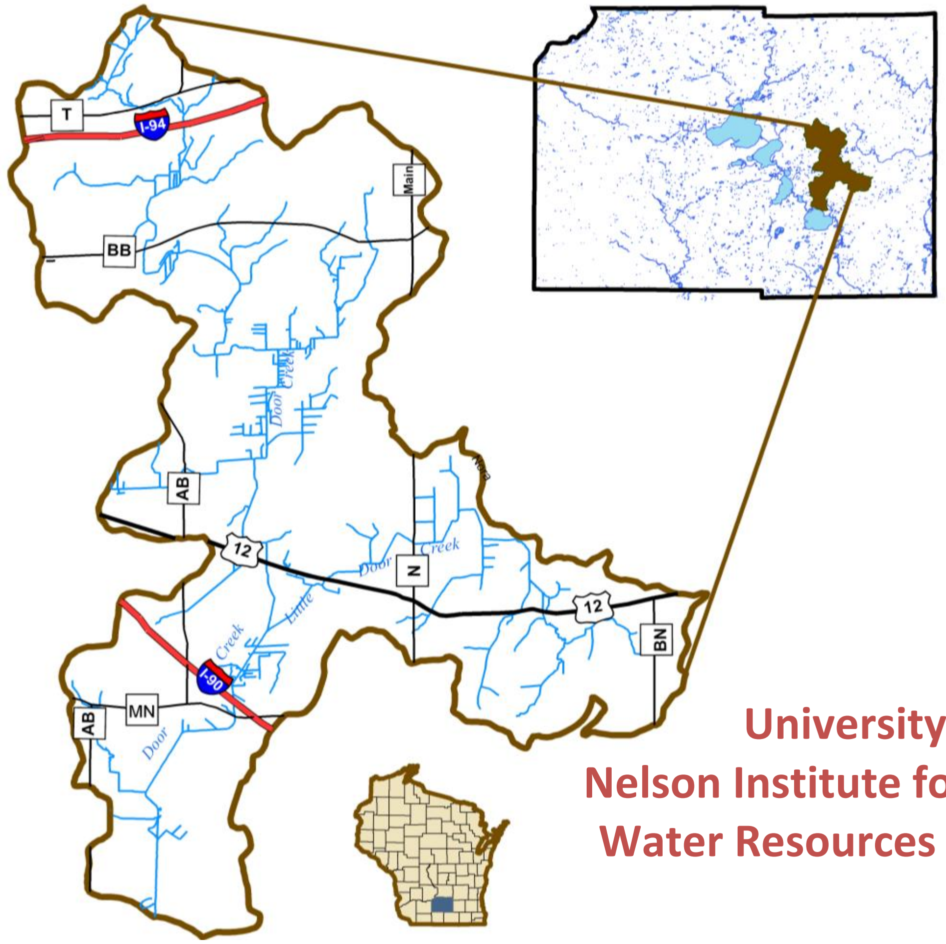
# Door Creek Watershed Assessment:

## A Sub-Watershed Approach to
## Nutrient Management for the Yahara Lakes



University of Wisconsin – Madison
Nelson Institute for Environmental Studies
Water Resources Management Workshop
2009



# Door Creek Watershed Assessment:

## A Sub-Watershed Approach to Nutrient Management for the Yahara Lakes

**University of Wisconsin – Madison**
**Nelson Institute for Environmental Studies**
**Water Resources Management Workshop**
**2009**

The Water Resource 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.

The conclusions and recommendations are those of the graduate authors and do not necessarily reflect the official views or policies of any of the cooperating agencies or organizations, nor does the mention of any trade names, commercial products, or companies constitute endorsement or recommendation for use.

*For more information contact:*

Nelson Institute for Environmental Studies
Community and Alumni Relations Office
40 Science Hall
550 North Park Street
Madison, WI 53706
608/265-2563
www.nelson.wisc.edu

# TABLE OF CONTENTS:

# TABLE OF FIGURES:

# LIST OF TABLES:

**Common Abbreviations:**

CARPC – Capital Area Regional Planning Commission
CWA – Clean Water Act
DATCP - Department of Agriculture, Trade and Consumer Protection
DCRPC- Dane County Regional Planning Commission
DO – Dissolved Oxygen
FOLKS – Friends of Lake Kegonsa Society
MMSD - Madison Metropolitan Sewerage District
MOU - Memorandum of Understanding
NRCS – Natural Resource Conservation Service
SPAL - University of Wisconsin Soil and Plant Analysis Lab
TDP – Total Dissolved Phosphorous
TKN – Total Kjendahl nitrogen
TMDL - Total Maximum Daily Load
TP – Total Phosphorous
TSS – Total Suspended Solids
USGS - United States Geological Survey
USDA – United States Department of Agriculture
WDNR – Wisconsin Department of Natural Resources
WGNHS – Wisconsin Geological and Natural History Survey

# PERSONAL ITEMS FROM MCFARLAND:

## BY MRS. DOROTHY HELMKE
## FEBRUARY 21, 1974

I had that special feeling long ago when I was in grade school. I thought I had seen the most beautiful spot in the world on a Sunday afternoon when a group of us decided to visit a neighbor.

We walked along a quiet country road, crossed a railroad track, and when we arrived, our neighbor said, "How would all of you like to go for a ride? I want very much to show you my beautiful woods."

He hitched his horses to the wagon and as we drove along he called our attention to a 'sink hole' and told about the work the railroad company had trying to build the tracks across it.

"We are now following a trail once much used by Indians", he said, as we entered the woods. In the woods we were spellbound looking at those strong, healthy trees with their leaves turning brown, gold and yellow, the sumacs with beautiful reddish colors, wild grapes hanging from trees adding touches of purple and the birds singing all around us.

We came to an open space and our neighbor said as he gave us a drink of cold spring water from a tin cup hanging by a piped spring, "This open space is where the Indians camped, putting up tepees and living here while they hunted and fished in Door Creek and Lake Kegonsa. The women made baskets."

Indians still came to this territory in the early 1900s, even after they had been placed on reservations or gone west. They liked to do their hunting and fishing there.

For a long time that beautiful picture of the woods has remained in my memory.

# PREFACE:

The Water Resources Management (WRM) Master's degree program in the Gaylord Nelson Institute of Environmental Studies at the University of Wisconsin – Madison is an interdisciplinary program designed to prepare students for employment as water resource management professionals. Since the 1970s the cornerstone of the WRM program has been a seminar focusing on current issues in Wisconsin water resource management. This seminar has developed into a year-long applied learning opportunity known as the WRM Practicum that is the central requirement of the program's Master of Science Degree.

The purpose of the 2009 WRM Practicum is to support the mission of the Yahara Capital Lakes Environmental Assessment and Needs (CLEAN) via an in-depth study of the Door Creek watershed. This study uses Door Creek as a model sub-watershed within the Yahara Lakes watershed for addressing concerns of nutrient loading to the Creek and for making management recommendations based on the findings of the study. The 2009 Practicum is funded by a Lake Planning Grant from the Wisconsin Department of Natural Resources through the Dane County Office of Lakes and Watersheds. This project was completed and printed August 2010

Participants in the 2009 WRM Practicum

❖

Andrew Aslesen
Amanda Boyce
James Hook
Janice Hwang
Cheng Ji
Katharine Lund
Kristin McConnell
Andrea McMillen
Kyle Magyera
Kimberly Meyer
Kyle Minks
Erin Oost
Marit Sallstrom
Zachary Schuster
Carol Warden
Zachariah Zopp

❖

Faculty Advisor for the 2009 WRM Practicum

Professor Kenneth W. Potter, Nelson Institute, and the
Department of Civil and Environmental Engineering

# ACKNOWLEDGEMENTS:

This project was truly a collaborative effort among the Practicum members. However, it would not have been possible without the professional guidance, knowledge and feedback from a large number of individuals throughout the academic, professional and local community.

First, we would like to thank Dane County for their collaboration and funding for this project.

