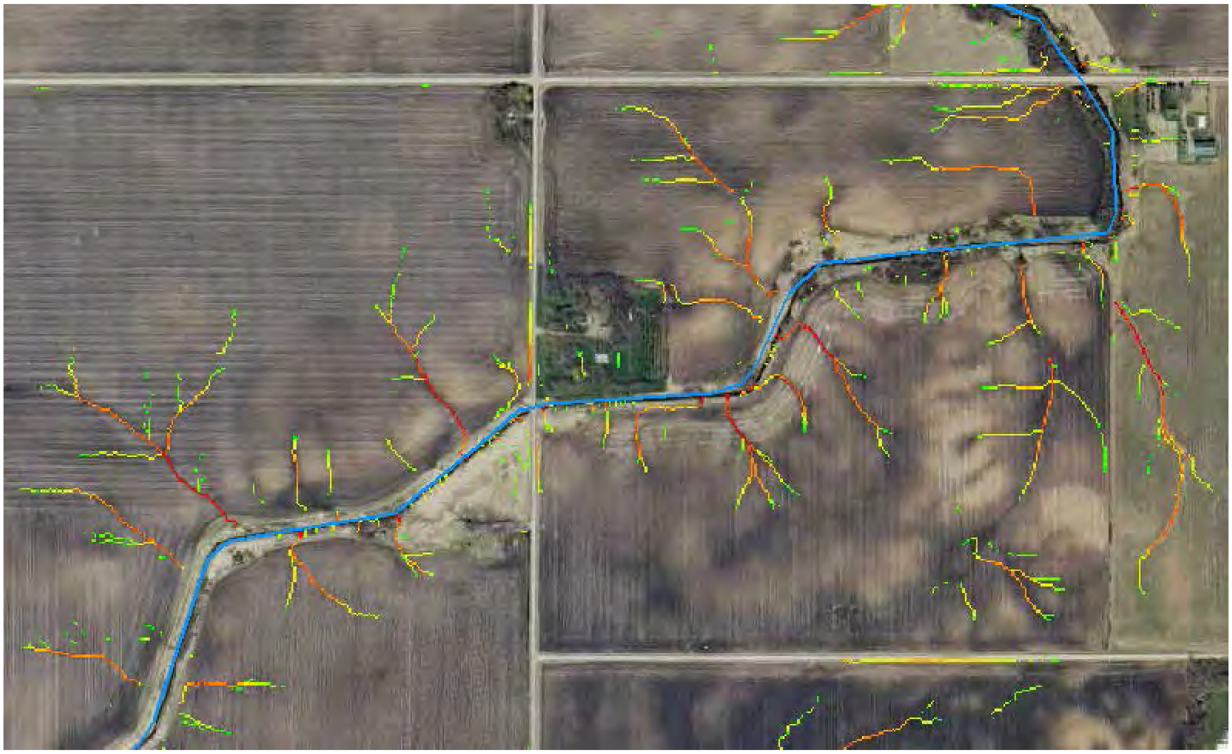
- Magnitude of the pollutant source and risk for erosion
    - Contributing area
    - Average and/or maximum SPI values
    - SPI signature length
- Hydraulic transport of pollutants and proximity to the water resource
- Land use/land cover/land management
- Subwatershed soil characteristics
- Existing conservation practices
- Crop productivity indices

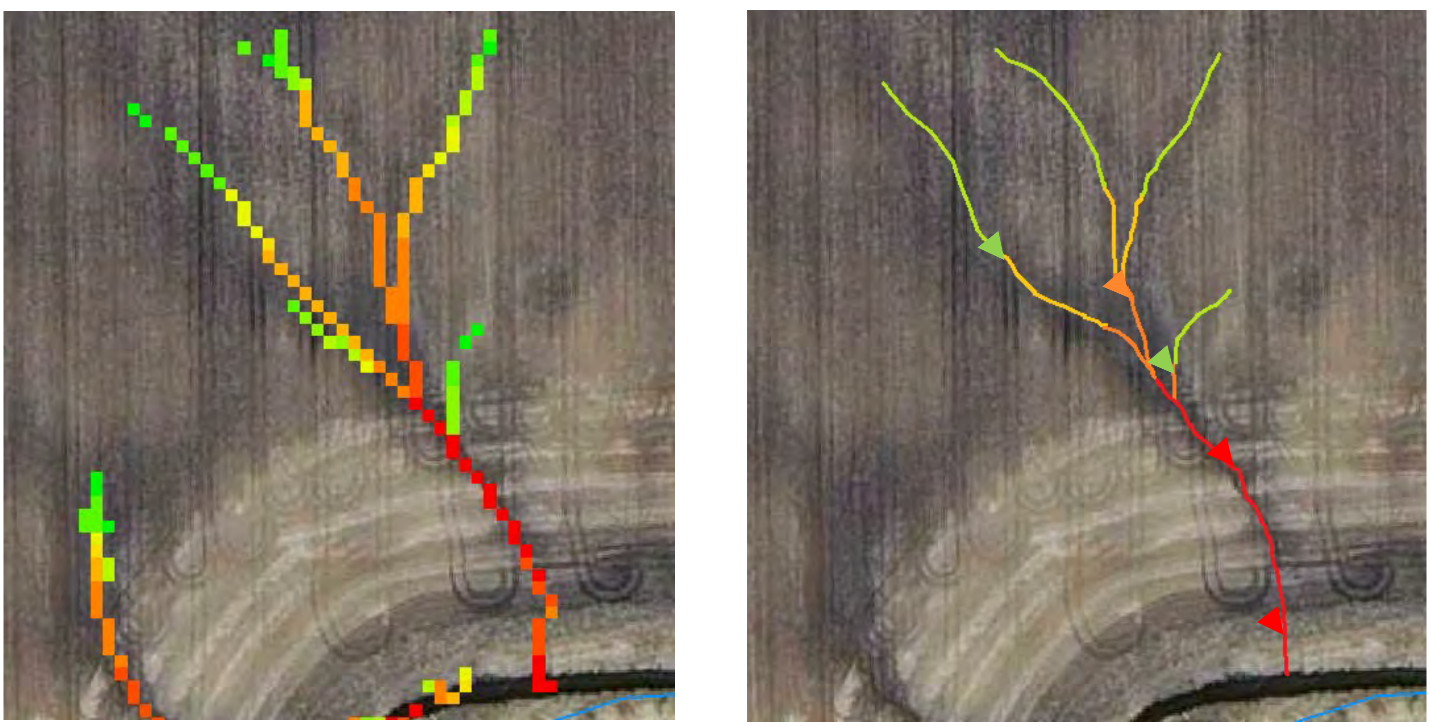
Terrain analysis users should select these CSA sites for field visits and evaluation based on:

- GIS analysis results
- In-house knowledge
- Available resources (e.g., funding, staff time, etc.)

Time commitments should be factored in when determining how many points to place, as creating a potential CSA at each hydrologically connected SPI signature could involve substantial validation time spent in the field. It may be preferable to only place CSAs at the locations where signature lengths are longest and in close proximity to surface water, the average SPI signature(s) value is high, no BMPs exist, and soil characteristics show high potential risk for soil erosion. It is also important to note any regional-specific factors that may exist in the area of interest, such as sinkholes, feedlots and/or cattle grazing operations, and their proximity and contribution to any potential CSAs.

1. Using your orthophoto and surface water layers in ArcMap, activate the SPI layer previously set with your desired threshold display, then zoom into your area of interest. The SPI signatures should resemble surface runoff flow paths in the following maps.

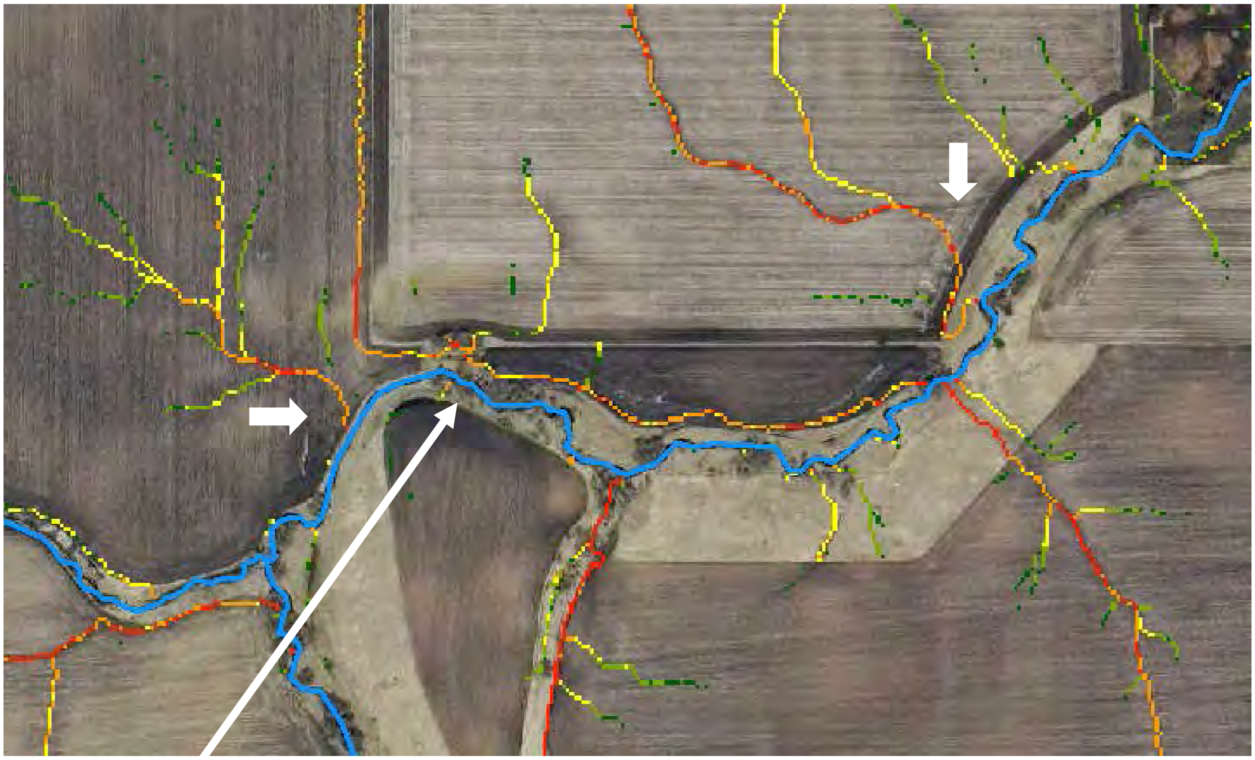




**The above images depict how an SPI signature can be visualized as a flow path. The arrows represent flow direction**

2. The following metrics should be considered for each potential CSA. They are not listed in order of importance – the weight of each metric should be tailored to fit your project goals.
   - Identification by aerial photography – High resolution orthorectified aerial photos play an important role in the CSA identification process. The orthorectification process geometrically corrects aerial imagery such that the scale of the image is uniform. In GIS, orthophotos help match SPI and CTI signatures to physical features on the landscape. Though some large features can be identified using only aerial photos, they are most useful when overlain with SPI or CTI signatures. The layers can then be turned on and off for photo comparisons, or the swipe function can be used for the same purpose. When land cover type cannot be distinguished from aerial photography, land cover/land use layers can be used with the swipe function in a similar fashion.

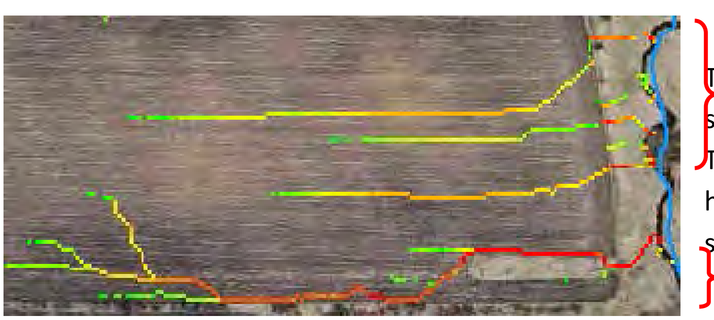
     If multiple aerial photos are available for your area of interest, consider date, time of year, and surface moisture conditions present at the time of photo acquisition. Common orthophotos available from Minnesota Geospatial Information Office include Spring, Summer and Fall series. The most recently available leaf-off imagery taken during Springtime is often most preferable for CSA identification, as soil moisture and areas prone to ponding are most evident, and surface erosional features have not yet been worked through in the field.



The first image (previous page) is an orthophoto taken in the spring of 2011 with several gullies evident, followed by the same photo with an SPI layer overlain (above). The SPI signatures closely match the surface erosion where flows concentrate. Note the white arrows highlight differences between apparent erosion on the photo vs SPI signatures, likely explained by the gap between date of LiDAR flown (11/27/2008) and aerial photo acquisition (mid-April, 2011).

- Signature length – SPI signature lengths are representative of their associated contributing areas. Longer SPI signatures will typically have larger upland contributing areas and therefore increased risk of sediment and nutrient load conveyance. The length should be considered in relation to other signatures in close proximity in order to ignore threshold bias. Slope must also be considered in relation to signature length, as short signatures occurring over an area of high relief can exhibit considerable surface erosion vs. a short signature over flat topography.
  - *Note:* Signature lengths can be easily calculated when using line vector data in lieu of a raster SPI dataset [see Average SPI value metric below].

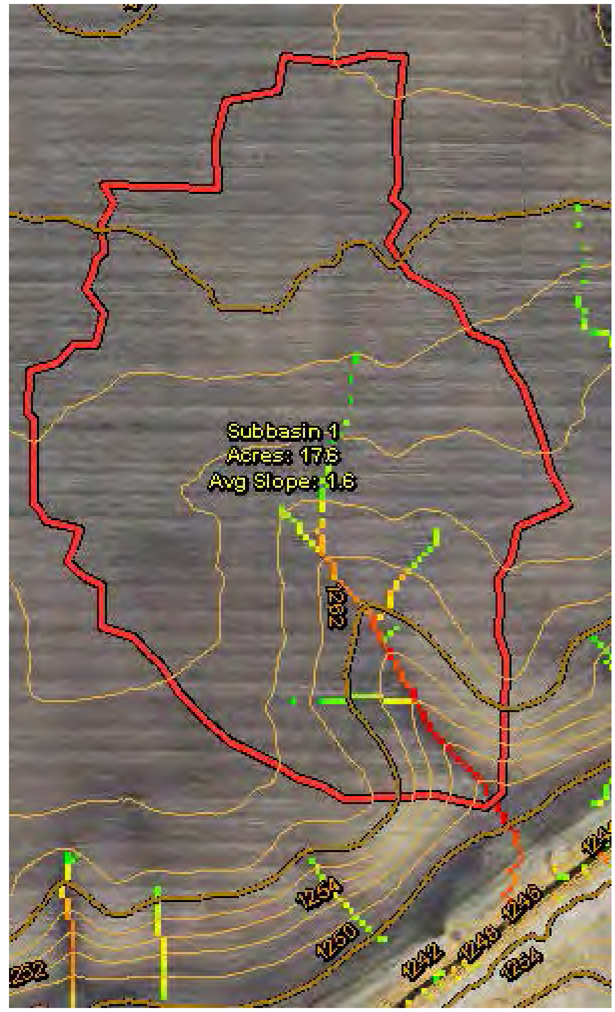
- Average SPI value – The portions of a signature with the highest SPI values have the greatest potential to erode the landscape. The overall SPI value of a signature flow path can be visualized using a smoothed or "stretched" color gradient.
  - *Note:* Advanced GIS users may prefer a quantitative approach over this qualitative visualized one by converting a reclassed SPI raster to polyline vector data. Individual SPI statistics can then be calculated for each signature. The mean, minimum, maximum, sum, and standard deviation can be particularly useful for prioritization purposes. Signature length can also be easily calculated if using line vectors.

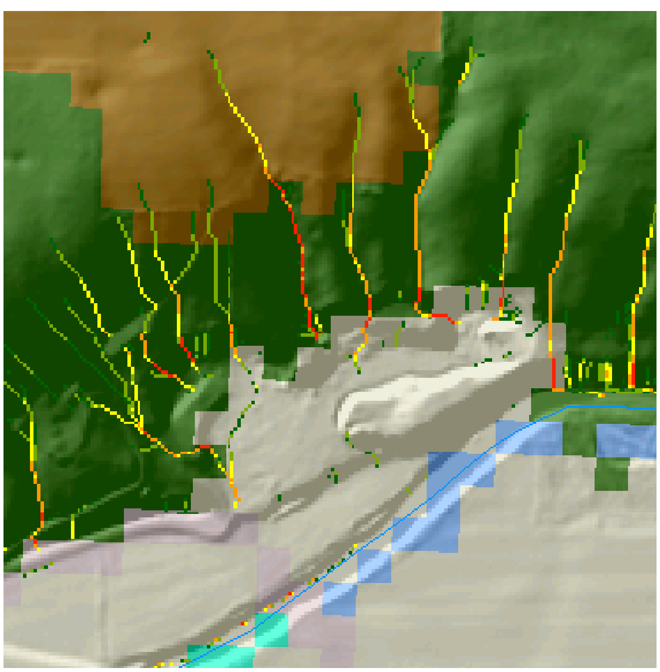


The figure on left shows differences between signatures of different average SPI values. The signature on the bottom has a noticeably higher overall SPI value than the top three signatures.

- Contributing area – The contributing area upland of CSAs can be used to estimate the amount of potential sediment and nutrient delivery at those pour points. Contributing areas can be manually created by "heads-up" digitization using elevation contours, or by using third party software to automatically create catchments. A free-to-use ArcToolbox set is available from the NRCS named 'NRCS GIS Engineering Tools v1.17' which allows creation of contributing area catchments from a user defined point (along with many other great scripts). The image on right shows an example of the NRCS tool's Watershed Delineation toolset over an SPI layer and orthophoto. The acres and average slope are automatically calculated as shown.

  See Appendix section A.6 for step-by-step instructions for watershed creation using the NCRS tool.



- Land use/land cover – land cover information can aid initial large-scale screenings for CSAs and be used to filter out use-types that are of low priority. Historical land use information combined with historic aerial photos can also be a great asset for checking crop rotation practices at the field scale. For instance, priorities can be targeted to fields identified as implementing several sequential seasons of continuous corn.

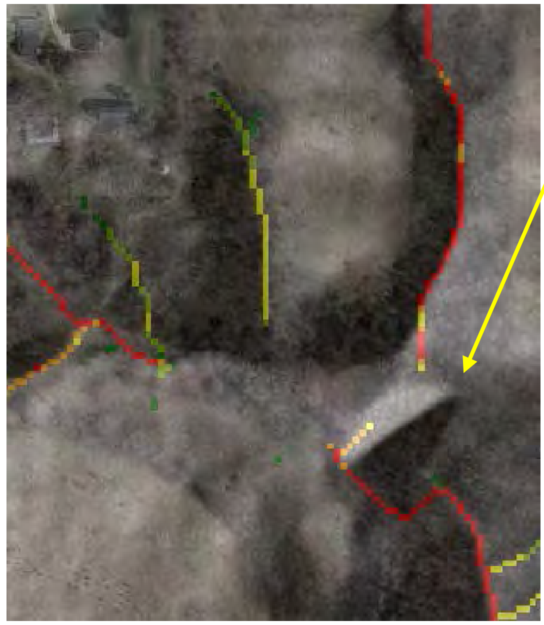
  The image on left shows land cover in several colors – brown/cultivated crop; green/forest; white/grassland; and blue/water. In this example, the three SPI signatures advancing into the cropland may be of higher priority than the surrounding signatures confined to forestland.

- Proximity to water – Signatures that terminate in or near surface waters are typically of highest concern, though the exact location of the CSA point placement may vary depending on project goals. For instance, if agricultural funds are to be used to install BMPs in upland areas, users might only target upland field SPI signatures and place points at field edges, whereas TMDL concerns may shift user focus to riparian areas and signatures entering waterways.
    - *Note:* Advanced users may wish to create an SPI layer clipped from a stream corridor buffer for riparian-only CSA identification, and vice versa for upland-only identification.

The grey horizontal lines represent the extent of the stream buffer. The top signature terminates at the buffer-field edge. The lower signatures terminate at the stream edge. *Note:* the bottom middle signature terminates just past the buffer. A field visit verified a steep knick point drop to water level at the signature terminus.

- Existing conservation – Conservation practices (CPs) may already exist that address potential CSAs, some of which may be evident using high resolution aerial photos. Local knowledge of existing best management practices and conditions should be used when locating CSAs. It should be noted that the presence of CPs shouldn't necessarily eliminate the placement of a CSA point unless the condition of the practice is known. All CPs have a useful lifespan, and their condition cannot always be ascertained from GIS and remotely sensed data.

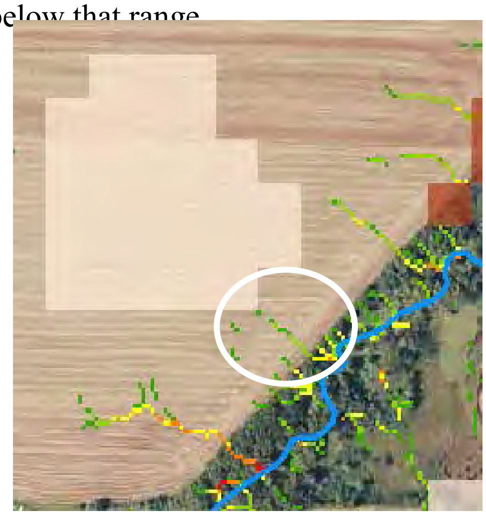
The three images, starting from the furthest left, show an SPI signature leading to an intermittent stream. The middle image shows conservation practices exist under the SPI signature, in this case a grassed waterway. Using CIR orthophotos, shown in the right image, can also greatly aid in detecting vegetated areas. CIR photos show vegetation as red and bare soil as green color.



The hillshade layer can aid in locating existing topological conservation practice features, such as the water and sediment control basin pictured above and middle. These features can be hard if not impossible to spot with just aerial photos and SPI signatures (far left image).

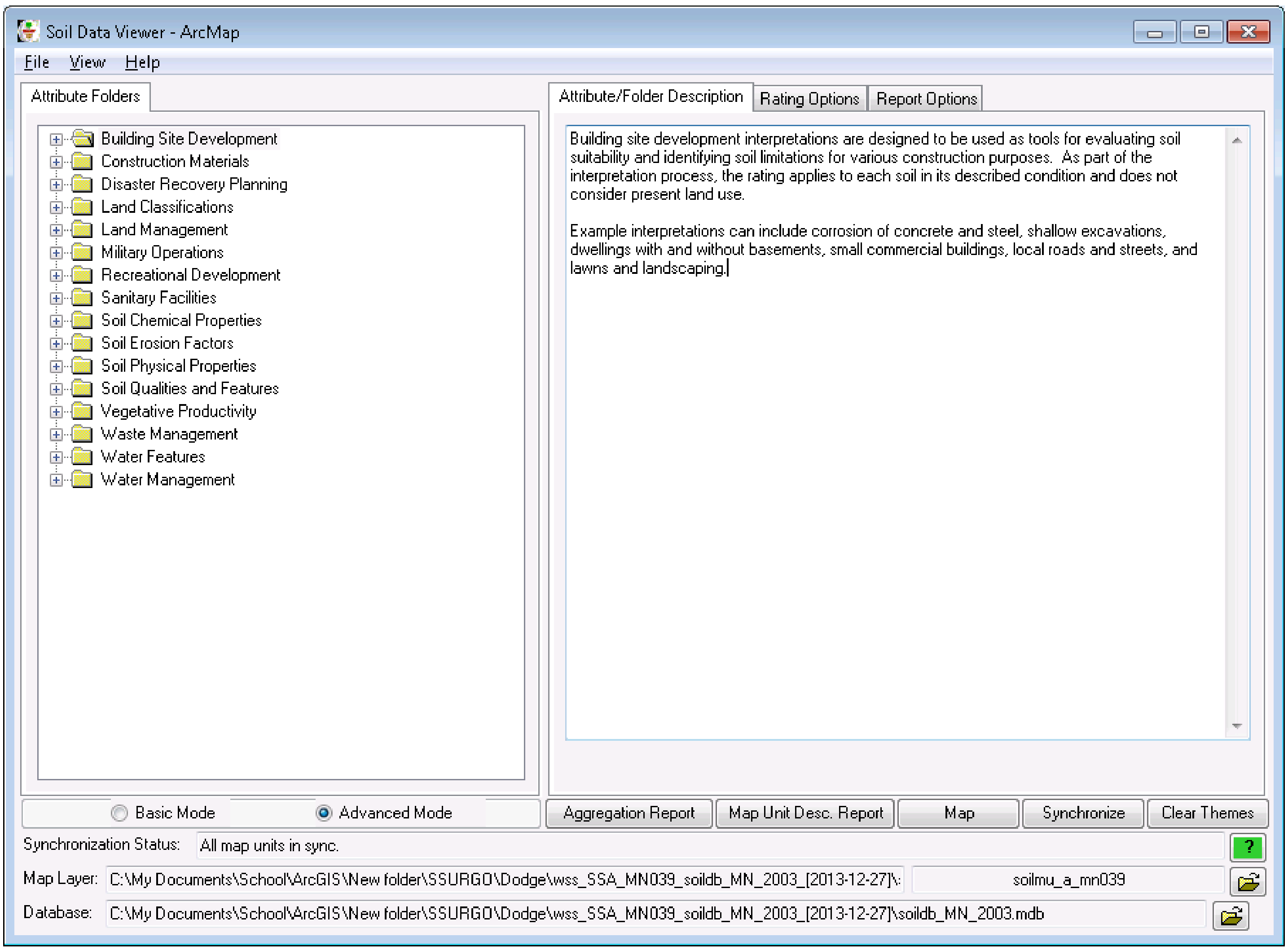
- Sub-catchment soil characteristics – A Soil Erosion Risk raster layer can be used to display soils that are of high risk for sheet and rill erosion. The raster layer is available as part of the Minnesota EBI series from the BWSR website (see 'Data acquisition' section on page 9 for link). Based on the USLE, the 30 meter spatial resolution raster was calculated using rainfall erosivity (R), soil erodibility (K), and topographic length and slope factors (LS). The cropping management (C) and conservation practice (P) factors were omitted (CP=1) as they would warrant field specific data that is not readily available.

  The Soil Erosion Risk raster layer, much like SPI/CTI layer(s), is most useful when displayed with values above a certain threshold. These can be created in the same manner as the percentile thresholds calculated previously with SPI and/or CTI layers. Common thresholds used to display areas of elevated soil erosion risk can range from the top 30% of values and up, though with inherent USLE factor and source data variability, users may find useful thresholds significantly below that range.



The image on left shows a series of small SPI signatures originating in an upland cultivated crop field. The large, tan colored shape represents the top 15% of the Soil Erosion Risk values (30 meter pixels) within the Pelican Lake HUC12 catchment (Stearns Co., MN). A field visit confirmed slight erosion occurring from the signature nearest the high Soil Erosion Risk percentile values (circled in white).

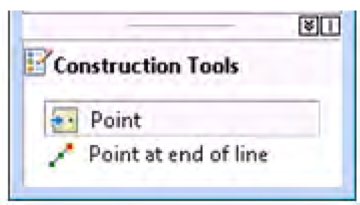
- SSURGO soils data – The NRCS SSURGO is a large collection of soil-related data that can be used to inform CSA identification. The SSURGO nationwide database contains a multitude of information sorted within unique soil map units. SSURGO data can also be integrated within the ArcGIS environment by use of the NRCS Soil Data Viewer extension which provides the ability to visually map each individual criterion with matching attributes. Available data range from physical soil properties to construction, development, and planning suitabilities (see next image). Several criteria within the database can be of particular use for CSA identification, including depth to water table, ponding and flooding frequency, crop productivity index, drainage class, and hydric rating, among others.



3. When suitable locations have been identified for CSA placement, start editing on your CSA point shapefile/feature class.
   - **ArcGIS ver. 9.**x: Using the editor toolbar:

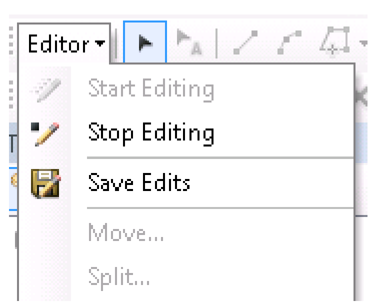

Set the Task pull down to "Create New Features" and the Target to your CSA point layer. Use the Sketch function (the pencil-shaped icon) to place a single geographic CSA point on the map with each click.
*Note:* You can use the Undo button or press Ctrl+Z to remove the last point placed while editing.

   - **ArcGIS ver. 10.**x: Start an editing session with the CSA point layer and the Create Features window will open. Select the CSA point layer in the Create Feature window. At the bottom of the window under **Construction Tools**, click the Point button.




The cursor will turn into a point editor, and each click on the map will place a geographical point at that location.

4. When finished creating new features, save your edits, and stop editing using the Editor toolbar pull down menu.



### CSA output and evaluation

Once the CSA point layer has been completed, it can be used to create physical and digital maps, and exported into a variety of mobile devices to guide field work. Common mobile devices include:

- Tablets with ArcGIS for Windows Mobile installed (one mobile deployment license is included with each ArcGIS Desktop license)
- iPad with ArcGIS free app
- Handheld Global Positioning System (GPS) units with a Windows mobile operating system installed

The following Field Assessment section can aid in data collection and evaluation during field visits. An overall determination of site status at each CSA should be made, for example:

- Where appropriate conservation measures are in place, recognize good site management
- Where improvements could be made, suggest possible conservation measures
- Where CSA tools were in error, record the findings (tracking errors will improve both the GIS protocols and a GIS professional's judgment that is required during evaluation)

# Field Assessment

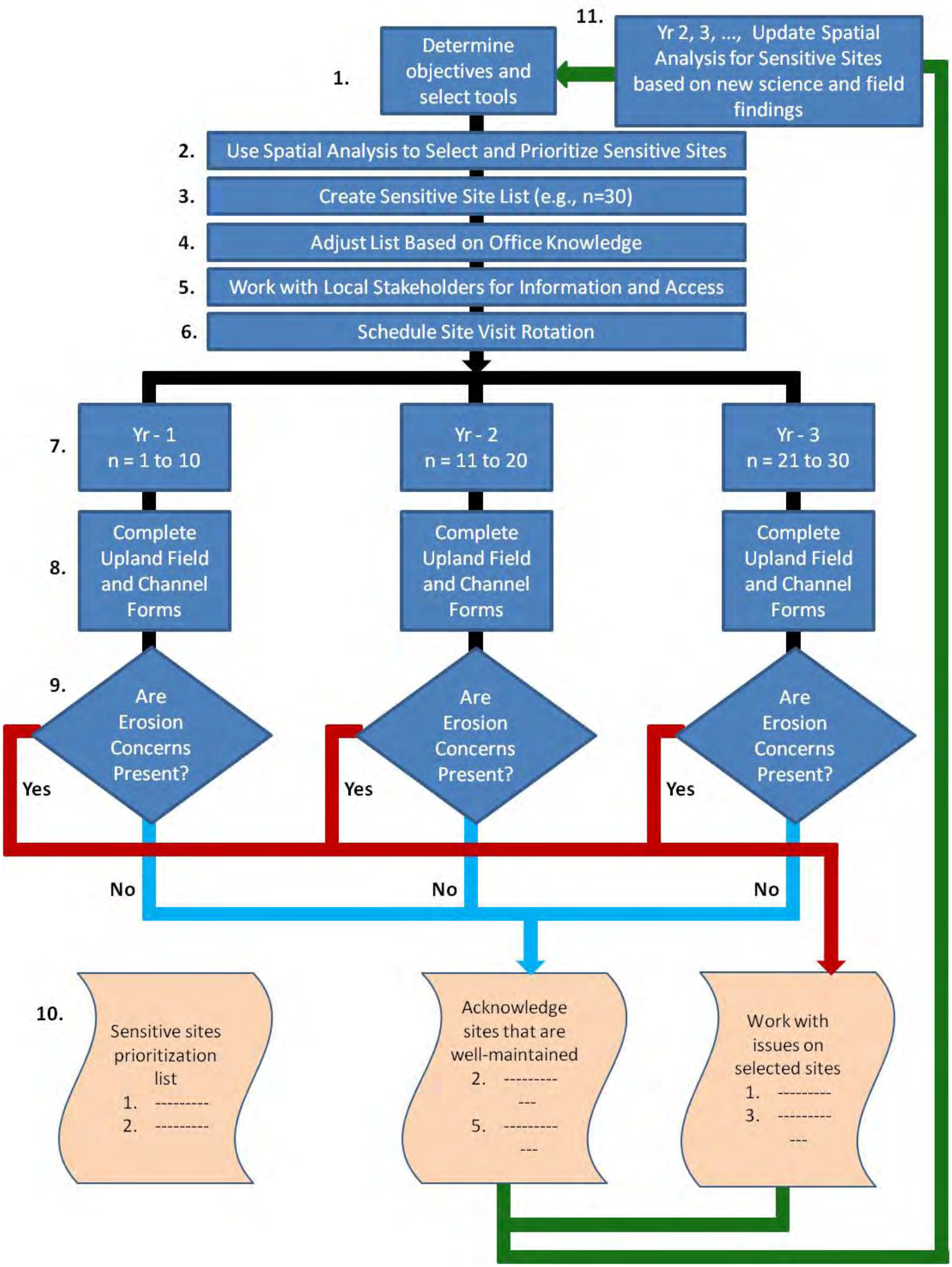
## Field Assessment

The process described herein will provide guidance for walking the user through the various steps associated with applying terrain analysis and other spatial analyses to identify PMZs and CSAs. This process incorporates a GIS analysis to inform field assessments. The GIS analysis is not intended to replace on-site field assessments, but rather to supplement those efforts. Spatial analyses can be used to help identify potential high-priority sites, based on their vulnerability to erosion and other characteristics that potentially impact water quality. The GIS assessment results can enhance data collection efforts and reduce the amount of time spent in the field.

This section is intended to provide a big-picture view of the procedures and decisions that can be used when applying a GIS analysis to identify sites that potentially are a high-priority for conservation. The guidance builds upon the sections that describe suggested procedures for conducting the digital terrain analyses and performing the field assessments. These sections will be referenced during the relevant process steps.

The organization of this guidance follows the steps in the decision tree on the following page. The first step involves identifying specific management objectives and the intended purpose of the spatial analysis. During this step, the conservation technician will identify whether the pollutant of concern is sediment, phosphorus, or both. Although the decision tree only directly addresses erosion concerns, the individual steps describe how to incorporate phosphorus. Steps 2 through 4 involve creating and refining the list of potentially sensitive sites based in part on the selected GIS results, as well as office knowledge of the local setting. This is followed by steps 5 through 9, which involve reaching out to landowners, scheduling site visits, performing field assessments, identifying potential concerns that impact water quality, and identifying appropriate management practices. The final steps – 10 and 11 – involve adjusting and updating the list of potentially sensitive sites based on information gathered in the field, as well as updated spatial analyses.

**Decision Tree**



## Process Flow

### 1 Determine objectives and select tools
- Determine management objectives (PMZ and CSA)
- Identify pollutant(s) of concern
- Select spatial analysis tools that fit with identified objectives

### 2 Use Spatial Analysis to Select and Prioritize Sensitive Sites
- Run selected tools
- Use analysis results to identify high-priority sites

### 3 Create Sensitive Site List
- Determine an appropriate number of sites to select for further examination
- Base the list length on management objectives and available resources
- Determine the number of sites that can be visited each year
- Populate site list using highest-ranked sites from terrain analysis results

### 4 Adjust List Based on Office Knowledge
- Review site list for obvious errors in spatial analysis results
- Move sites with known management practices that address issues to Acknowledgement List

### 5 Work with Local Stakeholders for Information and Access
- Reach out to local producers to share project goals
- Gather information on site practices to refine target list
- Identify producers who are willing to allow site access

### 6 Schedule Site Visit Rotation
- Work with producers to schedule site access (only portion of sites will be visited each year)
- Establish a longer-term rotation for re-visiting sites

### 7 Visit Sites Selected for Given Year
- Conduct assessments of the identified sites
- Ensure assessor has permission to access site prior to conducting examinations

### 8 Complete Upland Field and Channel Forms
- Record the findings on the assessment protocol forms, communicating institutional memory
- Compare field assessments to spatial analysis results

### 9 Are Erosion Concerns Present?
- Use field assessment to identify presence of erosion concerns
- Note whether concerns are being addressed by management practices

### 10 Generate Acknowledgement and Issue Lists
- Place well-maintained fields on acknowledgement list
- Place fields in need of additional management practices on list of concerns
- Work with landowners to increase management on sites of concern
- Maintain master list that includes sites of concern and acknowledgement sites

### 11 Update Spatial Analysis for Sensitive Sites
- Revisit sensitive site list periodically
- Add new priority sites as other sites move to acknowledgement list
- Conduct new spatial analyses as necessary to update priority site identification

### Determine objectives and select tools

During this initial step, the conservation technician should identify the management objectives that can be assisted by the spatial analyses described in this guidance. These objectives will influence selection of the pollutant parameter(s) of concern in the watershed and influence the application of spatial analysis tools (explained in more detail in step 9). If the management objectives involve addressing excessive nutrient loading, both sediment and phosphorus should be selected as pollutant parameters of concern. Alternatively, for sediment and turbidity management the conservation technician could select sediment as the sole parameter of concern.

The pollutant parameter(s) of concern will inform the determination of which spatial analysis procedure is conducted (Figure 2).

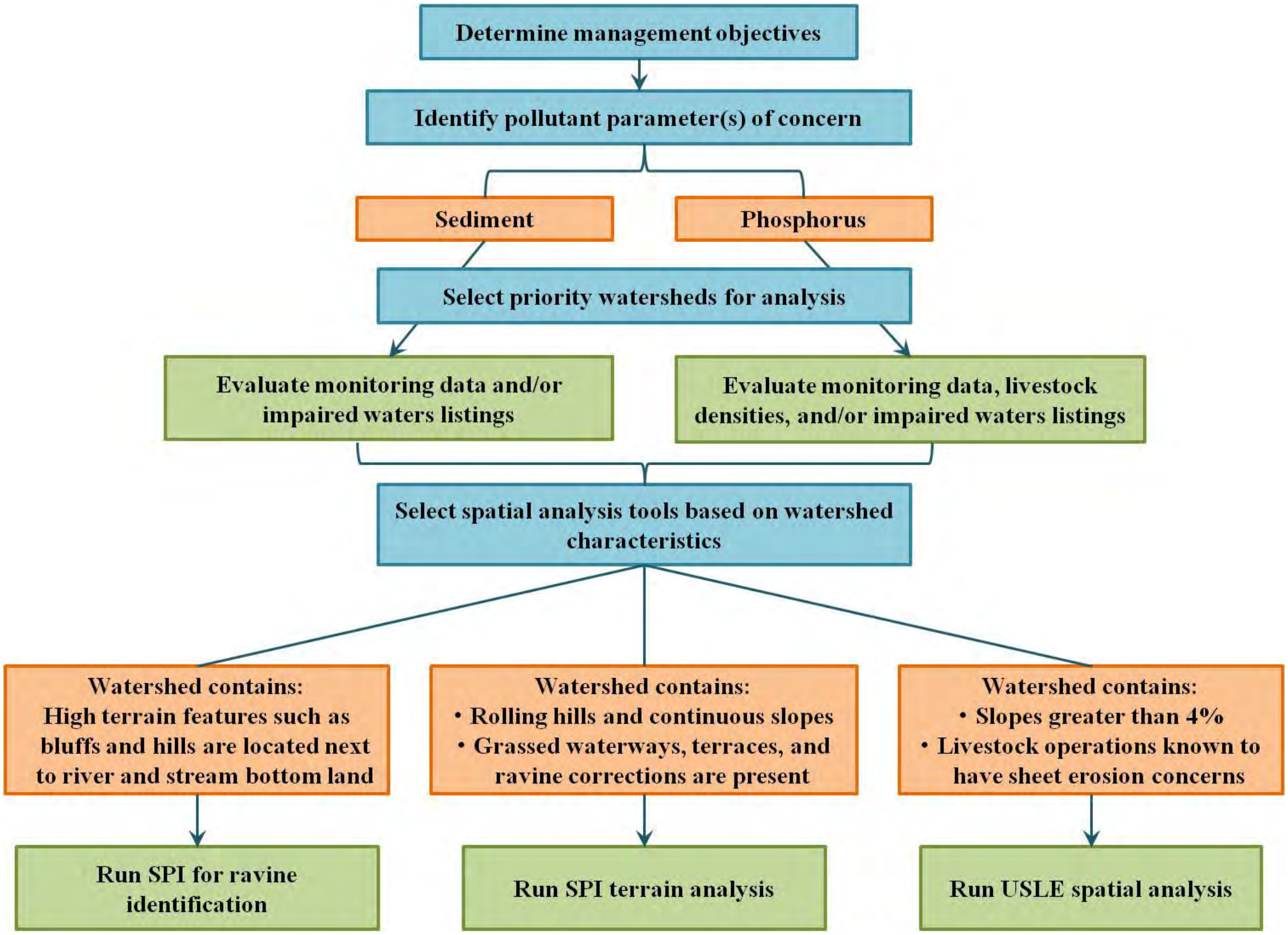



Figure 2. The selection of the pollutant parameter of concern determines the spatial analysis performed.

If the pollutant parameter of concern is phosphorus, the spatial analyses conducted will involve both a bare soil USLE and terrain analysis to calculate SPI. If the pollutant parameter of concern is sediment, the conservation technician might opt to only conduct a spatial analysis of USLE and proximity to streams. However, this decision should take into account knowledge of the local setting. If gullies are present in the watershed, the spatial analysis should also incorporate an SPI analysis. A ravine script should be added if ravines exist in the area of interest. For flat landscapes, the USLE spatial analysis might not provide much additional information. This assessment is most informative where slopes are greater than two percent. It should be noted that the USLE applied for this process is for bare soil and does not incorporate cover or practice factors.

Additional points for consideration when determining whether the SPI terrain analysis should be conducted to evaluate sediment concerns are provided in the following inset box.

## Assessing SPI as a Tool for Sediment Management:

- Gather local knowledge and information regarding the magnitude and/or history of the presence of gullies in the watershed. The extent of past implementation of grassed waterways, terraces, and contour farming provides a strong indicator of whether gullies were or are an issue.
- Consider the potential that ephemeral gullies have been masked by plowing or perennial vegetation.
- Apply these considerations to inform decisions regarding whether the SPI terrain analysis will provide beneficial indicators of potentially larger channelized flow paths that could result in gully sites or masked ephemeral gullies.
- Also consider the potential for using the SPI results to start a dialogue with producers about the likely areas where ephemeral gullies might be appearing on their land.

The conservation technician also should incorporate other existing data to select an appropriate scale for the spatial analysis that targets specific regions of concern. This approach will help narrow the focus of the analysis to a manageable area. Running an analysis on a large hydrologic unit potentially will identify more high-priority sites than can be effectively managed, given the available resources. In addition, if management objectives include measuring water quality improvement in stream, then implementing a few sites within a large scale watershed will likely not result in measurable concentration or load reduction improvements in the river or stream itself. Based on these concerns, it is suggested that the technician consider whether it is appropriate to scale down the GIS spatial analysis to a high-priority subwatershed. Selection of this subwatershed could be based on the extent of impaired waters, evaluation of monitoring data, or other conservation management objectives, such as critical habitat areas.

Additional tools also could be incorporated into the analysis to select high-priority sites. For example, additional spatial analyses could include assessing livestock animal density or identifying wetland restoration potential. Conservation technicians may incorporate any other assessments that are conducted for specific watershed management objectives. However, steps for incorporating these additional options are not included in this protocol.

### Use Spatial Analysis to Select and Prioritize Sensitive Sites

During this step, the technician performs the spatial analyses needed to identify potentially sensitive sites. The specific analyses that are conducted will depend on the pollutant parameters of concern identified in step 1. This step applies the procedures outlined in the Digital Terrain Analysis Section. To conduct the spatial analyses, the following process should be followed:

- Acquire necessary data
- Prepare data for analysis
- Run selected tools based on the management objectives identified in step 1
    - USLE
    - SPI
- Use analysis results to identify high-priority sites

When generating the spatial analysis results, the technician should keep in mind that some agricultural fields that drain through naturally vegetated zones might have two points at which the delivery of eroded materials might be of concern. Suggested guidance for addressing each of these delivery points is provided in step 8.

### Create Sensitive Site List

The sensitive site list should be created using the spatial analysis results that identify the high-priority sites. The length of the list should reflect an appropriate number of sites that can be selected for assessment. It should be noted that not all sites on the list will be visited each year. Rather, a site visit rotation will be established (step 7). As such, the length of the list should be determined based on the total number of sites that can be assessed during the multi-year rotation. Considerations for determining the length include management objectives and available resources. The list can be adjusted later if these factors change.

### Adjust List Based on Office Knowledge

In this step, the sensitive site prioritization list should be adjusted based on office knowledge of the specific sites. The list should be reviewed for potential errors in the spatial analysis results.

Identification of these errors can be informed by comparisons with recently collected data and other site information, such as recently implemented projects. Sites can be removed from the prioritization list, as appropriate. However, it should be noted that these sites are only removed from the prioritization list used to schedule site visits. All sites should be maintained on a master database list. The process for adjusting the site list is illustrated in Figure 3.

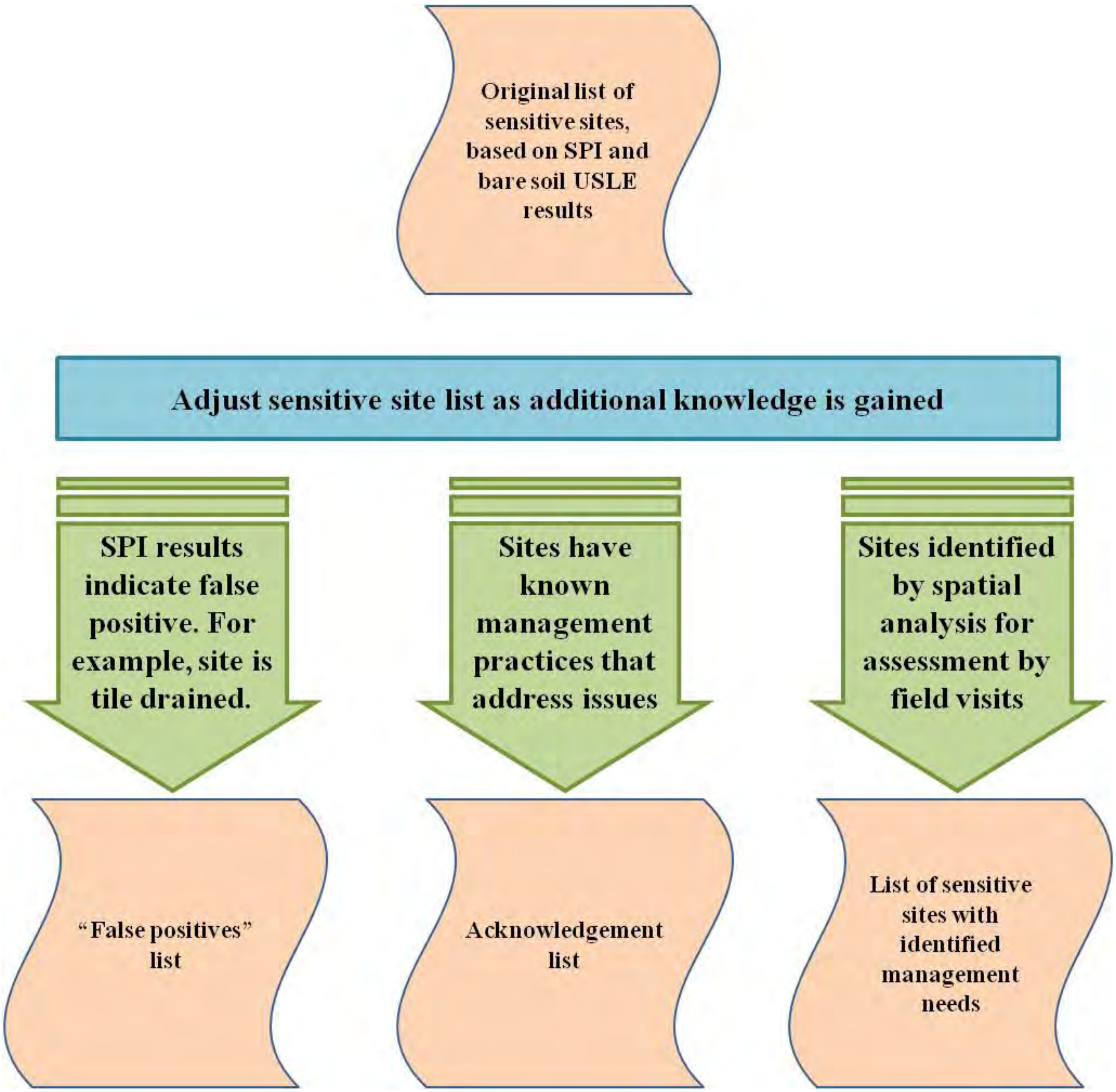



Figure 3. Process for adjusting sensitive site prioritization list.

The site prioritization list can be adjusted for several reasons. Sites can be removed from the prioritization list (but maintained on the master list) if office knowledge confirms these locations are not issues. For example, the SPI results could indicate false positives. This could occur for several reasons, including if the site has tile drainage. In this case, the site is not experiencing the overland flow indicated by SPI. However, a technician still might choose to visit these sites if the tile outlets could be a concern or if other potential issues might exist. Another potential cause of a false positive result could involve the presence of a culvert. The digital elevation data might view roads as a dams or berms if the data are not hydrologically conditioned. In these circumstances the SPI will not account for the channel flowing beneath the road. Likewise, the conservation technician should be aware that the spatial analysis also could miss some high-priority sites. These "false negatives" would not show up in the analysis results. This could occur, in part, due to the hydrologic conditioning performed on the digital elevation data. The pit filling procedure conducted when preparing the data for analysis can alter the results of the SPI terrain analysis. If pit filling overly flattens areas, a portion of the flow from the contributing area might be redirected along other pathways. This could result in less of the contributing area being associated with the SPI ranking and therefore the SPI terrain analysis results would artificially indicate the site was a lower priority. Likewise, insufficient pit filling could treat an area as landlocked when it is frequently connected.

Sites can be removed from the prioritization list if these sites have known management practices that address issues. These sites should be moved to the "Acknowledgement List," which can be used to recognize producers for their conservation management efforts.

### Work with Local Stakeholders for Information and Access

During this step, conservation technicians should reach out to local producers in order to gain information and permission to access sites on the prioritization list. This outreach involves communicating project goals and what a site visit would entail. Guidance and/or considerations for initiating contact is provided by a suggested script (Appendix A.7). This script can be considered by the office supervisors or managers, but it is not necessary to follow the language specifically. After the initial contact, it is recommended that the conservation technician send letters and follow-up with phone calls.

The results of the stakeholder outreach will determine which sites can be visited for field assessments. Producers willing to allow site access should be identified. If access is denied, the prioritization list should be refined. Any sites removed from the list due to the lack of access should be maintained on the master database list.

### Schedule Site Visit Rotations

A site visit rotation is recommended to schedule field assessments. Limited resources might restrict efforts in that only a portion of the sites on the prioritization list can be visited within a given year. The number of priority sites selected for evaluations can be adjusted to accommodate available office resources. In this way, a manageable distribution of sites over several years can be planned.

The process for scheduling the rotation is as follows:

- Determine the number of sites that can be visited each year
    - Based on available resources
    - Staff time
- Establish a rotation for re-visiting sites
    - Revisit sites on a regular time period (i.e. 5 years)
    - Based on available resources

If sites identified through the spatial analysis overlap with farms that are already on a staff's visitation schedule for other conservation program efforts, these sites could be moved up in priority. The list of prioritized sensitive sites does not have to be visited in the ranking order as they might appear on a list; rather, prioritization can be based on multiple objectives, including managing of office activities.

Two separate site rotation schedules also should be considered. The first is the initial assessment of sensitive sites. The second site visit rotation involves follow-up visits to sites identified as high priority. This includes sites with water quality concerns, as well as sites where conservation measures were in place to address the sensitive issues. Long-term confirmation of site performance is recommended to track BMP conditions and/or land use cover in order to validate protection remains in place.

### Visit Sites Selected for Given Year

During this step, sites are visited for conducted field assessments. The process for visiting sites is as follows:

- Schedule site visits for the current assessment season
- Ensure assessor has permission to access site prior to conducting examinations
- Keep open communications with the producer regarding visit date and number of assessors
- Visit the sites scheduled for that season
- Conduct the field assessment (detail provided in step 8)

### Complete Field Assessment Forms

During this step, the field technician should complete the site assessment forms. Additional detail regarding conducting field assessments is provided in the following sections. The chosen field assessments and associated forms were developed and refined based on field testing and feedback received from the project partners as a part of this project (see Appendix A.8).

The field assessments conducted include:

**Upland Field and Channel Assessment Worksheet**

This worksheet is used to record general site information. In addition, the technician documents field features using an aerial photograph, as well as a land use / Ag field characteristics form. The technician also walks the channel and completes a channel characteristics form and adapted Technical Note 99 form. While walking the channel, the technician also notes pour points and completes the pour point form. This pour point assessment should address all points at which eroded materials might be delivered to a resource of concern, or a change in management objectives. For example, a field that drains through a wooded buffer might have a pour point where the flow leaves the field as well as where the flow enters the channel. The pour point forms provide a method for documenting the various characteristics that might be encountered.

**Minnesota Rapid Phosphorus Index Form**

This form provides the necessary information for performing the Minnesota Rapid P-Index assessment. These data are used to identify indicators of phosphorus runoff risk. Identified issues then are discussed with producers to determine potential conservation management options. A list of identified potential BMPs that could address the phosphorus risk indicators used by the P-Index is provided in the Rapid P-Index Screening Tool Table.

**Streambank Erosion Assessment Form**

This form is used when streambank erosion is observed. It is a qualitative assessment to document indicators of erosion. Erosion information collected about multiple sites can be combined and used to inform later watershed management initiatives regarding bank stabilization or pollutant loading estimation projects.

