Analysis of Sediment Basin Siting Locations using Components of the Ecological Ranking Tool and the Agricultural Conservation Planning Framework in a Sub-watershed of Garvin Brook, Winona County, Minnesota USA

Eric M. Lindberg
Department of Resource Analysis, Saint Mary's University of Minnesota, Minneapolis, MN 55404

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Abstract

Erosive processes are constantly changing the landscape. In the Garvin Brook watershed of Southeast Minnesota USA, agricultural production in areas of significant topographic relief exposes risk of high sediment and nutrient transport into ecologically sensitive trout stream and valley waterways. Local conservation efforts are focused on reducing soil loss risk and identifying opportunities to mitigate environmentally sensitive Non-Point Source (NPS) pollution impairment. The time and effort involved with identification of high soil loss risk and Best Management Practices (BMPs) can be significantly reduced with the advancement of new technologies. While many types of effective conservation measures are used in the agricultural landscape, the sediment basin often represents the last defense available to detain the soil leaving the field. This study employs weighted components from the Ecological Ranking Tool using advanced Light Detection and Ranging (LiDAR) resolution for Digital Terrain Analysis (DTA) and the Agricultural Conservation Planning Framework (ACPF) toolset within a Geographic Information System (GIS) to rank and characterize potential locations for sediment basins within the sub-watershed. Results analysis from this study produced a final siting map which illustrates field edge and off field characterized zones classified by a combined score of measures of erosivity and proximity to surface water. Potential sediment basin dam locations were selected using a modified ACPF tool for surface profiles supportive of a user specified minimum 3-meter embankment height.

Introduction

NPS pollution from agricultural producing landscapes causes environmental impairment to water bodies. In the midwestern United States, row-crop agriculture is the highest source of water pollution and is listed as a contributing factor to 70% of impaired streams (Zimmerman, Vondracek, and Westra, 2003). As explained in Stout, Belmont, Schottler, and Willenbring (2014), excessive loads of fine sediment cause water quality degradation, not only directly affecting aquatic habitat, but also indirectly as sediment is often laden with nutrients and toxins which can cause severe eutrophication and diminished oxygen concentrations (Edwards, Shannon, and Jarrett, 1999). Fine sediment, including sand, silt, and clay, dominates the materials in many rivers and plays a pivotal role in

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nutrient transport, channel morphology, light penetration, and food-web dynamics (Stout *et al.*, 2014). The costliest NPS damage occurs when soil particles enter lake and river systems. Deposits raise and widen waterways, causing more susceptibility to erosive overflow and flooding (Pimentel, 2006).

Government conservation agencies are purposed to reduce NPS pollution from both agricultural and urban areas. Methods suggested for decreasing NPS pollution include implementing BMPs such as contour farming, conservation tillage, terraces, and perimeter controls like sediment basins (Edwards *et al*., 1999).

Garvin Brook Watershed

The study area is a Department of Natural Resources (DNR) defined level 7 sub-watershed, a part of the larger 12-digit Hydrological Unit Code (HUC12) known as Garvin Brook Watershed in Winona County, Minnesota USA. This 9,809 acre sub-watershed extends from the city of Lewiston, northeast to the city of Stockton (Figure 1). Flowage continues east to the Mississippi River within the Mississippi River–Winona HUC8 watershed.

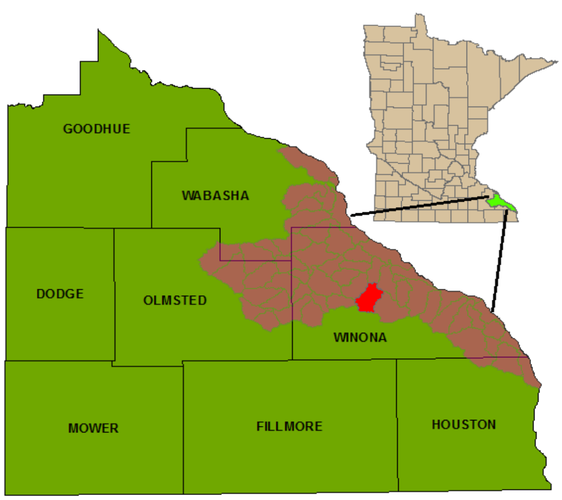

Figure 1. DNR level 7 sub-watershed location in the greater Mississippi Watershed, Winona County.

This area was chosen due to the availability of existing sediment basin data as well as hydrologically conditioned Digital Elevation Model (DEM) data made available through the Winona County Planning Department. The land use of the study area is primarily agricultural with 38.0% in row crops and 22.1% in grass/pasture. Deciduous forest covers 34.2% of the area where much of the steeper slopes occur. The average slope of the sub-watershed is 16.8%. Approximately 20% of the area is under 3% slope, and 42% overall is under 6% slope. The sub-watershed comprises 37 types of soils with silt loam as most predominate, Seaton silt loam at 29.7%, Mt. Carroll silt loam at 18.4%, and LaCrescent silt loam at 13.2%.

The sub-watershed is regionally located in a large unglaciated area of Southeastern Minnesota known as the Driftless Area where steep slopes, thin soils, and karst topography create a susceptibility to non-point pollution (Johnson, 2008). According to Johnson, cultivated cropland on rolling to steeply sloping topography contributes to higher sheet and rill erosion rates relative to level topography. The presence of short steep slopes in Southeastern Minnesota presents potential for high surface water impacts (Johnson).

Conservation Technology

GIS is designed to store, retrieve, manipulate, and display large capacities of spatial information derived from a variety of sources (Yitayew, Pokrzywka, and Renard, 1999). Linkage of GIS and erosion models is made possible by the spatial format in which erosion model factors are presented. Opportunities to combine GIS with soil erosion models have largely been carried out through raster GIS. Increased precision in terrain modeling has produced tools and frameworks through advanced GIS technology such as DTA and the ACPF toolset used in this study.

DTA

DTA involves the use of DEM data to model the topography of an area. According to (Moore, Grayson, and Ladson, 1991), topography significantly impacts hydrological, morphological, and biological processes. The mapping of digital terrain parameters reveals water pathways and areas of accumulation which are considered chief catalysts of soil and sediment transport within a landscape (Moore *et al*., 1991; Tomer, Porter, Boomer, James, Kostel, Helmers, Isenhart, and McLellan, 2015). In a Minnesota study, Galzki, Birr, and Mulla (2011) defined critical areas of overland flow as areas with connections to surface water where the likelihood of transporting contaminants is highest. Galzki *et al.* applied terrain attributes of slope, flow accumulation, and the Stream Power Index (SPI) to identify critical areas within a GIS with high resolution elevation data models.

LiDAR

LiDAR data are created by sending rapid laser light pulses from overflying aircraft towards ground locations and measuring the distance or range with advanced Global Positioning System (GPS) receiving devices. Plotted return data are recorded to produce highly accurate elevation readings which are processed into increasingly accurate DEM data. Terrain analysis and modeling techniques dependent on topographic detection are direct beneficiaries of the advanced resolution and accuracy of improved LiDAR technologies. The resulting DEM can be stored and manipulated within a GIS.

As a benefit to this study, high resolution 1-meter LiDAR data were available to create a very accurate DEM of the sub-watershed surface, flow direction, flow accumulation, and subsequent SPI and flow distance calculations.

ACPF

The ACPF toolset (Tomer *et al*., 2015; Porter, Tomer, James, and Boomer, 2015) was developed as a free resource toolset compatible with GIS offered through the North Central Region Water Network. The basis of the framework premise contends geographic analysis can be used to characterize an array of opportunities to influence water and nutrient transport within fields, off field edges, and in riparian zones (Tomer, Porter, James, Boomer, Kostel, and McLellan, 2013). According to (Tomer *et al*., 2013), while the framework is not intended to be followed prescriptively, it does locate and identify a multitude of practices to be further evaluated by conservation planners at watershed and field levels. This framework was used in this study for the primary terrain analysis functions and the siting of water storage practices as further discussed. The ACPF tool requires an accompanying download of TauDEM (Tarboton, 2016) which is utilized for geoprocessing function.

Hydrologic Conditioning

LiDAR is an amazing technology that can pierce tree canopies and provide bare earth and sensed object returns, yet it is not perfect. Bridges, overpasses, and culvert locations are examples of blocking objects that provide false returns in LiDAR derived stream networks. False returns in these areas create digital dams to water flow and require cuts to be made in the DEM to represent and regain actual water flow patterns and stream networks. The hydrologically conditioned DEM as obtained for this study was processed by the Winona County Planning Department using the ACPF toolset. An example of a hydrologically conditioned flow is shown in Figure 2.

Figure 2. Unseen culvert resulted in LiDAR produced flow line in yellow parallel to roadway. Hydrologic cut line (red) allows actual road passage and represents actual flow (blue).

Modeling Soil Loss

Among many emerging erosion models, the empirical Universal Soil Loss Equation (USLE) has remained the most practical method of estimating soil erosion potential at the field scale (Lim, Sagong, Engel, Tang, Choi, and Kim, 2005). Other physical process based erosion models have intensive data and computation requirements (Lim *et al.*, 2005). At the local (plot) scale, erosion rates are most commonly estimated using the empirical USLE model or some derivative thereof (Stout *et al.*, 2014). The main user for USLE has been resource conservationists, primarily the United States Department of Agriculture (USDA) / Natural Resources Conservation Service (NRCS) in measuring rill and interrill erosion (Yoder, Foster, Weesies, Renard, McCool, and Lown, 2004). An updated model, the Revised Universal Soil Loss Equation (RUSLE), further enhanced prediction of long-term average annual soil loss with the addition of agricultural practices such as cropping and management (Renard, Weesies, McCool, and Yoder, 1997).

