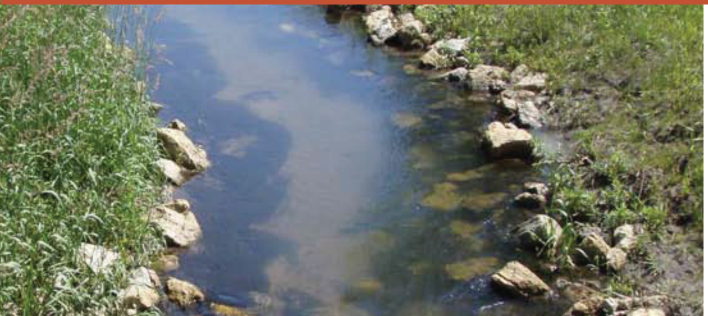
Rethinking nonpoint source pollution management in an agricultural watershed: An application of Wisconsin Buffer Initiative concepts in southwest Wisconsin



University of Wisconsin-Madison
Nelson Institute for Environmental Studies
Water Resources Management Workshop

2008

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The Water Resources Management Workshop is a regular part of the curriculum of the Water Resources Management Graduate Program at the University of Wisconsin-Madison. The workshop involves an interdisciplinary team of faculty members and graduate students in the analysis of a contemporary water resources problem.

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Table of Contents

Table of Figures

Appendix 2 Figures

Table of Tables

Preface

The WRM workshop program

The Water Resources Management (WRM) program is a Master of Science program within the University of Wisconsin-Madison, Nelson Institute for Environmental Studies. Its requirements include a one-year capstone workshop, whereby a team of graduate students collaborate with outside organizations to apply learned concepts to real environmental issues.

Goals for this workshop

This WRM workshop applies Wisconsin Buffer Initiative (WBI) concepts to a rural watershed in order to study connections between land use and stream conditions, to make recommendations for changes to current land management in order to improve stream conditions and established baseline geomorphic and biologic datasets for the Pleasant Valley Paired Watershed Project (PVPWP).

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Faculty advisors

We are particularly grateful to our faculty members, whose expert advice, connections, and humor helped keep us pointed in the right direction: Fred Madison, Pete Nowak, and Ken Potter.

Acknowledgements

We would also like to thank the many other people who patiently answered our questions and challenged our opinions, including Katie Songer (UW), Laura Ward Good (UW), Mike Miller (WDNR), Bob Hansis (WDNR), Kelly Forman (WDNR), Faith Fitzpatrick (USGS WWSC), Dave Grazyk (USGS WWSC), Pat Sutter (Dane County LWRD), Curt Diehl (Dane County LWRD), Michelle Richardson (Dane County LWRD), Kyle Magyera (UW), Gale Shea (UW), and Matt Krueger (UW).

This report is dedicated in memory of:

Brian E. Hamming

1984 - 2008

Abstract

Agricultural land use is the leading cause of stream and water quality degradation in the United States (USEPA, 2009). While agricultural point source pollution is well-regulated, conservation programs often do not efficiently address nonpoint source (NPS) pollution from farms. Most federal grants for remediation of NPS pollution are distributed on a first-come, first-served basis, without a targeted approach, even though sediment and nutrient delivery is not evenly spread across the landscape. According to the Wisconsin Buffer Initiative (WBI), conservation agencies should instead target fields with disproportionately high sediment and nutrient yields in order to more efficiently improve water quality in agricultural watersheds (WBI, 2005).

The Pleasant Valley Paired Watershed Project (PVPWP) is a collaboration between different agencies to test this targeted approach within a single watershed. Collaborators initially identified fields in Pleasant Valley that had disproportionately high phosphorus (P) and fine sediment delivery to streams. Conservation agencies then began working with landowners to reduce sediment and nutrient loss by changing land management practices on these high-priority fields, or critical source areas (CSAs). Ultimately, collaborators hope to measurably improve water quality and stream habitat as a result of changes in land use.

The Water Resources Management (WRM) workshop contributed to the PVPWP in three ways by: 1) mapping P loss across the watershed to identify CSAs; 2) developing recommendations for alternative land management strategies on CSAs, recommendations that were applied by conservation agencies working directly with the landowners; and 3) helping measure the intimate connection between land use and nearby waters by establishing baseline data for stream conditions in the watershed.

The workshop identified CSAs by using Soil Nutrient Application Planning (SNAP-Plus) software to quantify phosphorus (P) yields of individual fields in the Pleasant Valley watershed. For each field, land use data such as crop history, tillage regime, and nutrient application were entered into SNAP-Plus to calculate a Wisconsin Phosphorus Index (WPI) value. A field's WPI is an estimate of its annual P delivery (lb/ac/yr) to nearby surface waters. Farms having at least one field with a WPI value greater than 20 were determined to be CSAs, areas having the highest potential for reduced P loss with the application of conservation practices.

The workshop created alternative management scenarios for several of the highest-priority fields by manipulating tillage practices and crop types within SNAP-Plus. Based on these scenarios, the workshop recommended specific changes in farming practices to the Dane County Land Conservation Division. These recommendations included commonly used best management practices (BMPs), such as: switching tillage practices to either no-till or strip-till; implementing contour farming for fields with steep slopes; leaving residue on fields over winter; and using portable fencing options between pasture fields for easier rotation of livestock.

The workshop collected stream data in Pleasant Valley to help measure the connection between its land use and surface waters. In 2008, we collected or compiled data on water chemistry, geomorphology, and stream biota, which indicated negative impacts from agricultural sedimentation. Nutrient and sediment samples were collected from several perennial streams; channel geometry, soft sediment depth, and habitat surveys were additionally conducted in three stream reaches. The baseline conditions, survey sites, and measurement protocols will be used by the United States Geological Survey (USGS) and Wisconsin Department of Natural Resources (WDNR) for continued channel stability and sedimentation monitoring in Pleasant Valley. We hope these data will help these agencies evaluate improvements in fish habitat and stream sediment storage as a result of the PVPWP's proposed changes in land use.

Chapter 1

Our report begins with a brief background on the agricultural conditions that lead to nonpoint source (NPS) pollution and how sediment and nutrient runoff are important components of NPS pollution. We then set the foundation for our study with a timeline of events that preceded and led to our workshop, followed by a preview of what this report includes. Finally, we introduce our study site and collaborators.

1. Agricultural nonpoint source pollution in Wisconsin

Agriculture is the leading cause of water quality problems and stream degradation in the United States (USEPA, 2009; Carpenter et al., 1998; USEPA, 1996; Allan, 1995). Agricultural land use activities can impair water quality, flow regime, channel habitat, and biota in streams and rivers (Karr & Dudley, 1981). Row crops reduce vegetative cover and surface roughness, which increase overland runoff and soil erosion; manure applications increase available nutrient loads; tile drainage can quickly deliver dissolved nutrients to water bodies; and channelization alters the flow and biotic habitats of streams.

As of 2004, agricultural activities had impaired 44% of surveyed river length and 64% of surveyed lakes in the US (USEPA, 2009). Agricultural runoff carries contaminants such as sediment, phosphorus (P), ammonia (NH_3), nitrate (NO_3^-), and it can lead to accelerated eutrophication—the excessive growth of algae, periphyton, and macrophytes in surface waters (Allan, 2004). Of particular concern in Wisconsin is phosphorus (P), an essential nutrient to crop production that binds closely to sediments and is largely delivered to streams from in-field runoff. In Wisconsin, P acts as a limiting nutrient that can accelerate eutrophication when applied in excess amounts (Sturgul et al., 2004).

Although eutrophication can cause wide diurnal swings in dissolved oxygen of lakes and sluggish streams (Schwar, 1996), hypoxic conditions are less common in steep-gradient streams (Allan, 1995; K. Potter, personal communication, 2009). In such fast-moving environments, high P concentrations and excessive primary production are not serious problems. Here, loading of fine sediment is the major issue; indeed, sedimentation is the primary cause of stream impairment in the US (USGS, 2006). Fine sediment covers macroinvertebrate habitat and fish spawning sites in the benthic substrate, increases turbidity in the water column, and reduces the number of sensitive fish and insect taxa that the stream can support (Wang et al. 1997; Allan, 2004). Phosphorus binds easily and is closely associated with fine sediment, and therefore P loss from fields can serve as a proxy for erosion, allowing researchers to use P loss to predict how farming practices affect sedimentation in nearby streams.

Conservation management practices that reduce sediment and P runoff from fields while ensuring optimum plant growth are available and have been advertised, but have not been adopted widely enough to alleviate widespread water quality problems. Technical assistance with the development of nutrient management plans and installation of best management practices (BMPs) is available to farmers through their local county land conservation divisions (LCD) and the Natural Resources Conservation Service (NRCS). However, many farmers have been unwilling to adopt new practices out of fear of the economic risk involved in adopting new techniques (P. Sutter, personal communication, 2009).

Agricultural nonpoint source (NPS) pollution is the main regulatory obstacle today, as point sources are regulated by the 1972 US Clean Water Act (Sharpley et al., 1994). Controlling NPS pollution is a complicated issue: nonpoint agricultural pollution has diffuse sources that affect water bodies across political and private boundaries, making it difficult to locate and quantify either its causes or effects (Sturgel et al., 2004). Attempts to reduce NPS pollution through regulation at the federal level began with the Water Quality Act Amendments to the Clean Water Act (Section

319) in 1987. Wisconsin had already established a NPS program in 1978 that delineated 131 priority watersheds (Wolf, 1995). The program provided technical assessments, recommended practices, and shared the cost of pollution control practices with landowners and communities who voluntarily participated. However, the Priority Watershed Program was deemed unsuccessful for the following reasons: watersheds were too large to document benefits of adopted practices, there were not enough participants, and there was no technical capacity to identify dominant pollution sources (Wolf, 1995). The program's lack of success also underlined the importance of targeting critical sources of high P and sediment loss, which is the goal of this study.

In 1997, the Wisconsin legislature recognized that while the program probably did reduce NPS pollution in some places, there was no capacity to measure the improvements. Therefore, 1997 Wisconsin Act 27 placed the Priority Watershed Program into a multi-year phase-out period ending in 2009 (WDNR, 2009). This legislation also created agricultural performance standards. The Wisconsin Department of Natural Resources (WDNR) responded to the act by developing NR 151, which contains performance standards and prohibitions for agricultural facilities and practices designed to meet water quality standards.

Buffers along agricultural streams were believed to be a critical component of the performance standards. After several years, however, a consensus could not be reached on a minimum width for buffers due to factors such as cost-sharing requirements for land out of production, inadequate science on buffer performance, and competing environmental and agricultural production interests. In May of 2002, the Natural Resources Board requested that agricultural buffer research be managed by the University of Wisconsin College of Agricultural and Life Sciences (CALS) and implemented through the Wisconsin Agricultural Stewardship Initiative. As a result, the Wisconsin Buffer Initiative Advisory Committee was formed. The committee included scientists from the University of Wisconsin-Madison (UW) and other campuses, federal and state agency staff, agricultural groups, conservation associations, and environmental organizations. The Wisconsin Buffer Initiative final report was delivered on December 22, 2005 (WDNR, 2007; UWCALS, WBI Report, 2005).

The Wisconsin Buffer Initiative (WBI) pulled together nearly three decades of study on controlling and preventing NPS pollution originating from agricultural fields. The fundamental recommendations provided by the WBI were based on the concept of disproportionality: that most P loss originates from a few fields, rather than coming from all fields throughout the watershed. Therefore, the recommendations were to: target fields that generate the greatest amount of pollution, particularly phosphorous, and to develop technical capacity to estimate the Wisconsin phosphorus index (WPI) that describes the annual amount of phosphorous exported from individual fields based on soil P, soil type, crop rotations, tillage practices and management practices.

In general, the proposed solution was to implement upland management changes first, and then consider the use of riparian buffers to achieve "measurable" and "substantial" improvements in water quality (UWCALS, WBI Report, 2005). The WBI report recommended focusing on watersheds smaller than the Priority Watersheds, with particular attention to field-scale areas where improvements would be most effective—that is, targeting critical source areas (CSAs) (UWCALS, WBI Report, 2005). The WBI Advisory Committee was confident that by using the best available technology they would be able to locate specific fields contributing the most excess nutrients and sediment, and therefore allocate financial resources and human resources more efficiently.

The WBI Science Group initiated the Pleasant Valley Paired Watershed Project (PVPWP) after the conclusion of the WBI final report to test and apply the concepts developed in the final report in an agricultural watershed. PVPWP objectives include testing the effectiveness of the WBI recommendations, and developing technical capacity to further apply the methods in more Wisconsin watersheds.

The WBI final report outlined the following steps to apply their recommendations across Wisconsin:

1. Delineate watersheds approximately 20 square miles in size for all of Wisconsin.
2. Rank these watersheds in order of most likely to respond to conservation practices and riparian buffers.
3. Give top ranking watersheds to County Land Conservation Division (LCD) staff to calculate Wisconsin Phosphorus Index (WPI) values for fields and identify areas that are contributing nutrients and sediment more than the majority of others. WPI values are calculated using soil nutrient application planning software (SNAP-Plus).
4. Fields with WPI values greater than or equal to six are considered "out of compliance" and practices on those fields should be changed by coordination between LCD staff and landowners5. Monitor the watersheds to determine if improvements are being made, then adjust land practices using adaptive management strategies and new knowledge.

Using the WBI's five step procedure the PVPWP would efficiently narrow down CSAs to specific farm fields and small non-agricultural areas. With a much smaller and more manageable area, cost-efficient conservation practices could be implemented. By using local knowledge and experience from the farmers (local topography, soil types, past use of fields) in tandem with the best scientific methods available (Geographic Information Systems, modeling), the likelihood of measurable improvements would be vastly increased.

2. The UW Water Resources Management 2008 Workshop's involvement in the Pleasant Valley Paired Watershed Project

Funding options and local interest led the PVPWP to focus their study on two watersheds that flow into the Pecatonica River: Pleasant Valley Branch and Ridgeway Branch. Both watersheds rank in the top 30 out of 452 WBI watersheds for likelihood that stream conditions can be improved through implementation of best management practices (BMPs). Improvements in stream conditions are considered to be reductions in sediment and P concentrations and increased sediment-sensitive fish species (UWCALS, WBI Report, 2005).

The PVPWP study began in 2006 and will continue beyond 2012. The study aims to monitor WPI-based land management changes as well as changes in Pleasant Valley Branch water quality, and determine correlations between the two datasets. The study design involves working with landowners to make WPI-based land management changes. Researchers will compare baseline water quality data collected before changes are made to data collected during and after those changes. Ridgeway Branch will serve as a reference watershed with water quality data collected over the same time period and without receiving WPI-based land management changes.

In order to develop technical capacity for LCD staff to calculate WPI values on their own, scientists at the UW will trouble-shoot and update the SNAP-Plus model to be more efficient and user-friendly for farmers and LCD staff. In return, LCD staff will offer feedback on the effectiveness and feasibility of the directives of the SNAP-Plus model and proposed targeting practices, creating an efficient template for future studies (UWCALS, WBI Report, 2005).

The PVPWP asked our UW Water Resources Management (WRM) Workshop to apply concepts and strategies from the WBI Final Report to Pleasant Valley, assess WPI scores for farms throughout the watershed (Chapter 3), recommend alternative practices (Chapter 4), and establish baseline stream data (Chapter 5). The PVPWP will use the information gathered here in their continued conservation efforts within the watershed (Chapter 6).

