Mead Lake Watershed
Sediment and Nutrient Export Modeling

Photo: Mead Lake Reservoir

Adam Freihoefer and Paul McGinley

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Executive Summary

The Mead Lake Reservoir (MLR) is exhibiting enrichment of nutrients, particularly phosphorus. The 1.3 km^2 impoundment was added to the Wisconsin's 303d impaired waterway list as a result of the sediment and nutrient loading. As a result of the impaired designation, a sediment and phosphorus Total Maximum Daily Load (TMDL) is being developed for the reservoir to meet water quality standards.

As a preliminary step in TMDL development for the MLR, the Soil and Water Assessment Tool (SWAT) model approach was used to simulate the influence of land management on sediment and phosphorus transfer throughout the Mead Lake Watershed (MLW). The SWAT model approach relied on detailed management information and two years of measured growing season discharge and water quality to calibrate the model. The calibrated model allowed for various alternative management scenarios to be implemented, evaluating the impact each scenario had on phosphorus contributions to the MLR. The SWAT's spatial discretization within each subwatershed of MLW required the application of the field-scale Wisconsin-based SNAP model to evaluate individual fields. The implementation of both models allowed greater flexibility in locating contributing sources of nutrient loss at varying scales.

The SWAT model was calibrated to discharge and water quality measured during the growing seasons (May to September) of 2002 and 2003. SWAT could be used successfully to simulate the daily discharge (R^2 = 0.63, N-S=0.62), monthly sediment (R^2 = 0.54, N-S=0.49), and monthly phosphorus (R^2 = 0.66, N-S=0.66). The majority of the phosphorus export within the watershed came from two specific agricultural hydrologic response units (HRUs) (113C and 114C).

The calibrated model was used to evaluate long term (1981-2004) alternative management scenarios. Reductions in soil phosphorus and soil erosion would both lead to a reduction in phosphorus transfer from the watershed. The modeling suggests that watershed-wide reductions in soil phosphorus and sediment loss could lead to an almost thirty percent reduction in phosphorus to Mead Lake.

Acknowledgements

We wish to acknowledge those groups and individuals who contributed to the successful completion of the project through funding, insight, and support.

This project would not have been possible had it not been for funding sources including Eau Claire and Clark Counties, Lake Altoona and Lake Eau Claire Associations, and the Wisconsin Department of Natural Resources.

The development of this project is a culmination of the efforts of many. Model calibration would not have been possible without the previous research conducted by William James and the Eau Galle Aquatic Ecology Laboratory of the U.S. Army Corp of Engineers. UW-Stevens Point (UWSP) staff provided assistance during all stages of the project. Digitizing and aerial photo analysis conducted by Alex Smith defined the spatial extent of land management throughout the watershed. The assistance of Steven Weiss during the data collection and model development periods allowed this project to finish in a timely manner.

Clark County Conservationists Gregg Stangl and Matthew Zoschke, GIS Analyst Bill Shockley, and the rest of the Clark County Conservation staff were integral in providing land management identification, organizing field visits, and offering insight into individual land management changes throughout the watershed. The Clark County staffs ability to foster a positive experience was necessary for project completion.

The data collection of field-scale information would not have been possible without individual landowner’s willingness to participate in a farm survey and grant UW-Stevens Point staff access to their land.

Thanks to Buzz Sorge, Ken Schreiber, and Patrick Oldenburg of the Wisconsin Department of Natural Resources for the active role they played during conceptual development, model evaluation, and alternative scenario design.

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List of Acronyms

ALPHA_BF	Alpha Baseflow
AMLE	Adjusted Maximum Likelihood Estimation
APM	Peak Rate Adjustment Factor for Sediment Routing
AVSWAT	ArcView Soil and Water Assessment Tool
AWC	Available Water Capacity
BE	Biomass Energy Factor
BMP	Best Management Practice
CMS	Cubic Meter per Second
CNOP	Operational Crop Curve Number
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
DEM	Digital Elevation Model
DRG	Digital Raster Graphic
EPIC	Erosion-Productivity Impact Calculator
ERORGP	Organic Phosphorus Enrichment Ratio
ESCO	Evapotranspiration Coefficient
FILTERW	Filter Strip Trapping Efficiency
GWSOLP	Groundwater Soluble P Concentration
GIS	Geographical Information Systems
GLEAMS	Groundwater Loading Effects on Agricultural Management Systems
HRU	Hydrologic Response Unit
ID	Internal Drainage
MLR	Mead Lake Reservoir
MLW	Mead Lake Watershed
N-S	Nash Sutcliffe coefficient of efficiency
NASS	National Agriculture Statistical Service
NCDC	National Climatic Data Center
ORL	Other Resource Land
P	Phosphorus
PEST	Parameter Estimation
PHOSKD	Phosphorus Soil Portioning Coefficient
PSP	Phosphorus Availability Index
RCN	Natural Resources Conservation Service Curve Number
SLSUBBSN	Average Slope Length
SOLBD	Soil Bulk Density
SOL_LABP	Initial Soluble P Concentration in Soil Layer
SOLK	Soil Hydraulic Conductivity
SWAT	Soil and Water Assessment Tool
SWRRB	Simulator for Water Resources in Rural Basin
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
UBP	Phosphorus Uptake Coefficient
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USLE_P	USLE equation Support Practice Factor
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
UWSP	University of Wisconsin at Stevens Point
WIDNR	Wisconsin Department of Natural Resources

1.0 Introduction

1.1 Purpose

The U.S. Environmental Protection Agency (USEPA) lists eutrophication as the main cause of impaired waters in the United States (EPA 1996). Eutrophication is nutrient enrichment and subsequent excessive biological productivity in lakes and streams. While they grow, biota reduce water clarity and impair water use. When the biota die and decompose, dissolved oxygen levels are reduced impairing aquatic community composition within the lake. Although nitrogen also affects water quality, phosphorus is usually the limiting nutrient for eutrophication of inland lakes (Correll 1998). The effects of eutrophication in Midwestern lakes are often observed when concentrations of total phosphorus reach 0.02 mg/L (Shaw *et al.* 2000).

Phosphorus (P) concentrations in lakes are controlled by both internal and external phosphorus loading. Internal phosphorus loading occurs when phosphorus already in the lake system becomes available for use by biota. In eutrophic lakes, reduced dissolved oxygen creates an anoxic environment favorable for the release of phosphorus that was previously buried in lake sediment. External phosphorus loading is phosphorus transported into the lakes from the watershed or the atmosphere. External loading can be increased by land management that increases the movement or availability of phosphorus. There is little argument that the phosphorus delivered externally to a reservoir system is a principle cause of eutrophication. Slowing or reversing eutrophication requires that the external and/or internal loads be reduced. Because internal loads are already in the lake, it is critically important to understand and reduce, if possible, the external loading. To efficiently address external loads, it is important to locate and manage the critical areas within the watershed which are the largest phosphorus contributors.

Mead Lake is listed as a high priority on the Wisconsin Department of Natural Resources (WIDNR) 303d impaired waterway list (WIDNR 2006). Impaired waters, as defined by Section 303(d) of the federal Clean Water Act, are those waters that are not meeting the state's water quality standards or use designations. The pollutants of concern are phosphorus and sediment from non-point sources entering the lake by external loading.

A two year study in 2002-2003 of Mead Lake's water quality was conducted by the Army Corps of Engineers (USACE) (James 2005). The study focused on external loading (suspended sediments and nutrients from the South Fork of the Eau Claire River), internal P fluxes from aquatic sediment, and in-lake water quality measurements. The study found that on average 83% of the P load came from tributaries of Mead Lake. The study concluded that "*because Mead Lake impounds a large portion of the agriculturally-dominated South Fork of the Eau Claire River watershed, it receives substantial P loads that overwhelmingly contribute to poor water quality conditions*." The study went on to recommend that "*the management of internal P loading from the sediment should not be attempted in Mead Lake until significant tributary P loading reduction has been achieved through Best Management Practices (BMP)* " (James 2005). This project serves as a preliminary step in identifying and managing P loading from the South Fork of the Eau Claire River.

1.2 Site Description

The Mead Lake Watershed (MLW), a subbasin of the Eau Claire River Watershed, drains 248 km^2 (61,282 acres) of West-Central Wisconsin (Figure 1). Approximately 99 percent of the watershed is within western Clark County, with the remaining one percent in southwestern Taylor County. The northern section of the watershed is bisected by State Highway 29. The watershed empties into Mead Lake, a 1.3 km^2 impoundment west of Greenwood, Wisconsin. Mead Lake has a volume of 1.9 hm^3 and mean and maximum depths of 1.5m and 5m, respectively (Figure 2) (James 2005). Mead Lake was created when the South Fork of the Eau Claire River was dammed in the late 1940s. The South Fork of the Eau Claire River (43.8 km channel length) is the primary tributary contributing to Mead Lake.

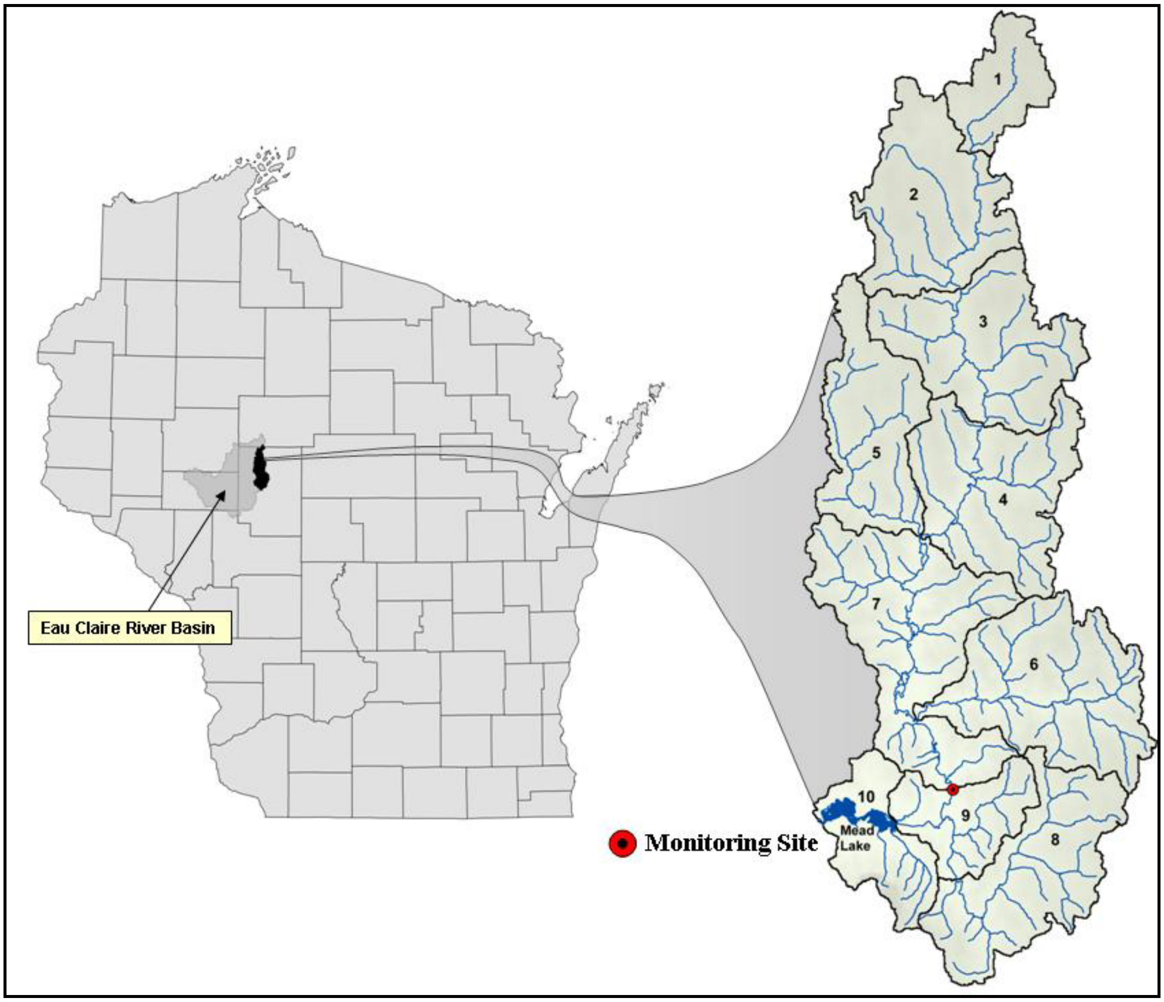

Figure 1: Location of Mead Lake Watershed within Wisconsin

2.0 Methods and Materials

To understand sediment and phosphorus loading from nonpoint sources within the watershed, a three phase project was developed. The first phase calibrated a watershed-scale model to measured discharge and water quality. The second phase tested alternate management practices with the calibrated watershed model to determine effective measures of reducing sediment and nutrients to the reservoir. In the third phase, the simulated discharge and water quality export from the watershed model was incorporated with a reservoir routing model, simulating reservoir processes.

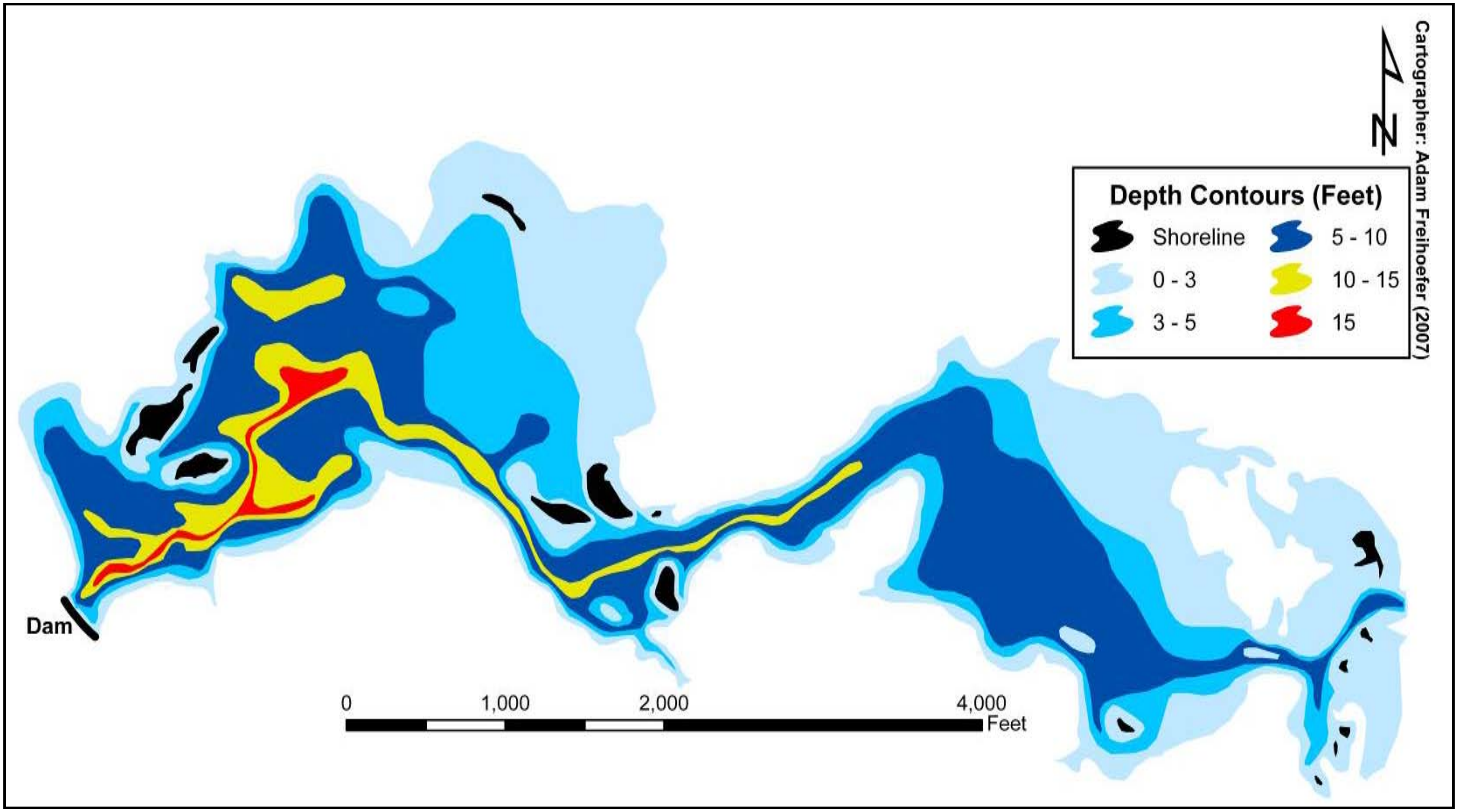

Figure 2: Mead Lake Depth Contour Map

2.1 SWAT Model Description and Approach

The SWAT model is a physically based, continuous daily time-step, geographic information system (GIS) based model developed by the U.S. Department of Agriculture - Agriculture Research Service (USDA-ARS) for the prediction and simulation of flow, sediment, and nutrient yields from mixed landuse watersheds. The SWAT model incorporates the effects of climate, surface runoff, evapotranspiration, crop growth, groundwater flow, nutrient loading, and water routing for different land uses to predict hydrologic response. A modified version of the SWAT2000 executable code was used in all model simulations. The FORTRAN model modifications were made by Paul Baumgart of the University of Wisconsin at Green Bay to improve simulation within a watershed in northeast Wisconsin. Modifications to the SWAT program included a correction to the wetland routine to correct P retention, a modification to correctly kill alfalfa at the end of its growing season. Another modification included using root biomass for the direct computation of the fraction of biomass transferred to the residue fraction when a perennial crop goes dormant is computed using root biomass. For a complete list of the FORTRAN code modifications completed by Paul Baumgart, refer to Baumgart (2005).

The ArcView extension (AVSWAT) (version 1.0) of the SWAT model (Di Luzio *et al.* 2002) was used in this project. The SWAT uses algorithms from a number of previous models including the Simulator for Water Resources in Rural Basin (SWRRB) model, the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model, the Groundwater Loading Effects on Agricultural Management Systems (GLEAMS), and the Erosion-Productivity Impact Calculator (EPIC) (Neitsch 2002). The SWAT model incorporates the effects of weather, surface runoff, evapotranspiration, crop growth, irrigation, groundwater flow, nutrient and pesticide loading, and water routing for varying land uses (Kirsch *et al*. 2002; Neitsch *et al*. 2002). SWAT was selected because it is being used to simulate P loading for watersheds throughout Wisconsin (Kirsch *et al*. (2002), Baumgart (2005), FitzHugh and MacKay (2000)).

