Rapid Procedural Methods for Guiding Subwatershed Conservation Analysis in Northeastern Iowa

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Keywords: Geographic Information Systems, Williams Creek Subwatershed, Yellow River Watershed, buffers, erosion, images, karst, slope, soil, sinkholes, stakeholders

Abstract

Northeastern Iowa has seen dramatic landscape changes in the last 160 years. What was once a pristine forest and prairie landscape embedded in karst topography is now encased in intensified agriculture and urbanization. The result of our rush to convert these naturally sustained habitats of northeastern Iowa's Yellow River Watershed into a "better life" and recent attempts to maximize profits with concentrations of land holdings and production methods is a degraded state of the environment, as reflected in water quality reports. A rapid procedural method for conservation measures using geographic information systems was developed by this research and tested on the Williams Creek Subwatershed. The results describe a subwatershed procedural methodology while indicating 179.2 acres of impervious cover and 5.4 acres of potential erodable slopes contained within a buffered Postville headwater stream. The procedures developed for this project can be modified and applied elsewhere to help target land conservation measures such as riparian buffers, erosion and sediment controls, as well as land treatments and other stewardship activities.

Introduction

The Yellow River Watershed (YRW) conservation partners are in desperate need of finding procedural methods that complement field work with geographical information system (GIS) applications. The use of these techniques is exceedingly important for the Yellow River subwatersheds because of time constraints and limited funding under current economic and environmental conditions.

By addressing several conservation issues with GIS applications for subwatersheds, a rapid procedural methodology is explained and performed in this project. This type of project management system will accomplish the goals set by dedicated partners for northeastern Iowa. Through this procedure dedicated partners will be able to manage and conserve subwatersheds in a rapid time frame and with limited funding.

Landform analysis has shown that individual watersheds have their own unique character. Among many other important factors, watershed assessment criteria call for evaluations of landcover, slope, and soil types within various geological formations (Dopplet et al. 1993).

Formulating watershed conservation methods may be compromised by believing that a terraced slope or buffered stream will prevent pollutants from invading our waters, when the actual causes of observed effects may be located many miles from the problem. Managers must include all appropriate conservation methods when considering the various ecological degradations caused by urban and rural impacts to our watersheds. It is as important to diagnose and treat sources, as it is to recognize symptoms.

Conversion of forests, wetlands, and meadows, to buildings, roads, ditches, and recreational lawns creates additional layers of unnatural surfaces that can exacerbate erosive agricultural practices. Because of these unnatural surfaces, proportions of our stream channels are no longer in equilibrium with their hydrologic regime. These higher flow rate events of the urban and rural streams are capable of performing more "effective work" in moving sediment than they had been done before the streams were altered (Wolman, 1954). However, in a natural setting, surprisingly little rainfall is converted to runoff because permanent vegetative cover assists infiltration and complements natural catchments and helping to supply deep-water aquifers and adjacent surface waters.

Since intensive efforts to enhance stream hydrology, channel stability, and riparian habitat have yet to be defined or implemented on the YRW, a comprehensive planning process has been recently targeted for assessment of resource potentials and conservation needs (Hawkins, 2003). Currently, various federal, state, and local conservation agencies in cooperation with non-government organizations and other private partners have been focusing on the YRW subwatersheds in the "Driftless Area" of northeastern Iowa.

YRW is approximately 154,666 acres within the jurisdictions of Allamakee, northern Clayton, and eastern Winneshiek Counties. Several perimeter towns are located in the YRW (Figure 1). Major U.S. and state highways that traverse the YRW karst landscape connect these towns.

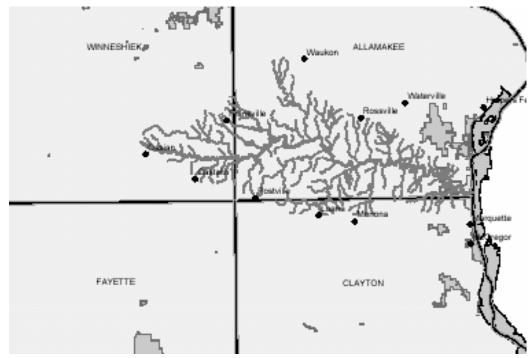

Figure 1. Counties impacted by the Yellow River Watershed.

YRW includes the 8,963 acre Williams Creek Subwatershed (WCS) where ongoing water quality studies are being carried out by the United States Geological Survey (USGS) and volunteer groups (USGS, 2003). A water quality project with cooperating farmers throughout the WCS is currently under state supervision as well.

The YRW is mapped in ArcView 3.3 geographic information systems and contains the WCS as one of 12 subwatershed designations (Figure 2).

Figure 2. Yellow River Watershed, including the Williams Creek Subwatershed.

The YRW landscape is characterized by rugged karst topography with regions of carbonaceous rock formations typified by limestone caverns and sinkholes. The surface and groundwater runoff from this karst landscape eventually flows into the Mississippi River near Effigy Mounds, Iowa (Figure 3).

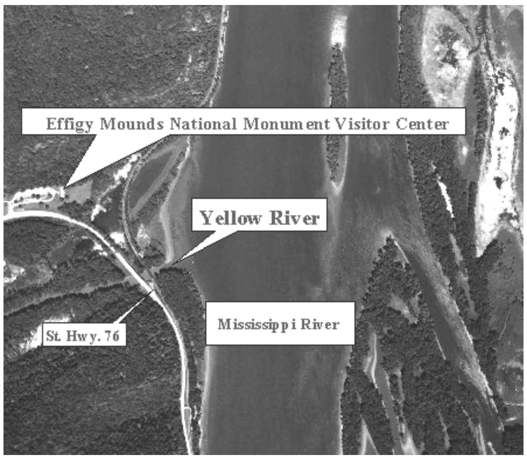

Figure 3. Yellow River-Mississippi River confluence located in Allamakee County. Color infrared photography was downloaded from the USGS web site.