The following individuals provided us with information about and access to their property, Louis Breunig, Ted Breunig, John Endres, Paul Haag, Hank Hanzel, Otto Otteson, Tom Richgels, Brett Skaar, Larry Skaar, and T. Wesley Skaar

In addition, we would like to thank the following individuals and organizations who patiently answered our questions, provided valuable resources, and insight to many aspects of this project.

Nolan Anderson, UW Extension
Jeremy Balousek, Dane County LWRD
Tom Bernthal, WDNR
George Bowman, Wisconsin State Lab of Hygiene
Kris Byrne, Farm Service Agency
Mark Cain, WDNR
Kevin Connors, Dane County LWRD
Dea Larsen Converse, Editor
Phil Frederickson, Door Creek Golf Course
Laura Ward Good, UW-Madison
Laura Guyer, Dane County Parks
Pattie Haack, NRCS - Dane County
Josh Harder, Dane County LWRD
John S. Hausbeck, Public Health Madison and Dane County
Fred Hegeman, WDNR
Jim Hessling, Village of Cottage Grove
Andrew Homburg, Homburg Equipment
David Jelinski, Wisconsin DATCP
Sue Jones, Dane County LWRD
Michael Kakuska, CARPC
Kevin Kirsch, WDNR
Robert Liska, WDNR
Darren Marsh, Dane County Parks
Seth McClure, Wisconsin DATCP
Tom McFarlane, McFarlanes Implement
Mike Northouse, MMSD
Pat O'Brien, Dane County Farm Bureau
Steve Ottelien, Dane County LWRD
Cami Peterson, WDNR
Sue Porter, Wisconsin DATCP
Jim Post, MMSD
Michelle Richardon, Dane County LWRD
Nicole Richmond, WDNR
Dale Robertson, USGS
Doris Rusch, Dane County LWRD
Pat Sutter, Dane County Conservationist
Dave Taylor, MMSD
Patricia Trochlell, WDNR
Steve Ventura, UW Madison
Duane Wagner, Dane County LWRD
Kurt Welke, WDNR
Dr. Dick Wolkowski, UW-Extension
Joy Zeigler, UW-Madison
Friends of Lake Kegonsa
Town of Dunn Historical Society

# EXECUTIVE SUMMARY:

## DOOR CREEK AND WATERSHED

The Door Creek watershed drains a 29.5 square mile area located in the Yahara River watershed of the greater Lower Rock River watershed in South Central Wisconsin. It is the main tributary stream of Lake Kegonsa, the southernmost lake of five that are collectively known as the Yahara Lakes system. Door Creek was selected as an ideal study area due to its history of extensive man-made ditching, predominantly agricultural land-use, increasing urbanization, and because it contains a large area of county-owned wetlands.

The Yahara CLEAN Memorandum of Understanding (MOU) funded the nutrient assessment research. Through them, we were able to conduct a study of water quality in Door Creek, recognize and address potential sources of nutrient loading, and identify management techniques and wetland conservation opportunities that could potentially be applied to the larger Yahara Lakes chain. This sub-watershed approach was designed to be a template for future water resource management activities in this region. It provides a means of collecting measureable results within a short timeframe by focusing on the main watershed that contributes to Lake Kegonsa, instead of the water quality of the lake as a whole. By improving water quality where the flow to the lake originates, it is possible to drastically improve the condition of the entire lake ecosystem.

## CURRENT WATER QUALITY CONDITIONS

To determine the effect that Door Creek has on Lake Kegonsa, we conducted water quality testing on present stream conditions. The primary objective was to look for potential sources of nitrogen and phosphorous loading to the stream. Sampling was conducted to represent three distinct streamflow conditions,, including baseflow; a 1 year, 24 hour rainfall event; and a 25 year, 24 hour rainfall event.

Sampling results indicate that total nitrogen concentrations are highest during baseflow and that groundwater is the likely contributing source. Total phosphorous concentrations, however, were highest during the large storm event. This demonstrates that elevated amounts of surface runoff can significantly influence the amount of phosphorous present in Door Creek. As a whole, more research is needed to determine if agricultural activities are impacting the overall water quality of the stream because phosphorous loading did not occur when soil moisture was low and the storm event was small.

## ASSESSMENT OF NUTRIENT SOURCES

In order to address potential sources of nutrient loading, it was important to see which land-use practices in the Door Creek watershed may have the greatest impact on overall water quality. Our evaluation focused on agricultural practices, the Madison Metropolitan Sewerage District (MMSD) Metrogro Program, and urban runoff, including construction sites.

The Snap-Plus nutrient management model, which was developed at the University of Wisconsin-Madison, was used to identify farming practices and field conditions that could potentially contribute high phosphorous loads to Door Creek. The Snap-plus model indicated that the areas most likely to contribute high phosphorous loads are fields with slopes greater than 6% and high soil phosphorous levels. We recommend that conservation practices, such as no-till farming, be used on these areas of concern and that alternative, non-row crops be incorporated into crop rotations.

With respect to MMSD Metrogro, a liquid biosolid application that contains high levels of nutrients such as phosphorous and nitrogen and is applied on approximately 1300 acres (2.03 square miles) of agricultural land within the Door Creek watershed, it was determined that repeated applications can cause an undesirable accumulation of soil phosphorous. Snap-Plus modeling results indicate that out of the 50 fields that received Metrogro, only 8% had a phosphorous index value greater than 6.0, which is the maximum allowable level by NRCS. These 8% were consistently found to be fields with soil slopes between 6 to 12%. Based on the model, Metrogro is not likely to be a major contributing source of nutrient pollution to Door Creek. However, NR 204, which governs nutrient applications, lacks several key provisions that could minimize the risk of over-application, and prevent Metrogro application from becoming a water quality issue in the future.

Finally, urban areas and construction sites were analyzed for their potential to provide nutrient loading to the stream. This was an important component of our analysis because several municipalities within the Door Creek Watershed are experiencing rapid rates of growth and development. After reviewing the maximum allowable soil loss from construction sites, we recommend that soil levels be tested for high phosphorous levels prior to construction and that allowable soil loss be decreased proportionately to prevent this sediment from entering surface waterbodies.

## MANAGEMENT OPPORTUNITIES

As mentioned earlier, the Door Creek watershed contains a large area of county-owned wetlands. Due to the known ability of wetlands to provide vital ecosystem services, such as removal and storage of both phosphorous and nitrogen, we conducted a study to determine whether this particular wetland system is improving the overall water quality of Door Creek and evaluated possible strategies for optimizing potential benefits.

To accomplish this, we took soil and water samples from the wetland, and conducted a scientific literature review and policy analysis. The results indicate that the Door Creek wetlands improve water quality by removing and storing phosphorous and nitrogen. In addition, wetland conservation is an important part of addressing water quality problems and should be pursued. We recommend using an Adaptive Restoration Framework for wetland conservation (explored in detail in Chapter 5). Finally, since Door Creek is no longer directly connected to the wetlands due to extensive ditching, the possibility of reestablishing hydrologic connectivity should be examined.

Additional laws and ordinances that impact natural resource management in the Door Creek watershed were also examined. During the review, we found that there are three potential changes to current water quality legislation, including alterations to the Rock River Watershed Total Maximum Daily Load (TMDL); NR 151, which governs runoff management; and Chapter 11, which governs county shoreland zoning. To address these concerns the following Key Recommendations are suggested for both regulators and producers.