Simulating P export from the landscape using SWAT begins at the subwatershed scale. Subwatersheds are delineated using topography and user-defined sampling points or stream junctions. Each subwatershed may contain multiple agricultural fields, depending on the subbasin discretization. SWAT does not retain the spatial identity of each field and its proximity to the stream reach becomes lost as the subwatershed is split into the unique combinations of landuse and soil with a given slope called hydrologic response units (HRUs). Landscape processes are simulated within each individual HRU and each HRU is assumed to contribute directly to the stream reach.

Watershed water quality studies completed with SWAT frequently use a similar calibration technique. The user compares the SWAT simulated values to data measured in the field and then adjusts several HRU specific variables, such as the soil available water capacity (AWC), evapotranspiration coefficient (ESCO), and NRCS runoff curve numbers (RCN), to better fit the measured data set (SWAT Calibration Techniques 2005). Typically, it is assumed values for these parameters are known based on previous measurements or estimating tools (i.e. RCN). Many studies used a RCN value close to that recommended by the NRCS, while others have used it as a calibration parameter.

The calibrated SWAT model can be used to evaluate the sensitivity of watershed phosphorus export to changes in management practices. Different scenarios can be simulated by making adjustments in the model reflecting the changes in management. While the variability of P source and transport mechanisms in the watershed requires understanding the impacts of changes made at the field-scale (Gburek and Sharpley 1998). SWAT results provide a watershed-wide average response. The modeling results can be combined with tools that provide a site-specific evaluation of management changes to develop an implementation strategy.

2.2 Collection of Data

2.2.1 Discharge

Seven of the ten subwatersheds (192 km^2) contribute to the gauged discharge and water quality at Hwy MM on the South Fork of the Eau Claire River. During the non-melt periods of 2002 and 2003, a daily stage elevation (averaged from 15-minute interval stage readings) was converted to average daily volumetric discharge using a rating curve. Discharge readings were collected for 377 days between April 2002 and October 2003 and excluded the November through March time period (Table 1, Figure 3). The fraction of flow from the MLW contributed by subsurface flow (groundwater contributed) was estimated using a baseflow separation program developed by Arnold and Allen (1999). Approximately 41% of the total discharge during the 377 observations days was baseflow.

2.2.2 Water Quality

Water quality samples (total suspended solids and total phosphorus) were collected semimonthly (James 2005) at Hwy MM. The water quality sampling protocol follows research indicating that systematic sampling of studies of 2 years or more provided the least biased and most precise annual loads (Robertson and Roerish, 1999). The samples collected captured both baseflow and events during the observed stream discharge. The resulting 27 water quality samples were then converted into flow weighted monthly mean load estimates (kg/d) of total phosphorus (TP) and total suspended solids (TSS) with LOADEST, a Fortran-based program developed by the United States Geological Survey (USGS) (Runkel *et al* 2004). Input files included instantaneous daily measures of flow ranging from 0.21 to 30.91 cubic meter per second (cms). Calibration files included 27 instantaneous measures of TP and TSS taken during a 7 and 6 month period in 2002 and 2003, respectively.

Eleven separate regression models were available through LOADEST. The adjusted maximum likelihood estimation (AMLE) was used to calculate estimated monthly loads. Regression model 2 ($a_0 + a_1 \ln Q + a_2 \ln Q^2$) (where Q is the average daily flow and a_1 and a_2 are fitted constants) was selected because the results were similar to those presented in the Mead Lake water quality report (James 2005). For two monitored years, the phosphorus loading estimated using LOADEST were 3% and 15% higher than those presented in James (2005).

In addition to the South Fork of the Eau Claire River, water quality has also been measured within Mead Lake. The 2005 James study collected in-lake TP and TSS from Mead Lake 12 times in 2002 and 11 times in 2003. Secchi Disk depths, used to determine water clarity and algal productivity, were monitored by citizens in correlation with the self-help lake monitoring promoted by the WIDNR. Secchi measurements were collected during the summer seasons of 1996 through 2006. The in-lake water quality measurements were used with the reservoir modeling effort discussed in Section 4.0.

2.3 Model Inputs

2.3.1 Topography

The topographic relief of a watershed influences nutrient transport from subwatersheds to the stream reaches through slope length/degree and contributing area. Topography is represented within the SWAT model using digital elevation models (DEM). DEM's are terrain elevation points located at regularly spaced horizontal intervals. The SWAT model uses topography to delineate the subwatershed boundaries and define parameters such as average slope, slope length, and the accumulation of flow for the definition of stream networks. The average slope and slope length are calculated per HRU. The MLW was topographically subdivided into 10 subwatersheds based on the stream network and sampling site location using the statewide 7.5 minute (or 1:24,000 scale) 30-meter grid based DEM obtained from the WIDNR. The 10-meter resolution DEM is not currently available for this watershed.

The majority of the MLW had slopes of 0 to 5 percent. The northern section (north of Country Highway N) of the watershed measured lower percent slopes than the southern section of the watershed. The majority of the southern portion of the watershed contained slopes between 3 and 10 percent.

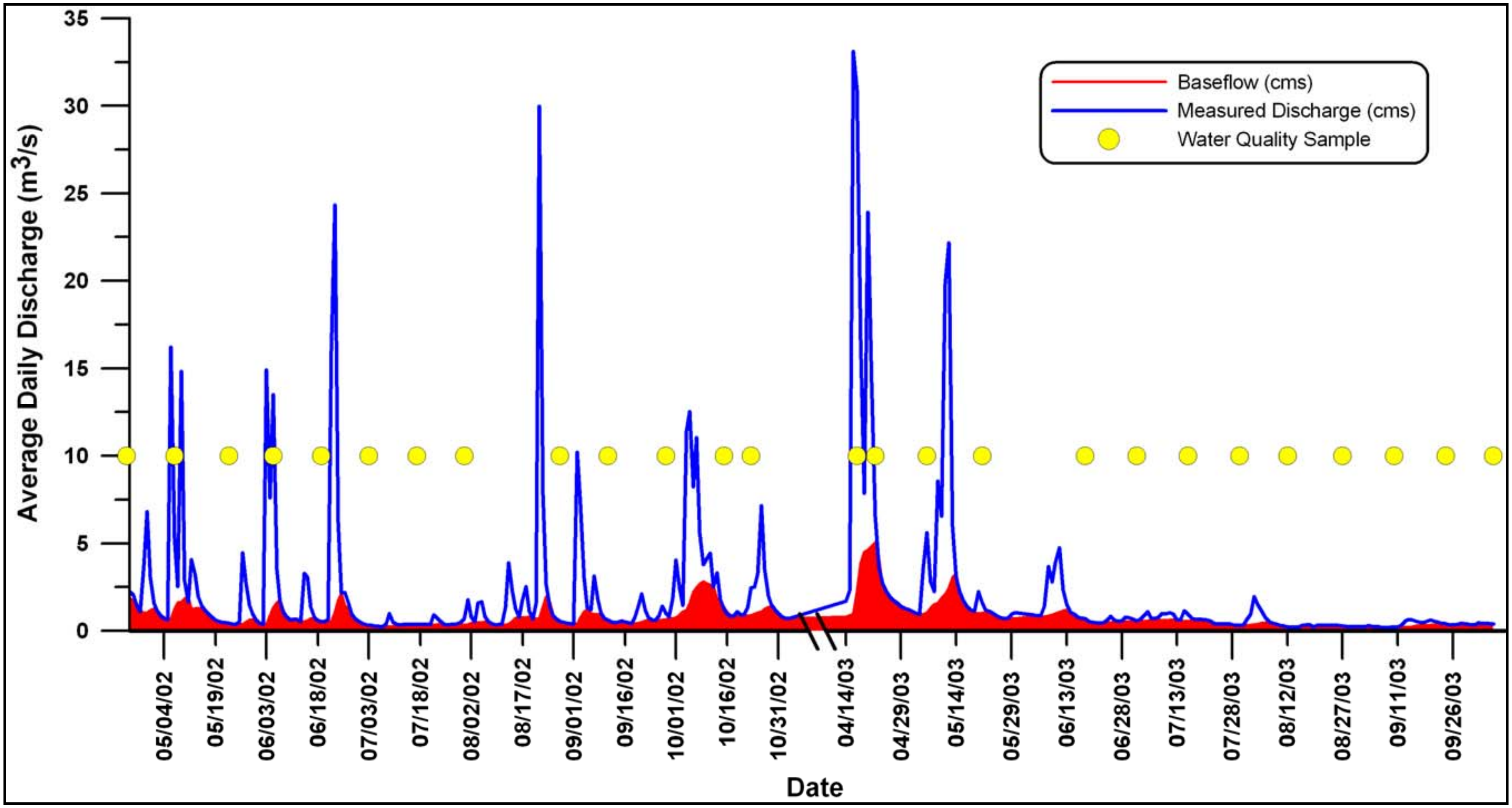

Figure 3: Discharge and Water Quality Monitoring at Cty Hwy MM in the MLW

2.3.2 Soils

Soil characteristics, coupled with other landscape factors, are used to determine soil moisture properties and erodibility potential within SWAT. Silt loam, located predominantly in the upper half of the MLW, is the dominant soil texture. SWAT uses the hydrologic soil group to determine the runoff potential of an area (A has the greatest infiltration potential and D is the greatest runoff potential). The MLW is a mixture of the B and C hydrologic soil group (Figure 2) with less permeable soils in the northern section.

The STATSGO soils database created by the USDA Soil Conservation Service can be used to define soil attributes in SWAT. STATSGO provides a general classification within the Mead Lake. Based on the STATSGO soils layer, the MLW contained six soil groups, three of which contained similar hydraulic conductivity, available water capacity, and bulk density and were therefore grouped together for analysis. The STATSGO soil groups were identified as WI 15, 20, 26, 43, 56, and 58.

Soil nutrient levels are used as an input for simulating P export from subwatersheds. The Clark Country Land Conservation Department collected soil test P data during 2004 from 517 individual fields throughout the watershed. Soil test P is an estimate of the plant available P in the soil and is often used as a measure of labile P in SWAT (Chaubey *et al.* 2006). Soil test P levels (Bray 1 P) within the MLW ranged from 9 mg/kg to 210 mg/kg, with a watershed average of 34 mg/kg. The Clark County average between 2000 and 2004 is 40 mg/kg (UW-Madison Soil and Plant Analysis Lab, 2007). The average P value within each subwatershed field was used in the model simulation.

2.3.3 Hydrologic Network

The stream network is the primary means of surface water and sediment routing. The SWAT model requires a user defined hydrology data set to determine preferred flow paths within the watershed. Prior to being received by Mead Lake, two larger tributaries flow into the South Fork of the Eau Claire (Norwegian Creek and Rocky Run) as well as several unnamed creeks. The WIDNR 24K hydrography database was used as the hydrology input layer for SWAT. The 24K Hydro layer was processed at double precision to accuracy consistent with national map accuracy standards for 1:24000 scale geographic data.

2.3.4 Closed Depressions

Internally drained closed depressions (ID) are areas of land that do not contribute overland flow and subsequent water quality to the stream network as a result of topography. The water contributing to these areas only contributes to the lake's water budget in the form of groundwater recharge (baseflow). Frequently the ID areas terminate in disconnected wetlands or small ponds. The ID areas within the MLW were determined using the ArcGIS extension ArcHydro with a 30-meter DEM and 10-meter vertical threshold to fill topographic sinks. Using a 10-meter threshold, areas that were internally drained were excluded from the watershed delineation. The polygons created from the GIS ID analysis went through a series of quality control steps prior to being accepted. From the GIS derived ID shapefile, Digital Raster Graphics (DRGs) were used to verify the presence of ponds or disconnected wetlands within internally drained areas. A 1000-foot buffered shapefile was created around all streams and all internally drained areas partially or fully within this buffer zone were removed. Approximately 80 percent of the GIS defined internally drained areas were then field verified in April 2007. Field examination was necessary as several ID areas were near the stream network and were interconnected through man-made ditches. Areas in the northern section of the MLW were relatively flat resulting in possible delineation error related to a 30-meter DEM. Approximately 3.7% of the MLW is internally drained. Of the 3.7% of the land that is ID, 73% of ID is found in the northern subwatersheds (1-5). The ID areas were separated by subwatershed to assist in model analysis.

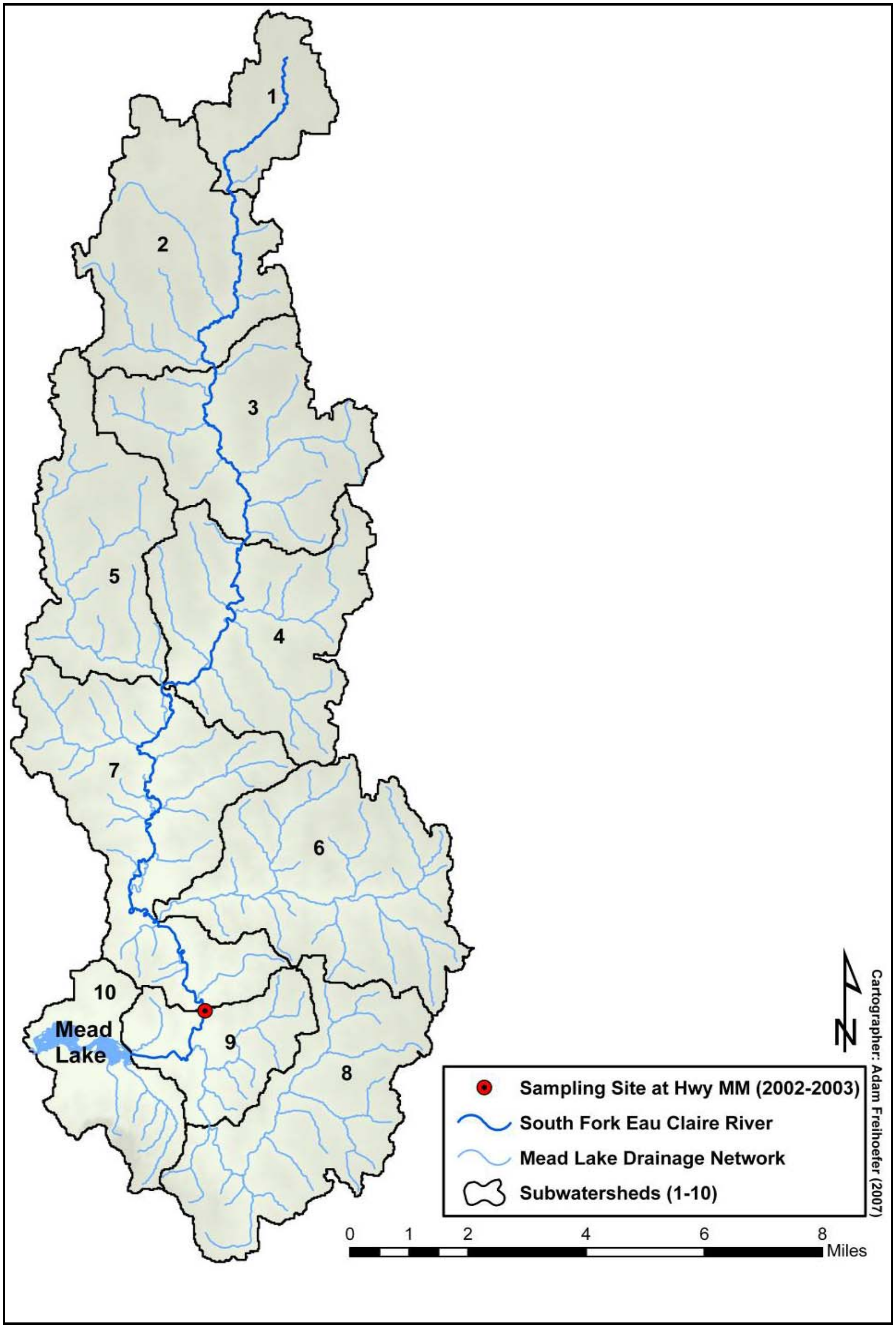

Figure 4: Mead Lake Watershed Stream Network and Monitoring Location

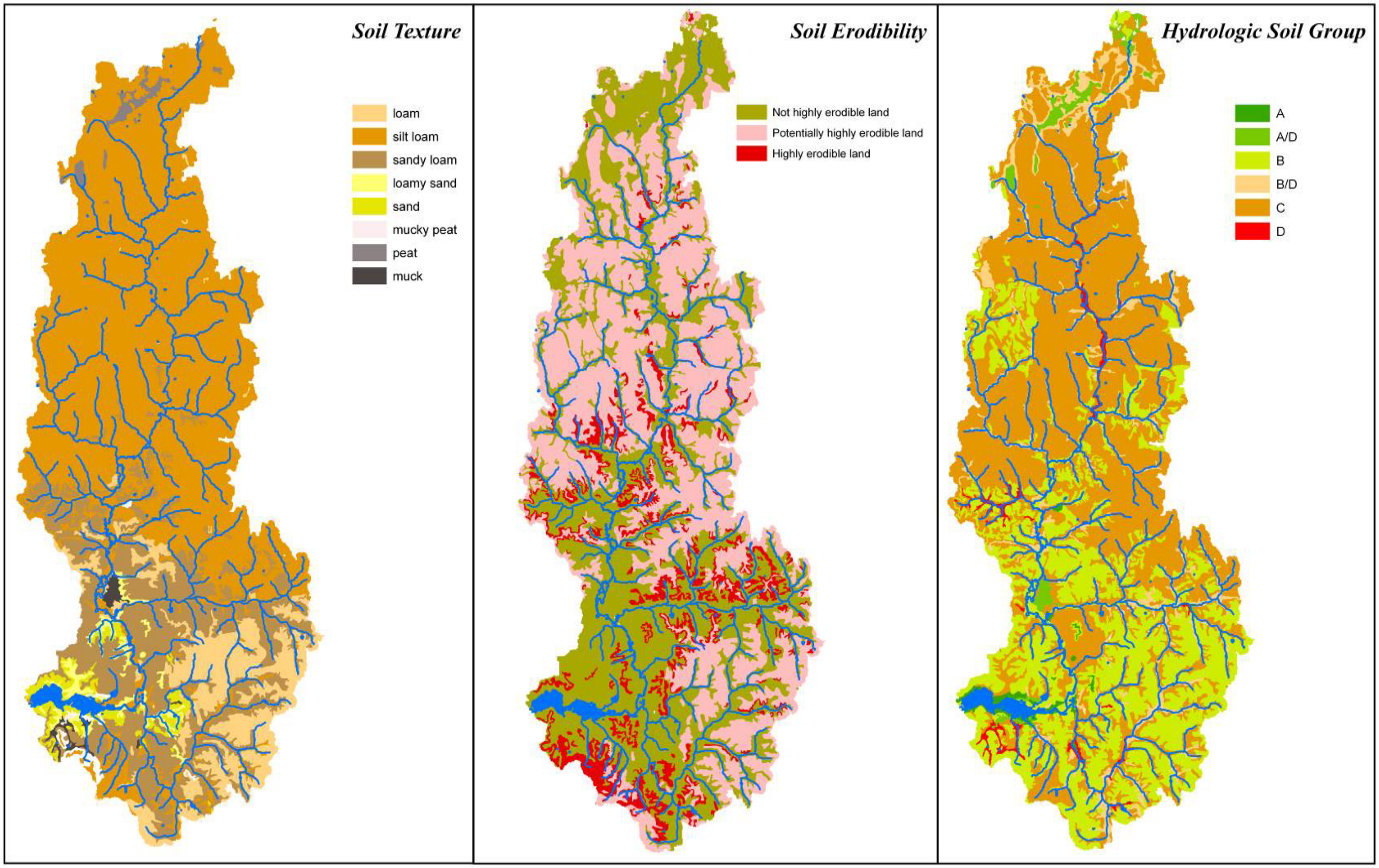

Figure 5: MLW Soil Characteristics (Texture, Erodibility, and Hydrologic Group)