We used two main processes to meet our objectives: one process concentrated on working with WPI values within the watershed, while the other focused on the collection and analysis of baseline stream data from the watershed.

The WPI process involved incorporating soil chemistry information for farms around the

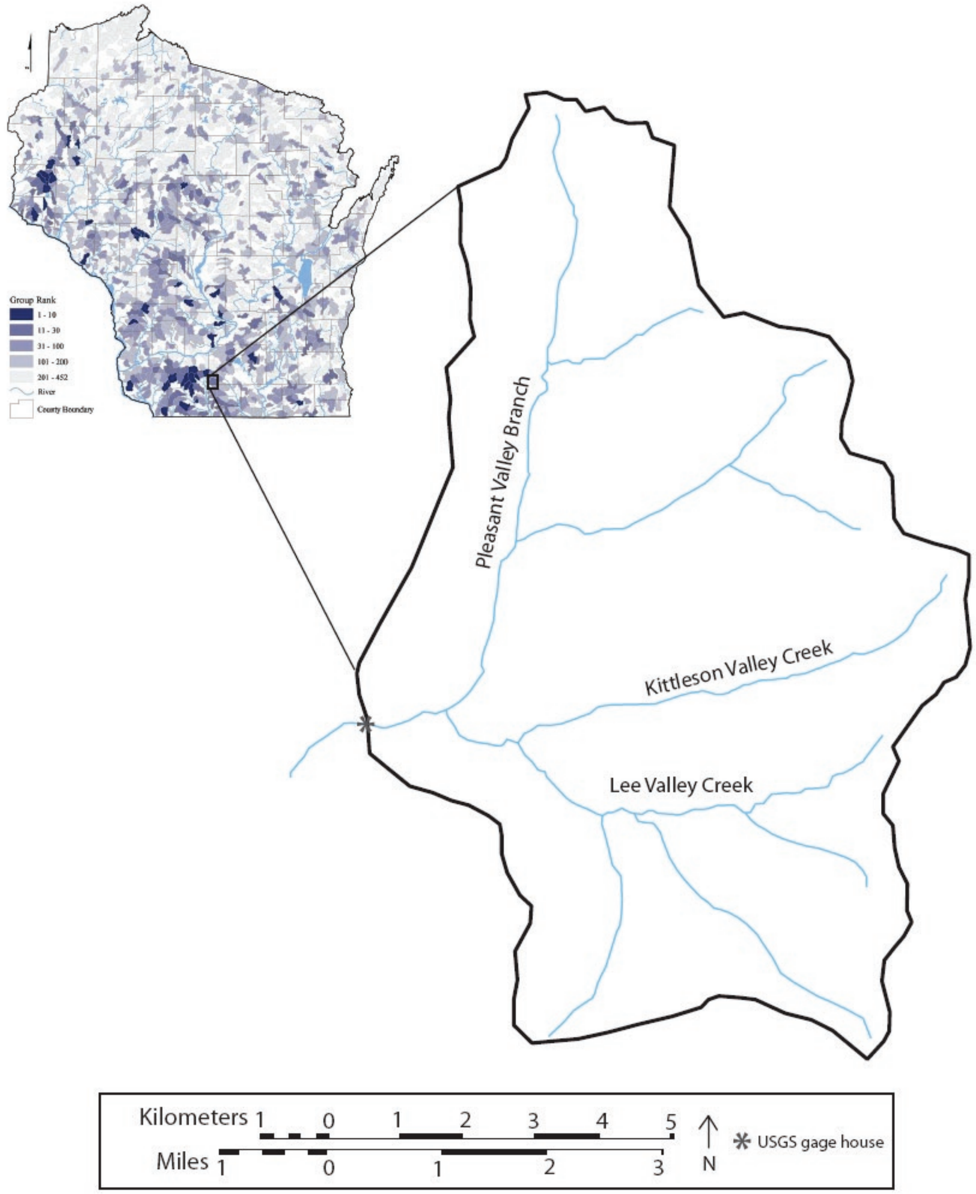

Figure 1. *The Pleasant Valley Watershed (19 square-miles) is located in the Driftless Area in southwest Dane County and north-west Green County, Wisconsin*

Pleasant Valley area and obtaining additional data about each farm's agricultural practices, including tillage, crop rotation, animal counts and nutrient management plans from a graduate student in the UW Land Resources program (Songer, 2009). We then entered this information into SNAP-Plus software, a program that incorporates the Revised Universal Soil Loss Equation 2 (RUSLE2). SNAP-Plus software estimates soil erosion in tons per acre per year, and the P Index in pounds per acre per year. SNAP-Plus provides quantitative P loss values on a field-by-field basis to allow comparisons of sediment and nutrient yields between different fields within the targeted watershed.

We then entered SNAP-Plus WPI values into a Geographic Information System (GIS) in order to have a spatial reference of where CSAs were located within the watershed. These areas were identified based on the WPI threshold of six pounds of phosphorus per acre, per year. We manipulated practices and crops on CSA fields within SNAP-Plus to evaluate what changes in those variables would result in lower WPI values.

Our workshop began collecting baseline stream data before the GIS was completed using information from the Dane County LCD and local knowledge to identify areas to conduct geomorphic channel characterization, habitat assessment, and short-term water sampling. We conducted our surveys at locations that are also monitored by the WDNR. Biotic indicator data from the WDNR were available for the survey sites and were incorporated into the baseline data set.

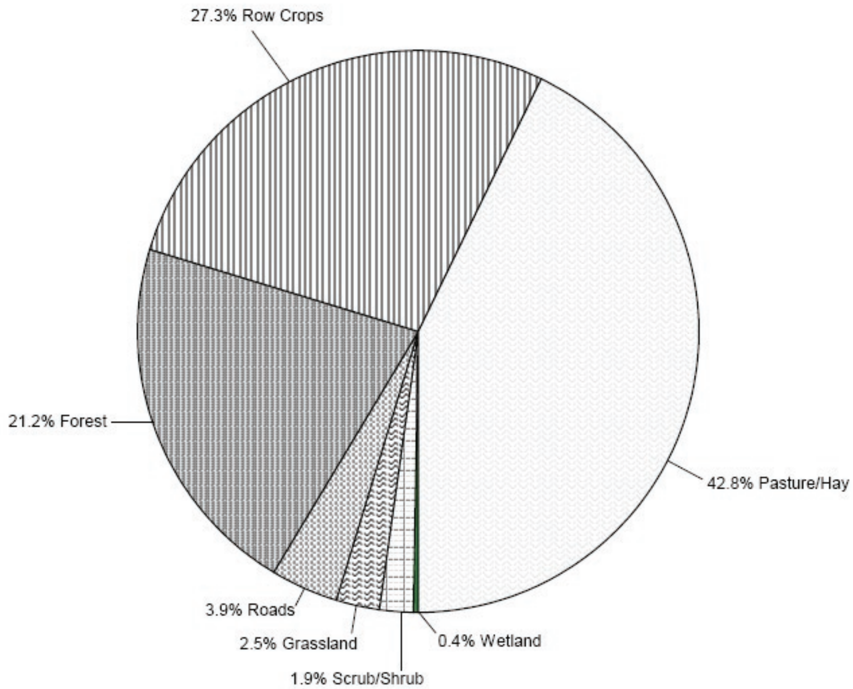

Figure 2. *Percent land use in Pleasant Valley watershed based on the 2001 National Land Cover Dataset. 70% of the watershed is in agricultural land use (pasture, hay or row crops).*

3. Description of study site

Pleasant Valley Branch is a five-mile long tributary in western Dane County that empties into Kittleson Valley Creek (WDNR, 2005). We delineated the 19 square-mile Pleasant Valley watershed to include all land and stream channels upstream of the USGS stream gage house on County Hwy H (Figure 1).

Pleasant Valley watershed is characteristic of the Driftless Area with a mature, dendritic drainage system, deep, narrow valleys and broad, flat ridge tops. Streams have carved through bedrock layers of Ordovician dolomite, limestone, and sandstone (Dott & Attig, 2004). The watershed has three named creeks—Pleasant Valley, Kittleson Valley, and Lee Valley—as well as several unnamed tributaries.

Historically, Pleasant Valley watershed supported a high density of dairy farmers upon steep terrain. In recent decades, there has been a decrease in the number of dairy farms, dairy livestock, beef cattle, and hog production and an increase in hobby farmers and absentee landowners. Land cover in the watershed is primarily agricultural with 43% in pasture and 27% in row crops. Forested land covers 21% of the watershed while roads, grassland, and wetland account for the remaining 9% (Figures 2 and 3; USGS, 2008).

Pleasant Valley Branch has been on the 303(d) list of Impaired Waters since 1998 due to sedimentation, but several stream bank stabilization and habitat restoration projects are currently underway in the watershed (WDNR, 2008; P. Sutter, personal communication, 2008). Because these streams have high biotic and recreational potential, many organizations, such as Dane County LCD, Natural Resources Conservation Service (NRCS), Trout Unlimited (TU), The Nature Conservancy (TNC), and WDNR have already invested significant amounts of funding in several restoration sites within its boundaries. These projects often cost more than $100,000 per stream mile and include such activities as removing sediment and woody plants from floodplains, re-sloping banks, and installing native vegetation, riprap, and lunker structures to improve trout habitat (L. Hewitt, personal communication, 2007).

In 2003, a section of Pleasant Valley Branch, starting at the northern County Hwy H crossing, and extending about one-half mile downstream, had stream bank work done as part of a Wildlife

Figure 3. *Pleasant Valley watershed at bridge crossing. St. Peter Sandstone outcrop in background, corn field in midground and bridge crossing over Pleasant Valley Branch in foreground*

Rehabilitation on Kittleson Valley Creek, a Class II trout stream containing a partly sustainable trout population, began in 2007.

Pleasant Valley has similar conditions to Blue Mounds Creek and Syftestad Creek, two nearby examples of biotic habitat responding to land use change. In Blue Mounds, Marshall and others (2008) found that switching land from cropping systems to Conservation Reserve Program (CRP) grasslands significantly reduced surface runoff, and that edge-of-field grass filter strips prevented nearly all sediment and total phosphorus from entering streams. Reduction in the amount of cropland—often through the implementation of CRP grasslands—correlated with reduced sediment and P loss as well as a shift toward a more native fish assemblage dominated by cool and coldwater species (Figure 4). Switching to conservation practices can decrease surface runoff and increase base flow as well as the number of pollution intolerant species of fish, insects, mussels, crustaceans, and plants (Wang et al., 1997; UWCALS, WBI Report, 2005).

Habitat Improvement Program (WHIP) grant. Prior to this work, the stream was wide, shallow, and the bottom was covered primarily in sand and silt. Additional lands in the watershed were enrolled in the Conservation Reserve Enhancement Program (CREP) and another section of stream corridor was rehabilitated in 2005 under the state's Targeted Runoff Management Program due to its potential to support a cold-water fishery (WDNR, 2005).

Figure 4. *Conservation Reserve Program (CRP) grassland near Pleasant Valley Branch.*

4. Pleasant Valley Paired Watershed Project collaborators

This report is intended for all participants of the ongoing Pleasant Valley watershed study (PVPWP), particularly: the Dane County Land Conservation Division (LCD), US Geological Survey (USGS), Wisconsin Department of Natural Resources (WDNR), The Nature Conservancy (TNC), the University of Wisconsin-Madison (UW), as well as the landowners and land managers in the watershed. We especially want this report to be accessible to farmers, the primary land managers of this area whose land use decisions will ultimately determine the project's success or failure.

The key link to land managers in the watershed is provided by the Dane County LCD. The LCD staff has first-hand knowledge of Pleasant Valley, having worked with its landowners for decades implementing Nutrient Management Plans (NMPs) and best management practices (BMPs) throughout the watershed. To connect land use changes to stream conditions, the Dane County LCD is collaborating with USGS and the WDNR, who are monitoring changes in water chemistry, nutrient levels, physical habitat, sediment transport, and biotic communities. TNC is also involved as a major nearby landholder interested in how upland conservation practices can improve riparian habitat.

Researchers from the UW-Madison Soil Science

Department and the Nelson Institute for Environmental Studies (IES) collaborated with these various agencies to collect and analyze Pleasant Valley watershed data, helping to pilot the WBI and refine the SNAP-Plus model. The completion of this report represents the output of the UW-Madison Water Resources Management workshop, a team of graduate students working within the context of the larger project.

Chapter 2

A major component of our study involved learning and using various metrics and models developed for land managers including the Wisconsin Phosphorus Index (WPI) and the SNAP-Plus Model. In this chapter, we present information about the WPI and SNAP-Plus to provide a basic understanding of the tools we used to perform our study.

1. Wisconsin Phosphorus Index and background information on SNAP-Plus

Phosphorus indices (PIs) are quantitative assessment tools used for identifying those areas most vulnerable to P loss (Lemunyon & Gilbert, 1993; Sharpley et al., 2003). PIs use information that is readily available to farmers and agricultural consultants to evaluate the potential for phosphorus in runoff from a specific field entering a nearby stream. Ideally, a P Index can offer field staff, watershed managers, and farmers an efficient tool to estimate each field's potential for annual P loss and sediment erosion to nearby surface waters. The Wisconsin PI (WPI) was incorporated into the Wisconsin Soil Nutrient Application Program (SNAP-Plus), a computer model that estimates P loss on a field-by-field basis. Fields with the highest PI are most vulnerable to P loss to surface waters and are high-priority sites for conservation efforts.

The WPI uses a set of equations to estimate P losses from an individual field to nearby surface water based on county rainfall records. The SNAP-Plus software has two major components: 1) the Revised Universal Soil Loss Equation 2 (RUSLE2), which estimates soil erosion in tons per acre per year, and 2) the WPI, which estimates P loss in pounds per acre per year. SNAP-Plus integrates RUSLE2 into the WPI and provides quantitative P loss values to allow comparisons of sediment and nutrient yields between different fields. If there are changes in crop rotations, manure applications, or tillage practices, the amount of sediment transport to the edge of a field can be estimated using RUSLE2. The WPI uses soil data with current land use practices (including fertilizer and manure applications, and crop rotations) to give an annual amount of phosphorus that is lost to the edge of a field. This amount is then multiplied by a transport factor (<1), which estimates the amount of phosphorus that makes it to the stream or other water systems.

The WPI threshold is six pounds P lost per acre per year; fields with WPI values above six must not receive additional manure and fertilizer application (NRCS-WI, 2005; Good, L.W., personal communication, 2009). The majority of Wisconsin farms already have a WPI less than six, and those currently not in compliance can be brought into compliance with existing practices.

2. Wisconsin Phosphorus Index factors

The WPI incorporates many source and transport factors known to affect P loss for each field, including:

crop rotations (e.g. 4-8 year rotations of various crops, including corn silage, corn grain, alfalfa, oats.)

manure management (e.g. machinery, surface applied or incorporated, animal type and amount, timing.)

fertilizer applications (e.g. machinery, surface applied or incorporated, timing.)

tillage regime (e.g. machinery, timing.)

herd sizes (e.g. animal type, number.)

soil test P (e.g. Bray 1 method)

soil type (e.g. Dunbarton.)

slope (e.g. A, B, C, D)

rainfall and snowmelt runoff volumes (e.g. annual overland flow estimates based on empirical data)

runoff flow path (e.g. distance to nearest surface water body)

The SNAP-Plus model gives each component a weight by using a series of equations based on empirical runoff data from the local area. The results of those equations (for total phosphorus, dissolved phosphorus, and phosphorus delivery ratio) are combined to give an average WPI value for each field.

