LINKING FIELD-SCALE PHOSPHORUS EXPORT TO A WATERSHED-SCALE MODEL

by

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ABSTRACT

Agricultural runoff is an important non-point pollution source in many Wisconsin watersheds including southwestern Wisconsin's Fever River. The Fever River (a tributary to the Galena River Watershed) was recognized as affected by nonpoint source pollution (sediment and phosphorus) and served as one of Wisconsin's first non-point pollution control sites (WIDNR 2001). Controlling the sources of nutrients from the landscape is particularily complex because end-of-pipe monitoring is not available and simulation tools are usually necessary. Management practices were originally installed to mitigate sediment and phosphorus loading in the Fever River to protect its aquatic ecosystem. The excellent smallmouth bass fishery resulted in the Fever River being recognized as part of Wisconsin's exceptional resource waters (ERW) in 1995. Since the ERW classification, uncontrolled non-point source pollution within the Fever River Watershed has resulted in the deterioration of the waterway for recreation and a sustainable fishery. Currently within the headwaters of the Fever River Watershed, extensive water quality monitoring is being conducted to determine the effectiveness of alternative management practices.

To understand and eventually control phosphorus loading from nonpoint sources into the Fever River, the Soil and Water Assessment Tool (SWAT) model approach was used to simulate the influence of land management on phosphorus transfer at different spatial scales within the headwaters of the Fever River. Runoff volume and composition was measured for four years from alfalfa and corn fields of the University of Wisconsin – Platteville Pioneer Farm in the southern portion of the 7.8 km^2 Upper Fever River Watershed. Runoff volume and composition data was also collected from the URFW outlet. SWAT was applied at the field and watershed-scales on an event basis to be consistent with field collection efforts.

The results show that SWAT can be used at the different spatial scales. Simulating field-scale watersheds was challenging because SWAT does not incorporate variations in precipitation intensity with its daily time step. Nevertheless, SWAT was successful simulating the field runoff events. The watershed simulations were also successful, but there were differences in the calibration between the field and watershed. The differences in calibrated parameter model values appear to be the result of a delivery disconnect between fields and perennial waterways in SWAT. In both field and watershed simulations, statistical variation for discharge and water quality was likely the result of using individual measured storm events rather than monthly or yearly average as historically has been done. The calibrated field-scale simulations were then used for comparison with a tool for phosphorus loss risk at the field-scale. The research showed a general agreement between SWAT and the Wisconsin Phosphorus Index.

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AVSWAT	ArcView Soil and Water Assessment Tool
AWC	Available Water Capacity
BMP	Best Management Practice
CMS	Cubic Meter per Second
CN	Curve Number
CNOP	Operational Crop Curve Number
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
DEM	Digital Elevation Model
EPA	United States Environmental Protection Agency
EPIC	Erosion-Productivity Impact Calculator
ERW	Exceptional Resource Waters
ESCO	Evapotranspiration Coefficient
GIS	Geographical Information Systems
GLEAMS	Groundwater Loading Effects on Agricultural Management Systems
HA	Hectare
HRU	Hydrologic Response Unit
MET	Meteorological Station
MUSLE	Modified Universal Soil Loss Equation
NAIP	National Agriculture Imagery Program
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
SBD	Soil Bulk Density
SNAP	Soil Nutrient Management Application Program
SOLK	Soil Hydraulic Conductivity
SURQ	Surface Flow Output (.bsb file)
SWAT	Soil and Water Assessment Tool
SWRRB	Simulator for Water Resources in Rural Basin
TIN	Triangulated Irregular Network
UFRW	Upper Fever River Watershed
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
UWSP	University of Wisconsin at Stevens Point
WEAL	Water and Environmental Analysis Lab
WGNHS	Wisconsin Geological and Natural History Survey
WIDNR	Wisconsin Department of Natural Resources

1.0 Introduction

Nonpoint source pollution from agricultural landuse leads to excessive phosphorus additions to surface waters (EPA 1992). Phosphorus (P) is dissolved in the runoff water or is associated with particles such as soil carried in the runoff. The addition of this P to surface waters contributes to nutrient enrichment and excessive biotic growth and decomposition.

Maintaining surface water quality in agriculturally dominated watersheds requires an understanding of how nutrient application and land management practices influence nonpoint source P losses. Not all fields contribute P to surface water equally. Focusing management efforts to those critical areas with respect to P loss is necessary for most effectively targeting efforts to reduce P loads to surface waters.

Computer models may be a tool to identify those areas critical to controlling runoff P and to evaluate the impact of changes in management. By simulating landscape processes, models have been used to simulate P application, transport, and delivery between agricultural fields and surface water bodies. Unfortunately, management decisions are most effectively directed at field-scale problems and many models have been developed for watershed-scale applications. In addition, models are still imperfect in their ability to simulate landscape processes. For example, quantifying delivery between individual fields and the watershed outlet is still widely misunderstood.

Mathematical models have previously been applied to various landscapes and watershed scales. An understanding of the landscape processes and the algorithms that simulate them is integral when managing P with models.

2.0 Literature Review

2.1 Field-Scale Phosphorus Management

Phosphorus (P), an essential nutrient for plant growth, can accelerate eutrophication of receiving waters. Excessive P in surface runoff can originate from different portions of a watershed. Locating and effectively managing P source areas is the first step in reducing eutrophication.

P accumulates in the uppermost layers of the soil when annual applications exceed annual removal. Farmers do not see the accumulation of P as an economic concern, but the increased soil P levels lead to higher concentrations of P in runoff (Sharpley *et al.* 2003). When combined with high surface runoff volumes from agricultural land, this can lead to large quantities of P that are contributed to stream reaches from surface runoff (Sharpley *et al.* 2003).

Spatially and temporally characterizing P transport from the edge-of-field to receiving waters is a challenge because the variable sources, sinks, and transport processes on land are also a dynamic system (Gburek and Sharpley 1998). Changes in source area over time driven by precipitation and landscape conditions add to the difficulty of management. Current field and watershed-scale computer models attempt to describe landscape processes and quantify P movement from field to receiving waters.

2.2 Field-Scale Simulation Approach

Models have been used to understand and manage the P export from agricultural lands. Tools for farmers and conservationists are often simple, allowing them to be applied with limited training. In recent years, county conservationists in Wisconsin have been working with farmers to implement a simple nutrient export model called the

Wisconsin P Index (WI P Index) that relates data from a farm field's nutrient management plan to average annual sediment and P losses (SNAP 2005). The WI P Index is applied on a field-scale basis, allowing individual farmers to create a balanced P budget; however, the WI P Index can not be applied to large watershed management issues.

Complex models that simulate P export on large (>260 km^2) watersheds have also been developed over the past three decades. One of the more recently developed models is called the Soil and Water Assessment Tool (SWAT). The SWAT model is a physically based model developed by the U.S. Department of Agriculture - Agriculture Research Service (USDA-ARS) that simulates stream flow, sediment loss, and nutrient exports (Neitsch *et al.* 2002). SWAT was designed for large, ungauged watersheds and has successfully been used as a nutrient management tool in several Wisconsin watersheds (Baumgart 2005, Kirsch *et al.* 2002). SWAT can be used with Geographical Information System (GIS) data to delineate subwatersheds and subdivide those into hydrologic response units (HRUs) characterized by unique combinations of land and soil cover.

The consistency between field-scale and watershed-scale models is still largely unknown and only a few studies have examined the ability of the SWAT model to incorporate field level management changes. Saleh *et al.* (2003) used a field-scale model to describe SWAT HRU response and FitzHugh and Mackay (2000) examined the impact of subwatershed size on SWAT results. Neither study used field-scale monitoring data or looked at P in detail. Recently, Veith *et al.* (2005) compared SWAT to a P index tool similar to the WI P Index within fields. They simulated a 22 field watershed, contributing to a single flume and found a similar outcome between the P index tool and SWAT.

Although these studies provide some insight into how field and watershed simulations compare, they used a rather general calibration approach. The calibration of Saleh *et al.*, FitzHugh and Mackay, and Veith *et al.* compared model simulations using monthly totals or averages. Although SWAT was designed as a detailed process-based model with a daily time-step, SWAT output is often aggregated to provide for yearly and monthly predictions (Neitsch *et al.* 2002, Borah and Bera 2004). The monthly coefficient of efficiency, defined as the sum of the deviations of the observations from a linear regression line with a slope of one, is always higher than daily coefficient of efficiency (Spruill *et al.* 2000; Van Liew *et al.* 2003). Unfortunately, monthly simulation may not examine individual storm events that can vary greatly in P export.

SWAT can be used to simulate runoff events at the field or watershed-scale. Choi *et al.* (2005) conducted a field-scale SWAT simulation of two 1.4-ha turfgrass fields in Texas and found SWAT suitable for daily simulation comparison of flow, sediment, and P export. The ability to simulate individual runoff events should greatly strengthen the interpretation of best management practices (BMPs) applied to the subwatershed as well as the interaction of flow, sediment, and nutrients among land uses.

Simulating P export from individual agricultural fields 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. Unfortunately, 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 contributes directly to the stream reach (Figure 1). Arbai *et al.* (2006), FitzHugh and MacKay (2000), and Jha *et al*. (2004) concluded that creating subwatershed sizes between 2 and 5 percent of total watershed provides a reasonably accurate simulation of sediment and nutrient export. These studies did not provide guidance on how model scale affects parameter selection. It is also unclear how SWAT will perform with Wisconsin field-scale watersheds and how P loads estimated with a simplified field-scale model like the WI P Index can be translated accurately to a watershed-scale using SWAT.

Field scale models like the WI P Index do not use HRUs and process simulations, but rely on empirical data that reduces P export to estimates of hydrology, sediment loss, and P partitioning between soil and runoff. Models like the WI P Index are being used by farmers, crop consultants, and agency staff; therefore, it is important to understand how they compare to process-based models.

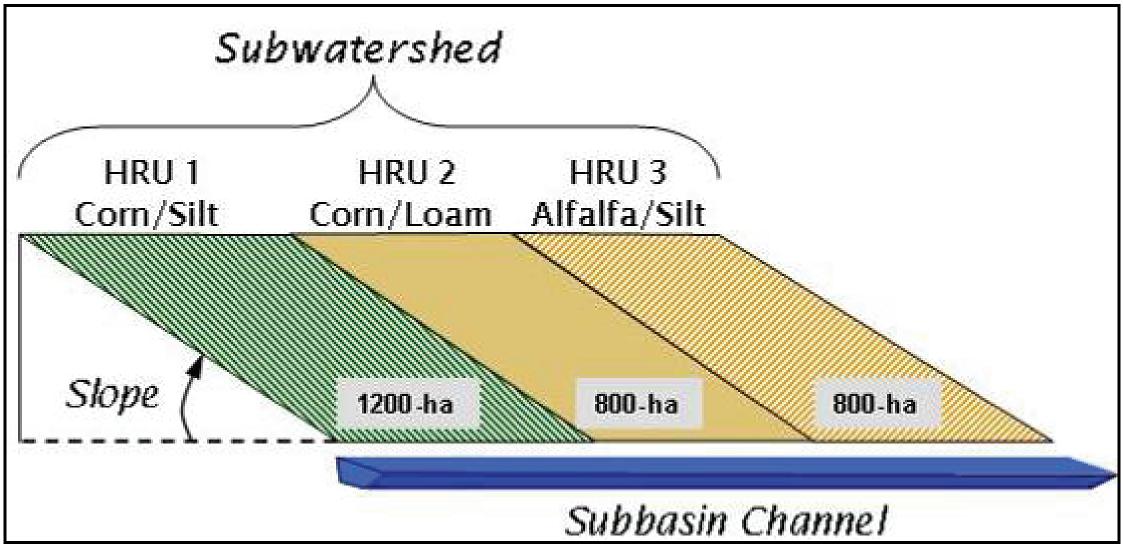


Figure 1 - HRU Composition within SWAT

2.3 Calibration Techniques of SWAT

The SWAT model can be used to estimate watershed P export and to quantify external loading to receiving waters. The model incorporates the effects of climate, surface runoff, evapotranspiration, crop growth, groundwater flow, nutrient loading, and water routing for varying land uses to predict hydrologic response (Kirsch *et al*. 2002; Neitsch *et al*. 2002). Although the model can be applied to areas where no monitoring has been performed, it is usually used in situations where hydrologic data has been collected and are used for model calibration. SWAT model calibration has taken many forms depending on the data available and the objectives of the study. Studies such as those completed by Kirsch *et al*. (2002), Santhi *et al*. (2001), and Baumgart (2005) indicate that with the appropriate calibration of stream flow, sediment, and nutrients, the model fit is improved. As a result, most previous studies that have explored the effects of alternative management scenarios have used calibrated models.

Watershed water quality studies completed with SWAT often 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 Natural Resources Conservation Service (NRCS) curve number (CN), 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. NRCS CN). Many studies used a CN value close to that recommended by the NRCS, while others have used it as a calibration parameter.

One of the challenges in assigning values to the many parameters in a complex model like the SWAT model is understanding whether a process description used in the model is mechanistically correct or a simplified description that is lumping more complex or poorly understood processes. One example is the CN approach used in SWAT to partition rainfall into overland and subsurface runoff. While the CN approach is widely used for most nonpoint source pollution models, Garen and Moore (2005) argue that CN based models do not account for all the runoff processes occurring within a system. Instead, Garen and Moore believe that modelers should deviate from such empirical algorithms and focus on improving the physically based algorithms with assistance from GIS technology (Garen and Moore 2005). Although Garen and Moore's suggestion is ideal, others have pointed out that one of the CN methods biggest advantages is its simplicity (Ponce and Hawkins 1996). As a result, the NRCS CN approach to describing watershed runoff remains the most frequently used. These arguments do emphasize, however, that the relationship between input variables in a complex process based model such as SWAT may not exactly reflect what is occurring on the landscape. Unfortunately, our understanding of how complex models are actually aggregating even more complex landscape processes is incomplete.

The input parameter aggregation of processes that is necessary in watershed models can confound initial parameter selection. While it is clear that model output uncertainty is correlated with input uncertainty (Chaubey *et al.* 2003), the accuracy of the default parameter values to specific locations is unknown. It is also unclear how the model variables change to accommodate the change in scale from field to watershed scale. As we move towards a greater acceptance of modeling results in prioritizing management decisions, it is important to understand parameter selection to simulate runoff processes and P movement. In particular, it is important to understand if these models interpret P movement similarly at both the watershed - and field-scale.

As a result of EPA policy, nutrient management and water quality law regulations are being directed by a watershed-scale approach (EPA 2005). In order to develop economically viable watershed management plans, a nutrient loss must not be viewed as uniformly distributed across the landscape. The variability of P source and transport mechanisms in the watershed requires monitoring the impacts of field-scale management practices while farms are used to represent individual management units (Gburek and Sharpley 1998). Unfortunately, it is difficult and expensive to evaluate the relationship of P loss between the field and delivery to perennial waterways. For example, it may require monitoring at the field, farm, and watershed outlet.

This research seeks is designed to improve our ability to simulate P loss from agricultural watersheds. In the first two phases of the research the same modeling tool, SWAT 2000, is used at two separate scales: the individual field watersheds and the downstream outlet of a multi-field watershed. The model parameters values at the two scales are compared to better understand how parameters need to be adjusted with changes in spatial and temporal scale. This will strengthen the link between field and watershed-scale model applications. It is intended to improve the performance of a process-based model by evaluating the sensitivity of common calibration parameters to watershed size. In the third phase of the research, two field-scale models will be compared. The calibrated SWAT model will be compared with the Wisconsin P Index.

This will strengthen the link between tools for P management at the larger scale with those used by farmers and managers at the field-scale.

3.0 Methods and Materials

To understand how the simulation of agricultural management at the field-scale compares with simulation at the watershed, a three phase project was developed. The first phase calibrated a watershed-scale model to measured discharge and water quality at three field-scale watersheds. The second phase evaluated SWAT parameter variation between the field and watershed-scale measured flow and water quality datasets. In the third phase, the estimated P loads from the three fields were compared using both the calibrated distributed parameter SWAT model and a field-scale Wisconsin P Index tool.

3.1 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. 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)).

3.1.1 SWAT Model Hydrology

SWAT uses the water balance equation to simulate the hydrologic cycle. The hydrologic budget is the basis for the flow, and export of sediment and nutrients. The water balance equation is defined as:

$$SW_t = SW_0 + \Sigma\,(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \qquad [1]$$

where SW_t is the final soil water content (mm H_2O), SW_0 is the initial soil water content (mm H_2O), t is the time (days), R_{day} is the amount of precipitation (mm H_2O), Q_{surf} is the amount of surface runoff (mm H_2O), E_a is the amount of evapotranspiration (mm H_2O),

w_{seep} is the amount of water entering the vadose (unsaturated) zone from the soil profile, and Q_{gw} is the amount of return flow (mm H_2O) (Neitsch *et al.* 2002).

To estimate surface runoff, SWAT uses two methods: a distributed NRCS curve number procedure or the Green & Ampt infiltration method. Although SWAT can use the Green-Ampt infiltration method, it requires sub-hourly precipitation inputs, which are not usually available. Therefore, the NRCS CN method has been used in nearly all previous SWAT model studies. The NRCS CN was developed to estimate the volumes of direct runoff from ungauged rural catchments and uses a nonlinear runoff versus rainfall relationship. The curve number method is empirically based and relates runoff potential to land use and soil characteristics within each HRU. A major limitation of the curve number method is that rainfall intensity and duration are not considered, only total rainfall volume.

Infiltration is calculated in SWAT as the precipitation minus runoff volume. It is assumed to move into the soil profile where it is routed through the soil layers. When water percolates past the bottom soil layer, it enters the shallow aquifer zone (Arnold et al., 1993).

In areas with impermeable subsurface layers at shallow depth, subsurface lateral flow, or interflow, is simulated within the SWAT model. SWAT relies on a kinematic storage model that simulates interflow soil depth, soil hydraulic conductivity, and hill slope length.

3.1.2 SWAT Model Sediment

The SWAT model simulates sediment transport using a modified version of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978). The Modified Universal Soil Loss Equation (MUSLE) utilizes a runoff factor instead of rainfall energy in the prediction of soil erosion. The antecedent moisture and rainfall energy are represented in MUSLE via the runoff volume (Q) and peak runoff rate (q_{peak}). The total sediment yield is then based on runoff volume, peak flow, and USLE factors for each HRU. The MUSLE equation (Williams, 1995) is:

$$sed = 11.8 \times \left(Q_{surf} \times q_{peak} * area_{hru}\right)^{0.56} \times K_{USLE} \times C_{USLE} \times P_{USLE} \times L_{USLE} \times CFRG \qquad [2]$$

where: *sed* is the sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm H_2O/ha), q_{peak} is the peak runoff rate (m^3/s), $area_{hru}$ is the area of the HRU (ha), K_{USLE} is the USLE soil erodibility factor, C_{USLE} is the USLE cover and management factor, P_{USLE} is the USLE support practice factor, L_{USLE} is the USLE topographic factor, and CFRG is the coarse fragment factor. The CFRG considers the amount of rock in the upper soil layer. Sediment is routed through the river reaches using the Bagnold stream power equation (Bagnold 1977) where the maximum amount of sediment transported from a reach is a function of the channel velocity at peak flow. The modified version of SWAT2000 allows the subwatershed channel length and area to be used in the calculation of the time of concentration within the MUSLE equation. This study used the unmodified MUSLE equation that relied on HRU size for the time of concentration.

3.1.3 SWAT Model Phosphorus

Surface runoff is the major carrier of phosphorous out of most catchments. P movement in runoff occurs primarily in the particulate form (Sharpley *et al.* 1987). P can be added to soil through fertilizer, manure and from biomass, while it can be removed by plant uptake, erosion and runoff. The transport and fate of P is simulated in SWAT through soil-water interaction processes: mineralization, decomposition, and immobilization, P sorption, and leaching. Within SWAT soil P exists in six pools, three are represented as mineral and three are organic (Figure 2). The transformation of P between pools is controlled by SWAT model process-based algorithms. SWAT also provides the option to simulate in-stream P cycling using QUAL2E, a steady-state stream water quality model (Neitsch *et al.* 2002).

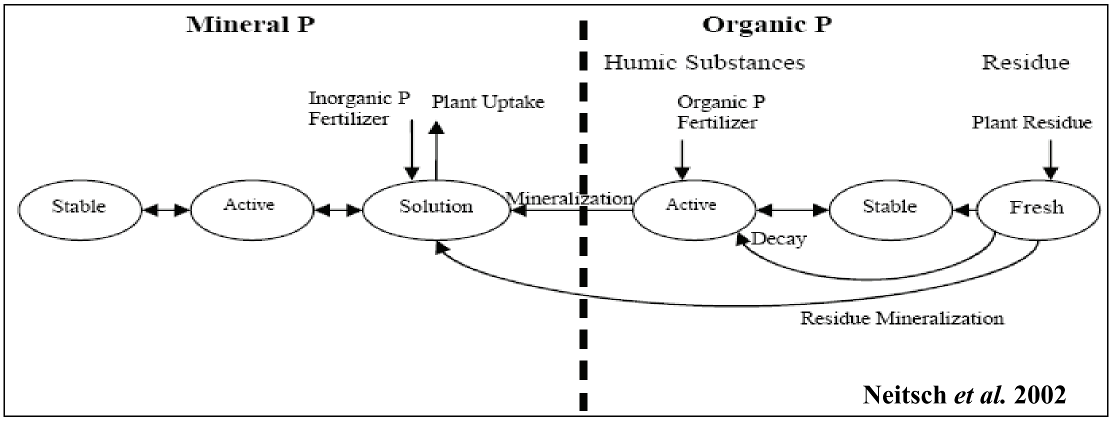


Figure 2 - SWAT Simulated Phosphorus Cycle

3.2 Site Description

The Upper Fever River Watershed (UFRW) in southwestern Wisconsin's Lafayette County is the location of this study. The UFRW drains 7.8 square kilometers of primarily agricultural land east of Platteville, Wisconsin. In 1995 the Fever River was added to the exceptional resource waters (ERW) due list to the significant smallmouth bass fishery and previous attempts have been made to control the non-point source pollution that negatively impacts recreation and the bass fishery (WIDNR 2001). The portion of the UFRW for this study was delineated from the USGS monitoring site (05414850), located on College Farm Road (Figure 3). The Upper Fever River joins the Galena River and ultimately the Mississippi River.

The 174 hectare (ha) University of Wisconsin – Platteville Pioneer Farm is in the southern region of the UFRW (Figure 4). Pioneer Farm is a working farm located on College Farm Road that "focuses on discovering new applications that can offer the farmer both environmental stability and economic viability while complying with environmental regulations and guidelines (Southwest Badger 2007)." The farm manages approximately 134 ha of tillable land. Pioneer Farm uses edge of field outlet flumes, stream gauges, soil testing, and other methods to study environmental impacts related to farming practices. Edge-of-field references a field's crop landscape, terraces, and grass waterway as it contributes to the field's hydrologic outlet. Conservation practices such as terraces, contour strips, grassed waterways, and filter strips have been installed to reduced sediment and nutrient loss from the farm's cropland. In conjunction with detailed management records, Pioneer Farm is developing baseline conditions regarding the impact of various agricultural best management practices in southwestern Wisconsin.

For the scope of this study, three field-scale watersheds are used to simulate edge-of-field loss of sediment and P. Sub-area S2 is an 8.87 ha watershed in the northwestern corner of Pioneer Farm, S3 is a 5.16 ha watershed on the eastern edge of Pioneer Farm, and S4 is 30.14 ha area between S3 and the Fever River. S2 and S3 are single crop (corn and alfalfa) watersheds, while S4 is contoured strips of corn and alfalfa.

3.3 Collection of Data

3.3.1 Edge-of-Field Monitoring Stations

Pioneer Farm has multiple edge-of-field monitoring stations located at the surface outlet of agricultural fields to monitor flow, sediment, and water chemistry from individual storm or snowmelt events. The edge-of-field represents all components of the field watershed including the cropped land, terraces, and grass waterway. A grass waterway is used as a preferential path to funnel the individual field-scale watersheds toward the monitoring station. Each station consists of a rain gauge, solar panel, gaging station, shaft encoder stage sensor, fiberglass H-flume, ISCO 3700R refrigerated sampler, Campbell Scientific CR10X datalogger, radio antenna, 2800-watt RV generator, and plywood wing walls (Figures Figure 5 and Figure 6). Heating coils positioned above the flume and along the sample intake line prevent freezing during snowmelt events. The monitoring stations were installed and are maintained by the United States Geological Survey (USGS). Three of Pioneer Farm's edge-of-field monitoring stations were used in this study: S2 (USGS Station 424314090240601), S3 (USGS Station 424302090225601), and S4 (USGS Station 424256090234001). A complete standard operating procedure for monitoring station design and construction is located in Appendix A as part of a draft sampling report by Pioneer Farm.

3.3.2 USGS Fever River Station

There are two USGS continuous streamflow gaging stations on the Fever River. The first, USGS Station 05414849, is located at the northern border of Pioneer Farm and has been operational since October 2005. The second gauge (USGS Station 05414850) is located 1,520-meters downstream at the southern end of the farm, south of College Farm Rd, and has been operating since August 2002.

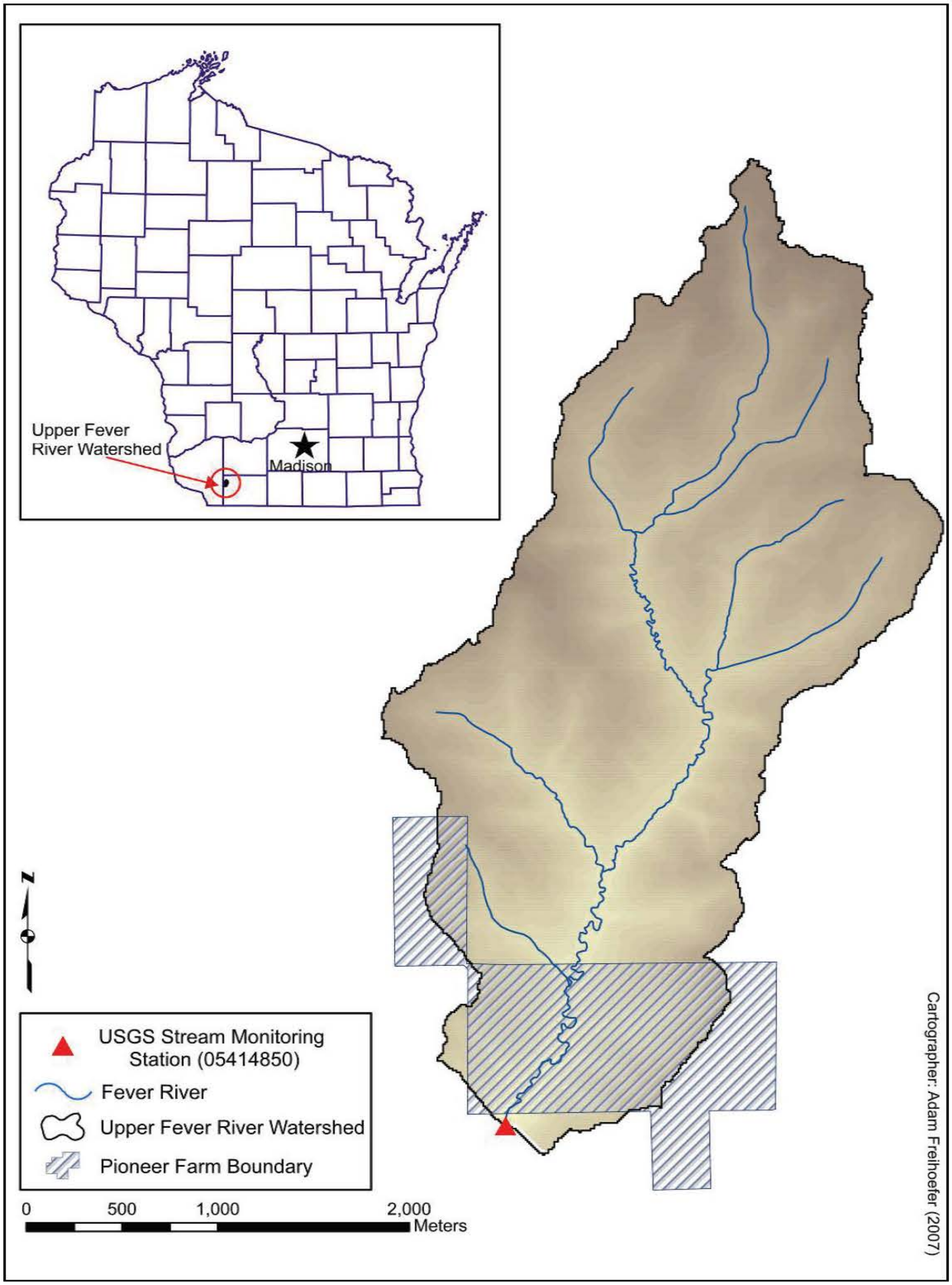
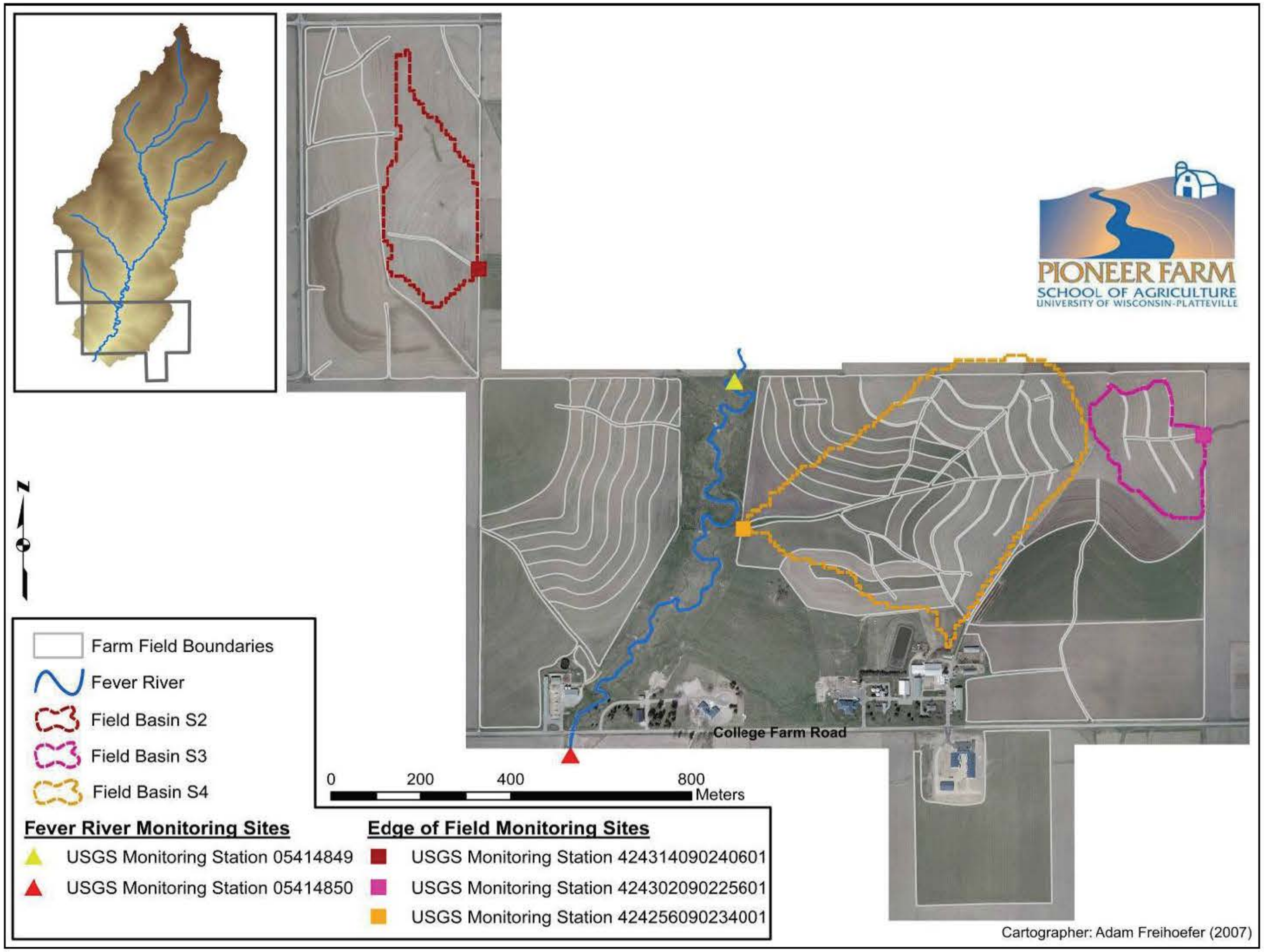


Figure 3 - Upper Fever River Watershed Location within Wisconsin



Cartographer: Adam Freihoefer (2007)

Figure 4 - Pioneer Farm Sampling Sites and Delineated Field-Scale Watersheds

Figure 5 - USGS Edge-of-Field Monitoring Station and Flume Design

Figure 6 - USGS Edge-of-Field Automated Sampler

3.3.3 Water Quality Samples

At each edge-of-field and in-stream monitoring station, water quality samples were taken via an ISCO3700R™ stainless steel refrigerated autosampler for events and grab samples were taken for baseflow conditions. The samples were taken to the University of Wisconsin at Stevens Point (UWSP) Water and Environmental Analysis Laboratory (WEAL). Individual samples were proportionally mixed into a single sample representing the flow-weighted average concentration over the duration of the storm. The measured flow volume and known concentrations are used to calculate sediment and nutrient loads. Constituents measured in the water quality samples include: total suspended solids, total P, total dissolved P, and dissolved reactive P.

3.4 Model Inputs

3.4.1 Topography

The topography within the UFRW is an important factor influencing nutrient transport from individual fields to the perennial waterway. 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. A digital elevation model (DEM) was used to simulate topography for both field-scale watersheds and the entire UFRW. DEMs are terrain elevation points located at regularly spaced horizontal intervals. A 1-meter DEM was used for the SWAT topographic input at the field-scale and a 10-meter DEM was used for the watershed-scale simulation.

A 1-meter DEM was created for Pioneer Farm for simulation of field-scale watersheds contributing to edge-of-field monitoring stations. The 1-meter DEM was originally created as an AutoCad file by Aero-Metric, Inc. of Sheboygan, WI. Aero-metric created the DEM elevation points using stereophotogrammetry. Stereophotogrammetry is the measurement of ground surface elevation differences from air photographs using overlapping stereo photo pairs is used. Jeffery Topel (University of Wisconsin at Madison) exported the AutoCad contours at a 0.076-meter interval and used them to create a triangulated irregular network (TIN) in ArcGIS. TINs are irregularly spaced points and breakline features containing an x, y coordinate and a elevation value. DEMs were then interpolated from the TINs using the ArcGIS toolbox natural neighbor interpolation function and a z-factor of one.

The 7.5 minute (or 1:24,000 scale) 10-meter grid based DEM obtained from the USGS was used for the UFRW simulations. The 10-meter DEM was the best resolution dataset available for the entire watershed.

3.4.2 Hydrology

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. Two separate GIS layers were used for the UFRW simulation: an ephemeral stream reach for each field-scale basin and the perennial portion of the Fever River for the watershed-scale simulation.

The individual field-scale watersheds contributing to monitoring stations S2, S3, and S4 each have an ephemeral grass waterway contributing to the station (Figure 7). Depending on storm event intensity, water moves laterally across the field’s terraces before traveling downgradient along the grass waterway toward the H-flume. The grass waterway of each field, indicating the main channel, was hand digitized from a May 2004 0.076 meter resolution aerial cover created by Aero-Metric and 2005 1-meter resolution National Agriculture Imagery Program (NAIP) aerial photography.

The watershed-scale stream network originated from the Wisconsin Department of Natural Resources (WIDNR) 1:24,000 hydrography database. The 24K hydro layer was processed at double precision to accuracy consistent with national map accuracy standards for 1:24000 scale geographic data. The WIDNR layer was then modified to incorporate additional detail (meanders, etc) not included in the WIDNR layer. The modifications were derived from overlaying 1-meter resolution 2005 NAIP aerial photography. The WIDNR version also included all ephemeral portions of the UFRW. A total of 14,756 stream meters were included in the modified stream network. Of the 14,756 stream meters, 6,131 stream meters were perennial. The modified version of the stream network used for the watershed-scale SWAT modeling included only the perennial section of the stream (Figure 7). The perennial sections were distinguished during a 2004 stream walk and 2006 field verification.

3.4.3 Soils

Soil characteristics, coupled with other landscape factors, are used to determine soil moisture properties and erodibility potential within SWAT. According to the NRCS soil survey, the UFRW has soils with a silt loam soil texture, with Tama being the dominant series (USDA, NRCS 2006). Borings at Pioneer Farm confirmed the silt loam texture and found the unconsolidated layer was one to four meters thick. The Tama soils are generally well-drained (USDA, NRCS 2006). Artificial drainage is rare in the UFRW

(Mentz 2007). SWAT uses the NRCS 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 silt loams of the UFRW are hydrologic soil group B. Soil properties such as available water capacity (AWC), soil hydraulic conductivity (SOLK), and soil bulk density (SBD) are available from the NRCS.

The STATSGO soils database created by the USDA Soil Conservation Service was used as the GIS data input for the SWAT simulations for both the field and watershed-scale simulations. The STATSGO soil layer defines the entire UFRW as being Tama Silt Loam. There are eight other silt loam soil series present within the UFRW; however, soil properties such as AWC and SOLK are similar. The uniform soils in the URFW did not require the use of the more detailed SSURGO soils spatial dataset.

Soil nutrient levels are used as an input for simulating P export from subwatersheds. Pioneer Farm has collected soil test P data annually since 2003. 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) on Pioneer Farm range from 34 mg/kg to 150 mg/kg (Figure 8). Higher soil P levels were found near the manure storage and barns. An average P value within each field was used for each field-scale basin and a farm average was applied to UFRW simulations. Soil P levels for the properties north of Pioneer Farm were unknown. The soil samples used to determine to soil test P were also used to calculate the P portioning coefficient. An average PHOSKD value was calculated in the UWSP WEAL for each field using a ratio of water extractable P to Bray-1 P.