## KEY RECOMMENDATIONS

### FOR PRODUCERS:

1. Perform regular soil tests on cropped fields
2. Apply nutrients according to crop needs
3. Avoid application of fertilizer or manure when soil is wet
4. If receiving biosolids, be aware of application rates and nutrient content

### FOR DANE COUNTY:

1. Protect existing wetlands
2. Restore wetlands
3. Have MMSD use up-to-date soil tests prior to application
4. Support techniques to reduce P loading, including
    i. No till farming (except on drain tiled fields)
    ii. Minimize farming on >12% slope
    iii. Incorporate some type of non-row crop on slopes greater than 6%
5. Monitor fertilizer applications post storm events
6. Focus on P control management post storm events
7. Test soil P levels prior to construction and reduce allowable soil loss accordingly
8. Promote improved consistency between NRCS 590 and NR 204

# CHAPTER 1:

# PROJECT INTRODUCTION

## 1.1 INTRODUCTION

The Yahara Lakes system includes one of the most studied lakes in the world, Lake Mendota, which has a water quality record dating back to 1894. Since the early 1900s, these lakes have been classified as highly eutrophic (Lathrop *et al*., 1992). Over the years, the water quality of the Yahara Chain of Lakes, Mendota, Monona, Waubesa and Kegonsa, has worsened, which is apparent in displays such as annual algal blooms which occasionally result in beach closings, unpleasant odors, and a decrease in the lake's aesthetic appeal due to the green color of the water. In 2007 Dane County, the Wisconsin Department of Natural Resources (WDNR), the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) and the City of Madison signed a Memorandum of Understanding (MOU) to initiate the "Yahara CLEAN" program. This program is a two-year project to assess current nutrient and sediment loading in the Yahara Lakes, in order to develop achievable goals to lower nutrient concentrations and to identify actions to meet those goals. In the spring of 2008, the Watershed Management Coordinator for the Dane County Lakes and Watershed Commission requested that the 2009 Water Resource Management (WRM) Practicum provide technical assistance to Yahara CLEAN.

**Figure 1.1: Algal bloom in Door Creek Wetlands.**

Photo: WRM practicum 2009

The Yahara Lakes are a landmark of great importance, not only to the surrounding community, but also for the whole region. They provide for a number of recreational activities, such as swimming, boating, skiing and fishing. The lakes and their associated streams and adjoining wetlands, are also characterized by important habitat for different types of wildlife. The Door Creek watershed, a tributary to Lake Kegonsa, was selected as a model sub-watershed in which to develop applications and management recommendations that could be extrapolated to the entire Yahara Lakes system. In order to further the goals and objectives of Yahara CLEAN, this study addressed the sources of nutrients that primarily affect water quality, notably phosphorous and nitrogen, through four different perspectives.

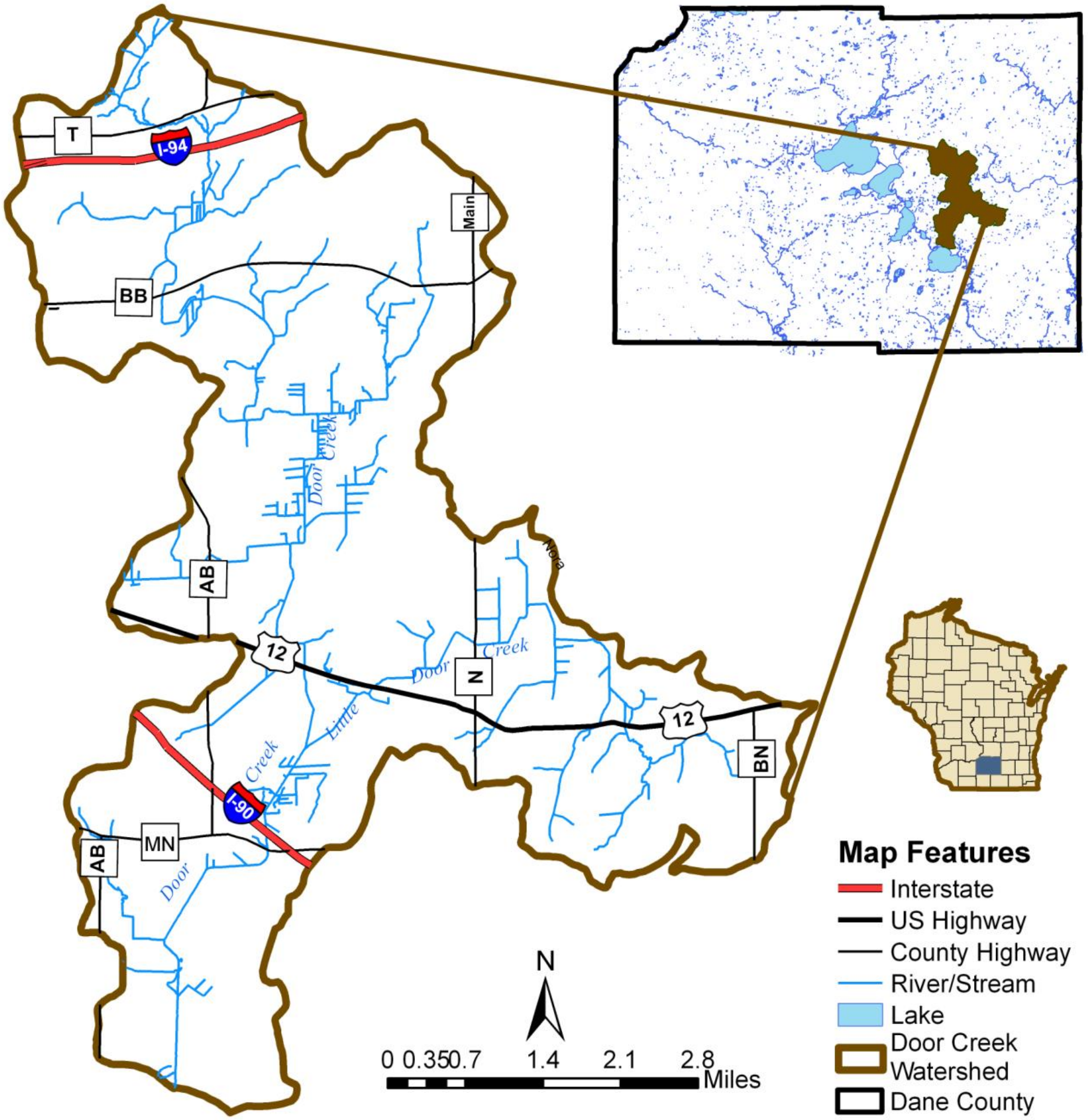


**Figure 1.2: Location of Door Creek Watershed within Dane County, Wisconsin.** Source: Dane County Streams Land Information Office; Streams Layer 2000, Road Centerlines 2007. Created on August 9, 2009 by 2009 WRM Practicum.

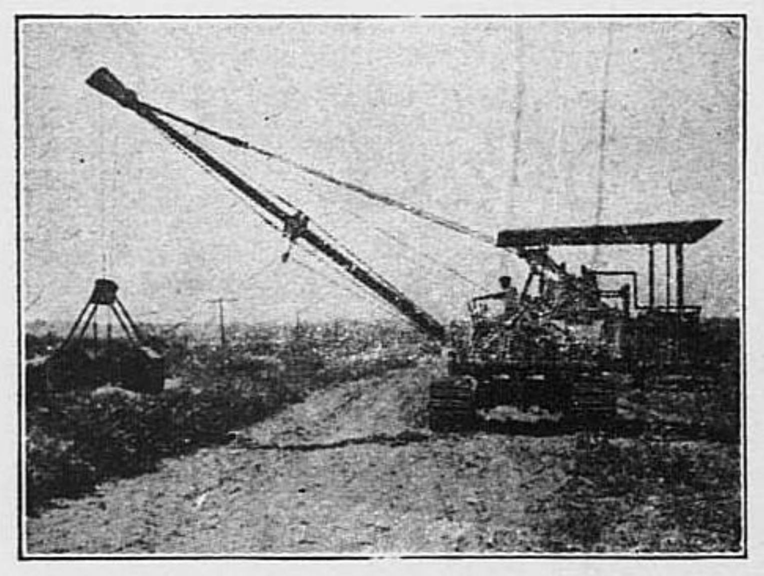
First, a water quality analysis of both historic and current data was needed to identify areas in the stream's channel where increased levels of nutrients are present. Second, was an assessment of agricultural land use with the nutrient management planning program, SNAP Plus, in order to identify practices that may be contributing to an unequal load of nutrients to Door Creek, as well as provide recommendations to improve areas of greatest concern. Third, an assessment of the wetlands investigated ways to maintain and promote the health of such ecosystems, through wetland protection and restoration. Fourth, review of the legal framework governing Door Creek on federal, state, and local levels helped to identify both the strengths and shortcomings to protecting, restoring and managing this complex system. Finally, recommendations were presented to promote improving water quality in the Door Creek Watershed as part of the actions to improve the entire Yahara Chain of Lakes.

