Land-use change and agricultural practices in the Willow River watershed, western Wisconsin, 1992-2004

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Table of Contents

LAND-USE CHANGE AND AGRICULTURAL PRACTICES IN THE WILLOW RIVER WATERSHED, WESTERN WISCONSIN, 1992-2004 1

ABSTRACT 1

INTRODUCTION 2

METHODS 2

RESULTS AND DISCUSSION 4

- LAND-USE CHANGES 4
  - *Cropland Losses and Crop Percentages 4*
  - *Where Cropland Was Lost, and Which Land Uses Replaced It 6*
- AGRICULTURAL MANAGEMENT PRACTICES 7
  - *Crop Rotations 8*
  - *Livestock and Manure Management 10*
  - *Inorganic Fertilizer Applications 13*
  - *Tillage and Irrigation Practices 14*
  - *Synthesis into SWAT Management Rotations 15*

SUMMARY AND CONCLUSIONS 16

ACKNOWLEDGEMENTS 18

REFERENCES 18

(Tables and Figures follow)

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Abstract

This report summarizes recent land-use changes and agricultural management practices in the Willow River watershed, particularly for the years 1992 to 1999, to improve data input to a SWAT computer model of the watershed. From 1992 to 1999, the cropland in the watershed declined by about 8.5–12%, depending on data source, or up to about 7,500 acres. Essentially all the cropland loss was from loss of hay acreage, as corn acreage remained steady and soybean acreage increased slightly. This change is consistent with a gradual shift from dairy farming to cash cropping of corn and soybeans. About 80% of this cropland loss occurred in the lower watershed, below New Richmond, and almost two-thirds of this loss was due to residential development. Forest and small amounts of recreational lands increased at the expense of cropland during the same time.

Agricultural practices examined included crop rotations, manure management, inorganic fertilizer applications, and tillage practices. Over 95% of the cropland was attributable to corn (C), soybeans (S), and hay (A) composed primarily of alfalfa but including oats and forage grasses. In 1999 on a whole-basin basis, we infer that about 60% of the watershed was planted in a C-A rotation, about 20% in a C-S rotation, and about 20% in a C-S-A rotation. From 1980 to 2001, the number of cattle in the watershed declined from about 85,000 to 50,000, with manure production consequently declining from about 500,000 short T/yr down to about 300,000 short T/yr. During most of this time, beef cattle composed about 8–9% of the total but have recently increased to about 12%. Hog and turkey manure accounted for about 2% and 1%, respectively, of the total manure tonnage in the watershed in 1999. Estimates of which agricultural lands receive these manures are needed as input to the SWAT model, and for this purpose the annual manure production was partitioned as follows. About 9% of dairy manure and 46% of beef manure were applied to pastureland at a combined rate (dairy plus beef) of 4.33 T/acre/yr. About 21% of dairy manure and 23% of beef manure were applied to part of the C-A rotation on a daily-haul basis at a combined rate of 9.53 T/acre/yr. The remainder of manure was then applied to year-2 corn in the C-S-A and remaining C-A rotations at a combined rate of 22.06 T/acre. In the watershed model, typical application rates of inorganic fertilizer were 300 lbs of 46-0-0 pre-plant for corn plus 200 lbs of 9-23-30 starter. For year-2 corn receiving manure amendments, these rates were reduced to 100 lbs each. Soybeans received 200 lbs of the 9-23-30 (pre-plant) fertilizer. The most common tillage practices appeared to be chisel plowing followed by disking. Moldboard plowing was still used to turn over old alfalfa fields prior to being planted with corn. No-till planting has become increasingly common for soybeans, about 50% of which were no-till in 2000 and 60% in 2004.

Introduction

Use of the SWAT, the Soil and Water Assessment Tool (Arnold et al. 1995), to model the hydrology of the Willow River requires knowledge of land-use practices in the watershed. One of the main strengths of SWAT is its ability to simulate the loading of nonpoint-source (NP-S) pollution from agricultural lands, and so the areas of different crops and agricultural management practices are critical input variables to the model. In particular, the land-use data in the model should correspond to those years with hydrologic monitoring data to allow the best possible model calibration. The model requires input of spatially referenced land-use data (i.e., a map with either polygons or a grid of land-use values), and the best available data set is from interpretation of satellite imagery from 1992 (WDNR 1998). However, hydrological monitoring data for calibrating the Willow model are available only for 1999 (Lenz et al. 2001). Because land-use has been changing rapidly in the watershed, the 1992 land-use data may not adequately represent 1999 conditions.

Consequently, the main purpose of this interim report was to gather the available land-use information needed to convert the 1992 spatially referenced land-use data set such that it represented 1999 conditions. The amount of cropland lost between 1992 and 1999 needed to be determined, land use in these areas had to be converted to something else, and these changes had to be distributed across the watershed in representative manner. The scope of the report is limited almost exclusively to data from or about St. Croix County, which encompasses the majority of the watershed. The temporal emphasis is on three years: 1992, the year with spatially referenced land-use data; 1999, the year with continuous hydrologic monitoring data; and 2004, as a snapshot of the most recently estimated land use.

The principal results of this report are that acreage of cropland in the watershed decreased by about 8.5 – 12% (depending on data source) from 1992 to 2004. About half this land was converted to low-density residential development, about one-third to woodland, and the remaining amounts to rural recreational lands (e.g., golf courses) and to urbanized additions to New Richmond. Relative crop percentages shifted as row crops increased at the expense of forage crops. Considering only the three main crops, from 1992 to 2004 hay went from 47% to 37% of the crop acreage, corn from 42% to 45%, and soybeans from 12% to 19%. Dairy cattle have gradually declined in numbers as farmers have shifted to cash cropping of corn and soybeans or to beef. Alternate tillage practices seem to be increasing, especially no-till for soybeans within the last five years.

Methods

This report accessed data from at least eight different sources. Because these sources compiled data over land of different spatial extent, each data set had to be scaled to a common land area to be comparable. Unless otherwise stated, this report scaled all data to the *gauged watershed area* of the Willow River (292 mi^2), which corresponds to the available hydrologic monitoring data set (Watershed 1a, Table LU-1). This is the watershed area reported by Lenz et al. (2001) as contributing to the river at the gauging station location. Watershed 1b (272 mi^2; Table LU-1) is the area contributing to the same location as automatically delineated by the ArcView geographic information system

(GIS) interface to SWAT. The delineation routine analyzes the 30-m digital elevation model (DEM) for the region and determines the watershed for any specified location along the river channel. However, for glacially pocked terrains such as the Willow, the automatic routine commonly excludes small closed depressions along the watershed boundary; hence the modeled watershed area is slightly smaller than the stated gauged area, by about 20 mi^2. Some data from St. Croix County were reported for the Willow River watershed within the county boundaries (watershed 2, Table LU-1). This is the watershed area as delineated by the Wisconsin Department of Natural Resources (WDNR), but clipped by the county boundary. This area includes not only the part of the Willow River watershed below the gauge location, but also some land that drains directly to the St. Croix. Finally, some data were available only on a countywide basis for St. Croix County, with no further spatial detail. Data that referred to any of these areas were scaled to the gauged watershed area (1a) by simple ratios and assumed to be representative. For example, because the gauged watershed covers 292 mi^2 and the county covers 735 mi^2, countywide data were multiplied by the ratio 292/735 to obtain values assumed to be representative for the gauged watershed area (including those areas inside the watershed but outside the county boundary). We recognize that spatial trends across the county can bias results, making them not entirely representative of the Willow River watershed. Such effects were taken into consideration to the degree possible.

Five main data sources were consulted. First was the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) data set (WDNR 1998). Data were derived from LANDSAT Thematic Mapper (TM) satellite imagery mostly from 1992, with some additional data from 1991 and 1993. Each pixel in the imagery represents a 30-m square. Based on ground-truthing plots, known land-cover types were correctly identified about 86% of the time statewide. Pixels identified as corn, other crops, or forage crops were correct 95%, 88%, and 90% of the time, respectively. Forage crops include all crops cut for hay, which evidently includes acreage planted with oats as a nurse crop. Other crops could include small grains but evidently is commonly soybeans, if not otherwise identified. The WISCLAND data set is commonly used to provide land-use data for SWAT modeling in Wisconsin, as we have done here with the model of the Willow River watershed.

Second was the National Agricultural Statistics Service (NASS), which surveys farmers annually across the nation by a combination of mailed questionnaires and telephone interviews and compiles the data on a countywide basis (NASS 2005). The NASS data set for St. Croix County included acreage planted and harvested for all common crops from 1981 through 2001 and hence provided an important mechanism to assess changes in cropland in the Willow watershed from 1992 to 1999. These countywide data were scaled to the gauged Willow watershed on the assumption that they were areally representative.

Third was the transect data set from the St. Croix County Land and Water Conservation Department (SCC-LWCD; Steve Olson, rural land specialist, personal communication, 2005). The LWCD makes an annual survey of cropland by returning to selected points at frequent intervals along roads in the county and estimating acreage of crops in the adjacent fields. These data were available for 1999-2004 and provided another check on 1999 crop acreage, to compare with the NASS data. These LWCD-transect data were compiled for the area of the Willow River watershed in the county (watershed 2, Table LU-1), and scaled to the gauged watershed area (watershed 1a). In addition to providing the transect data, LWCD staff were instrumental in explaining representative agricultural practices in the watershed, including crop rotations, fertilizer applications, tillage practices, and manure management.