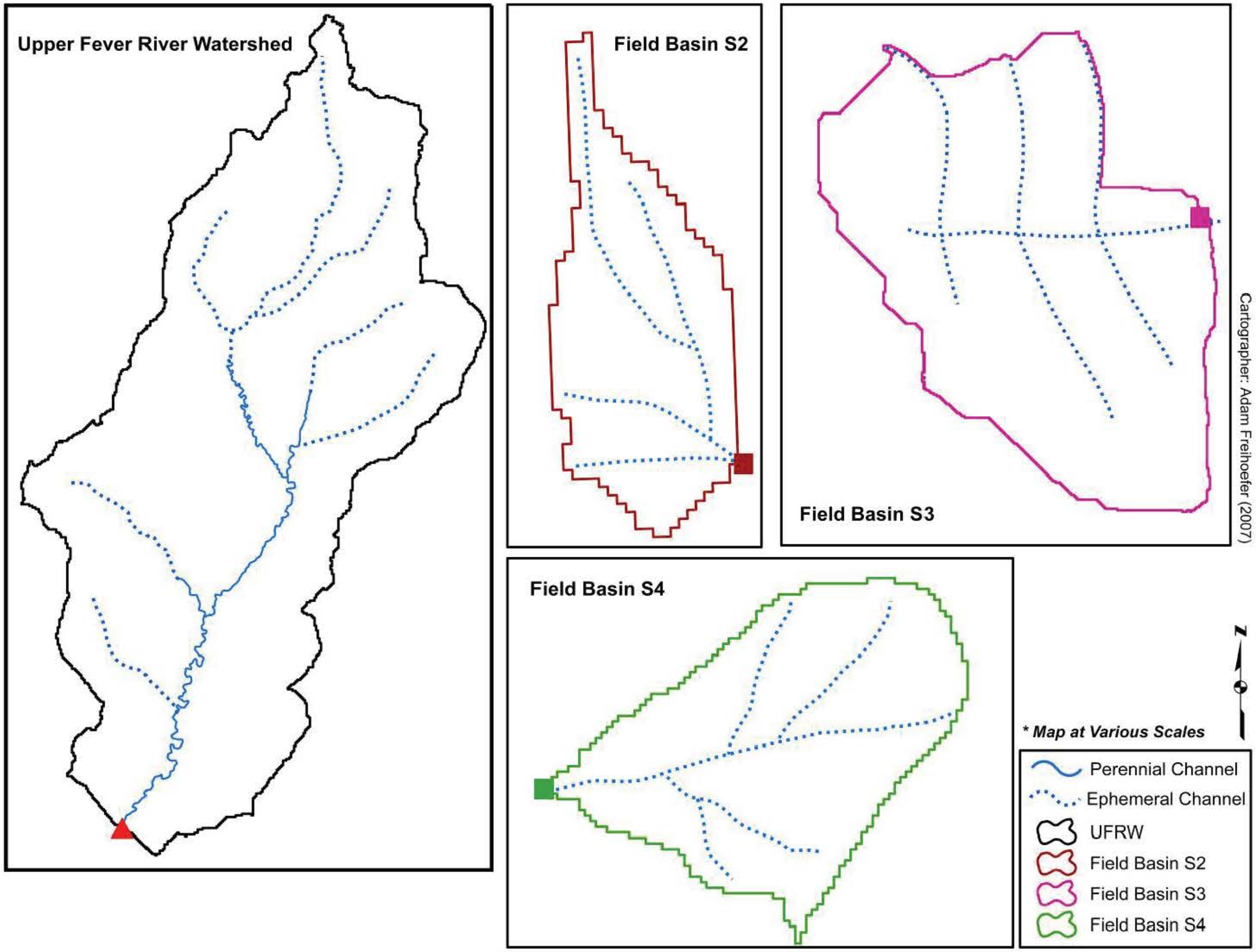
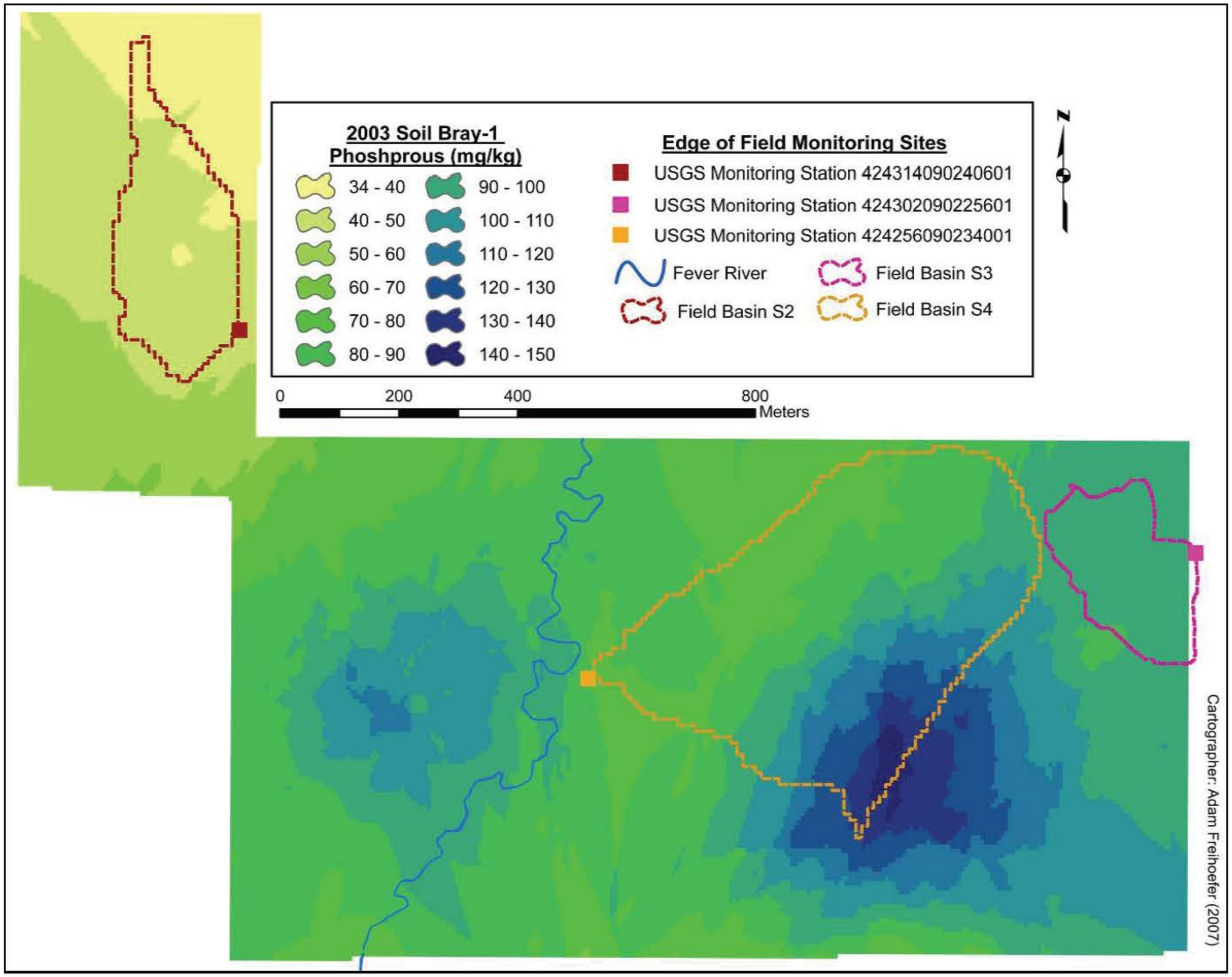


Figure 7 - Hydrologic Network for Each Modeled Watershed



Cartographer: Adam Freihoefer (2007)

Figure 8 - Pioneer Farm 2003 Bray-1 Phosphorus Concentrations

3.4.4 Hydrogeology

Beneath the one to four meters of Tama silt loam there is approximately 550 meters of Cambrian and Ordovician rocks. The upper section of the Cambrian and Ordovician is comprised of the Galena, Decorah, and Platteville unit, followed by the Glenwood unit (Masarik *et al.* 2007). The Galena and Platteville groups are fractured and weathered dolostonses hydraulically conducted to surface water (Olcott 1992). A 76 meter boring logged by the Wisconsin Geological and Natural History Survey (WGNHS) near the Fever River indicates 4.5 meters of silt at the surface, followed by 35 meters of Galena Formation dolomite, 3 meters of Decorah Formation, 24 meters of Platteville formation dolomite, and 9 meters of sandstone. Drilling near Pioneer Farm suggests little elevation variation of the geologic layers throughout the watershed; however, the depths of the layers differ due to topography. Depth to water, varying with topography, is between 0 – 5.5 meters. Groundwater recharge to the UFRW watershed is significant, but spatially variable. A 2004 stream walk noted several zones of groundwater upwelling along the Fever River.

The fraction of flow from the UFRW contributed by subsurface flow (groundwater contributed) was estimated using a baseflow separation program developed by Arnold and Allen (1999). Approximately 77% of the total discharge between August 1st, 2002 and December 31st, 2005 was baseflow. The alpha factor for baseflow in SWAT was calculated to be 0.0094 days. The alpha baseflow value is an input parameter used to describe the steady-state response of groundwater flow to recharge and is a direct index of groundwater flow response to changes in recharge. SWAT calculates the alpha baseflow recession constant using hydraulic conductivity of the aquifer, distance from the ridge or subbasin divide for the groundwater system to the main channel, and the water table height.

3.4.5 Climatological Inputs

Two weather stations were used for inputs to the field and watershed-scale simulations. The first station used was the meteorological (MET) station, located on Pioneer Farm, south of College Farm Road. The MET station has been in operation since 2003. In conjunction with the MET station, the edge-of-field monitoring stations on Pioneer Farm collect additional metrological data. The second station was located in the City of Platteville, Wisconsin. It is a National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS) station (COOPID #476646) that has been in operation since 1949. The City of Platteville station is 7.84 km northwest of Pioneer Farm MET station.

Field-scale SWAT simulations used daily maximum and minimum air temperature and total precipitation collected from Pioneer Farm MET station between January 1, 2003 and December 31, 2005. For dates prior to 2003 the daily median precipitation from edge-of-field monitoring stations S1, S2, S3, and S4 was used for field-scale simulations. Maximum and minimum air temperature data from the City of Platteville station was used for field-scale simulations for dates prior to 2003. As a result of the proximity between the simulated field watersheds and the MET station (no greater than 2,230 meters) it was assumed that the precipitation was uniform for all field-scale events.

The watershed-scale simulation relied on both the City of Platteville station and Pioneer Farm MET station. Daily precipitation at the two stations varied considerably. Of the 1249 daily observations (August 1, 2002 to December 31, 2005), 80 days recorded a difference of 12.7 mm or greater between the two stations. Precipitation variations at small scales complicate efforts to predict the response to individual events. As a result, two separate climatological model inputs were used in the watershed-scale simulation. The first focused calibration efforts on those days that had a relatively small (≤ 66%) difference between the two stations. Of the 381 days with measured precipitation, 145 days had ≤ 66% variation (Figure 9). The second input dataset used the City of Platteville dataset but substituted Pioneer Farm MET station data when it was clear from stream response and precipitation variation that the City station was not representative of the watershed. The dataset substitution acknowledged the precipitation difference and the streamflow difference (baseflow vs. eventflow) to determine what days were replaced. Some dates were replaced with a smaller precipitation value from the MET station as there was no change from baseflow discharge on and preceding the measured event. For example, on July 23rd, 2005 the City of Platteville station recorded 0.0 mm of rainfall and the MET station recorded 53.09 mm. The average daily discharge at the UFRW outlet on July 23rd was 0.12 m^3/s, a value well above the separated baseflow value of 0.02 m^3/s. As a result, the MET station precipitation record replaced the City of Platteville station to best simulate the runoff event. The MET station precipitation records were used for 46 of the 1,249 simulated days.

Other weather parameters such as solar radiation, wind speed, and potential evapotranspiration were simulated from a SWAT weather generator database using the closest weather station within the SWAT model's internal database (Dubuque, Iowa).

3.4.6 Land Coverage

The UFRW is between 80% and 90% cropped agricultural land as shown in Table 1. The land coverage dataset for the SWAT model was developed through digitizing a 2005 1-meter resolution NAIP digital aerial photo in combination with windshield verification in 2006 (Table 1, Figure 10). Each land cover was given a GRIDCODE attribute symbolizing the management rotation for that parcel of land. Pioneer Farm property was previously digitized by Pioneer Farm staff using high resolution digital aerial photography and merged into the UFRW coverage. A single URFW land coverage was utilized at both the field and watershed-scale.

Table 1 - UFRW Land Coverage Change between 1992 and 2006

Land Cover	1992 Landuse Area (Hectares)	1992 Landuse Percent of Basin	2006 Landuse Area (Hectares)	2006 Landuse Percent of Basin
Cropped Farmland	688.33	90.15	611.17	79.80
Farmsteads	---	---	33.35	4.35
Forest	27.73	3.63	2.57	0.34
Grassland / Pasture	34.78	4.56	101.74	13.28
Urban / Impervious	---	---	16.29	2.13
Water	0.40	0.05	---	---
Wetland	---	---	---	---
Barren	12.28	1.61	0.72	0.09

**Note: The 1992 WISCLAND coverage used LANDSAT imagery and the 2006 UFRW coverage was hand digitized aerial photography and field verified.*

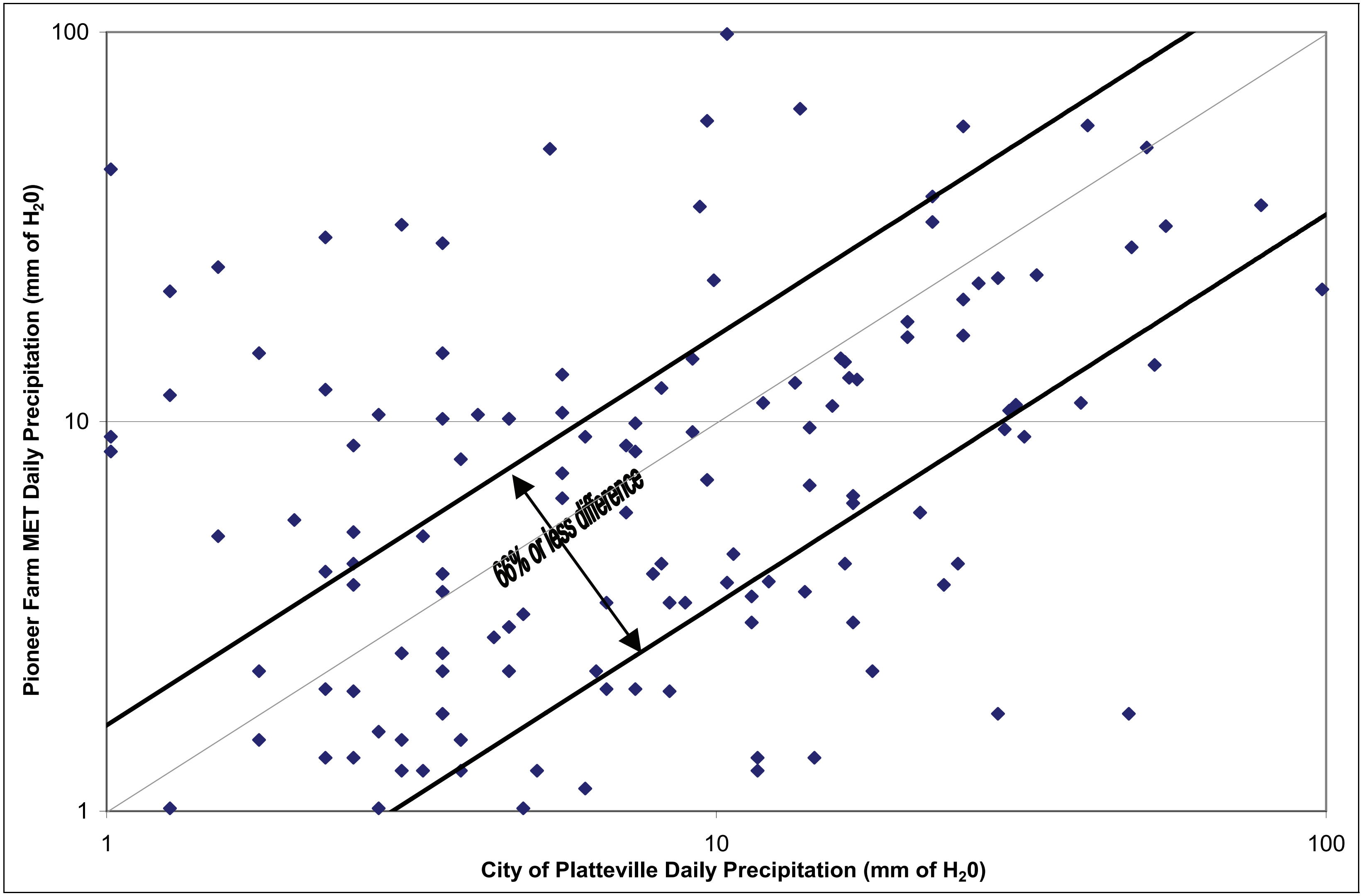


Figure 9 - City of Platteville Precipitation versus Pioneer Farm MET Station Precipitation

3.4.7 Land Management

Management operations simulated by SWAT include tillage, planting and harvest dates, timing and application rates of fertilizers and pesticides, residue levels and filter strips.

The majority of Pioneer Farm's 134 hectares of tillable land is used to maintain the farm's dairy operation with the remainder used to support beef and swine. As of 2006, the farm housed 100 milking cows, 50 dry cows and heifers, and 50 calves and young heifers. Pioneer Farm's tillable land is broken into 27 fields. Crops are grown using a dairy forage rotation: three years corn (C), one year oats (O), and three years alfalfa (A) (Pioneer Farm 2006). The dairy forage rotation is varied throughout the farm as to create contour strips to prevent water and sediment erosion. A detailed management timeline located in Appendix B has been kept by Pioneer Farm staff and was used in the development of the management scenarios within SWAT (Appendix C). Crop yields were measured by Pioneer Farm staff for each field and are used as part of the SWAT model calibration.

Conventional tillage, the most common system for corn, is applied to all fields on Pioneer Farm. Conventional tillage holds < 15% residue cover on the fields after planting. Tillage impacts the runoff potential represented by the curve number and the biological mixing of soils and residue burial within SWAT. SWAT contains a database of tillage practices. The manure produced by the dairy, beef, and swine populations is applied to the cropland. The application dates, rates, and composition of manure applied to fields can be found in Appendix D. Liquid manure is injected into the soil during application. Manure composition is analyzed whenever manure is applied to a field or sold off the farm. The manure samples are collected and analyzed to keep track of the farm's nutrient balance on a field-by-field level. The SWAT fertilizer input requires the date of application, type of fertilizer applied, and the depth of distribution of the fertilizer.

Area specific land management within the entire UFRW was collected in the summer of 2006. The UFRW's land management is 61% cash grain corn-soybean rotation (Table 2). The majority of the corn crop is harvested for grain. After corn harvest, fields are tilled via a heavy disk or chisel plow. Little or no tillage is conducted for the soybean crop. The corn-soybean crop rotation tends to be unrelated to dairy farming, typically relying on chemical fertilizers for optimal growth. The grassland corridor within the southern portion of the watershed is managed for dairy cattle grazing. The UFRW farm community works with local agronomists to determine the correct composition of nitrogen, P, and potassium needed for each field. With the exception of Pioneer Farm acreage, the quantity, composition, and application date of the fertilizer applied to each field in the UFRW was unknown. Steve Austin, an agronomist in Platteville, WI, indicated that if the soil test results are unavailable, that 91 kg of 09-23-30 be placed on corn fields to replace what is lost by a corn harvest of 180 bushels/acre. Soybeans use 68 kg of 09-23-30 as a maintenance fertilizer (Austin 2006). Austin also indicated that most fields grown for corn and soybeans receive 45 kg of 9-23-30 starter fertilizer. In addition to Pioneer Farm's dairy forage rotation, there is also an additional land owner with crops in a dairy rotation within the UFRW. It was assumed that manure application on that farm was similar to Pioneer Farm. Refer to Appendix C for management scenarios utilized within SWAT.

For management and nutrient export identification purposes the UFRW was broken into 6 subwatersheds. The subwatersheds were divided based on the stream network and changes in land management. The land management practices were integrated into the GIS land coverage layer using a primary key identifier, an attribute called the gridcode. Every digitized parcel of land was assigned a gridcode. Each gridcode represented an individual management rotation. For example, a corn-soybean rotation is labeled as gridcode 116 and a soybean-corn rotation is labeled as gridcode 118.

The crop rotations, tillage, and fertilizer management practices were identified via a 2006 windshield survey, the 2000-2005 Lafayette County transect survey data (Appendix E), meeting with Al Brandt of the Lafayette County Land Conservation Office, and phone interviews with two local agronomists (Figure 11).

Table 2 - Land Management Composition Per Subwatershed

	Subwatershed Percentage (%)					
	1	**2**	**3**	**4**	**5**	**6**
% of Watershed	6.3	18.7	35.0	15.8	9.2	15.0
Dairy Rotation	2.1	58.1	5.9	---	9.9	30.4
Corn - Soybean	75.8	15.9	78.1	80.0	73.0	45.3
Grass / Pasture	0.3	15.3	4.4	9.1	0.1	12.0
Grass / Waterway	21.9	2.4	5.0	1.9	13.2	3.5
Forest	---	---	0.8	---	---	0.3
Farmstead	---	7.5	2.9	4.0	3.8	6.4
Road / Impervious	---	0.7	2.6	4.9	0.1	2.0
Other	---	---	0.3	---	---	---

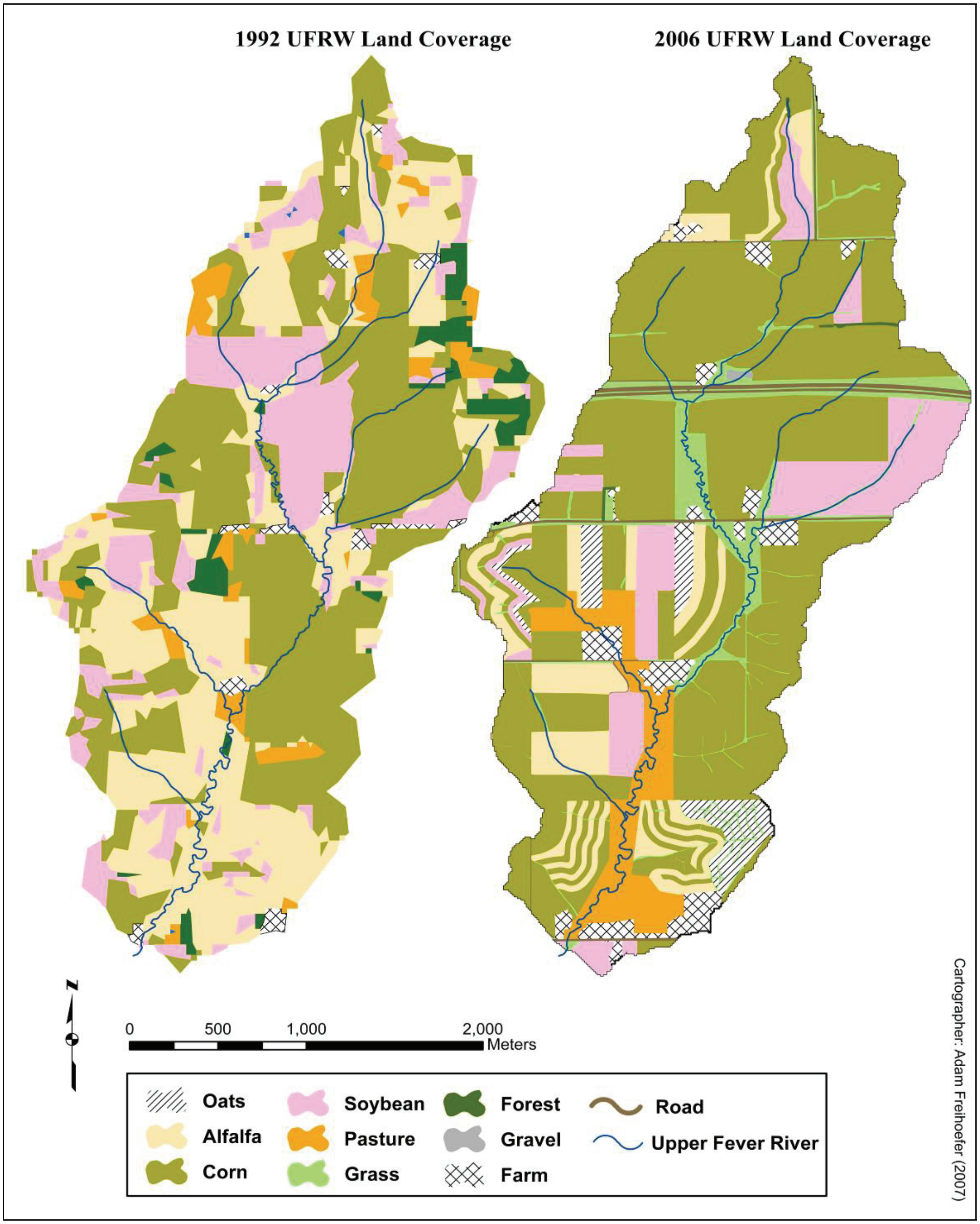


Figure 10 - Upper Fever River Watershed Location within Wisconsin

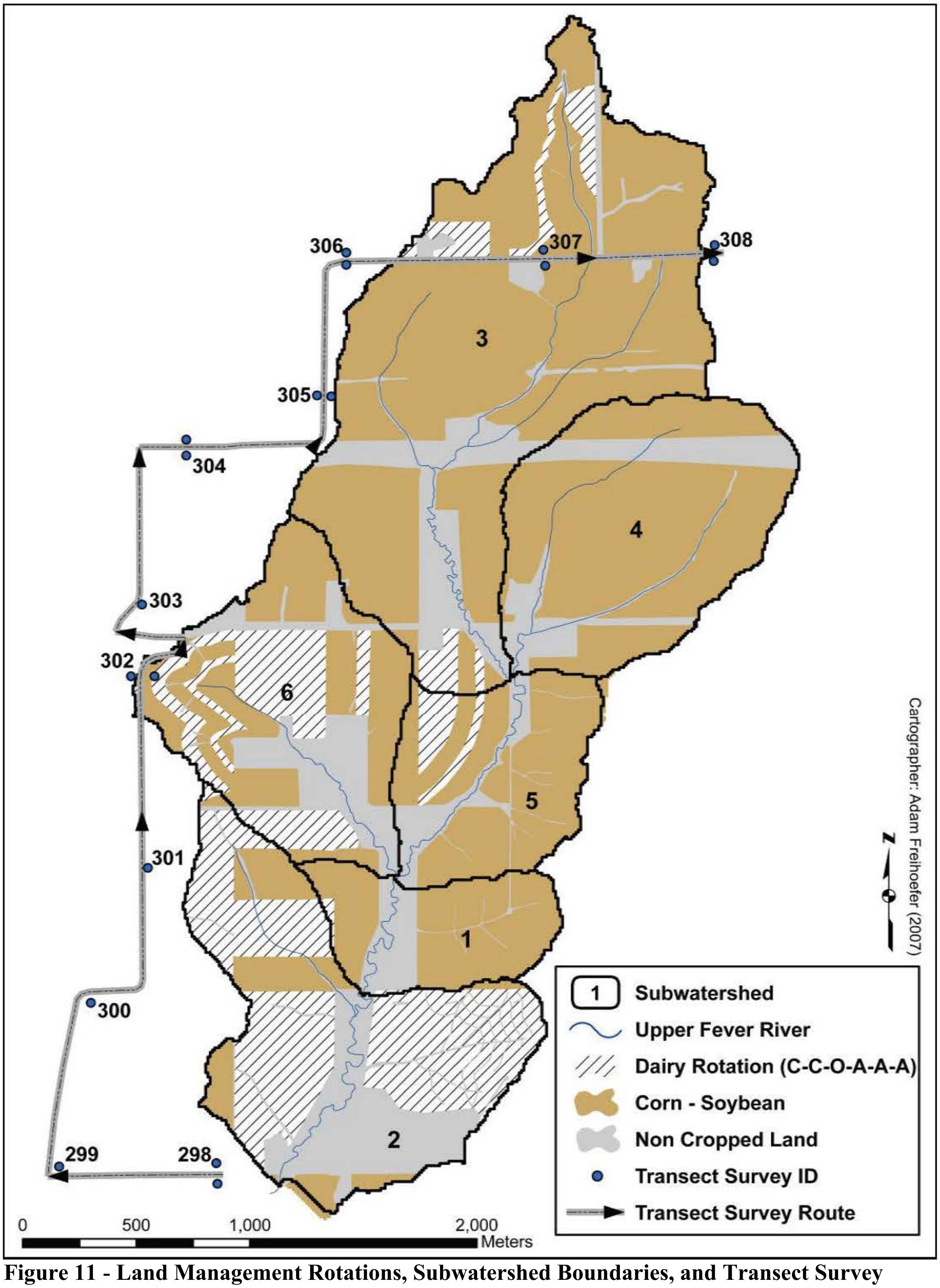


Figure 11 - Land Management Rotations, Subwatershed Boundaries, and Transect Survey Points for the Upper Fever River Watershed

3.5 Calibration

Calibration is the process of matching simulated model results to results measured in the field. 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 trail 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 and tedious 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).

Another approach to model calibration uses a parameter estimation tool such as the Parameter ESTimation (PEST) software (Doherty 2004). PEST, a freeware tool, assists with data interpretation, model calibration, and predictive analysis (Doherty 2004). PEST 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 field-scale watersheds using PEST was completed on a storm event basis. Several storm events occurred over the midnight hour and required an aggregation of two days. A pre-processor using Python script was used to aggregate the two day events prior to PEST algorithm evaluation. 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 determine the most sensitive parameters to adjust with PEST. A template of the PEST input file is in Appendix F.

The use of PEST for the calibration of the UFRW was similar to that of the field-scale watersheds. Although there were many more observations points due to continuous flow data on the Fever River, the PEST setup files were created the same way.

3.6 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 typically range 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. The problem with N-S is that the differences between observed and simulated values are squared values, resulting in larger values being overestimated in comparison to smaller 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).

4.0 Field-Scale SWAT Modeling

4.1 Field-Scale Approach

The first phase of this research calibrated SWAT to three field-scale watersheds at Pioneer Farm. Field-scale simulations were made for individual storm events on field watersheds S2, S3, and S4. As a result, only those days for which measured runoff occurred were used for model calibration. Field watersheds were modeled for non-melt events (April 1 – November 31) and total events (January 1 – December 31) between June 2002 and December 2005 (Table 3). The events were simulated for discharge volume, suspended sediment load, and total P load.

Of the 102 storm events that were simulated, 75 were non-melt events measured between the three stations, 29 and 19 of the events were aggregated over two or more days. Days were aggregated if a storm event occurred six hours +/- midnight. For example, if a storm began 9:00PM on Monday and lasted through 2:00AM Tuesday, then the sum of the SWAT output for both days was used (Appendix G). Although this aggregation was necessary because of the daily time step, it can lead to problems. One shortcoming of the storm aggregation is due to the non-linear relationship between rainfall and runoff in the CN method. The CN method may simulate a different discharge if the two days rainfall was lumped into one day since the storm is treated as a single event.

Table 3 - Individual Field Basin Measured Events with Seasonal Variation

Field Basin	All Events (January 1 – December 31)	Non-Melt Events (April 1 – November 31)
S2	39	32
S3	31	22
S4	32	21

Results for flow, sediment, and P were taken from different SWAT output files. Flow simulation results were taken from the surface flow output (SURQ) in the HRU output file (.sbs) in the SWAT model directory. The SURQ file is the surface runoff contribution to streamflow in the main channel during the time step (mm H_20). The SURQ was does not factor in groundwater contributions as they were assumed to be negligible on small field watersheds. Sediment simulation results were derived from the SED_OUT file in SWAT's main channel output file (.rch). SED_OUT is the sediment that is transported with water out of the reach daily (metric tons). Modeled total P results originated from the subbasin output file (.bsb) in the SWAT model directory. Three forms of P (Organic (ORGP), soluble (SOLP), and mineral (SEDP) phosphorus) in the SWAT output were summed together for the total P yield (kg/ha). The measured sediment and total P load events were defined by the composite of multiple discrete samples taken during the course of a single event.

Management characteristics were defined for each field using farm records. Field watersheds S2 and S3 were simulated as a single crop, single HRU. Field watershed S4 consisted of multiple crops and thus multiple HRUs. The multiple HRU's of field watershed S4 were defined using a 10% landuse composition threshold in AVSWAT. No threshold was set for the soils layer as it was uniform. Each field was simulated with a six year rotation. The model was run for 12 years (1994 – 2005) with the first 8 years acting as a warm-up period for the simulation.

All simulations used the Penman-Monteith method of evapotranspiration. The Penman-Monteith method requires inputs for solar radiation, air temperature, wind speed, and relative humidity. SWAT generates the values for solar radiation, wind speed, and relative humidity using statistical data from the weather generator input file.

The SWAT model input datasets were previously described in Section 3.0. The datasets were created with as much detailed as possible to reflect the field-scale watersheds. A brief overview of the datasets used for each field-scale basin is outlined in Table 4.

Table 4 - Summary of SWAT Model Input Dataset for Field-scale Simulation

Input Data	Dataset
Topography	1-meter DEM
Hydrology	Hand Digitized Ephemeral Waterway
Precipitation and Temperature	Pioneer Farm MET Station
Land Use	2006 Hand Digitized Land Coverage
Soils	STATSGO Soils

4.2 Discharge Calibration

Discharge was calibrated by adjusting the most sensitive hydrologic model input parameters to improve the fit between observed and predicted. The model input parameters were selected based on previous SWAT studies (White and Chaubey, 2005; Lenhart *et al.* 2002; Heuvelmans *et al.* 2004) and by running model parameters through PEST. Both techniques yielded similar results. The parameters used for surficial hydrologic model field-scale calibration were the crop curve number (CNOP), soil available water capacity (AWC), soil hydraulic conductivity (SOLK), and the evapotranspiration coefficient (ESCO). Initial input values for soil parameters (AWC and SOLK) were those values listed by the NRCS soil survey for Lafayette County. The NRCS CN table was used for the default CNOP values for each land use, and the ESCO value utilized the default value of 0.95 for each field-scale simulation.

PEST was used to find the optimal combination of parameter values to best match the measured runoff volume from each event. The optimal parameter set altered the CNOP and ESCO. The SOLK and AWC parameters remained fixed, relying on the recommended NRCS values for the area. The input parameter values at the field-scale did not differ greatly from the initial default parameter values in both all event and non-melt event simulations. A detailed list of calibrated discharge parameters at the field-scale is included in Table 5.

Calibration of the field-scale watersheds was conducted for both melt and non-melt events, but only the non-melt events were used to evaluate the success of the field-scale approach since snowmelt simulation was not the focus of this research. The simulation of field-scale melt events was used in the analysis of annual export for comparison to another model as described in Section 6.

In all the field-scale simulations, larger runoff events were more easily replicated than smaller ones. Larger events typically occurred after crop harvest and before or just after planting when the soil had minimal surface cover and no snow. Figure 12, Figure 13, and Figure 14 compare the simulated individual storms. The figures show how management and landscape factors impact discharge from the three separate field watersheds with uniform precipitation as shown with the event occurring on October 4, 2002.

The relationship between predicted and observed runoff results from the S2, S3, and S4 field watersheds during the non-melt period was statistically significant. The single HRU fields S2 and S3 produced a strong correlation and efficiency with R^2 and N-S values both above 0.80 (Table 6). The multiple HRU watershed S4 had acceptable R^2

and N-S values (0.75; 0.75); however, the total simulated event flow over the four years from S4 had an error greater than 25%. An additional 0.74, 2.76, and 0 mm H_20 was simulated for field watersheds S2, S3, and S4, respectively, when all non-melt days (April 1 – November 30) were examined. A comparison between all discharge events from the three fields indicated correlation and efficiency values of 0.85 and 0.84, respectively (Figure 15). The smaller discharge events were more variable due to factors such as surface storage, soil moisture levels, and local terrain characteristics.