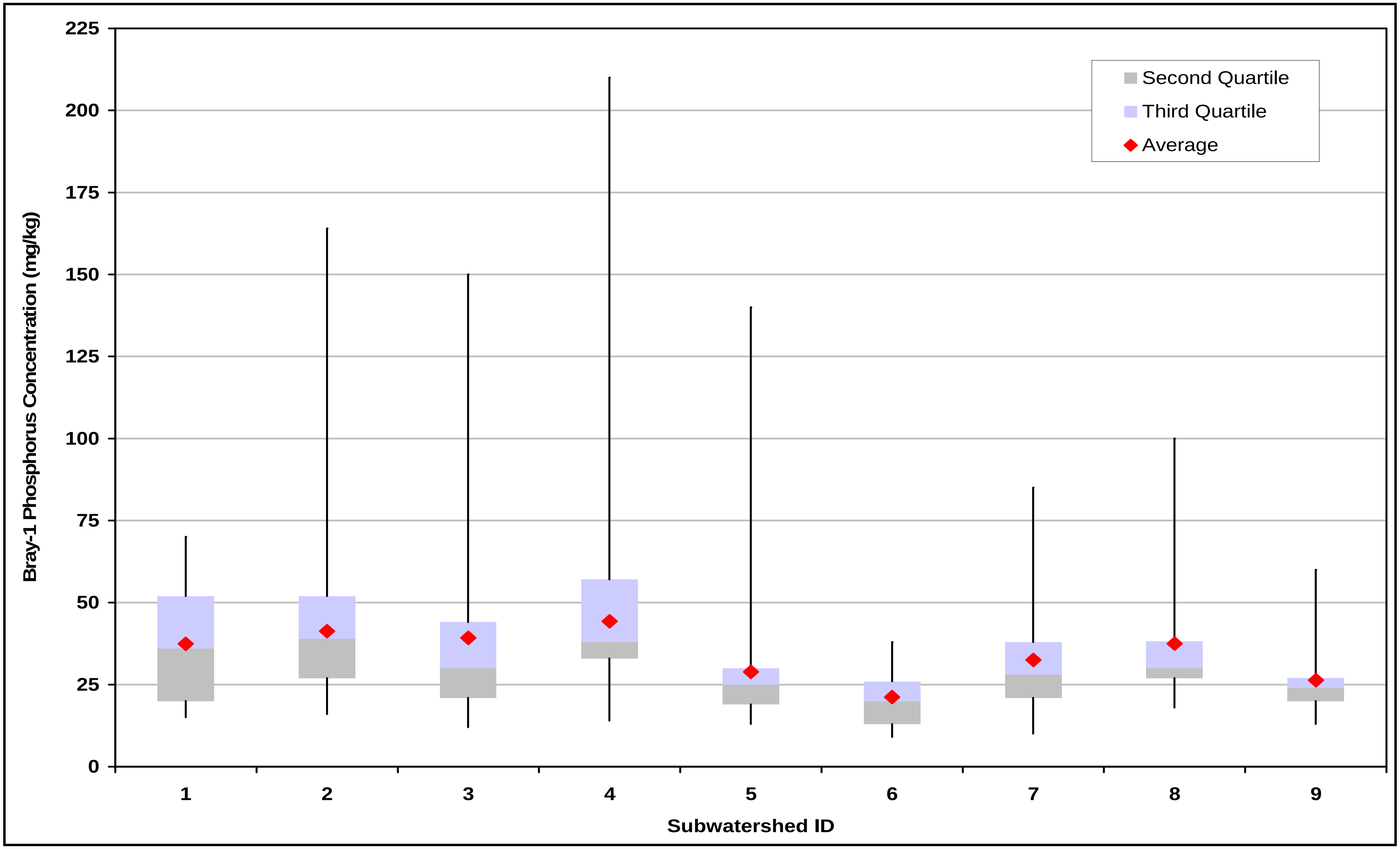

Figure 6: MLW Bray-1 Soil Phosphorus Concentrations (mg/kg) per Subwatershed

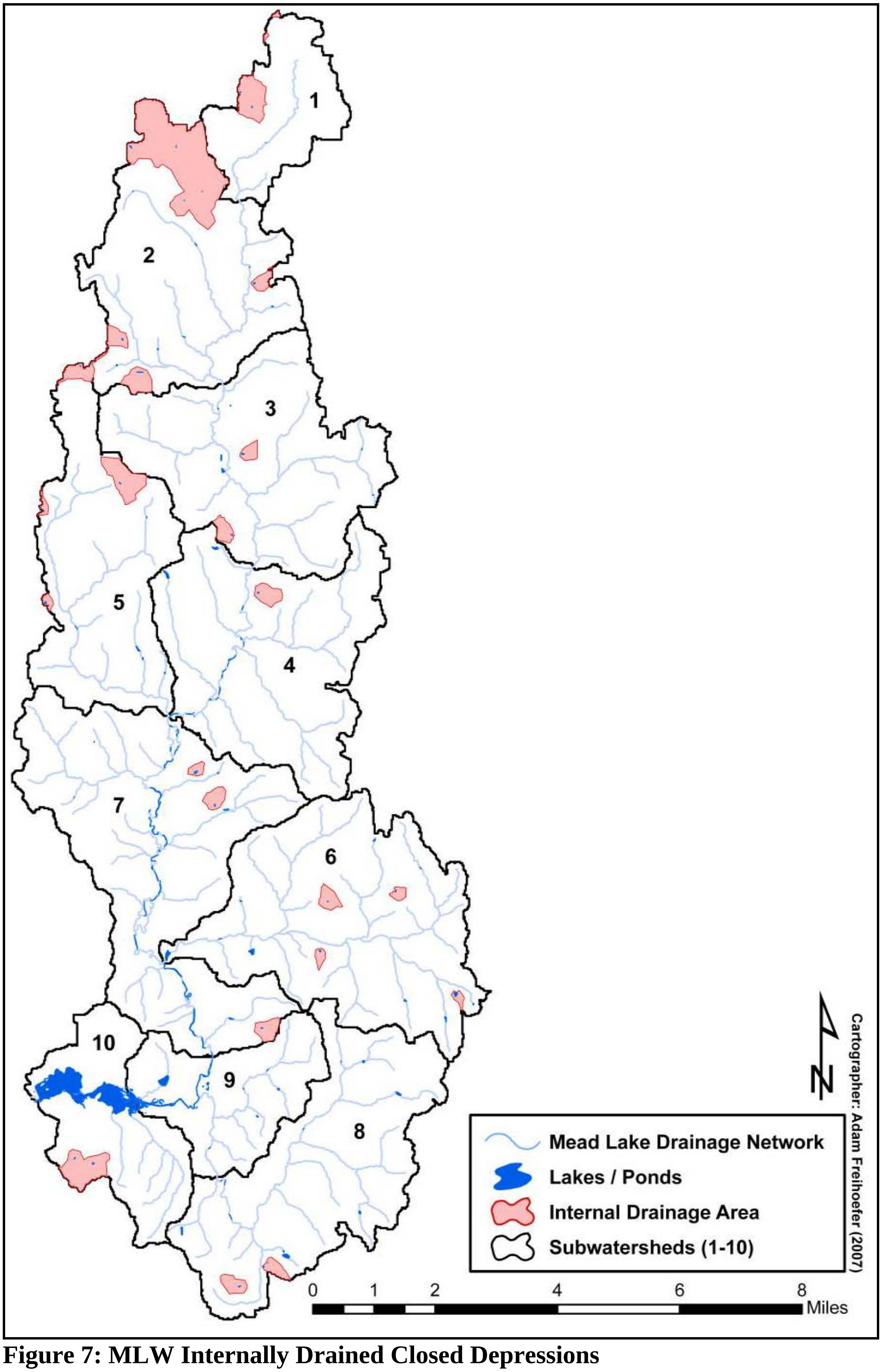

Figure 7: MLW Internally Drained Closed Depressions

2.3.5 Climate

SWAT can use observed weather data or simulate it using a database of weather statistics from specific weather stations. The use of measured climatological data greatly improves SWAT's ability to reproduce stream hydrographs. Observed daily precipitation and min/max temperature data were used from two weather stations within the Eau Claire River Watershed (Table 2). Other weather parameters such as solar radiation and wind speed were simulated from a SWAT weather generator database using statistical information from the closest weather station within the SWAT model's internal database (Neillsville, WI).

Historic climate data for 2 monitoring stations was obtained from the National Climatic Data Center (NCDC). Multiple stations are used for improved spatial climatological definition. Each subwatershed uses the individual climatological station closest to the subwatershed. The average measured annual precipitation from the two stations in 2002 was 965 mm and 2003 recorded 508 mm. The average annual precipitation in Wisconsin is 813 mm.

Table 1: Mead Lake Watershed Climatological Collection Stations and Durations

Station Identification	Climatological Collection Time Period
Stanley, Wisconsin	09/1903 to 11/2005
Owen, Wisconsin	07/1946 to 12/2005

2.3.6 Land Coverage

The MLW land cover is predominately cropped agricultural land (41%), with a higher percentage (68%) of cropped land in the northern half (subwatersheds 1 through 5) of the watershed (Table 3, Figures 4 & 5). A 2001 land coverage developed by Clark County shows a decrease in agriculture and increase in forested land compared to the 1992 WISCLAND land coverage. This change may be a result of conversion of agricultural to private / recreational land, or it may be due to the differences in coverage production. The 1992 WISCLAND coverage used LANDSAT imagery and the 2001 Clark County coverage was hand digitized from a 1997 aerial photography and verified during a 2001 windshield verification. Refer to Appendix A for land coverage percentages per subwatershed.

Table 2: Mead Lake Watershed Landuse Comparison between 1992 and 2001

Land Cover	1992 Landuse Area (Hectares)	1992 Landuse Percent of Basin	2001 Landuse Area (Hectares)	2001 Landuse Percent of Basin
Cropped Farmland	11,925	48.13	10,383	41.38
Farmsteads	---	---	242	0.97
Forest	5,888	23.76	7,964	31.74
Grassland / Pasture	2,875	11.60	2,690	10.72
Urban / Impervious	---	---	1,214	4.84
Water	136	0.55	172	0.69
Wetland	2,423	9.78	2,423	9.66
Barren	1,530	6.18	---	---

The Clark County landuse was categorized into cropped farmland, forested areas, roads, urbanized areas (residential, commercial, etc), and a category for other resource land (ORL). The ORL is land under private ownership including grassland, pasture, wetlands, and upland. The 1992 WISCLAND wetlands layer was merged into the 2001 Clark County land coverage since wetland boundaries where not delineated with the 2001 coverage and the assumption was made that the wetland boundaries did not change considerably between 1992 and 2001. Once the wetland landuse was merged into the 2001 coverage, all remaining ORL was reclassified as grassland / pasture or forest.

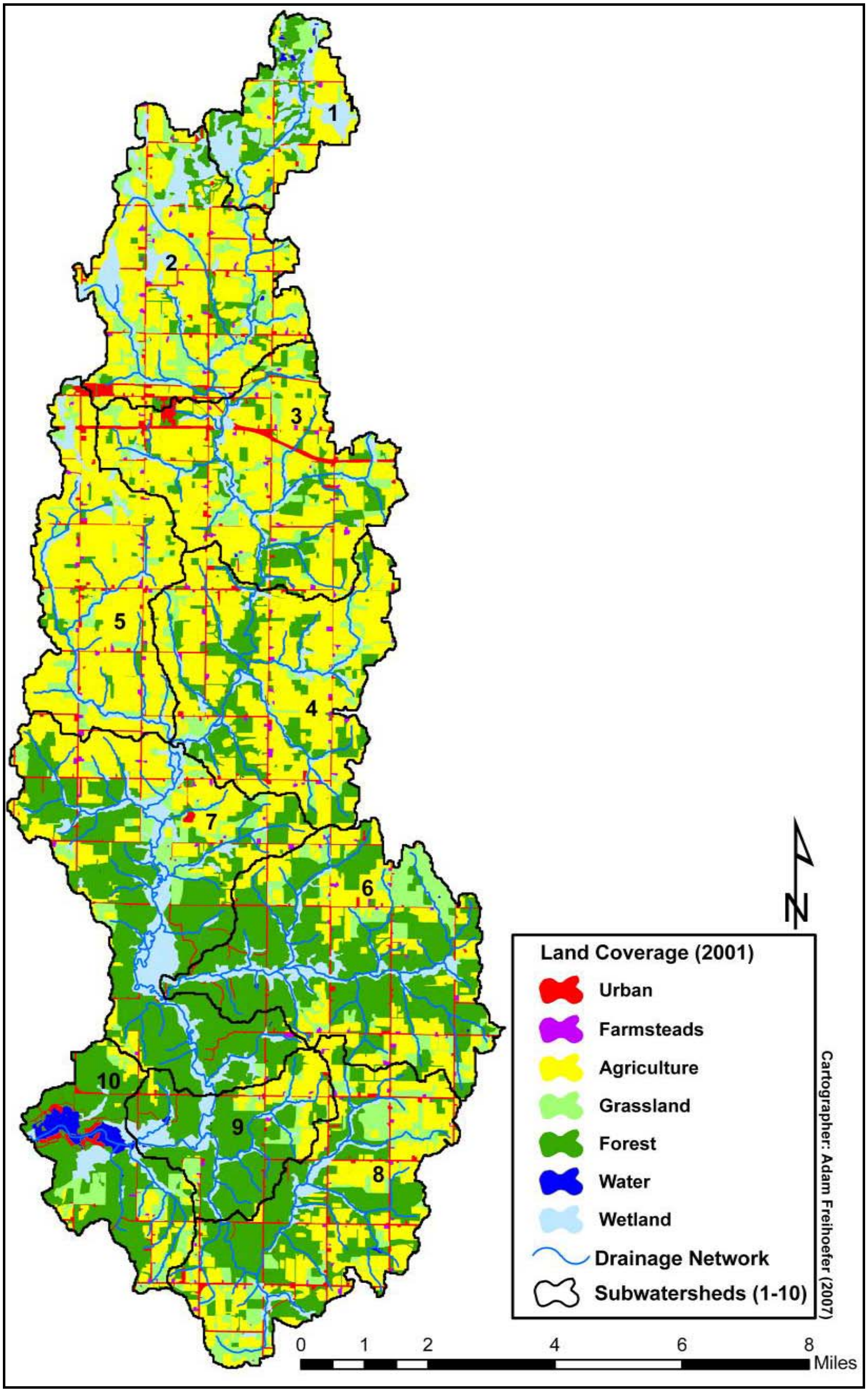

Figure 8: Mead Lake Watershed Land Cover Classification

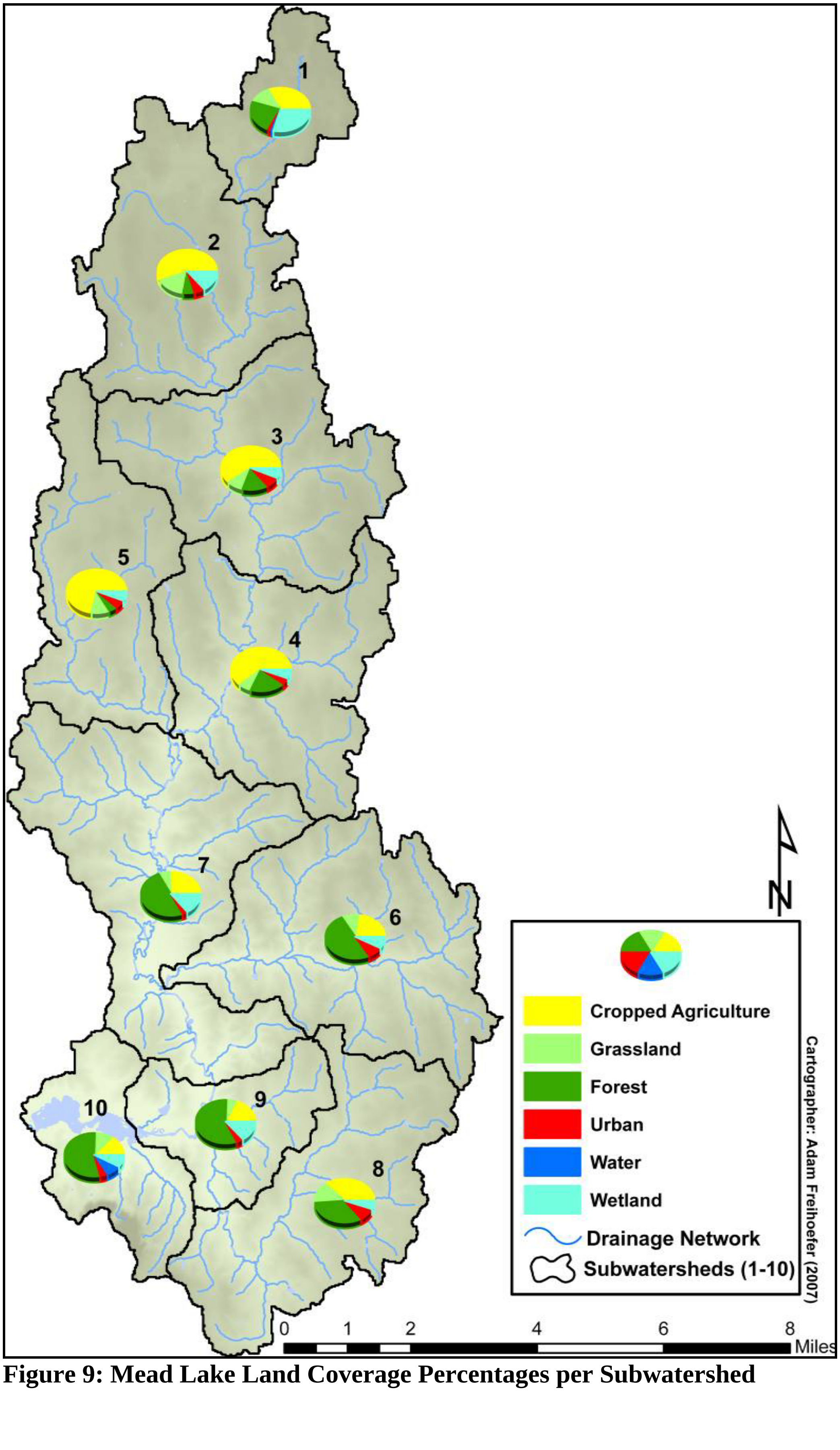

Figure 9: Mead Lake Land Coverage Percentages per Subwatershed

2.3.7 Land Management

The land management of the MLW was assessed using a 2002 farm survey, a land evaluation completed by the Clark and Taylor County Land Conservation departments, interviews with Clark County Land Conservation personnel, and a 1999 transect survey conducted by the Clark County Land Conservation department.