Fourth was the SCC-LWCD survey data set (SCC-LWCD 2004). The survey was conducted by the SCC-LWCD in the summer of 2004 by mailing questionnaires to all owners of parcels of agricultural land 30 acres (about 12 ha) or larger within the watershed (i.e., watershed 2, Table LU-1). About 900 questionnaires were mailed; about 40% of the recipients responded, and about a fourth of these (94 responses) were from active farmers. The parcel acreage of those respondents who were actively farming accounted for about 20% of the watershed area. The survey provided information on agricultural management practices in general in the watershed, including planting and tillage dates, fertilizer application, livestock production, and manure management. However, the acreage of cropland referenced in this survey could not be accurately scaled to the whole watershed area.

Fifth was the St. Croix County Development Management Plan as available on-line (SCC-Planning Dept. 2000). According to this report, land-use changes from 1973-93 were interpreted from aerial photographs and quantified within an Arc/Info GIS, and population trends were based on 1990 and 2000 census data. Data were available typically on a countywide basis; however, several data sets were available for each town, village, and city in the county, which helped clarify spatial differences in population growth and land-use change within the county.

In addition to these five main sources, several other sources were accessed as needed. Specific information about land use in the City of New Richmond was available in their Comprehensive Planning Program (Vierbicher Associates 2005). The web pages of the U.S. Census Bureau were consulted for further demographic data about St. Croix County. Land-use status and trends for nearby areas experiencing comparable development was obtained from the web pages of the Metropolitan Council of Minnesota.

Results and Discussion

The first part of this section will discuss land-use change, primarily from 1992-99: how much crop land was lost, and what new land use replaced it? The second part will discuss the agricultural management practices on the remaining agricultural land, as required for input into the SWAT model.

Land-Use Changes

Cropland Losses and Crop Percentages

In 1980 harvested crop acreage accounted for 55% of the area of St. Croix County; by 2001, this acreage had dropped to 40%, a decline of 27% (NASS 2005). We infer the same changes occurred in the Willow watershed, with crop acreage declining from 162 mi^2 (420 km^2) down to 117 mi^2 (303 km^2) during the same time period (Figure LU-1). Virtually all of this loss can be attributed to a reduction in acreage of hay, because acreage of corn remained relatively steady and acreage of soybeans increased. These changes are consistent with the trend away from dairy farming toward cash-cropping of corn and soybeans.

For our specific years of interest (1992, 1999, and 2004), we compared similar data sets that overlapped in time to check for consistency in both total cropped acreage as well as relative proportions of the major crops on the landscape. For 1992, we had data from WISCLAND and NASS (Table LU-2). The WISCLAND data identified only three crop categories in the watershed: corn, other row crops, and forage crops. The NASS data included estimated acreages, both planted and harvested, for many crop categories, including corn (both silage and grain), soybeans, wheat, oats, barley, green peas, snap beans, alfalfa (separately as dry hay and haylage), and other forage (also as dry hay and haylage). In terms of total cropped acreage, the WISCLAND acreage corresponded most closely with *harvested* acreage in the NASS data set; planted acreage was considerably larger. Apparently acres that were planted but not harvested either failed or were otherwise not identified as crops in the satellite imagery. The acreage of corn matched well between the two data sets, as did the acreage of soybeans, assuming "other row crops" in WISCLAND was entirely soybeans in our watershed. As for forage crops, acreage in the WISCLAND data exceeded the forage acreage in the NASS data set, until the acreage of oats was added. This combination is reasonable because most oats were probably grown as a nurse crop over first-year alfalfa. These acres were harvested for oats but evidently identified as alfalfa forage in the satellite imagery after the oats were removed. Under these assumptions, the WISCLAND and NASS data sets agreed to within about 2% of the averaged total acreage, and relative percentages of the major three crops (corn, soybeans, and hay) agreed to within 1–4% of each other (Table LU-2). Based on this correspondence, we felt that the WISCLAND data was an accurate representation of agricultural land cover in 1992.

For 1999, we had both NASS data and SCC-LWCD Transect data available (Table LU-2). With the same rules applied to the NASS data as above, the total cropped acreage in the NASS data set was about 15% larger than the acreage estimated by the SCC-LWCD Transect data. We found no obvious explanation for this difference, and because the 1992 NASS data matched the input data to the SWAT model (the 1992 WISCLAND data) reasonably well, we assumed the total acreage from the 1999 NASS data would be more consistent with our 1992 starting point. In contrast to total acreage, crop percentages agreed well between the two data sets, within 1–4% for all crop categories.

For 2004, we had data from both SCC-LWCD Transect and Survey efforts (Table LU-2). However, as previously noted, the acreage estimates from the Survey were not interpretable with quantitative precision; note the wide range of estimates given in the table, depending on assumptions used to scale up the acreage estimates to the entire watershed. While the NASS data were not strictly available for 2004, it seemed reasonable to extrapolate the total acreage estimate from previous values, because these values were most consistent with our selected model initial conditions (the 1992 WISCLAND input data). A simple linear extrapolation of total acreage from the 1992 and 1999 data to 2004 gave 122 mi^2 (31,659 ha) of cropland. While this is again significantly larger than the SCC-LWCD Transect estimated acreage, at least the loss in cropland acreage from 1999 to 2004 is consistent between the two data sets: about 4.2 to

4.6 mi^2 (1,100 to 1,200 ha). Again, the crop percentages agreed well between the two data sets, within 1–3% for all crops. Crop percentages from the SCC-LWCD Survey (2004) data were slightly different, with less hay and more soybeans.

Where Cropland Was Lost, and Which Land Uses Replaced It

Cropland losses were probably not evenly distributed across the watershed area. For this analysis we arbitrarily divided the watershed at the city of New Richmond into upper and lower sub-watersheds. Of the total loss of agricultural land from 1973-93 in the townships ("towns" in Wisconsin) that intersected the watershed, approximately 80% of the loss occurred in the lower sub-watershed and 20% in the upper sub-watershed (SCC-Planning Dept. 2000). We assumed that this spatial pattern held true for the crop acreage lost from 1992 to 2004.

Our strategy for determining which land uses replaced cropland in the Willow watershed from 1992 to 2004 was influenced by the same 1973-93 data set. During this 20-yr period, about 70% of the former agricultural land became developed (to either urban or rural-residential), 20% converted to forest, and 10% converted to recreational land (we assume golf courses or athletic fields) (SCC-Planning Dept. 2000). Clearly the main driver of land-use change was population growth and concomitant residential development, both rural and urban, with remaining lands converted to forest or recreational uses. Consequently, we first estimated population increases for the watershed, apportioned among the city of New Richmond, the upper watershed, and the lower watershed. Estimated acreage developed as a consequence of these population increases was subtracted from cropland acreage lost, and the remainder was distributed between forest and recreational lands (Table LU-3).

For the city of New Richmond, the population growth from 1992-99 was assumed to be 70% of the change from 1990-2000 (SCC-Planning Dept. 2000), or 843 people. We assigned 2.66 people per household, and 0.33 acres (0.135 ha) per house, based on 2000 census data, resulting in 106 acres (43 ha) being added to New Richmond. We further assumed that every 2 acres of this urban residential development was accompanied by 1 acre of high-intensity development, resulting in another 53 acres (21 ha) to be added to New Richmond. (We assumed that commercial, industrial, institutional, government, utility, and transportation land uses may be lumped under a single category for modeling purposes as "high intensity.") The percentage of high-intensity acreage relative residential acreage in similar communities is highly variable, and the 50% value used here falls about in the middle of the data examined. For example, recent data suggest that there is 93% as much high-intensity acreage as residential acreage in New Richmond (i.e., nearly a 1-to-1 ratio). However, land-use changes in similar communities indicated quite different percentages. For the land-use change occurring during 1990-2000, the percentage of high-intensity acreage gained relative to residential acreage gained was only 33% for Woodbury, MN, and 67% for Stillwater, MN, both rapidly growing communities in the Minneapolis/St. Paul metropolitan area.

For the rest of the watershed, we assumed that the 1992-99 population growth was 70% of the 1990-2000 population growth in the rural part of the county (towns and villages only, cities excluded), scaled to the area of the gauged watershed. Based on population growth in the individual townships (towns) overlapping the watershed, we assigned 90% the population increase to the lower watershed (2,152 people), and 10% in the upper watershed (239 people). We again assigned 2.66 people per household, but assumed each household occupied 4.57 acres (1.85 ha), the average size of rural lots developed from 2000-04 (SCC-Planning Dept. 2000), resulting in 3,697 acres (1,496 ha) being developed in the lower watershed and 411 acres (166 ha) in the upper.

The remainder of cropland lost from 1992-99 was assigned to either forest or recreational land. We made the arbitrary assumption that all recreational land created would be located in the lower watershed, in proximity to the large gains in population. Consequently all the remaining lost cropland acreage in the upper watershed was assigned to forest (mixed). In the lower watershed, we assumed the remaining acres were converted to forest and recreational lands in a 2-to-1 ratio, as indicated by the 1973-93 data.