### Are Erosion Concerns Present?

Use the results of the field assessments to identify the presence of erosion concerns. Also note whether concerns are being addressed by management practices. If erosions concerns are present, work with producers to address these issues. If erosion concerns are not present, acknowledge the producer for conservation management efforts (move the site to the "Acknowledgement List").

The process for assessing erosion will depend on whether the identified pollutant parameter is sediment and/or phosphorus. The process for phosphorus is depicted in Figure 4 and the process for sediment is depicted in Figure 5.

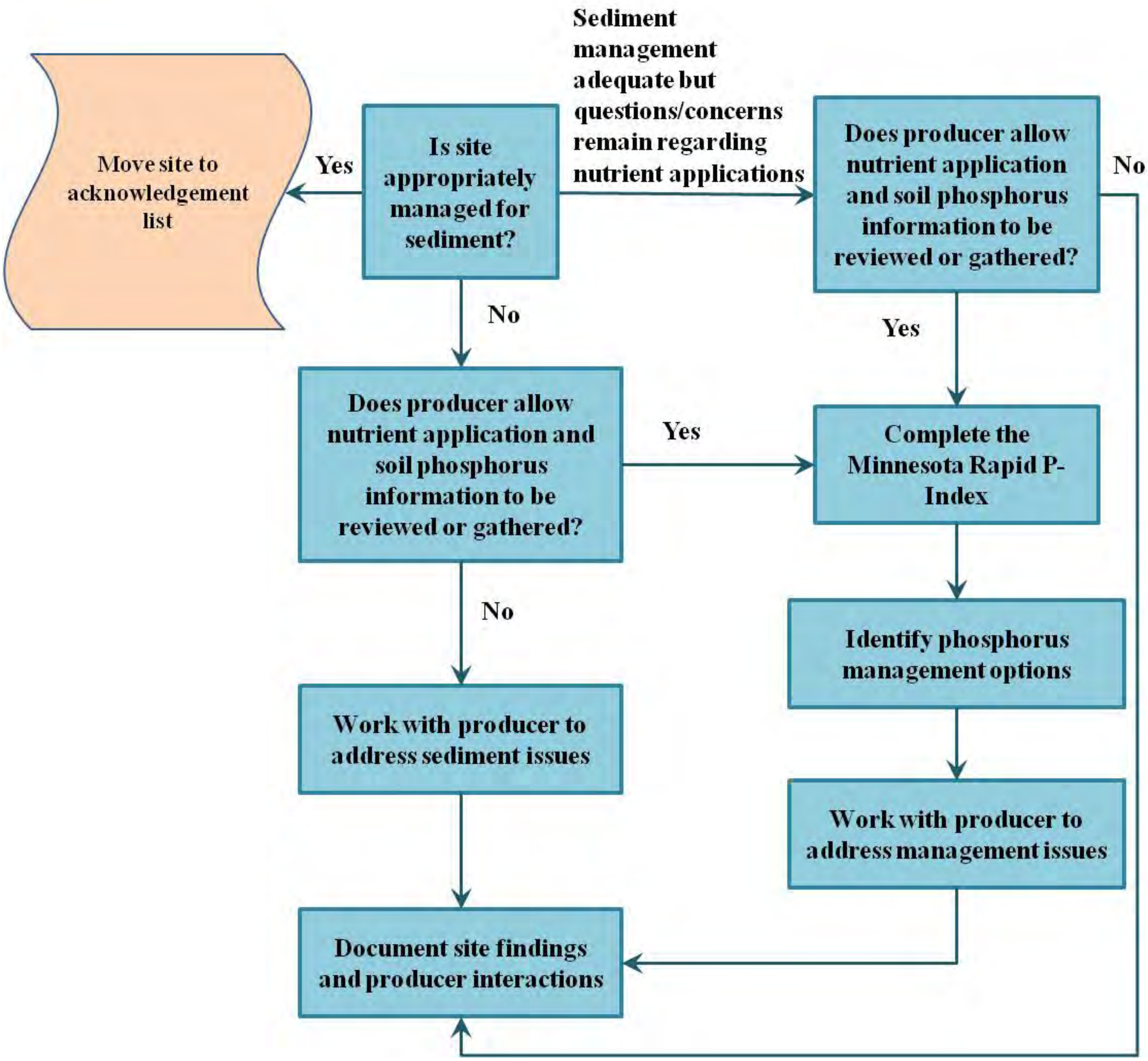



**Figure 4. Process flow for assessing erosion concerns associated with phosphorus.**

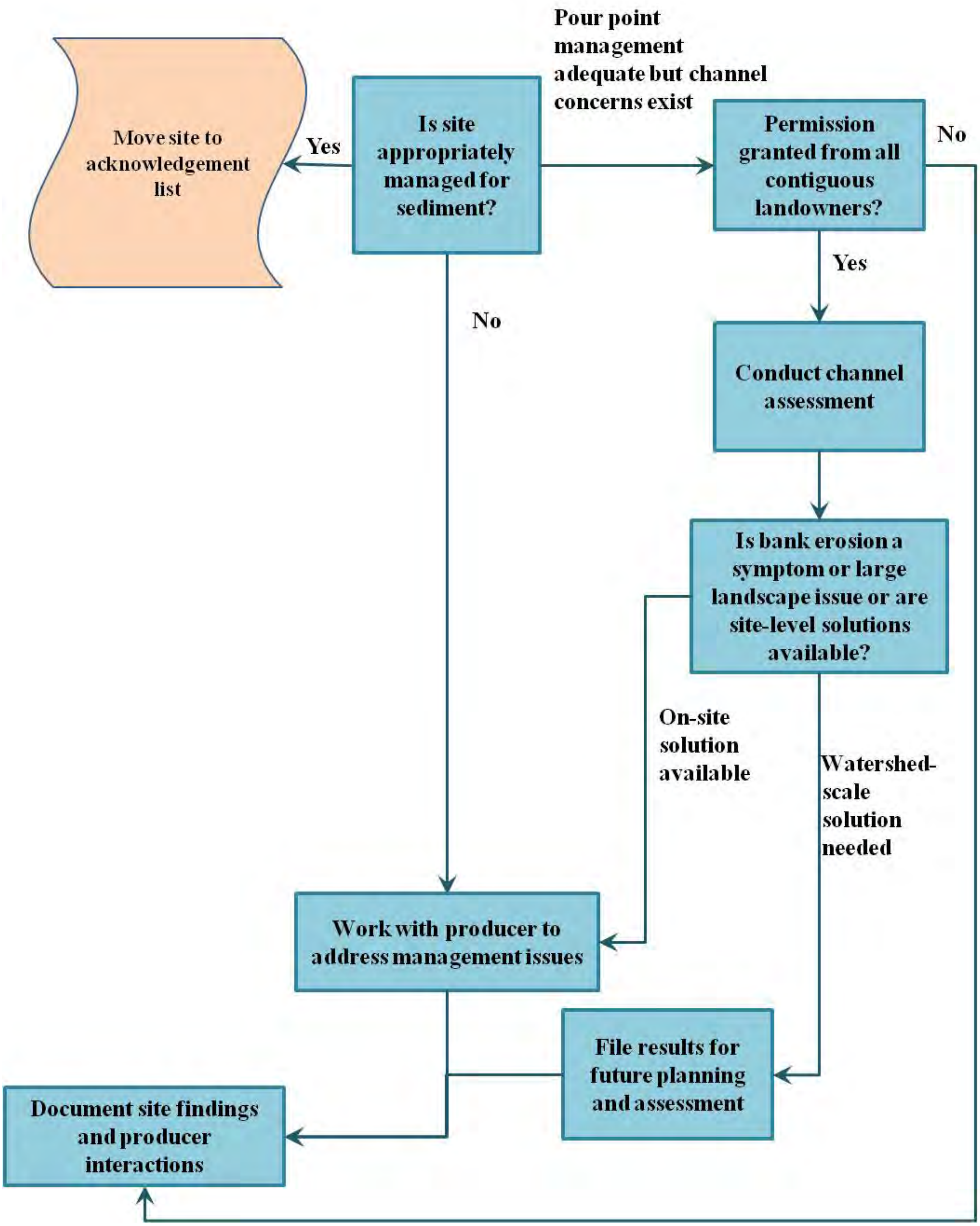



Figure 5. Process flow for assessing erosion concerns associated with sediment.

### Generate Acknowledgement and Issue Lists

During this step, the prioritization list will be adjusted to reflect the results of the field assessments and subsequent evaluation. Well-maintained sites should be moved to the "Acknowledgement List" and fields in need of additional management practices should remain on the list of concerns. Conservation technicians can work with landowners to increase management on sites of concern. In addition, all sites should be maintained on a master database list that includes sites of concern, acknowledgement sites, as well as sites that were removed from the prioritization list during step 4.

### Update Spatial Analysis for Sensitive Sites

The sensitive site prioritization list should be periodically reviewed and revised. New priority sites for assessment can be added as other sites are moved to the "Acknowledgement List". In addition, new spatial analyses can be conducted as necessary to update priority site identification. These analyses could be conducted when the following conditions occur:

- Critical land use changes take place (e.g., regional decline in conservation reserve program enrollment)
- Improved terrain analysis methods are developed (e.g., LiDAR)
- Newly identified watershed stressors emerge (e.g., biotic impairments)
- New technology becomes available
- Better/new datasets are provided

For this part of the guidance, field procedures are conducted to both complement and evaluate the performance of the GIS analysis. The field assessments can be used to assess the adequacy of the spatial analysis in predicting CSAs. These results, though mainly qualitative, provide substantial insight into locating bank-related PMZ and CSA sites of concern. In addition, the GIS analysis can be enhanced using field data to generate an inventory of streambank locations in need of stabilization. Field collection methods used to develop the inventory are designed to inform managers regarding the extent of sensitive banks and provide efficient information transfer to subsequent evaluation teams. For example, the field data can assist a fluvial geomorphologist performing more quantitative assessments such as the Bank Erosion Hazard Index, Near Bank Stress, or the CONCEPTS river modeling.

Field technicians can perform the following assessments: land use / Ag field characterization, channel characterization, stream assessment based on Technical Note 99 (USDA NRCS, 1998), and pour point characterization. Technicians also can gather data for the Minnesota Rapid Phosphorus Index (University of Minnesota, 2006) and conduct a qualitative streambank erosion assessment. The first four assessments are part of an Upland Field and Channel Assessment protocol designed for this project to provide on-the-ground information about sites identified as CSAs. The Minnesota Rapid Phosphorus Index (Rapid P-Index) is a screening tool designed to identify sites on which to perform the full Phosphorus Index. However, for this project, the full Phosphorus Index will not always be performed. Instead, the Rapid P-Index will be used to identify indicators of phosphorus runoff risk, and these issues then will be discussed with producers regarding conservation management options. It is important to note that many of the sites identified as sensitive by the GIS analysis will already have appropriate management and operation. Thus, these tools also provide an important opportunity to recognize producer accomplishments and track program progress necessary for supporting basin management and Total Maximum Daily Load efforts.

Depending on the objectives, watershed practitioners will likely use one or more of the following forms to record field data:

- **Upland Field and Channel Assessment Worksheet:** This worksheet contains multiple forms. On these forms, staff will record general site information, including site location and general Ag field and channel conditions. Staff first will document field features using an aerial photograph. Next, staff will complete the land use / Ag field characteristics form. Staff then will walk the channel associated with the field and complete the channel characteristics form, as well as an adapted Technical Note 99 (TN-99) form. While walking the channel, staff will note any pour points, defined as channelized flow from the field to an outlet, such as surface water. Tile intakes also are considered pour points. This information will be recorded on the pour point characteristics form and tile inlet pour point characteristics form.

- **Minnesota Rapid Phosphorus Index Form:** Completing this form will provide the necessary information performing the Rapid P-Index assessment.
- **Streambank Erosion Assessment Form:** Field technicians will use this form when streambank erosion is observed. Information recorded on this form can be used to provide a detailed inventory of identified stream sites experiencing bank erosion within a watershed. Requested inputs include, physical characteristics of the bank, noted animal and equipment impacts, presence of a perennial cover buffer, and a qualitative estimate of buffer quality.

**Upland Field and Channel Assessment Worksheet**

Site ID:____________________ Date: __________________________

Prepared By: ____________________________________

Worksheet # (write on the aerial photograph): ___________________

Field # _________________

Acres ________________________

GPS: ____________________________

Field conditions (e.g., weather: wet, snow melt, dry; Crop status: pre-plant, emerging, full canopy cover, harvest ...): _____________________________________

Photo #'s and brief description of feature (gully, buffer, tile outlet, etc):
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

*This form is used to document the characteristics of each field and the receiving water associated with that field. A field is defined as a plot of land with a continuous cropping system (i.e. the portion of a parcel planted to corn; Note: Plots with strip cropping would be considered one field).*

**Steps for completing this worksheet** *(a separate worksheet should be completed for each field)*:

1. Document features on the aerial photograph/map using the legend provided. Please be sure to write the worksheet number (listed above) on the aerial photograph. (Some aerial photographs will be used for multiple fields.
2. Assess the field characteristics, including management practices, tillage, etc. Fill out the "field characteristics" portion of this form, document features on the aerial photograph/map, and take photographs of any notable features. When taking photos, document the location of the feature by first photographing the GPS coordinates. Also record the photo numbers on the worksheet.
3. Walk the channel along the field you just surveyed. Complete the "channel characteristics" portion of this form, as well as the Technical Note 99 form. While walking the channel, note any pour points. Take any photographs of notable features. As before, document the location of the feature by first photographing the GPS coordinates and record the photo numbers on the worksheet.
4. Complete the "pour points" portion of this form for all of the pour points identified while walking the channel. A pour point is defined as channelized flow from the field to an outlet, such as surface water. Tile intakes also are considered pour points. Take any photographs of notable features. As before, document the location of the feature by first photographing the GPS coordinates and record the photo numbers on the worksheet.

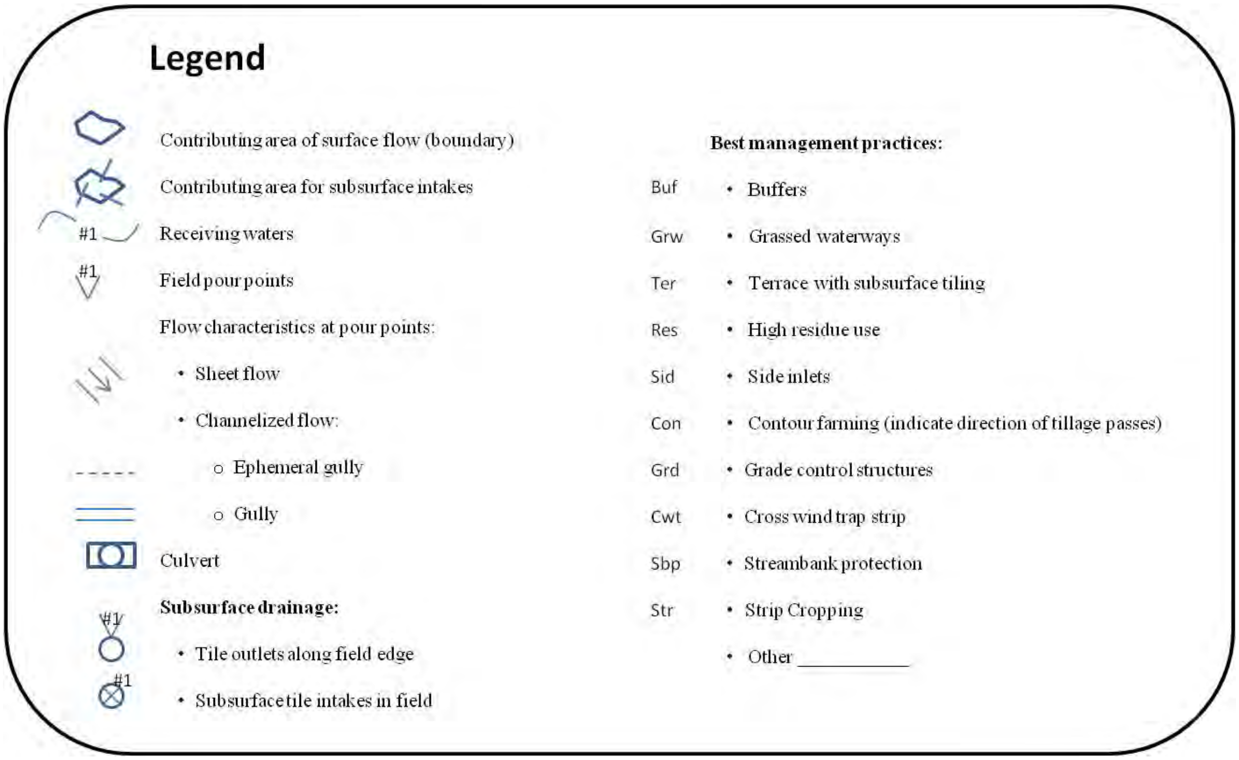
***Materials:***

- Aerial photos
- Camera
- Datasheet or log book
- Pens
- Tape measure
- White board and markers
- Topographical map
- Residue tool or photo guides

## Aerial Photograph Feature Identification Form

***Site ID: _______________________*** ***Worksheet #: ________________________***
***(Write this # on the aerial photograph)***

***Identify the following characteristics on the aerial photograph (using the legend below):***




- Contributing area of surface flow (delineate boundary visual from field edge typically without entering field). Might be compared later with LiDAR-based GIS topo map.
- Receiving waters
  - Number each receiving water on the map
  - On the Channel Characteristics form, write the ID number next to the corresponding description
- Field pour points into the receiving water (channelized surface flow)
- Culverts
- Subsurface drainage
  - Tile outlets along the field edge
  - Subsurface tile intakes identified in field
- Best Management Practices in place:
  - Buffers
  - Grassed waterways
  - Terrace with subsurface tiling
  - High residue use
  - Side inlets
  - Contour farming (indicate direction of tillage passes)
  - Grade control structures
  - Conservation cover
  - Cross wind trap strip
  - Streambank protection
  - Strip cropping
  - Other ________________

## Land Use / Ag Field Characteristics Form

***Site ID:* ______________________** ***Worksheet #:* _______________________**

| | |
|---|---|
| **Crop or Other Land Use** (Circle One)<br>*(If multiple crops are planted for a single field, please indicate the location of each crop on the map using the first letter of the crop type.)* | Corn Pasture<br>Soy Forest<br>Small grain Other __________________<br>Alfalfa |
| **Tillage Direction** (Circle One – the dominant slope) | Up/down slope<br>Cross slope or nearly flat land<br>Notes: |
| **% Crop Residue** (Circle One) | 0-15 15-30 >30 |
| **Evidence of Manure Land Applications** | Yes ________ No __________<br>Notes: |
| **Manure Incorporated** | Yes ________ No __________<br>Notes: |
| **Drainage Methods Present** (Circle One) | Field Ditch Drive-through Ditches<br>Subsurface Tiling Other _____________ |

***If subsurface tile drainage is present, please complete the following:***

| | |
|---|---|
| **Tile Style** (Circle One) | Clay Concrete<br>Corrugated metal pipe Plastic |
| **Tile Diameter** | ______________ in. |
| **Tile Intake Protection** (If Applicable)<br>*(Use the numbered tile intakes identified on the map to characterize the intakes. Write each ID # next to the corresponding description.)* | Count of tile intakes ___________<br>**Characteristics:**<br>Buffer (<30 ft): Map ID #'s______________<br>Rock inlets: Map ID #'s______________<br>Hickenbottom risers: Map ID #'s______________<br>Riser or beehive: Map ID #'s _____________ |

***Notes:***

## Channel Characteristics Form

***Site ID:* ______________________** ***Worksheet #:* _______________________**

| | |
|---|---|
| **Receiving Water Identification**<br>(*Write the ID number of each receiving water identified on the map next to the corresponding description. In some cases, a receiving water might apply to multiple fields. Mark this receiving water only once on the map, but include it on each field worksheet for which it is relevant.*) | Lake: Map ID #'s_______________<br>Perennial stream: Map ID #'s_______________<br>Intermittent stream: Map ID #'s_______________<br>Ag ditch: Map ID #'s_______________<br>Road ditch: Map ID #'s_______________<br>Wetland: Map ID #'s_______________ |
| **Active Channel Width** (Circle one) | 0-5 ft　　11-15 ft<br>6-10 ft　　>15 ft |
| **BMPs in Place within the Channel** (Circle all that apply)<br>*(Consider the types of BMPs that are located between and including the banks.)* | Two-stage ditch　　Rip rap<br>Grade control structures　　Streambank bioengineering<br>Drop structures　　Other ______________ |
| **BMP Recommendations** | |

**Site Diagrams (note: riparian borders, structures, land use, bends and culvert or bridge):**

**Upstream**

**Downstream**

## Adapted TN-99 Assessment Form (USDA NRCS, 1998)

***Site ID:* ______________________ *Worksheet #:* ______________________**

| Upstream / Downstream | | For full descriptions of the scores, please see Pages 99-106 | |
|---|---|---|---|
| **Channel Condition** *(Pg. 100-1)* | / | **10 –** Natural channel<br><br>**7 –** Evidence of past alteration but substantial recovery | **3 –** Altered channel<br><br>**1 –** Channel actively downcutting or widening |
| **Hydrologic Alteration** *(Pg. 101-2)* | / | **10 –** No visible evidence of channel straightening; no drainage features present; little or no sedimentation at downstream culverts<br><br>**7 –** Occasional drainage features present; little sedimentation at downstream culverts | **3 –** Frequent drainage features apparent; <60% of reach straightened; large sediment deposits at downstream culverts<br><br>**1 –** Drainage heavily altered; >60% of reach is ditch or straightened; large sediment deposits at downstream culverts |
| **Riparian Zone** *(Pg. 102-3)* | / | **10 –** Natural vegetation extends at least 2 active channel widths on each side<br><br>**7 –** Natural vegetation extends one active channel width on each side OR covers entire floodplain | **3 –** Natural vegetation extends 1/3 of active channel width on each side OR vegetative root system moderately compromised<br><br>**1 –** Natural vegetation less than a third of active channel width OR lack of generation OR root system severely compromised |
| **Bank Stability** *(Pg. 103-4)* | / | **10 –** Banks are stable and low; >33% of eroding surface area protected by roots<br><br>**7 –** Banks moderately stable and low; <33% of eroding surface area protected by roots | **3 –** Banks are moderately unstable; banks might be low but typically are high<br><br>**1 –** Banks are unstable; banks might be low but typically are high |
| **Water Appearance** **(**Rank only during moderate to high flows**)** *(Pg. 104-5)* | / | **10 –** Very clear or clear but tea-colored; objects visible at depths of 3-6 ft<br><br>**7 –** Occasionally cloudy; objects visible at depths of 1.5-3 ft | **3 –** Considerable cloudiness; objects visible to depths of 0.5-1.5 ft<br><br>**1 –** Very turbid or muddy; objects visible to depths of <0.5 ft |
| **Pools and Riffles** (Rank in natural streams only; record only if upstream and downstream length is longer than ~12 active channel widths and low flow) *(Pg. 105-6)* | / | **10 –** Deep and shallow pools abundant (~2-4); obvious riffles downstream of pools; >30% of pool bottom obscure due to depth<br><br>**7 –** Pools present but not as abundant; 10-30% of pool bottom obscure due to depth | **3 –** Pool or riffle present but shallow; 5-10% of pool bottom obscure due to depth<br><br>**1 –** Pools absent or entire bottom discernible |
| **Riffle Embeddedness** (Rank only if riffles are present) *(Pg. 107)* | / | **10 –** Gravel or cobble particles are <20% embedded<br><br>**7 –** Gravel or cobble particles are 20-40% embedded | **3 –** Gravel or cobble particles are 40-60% embedded<br><br>**1 –** Riffle is completely embedded |

***Please calculate the overall and total scores on the following page.***

| **Overall Score**<br><br>(Total divided by number scored) | **Upstream: (Σ ) / (# )**<br><br>**Downstream: (Σ ) / (# )** | **Total Scores**<br>**Upstream: ___________**<br>**Downstream: ___________** |
|---|---|---|

**Observations (note algal blooms, septage odors, presence of manure or other phosphorus sources, and turbidity-related findings):**

___

___

___

___

___

___

___

___

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___

___

**Pour Point and Upland Runoff Characterization Forms**. These forms are to be used to evaluate runoff from sites identified as high-priority by GIS analysis (e.g., SPI and USLE). These forms also should be used to evaluate additional areas of concern identified during site visits. The forms are sequenced to allow the field crew to differentiate between and characterize flows from an agricultural field that directly enter a surface water and flows that first pass through a natural vegetation corridor. Timing of the site visit, in relation to recent precipitation, stage of plant growth, and precipitation, will influence what erosion and pour point evidence is likely to be observed.

***It is recommended that the field crew develop its own systematic approach for evaluating a field. One method would be to begin the site evaluation by walking in the upland area. In this approach, the team first would evaluate runoff from the field and characterize management practices. The runoff evaluation would assess both pour points (based on the SPI metric) and sheet flow (based on the USLE metric). [It should be emphasized that the role of the SPI and USLE metrics is to inform initial site selection are not intended to restrict the field evaluation. The assessment team should note any erosion or potential water quality concerns observed, even if these are not indicated by the GIS analyses.] Buffer and filter strip BMPs are considered part of the upland Ag field, not a natural vegetated corridor, for the purposes of this assessment. The upland runoff evaluation should note whether the runoff flows directly to a receiving water or first passes through a natural vegetation corridor. If it passes through a vegetated corridor, the team should characterize the corridor and assess any water quality concerns associated with the flow entering the receiving water. This part can be completed during the upstream walk if the corridor is narrow, or on the return trip downstream.***

The forms should be used in the following sequence:

1. **Pour Point Identification Form and/or USLE Review Form**
    a. This is a two-part form used to evaluate the appropriateness of the GIS analyses for the specific watershed characteristics.
        i. The Pour Point Identification Form should be used to assess whether the SPI was a good indicator of pour points.
        ii. The USLE Review Form should be used to assess whether USLE was a good indicator of water quality risk associated with sheet and rill erosion.
    b. The Pour Point Identification Form should be filled out for each pour point identified by the terrain analysis and those additional points observed during the site assessment. It is especially critical to note whether the observed pour point was predicted by SPI.
    c. The USLE Review Form should be filled out for any crucial areas identified by the USLE analysis and areas with erosion risks identified during the site assessment.
2. **Upland Management Characteristics Form**
    a. This form should be used to characterize runoff flowing to receiving waters (as opposed to tile inlets). A separate form is designed to characterize flow to tile inlets (see Part 3).
    b. This form is divided into multiple parts, based on the land use where the flow originates. The land uses are:

i. Hay/pasture
ii. Row crop
iii. Natural vegetation

c. Only the parts relating to the relevant, observed land uses need to be completed during the field assessment.
d. The purpose of this form is to better characterize observed pour points and erosion risks, as well as identify cases where erosion likely would occur given field conditions (i.e., slope, soil type) but is being properly managed. For instance, evidence of a likely pour point might not be present due to field activities, such as contour cropping.
e. Multiple parts of this form might be used in some cases. For example, a pour point might be indicated by the SPI in an upland area currently planted to row crops. Plowing has removed on-site evidence of the pour point in the field, and a natural vegetated corridor exists between the field and receiving water. However, gullying is observed on the streambank. In this case, the field technician would complete both the Row Crop/Small Grains and Natural Vegetation Corridor sections of this form for the pour point. Although the pour point is not observed in the cropped field, completing the Row Crop portion of the form will help document the field activities that are impacting the pour point and existing management of runoff.

3. **Tile Inlet and Outlet Pour Point Characteristics Form**
   a. This form should be used to characterize the contributing area to tile intake, inlet protection, and tile outlet condition.
   b. Assess every tile inlet and outlet as a combined pour point. Complete this form where there is evidence of erosion in the field and/or on the streambank at the outlet.

## Pour Point Identification Form and/or USLE Review Form

*(Use this sheet to record information about the ability of SPI and/or USLE to identify pour points and erosion risk in different settings. This evaluation will help determine if these GIS analyses are appropriate tools for given watershed characteristics.)*

***Site ID:*** ______________________ ***Worksheet #:*** ______________________

### A. Pour Point Identification Form

| **Pour Point Map ID #** | | |
|---|---|---|
| **Was Pour Point Indicated by SPI?** | Yes No | Yes No | Yes No |
| **Flow Type at Pour Point** (Circle one) | Sheet Flow Ephemeral gully (< 2ft)<br>Tile Outlet Gully | Sheet Flow Ephemeral gully (< 2ft)<br>Tile Outlet Gully | Sheet Flow Ephemeral gully (< 2ft)<br>Tile Outlet Gully |
| **Gully Characteristics** | Width _________<br>Depth _________<br>Length ________ | Width _________<br>Depth _________<br>Length ________ | Width _________<br>Depth _________<br>Length ________ |
| **General Characteristics at Pour Point** (Circle all that apply) | Bermed with side inlet<br>Gentle slopes<br>Slight erosion | Bermed with side inlet<br>Gentle slopes<br>Slight erosion | Bermed with side inlet<br>Gentle slopes<br>Slight erosion |
| **Upland Land Use *** | Hay/Pasture<br>Row Crop/Small Grain<br>Natural Vegetated Corridor | Hay/Pasture<br>Row Crop/Small Grain | Hay/Pasture<br>Row Crop/Small Grain |
| **Pour Point Flows to **:** | Receiving Water<br>Natural Vegetation Corridor | Receiving Water<br>Natural Vegetation Corridor | Receiving Water<br>Natural Vegetation Corridor |
| **If Flows to Natural Vegetation Corridor, is there a Noticeable Pour Point from the Corridor to the Water Resource?** | Yes No | Yes No | Yes No |

* If the upland land use is hay / pasture, complete Form 2A; if the upland land use is row crop / small grain, complete Form 2B.

** If the pour point flows to a natural vegetation corridor, also complete Form 2C.

**Notes:**

## B. USLE Review Form

| Erosion Risk Area Map ID # | | | | | | |
|---|---|---|---|---|---|---|
| Was Erosion Risk Area Indicated by USLE? | Yes | No | Yes | No | Yes | No |
| Evidence of Erosion | Yes | No | Yes | No | Yes | No |
| Erosion Evidence Type | Gully / Eroded Surfaces (Rill) / Visual Redeposition / Bare Cropped Areas | | | | | |
| Basis for Erosion | Vulnerable Soil Type<br>Slope<br>Livestock<br>Field Road | | Sheet Flow<br>Tile Outlet | Ephemeral gully (< 2ft)<br>Gully | Sheet Flow<br>Tile Outlet | Ephemeral gully (< 2ft)<br>Gully |
| Gully Characteristics | Width _________<br>Depth _________<br>Length ________ | | Width _________<br>Depth _________<br>Length ________ | | Width _________<br>Depth _________<br>Length ________ | |
| Upland Land Use* | Hay/Pasture<br>Row Crop/Small Grain | | Hay/Pasture<br>Row Crop/Small Grain | | Hay/Pasture<br>Row Crop/Small Grain | |
| Erosion Area Flows to**: | Receiving Water<br>Natural Vegetation Corridor | | Receiving Water<br>Natural Vegetation Corridor | | Receiving Water<br>Natural Vegetation Corridor | |
| If Flows to Natural Vegetation Corridor, is there a Noticeable Erosion Risk from the Corridor to the Water Resource? | Yes | No | Yes | No | Yes | No |

* If the upland land use is hay / pasture, complete Form 2A; if the upland land use is row crop / small grain, complete Form 2B.

** If the erosion area flows to a natural vegetation corridor, also complete Form 2C.

**Notes:**

## Upland Management Characteristics Form (for flow to receiving waters)

*(Use this form to record information about the characteristics of the field contributing to each pour point and erosion risk area. This form is divided into three parts depending on the land use type where the flow originates. Only fill out the portions of the form relevant to each site.)*

### A. Hay/Pasture

| Pour Point or Erosion Risk Area Map ID # | | | | | | |
|---|---|---|---|---|---|---|
| **Hay or Pasture?** | Hay | Pasture | Hay | Pasture | Hay | Pasture |
| **Evidence of Livestock Access to Stream** | Yes | No | Yes | No | Yes | No |
| **Fence Restricting Livestock Access** | Yes | No | Yes | No | Yes | No |
| **Livestock Activity Erosion** | | Loafing Area<br>Foot Traffic | | | | |
| **Evidence of Equipment Impacts** | Yes | No | Yes | No | Yes | No |
| **Waterway Riparian Corridor Condition** | None<br>Poor | Fair<br>Good | None<br>Poor | Fair<br>Good | None<br>Poor | Fair<br>Good |
| **Contributing Area** (Estimate) | | | | | | |
| **Pour Point / Erosion Risk Area Flows to*:** | Stream Channel<br>Ditch<br>Natural Vegetation Buffer<br>Other______ | | Stream Channel<br>Ditch<br>Natural Vegetation Buffer<br>Other______ | | Stream Channel<br>Ditch<br>Natural Vegetation Buffer<br>Other______ | |

* If the erosion area flows to a natural vegetation corridor, also complete Form 2C.

**Notes:**

**Is the erosion/flow path connected to the water resource?**

**Is the erosion related to a heavy use area in the pasture?**

## B. Row Crops

| Pour Point or Erosion Risk Area Map ID # | | | |
|---|---|---|---|
| **Crop Type** | Corn Beets<br>Soy Other ______ | Corn Beets<br>Soy Other ______ | Corn Beets<br>Soy Other ______ |
| **Tillage Direction** | Parallel to Stream<br>Perpendicular to Stream<br>Other _______ | Parallel to Stream<br>Perpendicular to Stream<br>Other _______ | Parallel to Stream<br>Perpendicular to Stream<br>Other _______ |
| **Residue** (Circle one) | > 30% < 15%<br>30-15% None | > 30% < 15%<br>30-15% None | > 30% < 15%<br>30-15% None |
| **Contributing Area** (Estimate) | | | |
| **Pour Point / Erosion Risk Area Flows to*:** | Stream Channel<br>Ditch<br>Natural Vegetation Buffer<br>Other______ | Stream Channel<br>Ditch<br>Natural Vegetation Buffer<br>Other______ | Stream Channel<br>Ditch<br>Natural Vegetation Buffer<br>Other______ |
| **Waterway Buffer Condition** | None Fair<br>Poor Good | None Fair<br>Poor Good | None Fair<br>Poor Good |
| **Field BMPs for Contributing Area** (Circle all that apply) | Grassed Waterways<br>High Residue<br>Strip Cropping<br>Contour Farming<br>Other: ____________ | Grassed Waterways<br>High Residue<br>Strip Cropping<br>Contour Farming<br>Other: ____________ | Grassed Waterways<br>High Residue<br>Strip Cropping<br>Contour Farming<br>Other: ____________ |

* If the erosion area flows to a natural vegetation corridor, also complete Form 2C.

**Notes:**

## C. Natural Vegetation Corridor

| **Pour Point or Erosion Risk Area Map ID #** | | | |
|---|---|---|---|
| **Corridor Condition** | Poor Fair Good | Poor Fair Good | Poor Fair Good |
| **Corridor Width** | < 33 ft.<br>> 33 ft. | < 33 ft.<br>> 33 ft. | < 33 ft.<br>> 33 ft. |
| **Vegetation Type** | Grass<br>Woody Shrubs<br>Trees | Grass<br>Woody Shrubs<br>Trees | Grass<br>Woody Shrubs<br>Trees |
| **Pour Point Contributing Area** (Estimate) | | | |
| **Erosion to Receiving Water** | None<br>Gully<br>Ephemeral Gully | None<br>Gully<br>Ephemeral Gully | None<br>Gully<br>Ephemeral Gully |

**Notes:**

## Tile Inlet Pour Point Characteristics Form (for flow to tile inlets)

*(Use this form to record information about pour points that flow to tile inlets.)*

***Site ID:*** ______________________  ***Worksheet #:*** _______________________

| **Pour Point Map ID #** | | | |
|---|---|---|---|
| **Field Type** | Cropped, Hay, Pasture, Natural Vegetation | Cropped, Hay, Pasture, Natural Vegetation | Cropped, Hay, Pasture, Natural Vegetation |
| **Tile Intake Protection** | Buffer<br>Rock inlets<br>Hickenbottom risers<br>Riser or beehive<br>High Residue | Buffer<br>Rock inlets<br>Hickenbottom risers<br>Riser or beehive | Buffer<br>Rock inlets<br>Hickenbottom risers<br>Riser or beehive |
| **Protection Condition at Pour Point** | None Fair<br>Poor Good | None Fair<br>Poor Good | None Fair<br>Poor Good |

## Minnesota Rapid Phosphorus Index Form (University of Minnesota, 2006)

***For detailed procedures on completing this worksheet, please see pages 107-109***

| | | | | | |
|---|---|---|---|---|---|
| **Field ID:** | | | | | |
| **GPS:** | | | | | |
| **Date:** | | | | | |
| **Prepared By:** | | | | | |
| **Field Conditions (e.g. weather):** | | | | | |
| **Manure* and fertilizer** (lbs $P_2O_5$/ac/yr) | 0 101-200 1-100 > 200 | 0 101-200 1-100 > 200 | 0 101-200 1-100 > 200 | 0 101-200 1-100 > 200 | 0 101-200 1-100 > 200 |
| Unincorporated (within 24 hours) or incorporated? | Uninc. Inc. | Uninc. Inc. | Uninc. Inc. | Uninc. Inc. | Uninc. Inc. |
| Was manure applied? | Yes No | Yes No | Yes No | Yes No | Yes No |
| **Erosion** (t/ac/yr) | | | | | |
| **Soil test P** (ppm Olsen) *(65 ppm Olsen = 90 ppm Bray = 100 Mehlich)* | ≤ 65 > 65 Unavailable | ≤ 65 > 65 Unavailable | ≤ 65 > 65 Unavailable | ≤ 65 > 65 Unavailable | ≤ 65 > 65 Unavailable |
| **Year of soil P test** | | | | | |
| **Distance from edge of field to water** (ft) | < 10 ft 10 - 100 ft > 100 ft | < 10 ft 10 - 100 ft > 100 ft | < 10 ft 10 - 100 ft > 100 ft | < 10 ft 10 - 100 ft > 100 ft | < 10 ft 10 - 100 ft > 100 ft |
| **Internal drainage** ***Good** = Artificially drained or naturally drained* ***Slow** = Soil hydrologic group C or D, or >27% clay and without artificial drainage* | Good Slow | Good Slow | Good Slow | Good Slow | Good Slow |
| **Recommendation for collecting STP when not available**** *(**X** in box indicates collecting STP is recommended. Add any notes, such as the producer resistance to conducting a soil test.)* | | | | | |

**** The lack of STP information is more of a concern when manure is being applied on fields experiencing substantial erosion. In addition, the field technician might consider recommending determining STP when the existing data are more than three years old.**

## RUSLE2 Form

**Estimate the following RUSLE2 factors using technician professional judgment:**

| **Field ID** | | | | | |
|---|---|---|---|---|---|
| **Dominant Slope (%)** | | | | | |
| **Slope Length (ft)** *Either estimated in the field or derived from MN NRCS eFOTG* | | | | | |
| **Soil Type** | | | | | |
| **Crop Management Template used to run RUSLE2** | | | | | |
| **Practice Factor** *e.g. 1 = no BMP, 100% delivered; 0.7 = tilling across slope* | | | | | |

| ***Approximate manure application rates equivalent to 100-200 lbs $P_2O_5$/ac** | | | | |
|---|---|---|---|---|
| | Solid manure (tons/ac) | Liquid slurry (1000 gals/ac) | Liquid anaerobic lagoon (1000 gals/ac) | Pasture (animal units/ac) |
| Beef | 25-50 | 5.9-11.8 | 34.5-69.0 | 3.2-6.4 |
| Dairy | 33-67 | 6.7-13.3 | 37.0-74.1 | 3.4-6.7 |
| Turkey | 2-4 | 2.6-5.1 | | |
| Poultry | 2-4 | 2.3-4.7 | 27.8-55.6 | |
| Swine | 13-25 | 2.9-5.7 | 45.5-90.9 | |
| Sheep | 10-20 | | | 3.3-6.6 |
| Horse | 25-50 | | | 6.0-12.0 |

**Rapid P-Index Screening Tool Table**

| Field ID: | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Any amount of manure or fertilizer is ***un**incorporated* | | | | | | | | | | | | |
| More than 100 lbs of $P_2O_5$/ac/yr *incorporated* (manure and/or fertilizer) | | | | | | | | | | | | |
| Soil test P is > 65ppm (Olsen) and soil loss is > 3 t/ac/yr | | | | | | | | | | | | |
| Soil test P is > 65ppm (Olsen) and drainage is poor | | | | | | | | | | | | |
| Erosion is > 8 t/ac/yr | | | | | | | | | | | | |
| Distance to water is < 100 ft and erosion is > 5 t/ac/yr | | | | | | | | | | | | |
| Distance to water is < 10 ft and erosion is > 3 t/ac/yr | | | | | | | | | | | | |

## Streambank Erosion Assessment Form

***For detailed procedures on completing this worksheet, please see page 110***

<table>
<tr><td colspan="2">Field ID:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">GPS:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Date:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Prepared By:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Field Conditions (e.g. weather):</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Length and Height of Eroding Bank (ft)</td><td>L:<br>H:</td><td>L:<br>H:</td><td>L:<br>H:</td><td>L:<br>H:</td><td>L:<br>H:</td></tr>
<tr><td colspan="2">Impacted by Livestock Access</td><td>Yes No</td><td>Yes No</td><td>Yes No</td><td>Yes No</td><td>Yes No</td></tr>
<tr><td colspan="2">Impacted by Equipment Access</td><td>Yes No</td><td>Yes No</td><td>Yes No</td><td>Yes No</td><td>Yes No</td></tr>
<tr><td rowspan="2">Riparian Cover Type</td><td>Perennial Cover</td><td>Woody<br>Grass</td><td>Woody<br>Grass</td><td>Woody<br>Grass</td><td>Woody<br>Grass</td><td>Woody<br>Grass</td></tr>
<tr><td>Managed Land Uses Within 10 ft of water body</td><td>Road<br>Homestead<br>Crop<br>Grazed<br>Livestock heavy use area</td><td>Road<br>Homestead<br>Crop<br>Grazed<br>Livestock heavy use area</td><td>Road<br>Homestead<br>Crop<br>Grazed<br>Livestock heavy use area</td><td>Road<br>Homestead<br>Crop<br>Grazed<br>Livestock heavy use area</td><td>Road<br>Homestead<br>Crop<br>Grazed<br>Livestock heavy use area</td></tr>
<tr><td colspan="2">Riparian Perennial Cover Quality<table><tr><th></th><th>Woody</th><th>Grass</th></tr><tr><td>Excellent</td><td></td><td>Dense, Deep-rooted</td></tr><tr><td>Good</td><td>Dense, full canopy</td><td>> 50% deep-rooted</td></tr><tr><td>Fair</td><td>> 50% canopy</td><td>< 50% deep-rooted, > 50% shallow</td></tr><tr><td>Poor</td><td>< 50% canopy</td><td>< 50%</td></tr></table></td><td>Excellent<br>Good<br>Fair<br>Poor</td><td>Excellent<br>Good<br>Fair<br>Poor</td><td>Excellent<br>Good<br>Fair<br>Poor</td><td>Excellent<br>Good<br>Fair<br>Poor</td><td>Excellent<br>Good<br>Fair<br>Poor</td></tr>
<tr><td colspan="2">Riparian Perennial Cover Buffer Width (ft)</td><td>30 ft<br>10 – 30 ft<br>< 10 ft</td><td>30 ft<br>10 – 30 ft<br>< 10 ft</td><td>30 ft<br>10 – 30 ft<br>< 10 ft</td><td>30 ft<br>10 – 30 ft<br>< 10 ft</td><td>30 ft<br>10 – 30 ft<br>< 10 ft</td></tr>
</table>

**Note the type of erosion indicators observed (exposed escarpment, exposed tree roots, slumped debris at the toe, etc.) and other erosion concerns:**

| | |
|---|---|
| **Field ID:** ________ | |
| **Field ID:** ________ | |
| **Field ID:** ________ | |
| **Field ID:** ________ | |
| **Field ID:** ________ | |

## Adapted TN-99 Protocol

*The following text was adapted from the Stream Visual Assessment Protocol produced by the USDA NRCS's National Water and Climate Center (NWCC) (USDA NRCS, 1998). This assessment protocol is also referred to as TN-99. The text below provides tables with ranking criteria for completing the TN-99 form. Additional background information is also included for each parameter.*

### Channel Condition

| | | | |
|---|---|---|---|
| **Natural channel; no structures, dikes. No evidence of down-cutting or excessive lateral cutting.** | **Evidence of past channel alteration but with substantial recovery of channel banks. Any dikes or levies are set back to provide access to flood plain.** | **Altered channel; <50% of reach with riprap and/or channelization. Excess aggradation; braided channel. Dikes or levees restrict access to flood plain.** | **Channel is actively downcutting or widening. >50% of the reach with riprap or channelization. Dikes or levies prevent access to the flood plain.** |
| **10** | **7** | **3** | **1** |

Stream meandering generally increases as the gradient of the surrounding valley decreases. Often, development in the area results in changes to this meandering pattern and the flow of a stream. These changes in turn can affect the natural stream processes, such as sediment transport.

Some stream channel modifications have more impact on stream health than others. For example, channelization and damming affect a stream more than the presence of pilings or other supports for road crossings. Active downcutting and excessive lateral cutting result in serious impairments to stream functions. Both conditions are indicative of an unstable stream channel.

Extensively bank armoring channels to stop lateral cutting usually leads to more problems (especially downstream). Often banks can be stabilized by using a series of structures (e.g., barbs, groins, jetties, deflectors, weirs, vortex weirs) that reduce water velocity, deflect currents, or act as gradient controls. These structures are used in conjunction with large woody debris and woody vegetation plantings.

***What to look for:*** Signs of channelization or straightening of the stream might include an unnaturally straight section of the stream, high banks, dikes or berms, lack of flow diversity (e.g., few point bars and deep pools), and uniform-sized bed materials (e.g., all cobbles where there should be mixes of gravel and cobble). In newly channelized reaches, vegetation might be missing or appear very different from the vegetation in unchannelized reaches (different species, not as well developed). Older channelized reaches might also have little or no vegetation or have grasses instead of woody vegetation. Drop structures (such as check dams), irrigation diversions, culverts, bridge abutments, and riprap also indicate changes to the stream channel.

Indicators of downcutting in the stream channel include nickpoints associated with headcuts in the stream bottom and exposure of cultural features, such as pipelines that initially were buried under the stream or tile lines extending far out into the ditch. Other examples include exposed footings in bridges and culvert outlets that are higher than the water surface during low flows. A typical indicator of incision is a lack of sediment depositional features, such as regularly-spaced point bars. A low vertical scarp at the toe of the streambank might indicate downcutting, especially if the scarp occurs on the inside of a meander. Another visual indicator of current or past downcutting is high streambanks with woody vegetation growing far below the top of the bank. (As a channel incises the bankfull flow line moves downward within the former bankfull channel.) Excessive bank erosion is indicated by raw banks in areas of the stream where such bank conditions would not normally be found, such as straight sections between meanders or on the inside of curves.

## Hydrologic Alteration

| | | | |
|---|---|---|---|
| **Access to the flood plain, bank height compared to stream bankfull height (BH/BFH) ratio in the range of 1 : 1, up to 1 : 1.2. Or No visible evidence of channel straightening, drainage pipes entering the channel, or urban conveyance alteration. Or Downstream culverts have no or little sedimentation and are at grade on both sides.** | **Access to the flood plain, BH/BFH ratio in the range of 1 : 1.2 up to 1 : 1.5. Or Occasional drainage features apparent, straightening less than 20% of reach, few inlet pipes. Or Downstream culverts have little sedimentation and are at grade on both sides.** | **Access to the flood plain, BH/BFH ratio in the range of 1 : 1.5 up to 1 : 2. Or Frequent drainage features apparent, straightening less than 60% of reach, inlet pipes common. Or Downstream culverts have large sediment deposits or are not at grade on downstream side.** | **Access to the flood plain, BH/BFH ratio in the range of 1 : > 2. Or Drainage is altered; waterbody is a ditch or straightened for more than 60% of reach, presence of inlet pipes substantial. Or Downstream culverts have large sediment deposits or are not at grade on downstream side, > 1 foot drop.** |
| **10** | **7** | **3** | **1** |

Bankfull flows, as well as flooding, are important to maintaining channel shape and function (e.g., sediment transport) and maintaining the physical habitat for animals and plants. High flows scour fine sediment to keep gravel areas clean for fish and other aquatic organisms. These flows also redistribute larger sediment, such as gravel, cobbles, and boulders, as well as large woody debris. The redistribution of these materials results in the formation of pool and riffle habitat that is important to stream biota.

Under natural conditions, the river channel and flood plain exist in dynamic equilibrium, having evolved in the present climatic regime and geomorphic setting. The relationship between the water and sediment forms the basis for the dynamic equilibrium that maintains the form and function of the river channel. The energy of the river (water velocity and depth) should be in balance with the bedload (volume and particle size of the sediment).

Changes in the flow regime will alter the balance between water and sediment. If a river is not incised and has access to its flood plain, a decrease in the frequency of bankfull flows and out-of- bank flows will decrease the river's ability to transport sediment. This can result in excess sediment deposition, channel widening and swallowing, and, ultimately, *braiding* of the channel. Rosgen (1996) defines braiding as a stream with three or more smaller channels. These smaller channels are extremely unstable, rarely have woody vegetation along their banks, and provide poor habitat for stream biota. A *split channel*, however, has two or more smaller channels (called side channels) that usually are very stable, have woody vegetation along their banks, and provide excellent habitat. Conversely, an increase in flood flows or the confinement of the river away from its flood plain (from either incision or levees) increases the energy available to transport sediment and can result in bank and channel erosion.

Changes in the low flow or baseflow of a stream also can affect stream conditions. If the low-flow rate decreases, a smaller portion of the channel will be suitable for aquatic organisms. The low flow or baseflow during the dry periods of summer or fall usually comes from groundwater entering the stream through the stream banks and bottom. Water withdrawals for irrigation or industry and dam placement often disrupt the normal low-flow pattern. Baseflow also can be affected by water management practices and land use within the watershed. Less precipitation infiltration or excessive drainage will reduce baseflow and increase the frequency and severity of high-flow events. For example, urbanization increases runoff, which can reduce low flows and increase the frequency of flooding. In some cases, flood frequency has increased to every year or more than once a year . Overgrazing and clearcutting can have similar, although typically less severe, effects.

***What to look for:*** Evidence of flooding includes high water marks (such as water lines), sediment deposits, or stream debris. These should be apparent on the banks, on the bankside trees or rocks, or on other structures (such as road pilings or culverts).

Excess sediment deposits and wide, shallow channels could indicate a loss of sediment transport capacity. The loss of transport capacity can result in a stream with three or more channels (braiding).

A landowner can provide information about the frequency of flooding and about summer low-flow conditions. A flood plain should be inundated during flows that equal or exceed the 1.5- to 2.0-year flow event (2 out of 3 years or every other year). It should be noted that water in an adjacent field does not necessarily indicate natural flooding. The water might have flowed overland from a low spot in the bank outside the assessment reach.

## Riparian Zone

| | | | | |
|---|---|---|---|---|
| **Natural vegetation extends at least two active channel widths on each side.** | **Natural vegetation extends one active channel width on each side.<br>Or<br>If less than one width, covers entire flood plain.** | **Natural vegetation extends half of the active channel width on each side.** | **Natural vegetation extends a third of the active channel width on each side.<br>Or<br>Vegetative root system moderately compromised.** | **Natural vegetation less than a third of the active channel width on each side.<br>Or<br>Lack of generation.<br>Or<br>Vegetative root system severely compromised.** |
| **10** | **8** | **5** | **3** | **1** |

The condition of the riparian zone is assessed by observing the width of the natural vegetation zone from the edge of the active channel out onto the flood plain. For the purposes of discussing this assessment, the word *natural* refers to plant communities with (1) all appropriate structural components and (2) species native to the site or introduced species that function similar to native species at reference sites.

A healthy riparian vegetation zone is one of the most important elements for maintaining a healthy stream ecosystem. The quality of the riparian zone correlates with the width and the complexity of the woody vegetation within it. A wider, more complex riparian zone typically is associated an enhanced functioning of the riparian zone. This zone:

- Reduces the amount of pollutants that reach the stream in surface runoff
- Helps control erosion
- Dissipates energy during flood events

The type, timing, intensity, and extent of alteration activities in riparian zones are critical for determining the impact of such activities. The functional value of a riparian area is reduced when riparian zones are narrow and/or riparian zones have roads, agricultural activities, residential or commercial structures, or substantial areas of bare soils. Concentrated flows also can compromise the filtering function of riparian zones. For proper functioning, no evidence of concentrated flows through the zone should be apparent. If concentrated flows are evident, such flows should be from land areas appropriately buffered with vegetated strips.

***What to look for:*** Compare the width of the riparian zone to the active channel width. The vegetation must be natural and consist of all structural components (aquatic plants, sedges or rushes, grasses, forbs, shrubs, understory trees, and overstory trees) appropriate for the area. One common problem is a lack of shrubs and understory trees. Another common problem is lack of regeneration. The presence of only mature vegetation and few seedlings indicates lack of regeneration. Incomplete plant communities should not be interpreted as natural conditions. In addition, there should be no evidence of concentrated flows that are not adequately buffered before entering the riparian zone.

Healthy riparian zones on both sides of the stream are important for the health of the entire system. If one side lacks protective vegetative cover, the entire reach of the stream will be affected. In doing the assessment, both sides of the stream should be examined. The assessor should note on the diagram which side of the stream has problems.

## Bank Stability

| | | | |
|---|---|---|---|
| **Banks are stable; banks are low (at elevation of active flood plain); 33% or more of eroding surface area of banks in outside bends is protected by roots that extend into baseflow elevations.** | **Moderately stable; banks are low (at elevation of active flood plain); less than 33% of eroding surface area of banks in outside bends is protected by roots that extend into the baseflow elevation.** | **Moderately unstable; banks may be low, but typically are high (flooding occurs 1 year out of five or less frequently); outside bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into stream annually, some slope failures apparent).** | **Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent.** |
| **10** | **7** | **3** | **1** |

Assessing the bank stability involves determining the existence of or the potential for detachment of soil from the upper and lower stream banks and its movement into the stream. Some bank erosion is normal in a healthy stream. Excessive bank erosion occurs where riparian zones are degraded or where the stream is unstable because of changes in hydrology, sediment load, or isolation from the flood plain.

