Agricultural Conservation Planning Framework ArcGIS® Toolbox User's Manual

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ABSTRACT: Agricultural Conservation Planning Framework (ACPF) comprises an approach for applying concepts of precision conservation to watershed planning in agricultural landscapes. To enable application of this approach, USDA/ARS has developed a set of Geographic Information System (GIS) based software tools to identify candidate locations for different types of conservation practices that can be placed within and below fields in order to reduce, trap and treat hydrologic flows, and thereby improve water quality in agricultural watersheds. This manual describes how to apply the ACPF planning tools, with instructions on input data, data maintenance and file management, digital-terrain-model processing, stream delineations, runoff risk assessment, and execution of Python programming scripts that are used to propose conservation-practice placements. Possible locations for surface-intake filters, drainage water management, grassed waterways, contour buffer strips, nutrient removal wetlands, and water/sediment control basins are identified and mapped by the ACPF tools. Routines that help the user assess a watershed's riparian corridors and identify appropriate riparian buffer placements are also included as part of the ACPF toolbox. Results from applying these tools provide an inventory of opportunities for conservation practice placement at the Hydrologic Unit Code (HUC)12 watershed scale, which is meant to help facilitate the watershed planning process. USDA/ARS has developed ACPF input data bases for land use and soils for Iowa, Illinois, southern Minnesota, and parts of northern Indiana. High resolution terrain data, typically obtained through LiDAR surveys, are required but becoming widely available. This manual accompanies these ACPF software tools as a training and referencing resource for use with the initial release version of these tools, written for use in the ArcGIS version 10.2 or 10.3 environment. The authors strongly recommend these tools be used as part of a collaborative planning effort that includes local landowners, and be applied by planning staff with knowledge of, and access to, the subject watershed.

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Suggested citation formats:

This manual:

Porter, S.A., M.D. Tomer, D.E. James, and K.M.B. Boomer. 2015. Agricultural Conservation Planning Framework: ArcGIS®Toolbox User's Manual. USDA Agricultural Research Service, National Laboratory for Agriculture and the Environment, Ames Iowa. Available: http://northcentralwater.org/acpf/ (Verified – date)

General concepts behind the ACPF:

Tomer, M.D., S.A. Porter, D.E. James, K.M.B. Boomer, J.A. Kostel, and E. McLellan. 2013. Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. Journal of Soil and Water Conservation 68:113A-120A. http://www.jswconline.org/content/68/5/113A.full.pdf+html

Development of specific practice siting tools:

Tomer, M.D., S.A. Porter, K.M.B. Boomer, D.E. James, J.A. Kostel, M.J. Helmers, T.M. Isenhart, and E. McLellan. 2015. Agricultural Conservation Planning Framework: 1. Developing multi-practice watershed planning scenarios and assessing nutrient reduction potential. J. Environ. Qual. 44(3):754-767. https://dl.sciencesocieties.org/publications/jeq/articles/44/3/754

Development of the riparian classification scheme:

Tomer, M.D., K.M.B. Boomer, S.A. Porter, B.K. Gelder, D.E. James, and E. McLellan. 2015. Agricultural Conservation Planning Framework: 2. Classification of riparian buffer design-types with application to assess and map stream corridors. J. Environ. Qual. 44(3):768-779. https://dl.sciencesocieties.org/publications/jeq/articles/44/3/768

Preface and Input Data

a Background
The ACPF toolbox is specifically designed to work with the data and data structure provided by the Agricultural Conservation Planning Framework (ACPF) (Figure 1) that has been developed at the USDA/ARS National Laboratory for Agriculture and the Environment (NLAE) in Ames, IA. The results from applying this toolbox to data for a particular watershed provide an inventory of opportunities for placement of conservation practices, which is intended to assist towards improving the management of agricultural water quality. Results should be tested in a way that uses local knowledge through stakeholder/landowner participation, and is supported by field verification, to arrive at an actual watershed plan. Results can be used flexibly to enable the watershed plan to focus on nutrients (N and/or P), sediment, or both. Results do not provide engineering design for practices but should be successful in identifying locations where particular types of conservation practices could be installed. However, no guarantee is made concerning any practice or any suggested practice location in any watershed. Local knowledge and local planning expertise will be required to apply results in a way that actually benefits the watershed planning process and watershed conditions. Further information on the intended benefits and application of the ACPF are given in Tomer et al. (2013; 2015a; 2015b). It is assumed herein that ACPF users are experienced with the ArcGIS environment and its file/data handling protocols.

b Structure
All data in the ACPF database are stored in an ArcGIS file-geodatabase (fgdb) structure, with a separate fgdb for each HUC12 watershed in a 3-state study area (Figure 2). The name of each file geodatabase, when initially downloaded, will be “acpf” + HUCID, where HUCID is the 12-digit HUCID number of that watershed (i.e. acpf070802010901.gdb). Changes can be made to the name of the fgdb, but the name should ***“ALWAYS”*** end in the 12-digit HUCID number. For example, “new_acpf070802010901” OR “acpf_new_070802010901”, but NOT “acpf070802010901_new”.

Within each fgdb, numerous base layers have been developed. Descriptions of these base layers are contained in Table 1. ***Prior to using the ACPF toolbox, it is highly recommended*** that the user both verify that the base layers exist in the fgdb and become familiarized with their structure and content. Discussions are underway to expand the area for which the land use and soils input data are available.

Descriptions of output files to be created while running the ACPF toolbox are contained in Table 2. It is suggested that output files be saved back to the same fgdb that is currently being worked on. While output filenames are not fixed, suggestions are provided for each output layer. ***Again, at a minimum, it is suggested that the 12-digit HUCID number for the watershed end the name of every file***. For example:
“Wetlands071000081505”, where “071000081505” is the 12-digit HUC ID number for the watershed.

A high-resolution digital elevation model (DEM) is **NOT** included as a base layer for each HUC12, but is a key data requirement for many of the tools. High-resolution DEMs are becoming commonly available in many areas, often derived from light detection and ranging (LiDAR) sensor surveys. It is the responsibility of the user to obtain an appropriate DEM for each HUC12 watershed to be processed and add this layer to the fgdb. ***The horizontal map unit of the DEM MUST be meters,*** although any horizontal or vertical resolution is accepted***.*** The ACPF tools have been developed using 3-meter resolution DEMs available from the State of Iowa. In addition, the DEM should be in the same Universal Transverse Mercator (UTM) projection as the base layers. The DEM should also extend beyond the watershed boundary enough to ensure coverage of all fields that may lie only partly within the watershed. The base layer "buf" + inHUC, which is included in the fgdb, provides a convenient extent (watershed and field boundary feature classes buffered by 1000 meters) by which to clip the DEM.

The remainder of this manual steps through each tool in the ACPF toolbox in order, defining first the required inputs to each tool and the outputs to be created, followed by a description of the function each tool performs.

c Software Requirements:

The ACPF toolbox requires that the user have the following software installed:
1) ArcGIS Advanced version 10.2 or higher, with Spatial Analyst Extension
2) TauDEM (Terrain Analysis Using Digital Elevation Models, Copyright © 2004 David Tarboton, Utah State University). Available for download at no cost from:
    http://hydrology.usu.edu/taudem/taudem5/downloads.html

d ArcMap Settings:

In Geoprocessing ---> Geoprocessing Options: Make sure "overwrite the outputs of geoprocessing operations" is checked and that Background Processing is "Enabled".

- The ACPF toolbox should be stored in a permanent file location on your computer ***(not the desktop), in the same data structure that the ACPF toolbox was obtained***. This data structure includes a parent directory "ACPF_V1", which contains an "ACPF_V1.tbx" file, a "scripts" folder, which contains the python programs that the toolbox needs to access, and a "docs" folder, containing any documentation. ***In addition, the pathname to the "ACPF_V1" directory should not contain any spaces!*** For example:

    - Incorrect pathname: C:\\DATA\\ACPF Testing\ACPF_V1
    - Correct pathname: C:\\DATA\\ACPF_Testing\ACPF_V1

e Tips and Tricks:

- The ACPF toolbox is designed to run using the ArcGIS 64-bit background geoprocesssor, although foreground, 32-bit processing is also supported. When taking advantage of background geoprocessing, the toolbox is not fully responsive to the current ArcMap session. Errors may occur if input layers are open in the current ArcMap session **AND** involved in a join. ***Joins should be removed from any input layers prior to running a tool.*** The ArcGIS 64-bit geoprocessing environment requires an additional software installation package available from Esri.

- Output layers of the ACPF toolbox are often used as inputs to other ACPF tools. Many times this requires that the attribute table of both input and output layers remain in a predictable structure. ***If the user plans to add/delete/alter fields of any of the ACPF datasets, it is recommended that changes be made to a copy of the original layer.***

- ***Pay attention to the z-factor!*** The z-factor is required as an input to many of the tools. Be sure you know both the horizontal and vertical units of your digital elevation model; if they are not the same units then a correction must be applied, i.e., the z-factor. The z-factor is a conversion factor that provides equivalence between the units of measure for the vertical (or elevation) units when they are different from the horizontal coordinate (x,y) units of the input surface. It is the number of vertical (z) units in each ground (x,y) units. ***If the vertical units are not corrected to the horizontal units, the results of surface tools will not be correct*** (Esri, 2014).

- Any vertical resolution (integer or float, feet, cm or m) DEM may be used with the ACPF toolbox. However, the ***horizontal resolution MUST be in meters***.

- When running any ACPF tool, progress can be monitored from within ArcMap by viewing the Results window, found under the Geoprocessing tab. This window will also contain any error messages generated by the ACPF toolbox.

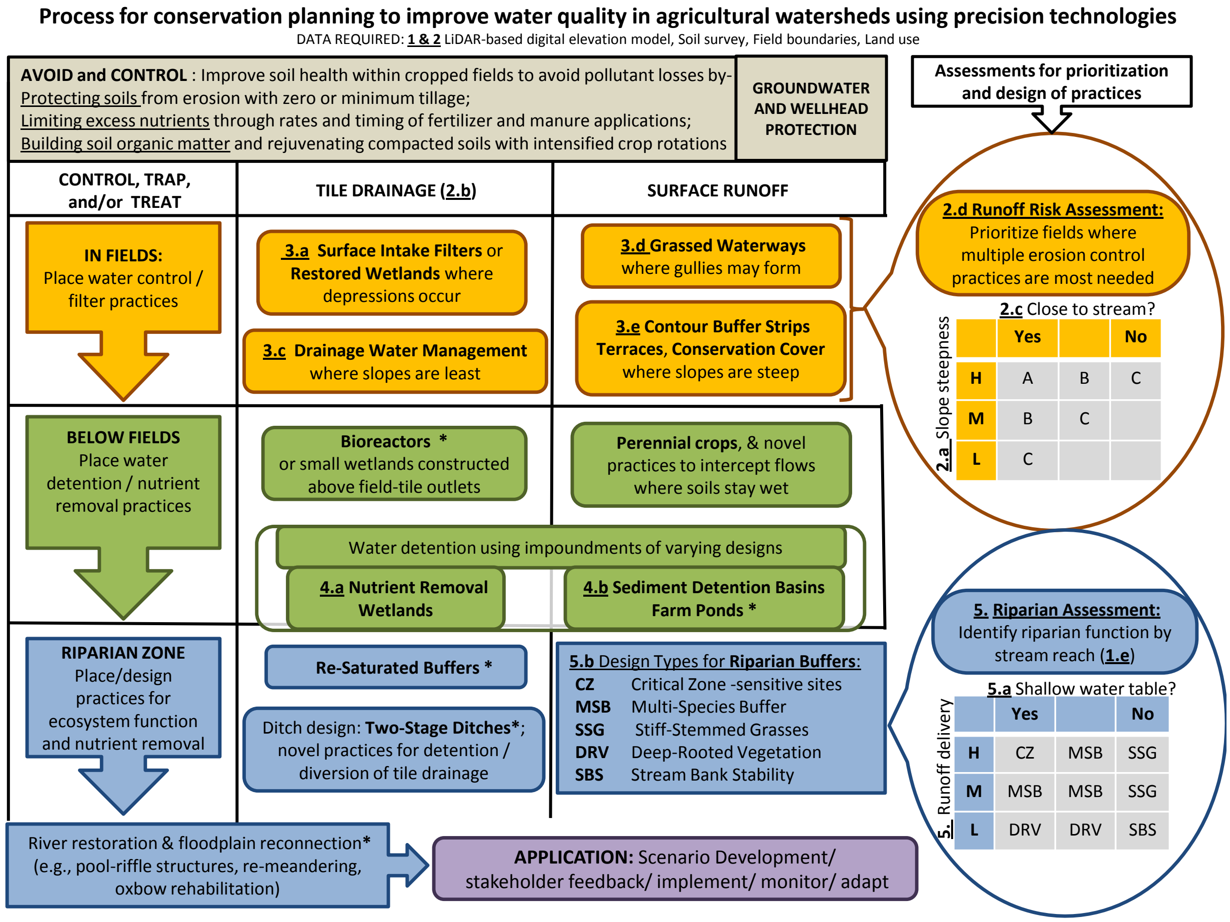


Figure 1. Conceptual diagram for the Agricultural Conservation Planning Framework (Tomer et al., 2013), with section numbers in this manual identified where appropriate. Asterisks indicate topics for which siting criteria have been proposed or are under discussion, but that are not described in this (Ver. 1) manual.

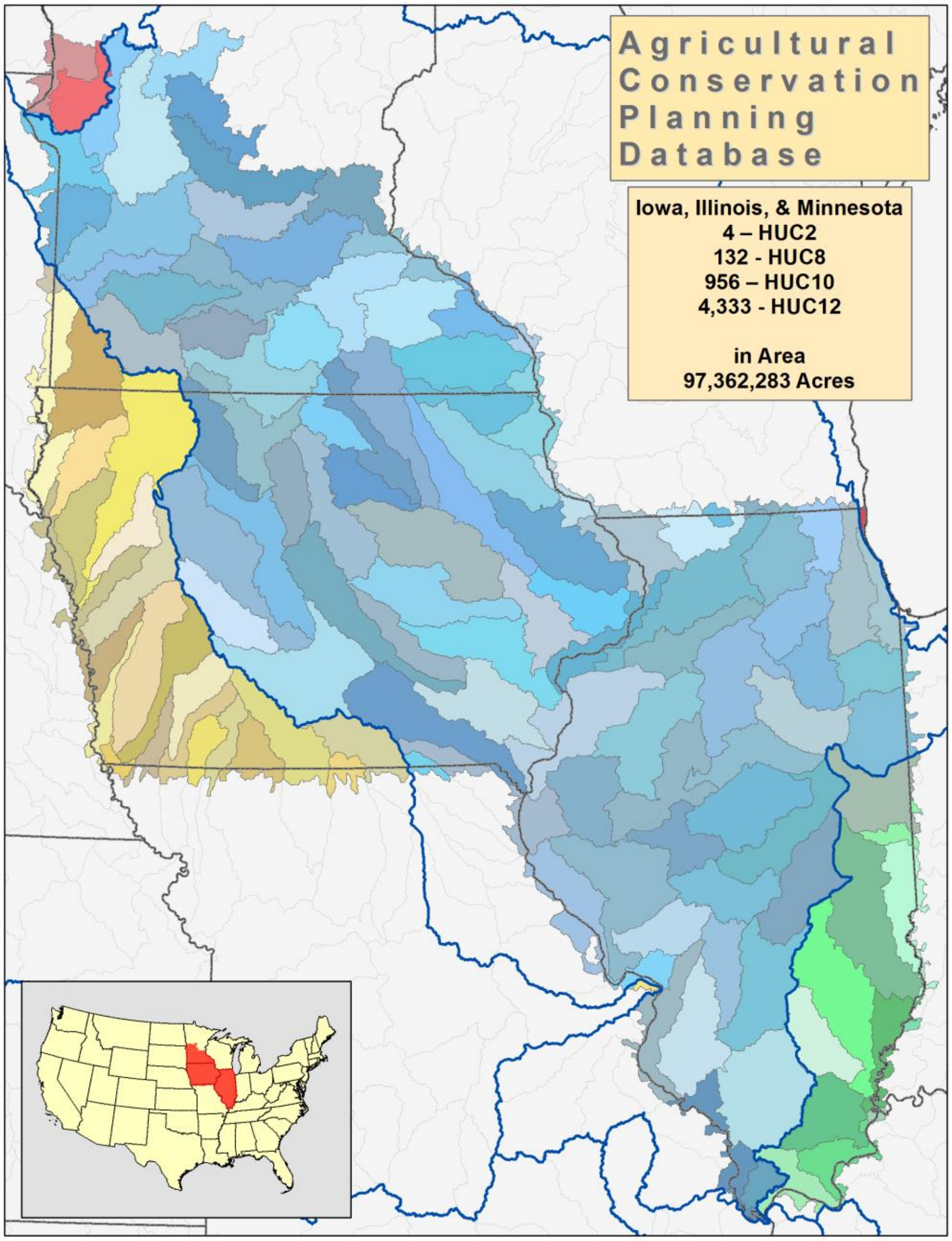


Figure 2. Current extent of study area included in the Agricultural Conservation Planning Database (as of summer 2015).