For the period 1999-2004, we simply scaled the changes based on total acreage to be converted (i.e., total acreage of cropland lost; see Table LU-2, shaded values). The total acreage of cropland lost from 1999 to 2004 was estimated to be 2,994 acres (1,212 ha), which is 40% of the loss from 1992 to 1999 (7,469 acres, or 3,023 ha). Consequently we assumed that the gain from 1999 to 2004 in each land-use category to which the cropland was being converted was simply 40% of the gains these land uses made from 1992 to 1999. For example, if New Richmond grew by 158 acres from 1992 to 1999, then we assumed it grew by another 40% of that gain (64 acres) from 1999 to 2004 (see Table LU-3).

To summarize our methods here, we first determined cropland acreage losses from available agricultural statistics. We then used population estimates to apportion some of these cropland losses to urbanization and rural-residential development. The remainder of the cropland losses was assigned to forest or recreational lands. These land-use changes were distributed among the upper watershed, the lower watershed, and the city of New Richmond to the degree possible. We realize there was land-use change not addressed by these methods; for example, there was certainly agricultural land that was not cropland that was converted to some other land use – cropland was not the only type of agricultural land lost. We assume here that these changes, such as from pasture or CRP lands to forest or recreational lands, are much more neutral from a hydrologic point of view than is the conversion of cropland to perennial cover. More practically, we assume that the conversion of cropland to other land uses is a large enough change that SWAT has some chance of producing robust results, whereas conversion of non-cropped land to a land use with similar perennial cover is likely too subtle to have hydrologic changes confidently predicted by SWAT, given all the other potential errors in the modeling process.

Agricultural Management Practices

The above assumptions and calculations regarding land-use change resulted in estimates of the acreages of the three major crops, namely, corn, soybeans, and hay (plus oats, when planted) for our three selected years of interest, 1992, 1999, and 2004 (Table LU-2). SWAT is not generally sensitive enough to be influenced significantly by land-cover types occupying less than 5% any given sub-basin in the model. Hence other crops such as wheat, snap beans, and green peas were disregarded in the model, and all crop acreage was assigned to one of the three major crops. Among the four data sources (WISCLAND, NASS, SCC-LWCD Transect, and SCC-LWCD Survey), the percentages of these crops were very comparable in any one year, and so they were simply averaged to obtain a "best estimate" of the crop percentages for each year (shaded percentages, right side of Table LU-2).

One goal of the modeling effort is to reproduce these relative percentages of the acreage of major crops; i.e., these percentages are the "target" crop coverages that the model is trying to simulate. Each target could be hit perfectly (and most easily) by modeling continuous corn, soybeans, and hay in the target percentages in the modeled watershed – but the model would not be very realistic, because these crops are grown in rotation, and each rotation has particular management practices associated with it. Growing crops in rotation has tremendous benefits for reducing soil erosion, maintaining soil fertility, and reducing the need for fertilizer and pesticide applications, which in aggregate have tremendous implications for water quality. Because water quality is the primary concern of our modeling effort, crop rotations must be simulated to the degree possible. Consequently the rest of this section will investigate how the target crop coverages can be simulated in the SWAT model in such a way that crop rotations, manure management, fertilizer applications, and tillage practices are realistically reproduced in the model. The ability of SWAT to handle each of these agricultural management practices at the watershed scale is perhaps the main reason SWAT is so widely used.

Crop Rotations

"Crop rotation" here refers to a sequence of crops grown over a set number of years, after which the rotation may begin again. Probably the simplest rotation is a 2-yr rotation of corn and soybeans, where the crops are grown in alternative years and the rotation may be abbreviated by C1-S1. A 3-yr rotation might be symbolized by C2-S1, for two years of corn followed by one year of soybeans. Other rotations incorporate hay, which includes alfalfa and various forage grasses. Alfalfa is the major component, however, and we assume it is hydrologically similar to forage grasses. Consequently, to simplify the model rotations we assumed all hay on the landscape could be simulated as alfalfa.

From the SCC-LWCD (2004) Survey data, it was apparent that most farmers were growing either corn and alfalfa; or corn and soybeans; or corn, soybeans, and alfalfa in rotation. Given these three general rotations (C-A, C-S, and C-S-A), the puzzle became the following: what is a realistic sequence of years for each of these rotations, and how are these rotations distributed in the landscape (i.e., within the cropland in each modeled sub-basin) such that the target percentage of crops on the landscape is faithfully reproduced? While any number of detailed rotations could be devised for these three general rotations, we also wanted to keep the model as simple as possible, not only to increase model efficiency but also to limit the number of model variables to the most essential set to aid interpretation of model results.

We constructed three main specific rotations: C2-A3, C1-S1, and C3-S1-A3 (Table LU-4). We assumed that alfalfa was always grown for three years in a row. It is rarely grown for only two years, and sometimes for four, but three years seemed to be the most common period. If the farmer was growing alfalfa, we then also assumed that he would be growing some corn for silage as well as for grain. Thus, in the 5-yr C2-A3 rotation, the first-year corn is for grain and the second-year corn is for silage. In the 7-yr C3-S1-A3 rotation, we assumed the actual sequence would be corn-grain, corn-silage, soybeans, corn-grain, and then three years of alfalfa. Certainly the simplest rotation was the 2-yr C1-S1 rotation.

For each of our selected years (1992, 1999, and 2004), the acreage of each of these rotations was adjusted by trial and error in an attempt to reproduce the target acreage of each crop on the landscape (Table LU-4). *[Note: Because these areas are to be directly input into SWAT, which requires metric units, the areas in Table LU-4 are given in ha, and the total area refers to the SWAT-modeled watershed, 1b in Table LU-1.]* Crop acreages were estimated from the acreage of rotations by assuming that the spatial distribution of crops on the landscape was the same as the temporal distribution of crops within the rotation. For example in the 5-yr C2-A3 rotation, we assumed that 1/5 of the land was in first-year corn, 1/5 in second-year corn, 1/5 in first-year alfalfa, 1/5 in second-year alfalfa, and 1/5 in third-year alfalfa – or more simply, 40% in corn, and 60% alfalfa. Likewise, for the 7-yr C3-S1-A3 rotation, 3/7 of the land would be in corn, 1/7 in soybeans, and 3/7 in alfalfa.

In general, on a whole-basin basis, target crop percentages (shaded values, right side of Table LU-2; and far right-hand column, Table LU-4) could be reproduced within 1% by adjusting the areal coverage of the three main crop rotations. It may be that this watershed-wide distribution of rotations would give adequate model results. However, it was evident from the WISCLAND data, from the SCC-LWCD Survey data, and from discussions with county personnel that cropping patterns were different between the upper and lower watersheds, and we felt it could be important to try to take this difference into account.

For 1992 we can quantify the target crop percentages in the upper versus the lower watersheds directly from the WISCLAND data set and thereby demonstrate the cropping pattern difference. On a percentage basis, the upper watershed had more alfalfa and less corn than the lower watershed, consistent with the observation that dairy farming was more prevalent in the upper watershed. In order to reproduce these target crop percentages for 1992, the simulated rotations had to be modified somewhat to include a C1-S1-A3 rotation in the upper watershed and a C2-S1 rotation in the lower watershed.

We had no comparably quantitative method for obtaining target crop percentages separately for the upper versus lower watersheds for 1999 and 2004. We assumed the following constraints: (1) with the gradual decline in dairy farming, the percent acreage of C2-A3 rotation would decline over time in both sub-watersheds; (2) the percent acreage of C1-S1 rotation would increase over time in both sub-watersheds; and (3) the watershed-wide crop percentages when the sub-watersheds were combined still had to match the whole-basin targets given in Table LU-4. The percent acreage of C3-S1-A3 rotation was allowed to make up the difference in each sub-watershed. Under these constraints the acreage of each rotation in each sub-watershed was adjusted by trial and error to produce the results given in Table LU-4 for 1999 and 2004.

Livestock and Manure Management

The primary purpose of determining livestock numbers in this report was to determine the amount of manure to be applied to the land for 1999, as this is an important input into SWAT. Livestock considered in this report include dairy cattle, beef cattle, horses, sheep, hogs, chickens, and turkeys. No distinction was made between different breeds within these basic species groups. Countywide data for St. Croix County in 1999 were downloaded from NASS (2005), interpolated when needed to fill data gaps, and scaled to the gauged watershed area for dairy cattle, beef cattle, and hogs (Table LU-5). Numbers of sheep, chickens, and horses were estimated from the SCC-LWCD Survey data (2004); though these estimates are not likely very accurate, they are probably small enough to justify omitting these manure types from the model. Numbers of turkeys were not pursued in detail because the total amount of turkey manure applied in St. Croix County was directly available (K. Hafstad, Jenny-O Turkey Store, personal communication, 2005; see Table LU-5).

Livestock numbers of each species were translated into quantities of manure per year based on typical animal weights and empirical conversion factors per 1000-lb body weight (Table LU-5; modified from ASAE 1998). Typical nitrogen and phosphorus contents are given in the table for reference. Resulting tonnage of manure, based on numbers of animals and estimated weights, is given both as short tons of raw manure per year (shT/yr) and metric tons of manure dry weight per year (metric T/yr). The metric values are given to conform to data input requirements for SWAT, which calculates nutrient loadings based on manure dry weight to avoid errors caused by variations in moisture content. The use of dry weight by SWAT can be somewhat confusing because most agricultural statistics given in the USA are for raw manure, which includes the water content of manure, as excreted from the animal as both urine and feces. This value does not include bedding material, which would add a few percent to the weight total if present. Raw manure (with or without bedding) is realistically what the farmer manages, whether the manure loses some moisture content and is handled as a solid, or whether water is added to the manure so it can be stored and applied as a liquid.