Slope, soil type, distance to water, and in-field practices are the major determinants for P loss. Agricultural watersheds with steep slopes and erodible soil types are most vulnerable to severe erosion (UWCALS, WBI Report, 2005). Within these areas, fields with high P concentrations directly adjacent to streams often have the highest P loss potential (Gburek & Sharpley, 1998) (Figure 5).

Figure 5. *Slope, soil type, distance to water, and in-field practices are the major determinants for P loss.*

To obtain information necessary to run SNAP-Plus, K. Songer (UW) interviewed farmers in the Pleasant Valley watershed about their agricultural practices in exchange for agronomic soil P tests, a requirement for their nutrient management plans. Remaining data were obtained through a GIS-based analysis from free and public sources: the Dane County 10-ft digital elevation model (DEM), the NRCS Web Soil Survey, and USGS runoff estimates (UWCALS, WBI Report, 2005).

3. Wisconsin P Index and SNAP-Plus assumptions

Although the Wisconsin P Index is an effective tool for calculating P loss potential, it ignores tile drainage and point sources of phosphorus. Surface runoff is reduced where tile drains are present and therefore the P Index overestimates surface runoff P. The UW-Extension staff is in the process of integrating this process into the Wisconsin PI

(L.W. Good, personal communication, 2008). Point sources that are left out of the current model of SNAP-Plus include barnyard runoff, night pastures, manure storage facilities, and direct cattle access to streams. Many of these are major contributors to watershed-scale P loss and could be a vital component missing from SNAP-Plus results. To supplement SNAP-Plus, county field staff uses a point source model, such as the Wisconsin barnyard runoff model (BARNY), and utilizes local knowledge of potential P sources (T. Cox, personal communication, 2008).

The current WPI calculations also assume fields have a minimum distance from water bodies defined either by the floodplain of a stream, or distance from the defined ordinary high water mark or the defined bed and bank. This area is not a buffer but rather a strip that can be harvested provided it stays in continuous vegetation and is not subjected to tillage operations. The purpose of setting back fields from the stream is to provide bank stabilization and prevent soil from being directly deposited in water bodies through tillage operations. The current WPI calculations assume minimal to no direct access of livestock to water bodies. It is important to note that livestock often did have more than minimal access to streams in the Pleasant Valley watershed during this study (Figure 6).

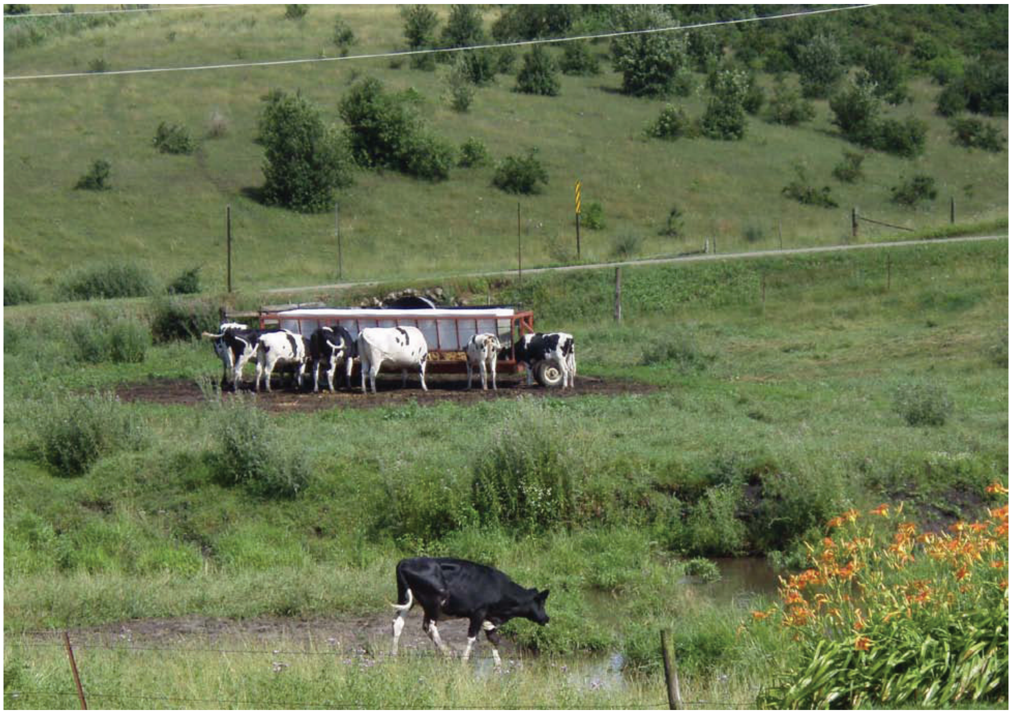

Figure 6. *Pleasant Valley watershed with steep slopes in background. Several pastures in this watershed give livestock access to streams.*

4. Wisconsin P Index and SNAP-Plus as management tools

The results from SNAP-Plus can help to quantify the P loss potential within a watershed. In particular, the WPI results can help county agencies work more efficiently to identify fields with the highest potential to improve watershed stream quality through conservation practices. The WPI can be an especially efficient tool when used with an initial GIS-based screening process.

SNAP-Plus can offer a realistic array of management options for farmers and field staff to weigh the costs and effectiveness of different conservation practices on both the field- and watershed-scales (UWCALS, WBI Report, 2005). However, this P loss model currently requires extensive staff time to input data for every field in a watershed, and requires that all farmers share their farming practices with government staff. Researchers are currently analyzing SNAP-Plus data and P Indices to find factors that are easy to collect that may predict WPI. Factors such as animal density and soil type may be good predictors of WPI, enabling agencies to find vulnerable areas without performing extensive surveys.

Collaborators with the greater Pleasant Valley Paired Watershed Project called for us to evaluate the Pleasant Valley watershed according to the Wisconsin Phosphorus Index (WPI) values obtained from SNAP-Plus software. The following chapter describes the method and process used. We first created a map of the WPI distribution across the watershed in order to visualize where critical source areas (CSAs) were located. Using this map, we examined the affect that alternate practices had on those fields and farms in order to create practical suggestions for changes in management that might lower WPI and therefore sediment and phosphorus delivery to streams. The SNAP-Plus software enabled us to manipulate many variables within a farm system, therefore allowing us to evaluate if changes in crop type, fertilizer application, crop rotation, or conservation measures would provide the most practical solution to a high WPI value.

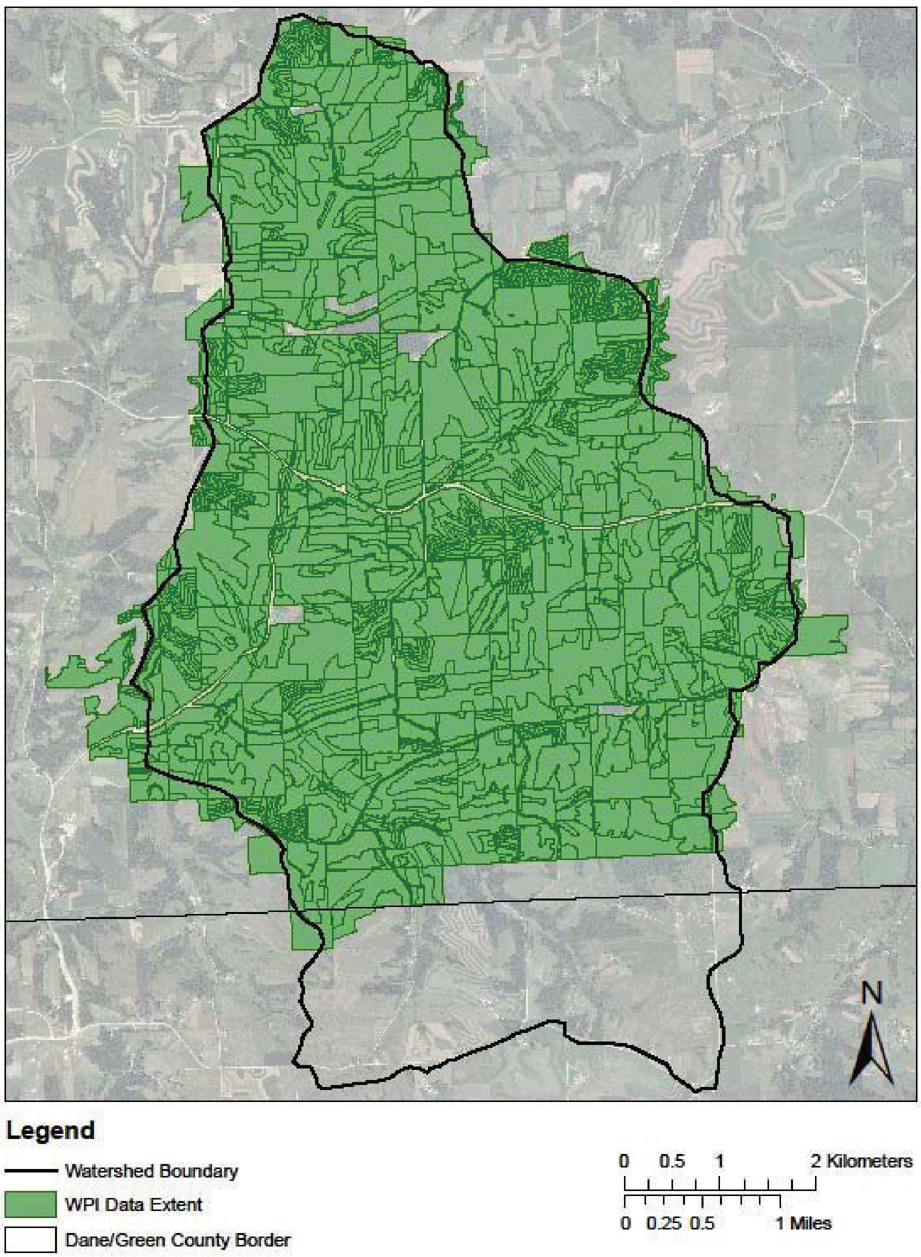

Figure 7. *GIS map of WPI data extent as of June, 2009. Land parcels are outlined in dark green. Parcels with WPI data are filled in with light green.*

1. Creation of Critical Source Area map using ArcGIS

To better visualize the proximity of CSAs to each other, streams, and fields with lower WPI values, we used ArcGIS 9.3 software to map WPI values across the Pleasant Valley watershed. We obtained farm system data from surveys of landowners conducted by K. Songer (2009) for 50% of the watershed. These data were entered into SNAP-Plus software by K. Songer, members of the WRM workshop, and undergraduate student assistants in the UW-Madison Soil Science Department. We then ran the SNAP-Plus model to obtain WPI values for surveyed fields under the land

Consideration	Explanation
Soil Type	The soil type determines the quality and depth of the soil, an important factor for crop yields. It is most likely that only tilling practices on fields with good soil would be changed, while crop rotations would remain the same. In contrast, fields with poor soil may not produce high crop yields and alternatives such as CRP might be more economically feasible.
Field Slope	Fields with steep slopes are more prone to erosion and might be difficult to farm; therefore they also might make good candidates for CRP.
Proximity to stream	Priority was given to fields that were in close proximity to a water source. Where it was feasible, implementation of a riparian buffer was suggested.
Amount of Corn Silage	The practice of farming corn for silage leaves little to no residue on the ground surface, promoting runoff. Moving silage rotations farther away from the stream and planting a higher residue crop between the silage crop and the stream reduces runoff.
Equipment	Not all farmers have the equipment necessary to implement certain practices. Equipment for farming corn and soybeans, for example, is different from the equipment needed to plant and harvest winter wheat, a viable cover crop that acts as residue from fall to spring.
Fertilizer	Fertilizer application on top of manure application is often unnecessary.
Assumptions Made	
Crop Yields	One of the variables in SNAP-Plus is crop yields. If crops in a rotation were changed during the scenario process, yield values for crops were picked to reflect yields of that same crop on other fields on the farm.
Buffer Strips	SNAP-Plus did not simulate a buffer strip at the time of evaluation, therefore in certain circumstances we offered this as a possible future option given the conditions.

Table 1. *Considerations taken into account during the evaluation process (K. Songer, 2009).*

management practices specified by each landowner at the time of Songer's survey.

To create the map, we averaged yearly WPI results for the entire rotation specified by the farm operator and entered them into the GIS database. The resulting map showed the distribution of high to low WPI fields in the watershed. We were able to easily identify fields with high WPI values, and examine their proximity to other fields with either high or low PI values, and their proximity to surface waters. Our GIS map (Figure 7) shows the field outlines for which data were available as of June, 2009. In the interest of confidentiality for landowners with high WPI fields, we have not included the layer with WPI values.

2. Selection process for field evaluations

The Pleasant Valley watershed was ranked in the top 30 out of 452 WBI watersheds (UWCALS, WBI Report, 2005). A large percentage of fields within the watershed have a WPI value over six, the cutoff value for continued nutrient and manure application. We chose eleven (11) fields to focus our evaluation on based on several criteria. Our priority was to choose farms that had at least one field with a very high WPI (>20). From these farms, we selected fields where changes in farming practices would provide the most improvement to overall water quality based on: 1) if conservation practices were being applied in close proximity to the field; 2) the field's proximity to streams; 3) slope of the field; 4) crop rotation on the field, and other case-specific criteria.

These conditions were based on the following logic. We reasoned that if the farm operator applies conservation practices on land near the field in question it would be a practical option to extend those practices to the field with a high PI. Also, a field's proximity to a stream increases the potential for sediment to reach the stream, making those fields a priority to evaluate. Sediment erosion from fields is also highly dependent on the slope of the field, as well as the crops planted on it from year to year. We used several layers in the GIS to help us evaluate fields according to our conditions: surface water and stream channels, provided by J. Maxted (UW doctoral student), a ten-foot digital elevation model provided by the Dane County Land Conservation Division (LCD), and aerial photographs of specific farms, also provided by the Dane County LCD.

In terms of case-specific criteria, we found that each group of fields on a specific farm had particular attributes that set it apart from other fields we were evaluating, such as field sizes, shapes, or amount and type of fertilizer applied. Therefore, each evaluation presented different combinations of attributes to work with, hindering a streamlined process but highlighting the individuality of farms within the watershed. When policy makers develop an overarching policy for Wisconsin it is important to note that there will not be a single simple way to quickly identify problems and offer solutions. Rather, the process our study undertook shows that a great deal of footwork and rapport with land owners is necessary to create the desired changes.

3. Generating scenarios to reduce WPI

We created a Microsoft Excel template to evaluate management changes for each field. The spreadsheet contained information such as crop rotation, soil type, original WPI value, tillage type, manure application, annual tolerable soil loss (Field "T"), and average soil loss (Table 1). To create alternate management scenarios, we varied factors such as crops, crop rotations, tillage regime, and fertilizer application within SNAP-Plus. Also, SNAP-Plus allowed us to evaluate whether the use of contour strips changed a field's WPI. We were unable to analyze the effect of a buffer strip on WPI values in SNAP-Plus, although that feature will be soon integrated into the program (L.W. Good, personal communication, 2008). We altered one factor at a time from the original field parameters, running each new scenario in SNAP-Plus and recording any changes to the WPI value. We chose a specific group of factors to alter based on evaluation of the farm system and the management practices used on the fields around the field in question. After compilation of

Scenario: A

Factors			
Field Acreage:	16.1	Manure:	Yes
Field Slope (%):	9	Crop Rotation:	Cs-Cs-Cs-Cs
Soil Type:	PORT BYRON	P-Index:	221 ppm
Next to Water:	Yes	**PI Value:**	**27.1**
Recommendation(s)			
1. Change tilling practices to either no till or strip till 2. Change tilling practices and split field to grow Cg in section closest to water			
Modification		**Estimated New PI Value**	
No Till		10.5	
Strip Till		12.8	
Reason(s) for Recommendation:			
• Cs leaves no residue and since the water is so close having some type of buffer would help. This field has very productive soil and is flat so it will stay in production. Changing tilling practices will disturb the soil less and reduce runoff. • The farm will need to evaluate the amount of Cs needed to feed cows and see if they are overproducing Cs.			