RUSLE Overview and Factors

RUSLE's empirical modeling utilizes comparisons to observed base conditions to which all other topographic, cropping, management and conservation practices were compared (Renard, Yoder, Lightle, and Dabney, 2011). Data from plots with differing slopes, lengths, and crops were adjusted and contrasted from unit plot benchmarks to develop impacting factors involving characteristics of climate, soil erodibility, topography, vegetative cover, and soil conservation to predict average soil loss (Renard *et al.*, 2011).

RUSLE appears as:

$$A = R * K * LS * C * P$$

Where A is the amount of erosion for the specified field slope measure in tons/acre/year; R is a rainfall erosivity factor; K is a soil erodibility factor; LS is a combined product of slope length and steepness factors; C is a vegetative cover factor; and P is a support practice factor (Yitayew *et al.*, 1999).

Rainfall Erosivity, R-Factor

The R-Factor expresses the effect of rainfall precipitation amounts and intensity on soil erosivity with other factors held constant. It is expressed as proportional to a rainstorm's total storm energy times the maximum 30-minute intensity (Renard *et al.*, 1997). This value is reflective of both the raindrop impact and the amount and rate of overland runoff produced by the rainfall. Raindrop erosion has been observed to increase at higher storm intensities (Renard *et al.*).

Soil Erodibility, K-Factor

The K-Factor, also called soil erodibility, is represented by the effect soil properties and profile characteristics have on soil erosion (Renard *et al.*, 2011). As seen in Renard *et al.* (1997), Wischmeier; 1978, explores the K-Factor as the rate of soil loss measured in tons per acre per plot unit. The entire effect of soil detachment, transport through raindrop detachment and runoff, surface roughness, and soil infiltration contributes to an integrated soil loss (Renard *et al.*, 1997). A comparison of a soil's structure, permeability, and content of silt, sand, and loam is used to determine this factor (Renard *et al.*).

Topographic LS-Factor

The L-Factor or length of slope is predicated on the observation erosion increases as length increases (Renard *et al.*, 1997). As seen in Renard *et al.* (1997) Wischmeier and Smith; 1978, the length of slope is measured from the origin of overland flow to either the point at which gradient causes deposition or the point where runoff has become concentrated in a channel. According to Renard *et al.* (1997), the L-Factor can be best described as a ratio of predictive soil loss based on slope length as compared to the observed plot unit length of 22.13 meters with the following formula:

$$L = (\lambda / 22.13)^m$$

Where:

L = L-Factor for length
λ = slope length in feet
m = variable slope length exponent
(Renard *et al.*, 1997)

The S-Factor or slope steepness represents the effect of slope grade on soil erosion (Renard *et al.*, 1997). The soil loss at the measured slope is compared to loss at the unit plot standard of 9%. Differing formulas exist for calculating the slope factor depending on whether actual slope is more or less than 9% and alternatively based upon the shape of the slope (Renard *et al.*).

For the slope steepness factor above, it is assumed rill erosion is insignificant on slopes shorter than 4.6 m (15 ft), and interrill erosion is independent of slope length (Renard *et al.*, 2011). It is noted by Renard *et al.* (1997) soil loss increases more swiftly as a result of increased slope steepness opposed to increased slope length.

For this study, the following formula from (Moore *et al.*, 1991; Lim *et al.*, 2005) is applied to primary terrain attributes as follows:

$$LS = \left(FA * \frac{1}{22.1}\right)^m * \left(\text{Sin[Slope]} * \frac{.01745}{.0896}\right)^n * (m+1)$$

Where:

FA = flow accumulation
m = modifying factor (.4 for croplands)
n = modifying factor (1.4 for croplands)

Vegetative Cover, C-Factor

The C-Factor is used to represent the effect vegetative cover has on soil loss. The C-Factor is important because it is not a constant and represents managed conditions for erosion reduction (Renard *et al.*, 2011). The factor compares the current managed cover conditions to the unit plot with no management. The values of the C-Factor ranges from 0 as a non-erodible soil to a value at or slightly over 1.0. Values over 1.0 indicate cover conditions more erodible than those observed under the near worst case modeled unit plot conditions.

Conservation Practices, P-Factor

The P-Factor in RUSLE involves assigning a positive dimensionless value for the effect of soil loss from contouring, strip cropping and terracing and calculating and assigning an erosion reduction percentage as outlined in the USDA Agriculture Handbook 703 (Renard *et al.*, 2011; Renard *et al.*, 1997).

The resultant and sourced RUSLE factors are further discussed in the methods sections of this paper. This study utilizes the combined weighted components of the Ecological Ranking Tool to determine spatial risk assessment for potential sediment basin siting. Surface profiles supporting user specified sediment basin dam structures are determined with the ACPF toolset. Data, tools, and processing methods are described below.

Methods

Data

Data used in the project were obtained from the following sources:

Winona County Planning Department

- Hydrologically conditioned DEMs 1-meter filled and 1-meter unfilled Garvin Brook HUC12 buffered watershed
- Existing sediment basin polygon shapefile

ACPF Data

- Field boundary polygon feature class
- 2014 National Agricultural Statistics Service (NASS) crop data layer

Minnesota Geospatial Commons

- Minnesota DNR level 7 minor watershed feature class
- Web Mapping Service (WMS) aerial imagery
- Minnesota roads layer polyline shapefile

NRCS Gateway / Data Viewer 6.2

- Soil Survey Geographic Database (SSURGO) soil unit shapefile
- Microsoft Access soil table data
- National Agriculture Imagery Program (NAIP) 2014 raster aerial imagery

Ecological Ranking Tool

The Ecological Ranking Tool was developed by the University of Minnesota and the Board of Water and Soil Resources. The tool combines percentile ranking for soil erosion risk, water quality, and habitat quality to guide funding to the landscapes determined to be most critical. In this study the general framework of the first two components of this tool were considered as the ranking basis for sediment basin siting criteria. The methodology for the soil erosion risk was ranked (0-100) from a raster utilizing RUSLE. The water quality raster was determined by the combination of 50% of the value of significant SPI (0-100) ranking and 50% of the value of the Proximity to Stream (0-100) ranking of measured flow accumulation distance to main channel stream. For this study, no specific Habitat Quality was identified as a protection target, therefore the Habitat Quality ranking component was not considered in this study. The overall rank was a combined sum of the rankings resulting in a weighted value between 0 and 200.

Primary Terrain Attributes

The ACPF toolset was used on the hydrologically conditioned DEM with D8 (8 flow direction) terrain processing to produce primary terrain attributes of flow direction and flow accumulation, as well as hillshade and a sink-filled DEM. An attributed flow network was created with the Peuker Douglas tool. Slope was created through ArcGIS Spatial Analyst.

SPI

The SPI is a secondary attribute measure of erosive power in flowing water (Moore *et al.*, 1991). It is the product of flow accumulation and slope and according to (Maathuis and Wang, 2006) can be used to identify siting locations for conservation practices to reduce concentrated surface flow. SPI was calculated as:

$$SPI = \ln((FA + .001) * (Slope + .001))$$

Where:

FA is the flow accumulation
Slope is measured as percent

For each cell within the DEM a SPI value was calculated. A sampling method and corresponding table (Wilson, Mulla, Timm, and Klang, 2014) were used to determine a significance threshold of SPI value. SPI values were extracted from a randomly selected point sample. The sample size was determined at a 99% confidence interval and 1% error margin. The extracted values were exported to a Microsoft Excel database and an array at 99% determined that SPI threshold values over 11.482 were significant in this sub-watershed. The SPI layer was then reclassified omitting values below the significance threshold. The remaining values were visually examined to determine high downslope SPI values at intersecting drainage points. A point feature class was created with points added along the downslope SPI signature nearest the intersecting drainage network. Point placement priority was given to areas with significant flow extents extending into fields. A total of 163 points were determined to have significance and SPI values at each of these points were extracted from the SPI index (Figure 3).

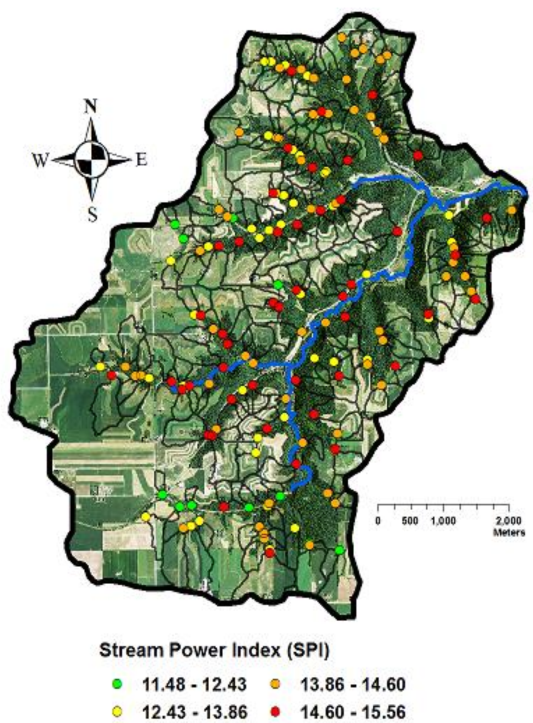

Figure 3. SPI points were placed slightly upstream from flow intersections. Green represents lowest erosive power, red represents highest erosive power potential.