High and steep banks are more susceptible to erosion or collapse. All outside bends of streams erode, so 50 percent of the banks in even a stable stream might be eroding. A healthy riparian corridor with a vegetated flood plain contributes to bank stability. To enhance stability, the roots of perennial grasses or woody vegetation typically should extend to the baseflow elevation of water in streams that have bank heights of 6 feet or less. Root masses help hold the bank soils together and physically protect the bank from scour during bankfull and flooding events.

Vegetation seldom becomes established below the elevation of the bankfull surface because of the frequency of inundation and the unstable bottom conditions as the stream moves its bedload.

Specific details about the vegetation and soil also should be noted when assessing bank stability. Although the presence of vegetation is important for bank stability, the type of vegetation also matters. For example, trees, shrubs, sedges, and rushes have the type of root masses capable of withstanding high streamflow events, while Kentucky bluegrass does not. Soil type at the surface and below the surface also influences bank stability. For example, banks with a thin soil cover over gravel or sand are more prone to collapse than banks with a deep soil layer

***What to look for:*** Signs of erosion include unvegetated stretches, exposed tree roots, or scalloped edges. Additional conditions that might lead to bank collapse include evidence of construction, vehicular, or animal paths near banks or row cropping and grazing areas leading directly to the water's edge.

## Water Appearance

***(to be ranked only during moderate to high flows)***

| | | | |
|---|---|---|---|
| **Very clear, or clear but tea-colored; objects visible at depths of 3 to 6 feet (or less if slightly colored).** | **Occasionally cloudy, especially after storm event; objects visible at depth 1.5 to 3 feet; might have slightly green color.** | **Considerable cloudiness most of the time; objects visible to depths of 0.5 to 1.5 feet.** | **Very turbid or muddy appearance; objects visible to depth of < 0.5 feet.** |
| **10** | **7** | **3** | **1** |

Assessing the water appearance involves comparing turbidity, color, and other visual characteristics with a healthy or reference stream. Turbidity primarily is caused by suspension of soil particles and organic matter in the water column. Streams often exhibit moderate turbidity after a storm event because of runoff carrying soil and organic particles or turbulence causing increased suspension of particles. One measure of turbidity is to determine the depth to which an object can be clearly seen.

Many factors can influence the color of the water in a stream. The water in some streams might be naturally tea-colored. This is particularly true in watersheds with extensive bog and wetland areas. Water that has slight nutrient enrichment might support algae communities, which causes the water to be a greenish color. Heavy nutrient loads in streams often result in thick algae coatings on rocks and other submerged objects. In degraded streams, floating algal mats, surface scum, or pollutants, such as dyes and oil, might be visible. These observations should be noted, but green scum or algal scum should not be considered in the ranking of this indicator

***What to look for:*** Water clarity is an obvious and easy feature to assess. This measure should be taken after a stream has had the opportunity to "settle" following a storm event.

Turbidity is easily assessed by observing the depth at which an object is visible. The deeper an object can be seen, the lower the amount of turbidity. This method for evaluating turbidity should only be used when the stream is sufficiently deep. For example, if the water is clear but only 1 foot deep, the stream should not be rated as if the object became obscured at a depth of 1 foot.

Water color also can be easily determined through quick visual observation. The color can be used as an indicator of other potential water quality issues. For example, a pea-green color indicates nutrient enrichment beyond what the stream can naturally absorb.

## Pools and Riffles

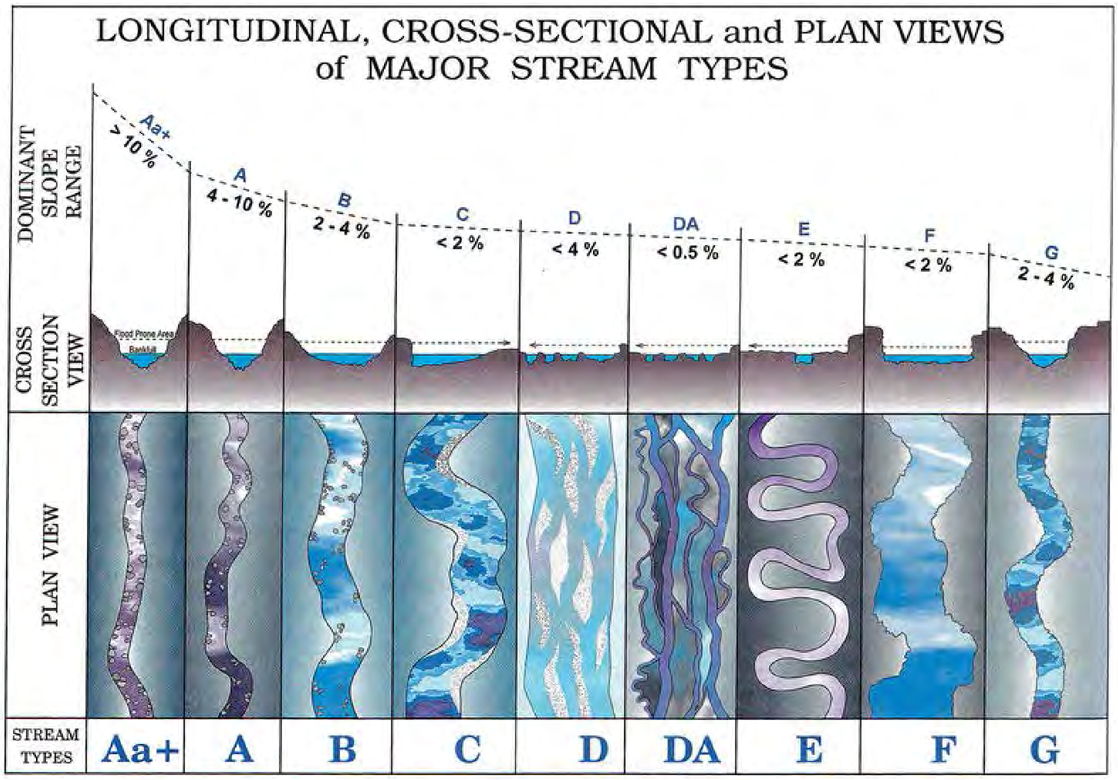
***(rank in natural streams only; combine upstream and downstream observations; record visible findings only if upstream and downstream length is longer than approximately 12 active channel widths (<u>about two reaches)</u> and flow regime is low)***

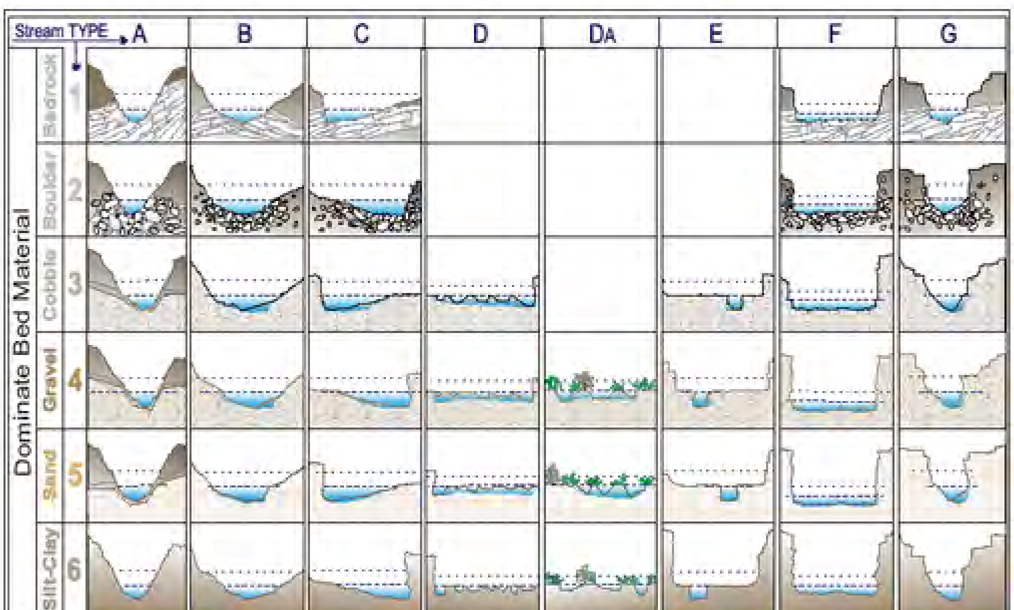
| | | | |
|---|---|---|---|
| **Deep and shallow pools abundant (~2-4 of each); obvious riffles downstream of pools. If near a pool, note if more than 30 percent of the pool bottom is obscure due to depth, or the pool is deeper than 1.6 to 2 times the prevailing depth.<br>Or<br>Bedrock or large boulders abundant (not a D, DA or E stream classification).** | **Pools are present but not as abundant (~1 of each). If near a pool, note if 10 to 30% of pool bottom is obscure due to depth, or the pool is less than 1.5 times the prevailing depth.<br>Or<br>Moderate pools and riffles apparent from road crossing.** | **Pool or riffle present, (not a run) but shallow. Five to 10% of the pool bottom is obscure due to depth, or the pools are less than 1.5 times the prevailing depth.<br>Or<br>Sparse pools and riffles visible.** | **Pools absent, or the entire bottom is discernible (not an E channel).** |
| **10** | **7** | **3** | **1** |

Pools, riffles, and runs are natural river features. The presence of pools and riffles are an important indicator of natural stream functions. A healthy stream has a mixture of shallow and deep pools. A pool is considered *deep* when it is 1.6 to 2 times deeper than the prevailing depth, while a *shallow* pool is less than 1.5 times deeper than the prevailing depth. Pools are considered abundant if each of the meander bends in the reach being assessed contains a deep pool. To determine the abundance of pools, the assessor should observe a sample length longer than 12 active channel widths. Generally, only 1 or 2 pools typically would form within a reach as long as 12 active channel widths. In low order, high gradient streams, pools are considered abundant if there is more than one pool every 4 channel widths.

***What to look for:*** Pool diversity and abundance typically are estimated by walking the stream or probing with a stick or length of rebar from the streambank. Deep pools should be on the outside of meander bends.

In shallow, clear streams a visual inspection might provide an accurate estimate of pools and riffles. Since this is a windshield survey, the assessor should ***only*** note the ***visual presence*** of riffles and pools. Do not measure depth by walking banks. Landowners have not granted permission for bank access. In deep streams or streams with low visibility, this assessment characteristic might be difficult to determine and should not be scored.




| Stream TYPE | A | B | C | D | DA | E | F | G |
|---|---|---|---|---|---|---|---|---|
| Entrchmnt | < 1.4 | 1.4 - 2.2 | > 2.2 | n/a | > 4.0 | > 2.2 | < 1.4 | < 1.4 |
| W/D Ratio | < 12 | > 12 | > 12 | > 40 | < 40 | < 12 | > 12 | < 12 |
| Sinuosity | 1 - 1.2 | > 1.2 | > 1.2 | n/a | variable | > 1.5 | > 1.2 | > 1.2 |
| $H_20$ Slope | .04-.099 | .02-.039 | < .02 | < .04 | <.005 | < .02 | < .02 | .02-.039 |

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## Riffle Embeddedness

***(use only if riffles are present)***

| Gravel or cobble particles are <20% embedded. | Gravel or cobble particles are 20-40% embedded. | Gravel or cobble particles are 40-60 % embedded. | Riffle is completely embedded. |
|---|---|---|---|
| 10 | 7 | 3 | 1 |

***Do not assess this element unless riffles are present or they are a natural feature that should be present. Sand substrates are not expected to have riffles.***

Riffles are areas where the water is breaking over rocks or other debris causing surface agitation. Such areas typically are located downstream of a pool. This element is sensitive to regional differences and should be related to reference conditions.

Riffles are critical for maintaining high species diversity and abundance of insects for most streams. Riffles also serve as spawning and feeding grounds for some fish species. For this assessment, embeddedness measures the degree to which gravel and cobble substrate are surrounded by fine sediments (sands silts and clays). Embeddedness directly relates to the balance between the stream energy and sediment load. Substantial embeddedness is an indicator of too much sediment.

***What to look for:*** If the riffle can be seen clearly from the road, the score should be based on the depth to which gravel and cobble objects are buried by sediment. [This assessment usually is conducted by picking up particles of gravel or cobble with fingertips at the fine sediment layer. The particles are pulled out of the bed and the assessor estimates the percent of the particle that was buried. Some streams have been so smothered by fine sediment that the original stream bottom is not visible. The test for complete burial of a streambed is conducted by probing with a length of rebar.] For a windshield survey, riffles will be assessed by visually estimating the top radius of the gravel or cobble stone against the amount of sands, silts and clays surrounding it. Riffles can be limited to a few rock widths wide, and the measurement should be taken between the first row of rocks looking upstream.

## Minnesota Rapid Phosphorus Index Protocol

### Overview

A modified version of the Minnesota Rapid Phosphorus Index (Rapid P-Index) will be used in this project. The Rapid P-Index was created by the University of Minnesota to identify indicators of phosphorus runoff risk (University of Minnesota, 2006). For this project, the Rapid P-Index will be used to indicate the type of BMPs to emphasize during conservation implementation discussions with producers. The BMP categories are identified based on the risk factors included in the Rapid P-Index. When facing multiple risk factors and/or situations where mitigation measures are not feasible or sufficient, the full Minnesota Phosphorus Index (P Index) is recommended. The P Index tool provides additional information regarding the phosphorus runoff risk, as well as comparison scenarios that provide evaluations of the potential management options for water quality improvements.

The Rapid P-Index was designed to be used as a preliminary screening tool prior to implementing the full Minnesota Phosphorus Index. This rapid assessment allows technicians to quickly evaluate the risk of phosphorus runoff from agricultural sites. Sites that are identified as posing the lowest risk of phosphorus runoff can then be excluded from further assessment. This screening saves time and resources that otherwise would be spent conducting more detailed evaluations of low-priority areas.

The Rapid P-Index was designed to allow the assessor to select from one of three screening tools. These three separate tools each reflect a level of sensitivity. In this case, "sensitivity" refers to the likelihood of the tool to identify the site as "high risk" for phosphorus runoff and does not refer to potential impacts to the water body. Having multiple tools with different levels of sensitivity provides assessors with options for different evaluation thresholds that trigger performing a full P Index. The high sensitivity tool will identify the largest number of sites while the low sensitivity tool will identify the least. Identifying a large number of sites might be over-inclusive but is less likely to accidentally omit a high-priority site. Identifying a smaller number of sites might leave out a high-priority site but will reduce the amount of resources required to conduct additional evaluations.

For this project, the team decided to use the "high sensitivity" tool. This tool is designed to identify sites that are likely to have a P Index score greater than 2. This score indicates the site has a relatively high risk of phosphorus runoff and associated impacts on highly sensitive surface waters. This threshold is also appropriate if the intent is to eliminate most phosphorus inputs. The index value can range from zero to levels above a value of 6 if there is a very high risk of a field being a source of phosphorus pollution to a nearby body of water.

## Procedure

1. **Compile data** – Gather the information listed to complete the **Rapid P-Index worksheet** for each field:
    - Manure and fertilizer application rates
    - Whether manure/fertilizer is incorporated or unincorporated
    - Erosion rate
    - Soil test P
    - Year of most recent soil test P
    - Distance to water
    - Internal drainage (whether drainage is good or slow)

2. **Note recommendations regarding soil test P**
    - The following criteria can be used, along with professional judgment, to generate a recommendation to gather STP data from a specific site:
        - STP data has never been taken
        - STP information is more than 3 years old
        - Manure is being applied to a field exhibiting substantial erosion (the lack of STP information is more of a concern on these fields)
    - If the field technician concludes that conducting a soil test is recommended, an "X" should be placed in the appropriate box on the Rapid P-Index Worksheet (the last row of the worksheet addresses soil test P recommendations).
    - The field technician also can note in the worksheet any additional factors that should be considered regarding STP (i.e. the producer seemed especially resistant to the idea of a soil test).

3. **Perform the screening** – Fill out the **Screening Tool Table** based on the information collected in the **Rapid P-Index Worksheet**. Place a checkmark in each box that corresponds to a characteristic exhibited by the assessed field.

4. **Identify potential BMPs/additional assessment needs**
    - Conduct additional analysis if substantial erosion is occurring, manure is being applied, and no soil test P is available
    - If the Rapid P-Index resulted in a "hit" on any of the checklist categories, determine if a straightforward mitigation measure is possible (see Table 2 for possible BMP options based on the P risk indicator)
    - Assess if BMP combinations will address P risk
    - Conduct full P-Index on sites where more detailed assessments are needed and/or straightforward BMPs will not address the identified issues

**Table 2. Potential BMPs corresponding to indicators of phosphorus release risk.**

| Potential BMP | P Risk Indicator |
|---|---|
| **Nutrient Incorporation** | **Any amount** of manure or fertilizer is ***un**incorporated* |
| **Nutrient Management** | **More than 100 lbs** of $P_2O_5$/ac/yr *incorporated (*manure and/or fertilizer) |
| **Phosphorus Agronomic Rates** | Soil test P is > 65 ppm (Olsen) and soil loss is > 3 t/ac/yr |
| | Soil test P is > 65 ppm (Olsen) and drainage is poor |
| **Erosion Control** | Erosion is **> 8 t/ac/yr** |
| | Distance to water is **< 100 ft** and erosion is **> 5 t/ac/yr** |
| | Distance to water is **< 10 ft** and erosion is **> 3 t/ac/yr** |

## Streambank Erosion Assessment Protocol

### Overview

A qualitative assessment will be used to document areas where streambank erosion is occurring. The following form should be completed when a field technician observes signs of bank erosion. These signs include the presence of an exposed escarpment, soil cracking near the bank, exposed tree roots and/or obvious slumped debris at the toe, or other signs. Where erosion is present, the technician should measure the length and height of the eroding bank. A qualitative judgment regarding the vegetative cover also should be indicated, along with impacts from livestock or equipment access.

### Procedure

1. **Identify indicators of streambank erosion** – This streambank assessment only needs to be performed on sites where indicators of streambank erosion are present.
2. **Compile data** – Gather the information listed to complete the **streambank erosion worksheet** for each location with indicators of streambank erosion.
    - Length and height of eroding bank
    - Impacted by livestock access
    - Impacted by equipment access
    - Riparian cover type
        - Perennial cover, or
        - Managed land uses within 10 feet of water body
    - Riparian perennial cover quality (N/A if managed land uses are within 10 feet of water body)
    - Riparian perennial cover buffer width (N/A if managed land uses are within 10 feet of water body)
3. **Note the type of erosion indicators observed and other erosion concerns**

**Examples of Different Bank Conditions**

**Figure A. Tributary, Kalamazoo River watershed**

**Figure A depicts a small stable stream setting.**

**Completing a streambank erosion inventory form at this site would not be necessary. This stream illustrates well-established perennial vegetative cover. The buffer width is > 30 feet.**

**Figure B. Kalamazoo River**

**Figure B depicts a site with noticeable bank erosion.**

**Exposed roots indicate active erosion. Slumped soils indicate undercutting typical for erosion induced by channel hydrology. This stream has poor perennial vegetative cover (shallow grass roots and sparse woody vegetation density). The buffer width is < 10 feet.**

**For this site, the evaluation would measure the bank height using the average dimension along the bank that stretches from submerged toe of the slope to grassed soil horizon.**

**Figure C. Rouge River**

**Figure C depicts a site with outside bend bank erosion.**

**For this site, a streambank erosion assessment would be conducted. The erosion illustrated here is typical of erosion induced by channel hydrology. Perennial vegetative cover is poor. The buffer width is < 10 feet.**

**This site is an interesting example of bank erosion. Grass/woody roots extend to the waterline, but are so few and shallow that they provide minimal bank protection. Also, this site is downstream from a dam (not pictured). Impoundments usually are associated with atypically high erosion due to increased sediment transport capacity as a result of the low sediment concentrations in the water released from the impoundment.**

**Figure D. Hagar Creek, Ottawa County, MI**

**Figure D depicts a site with active erosion on at least three bank locations.**

**The tree root balls shown slumping into the stream (middle of the photo) is typical of erosion inducted by channel hydrology. The near bank to the left has poor woody vegetative cover and poor grass understory cover. Buffer width is < 10 feet.**

(Photos and some narrative content were adapted from MI DEQ Standard Operating Procedure – Assessing bank erosion potential using Rosgen's Bank Erosion Hazard Index (BEHI). Available at: http://search.michigan.gov/search?affiliate=mi-deq&query=stream%20bank%20erosion )

**Full Minnesota Phosphorus Index**

*The full Minnesota Phosphorus Index (P Index) provides managers with an estimate the risk of phosphorus loading from an agricultural field to surface water. This tool enables the evaluation of potential options to reduce the risk of phosphorus loss. The Data Collection Sheet for the P Index can be found at the below web address:*

*http://www.mnpi.umn.edu/downloadfiles/DataCollectionSheet.pdf*

*This link provides both a data form and a one-page instruction sheet describing and defining the form fields. This information format follows the input requirements for the Minnesota Phosphorus Index tool.*

*For more information about the P Index in general, please see the following website: http://www.mnpi.umn.edu/ This link also will provide you with information on downloading the P Index computer tool.*

Instructions
**Minnesota Phosphorus Index**
Data Collection Sheet

By completing this form, you will have all the information needed to run the Minnesota Phosphorus Index.

**Part 1: Name.** Identify the field to be evaluated.

**Part 2: Field characteristics.**

2A..**Sediment traps.** Check the appropriate boxes if any of these structures intercept runoff from the field.

2B. **Depressions.** Check one of these boxes if the field has natural depressions, such as are found in the Prairie Pothole region of Minnesota.

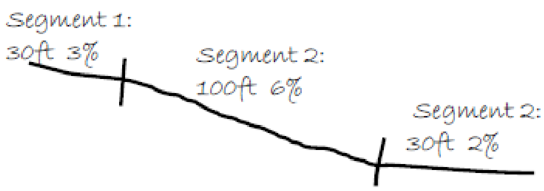
2C. **General tillage orientation.** Indicate the direction of the last field operation before winter.

2D. **Distance to water.** Indicate the distance from the edge of the field to the nearest surface water, which may be a drainage ditch, stream, wetland, or lake.

2E. **Drainage.** Note whether the field has subsurface tile drainage.

**Part 3: Critical slope.**

This information will be used for the RUSLE2 sediment delivery calculation. Identify the critical slope within the field that is most likely to lose phosphorus. This may be the steepest portion of the field or the slope closest to surface water. Define the slope as beginning where upland water flow originates and ending at the edge of the field. Note that the slope may have multiple segments of different gradients, and it may be longer than the simple slope that would be used to estimate soil loss. Here is an example of a slope with three segments:




If you don't know the name of the soil series, note three characteristics: the **soil texture** (coarse or fine), whether it is **calcareous** (pH>7.3), and the **Soil Hydrologic Group:** A, B, C, or D. (A=very high infiltration and low runoff, D=very low infiltration and high runoff).

**Part 4: Soil tests.**

Only one test is needed –the most recent test within 3 years. If you provide multiple tests for a single year, the program will average them.

**Part 5: Management.**

5A. Fill in one column of the table for each crop year of the rotation. The crop year begins after harvest in the fall. Select from the choices in italics.

For crop, indicate a typical yield.

For manure and fertilizer application methods, select from the following:

- St pt — Broadcast and incorporated within a week with a straight point chisel plow
- Twist — Broadcast and incorporated within a week with a twisted point chisel plow
- Sweep — Broadcast and incorporated within a week with a chisel plow with sweeps
- Disk-S — Broadcast and incorporated within a week with a small disk
- Disk-L — Broadcast and incorporated within a week with a large disk
- MB — Broadcast and incorporated within a week with a moldboard plow
- Inj — Injected
- Uninc — Broadcast and unincorporated

For residue, indicate the % residue cover after planting.

5B. **Alternative management systems:** The Minnesota P Index allows you to easily make changes to a management system and compare results to see if the risk of P loss goes up or down significantly. In this space, note any changes that should be examined, such as alternative tillage practices, crop rotations, or manure applications.

## Minnesota Phosphorus Index
Data Collection Sheet

**Part 1: Name.** County ______________ Farm name ____________________________ Field name ___________________

**Part 2: Field characteristics.**

2A. Sediment traps
- ❑ Impoundment with runoff storage
- ❑ Water and sediment control basin
- ❑ Buffers or filter strip
- ❑ Terraces

2B. Depressions and Inlets.
- ❑ Depressions without inlets
- ❑ Depressions with standard surface tile inlets
- ❑ Depressions with gravel/rock or buffered inlets

Percent of field area contributing runoff to depressions: ______________%

2C. General tillage orientation:
- ❑ Up/down slope
- ❑ Across the slope (or nearly flat land)

2D. Distance from field edge to surface water: ______ft

2E. Is artificial, subsurface drainage present?
- ❑ Yes
- ❑ No

**Part 3: Critical slope.**

| Slope segment | Gradient (%) | Length (ft) | Soil series name (or texture and hydrologic group) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

**Part 4: Soil tests.**

| Sampling date | Phosphorus (ppm) | Olsen, Bray, or Mehlich? | %OM |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**Part 5: Management.**

5A. Crop rotation

| | | Year of rotation (use as many columns as needed) 1st | 2nd | 3rd | 4th |
|---|---|---|---|---|---|
| Manure P | Date of appl.:<br>Manure appl rate:<br>P test of manure:<br>Method of appl./incorp: | | | | |
| Fertilizer P | Date of appl.:<br>Amount:<br>Method of appl./incorp: | | | | |
| Previous fall tillage | *None, Ridge, Lt Disk, Hvy Disk, Chisel, Strip, MB* | | | | |
| Fall anhyd. ammoni | *Yes or No* | | | | |
| Spring tillage | *None, Strip, Ridge, Disk, fcult, Chisel, MB* | | | | |
| Crop and yield | | | | | |
| Residue after plant | *<5%, 5-20%, >20%* | | | | |

5B. Alternative management practices:

# Case Studies

## Case Studies

Accurate delineation for modeling and controlling nonpoint source pollution requires identification of the mechanisms for generating runoff, the pathways for delivery and quantification of the relative pollutant loadings, as well as the risk for erosion. Field testing and case study summaries of the desktop analyses and site evaluation protocols from various agroecoregions across the state have been provided to enhance the transfer of the technologies to conservation districts across the state.

Watershed practitioners may be using a number of different tools and ancillary sources of data for pre-planning, targeting and project work besides the resources described in the previous sections of this report, including:

- Ortho Imagery
- Feedlots
- Impaired waters coverage
- Water monitoring data
- Endangered species data
- Drinking Water Supply Management Area (DWSMA) delineations
- RUSLE2
- MinnFARM
- SWAT
- HSPF
- Crop productivity indices
- Soil fertility
- BMP inventories
- Minnesota restorable wetlands
- Karst features

The PMZ case studies discussed in this section demonstrate how the available tools and data are adaptable to a wide range of conditions provided the user has a good knowledge of conditions. When trying to solve the complex issues involved with impaired waters it is important to examine all the attributes of the study area: hydrology, soils, land use and people. These assessments are a vital part of that process.

Each case study is organized either by location/watershed or integrated application, and they typically describe the agroecoregion, landscape and scale of the study area, known impairments, types of CSAs identified in both GIS and field, the type of field validation preformed, as well as observations and lessons learned, where appropriate.

## Agroecoregions

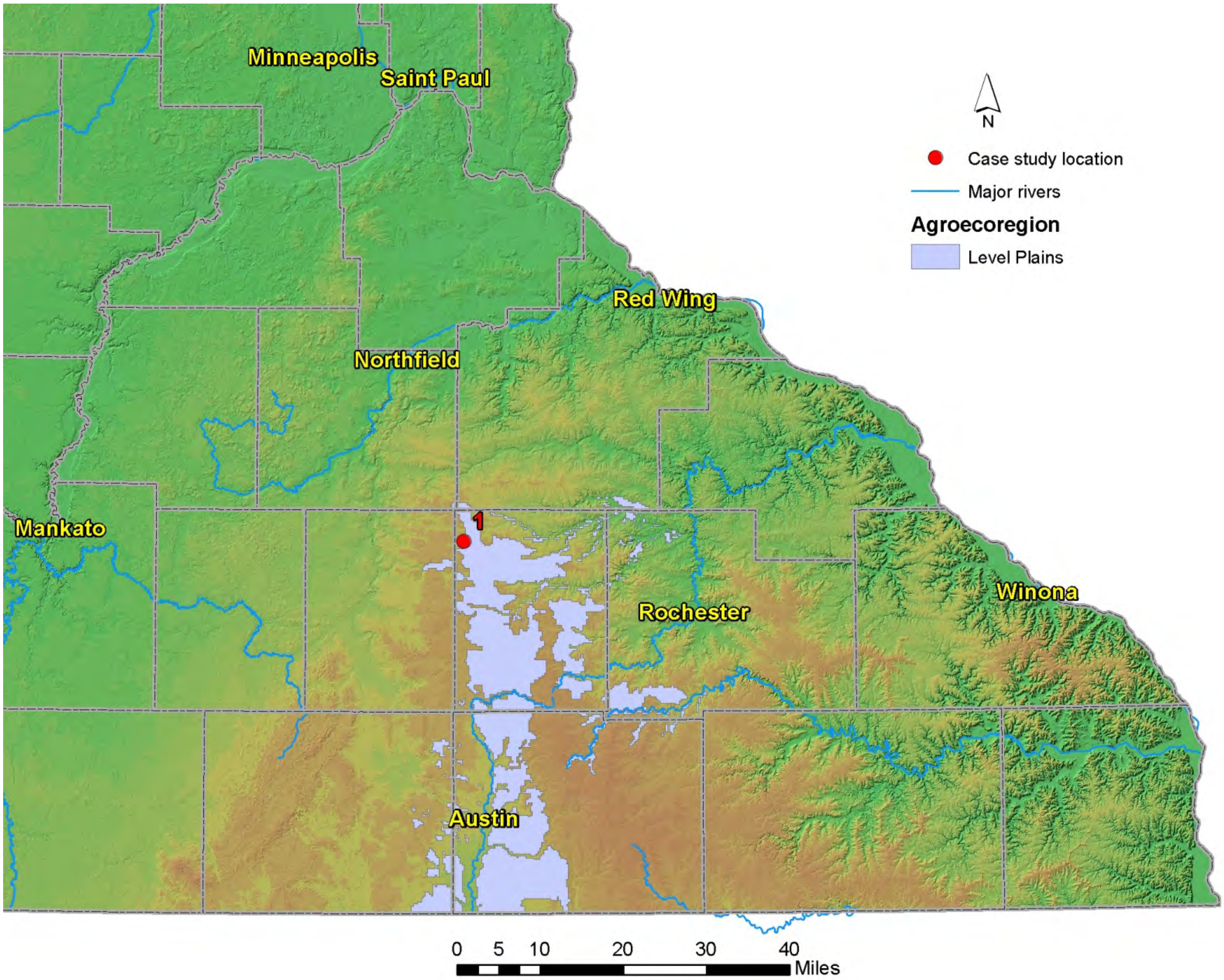
An agroecoregion is a concept stemming from an extensive multi-disciplined research project conducted at the University of Minnesota. The idea of agroecoregions was created to define regions with relatively homogenous physical characteristics in agriculturally impaired Minnesota watersheds. Minnesota has 39 distinct agroecoregions which are landscape units that share relatively uniform crop productivity, climate, geologic parent material, soil drainage, and slope steepness. The researchers found that the variance in soil erosion, stream biotic habitat, stream water quality, lake water quality, and ground water quality was smaller within agroecoregion boundaries than within watershed boundaries, and that through linked biophysical and economic modeling, the economic costs of reducing phosphorus loads to streams were lower when BMPs were targeted to specific agroecoregions compared with an untargeted strategy involving entire watersheds (Hatch et. al., 2001). Thus agroecoregions provide a nice complement to CSA identification and remediation.

The following site provides a link to download the Minnesota agroecoregion layer as a polygon feature class within and outside a file geodatabase (either can be directly accessed within ArcGIS software): http://devel.gisdata.mn.gov/da_DK/dataset/agri-agroecoregions/resource/f53059b9-8339-4528-a8b4-b291551062de

The Zumbro River watershed was the focus of a study involving digital terrain analysis and CSA identification; several locations in the watershed were visited between 2012 and 2013 and excerpts from those findings are highlighted in the first three agroecoregions and associated case studies described in the following sections.

### Level Plains

The Level Plains agroecoregion is located in Southeast MN (see next image) and composed of fine-textured, soils with row crop production on relatively flat to moderately steep topography without sinkholes. The majority of soils are poorly drained, while a significant portion is well drained. This agroecoregion has a very high density of intermittent streams and a moderate density of permanent streams. Water erosion potentials are high, while wind erosion potentials are low. Practices to control soil erosion by water and sediment delivery to streams are important. These include conservation tillage, and grassed filter strips along streams. Tile intakes at the base of steep slopes should be replaced with French drains or blind inlets (Olmsted[1]).



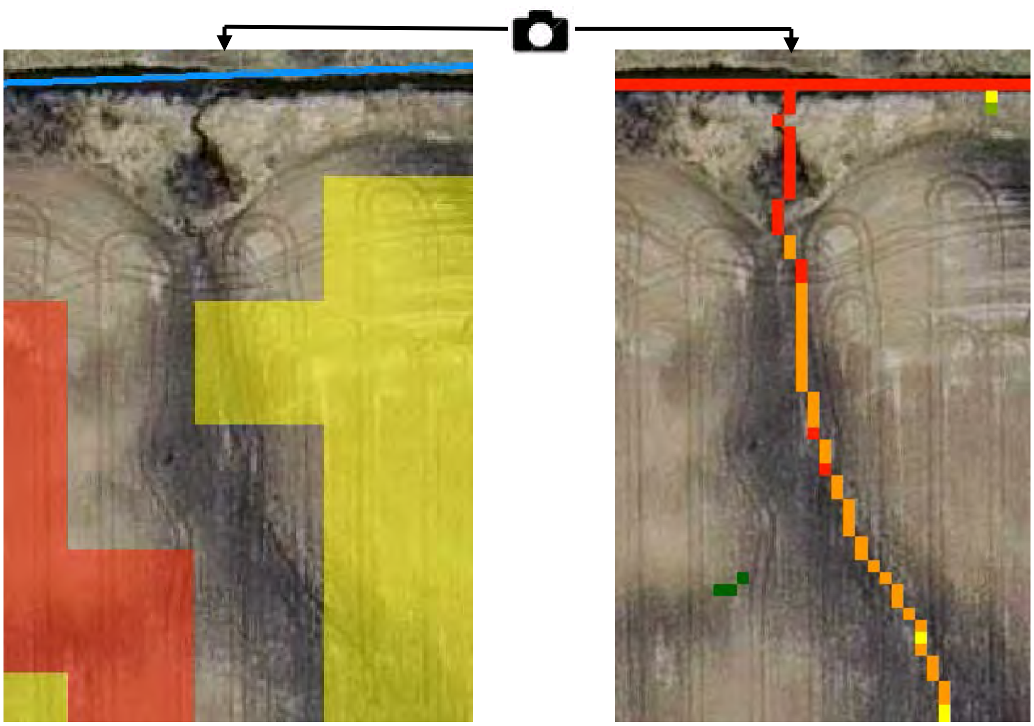

Case Study #1

Case study #1 is located in Dodge County, MN in the headwaters of the Middle Fork of the Zumbro River near West Concord, MN. A 1¼ mile long ditched stream section was walked on Nov. 18th, 2012.

November weather in 2012 as monitored at the Dodge County Municipal Airport had a mean temperature of 37°F and a total of only 0.19 inches of precipitation compared to a 30+ year average of 1.76 inches (NOAA archives). The region was considered to be in moderate drought at the time (droughtmonitor.unl.edu). The stream section walked has a turbidity impairment.

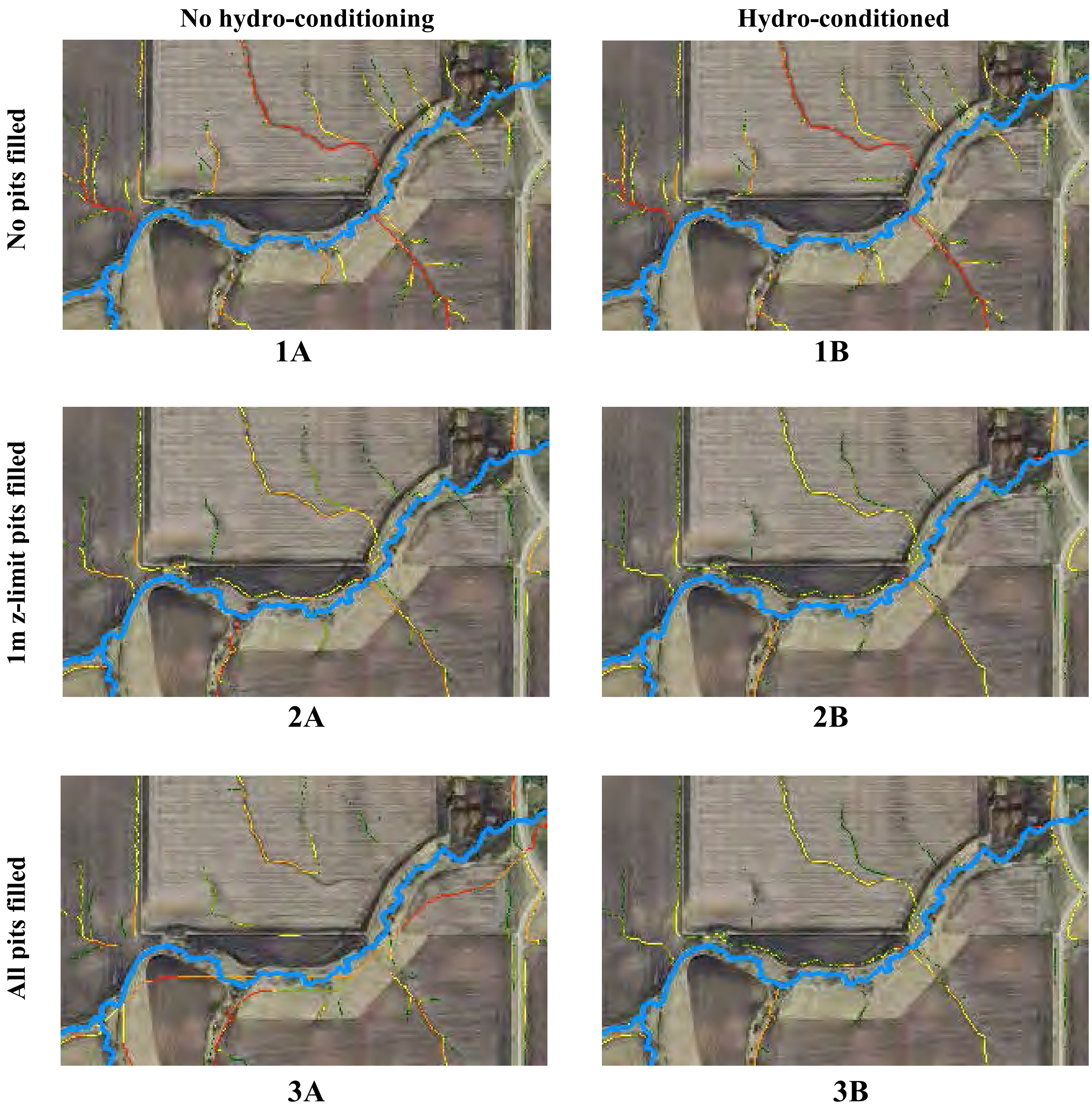
Several CSAs were identified in the field, nearly all of which were gullies and a few instances of bank slumping and tile outlet erosion. Length, width, and depth measurements were taken at each identified erosional feature.

The ephemeral gully shown in these images is entrenched starting approximately 185 yards from the pour point and drains an area of 43 acres with average slope of 3.9%. The bottom left image displays the top soil erosion risk raster values – the yellow corresponds to the top 3%, and red the top 1% within the HUC12 catchment. The bottom right image shows the SPI signature associated with the erosional feature, created using 1 meter pit fill z-limit. The picture on left was taken from the opposite (northern) bank looking south-southwest.



Observations and lessons learned: In ditched stream sections with steep, high walls, an SPI signature as short as one to two pixels (depending on threshold used) can often coincide with significant erosion in the field as compared to the same length signature along flat riparian areas. When using short SPI signatures to identify and rank potential CSAs, it is especially important to consider contributing area and soil erosion risk characteristics for each point.

Several SPI layers were calculated in the study area to show how both pit filling and hydro-conditioning affect signatures. The site shown in the following images was chosen for the presence of a large culvert road crossing and a high concentration of stream flow. Sites with those two characteristics tend to produce erroneous SPI signatures when pit filling without hydro-conditioning is used (**3A**). Note the signature that parallels the buffer just north of the stream, which doesn't exist in the non-pit filled images. Also note the signature that starts at top of images and either terminates at buffer (non-pit filled) or stream (pit-filled).




The above figures show SPI signatures calculated from a 3 meter DEM with varying degrees of pre-processing performed. All SPI signatures are from the 97.5th percentile within the extent shown (~136 acres). Figures in the left column were not hydro-conditioned, while figures in right column were – the DEM was hydro-conditioned by burning the stream (blue line) through the north-south oriented road crossing culvert in the top-right of image.

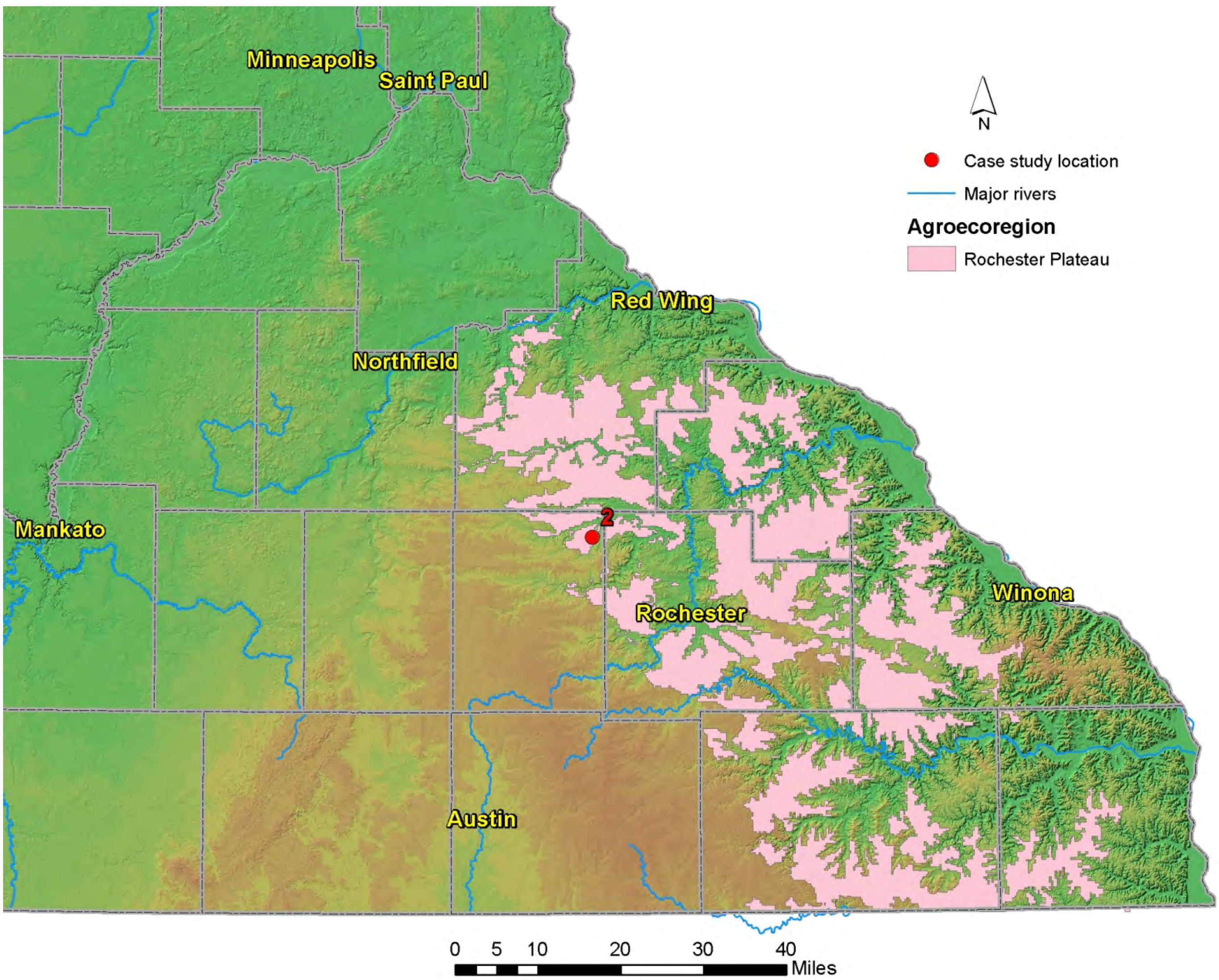
**1A & 1B –** Not pit filled. The results are essentially identical.

**2A & 2B** – Pit filled using a 1 meter z-limit. The displays are nearly identical with only slight color gradient variation between the two. Note the new signatures near the buffer just north of stream that didn't exist in **1A & 1B**. These additions can influence CSA predictions.

**3A & 3B** – Pit filled with no maximum z-limit, meaning all pits were completely filled. In this example, **2B** and **3B** are nearly identical. This is not always the case [see case study #5 – Steep Dryer Moraine]. Note the straight signature somewhat paralleling the stream in **3A**. This can be used to estimate where main channel flow will exist during flooding or culvert blockage. Caution should be used when identifying potential CSAs from those seemingly "erroneous" signatures.

## Rochester Plateau

The Rochester Plateau agroecoregion is located in Southeast MN and composed of well-drained, fine-textured loessial soils developed on moderate to steep slopes in karst with a high density of intermittent streams and sinkholes, and a mixture of row crop, livestock operations, and dairy production systems. Water erosion potentials are extreme, while wind erosion potentials are low. Stream water quality ranges from fair to poor. Phosphorus transport risks to surface waters are high to severe. Major resource concerns in this agroecoregion are soil erosion by water, cattle and hog operation management, nutrient management from manure and fertilizer, and rapid leaching or seepage of pollutants to ground water in areas with karst topography and sinkholes. Soil erosion should be controlled by any or all of the following practices where applicable: conservation tillage, contour farming, stripcropping, terracing, grassed waterways, and sediment detention basins. Riparian buffer strips are recommended along streams. Best management practices for cattle include livestock exclusion from streams, and practices to reduce feedlot runoff (Olmsted[1]).



Case Study #2

Case study #2 focuses on a small tributary to the Middle Fork of the Zumbro River in northeast Dodge County, MN approximately 5 miles from Pine Island, MN. The naturally meandering stream contains a Soil Conservation Service grade stabilization structure (shown below) that was constructed in 1967 for controlling gully erosion in the draw and was the site for several sedimentation surveys over the years. Several disjointed sections of the stream were field verified by walking along the stream corridor on October 15th, 2012, including the 1.2 mile section containing the pond.

**5 acre permanent pool surface area SCS Grade Stabilization Structure on un-named creek, Dodge Co., MN.**

October weather in 2012 as monitored at the Dodge County Municipal Airport had a mean temperature of 46°F and 1.28 inches of precipitation compared to an historical average of 2.24 inches. The region was considered to be in moderate drought at the time.

CSAs identified were mostly gullies along with some bank slumping and tile outlet erosion. Some areas were worsened by cattle grazing operations in and near the stream. Length, width, and depth measurements were taken at each identified erosional feature.

The gully shown in picture #1 near Berne, MN was the result of concentrated flow from a corrugated 6 in. drain tile outlet (picture #2), and further exacerbated by cattle livestock in and near stream. Forest canopy cover at the pour point reduced chance for vegetated filter establishment. The lower right image shows the SPI signature associated with this gully (all pits filled), which contains a lower average value compared to several surrounding signatures. The semi-transparent white pixels represent this HUC12's top 5% of values from the soil erosion risk raster [see Locate potential CSAs - Sub-catchment soil characteristics section].

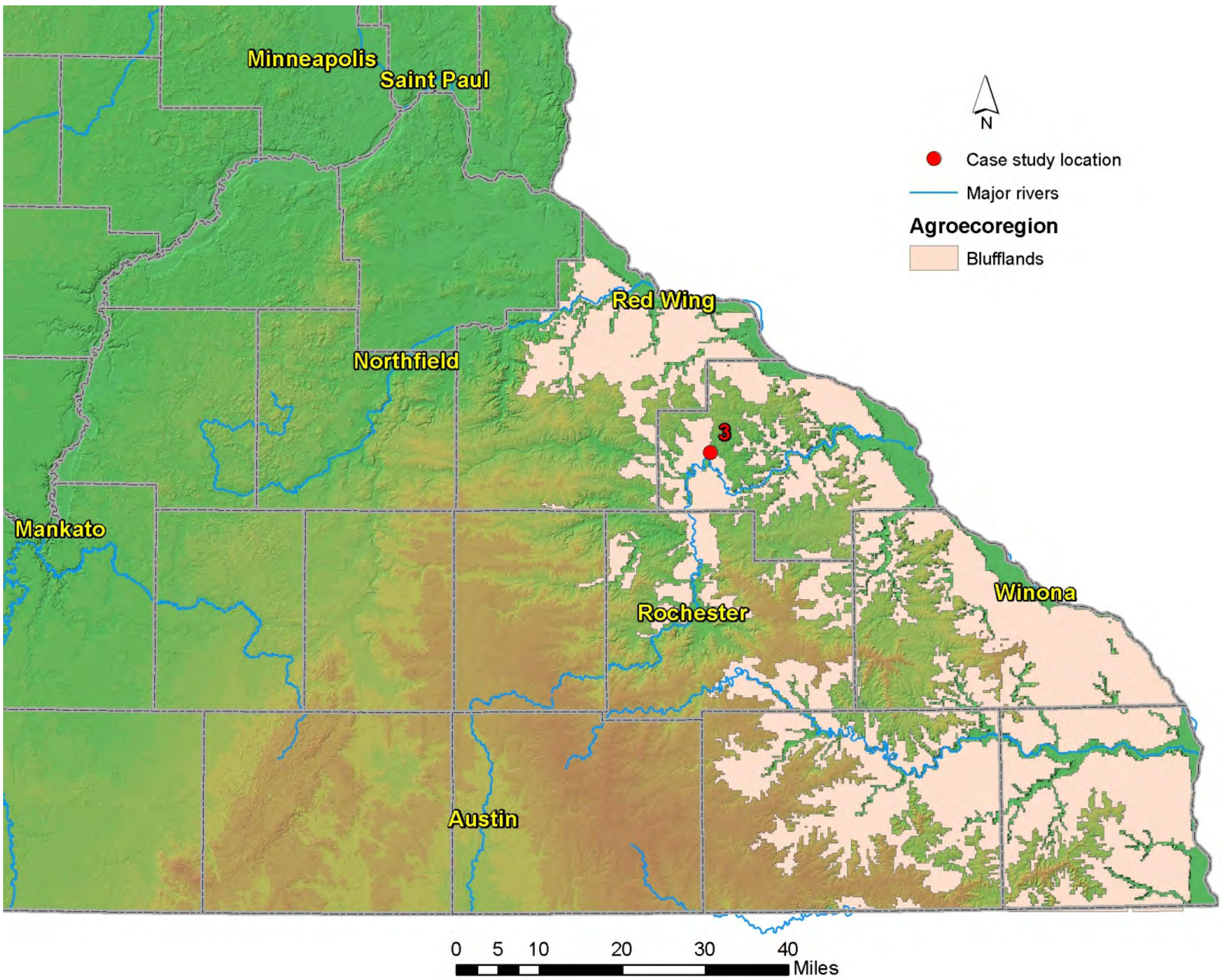

Observations and lessons learned: Most of the larger gullies near case study #2 flowed through riparian forestland where little underbrush was present and were formed from tile outlets located near the fluvial terrace.

Erosional features on the south side of the stabilization structure were expected to be verified in field due to the presence of multiple long SPI signatures, though none were located – possibly due to cattle exclusion in forested areas both north and south of the pond.


The image on left shows a long (~1/2 mile) SPI signature with several high SPI values following a forested ravine. Users would typically expect to see surface erosion associated with such an SPI, though a field visit showed very little erosion and soil deposition evident from the upslope tree line to the pour point due to a well maintained filter strip (circled in white).

## Blufflands

The Blufflands agroecoregion in SE MN has well drained, fine-textured soils on very steep to extremely steep slopes in karst topography. Sinkholes can occur near incised stream drainage networks. This agroecoregion has a very high density of intermittent streams and a moderate density of forested perennial stream networks. Water erosion potentials are extreme, while wind erosion potentials are low. The risk of phosphorus transport to surface waters is moderate to high. On steep lands, practices to control water erosion are important. These include avoiding row crops on steep lands, or if they must be grown on steep lands, using a combination of conservation tillage, strip-cropping, and terracing. Buffers, along with practices that provide stable conveyances of flow, should be provided for ravines and gullies (Olmsted[1]).