f Base Layers

Table 1. Base layers included in file geodatabase

Name	Type	Description
bnd + inHUC	Polygon	Watershed boundary (USGS WBD derived from NHD)
buf + inHUC	Polygon	Watershed boundary buffered out by 1000 meters – base data is clipped to buffered extent to ensure coverage for all fields that may lie partly within watershed
FB + inHUC	Polygon	Agricultural field boundaries that have been manually updated from 2005 USDA/FSA Common Land Unit (CLU) dataset. The field boundary feature class contains an "isAG" field in the attribute table. Possible "isAG" values include: • 0 = Non-agricultural (Forest, Water/Wetland, Urban, LT 15ac, and Unassigned) • 1 = Agricultural (Corn/Soybeans, Continuous Corn, C/S with Continuous Corn, Conservation Rotation, Extended Rotation, Mixed Agriculture, and Flood-prone Cropland • 2 = Pasture Note: The "isAG" field can be used for simple land use queries rather than performing a join with the land use table.
<u>Soils DATA:</u> gSSURGO SurfHrz + inHUC SurfTex + inHUC soilVALU + inHUC	 Thematic Raster Table Table Table	 USDA/NRCS 10-meter soils raster that can be joined to soil tables through mapunit or cokey field Surface horizon table Surface texture table Value added table
LU6_ + inHUC	Table	Land use table derived from the most recent 6 years of the NASS CDL; can be joined to field boundary layer by a unique FBndID. Contains information on majority crop found among the pixels (from original remote sensing data) in each field within the classified NASS data, % majority crop (indicates confidence in the crop cover assigned by year), 6–yr land cover strings (Tomer et al., 2015a), and a generalized land use classification for each field.
CH_ + inHUC	Table	Crop history table derived from all available years of the NASS CDL; can be joined to field boundary layer by a unique FBndID. Contains information on crop rotation, majority crop and % majority crop for each year in the dataset.
wsCDL2009 wsCDL2010 wsCDL2011 wsCDL2012 wsCDL2013 wsCDL2014	Thematic Raster	USDA NASS Cropland Data Layers for the most recent 6 years. The filename ends with the 4-digit year that it represents.
DEM + inHUC	Continuous Raster	A LIDAR-derived DEM of meter horizontal resolution ***must be generated by the user and added to the fgdb***. This should be an unfilled DEM, meaning that sinks still exist.

g Data Formats and File Naming Conventions

Table 2. Output Files (will usually be created in this order)		
Name	**Type**	**Description**
D8FlowDir + inHUC	Thematic Raster	Raster of flow direction from each cell to its steepest downslope neighbor, using ArcGIS D8 flow direction values.
D8FlowAcc + inHUC	Continuous Raster	Raster of accumulated flow. Cell values equal the count of the number of upstream cells flowing into each target cell in the output raster.
DEMFill + inHUC	Continuous Raster	DEM that has been processed so that all sinks have been filled.
Hshd + inHUC	Continuous Raster	Shaded relief. Derived from unfilled DEM.
AreaFlowNet + inHUC	Polyline	Flow network polyline derived from the Flow Network Definition – Area Threshold tool.
PDFlowNet + inHUC	Polyline	Flow network polyline derived from the Flow Network Definition - Peuker Douglas tool.
DepthGrid + inHUC	Continuous Raster	Depth grid, in which each cell represents the elevation difference between the filled and unfilled DEM.
NewDEM + inHUC	Continuous Raster	Unfilled DEM containing altered elevation values along user-provided cut and/or dam lines.
StreamReach + inHUC	Polyline	Polyline feature class representing each reach in a stream network.
Catchments + inHUC	Thematic Raster	Polygon feature class representing each sub watershed. The "gridcode" value of each polygon will equal the "LINKNO" of its corresponding reach in the StreamReach feature class.
Slope + inHUC	Continuous Raster	Slope raster derived from LIDAR DEM (in percent rise).
SlopeTable + inHUC	Table	Table that contains slope information on a field by field basis. Can be linked to the field boundary feature class through the FBndID.
DrainageTable + inHUC	Table	Table that, based on a user selected query of by-field slope and soils information, classifies agricultural fields (including pasture) as tile-drained or non tile-drained. Can be linked to the field boundary feature class through the FBndID.
DistToStrm + inHUC	Continuous Raster	The distance to stream raster calculates the horizontal distance (in meters) to the channel for each grid cell, moving downslope according to the D8 flow model, until a stream grid cell is encountered.
RunoffRisk + inHUC	Table	Table that contains runoff risk information on a field by field basis. Can be linked to the field boundary feature class through the FBndID. The ***runoff risk table contains information on agricultural fields only (including pasture)***, as identified by the 6-year generalized land use classification. As a result, the # of rows in the attribute table of the runoff risk table will usually be less than that of the input field boundary feature class.
Depressions + inHUC	Polygon	Polygon layer created as an output of the Depression Identification tool. Will contain a unique "Depress_ID".
Depress_Wsheds + inHUC	Polygon	Polygon layer created as an output of the Depression Watersheds tool. Will contain a unique "Depress_ID".

DrainageMgmt + inHUC	Polgyon	Polygon layer created as an output of the Drainage Water Management tool. Polygons will represent discrete areas (larger than a user-specified % of field) where all elevation values are within a user-specified contour interval that can be chosen between .3 and 1.5 meters (default is 1.0 m).
GrassWaterway + inHUC	Polyline	Polyline layer created as an output of the Grassed Waterway tool.
CBS + inHUC	Polygon	Polygon layer created as an output of the Contour Buffer Strip tool.
NRW + inHUC	Polygon	Output Nutrient Removal Wetland feature class (polygon). Each suitable site will contain 2 rows in the output attribute table - one for each wetland polygon (pooled area - permanent storage) and one for the buffer polygon (vegetated area - variable storage) polygon. Attributes will be the same for each of the 2 rows. Each polygon will have a unique “SiteID”.
NRWDrainageAreas + inHUC	Polygon	Output Nutrient Removal Wetland Drainage Area feature class (polygon). Each polygon will have a unique "SiteID".
WASCOBs + inHUC	Polyline	Output WASCOB polyline feature class. Each polyline will represent a transect line of 100 m length, and will contain site-specific information as attributes.
WASCOBbasin + inHUC	Polygon	Polygon layer representing the basin, or area which would pond water upstream of each WASCOB, for all input WASCOBS.
AdjFlowDir + inHUC	Thematic Raster	D8 flow direction raster. Flow directions have been modified to force flow from adjacent bank cells directly into channel.
WaterTableDepth + inHUC	Thematic Raster	Thematic raster representing a classification of an estimated depth to water table, used to identify riparian zone management opportunities.
RAP + inHUC	Polygon	Feature class containing riparian assessment polygons (RAPs). RAPs are generated along the stream network and are split by stream side. Each RAP is 250 meters long and 180 meters wide (90 meters on each side of stream). The feature class contains site-specific information for each riparian assessment polygon (RAP).

1. Stream Network Development

1.a D8 Terrain Processing

Required Input Layers	Output Layers
Unfilled DEM (DEM + inHUC)	D8 Flow Direction raster (D8FlowDir + inHUC)
	Filled DEM raster (DEMFill + inHUC)
	D8 Flow Accumulation raster (D8FlowAcc + inHUC)
	Hillshade raster (Hshd + inHUC)

The first set of tools in the ACPF toolbox, titled "Stream Network Development", are designed to prepare the digital elevation model (DEM) to accurately represent hydrologic flow routing. Accurate flow routing enables greater confidence in application of the ACPF conservation-practice siting tools. The DEM should extend about 1,000 meters beyond the watershed boundary. This buffered extent ensures that the elevation data can be used to delineate a new watershed boundary, which is necessary because discrepancies will exist between a LIDAR-derived watershed boundary and the boundary provided by the USGS National Hydrography Dataset. In addition, this wider extent ensures coverage of fields that only partly lie within the watershed.

The D8 terrain processing tool acts on the input DEM to generate four terrain processing derivatives. The tool first performs a fill operation. The fill process involves raising the elevation values within all depressions to that of the pour point of the depression, so that water will pour out of the depression and a continuous flow network across the watershed can be achieved. The fill process does not distinguish between types of depressions, resulting in all sinks in the DEM, including real depressions, to be filled. Prior to using this tool, the user may wish to condition the DEM using the DEM: Pit fill / Hole Punch tool found in the Utility section of the Toolbox.

The nest step in the D8 terrain processing tool applies the ArcGIS D8 flow routing algorithm (Esri, 2011), which assumes that overland flow from each grid cell is directed to a single neighboring cell that is determined by the steepest downward slope gradient, to the filled DEM to generate a flow direction raster. This flow direction raster is then used to generate a flow accumulation raster, in which the value at each grid cell represents the number of upstream grid cells draining to that point. A hillshade raster is also generated using the unfilled DEM for visualization purposes.

1.b Flow Network Definition (Area Threshold OR Peuker Douglas)

Area Threshold Flow Network

Required Inputs	**Outputs**
D8 Flow Accumulation raster (D8FlowAcc + inHUC)	Flow Network (AreaFlowNet + inHUC) (polyline)
D8 Flow Direction raster (D8FlowDir + inHUC)	
Area threshold (acres)	
Watershed boundary (bnd + inHUC) (optional)	

The Flow Network Definition – Area Threshold tool applies an area threshold (area of upstream drainage, in acres) to a flow accumulation grid to create an output flow network polyline. The area-threshold method is recommended for watersheds formed in more recent (Wisconsinan age) glacial landscapes, where classic stream formation and geomorphic land dissection processes have had little influence in the development of the landscape. Another way to think of this is that watersheds with dense networks of drainage ditches may be better suited to the area-threshold approach to begin the process of identifying streams. **NOTE:** Use of National Hydrography Datasets (e.g., NHD+) to forcibly assign stream locations is strongly discouraged. There are several reasons for this; in particular, the age (circa 1950s) and coarser scales from which those datasets originate will negatively impact the accuracy of flow routing, which will consequently impact results of the ACPF, particularly the riparian assessment (Section 6).

The flow accumulation grid is assigned a "NODATA" value for those grid cells that are below the threshold, and a "1" value for those grid cells above the threshold. The reclassified grid is then used, along with the D8 flow direction grid, in ESRI's "Stream to Feature" tool to generate the output flow network polyline. The stream order (Strahler, 1969) is also calculated and assigned to each segment of the output flow network. ***Attributes of this polyline coverage must be edited by the user (as described in forthcoming section) to enable the remaining ACPF tools to operate on perennial streams.*** It is better to err towards too small an area accumulation threshold than too large a one, to avoid errors of omission when identifying the perennial channel network (Section 1.e).

Important: The output flow network will often extend upstream beyond perennial and into ephemeral and intermittent drainageways. This distinction will impact the conservation planning results, including the possible distribution of several practices and the locations of riparian features in particular. Therefore, the "StreamType" field of the output flow network polyline ***MUST be manually populated*** by the user (see Section 1.e). This classification must be integer values and can be simple (1 to indicate perennial streams, 0 to indicate ephemeral or intermittent drainageways), or complex (e.g., 0 - ephemeral or intermittent, 1 - perennial, 2 - floodplain or braided, 3 - wide river centerline). Stream reach and catchments (Section 1.e) can be generated for only those stream segments with a "StreamType" value >= 1.

Peuker-Douglas Flow Network

Required Inputs	**Outputs**
Filled DEM (DEMFill + inHUC)	Peuker Douglas Flow Network (PDFlowNet + inHUC)
D8 Flow Direction raster (D8FlowDir + inHUC)	Pour Points (optional; not created if pour point(s) are provided by user)
Watershed boundary (bnd + inHUC)	Drop Analysis Text File (optional; contains information used to determine drop analysis threshold)
Pour Points (optional)	

The Peuker Douglas channel network tool combines the functionality of the "Peuker Douglas", "D8 Contributing Area" and "Stream Drop Analysis" tools available in TauDEM software to generate a flow network polyline for the watershed. This method is founded in classical geomorphology and historical studies that evaluated relationships between watershed size and channel slopes and lengths (found between confluences) in different regions.

Description taken from TauDEM (Tarboton, 2004):

> "With this method, the DEM is first smoothed by a kernel with weights at the center, sides, and diagonals. The Peuker and Douglas (1975) method (also explained in Band, 1986), is then used to identify upwardly curving grid cells. This technique flags the entire grid, then examines in a single pass each quadrant of 4 grid cells, and unflags the highest. The remaining flagged cells are deemed 'upwardly curved', and when viewed, resemble a channel network. This proto-channel network sometimes lacks connectivity, and/or requires thinning, issues that were discussed in detail by Band (1986). The thinning and connecting of these grid cells is achieved here by computing the D8 contributing area using only these upwardly curving cells. An accumulation threshold on the number of these cells is then determined via drop analysis."

Drop Analysis

A stream's drop is the difference in elevation from the beginning to the end of a stream segment, which is identified as the sequence of linked channel cells with the same stream order. Drop Analysis automatically determines a flow accumulation threshold value by searching for possible threshold values within a search range (between 500 and 100,000 grid cells) that meet the constant drop property. The approach divides the search range into 50 possible threshold values (using logarithmic spacing), and attempts to select the right threshold automatically by evaluating a stream network for a range of thresholds and examining the constant drop property of the resulting Strahler streams. Basically it asks the question: Is the mean stream drop for first order streams statistically different from the mean stream drop for higher order streams, using a T-Test. Stream drop is the difference in elevation from the beginning to the end of a stream defined as the sequence of links of the same stream order. If the T test shows a significant difference, then the stream network does not obey this "law" so a larger threshold needs to be chosen. The smallest threshold for which the T test does not show a significant difference (i.e. T-statistics is less than 2) gives the highest resolution stream network that obeys the constant stream drop "law" from geomorphology (Broscoe, 1959), and is the threshold chosen for the "objective" or automatic mapping of streams from the DEM. In practice, results of the drop analysis (or the area threshold) only provide estimates of where stream initiation points and channel locations occur throughout the watershed. These locations must be confirmed (or edited) to ensure that the stream network represents the actual distribution of perennial channels to the extent possible (see “Repair Flow Paths” and “Populating StreamType Field” Sections).

The user has the option to save the drop analysis table. The file contains one line of data for each threshold value examined in the stream drop analysis. The optimum threshold value can be found by examining the thresholds evaluated (in ascending order), and identifying the first threshold in which the t-value is less than +/- 2. The optimum threshold value is also printed as a message in the geoprocessing results window while running the tool.

Pour Points

The drop analysis procedure requires that watershed pour point(s) are provided. The user has the option to either 1) Provide their own set of pour point(s), or 2) Allow pour point(s) to be automatically generated. The automated process selects the highest flow accumulation grid cells (> 4 standard deviations from the mean flow accumulation value) that fall along the border of the USGS-derived watershed boundary. These locations are then converted to points and used as input to the tool. The user can optionally save the automatically generated pour point(s) by specifying an output file name and location. It is ***strongly suggested*** that the automatically generated pour point file be saved, then manually reviewed and edited by the user to ensure the appropriate location of the pour point(s). The tool may then be rerun, with the manually edited pour point(s) provided as an input.

The flow accumulation grid is assigned a "NODATA" value for those grid cells that are below the threshold (as determined via drop analysis), and a "1" value for those grid cells above the threshold. The reclassified grid is then used, along with the D8 flow direction grid, in ESRI's "Stream to Feature" tool to generate the output flow network polyline. The Strahler stream order is also calculated and assigned to each segment of the output flow network. ***Attributes of this polyline coverage must be edited by the user (as described in forthcoming section) to enable the remaining ACPF tools to operate on perennial streams.***

1.c Identify Impeded Flow (Depression Depth)

Required Inputs	**Outputs**
Unfilled DEM	Depth Raster (DepthGrid + inHUC)

When using an unfilled DEM, depressions present in the landscape will prevent continuous flow throughout the watershed. As a result, flowpaths that enter a depression will simply stop, as there are no surrounding lower elevations for that flow to travel towards. This is desirable for some analyses, where depressions are a natural feature of the landscape. However, false impoundments will also occur, particularly on the upslope sides of bridges, and roadways where road-side ditches drain through culverts. These false impoundments must be corrected, and the following sections describe both cutter and dam-builder DEM editing tools to help correct for false impoundments. However, the number and locations of such corrections that are necessary to prepare the DEM for a given watershed is a judgment call. This current tool (Depression Depth) is included to help users identify false impoundments and locate the end points of each cut line more accurately. When approaching this DEM editing process, bear in mind that too many or poorly placed edits will have unwelcome consequences for your analysis, as will too few edits

The tool identifies where surface depressions exist in the input DEM. This tool differs from the depression identification tool (see Section 3.a) in that it is designed to aid the user in identifying where to place "cut lines" as part of the hydro-conditioning process.

The tool acts by first filling the input DEM. Elevation differences are then found between the unfilled and filled DEM. The output depth grid is a continuous raster, in which each grid cell represents the elevation difference at that location, in the same z-units as the DEM. These elevation differences represent depressions, or sinks, in the landscape. While these sinks may represent real depressions, oftentimes false depressions are created behind road crossings or other obstructions to flow.

When used as a visual aid for the hydro-conditioning process, which is often an iterative process, the output DEM from the next tool (Section 1.d) will be used as the input DEM to this tool. Used in this way, the user can determine where depressions still exist after running the manual cutter/dam builder tool.