Pointsheds

A pointshed for each of the 163 points was created. Pointshed areas determine the extent of overland flow contributing to the highest SPI values. The pointsheds were clipped by sedimentation zone area to establish erodible areas upstream of and within the catchment of proposed sediment structures. The extent of the erodible area was used for soil loss risk using RUSLE (Figure 4).

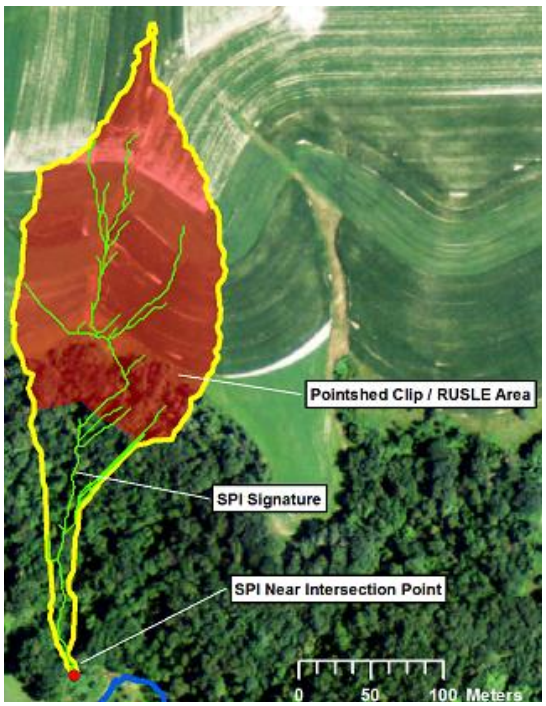

Figure 4. Pointshed delineated from SPI flowpoint. Red represents 6.5 acres as the erodible portion of the 7.8 acre pointshed for RUSLE modeling.

RUSLE Modeling

Rainfall Erosivity, R-Factor

The R-Factor is available on static iso-erodent maps and has been predetermined at a value of 145 inclusive of the study area in Winona County. A raster layer was created and attributed with a value constant of 145 which is near the highest rates in Minnesota while national rates range from 10 – 700.

Soil Erodibility, K-Factor

Using the ArcGIS based NRCS Soil Survey 6.2, the weighted rock free Kw factor was extracted and exported as a layer for the sub-watershed area. Soil erosivity is a significant soil loss factor in Winona County, as expansive areas of silt and silt loams exhibit high erosivity rates as illustrated in (Figure 5).

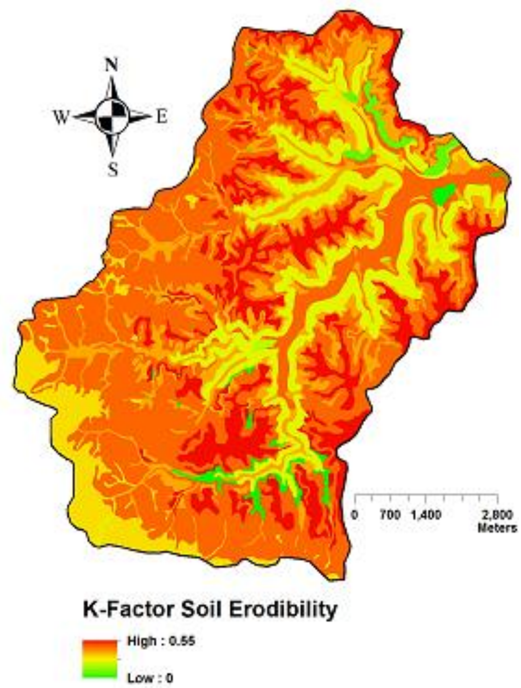

Figure 5. K-Factor; erodibility by soil type. Low soil erodibility values are represented in green and higher values are represented in red.

Topographic LS-Factor

Higher values of slope steepness have a greater effect on erosivity than the length of the slope when compared as independent factors. The combined LS-Factor (Figure 6) most closely represents a slope raster of the subject area extent. The majority of values range from 0-58. Outlier values up to 7075 occur where cliffs exhibit extreme slope steepness.

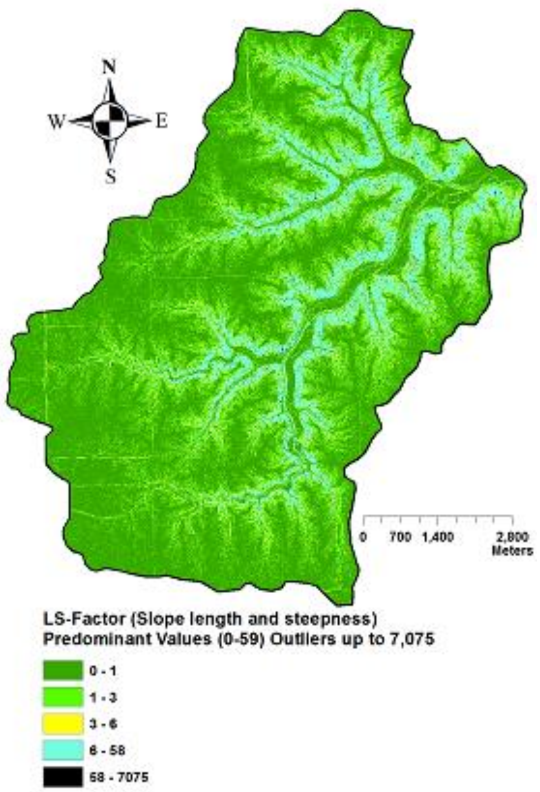

Figure 6. LS-Factor; slope length/steepness. Lowest values are represented in green while predominant high values are in blue. Long lengths and cliff locations of extreme slope are extremely rare and values > 54 up to 7075 are represented in black and visible only at extreme scale.

Cover Management, C-Factor

The NASS Crop Data Layer from 2014 was used to apply the assumed management C-Factor. The following table (Table 1) describes the NASS C-Factor attributed to each land type.

Table 1. NASS C-Factor value table suggestions from the PTMapp Users Guide (Houston Engineering, 2016).

C- Factor	NASS CDL Classification
0.200	Corn, Soybeans, Sunflower, Barley, Spring Wheat, Durum Wheat, Winter Wheat, Rye, Oats, Canola, Flaxseed, Peas, Herbs, Dry Beans, Potatoes, Other Crops, Fallow/Idle Cropland
0.100	Alfalfa, Other Hay/Non Alfalfa, Sod/Grass Seed, Herbs
0.005	Clover/Wildflowers
0.003	Developed/Open Space, Developed/Low Intensity, Developed/Medium Intensity, Developed/High Intensity, Barren
0.002	Deciduous Forest, Evergreen Forest, Shrubland, Mixed Forest
0.001	Grassland Herbaceous, Woody Wetlands, Herbaceous Wetlands
0.000	Open Water

Each land type and factor was applied to the sub-watershed and converted to a raster layer (Figure 7).

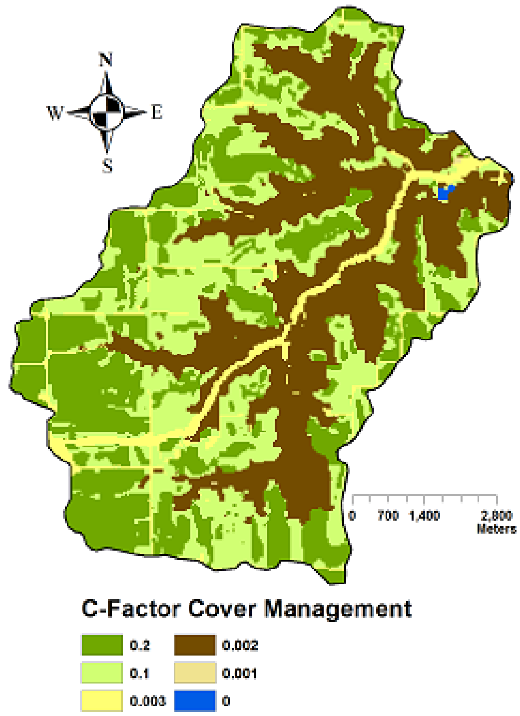

Figure 7. C-Factor; erodibility by ground cover.

Conservation Practices, P-Factor

Because of the scale and unknown local detail of each field, the P-Factor was given a value constant of 1 in a raster layer.

RUSLE Output

RUSLE layers were overlaid (Figure 8) to produce an overall soil loss for the sub-watershed.

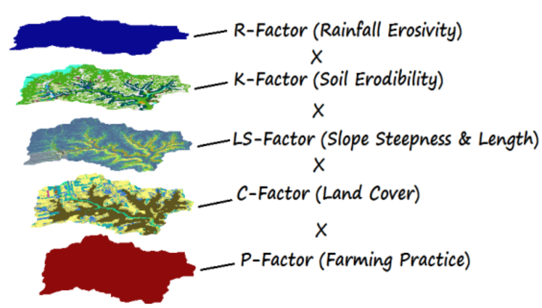

Figure 8. RUSLE factors overlay.