Case Study #3

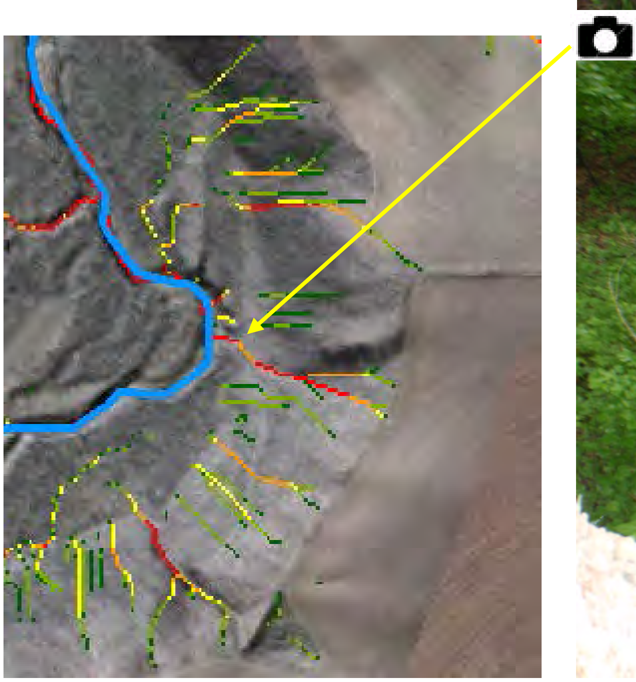
Cold Spring Brook is a designated trout stream in western Wabasha County and drains into the Zumbro River at Zumbro Falls, MN. The stream is located in the Bluffland agroecoregion where forested ravines are commonly found. Sedimentation from upland and in-stream sources have caused Cold Spring Brook to be the target of several in-stream trout habitat improvement and bank stabilization projects over the last several years, with Trout Unlimited funding and conducting much of the work.

Approximately five miles of Cold Spring Brook and its surrounding tributary stream corridors were walked in early to mid-June of 2013 for CSA field validation. The preceding winter at the Rochester International Airport (26 miles south of Zumbro Falls) recorded above average snowfall amounts totaling 73.1" from July 2012 to June 2013. The average annual snowfall for Rochester, MN is 48". The area also received record snowfalls in the first week of May, with Zumbro Falls reporting over 14 inches on May 2$^{nd}$ and 3$^{rd}$ (NOAA). The spring of that year was especially wet in Southeast MN, with April and May receiving precipitation well above average. April and May precipitation totals were 6.33" and 11.04" respectively, with average values of 3.24" and 3.63" respectively (as reported at the Rochester International Airport). Observations during the June field visits noted few crop fields around Zumbro Falls had worked fields due to very wet soils.

Several critical areas were identified in the field – ravines were the most commonly identified feature followed by edge of field gullies and bank erosion. Landowner attempts at remediating erosion were evident at many of the sites. The most common practice was rip-rap placement at head cuts/knick points to control gully erosion and felled trees in ravine channels to reduce flows. Length, width, and depth measurements were taken at each identified erosional feature.

Forested ravines with multiple branches are common in bluffland agroecoregions. Many of the ravine branches were actively advancing into upland fields (pictured). Hillshade layers can aid in identifying these ravines and existing conservation practices such as the grade stabilization structure shown (bottom right). The 98th percentile SPI threshold was found to best represent the flow paths during field verification of this bluffland agroecoregion. The SPI layer shown here was created using a 1 meter pit fill z-limit.

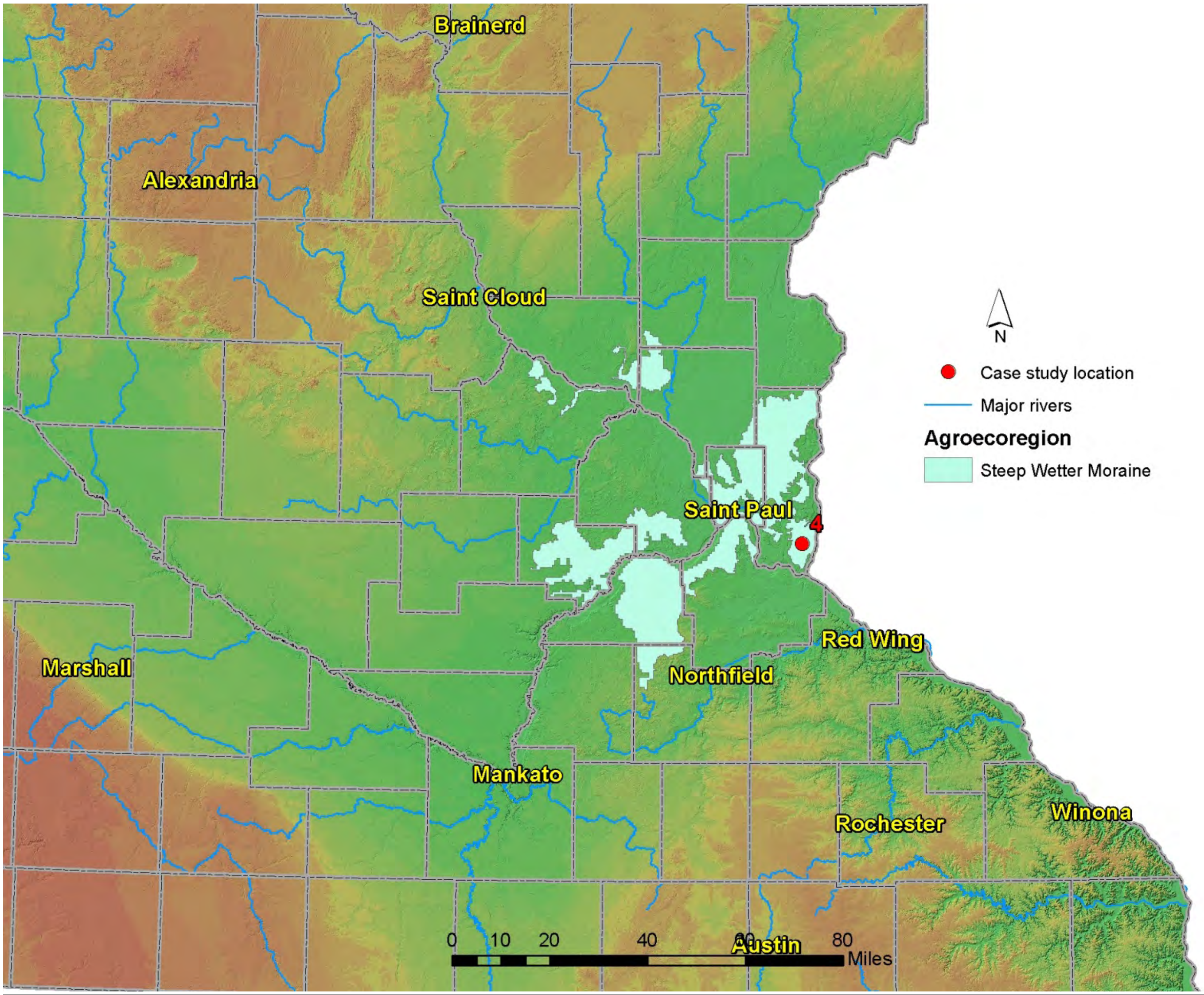
The image below shows a steep bluff near Cold Spring Brook. The bluff had a slope of ~50% (160ft high by 320ft wide). The hillshade layers help to visualize the area, and most SPI signatures can be seen terminating near the bluff's toe. During a field visit, one site along the bluff was found to have considerable active erosion. The gully had a near-vertical head cut of ~10 ft. The SPI signature associated with the feature was the only signature originating from the bluff with connectivity to the stream. This section of bluff was also within the top 10% of soil erosion risk raster values contained within this HUC12 catchment.



Observations and lessons learned: Despite the above average precipitation in spring, Cold Spring Brook – which is nearly 15 river miles long from headwaters to outlet – lost surface flow only 2 river miles from its outlet to the Zumbro River (as observed on June 5$^{th}$). This changed the priority of any CSAs upstream in dry runs as they presented lower risk of moving sediment downstream. This example emphasized the need for current stream data that includes both perennial and intermittent classifications.

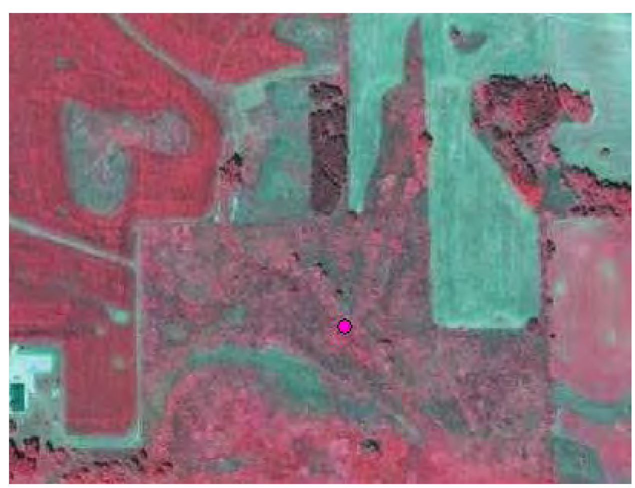
### Steep Wetter Moraine

The Steep Wetter Moraine agroecoregion, located in east-central Minnesota, consists of dissected till plain and outwash valleys with ravines commonly occurring along steeply incised river channels, and with a mix of row crops and pasture land.



Case Study #4

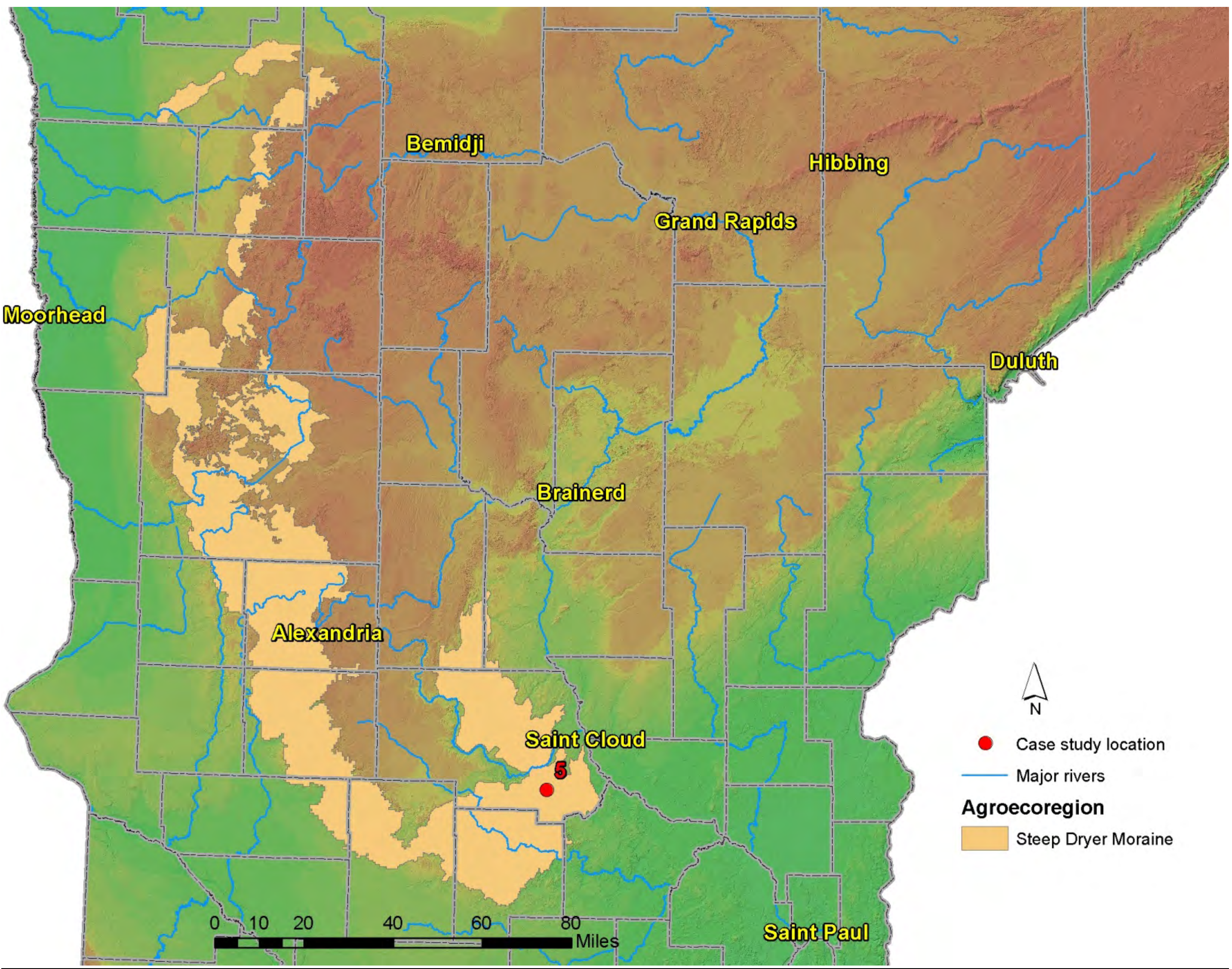
The case study #4 site is located in a HUC12 catchment adjacent to the St. Croix River near Basswood Grove, Washington, Co., MN. The site was visited to field verify the existence of a potential CSA that was located with GIS digital terrain analysis techniques. The site was selected due to the presence of a long SPI signature with a high mean value (top 1% of SPI from the HUC12) and flow through elevated soil erosion risk values (top 5% in HUC12, white areas in top right image). The SPI shown was created using no pit filling. Field verification showed no erosion present due to active landowner management of several conservation practices, such as the filter strip pictured bottom left and many grassed waterways. Color infrared ortho-imagery (bottom right image) can be used to locate these conservation practices and give a rough evaluation on their condition and density.



## Steep Dryer Moraine

The Minnesota Pollution Control Agency (MPCA) assembled a set of BMP implementation strategies for TMDL turbidity reduction compliance in the Chippewa River Watershed in central Minnesota and provided the following descriptions of the Steep Dryer Moraine and Central Till (following section) agroecoregions:

The [Steep Dryer Moraine located in Central to NW MN] agroecoregion consists of loamy soils such as the Chapett, Langhei, and Barnes series developed from glacial moraines. Soils are located on very steep slopes, and are well-drained. Water erosion rates can be severe to extreme, while wind erosion can be moderate to severe. The risk of phosphorus losses to streams and lakes by runoff and erosion is moderate. There are numerous lakes in this agroecoregion, and a moderate density of intermittent streams. Stream water quality is generally poor in this agroecoregion, while lake water quality is threatened. Drinking water wells have a median depth of 80 ft.
Original vegetation was prairie, aspen-oak, oak openings and barrens, and big woods - hardwoods. Protection of lake water quality is a high priority in this agroecoregion. Conservation tillage systems that leave crop residue and maintain soil surface roughness are important. Contour farming and strip cropping are recommended where feasible. Highly erodible land should be placed in permanent grass easements. Restoration of wetlands is encouraged.



Case Study #5

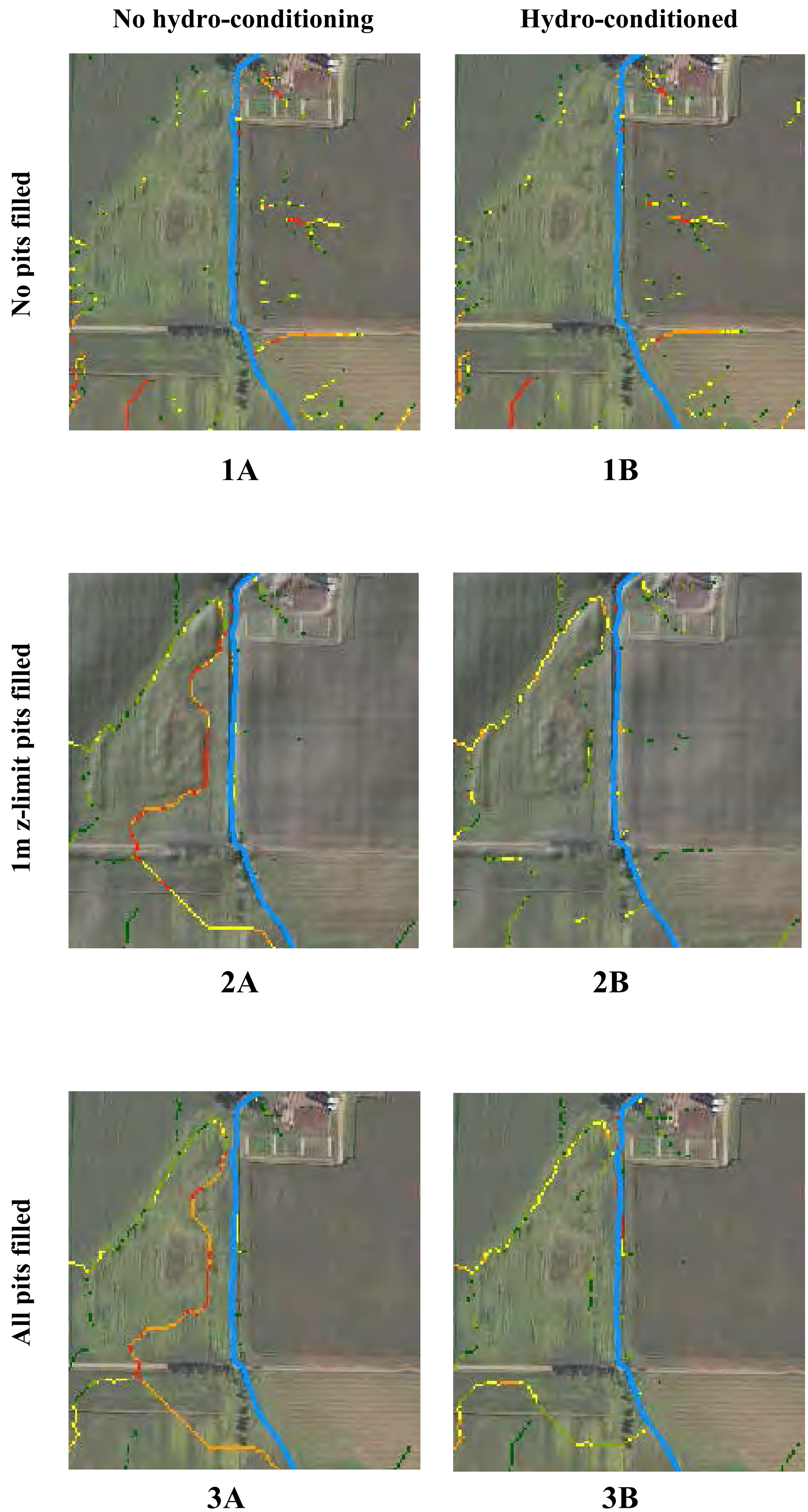
The Pelican Lake watershed, located 15 miles SW of St. Cloud, is a 28.5 sq. mi. catchment that is part of a current TMDL study focused on reducing phosphorus in the lake.

Saint Cloud, MN received 78.5” of snowfall between July 2012 and June 2013 which was above the average annual of 47”. The spring precipitation amounts for March, April and May were above average with totals of 2.63”, 2.90”, and 4.98” respectively compared to averages of 1.55”, 2.57”, and 2.95” respectively.

SPI layers were created in the watershed to locate potential sediment/nutrient erosion sources, followed with CSA predictions along the streams that discharge into the lake. Field visits to the area in mid-May of 2013 did not reveal significant sources of non-point source pollution adjacent to surface waters as most areas had wide buffers with thick perennial vegetation in combination with well drained soils.

The longest hydrologically connected SPI signature of the top 1% of values in the study area was along Mill Creek (pictured above left). The accompanying field photo shows signs of slumping in the small pasture (foreground) and the landowner had installed rip-rap along the stream bank for stabilization. There was no further evidence of erosion upland of the slumping.

Observations and lessons learned: Similar to the 1st case study from the Level Plains agroecoregion, several SPI calculations were also made throughout the Pelican watershed with varying amounts of DEM pre-processing occurring for each run, specifically pit filled and hydro-conditioning (see following graphics). One particular location showed what appeared to be spurious signatures when pit filling with no hydro-conditioning was employed (following graphic **3A**), though the flow was confirmed by the landowner stating that ice breakup frequently blocks flow at the road crossing culvert during spring melt and the SPI signature was actually where flow diverts. Out of the six graphics shown, the SPI signatures displayed in graphic **2B** created from a 1m z-limit pit filled and hydro-conditioned DEM was confirmed to most closely resemble surface runoff during periods of normal stream flow in the Pelican watershed.




The six graphics on left display SPI signatures calculated from a 3 meter DEM with varying degrees of pre-processing performed. All SPI signatures are from the 97.5th percentile within the extent shown (~41 acres). Graphics in the left column (**A**) were not hydro-conditioned, while graphics in right column (**B**) were – the DEM was hydro-conditioned by burning the stream (blue line) through the east-west oriented road crossing culvert.

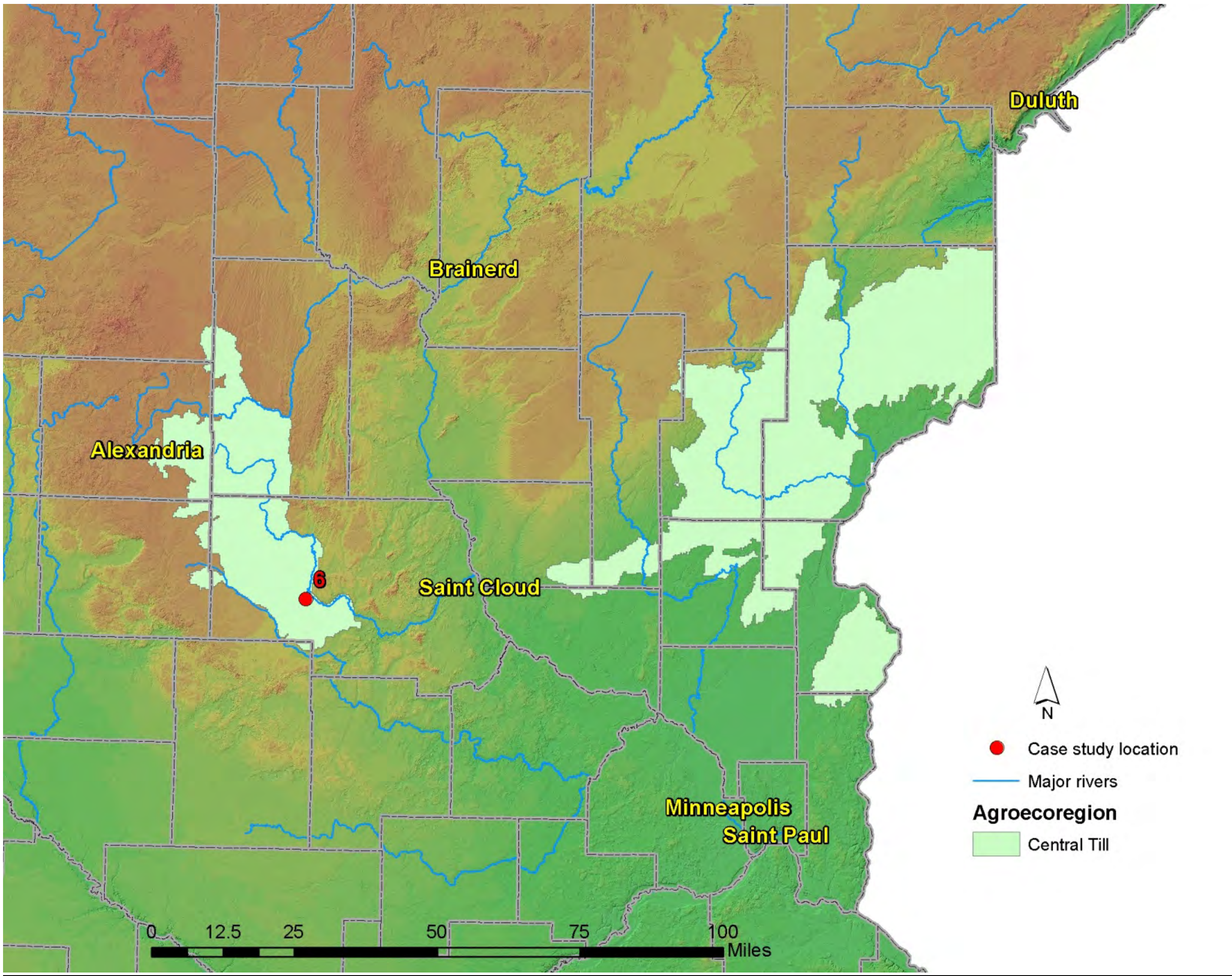
**1A & 1B** were not pit filled. The results are essentially identical.

**2A & 2B** were pit filled using a 1 meter z-limit.

**3A & 3B** were pit filled with no maximum z-limit, meaning all pits were completely filled.

## Central Till

This agroecoregion in central Minnesota consists of well-drained, moderately steep to steep landscapes with fine textured soils of the Ahmeek, Greenwood, and Mora series. Water erosion potentials can be high. Stream and lake water quality are generally fair. Ground water quality is generally fair. Original vegetation was big woods - hardwoods, conifer bogs and swamps, aspen-birch, and prairie (MPCA Chippewa River Watershed Draft TMDL BMP strategies).

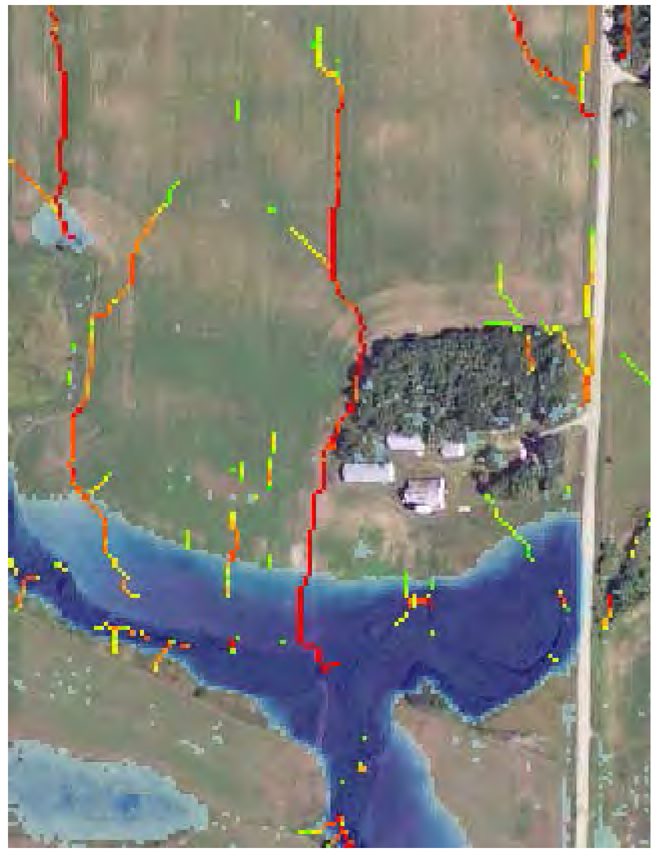



Case Study #6

The study area in case study #6 is near Spring Hill, MN in central Minnesota. The site was visited in mid-April of 2012 to field verify CSA predictions made using terrain analysis attributes. Factors that led to choosing the site include the presence of long SPI signatures with high average cell values through steep upland slopes.

The field visit did not verify considerable erosion present in the upland field containing the SPI signatures possibly due to the field being recently tilled. The downstream area from the pour point relating to the highest ranked SPI signature at the site had in-channel sedimentation evident. That particular SPI was found to terminate at an in-stream vehicle crossing built with course gravel and no buffer.

St. Cloud winter snowfall total received between July 2011 and June 2012 was 27.4" (http://climate.umn.edu/) – well below the average of 46.1". March and April precipitation totals were near average for those months.

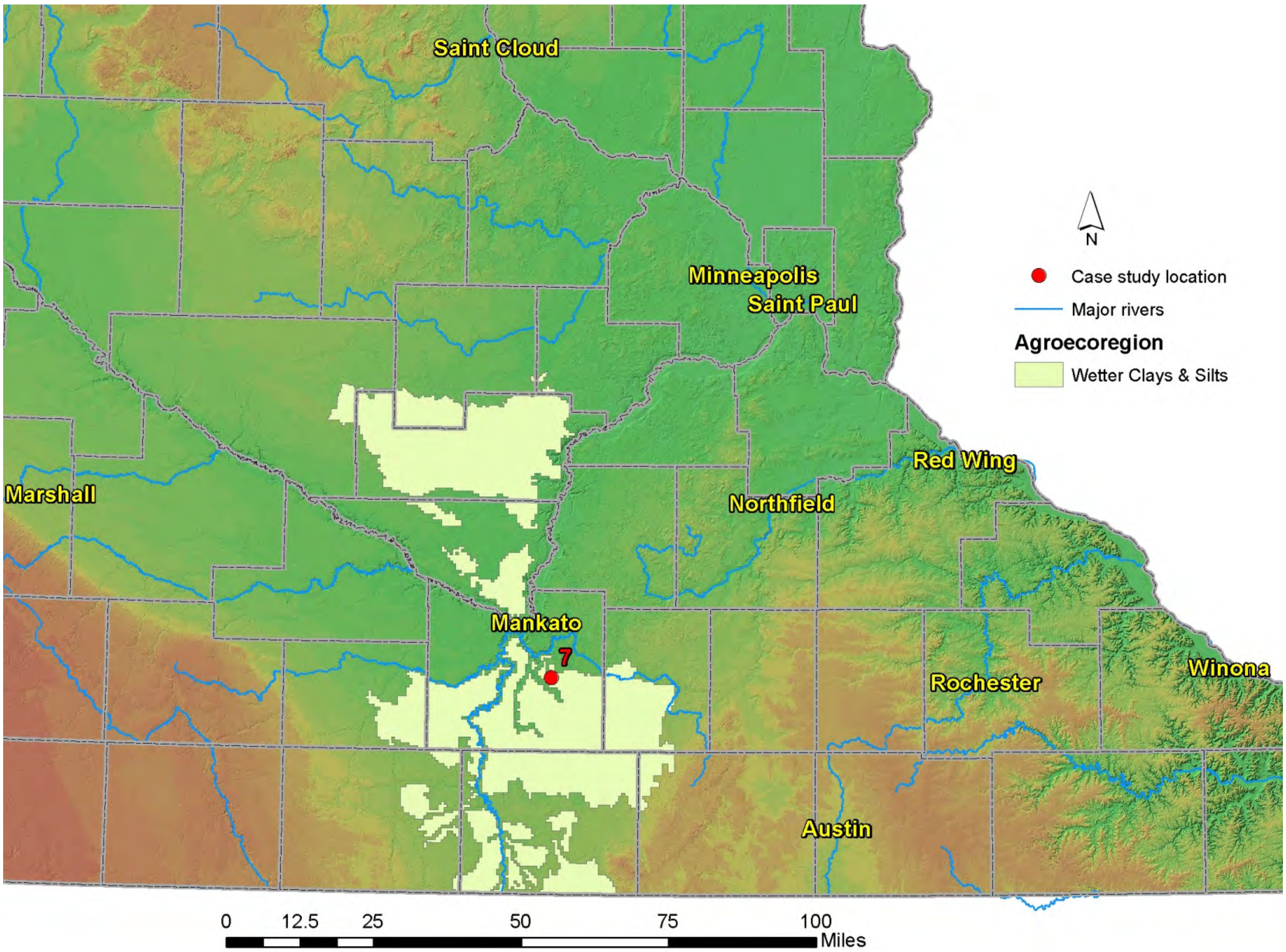


This example near Spring Hill, MN shows a long SPI signature with a high average value (centered, upper right photo) containing the top 1% of values in a 16.5 sq. mi. HUC12 catchment. A newly built concrete culvert was installed at the downstream road crossing (circled in yellow). A modified CTI raster was used in the top right image (blue pixels) to show the potential ponding if the culvert was to fail, or jam with ice, which could create additional hydrologic connections to several nearby SPI signatures.

The ponding raster also aided in locating a nearby sinkhole depression, shown in the right image with the sink circled in yellow.

## Wetter Clays & Silts

The Wetter Clays & Silts agroecoregion is located in south-central Minnesota and is a vast, flat fertile plain of poorly drained deep soils dominated by row cropping with low erosion rates and high nitrate losses. The region has had a dramatic increase of drain tile installation within the last two decades and the majority of fields now take advantage of artificial drainage.



Case Study #7

Case study #7 focuses on the small 8.6 $mi^2$ Beauford Watershed in Blue Earth County, MN – part of the larger HUC8 La Sueur Watershed in the Minnesota River Basin near Mankato, MN. All the ditched streams in the Beauford watershed were walked as part of a project to both identify upland erosion and assess the cost and time involved in doing so. Side inlets were the most commonly identified erosion-related feature in the watershed. Side inlets are a form of artificial drainage common in the Minnesota River Basin and other regions with very flat terrain. Ditch cleaning piles left along the channel corridors inhibit overland flow from entering streams at low points. This can often lead to gullies developing at the edge of fields parallel to the ditch, so a culvert drain pipe is installed to drain runoff at those points. Unfortunately this allows a direct discharge of untreated overland runoff to outlet into surface waters, unless a waterway or other type of conservation practice is present upland. Gullies were also identified during the survey.

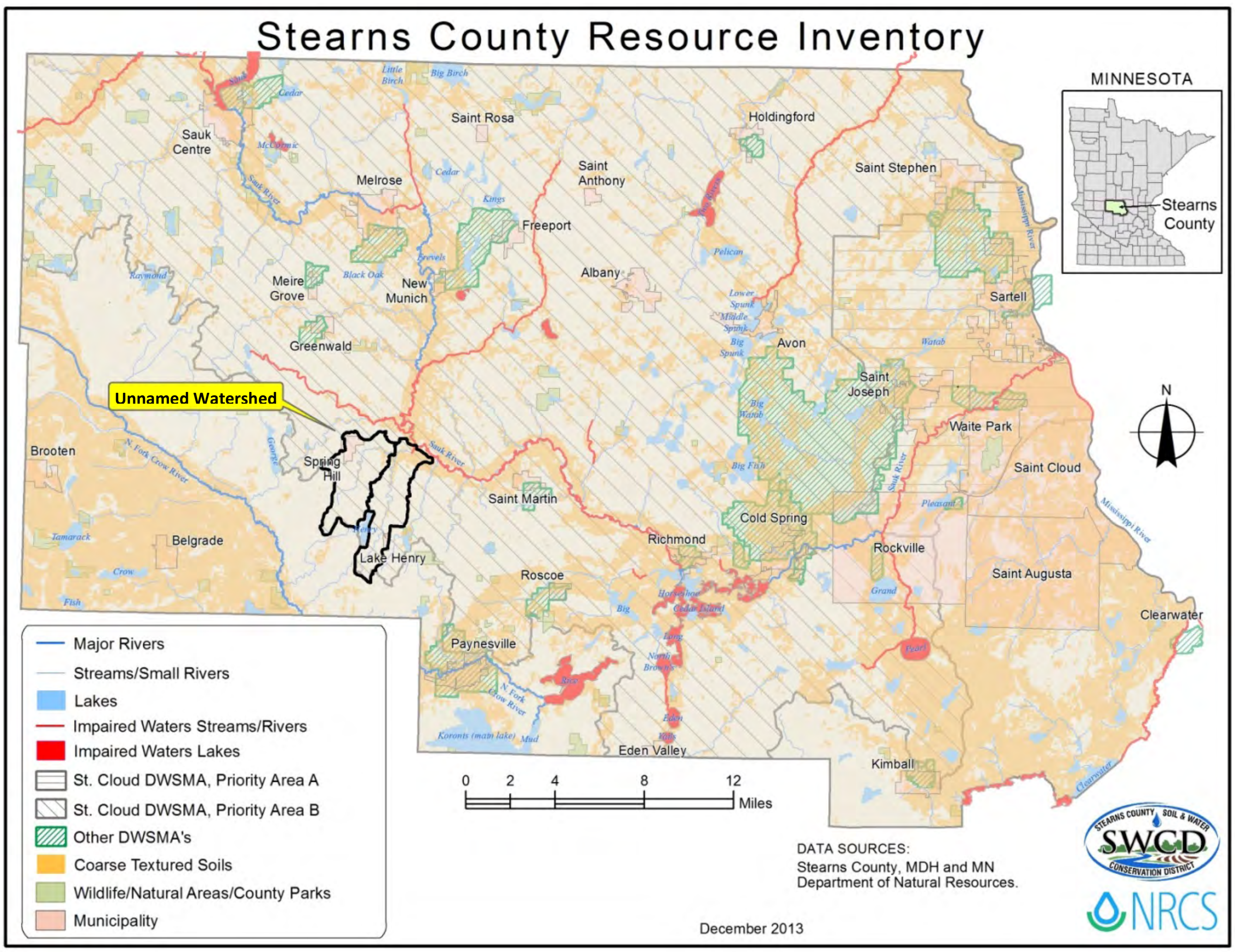
The erosional feature shown in this example is a side inlet near Beauford, MN. The multi-branching SPI signatures shown top left are common in this region due to very flat topography. The bottom right image shows a spring-time aerial photo of a long surface runoff flow network approximately 500 yards west of the side inlet shown above. Artificial drainage tile lines exist in the fields as shown in the inset photo (orange lines represent tile lines). The center of the photo shows a darker area with mineral deposits evident from evaporation where ponding still occurs during spring thaw and rainstorm events.

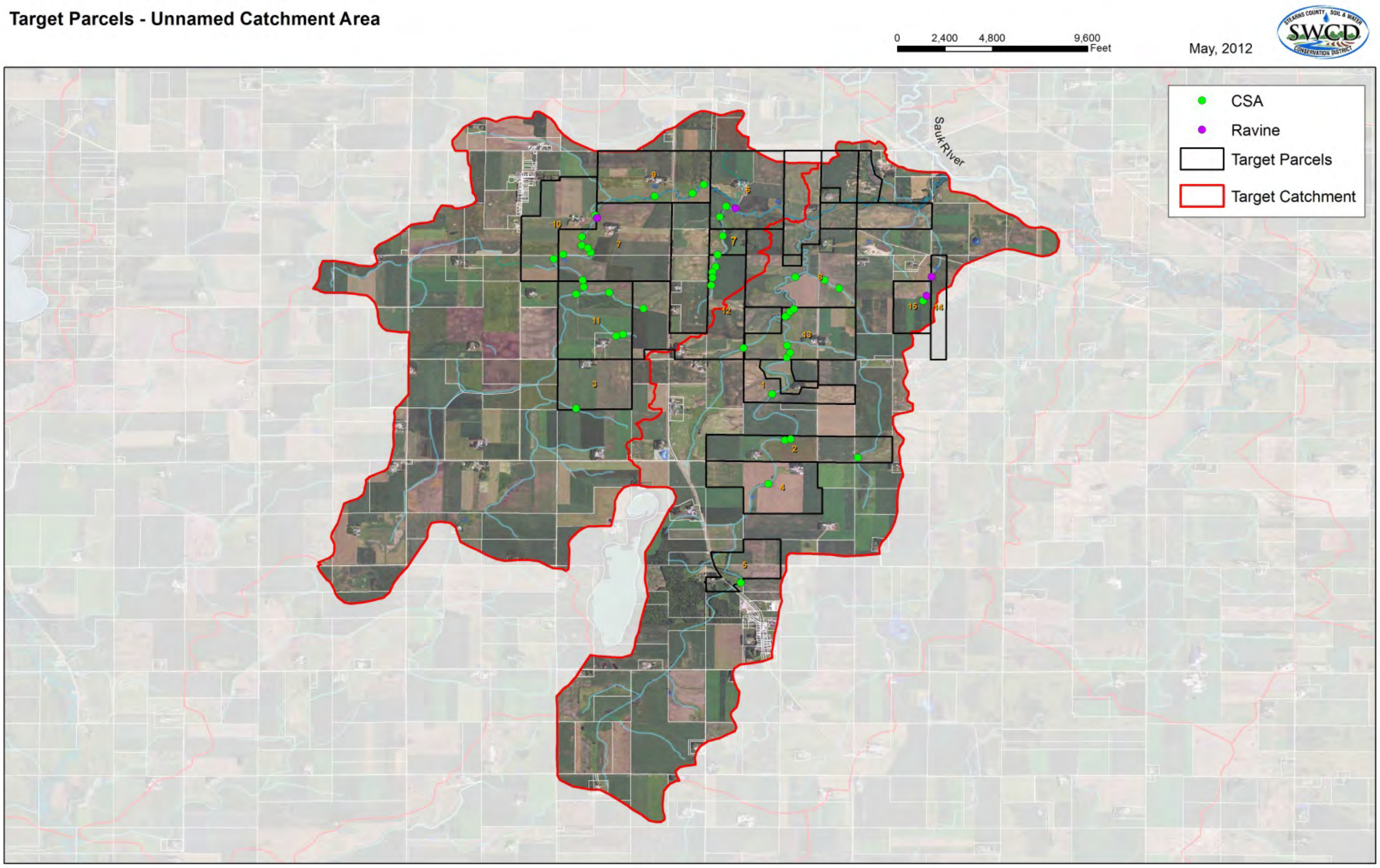
**Unnamed Creek (Stearns County)**

Case Study #8

Unnamed Creek watershed in the southwestern part of Stearns County was targeted for several reasons. Unnamed Creek is impaired for turbidity and has an approved TMDL Report. It also falls within an area in the county where there is access to additional Environmental Quality Incentives Program (EQIP) funding. This part of the Sauk River watershed is part of the USDA National Mississippi River Basin Initiative (MRBI) (NRCS MRBI website). A good working relationship with a number of farmers in this area increased opportunities to gain access to test the PMZ tools. We initially focused on landowners with known management information (soil tests, manure info, crop rotations).

Choosing this area to focus for this effort was an example of targeting at a county level. The area chosen with identified impairments allowed us to access existing funding to address priority concerns.





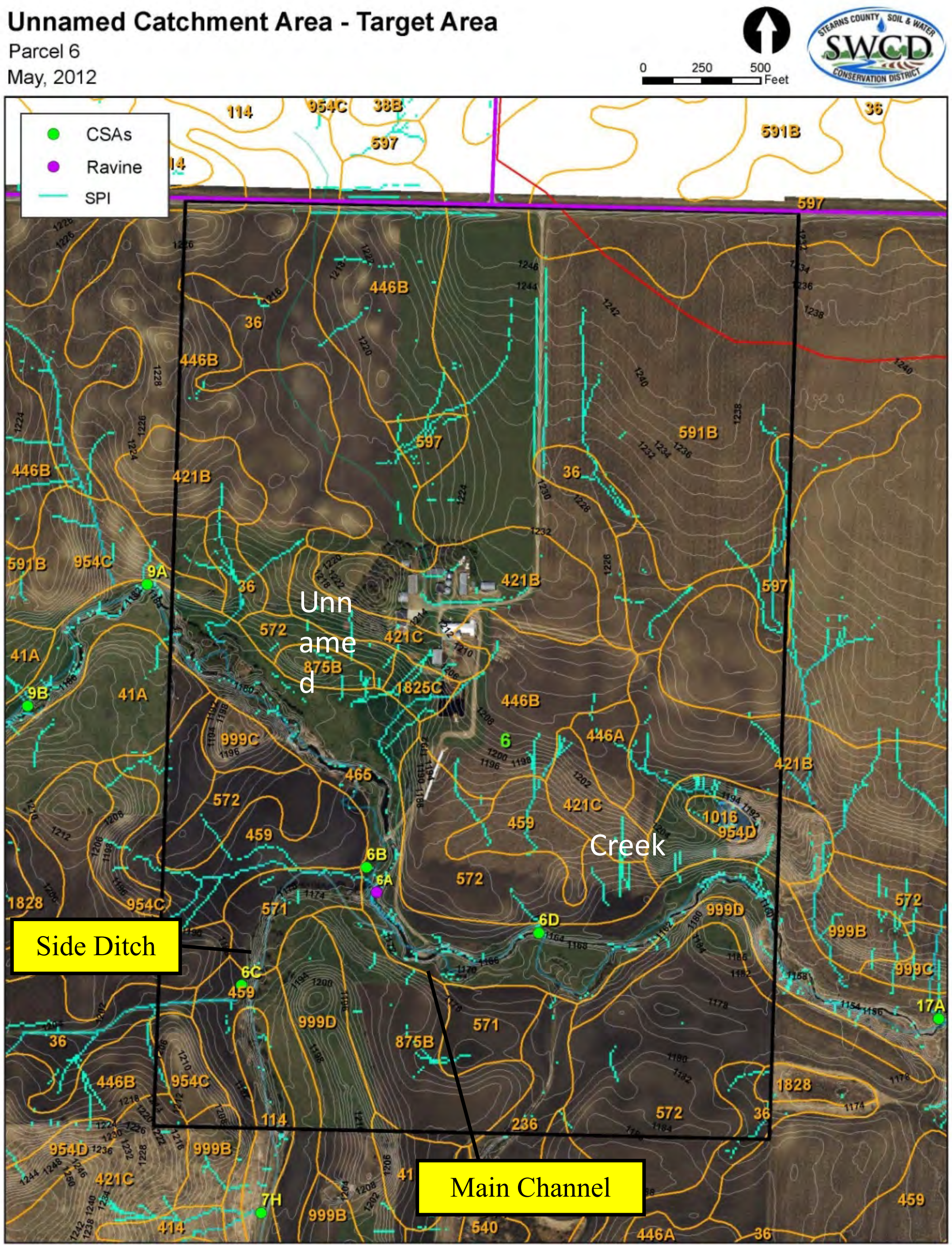

For the next step of the process, resources were evaluated at the watershed level. CSAs were identified (green/purple dots on the map above). Based on GIS analysis of the terrain model (using the freely available MnDNR LiDAR datasets), these points represent areas in the landscape that have the greatest potential for channelized overland flow and sediment and nutrient delivery (see the Digital Terrain Analysis section).

The county parcel data was overlaid to define tracts of land by ownership. The tracts with the greatest number of predicted CSA's were prioritized. These sites have the greatest potential of delivery of pollutant load to the stream.

Random identifiers were assigned to the tracts, using the same numbers for the fields and CSA's. This organized our work while maintaining landowner privacy. There are many things to consider, including the Freedom of Information Act (FOIA), relationships with neighbors, other organizations, regulations, etc.

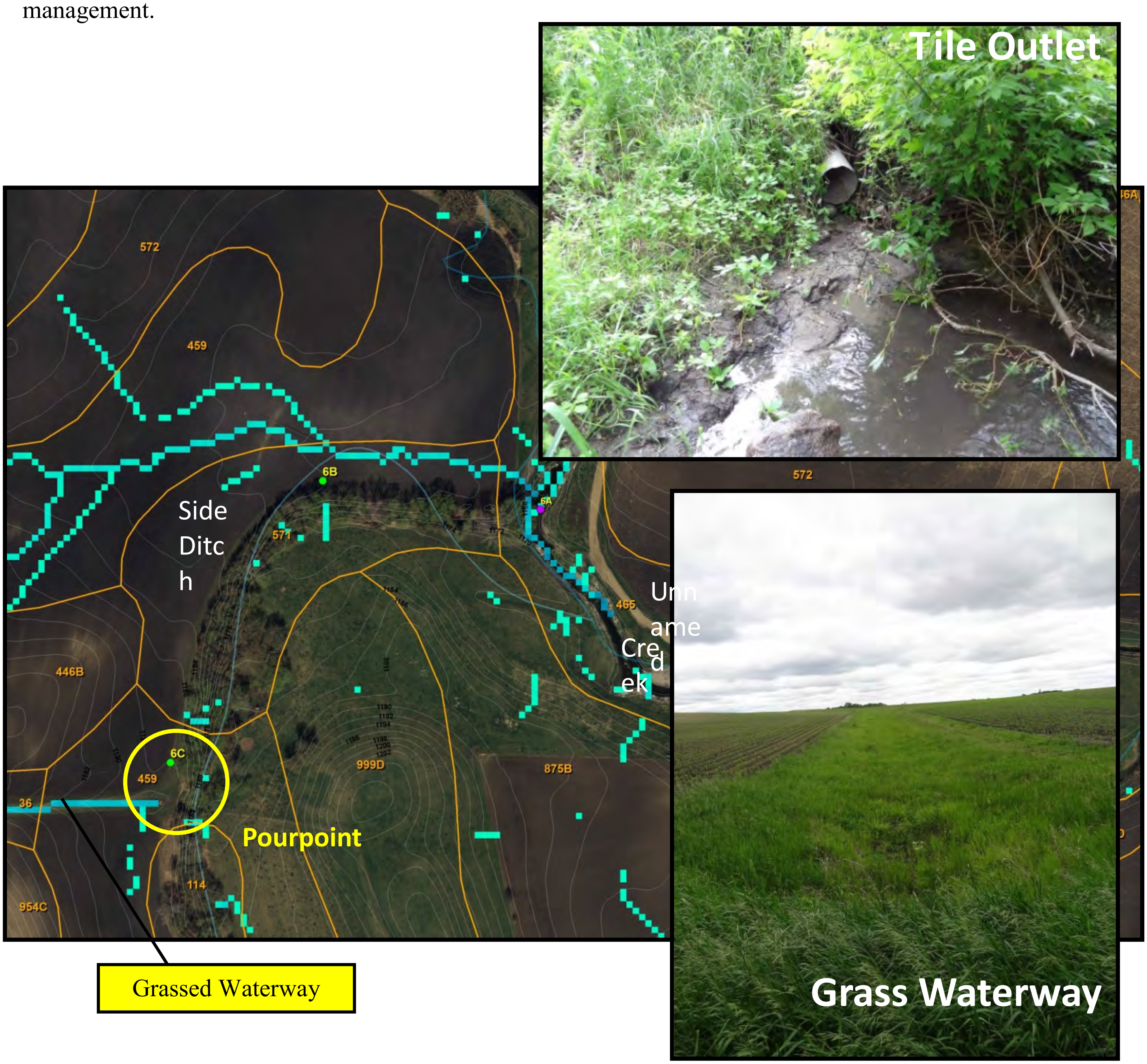
A few of the sites were visited in the Unnamed Creek watershed. A sample of CSA's was chosen from each area to give a good representation of the watershed for the case study. A multi-leveled targeting approach was now scaled down to the field level.

At Site 6, Unnamed Creek runs from west to east along the southern part of the property. There is also a side ditch that flows into the main channel.



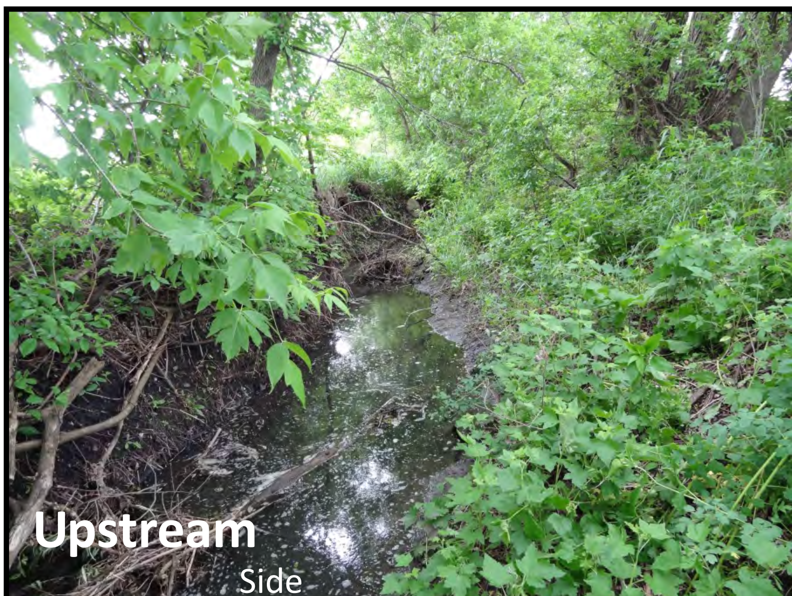
CSA 6C was a site with a fairly long Stream Powered Index (SPI) signature. The site visit revealed that a well maintained grassed waterway was present that discharged to a side branch of the targeted stream. The structure had an outlet pipe for the surface runoff and an outlet for a drainage tile. This site is still a potential CSA because you would want to evaluate that the waterway is functioning. You would also want to determine if you can locate a tile inlet to see if that is a potential source of nutrients/sediment. In this case, there was not an open tile intake.

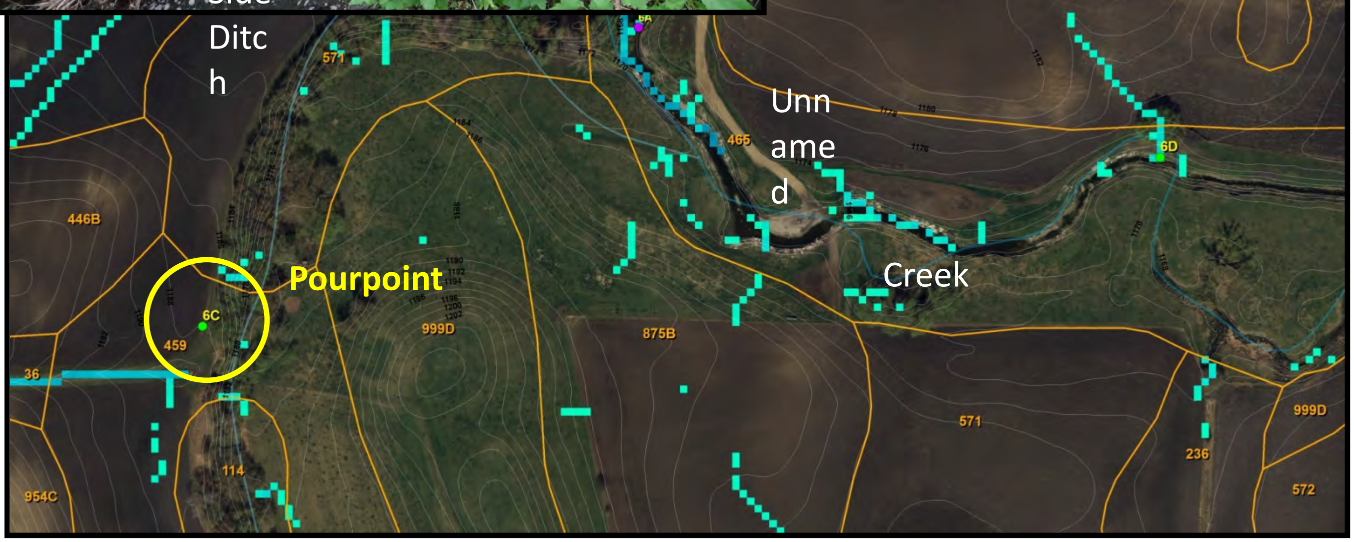
The MN Rapid Phosphorus Index was performed on the contributing field and the result was a "low" rating (low potential for phosphorus loss), good buffer conditions and good manure management.




The stream channel at this location was also evaluated using the Bank Erosion Hazard Index (BEHI) and found the channel rating to be "moderate" (ditched channel with limited access to a floodplain, but with good surface protection and root density).