The 2002 farm survey included 82 farms within the watershed, although some farmers chose not to participate or did not have knowledge of the land practices due to land rental. Of the 82 farmers, 74 gave information regarding herd size, manure management, and crop rotation. The majority of the farmers had some type of dairy rotation which usually consisted of two years of corn, one year of oats and alfalfa, followed by three years of alfalfa. Some farms rotated corn for more then two years and included soybeans, peas, or clover into the rotation. Farmers reported approximately 4,200 cattle within the watershed. At the time of the survey 68% of the watershed's farmers reported storing manure (Figure 6). The survey indicated several types of tillage occurring throughout the growing season. Typically the soil was disked prior to planting of corn, oats, and soybeans. During the growing season springtooth harrow, harrow tines, or row cultivator tillage were used for corn. Fall tillage included moldboard and paraplow.

The Clark and Taylor County Land Conservation Departments were each given a landuse map for their portion of the watershed. Dominant agricultural management practices were indicated on the map and then entered into GIS for spatial analysis and management practices were based on the 2001 Clark County land coverage attributes. The 2001 Clark County land coverage defines all agricultural land as cropped farmland (WISCLAND grid code 110); however, the land coverage was modified so that each cropped farmland polygon has a related management rotation (Table 4) assigned to it. The grid code, a numerical value assigned to a landuse in the WIDNR 1992 WISCLAND layer, was modified so that each rotation had a unique grid code value. The dominant rotations (dependent on being greater than 5% land area within the HRU threshold) of the watershed was used for model simulations.

County conservationists indicated approximately 55% of the agricultural land within the watershed was in a dairy rotation (one year corn, one year corn or soybean, one year oats and alfalfa, three 3 years alfalfa) with stored manure (Appendix A). The stored manure dairy rotation was the dominant management practice in five of the nine subwatersheds (Figure 7, Table 4). Another approximately 4% of the watershed was in cash grain with no storage and no manure.

A 1999 transect survey conducted by the Clark County Land Conservation Department indicated the crops for 1998 and 1999. The transect route consisted of approximately 18 sites within subwatershed six, eight, and ten. The transect survey points correctly corresponded to the management practice GIS layer created from the Land Conservation Departments.

The farm surveys, land evaluation, transect survey, and discussions with Clark County Conservationist Matt Zoschke were used to summarize land and nutrient management (Matt Zoschke, personal communication, June 2007). Six management rotations were developed for MLW simulations. Clark County Conservationist Matt Zoschke reviewed and confirmed the management rotations. Of the six rotations, two had manure storage, one used no manure storage, and two consisted of no storage and no manure. According to former Clark County Conservationist Gregg Stangl, the dairy rotation with no manure and no storage was leased land rented by farmers (Gregg Stangl, Personal Communication, November, 2006). That land is too far away from the main operation to haul manure, so chemical fertilizers are used instead.

Each type of management applied different amounts and types of nutrients to the landscape. The dairy management rotations assumed 56,043 kg/ha/year of wet manure was applied to corn, with a greater amount typically applied in the spring. The Amish rotation (Gridcode 115) incorporated 33,626 kg/ha/year of wet manure. The continuous hay / pasture with grazing incorporated approximately 26,900 kg/ha/year of wet manure. Fertilizers were applied to nearly all of the management rotations. In rotations were manure was not applied, fertilizer was used as the sole nutrient application. Typically, a starter fertilizer such as 09-23-30 or 05-14-42 was applied with planting of corn and soybeans at a rate of 224 kg/ha. A nitrogen based fertilizer such as 46-00-00 was applied in the spring.

Management rotations developed in the SWAT model were based on information from both sources and linked into SWAT using the GIS rotation layer. Refer to Appendix B for detailed management per rotation type.

Measured crop yields are also used in conjunction with SWAT to determine if the model is properly simulating plant growth. Historic annual crop yields (1995-2005) for corn, soybeans, and alfalfa were provided by the National Agriculture Statistical Service (NASS) for Clark County.

Table 3: Percentage of Management Practices per Subbasin

	Subwatershed Percentage									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
(C-C-C-S-A-A) (111) (Manure Storage)	---	---	1.7	---	14.9	---	---	---	---	---
(C-S-C-S-C-S) (112) (No Storage / No Manure)	2.9	1.8	0.8	6.6	0.9	10.4	6.1	3.6	6.8	19
(C-C-C-A-A-A) (113) (No Manure / No Storage)	80.2	16.2	29.3	33.0	23.2	45.1	39.9	19.0	20.6	27.2
(C-S-A-A-A-A) (114) (Manure Storage)	10.9	80.1	64.6	53.9	61.0	37.6	52.2	12.4	15.5	41.6
(C-A-A-A-C-A) (115) (No Manure Storage)	5.9	1.9	0.6	6.6	---	7.0	1.6	59.8	55.5	---
Continuous Hay / Pasture (Grazing) (120)	---	---	3.0	---	---	---	0.3	5.2	1.6	12.2

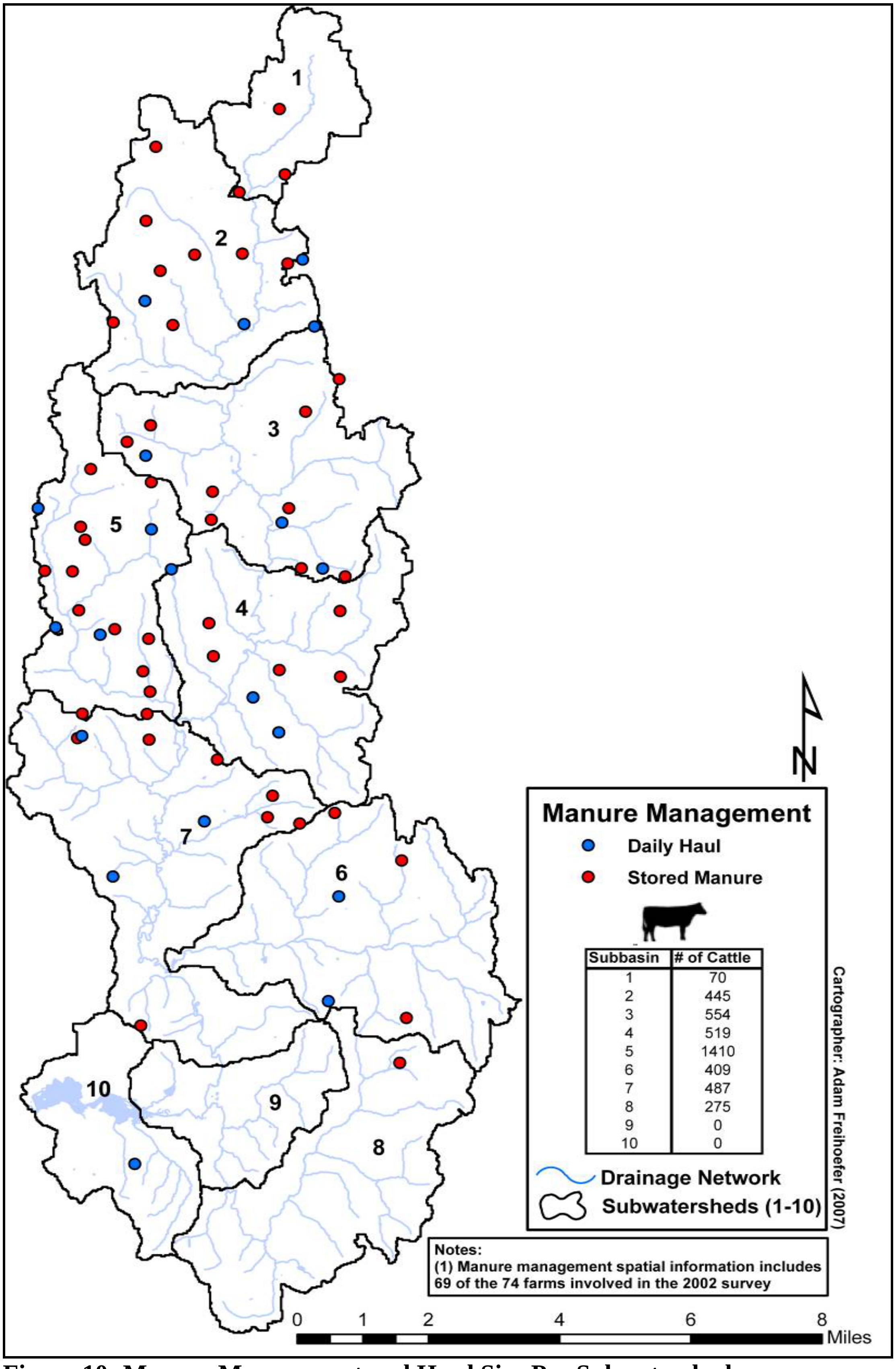

Figure 10: Manure Management and Herd Size Per Subwatershed

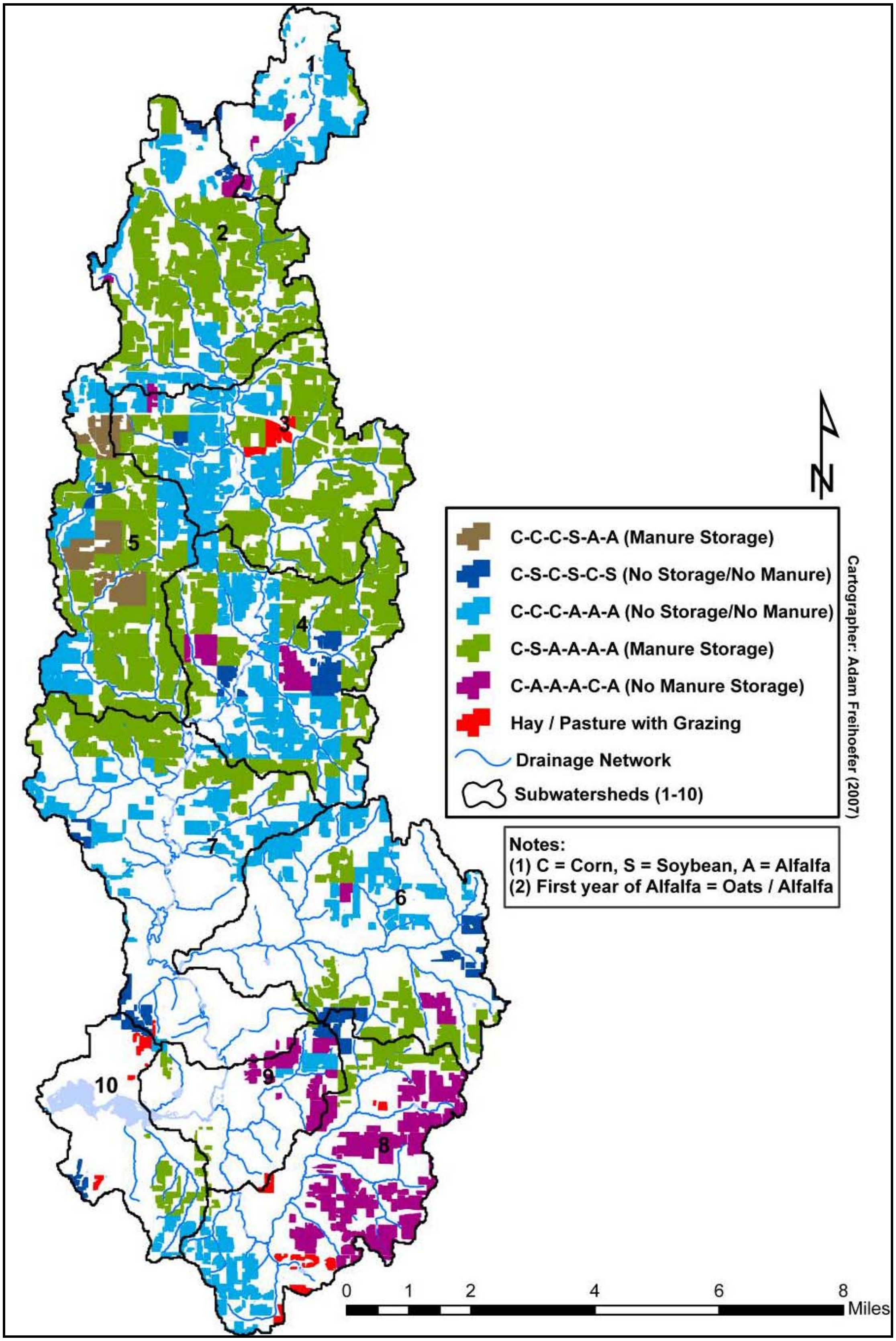

Figure 11: Agricultural Land Management within the Mead Lake Watershed

2.4 Calibration

Calibration is the process of matching simulated model results to measured results. Stream discharge, sediment, and nutrient yields are the primary calibration outputs with the SWAT model. The SWAT model allows the user to modify hundreds of input parameters to best simulate the study area. Manual trial and error calibration is the standard approach in calibrating the SWAT model (Van Liew *et al*. 2003, Muleta and Nicklow 2005). The large number of variables makes manual calibration a long, tedious, and subjective process, especially for a complex watershed. A calibration guide created by the SWAT developers directs users to the most sensitive input parameters for flow, sediment, and nutrient simulation (Neitsch *et al.* 2002).

The SWAT model calibration of the MLW used a parameter estimation tool, the Parameter ESTimation (PEST) software (Doherty 2004). PEST, a freeware tool, can be used with any model by reading a model's input and output files, finding optimum values and sensitivity for each input parameter. PEST allows for a large number of parameters to be fitted from nonlinear models like SWAT. PEST performs iterations using the Gauss-Marquardt-Levenberg algorithm. PEST was used for both field and watershed-scale simulation and calibration. In addition to the PEST Manual, Lin's (2005) paper "*Getting Started with PEST*" was used for instructional documentation to create the PEST batch file, SWAT model input template files, SWAT model output reading instruction files, and a PEST control file.

Calibration of the MLW used 377 streamflow measurements and monthly sediment and phosphorus export during the growing season (May through September). Water quality measurements were only collected during the growing season period. As a result of a relatively short residence time (days rather than months), the Mead Lake reservoir responds to seasonal inputs; therefore, the calibration did not include the non-measured months of October – April. PEST input required the date, measured value, an acceptable input variable range, and current values of the input variables. Previous SWAT model studies were used to identify the parameters to adjust with PEST.

2.5 Statistical Evaluation of SWAT Model

Two statistical measures are typically used in the evaluation of the SWAT model; the coefficient of determination (R^2) and the Nash Sutcliffe coefficient of efficiency (N-S) (Arabi and Govindaraju 2006). The R^2 value is the square of the Pearson's correlation coefficient and ranges from 0 to 1, with a value of 1 representing a perfect correlation between simulated and measured datasets. The N-S coefficient of efficiency has historically been used to evaluate hydrologic models. The N-S values range from negative ∞ to 1, with a value of 1 representing a perfect efficiency between the simulation and measured datasets. The efficiency compares the actual fit to a perfect 1:1 line and measures the correspondence between the measured and simulated flows. Both measures are particularly sensitive to any large differences between observed and simulated values (Krause *et al.* 2005). The R^2 values may be greater than N-S values as individual event outliers tend to have a greater impact on the N-S value (Kirsch *et al.* 2002). Previous studies indicate that N-S values ranging from 0 – 0.33 are considered poor model performance, 0.33 – 0.75 are acceptable values, and 0.75 – 1.0 are considered good (Inamdar 2004; Motovilov *et al*. 1999).

3.0 MLW SWAT Model Simulation

3.1 Watershed Model Approach

For all watershed-scale simulations, the MLW was divided into ten subwatersheds and 119 HRUs. The subwatersheds ranged from 1,011 to 3,773 ha in size. The HRUs were developed using a 5% landuse composition threshold in AVSWAT. No threshold was set for the soils layer (STATSGO). The cropped HRUs were a variation of dairy forage or cash grain rotation. The calibration modeling used 12 year simulations (1993 – 2004) with the first 6 years acting as a warm-up period for the simulation. The primary model run from 1993-2004 was the basis for all related scenarios discussed in this report. All simulations used the Priestly-Taylor method of evapotranspiration. The watershed was calibrated to daily output for discharge and monthly for water quality during the growing season months of May through September. The stream water quality processes and channel dimensions were deactivated within SWAT as a result of the inability to quantify the fraction of load delivered versus channel derived. PEST was used for calibration of input parameters and sensitivity analysis. Due to the relatively small dataset, no validation period was used.