## 1.2. Door Creek Setting and History

Door Creek is a tributary stream in south central Wisconsin that flows south to Lake Kegonsa, the most southern of the Yahara River Chain of Lakes. The watershed drains portions of five towns, two villages and a small segment of the city of Madison (Figure 1.2).

Door Creek was first recorded on a map in 1837, during the original survey of Wisconsin. The name "Door" is believed to refer to a narrow passage from which Little Door Creek, a tributary of Door Creek, originates. On a historic map from 1857 Door Creek is labeled as Skenda Creek, which is believed to be a Winnebago word meaning ‘the pure water’ (Cassidy, 1968).

The region’s unique landscape was formed approximately 15,000 years ago during the last glaciation period. This dramatically affected on the water resources and flow patterns of the region and formed the Yahara Chain of Lakes. The landscape was also flattened by glacial processes, resulting in gently sloped streams that are often adjoined by wetlands. The flattened slopes and altered hydrology of the post-glacial period resulted in a diverse combination of vegetation across the landscape, including prairies, oak forests, savannahs, and maple-basswood forests, as well as a variety of types of wetlands (WDNR, In Prep).



Handling One-half Yard Clamshell Bucket

**Figure 1.3: Example of Ditching Equipment used in Door Creek Watershed.**

Wisconsin Drainage Association, Seventh Annual Convention, Retrieved on February 23, 2009 from University of Wisconsin Images Library: http://images.library.wisc.edu/WI/EFacs/USAIN/RWSDA/reference/wi.rwsda04.i0005.pdf

This diverse set of habitats provided resources for the Native Americans who lived in the Door Creek watershed until the European settlement. As the initial European settlers arrived, agriculture began to flourish in the area. The increase in European settlers may have been a result in part due to the Swamplands Act of 1850. This act helped to promote the drainage movement by giving the land rights of wetlands to individual states that suffered from flooding (Figure 1.3). Wisconsin was able to sell wetland property to individuals at a low cost in an effort to encourage farming in the area. The money generated in the sale of the land was used to fund drainage and levee building and the new settlement benefited the state by increasing the tax base (USGS, 2009).

On March 10, 1913, a petition for the formation of the Door Creek Drainage District was filed at the Dane County Circuit Court. In 1915, the Wisconsin drainage districts and commissioners were designated. Construction began in 1920 under the engineering supervision of Philip H. Hintze, an independent civil and drainage engineer (Sherwood, et al., 1915). The wetlands were drained and Door Creek was ditched to provide adequate drainage (Carnes, 1914).
Though the landscape remains dominated by agriculture systems developed over the past 100 years, there is increased pressure towards urban development. As a consequence of both agricultural and urban development, more runoff has been produced causing higher loads of sediments and nutrients to enter the streams and lakes. This has resulted in a decline in water quality in the Yahara Lakes system. In addition, the functional values of the wetlands have been impaired due to channelization of the stream and wetland drainage.

Local and state governments, businesses, and citizens have voiced their concerns about the health of the lake system. Laws and ordinances on the local, state, and federal level are aimed towards protecting water resources through different land conservation programs and nutrient management options. These issues are also addressed though different non-profit organizations, for example, Friends of Lake Kegonsa Society (FOLKS), which is a volunteer organization of homeowners and businesses from the surrounding area. These groups, agencies, and businesses work towards protecting, maintaining, and enhancing the environmental and recreational values at Lake Kegonsa and its surroundings.

# CHAPTER 2:

# WATERSHED FACTORS

## OVERVIEW

In this chapter, important physical characteristics of the Door Creek watershed are discussed. This discussion takes into account both the stream's natural history, as well as the impact that human activities, such as agriculture and urbanization, have had on its present hydrology. An understanding of basic regional topography, land cover and use, climate, hydrology, and hydrogeology is an essential component of preparing effective and practical objectives for nutrient management.

## 2.1REGIONAL TOPOGRAPHY

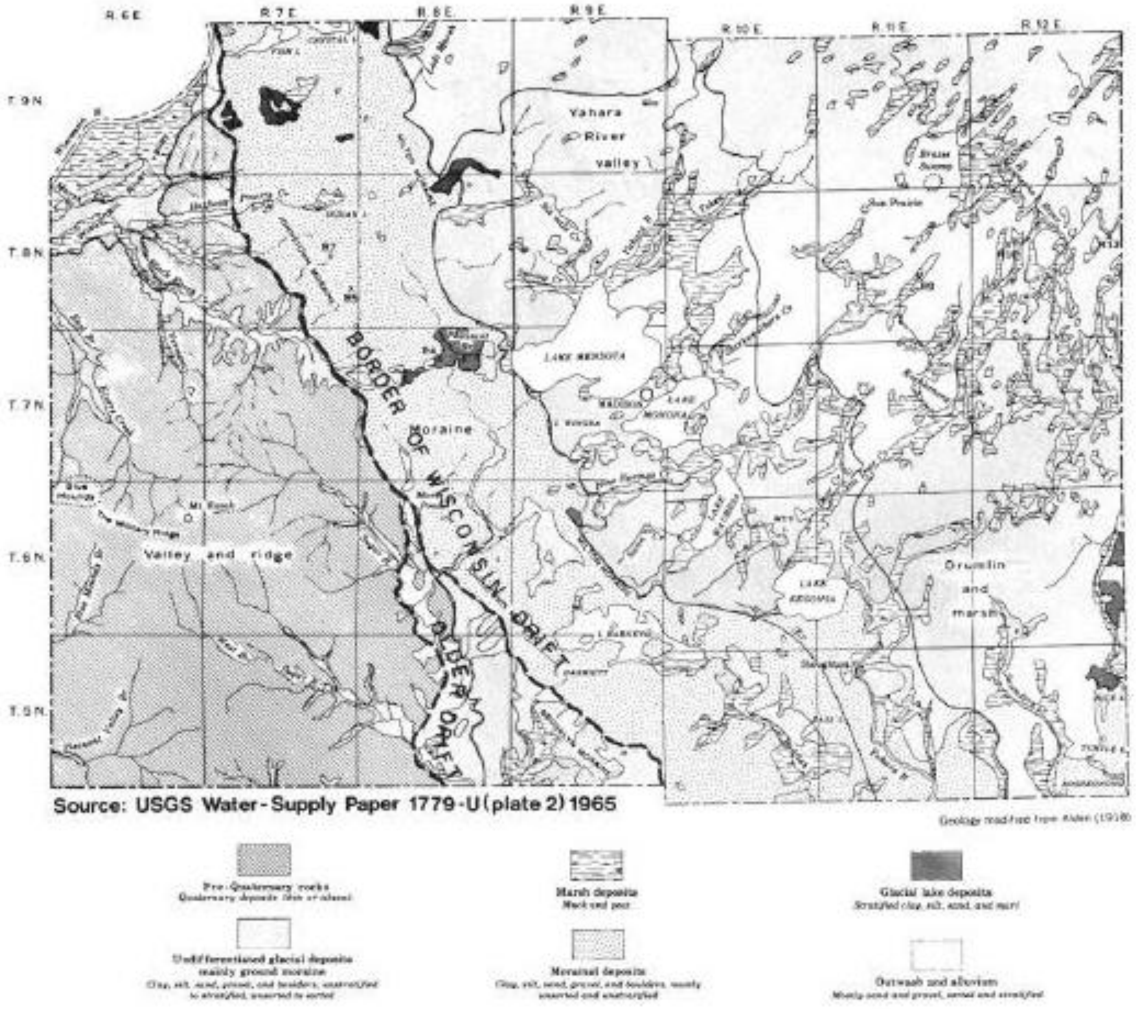
### 2.1.1 GLACIAL HISTORY OF THE YAHARA LAKES

Door Creek is located in the Yahara River watershed of the greater Lower Rock River watershed in South Central Wisconsin. The Yahara River connects a chain of four lakes that are called, from north to south: Lake Mendota, Lake Monona, Lake Waubesa, and Lake Kegonsa. A fifth lake, Lake Wingra, is not directly connected to the Yahara River but it is also considered part of the group of lakes known as the Yahara Lakes.