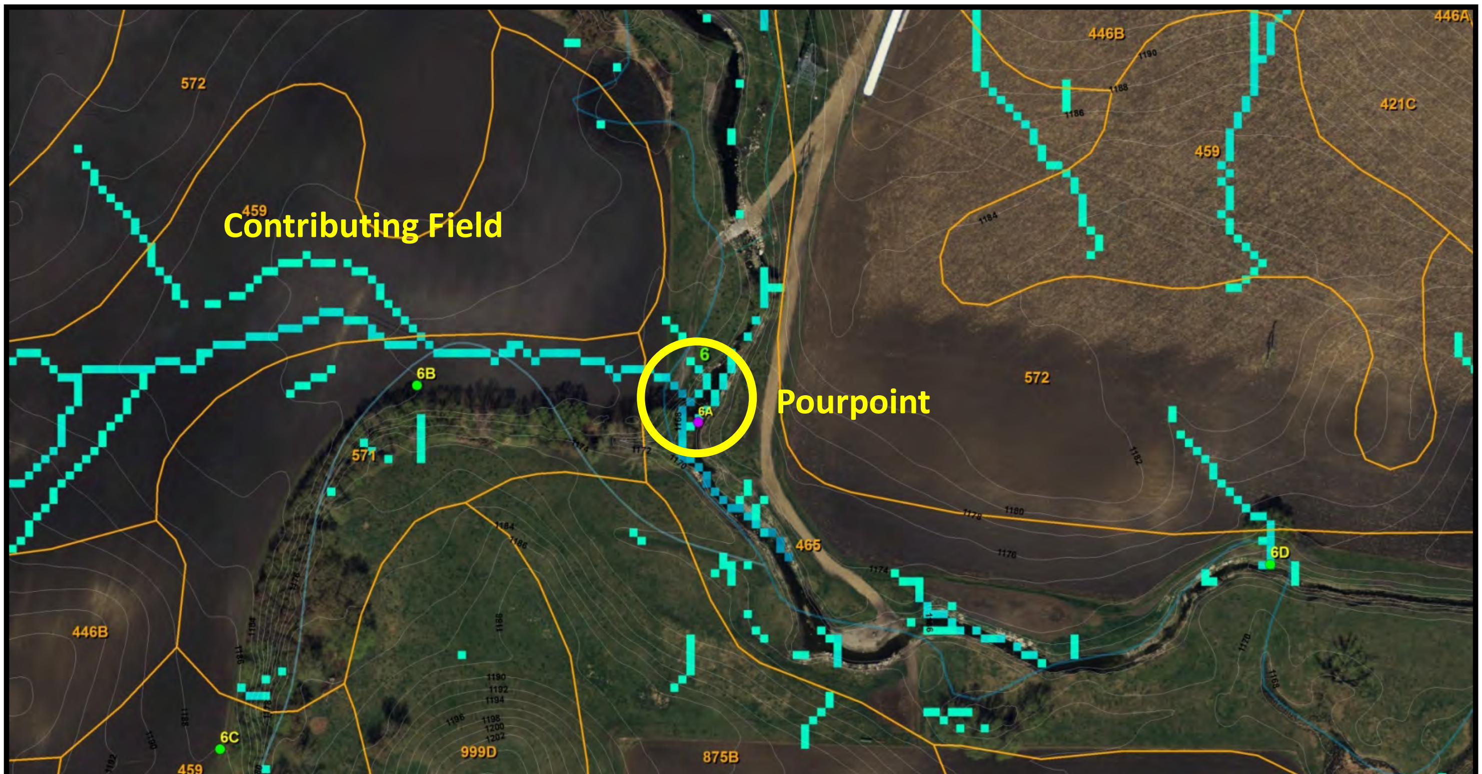
(The BEHI was later removed from this guidance due to time and confidence in expertise and replaced it with the Streambank Erosion Assessment Form).



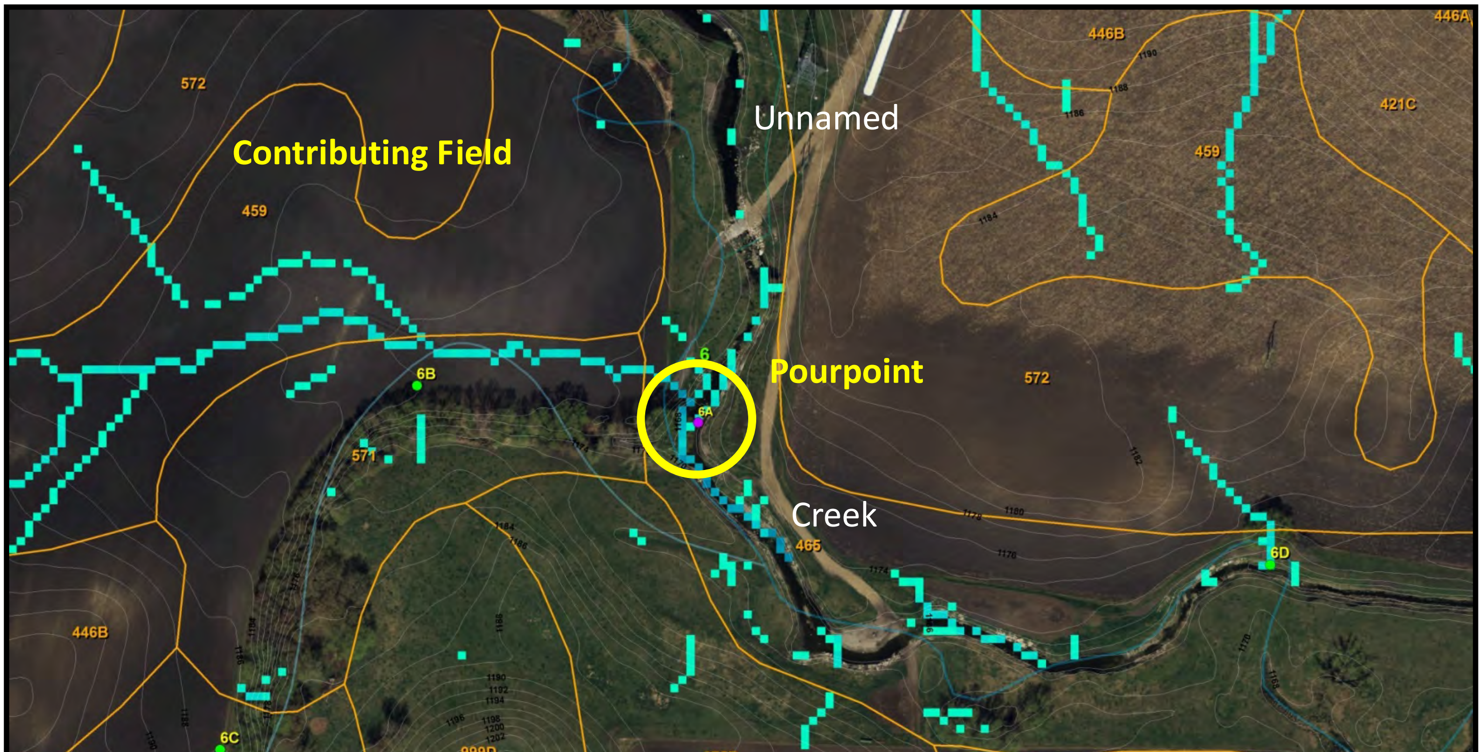
Unnamed Creek site 6A was showing signs of erosion. Although the contributing field has very minimal slopes the vegetation along the channel was highly degraded due to over grazing (frequent animal access). There was also a tile outlet at this location. It was desired to locate the tile inlet if possible and assess it as a CSA. There was no surface intake for this tile. This is a site where animal access and prescribed grazing plans should be discussed with this landowner to improve the vegetative cover at the CSA.

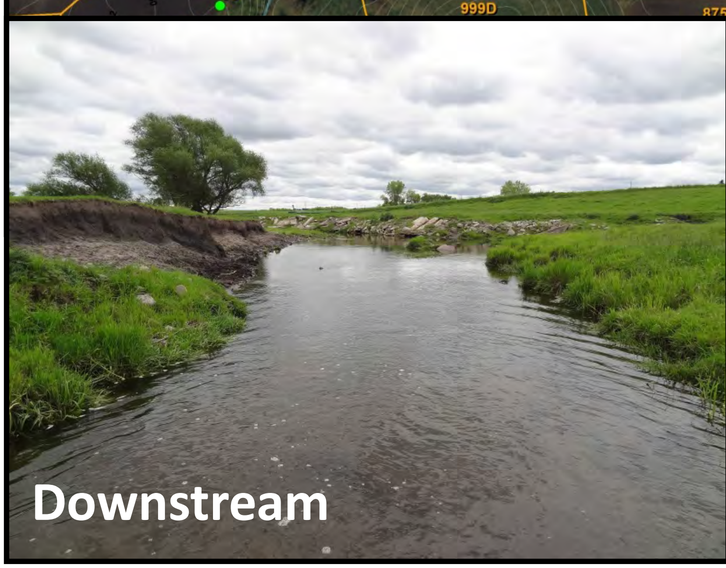
The MN Rapid Phosphorus Index was performed on the contributing field and the result was a “low” rating (low potential for phosphorus loss) due to low sheet and rill values and good manure management.

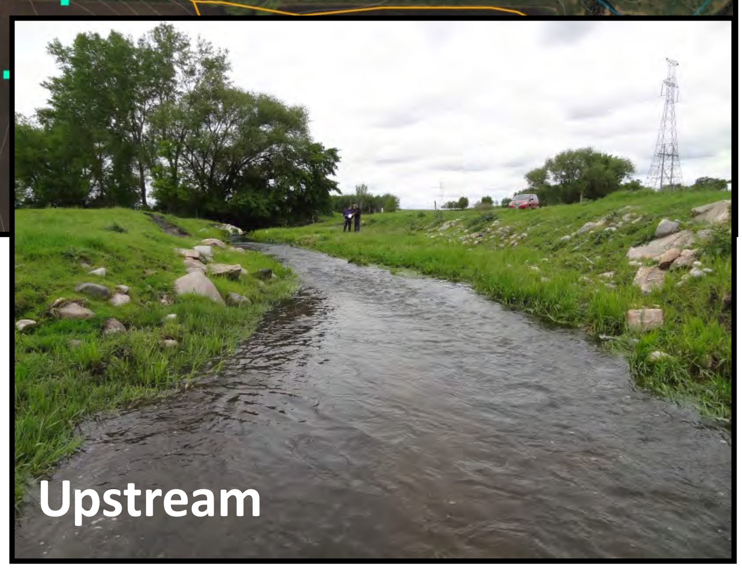




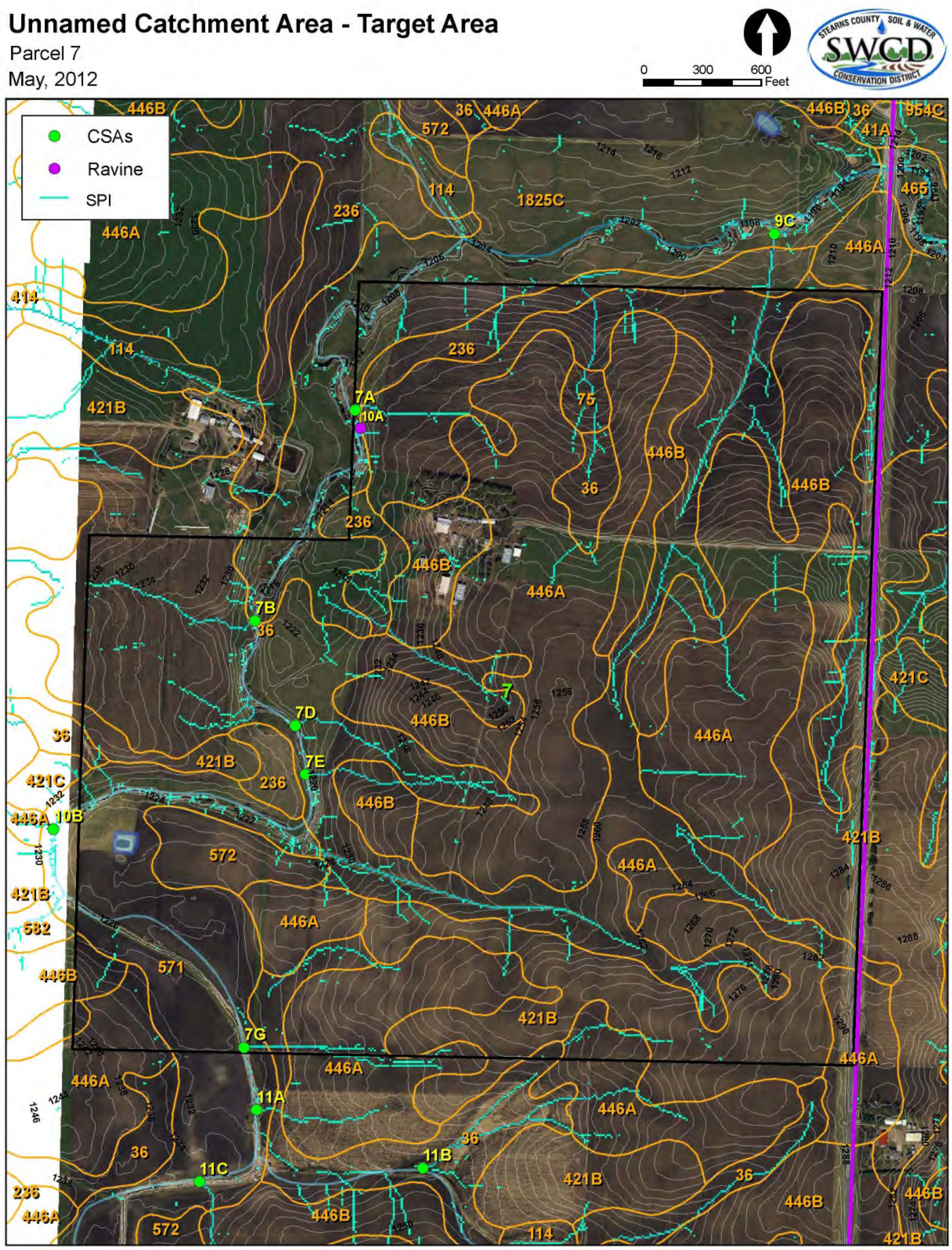
The BEHI and TN-99 were completed on the stream channel at this site. The BEHI index came up “high” in portions of the stream, due to the lack of vegetation and root depth of portions of the stream bank largely from animal impact as well as a high bank height to bank full height ration. Stabilizing this crossing by using selective animal access and a prescribed grazing would be beneficial on this site.



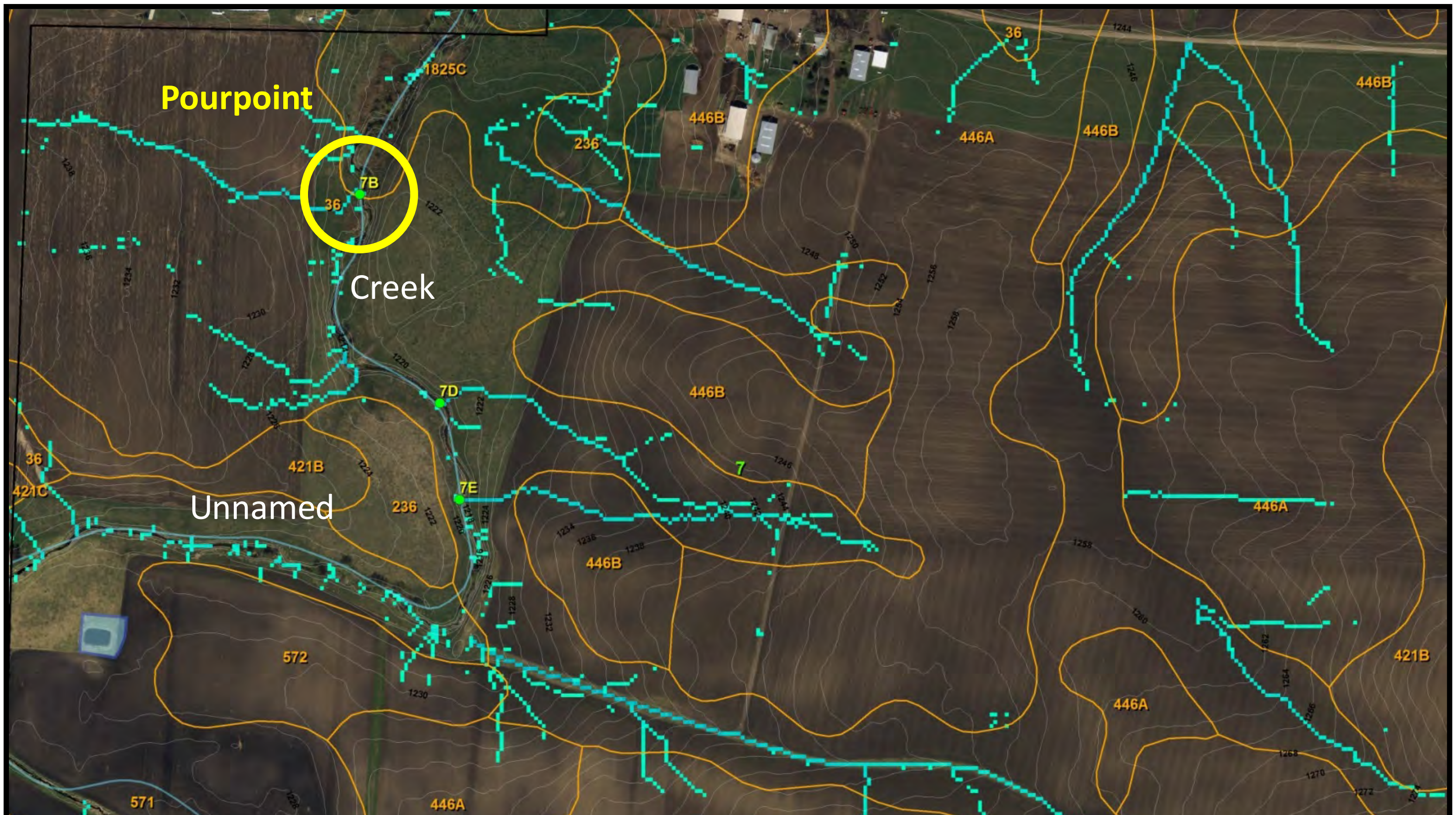



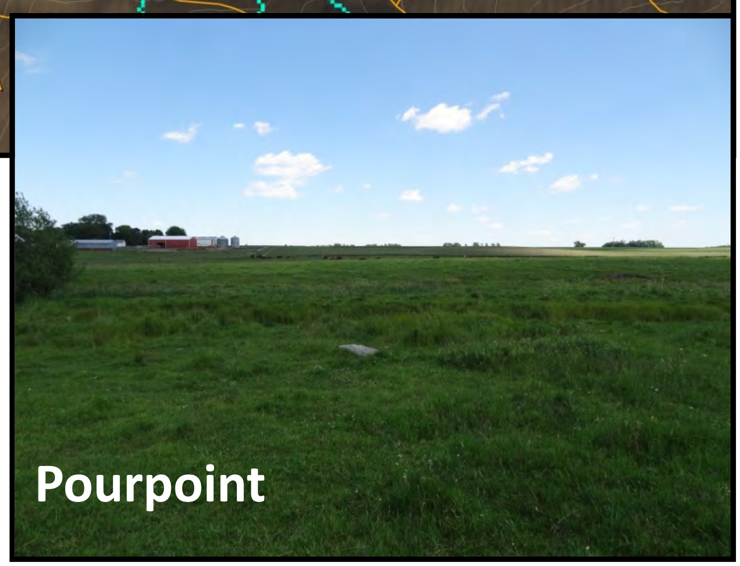
Unnamed Creek Site 7 is just upstream of the previous site. There were several CSA's predicted on this site. The majority of the area the channel flowed through was located within a well-managed grazing area.



The Site 7B CSA had a large contributing area coming off a field in a corn and soybean rotation. The first picture is looking in the contributing field. There was no evidence of channel erosion at the pourpoint. The grazed buffer had very good vegetative cover. The MN Phosphorus Index was performed and rated “very low” (low phosphorus runoff potential (no manure application, good commercial P management and low sheet and rill erosion value and a good buffer). The TN-99 rated “high” (good bank vegetation/root density, stabile hydrologic conditions and a good riparian zone). The stream channel was mostly in a natural cover.

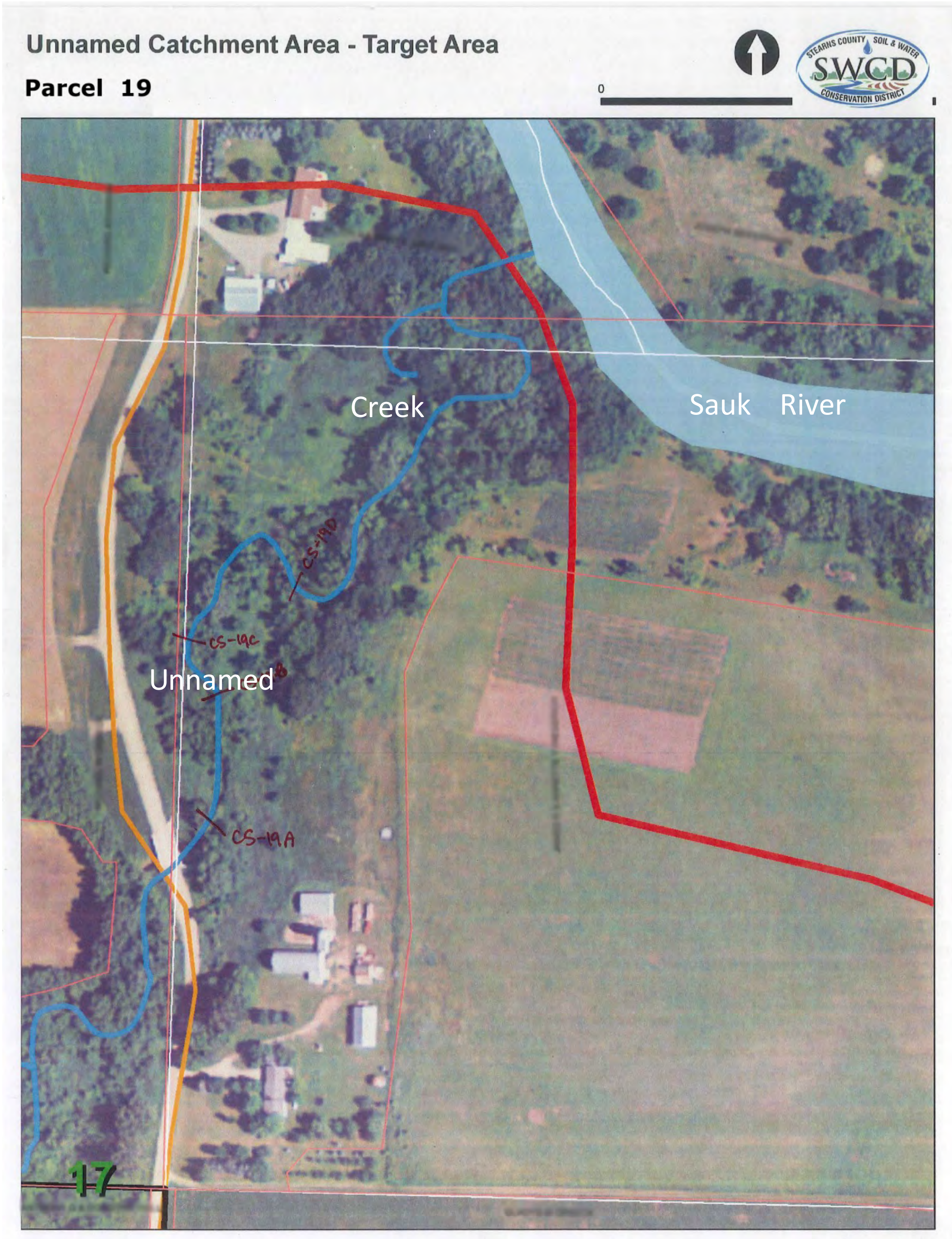






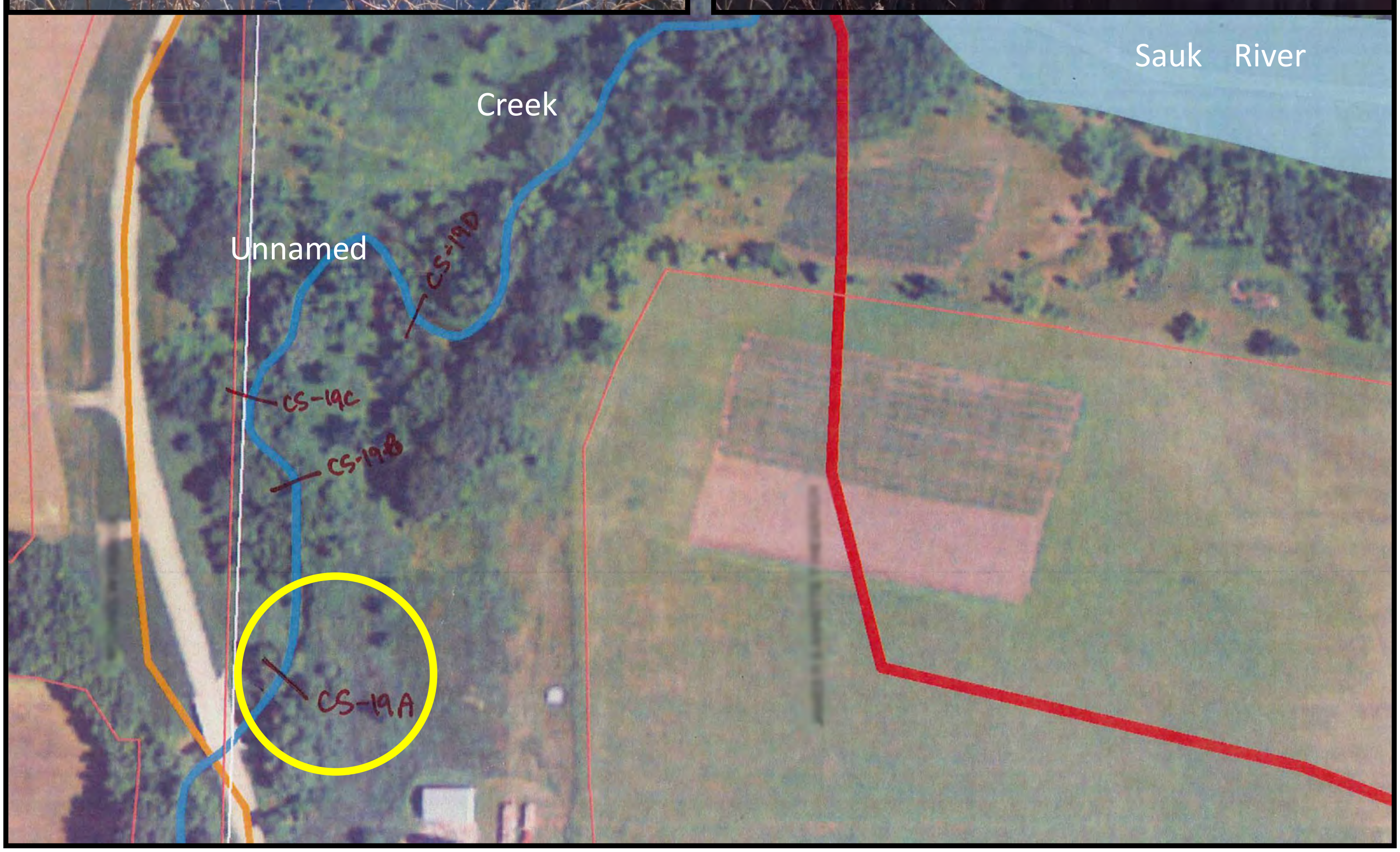
Site 7 did not initially have a CSA indicated on the map. The analyst saw the BMP (grassed waterway) in the aerial and did not place a CSA. The field survey indicated that there was significant stream bank erosion caused by the side inlet structure and that stream bank protection might be necessary. This finding resulted in the placement of a CSA when doing the terrain analysis despite that fact that an existing BMP was in place.


Site 19 represented the last segment of Unnamed Creek before it enters the Sauk River. It runs through a fairly undisturbed natural area, with adjacent fields. There were no signs of animal grazing in this area. There were no CSA's in this section, but while conducting initial road crossing assessments, it was determined that there was a great deal of stream bank instability in this area. The landowner granted access to do further evaluations.



Although no CSA's were present at Site 19, a number of the field tools were completed at selected cross sections along the channel. The BEHI determinations resulted in "moderate" to "high" ratings. The outside bends of this meandering stream exhibited poor root density, poor bank vegetation, and minimal access to the floodplain especially in wooded areas. The first site, Cross Section 19A, had a good buffer but a lack of access to the floodplain. The channel bed was full of fine eroded sediment.





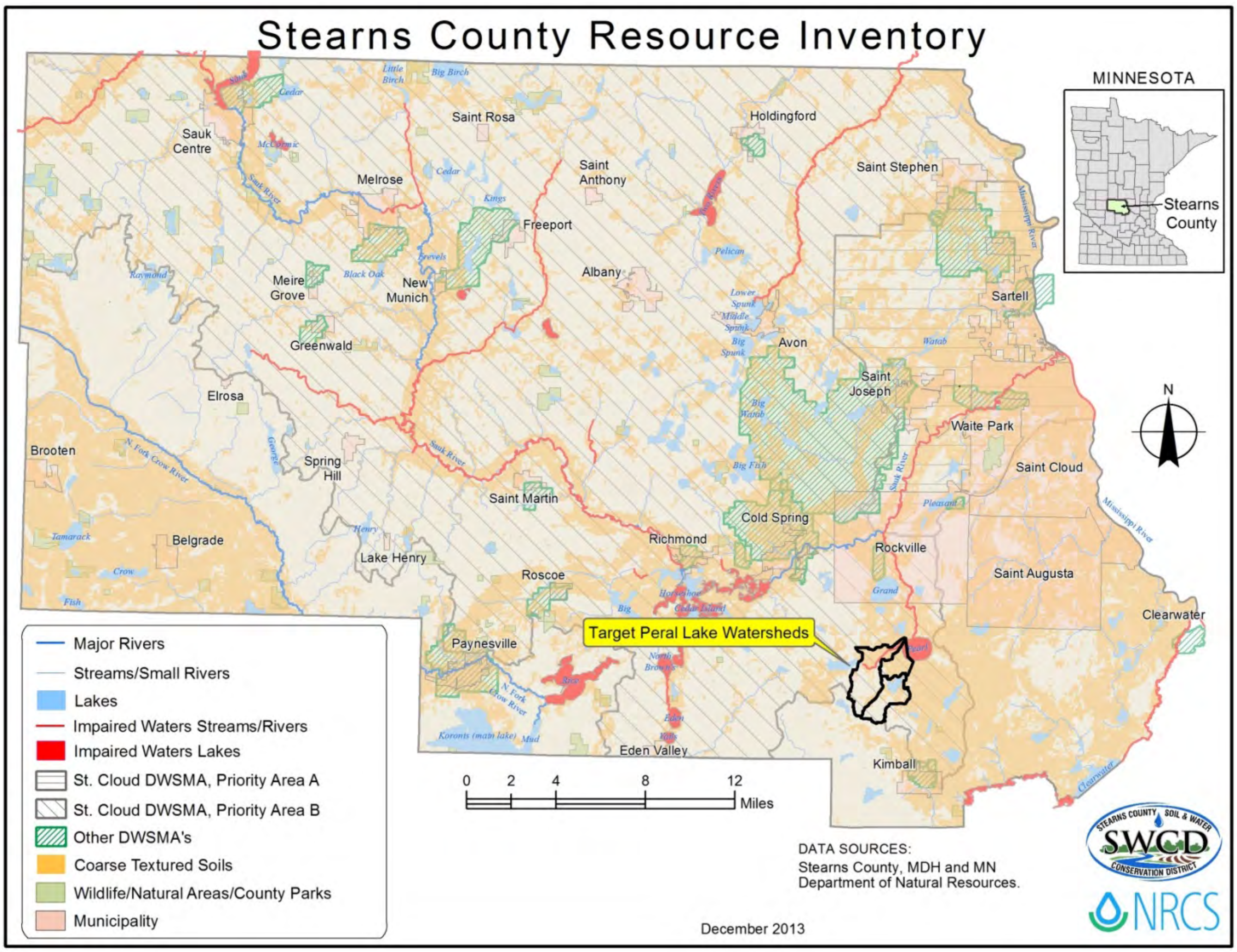
More severe bank erosion was observed in the wooded sections of the stream due to lack of understory growth and reduced root density. One of the reasons for this increased erosion in the lower section of stream was from a change in soil parent material. The soils tended towards more sand and gravel with unstable characteristics at high bank angles.

Hydrological modifications are believed to represent the major issue in this watershed. One landowner stated that the stream used to run year round with moderate flows but had changed to where it now runs higher and faster in the spring but almost dries up during the summer. Tiling, modification to the natural channel (straightening, deepening), wetland drainage may be the primary causes. The increased peak flow results in greater soil erosion from the stream bank. Practices that can store water will be promoted throughout the watershed to address peak flows and reduce the bank erosion causing the turbidity impairments.

**Pearl Lake/Mill Creek (Stearns County)**

Case Study #9

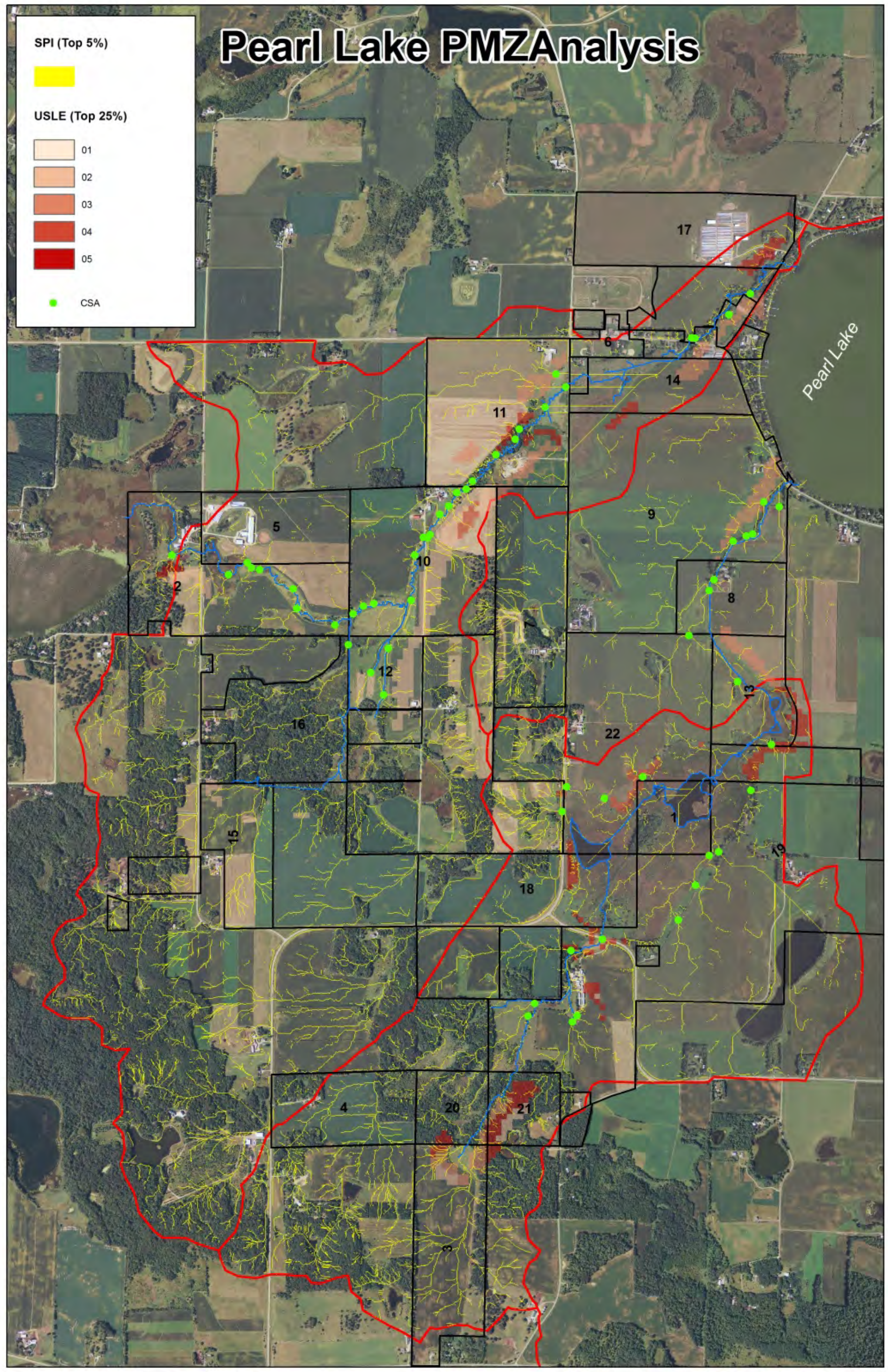
Pearl Lake is listed as impaired for Nutrients (Phosphorus) and portions of Mill Creek for E. coli. This area was also in a MRBI (*NRCS MRBI website*) (which is a special Environmental Quality Incentives Program (EQIP) funding) area. The president of the Pearl Lake Association raised concerns about the turbidity of the water entering the lake from Mill Creek at certain times of the year. The PMZ tools were applied to further evaluate the issues.



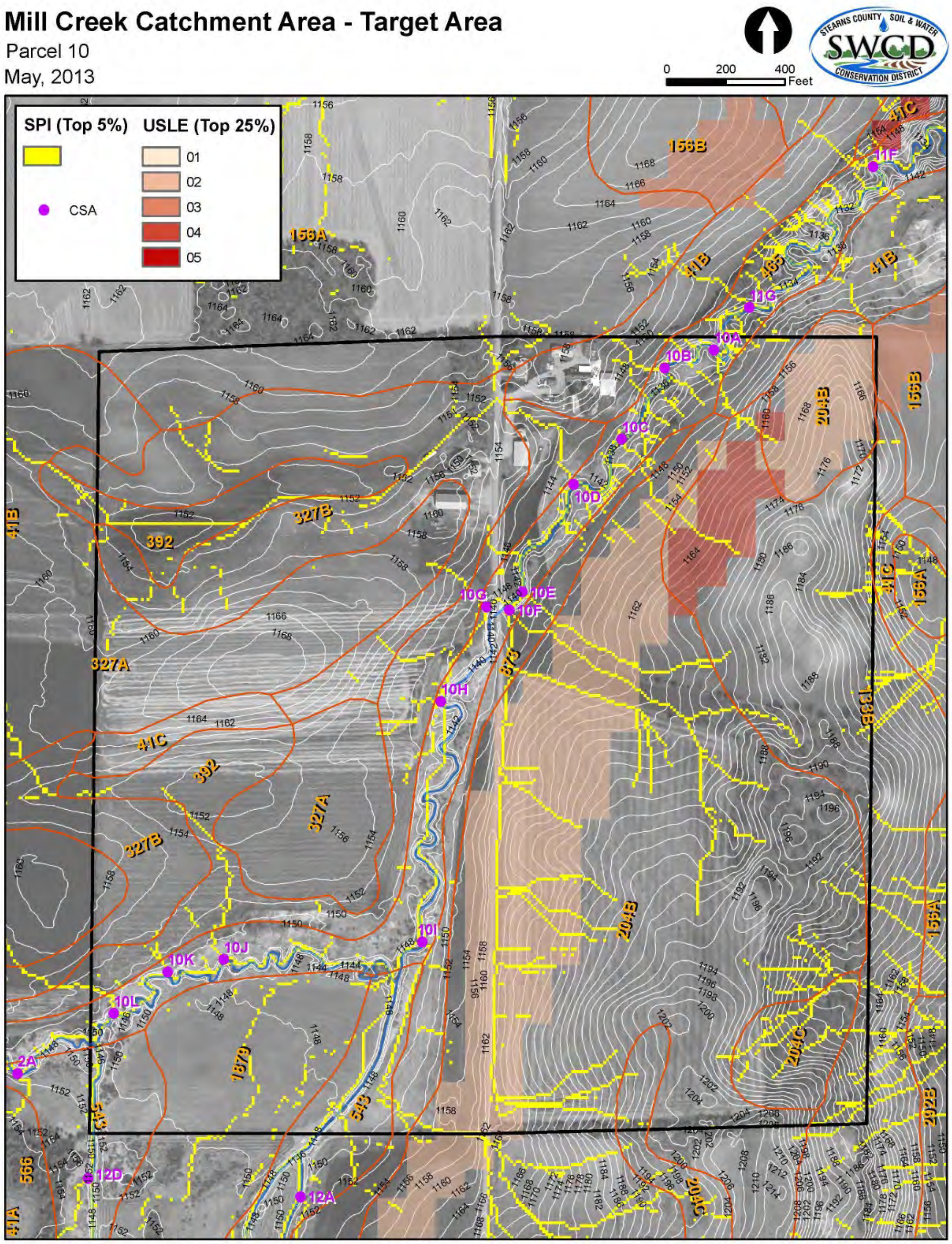
The digital terrain analysis focused on two channels entering the west side of the lake. Both outlets showed visible sediment flumes in the aerial photography. Initially, the analysis clipped out the combined watershed area of the two channels. After setting our threshold and placing the CSA's it was revealed that almost every CSA was on the north channel (Mill Creek) due to steeper terrain in that watershed which skewed the results. It was clear that the southern channel was also contributing to the lake impairment so the watershed of each channel was clipped out and the analysis was run separately on each to highlight the CSA's with the highest potential in each watershed.

In further advancement of the tools the Universal Soil Loss Equation (USLE) data was included in the mapping to further prioritize CSA's. SPI (Flow Channelization and Power) signatures that also ran though high USLE (potential for erodibility) areas signified the highest potential for nutrient and sediment delivery.

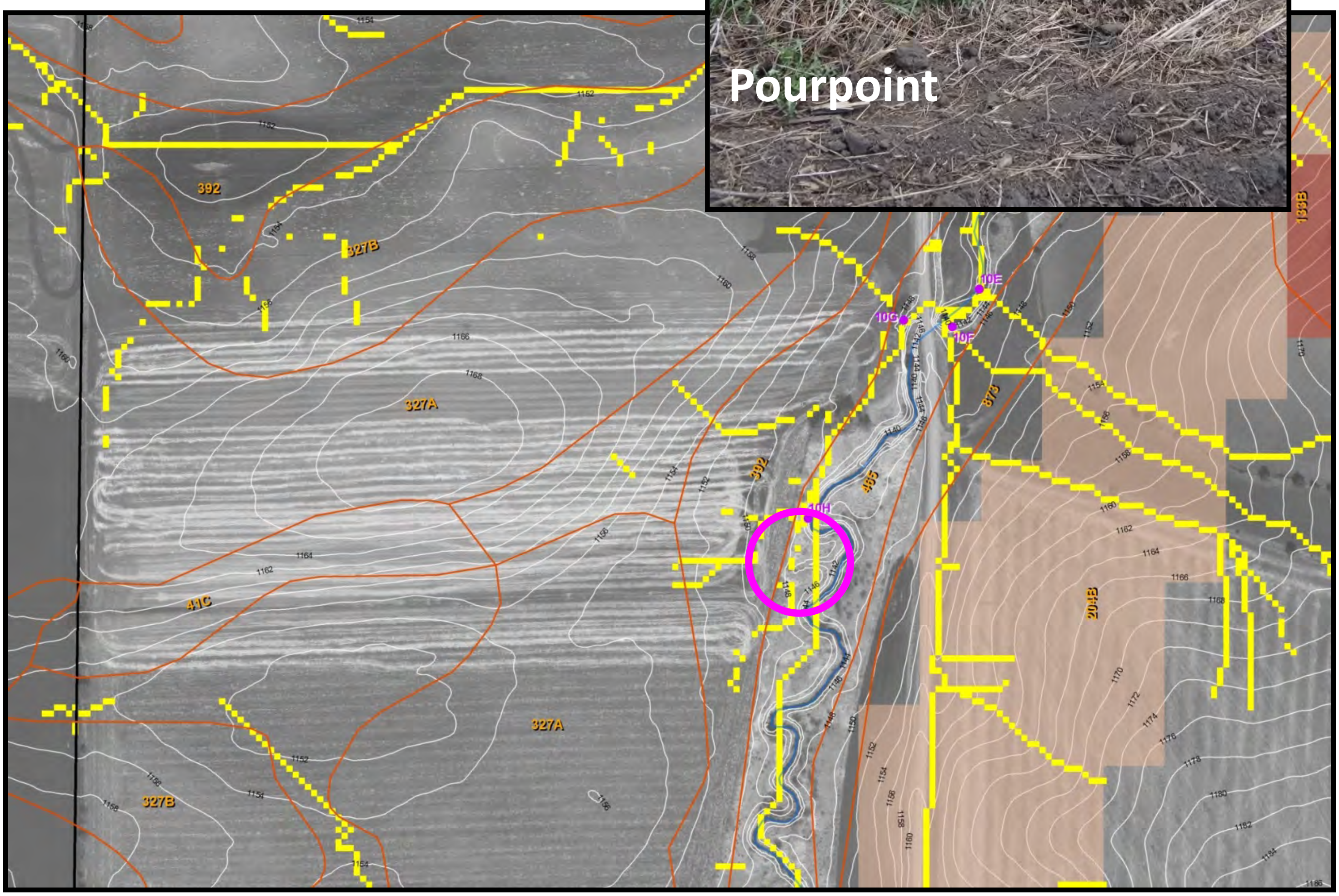
Next, CSA points were intersected with land ownership to target the parcels that had the greatest potential for loading and to maximize the effectiveness of time in the field.



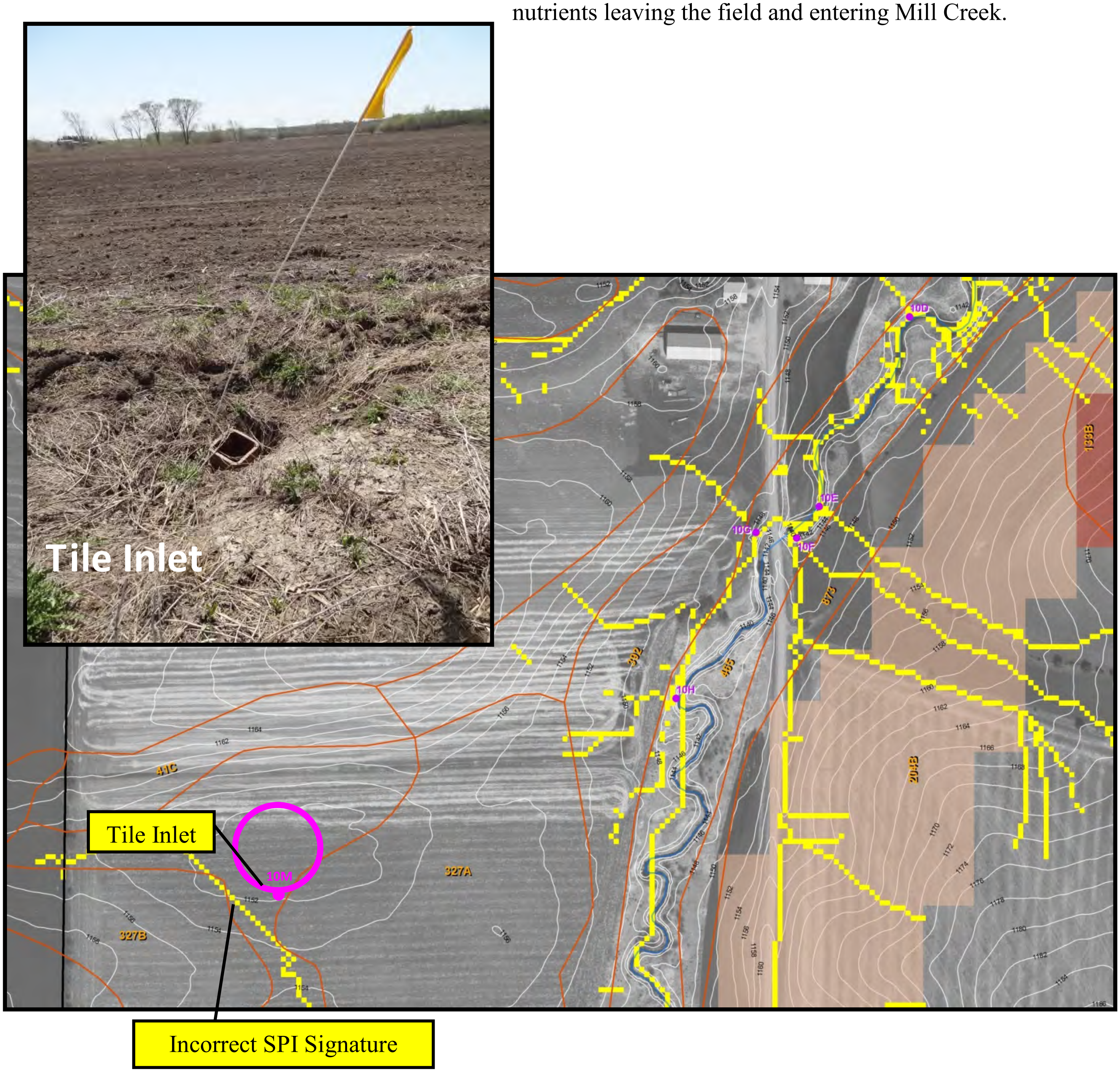
Site 10 had a very high concentration of CSA's with some very strong SPI signatures running through high USLE areas. It was also apparent in the aerial photo that there was an animal crossing at the creek near the road. This increased the priority of the site for the initial evaluation.



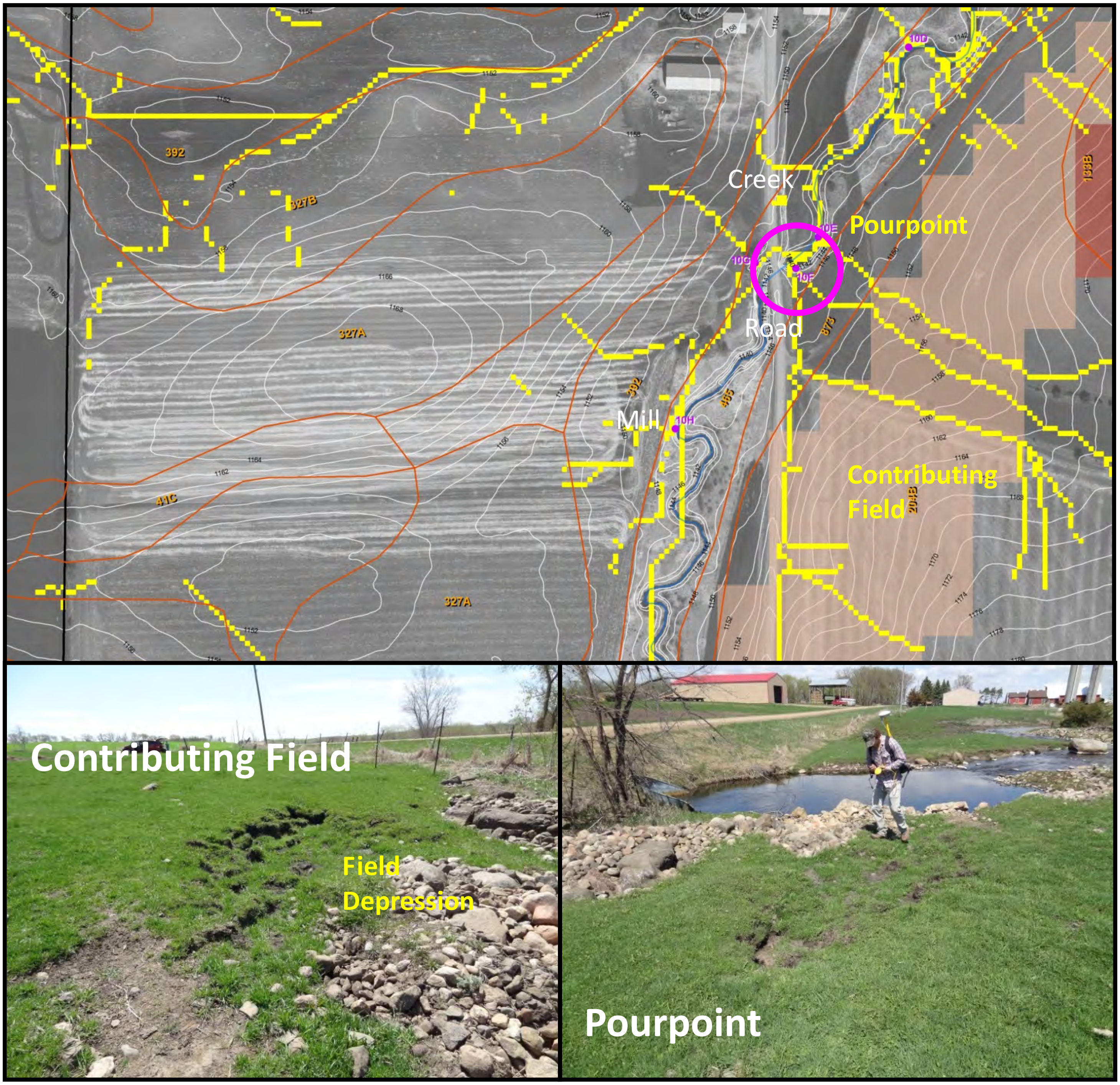
CSA 10H had a few SPI signatures converging on it and was a location where the meandering stream came very close to the field edge. When evaluated in the field no signs of channelization and very minimal signs of sedimentation were observed at the pour point. Good landuse management and a functional buffer were found at this site limiting the potential for issues at this CSA.