Cattle were clearly the largest source of manure by weight to the watershed in 1999, with dairy cattle (and calves) producing over 290,000 shT/yr (short tons raw manure per year; 82% of the total) and beef cattle producing 50,000 shT/yr (14%). Hog and turkey manure tonnage is not trivial but likely small enough to justify omitting it from our baseline calibration model. Given the relatively high nutrient content of turkey and hog manure, it would be interesting to create a test scenario to evaluate whether their modest tonnage might in fact have a discernable effect on water quality in the model. On the other hand, the amount of turkey manure spread in St. Croix County is planned to be decreased to less than 5,000 shT/yr countywide (or, about 2,000 shT/yr scaled to the gauged watershed area) after the next several years (K. Hafstad, Jenny-O Turkey Store, personal communication, 2005). And, as noted above, tonnage of sheep, chicken, and horse manure appears to be insignificant. To conclude, dairy and beef cattle are by far the dominant source of manure to the Willow River watershed and will be included in the model. Manure from other animals will be excluded, except possibly for some test runs to search for an effect from turkey or hog manures.

Livestock numbers and manure production have declined over the past few decades in the watershed (Figure LU-2). From 1980 to 2002, total tonnage of cattle manure declined from about 525,000 shT/yr to about 315,000 shT/yr. During this time, the average percentage attributable to dairy was 88% and that to beef was 12%, with a gradual trend toward increasing beef (in 2002, 84% dairy versus 16% beef).

Manure is spread on the land either mechanically by the farmers or by the animals themselves as they graze in pastureland. Application by farmers occurs either as a "daily haul" of fresh manure or as a less frequent but more massive application of manure after considerable storage. In the Willow River watershed out of 62 respondents to the questionnaire, about 15% said they applied manure as a daily haul, whereas about 75% said they stored manure for application in the spring and fall. About 10% claimed winter applications (SCC-LWCD 2004). From a nutrient management perspective, the advantages of storage and less frequent application include the ability to schedule manure applications to those seasons when the manure can be incorporated into the soil, thereby making more nutrients available to crops and reducing nutrient loss to runoff and volatilization. Incorporation of manure is particularly important for retaining nitrogen against volatilization. When manure is injected as a liquid or incorporated within 12 hours of surface application, only about 5-10% of the nitrogen will be lost. The loss increases to about 20% if the manure is not incorporated until 4 days after application, and reaches 35% if not incorporated at all (Schmitt and Rehm 2002). In the Willow River watershed, about 30% of the farmers said they incorporated their manure application (SCC-LWCD 2004); we suspect that this is an underestimate.

However, nutrients are also lost from manure during storage, depending storage method (Fulhage and Pfost, 1993). Manure stored as solids in an unprotected open lot can lose 30% of its N and 10-20% of its P and K after 90 days; after a year, losses increase to almost 50%. After initial losses of ammonia to volatilization, these nutrients are lost as either runoff or leachate into the soil, depending on the setting. Sealed storage tanks holding liquid manure and maintaining anaerobic conditions appear best at retaining nutrients, losing 10-30% of N and 5-20% of P and K. In open ponds or lagoons, nutrient loss varies greatly depending on surface-volume ratios and accumulation of solids on the pond bottom; losses range from 70-90% for N, 50-80% for P, and 30-80% for K. Such lagoons are inexpensive and can "treat" the manure by reducing its nutrient content for farmers who do not have enough land for application of raw manure. However, eventually the high-nutrient sludge that accumulates on the lagoon bottom must be disposed. In the Willow River watershed (out of only 36 respondents), about one-third stored manure as an unsheltered pile, about one-third as a sheltered pile, and about one-third in some sort of containment area, typically an earthen pond (SCC-LWCD 2004).

Grazing animals also spread manure, but to vegetated pastureland rather than tilled cropland. Losses of N would be expected to be similar to those for unincorporated surface applications of manure. Losses of P and K might be lessened if the vegetated surface reduced erosion due to overland runoff, or they might be increased if trampling created unstable soil, ruts, and consequent erosion. Although quantities are imprecise, in the Willow River watershed about 46% of the beef manure was spread by grazing, and about 9% of the dairy manure. These values were calculated from the SCC-LWCD Survey data (2004) based on the numbers of animals that were pastured for a stated number of days each year (the median 165 days was assumed if otherwise unspecified).

For completeness' sake, the survey indicated that about 25% of horse manure was spread by grazing, and about 70% of sheep manure.

Finally, what areas of which crops or pastureland received this manure? In other words, where was the manure applied and at what rate (weight per area per time)? We chose four rotations to receive manure: pasture that received manure from grazing animals, a C-A rotation that received daily-haul manure, and C-A and C-S-A rotations that received seasonal (fall and spring) applications of manure. We excluded manure from the C-S rotations because such farming operations do not always have livestock, and the land area in the other rotations was sufficient for the disposition of all the manure produced in the watershed.

Partitioning the annual tonnage of manure among these four rotations followed this sequence. First, the tonnage attributable to grazing was taken from the total (46% of beef manure and 9% of dairy manure, as discussed above) and applied to pastureland on a daily basis from about mid-May through October. The amount of pastureland was estimated (from data in the SCC-LWCD Survey, 2004) at about 14% of the area of cropland. That is, for every 100 acres of crops, a farmer may have an additional 10-20 acres of pasture, which seemed reasonable. The consequent application rate of combined dairy and beef manure onto pastureland by grazing came to 4.33 shT/acre/yr (on a fresh, wet-wt basis).

Second, of the remaining manure, we estimated the amount to be applied by the daily-haul method. Based on relative numbers of dairy and beef cattle on farms that used the daily-haul method versus those that did not, about 21% of the dairy manure and 23% of the beef manure was daily-hauled in the Willow watershed (SCC-LWCD 2004). Because dairy cattle greatly outnumber beef cattle, dairy manure composed about 90% of the total daily-hauled amount. Furthermore, from the same data set, the land area to which this manure was applied initially appeared to comprise about 28% of total cropland area. However, farmers tend to apply daily-haul manure only to the most convenient 23-44% of their cropland (Jackson-Smith et al. 2005). So, instead of 28% of the total crop acreage, we reduced the amount to simply 10% that would receive manure from daily-haul applications. We chose this 10% out of the C2-A3 rotation and applied the daily-haul manure every day to alfalfa fields at an annual (cumulative) rate of 8.23 shT/acre, and from November through April (half a year) to corn fields at an annual rate of 4.12 shT/acre (half that applied to alfalfa).

Third, the remaining manure was assumed to be applied to year-2 corn in the C-S-A rotation and the remaining acreage of the C-A rotation. Both the quantity of manure and the area of application were determined by previous calculations: the quantity was calculated as total annual production minus that applied to pastures and daily-haul fields, and the area of year-2 corn was determined as proportions of the areas of the C-A and C-S-A rotations required to reproduce the areal coverage of these crops in the watershed (see Crop Rotations section above; Table LU-4). Thus we had little latitude in adjusting variables in order to achieve a sensible application rate. Fortunately, resulting application rate of about 22 shT/acre/yr (dairy plus beef) seems entirely reasonable, recognizing that some farmers certainly apply far more manure while others may apply none.

Inorganic Fertilizer Applications

Inorganic fertilizers, also called mineral or chemical fertilizers, are those derived from mineral deposits rich in the major nutrients or from commercial manufacturing processes that concentrate these nutrients from other sources. In contrast, organic fertilizers are animal products such as manure, fish meal, and bone meal as well as plant materials such as compost or simply plowed-under alfalfa (green manure). Inorganic fertilizers are typically identified according to the weight percent of selected forms of the major nutrients: nitrogen as N, phosphorus as P_2O_5, and potassium as K_2O. The percentages of these nutrients in commercial fertilizers are calculated as if all of each nutrient was in the form (species) shown, regardless of the actual chemical form, in order to maintain relatively consistent guidelines over the years for application rates. For example, one hundred kilograms of 9-23-30 fertilizer would contain 9 kg N, 23 kg P_2O_5 or equivalent, and 30 kg K_2O or equivalent.

Use of inorganic fertilizer in the Willow River watershed was assessed primarily by the SCC-LWCD Survey (2004) that was mailed to owners of agricultural land. Seventy-three respondents reported 29 different fertilizer formulations, although only six of these were commonly used. The most common fertilizer was 9-23-30, followed by 0-0-60, 46-0-0, 20-10-10, 9-11-30, and 10-10-10 (in decreasing order of frequency). The first three of these accounted for about 55% of the fertilizers listed, and together the six types accounted for about 70%.