The Yahara River Valley is a broad, flat river valley that was formed during the last period of glaciation, the Wisconsin Glaciation Episode of the Pleistocene Epoch, which ended approximately 12,000 years ago (Fullerton & Bush, 2004). The Wisconsin Glacier covered the northern and eastern portions of the state and terminated in Dane County to the west of the City of Madison (Clayton & Attig, 1997).

The glacial advance had a significant impact on the topography of eastern Dane County. It flattened the area's physical features, filled the ancient Yahara River Valley with sediment and marshy peat deposits, and formed the Yahara Lakes chain (WDNR, 2001).

The impacts of the Wisconsin Glacier are clearly shown by contrasting the glacial Yahara River Valley to the unglaciated Driftless Area located in western Dane County (Figure 2.1). The Driftless Area features distinctive highlands that have been deeply cut by a well-defined network of dendritic streams (DCRPC, 2001).



Source: USGS Water-Supply Paper 1779-U(plate 2) 1965

**Figure 2.1: Major glacial features of Dane County and extent of glaciation during the Wisconsin glacial period.** Source: DCRPC, 1999.

### 2.1.2 DOOR CREEK WATERSHED

Door Creek is the main tributary stream of Lake Kegonsa, the southernmost lake in the Yahara Lakes system. The Door Creek watershed is oriented in a north-south direction, and drains an area of approximately 29.5 square miles (DCRPC, 1999). The focal point of the Door Creek watershed's topography is the large Door Creek Wetland adjacent to the north shore of Lake Kegonsa. The Door Creek Wetland is an extensive low-lying marsh that covers approximately one square mile. Door Creek and the Door Creek wetland exhibit very low elevation gradients due to the region's glacial history (WDNR, 2001). Their average water level is approximately 843 feet above sea level and reflects hydrological conditions in downstream Lake Kegonsa (Mead & Hunt, 1993).

Upland areas in the northern and eastern portions of the watershed "include many small drumlin hills interspersed with shallow glacial deposits [that] created an extensive system of interconnected wetlands with poorly defined drainage" (DCRPC, 1999). Drumlins are formed when pre-glacial hills are dragged into long, narrow features by the advance or retreat of glaciers (Clayton & Attig, 1997). Door Creek and Little Door Creek are divided by a ridge that runs through the northern half of the watershed. It extends in a northeasterly direction from the confluence of the two creeks toward the Village of Cottage Grove and reaches a maximum elevation of just over 1,000 feet above sea level (Vandewalle & Associates, 2008).

Door Creek, Little Door Creek, and their respective floodplains are located in the poorly-drained lowland areas between the glacial ridges. Drainage to the streams is poor, because the elevation gradients of both creeks are relatively low (Mead & Hunt, 1993). Man-made ditches that were constructed to improve drainage are located throughout much of the watershed. The mechanical construction of drainage ditches and the straightening of Door Creek has created a landscape that is characterized by a highly-unnatural stream network.

## 2.2 LAND COVER AND USE

### 2.2.1 OVERVIEW

Regional land cover and land use practices have implications for both land and water resource quality and function. The Door Creek watershed is divided into seven basic land use categories: agricultural, urban, transportation, wetland, forest, open water, and open land (Table 2.1 and Figure 2.2).

| Land Use Classification | Acres | % of Watershed |
|---|---|---|
| Agriculture | 10,312 | 53 |
| Urban | 2,770 | 14 |
| Transportation | 1,465 | 8 |
| Wetland | 1,684 | 9 |
| Forest | 1,668 | 9 |
| Open Land | 1,342 | 7 |
| Open Water | 69 | 0.5 |

**Table 2.1: Areas and percentages of land use in the Door Creek watershed by landuse type.** Source: CARPC, 2007.

Of these, agricultural, wetland, transportation, and urban land uses are most influential because of their associated impacts and management regulations. Of the approximately 18,000 acres covered by the watershed, approximately 3,000 acres, or 15%, is publicly owned. Public ownership is held by multiple municipalities as well as, Dane County, the Wisconsin Department of Natural Resources, and the Department of Transportation (Table 2.2). The remaining 16,400 acres, or 85%, of the watershed is privately owned.

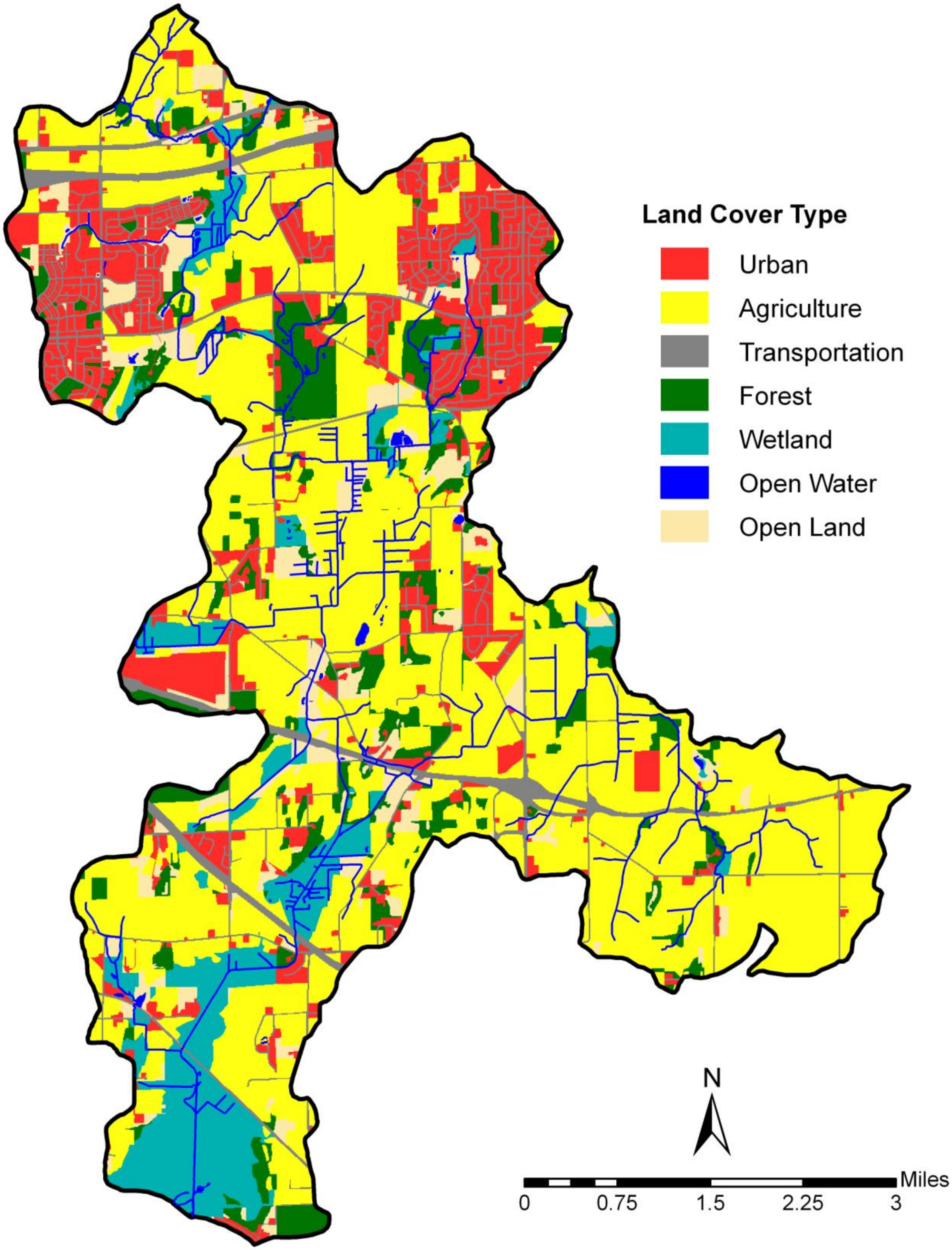


**Figure 2.2: Door Creek Landcover, 2007.** The major categories of land use within the Door Creek watershed. Source: CARPC, 2007; Dane County, 2005. Created Fall 2009 by 2009 WRM Practicum.