A calculation was used to create a resultant product layer from the overlay. Clipped pointshed polygons served as zones for zonal statistics to determine mean soil erosion rates and erosion sums. Sum units were converted by the field calculator to tonnage of detached soil per pointshed.

A standard tolerance (T-value), represents permissible soil loss rates as determined by soil scientists. T-values in Winona county are reported as a value of 5 tons/acre/year. While pointshed soil loss rates in this study exceeded the T-value of 5, not all conservation measures reducing rates were examined. Further, this study focused on the sum of pointsheds contribution to soil loss and delivered sediment to perennial streams.

Sediment Transport and Delivery

According to Lim *et al.* (2005) RUSLE alone is a field scale model and cannot solely be used to estimate the amount of sediment reaching the downstream area since eroded soil may get deposited during transport to the outlet. Lim *et al.* posits to account for these processes, the Sediment Delivery Ratio (SDR) for a watershed should be used to estimate total sediment transported to the watershed outlet. In addition, Lim *et al.* explains the SDR is expressed as:

$$SDR = SY / E$$

Where:

SDR = sediment delivery ratio
SY = sediment yield
E = gross erosion for entire watershed

The following SDR formula (Lim *et al.*, 2005) was used:

$$SDR = .0472\, A^{-0.125}$$

Where:

SDR = sediment delivery ratio
A = watershed/catchment size (km^2)

Attributes were created for the SDR of each pointshed and applied to the RUSLE sum by the field calculator to compute the proposed sediment delivered within each pointshed (Figure 9).

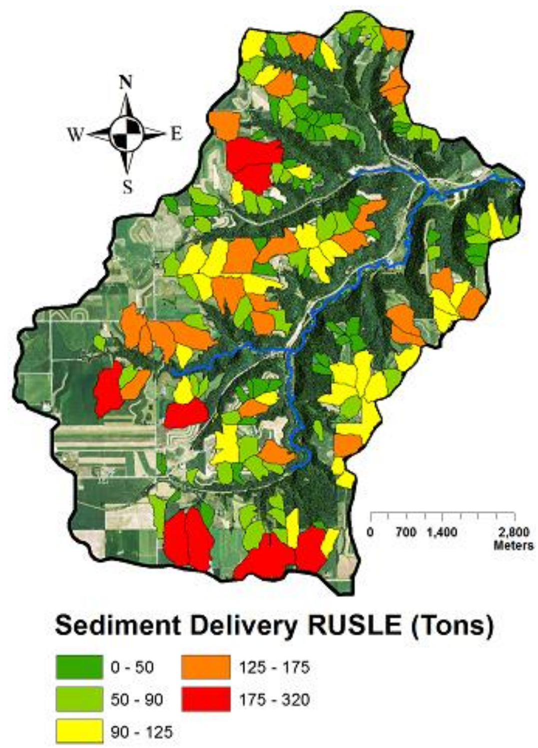

Figure 9. Soil loss per pointshed estimated by RUSLE and SDR.

Field Boundaries

A field boundary layer of attributed field polygons was downloaded from ACPF sources. It was necessary to edit non-agricultural parcels to agricultural use. A total of 45 fields containing 450 acres were edited and re-coded from non-agricultural to agricultural use to form a new agricultural field boundary layer. A 60-meter non-intersecting buffer ring was created outside the agricultural field boundaries. This Agricultural Ring Buffer (ARB) provides the area for the sediment basin zone.

Sediment Basin Priority Zone

The premium location of the sediment basin siting is at or below field edge and is consistent with the producer's desire to limit the loss of productive land to conservation practice. The ARB was the zonal extent for the implementation of sediment basins. To further identify optimal zones, the significant SPI was vectorized and clipped by both pointshed and ARB extents.

SPI vector signatures were buffered at 20 meters to create a sediment basin priority zone along the flow accumulation path and within the ARB (Figure 10). Spatial Analyst was used to explode the multi-part polygon into single parts within pointsheds with individual attributes.

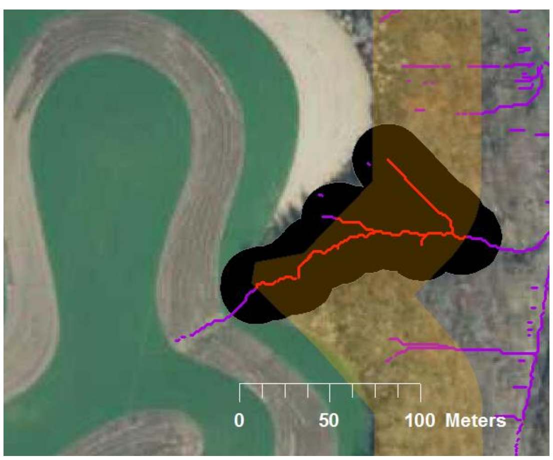

Figure 10. Creation of sediment basin priority location (black) by clip and buffer of vectorized SPI signature within ARB. The area of this sediment basin priority location is approximately 2.16 acres.

Distance to Stream

A distance to stream application is available as a tool in the ACPF toolset. The tool converted the previously designated perennial stream to a raster. The D8 flow accumulation was then used to measure the horizontal distance from each grid cell to the perennial stream channel output as a continuous raster (Porter *et al.*, 2015).

Manually, the maximum flow accumulation value was determined from zonal statistics for each sediment basin buffer zone. The cell determined to have maximum value within each sediment basin buffer zone was converted to a point and represents the furthest potential downslope location for a sediment basin. These points were then used to extract a distance to stream value. The shortest possible distance from any potential sediment basin to the perennial stream channel was represented by this value for each sediment basin priority zone (Figure 11). Close proximity of high flow accumulation represents the highest risk to perennial streams.

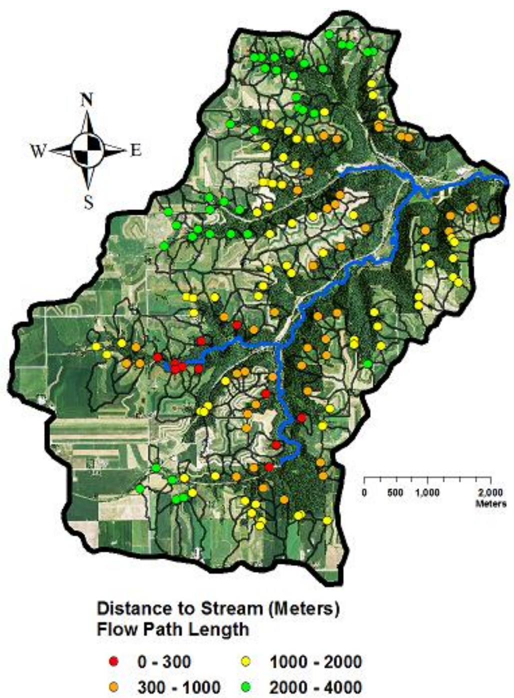

Figure 11. Minimal possible distance along accumulated flow path between sediment basin priority zone and perennial stream.

Sediment Damming Structures

There are many possible types and designs of sediment basins. The precise design and exact placement are beyond the scope of this study. However, the location of characteristically favorable zones has been established. The least complex type of sediment basin would be the result of blocking or damming accumulated flow within the priority placement zone. This type of sediment basin would incur little or no excavation of soils.

The ACPF creators have allowed and encouraged experimental alteration of the tools to determine best management criteria for specific landscapes and management objectives. While Water and Sediment Control Basins (WASCOBs) most commonly occur within the field boundary and may have repetitive siting along a flowpath, their designed purpose of reducing flow and inducing sediment settlement complement characteristics of sediment basins. Alteration of the WASCOB tool was determined to be serviceable in determining locations where dam structures could be placed to meet predetermined embankment heights. The Winona County Planning Department advised a 3-meter minimum embankment height for damming locations.

The ACPF WASCOB tool was modified to: search for damming locations in catchments ranging from 2 to 100 acres, search within a 60-meter distance along flow paths for embankment threshold heights of 3 or more meters, and attempt placement every 45 feet or 13.7 meters along the flow accumulation path to enhance the likelihood of placement within the relatively narrow sediment basin priority zone extent. The input for field boundary was established by adding the ARB layer to the new field boundary layer for agricultural fields to produce an input extent. Results were further refined to locations intersecting sediment basin priority zones (Figure 12).

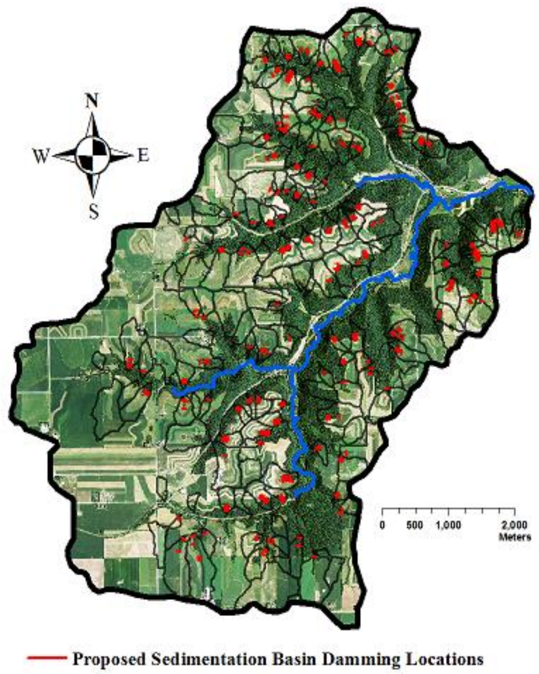

Figure 12. Red polylines indicate proposed damming structures intersecting the sediment basin priority zones.