Though the respondents did not indicate which fertilizer was applied to which crop, we assumed some customary applications to certain crops, especially for the three most common fertilizers. The all-N fertilizer (46-0-0, as urea pellets) was almost certainly applied to corn, probably pre-plant but sometimes post-plant. Although not listed above, a liquid 28-0-0 fertilizer is sometimes injected post-plant during corn cultivation in mid-June (S. Olson, SCC-LWCD, personal communication, 2005). The 9-23-30 fertilizer is a common starter fertilizer applied at depth at the same time corn is planted. The all-K fertilizer (0-0-60) is commonly applied to alfalfa. In contrast to corn and alfalfa, it was not clear which fertilizer was being applied to soybeans. Nationwide data for 1999 indicate that soybeans were fertilized at a rate of about 21 lb/acre N, 46 lb/acre P_2O_5, and 78 lb/acre K_2O (FAO 1999). These rates are comparable to an application of 9-23-30 fertilizer at 200 lb/acre. Hence we felt it was reasonable to assume that the 9-23-30 fertilizer was representative for soybeans as well as for corn, which was supported by discussions with county personnel (S. Olson, SCC-LWCD, personal communication, 2005).

According to the SCC-LWCD Survey, application rates varied from 50-400 lb/acre but averaged surprisingly close to 200 lb/acre (225 kg/ha) for all fertilizers given. If we assume that farmers are trying to provide about 150 lb/acre (168 kg/ha) of nitrogen to corn, then they would need 326 lb/acre of the 46-0-0 fertilizer, and the 200 lb/acre would seem to be too little. However, first-year corn commonly follows alfalfa, and second-year corn commonly receives manure before planting. Both cases result nitrogen being added to the soil, which, in combination with the 9-23-30 starter fertilizer, could add up to the desired 150 lb/acre. In contrast, corn following soybeans may well need the larger application of 300 lb/acre or more, if manure is not available.

For application in the SWAT model, we wanted to have the simplest possible array of fertilizers and application rates that were representative of actual use. For corn in the absence of manure applications, we applied 300 lb/acre of the 46-0-0 fertilizer prior to planting plus 200 lb/acre of 9-23-30 starter fertilizer. When manure was applied either as daily haul or as a fall-spring application, these quantities were reduced to 100 lbs/acre each. To simplify our rotations, we ignored the possible post-plant injection of 28-0-0 fertilizer, and assumed that the pre-plant and starter fertilizers covered the vast bulk of applied nitrogen (or could be increased to do so). We assumed all soybeans received 200 lb/acre of the 9-23-30 fertilizer pre-plant. We had originally planned to add 200 lb/acre of 0-0-60 (potash) to alfalfa each year. However, it appears that SWAT does not have an algorithm to allow alfalfa to respond to this treatment, and so it was omitted.

Tillage and Irrigation Practices

Primary tillage comprises those practices, typically plowing, that first breaks ground following a previous crop or other land cover. Secondary tillage includes those practices that reduce clod size and further prepare the soil to be planted. SWAT can consider a wide range of primary and secondary tillage implements. There are 74 implements in SWAT's tillage database, ranging from the common to the arcane, including the "DiscoVator," the "Crust Buster," the "Roterra," the evidently very versatile "Do-All," and the reliable "Packer," which has a huge number of fans in Wisconsin. However, we considered only the principal implements and practices used by the respondents to the 2004 SCC-LWCD Survey, which included moldboard plow, chisel plow, disk, field cultivator, and no-till. Of the 91 farmers responding to the survey, 52% used a moldboard plow, 40% a chisel plow, 57% a disk, 29% a field cultivator, and 26% no-till. (These percentages are inexact because they depend on how respondents were tallied, whether once for each respondent or multiple times to account for multiple parcels of land rented by that farmer.)

Usage of these implements in the Willow River watershed was summarized based on both the Survey data and advice from experienced agronomists. Primary tillage was accomplished with either a moldboard plow following alfalfa or a chisel plow following other crops (mostly corn and soybeans). Secondary tillage was commonly done with a disk. Other secondary tillage implements were used, such as a "field finisher" (S. Olson, SCC-LWCD, personal communication, 2005). However, disking was the most common implement mentioned and is likely representative of other implements that SWAT could theoretically simulate. Field cultivators are used to remove weeds and to incorporate post-plant fertilizer applications commonly on corn acreage and only rarely on soybeans. While the Survey data suggest only 29% of farmers use cultivators, county personnel believe that usage is much larger, perhaps closer to 75% (S. Olson, SCC-LWCD, personal communication, 2005). No-till agriculture is applied primarily to soybean acreage, which commonly follows corn in the crop rotation. In 2000 about half the soybean acreage was no-till, and by 2004 this figure increased to about 60% (data from S. Olson, SCC-LWCD, personal communication, 2005).

Primary tillage can take place either in the fall or spring, which are about equally common (S. Olson, SCC-LWCD, personal communication, 2005). In the SCC-LWCD Survey (2004), the average date for fall tillage was 22 October, and the average date for spring tillage was 22 April. For those who tilled in the fall, the average planting date was 29 April; for those who tilled in the spring, the average planting date was about a week later on 7 May. Though crops were not specified in the survey, we assume that these dates refer to planting either corn or alfalfa (with or without oats), and that soybeans were commonly planted several weeks later. We further assumed that disking or other secondary tillage practices took place about a week before planting, and that field cultivation (for corn only) took place about a month to 6 weeks after planting.

In addition to *which* implements are used, *how* they are used also has implications for controlling soil erosion and NP-S pollution. Of 91 respondents to the SCC-LWCD Survey, about 12-15% said they practiced either strip cropping, contour strip cropping, or contour tillage. We suspect that plain strip cropping, where straight strips of crops fill rectangular fields but do not exactly follow contours, is more common in the Willow River watershed than are true contour tillage and cropping. Even so, plain strip cropping is still a valuable practice that reduces soil erosion by shortening average flow-path lengths (S. Olson, SCC-LWCD, personal communication, 2005). In addition, about 66% of the respondents said they used grassed waterways to control erosion. Unfortunately, in contrast to the many implements simulated by SWAT, it has only limited ability to simulate the way they are applied. Contour tillage may be approximated by increasing the roughness (Manning's n) of the flow-plane surface SWAT, but such parameterization would require empirical calibration and is not well constrained.

Irrigation was applied to about 2-3% of the cropland acreage in St. Croix County, according to data for 1992, 1997, and 2002 (NASS 2005). This percentage is too low to be included in the SWAT modeling. Calculations based on the SCC-LWCD Survey suggested that irrigation was practiced on about 9% of the reported cropland acreage; however, we expect that this acreage is not representative and that the estimated percentage is too high.

Synthesis into SWAT Management Rotations

The above information on crop rotations, fertilizer applications, tillage practices, and manure management were combined into SWAT-specific agricultural management rotations, with each event scheduled throughout the year. The rates and rules of application are summarized in Table LU-6, and the targeted rotation schedules to be input into SWAT are given in Tables LU-7.1 to LU-7.7. In the interest of simplicity we tried to keep the rotations as similar as possible between the upper and lower watersheds. However, some slight variations were allowed so that the model could reproduce the estimated areal coverages of the main crops (corn, soybeans, and alfalfa). We also mixed dairy and beef manure within the same rotations, rather than having twice as many rotations with dairy and beef manure separated. While dairy and beef farms may commonly be separate operations, we felt that for water-quality purposes the most important factor was applying the proper total amount of manure at realistic rates on the landscape, and that the simplification afforded by mixing the two types of manure was justified. Note that SWAT (surprisingly) does not have an explicit "daily haul" operation, but it does allow for grazing. We simulate daily hauling by grazing phantom dairy and beef cattle that deposit manure at specified rates (kg/ha/day) but that neither consume nor trample the existing vegetation (if any).

The SWAT crop rotations given in Tables LU-7.1-7.7 are our targets to implement within SWAT, as they represent (to the degree possible) the areal coverages and actual agricultural practices in the basin. In theory, each rotation would be multiplied into daughter rotations, each identical to each other but lagged by one year, for as many years as were in the rotation. For example, the C2-S1-A3 rotation would result in 6 separate rotations: CCSAAA, ACCSAA, AACCSA, AAACCS, SAAACC, and CSAAAC. While this would result in the best areal representation of various crops in the watershed, it would also result in a large number of rotations that would complicate calculations within SWAT. We expect that we will need to reduce the number of these "daughter rotations" to achieve a workable model efficiency. The loss of complexity will be compensated by running the model long enough to achieve a stable solution, rather than stopping the model on any one year that may have unrepresentative relative amounts of corn, soybeans, or alfalfa.

Summary and Conclusions

The purpose of this report is to summarize recent land-use changes and agricultural management practices in the Willow River watershed, particularly for the years 1992 to 1999, in order to improve data input to a SWAT computer model of the watershed. Primary data sets examined included federal data from the National Agricultural Statistics Service (NASS), state data from the Wisconsin Department of Natural Resources (WISCLAND spatial data), and county data from St. Croix County (Land and Water Conservation and Planning departments). From 1980 to 2001, the acreage of cropland declined about 27%, from 55% of the county area down to 40%. From 1992 to 1999, the decline was about 8.5–12%, depending on data source, or up to about 7,500 acres in the Willow River watershed. Essentially all the cropland loss was from hay acreage, as corn acreage remained steady and soybean acreage increased slightly. This change is consistent with a gradual shift from dairy farming to cash cropping of corn and soybeans. About 80% of this cropland loss occurred in the lower watershed, below New Richmond, and almost two-thirds of this loss was due to residential development. Forest and small amounts of recreational lands increased at the expense of cropland during the same time.