Simulating a heterogeneous landscape of agricultural management required splitting each agricultural rotation (111, 113, 114, and 115) into 3 separate rotations to simulate different years of the given rotation (Table 5). This resulted in 10 unique rotations being applied to 40 different agricultural HRUs based on percent landuse within the subwatersheds (Appendix C). Crop staggering shown in Table 5 was used to simulate all phases of a crop rotation within a single model run.

Table 4: **Summary of SWAT Model Input Dataset for Simulation**

Input Data	Dataset
Topography	30-meter DEM (USGS)
Hydrology	1:24,000 WIDNR Hydrology
Precipitation and Temperature	Stanley and Owen Weather Stations
Land Use	2001 Hand Digitized Land Coverage
Soils	STATSGO Soils

Table 5: Summary of Agricultural HRU Rotation Staggering

Land Coverage ID	Rotation ID	Rotation Stagger
Gridcode 111 (CRN)	111 (Orginal)	CG-CG-CS-S-A-A
	111A	CG-CG-CS-S-A-A
Gridcode 113 (CSIL)	113 (Orginal)	CG-CG-CG-A-A-A
	113A	CG-CG-CG-A-A-A
	113B	A-A-CG-CG-C-A
	113C	CG-A-A-A-CG-CG
Gridcode 114 (SOYB)	114 (Orginal)	CG-S-A-A-A-A
	114A	A-A-CG-S-A-A
	114B	A-A-A-CG-S-A
	114C	S-A-A-A-A-CG
Gridcode 115 (OATS)	115 (Orginal)	CS-A-A-A-CS-A
	115A	CS-A-CS-A-A-A
	115B	A-A-CS-A-CS-A
	115C	A-A-A-CS-A-CS

3.2 Discharge Calibration

As part of the USACE Mead Lake assessment (James 2005), average daily stream discharge was simulated for 377 days between 2002 and 2003 at the County Highway MM station. The measured discharge includes groundwater and surface water contributions from the watershed.

To simulate landscape factors for the watershed, discharge was calibrated through the manipulation of the model's most sensitive hydrologic input parameters. Previous studies and observed parameter sensitivity were used to determine the input parameters for calibration. A combination of assigning parameter values based on default and measured values with parameter estimation using the PEST program was used to calibrate the model. The NRCS runoff curve numbers (RCN) were maintained at the ratio similar to that in NRCS TR-55 (NRCS, 1985) and similar percentage adjustments were made to all curve numbers in PEST to obtain the best agreement between the observed and simulated daily flow. The model calibration did not use multiple RCN changes within a simulation year because the current SWAT2000 program code does not always recognize RCN changes after tillage changes. In addition to the RCN (SWAT CNOP) other parameters used for surficial hydrologic model calibration were the soil bulk density (SOLBD), soil available water capacity (AWC), soil hydraulic conductivity (SOLK), and the evapotranspiration coefficient (ESCO). Some parameters were grouped together for PEST analysis. The calibration of the CNOP used two separate values per land use. The first group consisted of HRUs with soils in the hydrologic class C (Soil IDs 15, 26, and 58). The second group consisted of HRUs with soils in the hydrologic class B (Soil IDs 20, 43, and 56). The PEST calibration used four soil groups, based on similar soil properties, for calibration of SOLBD, SOLK, and AWC. The four groups were WI 20, WI 15, 26, and 58, WI 43, and WI 56. Prior to implementation of the PEST, the trial and error calibrated simulation of the MLW overestimated discharge during events and underestimated baseflow.

Parameter values were limited in how far they were allowed to deviate from default values during calibration. The RCNs were allowed a +/- 10% deviation. The soil properties (SOLBD, SOLK, and AWC) were allowed +/- 15 percent deviation from the default values used for each soil grouping. In general, AWC retained a value similar to the default range of 0.08 to 0.18 mm/mm. An increase in the AWC suggests greater infiltration. The three of the four soil groups decreased the calibrated SOLK from the default. This change reflects a larger retention of soil water. SOLBD increased from the default to the calibrated value.

Groundwater parameters were also adjusted to allow for increased baseflow to the Eau Claire River and its tributaries in the PEST calibration. The alpha baseflow (ALPHA_BF), the direct index of groundwater flow response to changes in recharge, was decreased from a default 0.048 days to 0.0095 days using PEST. The groundwater delay was increased from a default 31 days to 255 days. The wetland HRUs were simulated as having a larger evapotranspiration than other land uses.

Overall, SWAT was able to successfully simulate the daily discharge during the 377 non-melt days. The climatic conditions of the MLW in 2002 and 2003 created two extremes in discharge creating challenging conditions for model calibration. Year 2002 was above and 2003 was below average annual rainfall. Simulation of the MLW daily discharge had a R^2 and N-S value of 0.63 and 0.62, respectively. Total simulated discharge was less than one percent greater than the measured. The measured discharges of 2002 and 2003 required PEST to calibrate to an average fit between the two year's observations points. Individual years yielded slightly different results than the statistical evaluation of the entire measured period. In 2002, the R^2 and N-S values for discharge were 0.58 and 0.52, respectively with an overestimation in discharge of approximately 8%. In 2003, the R^2 and N-S values for discharge were 0.75 and 0.71, respectively with an underestimation in discharge of approximately 8%.

Table 6: Calibrated Parameter Values for Discharge in the MLW

Constituent	SWAT Variable	Description	Default Value	Calibrated Value
Discharge	CNOP (Corn)	Curve Number - Corn	83, 77	83, 77
	CNOP (Soybean)	Curve Number - Soybean	85, 78	85, 78
	CNOP (Alfalfa)	Curve Number - Alfalfa	72, 59	71, 64
	CNOP (Tillage)	Curve Number - Tillages	---	84, 69
	CNOP (Grassland)	Curve Number - Grassland	72, 59	66, 54
	CNOP (Wetland)	Curve Number - Wetland	79, 69	64, 52
	CNOP (Forest)	Curve Number - Forest	72, 59	64, 52
	CNOP (Urban)	Curve Number - Urban	80	66
	SOL_BD (20)	Moist Soil Bulk Density (g/cm^3) for soil WI 20	1.60	1.92
	SOL_BD (15,26,58)	Moist Soil Bulk Density (g/cm^3) for soil WI 15,26,58	1.50	1.80
	SOL_BD (56)	Moist Soil Bulk Density (g/cm^3) for soil WI 56	1.50	1.80
	SOL_BD (43)	Moist Soil Bulk Density (g/cm^3) for soil WI 43	1.45	1.74
	SOL_K (20)	Soil Hydraulic Conductivity (mm/hr) for soil WI 20	160.00	60.00
	SOL_K (15,26,58)	Soil Hydraulic Conductivity (mm/hr) for soil WI 15,26,58	14.00	11.32
	SOL_K (56)	Soil Hydraulic Conductivity (mm/hr) for soil WI 56	950.00	60.00
	SOL_K (43)	Soil Hydraulic Conductivity (mm/hr) for soil WI 43	51.00	61.20
	SOL_AWC (20)	Soil Available Water Capacity (mm/mm) for soil WI 20	0.12	0.10
	SOL_AWC (15,26,58)	Soil Available Water Capacity (mm/mm) for soil WI 15,26,58	0.16	0.18
	SOL_AWC (56)	Soil Available Water Capacity (mm/mm) for soil WI 56	0.07	0.08
	SOL_AWC (43)	Soil Available Water Capacity (mm/mm) for soil WI 43	0.12	0.14
	ESCO	Evapotranspiration Coefficient	0.95	0.516
	GW_DELAY	Groundwater Delay Time (days)	31.00	255
	ALPHA_BF	Base Flow Alpha Factor (days)	0.0480	0.0095
	GW_REVAP (Wetland)	Groundwater Revap Coefficient	0.02	0.20
	REVAPMN (Wetland)	Threshold Deptth for Percolation (mm)	1.00	0.00
	GW_REVAP (Other HRUs)	Groundwater Revap Coefficient	0.02	0.10
	REVAPMN (Other HRUs)	Threshold Deptth for Percolation (mm)	1.00	0.08
	CANMX (Cropped HRUs)	Maximum Canopy Storage (mm)	0.00	10.00
	CANMX (Other HRUs)	Maximum Canopy Storage (mm)	0.00	20.00
	SURLAG	Surface Runoff Lag Time (days)	4.00	1.00

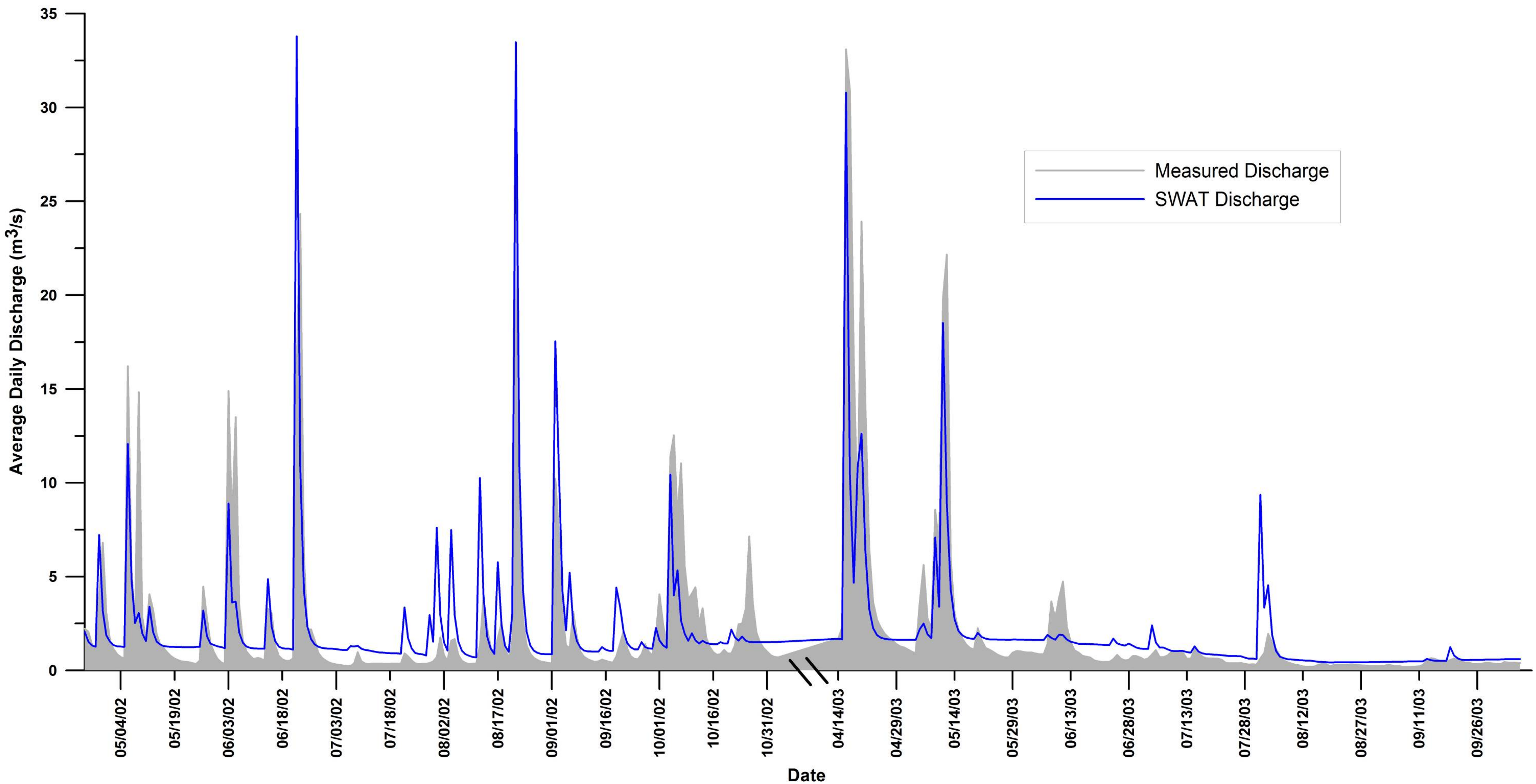

Figure 12: Measured versus SWAT Simulated Discharge at Cty Hwy MM in the MLW

3.3 Sediment Calibration

Watershed sediment load was simulated on a monthly total rather than continuous estimated daily load. Eleven months of measured sediment load was developed from 22 samples. Simulated sediment loss from the reach (metric tons) was totaled from the SED_OUT field in the SWAT main channel output file (.rch). Sediment yield from the HRUs represents a delivered sediment loss because we did not simulate downstream deposition or channel erosion. Sediment load was calibrated using five SWAT input parameters: USLE_P (USLE equation support practice factor), SLSUBBSN (average slope length), Slope (average slope steepness), APM (peak rate adjustment factor for sediment routing), and FILTERW (width of edge-of-field filter strip trapping efficiency).

Parameter estimation using PEST was used to identify values for the sediment calibration. The USLE_P value (.mgt) was decreased for agricultural HRUs from a default value of 1.00 to 0.50. Decreasing the USLE_P from the default decreases the amount of sediment transported from the landscape. The USLE_P parameter was the most sensitive of all sediment calibration parameters used with PEST, indicated by relative sensitivity value in the PEST output. The APM (.bsn) parameter was decreased from a default 1.00 to 0.64 to dampen the simulated flashy response from storm events in the watershed. FILTERW was used to trap a portion of the sediment on the landscape and served to simulate the loss of sediment during delivery between individual fields and the stream reach.

The objective of the calibration was to find the best parameter combination for simulating all the monthly sediment loads. We found that several months in particular were difficult to calibrate. Because there is uncertainty in the monthly sediment loads estimates from the USGS LOADEST estimating, we sought to minimize the overall difference between sediment totals on an annual basis and visually sought to match the monthly totals as closely as possible. The SWAT simulation of the eleven months of measured sediment load resulted in R^2 and N-S values of 0.54 and 0.49, respectively. The calibration period yielded a five metric ton underestimation of sediment (0.6% error). The greatest variability in calibrated values occurred during 2002 when above normal precipitation occurred. The sediment delivered from the landscape into Mead Lake originates primarily from agricultural lands; although due to spatial discretization of fields with the same management and soils we could not unable to pinpoint the exact location of the soil erosion.

Sediment export was analyzed during the six year calibration (1999-2004) per landuse. The greatest percentage (95%) of sediment loading came from agricultural lands. Of the 95% sediment load derived from agricultural lands, management types 114C and 113C contribute 89% of the sediment load to the stream reach. It is also important to distinguish sediment load from yield. Examination of sediment yield finds 114C and 113C still yield a large amount of sediment per land area. 111C also yields a large amount, but since it makes up a small percentage of land area, the sediment load is small.

Table 7: Calibrated Parameter Values for Sediment in the MLW

Constituent	SWAT Variable	Description	Default Value	Calibrated Value
Sediment	USLE_P (Cropped HRUs)	USLE equation support practice factor for Crops	1.00	0.50
	SLSUBBSN (Cropped HRUs)	Average Slope Length (m)	91.46	50.00
	SLOPE (Cropped HRUs)	Average Slope Steepness (m/m)	0.03, 0.024	0.021, 0.017
	FILTERW (All HRUs)	Filter Strip Width for Sediment Trapping Efficiency (m)	0.00	24.25
	APM	Peak Adjustment for Sediment Routing	1.00	0.64

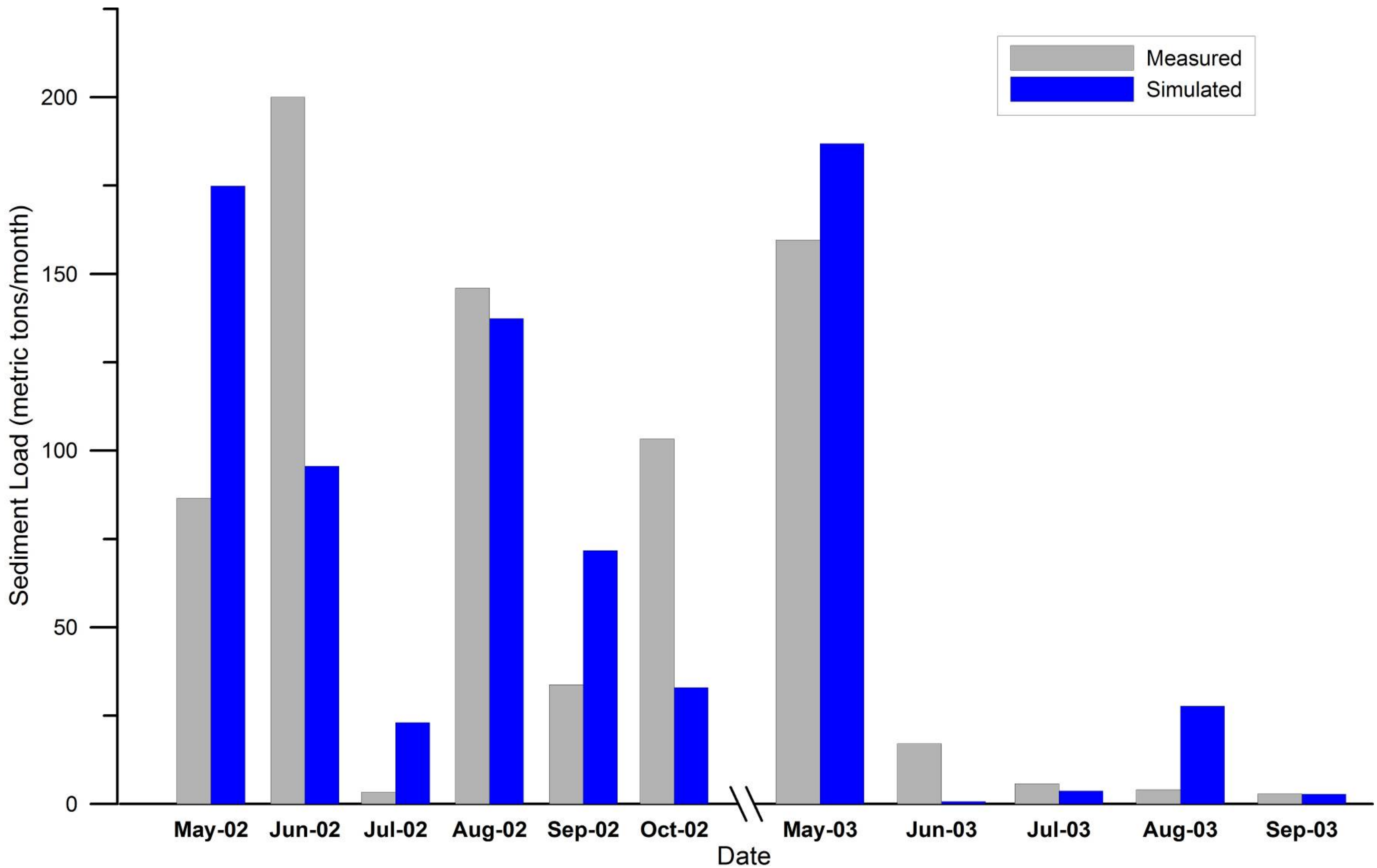

Figure 13: Measured Sediment Load vs. SWAT Simulated Sediment Load

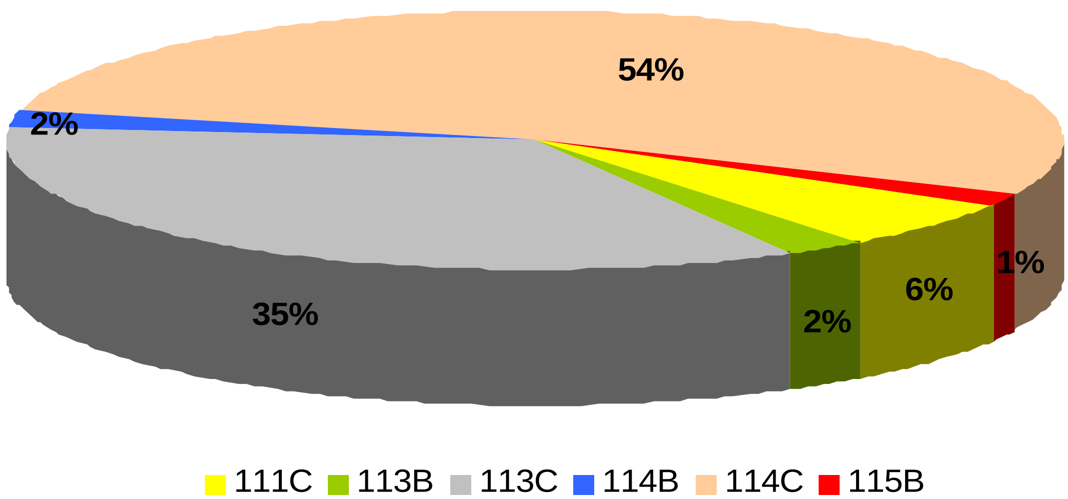

Figure 14: Percentage of Sediment Load Contribution (1999-2004) Per Agricultural Management Practice