Results

The RUSLE model and SDR produced soil loss risk results for pointshed erodible upslope areas and potential sediment basin locations. The SPI value was extracted at the bottom of slopes nearest flow convergent points to determine maximal erosive power of flows downslope of each potential sediment basin priority zone. Minimum distances to stream value was determined for each sediment basin priority zone. Values from the RUSLE sediment loss risk model, and SPI for water quality assessment were ranked in relativity for catchments within the watershed with the following formula:

$$Z = \frac{X - \min(X)}{\max(X) - \min(X)}$$

Where:

Z is rank defined (0-1)
X is the population values

For the distance to stream the inverse is used to rank locations. Lowest distances to the stream are representative of the highest risk values while higher distances represent decreasing risk as determined with the following formula:

$$Z = 1 - \frac{X - \min(X)}{\max(X) - \min(X)}$$

Resultant RUSLE rankings for sediment risk was multiplied by 100 (Figure 13) and resultant ranking for SPI (Figure 14) and distance to stream (Figure 15) were each multiplied by 50. Each rank was joined to a correlating sediment priority zone by a primary key.

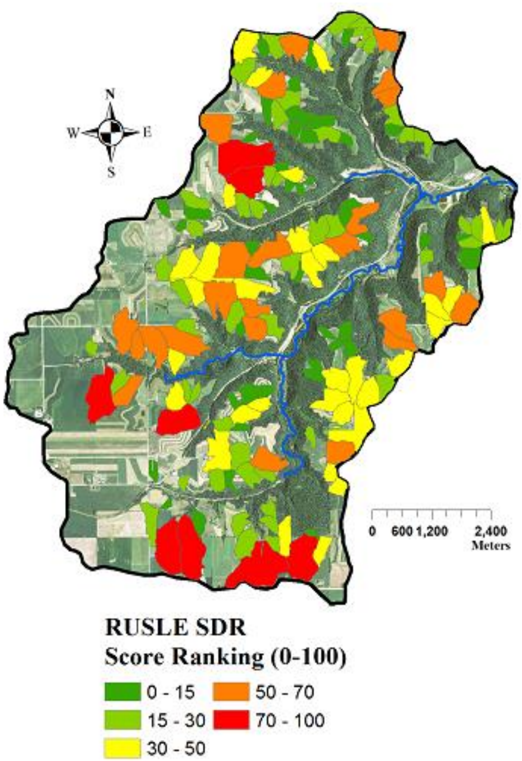

Figure 13. Soil loss per clipped pointshed rank score from 0-100 estimated by RUSLE modeling and the application of a Sediment Delivery Ratio.

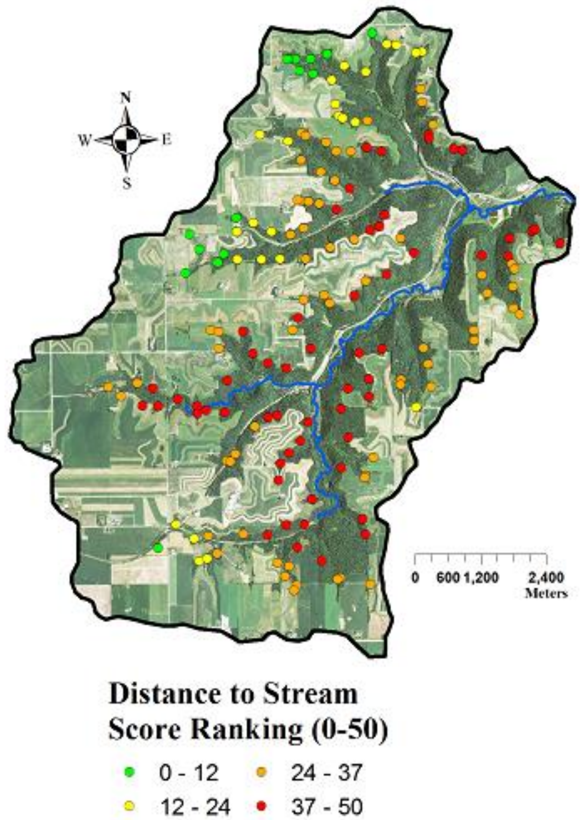

Figure 14. Distance to stream score from 0-50.

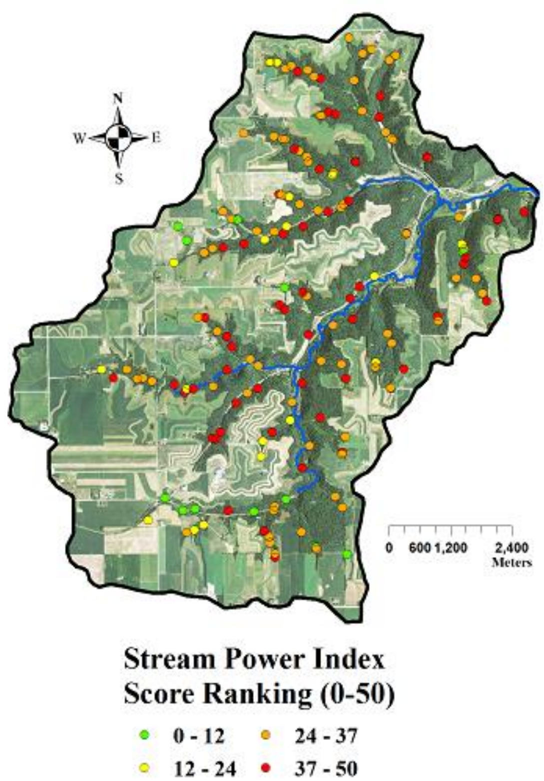

Figure 15. SPI signature rank score from 0-50.

Accuracy limitations of the digitized agricultural field boundary layer prevented the siting of four pointshed sediment basin priority zone locations. The remaining 159 sediment basin priority locations were scored within a table using the field calculator (Appendix A). Results were classified and displayed by total scored rank per pointshed (Figure 16).

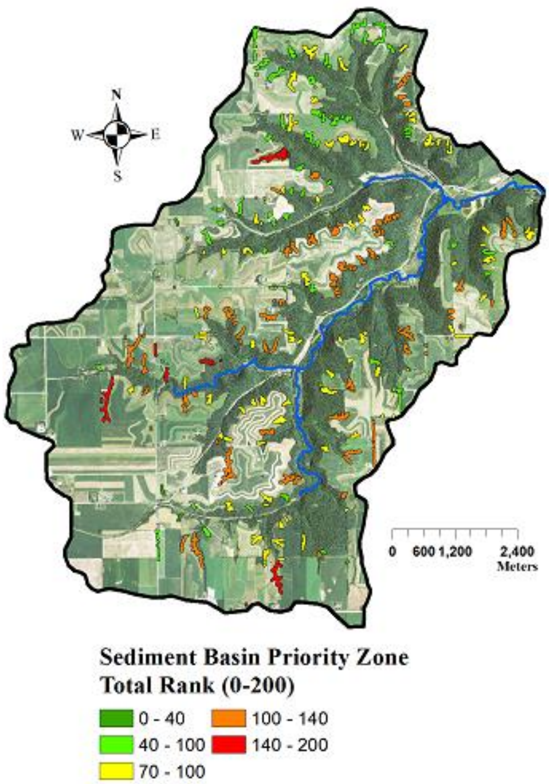

Figure 16. Total rank score attributed to each sediment basin priority zone within each pointshed. Total possible rank is (0-200) with red and dark green representing the highest and lowest ranking scores. Priority zones were classified up to the maximum possible score of 200 although the highest ranking priority zone score was 169.

The modified ACPF WASCOB tool produced multiple damming locations dependent on soil terrain profile fit within tool constraints. A map cutout area exemplifies possible dam locations intersecting ranked sediment basin priority zones (Figure 17). Within this cutout area three existing pond locations occur at intersecting locations.

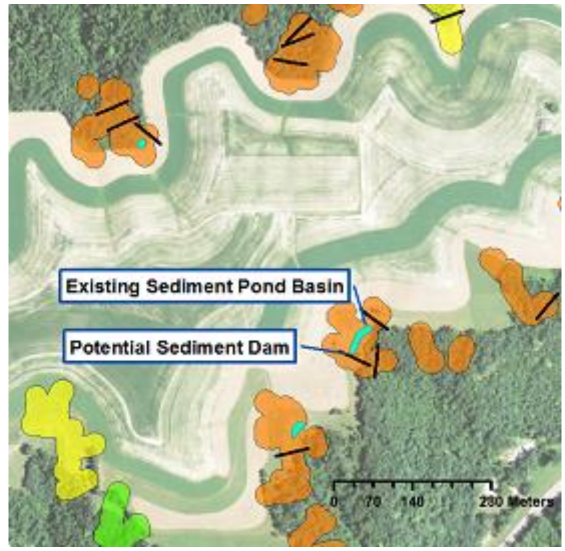

Figure 17. Map cutout area showing potential sediment basin dam locations as determined by the modified ACPF tool. Three ponds (shown in light blue) are located within colored sediment basin priority zones at or near intersections of proposed damming locations.