Table 5 - Summary of Discharge Calibration Parameters for Watersheds S2, S3, and S4

SWAT Variable	Description	Default Value	S2	S3	S4
CNOP (Row Crop)	Curve Number - Row Crops	77	74	55	67
CNOP (Alfalfa)	Curve Number - Alfalfa	59	59	66	57
CNOP (Tillage)	Curve Number - Tillages	---	73	59	60, 79, 61
SOL_K	Soil Hydraulic Conductivity (mm/hr)	32.40	32.40	32.40	32.40
SOL_AWC	Soil Available Water Capacity (mm/mm	0.22	0.22	0.22	0.22
ESCO	Evapotranspiration Coefficient	0.95	0.69	0.82	0.52

Table 6 - Summary of Measured versus Simulated Event Discharge

Field	Measured Total Event Discharge (mm H_20)	Simulated Total Event Discharge (mm H_20)	% Discharge Error	R^2	N-S
S2	92.71	93.33	0.68	0.85	0.85
S3	67.60	73.18	8.26	0.87	0.84
S4	26.75	38.41	43.60	0.75	0.75

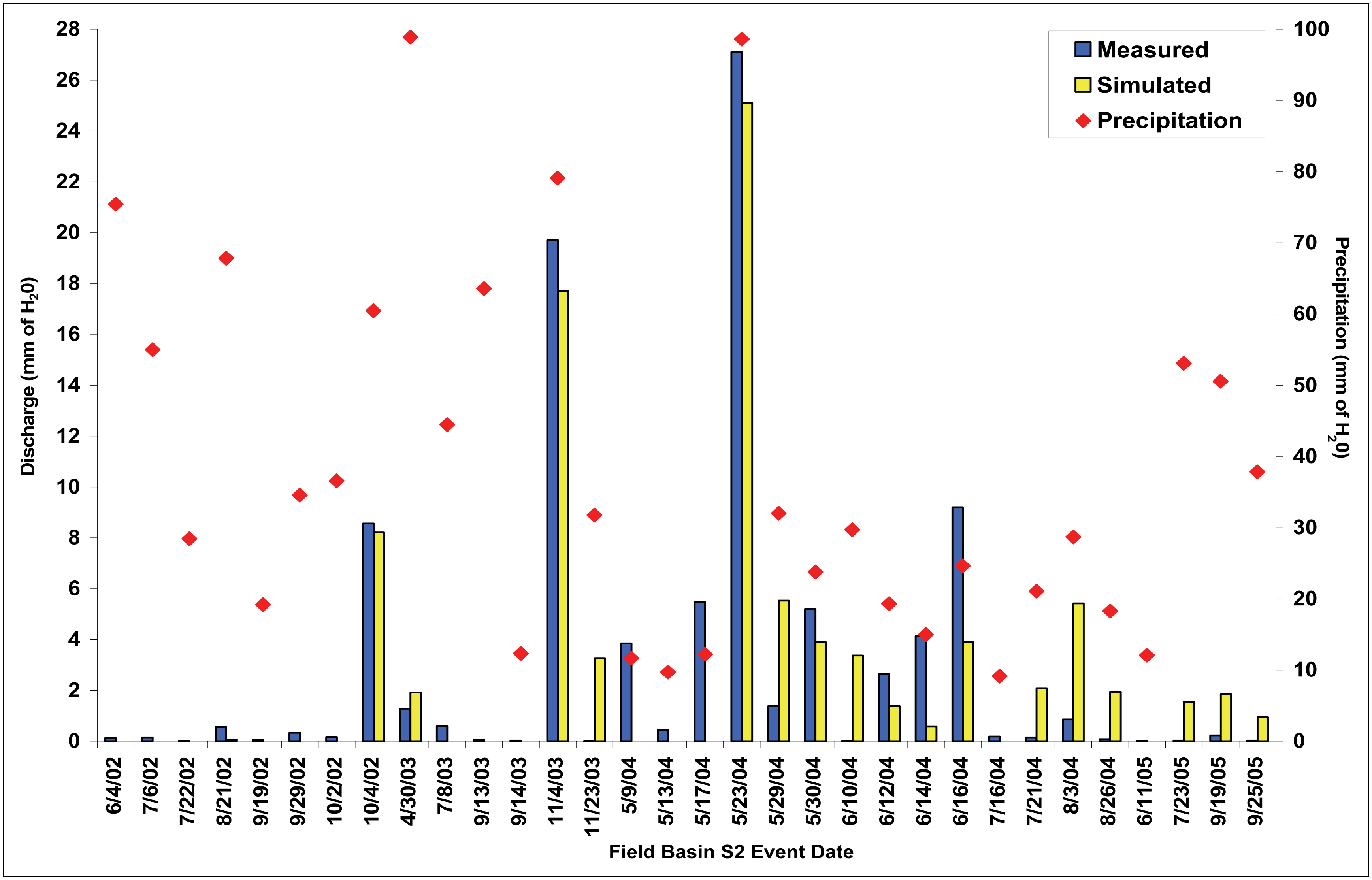


Figure 12 - Field Basin S2 Flow Calibration

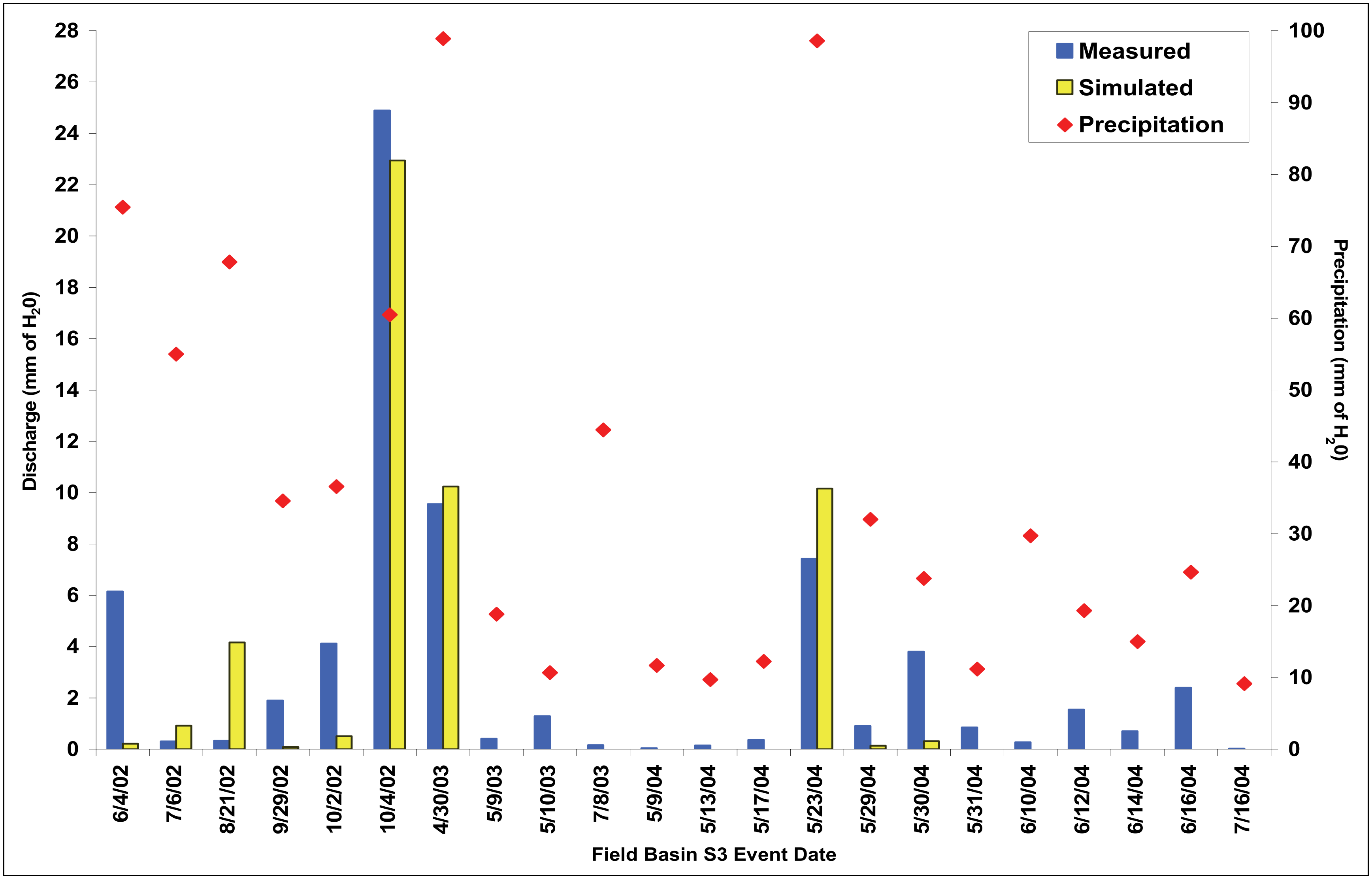


Figure 13 - Field Basin S3 Flow Calibration

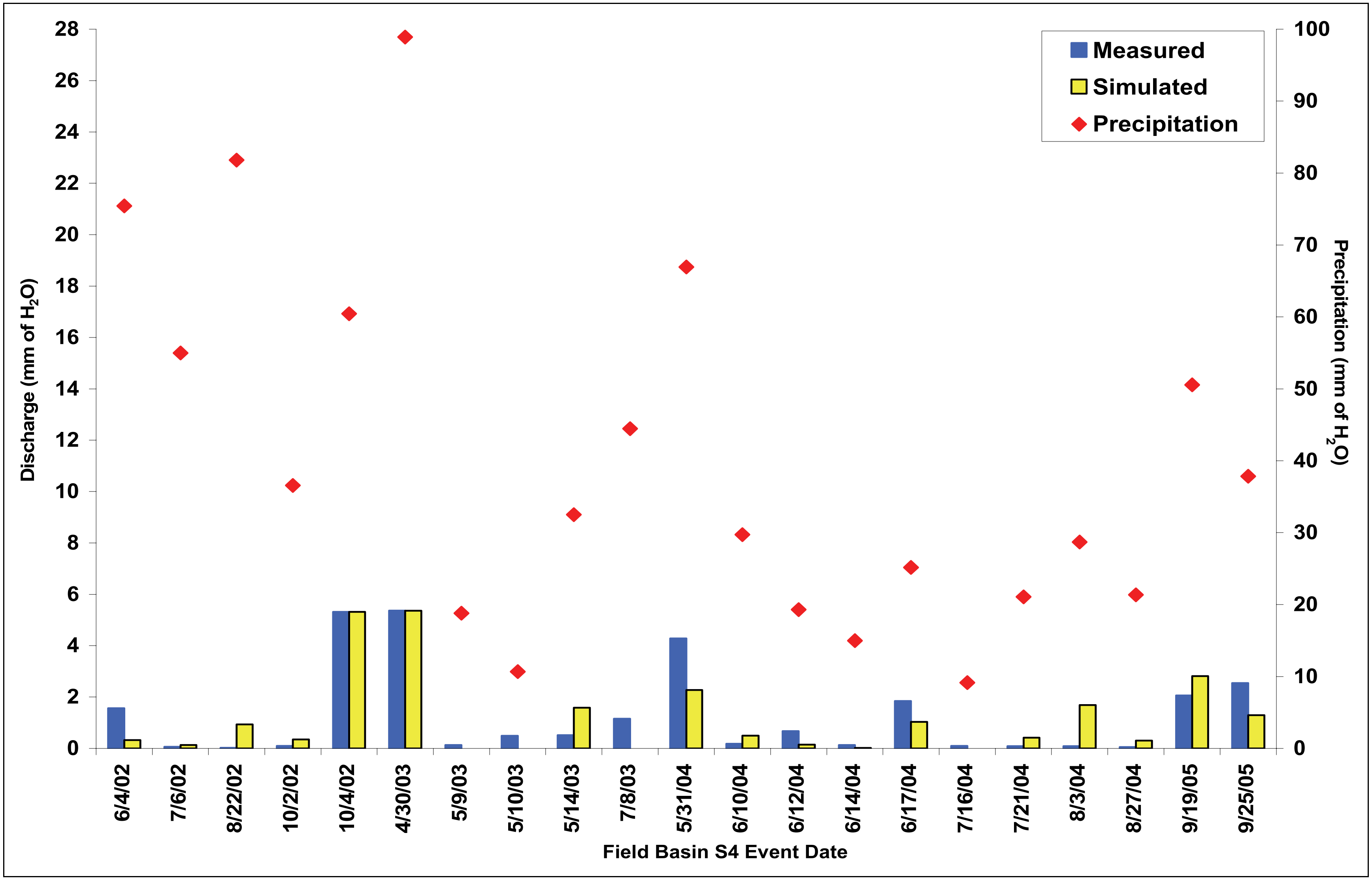


Figure 14 - Field Basin S4 Flow Calibration

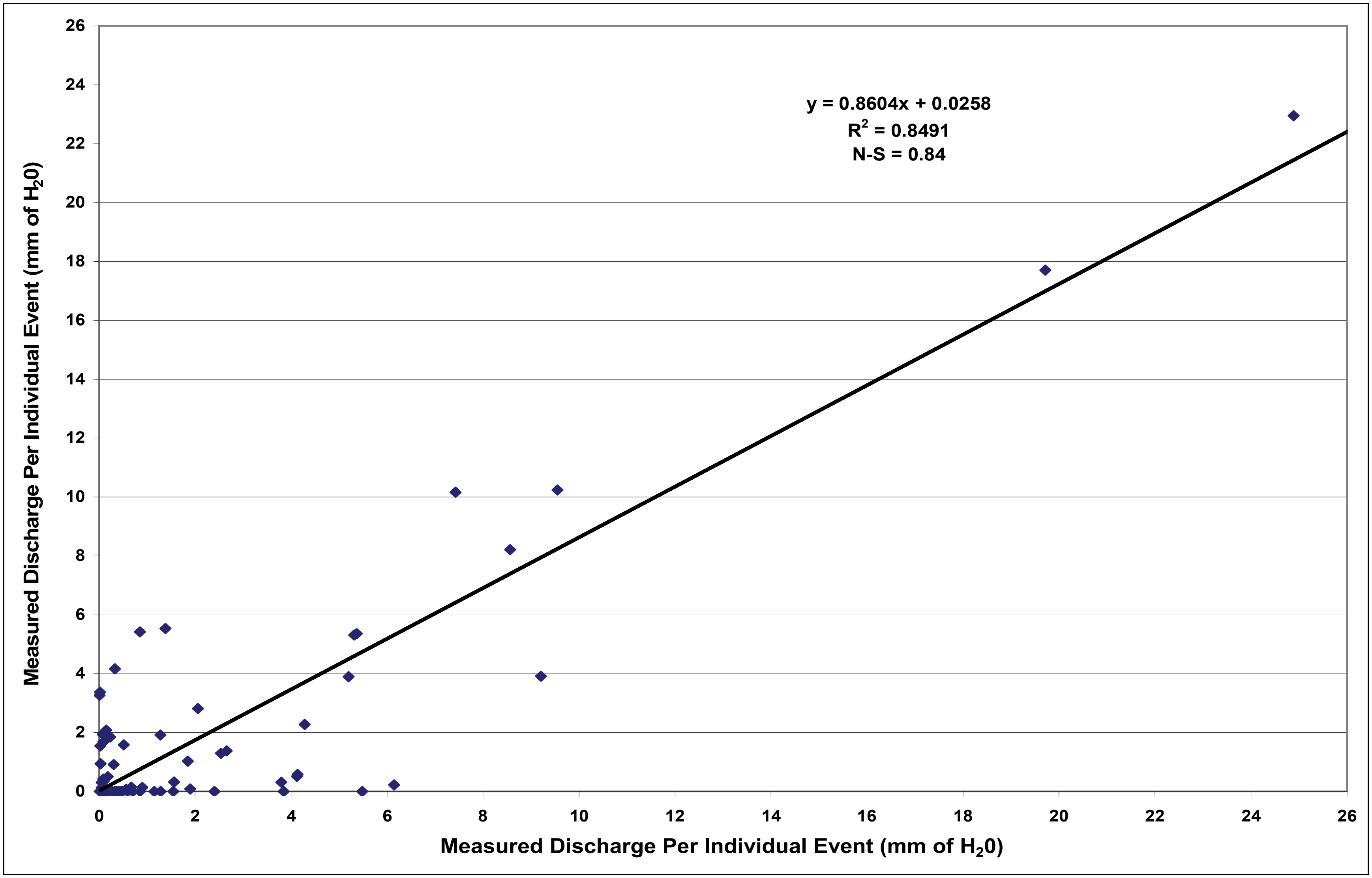


Figure 15 - Simulated vs. Measured Discharge for All Storm Events in Field Watersheds S2, S3, & S4

4.3 Sediment Load Calibration

Sediment export from field-scale watersheds was calibrated after completing the surface runoff calibration using the measured suspended sediment load (metric tons). Similar to discharge, events over two or more days were aggregated for total event sediment load. The simulated load was calibrated to a measured sediment load by modifying two SWAT input parameters, the universal soil loss equation (USLE) crop practice factor (USLE P) and the peak rate adjustment factor (APM). The USLE P, located in the .mgt input file, is the ratio of soil loss with a specific support practice to the corresponding loss. The USLE P value was changed from the default value of 1.0 to 0.75 for field basin S2, 0.40 for field basin S3, and 0.15 for field basin S4. The decrease in the USLE practice factor value from the default simulates the contoured, terraced crops of the modeled fields. The APM was adjusted from the default of 1.0 to 1.2 to simulate a larger sediment peak due to the flashy response of the simulated fields (Table 7).

Unlike the discharge simulation, no trend existed in the simulation of sediment (Figure 16, Figure 17, and Figure 18). For example, field S2 had a relatively large measured and simulated discharge event on November 4, 2003. Typically, a similar trend would follow with sediment; however, the measured sediment from the November 4, 2003 event was significantly lower. This illustrates the complexity of the landscape and its impact on individual events. Since in SWAT most model parameters are temporally uniform, the error in individual events is difficult to simulate. The lower sediment contribution from S2 may also be due to BMPs already present on the field.

Field S2 had a lower statistical confidence than S3 and S4 due to a single event in November 2003, which simulated approximately 14 times the measured sediment load (Table 8). Although individual events proved difficult in simulation, both correlation and efficiency were acceptable for all three fields. The simulated event sediment load was within an acceptable range of the measured load from all three fields, with a correlation and efficiency of 0.48 and 0.47 (Figure 19). The calibration of the both discharge and sediment load impacts one's ability to simulate P export in surface runoff. An additional 1.27, 3.23, and 7.65 metric tons sediment was simulated over the measured load for field watersheds S2, S3, and S4, respectively, when all non-melt days (April 1 – November 30) were examined.

Table 7 - Summary of Sediment Load Calibration Parameters for Watersheds S2, S3, and S4

SWAT Variable	Description	Default Value	S2	S3	S4
USLE_P (Crop)	USLE equation support practice factor for Crops	1.00	0.75	0.40	0.15
APM	Peak Adjustment for Sediment Routing	1.00	1.20	1.20	1.20

Table 8 - Summary of Measured vs. Simulated Sediment Load

Field	Measured Event Total Sediment Load (metric tons)	Simulated Event Total Sediment Load (metric tons)	% Load Error	R^2	N-S
S2	92.50	87.75	5.64	0.44	0.42
S3	15.09	14.59	3.3	0.68	0.54
S4	22.32	19.13	14.28	0.70	0.82

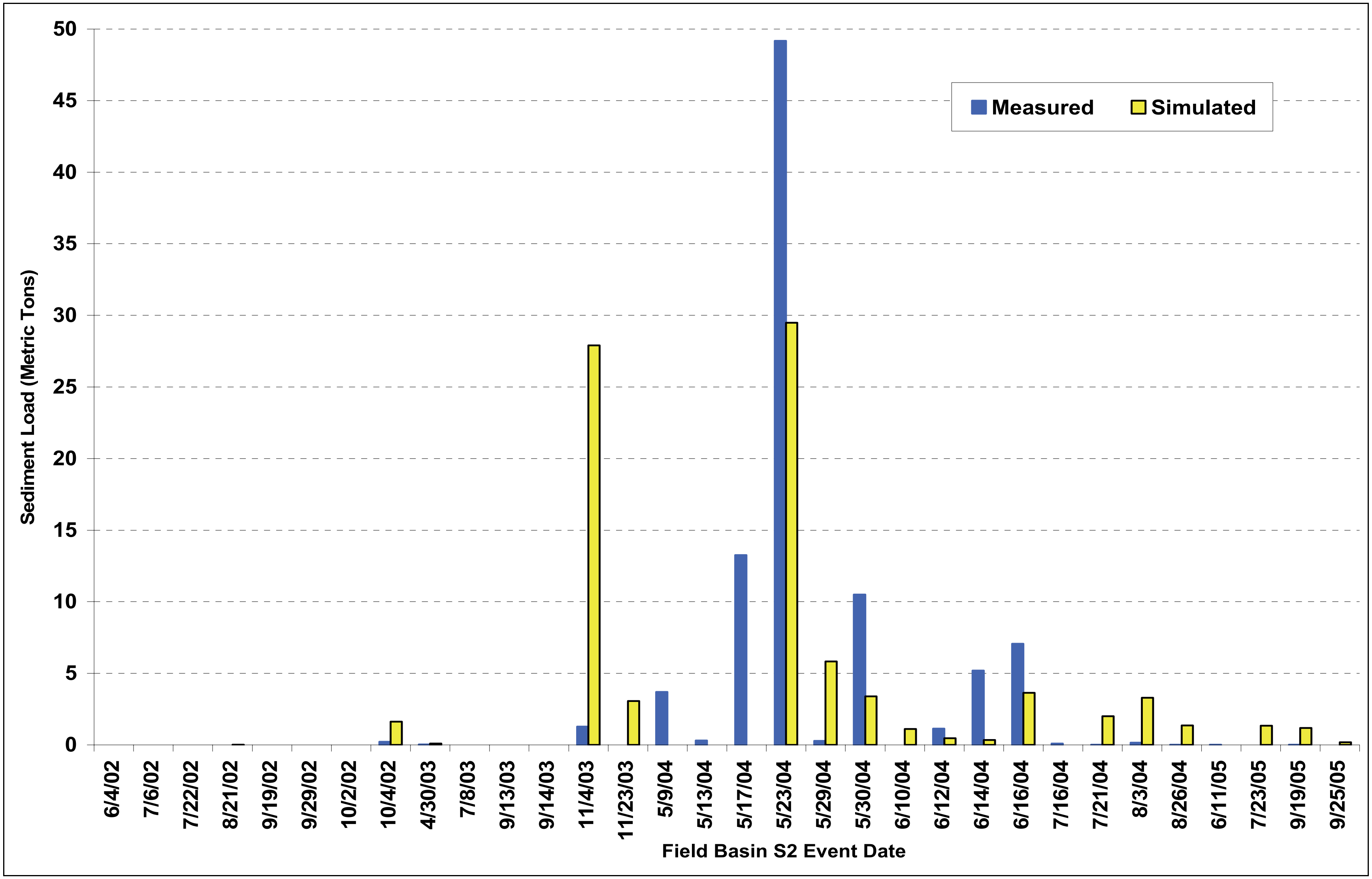


Figure 16 - Field Basin S2 Sediment Load Calibration

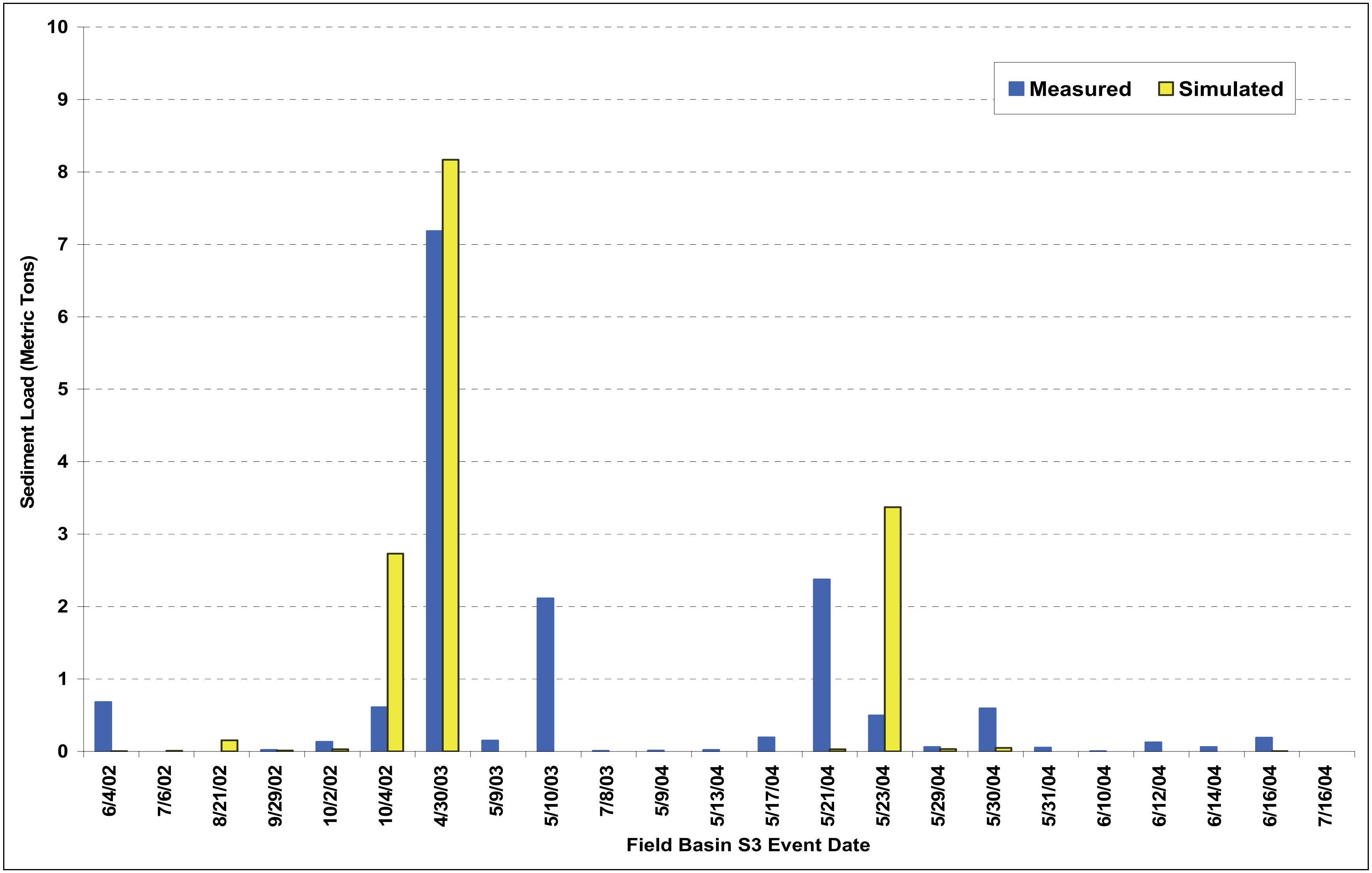


Figure 17 - Field Basin S3 Sediment Load Calibration

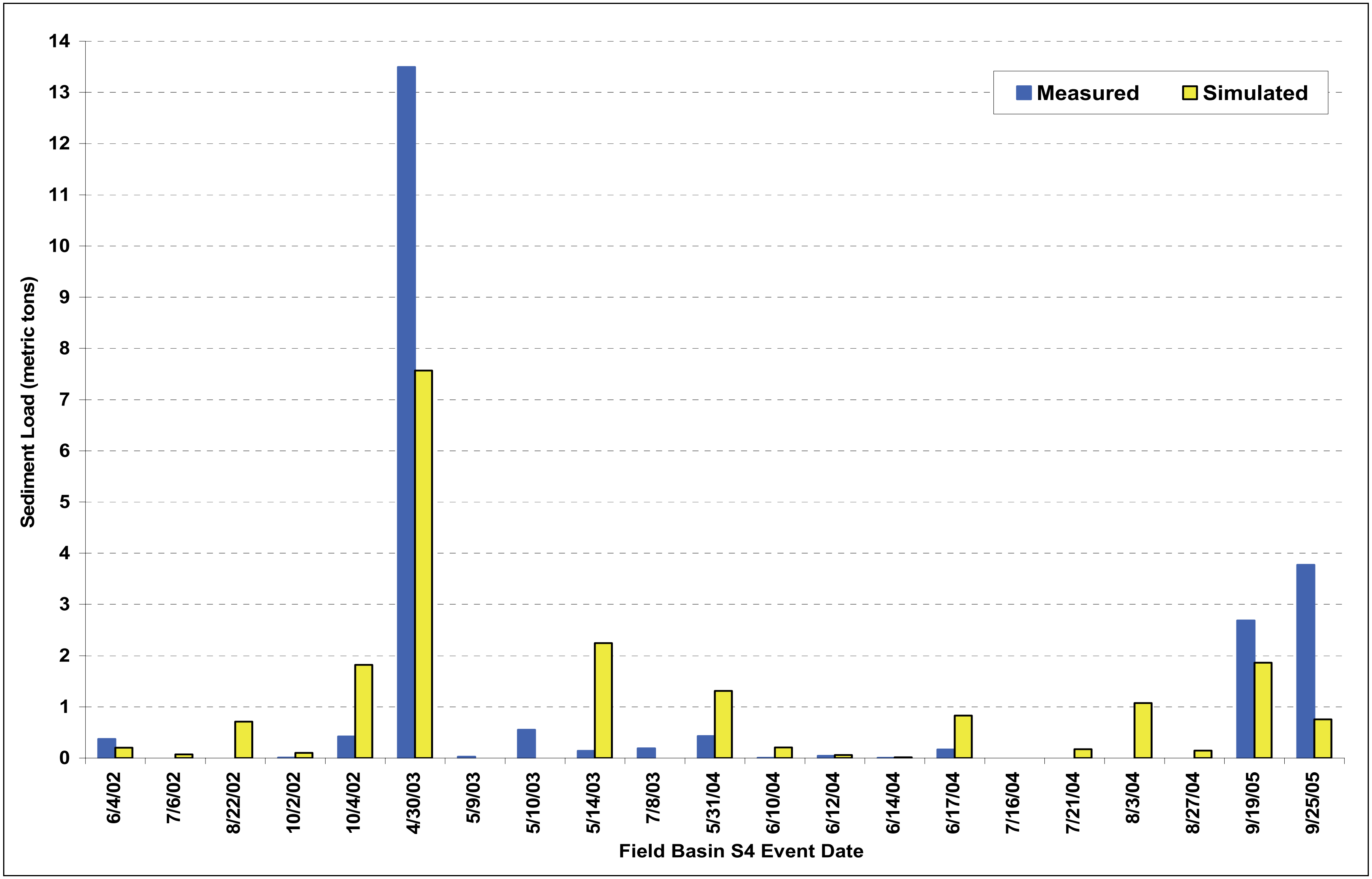


Figure 18 - Field Basin S4 Sediment Load Calibration

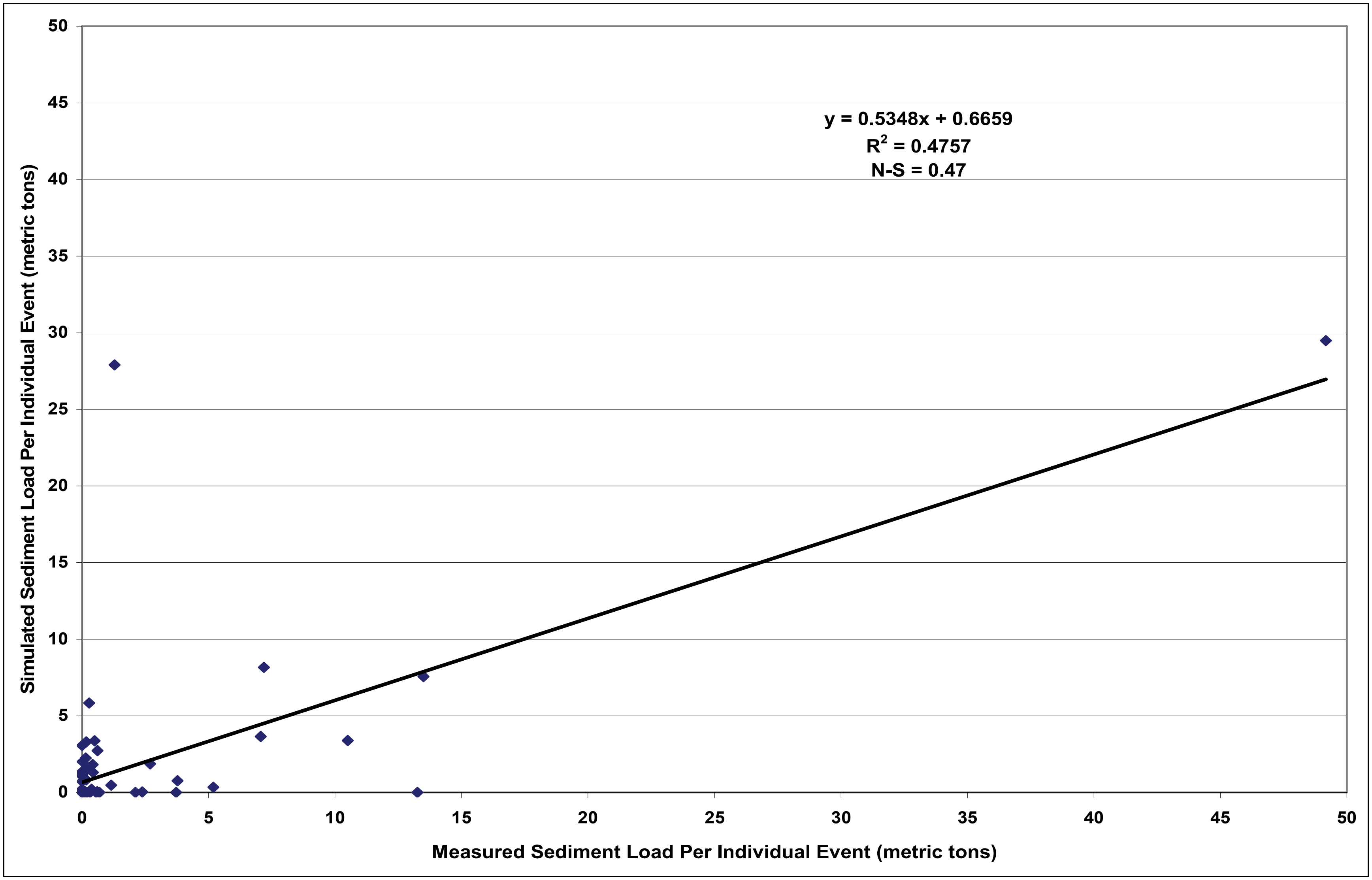


Figure 19 - Simulated vs. Measured Sediment Load for All Storm Events in Field Watersheds S2, S3, & S4

4.4 Total Phosphorus Load 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 total P was calibrated in the SWAT by modifying three input variables, initial soluble P concentration in soil layer (SOL_SOLP), the P soil portioning coefficient (PHOSKD), and the P availability index (PSP). The value of SOL_SOLP was determined using the average Bray-1 soil P concentration measured for each Pioneer Farm field between 2003 and 2005. A Bray-1 P concentration of 50 mg/kg was used for field S2 and 100 mg/kg was used for fields S3 and S4. The measured average PHOSKD values were less than 100 m^3/kg, the minimum PHOSKD value allowed in the SWAT. A value of 100 m^3/kg was used for PHOSKD rather than the default of 175 m^3/kg. The PSP was increased from a default of 0.40 to 0.55 for field S3 (Table 9). The PSP specifies the fraction of fertilizer P which is in solution after an incubation period.

Simulated total P loads followed a similar trend to that of sediment load. Unlike discharge both small and large events were both difficult to predict during calibration (Figures 20, 21, and 22). The statistical measures were strongly influenced by a few events such as occurred with field S2 on November 4, 2003. The correlation and efficiency for each field was acceptable, with one or two events strongly influencing statistical measures as in the case of field S2 (Table 10). Comparing all three fields simulations indicated a similar variable trend as total P simulation as the R^2 and N-S value was 0.49 and 0.34 respectively (Figure 23). An additional 0.39, 1.23, and 1.21

kg/ha total P was over simulated by SWAT for field watersheds S2, S3, and S4 when all non-melt days (April 1 – November 30) were examined.

Table 9 - Summary of Total Phosphorus Calibration Parameters for WatershedsS2, S3, and S4

SWAT Variable	Description	Default Value	S2	S3	S4
SOL_SOLP (LABP)	Initial Soluble Phosphorus Concentration in Soil (mg/kg)	0.00	50.00	100.00	100.00
PSP	Phosphorus Availability Index	0.40	0.40	0.55	0.40
PHOSKD	Phosphorus Partitioning Coefficient	175.00	100.00	100.00	100.00

Table 10 - Summary of Measured vs. Simulated Event Total Phosphorus Load

Field	Measured Total Phosphorus Load (kg/ha)	Simulated Total Phosphorus Load (kg/ha)	% Load Error	R^2	N-S
S2	6.33	7.88	24.40	0.44	0.28
S3	4.00	3.91	2.16	0.61	0.38
S4	1.94	2.04	5.24	0.86	0.81