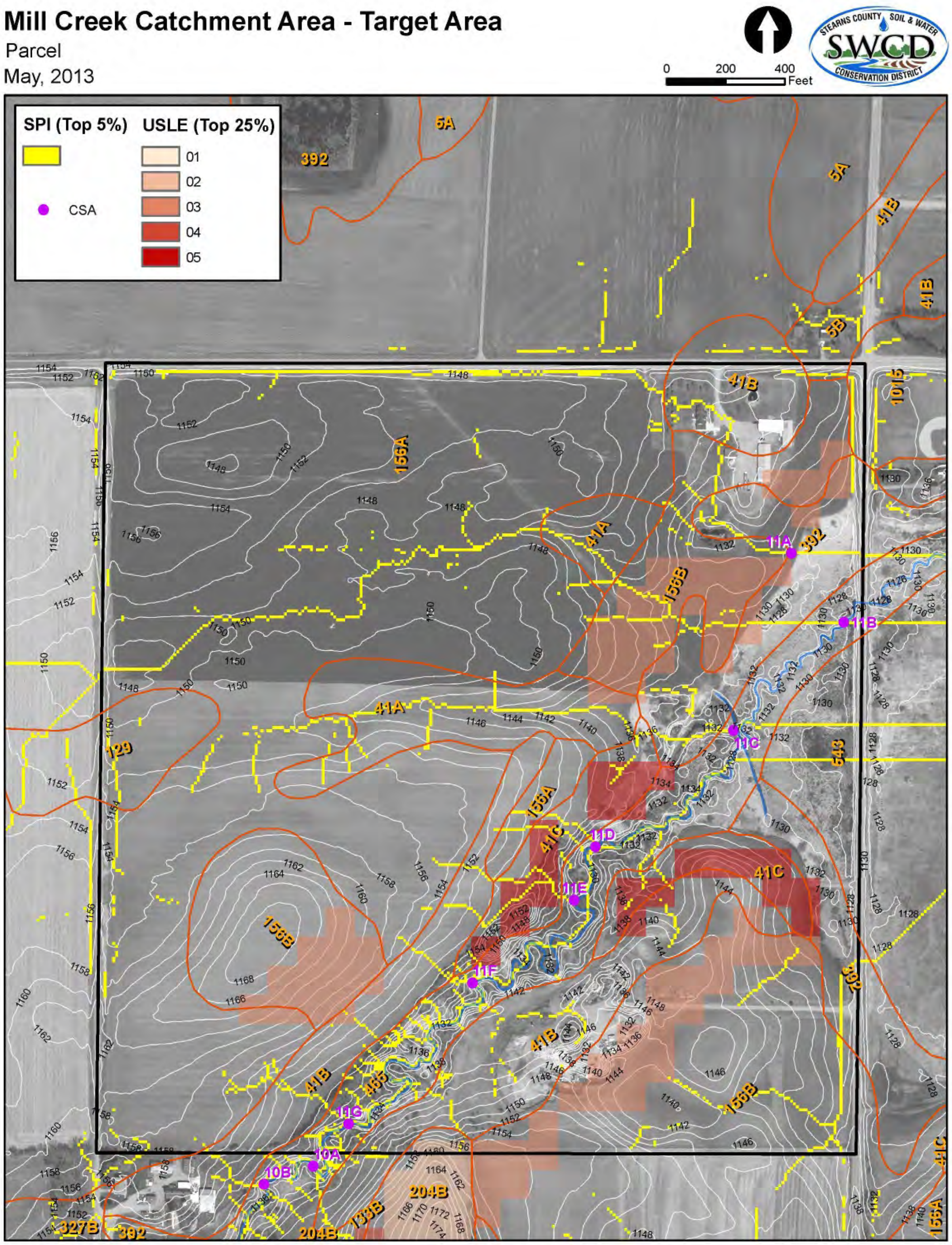
CSA 10M was not located during the original desktop analysis. It was a tile inlet located during the field visit. As shown in the aerial image there is a SPI signature to the southwest of the tile inlet. This was incorrectly located as a result of the pit filling function of the terrain analysis. What it is actually indicated on the map is what would happen if the field depression was to fill up with water and overflow. With the tile in place this would not happen. The tile inlet was identified as a potential nutrient source. The inlet was in a depression and was showing signs of erosion and soil loss. Also, there was no inlet protection in place (just an open tile). It is recommended that tile inlet protection be installed or the inlet be buffered to reduce the chances of sediment and nutrients leaving the field and entering Mill Creek.



CSA 10F represented a site with very strong SPI signature running through USLE areas. In addition, this area is a livestock crossing that was in need of better management. The stream at this site had been heavily lined with riprap. This indicated that there was a past issue with stream bank stability at this location. There was some active erosion occurring on the site as well. The landowner will be moving the livestock crossing to a better location and reestablishing vegetation along the stream at this location.

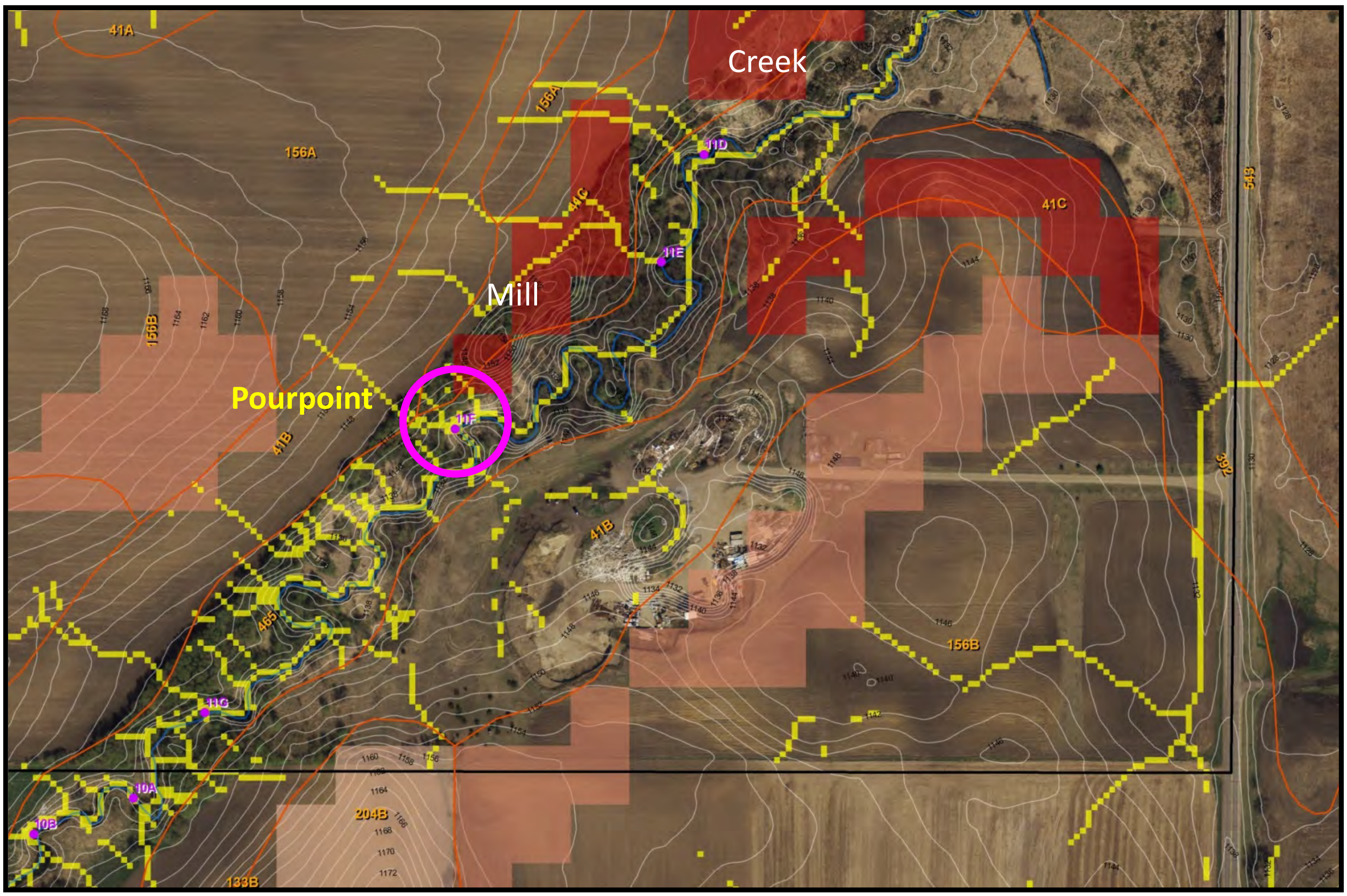


Site 11 was the next site downstream. It also had a high number of CSA's, strong SPI signatures and USLE signatures.

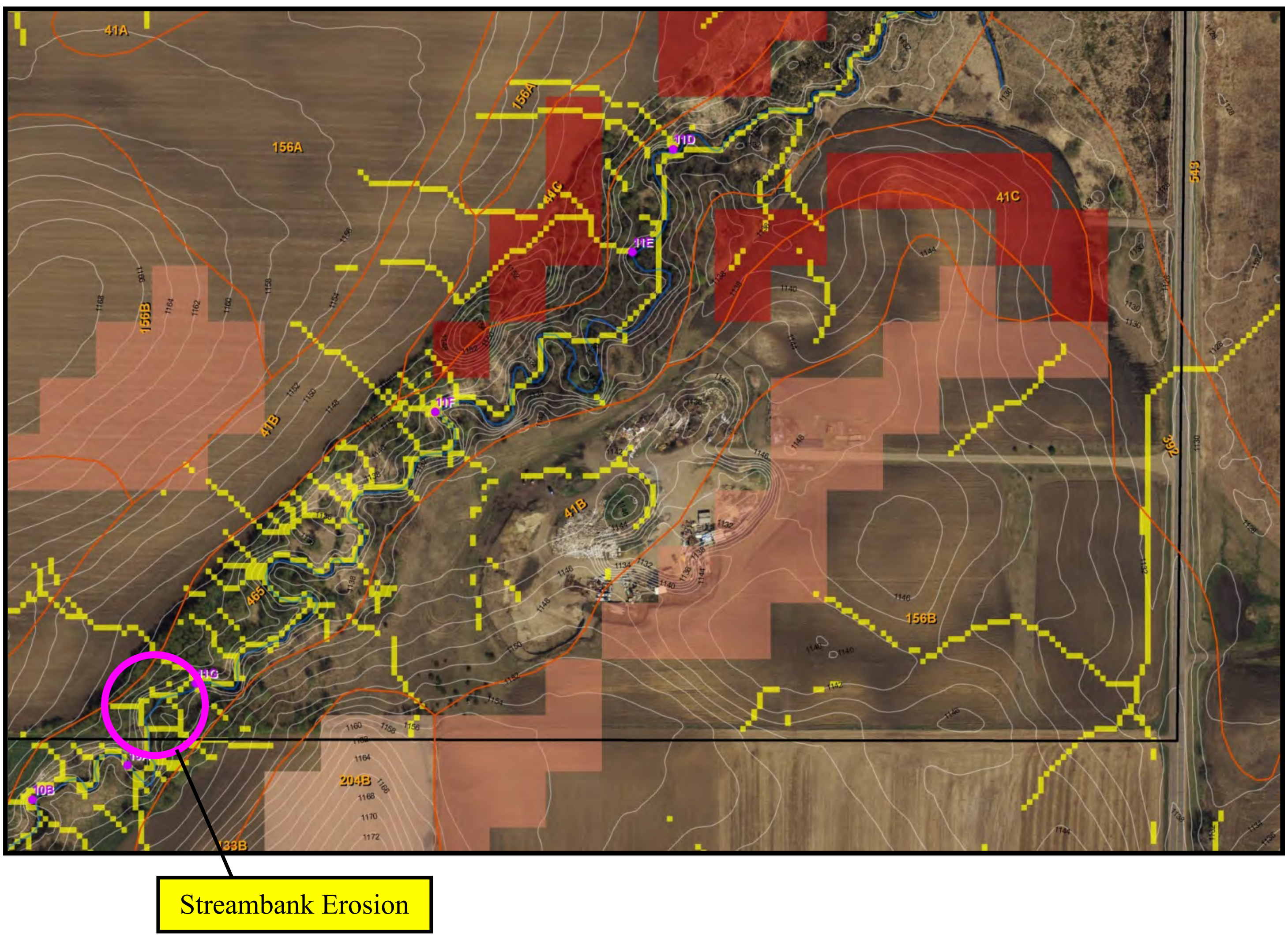


One of the sites evaluated (11F) showed stability in the field and had a wooded buffer with slight signs of channelization and erosion.

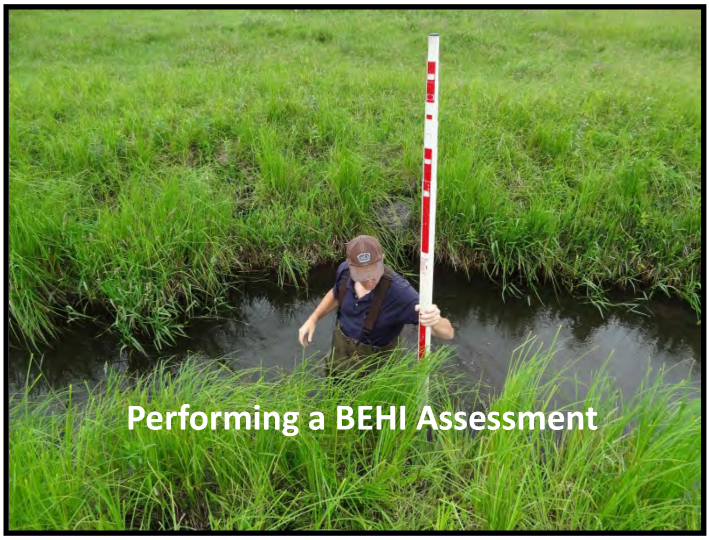




Although the office terrain analysis tools did point us towards issues in the field we found that field work can never be replaced completely with remote sensing tools. This stream bank erosion is something that would not be identified with the office analysis but has the potential to contribute a substantial load of sediment to the system. The stream analysis field tools were used at this site. If a number of issues like these were identified, the results of the field analysis tools can be used to prioritize a plan of action in addressing the erosion sites.

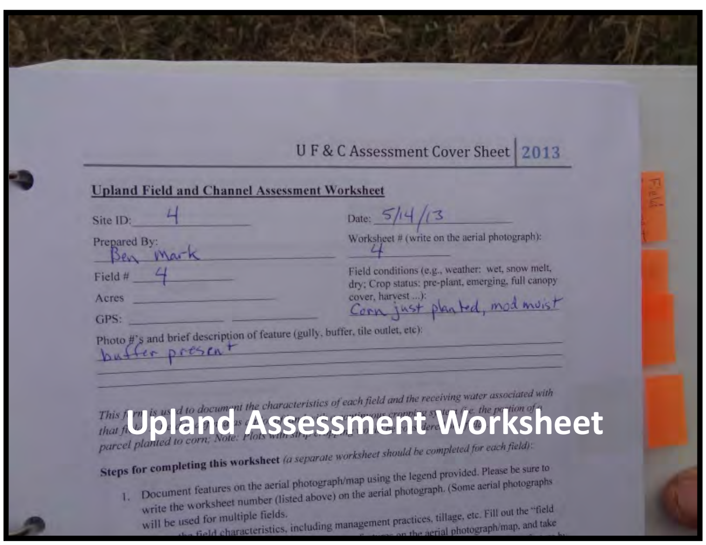



After going through the PMZ process on this channel the source of sediment/nutrients that may be contributing to the impairments of Pearl Lake have become more apparent. It is estimated that there are five to six main issues that we may need addressing (livestock stream crossing, a private ditching system, stream bank instability site s, unprotected tile intakes, etc.). Work is underway with the S auk River Watershed District to implement a water quality monitoring program to increase our understanding of the loading in this system. Wo rk will then be initiated with the local land owners to pursue implementation funding to address the issues.


Performing a BEHI Assessment


Performing a MN Phosphorus Index Assessment


Mill Creek Site 10



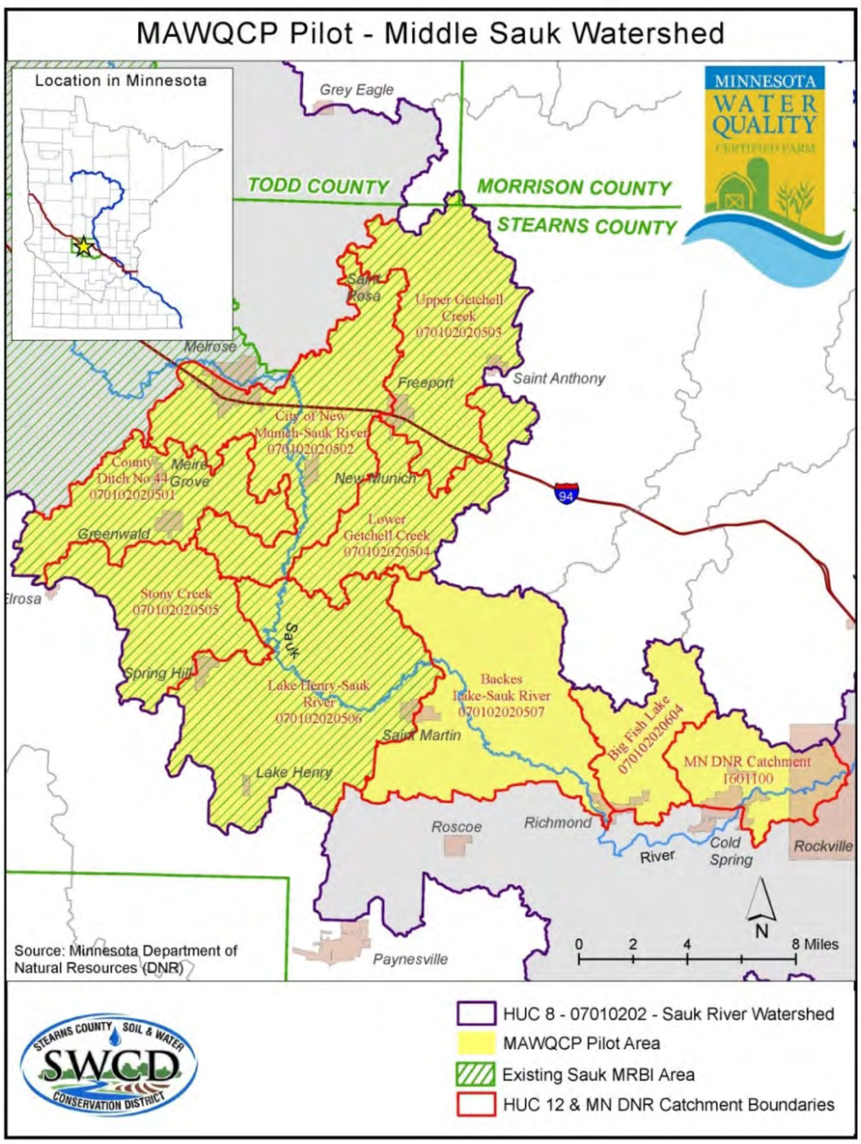
Upland Assessment Worksheet


Upper Part of Unnamed Creek

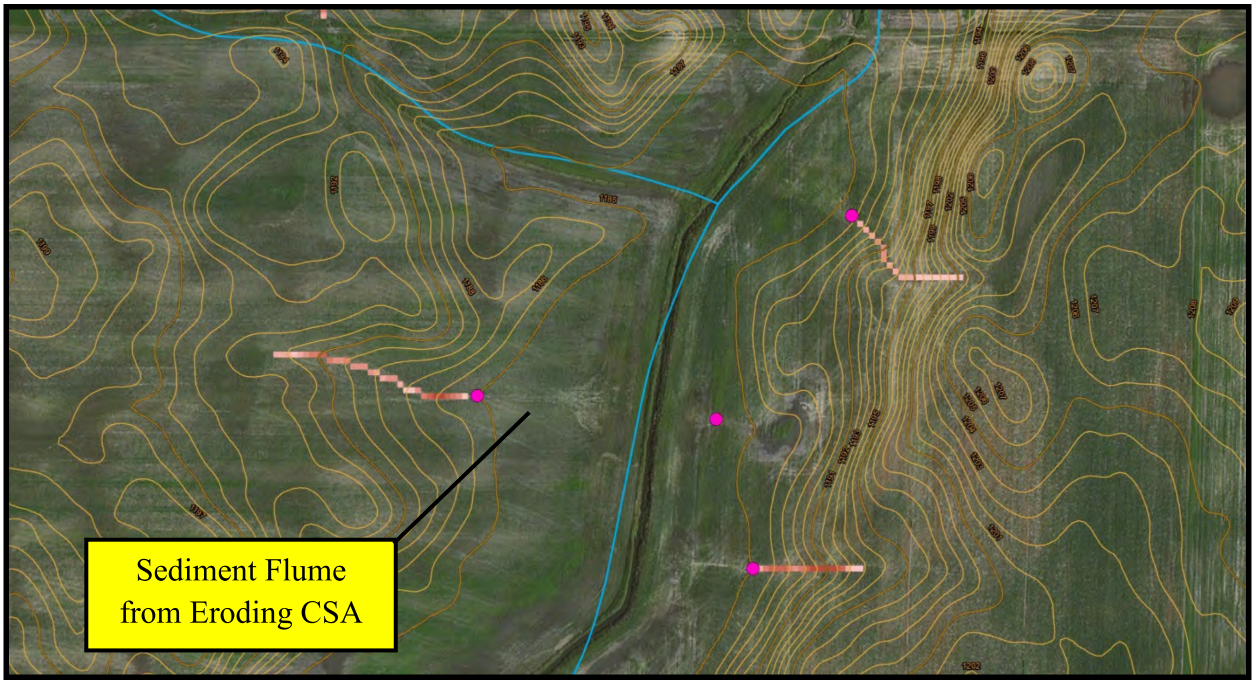
**MAWQCP (Stearns County)**

Stearns County is one of the four pilot areas for the MDA's MN Agricultural Water Quality Certification Program (MAWQCP). This Program is a joint effort of the MDA, MPCA, BWSR, MDNR, USDA NRCS, and the US Environmental Protection Agency. It's a voluntary program designed to accelerate adoption of on-farm conservation practices that protect Minnesota's lakes and rivers. Producers who implement and maintain approved farm management practices will be certified and in turn assured that their operation meets the state's water quality goals and standards for a period of 10 years (see more at http://www.mda.state.mn.us/protecting/waterprotection/awqcprogram.aspx).

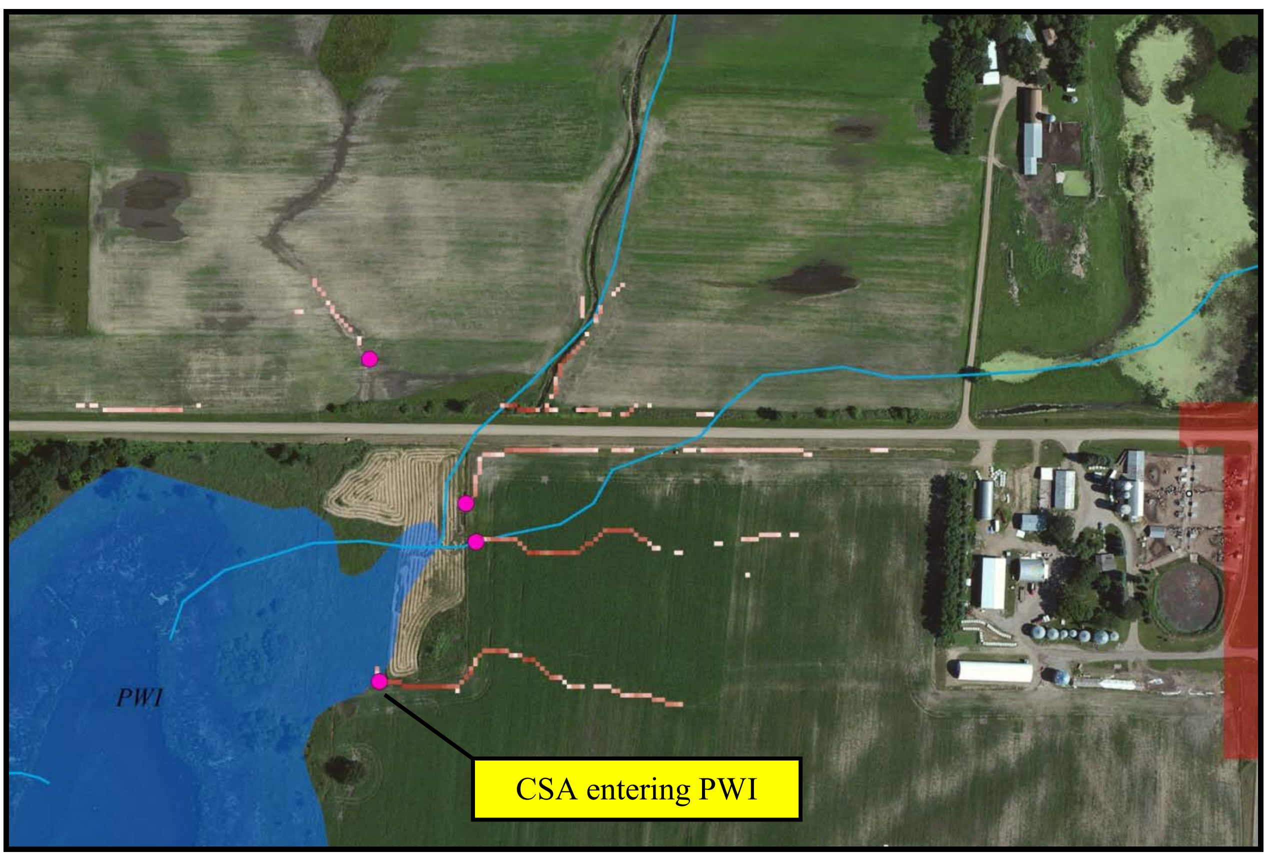
There are about 800 producers in the Stearns County pilot area that we will be participating. The tools discussed in this guidance will be used at multiple levels for this effort. First we will be running the terrain analysis guidance across the project area and prioritizing the areas within the pilot area with the highest potential for pollution to target as high priority sites. We will then follow the protocols on individual farms as a pre-planning tool that would be used with the farmer.



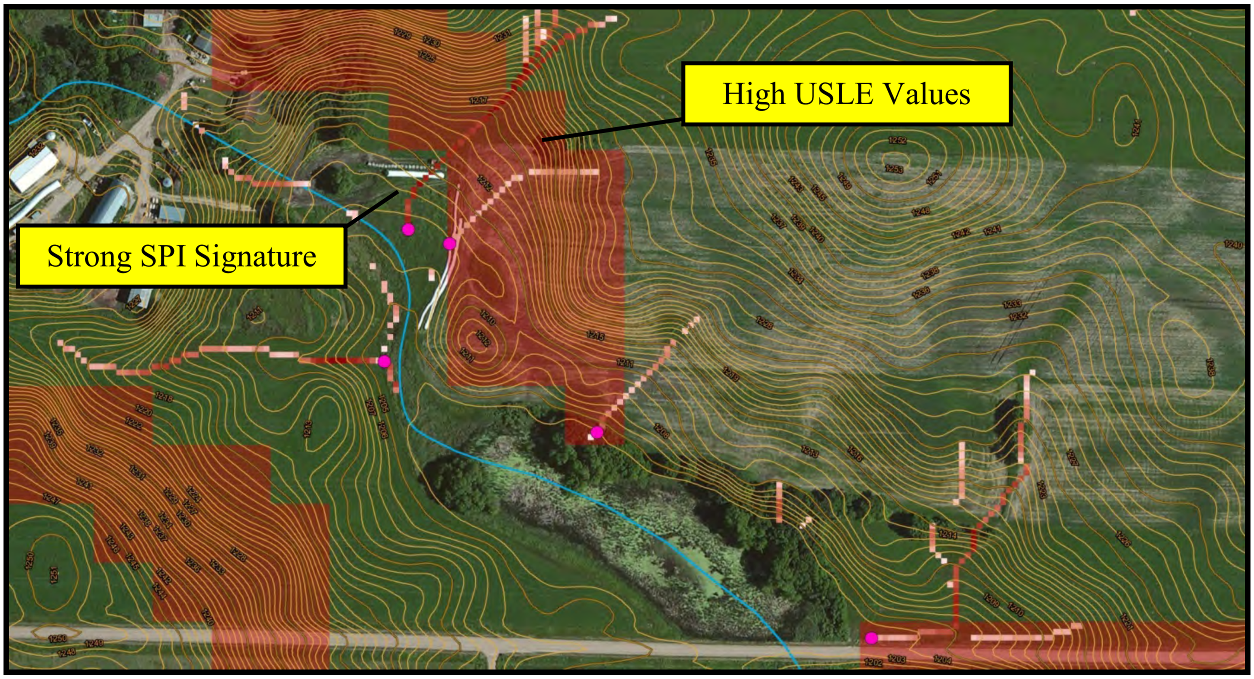
The desktop targeting tools allow us to identify several things before we get into the field. The following graphic shows strong signatures ending before they get to the channel, but we can clearly see sediment flume dumping into the flood plain. This sediment and nutrients could make their way into the channel during high runoff events.




This site shows long SPI signatures ending in water bodies and channels in the Public Water Inventory.

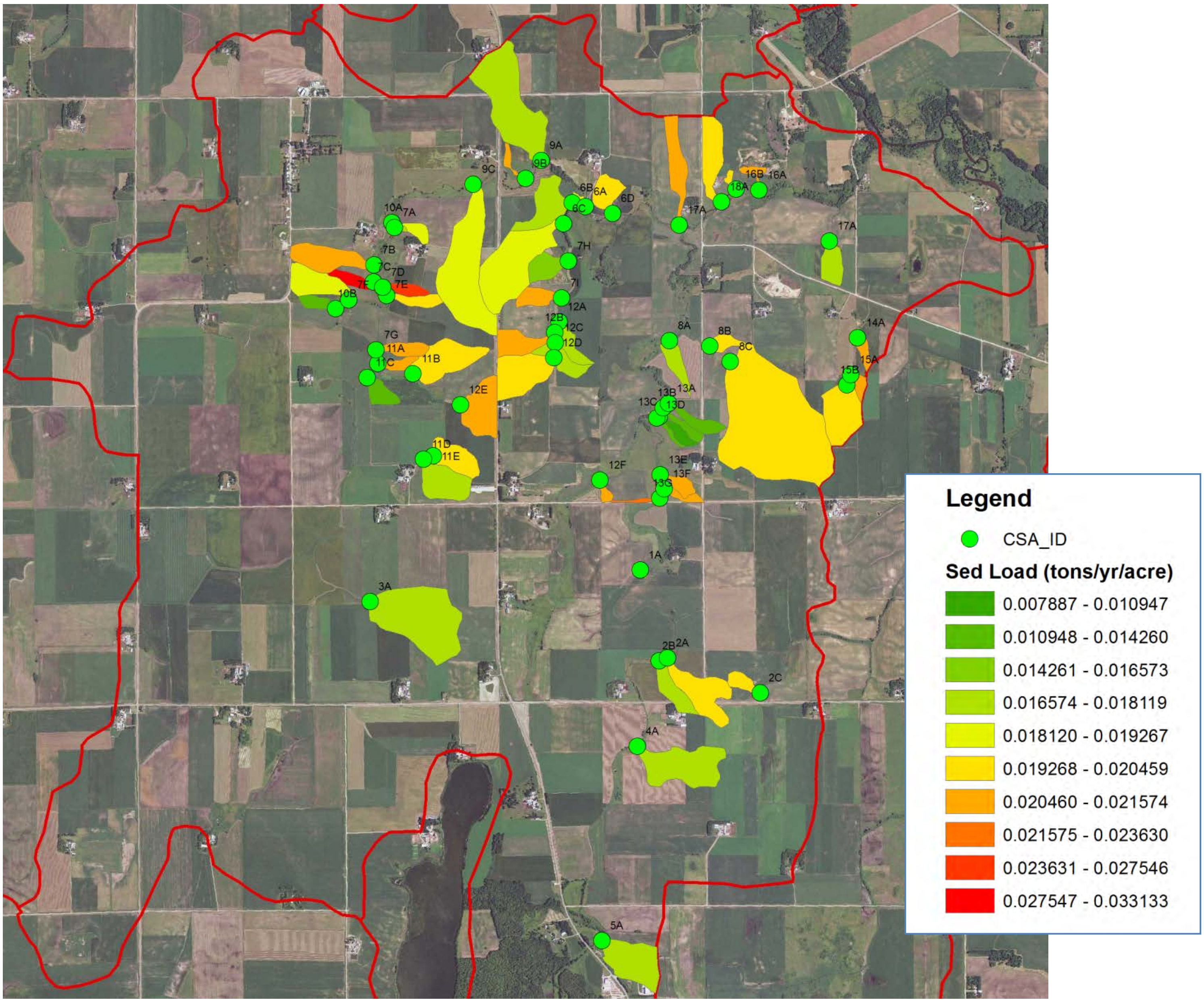


Here is another site exhibiting strong SPI signatures running though high USLE values. This site has some high priority CSA's that need to be discussed with the land owner.

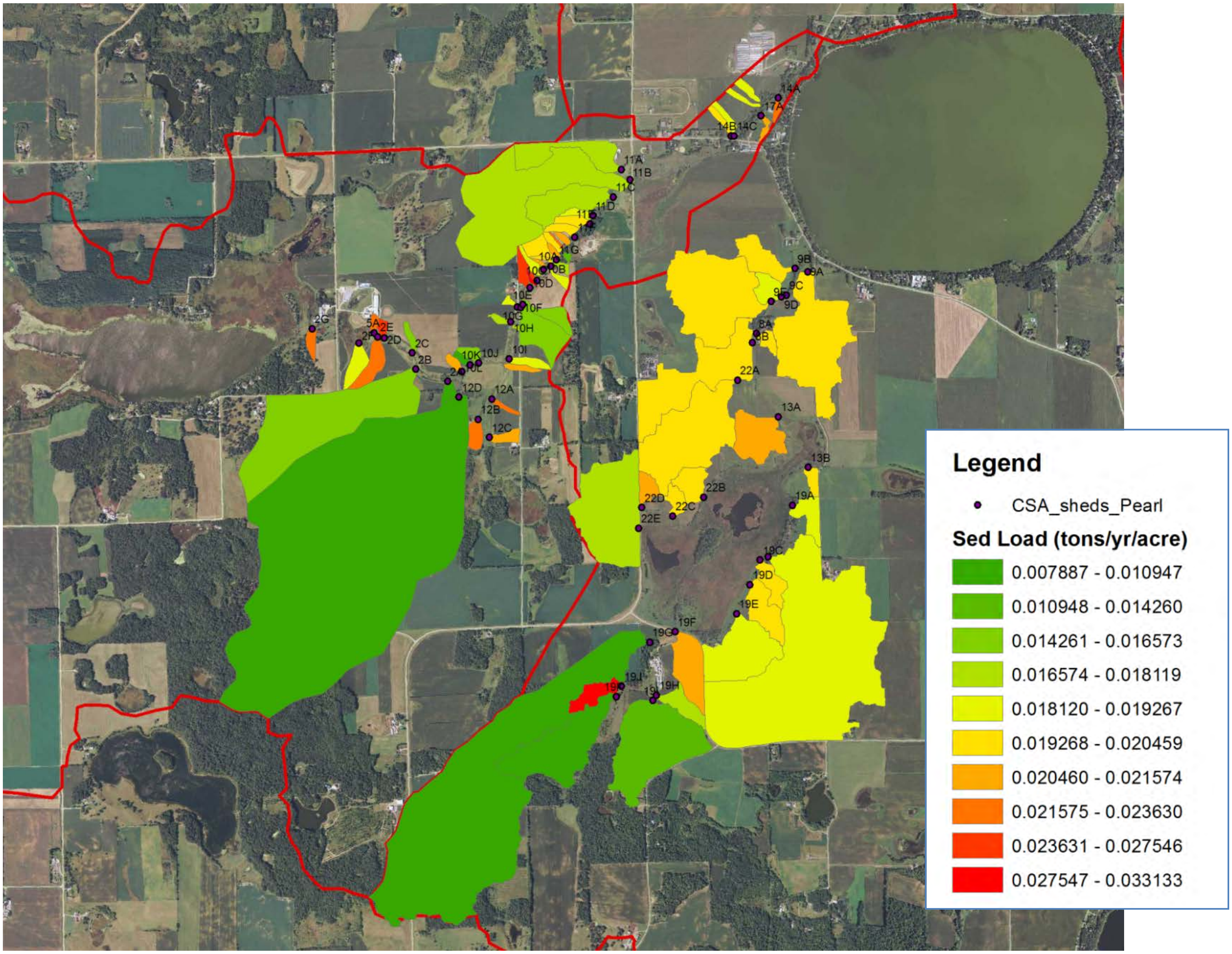


**Integrating HSPF Modeling with Stearns County Case Studies**

The drainage areas were delineated for each of the CSAs identified in the Unnamed Creek watershed and intersected with a GIS layer that contained the land segment areas modeled in HSPF. The HSPF modeling output was then obtained and integrated with the CSA subwatershed GIS data to determine the relative aerial sediment loading rates. The results of this analysis can then be combined with information from the field assessment to prioritize those areas that have the greatest need for implementation of conservation practices.



The drainage areas were delineated for each of the CSAs identified in the Pearl Lake watershed and intersected with a GIS layer that contained the land segment areas modeled in HSPF. The HSPF modeling output was then obtained and integrated with the CSA subwatershed GIS data to determine the relative aerial sediment loading rates.  The results of this analysis can then be combined with information from the field assessment to prioritize those areas that have the greatest need for implementation of conservation practices.

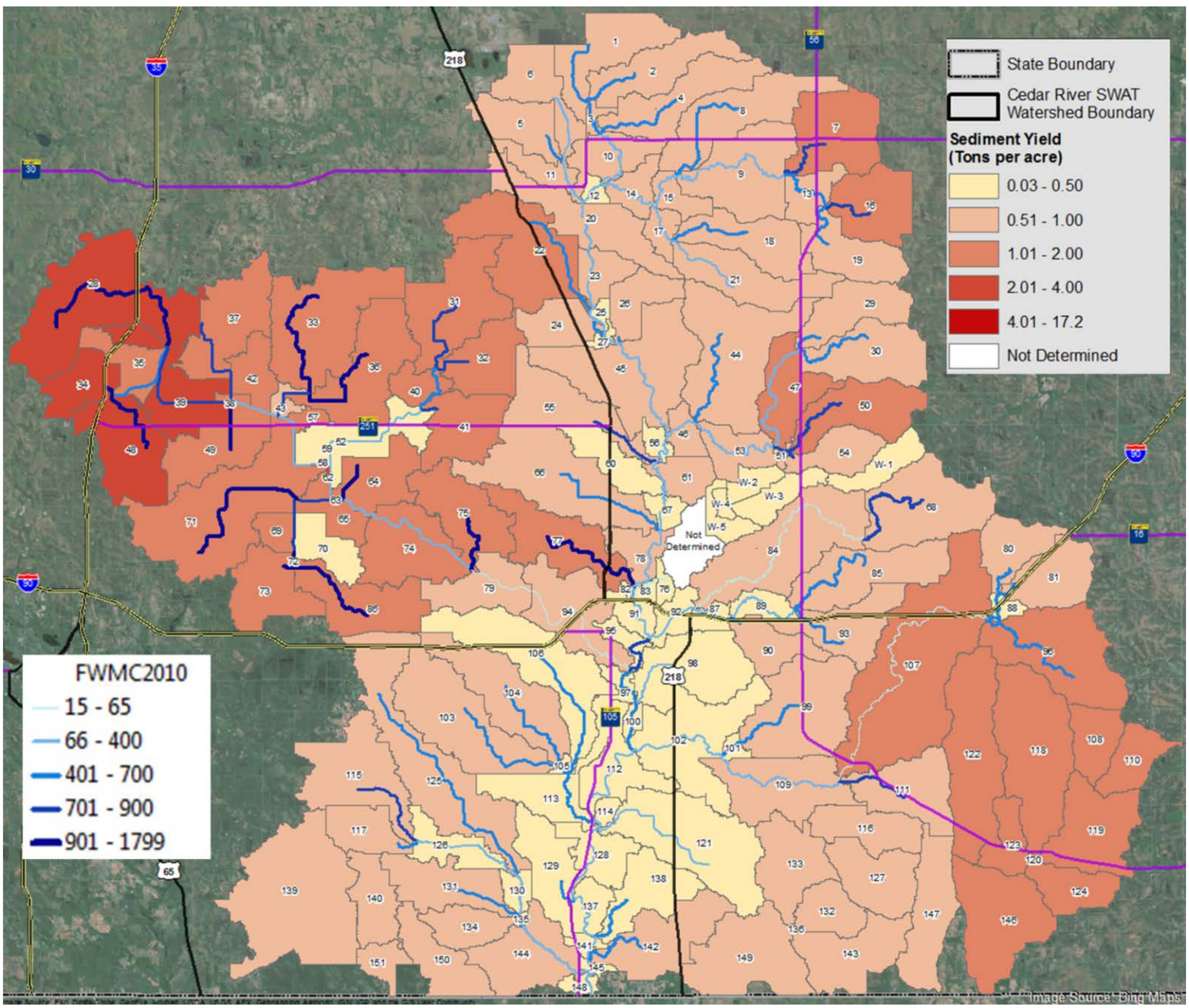


## Integrating SWAT Modeling with Cedar River Watershed Terrain Analysis

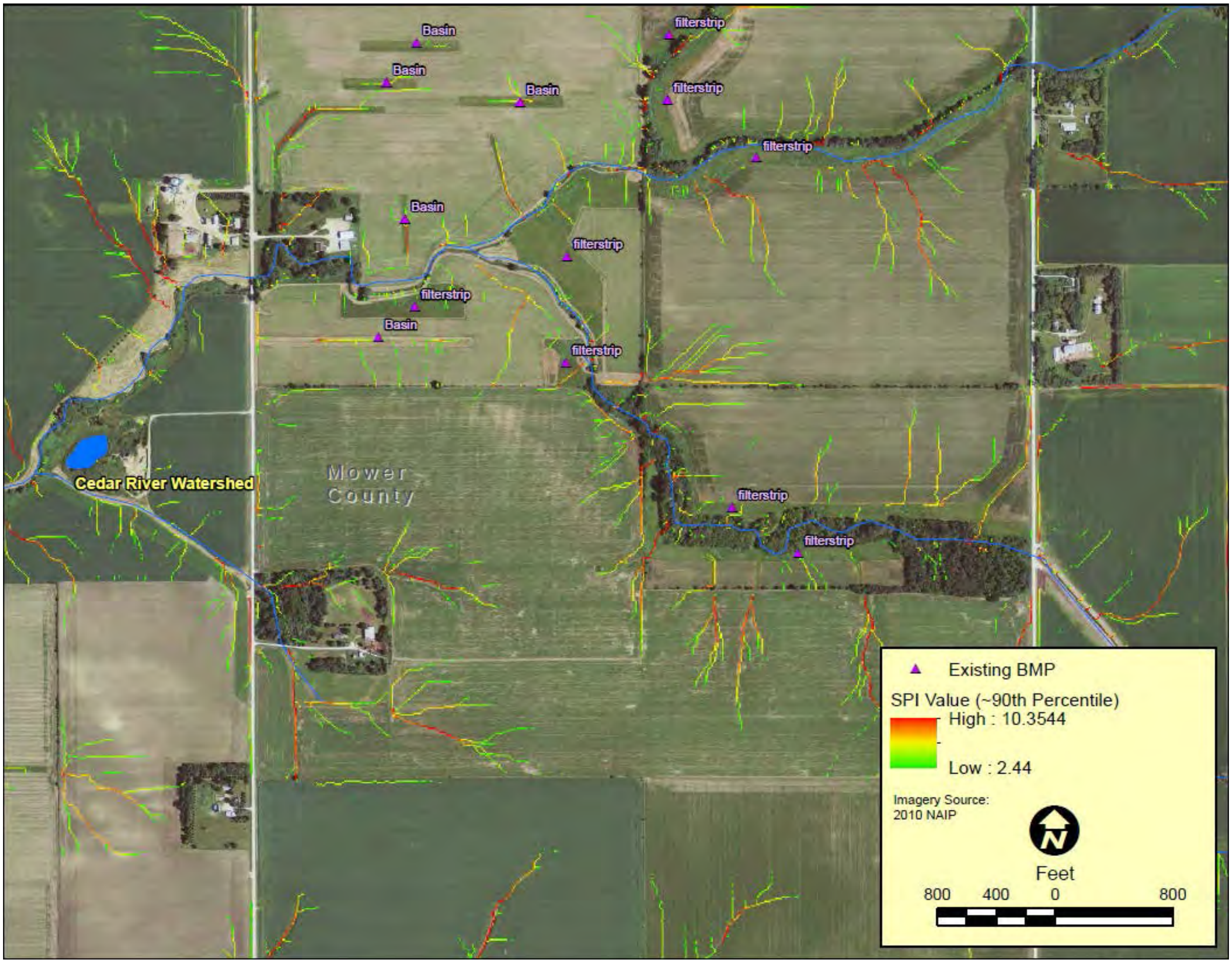
The Cedar River and Turtle Creek Watershed Districts encompass an 8-digit HUC scale watershed in southern Minnesota. Four larger reaches impaired for turbidity and the draft TMDL report (Barr, 2014) calls for greater than 80% solids reduction from high flows (0-10% flow duration). SWAT modeling, calibrated for flow and sediment loading at approximately the 10-digit HUC scale accounted for more than 900 existing BMPs, including:

- 830 filtration practices (grassed waterways, water and sediment control basins, filter strips and side inlet protection)
- Pond/wetland restoration areas (both parcel-based and regional treatment)

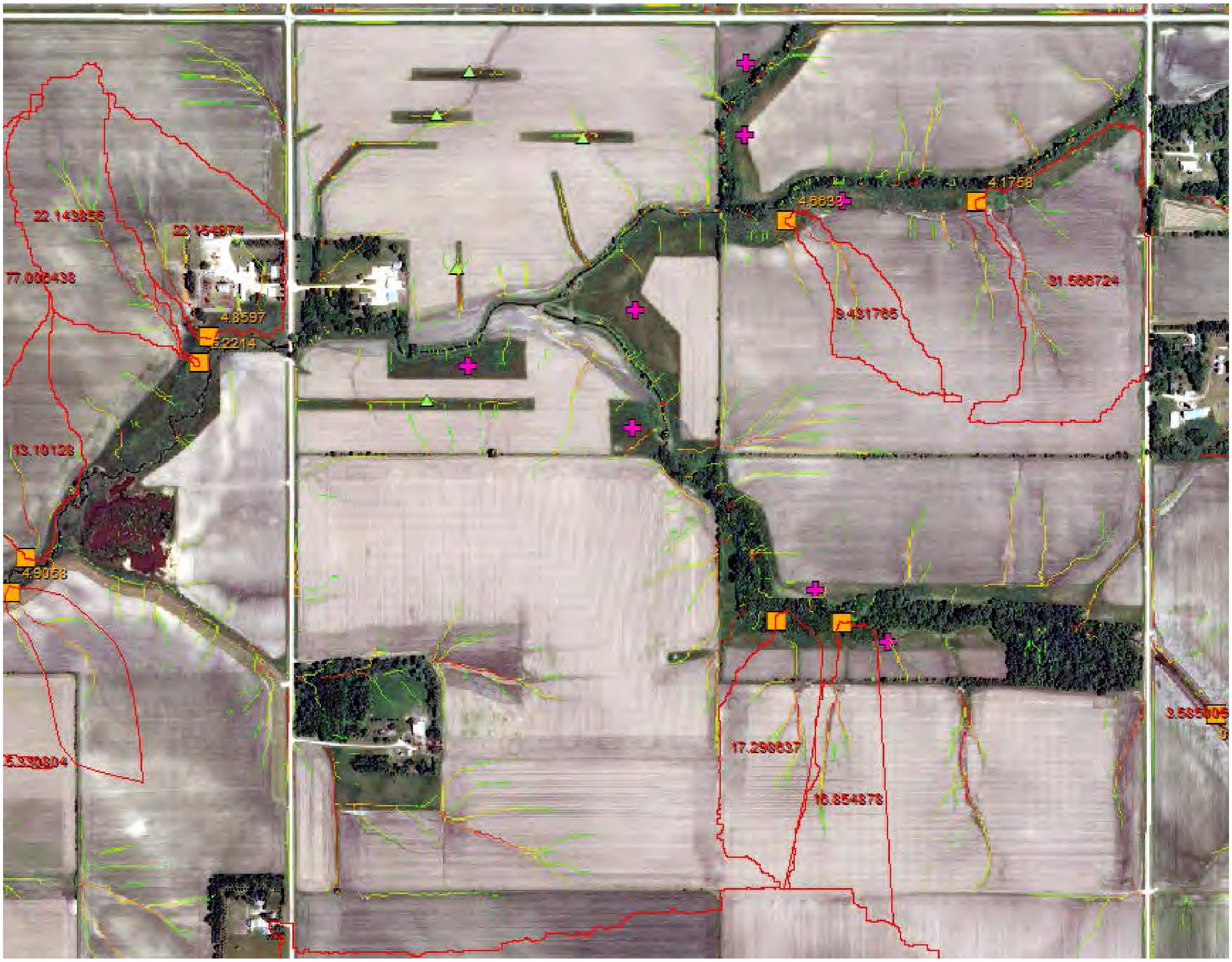
The following figure shows how the SWAT modeling sediment yields and flow-weighted mean suspended solids concentrations are anticipated to vary across the watershed. The modeled estimates can be combined with the results of the digital terrain analysis to further prioritize the areas of the watershed that are in need of conservation practices.



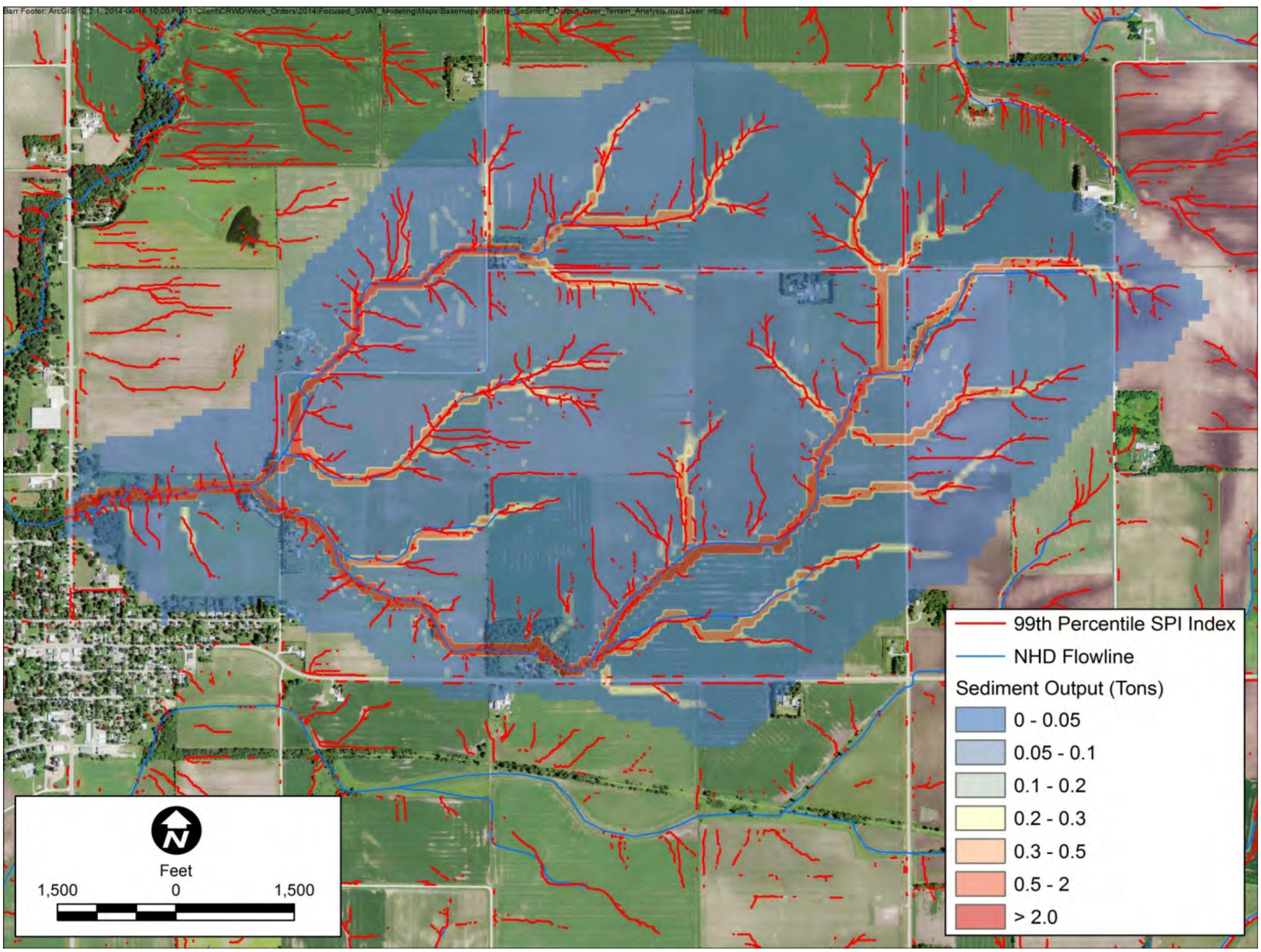
The following figure shows how the 90th percentile SPI signatures produced from the terrain analysis were compared with the locations of inventoried BMPs to identify and further refine the CSAs that require implementation of new BMPs.



For the same area, the following figure shows the delineated area tributary to each of the remaining CSAs. The resulting drainage areas for each CSA can be intersected with the watershed modeling output to further prioritize potential project areas following field verification of the delivery mechanisms and/or erosion potential.