1.d Manual Cutter / Dam Builder (Repair Flow Paths)

Required Inputs	**Outputs**
Cut Lines (manually created by user) (optional)	New unfilled DEM to reflect cut and/or dam lines (NewDEM + inHUC)
Dam Lines (manually created by user) (optional)	Filled DEM raster (DEMFill + inHUC) (generated from NewDEM)
Unfilled DEM	Flow Direction raster (D8FlowDir + inHUC) (generated from NewDEM)
	Flow Accumulation raster (D8FlowAcc + inHUC) (generated from NewDEM)
	Hillshade raster (Hshd + inHUC) (generated from NewDEM)

Following the creation of a flow network (either Peuker Douglas or Area Threshold), it is ***absolutely necessary*** that the user take the time to analyze the flow network polyline to identify errors, which often occur from the initial automated flow routing. These errors may include locations where the flow line becomes obstructed and “jumps out” of the channel, or is not routed under roads in locations of culverts.

The user has the option to run the “Repair Flow Paths - Manual Cutter/Dam Builder” tool, which involves a revision of the input DEM by altering elevation values along user-provided polyline features. Input line layers may include cut lines, dam lines, or both (separate feature class required for each), and may include multiple lines to be processed at once.

Cut lines may be desirable when an obstruction to flow is present in the DEM that should be "burned through", such as a culvert which routes flow beneath a road. When the culvert is not represented in the DEM, the flow routing process will encounter an obstruction (in this case a road) forcing the flow to “back up” rather than pass through it. Grid cells in the DEM that are located along each cut line will be replaced with the ***minimum*** elevation value found along the cut line.

Dam lines may be desirable when an obstruction to flow is desired yet absent in the DEM. An example may include low relief landscapes in which the direction of flow is not apparent, causing the watershed boundary to be ambiguous. By providing a dam line along the border of the watershed, flow direction can be guided towards the downstream drainage network. Grid cells in the DEM that are located along each dam line will be replaced with the ***maximum*** elevation value found along the dam line.

When the tool is run, a new DEM (containing altered elevation values along lines) will be created. The Terrain Analysis tool will automatically be rerun using the new DEM as the input, to ensure that all terrain derivatives (Filled DEM, Flow Direction, Flow Accumulation, and Hillshade), are created using the most current DEM surface raster. The user MUST recreate a flow network, using either the Area Threshold or Peuker Douglas method, using the new terrain derivatives as inputs. By performing these ‘corrective’ steps early in the process, the user will ultimately save time compared with finding errors in the flow network later when applying subsequent practice siting tools. If no errors in the flow network are found ***(a result one should not expect)***, the user can move on to the next step.

The user will be required to create a feature class containing the lines to be added. If both cuts and dams are to be used, a separate feature class must be created for cut lines and dam lines. Feature class file(s) can be stored in any location, as the user will be prompted to select the input line file(s) when running the tool. It is often easiest to store the file in the same fgdb that you are currently working with.

To create a feature class containing the cut or dam lines to be added:

1. Navigate (using ArcCatalog or ArcMap) to the location where the feature class will be located. Right click in the file location and select new ---> feature class. Any name can be given to the feature class, but you will want to ensure that it is unique. “CutLines” + inHUC or “DamLines” + inHUC is a good choice. ***Make sure to specify that it is a line feature type.*** Hit next and provide the correct projection (the ACPF database uses NAD83 UTM). Continue to hit next through the next several pages, accepting the default settings. Hit finish.

2. Add the newly created feature class to an ArcMap document and begin an editing session. Editor toolbar --->Start Editing. Select the newly created feature class as the layer to edit.

3. Using auxiliary data (aerial photography, hillshade, etc.) zoom into locations where incorrect flow pathways exist. ***Often, the hillshade, aerial photography, and LIDAR DEM are all required to determine where errors occur and where flow should be routed.*** To add a line, select the “CreateNewFeature” tool from the editor toolbar, and draw a line either through the obstruction to flow (cut line), or where you want to add an obstruction (dam line).

TIP: On-screen display techniques, such as contrast stretching, can improve one’s ability to locate where lines should be placed when viewing the LIDAR DEM. To adjust histogram stretching, right-click the DEM and select Properties ---> Symbology. Under Type – select either Standard Deviations (set n to either 1 or 2) or Histogram Equalization. Scroll down. From Statistics, select “From Current Display Extent”. These setting will help to visualize what is happening with discrete pixel elevation values as one zooms in or pans to different locations.

4. Once all desired lines have been created, save edits and stop editing. Editor toolbar > Save Edits. Editor toolbar --> Stop Editing.

NOTE: A conservative approach should be taken when drawing cut or dam lines, as it is preferred to modify the original DEM as little as possible. Obstructions to flow may not always exist at the exact location that the stream diverts from the correct flow path. An example is a stream road crossing that has not been cut to represent the existence of a culvert. This obstruction will create a ponded area above the road, causing the flow to be diverted at the upstream end of the ponded area. To correct this, a small cut line should be drawn across the road where the culvert exists, and not through the entirety of the ponded area.   In other cases, the location of the obstruction will not always be obvious. In such cases, drawing a line from the point where the stream diverts to a point where the flow pathway should follow is suggested. Examples of where to draw cut lines are shown in Figure 3.

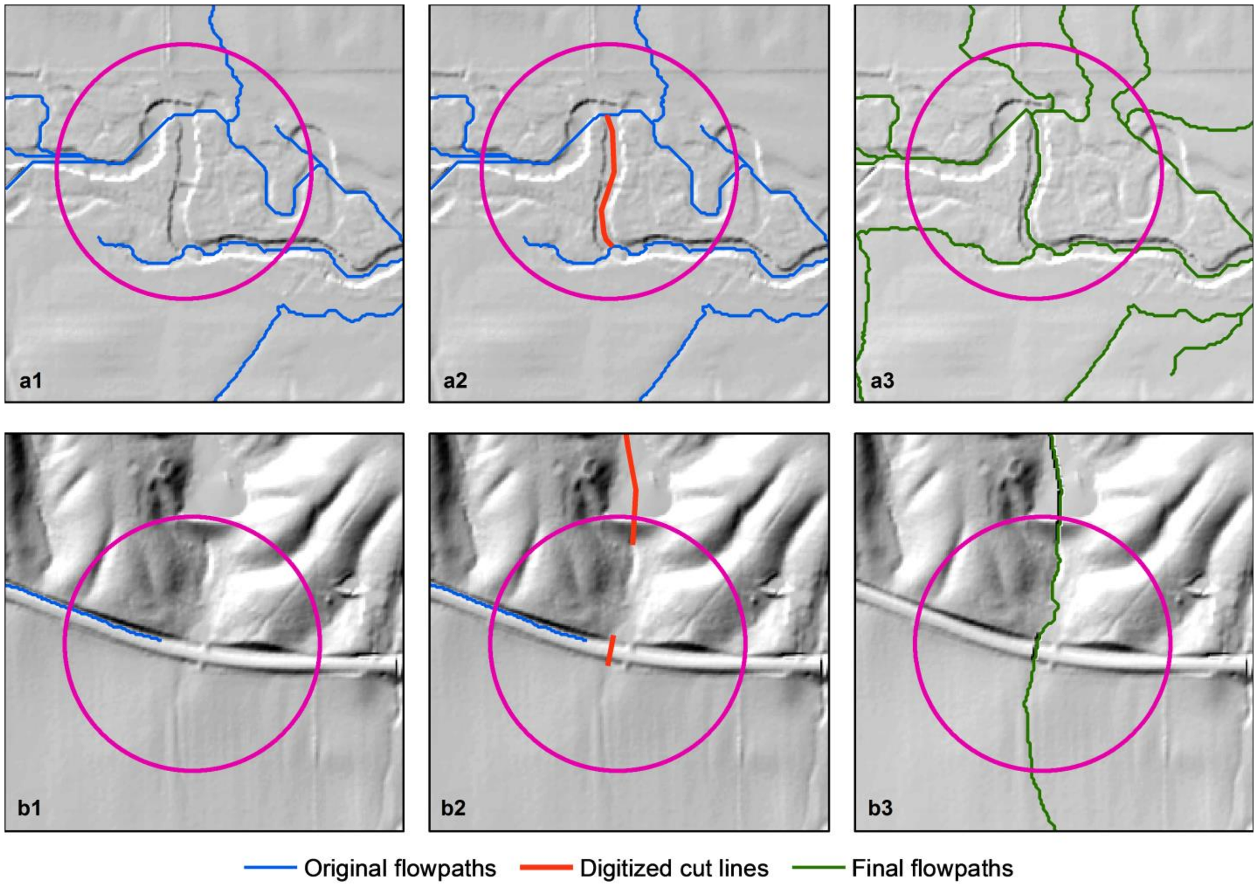


Figure 3. Manually digitized cut lines and their impact on derived flow pathways

NOTE: This is an iterative process. One round of cut and/or dam lines may not solve all issues, and often a second and even third round of edits are needed. During this process, it is suggested that ongoing edits be made to the line feature class that was created, such as adding additional cut lines or removing those that did not achieve the desired result. ***Each time the manual cutter/dam builder tool is run, the original DEM (not the output NewDEM from a previous run) should be used as the input raster.***

NOTE: ***Once a new DEM has been created, the Flow Network Definition tool (Area threshold or Peuker Douglas) should be rerun to identify if errors have been corrected.*** Once satisfied, ***the most recently created new DEM should be used as the input DEM in all remaining tools***. This new DEM will be unfilled, meaning that sinks will still exist. As D8 terrain processing is automatically rerun when the Manual Cutter/Dam Builder tool is run, all terrain processing derivatives (filled DEM, flow direction, flow accumulation, and hillshade) will be derived from this most recent DEM.

NOTE: It is useful to run the Identify Impeded Flow (Depression Depth) tool prior to the Manual Cutter/Dam Builder, to aid in the identification of suitable cut sites (see 1.c) For example, when a culvert is present that is not "cut" through, a depression will be present just upstream of the culvert/road intersection. Once the culvert has been "cut", flow is allowed to pass through the road rather than back up behind it, and the depression will no longer be present.

1.e Stream Reach and Catchments
Populating the "StreamType" field.

Required Inputs	Outputs
Flow Network (AreaFlowNet + inHUC) or (PDFlowNet + inHUC)	No separate coverage - Reclassification of stream polylines

Following the creation of a flow network and correction of errors in the DEM (sections 1.b – 1.d), the user ***is expected to*** populate the "StreamType" field in the attribute table of the flow network file. The goal of this step is to identify perennial stream segments with continuous (i.e. year round) flow along the stream bed (years of drought excepted).

While the flow network will delineate concentrated flow pathways in the watershed, these pathways will typically extend above perennial streams to include intermittent and ephemeral drainageways. For purposes of conservation planning, this distinction between flow network elements and relative constancy of flow is an important one. While riparian management opportunities occur along perennial streams, attributes of concentrated flow paths above streams are also important for conservation planning and erosion modeling along ephemeral drainageways. The approach used here preserves the capacity to use the ACPF input data for both types of applications. But here, we focus on mapping riparian areas and management opportunities along perennial streams, which are important because:

> "Riparian areas are transition zones between terrestrial and aquatic ecosystems that are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands, and include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems." (National Research Council, 2002).

While ephemeral drainageways may interact with a riparian area during high flows, these locations present different management opportunities than those that exhibit perennial flow with riparian attributes throughout most years. The "StreamType" field allows for classification of flow network segments into distinct conservation management areas, and at a minimum should designate flow segments considered to have a permanent riparian area appropriate for conservation management. In addition, runoff risk assessment of agricultural fields (see Runoff Risk Assessment Tool – Field Characterization), is based on proximity to perennial streams, rather than ephemeral channels. The accuracy of your delineations of perennial channels will influence how your results will be viewed by local stakeholders, so this is a critical step in developing your input data.

The process requires that the user view the flow network, a vector polyline layer, on-screen and interactively select those segments that fit the above description of a perennial stream segment. Using the field calculator in ArcMap, the segments selected should be calculated to a unique "StreamType" value (suggested value of "1" for perennial streams). It is useful during this process to utilize the hillshade ***AND*** aerial photography to determine where a channel and/or water are present. Additionally, the stream order of each flow network segment is included in the "StrahlOrd" field of the attribute table, and may help speed the process. CIR photography flown in the spring is particularly useful, as most streams will have water in them during this time. It is also easier to see streams when the leaves are off hardwood trees. By default, all flow network segments are originally given a “StreamType” value of 0.

While the user may come up with their own classification scheme, ***“StreamType” field values must be integers***. The classification scheme can be simple (1 to indicate perennial streams, 0 to indicate ephemeral or intermittent drainageways), or complex (0 – ephemeral or intermittent, 1 - perennial, 2 – floodplain or braided, 3 – wide river centerline). Many of the remaining ACPF tools generate more accurate results if they act upon a subset of “StreamType” classification values. For example, the stream network and catchments should be generated for only those flow network segments with a "StreamType" value >= 1, indicating perennial streams."

To calculate segments to a “StreamType” value of 1 (Figure 4):

1. Interactively select segment(s) where the “StreamType” field should be = 1. (To select multiple segments at once, hold the shift key down while selecting elements. It is helpful to make the flow network the “Only Selectable Layer” by right-clicking on the flow network feature class in the TOC and choosing the Selection tab.

TIP: If only part of a segment should be categorized as “StreamType” = 1, the segment may be split, which involves entering an editing session. Editor toolbar --->Start Editing ---> select the flow network as the layer to edit. Select the segment that should be split (only one segment can be selected at a time), and using the split symbol, split the line. The editing session must be ended before moving on to the next tool (Figure 5).

2. Once the segment(s) is selected, open the attribute table and right click on the “StreamType” field, then select “Field Calculator”.
3. Enter the value 1 in the box (figure 4), and hit OK. The segments selected should now have a “StreamType” = 1.
4. If a mistake is made during the field calculator process, simply select the segment where the mistake was made and calculate the “StreamType” field to the correct value.

NOTE: Segments classified to a “StreamType” value of 1 should (although not required) constitute a continuous, perennial flow network. Care should be taken that small segments between stream confluences are not overlooked. There may be rare instances, however, in which a disconnected perennial stream network may be more representative of the surface hydrology, such as in the case of disappearing streams (seen more often in karst landscapes), or in landscapes with broad floodplains, reduced stream velocities, and braided stream systems, where surface flow is not constrained to within a discrete channel. It is ultimately a judgment call by the user to determine which stream segments constitute a perennial flow network. Firsthand knowledge of the watershed will often be helpful to make the judgments involved with defining the stream network.

NOTE: Only perennial flow segments (“StreamType” = 1) should be used to generate the stream reach and catchments in the next step of the toolbox. The resulting stream reach will constitute the stream network in all future tools, including riparian analysis (riparian analysis will only be processed along the stream reach, which should represent perennial flow) and runoff risk assessment (distance to stream will be calculated as the distance from the edge of each field to the nearest perennial flow segment). Therefore, population of the “StreamType” field is a critical step in the conservation planning toolbox.