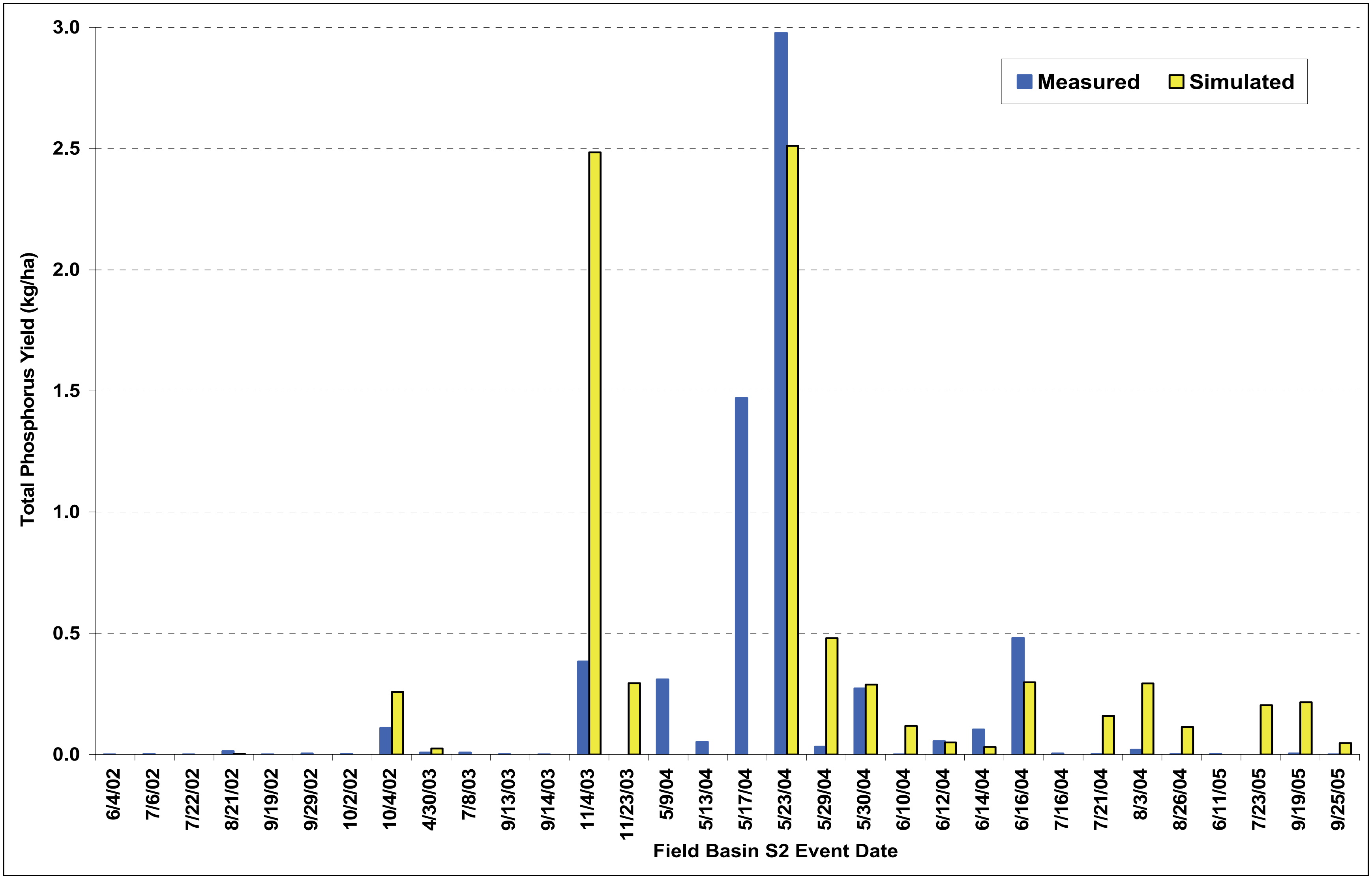


Figure 20 - Field Basin S2 Total Phosphorus Load Calibration

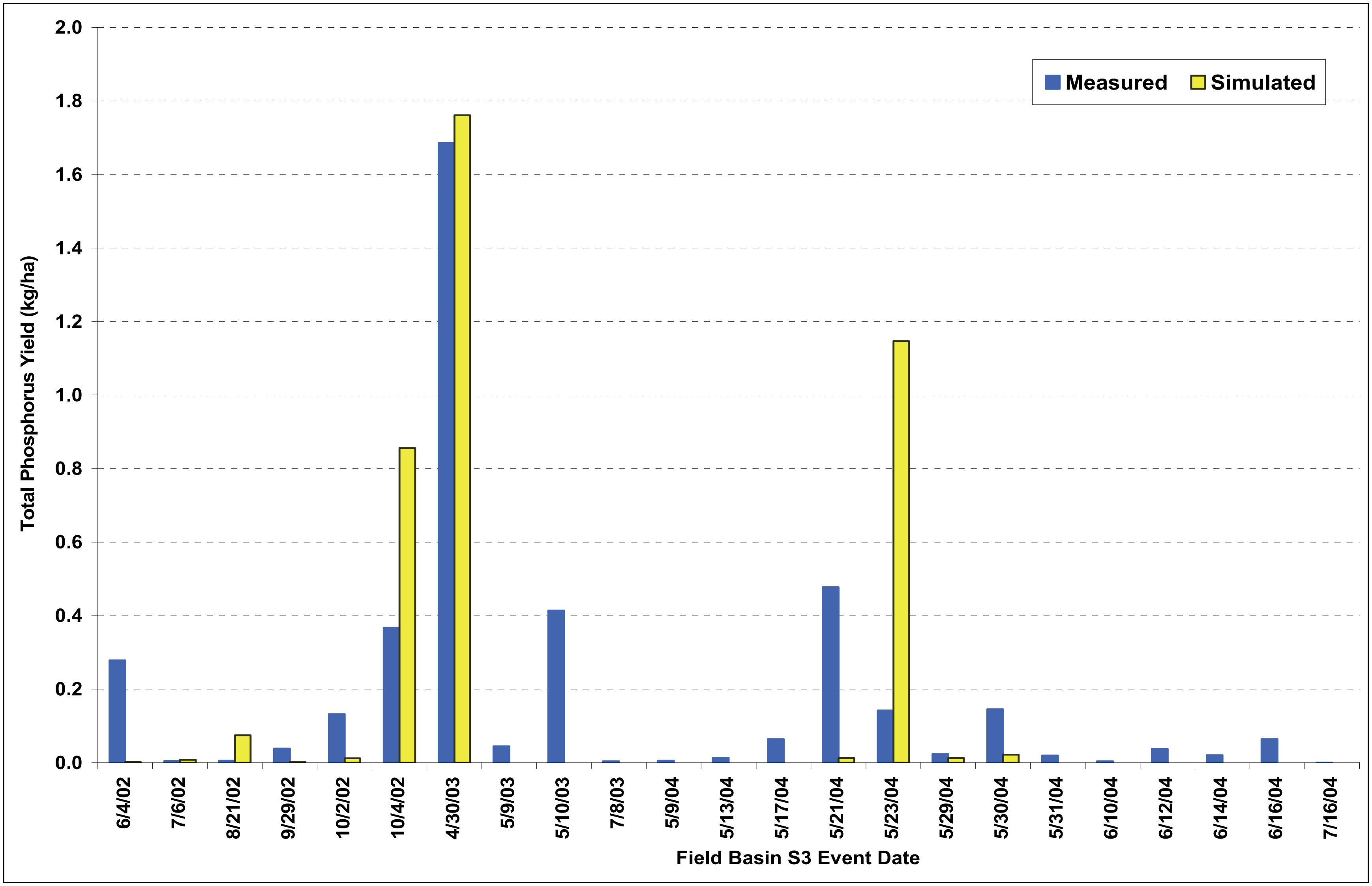


Figure 21 - Field Basin S3 Total Phosphorus Load Calibration

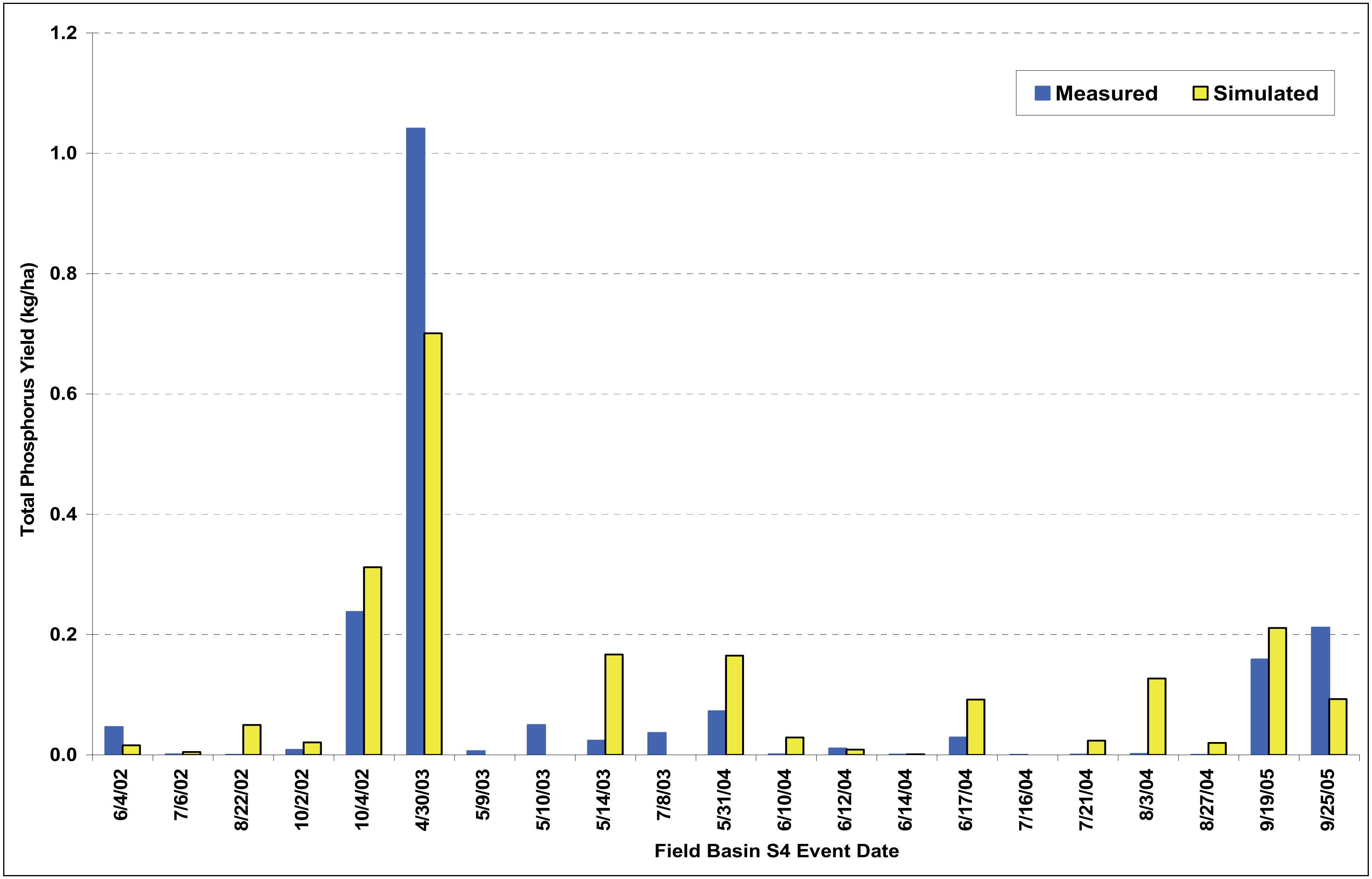


Figure 22 - Field Basin S4 Total Phosphorus Load Calibration

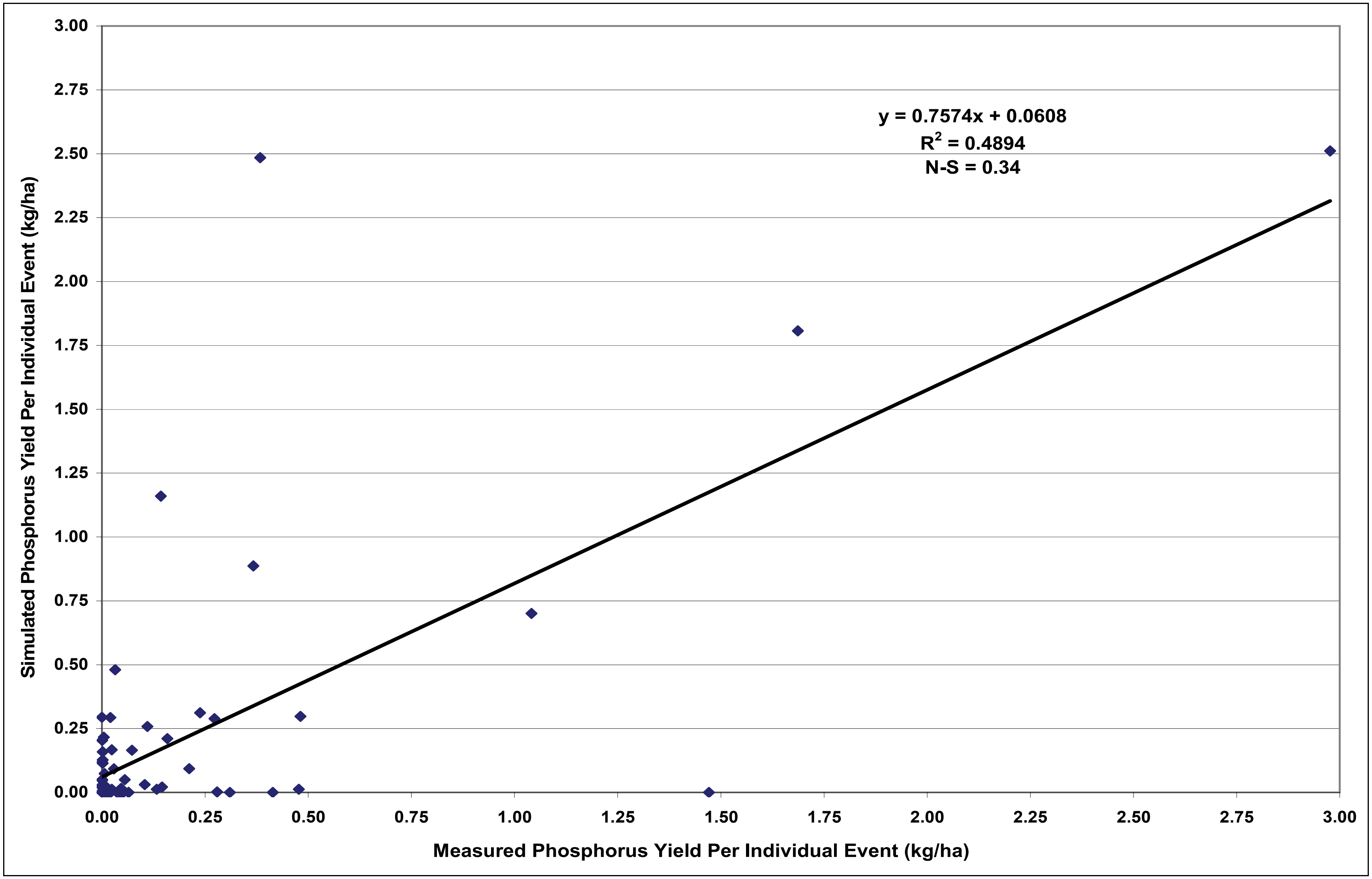


Figure 23 - Simulated vs. Measured Sediment Load for All Storm Events in Field Watersheds S2, S3, & S4

4.5 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 field-scale basin's 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's BE was kept at the default, 20. The simulated crop yields were within +/- 30 percent of Pioneer Farm measured yields and +/- 20 percent of the National Agriculture Statistics Service (NASS) for Lafayette 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 elevated denitrification rates.

4.6 Field-Scale Conclusions

SWAT successfully simulated flow, sediment, and nutrient export at the field-scale during individual non-melt events between June 2002 and November 2005. Calibration of each field utilized model parameter values similar to those recommended by outside sources such as the NRCS CN table and the NRCS Soil Survey of Lafayette County. The PEST software created an efficient approach to calibration by optimizing the parameter set to match the measured dataset. PEST demonstrated the interconnection of input variables.

For the performance measurs used (Nash-Sutcliffe efficiency), the statistical significance was driven by larger discharge events, which is reasonable as these events act as the dominant transport mechanism of nutrients. As a result, calibration to field-scale watersheds concentrated on larger events. In most previous studies, SWAT was calibrated for monthly and yearly outputs (Borah and Bera 2004). The simulation of the three fields at Pioneer Farm indicate that SWAT can not only simulate individual event discharge, but can do so with a R^2 and N-S confidence greater than 0.75. The sediment and P were more difficult to calibrate resulting in lower R^2 and N-S measures. The simulation success for sediment and total P load was statistically misleading as single events greatly influenced the R^2 and N-S values for fields S2 and S3. It was noted that several, smaller sized storms had greater mean error than did the larger storms. This may be in part due to errors in Penman-Monteith evapotranspiration SWAT dataset and the antecedent moisture condition which relies on an input precipitation dataset.

5.0 Field to Watershed-Scale Calibration

5.1 Watershed Scale Approach

Previous studies connecting the SWAT model calibration of a watershed and its contributing individual fields have been limited. As a result of subwatershed aggregation, and absence of delivery simulation, the use of recommended values for input parameters such as the NRCS CN and the AWC determined by the NRCS may not be the same at the two scales. The second phase of this research evaluates parameter sensitivity between the fields and watershed-scale calibrations.

For all watershed-scale simulations, the UFRW was divided into six subwatersheds and 30 HRUs. The subwatersheds ranged from 40 to 270 ha in size. The HRUs were developed using a 10% landuse composition threshold in AVSWAT. No threshold was set for the soils layer as it was uniform. The cropped HRUs were a variation of dairy forage (C-C-OA-A-A-A) or cash grain rotation (C-S). The model was run for 12 years (1994 – 2005) with the first 8 years acting as a warm-up period for the simulation. All simulations used the Penman-Monteith method of evapotranspiration. The watershed was calibrated to daily or event output, rather than monthly or yearly. PEST was used for calibration of input parameters. Due to the relatively small dataset, no validation period was used to maximize calibration efficiency.

Two separate calibration scenarios were used for the UFRW simulations. Scenario I followed previous SWAT studies by calibrating to continuous flow and individual sediment and total P samples (August 1, 2002 to December 31, 2005) from the UFRW outlet (USGS Station 05414850). Scenario I used the City of Platteville dataset but substituted Pioneer Farm MET station data when it was clear from stream response that the City station was not representative of the watershed. Scenario II calibrated simulations to non-melt (April 1 – November 30) events with 66% or less precipitation variation between the City of Platteville station and the MET station. It was assumed that these events were more likely to have uniform precipitation across the watershed. Scenario II used the groundwater and snowmelt parameter values calibrated during Scenario I.

The SWAT model input datasets were created as detailed in Section 3.0. The datasets were created as detailed as possible to reflect the basin size. A brief overview of the datasets used for the watershed-scale basin is outlined in Table 11.

Table 11 - Summary of SWAT Model Input Dataset for Watershed-scale Simulation

Input Data	Dataset
Topography	10-meter DEM (USGS)
Hydrology	Hand Digitized Perennial Stream Network
Precipitation and Temperature	City of Platteville Weather Station
Land Use	2006 Hand Digitized Land Coverage
Soils	STATSGO Soils

5.2 Overall Watershed Calibration (Scenario I)

5.2.1 Discharge Calibration

Average daily stream discharge was simulated for 1,218 days at the watershed outlet gauge station managed by the USGS. The discharge represents groundwater and surface water contributions representative of surface properties (slope, plant growth, and management) and subsurface properties (soil properties) which can vary spatially.

To simulate landscape factors for the watershed, discharge was calibrated through the manipulation of the model's most sensitive hydrologic input parameters. Referenced literature and PEST sensitivity were used to determine the most sensitive input parameters for calibration. The parameters used for surficial hydrologic model calibration were the crop curve number (CNOP), soil available water capacity (AWC), soil hydraulic conductivity (SOLK), and the evapotranspiration coefficient (ESCO). Two different soil property sets were used for initial discharge calibration. The first used constant values of AWC and SOLK and the other allowed PEST to optimize to AWC and SOLK values. Unlike field simulations, there was a significant difference between the two soil property calibration techniques. As a result, the AWC and SOLK remained variable for better fit. Seven snowmelt parameters were also used in the calibration along with the five most sensitive parameters controlling groundwater recharge.

When simulating at the watershed-scale, discharge parameters were altered from default and field simulation values using PEST. The initial trial and error calibrated simulation of the UFRW overestimated discharge during events and underestimated baseflow. The large contribution of baseflow to total UFRW discharge led the PEST in directing calibration towards more infiltration and greater groundwater contribution into the stream. This impacted the values of several related hydrologic input parameters including the NRCS CN, AWC, SOLK, and ESCO.

The PEST calibration of daily discharge resulted in a NRCS CN of 35 for row crops, a decrease from the default of 77 and a field-scale average of 69. The same held true for alfalfa, decreasing the NRCS CN from a default 59 to 35. The decrease in CN values results in the model simulating greater infiltration. The AWC was increased from a default of 0.22 mm/mm to 0.26 mm/mm also suggesting greater infiltration. The calibrated SOLK was decreased from a default of 32.4 mm/hr to 9.79 mm/hr. This change also reflects a larger retention of soil water. The PEST calibration showed the SOLK and AWC were equally as sensitive as the CN to hydrologic response. All three parameters were adjusted to improve the fit. The use of a CN of 35 could be a result of macropore infiltration and fractured rock rather than tile drains as few tile drains exist in the UFRW watershed.

Groundwater parameters were also adjusted to allow for increased baseflow to the Fever River during non-event periods 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 0.0076 days using PEST. That is not unreasonable, as an alpha baseflow value of 0.0094 days was calculated using a baseflow separation program. The groundwater delay was increased from a default 31 days to 95 days.

Overall, the simulation of continuous daily discharge was moderately successful. The calibration emphasized matching baseflow and under predicted runoff. Simulation of the UFRW daily discharge had a R^2 and N-S value of 0.33 and 0.29, respectively. Total simulated discharge was less than one percent greater than the measured. The baseflow was accurately simulated between 2002 and 2004; however, in 2005 the baseflow was over predicted resulting in over-predicting total discharge (Figure 24). The over prediction became significant after the early 2005 spring snowmelt. It is unclear if the snowmelt infiltrated rather than runoff causing the increased recharge. The inability to simulate snowmelt runoff processes was likely the cause of the overall poor statistical significance of overall discharge. This was demonstrated in a comparison of simulated discharge during non-melt days. They had a R^2 and N-S value of 0.64 and 0.63 respectively. The total discharge comparison during non-melt days had a greater error (8.8%) likely due to the over prediction of baseflow in 2005.

It is important to note that most SWAT studies, including Santhi *et al.* 2001, Qi and Grunwald (2005), and White and Chaubey (2005), have gauged the success of calibration using a monthly averaging period. Some of the studies have calibrated to monthly totals, while others have calibrated to a daily time step and statistically evaluated the models success using a month long daily average. In the UFRW simulations described here, the monthly and yearly averaging periods always improve the statistical measures compared to a daily evaluation. For example, the monthly R^2 and N-S values are 0.53 and 0.53 respectively over the entire 3 ½ years of simulation. The monthly statistical significance would likely be even better if the model would have been calibrated to monthly discharge, rather than the daily discharge. Yearly R^2 and N-S values are 0.93 and 0.91 respectively. It is clear that increasing the averaging period improves the statistical evaluation of simulated discharge.

5.2.2 Sediment Load Calibration

Watershed sediment load was simulated on an event basis rather than continuous estimated daily load. A total of 48 events were simulated, 35 of them non-melt events. Simulated sediment loss from the reach (metric tons) was totaled from the sed_out field in the SWAT main channel output file (.rch). Sediment load was calibrated using four SWAT input parameters: USLE_P (USLE equation support practice factor), USLE_K (USLE equation soil erodibility factor), APM (peak rate adjustment factor for sediment routing), and CH_N (1) (Manning's n value for tributary channels).

Parameter estimation using PEST was used to identify values for the sediment calibration. The USLE_P value (.mgt) was decreased for cropped agriculture to 0.10 and changed from a default of 1.0 to 0.90 for farmsteads and grassland areas. 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 USLE_K value increased from a default 0.32 to 0.65. The APM (.bsn) parameter was increased from a default 1.00 to 1.90 to better simulate the flashy response from storm events in the watershed. The tributary Manning's n value was decreased from 0.014 to 0.010. The only parameter that was changed outside of the PEST calibration process was the average channel width (CH_W2) from 3.87 m to 2.0 m to better reflect previous measurements made on the Fever River.

Finding a parameter combination that enabled all event sediment loads to be accurately simulated was not possible. The inability to calibrate discharge to several storms in particular created difficulty in sediment load calibration. Total simulated sediment load was underestimated for both total events and non-melt events at the watershed outlet. Individual events were either over and under predicted. Together all 48 simulated events yielded a 5 percent underestimation (83 metric tons) in total sediment load (Figure 25). The 35 non-melt events underestimated sediment load by 42 metric tons. SWAT was unable to provide an acceptable simulation of all 48 events, with R^2 and N-S value of 0.13 and -0.12, respectively. When only non-melt events were examined, the R^2 and N-S values were to 0.34 and 0.32, respectively. As with the field-scale simulations, individual events skewed the overall statistical evaluation. For example, when the May 1, 2003 and March 6, 2004 events are eliminated from statistical evaluation of all 48 events, the R^2 and N-S are improved to 0.38 and 0.35. The total sediment load was predicted within 33% (354 metric tons), and similar to hydrology, SWAT statistical measures were improved when the averaging period was longer.

5.2.3 Total Phosphorus Yield Calibration

Total P (TP) loss from the watershed was simulated on an event basis. A total of 48 events were sampled, and 35 of them were categorized as non-melt events (April 1 – November 30). Simulations were statistically compared to both total and non-melt only events. The simulated SWAT TP load was calculated from the sum of three separate modeled forms: organic, soluble, and mineral P. The amount of each form is given as a yield (kg/ha) within the subbasin output file (.bsb). The yield was then converted to a load (kg) by factoring in the contributing watershed area.

Calibration of TP used three SWAT input parameters as well as the addition of available TP from manure and fertilizer inputs. The initial labile P concentration (SOL_LABP) is located in the soil chemical input file (.chm), the P availability index (PSP) found in the basin input file (.bsn), and the P enrichment ratio for loading with sediment (ERORGP) is found in the HRU input file (.hru). Fertilizer and manure types, rates and dates are directed within the HRU management input file (.mgt).

The SOL_LABP, referred as soil P, was assigned an initial concentration of 40 mg/kg for all cropped land. Grassland areas were not given a soil P concentration. Although several areas noted on Pioneer Farm were well above 40 mg/kg, the concentration was used as representative of the entire UFRW. The P availability index (PSP) was increased from a default 0.40 to 0.60. Increasing the PSP increases the amount of P in solution after fertilization. The ERORGP was increased from a default 0 to 2.00 to increase the plant uptake of P. The ERORGP default value calculates the P enrichment ratio for each storm. A constant enrichment ratio value improved TP simulation. The P portioning coefficient (PHOSKD) was sensitive to calibration, but was left unchanged from the default 175 m^3/Mg. Previous Pioneer Farm soil sampling indicated the PHOSKD less than 100 m^3/Mg. Lowering the PHOSKD ratio results in an increase in the concentration of soluble P in runoff; however, SWAT was already over estimating TP based on the soil P concentration of 40 mg/kg.

Simulation of TP from the UFRW was similar to sediment. Statistically the correlation and efficiency were strongly influenced by a few events (Figure 26). Examination of the three yearly non-melt load totals (2003-2005) indicated a strong correlation and efficiency (R^2 of 0.96, N-S of 0.56) which indicated that P loss was successfully being simulated; however, the culmination of the three years of all 48 events indicated a strong correlation (0.68), but a poor efficiency (-35). This highlights the difficulty in predicting snowmelt runoff contribution from the watershed. Measured and simulated TP yields were slightly less than other studies in Wisconsin (Baumgart 2005, Kirsch *et al.* 2002). The annual P yield varied from 0.61 kg/ha in subwatershed 5 to 0.89 kg/ha in subwatershed 2 (Table 12). Generally, each simulated subwatershed contributed similar amounts of P to the watershed on an annual basis. The values from each subwatershed are similar to the phosphorus export rates for a similar agricultural setting as calculated by Panuska and Lillie (1995) for Wisconsin. The values from their study indicated an export of 0.74 kg/ha.

Table 12 - Scenario I Average Annual TP Loads and Yields per Subwatershed (2002 – 2005)

	Average Annual Simulated Total P Load (kg)	**Average Annual Simulated Total P Yield (kg/ha)**
Subwatershed 1	539.62	0.70
Subwatershed 2	678.11	0.89
Subwatershed 3	514.14	0.67
Subwatershed 4	582.14	0.76
Subwatershed 5	465.48	0.61
Subwatershed 6	612.98	0.80

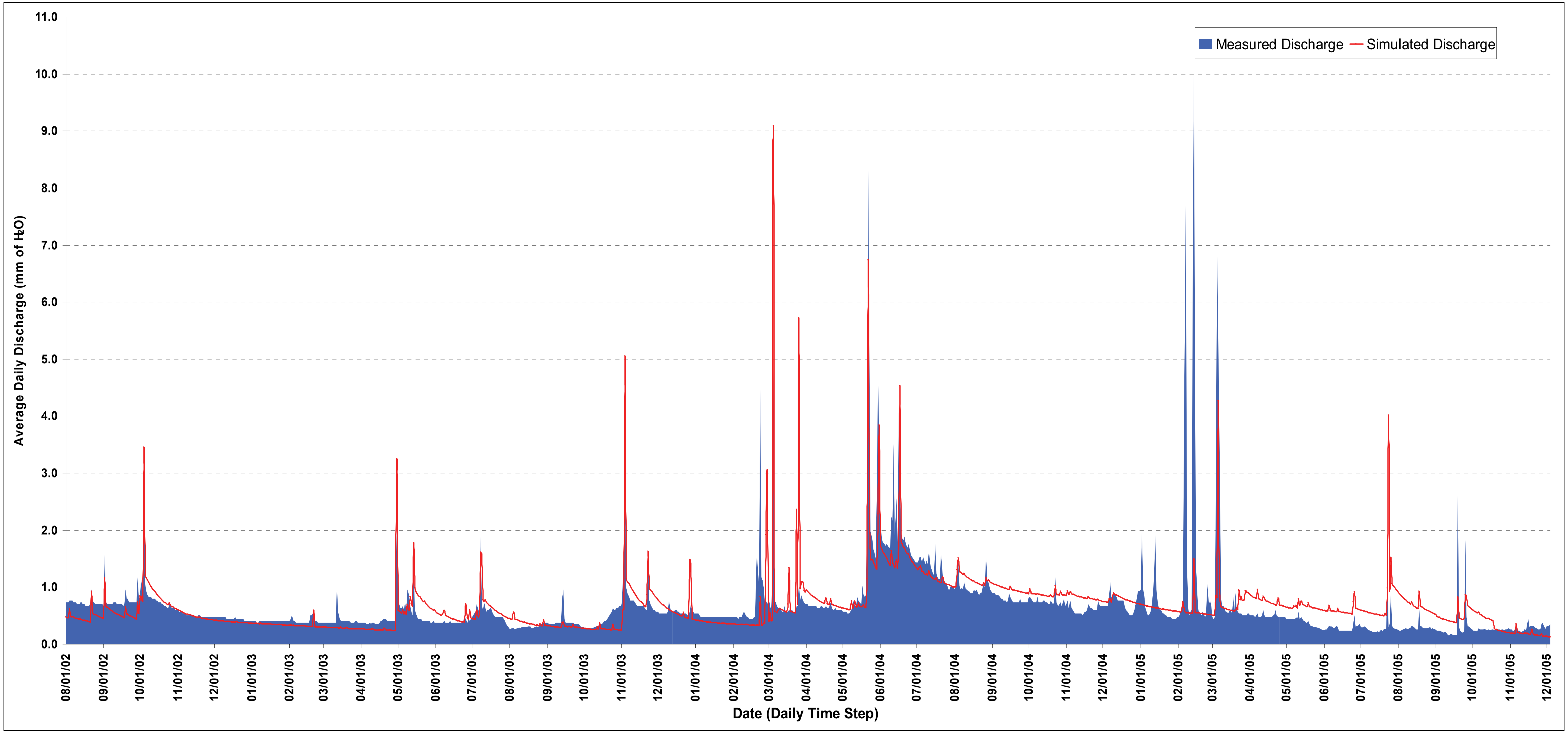


Figure 24 - Measured vs. Simulated Daily Discharge between August 2002 and December 2005 for the UFRW

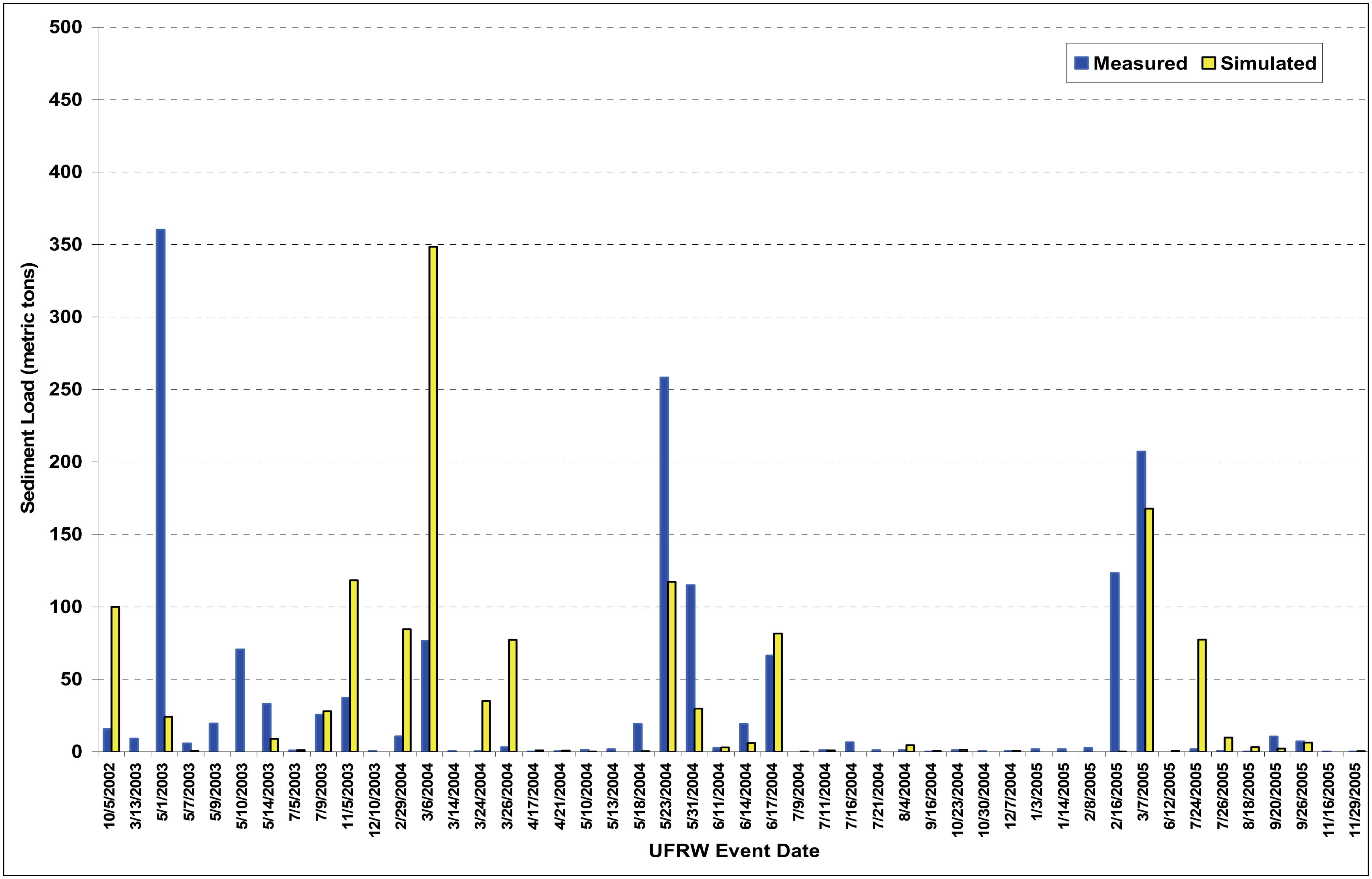


Figure 25 - Scenario I UFRW Sediment Load Calibration for all sampled events (48)

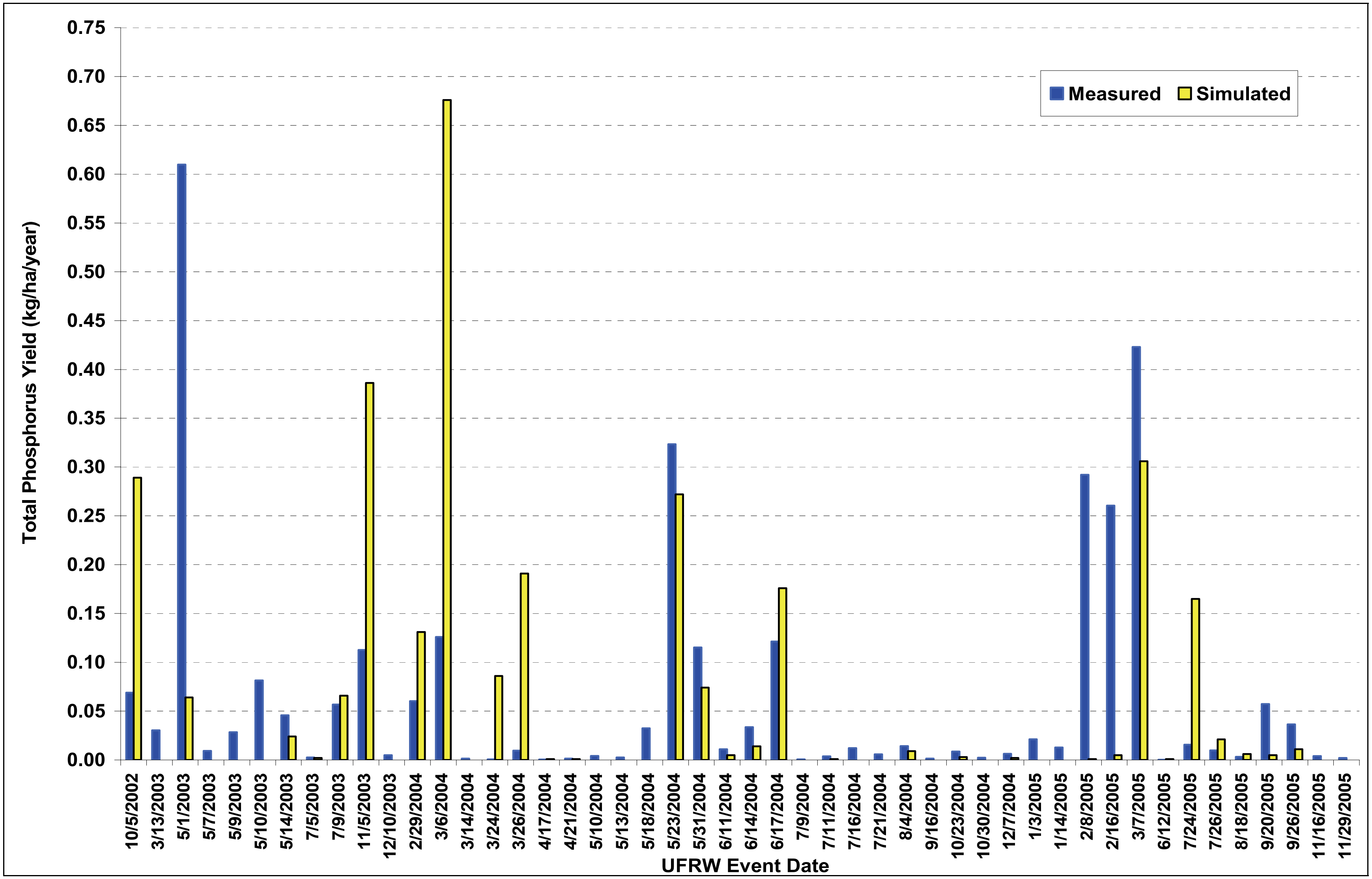


Figure 26- UFRW Total P Yield Calibration for all sampled events (48)

5.3 Event Based Watershed Calibration (Scenario II)

In addition to the overall watershed simulation (Scenario I), an event based simulation of the UFRW was conducted. This scenario calibrated to non-melt events using only those events where measured precipitation differed by less than 66% between the City of Platteville weather station and Pioneer Farm MET station. This scenario was developed to focus only on those events where precipitation was likely more uniform across the watershed. In addition, scenario II would illustrate differences in calibration between the overall watershed calibration and calibration to only runoff events. As with Scenario I, similar hydrologic, sediment, and total P SWAT input parameters were used in calibration. The SWAT model input parameters were calibrated to the events using PEST.

5.3.1 Discharge Calibration

Ninety-one discharge events were simulated with 66% or less precipitation difference between the two weather stations during the non-melt months between August 2002 and December 2005. The event measured discharge was measured at the UFRW outlet gauge station. Events were chosen by selecting non-melt days containing daily discharge significantly greater (≥ 0.003 cms) than baseflow. Baseflow contribution was calculated from the total discharge using a baseflow separation program. The entire storm occurred all in one day or multiple days. The events were calibrated using the same hydrologic parameters used in Scenario I. The NRCS CN for row crops remained significantly lower (35) than that of the default value (77); however, the CN values for alfalfa and grass increased from a default of 59 to 83 and 69 respectively. One explanation for this result is that the best-fit calibration was obtained by predicting higher infiltration on most of the watershed, but higher runoff for a smaller portion of the watershed. Because most of the watershed was in corn and soybean, the CN for those HRUs was estimated to provide for greater infiltration, but a smaller portion of the watershed was in alfalfa and grass, and that was allowed to have higher runoff. An acceptable simulation fit was identified when soil properties AWC and SOLK remained at their respective NRCS default values, 0.22 mm/mm and 32.4 mm/hr. The ESCO value was decreased from both default and Scenario I values to 0.10. As a result of calibrating to only non-melt events, snowmelt parameters were not changed between the two watershed scenarios. Groundwater parameters were also maintained between the two scenarios for consistency purposes. The success of the scenarios simulation was determined using both the ninety-one events and overall discharge comparisons from the watershed during the calibration period.

The simulation of the ninety-one non-melt events was successful. The increase of the NRCS CN for grassland and the SOLK and AWC of the entire watershed allowed for less infiltration and more overland runoff. As a result, events were better simulated (Figure 27). The ninety-one events had a correlation and efficiency of 0.75 and 0.68, respectively. The simulated non-melt total discharge was 1 percent less than measured and the discharge for all simulated days was 19 percent lower than measured values. As indicated in previous sections, the influence of individual storm events can impact the statistical relevance of the simulation.

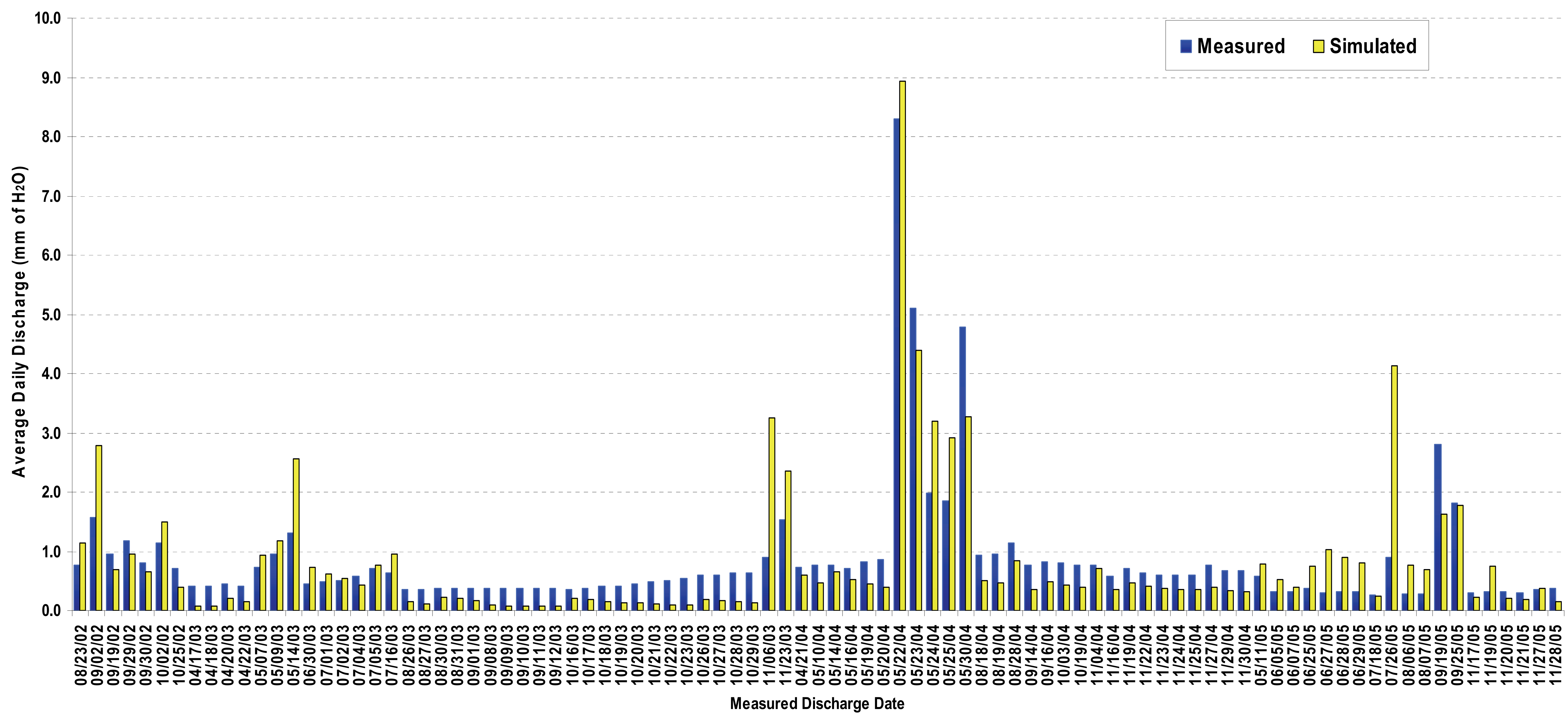


Figure 27 - Simulated vs. Measured Discharge for 91 Non-melt Events with ≤ 66% Precipitation Difference (Scenario II)

In addition, events varied in the simulation of flow, some events were overestimated and others were underestimated. When the simulated flow from Scenario I was statistically compared to the ninety-one events a correlation and efficiency of 0.82 and 0.79 was determined. The statistical significance of this shows the importance precipitation as a catalyst for the SWAT simulation.

5.3.2 Sediment Load Calibration

As with Scenario I, sediment load from the UFRW was simulated for all 48 measured events and for 35 non-melt events. The same input parameter set used for Scenario I was altered for this calibration. The USLE_P value for the agricultural landscape was changed from the default (1.00) to 0.10. The USLE_P value for grassland and farmsteads was left unchanged from the default 1.00. While these values may not reflect the recommended USLE_P values based on land management, the calibrated values aid in containing the sediment on the landscape. The USLE_K value increased from a default 0.32 to 0.65. The tributary Manning's n value and the average width of the channel were calibrated the same value as used with Scenario I. The APM (.bsn) parameter was increased from a default 1.00 to 1.80 to promote additional sediment that was being lost through simulated events.

Simulation of sediment using an event based calibration yielded improved results from the overall watershed calibration. Examination of all measured sediment samples (48), non-melt sediment samples (35), and non-melt sediment samples occurring with a precipitation error of ≤ 66% (9) were all proved relatively successful in comparison to Scenario I. The simulation of all 48 sediment events had a correlation and efficiency of

0.12 and -0.38, respectively, and the total sediment load for the simulated time period was over simulated by 203 metric tons (Figure 28). The over estimated sediment yield was reflective of the inability of SWAT to simulate the correct sediment load on March 6th, 2004 which was over estimated by 384 metric tons. Had other events, such as the May 1st, 2003 event, not under estimated sediment, the March 6th, 2004 over estimated load could be accounted for by decreasing the APM or USLE_P values. The non-melt sediment load set was not influenced by the March 6th, 2004, under predicted sediment by 263 metric tons and yielded a correlation and efficiency of 0.18 and 0.16, respectively. Examination of the 9 non-melt sediment events with less than 66% variation in precipitation was somewhat statistically successful. The accuracy of a single large event on May 23, 2004 determined the statistical significance (R^2 = 0.98, N-S = 0.38) of the eight smaller events for the sample set without precipitation variation.

