An Historical Perspective of Hydrologic Changes in Seven Mile Creek Watershed

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ABSTRACT

This study documented hydrologic changes, specifically wetland losses, in Seven Mile Creek Watershed. Historical aerial photos along with a Geographic Information System (GIS) were used to assess these changes as it relates to water resources management. The 95.3 km^2 (36.8 mi.^{2}) study area is a small, agricultural watershed located in south-central Minnesota. More than 130 aerial photographs from seven different periods dating back to 1938 were scanned and rectified for use in a GIS. Wetland areas converted to cropland were then interpreted and digitized. In addition, other land use changes, such as surface and sub-surface drainage modifications and cropping system shifts, were mapped and documented. Results from the study indicate significant hydrologic changes have occurred in the watershed. Analysis of pre-settlement maps and survey notes indicate that about 50% of the watershed was once covered by wetlands. Of those wetlands, it is estimated that 88% of the natural wetlands have been converted to cropland. About 47% of those losses occurred from early settlement (late 1800's) to 1938. From 1938 to 1985, an additional 41% of the wetlands were drained and converted to cropland. This translates to an average annual net wetland loss of 40 hectares (100 ac.) per year. During this same period (1938-1985), 40 km (25 mi.) of drainage ditches were constructed, more than 966 km (600 mi.) of public and private sub-surface drainage systems were installed, and it is estimated that total corn and soybean acreage increased from 30% to 96% within the watershed. The most rapid percent change, a 50% wetland decrease, occurred between 1955 and 1961. The construction of two county drainage ditch systems in 1955 accounts for this change. After 1985 the wetland loss trend has decreased. Wetland increases are a direct result of conservation programs combined with grants from private and state water resource protection programs.

KEYWORDS. wetland, GIS, watershed, water quality, hydrology, drainage water

INTRODUCTION AND BACKGROUND

Research relating to hydrology and water quality has been well documented in the Minnesota River Basin. Southern Minnesota is intensively managed for row crop production (Payne, 1991) and has been extensively drained via subsurface tile (Binstock, in Magner, et al., 2004). Agricultural drainage along with the construction of drainage ditches in southern Minnesota over the last century drained wetlands to improve soil productivity (Leach and Magner, 1992) for crop production. Agricultural drainage is integral to Minnesota's farm economy. However, the cumulative influence of large-scale drainage, particularly the increase in contributing drainage area, has initiated downstream channel instability across southern Minnesota (Magner and Steffen, 2000; Magner, et al., 2004) and accelerated nutrient losses. In particular, studies by Alexander (2000) Magner and others (2004) concluded that elevated nitrate concentrations in area watersheds were largely caused by a combination of increased pathways through subsurface drainage tile systems and minimal contact time with de-nitrifying environments like channel sediment and active floodplains. Gilliam and Skaggs (1986) examined drainage factors that influence nutrient concentrations in tile drained basins. They noted a 10-fold increase in surface water nitrate concentrations when subsurface tile were added to a drainage ditch system. Randall and others (1986) reported tile-drain nitrate concentrations ranged from 16-172 mg/l in shallow groundwater from sub-surface tile drainage systems at the Southern Minnesota Research and Outreach Center, in Waseca, Minnesota.

In addition to direct drainage effects on stream nitrate concentrations, cropping system shifts have been influential in determining the impact of water quality impairments. Cover types such as wetlands, small grains, and perennial crops such as hay, and pastures reduce peak flows. These perennial land covers transpire more in the spring than do corn and soybeans, thereby creating additional room for storage of rainfall in the soil. Compared to a corn-soybean rotation, alfalfa reduced tile drainage loss by 50% in a four-year study at Lamberton experimental station (1990-93) (Randall, 1997). In addition, University of Minnesota studies at Lamberton found nitrate losses in tile drainage from corn and soybean row crop systems to be 30 to 50 times greater than from perennial alfalfa and CRP grass systems. This was due to more water per acre being drained from the row crops and higher concentrations of nitrate in that water (22-28 mg/l) compared to the perennial crops (0.7-1.6 mg/l) (Randall, 1997).

Recognizing the influence hydrologic change can have on water quality, this study helps to quantify the magnitude of these changes in Seven Mile Creek Watershed (SMCW) by examining the historical extent of wetland loss to cropland, engineered surface and sub-surface drainage modifications, and general cropping system shifts. This information will serve as a valuable tool to help educate watershed residents and policy makers about the importance of restoring wetlands for water quality, flood control, and habitat enhancement purposes.

To document and quantify the hydrologic changes in SMCW, historical aerial photos were scanned and rectified for use in a Geographical Information System. More than 130 aerial photos from 1938 through 2003 were used to document the changes in land use and hydrology. In addition, digital elevation models (DEMs), geo-referenced 1854 Public Land Survey Maps, digital soil surveys, and digital ortho-photo-quads (DOQs) were used to estimate pre-settlement land use conditions (see appendix for more information).