Agricultural practices examined included crop rotations, manure management, inorganic fertilizer applications, and tillage practices. Over 95% of the cropland was attributable to corn (C), soybeans (S), and hay (A, for alfalfa, the main constituent). In this case, hay acreage included all oats grown as a nurse crop during the first year over alfalfa. In 1999 on a whole-basin basis, we infer that about 60% of the watershed was planted in a C-A rotation, about 20% in a C-S rotation, and about 20% in a C-S-A rotation. By 2004, the C-S-A rotation may have become dominant in the watershed. From 1980 to 2001, the number of cattle in the watershed declined from about 85,000 to 50,000, with manure production consequently declining from about 500,000 shT/yr down to about 300,000 shT/yr. During this time, beef cattle composed about 8–9% of the total but have recently increased to about 12%. Hog and turkey manure accounted for about 2% and 1%, respectively, of the total manure tonnage in the watershed in 1999; these amounts were probably too small to influence the model substantively. For modeling purposes, the amount of manure to be applied to pasture and cropland was calculated. About 9% of dairy manure and 46% of beef manure were applied to pastureland at a combined rate (dairy plus beef) of 4.33 shT/acre/yr. About 21% of dairy manure and

23% of beef manure were applied to part of the C-A rotation on a daily-haul basis at a combined rate of sh9.53 T/acre/yr. The remainder of manure was then applied to year-2 corn in the C-S-A and remaining C-A rotations at a combined rate of 22.06 shT/acre. Commonly used inorganic fertilizers in the watershed included 46-0-0 (urea pellets) and 9-23-30 starter for corn, 9-23-30 for soybeans, and 0-0-60 (potash) for alfalfa. In the watershed model, application rates were 300 lbs/acre of 46-0-0 pre-plant for corn plus 200 lbs/acre of the 9-23-30 starter. For year-2 corn where manure was applied, these rates were reduced to 100 lbs/acre each. Soybeans received 200 lbs/acre of the 9-23-30 (pre-plant) fertilizer. Potash applications to alfalfa were not included in the model because it lacks an appropriate response algorithm. The most common tillage practice appeared to be chisel plowing, both as a primary tillage pass prior to planting as well as a means to incorporate manure applications. Disking (or use of a similar implement) is a common, representative secondary tillage practice to reduce clod size and incorporate inorganic fertilizer applications. Moldboard plowing was used to turn over old alfalfa fields prior to being planted with corn. No-till planting has become increasingly common for soybeans, about 50% of which were no-till in 2000 and 60% in 2004.

In terms of data sets, the relative coherence between the 1992 WISCLAND and NASS data sets for both crop acreage and relative crop percentages (of corn, soybeans, and alfalfa) was encouraging and should prove useful in other tributary watersheds to the St. Croix in Wisconsin. The St. Croix County transect data were internally consistent and therefore useful for trend analysis; it is unclear why the estimated area of cropland was about 13% less than that estimated from the NASS data set, at least for 1999. These estimates were all normalized for the area of the gauged Willow River watershed by simple ratios, which may or may not be appropriate and are likely the source of the difference. The St. Croix County survey data (SCC-LWCD, 2004) provided some means of inferring practices where data were otherwise unavailable, such as the relative acreage of pasture to cropland, and the percentage of livestock manure that was applied by grazing directly to pastureland. One of the greatest difficulties of the survey was knowing what acreage each response represented; consequently scaling the data to a real value over the entire watershed area was unreliable. Thus, the while the survey was useful for inferring the relative proportions of certain agricultural practices in the watershed, for absolute values of acreages and livestock numbers we relied heavily on the NASS data set.

At present we cannot conclude anything about the value of the details presented in this report to the quality of the watershed model. It may be that updating the land-use data from 1992 to 1999 will be the critical factor allowing satisfactory model calibration. Or, we may find that the model is simply too inaccurate to make a difference, and that the model could be calibrated just as well with very general and simple crop rotations. At the very least we hope the model is sensitive enough to give meaningful relative changes in output given selected changes in input parameters.

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Table LU-1. Areas used to scale agricultural statistics for the Willow River watershed.

Name	Area	
	(mi^2)	*(km^2)*
Willow R. Watershed 1a: *Gauged area*	292	756
Willow R. Watershed 1b: *SWAT modeled area*	272	704
Willow R. Watershed 2: *Within St. Croix County*	305	791
St. Croix County	735	1904

Notes:
"Gauged area" refers to catchment upstream from gauging station operated in 1999 by the U.S. Geological Survey. "SWAT modeled area" refers to the catchment above the gauge as automatically delineated by the GIS interface to the model. "Within St. Croix County" area refers to that part of the watershed area as delineated by the Wisconsin Dept. of Natural Resources lying entirely within the county boundary. This area includes the catchment below the gauge as well as some areas that drain directly to the St. Croix.

Table LU-2. Comparison among four data sources of total cropped area and crop percentages within the gauged area of the Willow River Watershed for 1992, 1999, and 2004. Shaded values are those targeted for watershed modeling.

Year	Data Source	Total Cropped Area			Crop Percentages			
		(mi^{2})	*(acres)*	*(ha)*	Corn	Soybeans	Hay & Oats	Other
1992	WISCLAND	139	88,693	35,894	40%	12%	48%	0%
	NASS	133	85,414	34,567	42%	11%	44%	3%
	Average	*136*	*87,054*	*35,230*	*41%*	*11%*	*46%*	*2%*
	Average Crop %, excluding Other				*42%*	*12%*	*47%*	
1999	NASS	127	81,224	32,871	43%	12%	42%	3%
	SCC-LWCD *Transect*	110	70,586	28,566	40%	13%	46%	1%
	Average	*119*	*75,905*	*30,718*	*41%*	*13%*	*44%*	*2%*
	Average Crop %, excluding Other				*42%*	*13%*	*45%*	
2004	Extrapolated NASS	122	78,230	31,659	44%	14%	39%	3%
	SCC-LWCD *Transect*	106	67,766	27,425	45%	17%	36%	1%
	SCC-LWCD *Survey*	(83 to 143)	(52,947 to 91,574)	(21,428 to 37,059)	42%	23%	31%	4%
	Average	*114*	*72,998*	*29,542*	*44%*	*18%*	*36%*	*3%*
	Average Crop %, excluding Other				*45%*	*19%*	*37%*	

(Average acres here excludes Survey data)

Abbreviations:

WISCLAND, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data; NASS, National Agricultural Statistics Service; SCC-LWCD, St. Croix County Land and Water Conservation District; mi^2, square miles; ha, hectares.

Notes:

(a) WISCLAND identified only Corn, Soybeans, and Alfalfa as crops. No other crops, including small grains, were identified, though they were known to be present. If the WISCLAND "Alfalfa" is assumed to include all hayed areas, including those planted with oats as a first-year nurse crop, then acreage is more consistent with the NASS data. (b) NASS data are for harvested acres. Data for planted acres gave results that were inconsistent with the WISCLAND data. "Hay" includes alfalfa plus other forage crops, cut for both dry hay and haylage. Missing values for haylage reconstructed by assuming an average proportion of haylage to dry hay. All oats were assumed to be planted as a first-year nurse crop over alfalfa. "Other" crops included barley, wheat, snap beans, green peas, and sweet corn. (c) SCC-LWCD Transect data modified by assuming oats accounted for 70% of all small grains identified, and then combining that acreage with that for hay. (Oats accounted for an average of 70% of "other" crops in the NASS data, 1980-2001.) "Other" crops here include the remaining small grains, presumably wheat and barley. (d) SCC-LWCD Survey data constructed by applying interpreted crop rotations to acreage planted, as reported in the survey responses. Survey replies were not always easily interpretable, and result for total cropped area is not likely as reliable as other data sources. Crop percentages, however, are broadly consistent with other sources. (e) All areas were scaled to the gauged area of the Willow River watershed by applying a simple ratio of the gauged area to the area covered by each data source. WISCLAND data could be clipped directly to the gauged watershed area. Original NASS data were for all of St. Croix County, and original SCC-LWCD were for that part of the Willow River Watershed within St. Croix County (as delineated by the Wisconsin Dept. of Natural Resources).

Table LU-3. Conversion of crop areas to other land-use types in the Willow River gauged watershed area, 1992-99 and 1999-2004.

	1992-99			**1999-2004**		
Cropland converted to:	*(acres)*	*(ha)*	*(%)*	*(acres)*	*(ha)*	*(%)*
Inside New Richmond						
Urban, low intensity	106	43	67%	42	17	67%
Urban, high intensity	53	21	33%	21	9	33%
Subtotal	*158*	*64*	*100%*	*64*	*26*	*100%*
Outside New Richmond						
Upper Willow Watershed						
Residential, low density	411	166	28%	165	67	28%
Forest, mixed	1,051	425	72%	421	171	72%
Recreational	0	0	0%	0	0	0%
Subtotal	*1,462*	*592*	*100%*	*586*	*237*	*100%*
Lower Willow Watershed						
Residential, low density	3,697	1,496	63%	1,482	600	63%
Forest, mixed	1,442	583	25%	578	234	25%
Recreational	710	287	12%	285	115	12%
Subtotal	*5,848*	*2,367*	*100%*	*2,344*	*949*	*100%*
Total crop area lost	7,469	3,023		2,994	1,212	

Notes:

(a) 1992-99 crop area lost was set to 1992 WISCLAND crop area minus 1999 NASS crop area, scaled to gauged watershed area.