Scenario: B

Factors			
Field Acreage:	13.8	Manure:	No
Field Slope (%):	16	Crop Rotation:	Cg-Sb-Cg-Sb
Soil Type:	EDMOND	P-Index:	29 ppm
Next to Water:	Close but not next to	**PI Value:**	11.8
Recommendation(s)			
1. Change tillage practice 2. Implement contour strip			
Modification		**Estimated New PI Value**	
No Till		3.3	
Strip Till		9.7	
No Till and Contour		2.4	
Strip Till and Contour		6.5	
Contour only		8.6	
Reason(s) for Recommendation:			
The field is steep so contour stripping will reduce runoff. No till and strip till are less disruptive to the soil. Contouring will save fuel from up and down farming on steep slopes.			

Table 2. *Two of the scenarios created in SNAP-Plus showing how change in land management practices results in lower PI values for fields.*

a list of various scenarios with new WPI values, we evaluated the scenarios on practicality and the likelihood of implementation. At times, this analysis required contacting the Dane County LCD for more information about the farm system or incentives available to farmers in the area.

Two of the scenarios we generated are presented in Table 2; further scenarios are laid out in Appendix 1. Any place or name identifiers have been removed in the interest of confidentiality. The best scenario was not always the option that gave the lowest WPI value, as often the lowest WPI correlated with converting a field to CRP, an option that takes the field out of a traditional rotation. The "best" scenario instead balances lowering the WPI value with practical limitations given the particular circumstance and likelihood of implementation on each field or farm. Our scenarios were given to Dane County's LCD as recommendations for land use change within certain areas of the watershed. A detailed explanation of these recommendations can be found in the next chapter.

Chapter 4

Our evaluation of the Pleasant Valley watershed according to WPI values continues in this chapter. We present specific recommendations for land management changes within the watershed. These recommendations result from examining how changes to factors described in chapter 3 reduce the WPI. We found that several alterations to management plans consistently lowered WPI. As a result, we concluded that if land managers implemented these changes they would achieve the greatest reduction in the average WPI of the watershed. While we evaluated the management changes to the best of our ability, actually quantifying the cost of changes in practice or crops was outside the scope of this project due to the volatility of the agricultural market and the lack of economic expertise within the group.

1. Recommendations for land managers

Several alterations in land management practices emerged as broad-reaching solutions to reduce disproportionately high WPI values. These changes should be considered at the outset of evaluating how a farm might reduce its WPI value, which will effectively reduce its sediment input into streams. Please note, however, that these are general recommendations that may not be applicable to certain farms or farm systems. The Driftless Area's un-glaciated terrain contains numerous steep slopes, and fields tend to be smaller than one might find in an area of more level topography.

We found that switching tillage practices to either no-till or strip-till dramatically reduced WPI values. No-till and strip-till farming allow root structure to be maintained and increase surface roughness across a high percentage of a field due to standing dead or live vegetation. With increased roughness the soil surface is shielded from erosion caused by the impact of raindrops, and water is forced to move more slowly down a slope. As the water moves down slope at a slower rate it is forced to infiltrate rather than immediately running off carrying fine sediments - to which P readily attaches.

We also found that implementing contour farming on fields with steep to moderately steep slopes generally reduced WPI. Contour farming reduces runoff because tillage occurs along the contour of a slope. As water flows downhill over a slope that has been tilled on the contour, it encounters the regular small ridges and depressions created by tilling. These small changes in topography slow runoff down. Although many farms already use this practice in the Driftless Area, we encountered fields in Pleasant Valley with steep slopes that did not. Implementing contour farming on these fields will help reduce the number of CSAs in the area.

Two other recommendations come from both the SNAP-Plus analysis and field observations. The first is a suggestion to leave crop residue on fields over winter. Leaving residue on fields over winter allows for greater protection from erosion in the early spring, when snowmelt over bare, frozen soil causes an average of 60-75% of annual runoff (Frame, personal communication, 2009). Also, we suggest that farm operators consider portable fencing options for fields used as pastures. Repeatedly grazing cattle on the same field can lead to degradation of that field and the exposure of its soil to erosion (Frame, personal communication, 2009). Portable fencing allows easier rotation of livestock to different fields within a farm, reducing stress on highly trafficked areas within a single enclosure.

Finally, we suggest that farm owners and operators do a cost-benefit analysis to compare fertilizer application to crop yield. Several fields we analyzed were receiving applications of fertilizer as well as applications of manure, which may result in an overload of P, nitrogen, or both of these nutrients.

Please see Appendix 1 for more examples of reduction in WPI with the changes recommended above, as well as detailed explanations of recommendations for more case-specific criteria.

Chapter 5

A fundamental difference between Priority Watersheds and WBI watersheds is the potential for land management changes in the smaller WBI watersheds to correspond with measurable changes in water quality. To aid the Pleasant Valley Paired Watershed Project in demonstrating measurable change, we collected extensive baseline data for several stream channel water quality metrics. In this chapter, we discuss stream channel characteristics, our process for establishing semi-permanent sampling sites, and how we used these sampling sites to collect valuable baseline data. We then integrate our baseline data observations with stream biota data from the DNR. Future PVPWP studies will make use of these sampling sites and vital baseline data as stream channels are sensitive to flows and will change over time.

1. Baseline data overview

Our direct field measurements included 1) geomorphic channel characterization, 2) habitat assessment, and 3) short-term water sampling. These data provided us with a snapshot of stream conditions in the watershed, which we compared to reference streams in the Driftless Area. For information on our short-term water sampling

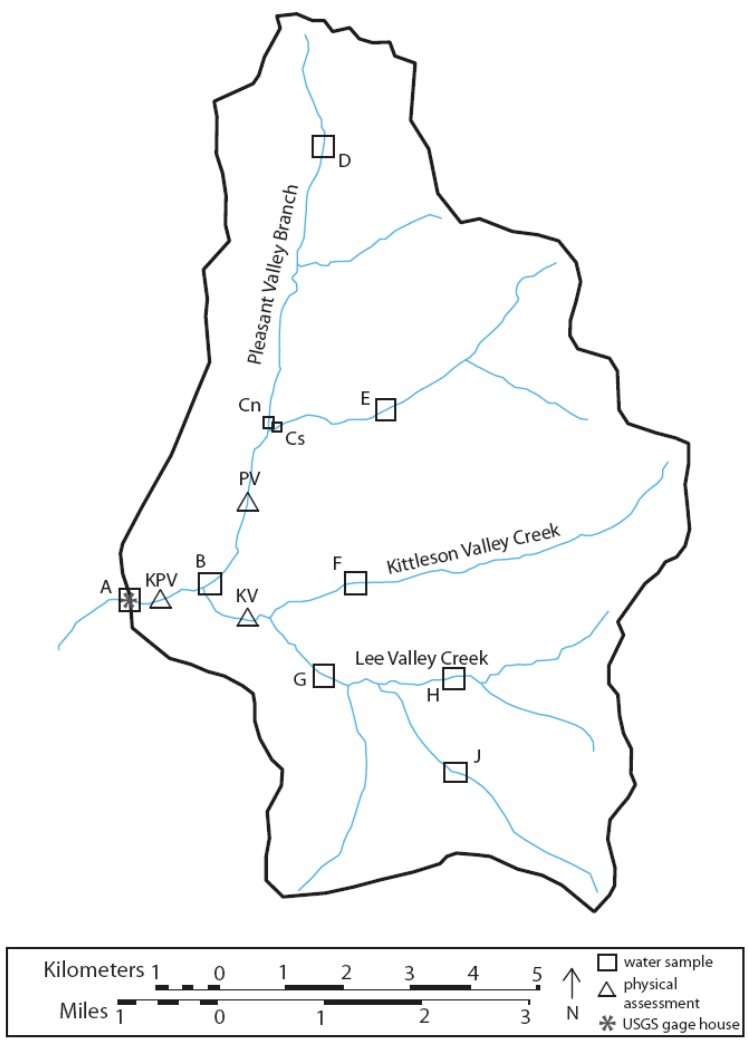

Figure 8. *Pleasant Valley Watershed (19 square-miles) with named tributaries. Squares show locations of samples taken at bridge-crossings. Triangles mark physical assessment sites, and the asterisk marks the location of the USGS gage house.*

Data available for physical assessment sites	KV	PV	KPV
Habitat Improvement		2003	2007
Fish survey	2006, 2007, 2008	2003, 2004	2002
Macroinvertebrate survey		2003	
Cross section survey	2008	2008	2008
Dissolved oxygen	2008	2008	2008
pH	2008	2008	2008
Discharge measurement	2008	2008	2008
Pebble count	2008	2008	2008
Habitat assessment		2008	2008

Table 3. *Data available at each assessment site. Dane County and the WDNR funded habitat improvements and the WDNR conducted fish and macroinvertebrate surveys. All other data were collected by WRM during the summer of 2008.*

please refer to Appendix 2.

2. Stream channel characteristics

A. Methods

We took several field measurements with the purpose of connecting WPI values to stream conditions, characterizing stream channels, and building a baseline dataset for the PVPWP. We chose three stream reaches for intensive physical assessment based on their position in the stream network (Figure 8), as well as their stage of rehabilitation. For the purpose of this study, we define rehabilitation as any type of channel “improvement,” such as stream bank stabilization, re-sloping and narrowing of channel banks, removal of riparian trees, and installation of fish habitat structures (L. Hewitt, personal communication, 2007). Further geomorphic studies in the watershed could provide a better understanding of in-stream sediment and phosphorus origins.

The three reaches we chose for baseline assessment included:

1. A site without habitat improvement in Kittleson Valley Creek upstream of the Pleasant Valley Br. confluence (site name KV).

2. A site in Pleasant Valley Br. with stream bank work as part of the Wildlife Habitat Improvement Program (WHIP) in 2003 (site name PV).

3. A site in Kittleson Valley Creek downstream of the Pleasant Valley Br. confluence that underwent habitat improvements in fall 2007 (site name KPV).

Habitat improvements had a significant impact on what type of vegetation, land surface, and sediment we found in each reach, however, we

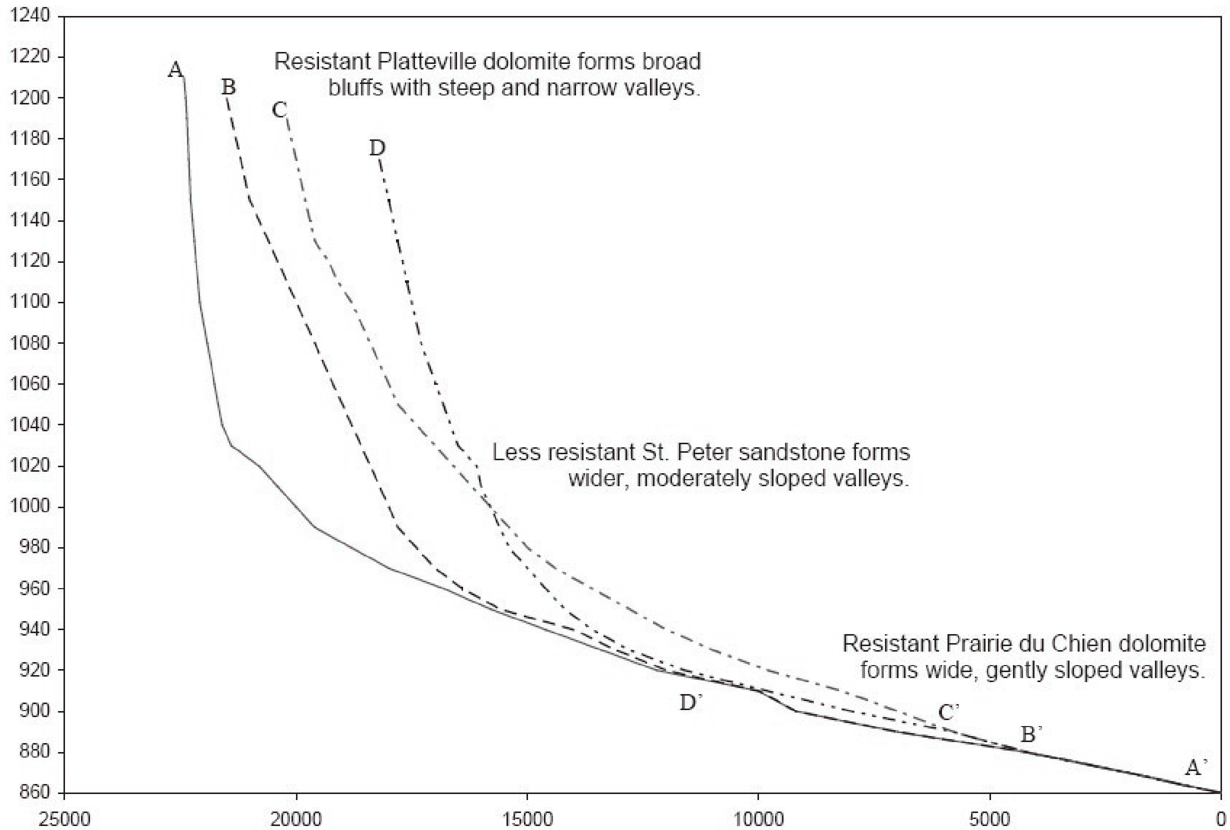

Figure 9. *Longitudinal stream profiles along four channels in the Pleasant Valley Watershed. Pleasant Valley Br is A to A', An unnamed tributary to Pleasant Valley Br is B to B', Kittleson Valley Cr is C to C', and Lee Valley Cr is D to D'. The steep-to-moderate concave profile illustrates steep headwaters and gentle valleys typical of Wisconsin's Driftless area. For a map showing profile transect locations refer to Figure 10.*

were not able to separate what conditions were due to rehabilitation versus nearby land use impacts. Our assessments could not describe sediment contributions from specific fields. Instead, they describe deposition in this watershed as a whole. Reach locations coincided with pre-established WDNR sampling locations so that we build on existing habitat, fish, and macroinvertebrate data (USEPA, 2006). We supplemented this historical data with current 1) longitudinal profiles, 2) habitat assessments, 3) pebble counts, and 4) cross section surveys, which were performed between August and October 2008. We provide a summary of the data we collected at each reach in Table 3.

B. Longitudinal profiles

We used longitudinal profiles to identify changes in stream slope related to geologic features, as well as to describe spatial position of streams in the drainage network (USGS, 2006a). We produced longitudinal profiles along four main tributaries in the watershed: Pleasant Valley Branch, an unnamed tributary to Pleasant Valley Branch, Kittleson Valley Creek, and Lee Valley Branch (Figure 9). We measured stream lengths using a map measurer on 7.5-minute USGS topographic maps with 10-foot contours. Each of the four longitudinal profiles has a concave-up profile from the headwaters to the outlet at the gage house.

Three geologic formations intersect the stream channels in this watershed, and can be seen as breaks in slope on the longitudinal profile. The dolomite of the Platteville formation forms broad ridge-tops and steep, narrow valleys.