STUDY AREA

The 23,551-acre (36.8 sq. mile) study watershed is located in the Minnesota River Basin, within the Middle Minnesota Major Watershed in south-central Minnesota (Figure 1). The watershed is located between the communities of Nicollet and St. Peter in Nicollet County. Flat agricultural fields (0-2% slope) with numerous small depressions dominate the landscape. Dominant soil types include Canisteo-Glencoe complex clay loam, Cordova clay loam, and Canisteo clay loam soils. The landscape transitions to deciduous forest and steep ravines as the creek descends into the Minnesota River Valley. As of 2002, 81% (19,172 acres) of the watershed land use was under cultivation. Cropland in the watershed is dominated by a corn-soybean rotation and accounts for 96% of the cultivated acres. The remaining crops consist of peas, sweet corn, and alfalfa.

Seven Mile Creek is one of Nicollet County's most visible natural resources with a 630-acre county park located at the mouth of the watershed. Since 1985, the Minnesota Department of Natural Resources (DNR) designated the creek as a class 1-D marginal trout stream.

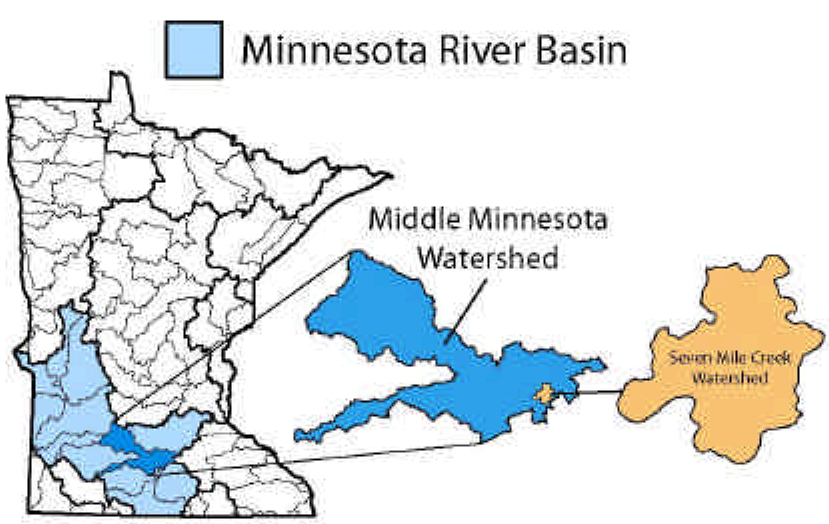

Figure 1. Project Area Location

METHODS

Aerial photos from years 1938, 1950, 1955, 1961, 1967, 1978, 1985, 1990, 2002, and 2003 were used in the analysis. Additionally, geo-referenced public land survey maps from 1854, combined with digital elevation models, and soil surveys, provide insight on the pre-settlement conditions within the SMCW (see figure 4 and appendix for more information). College level student interns provided free labor during the rectification process, thereby keeping overall project costs extremely low. A Pentium 4 desktop and a Pentium 3 laptop computer were used to process the images. A rectification software extension for ArcView® called SmartImage® was purchased for $300.00 from the Australian-based company, Mapping and Beyond. The historical photo project is estimated to have taken 500 hours.

The process for documenting the hydrological changes in Seven Mile Creek Watershed can be summarized in five steps:

1. Photo acquisition
2. Scanning
3. Rectification
4. Cropping and creating a mosaic image
5. Aerial photo interpretation, mapping, and analysis

The first step was to acquire the photos. Historical black and white aerial photos from 1950, 1955, 1961, 1967, and 1978 were collected from the U.S. Department of Agriculture, Farm Service Agency (FSA) and Natural Resources Conservation Service (NRCS) offices. All photos were 9x9 prints, except the 1950 and 1978 photos, which were 20x24 and 20x20 inches respectively.

The 1938 photos of Nicollet County were in digital format and obtained from the Minnesota Department of Natural Resources (MDNR). The MDNR acquired the 1938 photographs from the University of Minnesota, Borchert Map Library. (The Map Library has an extensive set of aerial photos for the state of Minnesota in their collection. Refer to their web site at: http://map.lib.umn.edu/.)

The 1990, 2002, and 2003 were in a digital ortho-photo quadrangle (DOQ) format. A DOQ is a computer-generated digital image of an aerial photograph in which displacements caused by camera orientation and terrain have been removed. The 1990 photo is a black and white United States Geological Survey (USGS) DOQ, and the 2002 and 2003 are color DOQs taken by the FSA Aerial Photography Field Office.