For reference purposes, the YRW is further broken down into smaller geographic units of 12 subwatersheds (Figure 4). The subwatershed management units (SWMUs) are deemed most practical for implementing local

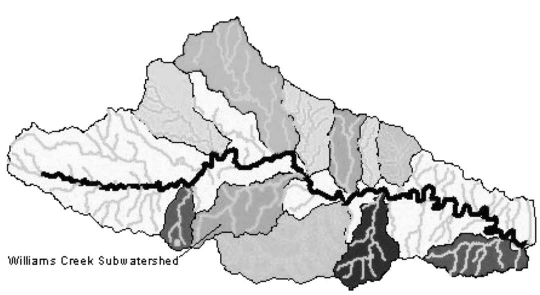

Figure 4. Yellow River Watershed comprises 12 subwatersheds.

conservation plans. These SWMUs have their own unique water resource characteristics and need independent analysis and adaptive management objectives (Center for Watershed Protection, 1998). Each of the SWMUs contains a network of small water channels that are known as headwater streams. While each headwater stream is short and narrow, collectively these streams represent the majority of the drainage network of any SWMU. Headwater streams can be exceptionally vulnerable to development from nearby towns of Postville, Monona, Waukon, and Ossian in the WCS (Figure 2).

The rapid procedural methodology for guiding subwatershed conservation modeling and analysis provides a comprehensive framework for applying management tools. This holistic model develops a pathway for achieving subwatershed conservation results. The model can be applied and adapted to other subwatersheds in a manner that also achieves the water resource goals envisioned by future YRW partners.

Locally, managers should consider the subwatershed as an appropriate planning unit because it is small enough to allow monitoring, mapping, and assessment tasks in a rapid time frame. A subwatershed conservation analysis can generally be completed in months, allowing sufficient opportunity for goal development, agency coordination, and stakeholder involvement (Center for Watershed Protection, 1998). A shorter timetable enables partner groups to generate subwatershed plans in a systematic cycle of information gathering and conservation practice implementation.

For this management project and in cooperation with the United States Fish and Wildlife Service (USFWS), the WCS procedural methodology assessed the importance of impervious surfaces and the distribution of erodable cropland juxtaposing hydrology, slope, and habitat buffering of WCS streams and catchments, where contributions from individual urban development projects or rural landscape alterations are easily recognizable. This methodology incorporates datasets that will deliver objectives that will "set a GIS model" for the other subwatershed conservation achievements in the region.

Methods

Watershed management requires comprehensive resource inventory, database development, analysis and evaluation of alternative conservation strategies. GIS provides useful tools for organizing, summarizing, correlating, and dynamically presenting plans or projects designed to achieve objectives defined by watershed managers.

The "rapid procedural" approach combines the analysis of various "off the shelf" data layers, such as landcover, hydrology, elevation, potential erosion areas, and recent color infrared imagery, available as downloadable files from state web sites, with stakeholder feedback and information from ongoing stewardship programs. Acknowledged throughout the project is the local concern for controlling erosion, sedimentation and nutrient impacts to public waters, addressing suburban stormwater and point-source discharges, as well as agricultural runoff, and for the maintenance of sufficient quality habitat for fish, and other wildlife, and overall ecosystem health.

An organizational flowchart of a specifically guided subwatershed analysis scenario used in this procedural application employs GIS applications. This process of information gathering and numerical analysis is centralized through the conservators who initiate and lead the subwatershed project. Their goal sets the guidelines for all the parties involved in the project.

The procedures provided to project managers are established by developing an organizational flowchart analysis of WCS (Figure 5). This flowchart simplifies applied conservation measures by incorporating GIS applications as a project management tool. The flowchart states procedures that can be applied to other subwatersheds in the region as well.

Step 1: Setup maps

Subwatershed maps are needed for all subwatershed plans. These maps depict basic information needed to make

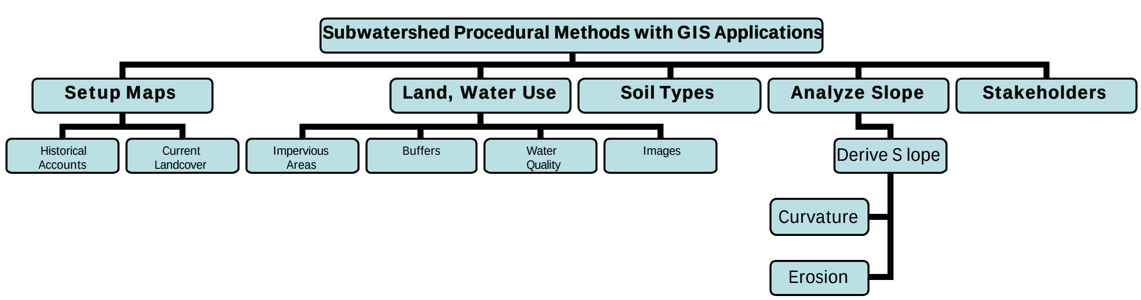

Figure 5. Subwatershed organizational flowchart for guiding subwatershed conservation analysis.

management decisions. Historical subwatershed maps begin procedural methods by identifying key landforms.

The objective of an historical account of a subwatershed is not to retreat to pre-settlement conditions, which are no longer practical or attainable, but to optimize economic and environmental benefits for land owners and society as a whole. Historical accounts for a subwatershed provide the background information from which to obtain crucial direction in planning conservation measures.

In this study, historical land survey records of the WCS provide a general planning base line for guiding restoration land projects. The historical data was traced, digitized, and incorporated into an ArcInfo project. The mapping of the WCS from years 1832 to 1859 display a large meadow splitting the two large forested areas (Figure 6). This map was prepared

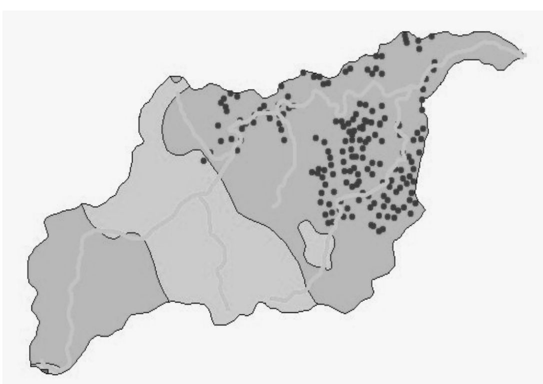

Figure 6. Years 1832-1859 Map of Williams Creek subwatershed karst topography containing prairie (middle), forest (dark sides), and sinkholes (dots).

with the aid of a global positioning system (GPS) for ground-truthing sinkholes and combining historical data provided by the United States Department of Agriculture (USDA) and the Natural Resources Conservation Service (NRCS), Waukon, Iowa (USDA, 1989).