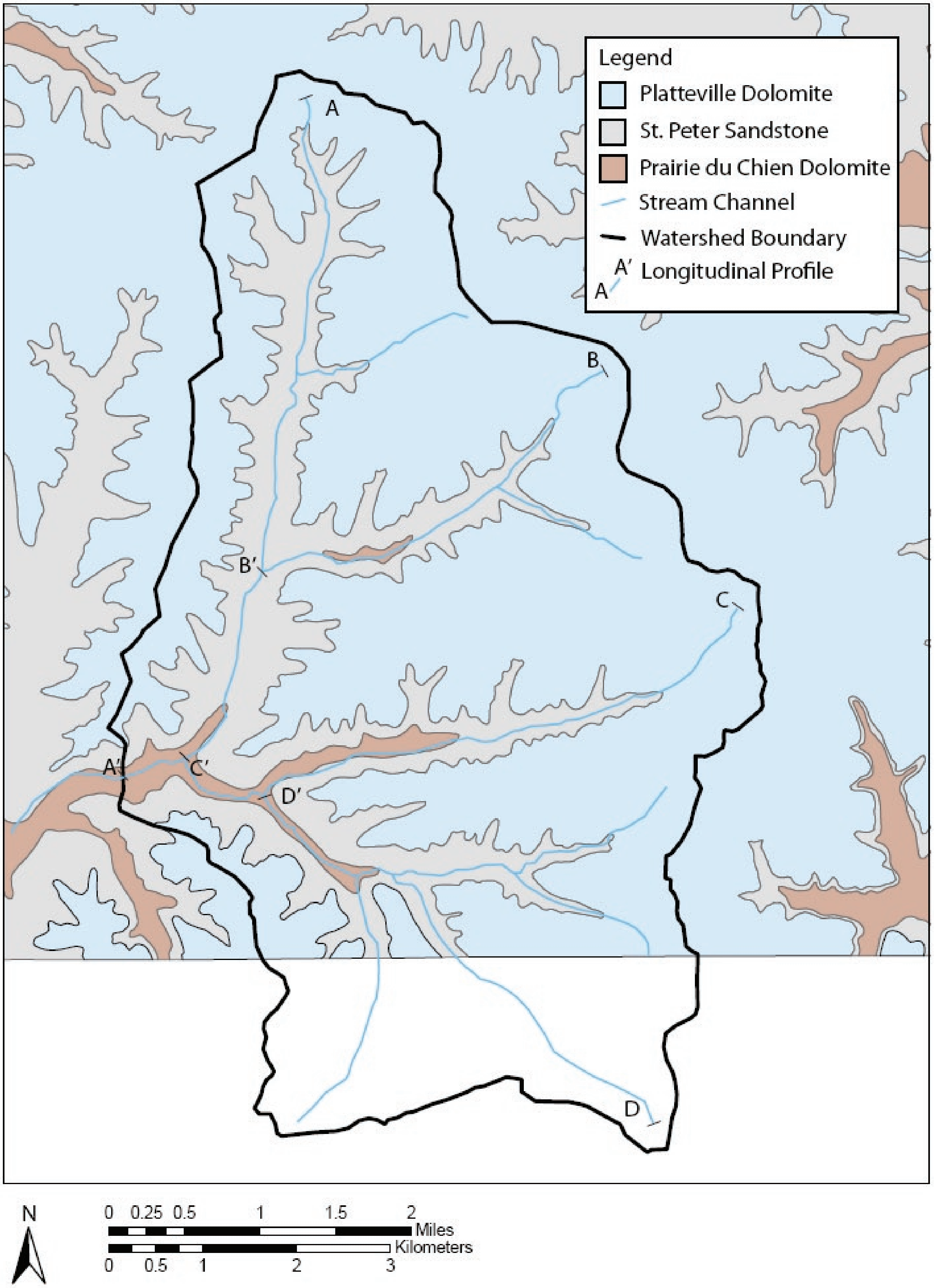

Figure 10. *Geologic formations in the Pleasant Valley watershed closely follow the drainage network. Platteville Dolomite forms broad ridge tops and narrow valleys, while St. Peter Sandstone forms wider valleys and narrow ridge tops. Also shown are locations of transects used in the longitudinal proles in Figure 9.*

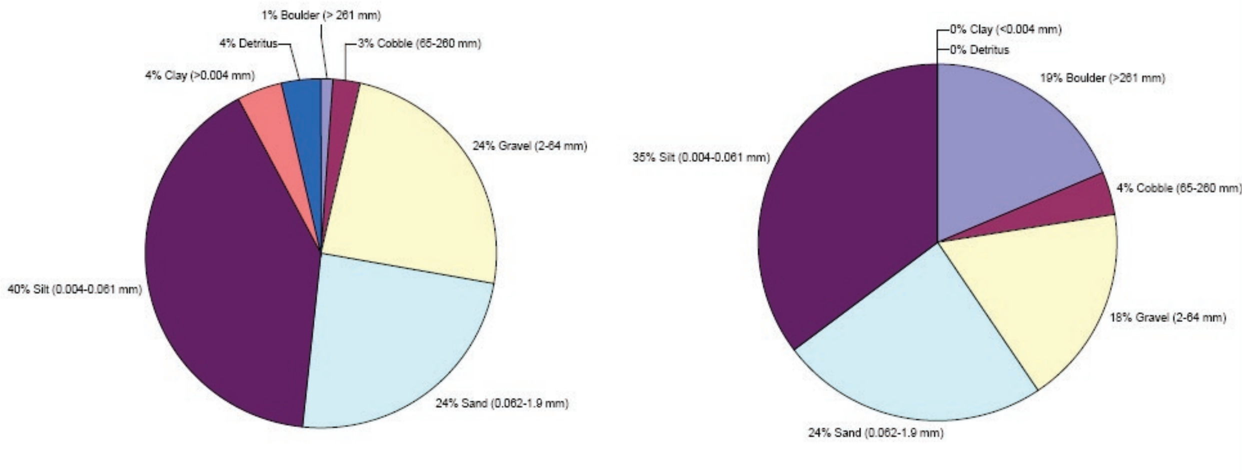

Figure 11. *Benthic sediment for KV (left) and KPV (right) found using WDNR habitat sampling protocol. While silt, sand, and gravel are similar between sites, there is a greater percentage of cobble and boulder at the site that has undergone habitat improvement (KPV) due to installation of rip-rap, and a lower percentage of clay.*

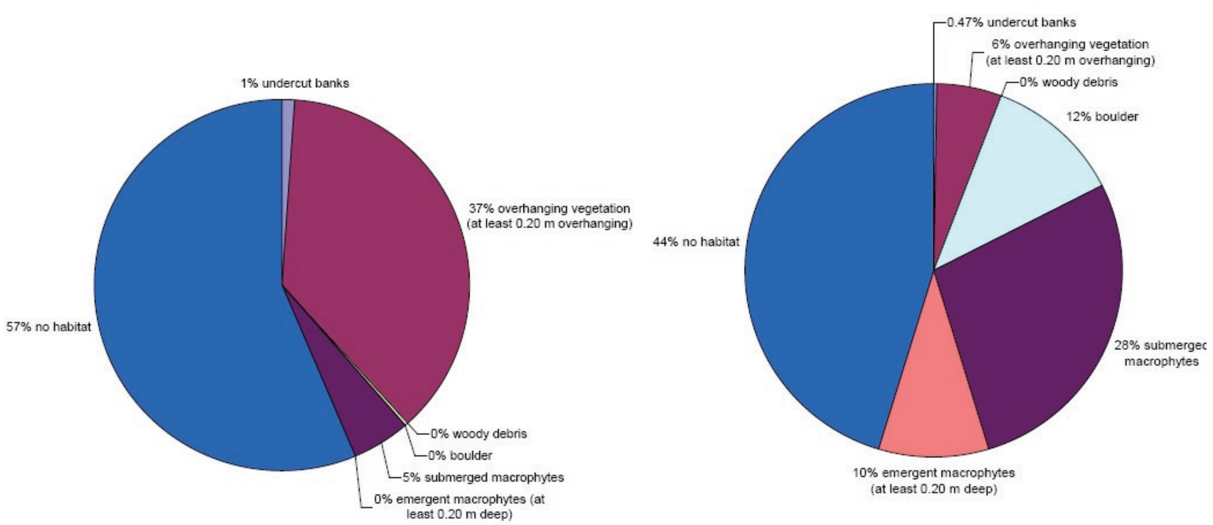

Figure 12. *Fish habitat cover for KV (left) and KPV (right) found using WDNR habitat sampling protocol. The site that has undergone habitat improvement (KPV) has both greater habitat diversity and more fish habitat than the non-improved site. Fish habitat cover at the non-improved site (KV) is mostly overhanging reed canary grass.*

The sandstone of the St. Peter formation is less resistant to erosion and forms narrow ridge-tops and wider valleys. The dolomite of the Prairie du Chien formation, exposed in the lower reaches of the watershed, is more resistant than St. Peter's sandstone and creates wider valleys at the contact between the two rock formations (Figure 10).

C. Habitat Assessment: Improved habitat versus non-improved habitat sites

We assessed KV and KPV for riparian and in-stream physical habitat characteristics. Following WDNR protocol, each study site length was calculated by measuring the mean stream width (MSW), then calculating 35 * MSW (Lyons, 1992). Within each reach we established 12 habitat assessment transects at an equal distance apart of 3 * MSW. In four quadrats along each transect line, we measured water depth, sediment depth, bank full water depth, overhead canopy, and visual estimates of percent substrate composition. We measured bank erosion, and visually estimated riparian land use and land cover characteristics along each end of transect, extending 10 meters laterally into the upland riparian zones (USEPA, 2006).

Site KV (non-rehabilitated) had a higher percentage of silt and clay than site KPV (rehabilitated), which had a higher percentage of cobbles and boulders (Figure 11). These cobbles and boulders were less embedded than those at KV, presumably due to the narrowing of the channel and the scouring effect from the increased current caused by narrowing of the channel due to rehabilitation (WDNR, 2005). Cover for game fish was higher at KPV; cover was mostly provided by submerged macrophytes (51%), whereas overhanging reed canary grass offered the most cover at KV (85%) (Figure 12). 55.7% of the MSW at the KPV stream segment provided fish cover, compared to 45.1% of the MSW at KV. This abundance of fish habitat at KPV site was presumably due to its stable boulder substrate and rooted macrophytes, providing cover for macroinvertebrates and fish.

Due to the rehabilitation efforts to remove riparian woody plants, KPV had less woodland cover (9.2%), canopy cover (5.8%), and embeddedness (10.9%), while KV had greater siltation, woodland cover (13.3%), canopy cover (22%), and embeddedness (12.6%). Stream reaches with riparian trees, like KV, have greater allocthonous organic inputs, such as woody debris, which reduces stream current and causes sediment to drop out of suspension.

D. Pebble counts

F. Fitzpatrick (USGS) conducted Wolman pebble counts (Wolman, 1954) during the same period as our other physical assessments. Pebble counts are a quantitative measurement of coarse substrate. Fitzpatrick chose one riffle within each survey reach, and used standard pebble selection techniques: she measured and recorded the diameters along the b-axis of 100 random pebbles, classifying sand-sized or smaller particles using a sand card (USGS, 1998). Fitzpatrick also noted the presence of any macrophytes and the depth of soft sediment (USGS, 2006a).

The particle size distribution of our three sites supports our observation that there are more fine sediments at KV (non-rehabilitated) and more cobbles and boulders at KPV (rehabilitated in 2007). PV (rehabilitated in 2003) had the least fine particles of all three sites, gravel similar to KPV, and an amount of cobbles and boulders between that of KV and KPV sites. The sediment distribution at PV is somewhere between that of KV and KPV, one explanation for this is that PV was rehabilitated four years before KPV and the sediment characteristics may be reverting back towards a non-rehabilitated state. New sediment accumulation, particularly gravel, may be covering some of the rip rap, while changed channel hydraulics still allows fine particles to pass through.

E. Cross section surveys

We surveyed channel cross sections with an automatic level at all three intensive physical assessment sites, establishing semi-permanent benchmarks (reinforcement bar stakes) at each cross section, and recording their locations were with a global positioning system (GPS) (USGS, 2006a). Cross section surveys included ground surface, water-surface, and soft sediment depth at each cross section. We found that KV was notably more rectangular than both PV and KPV reaches, had shallower stream depth, steeper banks, and an elevated floodplain.

Generally, restoration projects create narrow, fast moving currents that quickly scour the channel bed and improve benthic habitat. Re-sloping and re-stabilizing banks with native vegetation reduces bank erosion and incision, creating undercut bank cover for fish, and stable habitat for biota at the water-land interface (M. Miller, personal communication, December 14, 2008). Our data show that the rehabilitated sites (PV and KPV) provide more of such habitat, with scoured rocky substrate; narrow, deep channels; and lower

Metric	Reference Condition Threshold	Impairment Criteria	Score at physical assessment site: PV
IBI score	60	IBI score is < 60	35
Macroinvertebrate HBI score	3.92	HBI score > 3.92	5.97
Macroinvertebrate Species Richness	16	< 16 species	14

Table 4. *Fish and macroinvertebrate metrics. Reference conditions and impairment criteria were found by USEPA (2006). Data for Pleasant Valley Branch were collected by WDNR. Pleasant Valley is impaired according to all three metrics.*

Water Chemistry and Quality Measure	Reference Condition Threshold	Impairment Criteria	Pleasant Valley Bridge Crossings	USGS Gage at outlet
Oxygen Saturation (%)	73.3	< 73.3	100.5	
Dissolved Oxygen (mg/L)	7.6	< 7.6	10.3	
Water Transparency (cm)	122	< 122	101.5	
Total P (mg/L)	0.07	> 0.07	0.11	0.13
Total Dissolved P (mg/L)	0.04	> 0.04	0.05	0.04
Suspended Sediment (mg/L)			42	35

Table 5. *Water chemistry summary for six variables taken during summer base flow conditions. Median data are compared to reference criteria developed for the Driftless Area by USEPA (2006). Samples were collected at nine bridge crossings in Pleasant Valley on July, 4th 2008 and at the USGS gaging station at the outlet of Pleasant Valley between June and September, 2007 and from June to September, 2008.*

floodplains. Thick macrophyte beds of Canadian waterweed (Elodea canadensis) have become firmly established at PV; these macrophytes may improve habitat, but also slow the current velocity and increase soft sediment depth as sediment drops out of suspension (P. Sutter & L.W. Good, personal communication, 2009). This does not support the generalization that rehabilitated reaches will have less soft sediment, further study of soft sediments will be addressed in future studies of the Pleasant Valley Paired Watershed Project.

3. Biotic assessment of Pleasant Valley watershed: Correlations between water quality, fish and macroinvertebrates

Fish and benthic macroinvertebrates are another important part in collecting baseline data. Pollution-sensitive aquatic animals can reveal minute changes in organic pollution or habitat disturbance, serving as biological indicators of stream conditions. Researchers use fish and macroinvertebrate species richness and biotic indices as proxies for stream conditions to supplement other data. Numerous studies have found a negative correlation between in-stream phosphorus concentration and biotic index scores related to the health of fish and macroinvertebrate assemblages. These indices include the Fish Index of Biotic Integrity (IBI) and Hilsenhoff's Biotic Index (HBI) (Hilsenhoff, 1988; USGS, 2006b). USEPA (2006) set reference conditions for fish and macroinvertebrate assemblages in the Driftless Area in order to determine whether streams should be designated as human-impacted or least disturbed (Table 4). Impacted streams tend to have a shift from stenothermal, cool- and coldwater fish to eurythermal species associated with agricultural deposition and lower water quality (Marshall et al., 2008). Here we examine biotic data for reaches in the PV watershed and discuss how the biotic community may be affected by the water quality in the area.