The 1985 photos were taken by the Sidwell Company for county parcel mapping purposes and were in halftone emulsion on mylar format. A piece of white paper was placed on the back of the mylar for scanning purposes. The 1985 photos were obtained from the Nicollet County Environmental Services Department, St. Peter, Minnesota.

The 1938-1978 photos were taken during the summer, while the 1990 and 1985 photographs were taken soon after snowmelt. The 1990 and 1985 photos were especially useful for locating private drainage tile lines.

The second step in the process was to scan the historical photos. The main goal during this process was to maximize photo quality and resolution, while minimizing file size. Most aerial photos were scanned black and white (greyscale) at 400 dots per inch (dpi), and saved as .jpg images using a HPScanJet 5200C series scanner. The 1950, 1978, and 1985 photos were too large for scanning with the HP ScanJet so a Widecom SLC 1036C scanner from the Nicollet County Environmental Services Department was used to convert the photos to digital images. The Widecom scans photos up to 26 inches wide, and digital images were saved at 200 dpi to maintain a smaller file size. Scanning at higher resolution was not necessary with the large format photos.

Once in digital format, the images pertaining to the watershed were geometrically rectified and spatially registered within ArcView. This was the most time consuming of the steps during the historical photo project. Image rectification is the mathematical process of making image data conform to a map projection system. Smart Image version 8.0 (a relatively inexpensive and easy-to-use software extension to ArcView GIS), by Mapping and Beyond, was used to rectify the image. This software program warps the image to match an already registered image like a DOQ. Images are converted to ‘real world’ ground coordinates by referencing the image to another source that is in the desired map projection (called the ‘reference image’). Reference information may be obtained from another image, vector coverages, or map coordinates. In this analysis, the 1990 DOQ was used as the reference image and computer mouse clicks marked the ground control points (GCPs) to depict the same location on both the reference and non-rectified images. The images were rectified using a bilinear or 1.5-order polynomial transformation method with a minimum of 5-10 GCPs to maintain a Root Mean Square error at or below 0.7. The corners of buildings and road intersections were the most commonly used GCPs. Care was taken to spread the GCPs around the entire image.

Note that not all errors were completely eliminated using this rectification process. To correct for all distortion, such as that from relief, a process called orthorecfication must be completed. Orthorecification is the mathematical process of removing the distortion, caused by relief and the camera, within a photograph so that the scale is uniform throughout the output image. However, orthorecification was not considered necessary in this case since all of the cropland areas are located on flat topography (< 2% slope). Orthorecification software is expensive and, for the small gain in accuracy, was not considered cost-effective for this particular project.

After rectification, the images were cropped down to include just the SMCW. The cropped and rectified photos were then laid on top of each other to create one image, a mosaic. This process creates a single image file out of many separate image files. In essence, the image can be considered a geo-referenced digital map.

The last step in the historical aerial photo project was aerial photo interpretation and mapping within ArcView 3.2. The aerial photos were interpreted for land use changes by comparing 2002 cultivated land to non-cropped land in the historical photographs. Changes in land use, specifically wetland, grassland, pasture, and forest loss were then mapped through a heads-up digitizing process in ArcView. Attributes were then assigned to a polygon attribute table. The 2002 FSA Crop Land Unit was used to compare the cropped versus non-cropped areas in the watershed. For the most part, wetland cover type signatures were relatively easy to delineate. The most common interpretation methods used to distinguish between cropped fields and wetlands were photo tones, textures, and field pattern contrasts. Where there was difficulty determining what was wetland versus cropland, photographs preceding and succeeding the particular photo year were used to validate the polygon’s attribute. Wetland areas near farm sites were difficult to categorize and were considered pasture or fallow grassland for this project. For the purpose of this project, a wetland is defined as land area having the water table at, near, or above the land surface or that is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, and aerial photo-interpreted hydrophytic (water loving plants) vegetation. Open water was also coded as a wetland cover type. In all cases the upland area immediately surrounding the wetland was included as the wetland cover. It was assumed that if the upland area around the wetland was not farmed, then that area was considered hydric and not feasible for farming because of poor drainage during the growing season. These areas could also be interpreted as wet prairie and wet meadow, but for the purpose of this study were uniformly coded as a wetland cover type.

RESULTS AND DISCUSSION

Results from this exercise indicate significant hydrologic changes have occurred in the SMCW. Those changes include conversion of wetland to cropland, surface and subsurface drainage modifications, and cropping system shifts. Tables 1, 2, 3 and Figures 2, 3, 4 summarize the results of the historical photo analysis.