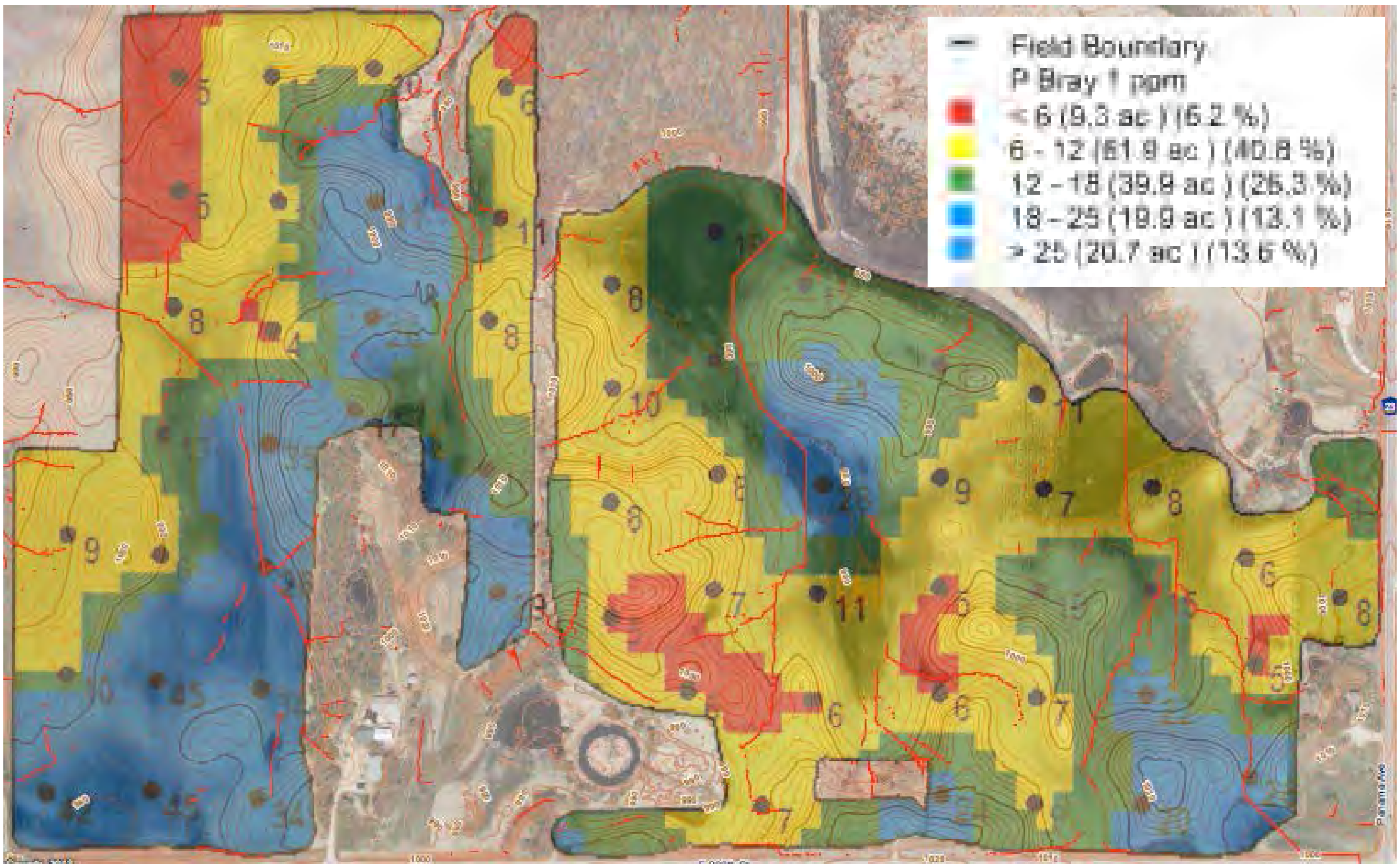


Based on the results of the watershed modeling, a smaller subwatershed was identified as a priority for demonstrating potential restoration options. To assist in locating and testing the benefit of potential BMPs, a grid-cell discretization of the SWAT model was applied to the study area shown in the following figure. This version of the SWAT model allows for detailed estimates of sediment export based on the two-dimensional interaction of 30x30-meter areas of the landscape, including the potential effects of stream power and channel erosion. As a result, the grid-cell modeling accounts for artificial drainage and erosion and deposition throughout the system, which allows for prioritization based on the estimated effects at various receiving water scales. Since the resolution of the model output is still larger than the 3-meter resolution used in the digital terrain analysis, the 99$^{th}$ percentile SPI signature lines were superimposed in the following figure to identify the 30-meter grid cells that have a defined hydrologic connection to the surface water system and would be expected to possess the highest risk for gully or channel erosion. The integrated data, combined with field verification, can be used to prescribe and prioritize the implementation of conservation practices.



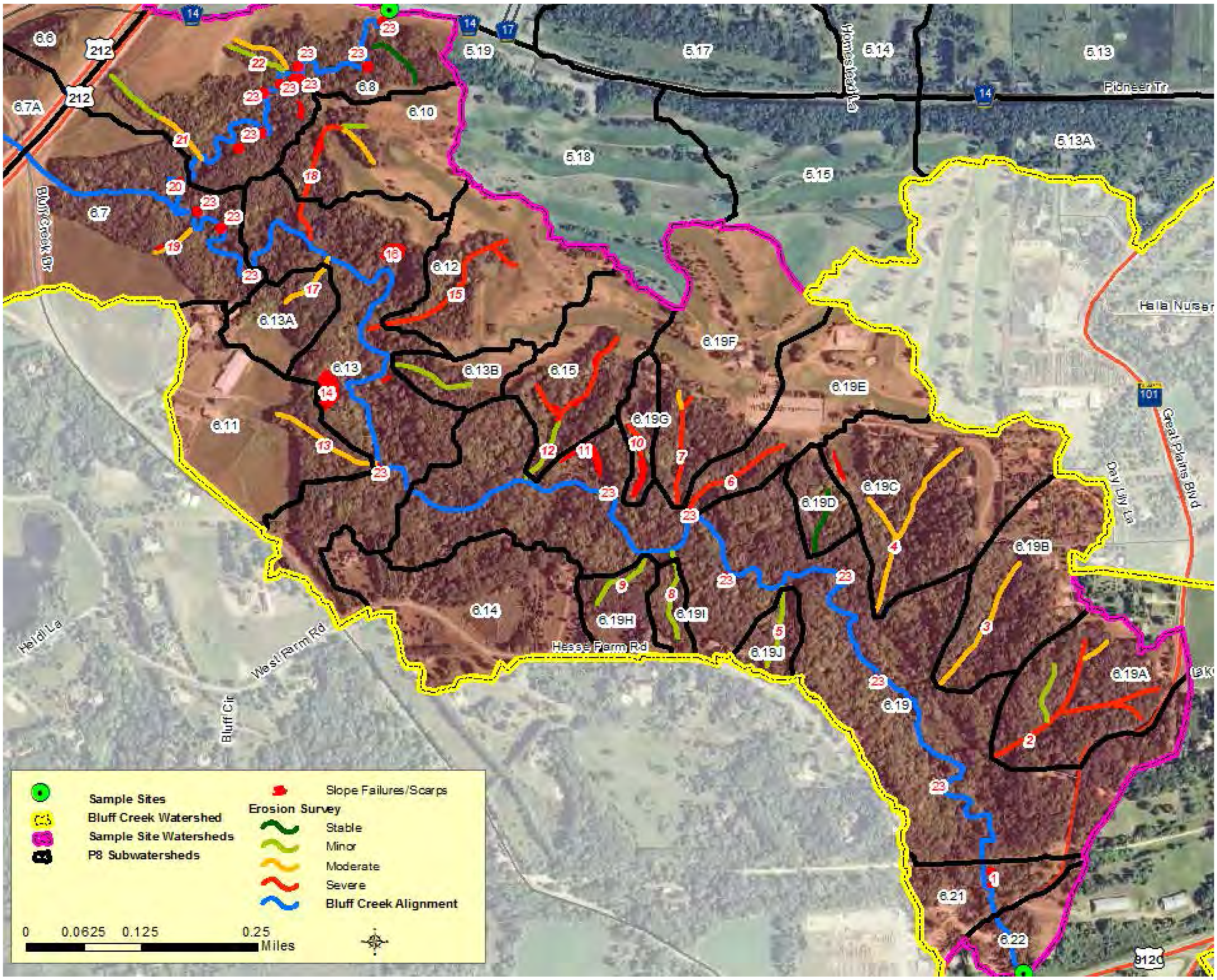
## Integrating Terrain Analysis with Sub-Field Soil Fertility

The following figure illustrates how the 99th percentile SPI signature data can be integrated with sub-field scale soil fertility data, using Bray phosphorus soil test results (previously generated from an outside testing lab), to prioritize the pourpoints that have the greatest need for implementation of conservation practices.



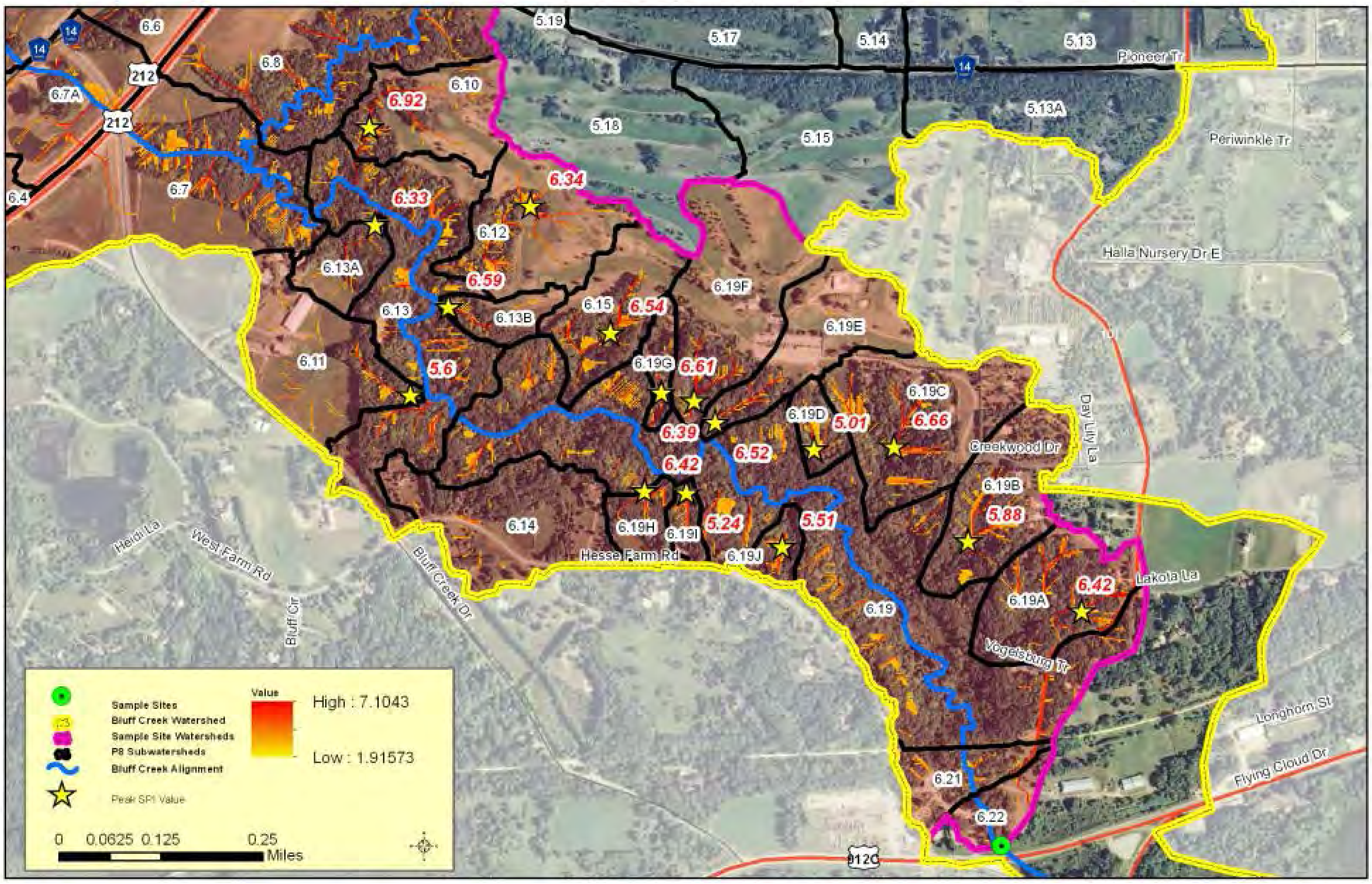
## Integrating Terrain Analysis with Watershed Modeling for Ravine Erosion

An inventory and assessment of the Bluff Creek Lower Valley completed in 2007 identified sites contributing sediment to Bluff Creek as well as the erosion severity at those sites. Erosion severity was qualitatively assessed by a geomorphologist based on the relative volumes of erosion observed at each site and divided into four categories: stable, minor, moderate and severe. Numbered site locations are shown in the following figure.

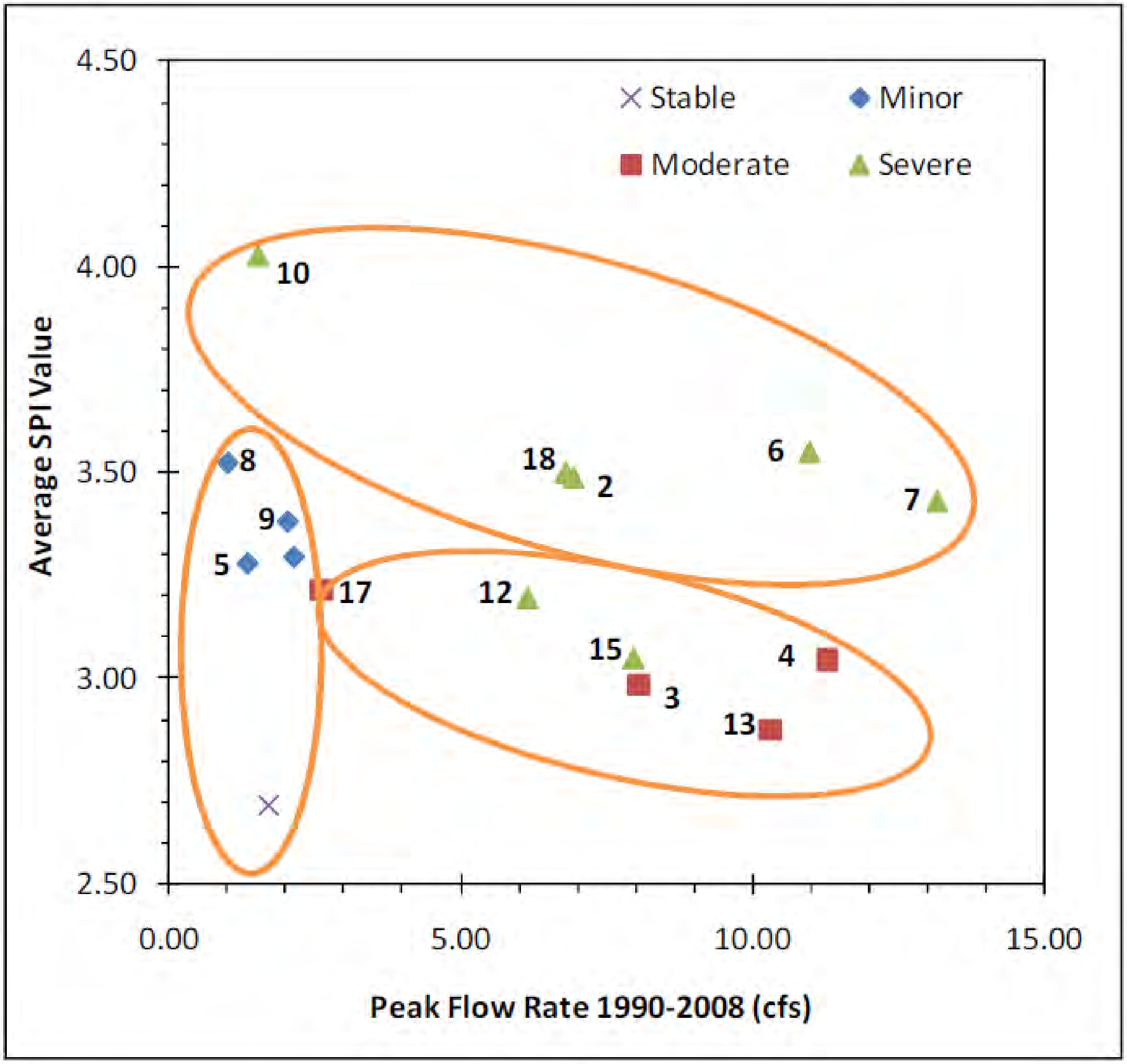


A terrain analysis was conducted for each of the ravines based on SPI calculations to further assess the erosion potential for each ravine (Barr, 2013). The SPI is a function of both slope and tributary flow accumulation area, but does not necessarily equate to volume of water flowing to a particular point on the ground. The SPI represents the ability of intermittent overland flow to create erosion, but the SPI values are not differentiated based on soils type or land cover effects on runoff volume or erosion. SPI values were calculated for every 100 $ft^2$ of the Bluff Creek watershed and the top 5 % of values are displayed in the following figure along with the peak SPI value and location for each of the ravine watersheds.

The terrain analysis, erosion survey and watershed modeling results were combined to help assess each of the ravines in the lower reach of Bluff Creek, including the ravine erosion classification, annual peak flow and runoff volume, and the max SPI value and average of the top 5 % SPI values for each of the ravine watersheds obtained through the terrain analysis.



The results of the integrated analysis were grouped in the following figure which shows the relationship between the average SPI and the modeled peak flow rate between 1990 and 2008 grouped by ravine erosion severity. On average, ravines with low modeled peak runoff rates were surveyed as having either stable or minor erosion. Ravines with a higher Stream Power Index showed minor erosion when compared to the stable ravines. Ravines surveyed with moderate erosion displayed higher average modeled peak flow rates with comparable SPI values than both ravines with minor or stable erosion. On average, ravines surveyed as having severe erosion had both higher SPI values and modeled peak flow rates than the ravines surveyed with minor or stable erosion and higher SPI values than those surveyed as having moderate erosion.



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# Appendix

## A.1 Digital terrain analysis accuracy results

Table 3 shows comparisons between the Sediment Delivery Potential (SDP) of erosional features identified or not identified in several Dodge Co., MN study areas using the GIS–based validation survey technique and a 97.5$^{th}$ percentile threshold calculated from each HUC12 study area.

SDP scores consist of three incremental values of risk: low, medium, and high (1, 2, and 3 respectively). The score was determined by a field technician's best professional judgment. Some of the factors that influenced the SDP score include general size and position of the feature in the landscape, the size of the drainage contributing area, and obvious indicators of sediment delivery, such as active alluvial fans. Although subjective, these SDP scores provide qualitative categories that can be used to compare the relative impact of gullies on potential water quality degradation (Galzki et. al., 2011).

**Table 3**

| | Validation result | | | | |
|---|---|---|---|---|---|
| SDP value of erosional features | Features identified | Features not identified | Total erosional features identified | Accuracy (%) | Commission errors |
| 1 (Low) | 44 | 15 | 59 | 75% | N/A |
| 2 (Medium) | 23 | 6 | 29 | 79% | N/A |
| 3 (High) | 8 | 0 | 8 | 100% | N/A |
| Total | 75 | 21 (omission errors) | 96 | 78% | 74 of 139 pts |

In total, 96 features (gullies, ravines, tile outlets, bank slumps, grassed waterways) were identified in the field.

Overall, GIS terrain analysis correctly predicted the location of 78% of field erosion source areas. Accuracy was greatest for large features (100%).

The 'Total' row is showing that out of the 96 features identified, 75 were closely associated with an SPI signature from GIS terrain analysis, and 21 were not (omission errors). The commission errors, also known as false positives, are predicted CSA points (there were 139 in total) placed using preliminary GIS analysis that were not closely associated with a field surveyed location.

The following two figures contain boxplots using data from the same Dodge Co. study areas. Figure 6 compares a 1-10 SPI rank to erosional feature SDP assigned values. The lower limit of the box represents the 1$^{st}$ quartile, the top limit is the 3$^{rd}$ quartile, and the middle solid line is the median value of the data. The whiskers are 1.5x the inner quantile range, with dots representing outliers. Figure 7 shows the same boxplot configuration with a comparison made between field verified points vs. an equal number of randomly generated points.

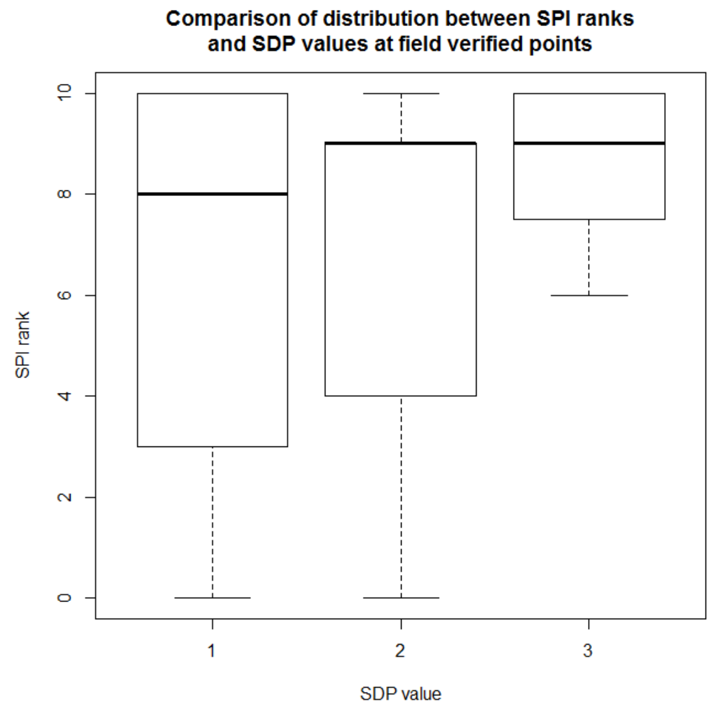



Figure 6

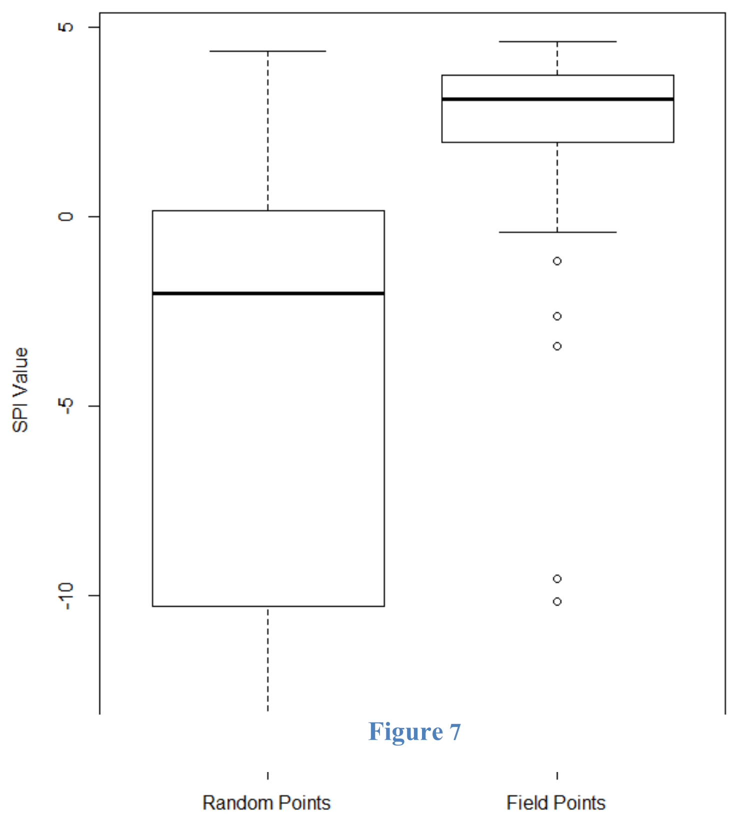



Figure 7

Table 4 shows comparisons between the SDP of erosional features identified or not identified in several Wabasha Co., MN study areas using the GIS–based validation survey technique with a 97.5th percentile threshold.

**Table 4**

| value of erosional features | Validation result: Features identified | Validation result: Features not identified | Total erosional features identified | Accuracy (%) | Commission errors |
|---|---|---|---|---|---|
| 1 (Low) | 12 | 1 | 13 | 92% | N/A |
| 2 (Medium) | 15 | 3 | 18 | 83% | N/A |
| 3 (High) | 3 | 0 | 3 | 100% | N/A |
| Total | 30 | 4 (omission errors) | 34 | 88% | 12 of 34 pts |

In total, 34 features (gullies, ravines, tile outlets, bank slumps, grassed waterways) were identified in the field.

Overall, GIS terrain analysis correctly predicted the location of 88% of field erosion source areas. Accuracy was greatest for large features (100%).

The ‘Total’ row is showing that out of the 34 features identified, 30 were closely associated with an SPI signature from GIS terrain analysis, and 4 were not (omission errors). The commission errors, also known as false positives, are predicted CSA points (there were 34 in total, it was a coincidence that there were also 34 field points) placed using preliminary GIS analysis that were not closely associated with a field surveyed location.

The following two figures contain boxplots using data from the same Wabasha Co. study areas. Figure 8 compares a 1-10 SPI rank to erosional feature SDP assigned values. The lower limit of the box represents the 1st quartile, the top limit is the 3rd quartile, and the middle solid line is the median of the data. The whiskers are 1.5x the inner quantile range, with dots representing outliers. Figure 9 shows the same boxplot configuration with a comparison made between field verified points vs. an equal number of randomly generated points.

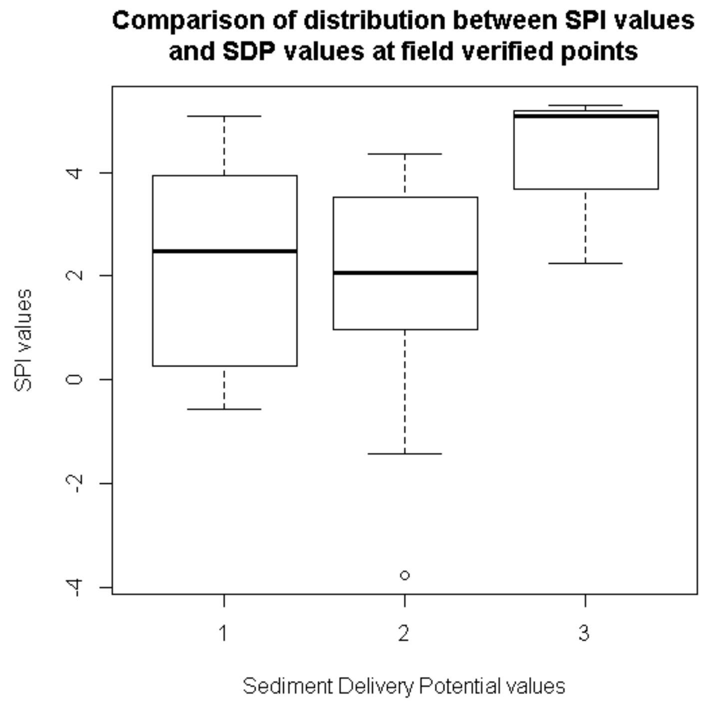



Figure 8

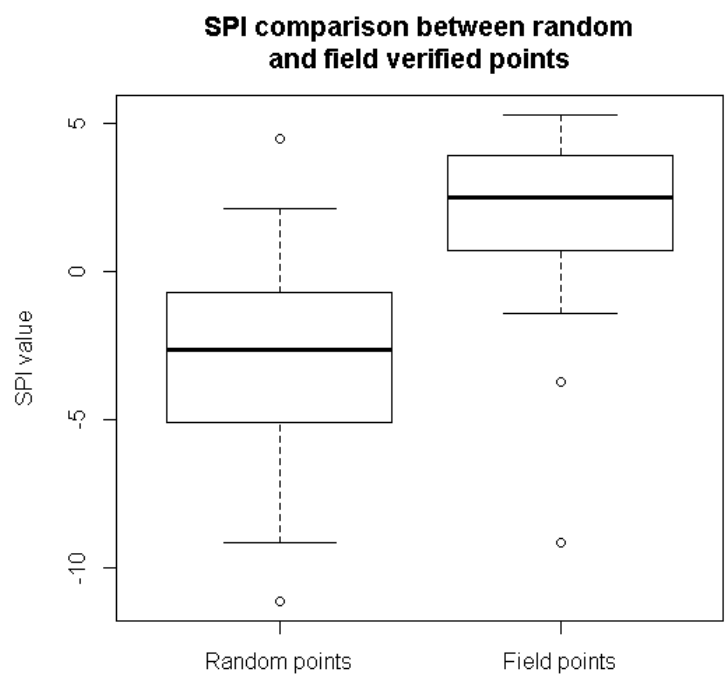



Figure 9

The following table and figure (Table 5 and Figure 10) were published in the 2011 Galzki, et. al. paper, published in the Journal of Soil and Water Conservation. They show terrain analysis accuracy results in the same format presented in the two proceeding examples. Galzki's study was conducted in two watersheds, named Beauford and Seven Mile Creek, within the Minnesota River basin, near Mankato, MN.

**Table 5**

Comparison between gully features identified or not identified in Seven Mile Creek watershed using the geographic information system–based validation survey technique with an 85th percentile threshold.

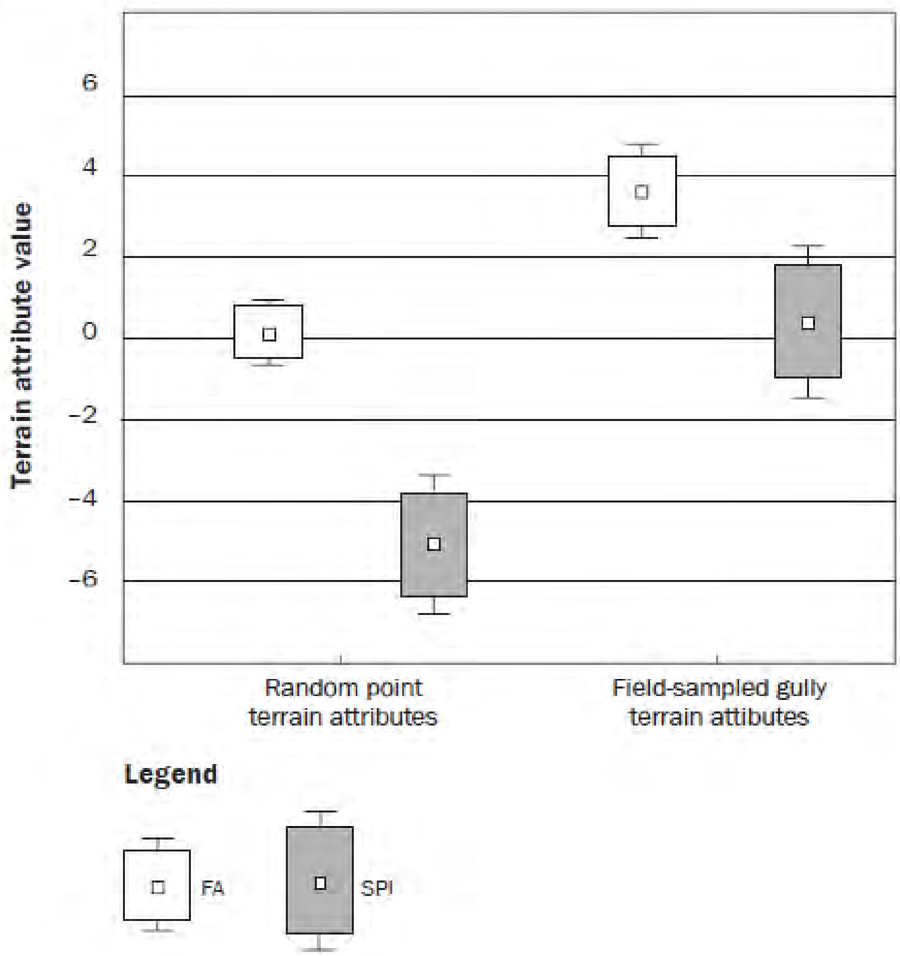
| | Validation result | | Total features present |
|---|---|---|---|
| Feature* | Identified | Not identified | |
| SDP 3 gully | 31 | 1 | 32 |
| SDP 2 gully | 17 | 5 | 22 |
| SDP 1 gully | 17 | 12 | 29 |
| Total | 65 | 18 (omission errors) | 83 |
| False positive | 43 (comission errors) | — | — |

Notes: SDP = sediment delivery potential. — = not applicable.

* A lower value of SDP indicates lower sediment delivery potential and a smaller catchment area.

**Figure 10**

Comparison of flow accumulation (FA) and stream power index (SPI) for random points versus field-sampled gully points in the Seven Mile Creek watershed. The whisker ends represent the 99% confidence interval.



## A.2 Create Stream Power Index for ravine identification

A ravine is defined as a small, narrow and deep depression, smaller than a valley, and larger than a gully (Bates and Jackson, 1984). Ravines grow by head cutting action, but unlike gullies, are too large to be transversed by farm equipment.

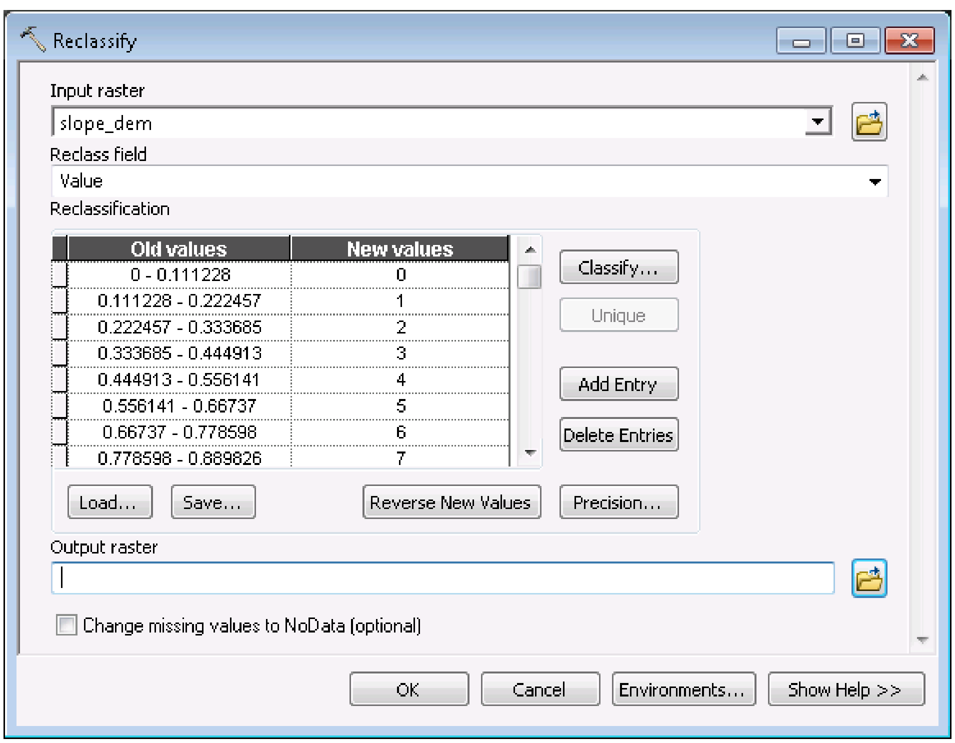
Researchers at the University of Minnesota's Dept. of Soil, Climate & Water developed an algorithm to aid in ravine identification while working in the Minnesota River Basin. The algorithm output is a topographic indice similar to the Stream Power Index, but includes aspect information which takes concave ravine profiles into account. This algorithm consisits of slope steepness greater than 7%, standard deviation of aspect greater than 40%, and a flow accumulation threshold between 200 and 7400 cells, depending on topography.

Starting from the procedures outlined in the Digitial Terrain Analysis section, the ravine algorithm will begin with a Digital Elevation Model.

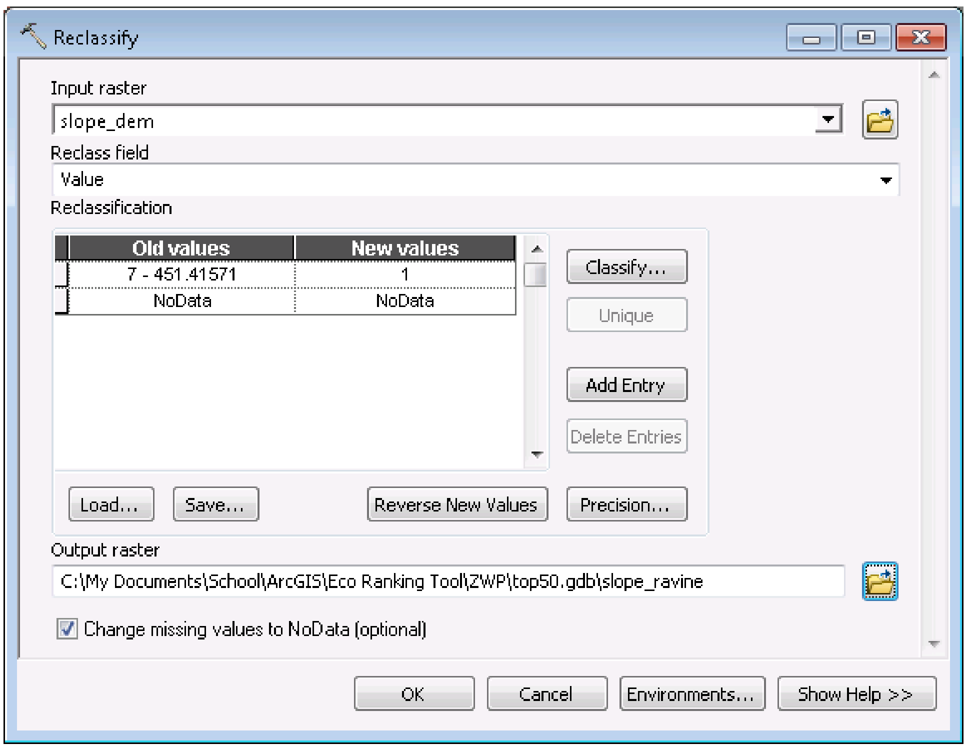
The algorithm output generally displays best results when pit filling is included during DEM pre-processing. This is explained in the 'Pre-process DEM' section.

The Slope and Aspect raster layers are calculated directly from the DEM as shown in the 'Calculate primary attributes' section. Remember to use 'PERCENT_RISE' in the arctool output measeurment. The Flow Accmulation raster is also used for the algorithm, and thus a Flow Direction raster will need to be created before Flow Accumulation.

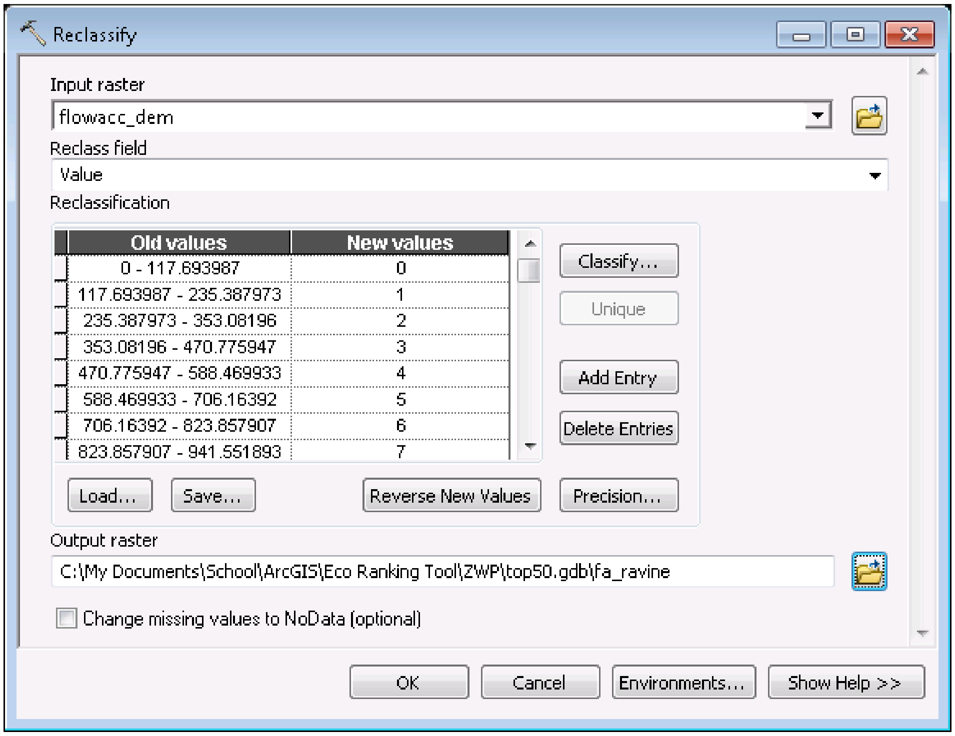
1. The **Reclassify** tool will be used to set the raster layer parameters for the ravine algorithm. Starting with the **Slope** raster layer, open the **Reclassify** Tool:
   a. In ArcMap, open **ArcToolbox > Spatial Analyst Tools > Reclass > Reclassify**



b. **Input raster:** Your Slope (slope_dem) layer.
c. **Reclass field:** This should default to 'Value'
d. **Reclassification:** Click on the 'Classify…' button.
   - Using the classification method pull down, select Equal Interval, and select 1 from the Classes pull down.
   - Click the 'Exclusion…' button and type '0-7' (without quotes) in the exclusion value field, and then click OK.
   - Click OK at the bottom right of the Classification window to return to the Reclassify tool.
e. **Output raster:** Browse to output workspace and name output layer 'slope_ravine'
f. Check the box next to **Change missing values to NoData (optional)**
g. Click OK to run. The output raster is added to your map as a new layer



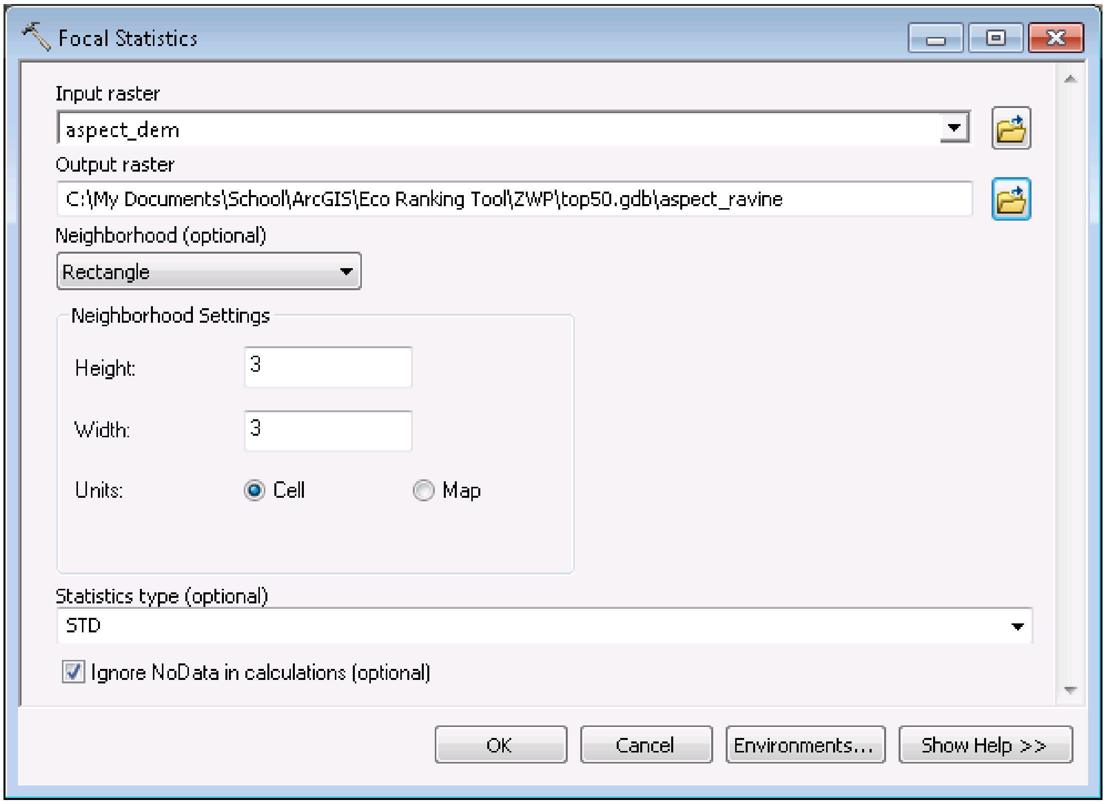
2. Open the **Reclassify** tool again to process the **Flow Accumulation** raster layer:




a. **Input raster:** Your Flow Accumulation (flowacc_dem) layer.
b. **Reclass field:** This should default to 'Value'
c. **Reclassification:** Click on the 'Classify…' button.
   - Using the classification method pull down, select Equal Interval, and select 1 from the Classes pull down.
   - Click the 'Exclusion…' button. The best exclusion range used here will vary depending on the overall topography steepness. As a general guideline: for steepest slopes, type '0-7400' in the exclusion range (without quotes), and for shallow slopes, type '0-200'.
   - Click OK at the bottom right of the Classification window to return to the Reclassify tool.
d. **Output raster:** Browse to output workspace and name output layer 'fa_ravine'
e. Check the box next to **Change missing values to NoData (optional)**
f. Click OK to run. The output raster is added to your map as a new layer

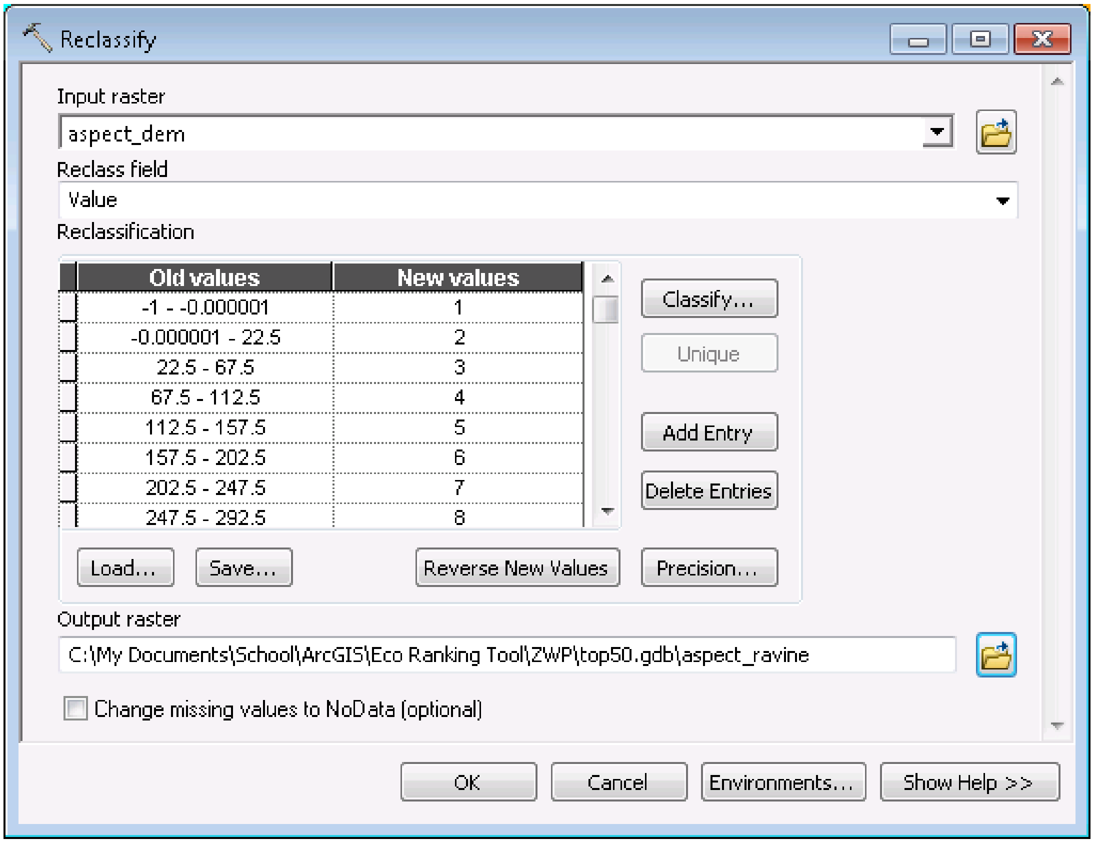
3. The **Aspect** raster layer is first processed using the **Focal Statistics** arctool before being reclassified. To begin processing the **Aspect** raster:

   a. In ArcMap, open **ArcToolbox** > **Spatial Analyst Tools** > **Neighborhood** > **Focal Statistics**

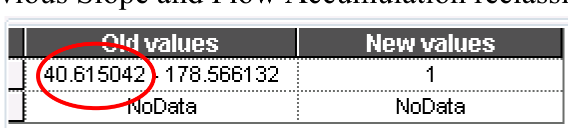



   b. **Input raster:** Your Aspect (aspect_dem) layer
   c. **Output raster:** Browse to output workspace and name output layer 'aspect_FS'
   d. **Statistics type (optional):** Select 'STD' (standard deviation) from the pull down menu.
   e. Leave the other options as default (as shown above) and click OK to run. The output raster is added to your map as a new layer

4. Open the **Reclassify** tool once more to continue processing the **Aspect** raster layer:




a. **Input raster:** Your Aspect Focal Statistics raster layer from the previous step (aspect_FS)
b. **Reclass field:** This should default to 'Value'
c. **Reclassification:** Click on the 'Classify…' button
   - Using the classification method pull down, select Equal Interval, and select 1 from the Classes pull down.
   - Click the 'Exclusion…' button and type '0-40' (without quotes) in the exclusion value field, and then click OK.
   - Click OK at the bottom right of the Classification window to return to the Reclassify tool dialog.
     - *Note:* The 'Old values' range listed may not be rounded to 40. It is okay to leave the value as is, or simply click the value and change it to 40, without decimals. The same is true for previous Slope and Flow Accumulation reclassifications.

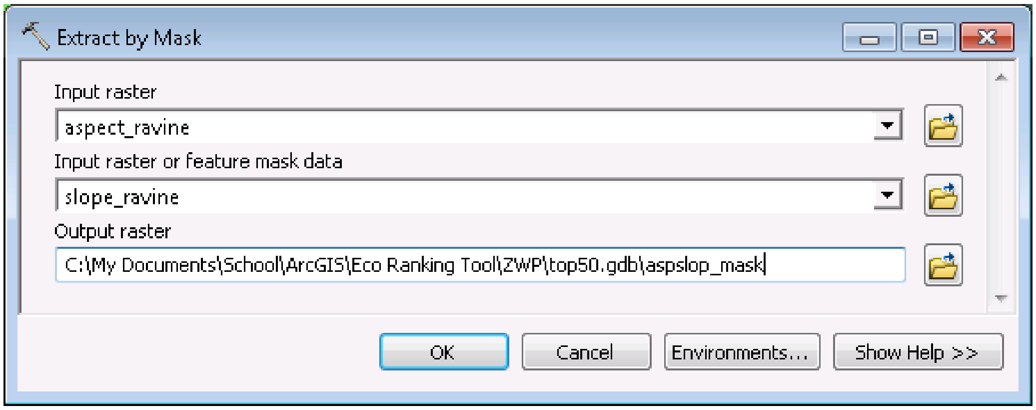


| Old values | New values |
|---|---|
| 40.615042 - 178.566132 | 1 |
| NoData | NoData |

d. **Output raster:** Browse to output workspace and name output layer 'aspect_ravine'
e. Check the box next to **Change missing values to NoData (optional)**
f. Click OK to run. The output raster is added to your map as a new layer

5. Now that all thee raster layers have been reclassified into single-level rasters, the **Extract by Mask** Arctool will be used to extract only the pixels from all three layers that overlay each other.