The landscape changes that occurred when settlements arrived can be generally appreciated by noticing the dramatic differences from the historical landscape data to that of the year 1992 landcover datasets that were reclassified in ArcMap (ESRI, 2002).The subwatershed base map (Figure 7) was the first map produced for this subwatershed planning

Figure 7. Williams Creek Subwatershed year 1992 including roads and streams (lighter color lines), pasture/hay (darker areas),and row crops (lighter areas).

process. The map contains basic information for the entire subwatershed. This map defines the subwatershed, identifies resource protection areas, and acts as a template on which other management maps are based.

Roads and streams (Figure 7) were edited in ArcInfo and topology was created from the Allamakee, Winneshiek, and Clayton County datasets. These datasets were imported into an ArcView 3.3 project. In ArcView, the GeoProcessing Wizard merged and clipped the three-county datasets. The Grid Analyst extension tools (Saraf, 1998) extracted the grid National Land Cover Data (NLCD) from the WCS polygon boundary. Previous fish kill locations (square blocks at left-center of Williams Creek) along with their attributes and wastewater treatment plants (lower left triangles) were mapped to distinguish previous areas of environmental concern in the WCS.

Management maps offer information to organizations regarding the future management of the resource. Some management maps can be made to incorporate current and proposed zoning, buffers, and existing and proposed stormwater management facilities for impervious areas.

Step 2: Land and Water Use

This conservation outline prepares a relatively unique method for mapping subwatersheds and the aquatic corridor. The mapping system plays a key role in helping planners, citizens, and developers visualize the spatial implementation of the subwatershed plans. Watershed managers need to make careful choices about which data layers to include on the map. GIS data layers are applied by combinations based on choices made by the desires of the stakeholders and managers.

Impervious Areas

The process of urbanization and suburbanization has a profound influence on hydrology, stream morphology, and aquatic ecology (Horner et al. 1996). Recent research has shown that exceeding a 25% threshold of impervious cover on any surface in an urban landscape that cannot effectively absorb or infiltrate rainfall can have a dramatic negative effect on water quality.

GIS and hydrological information provides evidence suggesting that impervious cover is linked to the quality of other subwatershed resources, such as lakes, reservoirs, estuaries, and aquifers. Sensitive streams are characterized by having less than ten percent impervious cover with a high habitat/water quality rating (Booth and Jackson, 1997). In some parts of the country, stream degradation has been linked to percentages of subwatershed impervious cover as low as ten percent, and the effect becomes more severe as impervious cover increases (Schuler, 1995). As the level of impervious cover increases, number of sensitive species decreases.

Necessary precautions in land and water use include inspecting septic systems, controlling urban sprawl, providing product recycling centers, and placing restrictions on package treatment plants. Stormwater "hotspots" and other activities that generate highly contaminated runoff should be actively prosecuted. Regulations already in place, such as restrictions on areas that may alter the stream flow or quality of biodiversity are enforced by the National Pollutant Discharge Elimination System (NPDES) of section 402 included in the Clean Water Act (CWA). The CWA is federally mandated to regulate point and non-point source pollution (Sullivan, 1999).

Subsets of GIS landcover shapefiles and photographs with scales of 1:3000 meters for roads and structures obtained from the NRCS were used to interpret impervious areas. GIS applications are the most cost effective way to measure and estimate impervious cover, although not as accurate as direct measurement.

Buffers

Buffers can be placed along a stream or shoreline or around natural wetlands surrounding aquatic corridors where land and water meet. A buffer has many uses and benefits. Its primary use is to physically protect and separate a stream, lake or wetland channel from future disturbance or encroachment. For streams, a network of buffers acts as a right-of-way during floods and sustains the integrity of the stream ecosystems and habitats. Technically, a buffer is one type of land conservation area, but its functional importance in watershed protection merits some discussion on how they work and why they are significant.

Past research has suggested that each stream for a subwatershed should be analyzed starting with its headwaters (Center for Watershed Protection, 1998). Headwater streams are important starting points for habitat improvement. The buffers establish a means for restoring headwater natural areas. However, when the headwater stream is transgressed with urban encroachment and tiling, adverse landscape alterations take place and stream buffer effects are minimized. The disruption of normal channel flow from urban runoff effectively "short cuts" the buffer. In addition to increasing channel flow, roads with adjacent ditches have the capability of transferring pollutants and bypass the benefits of buffers.

Buffers have the ability to remove pollutants traveling in stormwater or groundwater that flows through them. They have been found to remove sediment, nutrients, and bacteria from stormwater runoff and septic system effluent in a wide variety of agricultural and urban settings (Dunlap and Harrison, 1997). For overland and some subsurface transport, the buffers aid in runoff prevention, but stream bank erosion problems still exist when the hydrological water levels are not at a presettlement flow regime. This is aggravated as farmers continually move water off their fields to plant and harvest crops and cause a higher degree of stream flooding.

The use of several techniques, including riprap, buffers, contour farming, and no till are known to reduce runoff down to T level, considered a level of designation where the soil will regenerate on its own. The T level is calculated at about two to three tons per acre in northeastern Iowa. Bill Kalishek, the fisheries biologist at Decorah, Iowa, states that by using these conservation techniques, "We've addressed the system's problem, not the cause (Kalishek, 2003)." Remember, buffering is not a cure-all method for addressing conservation practices in a subwatershed. However, buffering in combination with other conservation measures, contributes to habitat improvements. Indeed, habitat improvements involve buffering processes that take into account historical or significant topography. Sinkholes located within the WCS and YRW are examples of significant landform areas of karst topography.

There are approximately 177 sinkholes located in the WCS where agricultural runoff contributes to non-source groundwater pollution. Often surface areas surrounding sinkholes are cropped or pastured, producing runoff that delivers nutrients to streams. Dye testing measures can assess where these nutrients flow in the WCS.

Stream bank erosion areas should be actively managed and monitored by cooperative parties as part of the overall health of the ecosystem and for water quality improvements. Water quality and temperature gauges provide a fisheries biologist with essential information on cold, cool, and warm water stream regimes. Buffered stream banks with proper native vegetation improve water quality and temperature requirements as well.