5.3.3 Total Phosphorus Yield Calibration

As with Scenario I, TP yield from the UFRW was simulated for all 48 measured TP yield events, including 35 non-melt TP yield events (Figure 29). The event based calibration of TP in the UFRW employed a similar set of input parameters as Scenario I. The SOL_SOLP value in the soil remained at 40 mg/kg in both scenarios. The PSP was decreased from a 0.60 in Scenario I to 0.55 in Scenario II. One additional parameter was used in the calibration of total P on an event basis: the P enrichment ratio for loading with sediment (ERORGP). The ERORGP was increased from a default 0 to 2.00 to increase the plant uptake of P.

Calibrating to the events using similar input parameters as in Scenario I originally led to an over prediction of TP. An examination of the three simulated fractions defining

TP indicated that the organic fraction was significantly higher than the mineral and soluble fractions during larger events. Organic P is directly tied to sediment within SWAT (Figure 30). In order to decrease the organic fraction of TP, the ERORP was increased and the APM parameter for peak sediment routing was decreased to hold additional sediment on the landscape.

Simulation of all measured TP samples (48), non-melt TP samples (35), and non-melt TP samples containing a precipitation error ≤ 66% (9) generated results slightly better than Scenario I. Simulation of daily P export versus all melt/non-melt events (48) simulated a TP yield within 2.3% of the measured yield, yet the correlation and efficiency were poor, 0.24 and 0.12. During non-melt months, TP was over estimated by 2% resulting in correlation and efficiency of 0.20 and 0.13. Of the 9 events with ≤ 66% precipitation variation, the TP was simulated with a correlation of 0.98 and efficiency of 0.95. Comparison of non-melt events only under simulated the TP Load (76 kg). The yearly simulated TP was underestimated (255 kg). As with Scenario I, Subwatersheds 2 and 6 had an elevated TP yield and load; however, the values were less than Scenario I (Table 13).

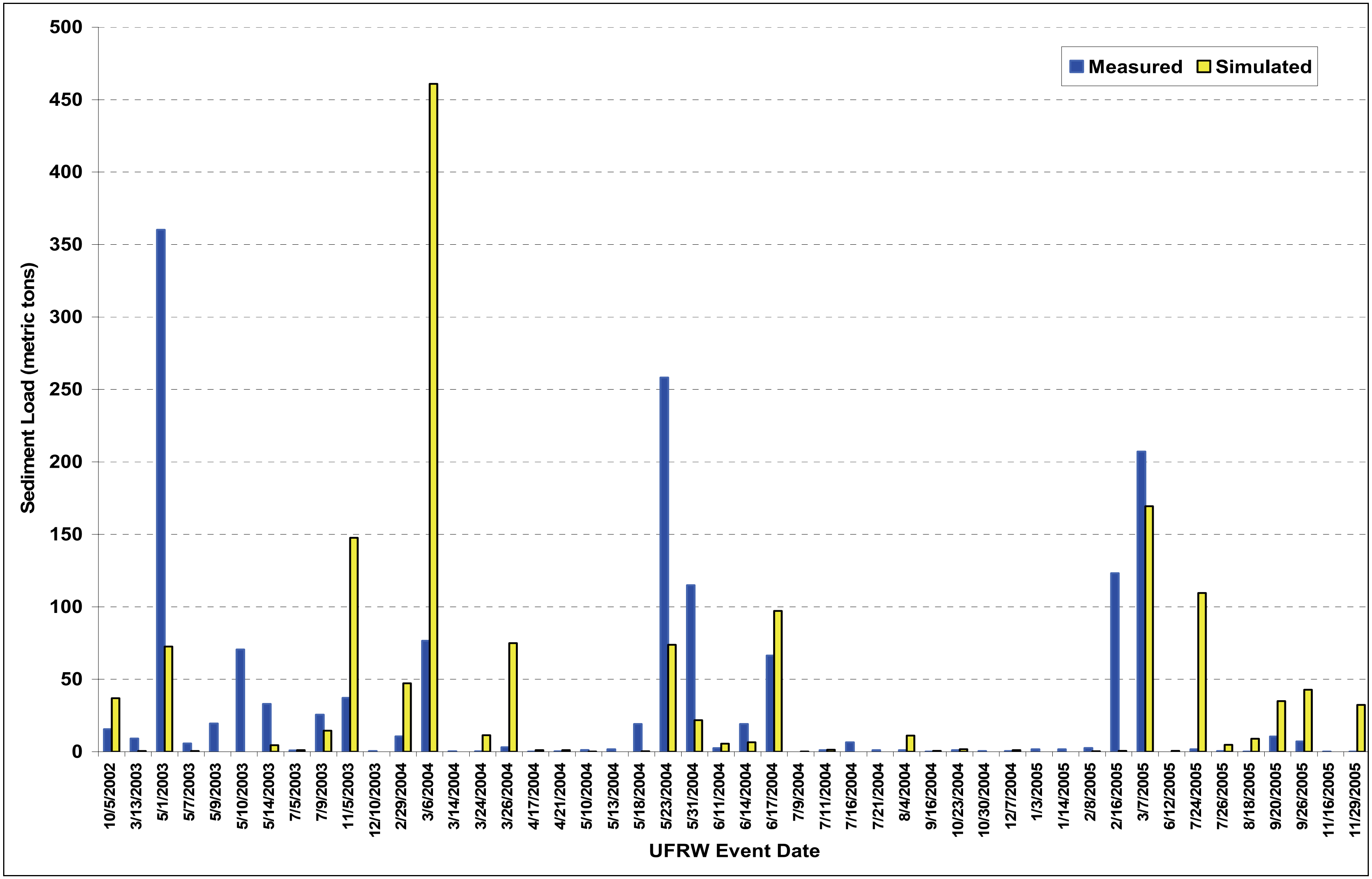


Figure 28 - Scenario II UFRW Sediment Load Calibration for all sampled events (48)

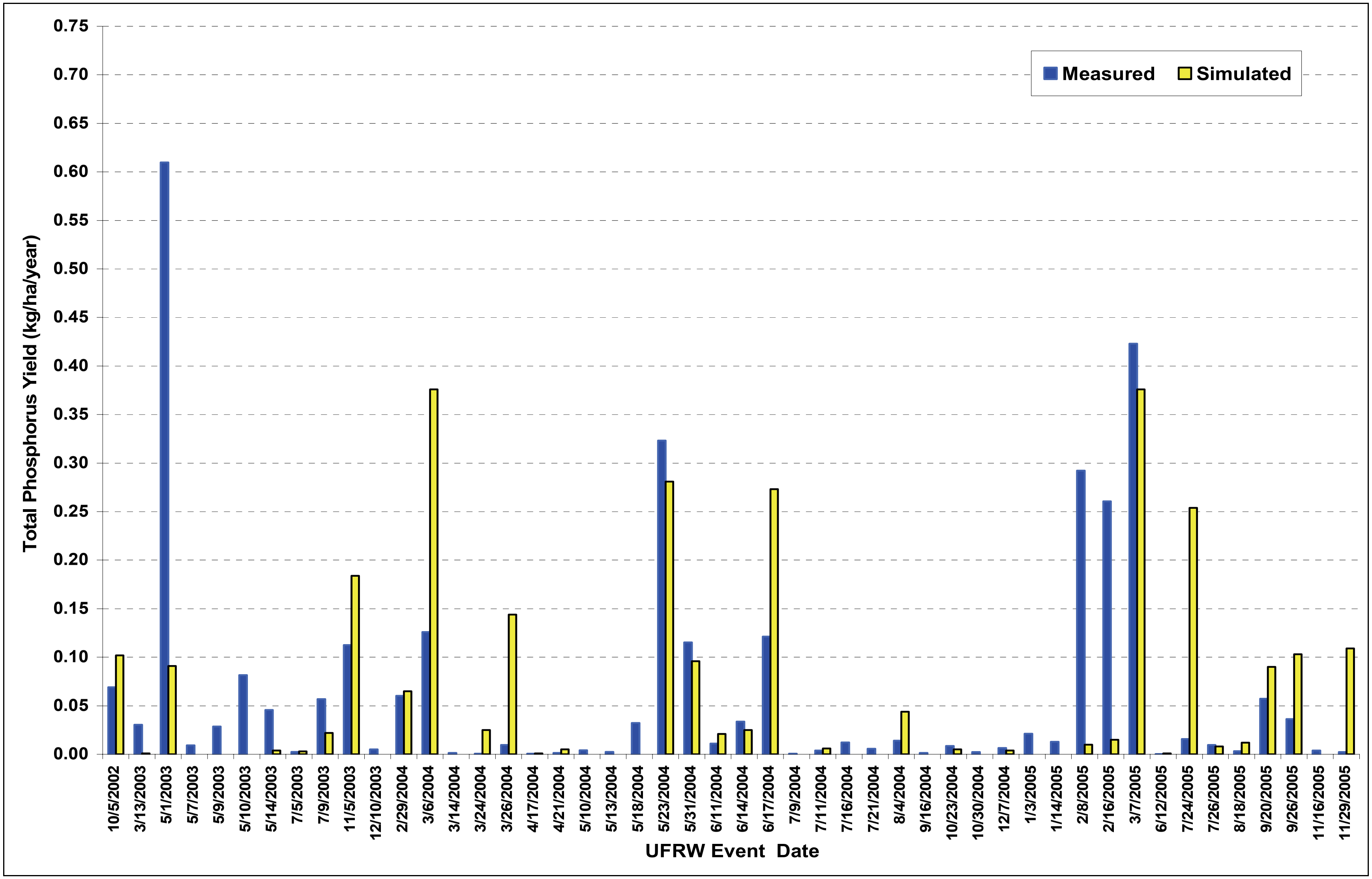


Figure 29 - Scenario II UFRW Total P Yield Calibration for all sampled events (48)

Table 13 - Scenario II Average Annual TP Loads and Yields per Subwatershed (2002 – 2005)

	Average Annual Simulated Total P Load (kg)	Average Annual Simulated Total P Yield (kg/ha)
Subwatershed 1	222.02	0.29
Subwatershed 2	649.95	0.85
Subwatershed 3	296.91	0.39
Subwatershed 4	258.03	0.34
Subwatershed 5	279.10	0.36
Subwatershed 6	517.21	0.68

5.4 Watershed-Scale Conclusions

Increasing the scale of simulation from individual fields to the UFRW proved challenging, yet provided insight into SWAT application and user input parameter interpretation. The UFRW was simulated using 6 subwatersheds and 30 HRUs.

Calibration at the field-scale relied on input variables similar to the field measured default SWAT values. At the watershed-scale the input parameters had to be adjusted by a larger percentage to simulate discharge, sediment, and P (Tables Table 14 and Table 15). Both scenarios required the manipulation of the NRCS CN row crop value from the recommended 77 to a value of 35. The NRCS CN change to 35 represents the need for greater infiltration as well as the effects of field aggregation through the loss of ephemeral flow paths and possible drainage sinks. The SWAT's simulation of the landscape is important in determining how input parameters must change to accommodate SWAT's portrayal.

The low TP yield from each subwatershed is likely due to the baseflow dominated nature of the UFRW and the fact that approximately 58% of the stream network is ephemeral. The transport of sediment and TP from edge-of-field to stream is difficult to simulate because of the variable sources and sinks within the watershed and the aggregation of analogous landuse and soil types into single HRUs.

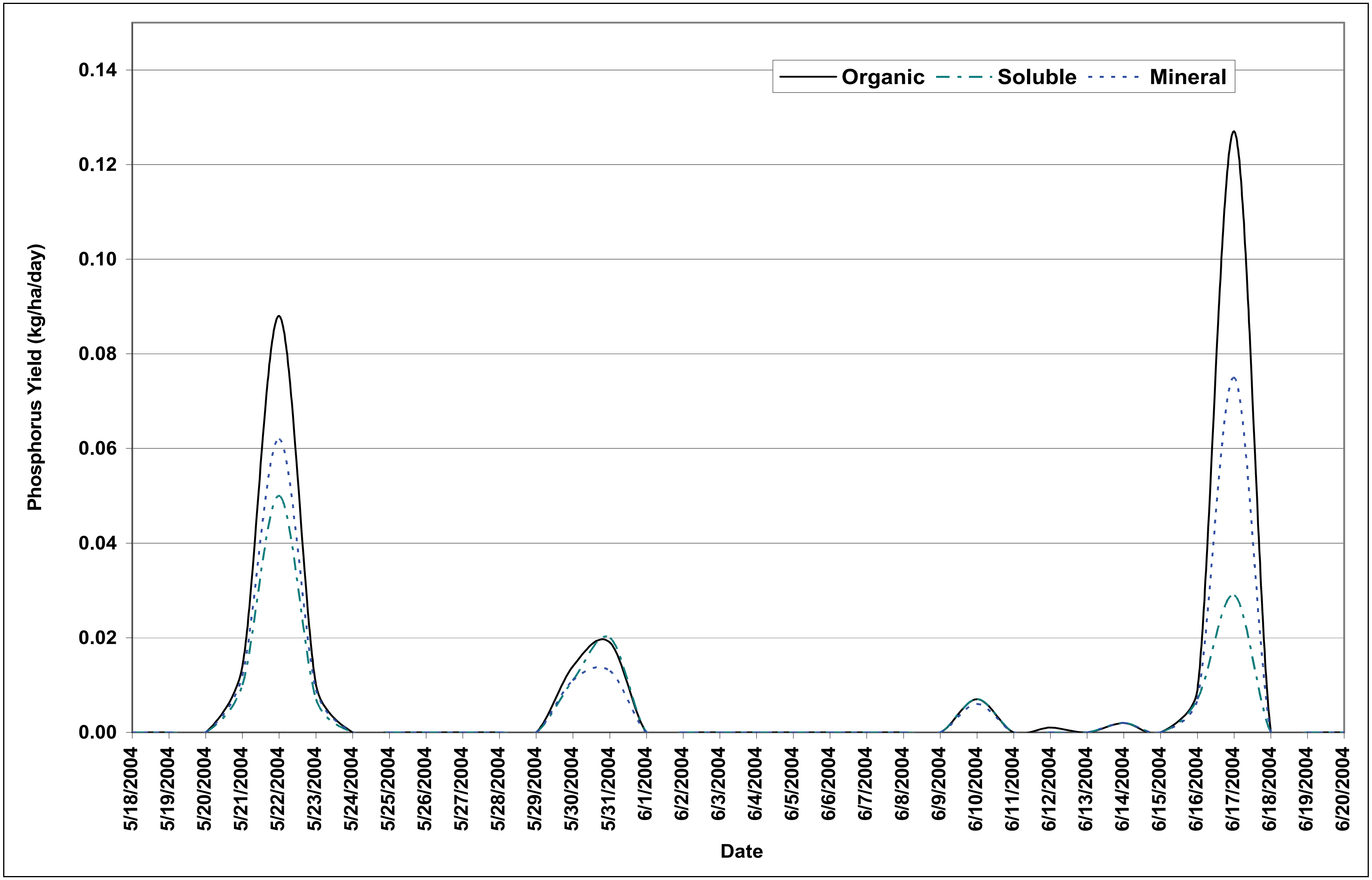


Figure 30 - Simulated P Fractions between 5/18/2004 and 6/20/2004 Using Event Based Calibration

In Scenario I, statistical evaluation was acceptable for daily discharge and poor for event simulated sediment and TP. Temporal aggregation and seasonal comparison improves the statistical evaluation of discharge. Simulated daily discharge held a correlation and efficiency of 0.33 and 0.29. If snowmelt contributed discharge was eliminated, the correlation and efficiency improved to 0.64 and 0.63. Aggregation of daily discharge into a monthly summary provided a correlation and efficiency of 0.53 and 0.53 and a correlation and efficiency of 0.74 and 0.72 for non-melt days (April – November) only.

Simulating discharge, sediment load, and total P yield using non-melt events with ≤ 66% precipitation difference (Scenario II) did not significantly improve the strength of the SWAT simulation. Calibration parameters for discharge used in Scenario II differed somewhat in comparison to Scenario I. The NRCS CN for cropped agriculture remained at the minimum value of 35. It is unclear if this was a result of having too many small events or the need to simulate the appropriate baseflow contribution to event flow. Another impact is the use of the daily time step within SWAT to aggregate storm intensities into a single daily value which may skew runoff events. The ESCO was decreased considerably from the default and Scenario I value to 0.10. The ESCO decrease allows lower soil layers to compensate for water deficits in the upper layers, resulting in higher soil evaporation. The ESCO variable calibration is dependent on the potential evapotranspiration equation being used.

Scenario II simulated discharge for the ninety-one unbiased precipitation events with strong statistical confidence. The non-melt days and total discharge were simulated with poor correlation and efficiency. The composition of flow may have skewed the results as the calibration examined only the ninety-one events. Acknowledgement of the groundwater regime using a modified set of groundwater input variables different from Scenario I did not produce a stronger simulation. Simulated sediment load and TP yield per sampled event was not statistically strong, but total sediment load and TP yield over the entire given time period was acceptable. Calibrating to individual events rather than continuous extrapolated load and yield may be the cause of poor correlation and efficiency. Determination of the contribution of each P fraction was important in calibrating the TP. Since the organic P fraction was the largest contributor of TP yield, sediment loading had to be decreased since organic P and sediment are directly correlated. Of the ninety-one discharge events with unbiased precipitation, only 9 events of the 48 total were collected during days without precipitation variation. As a result, determining the success of the event based simulation on sediment and P was problematic. The 9 events indicated that sediment and total P were under estimated.

In the end there was no clear difference between the two calibration scenarios at the watershed-scale (Tables 16, 17, and 18). Both scenarios performed better when precipitation variation was considered for non-melt events highlighting the importance of unbiased precipitation to better simulate the storm events. Scenario I predicted total discharge much better as the acknowledgement of baseflow in calibration yielded improved results. Scenario I also provided a better simulation of sediment. Scenario II simulation of TP prediction was statistically more significant than Scenario I. Calibration to individual sediment and P samples may be the cause of simulation difficultly in both scenarios.

Table 14 - Scenario I SWAT Calibrated Parameters for Discharge, Sediment, and P

Constituent	SWAT Variable	Description	Default Value	Calibrated Value
Flow	CNOP (Row Crop)	Curve Number - Row Crops	77	35
	CNOP (Alfalfa)	Curve Number - Alfalfa	59	35
	CNOP (Grass)	Curve Number - Grassland	59	65
	CNOP (Tillage)	Curve Number - Tillages	---	45
	SOL_K	Soil Hydraulic Conductivity (mm/hr)	32.40	9.79
	SOL_AWC	Soil Available Water Capacity (mm/mm)	0.22	0.26
	ESCO	Evapotranspiration Coefficient	0.95	0.77
	GW_DELAY	Groundwater Delay Time (days)	31	94.58
	ALPHA_BF	Base Flow Alpha Factor (days)	0.0480	0.0076
	GW_REVAP	Groundwater Revap Coefficient	0.02	0.10
	REVAPMN	Threshold Deptth for Percolation (mm)	1.00	80.00
Snowmelt	SMTMP	Snow Melt Base Temperature (°C)	0.50	1.12
	SMFMX	Snow Melt Factor on June 21 (mmH$_2$0/°C-day)	4.50	0.002
	SMFMN	Snow Melt Factor on December 21 (mmH$_2$0/°C-day)	4.50	3.63
	SNOCOVMX	Minimum snow water content (mm H$_2$0)	1.00	4.69
	SNO50COV	Fraction of snow volume	0.50	0.11
	TIMP	Snow Pack Temperature Lag Factor	1.00	0.88
Sediment	USLE_P (Crop)	USLE equation support practice factor for Crops	1.00	0.10
	USLE_P (Grass)	USLE equation support practice factor for Grassland	1.00	0.90
	USLE_K	USLE Soil Erodibility Factor	0.32	0.65
	APM	Peak Adjustment for Sediment Routing	1.00	1.90
	CH_N	Mannings "n" for Tributary Channels	0.014	0.010
Phosphorus	SOL_SOLP (LABP)	Initial Soluble Phosphorus Concentration in Soil (mg/kg)	0.00	40.00
	ERORGP	Organic P Enrichment Ratio for Loading with Sediment	0.00	2.00
	PSP	Phosphorus Availability Index	0.40	0.60

Table 15 - Scenario II SWAT Calibrated Parameters for Discharge, Sediment, and P

Constituent	SWAT Variable	Description	Default Value	Calibrated Value
Flow	CNOP (Row Crop)	Curve Number - Row Crops	77	35
	CNOP (Alfalfa)	Curve Number - Alfalfa	59	83
	CNOP (Grass)	Curve Number - Grassland	59	69
	CNOP (Tillage)	Curve Number - Tillages	---	45
	SOL_K	Soil Hydraulic Conductivity (mm/hr)	32.40	32.40
	SOL_AWC	Soil Available Water Capacity (mm/mm)	0.22	0.22
	ESCO	Evapotranspiration Coefficient	0.95	0.10
	GW_DELAY	Groundwater Delay Time (days)	31	94.58
	ALPHA_BF	Base Flow Alpha Factor (days)	0.0480	0.0076
	GW_REVAP	Groundwater Revap Coefficient	0.02	0.10
	REVAPMN	Threshold Deptth for Percolation (mm)	1.00	80.00
Snowmelt	SMTMP	Snow Melt Base Temperature (°C)	0.50	1.12
	SMFMX	Snow Melt Factor on June 21 (mmH$_2$0/°C-day)	4.50	0.002
	SMFMN	Snow Melt Factor on December 21 (mmH$_2$0/°C-day)	4.50	3.63
	SNOCOVMX	Minimum snow water content (mm H$_2$0)	1.00	4.69
	SNO50COV	Fraction of snow volume	0.50	0.11
	TIMP	Snow Pack Temperature Lag Factor	1.00	0.88
Sediment	USLE_P (Crop)	USLE equation support practice factor for Crops	1.00	0.10
	USLE_P (Grass)	USLE equation support practice factor for Grassland	1.00	1.00
	USLE_K	USLE Soil Erodibility Factor	0.32	0.65
	APM	Peak Adjustment for Sediment Routing	1.00	1.80
	CH_N	Mannings "n" for Tributary Channels	0.014	0.010
Phosphorus	SOL_SOLP (LABP)	Initial Soluble Phosphorus Concentration in Soil (mg/kg)	0.00	40.00
	ERORGP	Organic P Enrichment Ratio for Loading with Sediment	0.00	2.00
	PSP	Phosphorus Availability Index	0.40	0.55

The dominant contribution of baseflow to total discharge and the lumping of individual fields into HRUs are likely the two largest problems facing the SWAT calibration of the UFRW. The watershed daily discharge and sample based sediment and TP calibration of the UFRW proved difficult using both scenarios methodology.

SWAT reasonably simulated field and watershed-scale discharge, sediment, and P. The simplistic single HRU field-scale simulations used values representative of the recommended default values for the region. The watershed-scale simulation deviated from the default and field-scale simulation. The cause of this was likely the way SWAT handles the delivery mechanism of discharge, sediment, and nutrients from the edge-of-field to stream reach. Within the UFRW, the discharge that leaves S2 is routed through several fields before nearing the stream reach. During that time the discharge has time to infiltrate into the soil and become baseflow. That is not considered in a SWAT simulation as SWAT lumps the field characteristics of S2 with other similar land and directly routes the water into the stream reach and does not account for landscape variation. Disregarding an HRU's distance to stream and HRU interactions impacts the validity the SWAT model has in locating areas of greater TP loss. SWAT needs to take into account the landscape position. Even with detailed input datasets, SWAT is unable to translate representative edge-of-field loss to the reach dependent on landscape position.

Table 16 - Comparison of Discharge over varying temporal scales between Scenarios I& II

	Non-Melt Days (April - Nov)			Non-Melt Events w/o Precipitation Variation			Total Daily Discharge			Average Non-Melt Monthly Discharge		
	R^2	N-S	% Error	R^2	N-S	% Error	R^2	N-S	% Error	R^2	N-S	% Error
Overall Calibration (Scenario I)	0.64	0.63	8.8	0.82	0.76	15.0	0.33	0.29	0.5	0.74	0.72	9.0
Non-Melt Event Calibration with ≤ 66% Precipitation Error (Scenario II)	0.4	-0.57	1.4	0.75	0.68	2.9	0.23	-0.36	19.0	0.48	0.30	1.9

Table 17 - Comparison of Sediment Load over varying temporal scales between Scenarios I & II

	Total Sediment Load			Non-melt Sediment Load (April - Nov)		
	R^2	N-S	% Error	R^2	N-S	% Error
Overall Calibration (Scenario I)	0.13	-0.12	5.4	0.34	0.32	5.8
Non-Melt Event Calibration with ≤ 66% Precipitation Error (Scenario II)	0.12	-0.38	13.4	0.18	0.16	24.3

Table 18 - Comparison of TP Yield over varying temporal scales between Scenarios I & II

	TP Yield			Non-melt TP Yield (April - Nov)		
	R^2	N-S	% Error	R^2	N-S	% Error
Overall Calibration (Scenario I)	0.12	-0.4	4.0	0.16	-0.04	9.8
Non-Melt Event Calibration with ≤ 66% Precipitation Error (Scenario II)	0.24	0.12	2.3	0.20	0.13	1.9

6.0 Relationship between SWAT and Wisconsin P Index

6.1 Wisconsin P Index

The development of a phosphorus index (P Index) was the result of the USDA-NRCS request for a tool to determine areas where P movement from the landscape was more likely to occur. The first P Index was developed in 1993 using a weighted procedure based on site specific characteristics to develop a relative potential risk of P loss (Lemunyon and Gilbert, 1993). Several states have since developed state specific P Index tools. Wisconsin developed a P Index tool that assesses the potential risk of a cropped or grazed field to contribute P to the nearest perennial waterway (WI P Index 2007). The Wisconsin P Index (WI P Index) assists Wisconsin's agricultural community in becoming better stewards of the landscape through nutrient management planning. Nutrient management plans are required as part of NRCS Code 590 (NRCS 590) as a way to curb excessive nutrient loss from the landscape. As required by NR 590, the WI P Index is used determine if manure application is allowable based on the risk of P loss.

The WI P Index requires information similar to that needed for a nutrient management plan including Bray-1 soil P test, fertilizer types, rates and timing, manure types, rates, and timing, crop, tillage, slope length, and distance to waterway. The WI P Index relies on equations that are derived from Wisconsin research. The WI P Index calculates the P risk using the following equation:

P Index = *[Edge-of-field Particulate P Loss + Edge-of-field Dissolved P Loss + Acute P Losses from surface applications of manure / fertilizer] * Total P Delivery Ratio (Includes Slope and Distance to Stream)* [3]

The WI P Index uses RUSLE2, a revised version of the USLE equation to calculate sediment loss (particulate P loss). The WI P Index calculates dissolved P loss using annual runoff volume (unique to each county), soil soluble P, and extraction efficiency determined by the NRCS hydrologic soil group. Acute losses are determined for events on both frozen and non-frozen ground events. A total P delivery is factored into the P Index after all the edge-of-field contributions have been considered. The WI P Index output is calculated as total P in lbs/acre/year; however, the use of a risk index has been generally accepted throughout the state of Wisconsin. A complete list of the calculations and assumptions used for WI P Index is found at Wisconsin's P Index website (http://www.snapplus.net/).

The WI P Index is a P export in lbs/ac/yr to the edge of field. Currently the WI P Index is being improved in the numerical quantification an annual total P load being contributed from edge-of-field / farm. For general use between all sectors, the WI P Index uses a numerical scale to describe annual P delivery risk (Table 19). Previous field-scale studies conducted through out the state of Wisconsin indicate that the WI P Index is reflective of P loss with varying management and landscape factors (Ward Good and Bundy, 2006). A major benefit of the WI P Index is that the risk factors in the distance to a perennial waterway using a delivery multiplication factor, a control that the SWAT model current does not use. This is the first comparison of SWAT and WI P Index. It creates the opportunity to contrast the two models and examine how they might be used in TMDL management of Wisconsin's watersheds.

Table 19 - P Index Values Related to Potential P Delivery Risk

P Index Range	Potential for P Delivery to Perennial Waterway
0 - 2	Low to Medium
2 – 4	Medium to High
4 - 6	High to Excessive
≥ 6	Excessive

(*WI Phosphorus Index 2007*)

6.2 SWAT and Wisconsin P Index at the Field-Scale

The SWAT and WI P Index models were compared to edge-of-field datasets collected from stations S2, S3, and S4 at the UW-Platteville Pioneer Farm. Each station's measured events were aggregated into a yearly total (2002 – 2005) output. S2 and S3 were single crop fields and S4 consisted of 11 contour stripped fields contributing to a single outlet. The measured dataset was the same used for simulation comparison in Section 4.0.

The WI P Index tool was applied to all fields contributing to monitoring stations S2, S3, and S4. The WI P Index model input was developed using Pioneer Farm management information and was setup by Laura Ward Good of University of Wisconsin at Madison and Chris Baxter of University of Wisconsin at Platteville. Sites S2 and S3 were based on a single field P Index and site S4 had multiple fields from which an area weighted P Index was calculated (Appendix H). Two separate P Index values were derived per year per field. The first P Index was based on non-melt contributions only, thus excluding the acute frozen ground manure loss. The second P Index represented all P loss (melt and non-melt) and included the entirety of Equation 3. The total P delivery ratio, which is based on distance to stream and slope, was examined all fields. A P index increase of 5 – 10 percent was simulated when the delivery component was standardized using a distance to stream of 0 to 91.44 meters for each field. As a result of the negligible increase, the measured distance to stream value ranges were used.

A melt/non-melt event, all year SWAT model simulation was created for comparison with the WI P Index. The SWAT model calibrated each field to all events (melt and non-melt). The SWAT was calibrated to event discharge, sediment and total P between 2002 and 2005 using PEST autocalibration. The all event field-scale calibration adjusted the same parameters as the non-melt calibration in Section 4.0 and added the snowmelt parameters. The same management scenarios, weather dataset, potential evapotranspiration routine, and manure/fertilizer applications were used as in the non-melt model in Section 4.0. Calibration was performed separately for each field. Groundwater parameters were again eliminated from the calibration process (Table 17). The event discharge, sediment, and total P were satisfactorily simulated for each field-scale basin (Table 18). Similar to the previous event calibrations, single events greatly impacted statistical significance.

Comparison of SWAT and the WI P Index outputs for the three field watersheds during the four measured years (2002 – 2005) shows a similar trend between SWAT simulated P yield and the WI P Index P loss risk (Figure 31). SWAT's predicted non-melt total P yield was similar to the measured dataset (Table 19). Climatological variability impacts the accuracy between SWAT and the WI P Index and the measured edge-of-field TP loss. The correlation between the WI P Index and SWAT shows a similar trend between changes in crops from year to year.

The calibrated SWAT model was used to simulate total P yield from field-scale watersheds S2, S3, and S4 over a long term (25-year) period (Figure 32). The all event calibrated SWAT model used the City of Platteville weather station dataset because it contained historic (1936 to present) daily precipitation, maximum and minimum air temperature. A six year rotation was simulated for each field and then offset one year. For example, a simulation was run from 1994 to 2005, then 1993 to 2004, and so on 1970 to 1981 to simulate the variability in P yield with climatological variability. The first rotation (6 year) of the 12 year cycle was dismissed as a warm-up period for the model. For statistical evaluation a year corn and alfalfa (typically the second consecutive year if possible) was picked from the second six-year rotation. The representative year of corn and alfalfa had 25 separate P yields that were averaged together for a separate average total P yield for corn and alfalfa. Field basin S4 had multiple HRUs and therefore used area weighted averaging to calculate the total P yield for corn and alfalfa since some years had two HRUs growing corn and one with alfalfa.

A positive correlation exists between measured, SWAT simulated, and the WI P Index's perceived risk of loss. The averaging of TP from SWAT over 25 years represents a long term precipitation average, much like what the WI P Index assumes. Both SWAT and the WI P Index rely on a version of the USLE to predict soil loss. The results show both the SWAT and WI P Index model can be used to estimate to work towards P loss. For example, SWAT can be used to indicate subwatersheds of concern and the WI P Index can be applied to farms/fields within the subwatersheds to locate those with the greatest relative risk.

The long term climatological simulation using SWAT resulted in average corn total P export between 2 and 6 kg/ha/yr and alfalfa total P export between 0.17 and 0.69 kg/ha/yr. The 25 year average of annual TP yield resulted in more variability in corn annual yield values than the alfalfa, likely due to the greater impact of precipitation on a corn field than alfalfa as well as the introduction of manure on corn fields (Figure 32). Historically field-watershed S3 has yielded a greater P export and also contains a higher soil P level than field-watershed S2, yet S2 has a higher average P output than S3 over the 25 year average. The simulation of the two fields did not acknowledge different crop residues and tillages, which may explain field-watershed S2's elevated average TP export in comparison to S3. It may also be due to the fact the forage rotations differ between the two fields and the first year of corn for S2 occurred in 2002, a year of increased precipitation.

Table 17: Calibrated SWAT Input Parameters for All (Melt and Non-melt) Measured Field-Scale Events

Constituent	SWAT Variable	Description	Default Value	S2 All Event Calibration	S3 All Event Calibration	S4 All Event Calibration
Flow	CNOP (Row Crop)	Curve Number - Row Crops	77	74	57	75
	CNOP (Alfalfa)	Curve Number - Alfalfa	59	59	69	71
	CNOP (Tillage)	Curve Number - Tillages	---	73	65	53, 83, 61
	SOL_K	Soil Hydraulic Conductivity (mm/hr)	32.40	32.40	32.29	44.61
	SOL_AWC	Soil Available Water Capacity (mm/mm)	0.22	0.22	0.26	0.32
	ESCO	Evapotranspiration Coefficient	0.95	0.76	0.84	0.75
Snowmelt	SMTMP	Snow Melt Base Temperature (°C)	0.50	1.04	3.36	-2.44
	SMFMX	Snow Melt Factor on June 21 (mm$H_2$0/°C-day)	4.50	8.22	0.0043	4.50
	SMFMN	Snow Melt Factor on December 21 (mm$H_2$0/°C-day)	4.50	3.69	2.26	5.15
	TIMP	Snow Pack Temperature Lag Factor	1.00	0.98	1.00	1.00
	SNOCOVMX	Minimum snow water content (mm H20)	1.00	1.00	0.85	1.00
	SNO50COV	Fraction of snow volume	0.50	0.02	0.50	0.50
Sediment	USLE_P (Crop)	USLE equation support practice factor for Crops	1.00	0.40	0.25	0.15
	APM	Peak Adjustment for Sediment Routing	1.00	1.00	1.00	0.55
TP	SOL_SOLP (LABP)	Initial Soluble Phosphorus Concentration in Soil (mg/kg)	0.00	40.00	100.00	100.00
	PSP	Phosphorus Availability Index	0.40	0.35	0.42	0.40
	ERORGP	Organic P Enrichment Ratio for Loading with Sediment	0.00	0.00	2.00	0.00
	PHOSKD	Phosphorus Partioning Coefficient	175.00	100.00	100.00	125.00

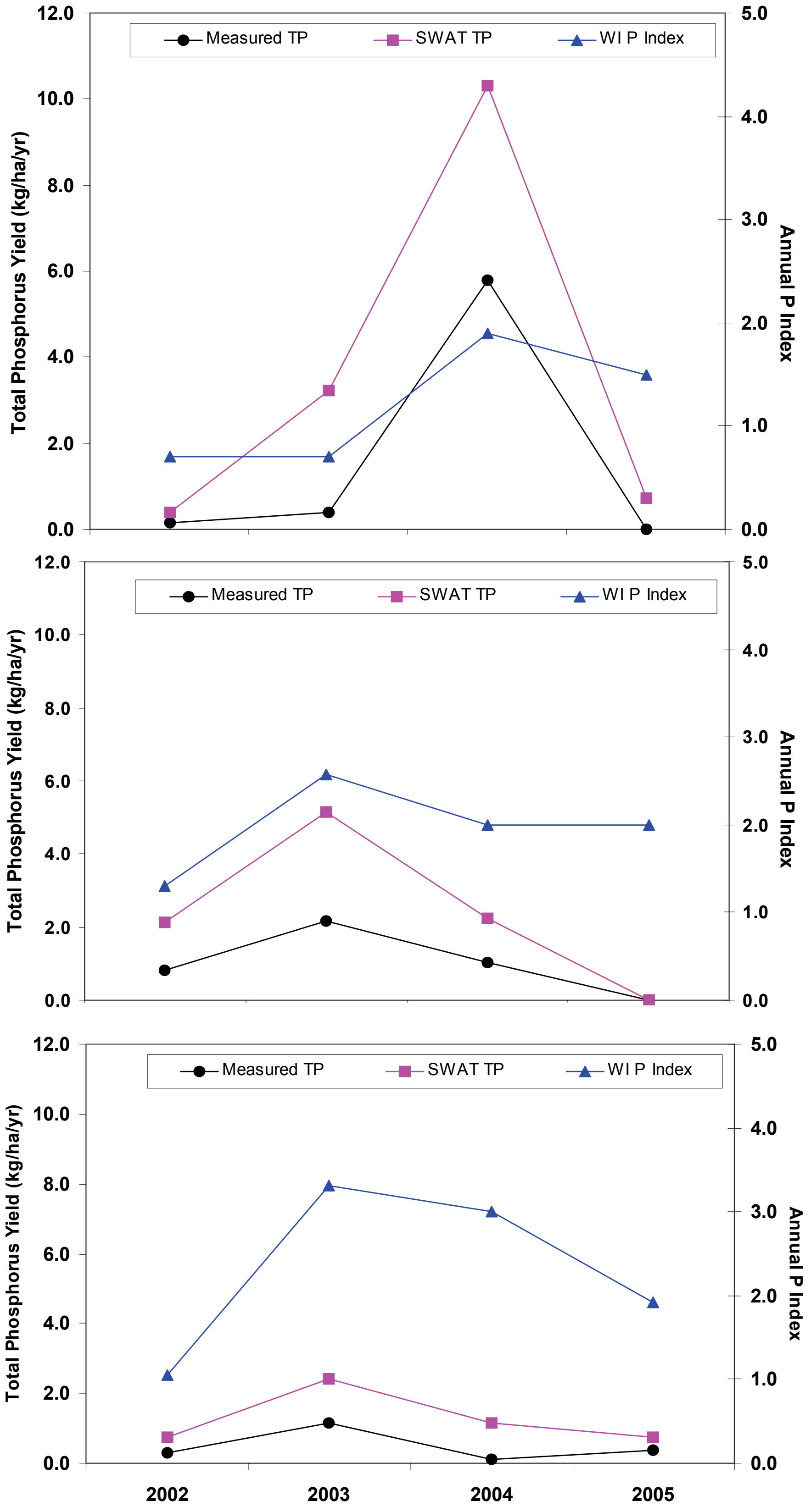


Figure 31 - Non-melt Comparison of Measured TP Yield, SWAT Simulated TP, and SNAP

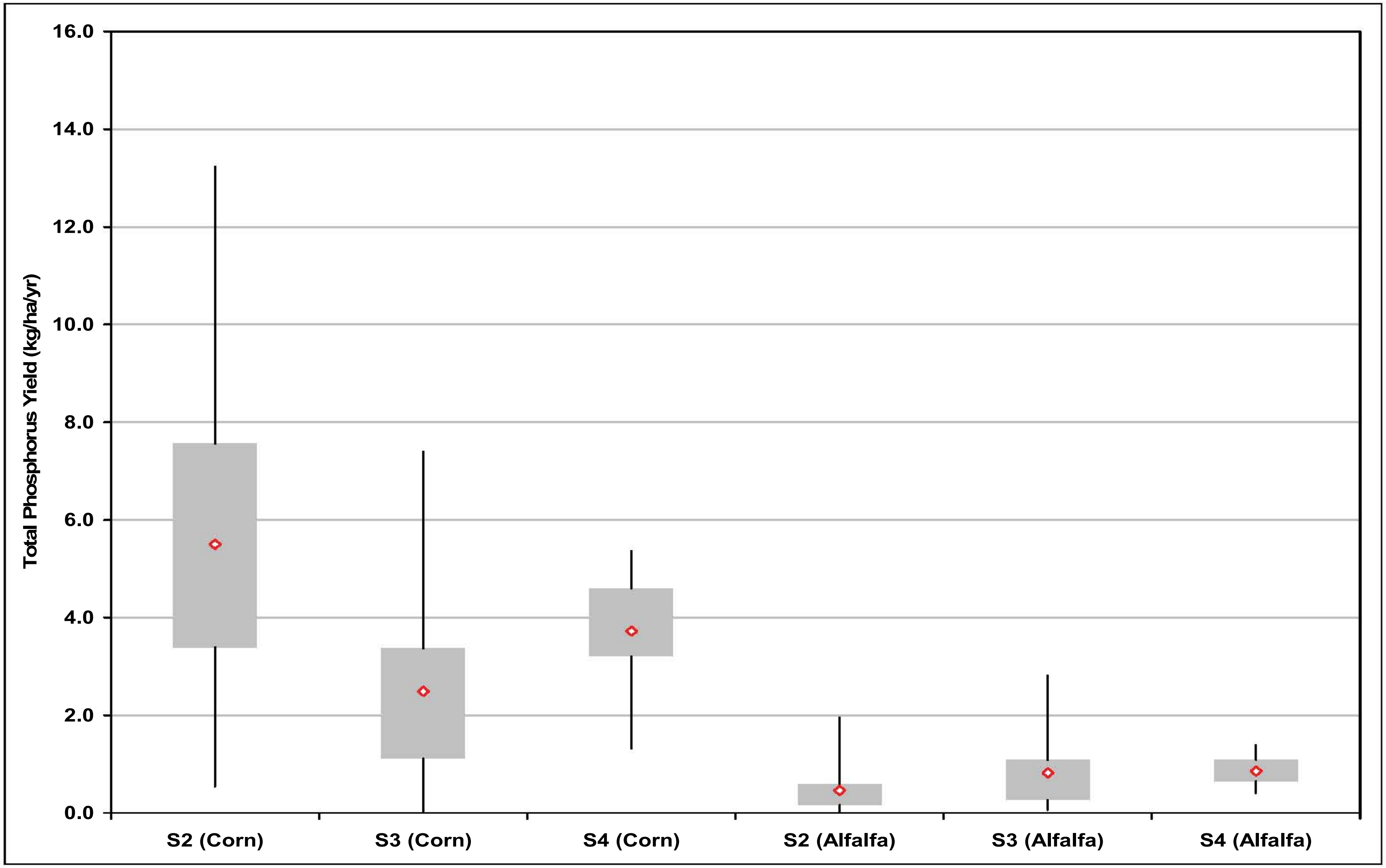


Figure 32 – SWAT Simulated Average Annual TP Yield (All event (Melt/Non-melt) Calibration) For 25-Year Period (1981-2005) Using

Table 18: SWAT Simulated All Event (Melt and Non-melt) Discharge, Sediment, and TP Yield

	Discharge			Sediment Load			Total Phosphorus Yield		
Field Basin	R^2	N-S	% Error	R^2	N-S	% Error	R^2	N-S	% Error
S2	0.58	0.56	7.17	0.40	0.29	33.71	0.41	0.40	4.40
S3	0.34	0.20	15.40	0.62	0.61	7.17	0.54	0.36	8.73
S4	0.04	-0.08	34.58	0.34	0.29	10.02	0.30	0.25	8.11

Table 19: Non-melt Comparison of Measured TP Yield, SWAT Simulated TP, and WI P Index

SWAT Simulated TP Yield (kg/ha/yr)				
	2002	2003	2004	2005
S2 (A-A-C-C)	0.27	2.83	4.53	0.70
S3 (A-C-C-C)	1.30	2.99	1.23	0.00
S4 (Corn)	2.45	1.76	1.88	0.47
S4 (Alfalfa)	0.05	0.01	0.03	0.00
S4 Overall	0.46	1.25	1.03	0.39
Wisconsin P Index (Unitless)				
S2 (A-A-C-C)	0.70	0.70	1.90	1.50
S3 (A-C-C-C)	1.30	2.57	2.00	2.00
S4 - Corn	1.33	4.29	5.43	2.43
S4 - Alfalfa	0.86	1.21	1.29	1.16
S4 Overall	1.05	3.32	3.01	1.91
Measured TP Yield (kg/ha/yr)				
S2 (A-A-C-C)	0.14	0.40	5.78	0.01
S3 (A-C-C-C)	0.83	2.15	1.02	0.00
S4	0.29	1.16	0.12	0.37

7.0 Conclusions

This study examined the ability of a hydrologic and water quality model to simulate runoff from agricultural fields. A detailed, process-based model, SWAT, was calibrated to runoff monitoring collected at edge of fields. The results of the field-scale calibration were compared to the watershed-scale calibration and to the P loss risk predicted by a simple field-scale tool. The study compared the SWAT model at two different spatial scales. The SWAT simulated hydrology (event discharge) and water quality (suspended sediment and TP events) for three field-scale watersheds (S2, S3, and S4) and a small headwater watershed (Upper Fever River Watershed). SWAT was able to successfully simulate hydrology and water quality at both scales.