Sediment basin priority zones were ranked based on potential risk. Of the 159 sediment basin priority zone siting polygons, 45 or 28% of siting locations received high or very high risk ratings with total scores over 100 and up to 170. According to Winona County Planning Department records, there are 23 existing sediment ponds within the project's DNR level 7 sub-watershed. 13 of 23 or 57% of ponds intersected siting polygons and 18 of 23 or 78% of ponds were within 30 meters of siting polygons. There were 5 of 23 or 22% of pond locations not located within 30 meters of a siting polygon. Table 2 and Appendix A identify pointshed sediment priority zone's scoring rank, predictability of existing pond locations, and identification of terrain profile characteristics supportive of sediment damming as determined by the modified ACPF WASCOB tool.

Table 2. Sediment basin priority locations ranked by total score/risk. IXP (Intersects Existing Ponds), PWI30 (Existing Pond within 30 meters), Sed Dam indicates supporting terrain for sediment damming.

OBJECTID	Rank	TotalRank	IXP	PWI30	Sed Dam
5	VERY HIGH	169.3	NO	NO	NO
17	VERY HIGH	156.4	YES	YES	YES
35	VERY HIGH	150.4	NO	NO	NO
31	VERY HIGH	149.9	NO	NO	YES
30	VERY HIGH	140.6	NO	NO	NO
32	HIGH	134.3	NO	NO	YES
38	HIGH	133.3	NO	NO	YES
40	HIGH	131.4	NO	NO	YES
1	HIGH	130.7	NO	NO	YES
28	HIGH	129.3	NO	NO	YES
6	HIGH	128.5	NO	NO	NO
25	HIGH	126.4	YES	YES	YES
15	HIGH	124.2	NO	NO	YES
4	HIGH	122.9	YES	YES	YES
29	HIGH	119.8	NO	NO	NO
16	HIGH	119.0	NO	NO	YES
11	HIGH	117.5	NO	NO	YES
27	HIGH	117.3	NO	NO	YES
7	HIGH	115.6	NO	NO	YES
2	HIGH	115.1	NO	NO	YES
21	HIGH	114.8	NO	NO	YES
20	HIGH	114.5	YES	YES	NO
19	HIGH	113.8	YES	YES	YES
44	HIGH	113.8	NO	NO	YES
10	HIGH	113.0	NO	NO	YES
12	HIGH	112.9	NO	NO	YES
26	HIGH	112.2	NO	NO	YES
39	HIGH	112.0	NO	NO	YES
24	HIGH	112.0	NO	NO	YES
37	HIGH	111.6	NO	NO	YES
13	HIGH	111.6	YES	YES	YES
3	HIGH	111.0	NO	YES	YES
33	HIGH	110.0	YES	YES	YES
18	HIGH	109.7	NO	NO	YES
23	HIGH	108.8	NO	NO	YES
9	HIGH	107.2	NO	YES	YES
45	HIGH	107.0	YES	YES	YES
42	HIGH	105.3	NO	NO	YES
8	HIGH	104.9	NO	NO	YES
41	HIGH	104.2	NO	NO	YES
36	HIGH	103.5	NO	NO	NO
22	HIGH	103.2	NO	NO	YES
34	HIGH	101.4	NO	NO	YES
43	HIGH	101.2	NO	NO	YES
14	HIGH	100.3	NO	NO	YES

Of the 45 siting polygons rated as high or very high, 10 or 22% have record of a sediment basin within 30 meters. 35 or 78% of siting polygons have no basin in place. 29 or 64% of sited polygons rated high or very high with no existing basins within 30 meters also have terrain attributes supporting installation of sediment basin dam structures.

Discussion

This study employed advanced DTA with 1-meter resolution LiDAR in a region of high relief prone to overland soil loss and nutrient transport. Utilizing SPI signatures, pointshed areas of critical erosive risk from overland flow were created. Field edge boundary buffers presented a zone where implementation of off-field sediment basins could be implemented and least affect displacement of production area. Upslope soil risk was determined by implementing RUSLE modeling. Downslope erosive potential was determined from values of SPI extracted prior to stream flow junctions. The risk to surface water was measured as the minimum overland flow distance from potential basin area to a perennial defined stream network with a tool from the ACPF toolset. Ranked scoring of the RUSLE, SPI, and distance to stream values were weighted according to the Ecological Ranking Tool and combined scoring was attributed to individual priority sediment basin locations. Finally, a modification of the ACPF WASCOB tool was employed to locate potential sediment damming areas which met topographic profile criteria allowing side embankments of 3 meters or more near accumulated flow. Resulting damming areas intersecting sediment basin priority zones were illustrated in a sediment basin priority map.

The ACPF toolset is intended to present all options of conservation practice and the isolation of sediment basins in this study does not imply exclusion of other existing or prescriptive conservation practices. Ideal conservation plans most often consist of combinations of management practices, both sized and located optimally for specific landscape conditions. While the ACPF creators consent to free use and modification of existing tools, there is no implied accuracy of user-modified tools or outputs which applies to the modification of the WASCOB tool in this study.

Future enhancements to this study would include the input of higher precision digitized field boundary maps to define field edge locations and limit missed opportunities. Encroachment of potential pond basins to roadways could be considered within the ACPF toolset. Inclusion of known Karst topographical features and subterranean flow networks may influence siting zones significantly and should be considered and further investigated prior to accepting results. There are many forms of soil loss modeling apart from and within USLE/RUSLE modeling. Use of RUSLE2 on a regional level was data access prohibitive for this study. Advanced SDR analysis for overland transport can include substantial examination of the soil profile dimension not implemented as part of this study.

Conclusions

The initial siting criteria of SPI signature strength and field edge boundaries appear to have been most influential in sediment basin priority ranking. Firstly, SPI values are determined by a product of flow accumulation and slope. The main areas that appear to have produced the largest SPI values and very high overall rank scores are those that had vast watershed areas resulting in the largest flow accumulations. Larger field locations with main channels draining to the periphery of higher relief areas exhibited the highest overall scores despite not being located closest in proximity to perennial streams. The top 5 overall ranking scores exhibited erodible watershed areas in the top 15 in acreage area. Lesser slopes in these areas appear to encourage intense agricultural production within close field edge proximity to roads and homesteads leading to competition for space with conservation practices such as sediment basin damming. Damming in areas of lesser slope requires more surface area per water volume. Secondarily, another area of high SPI values and high overall rank scores included areas of severe slope in close proximity to perennial streams. Pointsheds in these areas had high soil loss rates but modest soil loss volumes because of the smaller size of the overall watershed. Opportunities for sediment basin damming in these areas is largely dependent on topographic soil profiles and basin size requirements relative to field edges and slope drop-offs.

Existing ponds that were not found to be within mapped priority zones appear to have been mostly missed as a result of errors in field boundaries. Visual observation of aerial images found ponds in areas of no agricultural production that were mapped as active production areas. Existing ponds were found dispersed in both of these types of areas. While sediment basins appear to be productive to various degrees, this study would suggest the historically wide dispersal of existing basins has been primarily a matter of an agricultural producer’s prerogative to install them versus a results based prescription. It appears conservation managers could have significant impact on flow accumulation and sediment volume by prioritizing sediment basin installation on large field drainages. Secondarily high scoring areas with high slopes in close proximity to streams and sensitive biological habitats would represent other target areas of sediment basin priority.

Conservation efforts using advanced technologies have the potential to maximize non-point pollution control benefits while minimizing associated costs. While not intending to be a prescriptive recommendation for a stand-alone management practice, this study isolated potential siting areas of sediment basins to specific priority zones and ranked those areas by their potential erosion risk to perennial streams. This study does not completely overcome a need for in-field surveys and local knowledge for absolute pinpoint siting and engineering design, however, the time, labor, and cost savings of focused practice siting as part of the decision process of the conservation planner is substantial. A location priority map of BMP siting produced with a GIS is of great benefit when communicating BMP spatial relationships, distribution, and prioritization to producers and financial stakeholders.

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Appendix A. The following table represents the full sediment basin priority zone areas as determined by this study. Total Rank was determined by the summation of SPI50 (Stream Power Index rank multiplied by a weighting factor of 50), SDR100 (estimated sediment delivery rank as determined by ratio and RUSLE multiplied by a weighting factor of 100), and D2S50 (distance to stream rank multiplied by a factor of 50). IXP (Intersects Existing Ponds), PWI30 (Existing Ponds within 30 meters), Sed Dam indicates supporting terrain for sediment damming. X,Y coordinates for location are indicative of polygon centroids. Oddly shaped or multipart polygon centroids can occur outside of polygon boundaries.