WDNR fish data between 2002 and 2008 are available at the same intensive physical assessment reaches described above (PV, KV, and KPV). We used these data to compare streams in the Pleasant Valley watershed to reference conditions. Pleasant Valley Branch supports some warm-water fish species, but the presence of brown trout and mottled sculpin indicates its potential to support a cold-water fishery (WDNR, 2005). Fish IBI scores at PV were 20 in 2003 (pre-rehabilitation) and 50 in 2004 (post-rehabilitation), respectively "poor" and "fair"—both below the reference condition threshold of 60 for Driftless Area streams (Table 4). Pleasant Valley Branch is currently on the WDNR 303(d) list for its impaired fish habitat due to overgrazing and agricultural runoff (WDNR, 2005 and 2008). In comparison, fish IBI scores for Kittleson Valley Creek (sites KV and KPV) were both "good" (60) due to healthy brown trout and mottled sculpin populations. All three sites are stocked with trout, which drastically affects IBI scores, but also indicates the aquatic system's ability to support those fish species.

Fish are generally good indicators for broad-scale water quality and connectivity because of their mobility, but do not necessarily reflect the impacts of local land use (D. Vetrano & M. Miller, personal communication, 2009). In contrast, benthic macroinvertebrates—aquatic larvae, bugs, and invertebrates smaller than .5 mm (USEPA, 2009)—are more reliable as biological indicators. Macroinvertebrate species are long living, have a smaller range of mobility, a variety of sensitivities to pollution, and are therefore strong indicators of water quality and immediate land use (M. Miller, personal communication, 2009). Kittleson Valley (KPV) had an HBI of 5.97, which was below the reference threshold (3.92). We also found that the macroinvertebrate species richness (14)—the number of species found in a sample—did not meet the reference threshold (16) (Table 5). The HBI score (within the 5.51-6.50 range) indicates "fair" water quality with a significant degree of organic pollution, likely due to agricultural sedimentation covering benthic habitat (WDNR, 2005). For all biotic measurements, the Kittleson Valley Creek was at least moderately impaired by sedimentation and below reference conditions for the Driftless Area.

Chapter 6

Many Wisconsin streams and lakes are impaired by pollution from agricultural phosphorus (P) and fine sediments. In the Pleasant Valley Paired Watershed Project (PVPWP)—a collaborative effort among UW-Madison, Dane County LCD, USGS, WDNR, and TNC—a watershed-scale study and the Wisconsin P Index (WPI) are being used to test targeting strategies to reduce sediment and P delivery to streams. The PVPWP and this study are based on the assumption of disproportionality: that most P loss comes from a few farm fields, rather than being evenly spread across the watershed. In this final chapter we summarize our process, findings, and discuss the future of the PVPWP.

1. Summary of the 2008 WRM Workshop

The WRM workshop aimed to test the efficiency of current software in finding critical source areas (CSAs), to use SNAP-Plus to develop alternate management plans for farms with single or multiple CSAs, and to collect baseline data for the PVPWP. With the use of SNAP-Plus and ArcGIS, we created informative maps of the watershed and developed multiple recommendations for landowners with CSAs. Once the data were entered into SNAP-Plus, it was easy to evaluate how potential changes in land management could decrease the amount of P leaving the fields. However, we highly recommend having sound knowledge of farming practices and practicalities in order to make realistic decisions about factors to alter within SNAP-Plus.

While this study relied on relatively inefficient, intensive data collection and entry by collaborators in the PVPWP, several collaborators are currently analyzing the SNAP-Plus software and the WPI to find factors that are easy to collect that may predict WPI, such as animal density and soil type, so agencies can identify CSAs more efficiently in the future. The Dane County LCD is using the results of the CSA targeting and recommendation process performed by this workshop as a tool for advising changes in land management in Pleasant Valley.

Project collaborators including the USGS and the DNR are using our baseline data as well as the survey locations established by our workshop for continued channel stability and sedimentation monitoring. The data will be used as part of their evaluation of fish habitat improvement and stream sediment storage in Pleasant Valley.

2. The future of the PVPWP Study and recommendations

After surveying farm practices and estimating WPIs for every field in the watershed by the fall of 2009, the Dane County Conservation staff will work with farmers on identified CSAs, offering 100% cost-share funds to these target areas whenever possible. County field staff will also adopt a screening tool to efficiently locate CSAs following suggestions from ongoing research (K. Songer & L.W. Good, personal communication, 2009). Researchers will also continue to measure changes in water quality and stream conditions over time.

Measuring changes in stream conditions over time requires that contributions from edge-of-field and stream sediment storage be evaluated separately in order to observe the effects of land use. To discern between these different sediment sources, a watershed channel stability assessment for Pleasant Valley watershed will be conducted by the USGS to assess the contribution of in-channel processes to sediment and P delivery at the mouth of the watershed.

We recommend that researchers take an increased number of water samples for total phosphorus (TP), dissolved phosphorus (DP), and suspended solids (SS) at bridge crossings. The samples are relatively inexpensive, take little time to collect and process, and give spatial distribution of water quality in the watershed—a parameter that the USGS gage house lacks. It is particularly important to monitor these concentrations over the course of the long-term project in order to see if and how ongoing changes in the land use of the Pleasant Valley watershed affect stream conditions, how long it takes to see such changes, and whether or not other actions should be taken to improve water quality.

Future studies of other watersheds outside of the Driftless Area should be specific to those regions. We compared the relative conditions of the streams in the Pleasant Valley watershed to reference streams in the Driftless Area. However, recommendations and data presented in this study may not apply to streams in the flat region of southeastern Wisconsin. Each watershed's stream data should only be compared to reference conditions in its particular Level III ecoregion: the Driftless Area, North Central Hardwood Forests, Northern Lakes and Forests, or Southeastern Wisconsin Till Plains (USEPA, 2006). Comparing watersheds at the ecoregion-level will provide a more meaningful understanding of each watershed's stream conditions. Also, it would be prudent to acknowledge the differences in groundwater hydrology and surface drainage caused by underlying geology of different regions throughout the state.

With conservation land management, stream water quality can improve, and stable stream substrate will be able to support more diverse biotic communities. We hope that the information gathered here, as well as future information from the PVPWP, will aid farmers and conservationists throughout Wisconsin to make sound land management decisions that will improve the quality of their land and the water that moves through it.

References

Chapter 1

Allan, J.D. (1995). *Stream Ecology.* Chapman & Hall, London, UK.

Allan, J.D. (2004) Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. Annual Review of Ecology, Evolution, and Systematics, 35, 257-84.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8(3): 559-568.

Diebel, M.D. (2008). University of Wisconsin-Madison, Center for Limnology. Personal Communication.

Dott, R.H. and J.W. Attig. (2004). Roadside Geology of Wisconsin. Mountain Press Publishing Company, Missoula, MT.

Gburek, W.J. & Sharpley, A.N. (1998). Hydrologic controls on phosphorus loss from upland agricultural watersheds. Journal of Environmental Quality, 27(2), 267-277.

Good, L.W. (2009). University of Wisconsin-Madison, Department of Soil Science. Personal Communication. Hastings, J. (2007). Trout Unlimited Driftless Area Restoration Effort (TU-DARE). Personal Communication.

Hewitt, L. (2007). Wisconsin Trout Unlimited. Personal Communication.

Karr, J. R. & Dudley, D.R. (1981). Ecological perspective on water quality. Environmental Management, 5, 55 – 68.

Potter, K. (2009). University of Wisconsin-Madison, Civil and Environmental Engineering. Personal Communication.

Schwar, M. (1996). The Effects of Phosphorus in Running Waters: A Review of the Literature. University of Wisconsin-Madison. Unpublished.

Sharpley, Andrew, S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing Agricultural Phosphorus for Protection of Surface Waters: Issues and Options. J. Environ. Qual. 23: 437-451.

Songer, K.S. (2009). A screening tool for identifying areas of high phosphorus loss in agricultural watersheds. M.S. thesis. University of Wisconsin. Madison, Wisconsin.

Stanley, E. (2008). University of Wisconsin-Madison, Center for Limnology. Personal Communication.

Sturgul, Scott J. and Larry G. Bundy. 2004. Understanding soil phosphorus: an overview of phosphorus, water quality, and agricultural management practices. Univ. Wis. Coop. Ext. Serv. Bull. A3771.

Sutter, P. (2009). Dane County Land and Water Resources Department, Land Conservation Division. Personal Communication.

University of Wisconsin-Madison, College of Agricultural and Life Sciences, (2005). The Wisconsin buffer initiative: a report to the Natural Resources Board of the Wisconsin Department of Natural Resources. Madison, WI.

USEPA (US Environmental Protection Agency). 1990. National water quality inventory. U.S. Gov. Print. Office, Washington, D.C.

USEPA. 1996. Environmental indicators of water quality in the United States. EPA 841-R-96-002. Washington, D.C.

USEPA, Office of Water. *National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle*. EPA 841-R-08-001. Washington, DC. 2009.

U.S. Geological Survey. (2006). Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin (Professional Paper 1722). Wisconsin: Robertson, D.M., Gracyk, D.J., Garrison, P.J., Wang, L., LaLiberte, G. & Bannerman, R.

U.S. Geological Survey. (2008). National Land Cover Database. Retrieved from http://www.mrlc.gov/ncld_multizone_map.php

Wang, L., Lyons, J., Kanehl, P. & Gatti, R. (1997). Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries 22(6), 6-12.

Wisconsin Department of Natural Resources. (2005). TMDLs for Sediment Impaired Streams in the Sugar- Pecatonica River Basin. Retrieved from http://www.dnr.state.wi.us/org/water/wm/wqs/303d/ApprovedTMDLs/Sugar_Pec_TMDL.pdf

Wisconsin Department of Natural Resources. (2007). Incorporation of WBI into NR 151: Grass Filter and Phosphorus Index Performance Standard [data file]. Retrieved from http://www.dnr.state.wi.us/runoff/pdf/rules/nr151/WBI_NR151.pdf

Wisconsin Department of Natural Resources. (2008). Complete 2008 Impaired Waters List [data file]. Retrieved from http://dnr.wi.gov/org/water/wm/wqs/303d/2008/2008methodology.htm

Wisconsin Department of Natural Resources. (2009). *Wisconsin's priority watershed and priority lake program*. Retrieved from http://dnr.wi.gov/runoff/watershed.htm

Wolf, A. (1995). Rural nonpoint source pollution control in Wisconsin: the limits of a voluntary program. *Water Resources Bulletin 31*:1009–1022.

Wu, Z., Satter, L.D., Blohowiak, A.J., Stauffacher, R.H., & Wilson, J.H. (2001). Milk Production, Estimated Phosphorus Excretion, and Bone Characteristics of Dairy Cows Fed Different Amounts of Phosphorus for Two or Three Years [electronic version]. American Dairy Science Association, 84.

Chapter 2

Cox, T. (2008). University of Wisconsin-Madison, Extension. Personal Communication.

Good, L.W. (2009). University of Wisconsin-Madison, Department of Soil Science. Personal Communication.

Lemunyon, J.L. & R.G. Gilbert. 1993. The concept and need for a phosphorus assessment tool. J. Prod. Agric. 6: 483-496.

Natural Resources Conservation Service, Wisconsin (NRCS-WI). 2005. Nutrient Management Code 590 NRCS Conservation Practice Standard. NRCS, Madison, WI.

Sharpley, A.N., J.L. Weld, D.B. Beegle, P.J.A. Kleinman, W.J. Gburek, P.A. Moore, Jr., and G. Mullins. 2003. Development of phosphorus indices for nutrient management planning strategies in the United States. Journal of Soil and Water Conservation 58(3): 137-152.

University of Wisconsin-Madison, College of Agricultural and Life Sciences, (2005). The Wisconsin buffer initiative: a report to the Natural Resources Board of the Wisconsin Department of Natural Resources. Madison, WI.

Chapter 3

Songer, K.S. (2009). A screening tool for identifying areas of high phosphorus loss in agricultural watersheds. M.S. thesis. University of Wisconsin. Madison, Wisconsin.

Good, L.W. (2009). University of Wisconsin-Madison, Department of Soil Science. Personal Communication.

Chapter 4

Frame, D.R. (2009). University of Wisconsin-Madison, Department of Soil Science. Personal Communication.

Chapter 5

Diebel, M. D., Maxted, J.T., Nowak, P. J., & Vander Zanden, J. M. (2008). Landscape Planning for Agricultural Nonpoint Source Pollution Reduction I: A Geographical Allocation Framework. Environmental Management, 42, 789-802.

Good, L.W. (2008, 2009). University of Wisconsin-Madison, Department of Soil Science. Personal Communication.

Hewitt, L. (2007). Wisconsin Trout Unlimited. Personal Communication.

Hilsenhoff, W.L. (1988). Rapid Field Assessment of Organic Pollution with a Family-Level Biotic Index. Journal of the North American Benthological Society. 7(1):65-68.

Lyons, J. (1992). The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management, 12, 198-203.

Marshall, D.W., Fayram, A.H. & Panuska, J.C. (2008). Positive Effects of Agricultural Land Use Changes on Coldwater Fish Communities in Southwest Wisconsin Streams. North American Journal of Fisheries Management, 28, 944-953.

Miller, M. (2009). Wisconsin Department of Natural Resources. Personal Communication.

Songer, K. (2008, 2009). University of Wisconsin-Madison, Nelson Institute for Environmental Studies. Personal communication.

University of Wisconsin-Madison, College of Agricultural and Life Sciences, (2005). The Wisconsin buffer initiative: a report to the Natural Resources Board of the Wisconsin Department of Natural Resources. Madison, WI.

U.S. Environmental Protection Agency, Office of Research and Development. (2006). Report on the Regional Environmental Monitoring and Assessment Program Study of Wadeable Streams in the Driftless Area Ecoregion in Western Wisconsin. Wisconsin: Miller, M.A., Colby, A.C.C. & Kanehl, P.

U.S. Geological Survey. (1998). Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program in U.S. Geological Survey Water-Resources Investigations Report (98, 4052, 67 p) Madison, WI: .Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A. & Gurtz, M.E.

U.S. Geological Survey. (2006a). Geomorphic characteristics and classification of Duluth-area streams, Minnesota in US Geological Survey Scientific Investigations Report 2006 (5029). Minnesota: Fitzpatrick, F.A., Peppler, M.C., DePhilip, M.M. & Long, K.E.

U.S. Geological Survey. (2006b). Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin (Professional Paper 1722). Wisconsin: Robertson, D.M., Gracyk, D.J., Garrison, P.J., Wang, L., LaLiberte, G. & Bannerman, R.

Vetrano, D. (2009). Wisconsin Department of Natural Resources. Personal Communication.

Wisconsin Department of Natural Resources. (2005). TMDLs for Sediment Impaired Streams in the Sugar- Pecatonica River Basin. Retrieved from http://www.dnr.state.wi.us/org/water/wm/wqs/303d/ApprovedTMDLs/Sugar_Pec_TMDL.pdf

Wisconsin Department of Natural Resources. (2008). Complete 2008 Impaired Waters List [data file]. Retrieved from http://dnr.wi.gov/org/water/wm/wqs/303d/2008/2008methodology.htm

Wolman, M.G. (1954). A method of sampling coarse riverbed material: Transactions of the American Geophysical Union, 35, 6, 951–956.