At the field-scale, the SWAT simulated runoff event volumes with an R^2 and N-S no less than 0.75 using model parameters largely from within the range recommended by NRCS for soil and hydrology. Modeled and observed sediment and TP R^2 and N-S values spanned from 0.44 to 0.82 and 0.28 to 0.86 respectively. At both the field and watershed-scale performance measures were strongly controlled by a few large events. Given the simplicity of the SWAT algorithms, single event outliers are not surprising. The SWAT model parameters used for sediment calibration incorporated conservation efforts on each field, while P calibration used measured soil P and the P portioning coefficient.

The SWAT simulation of the 7.8 square kilometers UFRW hydrology (daily discharge) required adjustment of parameters from the default or NRCS recommended values. SWAT calibration of the UFRW required CN and soil properties significantly different than those recommended by NRCS. In several applications it appeared that these values had to be adjusted to describe additional infiltration. This adjustment was necessary to mimic the large baseflow contribution to the river. The differences between the field and watershed hydrology calibrations show how SWAT simplifies the interpretation of landscape processes. The SWAT is a semi-distributed model that begins lumping land characteristics at a subwatershed level as hydrologic response units (HRUs). It then simulates runoff from the HRUs. Although the HRUs provide computational simplicity in that the calculations performed in the HRU can then be applied throughout the modeled area, HRUs are not defined by proximity or connection to the stream reach. The watershed simulation lumped multiple fields into single HRUs. The CN applied to those HRUs describe not only runoff from the field, but also delivery to the stream. This led to substantial changes in the calibrated CN from the field to watershed-scale. The decrease in cropped agriculture CN simulates greater infiltration or reduced delivery in the watershed. The results can be surprising in places. The best-fit watershed-scale calibration actually would increase the CN for some smaller land uses in the watershed such as grassland and alfalfa.

Similar changes were necessary to model sediment at the field and watershed-scale. Sediment parameters were also decreased to prohibit sediment from entering the stream reach. Calibrating to a decreased sediment load is a result of SWAT's inability to recognize that not all fields contribute sediment to the stream reach.

The simulation of total daily discharge, sediment, and TP (ScenarioI) yielded a R^2 of 0.33, 0.13, and 0.12 respectively. The N-S for discharge, sediment, and TP was 0.29, -0.12, and -0.40 respectively. The poorer R^2 and N-S values for sediment and P compared to hydrology is likely a result of calibrating to the 48 total individual samples rather than an extrapolated daily concentration using a load estimation algorithm. The ability to simulate a single event can determine the correlation and efficiency. The other variable that resulted in a poor prediction was the combination of both melt and non-melt time periods. The R^2 and N-S for discharge during the non-melt period were 0.65 and 0.61, an improvement from examining both periods of discharge. Aggregation of daily discharge into a monthly summary provided a correlation and efficiency of 0.51 and 0.53 and a correlation and efficiency of 0.76 and 0.69 for non-melt days (April – November) only.

Watershed-scale simulation using ninety-one non-melt event days with $\leq$ 66% precipitation error did not significantly improve the strength of the SWAT simulation. The discharge was improved (R^2 = 0.81, N-S = 0.51), however, water quality was still difficult to simulate as a result of calibrating to only individual samples which occurred during the ninety-one days.

The SWAT's ability to simulate P export from a field watershed was compared to the WI P Index. The WI P Index is designed to provide an index of the long term annual average P loss. This is the first time that SWAT and WI P Index have been compared. SWAT and the WI P Index were compared during the 2002 – 2005 time period and both models were evaluated against measured yields. A 25 year annual average P yield was also simulated with SWAT and compared to the WI P Index. The WI P Index predicts P export in lbs/ac/yr; however, the P export is expressed as a risk rather than a yield for the user output. The two models both predicted changes in P loss related to different crop types. Year-to-year variability is more accurately shown with SWAT because it accounts for variation in precipitation. The WI P Index does include a factor to account for distance to perennial waterway which does improve the simulation over SWAT.

SWAT Model Technique

The calibration of the SWAT model for this study provided insight on model setup to the reaction of the simulation. The use of a modified version of the SWAT model developed by Paul Baumgart (2005) acknowledged persistent problems previously encountered with SWAT2000. Currently a new version of SWAT (SWAT2005) has been released and has corrected many model deficiencies recognized in the 2000 version. The implementation of an improved SWAT GIS interface will also improve the spatial identification within SWAT, possibly improving the delivery between field and stream.

Additional improvements in the SWAT model calibration occur when several components of model input are recognized. The following improvements will assist in improved calibration using SWAT2000 or SWAT2005:

1.) *Model Simulation Warm-up Period*

A warm-up period initializes and equilibrates starting values for model variables such as soil moisture. For this study a 6-year warm up period was used. Significant differences in calibration were noted without using the warm-up period.

2.) *Implementation of Land Management GIS layer*

The use of a land management spatial layer rather than landuse allowed representation that is more accurate in SWAT. The current land use spatial layer was numerically coded to represent the rotation or management rather than the current land use. The land management spatial layer was developed with assistance from the local county conservationist.

3.) *Precipitation Variation*

Precipitation can be a source of error in SWAT modeling as seen with the variation between the two stations in this study. The use of NEXRAD radar precipitation estimates are currently being used to improve measured precipitation model input.

8.0 Recommendations

The SWAT model simulation of the UFRW landscape has suggested areas of additional research and model improvement that could improve P export simulation in Wisconsin and elsewhere.

Additional Field-Scale Data and Research

The use of user defined datasets is recommended and improves the ability to simulate the landscape. All of the datasets used in this study were user defined except for certain climatological variables (solar radiation, air temperature, wind speed, and relative humidity). The climatological variables that are used for the Penman-Monteith potential evapotranspiration routine relied on SWAT database input rather than a user defined database. The climatological information is critical for determining soil conditions and the relationship to runoff and infiltration. Improved regional climatological datasets will assist in SWAT model simulation.

Pioneer Farm's extensive edge-of-field discharge and water quality dataset was crucial for validation of SWAT at the field-scale. While this project tests the validity of SWAT in Southwestern Wisconsin, other regions in the state may yield different results. Many farms throughout Wisconsin are part of the Discovery Farm program. The farms measure edge-of-field loss using USGS monitoring stations similar to the Pioneer Farm. It is recommended that SWAT be applied to those farms for regional contrast in calibration of SWAT for field watersheds. The SWAT calibrated fields could then be used to test BMPs in different regions of Wisconsin.

Best Management Practices (BMPs)

SWAT is currently being used as a tool to create and evaluate future BMPs in the watershed. For example, implementing changes to the SWAT model's HRU slopes, NRCS CN, and the filter strip width can simulate the implementation of terraces, changes in tillages, and riparian implementation. The use of SWAT can help determine the types and locations of BMPs throughout an impaired watershed. Previous implementation of simulated BMPs has typically been done with a watershed-scale simulation. HRUs may be referred to as farm / field-scale as HRU's can be much smaller in size than the delineated subwatershed. However, unless each field has a unique HRU, fields may be aggregated within SWAT. Even with individual field HRU's the relationship to the perennial waterway is not acknowledged. The spatial aggregation prevents the SWAT modeler from viewing the real impact of the BMPs at the edge-of-field. In addition to SWAT's spatial aggregation the use of monthly and yearly output aggregation hinders the ability to view the BMPs effectiveness during individual larger events.

If edge-of-field data exists, SWAT can be used to evaluate field watersheds and apply BMPs to them with success. The combination of SWAT with field-scale models such as APEX is likely to improve the ability to evaluate BMPs at the field-scale and apply them to the watershed.

Auto Calibration

This research relied on the autocalibration of SWAT with PEST. The use of autocalibration improves efficiency and determines the sensitivity of parameters. It also improved the ability to evaluate different parameter set combinations. It is recommended that automatic calibration be used while considering not using extreme values for input parameters unless warranted.

Variable Source Areas

The addition of a numerical factor or spatial buffer that relates field to stream proximity would improve P loss identification. The use of the detailed SSURGO soils dataset improves variable source definition using soil properties such as soil hydrologic group, SOLK, and AWC. The addition of a field to stream identity would disregard those areas far from the waterway as likely to contribute P. At present each HRU contributes flow to the stream reach. Each HRU can be a combination of fields from various locations within the subwatershed. A stream distance numerical factor or buffer would create added complexity by increasing the number of HRUs, but it would better represent reality.

References

Arabi, M., R. Govindaraju, M. Hantush, B. Engel (2006). Role of Watershed Subdivision on Modeling the Effectiveness of Best Management Practices with SWAT. *Journal of the American Water Resources Association* 42(2), 513-528.

Arnold, J.G., Allen, P.M. and G. Bernhardt. 1993. A comprehensive surface-ground water flow model. *Journal of Hydrology* 142: 47-69.

Arnold, J. G. and P. M. Allen, 1999. Validation of Automated Methods for Estimating Baseflow and Groundwater Recharge from Stream Flow Records. *Journal of American Water Resources Association* 35(2): 411-424.

Austin, Steve. Agrelieance Agronomist. Platteville, Wisconsin. Personal Phone Interview. July 18, 2006.

Bagnold, R. (1977). Bedload Transport in Natural Rivers. Water Resources Research. (13) 2, 303-312.

Baumgart, P. (2005). Source Allocation of Suspended Sediment and Phosphorus Loads to Green Bay from the Lower Fox River Subbasins using the SWAT. Report to the Onidea Tribe, 9-127.

Borah, K. and M. Bera (2004). Watershed-Scale Hydrologic and Nonpoint-Source Pollution Models: Review of Applications. *Transactions of the ASAE* 47, 789-803

Chaubey, I. T.Costello, K.White, A.Cotter (2003). Stochastic Validation of SWAT Model. TMDL Environmental Regulations-II Proceedings, Albuquerque, New Mexico. November 8, 2003. ASAE Publication Number 701P1503.

Chaubey, I., K.Migliaccio, C.Green, J. Arnold, R. Srinivasan. Phosphorus Modeling in Soil and Water Assessment Tool (SWAT) Model. In *Book Modeling Phosphorus in the Environment.* Radcliff,D., M.Cabrera. CRC Press: Flordia, U.S., 2006, 163-187.

Choi, I., C.Munster, D.Vietor, R.White, G.Stewart, C.Richards (2005). Calibration and Validation of the SWAT Model on a Field-Scale Watershed for Turfgrass Sod Establishment. In *Watershed Management to Meet Water Quality Standards and Emerging TMDL (Total Maximum Daily Load) Conf.* ASAE, 338-347.

Di Luzio, M., R. Srinivasan, J.G. Arnold, and S. Neitsch. 2002. ARCVIEW interface for SWAT 2000 user's guide. Blackland Research Center. Texas Agricultural Experiment Station, Temple, Texas. Available at: http://www.brc.tamus.edu/swat/doc.html. Accessed July 2006.

Doherty, J. (2004) PEST: Model-Independent Parameter Estimation Users Manual. 5th Edition.

EPA (1992). The Quality of Our Nation's Water. Office of Water. Executive Summary. http://www.epa.gov/305b/92report/92summ.pdf , 1-38.

EPA (2005). Committing EPA's water program to advancing the watershed approach. http://www.epa.gov/owow/watershed/memo.html Accessed March 28, 2007.

FitzHugh,T. and D.Mackay (2000). Impacts of Input Parameter Spatial Aggregation on An Agricultural Nonpoint Source Pollution Model. *Journal of Hydrology* 236, 35-53.

Garen, D. and D.Moore (2005). Curve Number Hydrology in Water Quality Modeling: Uses, Abuses, and Future Directions. *Journal of the American Water Resources Association* 41(6), 377-388.

Gburek,W. and A.Sharpley (1998).Hydrologic Controls on Phosphorus Loss from Upland Agricultural Watersheds. *Journal of Environmental Quality* 27, 267-277.

Inamdar, S (2004). Assessment of Modeling Tools and Data Needs for Developing the Sediment Portion of the TMDL Plan for a Mixed Watershed. Final Report to the Great Lakes Basin Program. Buffalo, New York, 10-12.

Jha, M., P. Gassman, S. Secchi, R. Gu, J.Arnold (2004). Effects of Watershed Subdivision on SWAT Flow, Sediment, and Nutrient Predictions. *Journal of the American Water Resources Association* 40, 811-825

Kirsch, K., A. Kirsch, J.Arnold (2002). Predicting Sediment and Phosphorus Loads in the Rock River Basin Using SWAT. *Transactions of the ASAE* 45(6), 1757-1769.

Krause, P., D. Boyle, K. Bäse (2005). Comparison of Different Efficiency Criteria for Hydrological Model Assessment. Advances in Geosciences 5, 89-97.

Lemunyon, J., R.Gilbert. (1993). The Concept and Need for a Phosphorus Assessment Tool. *Journal of Production Agriculture* 6(4), 483-486.

Lin, Z. (2005). Getting Started with PEST. Dept. of Crop and Soil Sciences. University of Georgia. http://linzhulu.myweb.uga.edu/pdf/teaching/starting%20pest.pdf

Masarik, K. G.Kraft, D.Mechenich, B.Browne (2007). Groundwater Pollutant Transfer and Export from a Northern Mississippi Valley Loess Hills Watershed, *Draft Report*. Submittal to the Water Resources Institute, University of Wisconsin – Madison.

Mentz, Randy. Pioneer Farm Scientist. University of Wisconsin – Platteville Pioneer Farm. Personal Interview. March 28, 2007.

Motovilov, Y., L.Gottschalk, K.Engeland, A.Rodhe (1999). Validation of a Distributed Hydrological Model against Spatial Observations. Agricultural and Forest Meteorology 98-99, 257-277.

Muleta, M. and J.Nicklow (2005). Sensitivity and Uncertainty Analysis Coupled with Automatic Calibration for a Distributed Watershed Model. *Journal of Hydrology* 306, 127-145.

Neitsch, S., J. Arnold, J. Kiniry, J.Williams, K.King (2002). Soil and Water Assessment Tool Theoretical Documentation – Version 2000. Texas Water Resources Institute, College Station, Texas. TWRI Report TR-191.

Panuska, J. and R.Lillie (1995). Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds Research Management Findings, Number 38. Wisconsin Department of Natural Resources.

Ponce, V. and R. Hawkins (1996). Runoff Curve Number: Has It Reached Maturity? *Journal of Hydrologic Engineering*. 1(1), 11-19.

Saleh, A. P.Gassman, J.Abraham, J.Rodecap (2003). Application of SWAT and APEX models for Upper Maquoketa River Watershed in Northeast Iowa. American Society of Agricultural Engineers Annual International Meeting.

Santhi, C., J.Arnold, J. Williams, W. Dugas, R.Srinivasan, L.Hauck (2001). Validation of the SWAT Model on a Large River Basin with Point and Nonpoint Sources. *Journal of the American Water Resources Association* 37(5), 1169-1188.

Sharpley, A., S. Smith, J.Naney. (1987) The Environmental Impact of Agricultural Nitrogen and Phosphorus Use. *Journal of Agricultural Food Chemistry*. 26, 812-817.

Sharpley, A., T. Daniel, T.Sims, J.Lemunyon, R.Stevens, and R.Parry (2003). Agricultural Phosphorus and Eutrophication. United States Department of Agriculture, Agricultural Research Service Guidance Document, 2nd Edition, ARS-149.

Spruill, C., S. Workman, J. Taraba (2000). Simulation of Daily and Monthly Stream Discharge from Small Watersheds Using the SWAT Model. *Transactions of the ASAE* 43, 1431-1439.

SNAP-Plus Users Manual, Version 1.114 (2005). University of Wisconsin Soils Department, Madison, Wisconsin. http://www.snapplus.net/download/SnapPlusManual.pdf

Southwest Badger (2007). Southwest Badger Resource Conservation & Development Council. March 28, 2007. http://www.swbadger.com/galena.html

SWAT Calibration Techniques (2005). USDA Agricultural Research Service. http://www.brc.tamus.edu/swat/publications/swat-calibration-techniques_slides.pdf

United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). December 17, 2006. Spatial and tabular data of the Soil Survey for Lafayette County, Wisconsin. United States Department of Agriculture, Natural Resources Conservation Service. “http://soildatamartnrcs.usda.gov/" Fort Worth, TX.

Olcott, P. (1992). Ground Water Atlas of the United States, Segment 9, Hydrologic Investigations Atlas 730-J. United States Geological Survey.

Qi, C., S.Grunwald. (2005). GIS-Based Hydrologic Modeling in the Sandusky Watershed Using SWAT. *Transactions of the ASAE* 48(1), 169-180.

Van Liew, M., J.Arnold, J.Garbrecht (2003). Hydrologic Simulation on Agricultural Watersheds: Choosing Between Two Models. *Transactions of the ASAE* 46(6), 1539-1551.

Vieth, T., A.Sharpley, J.Weld, W.Gburek. (2005). Comparison of Measured and Simulated Phosphorus Losses with Indexed Site Vulnerability. *Transactions of the ASAE* 48, 557-565.

Ward Good, L., L. Bundy (2006). Development and Validation of the Wiscosnin Phosphorus Index. 2006 Wisconsin Fertilizer, Aglime, and Pest Management Conference, 45, 135-138.

White, K., I.Chaubey. (2005). Sensitivity Analysis, Calibration, and Validations for a Multisite and Multivariable SWAT Model. *Journal of the American Water Resources Association* 41(5), 1077-1089.

Williams, J.R. 1995. The EPIC model. In: V.P. Singh (ed.), *Computer Models of Watershed Hydrology*. Water Resources Research Publications. Highlands Ranch, CO. pp.909-1000.

WI Phosphorus Index (2007). Wisconsin Phosphorus Index Homepage. Unversity of Wisconsin – Extension. http://wpindex.soils.wisc.edu/pi.php. Site Accessed March 20, 2007.

Wischmeier, W. and D. Smith (1978). Predicting Rainfall Erosion Losses – A Guide to C Conservation Planning. U.S. Department of Agriculture Handbook No. 537.

Wisconsin Department of Natural Resources (2001). Grant-Platte Rivers State of the Basin Report, Galena River Watershed. Volume 3. Publication PUB-WT-660 2001.

APPENDIX A

Pioneer Farm Runoff Project Manual (DRAFT)

Runoff Project Manual

Pioneer Farm

A Detailed Guide to the Runoff Monitoring Study at University of Wisconsin – Platteville's Pioneer Farm

DRAFT
June 7, 2006

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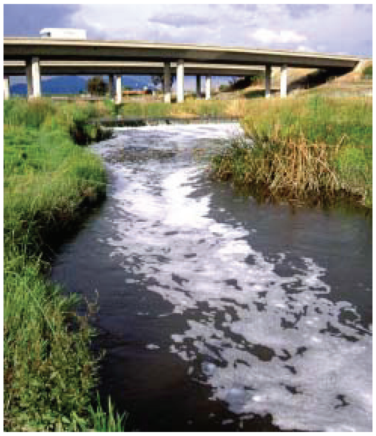
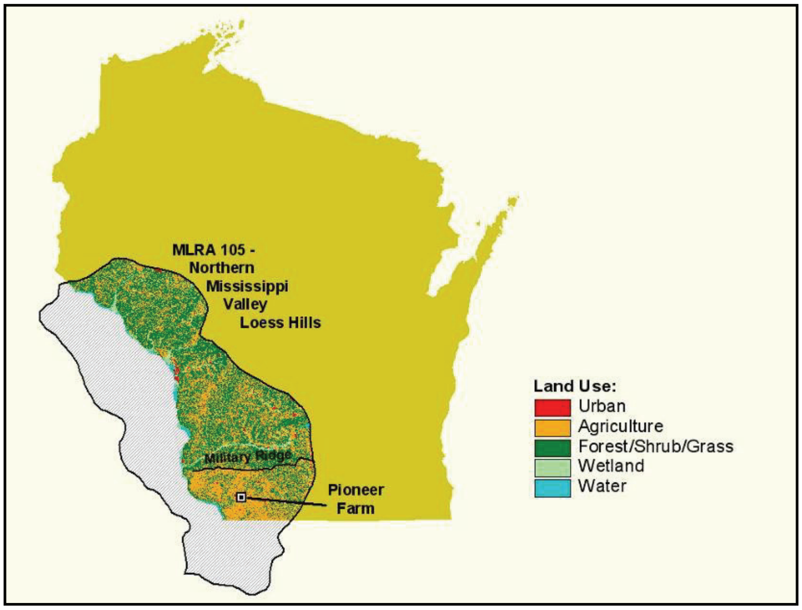
Introduction



Runoff water from urban areas, housing developments, agricultural areas and other disturbed settings has an adverse impact on aquatic ecosystems. Research has documented that many streams flowing through agricultural areas have impaired water quality. These streams are rich in sediment and nutrients and have altered aquatic eco-systems as a result. One component contributing to this impairment is the episodic runoff water contribution to streams which occurs during rain storms and snow melt events.

The runoff monitoring at Pioneer Farm was designed to quantify this component to improve our understanding of how it affects stream water quality. To accomplish this, the United States Geological Survey (USGS) was contracted to install and maintain monitoring stations around the farm. In short, these stations measure and sample flow from a given field-scale drainage basin. Samples from each event are analyzed in a laboratory for sediment and nutrient content. Laboratory results are used in conjunction with discharge data to calculate load values for the various constituents (sediment, nitrogen, phosphorus, etc.).

Pioneer Farm

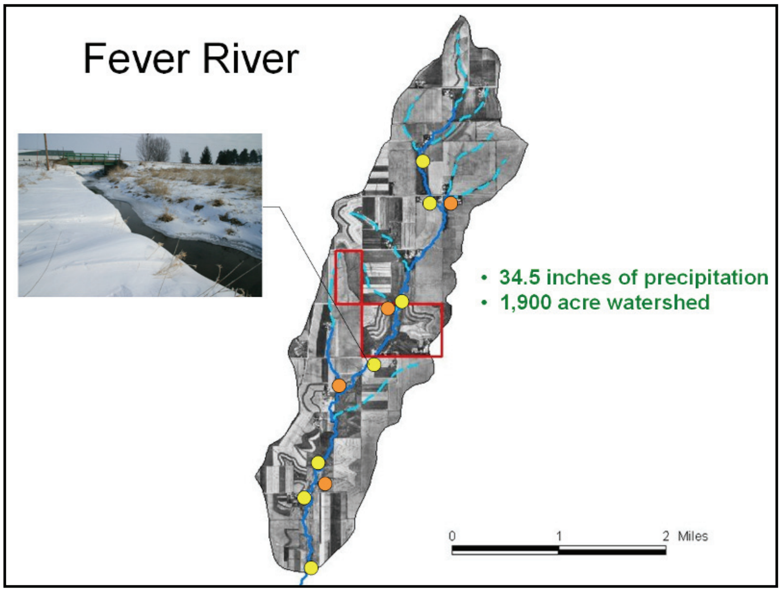


Pioneer Farm is a 430 acre livestock farm owned and operated by UW-Platteville. It is located about 6 miles southeast of the city of Platteville, Wisconsin. The farm is located in the Northern Mississippi Valley Loess Hills (MLRA 105), a region characterized by rolling hills and silty soils underlain by limestone bedrock. A large percentage of this region is farmland, but only about 40 percent is cropland. 20 percent of the land is in permanent pasture and 30 percent is woodlots. Most of the crops that are grown are forage grains to support dairy operations, however, there are some cash-crop grain operations as well. Valleys along streams tend to be narrow and are often put into permanent pasture. The region averages 30 to 35 inches of precipitation per year.

Pioneer Farm's dairy operation includes 100 milking cows, 50 dry cows and heifers, and 50 calves and young heifers. Plans are in place to double the size of the milking herd after the completion of the new dairy center in 2006. The new swine center is a farrow to finish operation and has a capacity of 1,500 pigs. The beef center houses about 30 cow/calf pairs and a bull. Pioneer Farm is also home to a bull-test facility that can house a maximum of 125 bulls between November and April. Crops on the farm are grown in the following rotation: three years corn, one year oats, and three years alfalfa. Conventional tillage, planting, and harvesting methods are used. Nearly all crops grown on the farm are used to feed on-farm livestock.

Several conservation practices are in place to reduce soil and nutrient losses from the farm's cropland. Terraces, grassed waterways, filter strips, and a riparian buffer are in place and regularly maintained. Historically, all manure produced on the farm has been applied to cropland. In the fall, the one million gallon lagoon (containing one year of dairy wastewater and manure) is injected into the soil as the field is chisel plowed. Solid manure from feedlots is stored and land-spread as needed. As a result, soil-test phosphorus is quite high, averaging between 50 and 150 ppm. Plans are now in place to export a large portion of manure in the form of a quality compost product.

The Fever River (sometimes incorrectly referred to as the Galena River) flows through the center of the farm running from north to south. This small stream originates about 2 miles north of Pioneer Farm. The average discharge at the USGS in-stream gaging station is about 1.2 cubic feet per second (cfs) during baseflow conditions. Runoff event discharge has been recorded as high as 80 cfs. Recent research has shown that baseflow recharge into the Fever River is not continuous but sporadic. Seeps, springs, and tile drains are the primary contributors to baseflow.



Project History

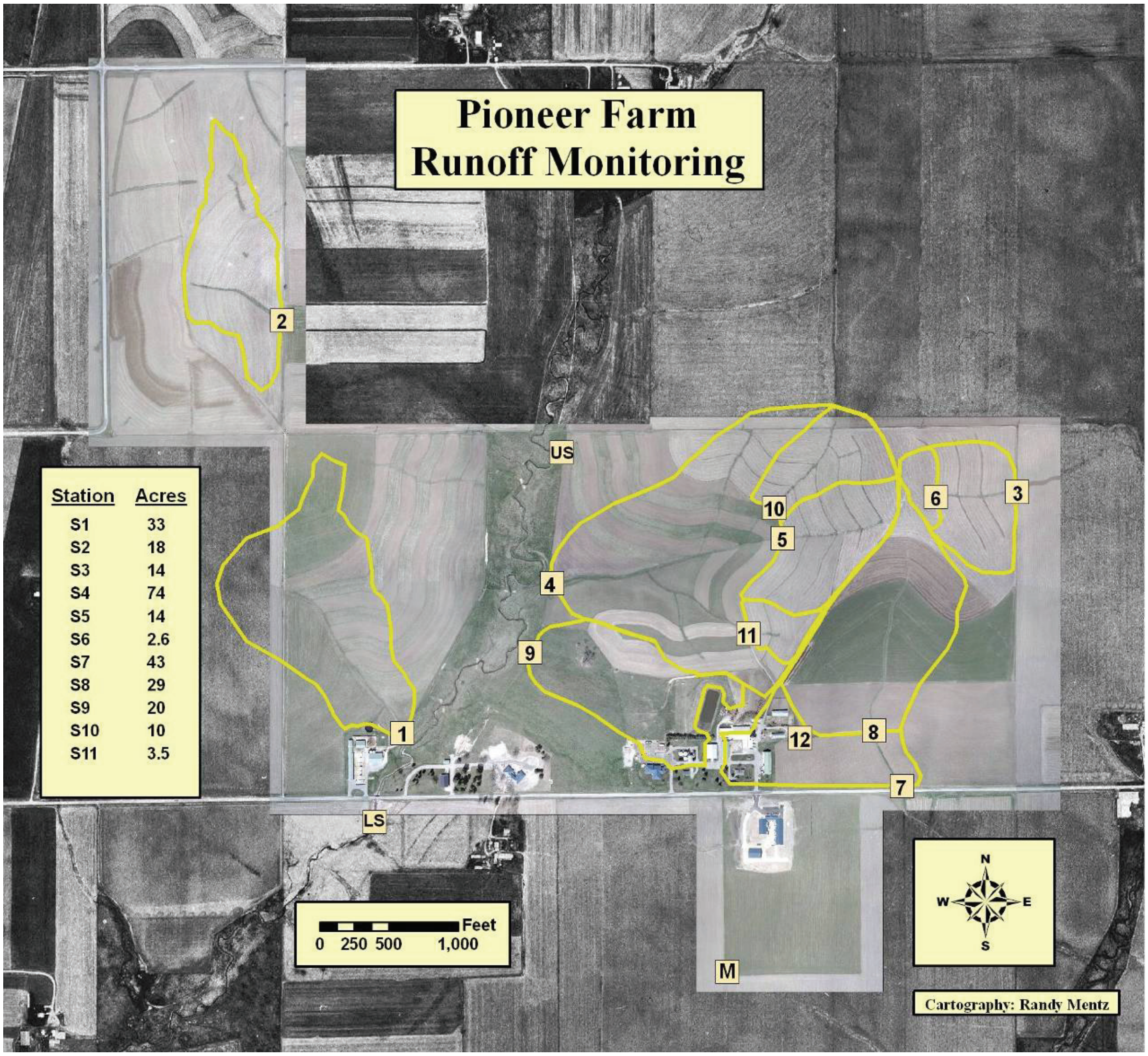
Shortly after the Wisconsin Agricultural Stewardship Initiative was formed, a need was identified to quantify agricultural runoff and the sediment and nutrients carried with it. To accomplish this, the United States Geological Survey was brought on board to design monitoring stations that would get the job done. Construction of the first sites began in fall of 2001 when sites 1, 2, 3, and 4 were put into place. The basic design consisted of a berm and wingwall structure at the bottom of a designated watershed to direct storm runoff water through a fiberglass H-flume so that it could be measured and sampled. Initially, basic Isco samplers were used in conjunction with ice during storm events and samples were split on site using a churn-splitter. This was soon found to be overwhelming for on-site staff and existing stations were retrofitted with Isco 3700R stainless steel refrigerated samplers.

In fall of 2002 and spring of 2003, sites 5, 6, 7, and an in-stream gaging station were installed. These sites all included an updated stage measurement device that employed a pressure transducer, sight feed, and pressurized nitrogen gas to measure stage. The older design used a float and standpipe system to measure stage. The newer design was found to have fewer errors and reduced maintenance time and cost. In fall of 2005, the original 4 stations were retrofitted with pressure systems. A need for high-quality, on-site, meteorological information was identified in the fall of 2002 and addressed in the spring of 2003 by installing the meteorological station to measure, wind velocity, air temperature, precipitation, soil moisture, soil temperature, sunlight (flux density), and relative humidity.

After reviewing runoff data in spring of 2003, the water science team determined that a sampler was needed in a sub-basin of S7 to separate field runoff water from feedlot runoff water. It was also determined that a station was needed to monitor grazing land runoff water. In the summer and fall of 2003, sites 8 and 9 were installed to meet these needs. Since little runoff was recorded at sites 1 and 6, the samplers and housings for these stations were moved to sites 9 and 8, respectively. Sites 1 and 6 continued to monitor discharge, but no longer have equipment for sampling.

In spring of 2005, needs were identified for more paired watershed opportunities, a closer look at the effectiveness of the filter strip, and a monitoring station at the north boundary of the farm to compare to data collected at the in-stream station at the south boundary of the farm. In the summer of 2005, sites 10, 11, 12, and the upstream station were built to address these needs.

Monitoring Station Locations



Pioneer Farm's runoff monitoring stations have been placed to meet specific data needs. The initial four stations and site 7 were placed at the edges of fields so that a maximum acreage could be monitored. Site 5 was placed to be paired with site 3 for future research studies. Site 8 was placed to collect field-only runoff to compare to site 7 chemistry which receives runoff from cropland and feedlots. Site 9 was placed to measure runoff from grazing land. Sites 10 and 11 were placed to be paired with site 5. Finally, the original stream site and upstream site were placed to measure and compare inflows and outflows from Pioneer Farm.

Standard Monitoring Station Design

The current USGS runoff monitoring station design includes the following:

1. Soil berm
2. ¾" treated plywood wingwall
3. Tracom fiberglass h-flume (trapezoidal flumes at S12)
4. Teflon sample line
5. Bubble line (for stage measurement)
6. Erosion control measure downstream of flume
7. CNC'd aluminum housing for equipment
8. Solar Panels
9. Isco 3700R refrigerated sampler
10. Solar charger/controller
11. 12 V deep cycle marine battery
12. 12 V 7.2 amp/hr battery
13. Sight feed
14. Pressure transducer
15. Pressurized nitrogen gas
16. Campbell Scientific CR10X datalogger
17. Campbell Scientific RF400 radio
18. Directional antenna
19. Digital timelapse camera (S1, S2, S3, S4, S7, S9)
20. Precipitation gage (S2, S3, S4, S5, S7, S8, S9, Stream)
21. Onan RV generator
22. 6-gallon gas tank

Site Descriptions

				Samples Collected								
	Contributing Area (acres)	Average Slope %	Year Finished	2002	2003	2004	2005	2006	Land-Use	Flume	Camera	Getaway
S1	33	2.8	2001	x	x				Multi-Crop	2.0 ft H	Yes	Rock
S2	18		2001	x	x	x	x	x	Single-Crop	2.5 ft H	Yes	Rock
S3	14	6.3	2001	x	x	x	x	x	Single-Crop	2.0/2.5 ft H	Yes	Rock
S4	74	3.4	2002	x	x	x	x	x	Multi-Crop	3.0 ft H	Yes	Rock
S5	14	4.9	2002		x	x	x	x	Single-Crop	2.0 ft H	No	Board
S6	2.6	4	2002		x				Single-Crop	2.0 ft H	No	Board
S7	43	2.7	2002		x	x	x	x	Crop and Feedlot	2.5 ft H	Yes	Rock
S8	29	3.7	2003		x	x	x	x	Single/Multi-Crop	2.5 ft H	No	Concrete
S9	20	3.9	2003		x	x	x	x	Grazing, Some crop	2.5 ft H	Yes	Rock
S10	10	4.5	2005				x	x	Single-Crop	2.5 ft H	No	Rock
S11	3.5		2005				x	x	Single-Crop	2.5 ft H	No	Rock
S12			2005				x	x	Feedlot	1.0 ft Trapezoidal	No	Board

Runoff Event Preparations

If a major storm is forecast for the Platteville area, there is a good chance that runoff will flow off of the farm fields and samples will be collected. If the following preparations are made in advance, the sample collection process will go much faster and smoother.

1. Make sure the ATV has enough gas and is ready for use.
2. Have empty, clean Isco bottles capped with a piece of Fischer Scientific orange water-proof labeling tape on the caps.
3. Have the bottles ready to go in coolers (24 bottles per cooler). Have at least 10 coolers ready.
4. Make sure that the Isco samplers at each site are turned on and ready to sample.
5. Make sure nitrogen tanks have at least 100 psi and check the sight feed for a 90 bubble-per-minute rate
6. Make sure each station has at least ½ tank of gas available for the generator
7. Have at least one Sharpie marker available for labeling bottles.
8. Have a headlamp on hand if the storm is forecast at night.
9. Have a keypad on hand.
10. Check telemetry to make sure all sites can be connected to remotely
11. Have cell phone charged and pre-programmed with the USGS contact's phone number

Storm Event Procedures

It is a rare occasion that runoff occurs during business hours. Do everything possible to have someone on-site during a runoff event. Observations and photographs taken during runoff events are extremely valuable; it's the only way to know for sure that the stations are functioning properly.

Procedures:

- Go from site to site as efficiently as possible and take digital photographs and write down observations.
- Be sure to write the site name, date, time, and initials each time you visit a site and take notes, without this information your notes will have no context and will be useless.
- If possible, put a date stamp on the digital photos for reference.
- Be sure to check the date and time on the digital camera and make sure it is exact.