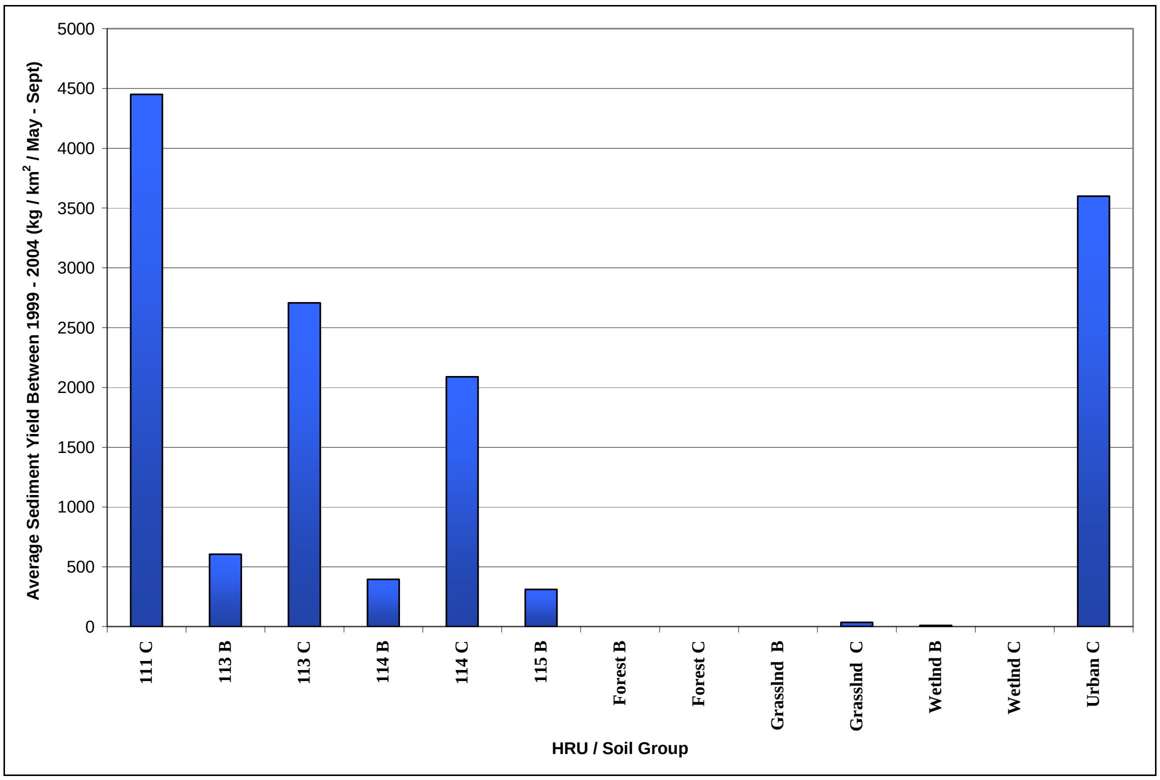

Figure 15: Average growing season sediment yield (1999-2004) for different HRU combinations of land management and soil hydrologic group.

3.4 Total Phosphorus Calibration

The SWAT simulates P soil input as inorganic P fertilizer, organic P fertilizer, and P tied up in plant residue. During storm events, the P can be transported to the stream reach two ways: organic and mineral P attached to sediment or as soluble P. The phosphorus calibration used the hydrology and sediment calibration with adjustments for groundwater phosphorus concentration, phosphorus partitioning to soil solids, and phosphorus enrichment in the eroded solids. The P related SWAT parameters included modifying six input variables: initial soluble P concentration in soil layer (SOL_LABP), the P soil portioning coefficient (PHOSKD), P availability index (PSP), the P uptake distribution parameter (UBP), organic phosphorus enrichment ratio (ERORGP), and groundwater soluble P concentration (GWSOLP). The value of SOL_LABP was determined using the average P value within each subwatershed field was used in the model simulation since multiple fields may represent a single HRU. A value of 20 m^3/kg was used for PHOSKD rather than the default of 175 m^3/kg to reflect lower phosphorus partitioning between solid and solution in the soil. This adjustment was necessary to increase the soluble P quantity in the runoff. Because we used the filter option to trap sediment in the watershed and that also removes soluble P, the change in the PHOSKD was based on matching the relationship between MINP (which is largely the SWAT's soluble P) and the total P in the runoff. The simulation did not include stream processes, so this represents the phosphorus delivered. We would anticipate that the fraction of the P that is soluble would decrease as the TSS concentration increases. The PSP was decreased from a default of 0.40 to 0.30. The PSP specifies the fraction of fertilizer P which is in solution after an incubation period. The P uptake distribution parameter (UBP) was decreased to allow for additional P to remain on the landscape.

The groundwater phosphorus was estimated based on observations of low-flow phosphorus concentrations in the stream. Figure 16 shows that at very low suspended solids concentration soluble reactive phosphorus concentrations range from 0.02 to more than 0.1 mg/l. A groundwater P concentration of 0.08 mg/L was used to match the stream concentrations. The phosphorus enrichment of eroded solids (ERORGP) is estimated in SWAT based on the suspended solids concentration in the runoff. SWAT assumes that as the solids concentration is increased, the phosphorus content of the solids decreases (the solid line in Figure 17). In Figure 17, the enrichment in the stream solids estimated the phosphorus content by the difference between total P and soluble reactive P and dividing by the suspended solids concentration. One of the difficulties with this relationship in SWAT is that when relatively high solids concentrations are generated during event days, the enrichment factor can be quite low. To better approximate the observed enrichment, an enrichment factor of 10 was fixed. This does not allow higher enrichment factors on low suspended solids events, but this increased the phosphorus export consistent with the observed export.

Similar to the sediment calibration, the phosphorus calibration illustrated greater variability in 2002 then 2003. The SWAT simulation of the eleven months of measured sediment load resulted in R^2 and N-S values of 0.66 and 0.66, respectively (Figure 18). The calibration period yielded a 73 kg underestimation of total phosphorus (1.1% error).

Figure 19 compares the different sources of phosphorus by different management rotations within the subwatersheds. The simulations show that between 1999 and 2004 over 75% of the phosphorus load originated from agriculturally managed lands. Approximately 90% of that agricultural phosphorus was from lands managed within the 113C and 114C management classification. These are agricultural rotations on soils that have higher runoff potential (hydrologic soil group C). .

The SWAT modeling identifies management rotations and soil combinations that are likely to have higher phosphorus export, but it does not identify specific parcels of land. Within each subwatershed, the variations in slope, soil type, cropping and weather timing, and proximity to ephemeral and perennial pathways will also need to be considered in identifying sites that are likely to be most critical with respect to phosphorus loss. Figure 20 shows the relative difference in average phosphorus loss that was projected with the SWAT modeling. With this simulation, the hydrologic soil group was a very strong indication of likely phosphorus loss and is consistent with water movement from fields to streams as a dominant control over phosphorus export.

Table 8: Calibrated Parameter Values for Phosphorus in the MLW

Constituent	SWAT Variable	Description	Default Value	Calibrated Value
Phosphorus	SOL_LABP (Cropped HRUs)	Initial Soluble Phosphorus Concentration in Soil (mg/kg)	0.00	21 - 44
	PHOSKD	Phosphorus Partitioning Coefficient (m^3/mg)	175.00	20.00
	UBP	Phosphorus Uptake Distribution Parameter	20.00	5.00
	ERORGP	Organic Phosphorus Enrichment Ratio	0.00	10.00
	GWSOLP	Groundwater Soluble P Concentration (mg P/L)	0.00	0.08
	PSP	Phosphorus Availability Index	0.400	0.300