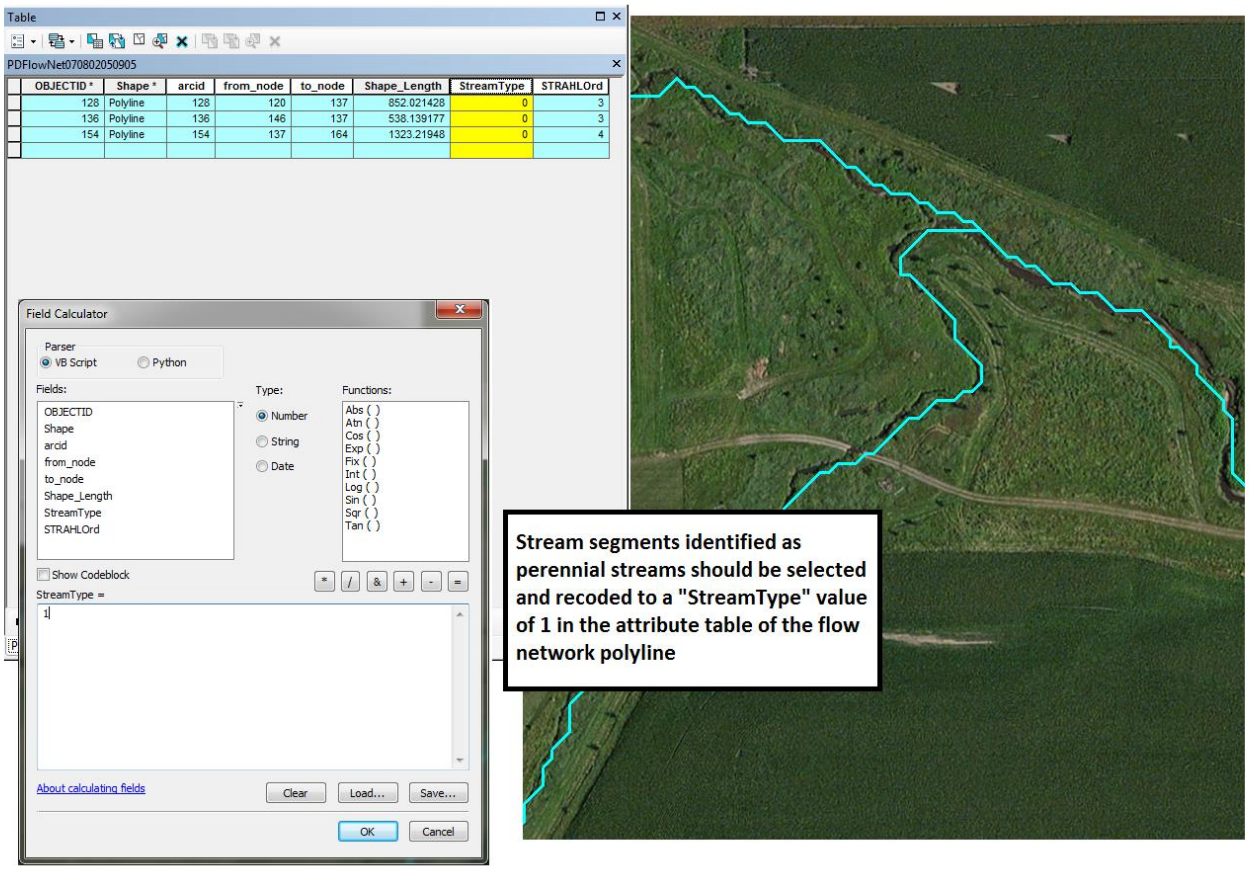


Figure 4. Field Calculation of “StreamType” field of the flow network

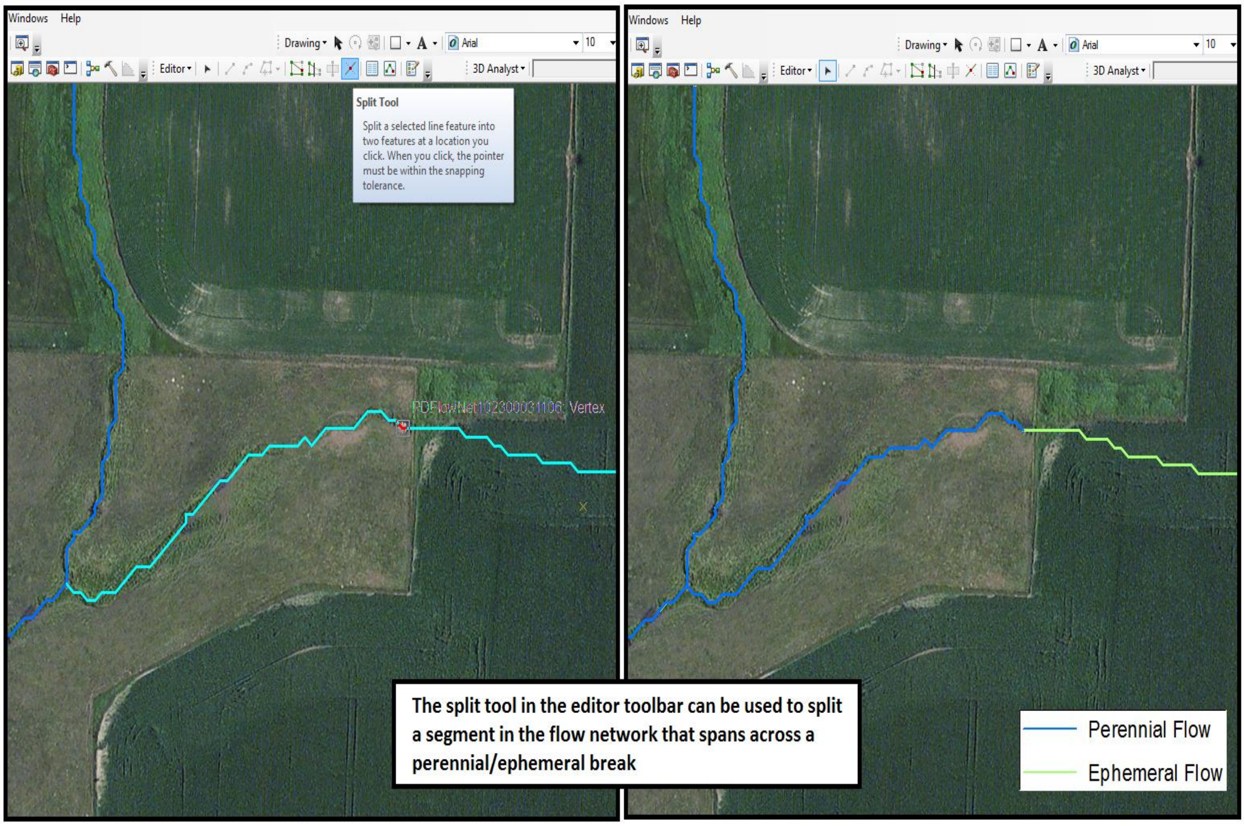


Figure 5. Splitting a stream segment using the editor toolbar

Generate Stream Reach Outputs

Required Inputs	Outputs
Flow Network (AreaFlowNet + inHUC) or (PDFlowNet + inHUC)	Stream Reach polyline layer (StreamReach + inHUC)
D8 Flow Direction raster (D8FlowDir + inHUC)	Catchments polygon layer (Catchments + inHUC)
Filled DEM raster (DEMFill + inHUC)	New Watershed Boundary polygon layer (optional)
Pour Points (optional)	

Once the “StreamType” field in the flow network file has been populated, a stream network (in the form of a stream reach polyline feature class) and a catchments file (in the form of a polygon feature class) are created. ***It is strongly advised to limit catchment and stream reach delineation to perennial flow segments, or those identified as having a “StreamType” value equal to 1*** (See step 1.e – Populating the “StreamType” field).

Both the stream reach and catchments layer are generated using the TauDEM software program. The stream reach will contains numerous fields in the attribute table (Table 3), several of which are required for use in later tools in the ACPF toolbox.

NOTE: The stream reach layer will represent the stream network in all future tools, including Runoff Risk Assessment, Riparian Function Assessment, and others.

NOTE: If the “Create New Watershed Boundary” checkbox is selected, a new watershed boundary (polygon feature class) will be generated and output to the location provided. This will move existing watershed boundaries to provide a new boundary based on the finer resolution of current DEM data sources. Note the original HUC boundaries were mapped at least several decades ago, through manual interpretation of relatively coarser resolution data and imagery. This can obviously improve accuracy but a new watershed boundary may have jurisdictional implications for your watershed project. It will often be helpful to identify and clarify differences in watershed boundaries that occur according to new data sources. Watershed boundaries often cross near level areas and even fine resolution LiDAR-based DEMs data can present challenges for discerning boundaries with consistent accuracy. Local knowledge can help identify actual flow directions in some situations.

NOTE: A new watershed boundary is created by dissolving all catchments for a HUC12 watershed into a single polygon. In a non-headwaters watershed, catchments will be generated upstream of the upstream pour point, and therefore should not be contained in the current HUC12 watershed. To account for this, ***the “Create New Watershed Boundary” checkbox will dissolve only those catchments that are centered in the current USGS HUC12 boundary.*** In instances where a catchment is inaccurately omitted from the new boundary due to not being centered in the old watershed boundary, the user can manually create a new boundary by dissolving the desired catchments into a single polygon.

Table 3. Stream Reach polyline attributes	
Attributes	**Description**
LINKNO	Link Number. A unique number associated with each link (segment of channel between junctions). This is an arbitrary number that varies depending on the number of processes used.
DSLINKNO	Link Number of the downstream link. -1 indicates that this does not exist.
USLINKNO1	Link Number of first upstream link. -1 indicates no links upstream.
USLINKNO2	Link Number of second upstream link. -1 indicates no links upstream.
DSNODEID	Node identifier for node at downstream end of stream reach.
Order	Strahler Stream Order
Length	Length of the link
Magnitude	Shreve Magnitude of the link. This is the total number upstream stream junctions.
DS_Cont_Ar	Drainage area at the downstream end of the link. Generally this is one grid cell upstream of the downstream end because the drainage area at the downstream end grid cell includes the area of the stream being joined.
Drop	Drop in elevation from the start to the end of the link
Slope	Average slope of the link (computed as drop/length)
Straight_L	Straight line distance from the start to the end of the link
US_Cont_Ar	Drainage area at the upstream end of the link
WSNO	Watershed number. Will be equal to both “LINKNO”and the “GRIDCODE” field of the output catchments feature class
DOUT_END	Distance, along flow paths, to the outlet from the downstream end of the link
DOUT_START	Distance, along flow paths, to the outlet from the upstream end of the link
DOUT_MID	Distance, along flow paths, to the outlet from the midpoint of the link

2. Field Characterization

2.a By-Field Slope Statistics

Required Inputs	Outputs
Input DEM (filled or unfilled)	Slope Raster (Slope + inHUC)
Field Boundary feature class (FB + inHUC)	By-Field Slope Table (SlopeTable + inHUC)

The by-field slope statistics tool generates 2 outputs: 1) a slope raster (in percent rise), and 2) a slope table, containing slope related statistics on a field-by-field basis. The slope raster is created using the input DEM and the Slope tool in ArcGIS.

The slope table can be linked to the field boundary feature class through a unique "FBndID" field, and contains the following information for each field as attributes:

Table 4. By-Field Slope Table attributes	
Attributes	**Description**
FBndID	Field boundary ID: join field
MeanSlope	Mean slope (% rise) of each field
Slope75Pct	3^{rd} quartile (75^{th} percentile) slope value (% rise) of each field
Pct_lt1:	percentage of field less than 1% slope
Pct1_2:	percentage of field 1 – 2% slope
Pct2_5:	percentage of field 2 – 5% slope
Pct5_10:	percentage of field 5 – 10% slope
Pct10_15:	percentage of field 10 – 15% slope
Pct_gt15:	percentage of field > 15% slope

Slope statistics contained in this table will provide information to identify the extent of tile drained fields in the watershed, the relative risk of runoff among fields, and identify fields suitable for runoff control practices such as grassed waterways and contour buffer strips.

2.b Tile Drainage Classification

Required Inputs	Outputs
Field Boundary feature class (FB + inHUC)	Drainage Table (DrainageTable + inHUC)
Slope Table (slopetable + inHUC)	
Soils Raster (gSSURGO)	
Land Use Table (LU6 + inHUC)	

The Tile Drainage Determination tool estimates which fields are likely to be tile drained based on a combination of by-field slope and soils information. The output of the tool is a drainage table (drainagetable + inHUC), containing by-field slope and soils information and a drainage classification (YES, NO, or NonAg). Pastureland is included as agricultural land in the classification. "Null" values in the drainage classification often indicate a field that drains entirely out of the watershed.

To run the tool, the user must choose "one" of 2 optional queries to define the tile-drainage determination:

Query 1:
>= 90% of field is less than 5% slope *OR at least* 10% hydric soils. The percentage of hydric soil in a field is estimated as the area-weighted mean (% hydric) of all soil map units in the field. As of the 2014 version of the NCSS database, soil survey information estimates the typical extent (percent of area) of hydric soils (defined below) that would be expected within soil map unit polygons. A weighted average for the proportion of soil map units found in each field is calculated to run this query.

Query 2:
>= 90% of field is less than 5% slope *OR* >= 40% of field consists of a dual drainage hydrologic group (A/D, B/D, or C/D) or D class soil.

NOTE: The slope criterion remains constant in both queries. The soils criterion is based on the % of the field consisting of either 1) hydric soils or 2) a dual drainage or 'D' hydrologic group. These soil attributes can be further defined as:

Hydric Soils
The National Technical Committee for Hydric Soils (NTCHS) defines a hydric soil as a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (Federal Register, 1994).

Hydrologic Group (Dual Drainage Classes)
Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high

water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

Dual drainage class soils are certain wet soils that are placed in hydrologic group D (i.e. water movement through the soil is restricted or very restricted) based solely on the presence of a water table within 60 centimeters of the surface, even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils have been adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition. (NRCS, 2009).

It is ***strongly suggested*** that the user become familiarized with the NRCS gSSURGO data layer prior to selecting a query from which to delineate tile-drained from non tile-drained fields. As soil surveys are traditionally based on county boundaries, oftentimes SSURGO data is characterized by discrete county breaks, where attributes differ on each side of a county line. While appearance of political boundaries in soil surveys are being reduced through annual revisions to soil survey databases, and these updates are being included in the ACPF soils database, county boundaries still can appear in the soil data in some instances. To avoid using the less consistent soils input data in this and other queries using soils data, it is useful to view the different soil attributes prior to running the Tile Drainage Determination tool (Figure 6). To view the different gSSURGO attributes:

1. Add the gSSURGO layer for the current HUC12 watershed to an ArcMap document. In the attribute table of the gSSURGO raster, the two fields, “HYDROGRP” and “HYDRIC”, contain information on the mean hydric percent and hydrologic group designation for each mapunit.

2. Right click on the gSSURGO layer ---> Properties.

3. Under Symbology ---> Unique Values, select either the “HYDROGRP” or the “HYDRIC” field, then ---> Add All Values.

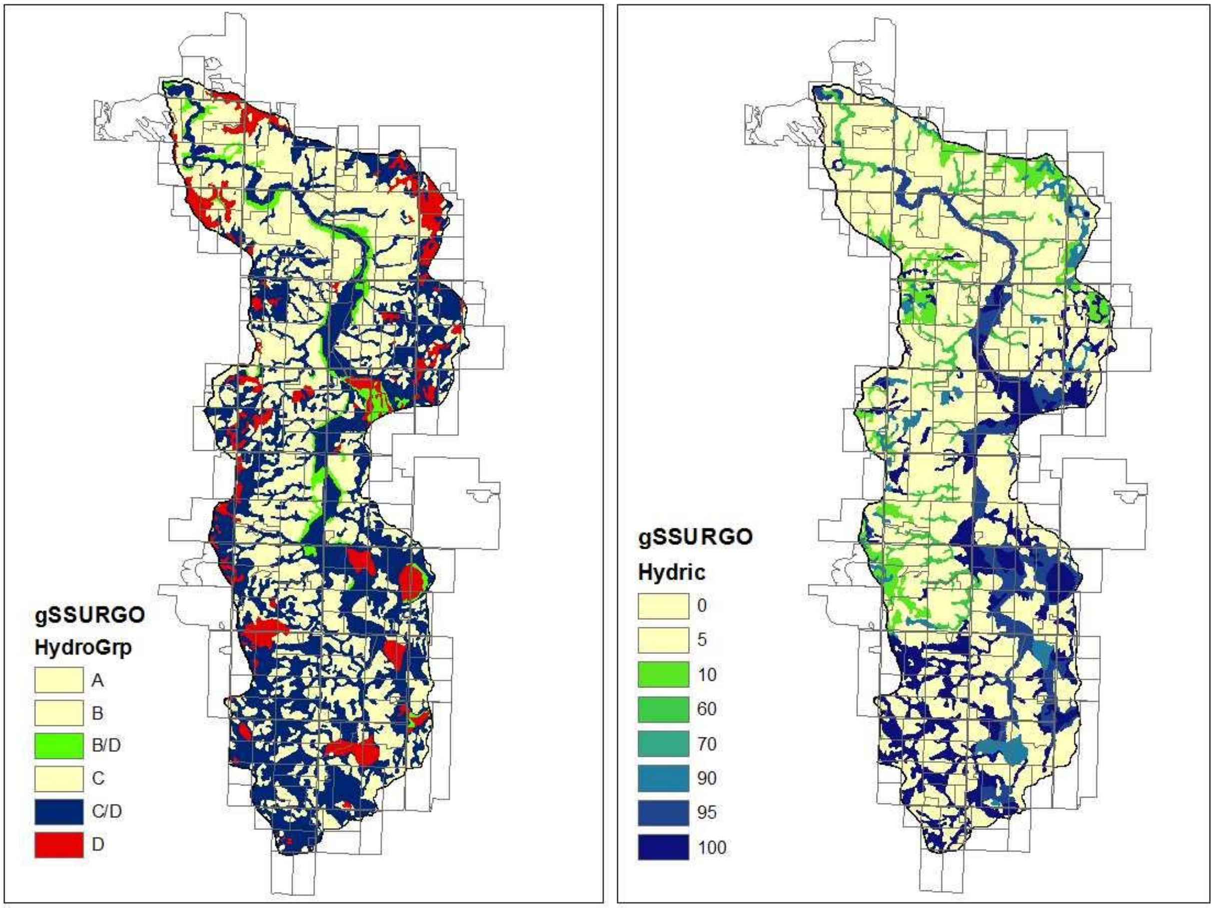


Figure 6. gSSURGO soil attributes included in Tile Drainage Determination tool

NOTE: The user may manually alter the drainage classification of a given field (i.e. altering a "NO" classification to a "YES" in the output drainage table) if additional local knowledge on drainage patterns exist, or if the user would like to alter the criteria used to determine the existence of tile drainage.

The drainage table can be linked to the field boundary feature class through the "FBndID" field, and contains the following information for each field as attributes:

Table 5. By-Field Drainage Table attributes	
Attributes	**Description**
FBndID	Field boundary ID: join field
PctHyd:	Mean % hydric soil – area-weighted mean % hydric of all soil mapunits in field
PctDualDrg:	percentage of field that is a "dual drainage– (A/D, B/D, or C/D) or D class soil
PctSlp_lt5:	percentage of field that is less than 5% slope
Drained:	Drainage classification: YES (tile-drained), NO (non tile-drained) or NonAg

2.c Distance To Stream (D8)

Required Inputs	**Outputs**
Stream Reach (StreamReach + inHUC)	Distance To Stream raster (DistanceToStream + inHUC)
D8 Flow Direction raster (D8FlowDir + inHUC)	

The “Distance to Stream (D8)” tool uses an input Stream Reach (polyline) and a D8 Flow Direction grid to calculate the horizontal distance (in meters) to the channel from each grid cell, moving downslope according to the D8 flow model until a stream grid cell is encountered. The stream reach should represent only perennial flow, a distinction that is achieved by populating the “StreamType” field of the flow network prior to running the “Stream Reach & Catchments” tool.