- If there is flow in the flume, check the stage in the flume and read the value from the staff gage (in the flume) to the nearest one-thousandth of a foot (example: 0.357 ft). Record this value as "Staff Stage"
- Plug the keypad into the datalogger and type * 6 A (for S12b, type * 6 10 A) to get the stage value being recorded by the datalogger. Record this value as "CR10 Stage"
- Take notes on apparent sediment load in runoff water, crop height, recent field practices, and anything you can think of that may help in the data interpretation. The more notes the better.
- Take your time and check the site over thoroughly and make sure everything is working. Specifically note each thing you check.

Collecting Samples

There are two situations where samples may need to be collected from a monitoring station. The most common occurrence is after an event is finished, and flow has stopped. Occasionally samples may need to be collected while an event is in progress. Follow the steps below for each case, but if you are collecting while an event is in progress, do not collect any information from the data logger, do not set flag 5 high, and be sure to note on the next sample retrieval sheet which bottle number is next.

A. Fill out sample retrieval sheet using info from both the CR10 (accessed with keypad) and the sampler (Note: if the event is not over, skip parts a and b)
    a. Plug CR10 keypad into the ribbon cable that connects the CR10 data logger keypad into RF400 radio
    b. Type: (*****)(**6**)(**A**). This reading is the stage reading, or Loc 1
        i. You can scroll through the Loc numbers by hitting **A** (advance) or **B** (back), or by entering: (*****)(**6**), (desired Loc #), then (**A**) [example: (*****)(**6**)(**52**)(**A**)]
        ii. Fill out the left column of the middle portion of the retrieval sheet accordingly
        iii. If the event is over, press (*****)(**6**)(**A**)(**D**)(**5**) to set flag 5 high (which tells the datalogger the event is over and the station is on standby)
        iv. Press (*****)(**6**)(**A**) again and fill out the right-hand column of the middle section of the sample retrieval sheet
        v. Be sure to log out before unplugging the keypad. Log out by pressing (*****)(**6**)(*****)(**0**)
    c. On the Isco sampler, press (**Exit Program**)
    d. Press (**Display Status**) (if a warning message comes up, press (**Enter**))
    e. Be sure the word "REVIEW" is selected (blinking) then press (**Enter**)
    f. Press the right arrow button until RESULTS is selected, then press (**Enter**)

g. Continue to press (**Enter**) to scroll through the information for each sample and record the information on the bottom portion of the sample retrieval sheet (press left arrow to go back)
h. Be sure to record how full each bottle is on the sample retrieval sheet
i. Indicate how the samples were labeled (example: **Strm-1, 4/25/06**)
    i. Standard Labeling Nomenclature: Field runoff station is labeled as follows (Site #) – (Bottle Number) with the date on the first bottle in the set. An example is as follows: S2-5
    ii. The upstream abbreviation is "US." Example: US-3
    iii. The stream site abbreviation is "Strm." Example: Strm-7
    iv. If more than one carousel of samples is collected during a storm event, or two closely spaced storm events, label consecutively. For example, if you collect 23 samples from S7 on March 3 and 12 samples on March 4, the first sample in the March 4 batch should be labeled S7-24. This reduces confusion at the lab.

B. Collect and label the samples
    a. Tightly cap bottles while still in the carousel (do not remove, as their order needs to be preserved).
    b. NOTE: The first bottle filled is indicated with "1" on the bottom of the carousel tray.
    c. Put orange tape on all the capped sample bottles and label them S# - sample number (Example: S4-13). Include the date on the first sample in the cooler. If this is the second (or more) round of samples being collected for the same event, be sure to label accordingly (Example: if samples S4-1 thru 23 were collected last time, start at S4-24)
    d. It's recommended that caps are pre-labeled indoors before visiting site
    e. Pull filled bottles out of the carousel and put them into the cooler in order. Be somewhat gentle with the bottles as they crack easily.
    f. Replace bottles containing samples with clean, empty bottles, reinsert carrousel into refrigerator and make sure the distributor arm lines up with samples properly

C. Reset the sampler
    a. Press exit program until sampler reads “PROGRAM HALTED”
    b. Be sure the distributor arm is over bottle 1

D. If it isn’t, press the next bottle button while program is halted until it gets to the 24th bottle. Then hit it again and the arm will go all the way around backwards to bottle 1
    a. Press (**Start Sampling**), make sure start is highlighted, press (**Enter**). Make sure one is highlighted, then press (**Enter**) again
    b. Sampler display should read “Bottle 1 after 1 pulses”

E. Record the following on the Misc. Field Notes
    a. Date, time, site number, initials, and number of samples taken
    b. Was flag 5 reset? Was the sampler reset? Record this information.
    c. Any observations made about the flume, equipment, field conditions, flow, etc. *The more notes the better, particularly during snowmelt events.*
    d. Crest gage measurement (measure from the bottom of the stick to the cork line)

F. If the event is over, bring the retrieval sheets and notes back to the office.

Post Event

A. Collect sample coolers and data collection sheets
B. After samples are placed in cooler bring them to a central location for easy loading the next day
C. Place ice/snow in sample coolers
    a. Use snow when available, pack around bottles
    b. Ice can be found in chest freezer located in Education Pavillion arena
    c. Use ¼ to ½ bag of ice, adjusting according to # of samples and outdoor temperature
D. Return data sheets to the research specialist's office, located in the Ag. Technology Center and place a photocopy of each in Sneha's mailbox
E. Scan copies of all notes and retrieval sheets with the flatbed scanner
    a. Notes: 200dpi, 8-bit grayscale, 50% jpg compression
    b. Retrieval Sheets: 150 dpi, 8-bit grayscale, 50% jpg compression
    c. Keep copies on file
    d. Email copies to Dave Owens (zip and send through Megaupload.com)
    e. Email Dave copies of photos taken during and after the event
F. Prepare coolers for shipment (only for small events with 3 or less total coolers)
G. Make a copy of shipment address located in water collection folder
H. Tape the shipment address to the cooler lid, use packing tape
I. Secure the cooler lid by taping them shut
J. For larger events, the samples need to be driven up to the UW-Stevens Point lab
    a. Call the motorpool and reserve as large a vehicle that is available
    b. Call the UWSP lab and see if anyone is available to meet in Portage. The traditional meeting place is the Petro station
    c. Load the samples in the vehicle and drive them to UWSP or Portage
K. Write up a Runoff Event Report
L. File all paperwork accordingly
M. Organized storage area for the next runoff event
N. Perform required maintenance on sites that ran off (gasoline, etc.)

Snowmelt Event Preparation

A. In November, build enclosures around all of the flumes and install heaters.
   a. Use treated three-quarter-inch plywood for the cover and half-inch untreated plywood for the sides
   b. Place a heavy canvas flap on the front and back sides to reduce the thermal disadvantages of wind
   c. Avoid heaters with fans. The best heater used to date is an overhead radiant quartz heater. They are often marketed as shop or garage heaters.

B. Clear snow from the flume, entrance, and getaway
   a. All snow and/or ice in the flume must be removed. Be careful not to damage the flume, sample line, or the orifice line. Use a portable steamer to remove snow and ice from the sample line and orifice line to avoid damaging them.

   b. Be sure that culverts downstream of flumes are clear. If they are clogged with snow, shovel out as much as possible and remove the remaining snow with a high-power portable heater (Dayton kerosene torpedo heater)
   c. If snow is not removed properly, water will back up into the flume and cause inaccurate flow data

In 2004, the culvert downstream of S7 was not properly cleared of snow.

C. Make sure the sample line is not blocked by ice
   a. Run the sample pump in reverse and place finger over the end of

the sample line in the flume. If you can feel air pressure, the sample line is clear

   b. If the sample line is plugged with ice, plug in the sample line heat tape, start generator and let it run for about five to 10 minutes, and run the sample pump in reverse again to remove ice.
   c. If the line is still plugged, allow the generator to run for another five to 10 minutes and try again
   d. If it is still plugged, try using a steamer to melt ice near the end of the sample line
   e. If none of this works, try pumping hot water in through the refrigerator out into the flume

D. Check the stage with the keypad and make sure it is around 0 (if there is no flow). If it is higher, steam the orifice line until the ice melts out of the line and purge if necessary (instructions for purging the orifice line are on plastic cards that should be hanging from the sight feed

E. Make sure the sampler is on and ready to sample

F. Make sure gas tanks are full

G. Pull string to turn on heater if it will be needed overnight

Snowmelt Event Procedures

A. Immediately before the snowmelt event starts, set timelapse cameras to a tighter interval (one hour) to capture the detail of the event

B. Once the snowmelt begins, continuously visit sites to take photographs, collect samples, and address problems such as ice development

C. Be sure to get as many staff measurements as possible (see "Storm Event Procedures" section)

D. Include as much detail in the notes as possible. Simple observations can sometimes make a huge difference when interpreting data. Soil conditions (frozen/thawed, dry/saturated), snow depth, weather conditions, manure applications, sampling success/failure, development of ice shelves, backwater, etc., are all highly valuable observations.

E. Collect samples as needed and take extra care to keep track of how many samples were collected at what site and when. This will make consecutive sampling much easier.

Snowmelt Post Event Procedures

A. Snowmelt post event procedures do not differ from standard post event procedures

Maintenance

A. Mowing/Weed-eating

  a. Before mowing, check area to be mowed for misplaced objects and stones.
  b. Know where site lines are located.
  c. Mow the berms & 2-3 passes on the upstream or intake side of the flume.
  d. Weed-eat areas that cannot be reached with the mower.
  e. Mow around station.
  f. Use Roundup on weeds growing in rip-rap and underneath station.

B. Winter Snow Removal

  a. Remove snow from immediately in front of the wing wall.
  b. Remove snow from the flow line of the waterway to approximately 10 feet upstream of the flume.
  c. Remove snow and ice from the flume.
    i) If ice is present use a dead blow hammer or other object that will not break the flume to break up the ice.
  (1) Note: Be very careful not to hit the sample line or the orifice line. Use the steamer to clear ice away from these lines.
    ii) Make sure that the sampling intakes in the flume are clear of ice and snow.
  d. Remove snow & ice from the area around the outfall of the flume.

C. Precipitation Gage Calibration

  a. Remove the precipitation gatherer/funnel and clean off the dripper at the bottom of the gatherer and the dipper and housing attached to the pole.
  b. Replace the precipitation gatherer/funnel.
  c. Take cumulative precipitation measurement (plug in keypad and enter "*65A") and record information given.
  d. Fill the calibration bottle to the fill line and put on the circular dripper head found with the bottle.

e. Place the calibration bottle over the precipitation gage and flip onto the precipitation gatherer without spilling any water.
f. Allow bottle to empty (this will take approximately 30 minutes).
g. Record cumulative precipitation measurement again (see step 3).
h. Subtract the calibration stage measurement from the initial stage measurement (number from step 3 – number from step 7).
i. If the change in accumulated precipitation is less than 1.85 or greater than 1.95, the precipitation gage will need to be adjusted.
    - i) On the precipitation gage there is an adjustment screw.
    - ii) If the number is less than 1.85, turn the screw clockwise, and if its greater than 1.95, turn the screw counter clockwise.
    - iii) Repeat steps 3 – 9 until the calibration gives a value between 1.85 and 1.95.

D. Replacing Camera Memory Card/Resetting Camera Settings
    - *i) Note: Steps 5 through 9 need to be done if the marine battery is replaced at the site.*

b. Turn off the camera with the black power button on the top of the camera (green light on back is off and lens is not protruding from the front of the camera).
c. Open the memory card door on the right side of the camera.
d. Eject the memory card.
    - i) Flip up gray lever and push in.
    - ii) Remove the filled memory card.

e. Insert the empty memory card.
f. Turn the camera back on using the black power button on top of the camera (green light flashes and lens sticks out about 2 inches).
g. Press “Menu” button and select “Time-lapse”.
    - i) Flash: Off.
    - ii) Number of Pictures: Set to 150.

(1) *Note: Some memory cards are smaller and will not allow 150 pictures to be taken. If this is the case, set the number of pictures to a smaller number.*

iii) Time Interval: 24 hrs.

iv) Select "Done".

h. Click "Display" and ensure camera is aligned to view the waterway, and if possible parts of the fields nearby. The horizon should be near the top with the sky taking up only 10-20% of the frame.

i. Take a picture using the gray button on the top of the camera.

i) The display should show a countdown in hours, minutes and seconds from 24 hours at the top of the LCD display screen.

j. Click "Display" again to turn off the LCD display on the back of the camera.

E. Battery Maintenance

a. Measure battery charge every time a site is visited.

b. Use keypad and enter "*614A".

i) This will give battery charge in volts.

ii) Batteries are under numbers 14, 15 &16 (see table).

(1) To change the number displayed press the "A" button.

c. Battery charge can also be taken manually with voltage meter.

"*6A" No.	Peak Charge	Location Within Housing	What it Powers
#14	14-15 V	Fiberglass box w/ datalogger	CR10x Datalogger
#15	~14.5 V	Floor (Usually same battery as # 16).	ISCO Sampler
#16	~14.5 V	Floor	Generator Starter

At most sites the sampler and generator are hooked up to the same battery. S3 is the exception.

F. Generator Maintenance

- a. Air Filter Change: Necessary every 150 hrs.
  - i) Remove black plastic housing cap from front of air filter (labeled, located inside the generator access panel).
  - ii) Remove metal wire that holds the filter in place (two wire ends that lead left to right across the front of the air filter).
  - iii) Remove the old filter and replace with a new one.
  - *(1) Note: Be sure that the rubber seal on the air filter is toward the carberator, or to the right.*
  - iv) Replace the wire holder.
  - v) Replace the housing cap.
- b. Oil Change: Oil changed annually.
  - i) Run the generator for several minutes to warm up oil.
  - ii) Remove plug from the bottom of the generator engine and allow to drain into a bucket (See Fred for bucket and new oil).
  - iii) Replace plug.
  - iv) Change oil filter.
  - v) Fill with new oil.
  - vi) Fill out "Generator Oil Change History" sheet.
- c. Running the Generator.
  - i) Starting from CR10 commands.
  - ii) Starting from the outside.
  - (1) *Note: This will only allow the generator to run for 1 minute.*
  - (2) Remove the side panel from the generator.
  - (3) Pump the primer on the fuel line until the primer is hard.
  - (4) Press the start button inside the generator housing.
  - *(5) Note: Do not hold the start button constantly for an extended period of time.*
  - (6) If the generator does not fire, lightly pump the primer while holding the start button.

G. Crest Gage (small white PVC pipe located near the flume on the wall)

  a. Remove cap and pull out piece of wood inside the pipe.
  b. If necessary add cork pieces to the pocket to hold them at the bottom of the piece of wood.
    i) *Note: Cork can be found in a bottle inside the equipment housing at every site.*
  c. Replace cork and piece of wood and put cap back on the crest gage.

(1) ATV (Ranger) Maintenance

H. Oil Change: Necessary every 100 hrs. or 6 months

  a. Refer to the "Owner's Manual for Maintenance & Safety", pg. 62-63 (See Randy Mentz).
  b. The engine takes 2 quarts with a filter change.
  c. Necessary parts and tools can be found in the Service Center (see Fred).
  d. Fill out "Ranger Maintenance History" sheet.

I. General Lubrication: Necessary every 50 hrs. or 3 months

J. Refer to the "Owner's Manual for Maintenance & Safety", pg. 59 (see Randy Mentz).

K. Grease these locations, and any other grease circs located on the front and rear suspension (grease gun located in maternity barn on the ranger tracks).

L. Fill out "Ranger Maintenance History" sheet.

M. Winter Track Lubrication

N. Each individual track has 6 grease circs on it.

O. This should be done daily to every other day.

    i) *Note: These circs do not take much grease, some only a half of a pump.*

(1) Lawn Mower Maintenance

P. Fluids

    a. Refer to the "Tecumseh Operators Manual", pg. 4.
    b. Check oil level and fill if necessary.
    c. Fill with 30W oil (see Fred).
    d. Top off with gasoline before starting.

Q. Starting
R. Refer to the "Tecumseh Operators Manual", pg. 6 and the "White Outdoor Operators Manual", pg. 10
S. Put throttle in "fast" position (picture of running rabbit)
T. Pump primer bulb 3-5 times.
U. Hold handle with levers depressed & pull to start.

(1) Weed-eater Maintenance

V. Fill weed-eater with 50:1 gas to oil fuel mix.

    a. 2 cycle oil is found in the Service Center.
    b. Read directions on 2 cycle oil bottle for making 50:1 fuel mixture.

W. Replacing the string on the weed-eater.
X. TURN THE WEED-EATER OFF!
Y. Remove the cap on the weed-eater head.
Z. Insert end of string into hole and wind the string on until the spool is full.
AA. Pull end of string out of the head.
BB. Replace cap.

(1) Bottle Organization

CC. Clean Bottles

  - a. Arrange clean bottles in the gray totes or coolers to be easily carried out to the sites. There should be 24 bottles per container.
  - b. Each cap should have a strip of orange tape to write down bottle identification.
  - c. Arrange totes in Maternity Barn so totes or coolers full of clean bottles are easily identifiable.

DD. Dirty Bottles
EE. Dirty bottles can be thrown into the dirty bottle bin in the Maternity Barn.
FF. Be sure that dirty bottles do not end up back in circulation with the clean bottles.

APPENDIX B

PIONEER FARM FIELD MANAGEMENT (2002-2005)

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S2 (Field 2)

Field 2 (40 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Alfalfa	Corn (Grain)	Corn (Grain)
Tillage	None	Chisel Plow (9/18)	Soil Finisher (4/26)	Soil Finisher (4/25), Fall Chisel
Plant Date	3/27	3/27	4/28	4/27
Harvest Date	6/13, 6/17, 7/13, 8/16, 10/22	6/16, 7/18, 8/14, 9/17	9/29	8/31

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S3 (Field 24)

Field 24 (30 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Corn (Grain)	Corn (Grain)	Corn (Grain)
Tillage	Fall Chisel	Spring Chisel (4/24), Fall Chisel	Soil Finisher (4/6, 4/28), Fall Chisel	Soil Finisher (4/26), Fall Chisel
Plant Date		4/25	4/08	4/28
Harvest Date	5/31, 6/25, 7/31, 8/29		9/29	6/2, 6/29, 8/8, 8/31

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S4 (Fields 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23)

Field 13 (4.9 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Corn (Grain)	Corn (Grain)	Oats / Alfalfa	Alfalfa
Tillage	Fall Chisel (11/23)	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/5), Fall Chisel	None
Plant Date	4/26	4/28	4/07	4/07
Harvest Date	9/26		8/13, 10/26	5/31, 6/29, 8/3, 9/6
Field 14 (4.4 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Tillage	None	None	None	Soil Finisher (4/26)
Plant Date	4/19	4/19	4/19	4/28
Harvest Date	5/28, 6/28, 8/7, 10/21	5/28, 7/2, 8/10, 9/8	6/9, 7/8, 8/12, 9/10	8/29
Field 15 (4.9 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Corn (Grain)	Corn (Silage)	Oats / Alfalfa	Alfalfa
Tillage	Fall Chisel	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/5), Fall Chisel	None
Plant Date	4/26	4/28	4/07	4/07
Harvest Date	9/6	9/4	8/13, 10/6	5/31, 6/29, 8/3, 9/6
Field 16 (4.9 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Tillage	None	None	None	Soil Finisher (4/26)
Plant Date			4/19	4/28
Harvest Date	5/28, 6/28, 8/8, 10/21	5/28, 7/2, 8/10, 9/8	6/9, 7/8, 8/12, 9/10	8/29
Field 17 (4.7 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Corn (Grain)	Corn (Grain)	Oats / Alfalfa	Alfalfa
Tillage	Fall Chisel	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/5), Fall Chisel	None
Plant Date	4/26	4/28	4/07	4/07
Harvest Date	9/6		8/12	5/31, 6/29, 8/3, 9/6
Field 18 (3.1 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Tillage	None	None	None	Soil Finisher (4/26)
Plant Date			4/19	4/28
Harvest Date	5/28, 6/28, 8/8, 10/21	5/28, 7/2, 8/10, 9/8	6/9, 7/8, 8/13, 9/10	8/29

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S4 (Fields 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23)				
Field 19 (3.1 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Corn (Grain)	Corn (Grain)	Oats / Alfalfa	Alfalfa
Tillage	Fall Chisel	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/6), Fall Chisel	None
Plant Date	4/26	4/28	4/07	4/07
Harvest Date	9/26		8/13	5/31, 6/29, 8/3, 9/6
Field 20 (6.3 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Tillage	None	None	None	Soil Finisher (4/26)
Plant Date	4/19	4/19	4/19	4/28
Harvest Date	5/28, 6/28, 8/7, 10/21	5/28, 7/2, 8/10, 9/8	6/8, 7/8, 8/7, 9/10	8/31
Field 21 (9 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Corn (Grain)	Corn (Grain)	Corn (Silage)	Oats / Alfalfa
Tillage	Fall Chisel (11/7)	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/04), Fall Chisel
Plant Date	4/26	4/28	4/28	4/05
Harvest Date	9/6		9/29	6/2 (Oats), 7/22 (Oats), 8/3, 9/6
Field 22 (1.9 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Alfalfa	Alfalfa	Alfalfa	Corn (Silage)
Tillage	None	None	None	Soil Finisher (4/26)
Plant Date	4/19	4/19	4/19	4/28
Harvest Date	5/28, 6/28, 8/7, 10/21	5/28, 7/2, 8/10, 9/8	6/8, 7/8, 8/7, 9/10	8/29
Field 23 (18.1 acres)	**2002**	**2003**	**2004**	**2005**
Crop	Oats / Alfalfa	Corn (Grain)	Corn (Grain)	Corn (Grain)
Tillage	Fall Chisel	Soil Finisher (5/12), Fall Chisel	Soil Finisher (4/27), Fall Chisel	Soil Finisher (4/26), Fall Chisel
Plant Date	4/11	5/13	4/28	4/27
Harvest Date	6/24, 7/16, 8/29		9/29	8/31

APPENDIX C

SWAT MANAGEMENT SCENARIOS

Dairy Rotation (A-A-C-C-OA-A) / ID CRN1 / Gridcode 113					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/29	Plant	Alfalfa		
2000	5/28	Harvest	Alfalfa		
2000	6/28	Harvest	Alfalfa		
2000	8/8	Harvest	Alfalfa		
2000	10/21	Harvest	Alfalfa		
2000	10/21	Kill	Alfalfa		
2000	10/21	Tillage	Chisel Plow		
2001	5/9	Plant	Corn		
2001	9/6	Harvest / Kill	Corn		
2001	9/6	Tillage	Chisel Plow		
2001	9/30	Manure	Dairy (15-15-28)	34,079	kg/ha
2002	5/8	Plant	Corn		
2002	9/26	Harvest / Kill	Corn		
2002	9/30	Manure	Dairy (15-15-28)	34,079	kg/ha
2002	10/1	Tillage	Chisel Plow		
2002	11/14	Manure	Dairy (15-15-28)	8,149	kg/ha
2002	11/14	Manure	Swine (17-14-27)	5,223	kg/ha
2003	5/1	Plant	Corn		
2003	9/26	Harvest / Kill	Corn		
2003	10/15	Tillage	Chisel Plow		
2004	4/20	Plant	Alfalfa		
2004	5/31	Harvest	Alfalfa		
2004	7/1	Harvest	Alfalfa		
2004	8/15	Harvest	Alfalfa		
2004	10/26	Harvest	Alfalfa		
2005	5/31	Harvest	Alfalfa		
2005	6/29	Harvest	Alfalfa		
2005	8/3	Harvest	Alfalfa		
2005	9/6	Harvest	Alfalfa		
2005	9/6	Kill	Alfalfa		

Dairy Rotation (C-CS-OA-A) / ID CRN2 / Gridcode 114

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	4/7	Plant	Alfalfa		
2000	6/2	Harvest	Alfalfa		
2000	9/10	Harvest	Alfalfa		
2000	8/10	Harvest	Alfalfa		
2000	8/10	Kill	Alfalfa		
2000	8/10	Tillage	Chisel Plow		
2001	5/1	Plant	Corn		
2001	9/15	Harvest / Kill	Corn		
2001	9/15	Tillage	Chisel Plow		
2002	4/25	Plant	Corn		
2002	9/10	Harvest / Kill	Corn		
2002	9/30	Manure	Dairy (15-15-28)	17,946	kg/ha
2002	9/30	Manure	Beef (11-7-17)	7,272	kg/ha
2003	2/20	Manure	Beef (11-7-17)	414	kg/ha
2003	4/25	Plant	Corn		
2003	9/10	Harvest / Kill	Corn		
2003	9/10	Tillage	Chisel Plow		
2004	4/20	Plant	Alfalfa		
2004	5/31	Harvest	Alfalfa		
2004	7/1	Harvest	Alfalfa		
2004	8/15	Harvest	Alfalfa		
2004	10/26	Harvest	Alfalfa		
2005	5/31	Harvest	Alfalfa		
2005	6/29	Harvest	Alfalfa		
2005	8/3	Harvest	Alfalfa		
2005	9/6	Harvest	Alfalfa		
2005	9/6	Harvest	Alfalfa		

Dairy Rotation (C-C-CS-OA) / ID CRN3 / Gridcode 115					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/29	Plant	Alfalfa		
2000	5/28	Harvest	Alfalfa		
2000	6/28	Harvest	Alfalfa		
2000	8/8	Harvest	Alfalfa		
2000	10/21	Harvest	Alfalfa		
2001	6/9	Harvest	Alfalfa		
2001	7/8	Harvest	Alfalfa		
2001	8/12	Harvest	Alfalfa		
2001	9/10	Harvest	Alfalfa		
2001	10/1	Kill	Alfalfa		
2001	10/15	Tillage	Chisel Plow		
2002	5/6	Plant	Corn		
2002	9/6	Harvest / Kill	Corn		
2002	9/30	Manure	Dairy (15-15-28)	12,958	
2002	11/7	Tillage	Chisel Plow		
2002	11/14	Manure	Swine (17-14-27)	12,668	
2003	5/8	Plant	Corn		
2003	9/29	Harvest / Kill	Corn		
2003	9/29	Tillage	Chisel Plow		
2003	11/14	Manure	Beef (11-7-17)	1,840	kg/ha
2003	12/2	Manure	Beef (11-7-17)	1,063	kg/ha
2004	2/19	Manure	Beef (11-7-17)	7,492	kg/ha
2004	5/8	Plant	Corn		
2004	9/29	Harvest / Kill	Corn		
2004	9/29	Tillage	Chisel Plow		
2005	4/20	Plant	Alfalfa		
2005	6/2	Harvest	Alfalfa		
2005	7/22	Harvest	Alfalfa		
2005	9/6	Harvest	Alfalfa		

Cash Grain (C-S-C-S-C-S) / ID CRN4 / Gridcode 116					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	5/4	Fertilizer	09-23-30	112	kg/ha
2000	5/5	Plant	Corn		
2000	9/15	Harvest / Kill	Corn		
2000	10/15	Fertilizer	03-10-48	168	kg/ha
2000	10/15	Tillage	Chisel Plow		
2001	4/30	Fertilizer	09-23-30	112	kg/ha
2001	5/1	Plant	Soybean		
2001	9/15	Harvest / Kill	Soybean		
2001	10/15	Fertilizer	09-23-30	224	kg/ha
2002	5/4	Fertilizer	09-23-30	112	kg/ha
2002	5/5	Plant	Corn		
2002	9/15	Harvest / Kill	Corn		
2002	10/15	Fertilizer	03-10-48	168	kg/ha
2002	10/15	Tillage	Chisel Plow		
2003	4/30	Fertilizer	09-23-30	112	kg/ha
2003	5/1	Plant	Soybean		
2003	9/15	Harvest / Kill	Soybean		
2003	10/15	Fertilizer	09-23-30	224	kg/ha
2004	5/4	Fertilizer	09-23-30	112	kg/ha
2004	5/5	Plant	Corn		
2004	9/15	Harvest / Kill	Corn		
2004	10/15	Fertilizer	03-10-48	168	kg/ha
2004	10/15	Tillage	Chisel Plow		
2005	4/30	Fertilizer	09-23-30	112	kg/ha
2005	5/1	Plant	Soybean		
2005	9/15	Harvest / Kill	Soybean		
2005	10/15	Fertilizer	09-23-30	224	kg/ha

Dairy Rotation (C-C-CS-OA-A-A) / ID CRN5 / Gridcode 117					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	5/10	Plant	Corn		
2000	9/10	Harvest / Kill	Corn		
2000	9/10	Tillage	Chisel Plow		
2001	5/10	Plant	Corn		
2001	9/10	Harvest / Kill	Corn		
2001	9/10	Tillage	Chisel Plow		
2002	5/6	Plant	Corn Silage		
2002	9/26	Harvest / Kill	Corn Silage		
2002	11/7	Tillage	Chisel Plow		
2003	4/30	Plant	Alfalfa		
2003	7/5	Harvest	Alfalfa		
2003	8/1	Harvest	Alfalfa		
2003	8/8	Harvest	Alfalfa		
2003	10/15	Harvest	Alfalfa		
2004	6/7	Harvest	Alfalfa		
2004	7/8	Harvest	Alfalfa		
2004	8/26	Harvest	Alfalfa		
2005	6/2	Harvest	Alfalfa		
2005	6/29	Harvest	Alfalfa		
2005	8/8	Harvest	Alfalfa		
2005	8/8	Kill	Alfalfa		

Cash Grain (S-C-S-C-S-C) / ID CRN6 / Gridcode 118

Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/30	Fertilizer	09-23-30	112	kg/ha
2000	5/1	Plant	Soybean		
2000	9/15	Harvest / Kill	Soybean		
2000	10/15	Fertilizer	09-23-30	224	kg/ha
2001	5/4	Fertilizer	09-23-30	112	kg/ha
2001	5/5	Plant	Corn		
2001	9/15	Harvest / Kill	Corn		
2001	10/15	Fertilizer	03-10-48	168	kg/ha
2001	10/15	Tillage	Chisel Plow		
2002	4/30	Fertilizer	09-23-30	112	kg/ha
2002	5/1	Plant	Soybean		
2002	9/15	Harvest / Kill	Soybean		
2002	10/15	Fertilizer	09-23-30	224	kg/ha
2003	5/4	Fertilizer	09-23-30	112	kg/ha
2003	5/5	Plant	Corn		
2003	9/15	Harvest / Kill	Corn		
2003	10/15	Fertilizer	03-10-48	168	kg/ha
2003	10/15	Tillage	Chisel Plow		
2004	4/30	Fertilizer	09-23-30	112	kg/ha
2004	5/1	Plant	Soybean		
2004	9/15	Harvest / Kill	Soybean		
2004	10/15	Fertilizer	09-23-30	224	kg/ha
2005	5/4	Fertilizer	09-23-30	112	kg/ha
2005	5/5	Plant	Corn		
2005	9/15	Harvest / Kill	Corn		
2005	10/15	Fertilizer	03-10-48	168	kg/ha
2005	10/15	Tillage	Chisel Plow		

Dairy Rotation (C-OA-A-A-A-C) / ID ALF1 / Gridcode 124

Year	*Date*	*Operation*	*Crop / Type*	*Rate*	*Units*
2000	5/7	Tillage	Soil Finisher		
2000	5/8	Plant	Corn		
2000	9/10	Harvest / Kill	Corn		
2000	9/10	Tillage	Chisel Plow		
2001	4/19	Tillage	Soil Finisher		
2001	4/20	Plant	Alfalfa		
2001	6/2	Harvest	Alfalfa		
2001	7/8	Harvest	Alfalfa		
2001	8/3	Harvest	Alfalfa		
2001	9/6	Harvest	Alfalfa		
2002	5/28	Harvest	Alfalfa		
2002	6/28	Harvest	Alfalfa		
2002	8/8	Harvest	Alfalfa		
2002	10/21	Harvest	Alfalfa		
2003	5/28	Harvest	Alfalfa		
2003	7/2	Harvest	Alfalfa		
2003	8/10	Harvest	Alfalfa		
2003	9/8	Harvest	Alfalfa		
2004	6/9	Harvest	Alfalfa		
2004	7/8	Harvest	Alfalfa		
2004	8/12	Harvest	Alfalfa		
2004	9/10	Harvest	Alfalfa		
2004	9/10	Kill	Alfalfa		
2004	9/10	Tillage	Chisel Plow		
2005	5/8	Plant	Corn Silage		
2005	8/25	Manure	Dairy (15-15-28)	1,284	kg/ha
2005	8/29	Harvest / Kill	Corn Silage		
2005	8/29	Tillage	Chisel Plow		
2005	10/17	Manure	Dairy (15-15-28)	6,811	kg/ha
2005	10/24	Manure	Dairy (15-15-28)	581	kg/ha
2005	10/25	Manure	Dairy (15-15-28)	8,731	kg/ha
2005	11/14	Manure	Dairy (15-15-28)	406	kg/ha

Dairy Rotation (A-A-A-C-C-C) / ID ALF2 / Gridcode 125					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	3/27	Plant	Alfalfa		
2000	5/31	Harvest	Alfalfa		
2000	6/25	Harvest	Alfalfa		
2000	7/31	Harvest	Alfalfa		
2000	8/29	Harvest	Alfalfa		
2001	5/31	Harvest	Alfalfa		
2001	6/25	Harvest	Alfalfa		
2001	7/31	Harvest	Alfalfa		
2001	8/29	Harvest	Alfalfa		
2002	5/31	Harvest	Alfalfa		
2002	6/25	Harvest	Alfalfa		
2002	7/31	Harvest	Alfalfa		
2002	9/9	Harvest	Alfalfa		
2002	10/8	Manure	Beef (11-7-17)	1,186	kg/ha
2002	10/8	Manure	Dairy (15-15-28)	1,487	kg/ha
2002	10/9	Manure	Beef (11-7-17)	986	kg/ha
2002	10/20	Kill	Alfalfa		
2002	10/20	Tillage	Chisel Plow		
2002	10/28	Manure	Beef (11-7-17)	94	kg/ha
2002	10/29	Manure	Dairy (15-15-28)	952	kg/ha
2002	11/18	Manure	Swine (17-14-27)	195	kg/ha
2002	11/19	Manure	Beef (11-7-17)	174	kg/ha
2002	11/26	Manure	Beef (11-7-17)	98	kg/ha
2002	12/11	Manure	Dairy (15-15-28)	737	kg/ha
2002	12/13	Manure	Beef (11-7-17)	189	kg/ha
2002	12/20	Manure	Swine (17-14-27)	159	kg/ha
2002	12/30	Manure	Beef (11-7-17)	571	kg/ha
2003	1/25	Manure	Beef (11-7-17)	1,912	kg/ha
2003	5/7	Manure	Swine (17-14-27)	350	kg/ha
2003	5/8	Plant	Corn		
2003	9/8	Harvest / Kill	Corn		
2003	9/8	Tillage	Chisel Plow		
2003	10/20	Manure	Dairy (15-15-28)	3,348	kg/ha
2003	11/10	Manure	Dairy (15-15-28)	10,176	kg/ha
2004	5/1	Plant	Corn		
2004	9/29	Harvest / Kill	Corn		
2004	10/22	Manure	Dairy (15-15-28)	13,740	kg/ha
2004	11/30	Manure	Dairy (15-15-28)	283	kg/ha
2005	4/28	Plant	Corn		
2005	8/31	Harvest / Kill	Corn		

Dairy Rotation (OA-A-A-A-C-C) / ID ALF3 / Gridcode 126					
Year	***Date***	***Operation***	***Crop / Type***	***Rate***	***Units***
2000	4/1	Plant	Alfalfa		
2000	6/8	Harvest	Alfalfa		
2000	7/10	Harvest	Alfalfa		
2000	8/20	Harvest	Alfalfa		
2000	10/1	Harvest	Alfalfa		
2001	6/8	Harvest	Alfalfa		
2001	7/8	Harvest	Alfalfa		
2001	8/10	Harvest	Alfalfa		
2001	10/15	Harvest	Alfalfa		
2002	6/16	Harvest	Alfalfa		
2002	7/13	Harvest	Alfalfa		
2002	8/16	Harvest	Alfalfa		
2002	10/22	Harvest	Alfalfa		
2003	6/16	Harvest	Alfalfa		
2003	7/18	Harvest	Alfalfa		
2003	8/14	Harvest	Alfalfa		
2003	9/17	Harvest	Alfalfa		
2003	9/17	Kill	Alfalfa		
2003	11/1	Tillage	Chisel Plow		
2004	5/3	Plant	Corn		
2004	9/29	Harvest / Kill	Corn		
2004	9/29	Tillage	Chisel Plow		
2004	10/13	Manure	Dairy (15-15-28)	631	kg/ha
2004	10/25	Manure	Beef (11-7-17)	421	kg/ha
2004	11/9	Manure	Dairy (15-15-28)	7,762	kg/ha
2004	11/10	Manure	Beef (11-7-17)	402	kg/ha
2004	11/11	Manure	Dairy (15-15-28)	1,435	kg/ha
2005	1/3	Manure	Beef (11-7-17)	399	kg/ha
2005	2/2	Manure	Dairy (15-15-28)	869	kg/ha
2005	2/3	Manure	Beef (11-7-17)	1,184	kg/ha
2005	5/8	Plant	Corn		
2005	8/31	Harvest / Kill	Corn		
2005	8/31	Tillage	Chisel Plow		

APPENDIX D

PIONEER FARM MANURE APPLICATIONS

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S2 (Field 2)

Field	Application Date	Pioneer Farm Manure Type	SWAT Manure Type	Composition (N-P-K)	SWAT Fraction (MN,OrgN,MP,OrgP)	Rate (kg/ha)
2	10/25/2004	Slurrystore	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	421
2	11/10/2004	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	402
2	1/3/2005	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	399
2	2/3/2005	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	1184
2	10/13/2004	Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	631
2	11/9/2004	Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	7762
2	11/11/2004	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	1435
2	2/2/2005	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	869

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S3 (Field 24)

Field	Application Date	Pioneer Farm Manure Type	SWAT Manure Type	Composition (N-P-K)	SWAT Fraction (MN,OrgN,MP,OrgP)	Rate (kg/ha)
24	10/8/2002	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	1186
24	10/9/2002	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	986
24	10/28/2002	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	94
24	11/19/2002	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	174
24	11/26/2002	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	98
24	12/13/2002	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	189
24	12/20/2002	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	167
24	12/30/2002	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	170
24	1/25/2003	Beef Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	234
24	1/25/2003	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	1912
24	10/8/2002	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	1487
24	10/29/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	334
24	10/29/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	618
24	12/11/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	69
24	12/11/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	121
24	12/12/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	547
24	10/20/2003	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	3348
24	11/10/2003	Dairy Lagoon	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	10176
24	10/22/2004	Dairy Lagoon	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	13740
24	11/30/2004	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	283
24	11/18/2002	Hog Pack	Swine Fresh Manure	17-14-27	0.0047; 0.0038, 0.0021, 0.0010	195
24	12/20/2002	Hog Pack	Swine Fresh Manure	17-14-27	0.0047; 0.0038, 0.0021, 0.0010	159
24	4/18/2003	Hog Pack	Swine Fresh Manure	17-14-27	0.0047; 0.0038, 0.0021, 0.0010	350

UW-Platteville Pioneer Farm Fields Contributing to Monitoring Site S4 (Fields 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23)

Field	Application Date	Pioneer Farm Manure Type	SWAT Manure Type	Composition (N-P-K)	SWAT Fraction (MN,OrgN,MP,OrgP)	Rate (kg/ha)
13	9/30/2002	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	5365
13	11/14/2002	Dairy Lagoon	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	8149
14	10/24/2005	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	581
15	9/30/2002	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	9329
15	10/17/2005	Hog Pack	Swine Fresh Manure	17-14-27	0.0047; 0.0038, 0.0021, 0.0010	2808
16	8/25/2005	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	1284
16	10/17/2005	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	6811
17	9/30/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	21719
17	11/14/2002	Hog Slurry	Swine Fresh Manure	17-14-27	0.0047; 0.0038, 0.0021, 0.0010	5223
18	10/25/2005	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	5358
19	9/30/2002	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	6995
20	11/14/2005	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	406
21	11/14/2003	Beef Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	1840
21	12/2/2003	Beef Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	1063
21	2/19/2004	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	7492
21	9/30/2002	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	820
21	9/30/2002	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	12138
21	11/14/2002	Hog Slurry	Swine Fresh Manure	17-14-27	0.0047; 0.0038, 0.0021, 0.0010	12668
22	10/25/2005	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	3363
23	10/17/2003	Bull Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	1289
23	10/18/2003	Beef Compost	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	2714
23	11/12/2004	Bull Pack	Beef Fresh Manure	11-7-17	0.0013; 0.0041; 0.0006; 0.0010	229
23	10/20/2003	Dairy Compost	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	5533
23	10/22/2003	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	12741
23	10/22/2004	Dairy Lagoon	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	13740
23	11/11/2004	Dairy Pack	Dairy Fresh Manure	15-15-28	0.0014; 0.0061; 0.0021; 0.0012	1630