The initial conversion of native prairie and wetland vegetation to cropland was most likely the single greatest hydrologic change within the watershed. The 1851 map in figure 4 estimates the extent of wetlands in the watershed before the area was settled. Pre-settlement vegetation on remaining acres within the watershed was characterized by prairie, big woods, and oak openings. Before the watershed was influenced by European settlement, an estimated 11,000 acres or 47% of the watershed was covered by wetlands. The earliest recorded public water management activity in the watershed began in 1889 when a drainage tile was installed to improve the land for farming. County ditch (CD) number 6, CD 58 and CD 29 were installed in 1889, 1917, and 1918 respectively (figure 3). CD 6 and CD 29 were constructed to drain the northern portion of the watershed into Goose Lake (figure 4). The first public drainage ditch, CD 46, was constructed in 1950 and helped drain the western portion of the watershed. In 1955 two more drainage ditches, CD 24 and CD 13, were constructed to drain the southern and northern portions of the watershed.

Table 1 reports the extent of wetland acres by year within the watershed. Figure 2 graphically illustrates the distribution of wetland acres by year. According to Table 1, the periods with the greatest average annual net change include: 1955-1961, 1950-1955 and 2002-2003. The average annual net change was determined by taking the wetland acreage difference between photo years and dividing that number by the total number of years between photos. For instance, the average annual net loss of 342 acres between 1955-1961 was determined by taking the difference between 4,095 acres and 2,042 acres. The result of 2,053 acres was then divided by 6 years. The change in wetland acreage in SMCW can be organized into three time periods. Those periods include: pre-settlement to 1938, 1938 to 1985 and from 1985 to 2003. During the first period, pre-settlement to 1938, it is estimated that 5,137 wetland acres were converted to cropland, resulting in a 47% loss. This represents an average annual loss of about 61 acres of wetlands per year. From 1938 to 1985 the watershed lost an additional 4,556 acres, resulting in a 41% decrease or a loss of about 97 acres per year. During this period the greatest wetland loss (2,053 acres, 50% change) occurred between the years 1955 to 1961. The construction of CD 13 and CD 24 and subsequent loss of Goose Lake accounts for this significant loss of wetlands. From 1985 to 2003, the wetland loss trend stabilized and decreased. During this period there was an average gain of about 14 acres of wetlands per year. Federal farm bill policies such as Swampbuster, state wetland protection programs such as the 1990 Wetland Conservation Act, and concentrated watershed efforts through a Clean Water Partnership project help explain this reversal.

Table 1. Extent of Wetlands by Year.

Year	Extent of Wetland (acres)	Average Annual Net Change (acres)	% Cumulative Loss	% Change Between Years
1851	~11,000	--	--	--
1938	5,863	-61	47	-47
1950	5,104	-63	54	-13
1955	4,095	-202	63	-20
1961	2,042	-342	81	-50
1968	1,662	-54	85	-19
1978	1,372	-29	88	-17
1985	1,307	-9	88	-5
1990	1,347	8	88	3
2002	1,441	8	87	7
2003	1,561	120	86	8

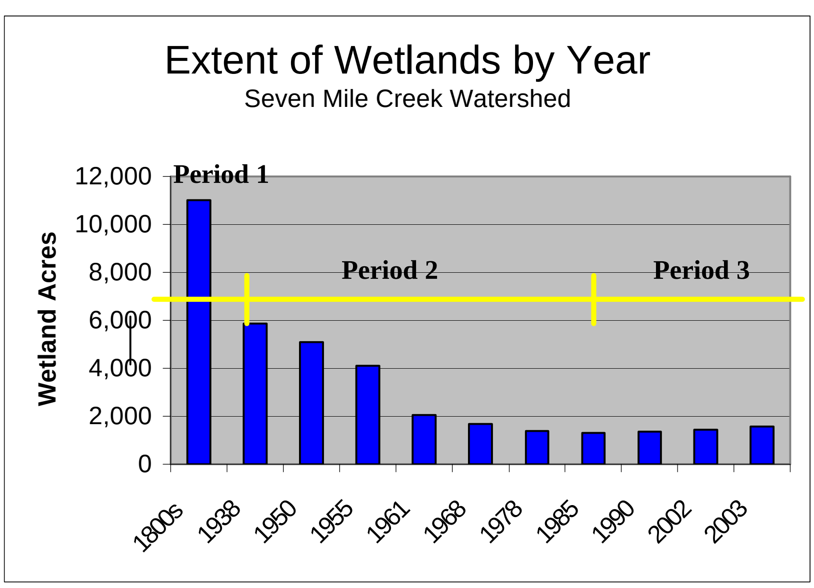

Figure 2. Extent of Wetlands by Year

When compared to wetlands, grassland and forestland conversion was found to be less substantial in the watershed. Table 2 quantifies the extent of forest and grassland conversion in SMCW since 1938. About 374 acres of deciduous forest and 951 acres of grassland and pasture were converted to cropland from 1938 to 1985. From 1985 through 2003 about 200 acres of cropland have been converted back to native grassland. Half of those acres were restored between 2002 and 2003. Restored native grassland serves as a valuable pollutant filter and as a wildlife habitat corridor between cultivated land and surface water within the watershed.