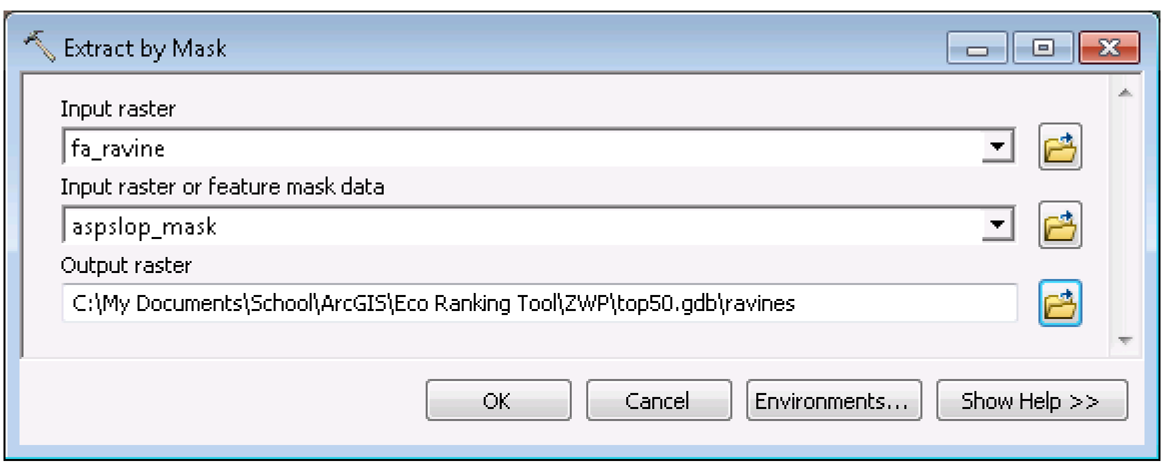
   a. In ArcMap, open **ArcToolbox > Spatial Analyst Tools > Extraction > Extract by Mask**




   b. **Input raster:** Your reclassified Aspect layer 'aspect_ravine'
   c. **Input raster or feature mask data:** Your reclassified Slope raster 'slope_ravine'
   d. **Output raster:** Browse to output workspace and name output layer 'aspslop_mask'
   e. Click OK to run. The output raster is added to your map as a new layer

6. The **Extract by Mask** Acrtool will be used one more time to create the final ravine raster.

   a. In ArcMap, open **ArcToolbox > Spatial Analyst Tools > Extraction > Extract by Mask**

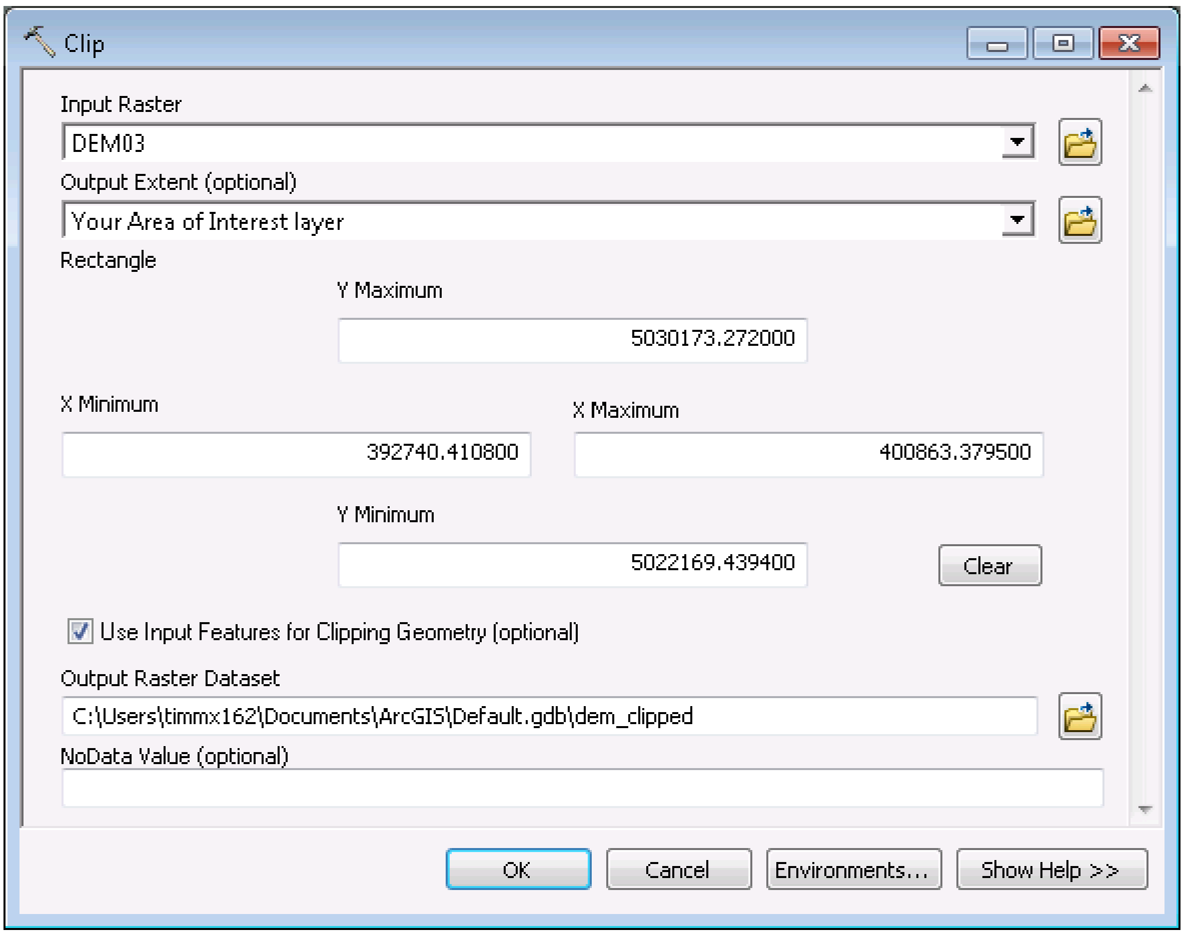



   b. **Input raster:** Your reclassified Flow Accumulation layer 'fa_ravine'
   c. **Input raster or feature mask data:** Your Aspect/Slope masked raster from the previous mask iteration 'aspslop_mask'
   d. **Output raster:** Browse to output workspace and name output layer 'ravines'
   e. Click OK to run. The final Ravine output raster is added to your map as a new layer

## A.3 Create Area of Interest DEM manually using Clip

- <u>Clip DEM Raster</u>
  Minnesota LiDAR data acquired at the county level can contain very large file sizes. It is therefore important to minimize the spatial area to be processed to reduce output files sizes and increase processing times. The **Clip** ArcMap tool creates a subset of a raster dataset and will be used for this purpose.
  - *Note:* There are two **Clip** tools in the ArcToolbox – only one of which will create a subset of raster data.

1. Open **Data Management Tools > Raster** > **Raster Processing** > **Clip**



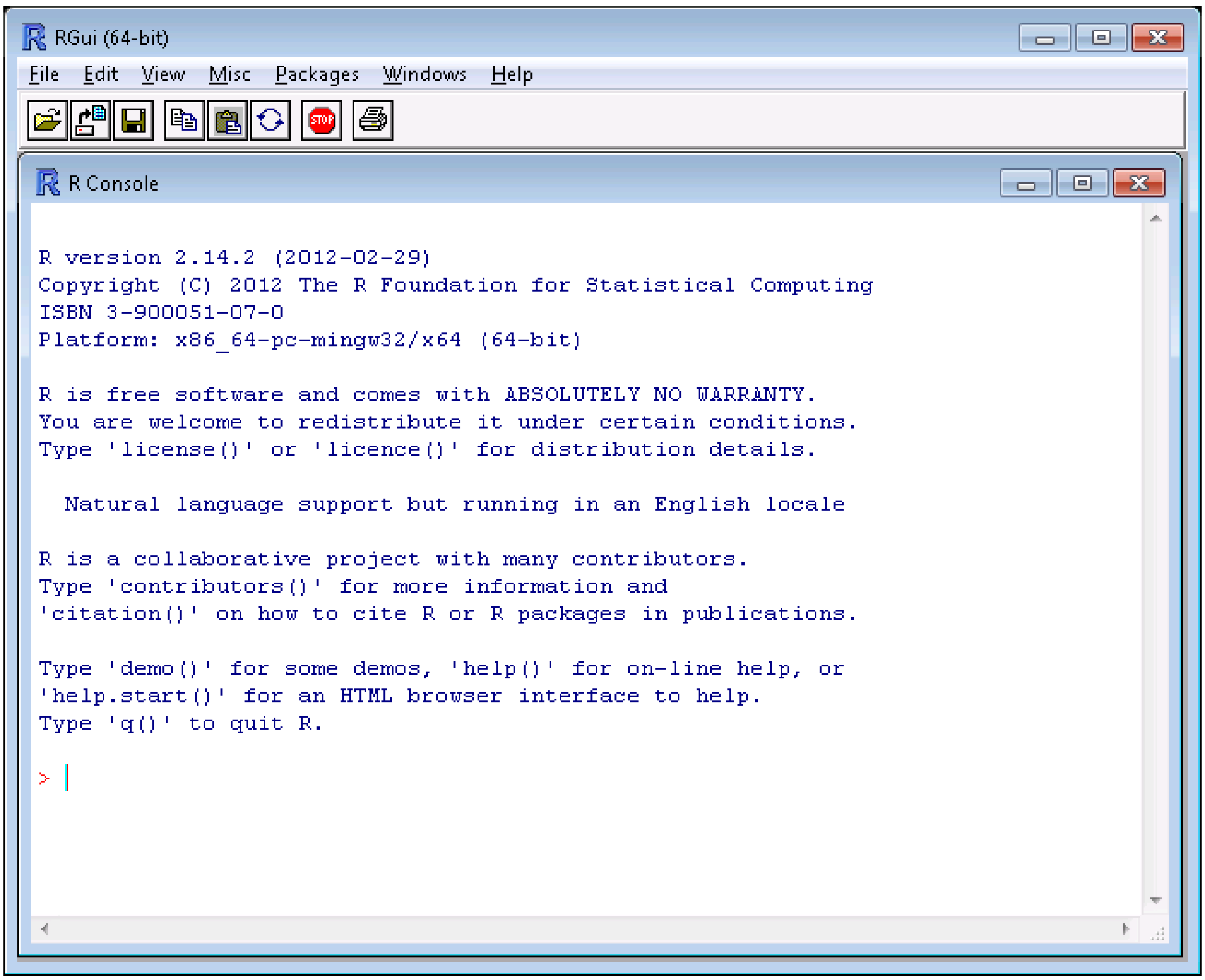

2. **Input Raster**: Your DEM
3. **Output Extent (optional)**: A raster or vector (point, line, or polygon) layer that covers the full extent of you AOI. For example, this could be a shapefile/feature class that you created yourself, HUC12 catchment(s), any digitized landscape feature, etc.
4. Check the box next to **Use Input Features for Clipping Geometry (optional)**.
5. **Output Raster Dataset**: Browse to output workspace and name with something you can remember, e.g. 'dem_clipped'.
6. Click OK to run. The clipped output surface raster is added to your map as a new layer.

## A.4 Calculating thresholds using R statistical package

It may be preferable to use a dedicated statistical software program to calculate percentile thresholds, as they are capable of handling large data sets. Though most any statistical program can be used for this calculation, R is recommended as it's both free to use and able to process simple to complex functions. The calculation of thresholds using R is straight forward and will require downloading and installing the R stats package along with a small add-on.

1. Acquire and install R
   Download R for your Windows, Mac, or Linux operating system from the following link:
   http://cran.r-project.org/bin/windows/base/old/2.14.2/
   - *Note:* It is recommended to install R version 2.14.2 for full compatibility with maptools.

2. Launch the R application. RGui will open with an active R Console window. The R console contains a command line that will be used for all R function inputs.



3. Install and load the maptools add-on package. This will allow the user to import dbf files directly into R.
   a. To install maptools, type in command line:

      **install.packages("maptools", repos = "http://cran.case.edu")**

      If prompted to use personal library, choose Yes.
      *Note:* Make sure computer is connected to internet for this step.

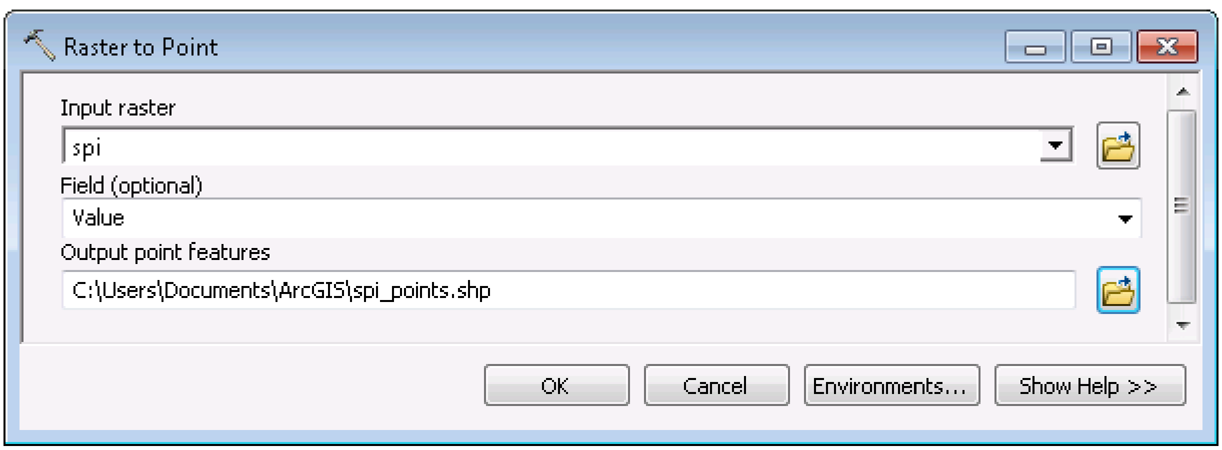
   b. Load maptools package into R by typing in command line:

      **library(maptools)**

      *Note:* The maptools package will need to be loaded into R each time the application is run using the above command. It will only need to be installed one time.

4. Prepare data for import into R. When exporting raster layer data for R input, any NoData cells around the area of interest will be exported as well. To circumvent NoData cells in exported data, convert raster cells to point shape data by using the **Raster to Point** Arctool as follows:

   a. Open **ArcToolbox > Conversion Tools > From Raster > Raster to Point**




   b. **Input raster:** your SPI or CTI layer.
   c. **Output point features:** Browse to output workspace and name output layer either spi_points or cti_points.
      - *Note:* Avoid storing the output feature in a geodatabase, as the .dbf table will be inaccessible from that location. Instead, store it in a folder as a shapefile.
   d. Click OK to run.
      - *Note:* The output from the **Raster to Point** shapefile contains three types of files, one of which is a .dbf file that contains attribute information. In this case, it contains each 3x3 meter cell value needed to compute a threshold (assuming a 3m DEM was used).

5. Import data into R

a. We will import the **Raster to Point** shapefile's .dbf table computed previously. Recall the output location of that file. R uses programming language that is case sensitive and requires certain formatting. We will use the following format for the **read** import function:

identifier <- read.dbf("directory address/file_name.dbf")

The identifier is a user created name assigned to data and is therefore not case sensitive. It cannot contain spaces. Users should adopt naming conventions using either no space or a period (.) symbol as a separator to make reading, sharing, and verifying code easier. The address location must use forward slash (/) as the directory separator.

Example of **read** import syntax:

SPIpoints <- read.dbf("C:/My GIS data folder/spi_points.dbf")

Press enter once the command has been typed. There should be no messages displayed.

*Note:* The program may not be responsive for a few minutes depending on the size of the imported file.

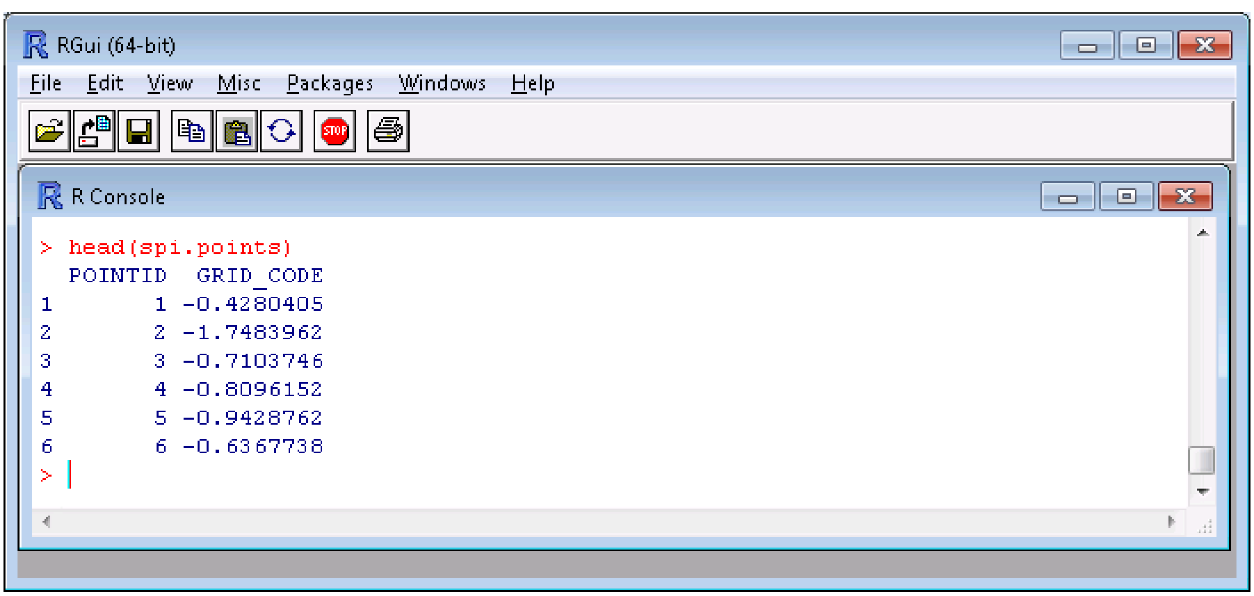
b. Check your imported data's header and make note of the column names by using the head function in the R console:

head(your.identifier.name)

Example:

head(SPIpoints)

The exact name of the raster value's column is needed for threshold calculations. Typically, **Raster to Point** dbf files use 'GRID_CODE' for the raster value column name.



6. <u>Calculate threshold percentile values</u>

   Percentiles are calculated using the quantile function in R.

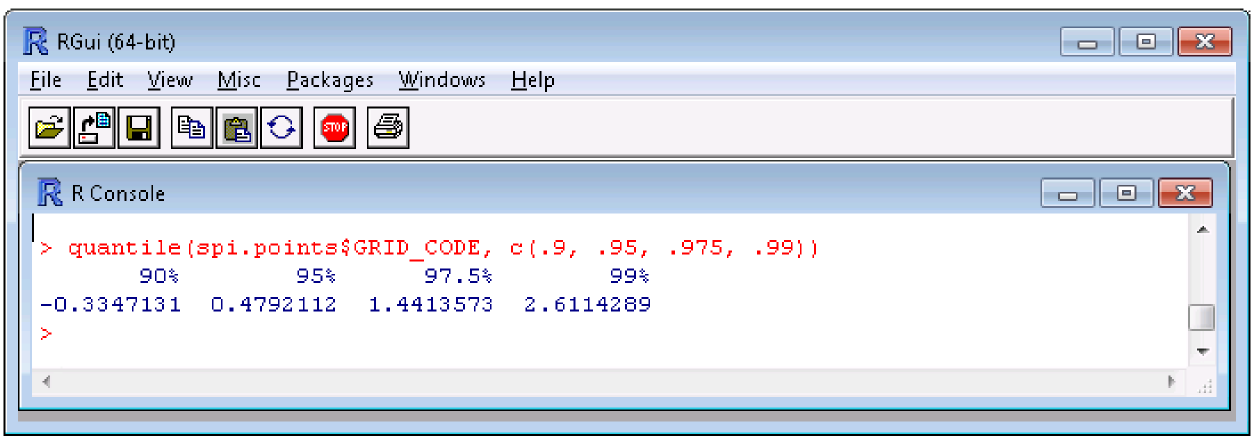
   quantile(your.identifier.name$raster_value_column_name, percentile)

   The ‘your.identifier.name’ is taken from previous step a; ‘raster_value_column_name’ is taken from previous step b; and percentile is recognized in R as a probability statement – any numerical value between 0 and 1 can be used.

   *Note:* a list of several percentiles can be used in one command line by using c(percentile1, percentile2,…percentileN)

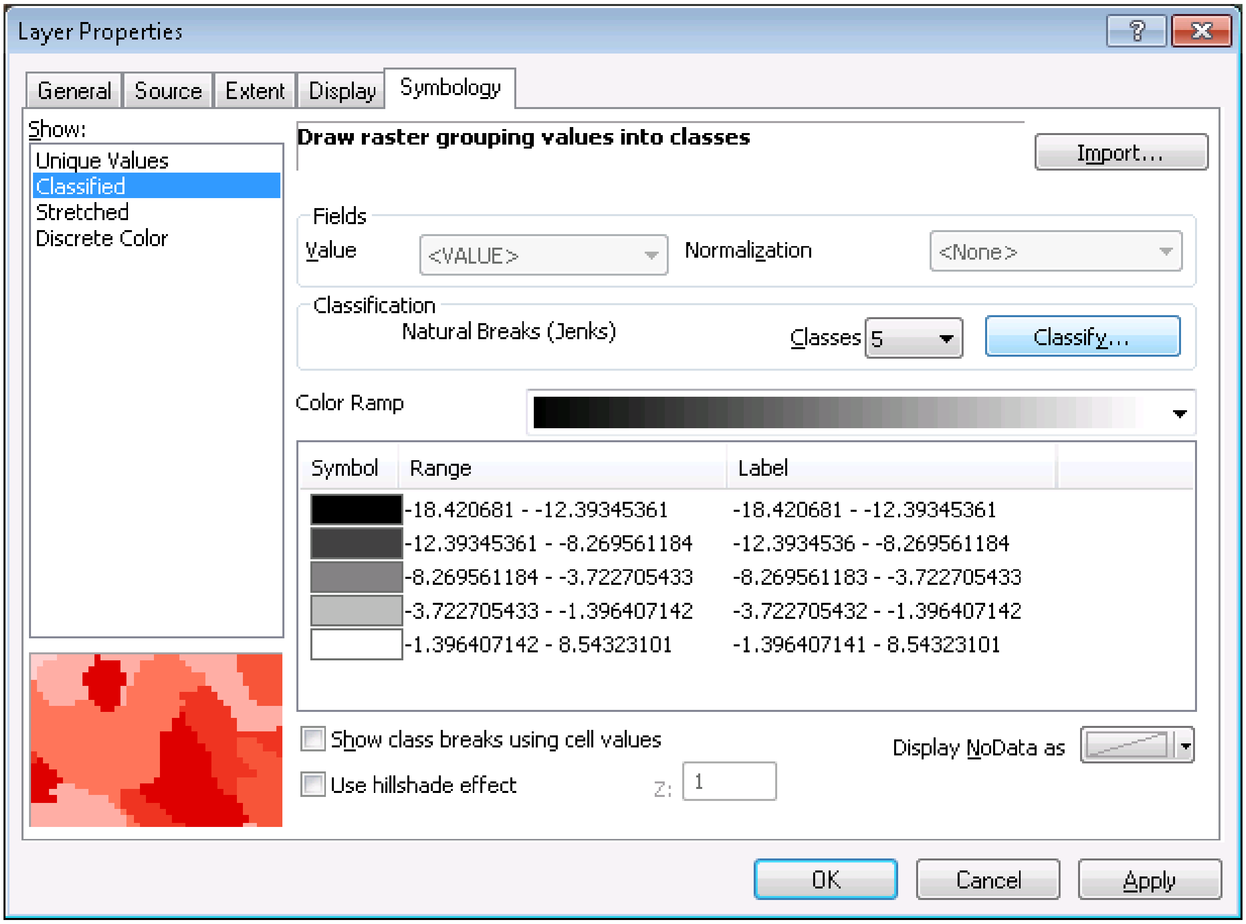
   Examples:

   quantile(spi.points$GRID_CODE, .85) #one percentile
   quantile(SPIpoints$GRID_CODE, c(.9, .95, .975, .99)) #multiple percentiles

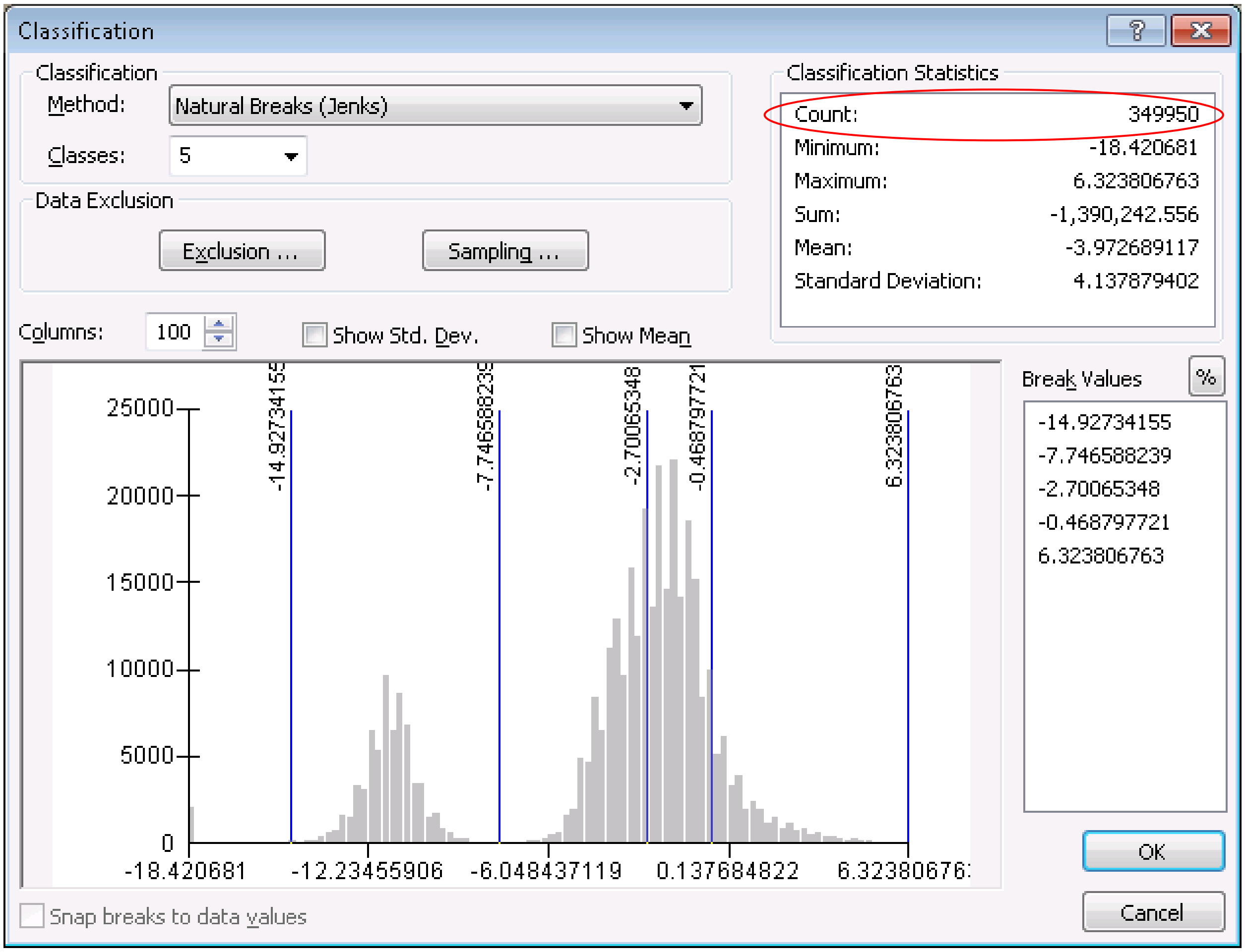


## A.5 Determine the cell count of your raster layer of interest

1. Double click on the layer in the table of contents window.
2. In the symbology tab, select ‘classified’ in the left window. If asked to calculate a histogram, say yes.
3. Click on the ‘Classify…’ icon.



4. The number of records in the raster layer will be displayed in the top right under Classification Statistics as Count. This can also be thought of as the population size of the SPI raster.

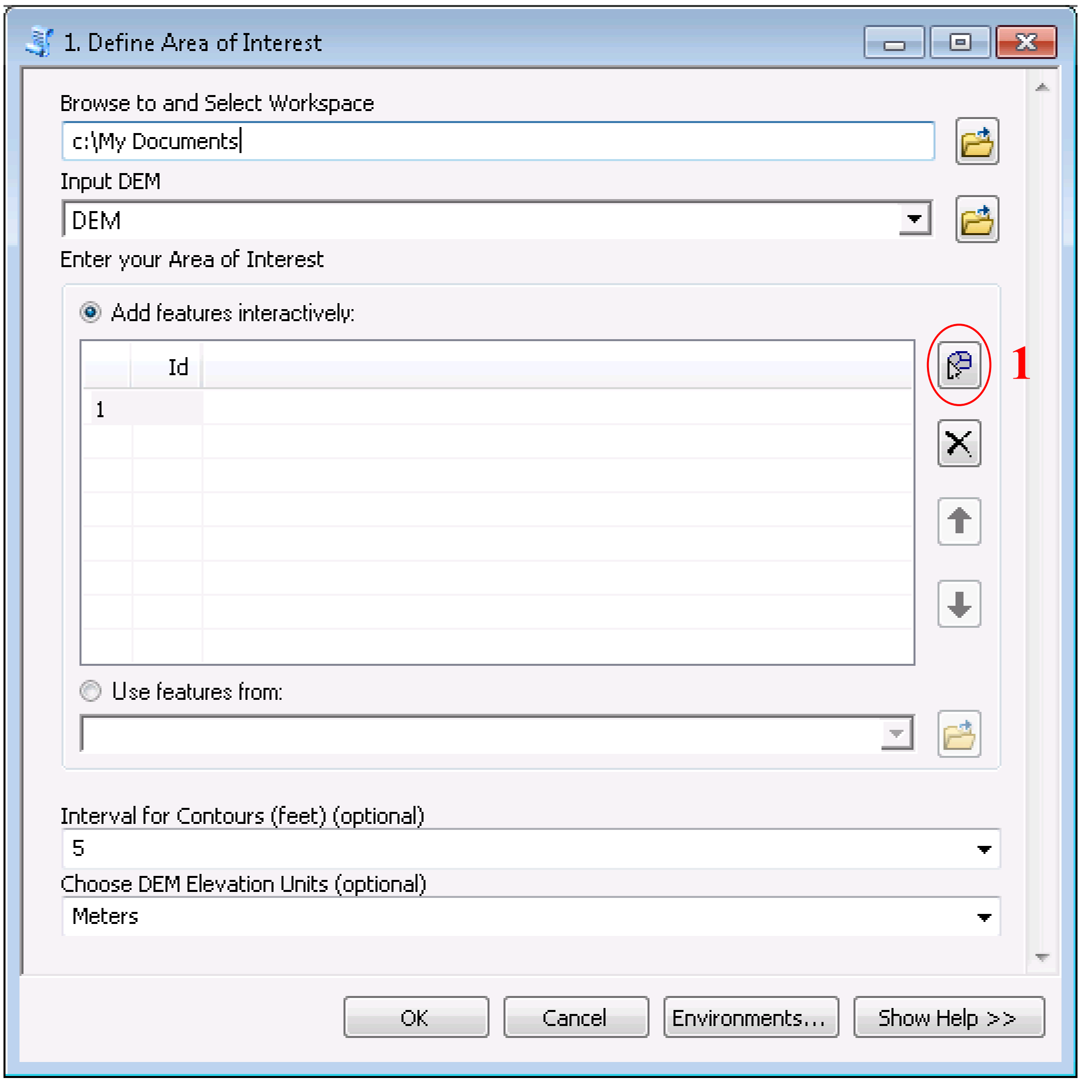



5. Click cancel on both windows to revert back to your original symbology.

## A.6 Delineate catchments using NRCS GIS Engineering Tools

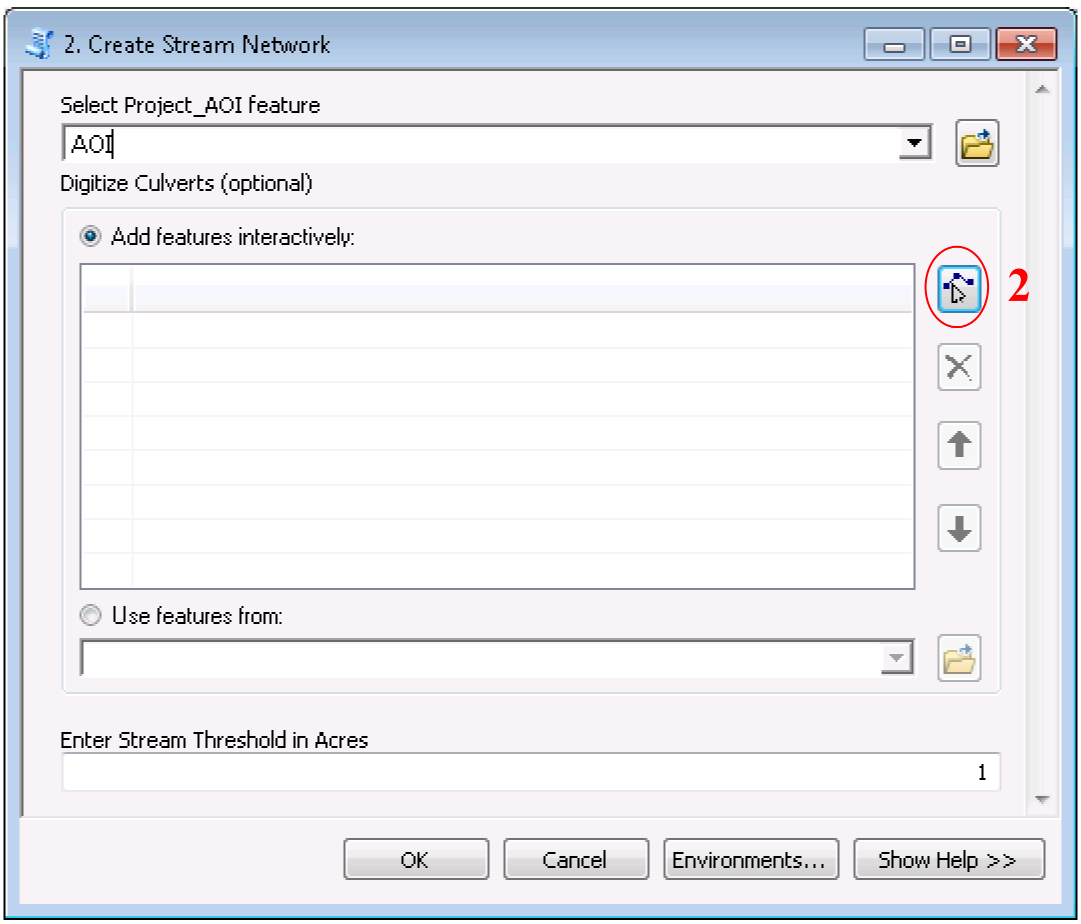
The contributing area upland of CSAs can be used to estimate the amount of potential sediment and nutrient delivery at those pour points. The NRCS offers a free tool called 'NRCS GIS Engineering Tools v1.17' which allows creation of contributing area catchments from a user defined point.

1. Define Area of Interest
   a. In the **NRCS Engineering Tools** toolbox, expand **Watershed Tools** followed by **Watershed Delineation** and double click the **Define Area of Interest** tool script



b. **Browse to and Select Workspace:** Choose your workspace folder where outputs will be stored
c. **Input DEM:** Your DEM, preferably a 3m LiDAR elevation dataset.
d. **Enter your Area of Interest:** Click the **Add feature** icon (**1** circled red in above image), then minimize the **Define Area of interest** window. The add feature tool works as a polygon editor, with each click creating a new vertex. The sketch is finished by double clicking to connect the first and last sketch vertices.
e. **Interval for Contours (feet) (optional):** Select desired contour foot contours. If left blank, no contours will be created
f. **Choose DEM Elevation Units (optional):** User preference
g. Click OK to run tool script. Several new layers will be added to your map

2. Create Stream Network
   a. In the **NRCS Engineering Tools** toolbox, expand **Watershed Tools** followed by **Watershed Delineation**, and double click the **Create Stream Network** tool script



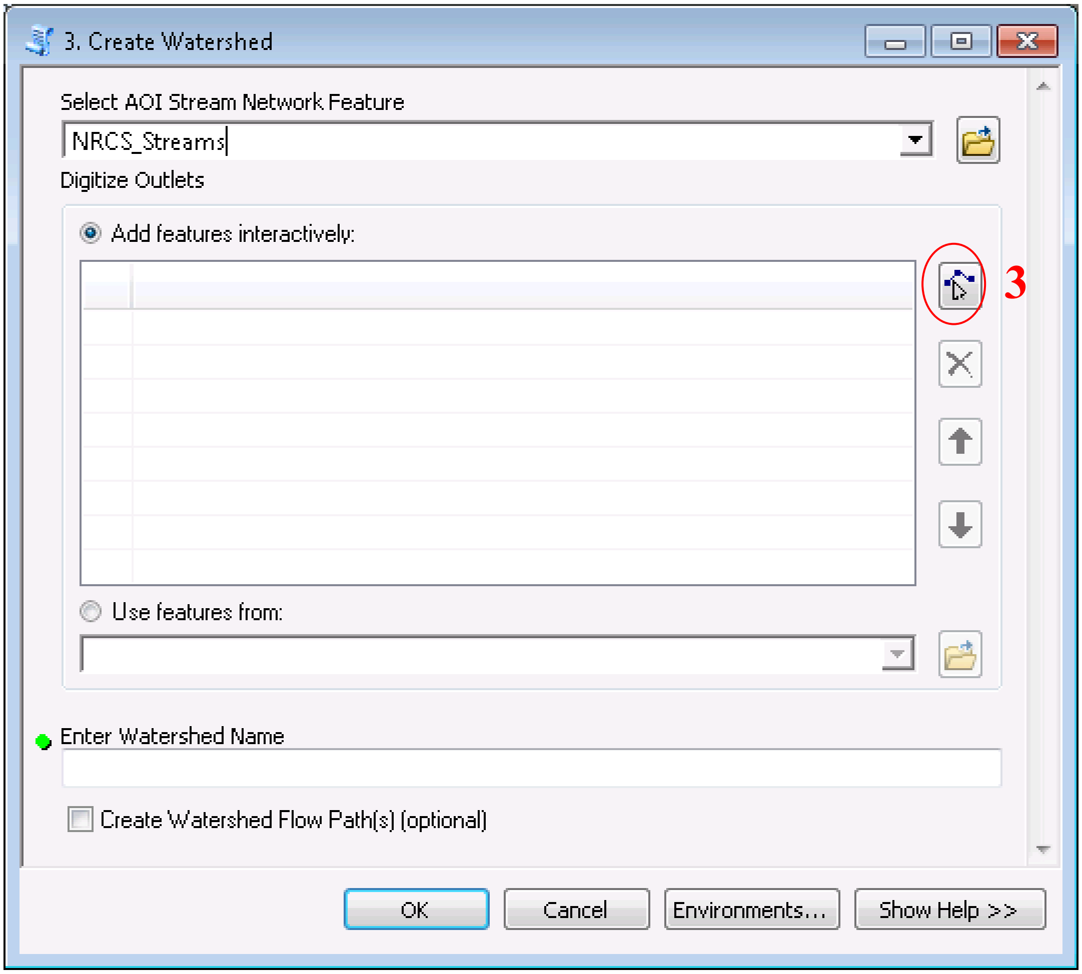
b. **Select Project_AOI feature:** Select the AOI that was created by the previous **Define Area of Interest** tool

c. **Digitize Culverts (optional):** Click the Add feature icon **2** circled in red above then minimize the current window. The add feature function works as a line sketch tool. Use the function to make a line that represents a culvert at any obvious or known locations where a culvert exists. The DephthGrid layer created by the previous tool can aid in showing where water backs up at impoundments such as road crossings. Culverts are likely to exist at these locations. Create as many digitized culverts as necessary to ensure an accurate stream network representation.

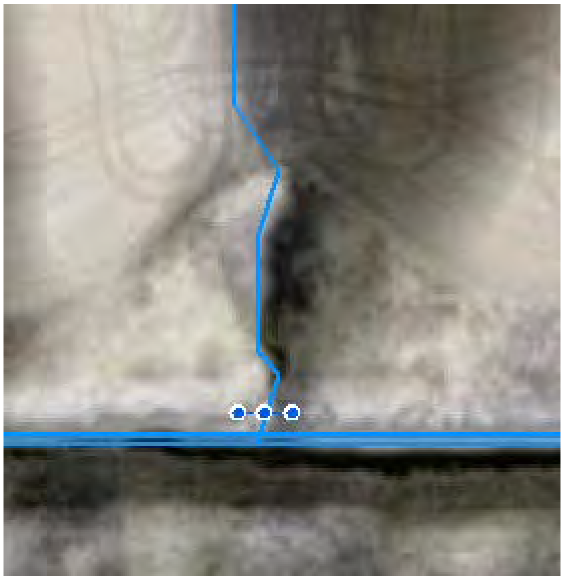
d. **Enter Stream Threshold in Acres:** This value is the minimum contributing area required to form a stream. The default value of 1 is adequate in most situations and will form stream headwaters near catchment boundaries.

e. Click OK to run tool script

3. Create Watersheds
   a. In the **NRCS Engineering Tools** toolbox, expand **Watershed Tools** followed by **Watershed Delineation**, and double click the **Create Watershed** tool script




   b. **Select AOI Stream Network Feature:** Select the stream network feature that was created by the previous **Create Stream Network** tool
   c. **Digitize Outlets:** Click the Add feature icon **3** circled in red above then minimize the current window. The add feature function works as a line sketch tool. Each click adds a vertex and double clicking ends the sketch. Use the function to make a small line perpendicular to any stream outlets where a watershed is to be created. A catchment will be created upstream of the digitized outlet line(s).
   d. Click OK to run tool script. The watersheds will be added to your map as a new layer



The blue stream line oriented north-south in the image on left is flowing south and empties into the east-west oriented stream. To create a catchment of the north-south stream, a digitized outlet (shown with blue dots) is made perpendicular on that stream near its outlet. The catchment will terminate at that perpendicular line.

e. **Enter Stream Threshold in Acres:** This value is the minimum contributing area required to form a stream. The default value of 1 is adequate in most situations and will form stream headwaters near catchment boundaries.

## A.7 Suggested Methods for Approaching Landowners and Operators

The following series of tips are provided as a guide for field staff requesting permission from landowners to conduct a site assessment associated with identifying PMZs and CSAs. The tips include ways to prepare prior to making the initial contact, methods to explain the purpose and uses of the site assessment, how the farmer can place restrictions on the use of the collected data, and brief descriptions of the assessment tools being used. At the end of this appendix is a suggested script for approaching landowners, provided for those who are interested in seeing an example approach. This script is intended to be adapted by users to fit the purpose of the specific data collection effort. When adapting the script, the user can include local knowledge of the watershed conditions and known personal interests of the producer being contacted. This document also includes talking points and answers to some frequently asked questions. In some cases, a producer might indicate that a PMZ or CSA on the property also is affecting the farm operation. These opportunities can be used to engage the producer regarding potential ways the site assessment can benefit both watershed conservation efforts and on-farm management.

**When approaching producers and gathering site information, it is important to be aware of the following data use restrictions:**

- Producers hold complete control over data regarding their operation.
- Data collected under other Farm Bill programs cannot be used for a new purpose without the written consent of the producer.
- Producers must be made aware of the uses of data collected under a new purpose. The level of commitment to share the data remains under producer control.
- The producer has three options for sharing data: Data is not to be shared, data may be shared when identification, location, and personal information is not revealed (e.g. data is presented in summary form), data sharing is unrestricted.

### Overview

Gaining access to lands is essential for conducting site assessments. These site visits serve dual purposes. The first purpose is to identify PMZs and CSAs for focusing conservation efforts. The second purpose is acknowledge producers for effective conservation efforts and/or engage producers regarding additional conservation practices that could be undertaken.

Sites for field assessments can be selected based on terrain analysis and other spatial analysis methods, as well as office knowledge of local watershed characteristics. (This site selection process is described in the Sensitive Site Identification Guidance document.) These spatial analyses utilize GIS software to characterize the physical features of the landscape. The analyses techniques are used to identify potential high-priority sites, based on their vulnerability to erosion and other characteristics that potentially impact water quality. Sensitive site identification using spatial analyses is intended to help conservation organizations delineate areas and zones that can be prioritized for further assessment and protection. The use of spatial analysis is intended to supplement, not replace, field assessments and can be used to inform site selection and enable organizations to focus limited resources on potentially high-priority areas.

Field assessment results also can document successful conservation efforts to acknowledge producers for their success and good work. These documented efforts then could be applied toward environmentally based initiatives, such as the Minnesota Agricultural Water Quality Certification Program. This program is being created to provide ten years of relief from new regulatory requirements to producers that meet certain requirements. Site assessment results also could provide some of the necessary information for participating in environmental initiatives like corporate supply chain sustainability programs. These programs allow food processors to label their products as environmentally friendly when a certain level of farm stewardship has been met. In return, the processor might make additional payments to producers for achieving the level of performance required by the label. Site visit results could provide supporting justification for future funding applications for BMP implementation based on indications that the site is of regional or watershed importance. In addition, the site assessment could document progress toward achieving TMDL nonpoint source load allocations.

The outcomes of site visits also can be used to provide feedback to producers regarding opportunities to improve conservation practices. In this scenario, the tools have identified sensitive management areas that are not currently being addressed by BMPs. This information can be used to engage the producer on how issues can be corrected in ways that also benefit the farm operation. These discussions should emphasize that the producer is not being penalized. Rather, the conversation should focus on how BMP opportunities can be beneficial to both the producer and water quality objectives. These discussions can incorporate educational materials about watershed goals and BMP options.

## Assessment Tools

The following tools are being applied through the site visits:

**Terrain Analysis:** Terrain analysis is a GIS-based assessment that analyzes changes in topography. For this project, elevation maps are used to identify locations that are likely to have a high erosion potential. This is combined with a spatial analysis of erosion risk based on soil type to provide indicators of locations that potentially are vulnerable to ephemeral rill and gully erosion.

**Spatial Analysis**: Spatial analysis is a GIS-based assessment that can analyze multiple landscape attributes. For instance, spatial analysis can be used to identify wetlands with different restoration potentials, variability in livestock densities, and/or the potential for sheet erosion. .

**Upland Field and Channel Assessment:** This assessment involves field evaluations that determine whether the GIS analysis correctly identified the sensitive site, as well as gather information about runoff pathways on that site. Several reasons could result in the GIS analysis not aligning with field observations. For example, the issue might be managed appropriately, therefore alleviating the issue. Alternatively, the GIS analysis results might have omitted a sensitive site. These limitations should be incorporated into the users understanding of the tool and possibly lead to later refinements of the tool itself.

**Streambank Erosion Assessment:** This is a river or stream assessment that indentifies banks with signs of active erosion. This is an inventory assessment to document the characteristics of the eroding sites. Erosion information collected about multiple sites can be combined and used to inform later watershed management initiatives regarding bank stabilization or pollutant loading estimation projects.

**Minnesota Rapid Phosphorus Index:** A version of the Minnesota Phosphorus Index called the Rapid Phosphorus Index (Rapid P-Index) can be used to evaluate the potential for phosphorus releases from a site. This screening tool is designed to be easy to use with minimal time requirements. If the results indicate a potential concern, the users are encouraged to perform the full Minnesota Phosphorus Index. However, the Rapid P-Index can be used to simply identify indicators of phosphorus runoff risk and open discussions for addressing the identified concerns.

## *Getting Started*

The initial contact with landowners should be direct, factual, and respectful; apply common sense; and easy to understand. Ultimately, the approach should create compelling reasons for producers to take a personal interest in the initiative. Experience has demonstrated that it is helpful to overlay parcel ownership information on the spatial analysis maps to aid in identifying the appropriate people to contact. Once landowners are identified, it can help to reach out to existing personnel who have first-hand knowledge of the identified landowners. These individuals can provide valuable background information, including occupation, history of work with the conservation agency, type of farm operation, etc. This knowledge can assist with selecting an appropriate approach tailored for each landowner.

### *Making the Initial Contact*

The following template can be used when contacting landowners to introduce the project and request access to the property:

1. **Identify yourself**
   State your name, organization, and ask if the landowner has time to talk. If not, arrange a time to call back.
2. **Introduce the project**
   Explain that you are working on a watershed study that will enable conservation funding to be allocated more efficiently. You would like to be able to access their site to apply the new tools. The visit will involve assessing potential sediment and nutrient runoff from the site. The data gathered will not be used for regulatory purposes and will be shared with others only to the extent the farmer allows.
3. **Emphasize the importance of their land and assistance for this effort**
   These tools will help with watershed planning and improving water quality. They also can be used to acknowledge conservation efforts made by landowners or assist landowners with identifying additional conservation opportunities.

**Offer to meet in person** to provide additional information and show the maps and tools being evaluated. If a short introductory visit is not necessary, proceed to the next steps.

4. **Explain exactly what will occur during the site visit**
   A team of a few people will walk the riparian zone, measure stream attributes, and look at the adjacent upland to determine the nature of the runoff. This information is being collected to help identify high-priority areas for conservation efforts. In some cases it is beneficial to obtain some management information (however, this might not always be the case).
5. **Re-emphasize that the assessment information will remain anonymous**
   The data collected will not be shared without the written consent of the producer and the land and operation will not be identified. The information will be used only for voluntary watershed planning. If the visit identifies an opportunity for an operation to benefit from soil and water conservation BMPs, potential options that would benefit both the operation and watershed goals can be discussed.
6. **Try to arrange a date and time for the site visit**
   Explain how many people will be going, their agency affiliation, when they will be there, and for how long. Emphasize that no regulatory agency personnel will be conducting the assessments. If nutrient management records or information on field equipment operations will be needed, alert the producer in advance.
7. **Ask if there is vehicle access to the stream**

8. **Invite the landowner to come along and offer them copies of the information collected**
9. **Ensure them that you will close all gates and won't drive over crops or leave ruts in the field**
10. **Thank them for their help**

After the site visit is complete, consider sending a thank you letter from the agency or project leader.

### EXAMPLE CONTACT LETTER TEMPLATE

[Recipient Name]:

My name is [Insert Sender Name Here] and I work for [Insert Organization Here]. As you may know, [Insert Water Body of Concern Here] is exhibiting serious problems with [Insert Pollutants of Concern Here], especially after large runoff events. These impairments are changing the nature of this stream and are impacting all downstream uses including agriculture, recreation, and wildlife. The [Organization] is currently in the process of assessing this watershed to determine where to best direct technical and financial assistance to its land users to address the source of these impairments.

We would like to visit with you on your property to discuss some of the watershed assessment tools that we are employing in this area. We can also discuss any other information or ideas that you have that could help us in this effort.

Please contact me at [Insert Phone Number Here] to set up an appointment or for more information.

Sincerely,

[Sign]

## Frequently Asked Questions

**Q: What organizations are involved in this project?**

*A: Explain your organization's title and purpose. If other organizations also plan to attend, provide their titles, organization affiliation, and reason for their interest. If beneficial and appropriate, reassure the producer that no regulatory personnel will be in attendance.*

**Q: What type of information will be collected?**

***A:*** *Data related to stream stability, topography, vegetation types, land use, and cropping systems will be collected. Sharing of the gathered information will remain under the control of the* *producer. Options range from being completely anonymous to providing written permission to release selected information (e.g., when used to justify funding for desired practices).*

**Q: How will the gathered information be used?**

**A:** *Initially, the information will be used to evaluate and efficiently select sites for the prioritization of providing technical assistance and public funding. The information also can be used to acknowledge producers who are effectively implementing conservation practices to manage their vulnerable sites.*

**Q: How many people will be on my property?**

**A:** *Generally, a team will consist of two or three field technicians from the office running the program (SWCD, Conservation District, Watershed Management Organization, ...).*

**Q: How long will people be on my property?**

**A:** *Gathering the information typically takes a few hours.*

**Q: How will you access my property?**

**A:** *We will park and walk into the fields and riparian areas selected for evaluation.*

## Talking Points

- Project purpose:
    - Outcomes of this project are not intended for any regulatory purpose.
    - The results of site assessments can be used to recognize producers who are successfully managing erosion issues.
    - Local planners can use these tools to create targeted water quality protection plans within watersheds with surface and groundwater concerns. The appropriate tools and models will help the planner determine where these problems are occurring, the extent of these problems, and the cost to implement the needed BMPs.
- Information sharing:
    - The use or sharing of the gathered information is controlled by the producer.
    - All data will remain anonymous, unless specific permission is granted by the producer.
- Utilizing the data for funding applications:
    - Accurately identified PMZs and their *associated water quality plans are the best way to access funds from many federal and State water quality improvement* programs. This includes improving the ability to leverage the public funds for production oriented BMPs such as precision agriculture systems for nutrient placement.

- Funding for soil and water conservation is becoming more and more targeted to PMZs because of mandatory TMDL assessments, grant sourced funding, increasing competition for conservation dollars, public demand for accountability, and reduced conservation agency budgets.
    - The Clean Water, Land and Legacy Amendment (3/8s of 1 percent of the State's sale tax revenue dedicated to natural resource conservation, parks and trails, and the arts) created an extraordinary opportunity in Minnesota for conservation funding. The Clean Water portion of this amendment is projected to generate 90 million dollars a year to protect, enhance, and restore the State's water resources.
    - Seven partnering agencies and the University of Minnesota administer these funds and each has an application review board or council.
- Properly prepared Clean Water Fund grant proposals will help conservation organizations access money that will go directly to land users to get the needed conservation practices on the ground.
- Land users can obtain funding to fix gullies that are interfering with field operations, stop eroding stream banks that are encroaching on fields and pastures, fix a feedlot that is out of compliance, set up prescribed grazing systems that can double forage production, or help pay for cover crops to improve the soil and stop erosion. *(Cite many examples specifically how these dollars can improve the farming operation and protect the water resource.)*

## A.8 SWCD Survey Results from Review of Field Evaluation Forms

The field evaluation forms were tested by the Stearns County, Washington County and Chisago County Conservation Districts (CD). The CD field staff provided feedback which altered the forms in order to ensure the forms and protocols were user friendly and effective. The field staff were supplied a draft field manual and accompanying evaluation forms. They also were provided with training on how to apply the field evaluation protocols presented in the manual.

The staff then used the protocols and forms to perform site evaluations. This included mapping features on an aerial photograph, performing visual stream assessments, and documenting pour point characteristics. The staff also performed a Minnesota Rapid Phosphorus Index and conducted a streambank erosion inventory.

The staffs were asked to complete a survey after conducting the field evaluations using the provided protocols and forms. The survey was used to inform revisions to the field manual and forms regarding:

- Overall value
- Ease of use
- Helpfulness of the training
- Effectiveness of site assessment
- Whether the staff would choose to use the protocol again
- Suggested ways for improving the protocols and forms

The results of this survey are summarized in the following table.

| Conservation District | Chisago | Stearns | Washington | All |
|---|---|---|---|---|
| Upland Field & Channel Site Assessment Time Required (minutes) | 15 | 30 | 4 | 16 |
| # of Sites Completed | 9 | 23 | 183 | 215 |
| Ease of Use | Good | Good | Undecided | Good |
| Informative? | Good | Good | Good | Good |
| Useful? | Good | Excellent | Excellent | Good+ |
| Will You Use this in the Future? | Yes | Yes | Yes | Yes |
| Visual Stream Assessment (TN-99) Time Required (minutes) | 15 | 15 | 15 | 15 |
| # of Sites Completed | 14 | 30 | 5 | 49 |
| Ease of Use | Good | Good | Undecided | Good |
| Informative? | Good | Good | Undecided | Good |
| Useful? | Good | Undecided | Undecided | Good |
| Will You Use This in the Future? | Yes | Yes | Yes | Yes |

The field manual protocols and forms were revised based on this feedback to make the field evaluations more effective and useful to the staff. For example, the full Minnesota Phosphorus Risk Index (P-Index) evaluation was replaced with the Rapid P-Index evaluation. This was considered to ease the rigor and associated time commitment while maintaining the value of the P-Index regarding implementation planning and generating discussions with farmers. If the results of the Rapid P-Index indicate phosphorus concerns, a full P-Index can be completed. The recording forms also were adapted to be more friendly for using in the all-weather conditions encountered in the field. In addition, the full Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) evaluations were replaced with a more qualitative inventory form. This approach better reflected the time constraints of field staff. After adjustment of the protocols the field staff in Stearns County tested the new protocols to ensure the performance of the materials were adjusted appropriately. The protocol cycle of generation, test and adjust was completed three times in order to provide documents that met the needs and expectations of the field staff.