OBJID	Gridcode	Rating	TotalRank	SPI_50	SDR_100	D2S_50	IXP	PWI30	SedDam	X_UTM	Y_UTM
23	503	VERY HIGH	169.3	39.73	100.00	29.54	NO	NO	NO	594825.605282	4869682.04197
49	1325	VERY HIGH	156.4	45.43	84.28	26.65	YES	YES	YES	594787.946362	4875803.72604
102	2609	VERY HIGH	150.4	38.05	79.38	33.01	NO	NO	NO	592367.475346	4872245.12772
89	2462	VERY HIGH	149.9	50.00	52.97	46.91	NO	NO	YES	593851.287786	4872824.21639
88	2320	VERY HIGH	140.6	44.54	48.35	47.73	NO	NO	NO	593164.623649	4872783.84342
91	2512	HIGH	134.3	43.20	64.13	26.94	NO	NO	YES	594769.017585	4875277.91451
126	2640	HIGH	133.3	36.83	75.11	21.34	NO	NO	YES	593476.728400	4870181.00150
132	2647	HIGH	131.4	30.71	64.70	35.96	NO	NO	YES	595457.095829	4870017.00029
8	160	HIGH	130.7	43.81	39.26	47.64	NO	NO	YES	595039.932446	4871116.70861
78	2160	HIGH	129.3	47.27	37.70	44.33	NO	NO	YES	594698.581711	4871802.72310
24	595	HIGH	128.5	43.29	47.93	37.24	NO	NO	NO	594166.402628	4873488.00868
73	2069	HIGH	126.4	43.04	33.36	50.00	YES	YES	YES	593509.521367	4872212.95698
43	1147	HIGH	124.2	32.48	45.76	46.00	NO	NO	YES	594746.858240	4873043.90104
21	397	HIGH	122.9	49.40	34.72	38.73	YES	YES	YES	595682.582397	4873945.21539
82	2273	HIGH	119.8	44.75	39.21	35.79	NO	NO	NO	594733.034036	4873474.79940
47	1293	HIGH	119.0	33.39	48.98	36.60	NO	NO	YES	592736.477906	4872991.23092
37	984	HIGH	117.5	30.09	53.25	34.14	NO	NO	YES	596755.898189	4873221.47780
77	2102	HIGH	117.3	41.14	39.37	36.75	NO	NO	YES	596396.704333	4874825.31954
25	604	HIGH	115.6	32.71	50.79	32.07	NO	NO	YES	597508.260775	4873923.16060
16	305	HIGH	115.1	29.58	50.40	35.15	NO	NO	YES	595867.567755	4871396.11700
63	1827	HIGH	114.8	38.98	51.56	24.29	NO	NO	YES	595038.858407	4874450.60159
60	1786	HIGH	114.5	48.45	23.74	42.30	YES	YES	NO	594317.701395	4873213.04615
57	1707	HIGH	113.8	35.40	37.85	40.56	YES	YES	YES	592912.494220	4872781.31976
153	2807	HIGH	113.8	41.62	36.67	35.51	NO	NO	YES	596144.832276	4871586.05171
32	871	HIGH	113.0	42.17	28.24	42.62	NO	NO	YES	595751.808322	4872024.28065
38	989	HIGH	112.9	40.60	35.21	37.04	NO	NO	YES	594888.514386	4873692.37352
74	2075	HIGH	112.2	42.12	45.23	24.84	NO	NO	YES	597966.141717	4873674.59554
129	2644	HIGH	112.0	41.84	32.37	37.80	NO	NO	YES	595908.375032	4872481.98420
71	1975	HIGH	112.0	44.18	32.40	35.42	NO	NO	YES	597365.483936	4873516.19537
108	2618	HIGH	111.6	46.61	29.23	35.76	NO	NO	YES	595392.996313	4875527.12391
40	1065	HIGH	111.6	42.02	33.02	36.55	YES	YES	YES	595837.080578	4874200.51991
20	394	HIGH	111.0	38.06	31.50	41.46	NO	YES	YES	598253.652728	4874780.25619
97	2578	HIGH	110.0	17.83	69.16	23.02	YES	YES	YES	593676.576627	4870094.60715
52	1385	HIGH	109.7	37.22	43.84	28.61	NO	NO	YES	596694.138372	4876620.21539
70	1963	HIGH	108.8	36.47	30.10	42.20	NO	NO	YES	595817.155773	4870882.16150
31	844	HIGH	107.2	24.99	39.23	42.93	NO	YES	YES	592937.962647	4872396.26671
157	2899	HIGH	107.0	42.58	34.07	30.32	YES	YES	YES	595348.634133	4874586.59869
148	2673	HIGH	105.3	34.04	39.58	31.70	NO	NO	YES	596777.791995	4872994.67570
26	640	HIGH	104.9	41.41	37.93	25.54	NO	NO	YES	596691.553558	4876908.89680
145	2661	HIGH	104.2	41.37	21.30	41.57	NO	NO	YES	598138.683074	4874737.68510
103	2611	HIGH	103.5	39.25	14.44	49.83	NO	NO	NO	593646.151545	4872350.62204
66	1884	HIGH	103.2	46.42	29.58	27.23	NO	NO	YES	594120.636588	4871297.57819
98	2604	HIGH	101.4	43.17	22.58	35.64	NO	NO	YES	595693.947336	4874741.45474
152	2802	HIGH	101.2	39.25	27.46	34.46	NO	NO	YES	593816.494599	4873541.67686
42	1133	HIGH	100.3	20.11	38.82	41.40	NO	NO	YES	596161.247367	4874351.50847
114	2624	MODERATE	99.6	40.51	18.75	40.30	NO	NO	YES	597053.775634	4876027.98387
104	2612	MODERATE	99.4	37.77	19.40	42.22	NO	NO	YES	595059.102922	4873180.24016
9	203	MODERATE	99.3	26.94	30.91	41.42	NO	NO	YES	595227.745588	4870196.90767
44	1167	MODERATE	98.7	41.55	30.61	26.49	NO	NO	NO	596935.448165	4872664.76909
61	1802	MODERATE	98.0	35.05	21.37	41.63	NO	NO	YES	594689.026184	4870823.47510
85	2292	MODERATE	97.4	34.62	14.05	48.69	NO	NO	YES	593859.046521	4872280.28027
113	2623	MODERATE	97.4	33.81	45.08	18.47	NO	NO	YES	596675.670252	4877378.04287
124	2638	MODERATE	97.2	35.45	25.19	36.53	NO	NO	NO	595976.414582	4871753.34852
28	741	MODERATE	96.7	44.69	12.68	39.33	NO	NO	YES	595854.833950	4876039.75549
127	2642	MODERATE	96.4	30.35	26.02	40.03	NO	NO	YES	595848.286066	4870666.28157
75	2083	MODERATE	95.6	33.17	23.51	38.91	NO	NO	NO	592720.521083	4872408.18437
99	2605	MODERATE	95.4	40.04	38.26	17.07	NO	NO	YES	594408.990135	4874436.14037
90	2507	MODERATE	94.9	36.91	18.04	39.95	NO	NO	YES	597293.916458	4875961.40115
55	1595	MODERATE	94.8	18.77	26.26	49.80	NO	YES	YES	593502.747562	4872516.02691
4	92	MODERATE	93.9	37.68	20.32	35.90	NO	NO	YES	594549.648839	4870241.35056
130	2645	MODERATE	93.9	29.02	37.44	27.42	NO	NO	YES	596306.650113	4872675.96429
59	1773	MODERATE	93.2	30.32	14.91	48.00	NO	NO	YES	595542.672180	4871558.04813
135	2650	MODERATE	93.2	40.91	41.87	10.39	YES	YES	YES	595066.572817	4876908.77006
46	1246	MODERATE	93.0	43.55	21.71	27.76	NO	NO	NO	595262.000569	4874030.71639
62	1818	MODERATE	91.5	38.23	11.27	41.96	NO	NO	YES	594634.397454	4872250.38265
146	2662	MODERATE	91.4	41.95	7.36	42.10	NO	NO	YES	596141.259834	4875056.16557
15	295	MODERATE	91.2	16.34	28.29	46.54	NO	NO	YES	594883.993340	4871970.83604
141	2656	MODERATE	91.1	37.44	14.63	39.04	NO	NO	YES	598514.985295	4874680.45469
7	125	MODERATE	90.9	38.28	20.58	31.99	NO	NO	YES	594151.678232	4870721.11585
79	2166	MODERATE	90.2	30.76	12.16	47.23	NO	NO	YES	594489.102545	4873079.31066
83	2279	MODERATE	90.1	36.43	42.64	11.00	NO	NO	YES	595323.080848	4877334.76027
22	471	MODERATE	89.7	36.10	34.14	19.45	NO	NO	YES	595792.090397	4877137.36322
2	37	MODERATE	89.6	28.31	20.46	40.80	NO	NO	NO	594928.278275	4870476.51693
115	2626	MODERATE	89.3	40.16	7.78	41.38	NO	NO	YES	596090.354038	4873174.51103