Table 2. Extent of Forest and Grassland by Year

Year	Forest acres	Pasture/Grassland acres
1938	1,852	1,594
1950	1,823	1,251
1955	1,789	1,181
1961	1,639	1,225
1968	1,503	1,022
1978	1,478	672
1985	1,478	643
1990	1,478	683
2002	1,478	733
2003	1,478	823

The general shift away from a wide diversity of hay and small grain crops to corn and soybean production has also produced hydrologic changes over time. Table 3 reports the estimated percentage of crop and wetland acreage within the watershed. Note that no specific crop history data exists for just the watershed. Instead, Nicollet County was assumed to be representative of SMCW, and county averages were used and applied to the watershed preceding 2001. Crop history information was acquired from the United States Agriculture Census data and Farm Services Agency. Using this information, it is estimated that corn and soybean acreage in the watershed has increased from 30% in 1939 to 96% in 2003. An increase in the amount of corn and soybeans grown in the watershed has been at the expense of hay and small grains like wheat, oats, barley, sorghum, flax. From a soil and water conservation perspective, small grain crops require fewer inputs like herbicides and fertilizers and, because they are established earlier than corn and soybeans, tend to transpire more in the spring reducing the potential for surface runoff. Today, 96% of cropland in the SMCW is planted to corn and soybeans with the remaining 4% split between alfalfa, peas and sweet corn. For comparison, 25% of the watershed land use was wetland in 1934 while 7% was in a wetland land cover in 2003.

Table 3. Percentage of Crop and Wetland Acres

Year	Corn	Soybean	Hay/Alfalfa	Small Grain	Other Crop		Wetland (% of watershed)
1872	10	--	3	87			
1934	31	--	24	39	6		26
1939	30	--	22	44	4		25
1950	39	9	14	36	2		22
1954	36	23	13	25	3		17
1964	45	22	13	15	5		9
1969	43	35	9	11	2		7
1974	48	34	6	11	1		6
2002	49	47	3	--	1		6
2003	49	47	3	--	1		7

Figure 3 is a map summarizing the extent of natural versus altered drainage in the watershed. The black, red, and green indicate public and private drainage systems while the blue indicates unaltered drainage. Using rectified historical photos, approximately 620 miles of private tile lines were documented. Since tile line signatures only appear in aerial photography when certain soil moisture and cover conditions are present, it is safe to say there are more private tiles than indicated. Most likely more than 1,000 miles of private tile have been installed in the watershed. Figure 3 illustrates the connectivity of the watershed. From a water quality perspective, this may increase the transport of nutrients like nitrate if nitrogen is applied at rates in excess of recommended agronomic rates. In addition the figure also suggests the contributing drainage area to Seven Mile Creek was significantly smaller and less efficient during pre-settlement conditions compared to current conditions. According to 1854 Public Land Survey Maps, tributaries to Seven Mile Creek totaled about 7.3 miles. Most of these tributaries meandered and extended from large upland, prairie pothole wetland complexes. Many of the prairie potholes that were once scattered throughout the watershed were closed flow intermittent wetland systems, which filled with rain and melting snow and then slowly evaporated or drained through the ground-water system during the later summer months. Under most soil moisture conditions, water was trapped in these potholes and only a small portion entered the creek as runoff. Today there are 25 miles of channelized tributaries that directly connect the watershed to the Creek. This represents a three-fold increase in surface drainage. The cumulative effect of these changes may increase peak flows, resulting in accelerated stream bank instability and water quality impairments (Magner, 2000).