APPENDIX E

LAFAYETTE COUNTY TRANSECT DATA 2000-2005 NEAR UPPER FEVER RIVER WATERSHED REGION

Field	Year	Present Crop	Previous Crop	Tillage System	Percent Slope	P-Factor	Ephermeral Erosion	T-Level	K-Factor	Residue Cover	Slope Length (ft)	Est. Soil	Rel. Soil	Soil Loss	Within Watershed Boundary?
298L	2000	Corn	Soybeans	No-till	5-6%	1.0	Yes	5 t/a	0.28	31-50%	125 (100-125)	7.8	1.6	2.8	No
298L	2001	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	1.0	No	5 t/a	0.28	76-100%	125 (100-125)	1.7	0.3	0.0	No
298L	2002	Corn	Soybeans	Conventional (<15% cover)	5-6%	1.0	No	5 t/a	0.28	0-15%	125 (100-125)	13.2	2.6	8.2	No
298L	2003	Corn	Corn	Mulch-till (≥30% cover)	5-6%	1.0	No	5 t/a	0.28	31-50%	125 (100-125)	3.7	0.7	0.0	No
298L	2004	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	1.0	Yes	5 t/a	0.28	76-100%	125 (100-125)	1.7	0.3	0.0	No
298L	2005	Corn	Soybeans	No-till	5-6%	1.0	No	5 t/a	0.28	16-30%	125 (100-125)	10.8	2.2	5.8	No
298R	2000	Corn	Soybeans	Conventional (<15% cover)	5-6%	1.0	Yes	5 t/a	0.28	0-15%	125 (100-125)	13.2	2.6	8.2	No
298R	2001	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	1.0	Yes	5 t/a	0.28	76-100%	125 (100-125)	1.7	0.3	0.0	No
298R	2002	Corn	Soybeans	No-till	5-6%	1.0	No	5 t/a	0.28	16-30%	125 (100-125)	10.8	2.2	5.8	No
298R	2003	Drilled Soybeans (Rows <15")	Corn	Other (mulch-till) 15-30% cover	5-6%	1.0	No	5 t/a	0.28	16-30%	125 (100-125)	6.1	1.2	1.1	No
298R	2004	Corn	Soybeans	Conventional (<15% cover)	5-6%	1.0	Yes	5 t/a	0.28	0-15%	125 (100-125)	13.2	2.6	8.2	No
298R	2005	Drilled Soybeans (Rows <15")	Corn	Mulch-till (≥30% cover)	5-6%	1.0	No	5 t/a	0.28	31-50%	125 (100-125)	4.4	0.9	0.0	No
299R	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	5-6%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	15.6	3.1	10.6	No
299R	2001	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	1.0	Yes	5 t/a	0.28	51-75%	175 (150-200)	4.0	0.8	0.0	No
299R	2002	Corn	Soybeans	No-till	5-6%	1.0	Yes	5 t/a	0.28	0-15%	175 (150-200)	15.6	3.1	10.6	No
299R	2003	Drilled Soybeans (Rows <15")	Corn	Other (mulch-till) 15-30% cover	5-6%	1.0	No	5 t/a	0.28	16-30%	175 (150-200)	7.2	1.4	2.2	No
299R	2004	Corn	Soybeans	Other (mulch-till) 15-30% cover	5-6%	1.0	Yes	5 t/a	0.28	0-15%	175 (150-200)	15.6	3.1	10.6	No
299R	2005	Drilled Soybeans (Rows <15")	Corn	Mulch-till (≥30% cover)	5-6%	1.0	No	5 t/a	0.28	51-75%	175 (150-200)	4.0	0.8	0.0	No
300L	2000	Corn	Corn	Mulch-till (≥30% cover)	1-2%	1.0	No	5 t/a	0.28	16-30%	175 (150-200)	1.4	0.3	0.0	No
300L	2001	Corn	Corn	Other (mulch-till) 15-30% cover	1-2%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	2.8	0.6	0.0	No
300L	2002	Corn	Corn	Conventional (<15% cover)	1-2%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	2.8	0.6	0.0	No
300L	2003	Drilled Soybeans (Rows <15")	Corn	Other (mulch-till) 15-30% cover	1-2%	1.0	No	5 t/a	0.28	16-30%	175 (150-200)	1.5	0.3	0.0	No
300L	2004	Corn	Soybeans	No-till	1-2%	1.0	No	5 t/a	0.28	16-30%	175 (150-200)	2.7	0.5	0.0	No
300L	2005	Drilled Soybeans (Rows <15")	Corn	Mulch-till (≥30% cover)	1-2%	1.0	No	5 t/a	0.28	31-50%	175 (150-200)	1.1	0.2	0.0	No
300R	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	3-4%	1.0	No	5 t/a	0.28	0-15%	125 (100-125)	6.9	1.4	1.9	No
300R	2001	Drilled Soybeans (Rows <15")	Corn	No-till	3-4%	1.0	No	5 t/a	0.28	76-100%	125 (100-125)	0.9	0.2	0.0	No
300R	2002	Corn	Soybeans	No-till	3-4%	1.0	Yes	5 t/a	0.28	0-15%	125 (100-125)	6.9	1.4	1.9	No
300R	2003	Drilled Soybeans (Rows <15")	Corn	Doesn't Apply	3-4%	1.0	No	5 t/a	0.28	16-30%	125 (100-125)	3.2	0.6	0.0	No
300R	2004	Corn	Soybeans	Other (mulch-till) 15-30% cover	3-4%	1.0	Yes	5 t/a	0.28	0-15%	125 (100-125)	6.9	1.4	1.9	No
300R	2005	Drilled Soybeans (Rows <15")	Corn	Mulch-till (≥30% cover)	3-4%	1.0	No	5 t/a	0.28	51-75%	125 (100-125)	1.8	0.4	0.0	No

Field	Year	Present Crop	Previous Crop	Tillage System	Percent Slope	P-Factor	Ephermeral Erosion	T-Level	K-Factor	Residue Cover	Slope Length (ft)	Est. Soil	Rel. Soil	Soil Loss	Within Watershed Boundary?
301L	2000	Alfalfa	Alfalfa	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	Doesn't Apply	175 (150-200)	1.1	0.2	0.0	No
301L	2001	Alfalfa	Alfalfa	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	1.1	0.2	0.0	No
301L	2002	Alfalfa	Alfalfa	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	Doesn't Apply	175 (150-200)	1.1	0.2	0.0	No
301L	2003	Corn	Alfalfa	Conventional (<15% cover)	7-8%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	10.6	2.1	5.3	No
301L	2004	Drilled Soybeans (Rows <15")	Corn	Other (mulch-till) 15-30% cover	7-8%	1.0	Yes	5 t/a	0.28	16-30%	175 (150-200)	10.3	2.1	5.3	No
301L	2005	Corn	Soybeans	Conventional (<15% cover)	7-8%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	22.3	4.5	17.3	No
301R	2000	Corn	Alfalfa	Conventional (<15% cover)	5-6%	0.4	No	5 t/a	0.28	0-15%	125 (100-125)	2.4	0.5	0.0	No
301R	2001	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	0.4	No	5 t/a	0.28	76-100%	125 (100-125)	0.7	0.1	0.0	No
301R	2002	Corn	Soybeans	No-till	5-6%	0.4	No	5 t/a	0.28	0-15%	125 (100-125)	5.3	1.1	0.3	No
301R	2003	Corn	Corn	Mulch-till (?30% cover)	5-6%	0.4	No	5 t/a	0.28	31-50%	125 (100-125)	1.5	0.3	0.0	No
301R	2004	Corn	Corn	Conventional (<15% cover)	5-6%	0.4	No	5 t/a	0.28	0-15%	125 (100-125)	4.5	0.9	0.0	No
301R	2005	Small Grains	Corn	Doesn't Apply	5-6%	0.4	No	5 t/a	0.28	Doesn't Apply	125 (100-125)	1.6	0.3	0.0	No
302L	2000	Corn	Corn	Conventional (<15% cover)	1-2%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	2.8	0.6	0.0	No
302L	2001	Drilled Soybeans (Rows <15")	Corn	No-till	1-2%	1.0	No	5 t/a	0.28	51-75%	175 (150-200)	0.8	0.2	0.0	No
302L	2002	Alfalfa	Soybeans	Doesn't Apply	1-2%	1.0	Yes	5 t/a	0.28	Doesn't Apply	175 (150-200)	0.2	0.0	0.0	No
302L	2003	Alfalfa	Alfalfa	Doesn't Apply	1-2%	1.0	No	5 t/a	0.28	Doesn't Apply	175 (150-200)	0.2	0.0	0.0	No
302L	2004	Alfalfa	Alfalfa	Doesn't Apply	1-2%	1.0	No	5 t/a	0.28	Doesn't Apply	175 (150-200)	0.2	0.0	0.0	No
302L	2005	Corn	Alfalfa	Conventional (<15% cover)	1-2%	1.0	No	5 t/a	0.28	0-15%	175 (150-200)	1.5	0.3	0.0	No
302R	2000	Alfalfa	Alfalfa	Doesn't Apply	5-6%	0.3	No	5 t/a	0.28	Doesn't Apply	125 (100-125)	0.2	0.0	0.0	Yes
302R	2001	Corn	Alfalfa	Conventional (<15% cover)	5-6%	0.3	No	5 t/a	0.28	0-15%	125 (100-125)	1.8	0.4	0.0	Yes
302R	2002	Drilled Soybeans (Rows <15")	Corn	Conventional (<15% cover)	5-6%	0.3	No	5 t/a	0.28	0-15%	125 (100-125)	2.8	0.6	0.0	Yes
302R	2003	Corn	Soybeans	Conventional (<15% cover)	5-6%	0.3	No	5 t/a	0.28	0-15%	125 (100-125)	4.0	0.8	0.0	Yes
302R	2004	Drilled Soybeans (Rows <15")	Corn	Conventional (<15% cover)	5-6%	0.3	No	5 t/a	0.28	0-15%	125 (100-125)	2.8	0.6	0.0	Yes
302R	2005	Corn	Soybeans	Conventional (<15% cover)	5-6%	0.3	No	5 t/a	0.28	0-15%	125 (100-125)	4.0	0.8	0.0	Yes
303R	2000	Corn	Corn	Other (mulch-till) 15-30% cover	3-4%	0.5	No	3 t/a	0.28	16-30%	125 (100-125)	1.4	0.5	0.0	No
303R	2001	Corn	Corn	Conventional (<15% cover)	3-4%	0.5	No	3 t/a	0.28	0-15%	125 (100-125)	2.9	1.0	0.0	No
303R	2002	Small Grains	Corn	Doesn't Apply	3-4%	0.5	No	3 t/a	0.28	Doesn't Apply	125 (100-125)	1.1	0.4	0.0	No
303R	2003	Alfalfa	Small Grains	?	3-4%	0.5	No	3 t/a	0.28	Doesn't Apply	125 (100-125)	0.2	0.1	0.0	No
303R	2004	Alfalfa	Alfalfa	Doesn't Apply	3-4%	0.5	No	5 t/a	0.28	Doesn't Apply	125 (100-125)	0.2	0.1	0.0	No
303R	2005	Corn	Alfalfa	No-till	3-4%	0.5	No	3 t/a	0.28	76-100%	125 (100-125)	0.1	0.0	0.0	No

Field	Year	Present Crop	Previous Crop	Tillage System	Percent Slope	P-Factor	Ephermeral Erosion	T-Level	K-Factor	Residue Cover	Slope Length (ft)	Est. Soil	Rel. Soil	Soil Loss	Within Watershed Boundary?
304L	2000	Corn	Corn	Other (mulch-till) 15-30% cover	9-10%	1.0	Yes	4 t/a	0.28	0-15%	175 (150-200)	26.4	6.6	22.4	No
304L	2001	Corn	Corn	Conventional (<15% cover)	9-10%	1.0	Yes	4 t/a	0.28	0-15%	175 (150-200)	26.4	6.6	22.4	No
304L	2002	Corn	Corn	Conventional (<15% cover)	9-10%	1.0	Yes	4 t/a	0.28	0-15%	175 (150-200)	26.4	6.6	22.4	No
304L	2003	Corn	Corn	Conventional (<15% cover)	9-10%	1.0	Yes	4 t/a	0.28	0-15%	175 (150-200)	26.4	6.6	22.4	No
304L	2004	Fallow (set-aside)	Corn	Doesn't Apply	9-10%	1.0	No	3 t/a	0.28	Doesn't Apply	175 (150-200)	1.6	0.4	0.0	No
304L	2005	Corn	Fallow	Conventional (<15% cover)	9-10%	1.0	No	4 t/a	0.28	0-15%	175 (150-200)	14.4	3.6	10.4	No
304R	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	5-6%	1.0	No	4 t/a	0.28	0-15%	125 (100-125)	13.2	3.3	9.2	No
304R	2001	Corn	Corn	Conventional (<15% cover)	5-6%	1.0	No	4 t/a	0.28	0-15%	125 (100-125)	11.2	2.8	7.2	No
304R	2002	Small Grains	Corn	Doesn't Apply	5-6%	1.0	No	4 t/a	0.28	Doesn't Apply	125 (100-125)	4.1	1.0	0.1	No
304R	2003	Corn	Small Grains	Conventional (<15% cover)	5-6%	1.0	Yes	4 t/a	0.28	0-15%	125 (100-125)	11.5	2.9	7.5	No
304R	2004	Small Grains	Corn	Doesn't Apply	5-6%	1.0	No	4 t/a	0.28	Doesn't Apply	125 (100-125)	4.1	1.0	0.1	No
304R	2005	Alfalfa	Small Grains	Doesn't Apply	5-6%	1.0	No	4 t/a	0.28	Doesn't Apply	125 (100-125)	0.7	0.2	0.0	No
305L	2000	Alfalfa	Small Grains	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	Doesn't Apply	125 (100-125)	1.0	0.2	0.0	No
305L	2001	Alfalfa	Alfalfa	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	0-15%	125 (100-125)	1.0	0.2	0.0	No
305L	2002	Alfalfa	Alfalfa	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	Doesn't Apply	125 (100-125)	1.0	0.2	0.0	No
305L	2003	Alfalfa	Alfalfa	Doesn't Apply	7-8%	1.0	No	5 t/a	0.28	Doesn't Apply	125 (100-125)	1.0	0.2	0.0	No
305L	2004	Corn	Alfalfa	Conventional (<15% cover)	7-8%	1.0	Yes	4 t/a	0.28	0-15%	125 (100-125)	8.7	1.7	3.7	No
305L	2005	Corn	Corn	Conventional (<15% cover)	7-8%	1.0	No	5 t/a	0.28	0-15%	125 (100-125)	15.9	3.2	10.9	No
305R	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	7-8%	1.0	No	5 t/a	0.28	16-30%	125 (100-125)	15.4	3.1	10.4	No
305R	2001	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	1.0	No	5 t/a	0.28	51-75%	125 (100-125)	4.8	1.0	0.0	No
305R	2002	Corn	Soybeans	No-till	7-8%	1.0	No	5 t/a	0.28	51-75%	125 (100-125)	5.8	1.2	0.8	No
305R	2003	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	1.0	No	5 t/a	0.28	76-100%	125 (100-125)	2.4	0.5	0.0	No
305R	2004	Corn	Soybeans	No-till	7-8%	1.0	No	5 t/a	0.28	51-75%	125 (100-125)	5.8	1.2	0.8	No
305R	2005	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	1.0	No	5 t/a	0.28	51-75%	125 (100-125)	4.8	1.0	0.0	No
306L	2000	Corn	Alfalfa	Other (mulch-till) 15-30% cover	7-8%	0.5	No	4 t/a	0.28	16-30%	175 (150-200)	3.1	0.8	0.0	No
306L	2001	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	0.5	Yes	4 t/a	0.28	76-100%	175 (150-200)	1.4	0.4	0.0	No
306L	2002	Corn	Soybeans	No-till	7-8%	0.5	Yes	4 t/a	0.28	31-50%	175 (150-200)	6.6	1.6	2.6	No
306L	2003	Small Grains	Corn	Doesn't Apply	7-8%	0.5	No	4 t/a	0.28	Doesn't Apply	175 (150-200)	3.4	0.9	0.0	No
306L	2004	Alfalfa	Small Grains	Doesn't Apply	7-8%	0.5	No	5 t/a	0.28	Doesn't Apply	175 (150-200)	0.6	0.1	0.0	No
306L	2005	Alfalfa	Alfalfa	Doesn't Apply	7-8%	0.5	No	4 t/a	0.28	Doesn't Apply	175 (150-200)	0.6	0.1	0.0	No

Field	Year	Present Crop	Previous Crop	Tillage System	Percent Slope	P-Factor	Ephermeral Erosion	T-Level	K-Factor	Residue Cover	Slope Length (ft)	Est. Soil	Rel. Soil	Soil Loss	Within Watershed Boundary?
306R	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	5-6%	1.0	No	4 t/a	0.28	0-15%	175 (150-200)	15.6	3.9	11.6	No
306R	2001	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	1.0	No	4 t/a	0.28	76-100%	175 (150-200)	2.0	0.5	0.0	No
306R	2002	Corn	Soybeans	No-till	5-6%	1.0	No	4 t/a	0.28	51-75%	175 (150-200)	4.8	1.2	0.8	No
306R	2003	Drilled Soybeans (Rows <15")	Corn	No-till	5-6%	1.0	No	4 t/a	0.28	76-100%	175 (150-200)	2.0	0.5	0.0	No
306R	2004	Corn	Soybeans	No-till	5-6%	1.0	No	4 t/a	0.28	31-50%	175 (150-200)	9.2	2.3	5.2	No
306R	2005	Corn	Corn	No-till	5-6%	1.0	No	4 t/a	0.28	51-75%	175 (150-200)	3.6	0.9	0.0	No
307L	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	7-8%	0.5	No	5 t/a	0.28	0-15%	175 (150-200)	11.1	2.2	6.1	Yes
307L	2001	Corn	Corn	Mulch-till (?30% cover)	7-8%	0.5	No	5 t/a	0.28	16-30%	175 (150-200)	4.6	0.9	0.0	Yes
307L	2002	Drilled Soybeans (Rows <15")	Corn	Conventional (<15% cover)	7-8%	0.5	No	5 t/a	0.28	16-30%	175 (150-200)	5.1	1.0	0.1	Yes
307L	2003	Corn	Soybeans	No-till	7-8%	0.5	No	5 t/a	0.28	16-30%	175 (150-200)	9.1	1.8	4.1	Yes
307L	2004	Drilled Soybeans (Rows <15")	Corn	Other (mulch-till) 15-30% cover	7-8%	0.5	Yes	4 t/a	0.28	16-30%	175 (150-200)	5.1	1.0	0.1	Yes
307L	2005	Corn	Soybeans	No-till	7-8%	0.5	No	5 t/a	0.28	16-30%	175 (150-200)	9.1	1.8	4.1	Yes
307R	2000	Corn	Soybeans	Other (mulch-till) 15-30% cover	3-4%	1.0	Yes	5 t/a	0.28	0-15%	175 (150-200)	7.8	1.6	2.8	Yes
307R	2001	Drilled Soybeans (Rows <15")	Corn	Mulch-till (?30% cover)	3-4%	1.0	No	5 t/a	0.28	31-50%	175 (150-200)	2.6	0.5	0.0	Yes
307R	2002	Corn	Soybeans	No-till	3-4%	1.0	No	5 t/a	0.28	16-30%	175 (150-200)	6.4	1.3	1.4	Yes
307R	2003	Drilled Soybeans (Rows <15")	Corn	No-till	3-4%	1.0	No	5 t/a	0.28	76-100%	175 (150-200)	1.0	0.2	0.0	Yes
307R	2004	Corn	Soybeans	Conventional (<15% cover)	3-4%	1.0	Yes	5 t/a	0.28	0-15%	175 (150-200)	7.8	1.6	2.8	Yes
307R	2005	Drilled Soybeans (Rows <15")	Corn	No-till	3-4%	1.0	No	5 t/a	0.28	76-100%	175 (150-200)	1.0	0.2	0.0	Yes
308L	2000	Corn	Corn	Other (mulch-till) 15-30% cover	7-8%	1.0	Yes	5 t/a	0.28	0-15%	175 (150-200)	18.8	3.8	13.8	No
308L	2001	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	1.0	No	5 t/a	0.28	76-100%	175 (150-200)	2.9	0.6	0.0	No
308L	2002	Corn	Soybeans	No-till	7-8%	1.0	Yes	5 t/a	0.28	16-30%	175 (150-200)	18.3	3.7	13.3	No
308L	2003	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	1.0	No	5 t/a	0.28	76-100%	175 (150-200)	2.9	0.6	0.0	No
308L	2004	Corn	Soybeans	No-till	7-8%	1.0	No	5 t/a	0.28	16-30%	175 (150-200)	18.3	3.7	13.3	No
308L	2005	Drilled Soybeans (Rows <15")	Corn	No-till	7-8%	1.0	No	5 t/a	0.28	76-100%	175 (150-200)	2.9	0.6	0.0	No
308R	2001	Drilled Soybeans (Rows <15")	Corn	Mulch-till (?30% cover)	5-6%	0.3	No	5 t/a	0.28	51-75%	75 (50-100)	0.8	0.2	0.0	No
308R	2002	Corn	Soybeans	No-till	5-6%	1.0	No	5 t/a	0.28	16-30%	75 (50-100)	8.4	1.7	3.4	No
308R	2004	Corn	Soybeans	Other (mulch-till) 15-30% cover	5-6%	1.0	Yes	5 t/a	0.28	0-15%	75 (50-100)	10.3	2.1	5.3	No
308R	2005	Corn	Corn	Other (mulch-till) 15-30% cover	5-6%	1.0	No	5 t/a	0.28	16-30%	75 (50-100)	4.2	0.8	0.0	No

APPENDIX F

PEST INPUT FILE

```
pcf
* control data
norestart   estimation
4  32  3  0  1
2  1  single point   1  0  0
5.0  2.0  0.3  0.03  10
5.0  5.0  0.001
0.1  aui
30  0.005  4  4  0.005  4
1  1  1
* parameter groups
leone  relative  0.001  0.001  switch  2.0  parabolic
leten  relative  0.01  0.001  switch  2.0  parabolic
lehun  relative  0.1  0.001  switch  2.0  parabolic
* parameter data
esco  none  factor  0.755  0.10  0.98 leone  1.0  0.0  1
cnop1  none  factor  73.695  30.0  90.0 leten  1.0  0.0  1
cnop2  none  factor  59.285  30.0  90.0 leten  1.0  0.0  1
cnop4  none  factor  73.264  30.0  90.0 lehun  1.0  0.0  1
* observation groups
mflow
* observation data
f1  0.12  1  mflow
f2  0.15  1  mflow
f3  0.02  1  mflow
f4  0.56  1  mflow
f5  0.05  1  mflow
f6  0.33  1  mflow
f7  0.16  1  mflow
f8  8.57  1  mflow
f9  1.28  1  mflow
f10  0.59  1  mflow
f11  0.06  1  mflow
f12  0.03  1  mflow
………………….
f30  0.03  1  mflow
f31  0.23  1  mflow
f32  0.03  1  mflow
* model command line
swat1.bat
* model input/output
hru10001.tpl  000010001.hru
mgt10001.tpl  000010001.mgt
platout.ins  agg.out
```

APPENDIX G

FIELD WATERSHED STORM DISCHARGE, SEDIMENT, AND TP AGGREGATION

Field Station ID	SWAT Aggregated Dates	# of Events Aggregated	Event Precipitation (mm)	Previous 5-Day Precipitation Total (mm)	Measured Event Volume (mm H_20)	Measured Sediment Load (metric tons)	Measured Total Phosphorus Load (kg/ha)
S2	06/03/2002, 06/04/2002	1	75.44	4.83	0.12	0.0065	0.001
S2	07/06/2002	1	54.99	0.00	0.15	0.0006	0.002
S2	07/22/2002	1	28.45	1.27	0.02	0.0000	0.001
S2	08/21/2002	1	67.82	0.51	0.56	0.0077	0.014
S2	09/18/2002, 09/19/2002	1	19.18	2.54	0.05	0.0005	0.001
S2	09/28/2002, 09/29/2002	1	34.55	0.51	0.33	0.0032	0.004
S2	10/01/2002, 10/2/2002	1	36.57	34.55	0.16	0.0048	0.003
S2	10/03/2002, 10/4/2002	2	60.45	71.12	8.57	0.2149	0.110
S2	03/12/2003	1	0.00	0.00	0.69	0.0028	0.006
S2	04/30/2003	1	98.91	0.00	1.28	0.0256	0.008
S2	07/08/2003	3	44.45	36.32	0.59	0.0026	0.008
S2	09/13/2003	1	63.58	0.00	0.06	0.0000	0.002
S2	09/14/2003	1	12.34	63.58	0.03	0.0000	0.001
S2	11/03/2003, 11/4/2003	4	79.10	40.92	19.71	1.2870	0.384
S2	11/23/2003	1	31.75	21.34	0.01	0.0003	0.000
S2	02/20/2004	3	0.00	0.00	3.15	0.0161	0.024
S2	02/21/2004, 02/22/2004, 02/23/2004, 02/24/2004, 02/25/2004	7	11.94	0.00	15.42	0.1075	0.123
S2	03/04/2004	1	34.54	4.80	25.89	2.5144	0.597
S2	03/25/2004, 03/26/2004	2	21.34	12.57	0.05	0.0081	0.002
S2	05/09/2004	1	11.68	8.38	3.85	3.7118	0.310
S2	05/13/2004	1	9.70	30.65	0.45	0.3097	0.052
S2	05/17/2004	1	12.22	14.28	5.49	13.2554	1.471
S2	05/21/2004, 05/22/2004, 05/23/2004	6	98.60	12.45	27.11	49.1759	2.976
S2	05/29/2004	2	32.00	3.43	1.38	0.2791	0.032
S2	05/30/2004	1	23.77	34.97	5.20	10.4996	0.273
S2	06/10/2004	1	29.72	3.05	0.02	0.0019	0.001
S2	06/11/2004, 06/12/2004	2	19.30	30.99	2.66	1.1472	0.055
S2	06/14/2004	1	14.99	49.78	4.14	5.1893	0.103
S2	06/16/2004	1	24.64	35.05	9.20	7.0628	0.481
S2	07/16/2004	1	9.14	13.97	0.19	0.0890	0.005
S2	07/21/2004	1	21.08	9.14	0.15	0.0220	0.002
S2	08/03/2004	1	28.70	7.36	0.85	0.1594	0.020
S2	08/26/2004	1	18.29	11.43	0.08	0.0100	0.002
S2	02/05/2005	1	0.00	0.00	15.49	0.0904	0.571
S2	02/13/2005, 02/14/2005, 02/15/2005	3	5.72	0.46	13.37	0.2329	0.435
S2	06/11/2005	1	12.07	9.60	0.02	0.0195	0.003
S2	07/23/2005	1	53.09	11.94	0.03	0.0001	0.000
S2	09/18/2005, 09/19/2005	1	50.55	3.56	0.23	0.0115	0.005
S2	09/25/2005	1	37.85	6.85	0.03	0.0032	0.001

Field Station ID	SWAT Aggregated Dates	# of Events Aggregated	Event Precipitation (mm)	Previous 5-Day Precipitation Total (mm)	Measured Event Volume (mm $H_2$0)	Measured Sediment Load (metric tons)	Measured Total Phosphorus Load (kg/ha)
S3	06/03/2002, 06/04/2002	3	75.44	4.83	6.14	0.6819	0.279
S3	07/06/2002	1	54.99	0.00	0.31	0.0015	0.005
S3	08/21/2002	1	67.82	0.51	0.33	0.0002	0.006
S3	09/28/2002, 09/29/2002	1	34.55	0.51	1.90	0.0210	0.039
S3	10/01/2002, 10/02/2002	1	36.57	34.55	4.12	0.1312	0.133
S3	10/03/2002, 10/04/2002	2	60.45	71.12	24.89	0.6092	0.367
S3	03/12/2003	1	0.00	0.00	2.74	0.0062	0.501
S3	04/30/2003	2	98.91	0.00	9.55	7.1844	1.687
S3	05/08/2003, 05/09/2003	2	18.79	26.67	0.42	0.1504	0.045
S3	05/10/2003	1	10.67	33.78	1.28	2.1133	0.414
S3	07/08/2003	2	44.45	36.32	0.16	0.0077	0.004
S3	02/20/2004, 02/21/2004	1	0.00	0.00	0.47	0.0022	0.030
S3	03/04/2004, 03/05/2004	1	34.54	4.80	6.63	0.0988	0.406
S3	05/09/2004	1	11.68	8.38	0.05	0.0126	0.006
S3	05/13/2004	1	9.70	30.65	0.15	0.0226	0.013
S3	05/17/2004	1	12.22	14.28	0.37	0.1939	0.065
S3	05/21/2004, 05/22/2004, 05/23/2004	4	98.60	12.45	7.43	2.8719	0.620
S3	05/29/2004	1	32.00	3.43	0.90	0.0628	0.024
S3	05/30/2004	1	23.77	34.97	3.80	0.5955	0.145
S3	05/31/2004	1	11.18	55.77	0.85	0.0512	0.019
S3	06/10/2004	1	29.72	3.05	0.27	0.0034	0.004
S3	06/11/2004, 06/12/2004	1	19.30	30.99	1.55	0.1254	0.038
S3	06/14/2004	1	14.99	49.78	0.70	0.0599	0.021
S3	06/16/2004	1	24.64	35.05	2.40	0.1916	0.065
S3	07/16/2004	1	9.14	13.97	0.03	0.0002	0.000
S3	02/05/2005, 02/06/2005, 02/07/2005, 02/08/2005	1	2.51	0.00	17.19	0.0421	0.677
S3	02/13/2005, 02/14/2005, 02/15/2005	3	5.72	0.46	22.93	0.1540	0.602
S3	03/04/2005	1	0.00	0.23	0.98	0.0014	0.034
S3	03/05/2005	1	0.00	0.00	1.34	0.0029	0.056
S3	03/06/2005	1	0.00	0.00	0.62	0.0007	0.024
S3	03/07/2005	1	2.06	0.00	1.58	0.0242	0.082

Field Station ID	SWAT Aggregated Dates	# of Events Aggregated	Event Precipitation (mm)	Previous 5-Day Precipitation Total (mm)	Measured Event Volume (mm H_20)	Measured Sediment Load (metric tons)	Measured Total Phosphorus Load (kg/ha)
S4	06/03/2002, 06/04/2002	2	75.44	4.83	1.56	0.3723	0.047
S4	07/06/2002	1	54.99	0.00	0.06	0.0012	0.001
S4	08/21/2002, 08/22/2002	2	81.79	0.51	0.03	0.0001	0.000
S4	10/01/2002, 10/02/2002	1	36.57	34.55	0.10	0.0088	0.009
S4	10/03/2002, 10/04/2002	2	60.45	71.12	5.31	0.4203	0.238
S4	03/12/2003	1	0.00	0.00	2.19	0.0783	0.060
S4	04/30/2003	2	98.91	0.00	5.37	13.4964	1.041
S4	05/08/2003, 05/09/2003	1	18.79	26.67	0.13	0.0253	0.006
S4	05/10/2003	1	10.67	33.78	0.49	0.5517	0.050
S4	05/13/2003, 05/14/2003	1	32.51	31.75	0.52	0.1411	0.024
S4	07/08/2003	3	44.45	36.32	1.15	0.1896	0.037
S4	02/20/2004 - 02/25/2004	10	11.94	0.00	10.14	0.2187	0.223
S4	02/26/2004	1	0.00	11.94	0.33	0.0039	0.006
S4	02/27/2004	1	0.00	11.94	0.14	0.0009	0.002
S4	02/28/2004	1	0.00	0.00	0.09	0.0004	0.001
S4	03/04/2004, 03/05/2004	4	34.54	4.80	6.88	0.4614	0.232
S4	05/29/2004, 05/30/2004, 05/31/2004	2	66.95	3.43	2.30	0.4304	0.073
S4	06/10/2004	1	29.72	3.05	0.18	0.0036	0.001
S4	06/11/2004, 06/12/2004	1	19.30	30.99	0.67	0.0457	0.011
S4	06/14/2004	1	14.99	49.78	0.13	0.0038	0.001
S4	06/16/2004, 06/17/2004	2	25.15	35.05	1.85	0.1661	0.029
S4	07/16/2004	1	9.14	13.97	0.05	0.0007	0.000
S4	07/21/2004	1	21.08	9.14	0.08	0.0007	0.001
S4	08/03/2004	1	28.70	7.36	0.09	0.0012	0.002
S4	08/26/2004, 08/27/2004	1	21.34	11.43	0.05	0.0009	0.001
S4	01/12/2005, 01/13/2005, 01/14/2005	1	12.19	0.00	2.15	0.0053	0.012
S4	02/06/2005, 02/07/2005, 02/08/2005	1	2.51	0.00	13.65	0.2520	0.359
S4	02/13/2005, 02/14/2005, 02/15/2005, 02/16/2005	3	5.72	0.46	27.15	1.1548	0.618
S4	03/04/2005, 03/05/2005	2	0.00	0.23	4.97	0.3986	0.129
S4	03/06/2005, 03/07/2005	2	2.06	0.00	1.68	0.6550	0.083
S4	09/18/2005, 09/19/2005	1	50.55	3.56	2.06	2.6850	0.159
S4	09/25/2005	1	37.85	6.85	2.54	3.7733	0.212

APPENDIX H

SNAP MODEL SETUP DATA AND OUTPUT

Fields Contributing to Monitoring Site S2

Field 2

Field Slope Length	300	**2002**	**2003**	**2004**	**2005**
% Slope	5	Alfalfa	Alfalfa	Corn (Grain)	Corn (Grain)
Size (Acres)	40	None	None	Spring Chisel	Fall Chisel
SNAP P Index		0.7	0.7	1.9	1.5
SNAP Particulate P		0.41	0.42	1.64	1.4
SNAP Soluable P		0.31	0.29	2.3	0.13
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	--	--	--

Fields Contributing to Monitoring Site S3

Field 24

Field Slope Length	150	**2002**	**2003**	**2004**	**2005**
% Slope	6	Alfalfa	Corn (Grain)	Corn (Grain)	Corn (Grain)
Size (Acres)	30	None	Spring Chisel	Fall Chisel	Fall Chisel
SNAP P Index		1.3	6.5	2	2
SNAP Particulate P		0.5	1.81	1.61	1.59
SNAP Soluable P		0.79	0.77	0.38	0.43
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	3.93	--	--

Fields Contributing to Monitoring Site S4

Field 13

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Corn (Grain)	Corn (Grain)	Oats / Alfalfa	Alfalfa
Size (Acres)	4.9	Fall Chisel	Fall Chisel	Fall Chisel	None
SNAP P Index		7.3	4.1	1.4	0.9
SNAP Particulate P		0.85	2.01	1.02	0.55
SNAP Soluable P		0.64	0.37	0.39	0.39
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		5.83	1.77	--	--

Field 20

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Size (Acres)	6.3	None	None	None	Spring Chisel
SNAP P Index		0.9	1.1	1.1	2.8
SNAP Particulate P		0.15	0.6	0.58	2.4
SNAP Soluable P		0.72	0.55	0.47	0.4
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	--	--	--

Fields Contributing to Monitoring Site S4

Field 21

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Corn (Grain)	Corn (Grain)	Corn (Silage)	Oats / Alfalfa
Size (Acres)	9	Fall Chisel	Fall Chisel	Fall Chisel	Fall Chisel
SNAP P Index		0.9	4.5	12.4	1.4
SNAP Particulate P		0.51	2.25	9.99	0.92
SNAP Soluable P		0.38	0.52	0.95	0.48
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	1.73	1.48	--

Field 22

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Size (Acres)	1.9	None	None	None	Spring Chisel
SNAP P Index		1.1	1.3	1.8	2.6
SNAP Particulate P		0.2	0.62	0.64	2.21
SNAP Soluable P		0.91	0.71	0.89	0.41
SNAP Acute Unfrozen Loss		--	--	0.23	--
SNAP Acute Frozen Loss		--	--	--	--

Fields Contributing to Monitoring Site S4

Field 14

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Size (Acres)	4.4	None	None	None	Spring Chisel
SNAP P Index		0.9	1.3	1.2	2.8
SNAP Particulate P		0.16	0.63	0.6	2.43
SNAP Soluable P		0.76	0.72	0.61	0.37
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	--	--	--

Field 15

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Corn (Grain)	Corn (Silage)	Oats / Alfalfa	Alfalfa
Size (Acres)	4.9	Fall Chisel	Fall Chisel	Fall Chisel	None
SNAP P Index		12.8	16.1	1.2	1
SNAP Particulate P		0.92	10.5	0.84	0.55
SNAP Soluable P		0.95	1.04	0.34	0.49
SNAP Acute Unfrozen Loss		0.67	4.62	--	--
SNAP Acute Frozen Loss		10.3	--	--	--

Fields Contributing to Monitoring Site S4

Field 16

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Size (Acres)	4.9	None	None	None	No Till
SNAP P Index		1	1.3	1.6	0.3
SNAP Particulate P		0.19	0.61	0.63	0.09
SNAP Soluable P		0.86	0.71	0.76	0.2
SNAP Acute Unfrozen Loss		--	--	0.24	--
SNAP Acute Frozen Loss		--	--	--	--

Field 17

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Corn (Grain)	Corn (Grain)	Oats / Alfalfa	Alfalfa
Size (Acres)	4.7	Fall Chisel	Fall Chisel	Fall Chisel	None
SNAP P Index		0.6	4.8	1.2	1.2
SNAP Particulate P		0.36	1.68	0.79	0.56
SNAP Soluable P		0.28	0.47	0.37	0.64
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	2.65	--	--

Fields Contributing to Monitoring Site S4

Field 18

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Alfalfa	Alfalfa	Alfalfa	Corn (Grain)
Size (Acres)	3.1	None	None	None	Spring Chisel
SNAP P Index		0.7	1.1	1.5	2.3
SNAP Particulate P		0.12	0.56	0.58	2.02
SNAP Soluable P		0.6	0.58	0.69	0.26
SNAP Acute Unfrozen Loss		--	--	0.23	--
SNAP Acute Frozen Loss		--	--	--	--

Field 19

Field Slope Length	200	**2002**	**2003**	**2004**	**2005**
% Slope	6	Corn (Grain)	Corn (Grain)	Oats / Alfalfa	Alfalfa
Size (Acres)	3.1	Fall Chisel	Fall Chisel	Fall Chisel	None
SNAP P Index		9.5	4.3	0.9	1.1
SNAP Particulate P		0.84	1.79	0.67	0.55
SNAP Soluable P		0.74	0.4	0.23	0.54
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		7.92	2.13	--	--

Fields Contributing to Monitoring Site S4

Field 23

		2002	2003	2004	2005
Field Slope Length	150				
% Slope	6	Oats / Alfalfa	Corn (Grain)	Corn (Grain)	Corn (Grain)
Size (Acres)	18.1	Fall Chisel	Spring Chisel	Fall Chisel	Fall Chisel
SNAP P Index		0.8	3.3	2.7	2.8
SNAP Particulate P		0.26	2.53	2.2	2.25
SNAP Soluable P		0.51	0.76	0.48	0.55
SNAP Acute Unfrozen Loss		--	--	--	--
SNAP Acute Frozen Loss		--	--	--	--