Land conservation applications need to identify, protect and manage springs, sinkholes, spawning areas, and riparian wetlands as well as prohibit uncontrolled use of steep slopes, floodplain forest and other critical habitat conservation areas. Current research suggests that stream containment, pollution control, and declining migratory bird habitats (Klass and Knutson, 1997) are becoming significant priorities. Buffering these areas provides wildlife habitat and recreation. In many regions of the nation, the benefits of a stream buffer are amplified when managed in a forested condition. The forest conditions promote the greatest rate of water infiltration.

Water Quality

Monitoring water quality requires critical data collection in order to apply preventative measures for preserving an area. Continuing water quality studies are being conducted by the USGS for the WCS. A preliminary study of those findings is included for WCS water quality results. Water quality data is gathered by conducting multiprobe techniques in Williams Creek. The data present the necessary recordings for identifying water quality "trouble spots". Data for specific conductance, pH, and water temperature were presented by the USGS in Iowa City, Iowa (USGS, 2003).

Imagery

Land use becomes exceedingly clear when buffered areas are displayed with finer spatial and spectral resolution images. Conservationists, to more accurately analyze potential land conservation areas, have suggested images at scales of less than 1:1000 meters (Center for Watershed Protection, 1998).

Informational extractions of images increase the accuracy of a subwatershed analysis. Image accuracy (Estes et al. 1983) is increased by removing system noise, atmospheric interference and sensor motion. Image restoration can reduce spectral channels and data demands as well (ESRI, 1998).

Each of the spectral channels of a mutispectral image forms a separate image. Each channel emphasizes landscape features that reflect specific portions of that spectrum. Changing spectral bands also reduces duplicate information so that the data sets can include the maximum information using a number of statistical relationships that exists between channels. Changing spectral bands with high-resolution images in combination with radiometric and geometric enhancements provide essential mapping aids for changing land use practices to a presettlement state.

Digital images are classified by assigning pixels to classes. Classes form regions as a uniform mosaic of parcels identified by color, shape, and symbols. The process of informational classification of images insures that specified areas of conservation initiatives are identified and applied as layers. These informational classes are obtained by recording brightness values of each image. Links between spectral and informational classes are used to define primary areas of interest (ESRI, 1998).

The 1-meter pixel color infrared (CIR) images were interpreted by the histogram minimum method while using regression techniques for examination of values of each band and their contribution to atmospheric scattering. These values were adjusted with the color of black set close to zero, indicating water. This type of analysis is only an approximation of radiometric image enhancement.

Step 3: Soil Types

Soil maps from the USDA-NRCS for the WCS show the formation of Fayette-

Nordness-Dubuque associations with some Lacrescent-Fayette-Village associations (USDA, 1989). Predominant Fayette soils formed under trees and the vegetation that existed underneath them. These soils are considered by NRCS staff to be well suited for reforestation of highly erodable cropland using the direct seeding method.

The parent material consists primarily of loess, a material deposited by the wind containing silt and clay and small traces of sand. Another parent material, alluvium, was deposited throughout the streams of the WCS. The silty alluvium washed from loess-covered slopes in the uplands. In addition to the loess and alluvium parent material, there are also colluvium, a soil material and rock fragments, and residuum, a weathered material that is silt and clay weathered from limestone or sandstone with a predominantly reddish hue. Soil formation is directly affected by climate, human activity, time, and living organisms of the parent material (USDA, 1989).

Relief of level to steep topography affects WCS soil formation through its effect on drainage. While level soils flood, other areas allow runoff on sloping surfaces with less penetration as seen on Nordness soils. The WCS has a wide slope range and can affect other soil properties, such as carbonates and clay in the B horizon. These properties decrease with increasing slope.

Since slope aspect, topographic position, and slope gradient have significant effects on soil formation, it is possible to examine these factors in combination to understand hydrological regime characteristics of the WCS. In addition, GIS spatial hillshading can be used to find soils on south-facing slopes which are warmer and drier than north-facing slopes. These slopes contain soils that allows for greater runoff and nutrient flow to streams and exacerbates erosion.

Information on soil formations contained within the WCS allows a GIS spatial analyst to assist planners in identifying areas of erodable slopes. The Fayette silt loam soils ranges from karsts with 2 to 14 percent slopes to 25 to 40 percent slopes. These slopes range from erodable to severely erodable. In this project, a systematic slope analysis was completed to allow WCS planners to prioritize areas of special concern.

Step 4: Derive and Analyze Slope

Land conservation for any subwatershed landscape analyzes important slope derivations. The landscape has slope characteristics that move and channel water when the normal hydrological regime of streams is maintained at sustainable levels, erosion and sediment control are contained, and contaminants are kept at bay.

The slope for the WCS was derived through the use of grid data sets. These data sets produced slope, hillshade, and their derivatives. The second derivative corresponds to the rate of change of slope in an area or the curvature of that part of the surface. The WCS potential erosion areas greater than or equal to 10 degrees were then ranked for prioritizing conservation efforts.

Step 5: Stakeholder Involvement

A subwatershed stewardship program for dedicated partners is necessary for including the processes and assistance throughout the preceding steps. Stakeholder involvement fosters a mostly favorable audience for a free exchange of ideas. For example, notify anglers or stream stewardship organizations such as

"Trout Unlimited" and farmers and other landowners whose land is directly affected by conservation techniques. Stakeholders provide feedback for planning and empower participants with a broad consensus to approve a subwatershed plan.

A questionnaire sent to the participating individuals at a conservation initiative meeting in Waukon, Iowa, asked for the most important factors that have a negative impact on watersheds. The questionnaire provided information for conserving the WCS.

Results and Discussion

The questionnaire results from polling 20 landowners and non-governmental and governmental employees indicated that altered land practices had the largest perceived negative impact on watersheds (Table 1). The following table was given a rating of 6 as the highest and 1 as the lowest negative impact. The ratings were added, recorded, and tabulated to reflect the levels of concern and potential for stakeholder involvement in the restoration of the YRW. The questionnaire gathered information that demonstrates basic attitudes that exemplify current awareness of a representative sample of stakeholders working on watershed projects.

The results indicate that farming practices and urbanization have a perceived negative impact on watersheds. Several negative impact answers in the questionnaire are related. For example, point and non-point source pollution have been known to come from farming practices or urbanization. Stakeholders also have concerns about water quality.