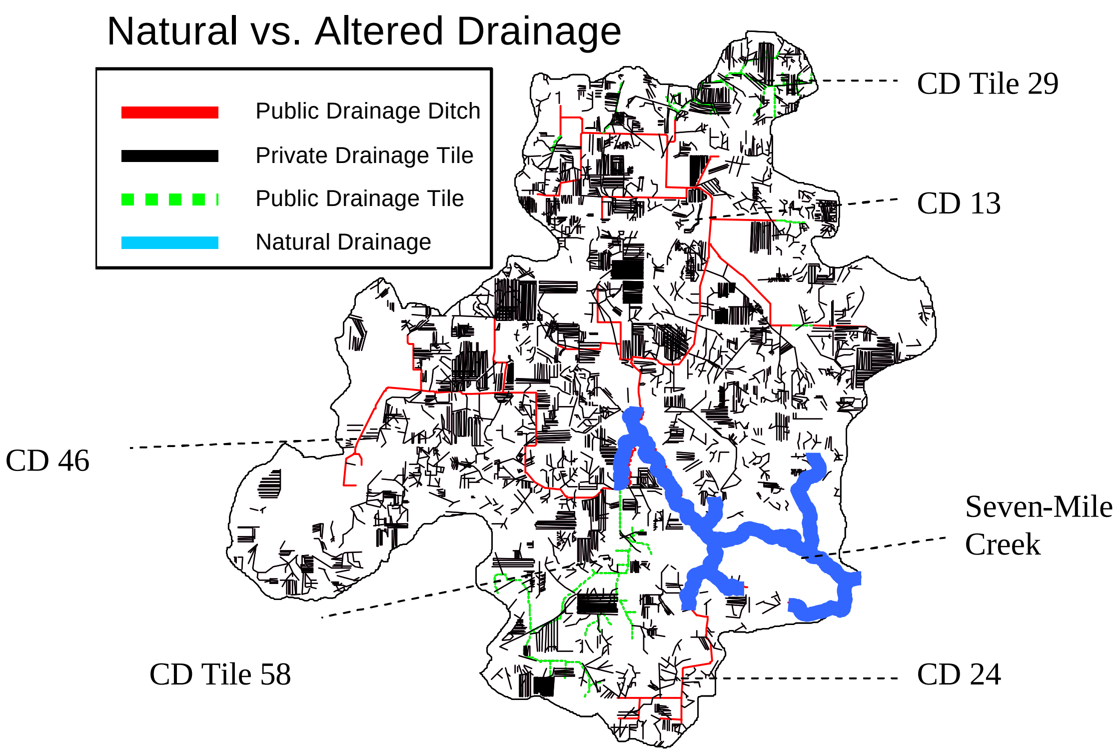

Figure 3. Natural vs. Altered Drainage in SMCW

The use of historical aerial photos and GIS has proved to be effective for quantifying hydrologic changes in the Seven Mile Creek Watershed. The hydrologic changes documented in this exercise also demonstrate the effectiveness of engineered agricultural drainage systems. The benefits of agricultural drainage are numerous. Drainage on wet agricultural soils allows timely field operations, helps plant growth to begin early, and helps achieve improved levels of productivity. In summary, drainage benefits crop production by minimizing risks, improving efficiency, and increasing net income. Although integral to the agribusiness economy, concerns relating to agricultural drainage systems including wetland habitat loss, impaired water quality, and hydraulic overloading has increased.

Recently, the SMCW Clean Water Partnership Project with funding from the McKnight Foundation are exploring ways to restore wetlands while maintaining agricultural productivity and profitability. Innovative solutions include linking wetlands to subsurface drainage systems for the purpose of filtering agricultural runoff before entering streams or ground water. For instance, in one project, a 12-inch public ditch tile (CD 58) draining 200 acres of cropland was petitioned by the Brown- Nicollet-Cottonwood Water Quality Board and Nicollet Soil and Water Conservation District through Minnesota Drainage Law 103e.227 to be routed into a newly restored 50-acre wetland (see map 2003 in figure 4). The wetland is expected to remove 4,400 lbs. of nitrate-N per year and act as downstream flood control by storing up to 55-acre feet of water during a 100-year, 24-hour storm. Additional research to determine how much restoration of this type is needed on a watershed scale to help address downstream environmental concerns will be beneficial for watershed managers. Furthermore, additional research on what the long-term significance of these hydrologic changes mean to the landscape and receiving water bodies in relation to runoff, erosion, nutrient and pesticide losses, turbidity, stream bank erosion, etc. will be useful in developing and implementing realistic water resource protection polices.

Results Summary

- Conversion of 9,693 wetland acres to cropland from 1800s to 1985 (88% loss).
- Surface drainage changes--Between 1938 and 1985, 33 miles of public drainage ditches installed. This represents a 3 fold increase in surface drainage to Seven Mile Creek compared to pre-settlement conditions.
- Sub-surface--40 miles of public drainage tile were added in the watershed. Also, more than 600 miles of private subsurface drainage tile systems were added.
- Corn and soybean acreage in the watershed has increased from 30% in 1938 to 96% in 2003.
- Most of the shift to corn and soybeans has been at the expense of large reductions in wetlands, small grains, and hay.
- 1,325 acres of forest, grassland and pasture are converted to cropland from 1938-1985.
- A total of 5,881 acres of wetlands, forest, pasture, and grassland were converted to cropland from 1938-1985. This represents 32% of the cropland in 2002.
- Four large lakes were drained and converted to cropland: Goose Lake, Fox Lake, Overson Lake, and an unnamed lake (figure 4).
- Top three periods of greatest average annual net wetland change.
    1. 1955-1961: loss
    2. 1950-1955: loss
    3. 2002-2003: gain
- From 1985 to present, federal farm bill policies, state wetland programs, and watershed-based water quality projects helped to reverse the wetland loss trend. Since 1985, 254 acres have been restored back to grassland and wetland.