Chapter 6

Karr, J. R. & Dudley, D.R. (1981). Ecological perspective on water quality. Environmental Management, 5, 55 – 68.

U.S. Environmental Protection Agency, Office of Research and Development. (2006). Report on the Regional Environmental Monitoring and Assessment Program Study of Wadeable Streams in the Driftless Area Ecoregion in Western Wisconsin. Wisconsin: Miller, M.A., Colby, A.C.C. & Kanehl, P.

Appendix I

Recommendations and Scenarios

Abbreviations:
Cg = Corn Grain
Cs = Corn Silage
Sb = Soybeans

The following section lists the results for the best scenarios for the nine fields we focused on. The best scenario was not always the option that gave the lowest PI value. The best scenario is an opinion that reflects balancing lowering the PI value with suggestions that seemed practical given the particular circumstance and likelihood of implementation. Please note: These scenarios are listed in no particular order and the fields are pooled from multiple farms. Respecting the privacy of landowners in the watershed is one of our highest priorities, which is the reason for anonymity.

Recommendations

Field 1

Field Acreage: 4.3
Field Slope (%): 16
Soil Type: EDMUND
Next to Water: No

Manure: No
Crop Rotation: Cg-Sb-Cg-Sb
P-Index: 26 ppm
PI Value: 21.1

Recommendation(s):
1. CRP

Modification	**Estimated New PI**
CRP	0.5

Reason(s) for Recommendation:
• Small plot, on a very steep slope with poor, shallow soil. Crop yields are probably not very high for the amount of time and money put into farming the land.

Field 2

Field Acreage: 16.9
Field Slope (%): 9
Soil Type: PORT BYRON
Next to Water: Yes

Manure: Yes
Crop Rotation: Cs-Cs-Cs-Cs
P-Index: 76 ppm
PI Value: 25.3

Recommendation(s):
1. Buffer Strip or replacing some Cs with a section of Cg by water.
2. Changing tillage type to either No Till or Strip Till.

Modification	Estimated New PI
No Till	8.7
Strip Till	12.5

Reason(s) for Recommendation:

- Cs leaves no residue and since the water is so close having some type of buffer region would help. This field has very productive soil and is flat so it will stay in production. However, if a buffer strip of Cg can be put in along the perimeter that will help reduce some runoff.
- The farm will need to evaluate the amount of Cs needed to feed cows and see if they are overproducing Cs.
- Also this field may be over fertilized because they are adding both manure and fertilizer. It is recommended that they switch to more specific fertilizers such as just N or K because there is too much P in soil, this may also save them money.
- By changing to tilling practices that are less disruptive to soil, such as no till or strip till, the PI value can be cut in half or more.

Field 3

Field Acreage: 16.1
Field Slope (%): 9
Soil Type: PORT BYRON
Next to Water: Yes

Manure: Yes
Crop Rotation: Cs-Cs-Cs-Cs
P-Index: 221 ppm
PI Value: 27.1

Recommendation(s):

1. Change tilling practices to either no till or strip till.
2. Change tilling practice and split field to grow Cg in section closest to water.

Modification	Estimated New PI
No Till	10.5
Strip Till	12.8

Reason(s) for Recommendation:

- Cs leaves no residue and since the water is so close having some type of buffer region would help. This field has very productive soil and is flat so it will stay in production. Changing tilling practices will disturb the soil less and reduce runoff.
- The farm will need to evaluate the amount of Cs needed to feed cows and see if they are overproducing Cs.
- Also this field may be over fertilized because they are adding both manure and fertilizer. It is recommended that they switch to more specific fertilizers that do not contain Phosphorus. This may also save them money.

Field 4

Field Acreage: 9.5
Field Slope (%): 9
Soil Type: PORT BYRON
Next to Water: Yes

Manure: Yes
Crop Rotation: Cs-Cs-Cs-Cs
P-Index: 129 ppm
PI Value: 24.1

Recommendation(s):
1. Change tilling practices to either no till or strip till.
2. Change tilling practice and/or switch to Cg, plant Cs in another location.

Modification	Estimated New PI
No Till	7.1
Strip Till	8.8
Corn grain only	11.6
Strip Till and Corn grain	3

Reason(s) for Recommendation:
- As stated in previous field examples, Cs leaves no residue and this can be particularly detrimental by a water source. In order to switch to Cg, the amount of Cs need for to feed the cows has to be evaluated. However, it might be easier to change tillage practices, which will at least cut the PI value in half.

Field 5

Field Acreage: 3.2
Field Slope (%): 9
Soil Type: ASHDALE
Next to Water: Yes

Manure: No
Crop Rotation: Cg-Sb-Cg-Sb
P-Index: 72 ppm
PI Value: 8.2

Recommendation(s):
1. Change tilling practices to either no till or strip till.

Modification	Estimated New PI
No Till	2.3
Strip Till	3.3

Reason(s) for Recommendation:
- Option is easiest to implement and leads to no changes in crops. A better option would be to remove the Sb because the years right after Sb crop have the highest PI values.

Field 6

Field Acreage: 11.7
Field Slope (%): 9
Soil Type: PORT BYRON
Next to Water: Yes

Manure: Yes
Crop Rotation: Cs-Cs-Cs-Cs
P-Index: 181 ppm
PI Value: 21.1

Recommendation(s):
1. Change tilling practices to either no till or strip till.
2. Change tilling practice and split field to grow Cg in section closest to water.

Modification	Estimated New PI
No Till	8.2
Strip Till	10.2
Corn grain and No Till	2

Reason(s) for Recommendation:

- Cs leaves no residue and since the water is so close having some type of buffer region would help. This field has very productive soil and is flat so it will stay in production. Changing tilling practices will disturb the soil less and reduce runoff.
- The farm will need to evaluate the amount of Cs needed to feed cows and see if they are overproducing Cs.
- Also this field may be over fertilized because they are adding both manure and fertilizer. It is recommended that they switch to more specific fertilizers that do not contain Phosphorus. This may also save them money.

Field 7

Field Acreage: 4.7
Field Slope (%): 9
Soil Type: ASHDALE
Next to Water: Yes

Manure: No
Crop Rotation: Cg-Cg-Sb-Cg-Cg
P-Index: 75 ppm
PI Value: 7.4

Recommendation(s):

1. Remove Sb year replace with Cg.
2. Remove Sb year and change tillage practice.

Modification	Estimated New PI
Replace Sb year with wheat	4.1
Replace Sb year with Cg	4.8
Replace Sb year with Cg and No Till	0.6
Replace Sb year with Cg and Strip Till	1.1

Reason(s) for Recommendation:

- Year after Sb has highest PI value. Sb crops do not leave a lot of residue, which make field more susceptible to runoff. Changing to strip tilling will disturb soil less.

Field 8

Field Acreage: 19.3
Field Slope (%): 16
Soil Type: EDMOND
Next to Water: No

Manure: No
Crop Rotation: Sb-Cg-Sb-Cg
P-Index: 29 ppm
PI Value: 13.5

Recommendation(s):

1. Change tillage practice.
2. Implement contour strips.

Modification	Estimated New PI
No Till	3.7
Strip Till	5.4
No Till and Contour	2.8
Strip Till and Contour	3.5
Contour only	9.2

Reason(s) for Recommendation:

• The field is steep so contour stripping will help control runoff. Also as mentioned above no till and strip till are less disruptive to the soil. Contouring will save fuel from up and down farming on steep slopes.

Field 9

Field Acreage: 13.8	Manure: No
Field Slope (%): 16	Crop Rotation: Cg-Sb-Cg-Sb
Soil Type: EDMOND	P-Index: 29 ppm
Next to Water: Close but not next to	PI Value: 11.8

Recommendation(s):

1. Change tillage practice.
2. Implement contour strip

Modification	Estimated New PI
No Till	3.3
Strip Till	9.7
No Till and Contour	2.4
Strip Till and Contour	6.5
Contour only	8.6

Reason(s) for Recommendation:

•The field is steep so contour stripping will help control runoff. Also as mentioned above no till and strip till are less disruptive to the soil. Contouring will save fuel from up and down farming on steep slopes.

Field 10

Field Acreage: 3.9	Manure: Yes
Field Slope (%): 9	Crop Rotation: Cs-Cs-Cs-Cs
Soil Type: GALE	P-Index: 282 ppm
Next to Water: Yes	PI Value: 35.7

Recommendation(s):

1. Change crop and tillage practice.

Modification	Estimated New PI
Plant Cg	11.1
Plant Cg and No Till	2.7
No Till	13.1
Strip Till	16.4

Reason(s) for Recommendation:
• This field is small and close to the water. Because of the extremely high PI value it is recommended that multiple changes be made since only changing the tillage practice still produces very high PI values.

Field 11

Field Acreage: 5.7	Manure: Yes
Field Slope (%): 9	Crop Rotation: Cs-Cs-Cs
Soil Type: ELEVA	P-Index: 39 ppm
Next to water: Yes	PI value: 19.8

Recommendation(s):
1. Change crop and tillage practice.

Modification	Estimated New PI
Plant Corn	9.7
Plant Corn and No Till	2.3
No Till	5.8
Strip Till	7.2

Reason(s) for Recommendation:
•As stated in previous field examples, Cs leaves no residue and this can be particularly detrimental by a water source. In order to switch to Cg, the amount of Cs need for to feed the cows has to be evaluated. However, it might be easier to change tillage practices.

Appendix II

Water Quality Samples

The USGS monitors Pleasant Valley Creek by recording continuous discharge and precipitation measurements and by taking automatic water samples during high flow events including rainstorms and snowmelt. They analyze water samples for total phosphorus (TP) and suspended sediment (SS) concentration. Base flow samples are also collected biweekly and undergo analysis for several additional constituents, including dissolved phosphorus (DP). The USGS record for this gage house began in October 2006 and will to continue after the conclusion of this report.

In addition to water samples from the gage house, we collected manual water samples at nine bridge-crossings in the watershed. This short-term water sampling provided us with TP, DP, and SS levels distributed across the watershed during three events in 2008: a snowmelt event on March 13th, summer base flow on July 4th, and a summer rain event on July 11th (Appendix II a through f). We took samples at each site with a hand-held DH-59 depth-integrating sampler according to the equal-width-increment method (USGS, 1999). To analyze for dissolved phosphorus we filtered samples in the field through 0.45-µm membrane filters. All chemical analyses of water samples were done by the Wisconsin State Laboratory of Hygiene in accordance with standard analytical procedures described in the "Manual of Analytical Methods, Inorganic Chemistry Unit" (Wisconsin State

Laboratory of Hygiene, 1993).

Findings from our water samples lack certainty due to the small sample size: we only took two to three manual samples at each of the nine sites. This type of sample cannot represent variations in P concentration during one rain event, across several events, or across seasons unless we obtain a large replication of samples. The USGS obtains much larger sample sizes by using the gage house to take several samples during most high water events (i.e. rainstorms and snowmelt) and takes samples regularly during periods of low flow.

Comparison of water quality in Pleasant Valley to regional conditions

Though the relationship between P concentrations and overall stream quality is difficult to understand due to many confounding environmental factors, we were able to make associations by comparing Pleasant Valley with least disturbed "reference streams" in the Driftless Area. In 2006, a regional study defined P thresholds for summer base flow in the Driftless Area, one of the EPA's level III nutrient ecoregions (USEPA, 2006) (Table 5). The threshold for TP (0.070 mg/L) is based on the upper 75th percentile of median concentrations of least disturbed sites in the Driftless Area ecoregion. This means that 75 percent of the minimally impacted sites in the Driftless Area have base flow TP values equal to or less than this reference condition (USGS, 2006b). The TP threshold for the Driftless Area is higher than the threshold for the rest of southern Wisconsin (0.033 mg/L) presumably because of its steep gradient and intense agriculture, including cropping and cattle pasturing in valley bottoms close to streams. According to these criteria, the streams in Pleasant Valley watershed exceed the TP threshold and are moderately impacted by agricultural runoff.

Data from the USGS gage house at the outlet of Pleasant Valley Branch show that the watershed has elevated levels of TP, DP, and SS when compared to reference conditions. According to base flow data taken at the gage house in the summers of 2007 and 2008, the median TP (0.13 mg/L) and DP concentrations (0.04 mg/L) for the watershed equaled or exceeded the reference criteria for the Driftless Area.

The majority of agricultural runoff happens during extreme runoff events. Corresponding to this, P and SS concentrations increased dramatically during extreme runoff events. The maximum TP (6.49 mg/L) and SS levels (4110

Water Chemistry and Quality Measure	Reference Condition Threshold	Impairment Criteria	Pleasant Valley Bridge Crossings	USGS Gage at outlet
Oxygen Saturation (%)	73.3	< 73.3	100.5	
Dissolved Oxygen (mg/L)	7.6	< 7.6	10.3	
Water Transparency (cm)	122	< 122	101.5	
Total P (mg/L)	0.07	> 0.07	0.11	0.13
Total Dissolved P (mg/L)	0.04	> 0.04	0.05	0.04
Suspended Sediment (mg/L)			42	35

Table 5. *Water chemistry summary for six variables taken during summer base flow conditions. Median data are compared to reference criteria developed for the Driftless Area by USEPA (2006). Samples were collected at nine bridge crossings in Pleasant Valley on July, 4th 2008 and at the USGS gaging station at the outlet of Pleasant Valley between June and September, 2007 and from June to September, 2008.*

mg/L) in the Pleasant Valley gage house data set occurred during the rising limb of a 5.7-inch rain event on August 5, 2007. Another extreme event on June 8, 2008 measured similar maximum concentrations of TP (6.28 mg/L) and SS (4480 mg/L). These storms greatly increased the annual P and SS load in only a few days.