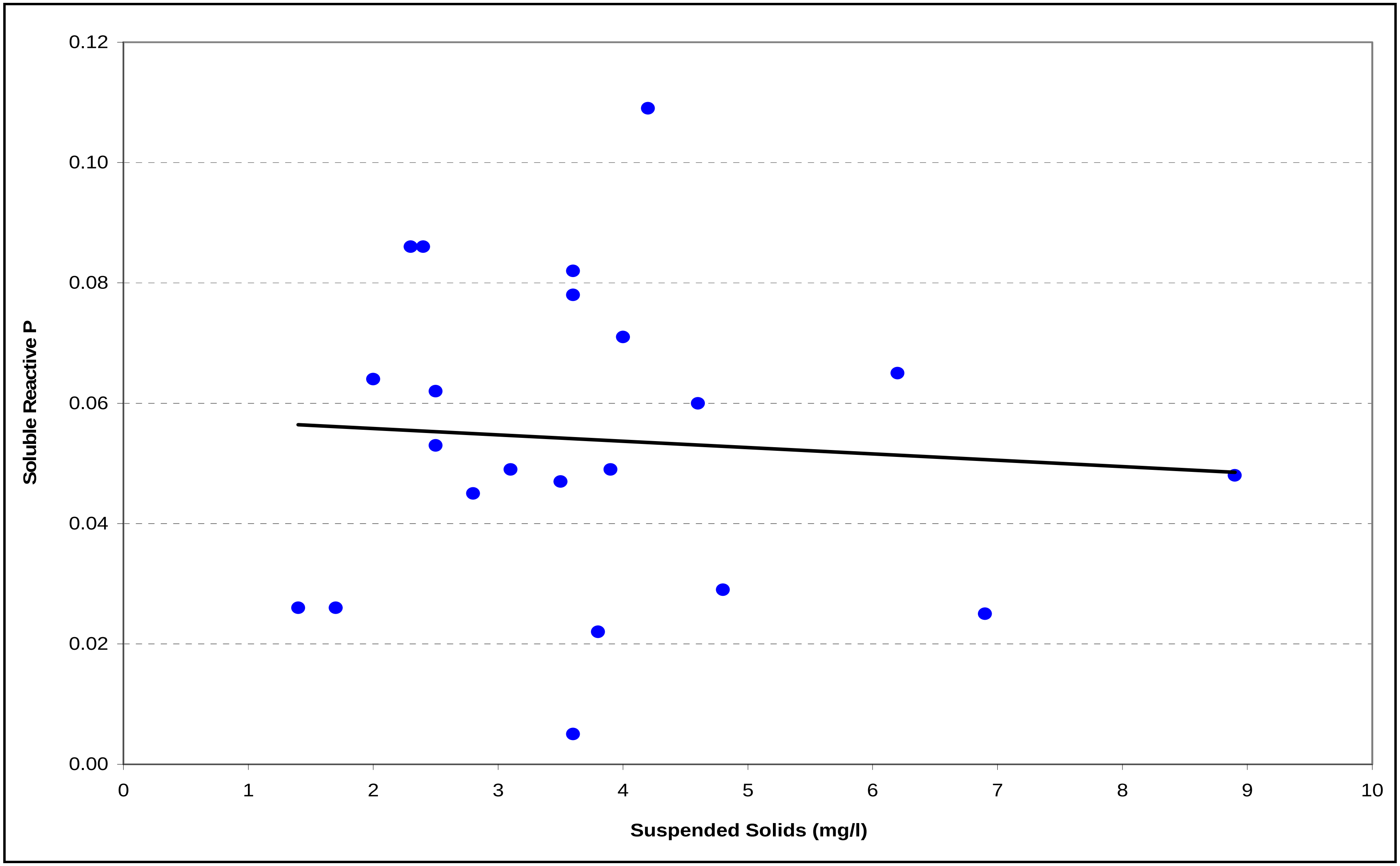

Figure 16: Soluble Reactive P versus Suspended Solids

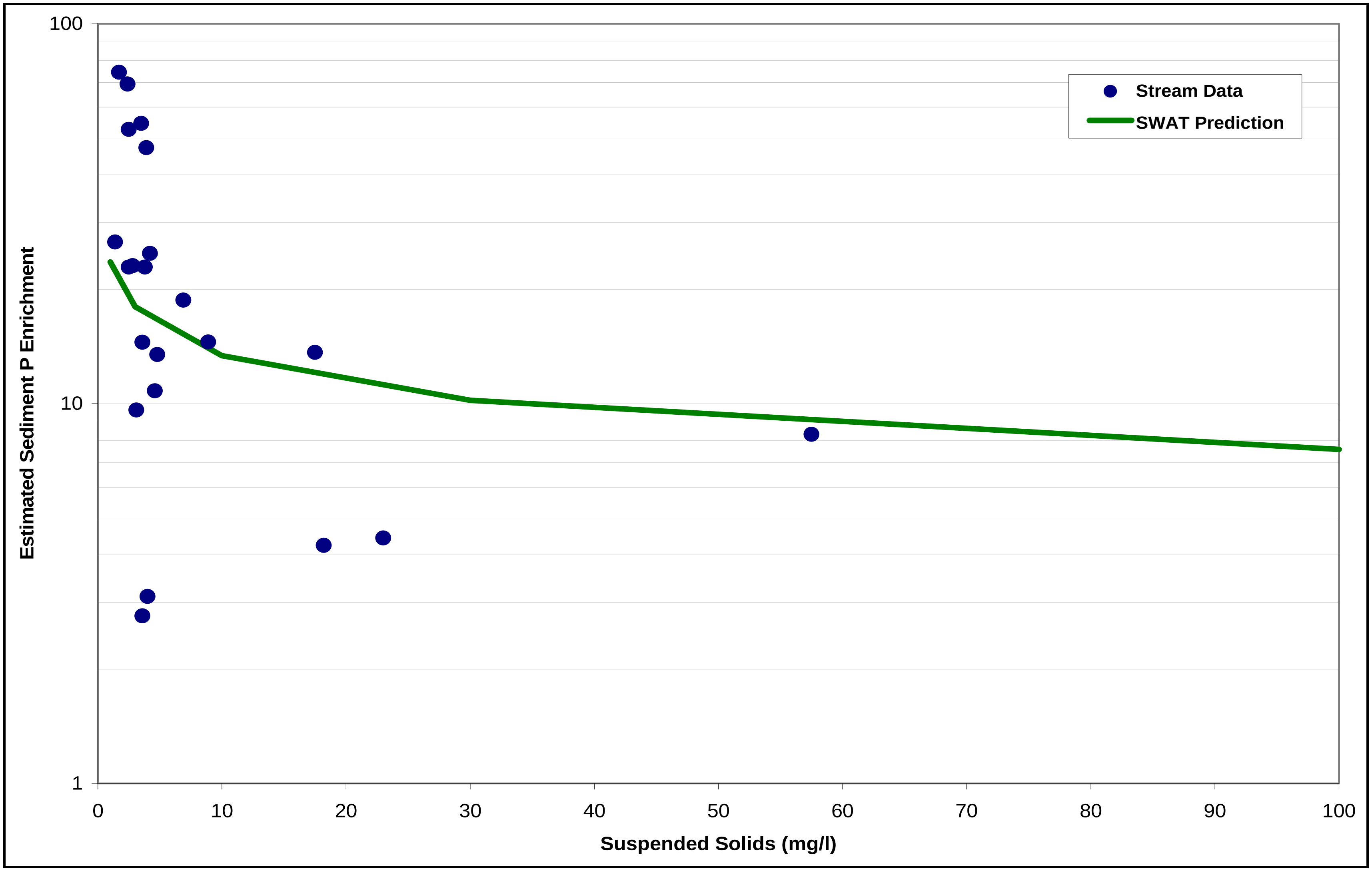

Figure 17: Estimated Sediment P Enrichment versus Suspended Solids

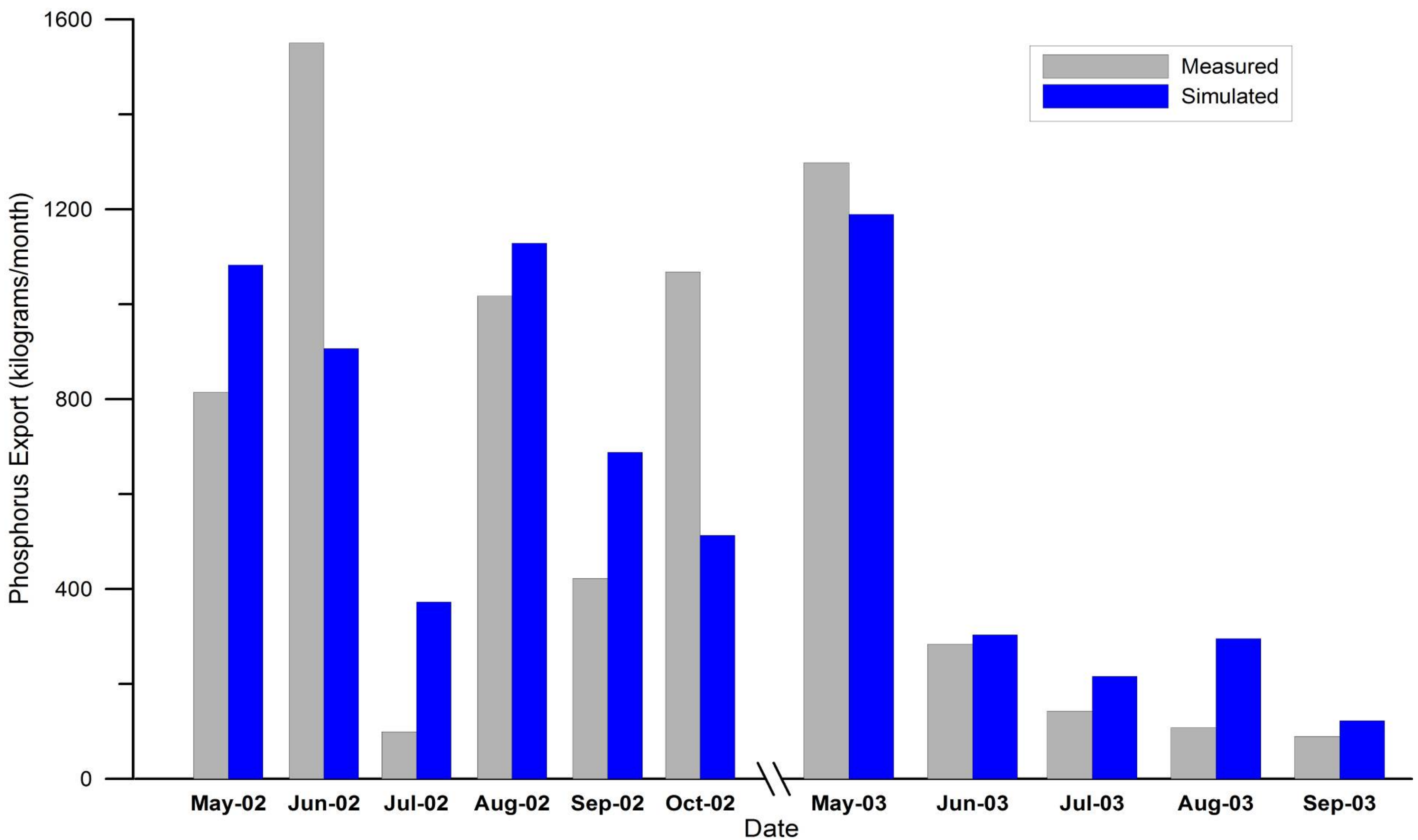

Figure 18: Measured TP Load vs. SWAT Simulated TP Load

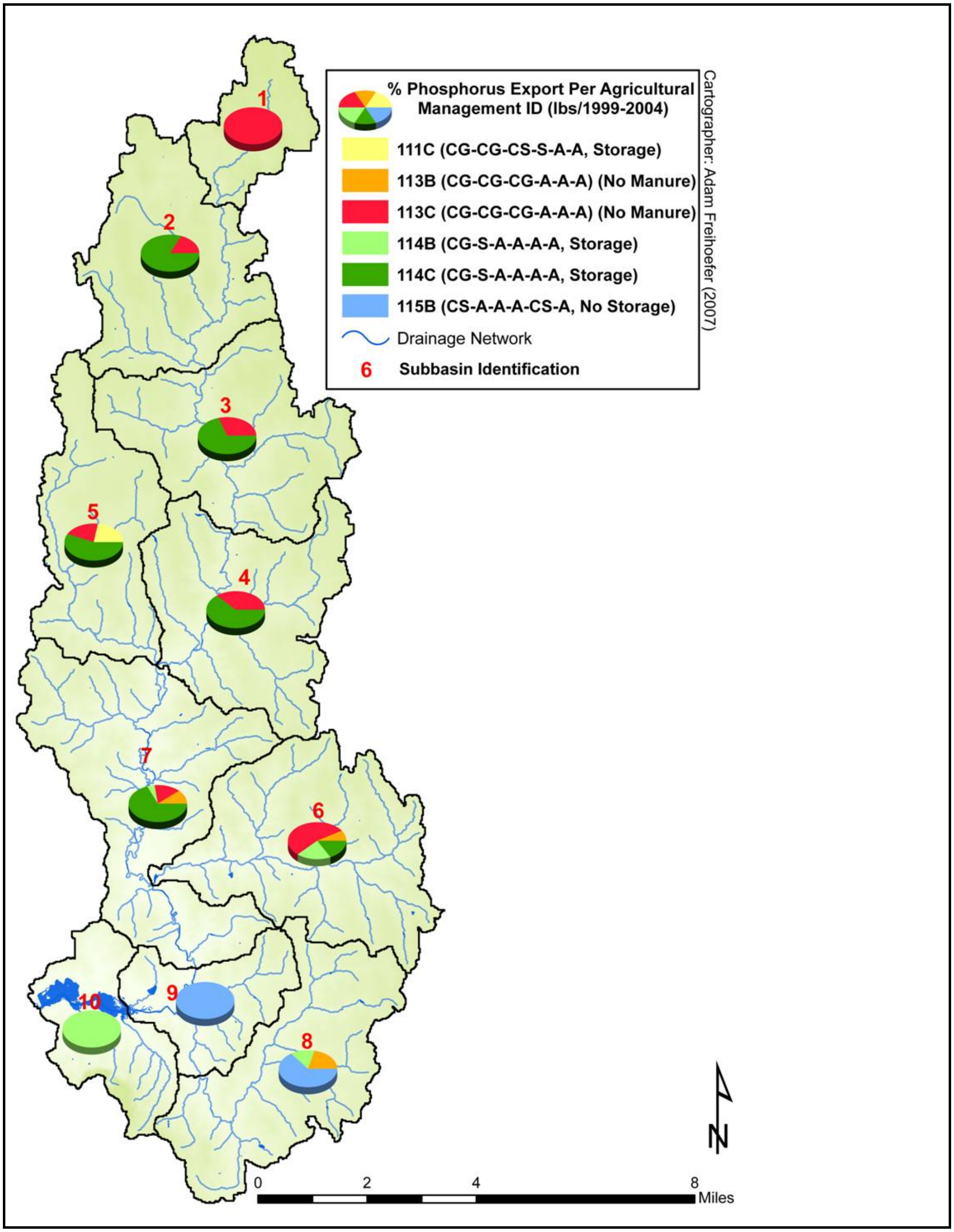

Figure 19: Percent TP Export per Agricultural Practice Between 1999 - 2004

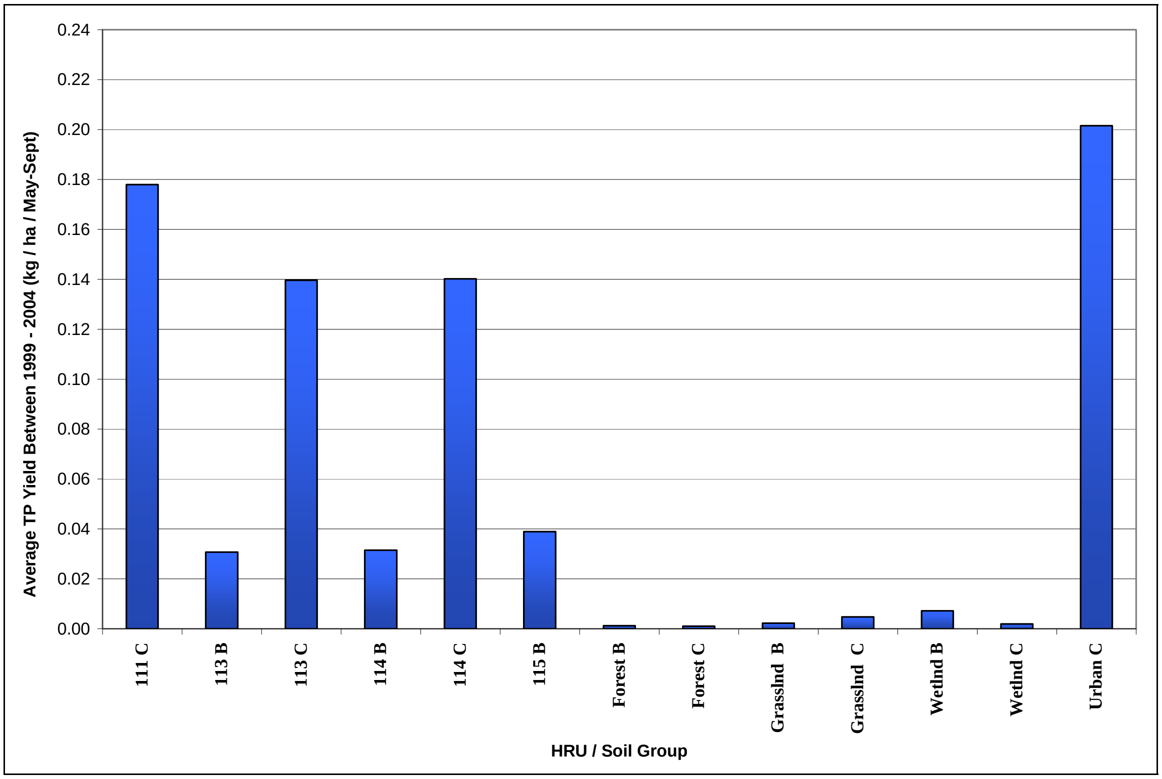

Figure 20: Average growing season phosphorus yield for different land management and hydrologic soil group combinations (1999-2004).

3.5 Crop Yield Calibration

Annual crop yield and daily biomass within SWAT is used to indicate the correct simulation of plant growth. Simulated crop growth affects soil moisture, evapotranspiration, and biomass. Simulation of additional biomass creates additional post-harvest residue on the landscape, which in-turn lessens the erosive potential during a runoff events (Baumgart 2005). Each annual crop yield was calibrated by modifying the biomass energy factor (BE) in the crop database. The default value of corn’s BE (39) was increased to a value of 49. Alfalfa and Soybeans’ BE were kept at the default values. The simulated crop yields were within +/- 20 percent of the National Agriculture Statistics Service (NASS) for Clark County.

Two additional adjustments within SWAT were used to more accurately simulate crop yields. First, an additional 10 days was added to the original planting date because SWAT assumes that the plant starts growing immediately instead of accounting for the initial time the seed germinates (Baumgart 2005). The second adjustment was the use of the auto-fertilization command for each management scenario. Initial simulations indicated that the crop growth was affected by frequent nitrogen stress. This is likely due to the model simulating excessive denitrification. It should be noted that this issue has since been resolved in the latest version of the model (SWAT 2005). The auto fertilization command added enough nitrogen to the system every year to displace the excess being removed by excessive denitrification rates.

4.0 Alternative Management Scenarios

Alternative management scenarios are modifications of the existing (baseline) model simulation to explore the impact of changes on phosphorus export. The SWAT can be used to explore different management and land use changes. These model simulations are based on adjusting model parameters in ways that reflect these changes. Nine alternative scenarios were developed from the original baseline model simulation. Each scenario was run from 1975 through 2004 to incorporate climatological variability required to develop a long-term average phosphorus contribution to Mead Lake. Besides the changes made to implement the alternative scenarios, there were no other changes made from the calibrated parameter set described in Section 3.0.

4.1 Baseline and Scenario Model Simulations (1999-2004)

The baseline model simulation was created from the calibrated Mead Lake model. The baseline model simulation used a 1999 through 2004 evaluation period following a warm-up period. To account for some of the variability associated with year-to-year cropping within the rotations, six different starting dates were used in the baseline and scenario simulations. The starting dates were from 1988 to 1993. This allowed simulation warm-up periods that ranged from six to eleven years prior to the 1999-2004 evaluation period. The results of the baseline and scenario model simulations are shown as a range between the average and the maximum annual export for sediment and phosphorus. The average is the mean of the thirty six different simulation years (six evaluation years with six different simulations by varying starting years). The maximum is the average of the highest export result for each year from the six different starting dates.

4.2 Scenario Implementation

Nine scenarios were implemented by deviating from the baseline calibration using model parameters representative of different landuse impacts. The nine scenarios and their associated techniques are outlined in Table 9. The nine scenarios were chosen as ones most likely to be implemented in the MLW.

4.2.1 Nutrient Management Scenarios (1, 3, 4, 8)

Scenario 1 decreased the average measured soil phosphorus in each subbasin agricultural HRUs to a standardized background concentration of 25 mg/kg. This decrease reflects improvements in nutrient management across the entire watershed. Scenario 3 changed the amount of phosphorus in cattle feed. This scenario had previously shown large reductions in the nearby Coon Fork watershed in conjunction with SWAT (Hung 2002). Scenario 4 decreased the amount of phosphorus in both the cattle feed and the chemical fertilizers applied to the fields. The application of scenarios 3 and 4 would likely not produce instantaneous results, but rather would result in a long-term decrease in soil phosphorus concentrations on agricultural HRUs. Scenario 8 was a combination scenario that combined the soil phosphorus reduction, the increased erosion control, and the reduction in dietary phosphorus.

4.2.2 Land Management Scenarios (2, 5, 6, 7, 9)

Scenario 2 implemented erosion control measures in the form of contour stripping applied to all agricultural HRUs within the watershed. Scenario 5 simulated presettlement conditions. During presettlement time the MLW was dominated by forested and wetland regions. Scenario 6 changed the land management of agricultural HRUs to continuous rotational grazing. With rotational grazing, manure is still applied to the land; however, no tillage practices are implemented. Scenario 7 altered conventional fall tillage to conservation tillage. This reduces the amount of runoff while the field is bare and exposed to erosion. Scenario 9 also reduced fall runoff by planting winter rye to serve as ground cover.

Table 9: Mead Lake Watershed Simulated Land and Nutrient Management Scenarios

Scenario ID	Management Practice	Conceptual Model Description and Mechanism	SWAT Model Representation	SWAT Model Parameter Identification and Range
1	Soil Phosphorus Concentration Decline	1.) Decrease phosphorus export from landscape (Sediment and Soluble P)	Change current Bray-1 Soil Phosphorus Levels for all cropped HRUs to 25mg/kg	- SOL_LABP (.chm file)
2	Contour Strip Cropping	1.) Decrase runoff by using contour strips	Decrease USLE_P from 0.50 to 0.25 for Agricultural HRUs	- USLE_P (.mgt file)
3	Decrease in Dietary Phosphorus Levels	1.) Decrease phosphorus concentrations applied to agricultural lands	Change composition of dairy manure applied to agricultural HRUs with 38% P Reduction	- Decrease Dairy Manure FMINP and FORGP by 0.002 (38%) (fertilizer dbase)
4	Decrease in Dietary Phosphorus Levels and Fertilizer P Levels	1.) Decrease phosphorus concentrations applied to agricultural lands	Change composition of dairy manure (38% Reduction) and fertilizers (33% Reduction) applied to agricultural HRUs	- Decrease Dairy Manure FMINP and FORGP by 0.002 (fertilizer dbase) - Decrease P component of fertilizer by 33%
5	Conversion to Presettlement Landuse	1.) Change in landuse elimating agricultural landscape	Repalce current land management file with Wisconsin presettlement layer	- Change Landuse Layer within the Landuse and Soil definition section
6	Conversion to Rotational Grazing	1.) Flow reduction 2.) Temporal variation in manure application rates/amounts	Convert all dairy HRUs to continous pasture with grazing	- Dairy Rotations (.mgt file)
7	Conventional Tillage to Conservation Tillage	1.) Decrease runoff by changing tillage practices	Replace Fall Tillage with No Tillage (CNOP decrease of 3 and no mixing efficiency)	- Agricultural Rotations (.mgt file) - Tillage dbase (EFTMIX and DEPTIL)
8	Combination of Soil Phosphorus Reduction, Contour Stripping, and Decrease in Dietary	1.) Decrease phosphorus export from landscape (Sediment and Soluble P) 2.) Decrase runoff by using contour strips 3.) Decrease phosphorus concentrations applied to agricultural lands	Convert all fall moldboard tillage with no tillage	- SOL_LABP (.chm file), - USLE_P (.mgt file) - Decrease Dairy Manure FMINP and FORGP by 0.002 (38%) (fertilizer dbase)
9	Implementation of Winter Rye	1.) Decrease phosphorus export from landscape (Sediment and Soluble P)	Addition of Rye (Nov 01 - March 1) between plantings of corn	- Dairy Rotations (.mgt file)

4.3 Baseline and Scenario Results

Table 10, shown below, shows a summary of the management scenarios and their impact on the annual average and growing season (May-September) phosphorus export from the watershed. The results demonstrate that watershed-wide implementation of reductions in soil phosphorus or sediment control could lead to a 10%-20% reduction in phosphorus export to Mead Lake. By combining management actions (e.g., Scenario 8) 20%-30% reductions in soil phosphorus might be possible.

Table 10: Simulated Average Phosphorus Export for Mead Lake Watershed

	Average Annual Phosphorus Export (Kg)	Average Growing Season Phosphorus Export (Kg)	Annual Percent Reduction
Baseline	7200 – 9315	2221 - 3047	---
Reduce Soil P (Scenario 1)	6072 - 7624	1893 - 2499	16%
Reduce Soil Erosion (Scenario 2)	5820 - 7086	1885 - 2388	19%
Dietary P Reduction (Scenario 3)	7035 - 8967	2159 - 2917	2%
Dietary & Fertilizer P Reduction (Scenario 4)	7034 - 8967	2159 - 2917	2%
Pre-settlement Land Use (Scenario 5)	2515 - 2656	857 - 934	65%
Rotational Grazing (Scenario 6)	5749 - 6084	1675 - 1856	20%
Conservation Tillage (Scenario 7)	5718 - 6882	2047 - 2616	21%
Combine Soil TP, Erosion and Dietary P Reduction (Scenario 8)	4931 - 5733	1596 - 1921	32%
Winter Rye (Scenario 9)	6657 - 8977	2208 - 3095	8%

Notes: Annual shown is January-December and growing season May-September. Results based on simulation from 1999-2004 using starting dates 1988-1993 (thirty six different year-simulations from six different years in the six simulations). Range developed from the average of the annual averages to the average of the annual maximums for the different simulations. Percent reduction based on average of annual averages.