The stream reach polyline is converted to a raster and serves as the input stream raster grid in the "D8 Distance to Stream" tool available in TauDEM software. The output is a Distance to Stream raster, a continuous grid where each cell value is the horizontal distance (in meters) from that cell to the stream reach, following the flow path defined by the D8 Flow Direction grid. Results of this tool are used to rank fields according to relative risk of sediment delivery (see Runoff Risk Assessment Tool).

2.d Runoff Risk Assessment

Required Inputs	Outputs
Field Boundary feature class (FB + inHUC)	Runoff Risk Table (RunoffRiskTable + inHUC)
Slope Table (SlopeTable + inHUC)	
D8 Distance To Stream raster (DistanceToStream + inHUC)	

The 3 x 3 “runoff risk assessment” matrix is completed for ***agricultural land use fields only*** (continuous corn, corn-bean rotation(s), extended rotation, conservation rotation, mixed agriculture, or pasture), and is used to classify a given field according to its risk of direct runoff contribution to stream channels in the watershed. Risk classification includes A (highest risk – most critical), to B (very high), C (high), and other (‘present’) designations.

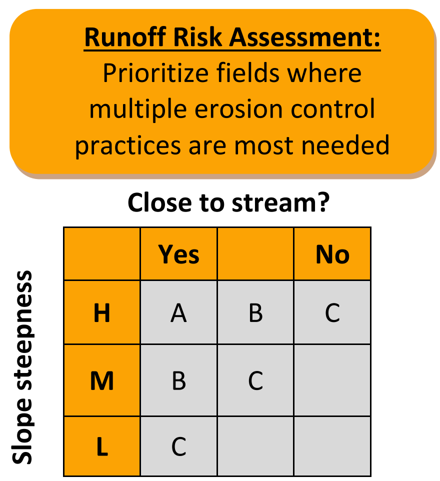


Figure 7. Runoff Risk Matrix (Tomer et al., 2015b)

The two sides of the matrix create a cross-classification of two variables: 1) slope steepness, and 2) proximity to stream. A sediment delivery ratio (SDR) is used as proxy for stream proximity. A slope steepness and SDR value is found for each agricultural field and converted to a rank (high, med, or low) for each field. These two variables are then used in a cross classification to characterize runoff risk on a by-field basis.

Input Variables

1. By-field Sediment Delivery Ratio

The sediment delivery ratio is calculated using an equation developed by Ouyang and Bartholic (1997), which is used in the Minnesota Phosphorus Index (Lewandowski et al., 2006) and is described by:

$$SDR = x^{-0.2069}$$

Where; x is the distance, in feet, from the ***edge of each field*** to the nearest stream.

A distance to stream raster, generated as an output of the "D8 Distance to Stream" tool, is used to calculate stream proximity. Each cell value in the input grid is equal to the horizontal distance (in meters) to the stream, moving downslope according to the D8 flow model, until a stream grid cell is encountered. Distance to the stream ***from the field edge*** is estimated using the ***minimum distance to stream value*** found within each field. This minimum distance value is translated to a sediment delivery ratio for each field using the equation above. Fields within 10 feet of the stream are considered to border the stream, and the distance value is converted to 1 foot, resulting in a SDR value of 1. To account for this adjusted distance measurement, a 10 foot width is subtracted from the minimum distance to stream value for every field. Fields within 10 feet of the stream are assigned an SDR value of 1, while fields 5,000 ft or further from the stream receive a value of 0.17, the lowest SDR value suggested using this P Index equation (Lewandowski et al., 2006).

2. By-field Slope Steepness

The slope steepness of each field is identified as the 3rd quartile, or 75th percentile, slope value (in % rise) within each field. That is, 25% of the field consists of slopes greater than this value. Use of the 75th percentile slope estimate is appropriate based on the following statement from the MN P Index:

> "Sediment and phosphorus are not lost evenly from all parts of a field, but come from a few critical source areas called the 'most limiting areas of significant extent', which are generally the areas with the steepest slope (Lewandowski et al., 2006). 'Of significant extent' means that the 'most limiting area' selected should represent the characteristics of at least 20% of the field."

Ranking of fields

Prior to performing a cross classification, each agricultural field must be classified into a high, medium, or low rank for each of the two input variables. The user is given two options for each of the input variables: 1) To provide thresholds for classification of slope and/or SDR values into a high, medium, or low classification, or 2) Allow thresholds to be automatically generated using a 20%-40%-40% split. These two options are described below.

User-Provided Thresholds

The user may provide thresholds to classify fields into a high, medium, or low rank for each of the two input variables.

1. Sediment Delivery Ratio

If specified by the user, the High SDR will represent the value (decimal between 0 and 1) ***above which*** a field will be classified as "high", and the Medium SDR will represent the value ***above which*** a field will be classified as "medium". Values below Medium SDR will be classified as "low". The lowest SDR value is 0.17, which corresponds to those field >= 5000 ft from the stream. We suggest considering stream buffer distances when selecting the SDR value that distinguishes High from Medium classes of sediment delivery. Fields bordered by a riparian buffer having widths of 20, 30, and 50 ft would have SDR values of 0.54, 0.49, and 0.45, respectively. A threshold of 0.4 (equates to ~80 feet from edge of field to channel) would highlight all fields near the stream that do not have relatively wide riparian buffers as having a ‘high’ SDR, while a threshold of 0.6 (equates to ~10 ft from edge of field to channel) would only select fields that have virtually no buffer between the field and the stream as having a ‘high’ SDR. The second threshold the users selects demarks the ‘medium’ from ‘low’ SDR classes. This value cannot be less than 0.17. Choosing a value between 0.30 and 0.17 is suggested to designate fields within >350 to >5000 ft of the stream as having ‘Low’ SDR. See table 6 and Figure 8 below for a conversion chart between SDR and distance.

Table 6. Conversion between SDR and distance from edge of field to stream. From the MN Phosphorus Index	
Distance From Edge of Field to Stream	**SDR (Sediment Delivery Ratio**
1 foot	1
10 feet	.62
20 feet	.54
30 feet	.49
50 feet	.45
75 feet	.41
100 feet	.39
150 feet	.35
200 feet	.33
500 feet	.28
1000 feet	.24
1500 feet	.22
2000 feet	.21
2650 feet (1/2 mile)	.20
5000 or greater	.17

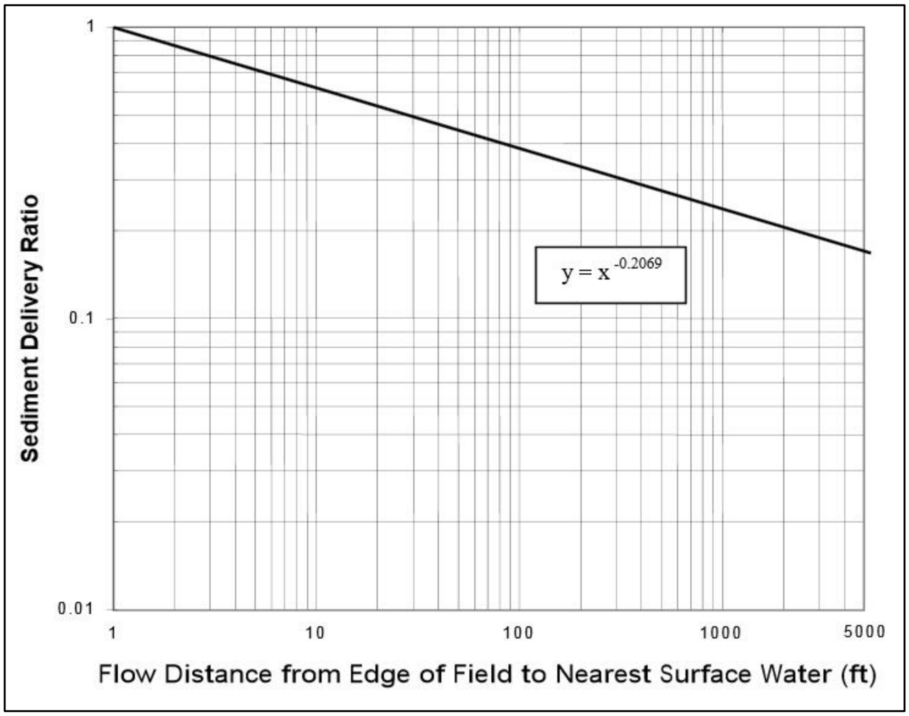


Figure 8. Sediment Delivery Ratio (SDR) plotted against Flow Distance from Edge of Field to Nearest Surface Water.

2. Slope Steepness

The by-field slope value represents the steepest 25% of the field. This option allows the user to specify two slope thresholds against which the 75th percentile slope will be classified to identify which fields will be classified as "High", "Medium" and "Low" steepness. The larger value will separate "High" from "Medium" steepness fields, while the smaller value will distinguish between "Medium and "Low" steepness fields. The user will need to consider the landscape in defining these breakpoints. In flat, heavily tile-drained watersheds, High > 5% and Low < 2% (with 5% < Medium < 2%) might adequately segregate the relative steepness of fields, whereas in more dissected terrain, values in 10 - 15% and 5 – 8% ranges might best segregate fields by relative steepness.

<u>No thresholds provided (default)</u>

If user-provided threshold values are not provided for SDR or slope, thresholds will be automatically generated according to a 20-40-40 breakdown of fields. That is, the top 20% of fields (steepest 20%, nearest 20% to stream) will be given a "high" classification, while the next 40% of fields will receive a "medium" classification, and the lowest 40% of fields will receive a "low" classification.

NOTE: The 20-40-40 breakdown may not always be consistent with the actual distribution of SDR estimates. For example, if more than 20% of the fields border the stream, and therefore receive a SDR value of 1, more than 20% of fields will be classified into the "high" category. This issue does not arise with the slope steepness classification.

NOTE: Threshold values may be provided for one of the input variables (slope steepness or SDR) while allowing the other variable to be classified according to the automatically generated 20-40-40 breakdown.

Runoff Risk Classification

Once the cross classification is applied, each agricultural field will receive a runoff risk classification, ranging from A (highest risk – most critical), to B (very high), C (high), and other ('present'). A "present" classification does not mean that a runoff-control conservation practice would not benefit a given field, but rather indicates that other fields have a greater potential impact on total sediment and phosphorus delivery to the stream.

The output runoff risk table contains detailed information for each agricultural field found during the runoff risk assessment. The table can be linked to the field boundary feature class through the "FBndID", and contains the following information for each agricultural field as attributes:

Table 7. Runoff Risk Table attributes

Attributes	**Description**
FBndID	Field boundary ID: join field
DTS_ft	Minimum distance to stream, in feet, for each agricultural field.
AdjDTS	Adjusted minimum distance to stream, in feet, for each agricultural field. If the distance is < 10 feet, the distance is converted to 1. A distance of 10 feet is subtracted from every other agricultural field.
SDR	Sediment delivery ratio for each agricultural field according to MN Phosphorus Index, using the AdjDTS
Slope75Pct	3rd quartile, or 75th percentile, slope value in % rise within each field
SDRRank	SDR rank (High, Medium, or Low)
SlopeRank	Slope steepness rank (High, Medium, or Low)
RunoffRisk	Runoff risk classification

3. Precision Conservation Practice Siting

3.a Depression Identification

Required Inputs	Outputs
Unfilled DEM (DEM + inHUC)	Depressions polygons (Depressions + inHUC)
gSSURGO soils raster (gSSURGO)	Depression Depth raster (optional)
Field Boundary feature class (FB + inHUC) (optional)	
Stream Reach (StreamReach + inHUC) (optional)	

Depressions are common in the glacial landscapes of the Midwest and present challenges for managing water quality and wetness of fields. Poorly drained and hydric soils are common in these depressions, and to enable cropping of areas subject to surface ponding, drainage has often been improved by installing surface drains (or intakes) as part of in-field tile drainage systems. Conservation practices that may be appropriate in depressions can include filter practices to treat water entering the tile intakes, with impacts on drainage rate that are acceptable. There are several types of intake filter practices including blind (sand-bed) intakes and grass buffers. Wetland restorations may also be feasible where soil wetness in depressions is frequently problematic for crop production. The potential benefits of these practices include reduced sediment and phosphorus loads, and water storage. See Smith and Livingston (2013), and Kessler and Gupta (2015) for further discussion of specific practice options to manage water in topographic depressions.

Locations of depressions in agricultural fields may be suited for several types of conservation practices, including **NRCS practice codes: 620 - Underground Outlet, 657 – Wetland Restoration**

The Depression identification tool identifies surface depressions in the input DEM. This is performed by performing a “fill” process on the input DEM, then subtracting the input DEM from the filled DEM. Depression regions are then converted to polygons, and polygons are overlaid with the input DEM to extract the range of elevation values within each depression. This range of values represents the maximum depths of ponding that may occur in each depression. Polygons are also overlaid with gSSURGO to determine the mean percent of hydric soils within each depression.

The user has the option to limit the extent of depressions based on user specifications. This can include none, all, or a combination of the following criteria:

1) The mean percent hydric soils within each depression must be greater than a user-specified value.
2) Depressions must be centered on agricultural fields (including pasture), as identified by an "isAG" value of “1” or “2” in the attribute table of the field boundary feature class.
3) Depressions cannot intersect the stream reach.
4) Depressions must have a minimum depth of (x) cm.

5) Depressions must have a minimum surface area of (y) acres.

NOTE: Even using a hydrologically conditioned DEM or after running the "Manual Cutter" tool, ***there will likely still be some artificial depressions*** associated with roads or artifacts of the terrain processing (Figure 9).

NOTE: After running the depression identification tool, it is ***strongly suggested*** that the output layer be reviewed, and any false depressions be manually deleted. Once edited, the layer can be used as an input to the "Depression Watersheds" tool to identify the drainage area to each depression. Alternatively, the user may interactively select true depressions on-screen rather than delete false depressions. When used as an input to the Depression Watersheds tool, the selection will be honored and watersheds will be found for only those depressions selected.

NOTE: If the "Output Depression Depth Raster?" is checked, a depth raster will be output to the file location provided. Each grid cell indicates the depth of the depression in that location, in the same vertical units as the input DEM.

The output depression feature class (Depressions + inHUC) contains the following information for each depression as attributes.

Table 8. Depression polygon attributes

Attributes	**Description**
Depress_ID	Unique ID for each depression
PctHydric	Mean % hydric soil of each depression
MaxDepthCM	Maximum depth (in cm) of each depression

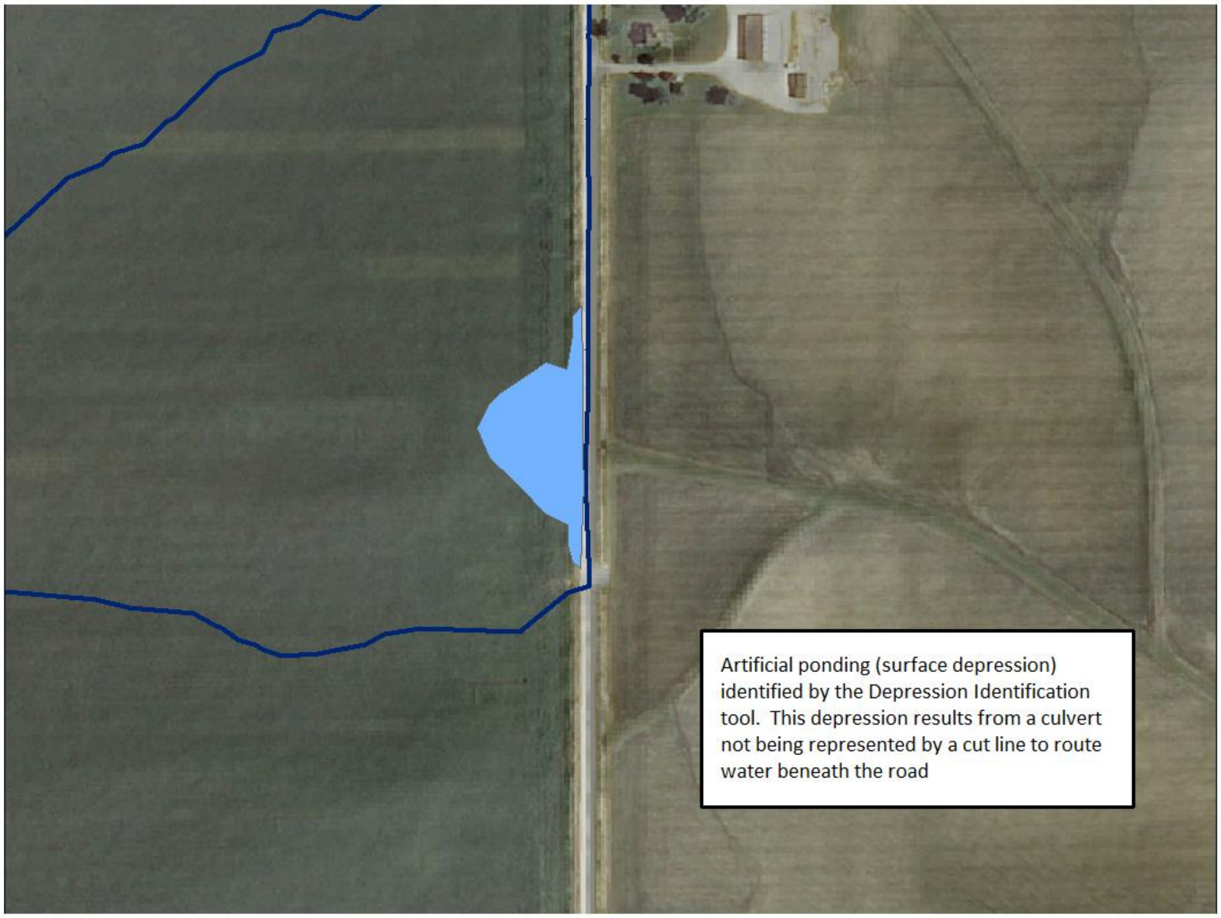


Figure 9. False depression identified as a result of a culvert/road intersection.