| Public Owner Name | Area (ac) | % of Public |
|---|---|---|
| Dane County | 824.16 | 46.26% |
| City of Madison | 410.50 | 23.04% |
| WDNR | 221.89 | 12.45% |
| Village of Cottage Grove | 187.51 | 10.53% |
| Monona Grove | 69.95 | 3.93% |
| WDOT | 28.47 | 1.60% |
| Town of Cottage Grove | 26.23 | 1.47% |
| Town of Blooming Grove | 12.85 | 0.72% |
| **Total Acreage** | 1781.56 | 100.00% |

**Table 2.2: Public land owners in the Door Creek watershed.** (Source: CARPC, 2007).

### 2.2.2 AGRICULTURAL LAND USE

Most of the land area within the Door Creek watershed is characterized by agricultural use, mainly devoted to grains such as corn, soybeans, and winter wheat (D. Wagner, personal communication, June 3, 2009). A small portion of the farms in the watershed raise animals such as dairy cattle, beef cattle, and pigs; with a few hobby farms hosting other animals like horses and goats. Since most of the land is used for grain crops, commercial fertilizers may be used more consistently than other common options such as manure. Regardless of the source, fertilizer is a key component of nutrient loading, specifically from phosphorus and nitrogen.

Agricultural land use plays an important role in the Door Creek watershed as it may be a primary source of both sediments and nutrients. Groundwater quality can be directly impacted as a result of nutrients and other contaminants leaching through the soil, particularly in the case of agricultural by-products such as phosphorous and nitrogen. Additionally, surface waterbodies are influenced by sediment and nutrient-laden runoff. There are a variety of agricultural practices that can be implemented to reduce erosion and runoff from fields. Specifically, a variety of different tillage practices can increase the amount of crop residue left on the field after harvest. By leaving crop residue on the surface of fields, raindrop impact, which initiates the erosion process, can be reduced, and runoff rates are slowed. Reducing impact and slowing runoff helps to keep soil on the fields and decreases the amount of sediment, nutrients, and chemicals that enter water systems (USDA, NRCS, UW-Ext, 2000).

In order to mitigate environmental impacts resulting from these effects, any agricultural operation receiving state funding is required by Wisconsin Statute 92, NR 151.2 and ATCP 50 to have a nutrient management plan that promotes soil and water conservation practices. Within the watershed, approximately 635 acres have been voluntarily enrolled in conservation programs; of these, 480 acres of land are enrolled in the Conservation Reserve Program (CRP) or the Wetland Reserve Program (WRP), both of which help to protect erosion-prone and environmentally sensitive lands through conservation practices or direct protection, enhancement, and restoration (Mitsch & Gosselink, 2007).

### 2.2.3 URBAN LAND USE

Urban areas and transportation infrastructure combine to account for the second largest regional land use in the Door Creek watershed. Rural subdivision developments are scattered throughout the municipalities in the watershed. In addition, the watershed contains the Village of Cottage Grove in the northeast corner, a small portion of the City of Madison along the northwestern edge, and the Village of McFarland to the west (Figure 2.3).

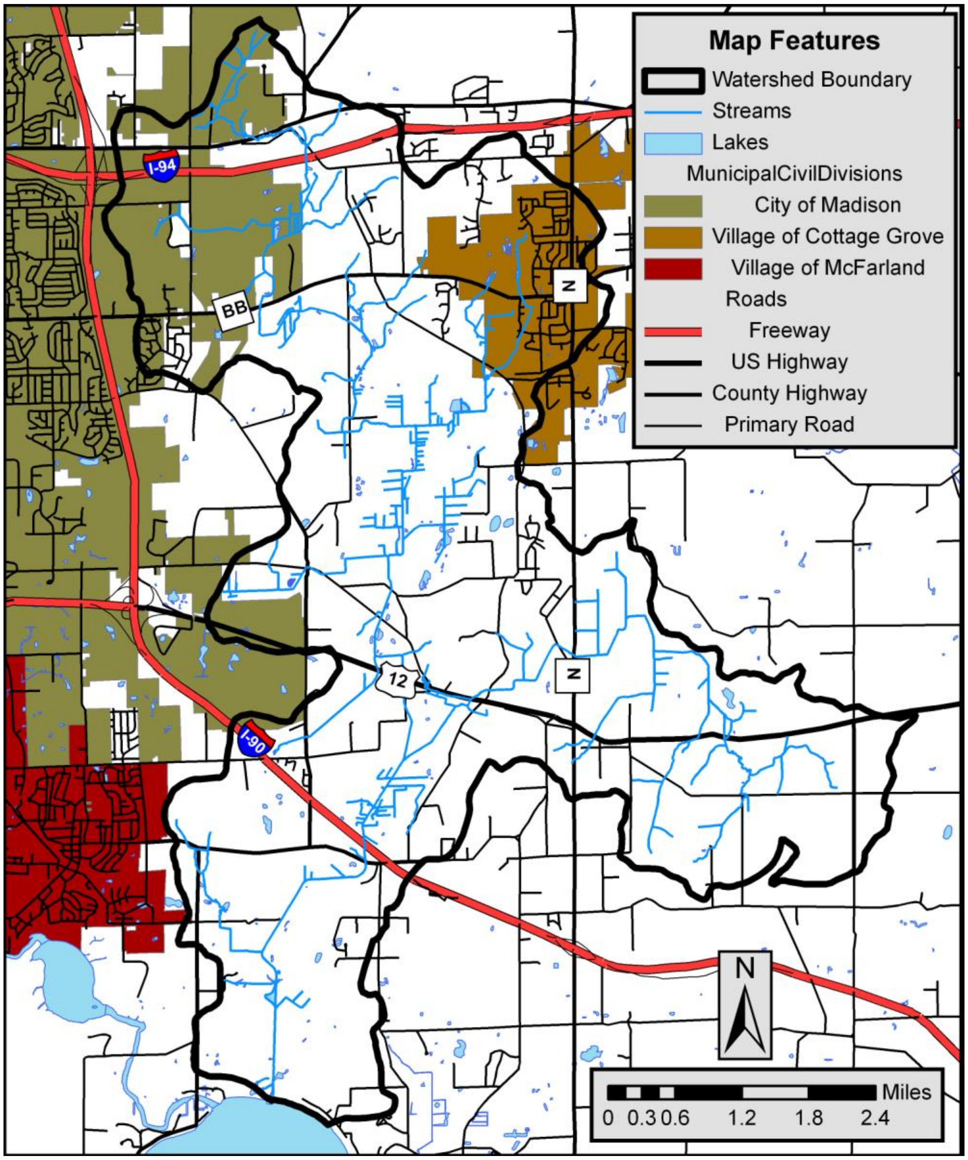


**Figure 2.3: Major Municipal Divisions within the Door Creek Watershed.** Source: Dane County Land Information Office 2006, Municipal Boundaries, WDNR Road Centerlines. Created September 2009, by the WRM Practicum.

These urban areas, in addition to transportation corridors, all impact the quantity and quality of runoff flowing into the Door Creek system, and are potential sources of contaminants to both surface and groundwater resources. Under Wisconsin Administrative Codes NR 151 and NR 216, as well as the Wisconsin Pollutant Discharge Elimination System developed by the WDNR, rules and guidelines have been set in place to reduce runoff pollutants and sediments from these urban sources in order to reduce their impact on surrounding land and downstream waterbodies.

### 2.2.4 WETLAND LAND COVER

Wetlands cover approximately 1,700 acres, or 9% of the total land area in the Door Creek watershed (Figure 2.4).