5.0 Conclusions and Recommendations

- Through calibration, the SWAT model was able to simulate growing season hydrology, sediment and total phosphorus in the Mead Lake watershed.

- Using the results of the SWAT model, it was determined that a little more than half of the phosphorus entering Mead Lake can be attributed to the row crop agricultural rotations in the Mead Lake watershed.

- SWAT was used to evaluate the magnitude of phosphorus export from the different agricultural rotations and soils. Those soils with increased likelihood of surface runoff such as hydrologic group C soils, are expected to have the greatest unit-area phosphorus export.

- Average annual phosphorus export to Mead Lake is expected to range from 7200-9300 kilograms. Growing season phosphorus export is expected to range between 2200 and 3500 kilograms.

- Management practices can reduce the runoff volume, sediment loss and phosphorus export from the watershed. An evaluation of a group of management practices suggests that overall phosphorus reductions up to thirty percent are possible with wide-spread implementation of practices.

- As with any modeling study, the results should be interpreted carefully. While the modeling discussed here is a general tool for estimating phosphorus loading, it used only the principal agricultural rotation. Structural sources of phosphorus (e.g., barnyards & cattle crossings) and local variations in proximity to stream and drainage pathways are averaged into the results presented.

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APPENDICES

Appendix A

Landuse Characterization

MEAD LAKE WATERSHED LANDUSE CHARACTERIZATION								
	Cropped Farmland (Hectares)	**Farmsteads (Hectares)**	**Forest (Hectares)**	**Grassland (Hectares)**	**Impervious (Roads, Urban) (Hectares)**	**Water (Hectares)**	**Wetland (Hectares)**	**Total (Hectares)**
Subbasin 1	360.41	4.8	235.19	132.41	19.78	11.77	323.99	*1088*
Subbasin 2	1552.99	33.06	216.37	461.35	146.87	4.90	380.03	*2796*
Subbasin 3	1713.10	39.67	485.45	277.94	173.10	4.20	179.87	*2873*
Subbasin 4	1758.87	38.23	640.51	219.6	82.00	9.07	162.57	*2911*
Subbasin 5	1666.63	33.73	115.46	273.62	95.29	0.84	138.22	*2324*
Subbasin 6	810.08	29.05	1776.89	389.43	264.19	5.08	258.73	*3533*
Subbasin 7	974.50	25.96	1910.10	292.92	88.71	4.01	537.00	*3833*
Subbasin 8	1117.26	25.32	1023.76	391.98	231.76	4.91	152.72	*2948*
Subbasin 9	239.32	7.36	772.83	86.06	47.65	8.55	178.78	*1341*
Subbasin 10	189.43	5.15	787.73	164.23	65.05	119.15	111.52	*1442*
Totals (Acres)	10383	242	7964	2690	1214	172	2423	**25089**
Total %	*41.38*	*0.97*	*31.74*	*10.72*	*4.84*	*0.69*	*9.66*	

	Cropped Farmland (%)	**Farmsteads (%)**	**Forest (%)**	**Grassland (%)**	**Impervious (Roads, Urban) (%)**	**Water (%)**	**Wetland (%)**
Subbasin 1	33.1	0.4	21.6	12.2	1.8	1.1	29.8
Subbasin 2	55.6	1.2	7.7	16.5	5.3	0.2	13.6
Subbasin 3	59.6	1.4	16.9	9.7	6.0	0.1	6.3
Subbasin 4	60.4	1.3	22.0	7.5	2.8	0.3	5.6
Subbasin 5	71.7	1.5	5.0	11.8	4.1	0.0	5.9
Subbasin 6	22.9	0.8	50.3	11.0	7.5	0.1	7.3
Subbasin 7	25.4	0.7	49.8	7.6	2.3	0.1	14.0
Subbasin 8	37.9	0.9	34.7	13.3	7.9	0.2	5.2
Subbasin 9	17.9	0.5	57.7	6.4	3.6	0.6	13.3
Subbasin 10	13.1	0.4	54.6	11.4	4.5	8.3	7.7

MEAD LAKE WATERSHED MANAGEMENT CHARACTERIZATION

	Dairy (CG-CG-CG-S-A-A) Code 111 (Manure Storage) (Ha)	Cash Grain (C-S-C-S-C-S) Code 112 (No Storage / Manure) (Ha)	Dairy (CG-CG-CG-A-A-A) Code 113 (No Storage / Manure) (Ha)	Dairy (CG-S-A-A-A-A) Code 114 (Manure Storage) (Ha)	Dairy / Amish (CS-A-A-A-CS-A) Code 115 (No Manure Storage) (Ha)	Hay / Pasture w/ Grazing Code 120 (Ha)	**Totals (Ha)**
Subbasin 1		10.44	289.22	39.39	21.37		360
Subbasin 2		28.27	251.51	1243.65	29.56		1553
Subbasin 3	29.11	13.06	502.69	1107.36	9.38	51.49	1713
Subbasin 4		115.85	580.10	947.13	115.8		1759
Subbasin 5	248.74	14.94	386.86	1016.11			1667
Subbasin 6		83.89	365.06	304.36	56.77		810
Subbasin 7		59.14	388.90	508.35	15.59	2.51	974
Subbasin 8		40.22	211.99	138.76	668.27	58.02	1117
Subbasin 9		16.30	49.26	36.98	132.85	3.93	239
Subbasin 10		36.05	51.44	78.80		23.13	189
Totals (Acres)	277.85	418.16	3077.03	5420.89	1049.59	139.08	**10383**
Total %	2.68	4.03	29.64	52.21	10.11	1.34	

	Dairy (CG-CG-CG-S-A-A) Code 111 (Manure Storage) (%)	Cash Grain (C-S-C-S-C-S) Code 112 (No Storage / No Manure) (Hectares)	Dairy (CG-CG-CG-A-A-A) Code 113 (No Manure / No Storage) (%)	Dairy (CG-S-A-A-A-A) Code 114 (Manure Storage) (%)	Dairy / Amish (CS-A-A-A-CS-A) Code 115 (No Manure Storage) (%)	Hay / Pasture w/ Grazing Code 120 (%)
Subbasin 1	0.00	2.90	80.25	10.93	5.93	0.00
Subbasin 2	0.00	1.82	16.20	80.08	1.90	0.00
Subbasin 3	1.70	0.76	29.34	64.64	0.55	3.01
Subbasin 4	0.00	6.59	32.98	53.85	6.58	0.00
Subbasin 5	14.92	0.90	23.21	60.97	0.00	0.00
Subbasin 6	0.00	10.36	45.06	37.57	7.01	0.00
Subbasin 7	0.00	6.07	39.91	52.17	1.60	0.26
Subbasin 8	0.00	3.60	18.97	12.42	59.81	5.19
Subbasin 9	0.00	6.81	20.58	15.45	55.51	1.64
Subbasin 10	0.00	19.03	27.16	41.60	0.00	12.21

Appendix B

Agricultural Management Rotations

Dairy (CG-CG-CS-S-A-A) (Manure Storage) (Gridcode 111)					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/25	Manure	Dairy	5,380	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/5	Plant	Corn Grain		
2000	5/5	Fertilizer	09-23-30	224	kg/ha
2000	6/15	Herbicide	Round-Up		
2000	10/15	Harvest/Kill	Corn Grain		
2000	10/20	Manure	Dairy	1,345	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2001	4/25	Manure	Dairy	5,380	kg/ha
2001	5/1	Tillage	Disk Plow		
2001	5/5	Plant	Corn Grain		
2001	5/5	Fertilizer	09-23-30	224	kg/ha
2001	6/15	Herbicide	Round-Up		
2001	10/15	Harvest/Kill	Corn Grain		
2001	10/20	Manure	Dairy	1,345	kg/ha
2001	10/25	Tillage	Moldboard Plow		
2002	4/25	Manure	Dairy	2,119	kg/ha
2002	5/1	Tillage	Disk Plow		
2002	5/5	Plant	Corn Grain		
2002	5/5	Fertilizer	09-23-30	224	kg/ha
2002	6/15	Herbicide	Round-Up		
2002	10/15	Harvest/Kill	Corn Grain		
2002	10/20	Manure	Dairy	1,345	kg/ha
2002	10/25	Tillage	Moldboard Plow		
2003	4/25	Manure	Dairy	1,345	kg/ha
2003	5/10	Tillage	Disk Plow		
2003	5/15	Plant	Soybeans		
2003	10/1	Harvest/Kill	Soybeans		
2003	10/25	Tillage	Disk Plow		
2004	4/25	Plant	Alfalfa		
2004	4/25	Fertilizer	05-14-42	224	kg/ha
2004	9/5	Harvest	Alfalfa		
2004	9/5	Fertilizer	00-00-60	224	kg/ha
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill Alfalfa	Alfalfa		
2005	10/15	Manure	Dairy	5,380	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Cash (CG-CG-CG-A-A-A) (No Storage/No Manure) (Gridcode 113)					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	5/1	Tillage	Disk Plow		
2000	5/5	Plant	Corn Grain		
2000	5/5	Fertilizer	09-23-30	280	kg/ha
2000	6/15	Herbicide	Round-Up		
2000	10/15	Harvest/Kill	Corn Grain		
2000	10/25	Tillage	Moldboard Plow		
2001	4/25	Fertilizer	46-00-00	336	kg/ha
2001	5/1	Tillage	Disk Plow		
2001	5/5	Plant	Corn Grain		
2001	5/5	Fertilizer	9/23/1930	280	kg/ha
2001	6/15	Herbicide	Round-Up		
2001	9/25	Harvest/Kill	Corn Grain		
2001	10/25	Tillage	Moldboard Plow		
2002	4/25	Fertilizer	46-00-00	336	kg/ha
2002	5/1	Tillage	Disk Plow		
2002	5/5	Plant	Corn Grain		
2002	5/5	Fertilizer	09-23-30	224	kg/ha
2002	6/15	Herbicide	Round-Up		
2002	9/25	Harvest/Kill	Corn Grain		
2002	10/25	Tillage	Moldboard Plow		
2003	4/25	Plant	Alfalfa		
2003	9/5	Harvest	Alfalfa		
2003	9/15	Fertilizer	00-00-60	336	kg/ha
2004	6/10	Harvest	Alfalfa		
2004	7/15	Harvest	Alfalfa		
2004	9/1	Harvest	Alfalfa		
2004	9/15	Fertilizer	00-00-60	336	kg/ha
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/1	Herbicide	Round-Up		
2005	10/25	Tillage	Moldboard Plow		

Dairy (CG-S-A-A-A-A) (Manure Storage) (Gridcode 114)					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/25	Manure	Dairy	5,380	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/5	Plant	Corn Grain		
2000	5/5	Fertilizer	09-23-30	224	kg/ha
2000	6/15	Herbicide	Round-Up		
2000	10/15	Harvest/Kill	Corn Grain		
2000	10/20	Manure	Dairy	5,380	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2001	5/1	Tillage	Disk Plow		
2001	5/15	Plant	Soybeans		
2001	5/15	Fertilizer	05-14-42	224	kg/ha
2001	6/25	Herbicide	Round-Up		
2001	10/1	Harvest/Kill	Soybeans		
2001	10/25	Tillage	Disk Plow		
2002	4/10	Manure	Dairy	1,345	kg/ha
2002	4/15	Tillage	Disk Plow		
2002	4/25	Plant	Alfalfa		
2002	4/25	Fertilizer	05-14-42	224	kg/ha
2002	9/1	Harvest	Alfalfa		
2002	9/15	Fertilizer	00-00-60	224	kg/ha
2003	6/10	Harvest	Alfalfa		
2003	7/15	Harvest	Alfalfa		
2003	9/1	Harvest	Alfalfa		
2003	9/15	Fertilizer	00-00-60	224	kg/ha
2004	6/10	Harvest	Alfalfa		
2004	7/15	Harvest	Alfalfa		
2004	9/1	Harvest	Alfalfa		
2004	9/15	Fertilizer	00-00-60	224	kg/ha
2005	6/10	Harvest	Alfalfa		
2005	7/15	Harvest	Alfalfa		
2005	9/1	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/15	Manure	Dairy	1,345	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Dairy/Amish (CS-A-A-A-CS-A) (No Manure Storage) (Gridcode 115)					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/1	Manure	Dairy	1,009	kg/ha
2000	5/1	Tillage	Disk Plow		
2000	5/1	Manure	Dairy	1,009	kg/ha
2000	5/20	Plant	Corn Silage		
2000	5/20	Fertilizer	09-23-30	224	kg/ha
2000	9/1	Manure	Dairy	505	kg/ha
2000	10/1	Harvest/Kill	Corn Silage		
2000	10/1	Manure	Dairy	505	kg/ha
2000	10/25	Tillage	Moldboard Plow		
2000	11/1	Manure	Dairy	505	kg/ha
2000	12/1	Manure	Dairy	505	kg/ha
2001	4/20	Tillage	Disk Plow		
2001	4/25	Plant	Alfalfa		
2001	9/5	Harvest	Alfalfa		
2002	6/10	Harvest	Alfalfa		
2002	7/15	Harvest	Alfalfa		
2002	9/1	Harvest	Alfalfa		
2003	6/10	Harvest	Alfalfa		
2003	7/15	Harvest	Alfalfa		
2003	9/1	Harvest	Alfalfa		
2003	10/1	Kill	Alfalfa		
2003	10/1	Manure	Dairy	1,009	kg/ha
2003	10/25	Tillage	Moldboard Plow		
2004	4/1	Manure	Dairy	1,009	kg/ha
2004	5/1	Tillage	Disk Plow		
2004	5/1	Manure	Dairy	1,009	kg/ha
2004	5/20	Plant	Corn Silage		
2004	5/20	Fertilizer	09-23-30	224	kg/ha
2004	9/1	Manure	Dairy	505	kg/ha
2004	10/1	Harvest/Kill	Corn Silage		
2004	10/1	Manure	Dairy	505	kg/ha
2004	10/25	Tillage	Moldboard Plow		
2004	11/1	Manure	Dairy	505	kg/ha
2005	4/20	Tillage	Disk Plow		
2005	4/25	Plant	Alfalfa		
2005	4/25	Plant	Alfalfa		
2005	9/5	Harvest	Alfalfa		
2005	10/1	Kill	Alfalfa		
2005	10/1	Manure	Dairy	1,009	kg/ha
2005	10/25	Tillage	Moldboard Plow		

Appendix C

HRU Rotation Assignments

SUBBASIN # 1				
HRU #		Acres	% Subbasin	Rotation ID
10	Corn Silage-->CSIL/WI020	74	2.97	113A2
11	Corn Silage-->CSIL/WI015	311	12.43	113C1
12	Corn Silage-->CSIL/WI026	461	18.45	113B1

SUBBASIN # 2				
HRU #		Acres	% Subbasin	Rotation ID
13	Soybean-->SOYB/WI015	35.51	0.54	114A1
14	Soybean-->SOYB/WI026	2925.46	44.72	114B1
21	Corn Silage-->CSIL/WI015	66.01	1.01	113B1
22	Corn Silage-->CSIL/WI026	531.47	8.12	113C1

SUBBASIN # 3				
HRU #		Acres	% Subbasin	Rotation ID
25	Soybean-->SOYB/WI026	2714.38	38.97	114B1
26	Soybean-->SOYB/WI058	66.68	0.96	114A1
33	Corn Silage-->CSIL/WI026	1292.59	18.56	113A1

SUBBASIN # 4				
HRU #		Acres	% Subbasin	Rotation ID
36	Soybean-->SOYB/WI026	1528.32	21.74	114A1
37	Soybean-->SOYB/WI058	981.61	13.97	114B1
38	Soybean-->SOYB/WI056	34.71	0.49	114C2
48	Corn Silage-->CSIL/WI026	136.04	1.94	113C1
49	Corn Silage-->CSIL/WI058	1383.35	19.68	113A1
50	Corn Silage-->CSIL/WI056	116.90	1.66	113B2

SUBBASIN # 5				
HRU #		Acres	% Subbasin	Rotation ID
51	Soybean-->SOYB/WI026	1814.63	32.97	114B1
52	Soybean-->SOYB/WI058	790.84	14.37	114A1
53	Soybean-->SOYB/WI056	1.41	0.03	114C2
54	Corn-->CORN/WI026	656.20	11.92	111A1
61	Corn Silage-->CSIL/WI026	706.42	12.83	113C1
62	Corn Silage-->CSIL/WI058	209.38	3.80	113A1

SUBBASIN # 6				
HRU #		Acres	% Subbasin	Rotation ID
65	Soybean-->SOYB/WI058	131.05	1.61	114B1
66	Soybean-->SOYB/WI043	494.37	6.06	114A2
67	Soybean-->SOYB/WI056	175.05	2.14	114C2
77	Corn Silage-->CSIL/WI058	510.00	6.25	113A1
78	Corn Silage-->CSIL/WI056	446.04	5.46	113C2

SUBBASIN # 7				
HRU #		Acres	% Subbasin	Rotation ID
79	Soybean-->SOYB/WI058	903.28	9.69	114B1
80	Soybean-->SOYB/WI043	37.44	0.40	114C2
81	Soybean-->SOYB/WI056	356.63	3.82	114A2
91	Corn Silage-->CSIL/WI058	247.35	2.65	113C1
92	Corn Silage-->CSIL/WI043	219.27	2.35	113B2
93	Corn Silage-->CSIL/WI056	500.31	5.37	113A2

SUBBASIN # 8				
HRU #		Acres	% Subbasin	Rotation ID
94	Soybean-->SOYB/WI043	375.88	5.54	114B2
100	Oats-->OATS/WI043	1715.80	25.57	115A2
101	Corn Silage-->CSIL/WI043	536.79	7.91	113C2

SUBBASIN # 9				
HRU #		Acres	% Subbasin	Rotation ID
108	Oats-->OATS/WI043	323.10	9.83	115A2
109	Oats-->OATS/WI056	45.18	1.37	115B2

SUBBASIN # 10				
HRU #		Acres	% Subbasin	Rotation ID
110	Soybean-->SOYB/WI043	216.28	6.35	114A2
111	Soybean-->SOYB/WI056	4.06	0.12	114C2