3.b Depression Drainage Areas

Required Inputs	Outputs
Depressions polygon feature class (Depressions + inHUC)	Depression Drainage Area polygons (Depress_Wsheds + inHUC)
Input DEM (unfilled)	

The “Depression Drainage Areas” tool delineates watershed contributing areas to each unique depression in the input Depressions feature class.

NOTE: In contrast to most other tools in the ACPF toolbox, D8 Flow Direction values for the Depression Drainage Area tool are derived from an ***unfilled DEM***. This is to prevent upstream depressions from being included in the drainage area of a lower depression.

NOTE: This tool should only be run following a manual review of the “Depression” feature class, during which false or inaccurate depressions are manually deleted. Alternatively, the user may interactively select true depressions on-screen rather than delete false depressions. When used as an input to the Depression Watersheds tool, the selection will be honored and watersheds will be found for only those depressions selected.

The output is a Depression Drainage Areas feature class (Depress_Wsheds + inHUC), which can be linked to the depression feature class through a “Depress_ID” field, and contains the following information for each drainage area as attributes.

Table 9. Depression Drainage Area polygon attributes

Attributes	Description
Depress_ID	Unique ID for each depression; can be used as join field with Potholes layer
DrainageHA	Drainage area (in hectares) to each unique depression

3.c Drainage Water Management

Required Inputs	Outputs
Input DEM (DEM + inHUC)	Drainage Management polygons (DrainageMgmt + inHUC)
Field Boundary feature class (FB + inHUC)	
Drainage Table (DrainageTable + inHUC)	

A controlled drainage system reduces nitrogen loads by raising the in-field water table during part of the year, thereby reducing overall tile drainage volume. Other processes such as denitrification may be enhanced but this has not yet been confirmed by research. Several published studies have evaluated tile discharge and nutrient loads under drainage water management systems (e.g., Williams et al., 2015). The water table is controlled through the use of gate structures that are adjusted at different times during the year. When field access is needed for planting, harvest or other operations, the gate can be opened fully to allow unrestricted drainage. When the gate is used to raise water table levels in the midst of the growing season, this may allow more plant water uptake during dry periods, which can increase crop yields. Crop grain yield increases have been documented with controlled drainage and this has primarily been attributed to the increased availability of soil water (Delbecq et al., 2012).

NRCS practice codes: 554 – Drainage Water Management

Controlled drainage may be used on fields with flat topography (typically one percent or less slope), such as in flood plains and on flat fields typical of the large areas of the glaciated Midwest. The practice can be expensive to design and install in areas with slopes steeper than about one percent because of the number of control structures required in a typical field.

A single control gate (depending on its design) can influence the water table in an area of a field that has about a 0.5 meter change in elevation. To identify fields potentially suited to this practice, the Drainage Water Management tool identifies all areas within tile-drained, agricultural fields where a contour interval between 0.3 and 1.5 m (chosen by the user) , comprises more than a user-defined percentage of the field (must be at least 40% of the field).

<u>**Process**</u>
The tool works by finding the number of contour intervals ***(rounded to the nearest integer)*** that can exist within a given field, based on the total range of elevation values. For example, a field with an elevation range of 432 cm contains approximately four 1-meter contours, while a field with an elevation range of 476 cm contains approximately five 1-meter contours.

432/100 = 4.32 -----> 4 (Round down)
476/100 = 4.76 -----> 5 (Round up)

The field is then sliced into that number of equal interval zones, and each zone is analyzed for drainage management suitability. If any zone occupies more than a user-defined percentage of the field, that field is flagged as a candidate for controlled drainage and the contour zone is added to the output drainage management opportunity feature class.

NOTE: There may be more than one contour-interval zone for a given field that meets the selection criteria, if more than one zone comprises more than the user-selected percentage of the field (applies if that percentage is <50%).

NOTE: Actual implementation of controlled drainage will typically require more detailed survey information on field topography and drainage patterns than ACPF products provide, because existing tile drainage patterns and possible impacts on neighboring fields must be determined. Alteration or replacement of tile may often be required.

NOTE: The user is expected to identify the contour interval (minimum is 0.3 m; maximum is 1.5 m; default is 1.0 m) and a minimum percentage of the field that the area found within the zone must occupy to be flagged as a candidate site, with a minimum of 30% of the field. The contour interval may be varied to allow for different designs and landscape settings in which water table control gates may be used as a part of drainage management systems. A contour interval that exceeds 0.5 m will increase the likelihood that multiple gate structures will be needed to control water table elevations. That is, more complicated engineering designs may be necessary if a large contour interval is selected. Choosing a smaller contour interval will reduce the number of fields that meet the criteria but this may be appropriate in very low relief (e.g., lacustrine) landscapes.

The output is a Drainage Management polygon feature class (DrainageMgmt + inHUC), which contains all contour zone(s) within each field that meet the above criteria.

Table 10. Drainage Management polygon attributes

Attributes	**Description**
FBndID	Field boundary ID: join field
cont_acres	Size (in acres) of area within the contour interval
fld_acres	Size (in acres) of the field
pct_field	Percentage of the field that lies within the contour interval

3.d Grassed Waterways

Required Inputs	Outputs
D8 Flow Accumulation raster (D8FlowAcc + inHUC)	Grassed Waterway polylines (GrassWaterways + inHUC)
D8 Flow Direction raster (D8FlowDir + inHUC)	
Field Boundary feature class (FB + inHUC)	
Stream Reach polyline layer (StreamReach + inHUC)	
Runoff Risk Table (RunoffRisk + inHUC) (optional)	

Grassed waterways are installed to reduce the risk of concentrated flow (gully) erosion. This practice may be effective in preventing gully erosion for three reasons. First, the growing grasses can reduce mean velocity of runoff, which encourages deposition of sediment and discourages soil detachment. Second, grass vegetation subjected to high water velocity may be pushed to lie flat on the surface, and the flattened grass may then provide a physical barrier to prevent gully formation. Third, the fibrous root systems of grasses lead to increased soil strength, which can limit detachment of soil particles that otherwise may be prone to occur with seepage from the soil surface under saturated conditions. Although grassed waterways are among the most common of conservation practices, they remain under-utilized in many of the country's steeper farmed landscapes, and their capacity to reduce erosion under saturation excess runoff (seepage) conditions may be under-appreciated. Grassed waterways have not been the most frequently evaluated practice in recent conservation-effectiveness research, but several papers by Fiener and Auerswald (2003; 2006) provide a good starting point to learn more.

NRCS practice codes: 412 – Grassed Waterway

The Grassed Waterways tool uses a simple flow accumulation threshold to identify collective flow pathways that may be suitable for grassed waterways. The stream reach polyline will remove locations where a perennial flow channel already exists.

In the tool interface, the user will define a drainage threshold between 1 – 15 acres, above which is identified as possible locations for grassed waterways. The field boundary feature class is used to limit the output to agricultural fields, as identified by an "isAG" value of "1". Fields identified as pasture (i.e. an "isAG" value of "2"), will be omitted from the analysis. To qualify as pasture, a field must have pasture, grass, or hay as the majority land cover in 5 of the last 6 years of record.

NOTE: As we do not have a record of current conservation practice locations, many of these locations may correspond to an area where a grassed waterway already exists.

NOTE: The runoff risk assessment is a valuable resource for prioritizing fields for grassed waterway installation. If specified by the user, grassed waterways will be limited to those fields with the runoff risk classification indicated.

3.e Contour buffer strips

Required Inputs	Outputs
Field Boundary feature class (FB + inHUC)	Contour Buffer Strip polygons (CBS + inHUC)
Slope raster (Slope + inHUC)	
Slope table (SlopeTable + inHUC)	
Unfilled DEM (DEM + inHUC)	
D8 Flow Accumulation raster (D8FlowAcc + inHUC)	
Runoff Risk table (RunoffRisk + inHUC) (optional)	

Contour buffer (or filter) strips are strips of perennial vegetation planted along topographic contours, which may be alternated with wider cultivated strips that are farmed on the contour. Contour buffer strips are in-field runoff control practices that use permanent vegetation to decrease the length of slopes along which runoff accumulates, and thereby reduce sheet and rill erosion. They are similar yet complementary to grassed waterways because both use grass vegetation, but contour buffer strips are oriented differently by being placed along topographic contours to intercept flows. This practice can be used in combination with grassed waterways, but the types of grass may differ with stiffer stems being preferred in buffer strips. The Contour Buffer Strip tool identifies locations for buffer strips in agricultural fields that, when located along the contour and in areas of high slope, will intercept the largest amount of runoff in a given field. This criteria is, in essence, based on recent research in Iowa that has documented benefits of reduced runoff volume and improved water quality derived from installation of contour buffer strips, particularly when placed lower on the slope; i.e., at footslope landscape positions (Zhou et al., 2014; Hernandez-Santana et al., 2013).

NRCS practice codes: 332 – Contour Buffer Strips

NOTE: The runoff risk assessment is a valuable resource for prioritizing fields for contour buffer strip installation. If specified by the user, buffer strips will be limited to those fields with the runoff risk classification indicated.

NOTE: The Contour Buffer Strips tool acts on ***agricultural fields only*** (i.e. an “isAG” value of “1”). Fields identified as pasture (i.e. an “isAG” value of “2”), will be omitted from the analysis. To qualify as pasture, a field must have pasture, grass, or hay as the majority land cover in 5 of the last 6 years of record.

Process

A mask of 4 - 15% slope is generated ***for agricultural fields only (excluding pasture).*** If the runoff risk table is provided, the mask will be further limited to those fields with the runoff risk classification indicated. The mask is smoothed by majority filter and interior holes smaller than 1/2 acre are filled in.

Table 11 shows the maximum allowable terrace spacing (as defined by the NRCS) for given slope ranges. (NRCS, 2014).

Table 11. NRCS Maximum Terrace Spacing based on erosion prediction tools

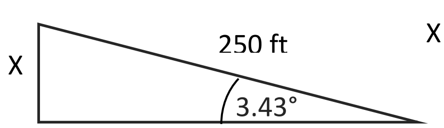
Field Grade in %	Maximum Spacing (in feet) with Soil Loss to "T"
3.6 - 5.5	300
5.6 - 8.5	250
8.6 - 12.5	200
12.6 - 18	150

Terrace spacing values from Table 11 are adapted for use in the ACPF as described in Table 12. Contours are generated ***within the slope mask*** on a by-field basis. ***Contour intervals are chosen so that resulting contours are spaced approximately equal to the NRCS-recommended spacing, using the 3rd quartile slope value of each field***. Three contour interval values are possible, and are determined using the mean value (representative slope) of each slope range. The process is described in detail in the below examples.

Table 12. Adapted ACPF spacing based on 3rd quartile slope and NRCS recommendations

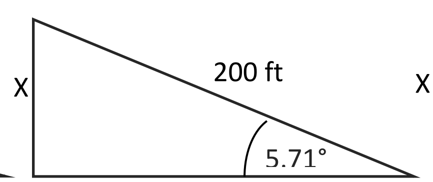
3rd quartile slope (%) value of field	Suggested spacing (feet)	Representative slope used to determine contour interval	Contour Interval (to achieve suggested spacing (ft in elevation)
4 – 8	250	6	14.75
8 – 12	200	10	19.8
12 - 15	150	13.5	20.1

Example 1:
3rd quartile slope range: 4–8%
Representative slope: 6%
6% slope = 3.43°
Recommended spacing: 250 ft



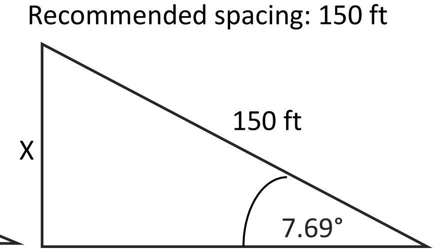
Contour interval = X
Sin(3.43°) = X / 250 ft
X = 14.75 ft

Example 2:
3rd quartile slope range: 8-12%
Representative slope: 10%
10% slope = 5.71°
Recommended spacing: 200 ft



Contour interval = X
Sin(5.71°) = X / 200 ft
X = 19.8 ft

Example 3:
3rd quartile slope range: 12–15%
Representative slope: 13.5%
13.5% slope = 7.69°
Recommended spacing: 150 ft



Contour interval = X
Sin(7.69°) = X / 150 ft
X = 20.1 ft

Contours ***that have a length of at least 100 meters*** are selected and buffered to a user-specified width (buffer strip width).

Concentrated flow pathways greater than 2 acres in upstream drainage are buffered by 10 meters on each side and removed from the contour buffer strip output. As a result, contour buffer strips are not sited through concentrated flow pathways, but are instead generated on the side slopes flanking these drainageways.

Output buffers strips are smoothed using a PAEK algorithm (Polynomial Approximation with Exponential Kernel) to smooth sharp angles and provide results that should better accommodate farming operations. Note output contour location will usually need to be further modified or smoothed to maintain trafficability for farm implements (that is, results should not be viewed as an actual design recommendation for the practice in any given field). A field boundary ID (FBndID) and mean slope is attributed to each contour buffer strip included in the output layer.

Table 13. Contour Buffer Strip polygon attributes

Attributes	**Description**
FBndID	Field boundary ID
Mean Slope	Mean slope (in % rise) of each buffer strip

4. Impoundment Siting

4.a Nutrient Removal Wetlands

Required Inputs	Outputs
Input unfilled DEM (DEM + inHUC)	Nutrient Removal Wetland polygons (NRW + inHUC)
D8 Flow Direction raster (D8FlowDir + inHUC)	Nutrient Removal Wetland Drainage Area polygons (NRWDrainageAreas + inHUC)
D8 Flow Accumulation raster (D8FlowAcc + inHUC)	
Watershed boundary (bnd + inHUC OR the new watershed boundary that was created in step 2.5 – Stream Reach and Catchments)	
Stream Reach (StreamReach + inHUC) (optional)	
Roads (Optional)	

Iowa's Conservation Reserve Enhancement Project (CREP) program developed general criteria for siting wetlands to strategically locate them below tile drained fields and provide an off-site strategy for reducing nitrate from tile drainage water. Nutrient removal wetlands have the potential to remove 40-90% of the nitrate in tile drainage, depending on the nitrate load intercepted by the wetland (which varies with watershed size, land use, and precipitation) and the area of the wetland. The Nutrient Removal Wetland siting tool allows the user to sample locations along collective flow pathways for suitability of nutrient removal wetlands. Candidate sites can be ranked based on watershed and wetland areas, and topographic buffers. Further details on wetland siting criteria and discussion of factors impacting prioritization of candidate sites can be found in Tomer et al. (2013b).

NRCS practice codes: 656 – Constructed Wetland, 658 – Wetland Creation

<u>Siting process</u>

Potential impoundment locations (points) are generated along all collective flow paths within the drainage range established for nutrient removal wetlands (> 60 HA (~ 150 acres) --> maximum watershed drainage). A threshold is applied to the input D8 flow accumulation grid to delineate flow paths, which is converted to a polyline. Points are then generated continuously along this polyline at a user-specified distance interval (spacing). Locations are sorted by contributing area and most downstream sites are tested first.

At each location, an impoundment is simulated in the DEM, creating both a pooled area (of user-specified height – measured from the top of the bank) and a vegetated buffer (of user-specified height – measured from the top of the wetland pool). The drainage area to each impoundment is delineated, and descriptive statistics are then generated, including the size of the pooled area, the size of the buffer, and the ratio of pooled area to the amount of drainage that it receives. If a site is found to be suitable according to suitability criteria, the site is "kept" and added to the output feature class. If not suitable, the site is omitted, and the next upstream site is tested.

Default settings for nutrient removal wetlands are listed in Table 12. The user can modify default settings within a predetermined range, including the impoundment height, buffer height, and spacing distance. Drainage range and suitability criteria are not modifiable.

Table 14 Default and optional parameters for nutrient removal wetlands

Parameter	**Description**
Drainage range	> 60 HA – maximum watershed drainage
Suggested Spacing Distance (* Modifiable)	default: 250 meters optional: 100, 150, 200, 250 meters
Impoundment Height (* Modifiable)	default: 0.9 meters optional range: 0.9 - 1.2 meters
Buffer Height (* Modifiable)	default: 1.5 meters optional range: 1 – 1.6 meters
Suitability Criteria	Pooled area/Drainage Area ratio: 0.5 – 2% Buffer area/Pooled area ratio: < 4.0

NOTE: Processing time will increase with a decrease in spacing distance (i.e., increase in sampling density).