Water quality assessments conducted by the USGS in Iowa City, Iowa, established specific conductance versus time, pH versus time, and temperature versus time for upstream and downstream locations in Williams Creek for year 2002. Their results show that pH ranged between 7 and 9 and temperature between 10 to 27 degrees Celsius (Figure 8 and Figure 9). A portion of those findings are provided as a visualization of water quality measurements. These multiprobe monitoring efforts aid in localizing a cooperative conservation

Table 1. Stakeholder's watershed questionnaire ranking system

What do you believe are the six most important factors that have a negative impact on watersheds? Rate these factors from the highest (6) to lowest (1).

Altered Landscapes(Farming-Urbanization)	90
Non-point source pollution	50
Point-source pollution	48
Deforestation	42
Polluted Water	30
Feedlots	22
Exotics	17
Lack of restoration funding	17
Erosion	17
Farm Subsidy Programs	14
Lack of Education	9
Loss of Pasture/Hay	5
Air Pollution	4
Quarries	4
Deer	4
Lack of proper Zoning	3
Stormwater Mismanagement	3
Private Property Rights	3

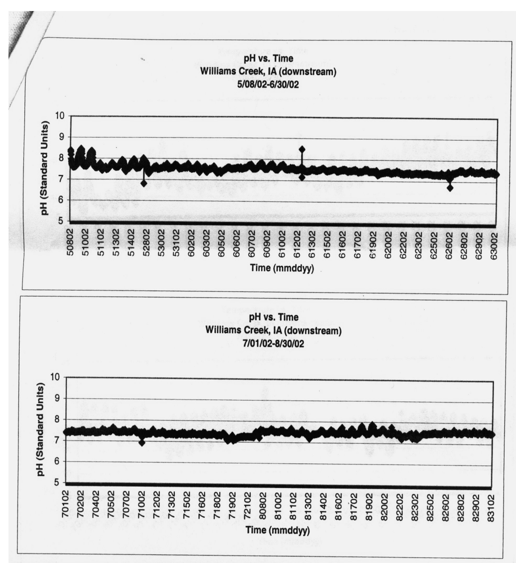

Figure 8. pH of downstream Williams Creek locations for Year 2002. Reprinted with permission from the NRCS office in Waukon, Iowa.

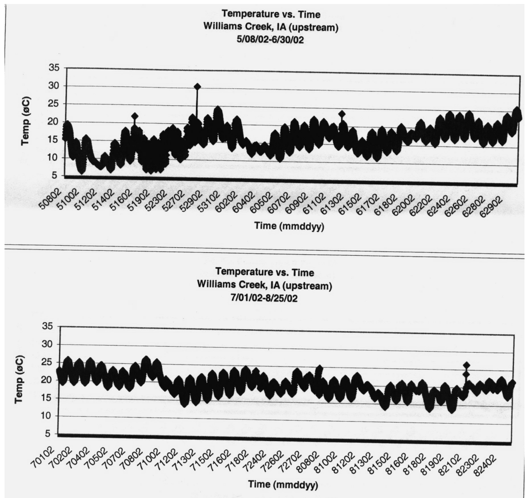

Figure 9. Temperature for Williams Creek, year 2002. Reprinted with permission from the NRCS office in Waukon, Iowa.

effort for Williams Creek. Temperature, pH, and conductance are also important components for maintaining a viable fisheries population. Water quality is directly defined by the amount of impervious area.

Impervious areas in the WCS were identified as roads, small rural housing developments and ditches (Figure 10). The

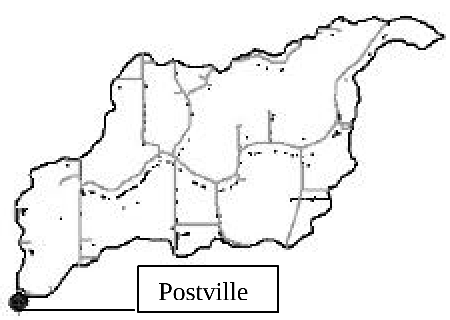

Figure 10. Impervious cover includes 173, one acre homesteads and farm structures.

XTools extension was used to tabulate impervious housing and development areas (Delaune, 2002). The total amount of impervious acres was summarized as 179.2 acres. For the WCS subwatershed, the amount is 0.50 percent of the total area. Impervious areas were also identified as other structures located in the WCS. These shapefiles were clipped and merged in ArcView 3.3. Bordering towns, roads and ditches located near the headwater drainage streams can add significant nutrients, sediments, and stream flow. Headwater reaches located near towns should be continually monitored, noting any changes in water quality. Water moving from roads to ditches should be filtered naturally before entering connecting streams.

For streams, impervious cover is also used to classify subwatersheds into various management categories. Impervious cover can be measured by direct measurement, interpreted land use areas such as road density and structures, and population data.

Another consideration is the town of Postville (Figure 11) where hydrological influences from nearby Hecker Creek have contributed contaminants to WCS. The southwestern portion of Postville is located at the beginning of Williams Creek. A 1-meter color infrared (CIR)

Figure 11. Williams Creek headwaters located in northeastern Postville, Iowa.

photograph was changed to grayscale visualizing the headwater areas and trees located along its borders.

Ditches located in the Postville area are important for management considerations. These ditches may become fast-flowing water conduits. To prevent this occurrence, it is important for the state and county to manage ditches with appropriate vegetation. Straight-pipes embedded in ditches conduct water in the Postville area as well. This type of conduction expedites water inflow into the headwater streams. Finally, road construction can also exacerbate these hydrologic alterations (Sutherland, 1995).

GIS measurement of impervious cover is more cost effective, requires less time, and enlists a smaller work force than land surveying method of direct measurement. Defining land imperviousness with GIS slope derivations also identifies locations of nutrient runoff into the streams of a subwatershed. Land and water use in combination with slope derived from Digital Elevation Models (DEM) allow managing partners to find solutions for the beginning of their conservation practices in a rapid time frame and with limited funding.