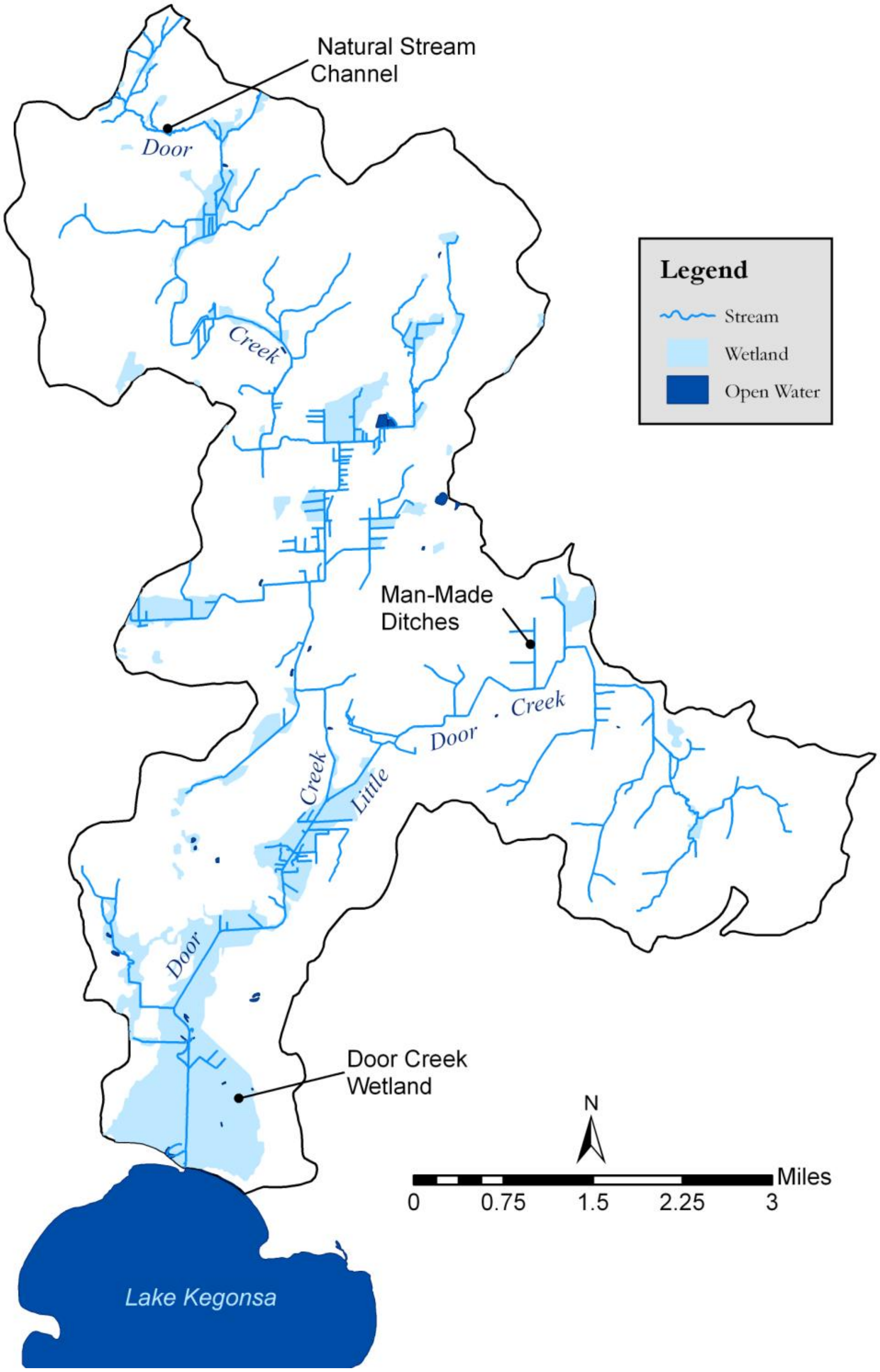


**Figure 2.4: Door Creek Hydrology.** Major hydrologic features of the Door Creek watershed. These include Door Creek, Little Door Creek, the Door Creek Wetland, and sample portions of the Creek that have undergone man-made ditching. Source: Dane County, 2000; WDNR, 2007; WDNR, 1994. Created Fall 2009 by 2009 WRM Practicum.

Despite this small percentage, wetlands are quite significant to the surrounding land, its uses, and also to the biological and ecological integrity of the aquatic communities of Door Creek and Lake Kegonsa. Wetland ecosystems provide three main services: flood abatement, water quality improvement, and biodiversity support (Zedler, 2003). Wetland loss, as well as increases in urban and agricultural land development, lead to higher concentrations of sediments and nutrients in storm water runoff, and compromise these vital natural functions. In recognition of the beneficial ecological impacts of wetlands, a range of regulations that encompass not only the wetlands themselves but also their surrounding uplands and adjoining water bodies, now protect many of these areas.

### 2.2.5 URBANIZATION

Development in the Door Creek watershed has been relatively slow. Between 2002 and May 2009, only 40 acres have been developed or are under construction. However, the watershed is not immune to the pressures of urbanization. Projected growth from 2000 to 2020 is 95% for the Village of Cottage Grove, 36% for the Village of McFarland, and 18% for the City of Madison (Village of Cottage Grove, 2009; Village of McFarland, 2006; City of Madison, 2006). Greater urbanization of the watershed could have significant impacts on water quantity, water quality, and groundwater flow. The possible development of these urban communities would increase the amount of impervious surfaces across the watershed. An increase in impervious surfaces can lead to an increase in stormwater runoff that may carry a variety of urban pollutants, as well as directly affect groundwater by reducing recharge following rain events. Additionally, construction activities associated with community development could directly affect water quality because runoff from construction sites can carry significant sediment loads, soil nutrients, and contaminants.

Wisconsin and Dane County have implemented rigorous erosion control and stormwater management standards. In addition to these standards, Dane County, as well as the other municipalities within the Door Creek watershed, are mandated by the state to have comprehensive plans that outline how erosion and stormwater will be managed. However, if not properly managed in the future, the urbanization activities within and around the watershed could lead to water quantity and quality problems for both surface water and groundwater resources. It is important to take into consideration the effects that future development could have in the watershed, and to take appropriate measures to uphold the standards designated at the State and County levels in order to minimize potential degradation to the Door Creek watershed.

## 2.3 CLIMATE

The Door Creek watershed has a humid, continental climate. The average annual temperature is 46 degrees Fahrenheit (°F), with a high monthly average of 72 degrees in July and a low monthly average of 17 degrees in January (Figure 2.5). The average precipitation is 33 inches per year, and the average yearly snowfall is 50 inches. (Climate data is taken from National Climatic Data Center (NCDC) Normals for 1971-2000 for Dane County Regional Airport, Madison, Wisconsin.)

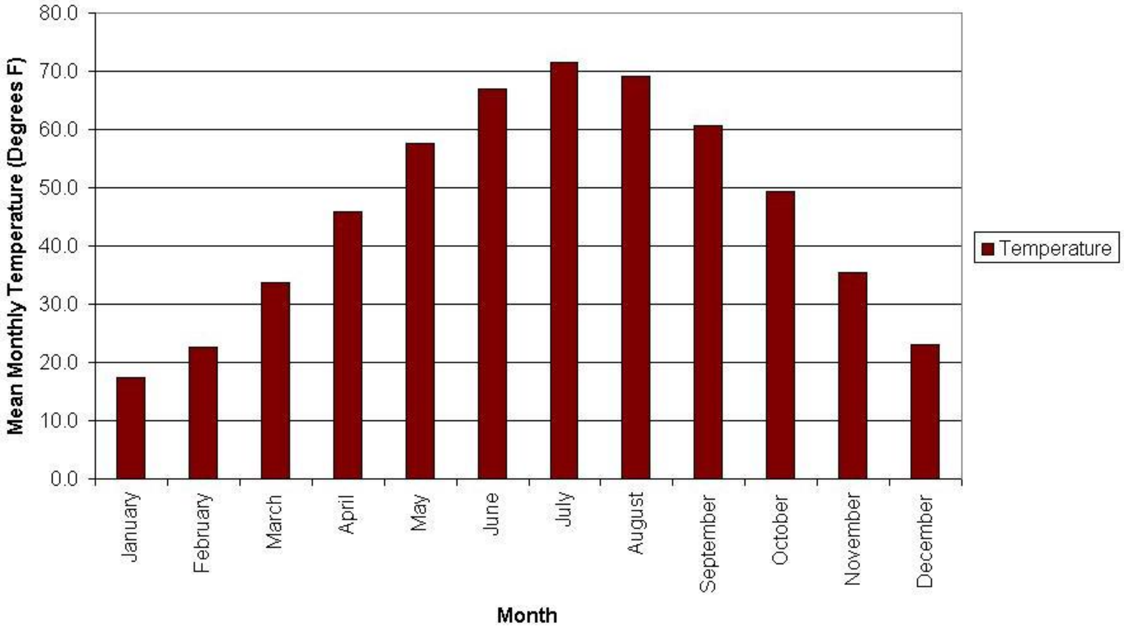


**Figure 2.5: Mean Monthly Temperatures.** Mean monthly temperatures for Madison, WI 1971-2000, obtained from the NCDC 30-Year Climate Normals for Madison, WI. Source: NCDC, 2003.