CONCLUSIONS

The use of rectified historical aerial photos and GIS has proven to be effective for quantifying hydrologic changes in the Seven Mile Creek Watershed. Results from this project indicate that significant changes in watershed hydrology have occurred. Some of those changes include the construction of more than 600 miles of drainage systems and subsequent conversion of 9,693 acres of wetlands to cropland (88 % loss). After 1938, the rate of wetland loss appeared to be the greatest between 1955 and 1961 (50% decrease). The construction of two drainage ditches account for this change. The average annual net loss of wetlands during the 1938 to 1985 period was about 100 acres per year. After 1985, the wetland loss trend decreased. The greatest wetland gain occurred between 2002 and 2003 (8% increase). Federal Conservation Reserve Programs (CRP) combined with grants from private and state water resource programs to help restore wetlands for water quality are primary reasons for this increase.

Acknowledgments

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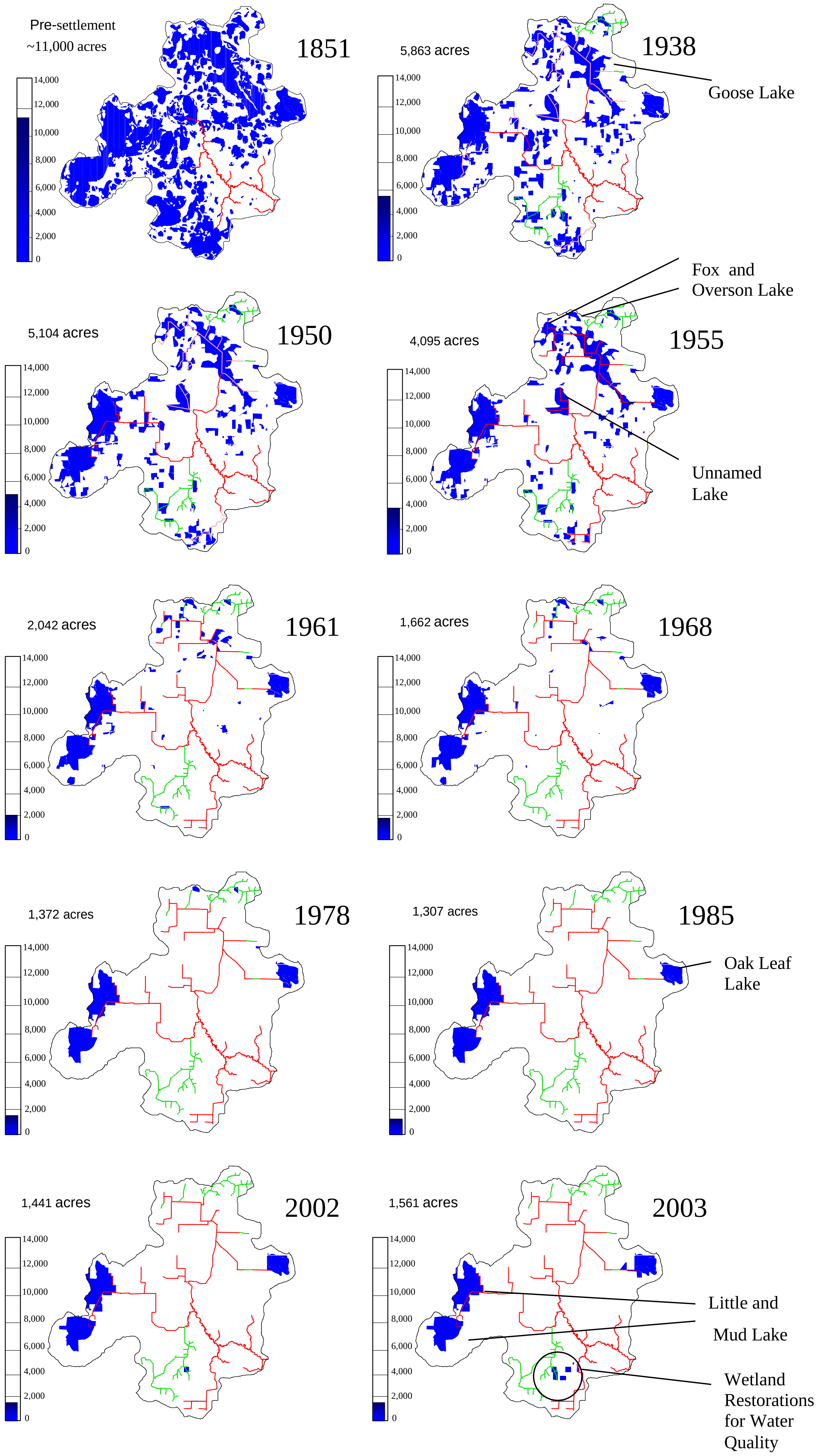