One approach to visualizing landcover is to examine elevation contour intervals and base contour lines derived from DEM data. A contour map was created for the WCS. The contours were changed to a z value of 50 feet (Figure 12). Landcover was overlaid on the DEM

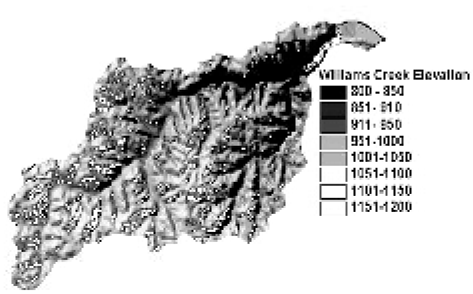

Figure 12. Hillshading and contoured landcover.

data and the hillshading algorithm was used in the Spatial Analyst extension (ESRI, 1996). Hillshading is useful for identifying areas that receive more sunlight during the course of the growing season. The darker areas in this case are located from the south and east.

Slope was derived from DEM models using the Spatial Analyst extension for possible erosion control. The slopes with the lightest contrast have the smallest grade slopes whereas the darker areas have steeper slopes. The lighter the setting is shown, the flatter the slope. Slope computes the greatest rate of change in z (height) over distance (the first derivative of the surface). The slope is expressed as degrees of rise over run. The minimum slope was 0 or flat; the maximum was 67.25 degrees (Figure 13). The mean slope

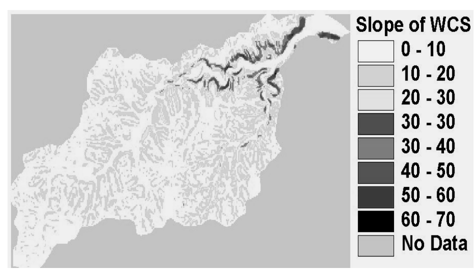

Figure 13. Slope of Williams Creek Subwatershed (in Degrees).

was 13.25 degrees with a standard deviation of 9.8. Any slope over 30 degrees is considered steep (ESRI, 1996). However, in a row cropped area, water will run off quicker and a more realistic 10-degree slope should be considered steep for Fayette soil agricultural areas (Center for Watershed Protection, 1998).

The lighter colored areas displayed as smaller slopes whereas the more northeasterly direction displays steeper slopes. These steeper areas have trees with less row cropping.

Sloping topography is characteristic of northeastern Iowa. A map query expression designating slope, displayed areas that are greater than or equal to 10-degrees for cropped land and hayfields. From the analysis menu, map query statements identified slopes greater than or equal to 10 degrees. The results were tabulated in ArcView as 1, being true for 10 degree or greater slope and false for less than 10 degrees (Figure 14).

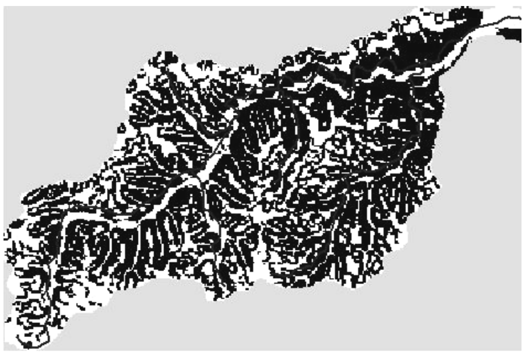

Figure 14. Slope >=10 degrees (black) and < 10 degrees (white).

After finding slope of 10 degrees or greater, a curvature request from the derived slope measures the behavior of a surface. Output delivers the rate of surface change in slope (Figure 15). The curvature request produces five cellular measures

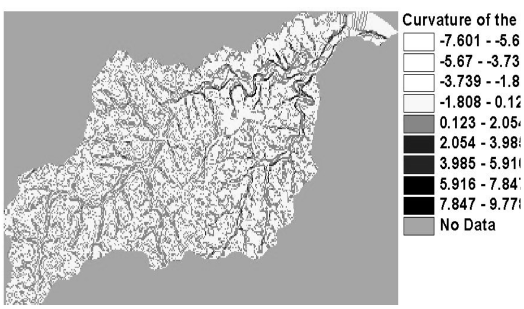

Figure 15. Curvature of the Williams Creek Subwatershed from -7.6 (depositional) to 8.778 (erodable).

of the shape of the surface. It works by fitting a fourth-order polynomial to a 3x3-m cell neighborhood centered on each input cell. The curvature grid is the primary output grid. The negative values are upwardly concave. Positive values are upwardly convex.

The Williams Creek elevation curvature model was incorporated as an Avenue programming script. The minimum curvature was -7.6 and the maximum was 9.77 with a mean curvature of 0.0105 and 0.811895 standard deviation. A negative value of curvature indicates depositional decelerating water surfaces while a positive number indicates erodable surfaces. From the curvature grid, a profile curvature grid ranks surface areas.

The profile curvature grid is a measure of the acceleration or deceleration of flow over the surface and is related to erosion and deposition (Figure 16). The

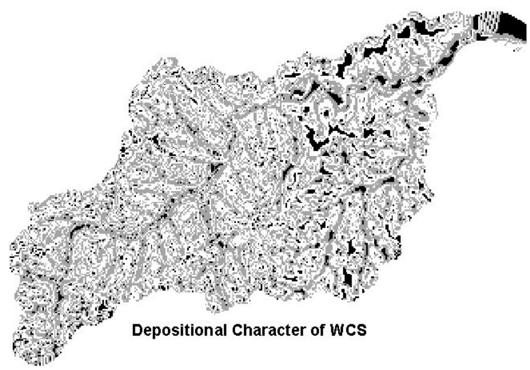

Figure 16. Williams Creek Subwatershed depositional character of a profile curvature grid with ranking system of flat (black), depositional (white), and erosional (gray) surfaces.

profile curvature grid isolates surface flow into ranking systems to delineate flat, depositional, and erosional surfaces. This ranking system provides valuable information by categorizing and delineating surface areas. Through this surface ranking system, conservation efforts for stakeholders and stewardship programs are prioritized by landcover.

The ranking system for the WCS was narrowed to two main factors, row cropping and hayfields for the primary WCS landcover. These land uses are typical of the WCS. In addition, feedlot and other land use practices were minor occurrences, but important nonetheless.