OBJID	gridcode	Rating	TotalRank	SPI_50	SDR_100	D2S_50	IXP	PWI30	SedDam	X_UTM	Y_UTM
36	892	MODERATE	88.8	43.49	10.38	34.92	NO	NO	YES	597925.114399	4874307.40392
76	2095	MODERATE	88.7	35.43	11.33	41.96	NO	NO	YES	594984.842735	4872220.22307
58	1742	MODERATE	88.6	27.64	26.77	34.17	NO	NO	NO	597484.889162	4873235.17897
111	2621	MODERATE	88.1	33.17	22.14	32.81	NO	NO	YES	596798.199436	4876381.40701
53	1492	MODERATE	87.5	35.15	19.71	32.60	NO	NO	YES	594678.676128	4869995.25350
142	2658	MODERATE	87.0	37.57	15.09	34.36	NO	NO	YES	597418.922784	4874248.74806
100	2606	MODERATE	86.9	39.15	34.34	13.39	NO	NO	YES	594054.540200	4874309.30989
5	101	MODERATE	86.3	37.12	20.01	29.12	NO	NO	YES	594082.337648	4871714.63671
54	1506	MODERATE	85.9	25.16	21.75	38.97	NO	NO	YES	595927.057815	4874805.47356
84	2285	MODERATE	85.5	31.24	28.05	26.25	NO	NO	YES	597839.013346	4873748.60106
56	1623	MODERATE	85.5	39.73	9.68	36.12	NO	NO	YES	594341.580859	4872116.29301
1	18	MODERATE	85.3	33.12	15.77	36.38	NO	NO	NO	593756.484502	4873184.38719
72	1990	MODERATE	83.8	44.64	1.52	37.63	NO	NO	NO	595576.918139	4872403.90965
131	2646	MODERATE	83.8	31.58	29.11	23.09	NO	NO	YES	596474.734015	4872138.26070
151	2798	MODERATE	83.3	34.22	9.43	39.67	NO	NO	YES	596059.942501	4874896.75045
158	2909	MODERATE	83.1	32.25	15.80	35.03	NO	NO	YES	594872.208619	4870201.20172
112	2622	MODERATE	82.9	39.09	2.53	41.27	NO	NO	YES	596107.380271	4875965.51969
144	2660	MODERATE	82.2	25.73	13.16	43.34	NO	NO	NO	597877.562393	4874736.24652
13	256	MODERATE	78.7	25.79	20.22	32.64	NO	NO	YES	593674.430210	4873540.97705
86	2309	MODERATE	76.8	32.39	18.69	25.67	NO	NO	YES	595047.954966	4876291.50080
48	1296	MODERATE	76.7	31.50	7.79	37.37	NO	NO	YES	595433.555644	4875182.80672
116	2627	MODERATE	75.0	26.85	4.55	43.64	NO	NO	YES	595615.947687	4872647.36580
150	2756	MODERATE	74.5	24.94	19.30	30.30	NO	NO	NO	594906.041204	4869952.21610
92	2514	MODERATE	74.3	30.54	5.79	37.95	NO	NO	YES	597844.092001	4874519.56200
149	2740	MODERATE	74.2	26.43	7.71	40.02	NO	NO	YES	595906.855480	4872841.88015
123	2636	MODERATE	74.0	23.33	9.13	41.56	YES	YES	YES	594604.315729	4871638.43863
107	2617	MODERATE	73.9	28.56	9.35	35.94	NO	NO	NO	595603.947341	4875988.51372
95	2545	MODERATE	71.9	28.33	4.21	39.39	NO	NO	YES	594498.969123	4872231.03510
120	2633	MODERATE	71.5	39.03	14.42	18.06	NO	NO	NO	595382.699358	4876624.03518
155	2854	MODERATE	71.0	24.86	18.54	27.63	NO	NO	YES	594928.299415	4875320.33329
93	2527	MODERATE	70.9	27.64	23.34	19.88	NO	NO	YES	594552.558832	4874883.89801
101	2607	MODERATE	70.4	29.53	31.80	9.10	NO	NO	NO	593780.175584	4874408.99559
133	2648	MODERATE	70.4	31.97	1.03	37.36	NO	NO	YES	595766.743908	4873136.78115
140	2655	MOD LOW	69.7	29.49	1.70	38.50	NO	NO	YES	596747.419108	4876121.34265
159	2913	MOD LOW	69.4	33.66	24.10	11.67	NO	NO	YES	596020.507340	4877701.58784
6	111	MOD LOW	69.3	31.24	30.30	7.79	NO	NO	YES	594826.961870	4876997.07655
10	220	MOD LOW	68.7	30.39	8.32	29.95	NO	YES	YES	597909.501006	4874104.32567
106	2615	MOD LOW	68.2	25.08	17.57	25.53	NO	NO	YES	594767.625160	4874892.58166
87	2312	MOD LOW	67.6	31.98	10.86	24.72	NO	NO	YES	594924.157968	4876312.22334
156	2866	MOD LOW	67.5	32.20	16.05	19.26	YES	YES	YES	596484.829341	4877411.94325
143	2659	MOD LOW	67.1	19.00	8.55	39.59	NO	NO	YES	597411.875182	4874512.15801
134	2649	MOD LOW	66.9	25.16	1.81	39.94	NO	NO	NO	596472.860099	4874544.46978
154	2814	MOD LOW	66.7	33.05	20.16	13.45	NO	NO	YES	596345.165778	4877590.52392
34	877	MOD LOW	66.3	25.69	9.79	30.79	NO	NO	YES	595214.030418	4875267.54621
122	2635	MOD LOW	66.2	35.76	10.97	19.43	NO	NO	YES	595405.944242	4876442.55294
109	2619	MOD LOW	65.7	33.16	0.00	32.52	NO	NO	YES	595175.141902	4875637.52030
96	2549	MOD LOW	65.5	28.49	6.64	30.39	NO	NO	NO	595361.536868	4873877.28836
41	1125	MOD LOW	65.4	14.76	19.61	31.08	NO	NO	NO	592251.933992	4872739.39143
27	715	MOD LOW	65.4	21.36	14.85	29.19	NO	NO	YES	595049.023478	4875302.55495
110	2620	MOD LOW	64.7	28.46	5.48	30.75	NO	NO	YES	595424.776635	4875987.92325
30	823	MOD LOW	64.5	26.25	9.75	28.49	NO	NO	NO	595311.958655	4876094.12925
29	795	MOD LOW	64.1	37.81	10.99	15.34	NO	NO	YES	595573.906888	4877172.42917
119	2632	MOD LOW	63.6	37.64	3.90	22.09	NO	NO	YES	595685.267555	4876319.77184
139	2654	MOD LOW	63.3	21.59	3.62	38.04	NO	NO	YES	596746.435398	4876206.86826
64	1833	MOD LOW	62.6	21.56	17.87	23.11	NO	NO	YES	596622.639086	4872303.25486
147	2671	MOD LOW	62.4	22.20	11.81	28.38	YES	YES	YES	596263.568965	4872819.21755
128	2643	MOD LOW	61.8	0.00	32.82	28.93	NO	NO	NO	595874.557584	4869918.96981
138	2653	MOD LOW	61.6	21.79	0.37	39.42	NO	NO	YES	595597.447077	4875422.92600
67	1893	MOD LOW	61.4	1.61	13.08	46.75	NO	NO	YES	594965.370750	4870852.93105
69	1938	MOD LOW	59.8	36.42	10.42	12.94	NO	NO	NO	594023.368267	4874838.06089
14	280	MOD LOW	57.7	28.95	3.98	24.75	NO	NO	YES	595722.830117	4876378.39673
3	79	MOD LOW	57.5	28.22	23.94	5.32	YES	YES	YES	594621.247873	4877130.22576
65	1857	MOD LOW	56.5	29.73	15.26	11.54	NO	YES	NO	594016.566437	4875034.95313
117	2629	MOD LOW	56.1	22.46	28.18	5.43	NO	NO	NO	594522.185623	4877472.77620
68	1906	MOD LOW	55.4	5.86	13.22	36.32	NO	NO	YES	597910.326154	4874414.44584
81	2261	MOD LOW	54.3	31.18	8.61	14.54	NO	NO	YES	596129.508133	4877523.86700
137	2652	MOD LOW	54.0	22.38	3.30	28.29	NO	NO	YES	594973.175820	4874934.95081
121	2634	MOD LOW	53.5	27.43	6.17	19.90	NO	NO	YES	595517.403757	4876367.19492
33	874	MOD LOW	52.6	5.48	22.47	24.60	NO	NO	NO	593630.169444	4870721.85179
12	247	MOD LOW	52.3	25.48	3.67	23.15	NO	NO	YES	594720.116510	4876079.54940
17	328	MOD LOW	52.2	15.97	11.03	25.18	NO	NO	YES	593819.440222	4870342.46688
80	2210	MOD LOW	51.5	7.35	28.63	15.51	NO	NO	YES	594311.726593	4875070.82592
50	1360	MOD LOW	51.2	25.33	16.38	9.52	NO	NO	YES	595056.404204	4877311.44574
118	2631	MOD LOW	49.5	24.45	10.05	14.98	NO	NO	YES	595353.587505	4876905.57698
51	1381	MOD LOW	48.8	0.91	9.79	38.09	NO	NO	NO	594444.987807	4870688.48999
94	2540	MOD LOW	48.7	24.03	14.22	10.40	NO	NO	NO	593823.961271	4874635.54440
18	344	MOD LOW	47.9	8.56	3.62	35.73	NO	NO	NO	595517.593074	4870059.22326
125	2639	MOD LOW	45.8	21.24	13.23	11.27	NO	NO	NO	593108.781025	4870156.74010
136	2651	MOD LOW	43.6	20.18	1.72	21.73	NO	NO	NO	594659.649178	4874438.32500
105	2614	MOD LOW	43.3	23.02	19.17	1.14	NO	NO	NO	593352.732240	4873903.23584
11	224	MOD LOW	40.7	6.22	8.93	25.58	NO	NO	NO	594837.473380	4873896.92604
45	1194	LOW	32.2	8.43	6.92	16.82	NO	NO	NO	593173.990430	4870963.48811
39	1038	LOW	26.6	1.46	3.16	21.99	NO	NO	YES	593430.184559	4870559.73177
35	880	LOW	18.0	10.41	3.95	3.68	NO	NO	YES	593531.274544	4874609.66777
19	369	LOW	7.8	2.50	5.32	0.00	NO	NO	NO	593385.563196	4874852.22740