(b) 1999-2004 crop area lost was set to 1999 NASS crop area minus crop area from NASS data extrapolated to 2004. This loss (1,212 hectares) was similar to that estimated from St. Croix County Transect data (1,141 hectares).

(c) Of this total crop area lost, 80% was attributed to the lower watershed and 20% to the upper watershed, based on land-use changes in individual townships during 1973-93.

(d) The portion of crop area converted to residential development and urbanization was based on population changes in New Richmond and St. Croix County.

(d1) For New Richmond, the 1992-99 population growth was assumed to be 70% of the 1990-2000 population growth. Each new residence was assumed to contain 2.66 people and occupy 0.33 acre (data from 2000 census). High-intensity urbanization (commercial, industrial, institutional, transportation, and utilities) was assumed to accompany residential development at a 50% rate, i.e., 1 hectare high-intensity per 2 hectares residential.

(d2) For the rest of the watershed, the 1992-99 population growth was assumed to be 70% of the 1990-2000 rural population growth in St. Croix County (towns and villages only; cities excluded), scaled by the gauged watershed area. Each house outside New Richmond was assumed to contain 2.66 people and occupy 1.85 ha (4.57 acres; countywide average for lots developed 2000-04). Of this increase in residential acreage, 90% was attributed to the lower watershed and 10% to the upper watershed, based on relative population growth in the individual townships from 1990-2000.

(d3) The remaining lost crop area was assigned to forest in the upper watershed, and to a 2-to-1 ratio of forest-to-recreational land in the lower watershed, based on 1973-93 land-use data.

(e) The 1999-2004 percentages of area gains for all land uses were assumed to be the same as during 1992-1999.

References:

WDNR 1998; NASS 2005; SCC-LWCD 2004; SCC-Planning Dept. 2000; U.S. Census Bureau on-line data

Table LU-4. Possible crop rotations that reproduce estimated crop coverages in the Willow River watershed, 1992-2004.

		Rotation Coverage			**Resulting Crop Coverage**			**Target**
Year	**Extent**	**Rotation**	**(ha)**	**(%)**	**Crop**	**(ha)**	**(%)**	**(%)**
1992	Whole Basin	C2-A3	20101	60%	Corn	14143	42%	42%
		C1-S1	5025	15%	Soybeans	3709	11%	12%
		C3-S1-A3	8376	25%	Alfalfa	15650	47%	47%
		Total	*33502*	*100%*	*Total*	*33502*	*100%*	*100%*
	Upper Sub-Basin	C2-A3	15905	70%	Corn	8748	39%	36%
		C1-S1	3408	15%	Soybeans	2386	11%	12%
		C1-S1-A3	3408	15%	Alfalfa	11588	51%	52%
		Total	*22722*	*100%*	*Total*	*22722*	*100%*	*100%*
	Lower Sub-Basin	C2-A3	5390	50%	Corn	5236	49%	48%
		C2-S1	3234	30%	Soybeans	1386	13%	13%
		C3-S1-A3	2156	20%	Alfalfa	4158	39%	39%
		Total	*10780*	*100%*	*Total*	*10780*	*100%*	*100%*
1999	Whole Basin	C2-A3	18412	60%	Corn	13063	43%	42%
		C1-S1	6137	20%	Soybeans	3945	13%	13%
		C3-S1-A3	6137	20%	Alfalfa	13677	45%	45%
		Total	*30686*	*100%*	*Total*	*30686*	*100%*	*100%*
	Upper Sub-Basin	C2-A3	13285	60%	Corn	8819	40%	na
		C1-S1	3321	15%	Soybeans	2583	12%	na
		C2-S1-A3	5535	25%	Alfalfa	10738	49%	na
		Total	*22141*	*100%*	*Total*	*22141*	*100%*	
	Lower Sub-Basin	C2-A3	2564	30%	Corn	4199	49%	na
		C2-S1	2564	30%	Soybeans	1343	16%	na
		C3-S1-A3	3418	40%	Alfalfa	3003	35%	na
		Total	*8545*	*100%*	*Total*	*8545*	*100%*	
2004	Whole Basin	C2-A3	7685	26%	Corn	12954	44%	45%
		C1-S1	7094	24%	Soybeans	5658	19%	19%
		C3-S1-A3	14779	50%	Alfalfa	10945	37%	37%
		Total	*29557*	*100%*	*Total*	*29557*	*100%*	*100%*
	Upper Sub-Basin	C2-A3	4382	20%	Corn	9577	44%	na
		C1-S1	4382	20%	Soybeans	4069	19%	na
		C3-S1-A3	13145	60%	Alfalfa	8262	38%	na
		Total	*21908*	*100%*	*Total*	*21908*	*100%*	
	Lower Sub-Basin	C2-A3	1530	20%	Corn	3781	49%	na
		C2-S1	2295	30%	Soybeans	1311	17%	na
		C3-S1-A3	3825	50%	Alfalfa	2557	33%	na
		Total	*7649*	*100%*	*Total*	*7649*	*100%*	

Abbreviations:
ha, hectares; C, corn; S, soybeans; A, alfalfa and other hay crops; na, not available
Notes:
The number after each crop refers to the years of that crop in the rotation. The areas of crops have been scaled to the SWAT modeled watershed area (rather than the gauged watershed area referred to by most of the rest of this report).

Table LU-5. Typical manure characteristics and calculated quantities in the Willow River gauged watershed area, 1999.

	(a) Manure characteristics				**(b) Manure in the gauged Willow watershed**				
Livestock Type	**Raw Manure** (lbs/day/1000-lb animal unit)	**Total Solids (Dry Wt)** (lbs/day/1000-lb animal unit)	**Nitrogen** (lbs/day/1000-lb animal unit)	**Phosphorus** (lbs/day/1000-lb animal unit)	**Numbers of Animals**	**Animal Est'd Wt** (lbs)	**Raw Manure** (short T/yr)	**Total Solids (Dry Wt)** (metric T/yr)	**Percent of Total** (%, raw manure)
Dairy cattle, adult	86	12	0.45	0.094	9,733	1,350	206,232	26,161	58.37%
Dairy calf	86	12	0.45	0.094	7,757	700	85,222	10,810	24.12%
Beef cattle, adult	58	8.5	0.34	0.092	2,572	1,200	32,663	4,352	9.24%
Beef calf	58	8.5	0.34	0.092	2,049	800	17,354	2,312	4.91%
Hogs	84	11	0.52	0.18	2,543	175	6,821	812	1.93%
Sheep	40	11	0.42	0.087	58	100	42	11	0.01%
Chickens (layers)	64	16	0.84	0.3	994	4	46	11	0.01%
Turkeys	47	12	0.62	0.23	n/a	n/a	3,526	818	1.00%
Horses	51	15	0.3	0.071	191	800	1,426	381	0.40%
Totals							353,333	45,667	100%

Abbreviations:

Dry Wt, dry weight; Est'd Wt, estimated weight; lbs, pounds; short T, short ton = 2000 lb; metric T, metric ton = 1000 kilograms; n/a, not applicable

Notes:

Manure charactistics obtained from American Society of Agricultural Engineers (1998), as cited by Neitsch et al. (2002).

Numbers of cattle and hogs for St. Croix County obtained from the National Agricultural Statistics Service web data, scaled from countywide totals down to the gauged watershed area. Beef cattle and total number of calves interpolated between 1997 and 2002 data. Calves apportioned according to the proportions of adult cattle.

Numbers of sheep, chickens, and horses estimated from 2004 survey of farmers in the watershed (SCC-LWCD 2004). We suspect that sheep and chickens were underestimated, but still unlikely to be a major contributor of manure relative to other sources. Turkey numbers in St. Croix County were not relevant, as turkey manure from other counties is trucked to St. Croix County; tons spread in 1999 were scaled down to the gauged watershed area from a countywide total (K. Hafstad, Jenny-O Turkey Store, personal communication, 2005).

Table LU-6. Manure application rates for different crop rotations in the SWAT model of the Willow River watershed, 1999.