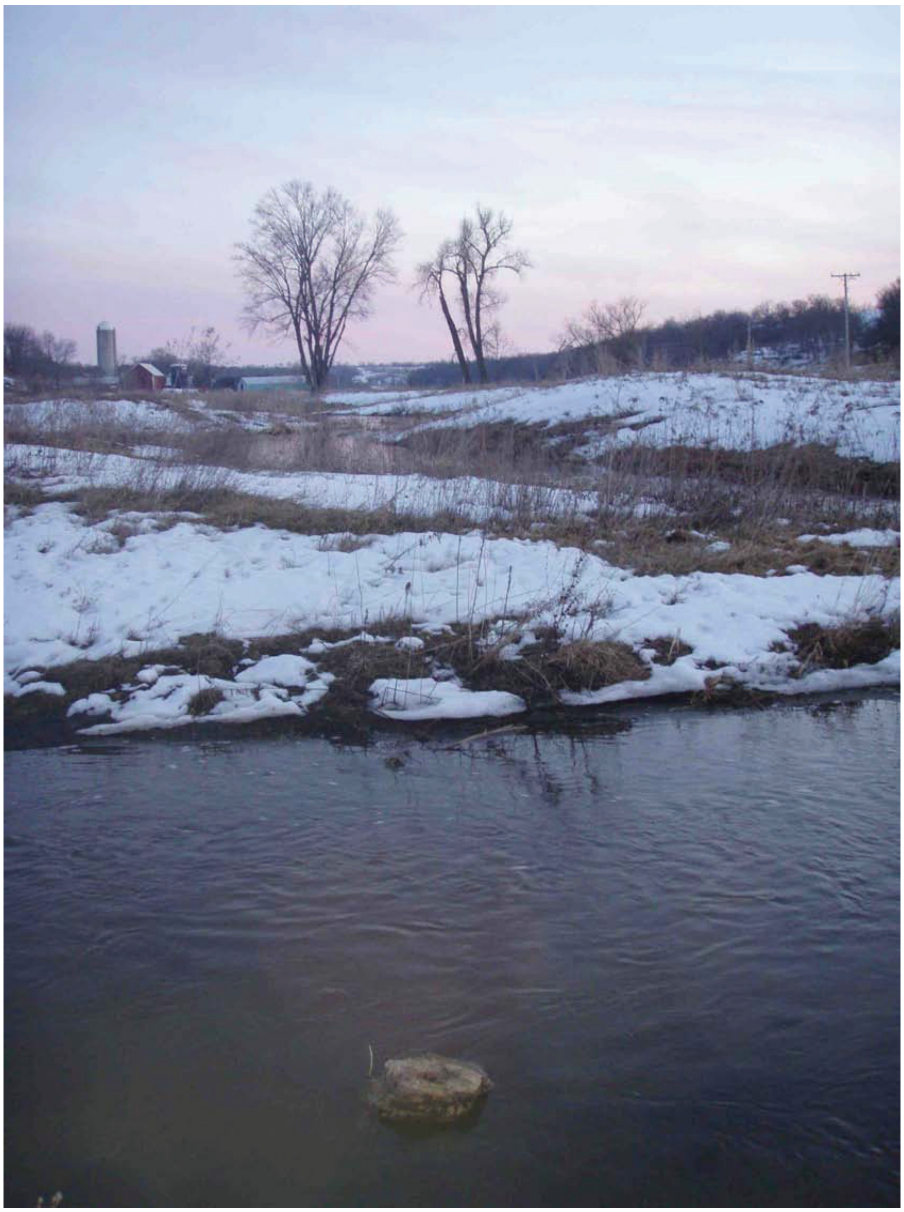

Figure A. *Stream conditions in Pleasant Valley while taking water samples during the March 13, 2008 snowmelt event.*

Figure B. *Stream conditions in Pleasant Valley while taking water samples during the July 4, 2008 base flow event. Note the same stick in lower right corner as in Figure C .*

Figure C . *Stream conditions in Pleasant Valley while taking water samples during the July 11, 2008 storm runoff event. Note the same stick in lower right corner as in Figure A.*

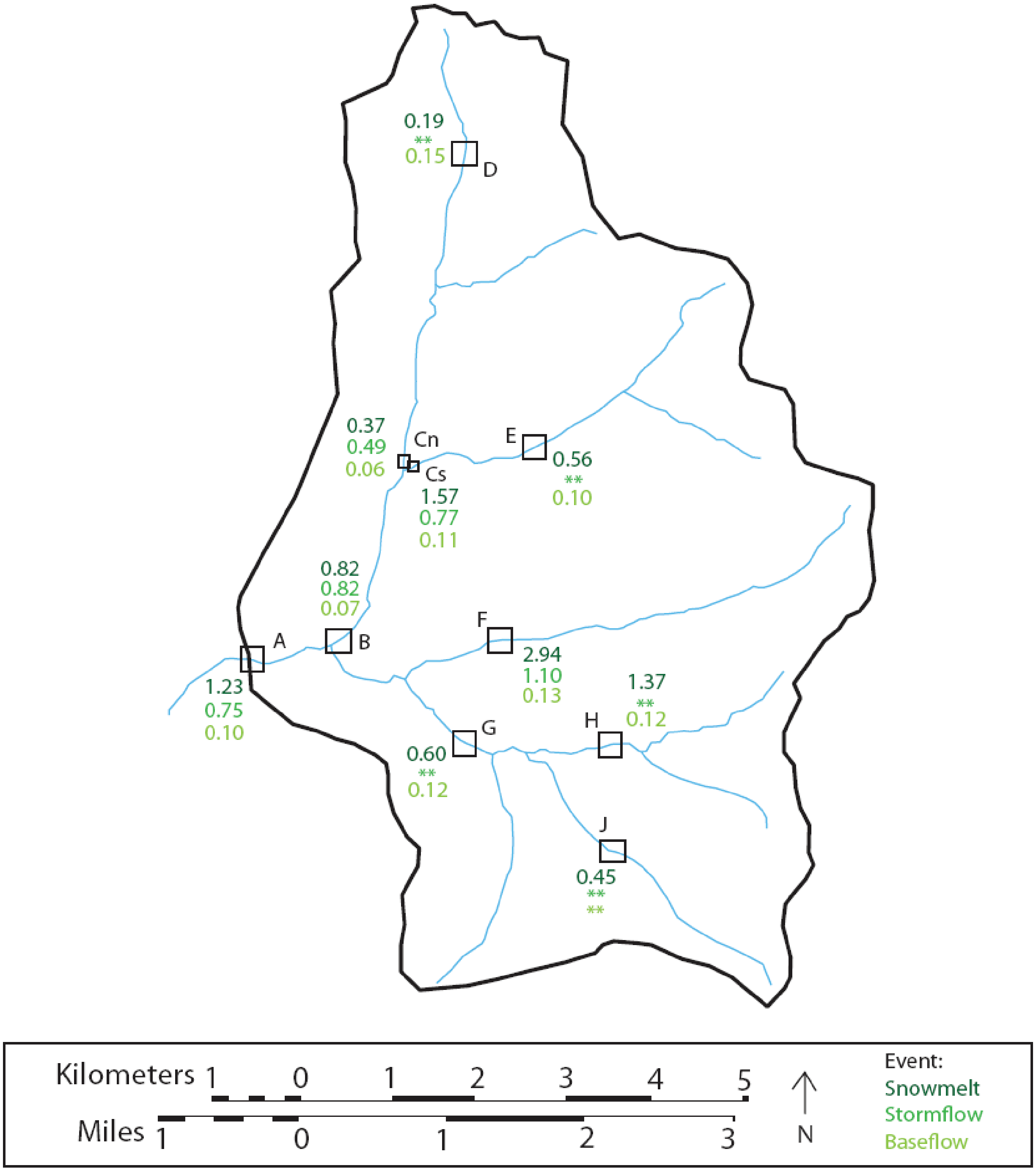

Figure D. *Total Phosphorus (TP) and water sample locations for each sampling event in the Pleasant Valley watershed. Average TP for the snowmelt samples was 0.82 mg/L, 0.79 mg/L for the storm event, and 0.11 mg/L for the base ow samples. Streams in southwest Wisconsin are considered impaired when they have a base ow TP concentration >0.07 mg/L.*

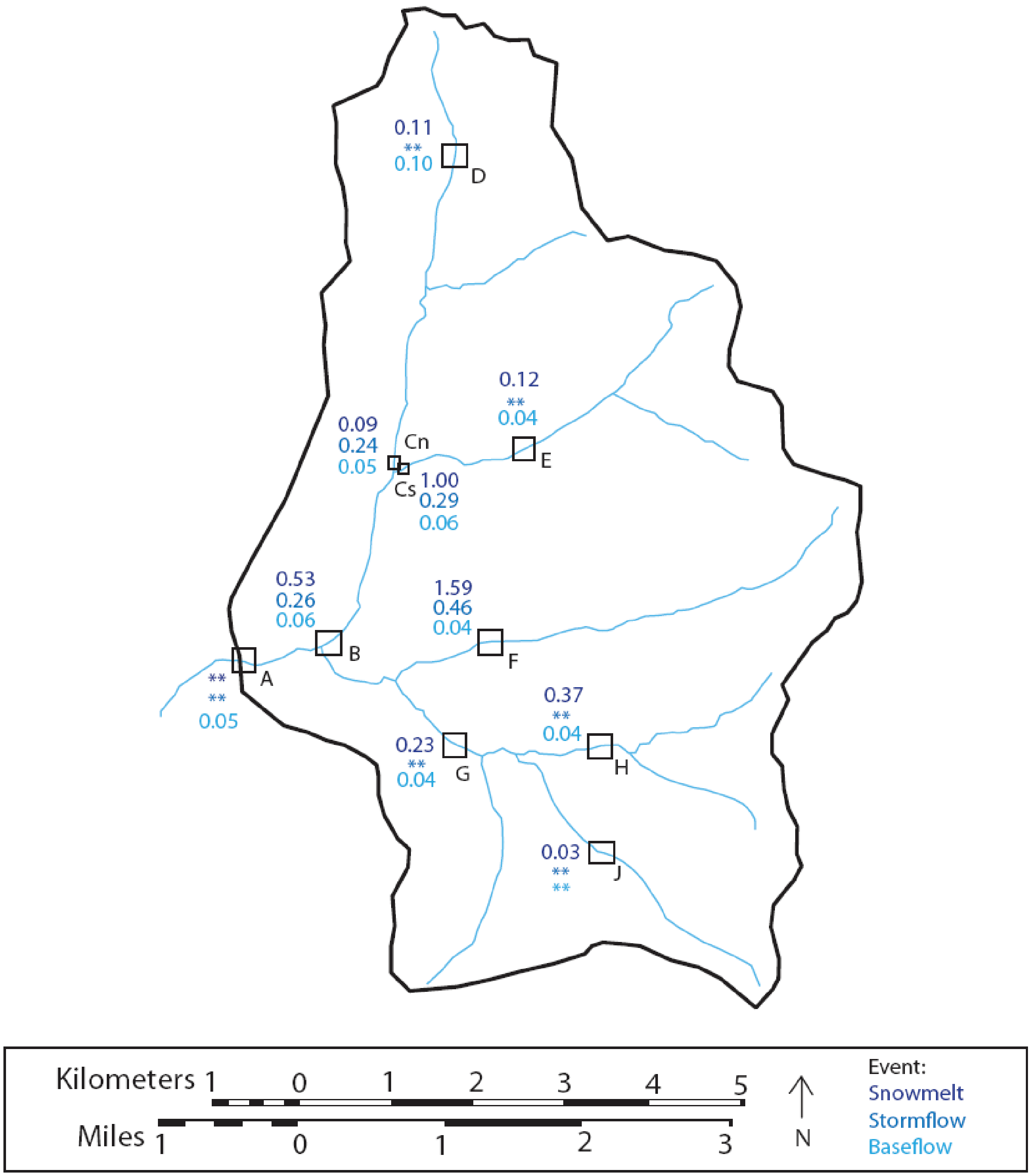

Figure E. *Dissolved phosphorus (DP) and water samples locations for each sampling event in the Pleasant Valley watershed. Average DP for the snowmelt samples was 0.30 mg/L, 0.27 mg/L for the storm event, and 0.05 mg/L for the base ow samples. Streams in southwest Wisconsin are considered impaired when they have a base ow DP concentration >0.04 mg/L.*

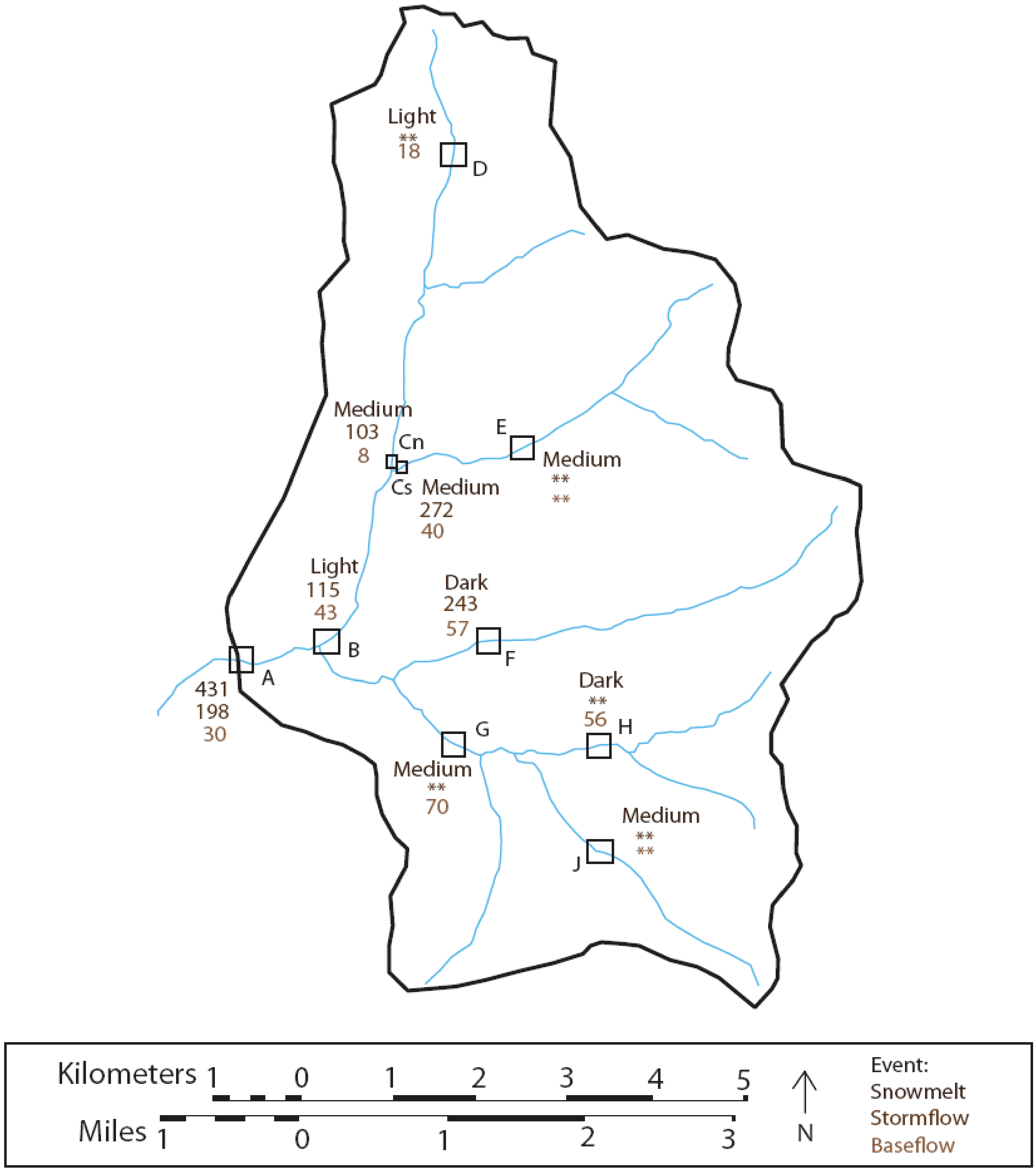

Figure F. *Suspended Sediment (mg/L) and qualitative sediment observations for each sampling event in the Pleasant Valley watershed.*

References

U.S. Environmental Protection Agency, Office of Research and Development. (2006). Report on the Regional Environmental Monitoring and Assessment Program Study of Wadeable Streams in the Driftless Area Ecoregion in Western Wisconsin. Wisconsin: Miller, M.A., Colby, A.C.C. & Kanehl, P.

U.S. Geological Survey. (1999) Field methods for measurement of fluvial sediment in U.S. Geological Survey Techniques of Water-Resources Investigations (3, C2, 89p) Washington, D.C.: Edwards, T.K. & Glysson, G.D.

U.S. Geological Survey. (2006b). Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin (Professional Paper 1722). Wisconsin: Robertson, D.M., Gracyk, D.J., Garrison, P.J., Wang, L., LaLiberte, G. & Bannerman, R.

Wisconsin State Laboratory of Hygiene, Environmental Sciences Section, 1993, Manual of analytical methods, inorganic chemistry unit: Wisconsin State Laboratory of Hygiene, variously paginated.

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