At each sample point, focal statistics of the input DEM are used to assign the following variables:

- **Bank height:** range of elevation values within a 20 meter buffer around each point
- **Top of bank elevation:** maximum elevation value within a 20 meter buffer around each point
- **Channel elevation:** minimum elevation value within a 20 meter buffer around each point

Points are omitted from analysis if the bank height exceeds 4 meters **OR** if the drainage area at the point does not fall within the drainage range specified for nutrient removal wetlands (minimum of 60 HA and maximum of total watershed drainage). The bank height restriction avoids identifying possible wetlands in locations with well-incised streams where high impoundments would be necessary and instability of riparian zone sediments would be a possible concern.

To mimic installation of a nutrient removal wetland, an impoundment is simulated at each sample point, creating a pooled area upstream of the sample point. The ***impoundment elevation*** is defined by adding the user-selected impoundment height (in meters) to the top of bank elevation at the sample point. The ***buffer elevation*** is defined by adding the user-selected buffer height (in meters) to the impoundment elevation at each sample point. This vegetated buffer is required to account for times of high flow, to estimate where drainage impedance may occur, and should usually be considered as an opportunity for permanent vegetation/habitat enhancement. Each impoundment is then tested for suitability following the default suitability criteria as detailed in Table 12.

NOTE: It is optional, but recommended in watersheds with wide rivers, that the user choose to avoid identifying wetlands along the main stream reach (representing perennial flow) by providing the Stream Reach polyline feature class in the tool interface. If provided, any sample points that intersect the stream reach will be omitted from analysis, leaving only those points with a contributing area exceeding 60 HA yet that still lie upstream of the channel initiation point to be tested for wetland suitability.

NOTE: It is optional, but recommended, that the user choose to avoid roads by providing a roads polyline feature class in the tool interface. A roads layer is not provided as a base layer in the ACPF database, but will usually be easily accessed from a GIS state database. A site will be considered unsuitable if either the pooled area **OR** the buffer area intersects the road layer.

Two output layers will be created as an output to the tool:
1) A polygon layer delineating the pooled area and buffer, and site-specific information for each suitable site.
2) A polygon layer delineating the drainage area to each suitable site. These rows will have a unique "SiteID" join field.

NOTE: In the attribute table of the polygon layer delineating the pooled area and buffer (output 1 above), there ***will be two rows allocated to each suitable impoundment site***; one for the pooled area polygon and one for the buffer polygon. These rows will have the same unique "SiteID".

The NRW feature class contains the following site-specific information as attributes:

Table 15. Nutrient Removal Wetland polygon attributes

Attributes	**Description**
SiteID:	ID field
ContAreaHA:	Contributing area in HA upstream of the wetland
PoolAreaHA:	Surface area of wetland pool in HA
BuffAreaHA:	Surface area of buffer in HA
StrmElev:	Estimated channel elevation (in cm) at the location that a wetland impoundment is simulated
BankHeight:	Estimated bank height (in cm) at the location that a wetland impoundment is simulated
BankElev:	Estimated top of bank elevation (in cm) at the location that a wetland impoundment is simulated
PoolStorAF:	Volume (in acre feet) of permanent storage provided by the pooled area
VarStorAF:	Volume (in acre feet) of variable storage provided by the vegetated buffer

4.b WASCOBS (Water and Sediment Control Basins)

Required Inputs	Outputs
Input DEM (DEM + inHUC)	WASCOB polylines (WASCOBs + inHUC)
D8 Flow Accumulation raster (D8FlowAcc + inHUC)	
D8 Flow Direction raster (D8FlowDir + inHUC)	
Field boundary feature class (FB + inHUC)	
Stream Reach (StreamReach + inHUC)	
Watershed Boundary (bnd + inHUC)	
Runoff Risk table (RunoffRisk + inHUC) (optional)	

WASCOBS, or water and sediment control basins, are small embankments built across (perpendicular) a drainageway in an agricultural field. This practice can reduce sediment and total phosphorus loads, attenuate peak runoff discharge, and reduce risk of gully formation down gradient. The WASCOB tool identifies potential locations for these structures on watersheds from 2 to 50 acres in size. A user-provided embankment height defines the height of the WASCOB (as measured from the bottom center of the drainageway). The WASCOB is a commonly installed practice in much of the Midwest, and information on design and sediment retention can be found in basic texts on engineering of hydrologic structures. However there is little information in the peer reviewed literature on this practice; Mielke (1985) is one of the rare examples we found. Gassman et al. (2010) evaluated conservation performance in an Iowa watershed following conservation improvements that included WASCOBs.

NRCS practice codes: 638 – Water and Sediment Control Basin

<u>Process</u>

Potential WASCOB locations (points) are generated approximately every 250 feet along flow paths within the drainage range established for WASCOBS (2 – 50 acres). A threshold is applied to the input D8 flow accumulation grid to delineate this drainage range, which is converted to a polyline.

Points are limited to ***agricultural land use fields only, including pasture***. Points are first removed if the elevation change between itself and the next upstream point is not enough to install a WASCOB at the user-specified height without flooding out the upstream location. At each remaining point, a 100 m wide transect is drawn perpendicular to the mean direction of flow of that drainageway. The elevation profile of the transect line is then analyzed to estimate the shape of the drainageway and determine the suitability of the location for WASCOB installation. Two requirements must be met for the embankment to be qualified and tabulated in the attribute table. First, the height of each side of the drainageway must be at least the height of the embankment to be qualified and tabulated in the attribute table. In other words, the drainageway must possess enough curvature (or slope convergence) to allow installation of a WASCOB at that location. Second, the height of each side of the drainageway must not be more than twice the height of the embankment. In other words, the drainageway is not too incised to prevent installation of a WASCOB at that location.

Transect lines that meet these two criteria are appended to the output WASCOB feature class. Additionally, WASCOBS that fall within 90 meters of the main stream reach (representing perennial flow) will be omitted from analysis. Lastly, WASCOBS that fall on the edge of a field boundary will also be deleted, in an effort to limit the practice to the interior of agricultural fields.

NOTE: The runoff risk assessment is a valuable resource for prioritizing fields for WASCOB installation. If specified by the user, WASCOBs will be limited to those fields with the runoff risk classification indicated.

NOTE: After running the WASCOB tool, it is strongly suggested that the output layer be reviewed, and any erroneous WASCOBs be manually deleted. For example, WASCOBS that intersect objects like homesteads or roads. The layer can then be used as an input to the WASCOB basins tool to identify the basin, or upstream area that would pond water during times of high flow, were the WASCOB to be installed. Alternatively, the user may interactively select WASCOBs on-screen rather than delete WASCOBs. When used as an input to the WASCOB basins tool, the selection will be honored and basins will be found for only those WASCOBs selected. The output polyline feature class will have the following site-specific information as attributes:

Table 16. WASCOB polyline attributes

Attributes	Description
WASCOBID	Unique Identifier
ContAreaAC:	Contributing Area (in acres) upstream of each WASCOB (derived from filled DEM)
Elevation:	Elevation at bottom center of drainageway (location of sample point)
EmbankHgt:	WASCOB embankment height as specified by the user (in vertical map units)
lbank_hgt	Height (range of elevation values) for the left bank of the drainageway
rbank_hgt:	Height (range of elevation values) for the right bank of the drainageway

4.c WASCOBS Basins

Required Inputs	Outputs
Input WASCOBs (WASCOBs + inHUC)	WASCOB polygons (WASCOBbasin + inHUC)
Filled DEM (DEMFill + inHUC)	
D8 Flow Direction (D8FlowDir + inHUC)	

The WASCOB Basin tool delineates the area which would pond water up-gradient of each WASCOB during times of high flow. The process involves “burning” each WASCOB into a filled DEM (using the user-defined embankment height for each WASCOB), then determining the sink regions that are created upstream of each WASCOB as a result.

NOTE: This tool should only be run following a manual review of the “WASCOBs” feature class, during which erroneous WASCOBS are manually deleted. This includes WASCOBS that intersect objects like homesteads or roads, or where installation is unfeasible due to other reasons. Alternatively, the user may interactively select WASCOBS on-screen. When used as an input to the WASCOB basins tool, the selection will be honored and basins will be found for only those WASCOBs selected.

Process

The WASCOB polyline feature class is specified by the user as an input to this tool. The embankment height of the input WASCOBs (in the same vertical units of the DEM) is obtained from the “EmbankHgt” field of the input feature class. The input WASCOB layer is converted to a raster, and the minimum elevation value (from a filled DEM) is found along each WASCOB. This elevation value represents the elevation at the bottom center of the drainageway. This elevation value is then added to the height of the embankment (for example, 150 cm) along the entirety of the WASCOB line. The new elevation values are then used to replace the elevation values along the WASCOB in the filled DEM. The result is a raster of the original filled DEM except where a WASCOB is present, in which case each grid cell is given the elevation value of the WASCOB. By using a filled DEM, no depressions should initially be present. Once WASCOBs have been burned into the filled DEM, the filled DEM is then put through a "fill" process to identify the depressions created as a result of adding the WASCOBs.

NOTE: If the “Output WASCOB basin depth raster?” is checked, a depth raster will be output to the file location provided. Each grid cell indicates the depth of the ponded area in that location, in the same vertical units as the input DEM. These data are summed to provide an estimated volume of water storage capacity above each WASCOB.

The output is a WASCOB basin polygon layer (WASCOBbasin + inHUC), which represents the ponded area behind each WASCOB during times of high flow, and contains the following information for each WASCOB basin as attributes.

Table 17. WASCOB Basin polygon attributes	
Attributes	**Description**
WASCOBID	Unique Identifier
StorageAF	Potential storage volume (in acre feet) of each WASCOB basin
BasAreaHA:	Surface area (in HA) of each WASCOB basin

5. Riparian Assessment

Conceptually, the riparian assessment component of the ACPF evaluates riparian settings in a watershed by discretizing its perennial stream corridors into a set of Riparian Assessment Polygons (or RAPs), determining and ranking the distribution of potential runoff contributing areas among the RAPs, and then determining and ranking estimated widths of shallow water table zones among the RAPs. A cross classification is applied to map the relative correspondence of potential runoff contributions with the extent of low-lying areas (where water tables are likely to be shallow) throughout the riparian corridors in the watershed. The results of the cross classification can be used to identify opportunities to improve riparian management by installing permanent vegetation in ways specifically designed to intercept surface runoff, influence shallow groundwater in low-lying areas, and stabilize stream banks. Details are provided by Tomer et al. (2015b); a review of riparian practices by Schultz et al. (2009), and a meta-analysis of nitrate removal in buffers by Mayer et al. (2009) were instrumental in developing the criteria used in the ACPF riparian classification scheme. The user is also referred to Dosskey et al. (2010) for a review of riparian vegetation and its potential functioning in water quality improvement. This riparian section begins by developing information on flow directions and estimated extents of shallow water tables along the riparian corridors (where stream segments were designated to have perennial flow from Section 1.e).

5.a Riparian Zone Flow Directions and Water Table Depths

Required Inputs	**Outputs**
Input DEM (unfilled)	Adjusted D8 Flow Direction raster (AdjFlowDir + inHUC)
D8 Flow Direction raster (D8FlowDir + inHUC)	Water Table Depth raster (WaterTableDepth + inHUC)
Stream Reach (StreamReach + inHUC)	Relative Elevation raster (optional)

The Water Table Depth tool uses an input unfilled DEM, D8 Flow Direction grid, and Stream Reach feature class (polyline) to find the elevation difference between each grid cell in the input DEM and the stream-channel grid cell that will receive overland flow from that cell. These elevation differences are reclassified into depth categories and used as a proxy for water table depth.

Process

The Stream Reach polyline is converted to a raster and expanded by one cell to identify "bank" grid cells, which are assigned false, “sky-high” elevation values. The input DEM is then "filled", and filled elevation values are extracted to the channel grid cells only. Flow direction is then calculated using just the bank cells and the channel cells. The”sky-high” elevation values for bank grid cells forces flow from the bank cells directly into the channel. This prevents flows parallel to the channel among bank cells, which means that contributing areas calculated for contiguous lengths of bank can be summed without introducing errors that would result if upslope contributing areas for one bank cell could be contributed to an adjacent bank cell. Also,"filled" channel elevation values prevent in-channel sinks and ensures that flow is forced downstream once it enters the channel. The new flow direction values are burned into the original flow direction grid to create an "Adjusted Flow Direction" grid.

Elevation differences are then found between the unfilled DEM and the "filled" channel elevation values, following D8 Adjusted Flow Direction flowpaths. The result is a continuous raster of elevation difference ***relative to the channel elevation***, which can optionally be output as the "Relative Elevation" grid.

The Relative Elevation grid is reclassified into the following depth categories and output as a thematic “Water Table Depth” grid. This grid is used as a proxy for water table depth:

- Channel: < 0
- Shallow water table (< 1.5 meters)
- Semi shallow water table (1.5 – 3 meters)
- Medium water table (3 – 5 meters)
- Deep water table (>5 meters)

5.b Riparian Function Assessment

Required Inputs	Outputs
Stream Reach polyline layer (StreamReach + inHUC)	Riparian Analysis Polygons (RAP + inHUC)
Field Boundary Feature Class (FB + inHUC)	
gSSURGO soils raster (gSSURGO)	
Surface Horizon Table (SurfHrz + inHUC)	
Drainage Table (DrainageTable + inHUC)	
Adjusted Flow Direction raster (AdjFlowDir + inHUC)	
Water Table Depth raster (WaterTableDepth + inHUC)	

The second supplemental matrix in the conservation planning framework, “Riparian Assessment” (Fig. 1), can be used to determine site-specific designs for buffers planted within riparian analysis polygons (RAPs). This tool for watershed-wide riparian buffer planning identifies where opportunities exist to intercept surface runoff (SSG-type buffers), shallow groundwater (DRV-type buffers), or both runoff and groundwater (CZ and MSB type buffers). Where neither opportunity exists, riparian plantings can be designed to reduce bank erosion (SBS-type buffers). RAPs are analytical units created along the stream network that represent functional riparian management areas. The concepts behind this classification system, development of the mapping approach, and justifications for classifications are detailed in Tomer et al. (2015b)

NRCS Practice Standards: Riparian Forest Buffer (391); Streambank Protection (580)

Riparian Assessment:
Identify riparian function by stream reach

Shallow water table width

Ruonff Delivery	H	M	L
H	CZ	MSB	SSG
M	MSB	MSB	SSG
L	DRV	DRV	SBS

Design types for Riparian Buffers:

CZ Critical zone/sensitive sites
MSB Multi-species buffer for water uptake, nutrient & sediment trapping
SSG Trap runoff & sediment with stiff-stemmed grasses
DRV Use deep rooted vegetation tolerant of saturated soils
SBS Emphasize stream bank stability

Figure 10. Riparian assessment matrix and riparian buffer design types. (Tomer et al., 2015b)

To generate RAPs, a set of rectangular 250x180 m polygons are individually centered and placed along each stream reach polyline, where the field designation for "StreamType" represents perennial stream segments (see Section 1.3). Each polygon is converted to a polyline, merged with the reach polyline, and then converted back to a polygon. The result is the creation of two RAPs from each 250x180 m box, one on each side of the stream, and each with a constant length of 250 meters and an average width of 90 meters (considering that stream meanders define one side of each RAP). Dimensions of the RAPs are arbitrary but meant to represent a length of riparian zone (250 m) that can be managed separately and a width (90 m) that would seldom be exceeded when installing a riparian buffer. Minor gaps between RAPs are located near confluence areas; otherwise, the feature conversions just described would become mired by topological complexity. Once created, the RAPs are appended to the output Riparian Polygon feature class, (RAP + inHUC). Various soil, runoff, and morphological characteristics are then extracted to each RAP through zonal statistics.

The two axes of the riparian assessment matrix create a cross-classification of two variables: 1) width of the shallow water table zone, and 2) runoff delivery (the amount of local surface runoff) to each RAP.

<u>Calculating Shallow Water Table Zone width for each RAP</u>

The input Water Table Depth raster (output from Water Table Depth tool) is used to calculate the average width of the shallow, semi-shallow, and medium water table depth zones within each RAP. The area of each water table depth zone is found within each RAP, and then divided by the RAP length of 250 meters to estimate the average width of each zone within the RAP. ***The average width of the shallow water table zone (< 1.5 meters) is then used in the cross-classification matrix to determine riparian function for each RAP.***

<u>Calculating runoff delivery to each RAP</u>

Local runoff is defined as overland flow delivered to the stream ***through the riparian zone of the RAP***. In contrast, ***watershed runoff*** is defined as all upstream drainage to that point in the watershed, including already channelized flow.

To calculate the area of ”local runoff” delivery to each RAP, results of the Adjusted D8 Flow Direction raster (Section 5.a) are used. In this process, each segment of the stream reach polyline is independently converted to a raster, and then expanded by 1 cell on each side to identify stream-bank grid cells. Up-gradient contributing areas are then extracted to each bank grid cell, which are each then assigned to a single RAP. The “***local runoff” delivery is estimated by summing the contributing areas for all bank cells in each RAP***. Again, up-gradient contributing areas were generated using the adjusted flow direction raster to ensure that flow is forced from bank cells directly into the channel, and to prevent ‘double counting’ of runoff delivery areas that would result from parallel flow paths. The summed “***Local runoff” values by RAP are next used in the cross-classification matrix to determine riparian function for each RAP.***

NOTE: In addition to calculating local runoff, watershed runoff (i.e. watershed size above each RAP, defined as the maximum contributing area among all ***channel cells*** in the RAP), local runoff ***through tile drained agricultural fields*** (using a tile-drained mask as a weight raster), and local runoff ***through non tile-drained agricultural fields*** (using non tile-drained mask as a weight raster), are also found for each RAP. These criteria may be used at the discretion of local planners to assess or rank riparian sites for alternative riparian practices such as bioreactors or saturated buffers.