Figure 4. Historical Distribution of Wetlands in SMCW

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Appendix

Creation of the Pre-settlement Wetlands Map

This map (1851 in figure 4) estimates the possible extent of wetlands before the watershed was settled, drained, and converted to cropland. For the purpose of this project, pre-settlement is considered before 1851 or after the signing of the Treaty of Traverse De Sioux. By no means does this represent the absolute extent or distribution of wetlands before European settlement, but represents a logical estimate. Combinations of data layers were used and are listed below. The 1938 aerial photography interpreted wetlands map was used as the base map. For the purpose of this study the blue areas on this map represent all types of prairie pothole wetlands including wet prairie and open water. The remaining land covers in the watershed were considered prairie, oak openings, and big woods forest. Using these data sources it is estimated that about 11,481 acres could have been a wetland land cover in the watershed before extensive settlement and water management of the watershed occurred.

- Rectified 1854 Public Land Survey Maps (PLS)

Original Public Land Survey records were used to assess the spatial extent of hydrologic conditions in the Seven Mile Creek Watershed prior to European settlement. From the late 1700s through the early 1900s, the US General Land Office oversaw the surveying of the unsettled lands of the lower 48 United States. Established by Thomas Jefferson, the Public Land Survey is a legal land reference system set up to ease the inventory and transfer of property.
The original public land surveys in Nicollet County were conducted over 150 years ago by A.D. Anderson and use a section, township and range grid system. In 1854 surveyors traversed Nicollet County to survey and mark section corners. At the same time the surveyors drew maps and notes of the surveyed area. The data derived from land surveyor notes included descriptions of the landscape, vegetation, stream locations, and wetlands found within eyesight of the survey transects. Although only accurate near the section lines and corners, the map and corresponding surveyor notes are the only detailed record of pre-settlement hydrologic conditions within the watershed.

As part of a historic surface hydrology pilot study of Nicollet County to predict archeological sites, geo-referenced PLS maps were acquired for Nicollet County from the Minnesota Department of Transportation in 2003 (Mustain, 2004). The rectified images help indicate the original extent and location of streams, and wetlands within the watershed. The PLS images were clipped to the watershed and wetland and stream features were mapped using ArcView. About 4,000 wetland acres were in the watershed were mapped using this historical information.

Since the survey only included the area immediately adjacent to the section transects, a more accurate reflection of past surface hydrology would be obtained through close exploration of elevation, geomorphology, soils and related data sets in addition to the 1854 Public Land Survey. The following data sets were used in combination with the Public Land Survey.

- MDNR Pre-Settlement Vegetation Map

Information contained in the surveyors' notebooks from the Public Land Survey are a valuable record of the composition and distribution of pre-European vegetation over much of the United States. This map was created to represent the presettlement vegetation of Minnesota based on Marschner's original analysis of Public Land Survey notes and landscape patterns. Marschner compiled his results in map format, which was subsequently captured in digital format by the MDNR.

- 1996 Digital Soil Survey

1996 digital soil survey and soil scientist interpretations were used to delineate additional wetland areas in the watershed. Land capability soils that were classified as hydric and IIIw were used.

Land classification shows, in a general way, the suitability of soils for most kinds of field crops. The soils are grouped according to their limitations for field crops. Capability classes range from 1-8 with 8 being the most severe limitation. A subclass of w, s, or c is also given to describe the limitation:

w= soil limitation because area is too wet.
s= soil limitation because it is shallow, droughty or stony.
c = limited soil potential for growing crops because of climate extremes- too cold or dry.

By selecting IIIw soils, areas with high water holding capacity and low permeability are selected. These areas would indicate a wetland land cover at one time. There are a total of 3,500 acres of IIIw soils in the watershed.

- 1990 National Wetland Inventory (NWI)

The National Wetlands Inventory is a national program sponsored by the US Fish and Wildlife Service (USFWS). The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service produces information on the characteristics, extent, and status of the Nation's wetlands and deepwater habitats. Linear wetland features (including selected streams, ditches, and narrow wetland bodies) are mapped as part of the National Wetlands Inventory. According to this information 1500 acres of wetlands are idendtified in the watershed.

- USGS 30 meter digital elevation model

Digital elevation models (DEM) are data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. USGS 30 meter DEM, Spatial Analysis and MDNR Hydro Tools Extensions in ArcView were used to identify low elevation signatures. The wetness index calculation was performed on each elevation cell. Low cell values indicate lower surface elevations, and therefore may be indicative of historic wetland basins.

Wetness index = $\ln(A_s/\tan B)$

A_s==contributing catchment area in meters squared
B= slope of cell measured in degrees

- June 2002 Color DOQ

June 2002 color FSA photos were used to delineate wetland basins. In June of 2002 the watershed received over 9 inches of rain, nearly four to five inches over the normal rate. Cropped prairie pothole basins are very distinguishable using photos during this period. Cropped wet areas were then mapped. This represents about 1,015 acres.