Flat surfaces are shown in black, erosional surfaces in gray and depositional surfaces in white (Figure 16). The depositional surfaces are categorized as being less destructive and given a value of 2 because water decelerates as it flows over the surface. Erosional surfaces are ranked higher (3) in terms of delivering sediment and runoff to Williams Creek and its tributaries. Flat surfaces were given values of one. By ranking the surface erosion "hot spots" and incorporating DEM elevation models of WCS, further computational parameters can be generated to prioritize localized conservation efforts.

From the profile curvature grid, the areas isolated were greater than or equal to a 10 degree slope. The Spatial Analyst extension's map query expressions of finding the "hot spots" were combined with elevation and slope grids of the WCS. The results prioritize row cropped and hay field areas (Figure 17). These erosion areas are susceptible to runoff, delivering nutrients and changing the hydrologic

Figure 17. Erosion slopes greater than or equal to 10 degree for the Williams Creek Subwatershed.

behavior of Williams Creek. From the table menu, a query of gridcode equal to 1 separated slope greater than or equal to 10 degrees from slope less than 10 degrees. There were 354.10 possible erodable acres that are greater than or equal to 10 degrees. The mean number of acres was 0.128 with a maximum of 21.743 acres and a minimum of 0.013 acres. Standard deviation was calculated at 0.711 and a variance of 0.506. The largest contiguous areas from 5 to 21.743 acres were located along the streams of the WCS.

High priority habitat restoration is culminated by including a numerical analysis of erodable slopes with imagery, buffering methods, soil types, and water quality. To accomplish this process, each headwater stream was given a 50-m buffer. The erodable areas contained within the buffered headwater streams exacerbate nutrient runoff and erosion by their proximity to Williams Creek.

Mapping the headwater reaches of a subwatershed provide important predictors of current and future water quality (Center for Watershed Protection, 1998). The buffering process of six headwater streams was performed in ArcView 3.3. Headwater streams are identified and indicated as segments 1 to 6 in Figure 18. Each headwater stream was numerically summarized for the amount of specific landcover in each of the six segments

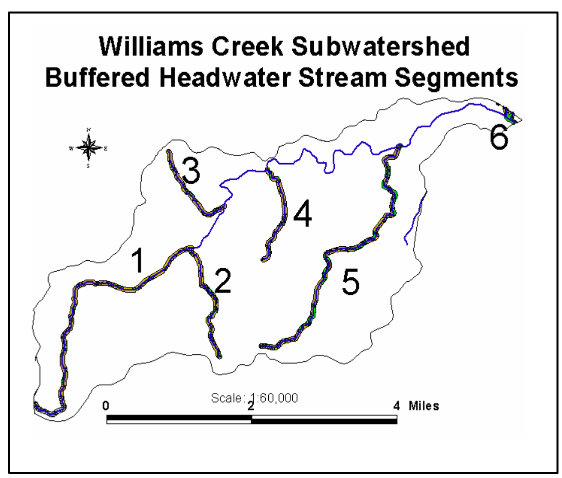

Figure 18. Headwater stream segments.

Table 2. Landcover totals calculated in acres for each of the headwater streams.

Headwater Stream Segments	1	2	3	4	5	6
Landcover						
Row Crops	4.5	3.8	0.91	0.3	1.4	0.11
Pasture/Hay	4.7	0.3	2.4	3.7	3.92	0.11
Deciduous Forest	0.2	0.1	0.51	0.1	3.11	1.194
Mixed Forest	0.007	0	0	0	0.3	0
Woody Wetlands	0.02	0.02	0	0	0.062	0.021
Grasslands/Herbaceous	0.3	0.11	0.24	0.11	0.3	0.021
Open Water	0	0	0	0	0	0.033
Urban	0.6	0.3	0	0.018	0.11	0
Urban/Recreation	0.45	0	0.02	0	0	0
Emergent/Herbs/Wetlands	0.2	0	0.02	0	0	0.012
Total Acres	10.977	4.63	4.1	4.228	9.202	1.501
Erodable Acres containing slopes >= 10 degrees of hay-row crops	5.4	1.9	1.3	1.5	1.7	0.01
% Hay-Row Crops/ Total Acres	83.80%	88.50%	80.00%	94.60%	57.82%	14.66%
% Erodable Acres/Hay-Row Crops	58.60%	46.30%	39.27%	37.50%	32%	4.50%

(Table 2). Row cropping and pasture/hay were given top priority for conservation measures because this landcover encompassed 75.5 percent of the buffered headwater streams.

Derived erodable slopes greater than or equal to 10 degrees contained within the headwater streams were recorded in acres as 5.4, 1.9, 1.3, 1.5, 1.7, and 0.01 for segments 1 through 6, respectively.

The Postville headwaters (segment 1) had the greatest area of potential erodable slope. The Postville 6473-m headwater stream is displayed with 14 sectional 9 by 9 meter CIR aerial photos. These photos depict row crops (light gray), contour strips (dark gray) and buildings or roads (white) (Figure 19). The photos were edged matched and clipped into a continuous image mosaic (Figure 20). A

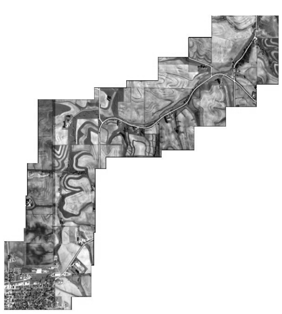

Figure 19. Postville headwater mosaiced segment.

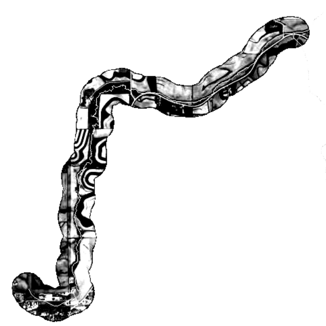

Figure 20. 50-M buffered Postville headwaters.

50-m buffer was recommended by managers for conservation landowner monetary incentives.

Aquatic corridors can be addressed at a finer scale to show the areas along the stream corridor or shoreline. A typical subwatershed of northeastern Iowa, such as the one described here, requires several aquatic corridors or shoreline maps to include all headwater stream segments. These base maps can be used as templates for individuals who conducted fieldwork and/or develop the subwatershed plan. Figure 21 of the WCS provides a visual example of a buffered imaged area along Williams Creek that has a 10 degree or greater erodable slope in need of conservation measures.