NOTE: Using an input gSSURGO raster and Soil Value Added table, the average soil organic carbon (in g/m^2) is found within the shallow water table and semi-shallow water table depth zones within each RAP at 2 depths; 20 - 50cm and 50 - 100cm. This is to provide a general indicator of the suitability of riparian subsoils as a carbon source to enhance nitrate removal through denitrification, which helps determine the suitability of the site for riparian practices such as saturated buffers.

Cross Classification

Prior to performing a cross classification, each RAP is classified into a high, medium, or low rank for each of the two input variables. The ranking of each variable within each RAP will be contained in the “WTInt_Rank” and “RunoffRank” field of the output riparian analysis feature class.

Shallow Water Table Width Rank

The classification of RAPs based on shallow water table width characterizes the natural capacity for a riparian zone to provide water quality benefits through denitrification. Riparian zones with a wide zone of shallow water table present opportunities to consistently influence groundwater with a widened buffer that includes deep rooted vegetation, leading to this classification of riparian site. These widths were determined based on a review of nitrogen removal in riparian buffers (Mayer et al., 2007).

- High – shallow water table (<1.5 m depth) extends on average to distances >50 m from the stream.
- Medium – shallow water table extends on average to distances between 25 and 50 m from the stream.
- Low – shallow water table extends on average to distances less than 25 m from the stream.

Runoff Delivery Rank

The classification of RAPs based on local runoff delivery identifies where a significant potential for runoff contribution exists, to show where buffer vegetation should be widened to at least 10 m and include stiff-stemmed grasses to effectively intercept runoff, leading to this classification of riparian sites:

- High - those RAPs that have the greatest potential to receive overland flow, and that would convey half the surface runoff from the watershed that flow through RAPs to the stream, if all areas were to contribute runoff equally. Riparian management in these sites should often be extended to include conservation treatments on ephemeral waterways that are up-gradient.
- Medium – RAPs where a buffer occupying exactly 2% of the total contributing area to the RAP would be wider than 10 meters. A 2% 'buffer-area ratio' will typically be needed to meet NRCS technical guidance (Dosskey et al., 2011). That is, if 2500/CA<0.02, where CA is the contributing area summed among bank cells in the RAP, expressed in m^2, and 2500 is the area of a 10-m wide buffer along a 250-m length RAP, then the runoff class is 'Medium'.
- Low – a 10 meter wide (or narrower) buffer provides the minimum recommended buffer- area ratio of 0.02. That is, the runoff class is 'Low' if 2500/CA>0.02. In this class, the buffer widths required for bank stabilization and for runoff interception are similar (see Tomer et al., 2015b).

Once the cross classification is applied, buffer widths are recommended for each riparian design as follows:

- A minimum of a 6 meter wide buffer (for RAPs with low runoff and a narrow shallow water table zone - SBS-type sites)
- A wider buffer (10 – 90 meters) to meet the NRCS recommended 0.02 buffer-contributing area ratio (in areas where surface runoff dominates - SSG and some MSB)
- A wider buffer (25 – 50 meters) if a wide shallow water table would allow denitrification opportunities (in areas dominated by wide zones of shallow water table – CZ, DRV, and some MSB).

The output feature class (RAP + inHUC) contains the following attribute information for each RAP:

Table 18. Riparian Analysis Polygon attributes

Attributes	**Description**
RAPID	ID field (structure is: Reach_PageNumber_ObjectID)
Strm_lngth	Length of stream defining the channel side of the RAP ---> can be divided by 250 to derive sinuosity
Wshed_Run	Contributing area in HA upstream of the RAP (channelized + lateral flow)
Local_Run	Contributing area in HA that enters the channel “laterally”, or through the riparian zone into the RAP
TD_Run	amount of local runoff in HA coming from fields identified as being tile-drained
NTD_Run	amount of local runoff in HA coming from fields identified as being non tile-drained
SWT_Width	Average width of shallow water table zone (< 1.5 meters) within the RAP
SSWT_Width	Average width of semi shallow water table zone (1.5 – 3 meters) within the RAP
MWT_Width	Average width of medium water table zone (> 3 meters) within the RAP
SWT20_50	Average soil organic carbon (in g/m^2) in the shallow water table zone within the RAP, at a depth of 20 – 50 cm
SSWT20_50	Average soil organic carbon (in g/m^2) in the semi-shallow water table zone within the RAP, at a depth of 20 – 50 cm
SWT50_100	Average soil organic carbon (in g/m^2) in the shallow water table zone within the RAP, at a depth of 50 - 100 cm
SSWT50_100	Average soil organic carbon (in g/m^2) in the semi-shallow water table zone within the RAP, at a depth of 50 - 100 cm
BufCARat10	Ratio of the area of a 10 meter buffer (2500 m^2) divided by local runoff. NRCS guidelines suggest an area/runoff ratio of at least 0.02, and wider buffers are suggested for ratios < 0.02
RunoffRank	Runoff Delivery Rank: High, Med, or Low
WTInt_Rank	Shallow Water Table Rank: High, Med, or Low
RAP_Func	Riparian Buffer Design Type
NRCSwidth	= (Local_Run * 10000 * .02) / 250 Note ‘Local_Run’ is as defined above.
BuffWidth	Suggested buffer width (in meters). See below.

The suggested buffer width for each RAP is populated using the following table, based on RAP_Func, SWT width, and NRCS width (width needed for runoff interception).

Riparian Function	**Suggested Buffer Width (BuffWidth)**
'Multi Species Buffer' and NRCSwidth > 90	90 meters
'Multi Species Buffer' and NRCSwidth < 25	25 meters
'Multi Species Buffer' and NRCSwidth >= 25 and NRCSwidth <= 90	NRCSwidth
'Critical Zone' and NRCSwidth > 90	90 meters
'Critical Zone' and NRCSwidth < 25	25 meters
'Critical Zone' and NRCSwidth >= 25 and NRCSwidth <= 90	NRCSwidth
'Stiff Stemmed Grasses' and NRCSwidth > 90	90 meters
'Stiff Stemmed Grasses' and NRCSwidth <= 90	NRCSwidth
'Deep Rooted Vegetation' and SWT Width > 50	50 meters
'Deep Rooted Vegetation' and SWT Width <= 50	SWT Width
'Stream Bank Stabilization' and NRCSwidth < 6	6 meters
'Stream Bank Stabilization' and NRCSwidth >= 6	NRCSwidth

6. UTILITIES

Included in the ACPF Toolbox are a suite of programs designed to assist the user in developing and maintaining the data that is used during conservation planning activities. The goal of including these tools is to allow the user to become independent of the authors in their use of the ACPF in the future. At this release, the following utilities are included;

- DEM: Pit Fill / Hole Punch - used to create an enhanced DEM that smoothes the surface while maintaining 'true' depressions.
- Get NASS CDL by Year - extract the NASS CDL data for the input year and modify it to work within the ACPF processing framework for the selected watershed.
- Update Edited Field Boundaries - rebuild the land-use lookup tables based on the contents of an edited field boundary feature class.

6.a DEM: Pit Fill / Hole Punch

Required Inputs	**Outputs**
Unfilled DEM (DEM + inHUC)	Conditioned DEM raster (Input DEM + '_p' + inHUC)
Maximum Fill Depth (Z-units)	

The ACPF Toolbox requires a high-resolution digital elevation model (DEM) suitable for terrain analysis and hydrologic modeling. The process to produce DEMs derived from active sensors datasets (i.e. LiDAR) can be challenging. These products are subject to high variability and the result is likely to include many pits and small depressions that should be considered artifacts of the collection process. In order to remove slight irregularities, the Pit Fill / Hole Punch tool can be used to create an enhanced DEM that smoothes the surface while maintaining 'true' depressions.

Pit-filling is the process by which all 'one cell sinks' are removed from a DEM. One cell sinks are those cells which are deeper than all surrounding cells but do not have any other cells contributing flow to them. The cells are removed by the process of setting all sinks (from the Sink tool) in the DEM to null. The DEM is then filled and a difference raster (filled - unfilled) is calculated. All cells that have positive fill are 'one cell sinks'. The elevations of these cells are changed to the filled elevation and all other cell elevations remain unaltered.

Hole-punching is a process where only 'true' depressions greater than a supplied depth parameter are retained in the output DEM. This process was developed to overcome the inconsistent filling of sinks in ESRI's Fill tool. The hole-punching tool begins this process by filling existing depression in the initial DEM using the Fill command. The difference, or depth of fill, between the initial and filled DEM is then calculated and all areas with positive fill are turned into unique 'fill regions' using Region Group. Depth and area statistics are calculated for each region and those meeting or exceeding the depth criteria (i.e. are deeper than the supplied depth parameter) are retained by setting the region's sink cells to Null in the initial DEM. The DEM is then filled again; the water 'flows' out the bottom of the previously identified depressions through the 'Null' sinks; and then new 'fill regions' that remain can be defined and evaluated. This process continues iteratively until no fill regions greater than the criteria remain. The final step is to return the original elevation values to all of the 'Null' sinks created during this process, creating a fully populated DEM.

- The input DEM can be a file-geodatabase raster or an independent file system raster that is supported by ArcGIS.
- The output raster will be returned in the same format as the input raster, unless the user chooses a different output format.
- The Maximum Fill Depth represents the deepest fill depth allowed in the output raster. No depressions deeper than this value will be filled.
- The Maximum Fill Depth value should be input using the same Z-units as the input raster. Typically 0.0-1.0 for Z-units in meters and 0-100 for Z-units in centimeters.
- The ACPF does not support horizontal units that are not in meters, thus the use of this tool with an elevation raster with horizontal units in meters and Z-units feet may require some thoughtful introspection to achieve a suitable result.

6.b Get NASS CDL by Year

Required Inputs	Outputs
Buffered Boundary feature class (buf + inHUC)	ACPF Land Use raster (wsCDL + Year)
Desired Year of NASS CDL data	

The NASS Cropland Data Layer for the ACPF has been assembled to support agricultural conservation planning in the states of Iowa, Illinois, and Minnesota. The **get NASS CDL by Year** tool allows ACPF users to augment the current six years of land use data found in the traditional ACPF database structure. The tool will extract the NASS CDL data for the input year and modify it to work within the ACPF processing framework for the selected watershed. It is important to note that not all states have the same period of record when it comes to the NASS CDL; some states, Illinois and North Dakota, have data back to 1999, while others have fewer years of data. The conterminous 48 states have a complete record starting in 2008. If you input a year that is incongruent with the states period of record, the tool will likely fail. See the metadata page, noted below, to determine of your area of interest has data for the year in question.

The metadata that pertains to the original NASS Cropland Data Layer can be found on the home web site at http://www.nass.usda.gov/research/Cropland/metadata/meta.htm.

- The NASS CDL data will extracted to the boundaries of the Input Buffered Boundary feature class. Traditionally, this is the ACPF 'buf' feature class (i.e.buf070802010302), which was established as a 1,000 meter buffer around the watershed's field boundary feature class. The ACPF 'buf' feature class was used to extract the existing land use data in the ACPF watershed file-geodatabase.
- The output land use raster will use the ACPF naming convention for land use data (i.e. wsCDL2009).
- The output land use raster will have the same projection as the Input Buffered Boundary feature class argument.
- The ACPF Land Use Lookup table is used to populate required fields in the ACPF land use rasters. A copy of the 2014 table has been included in the ACPF install directory.
- Valid years are from 2000 to 2020...but its only 2015, so we are planning for the future.

6.c Update Edited Field Boundaries

Required Inputs	**Outputs**
Edited Field Boundary feature class	Updated Field Boundqry feature class (FB + inHUC)
'Less Than' feature size (Acres)	
ACPF Land Use lookup table	

The ACPF field boundaries dataset has been assembled to support field-level agricultural conservation planning. The original data used to create this database are the pre-2008 Farm Bill FSA common land unit (CLU) datasets. Please note that all USDA programmatic and ownership information that was associated with the original data have been removed. Beyond that, these data has been extensively edited to reflect crop-specific land use consistent with 2009 land cover as derived from 2009 NASS Crop Data Layer datasets and 2009 aerial photography, and no longer reflects discrete ownership patterns.

As the original field boundary data were constructed using 2009 imagery, users of the ACPF Toolbox may find it necessary to update these data to reflect current conditions. The relationship between the field boundary feature class and the land-use lookup tables (e.g. FB070801050403; LU6_070801050403 and CH_070801050403) requires a one-to-one relationship based upon the FBndID field. If the field boundary feature class is edited, this relationship will be corrupted. The Update Edited Field Boundaries tool will rebuild the land-use lookup tables based on the contents of an edited field boundary feature class, using the NASS CDL rasters present in the watershed's file geodatabase.

Process

- The user inputs an edited version of the original field boundary feature class (e.g. FB070801050403_edit). The user must make a copy of the original field boundary feature class for editing purposes...the original feature class is an invalid input to this tool.
- When running this tool for the first time, the original field boundary feature class will be renamed to append '_orig' to the feature class name.
- Only existing watershed land use rasters will be used to update the new land use lookup table. The land use rasters must be named as 'wsCDL' + Year (e.g. wsCDL2012) or they will not be included in the processing.
- The 'ROTVAL' field must exist and be populated in each land use raster. The appropriate values for 'ROTVAL' can be found in the ACPF Land use Lookup Table. This table should exist in the base directory of the "ACPF" download folder.
- Six (6) years of land use data (rasters) must exist locally in the watershed file-geodatabase for the tool to run.
- The user may exclude small fields from processing by assign a numeric value to the 'Less Than' feature size argument. The default is 15 acres and the minimum value is 5 acres. Any field that has an area less than or equal to the input value will be assigned a GenLU value of 'Less Than 15 acres' or whatever the input value entered.

- The ACPF Land use Lookup Table enables the necessary assignment of a generalized, single-letter crop to each cover type in the land-use rasters. A copy of this table, ACPF2014_CDLlkup.dbf, is included in the main ACPF Toolbox directory.

7. Evaluating and Using ACPF Results

This Section provides brief advice towards using the ACPF results you have developed and placing them in context with and incorporating them into the watershed planning process. As a part of this, you need to ask yourself (and/or your planning team) four questions:

Do I have all the data I need to complete my inventory of conservation opportunities in this watershed? You should assume the answer to this is 'no'. Several states have information on locations of springs, tile drainage systems, biological resources (rare species), and wetlands. Planning must be done in a multi-resource context. Learn about other sources of information affecting water and other resources and be sure to access them. When we have considered that conservation opportunities beyond what ACPF map products can show in test watersheds may exist, we consistently identified features ranging from springs to gravel pits that could further considered for uniquely designed water quality improvement opportunities. Several of these appeared to be important, perhaps even critical, opportunities.

Are there conservation opportunities concerning land use and/or land use conversion in this watershed? This is probably the case, and the ACPF output should again be supplemented here. Essentially, what you have done in applying the ACPF toolbox is to identify where specific conservation practices can be used to interrupt and/or detain water flows at landscape and field scales, and you have conducted a riparian assessment that can be used to evaluate current, and to identify options for improving, riparian management in your watershed. Land use (agricultural) practices and land cover suitability are also critical topics for improvement of soil health and of watershed management (see Tomer et al., 2013), but we have not pushed these considerations in any specific direction within the ACPF toolbox. Be aware that additional geographic analysis to identify vulnerable lands will be beneficial to planning in many if not all watersheds. Soil survey and slope information may be used, as well as secondary terrain attributes (topographic wetness index, sediment delivery index) to help identify vulnerable lands and prioritize additional opportunities for watershed improvement. The TauDEM tools provide an excellent set of terrain analysis products that can help, and working with erosion-prediction tools will provide good information as well. Vulnerable lands assessment is being considered for future tool development as part of the ACPF.

How should I go about verifying the information I have developed? By using these tools (and analyzing other data gathered to address the above two questions), you have developed a unique data resource that is customized to the subject landscape and watershed. As with all data sources used in resource planning, their utility and accuracy should be evaluated. We have found detailed field reviews to be very helpful in this process in test watersheds. In some watersheds, it will be helpful to locate culverts or other drainage infrastructure to validate your edits to the LiDAR-based DEM to enforce hydrologic routing. If the ACPF results are to be followed by use of additional tools that enable engineered practice designs to be developed, then there may be cases where the accuracy of the LiDAR-based DEMs themselves should be confirmed with ground based topographic surveys.

How do I go about using these results to engage stakeholders towards participation in watershed planning and implementation? Briefly, with a sense of open-mindedness. There are as many ways to approach the question of stakeholder engagement as there are watersheds. We have found producers who are able to verify and endorse several results from ACPF planning tools, and others who have said some practice suggestions were not realistic. Expect to see a range of stakeholder responses to ACPF outputs. Ideally, ACPF results might best be used by landowners in a community-based and adaptive effort towards watershed improvement. However, in reality, conservation practices are installed by placing one practice in one field or one riparian setting at a time. Schemes to incorporate watershed scale information into farm-scale planning can now be developed using your ACPF results as well. Understanding each of your farmers/landowners as individual businessmen and conservationists will help you determine a pathway towards watershed planning involving both teamwork and individual decision making.

Please let us hear your feedback and lessons you learn in using these tools and applying them towards management of agricultural watersheds.

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