		Typical Units in USA			Units for SWAT Input				
Rotation	**Area Relative to Total Cropland Area** (%)	**Dairy** (sh T/acre/yr, wet wt)	**Beef** (sh T/acre/yr, wet wt)	**Total** (sh T/acre/yr, wet wt)	**Dairy** (see column to right for units)	**Beef**	**Total**	**Units**	**Rules**
Whole Basin									
Pasture	14%	2.31	2.02	4.33	4.39	4.04	8.43	kg/ha/day	Grazing 20 May to 1 Nov (165 days) each year
C2-A3, daily haul	10%	8.57	0.96	9.53	7.37	0.86	8.23	kg/ha/day	Everyday all year for hay fields, Nov-Apr for corn fields
C2-A3, seasonal	50%	20.06	1.99	22.06	6296	656	6952	kg/ha/year	Half in fall, half in spring before yr-2 corn
C3-S1-A3, seasonal	20%	20.06	1.99	22.06	6296	656	6952	kg/ha/year	Half in fall, half in spring before yr-2 corn
C1-S1, no manure	20%	n/a	n/a	n/a	n/a	n/a	n/a		
Upper Watershed									
Pasture	14%	2.31	2.02	4.33	4.39	4.04	8.43	kg/ha/day	Grazing 20 May to 1 Nov (165 days) each year
C2-A3, daily haul	10%	8.57	0.96	9.53	7.37	0.86	8.23	kg/ha/day	Everyday all year for hay fields, Nov-Apr for corn fields
C2-A3, seasonal	50%	20.06	1.99	22.06	6296	656	6952	kg/ha/year	Half in fall, half in spring before yr-2 corn
C2-S1-A3, seasonal	25%	20.06	1.99	22.06	6296	656	6952	kg/ha/year	Half in fall, half in spring before yr-2 corn
C1-S1, no manure	15%	n/a	n/a	n/a	n/a	n/a	n/a		
Lower Watershed									
Pasture	14%	2.31	2.02	4.33	4.39	4.04	8.43	kg/ha/day	Grazing 20 May to 1 Nov (165 days) each year
C2-A3, daily haul	10%	8.57	0.96	9.53	7.37	0.86	8.23	kg/ha/day	Everyday all year for hay fields, Nov-Apr for corn fields
C2-A3, seasonal	20%	20.06	1.99	22.06	6296	656	6952	kg/ha/year	Half in fall, half in spring before yr-2 corn
C3-S1-A3, seasonal	40%	20.06	1.99	22.06	6296	656	6952	kg/ha/year	Half in fall, half in spring before yr-2 corn
C2-S1, no manure	30%	n/a	n/a	n/a	n/a	n/a	n/a		

Abbreviations:

lbs, pounds; sh T, short ton = 2000 lbs; yr, year; wt, weight; kg, kilograms; ha, hectare; n/a, not applicable

Notes:

C, corn; S, soybeans; A, alfalfa; number following letter designates number of years of that crop in the rotation.

For C-A and C-S-A rotations: yr-1 corn is grain; yr-2 corn is silage; yr-3 corn (if any) is grain following soybeans. For C-S rotations: all corn is grain.

Cropland comprises the C-A, C-S-A, and C-S rotations and totals 100%.

Pasture is additional land, calculated at 14% of cropland area.

Table LU-7.1--Pasture Rotation, both upper and lower watersheds

Area	*% cropland*	*ha*
Upper	*14%*	*3100*
Lower	*14%*	*1196*

Year	Date	Operation	What	Rate	Units
Year 1	20-May	Graze start	Dairy manure	4.39	kg/ha/day
	20-May	Graze start	Beef manure	4.04	kg/ha/day
	1-Nov	Graze end	Dairy		
	1-Nov	Graze end	Beef		

Table LU-7.2--C2-A3 Daily Haul Rotation, both upper and lower watersheds

Area	*% cropland*	*ha*
Upper	*10%*	*2214*
Lower	*10%*	*855*

Year	Date	Operation	What	Rate	Units
Year 1	1-Jan	Graze start	Dairy manure	7.37	kg/ha/day
	1-Jan	Graze start	Beef manure	0.86	kg/ha/day
	30-Apr	Graze end	Dairy manure		
	30-Apr	Graze end	Beef manure		
	1-May	Fertilize	46-0-0	112	kg/ha
	3-May	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	112	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
	30-Oct	Tillage	Chisel		
	1-Nov	Graze start	Dairy manure	7.37	kg/ha/day
	1-Nov	Graze start	Beef manure	0.86	kg/ha/day
Year 2	30-Apr	Graze end	Dairy manure		
	30-Apr	Graze end	Beef manure		
	1-May	Fertilize	46-0-0	112	kg/ha
	3-May	Tillage	Disk		
	7-May	Plant	Corn-Silage		
	7-May	Fertilize	9-23-30	112	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Sep	Harvest&Kill	Corn-Silage		
	1-Nov	Graze start	Dairy manure	7.37	kg/ha/day
	1-Nov	Graze start	Beef manure	0.86	kg/ha/day
Year 3	1-May	Tillage	Chisel		
	3-May	Tillage	Disk		
	7-May	Plant	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 4	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 5	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest&Kill	Alfalfa		
	1-Nov	Tillage	Plow		
	31-Dec	Graze end	Dairy manure		
	31-Dec	Graze end	Beef manure		

Table LU-7.3--C2-A3 Seasonal Manure Rotation, both upper and lower watersheds

Area	***% cropland***	***ha***
Upper	*50%*	*11071*
Lower	*20%*	*1709*

Year	**Date**	**Operation**	**What**	**Rate**	**Units**
Year 1	15-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
	1-Nov	Fertilize	Manure-Dairy	3148	kg/ha
	1-Nov	Fertilize	Manure-Beef	328	kg/ha
	5-Nov	Tillage	Chisel		
Year 2	15-Apr	Fertilize	46-0-0	112	kg/ha
	25-Apr	Fertilize	Manure-Dairy	3148	kg/ha
	25-Apr	Fertilize	Manure-Beef	328	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Silage		
	7-May	Fertilize	9-23-30	112	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Sep	Harvest&Kill	Corn-Silage		
Year 3	20-Apr	Tillage	Chisel		
	30-Apr	Tillage	Disk		
	7-May	Plant	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 4	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 5	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest&Kill	Alfalfa		
	1-Nov	Tillage	Plow		

Table LU-7.4--C2-S1-A3 Seasonal Manure Rotation, upper watershed only

Area	*% cropland*	*ha*
Upper	*25%*	*5535*
Lower	*n/a*	*n/a*

Year	Date	Operation	What	Rate	Units
Year 1	25-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
	1-Nov	Fertilize	Manure-Dairy	3148	kg/ha
	1-Nov	Fertilize	Manure-Beef	328	kg/ha
	5-Nov	Tillage	Chisel		
Year 2	15-Apr	Fertilize	46-0-0	112	kg/ha
	25-Apr	Fertilize	Manure-Dairy	3148	kg/ha
	25-Apr	Fertilize	Manure-Beef	328	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Silage		
	7-May	Fertilize	9-23-30	112	kg/ha
	15-Sep	Harvest&Kill	Corn-Silage		
Year 3	20-Apr	Tillage	Chisel		
	10-May	Fertilize	9-23-30	225	kg/ha
	15-May	Tillage	Disk		
	20-May	Plant	Soybeans		
	15-Oct	Harvest&Kill	Soybeans		
Year 4	20-Apr	Tillage	Chisel		
	30-Apr	Tillage	Disk		
	7-May	Plant	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 5	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 6	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest	Alfalfa		
	1-Nov	Tillage	Plow		

Table LU-7.5--C3-S1-A3 Seasonal Manure Rotation, lower watershed only

Area	*% cropland*	*ha*
Upper	*n/a*	*n/a*
Lower	*40%*	*3418*

Year	Date	Operation	What	Rate	Units
Year 1	25-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
	1-Nov	Fertilize	Manure-Dairy	3148	kg/ha
	1-Nov	Fertilize	Manure-Beef	328	kg/ha
	5-Nov	Tillage	Chisel		
Year 2	15-Apr	Fertilize	46-0-0	112	kg/ha
	25-Apr	Fertilize	Manure-Dairy	3148	kg/ha
	25-Apr	Fertilize	Manure-Beef	328	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Silage		
	7-May	Fertilize	9-23-30	112	kg/ha
	15-Sep	Harvest&Kill	Corn-Silage		
Year 3	20-Apr	Tillage	Chisel		
	10-May	Fertilize	9-23-30	225	kg/ha
	15-May	Tillage	Disk		
	20-May	Plant	Soybeans		
	15-Oct	Harvest&Kill	Soybeans		
Year 4	25-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
Year 5	20-Apr	Tillage	Chisel		
	30-Apr	Tillage	Disk		
	7-May	Plant	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 6	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest	Alfalfa		
Year 7	25-Jun	Harvest	Alfalfa		
	10-Aug	Harvest	Alfalfa		
	10-Sep	Harvest	Alfalfa		
	1-Nov	Tillage	Plow		

Table LU-7.6--C1-S1, no manure rotation, upper watershed only

Area	*% cropland*	*ha*
Upper	*15%*	*3321*
Lower	*n/a*	*n/a*

Year	Date	Operation	What	Rate	Units
Year 1	20-Apr	Tillage	Chisel		
	25-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
Year 2	20-Apr	Tillage	Chisel		
	10-May	Fertilize	9-23-30	225	kg/ha
	15-May	Tillage	Disk		
	20-May	Plant	Soybeans		
	15-Oct	Harvest&Kill	Soybeans		

Table LU-7.7--C2-S1, no manure rotation, lower watershed only

Area	*% cropland*	*ha*
Upper	*n/a*	*n/a*
Lower	*30%*	*2564*

Year	Date	Operation	What	Rate	Units
Year 1	20-Apr	Tillage	Chisel		
	25-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
Year 2	20-Apr	Tillage	Chisel		
	25-Apr	Fertilize	46-0-0	337	kg/ha
	30-Apr	Tillage	Disk		
	7-May	Plant	Corn-Grain		
	7-May	Fertilize	9-23-30	225	kg/ha
	10-Jun	Tillage	Cultivate		
	15-Oct	Harvest&Kill	Corn-Grain		
Year 3	20-Apr	Tillage	Chisel		
	10-May	Fertilize	9-23-30	225	kg/ha
	15-May	Tillage	Disk		
	20-May	Plant	Soybeans		
	15-Oct	Harvest&Kill	Soybeans		