Radiometric enhancements of the Postville headwaters segment demonstrate the versatility and delineation of land use patterns through contrast and histogram stretches. The ArcView 3.3 Image Analysis extension provided the tools for separating crop and hayfields (ESRI, 1998).

CIR photos were downloaded from the Iowa NRGIS web site and used to develop a visual topographic display of the representative 6473-meter Postville headwater (segment 1) in WCS. Spatial and spectral resolutions at 1:3000 meter scales provided clear visual interpretation of a portion of that segment (Figure 21). This analysis could also be applied to other stream bank areas of the WCS. A finer resolution would be preferred if imagery becomes available.

Vegetation had a distinct appearance in certain spectral bands, a characteristic that allows it to be distinguished from other objects in the landscape.

Furthermore, the spectral signature of vegetation varies with species and environmental factors. Plants in various stages of life can be identified through these spectral channel alterations.

Vegetation has a distinct spectral signature by the very nature of reflecting green light in the visible spectrum. However, the amount of near infrared energy that is reflected is affected primarily by internal structures and the amount of moisture in the vegetation.

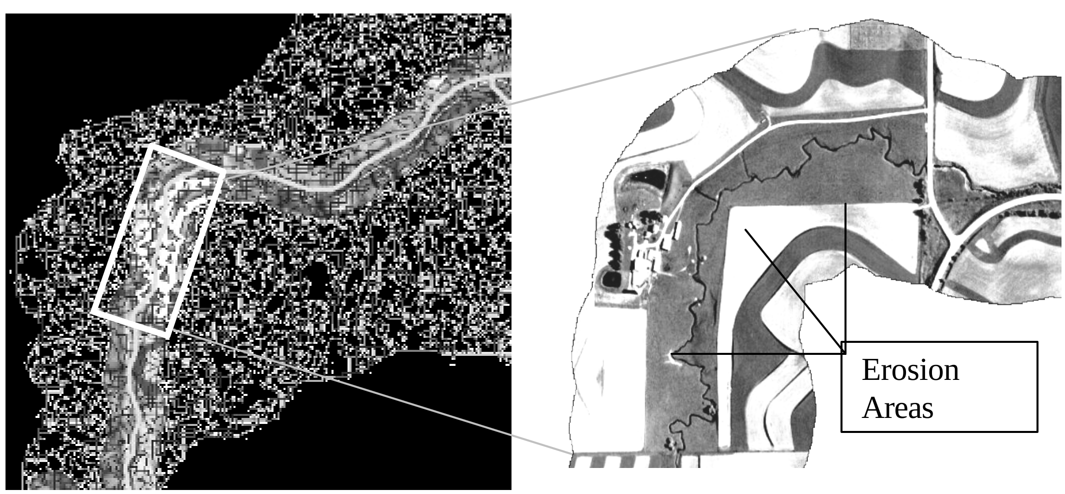

Figure 21. Sectional 1:3000-M photographic view of erodable areas contained within a buffered 200-m portion of the Postville headwater stream segment for clarification.

Higher 1-meter resolution multispectral imagery aerial photography allows detailed subwatershed analysis. In this case healthy spring (pre-crop emergence) vegetation reflects so much of the energy in the near infrared portion of the spectrum that detectors measure high digital number (DN) values. While this process is occurring, the same wavelengths are almost completely absorbed by water resulting in low DN values. The vegetation will appear light and water will appear dark.

The most common way to display the near infrared band for visual vegetation analysis is in combination with the visible red and green bands. In this case, a 3, 2, 1 band combination produced high DN values created by vegetation (fields). In general, the brighter red indicates healthier vegetation. In grayscale (Figure 21), the bands were able to distinguish crops, hayfields (darker color), buildings (white), streams, and ponds (black). Erodable areas were located on the Williams Creek headwater section enabling dedicated partners to prioritize conservation measures.

By numerically assessing and prioritizing the procedural steps previously indicated, a subwatershed analysis can be completed and delivered to partners, results achieved and recommendations made.

Conclusion

A rapid procedural methodology demonstrating conservation methods for subwatersheds was applied to the karst topography of the WCS.

An organizational flowchart provided recommended procedures of information gathering and conservation planning. The flowchart employs setup landcover datasets and stakeholder input. The procedure also identified a predominant Fayette silt loam soil type, land and water use and derived slope while developing conservation priorities.

Land conservation restoration measures need to identify, protect and manage springs, sinkholes, spawning areas, and riparian wetlands as well as other critical conservation areas. Land use and water quality monitoring efforts are important for identifying areas that are in need of conservation. Land use was calculated at a minimal 0.50 percent impervious cover contained within the WCS.

Numerical calculations of the Williams Creek subwatershed 50-m buffered headwater's landcover were totaled and percentages of hay/pasture and row cropping were recorded at 75.5 percent of landcover area. Also, each headwater stream was analyzed for slope derivations. The 6473-m Postville buffered headwater stream (segment 1) recorded 5.4 acres of potential erodable slopes equal to or greater than 10 degrees.

Finer resolution images at scales less than 1:3000 meters is an essential step in guiding field work and examining erodable sites. A segment of that stream containing erosion areas was radiometrically and geometrically enhanced to provide a visual perspective of conservation planning efforts.

The rapid procedural methodology for other subwatersheds would be similar in design, with some modifications to account for variations that occur with different topographies and ranking system analyses. The procedures used here can be adapted to similar subwatershed projects to help initiate partnering efforts for addressing conservation challenges.

Acknowledgements

My gratitude extends to Tex Hawkins, Watershed Biologist at the Upper Mississippi River National Wildlife and Fish Refuge (USFWS) for his suggestions and editing of this paper; District Conservationist LuAnn Rolling and her NRCS staff in Waukon, Iowa for providing critical information on land use, soil types, and agriculture; and Fisheries Manager Bill Kalishek at the Iowa DNR in Decorah for sharing his knowledge of aquatic ecology and advising on restoration potential relative to the WCS. Dr. David McConville and John Ebert provided the inspiration, editing, and encouragement behind my graduate work and project.

Additional credit goes to Dr. Philip Cochran, Jeff Knopf, Mara May, Ryan Kiefer, Jason Schuster, and Monta Hulsing for lending their expertise on subject matter and data management throughout my graduate studies.

I would especially like to thank Martha Roldan for her advice and assistance, not only with my graduate project, but during my graduate studies as well.

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