Winters are typified by cold temperatures and ample snowfall. The average winter temperature (December to February) is 21.0 °F, with a record low of -37 °F occurring in January, 1951; and the average snowfall is 34.4 inches. Summers are marked by warmer temperatures and more frequent precipitation than other seasons. The average summer temperature (June to August) is 69.2 °F, with an all-time record high of 104 °F occurring in July, 1976 (NCDC, 2003). Approximately 37%, or 12.3 inches, of the annual total precipitation falls during the summer months (Figure 2.6). The spring and fall months are milder and drier than the summer, with an average spring temperature of 45.8 °F and precipitation of 8.9 inches, and an average fall temperature of 48.5 °F and precipitation of 7.6 inches (NCDC, 2003).

The climate contributes to the region's hydrology by producing high volumes of runoff during both the spring and summer seasons. Spring runoff is produced by the melting of snow as temperatures rise, and summer runoff is produced by intense convective storms.

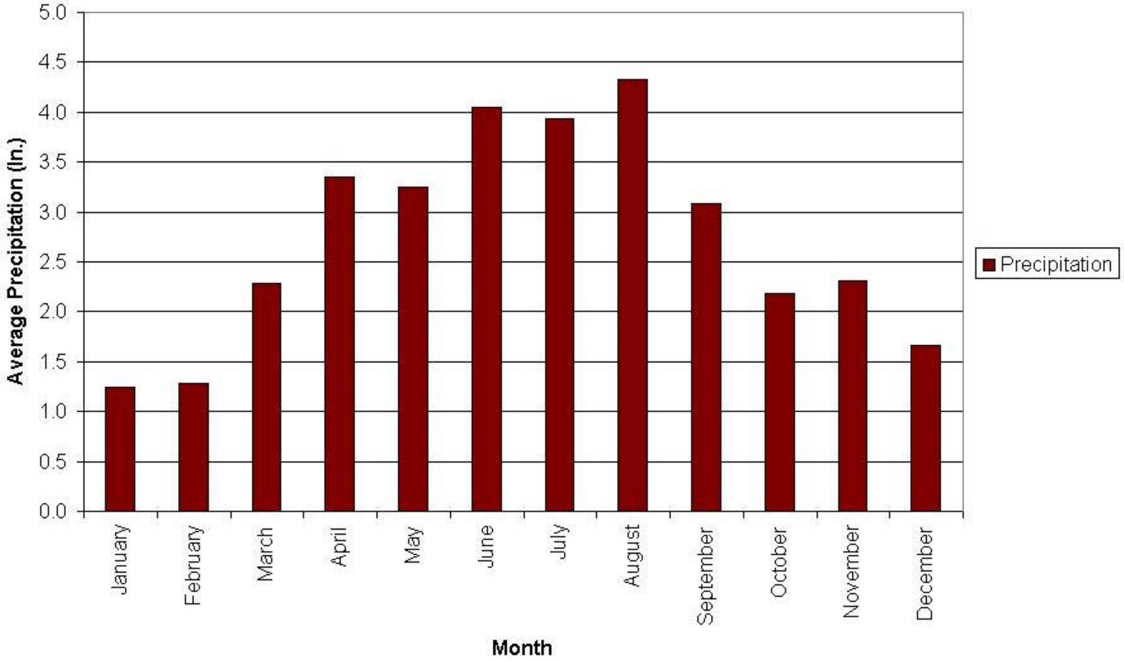


**Figure 2.6: Mean Monthly Precipitation.** Mean monthly precipitation totals for Madison, WI from 1971 – 2000 obtained from the NCDC 30-Year Climate Normals for Madison, WI. Source: NCDC, 2003.

## 2.4 HYDROLOGY

Door Creek generally flows from the higher drumlin area in the north to the lower marshy area in the south before discharging into northern Lake Kegonsa. The Door Creek stream network consists of the main stem of Door Creek, its tributary Little Door Creek, and a network of man-made drainage ditches.

In addition to Door Creek and Little Door Creek, the watershed also contains two unique features that help define its hydrologic character (Figure 2-4). The first is the extensive network of man-made lateral ditches and straightened main channel reaches that were constructed in the early 20th century to drain land for agricultural purposes. The second is the expansive, low-lying Door Creek Wetland that is located near Door Creek's outlet into Lake Kegonsa.

### 2.4.1 DOOR CREEK

Door Creek is a flat, slow-moving creek that flows from north to south for 12.7 miles before discharging into Lake Kegonsa. The average gradient of the creek is a very flat 2.4 feet per mile and the baseflow is a sluggish 9.4 cubic feet per second (cfs) (DCRPC, 2005). Door Creek, which originates as a narrow stream in the upland drumlin area near the Village of Cottage Grove, largely exists in its natural state north of the Wisconsin and Southern Railroad tracks. South of the railroad tracks, the stream becomes wider and straighter as its floodplain broadens between the drumlin ridges and then expands out into the broad marshy areas in the southern portion of the watershed.

The man-made dredging and straightening of Door Creek has had a significant impact on its hydrology. When the drainage work was performed prior to the 1920's, the resulting ditches were likely 4 to 8 feet deep and nearly 30 feet wide near its outlet into Lake Kegonsa (Carnes, 1914). Heavy silt and sediment transport, facilitated by the drainage modifications, has caused substantial silt and sediment deposition, especially in the reach that passes through the Door Creek Wetland (WDNR, 2001). The width and depth of Door Creek has been estimated at 16 feet and 1.0 feet, respectively (DCRPC, 2005). Field observations of the stream made by the Practicum indicate that widths and depths are smaller in the upland areas and likely reach approximately 30 feet and 3.0 feet, respectively, near the outlet.

### 2.4.2 LITTLE DOOR CREEK

Little Door Creek originates in the southeast corner of the watershed in the upland area near Liberty Mound. It flows for three miles to the west, at an average gradient of 9.7 feet per mile, before reaching its confluence with Door Creek south of Highway 12-18 (DCRPC, 2005). Nearly all reaches of Little Door Creek that have year-round flow have been transformed into small man-made drainage ditches. The modified stream carries an average baseflow of 1.8 cfs through ditches that average four feet in width and 0.75 feet in depth (DCRPC, 2005).

Off the main channel of Little Door Creek, the greatest density of lateral ditches is located north of Highway 12-18 near Highway N. Geographical data obtained from Dane County shows that this, broad and flat floodplain, situated between the uplands, was once covered by an extensive wetland complex near the creek. Dense ditch construction drained the land so it could be used for farming.

### 2.4.3 DRAINAGE DITCHES

For much of the 20th century, wetland drainage was encouraged based on the misconception that, by draining wetlands, disease would be eliminated, flooding would be reduced, and the land could be made profitable through agricultural use. When the Dane County area was settled in the mid-19th century, stream channels in the Yahara River Valley, such as Door Creek, featured broad, marshy floodplain areas that formed following Wisconsin's glacial periods. However, stream channelization for the purpose of lowering the water table and making wetland areas accessible for farming transformed Door Creek into an extensive network of man-made ditches (WDNR, 2001).

The result of the efforts of the early 20th century farmers and drainage engineers is that very few reaches of Door Creek and its tributaries exist in their natural states today.

From the perspective of effectively draining standing water from the land, the Door Creek drainage system has proven to be very successful. The ditches effectively lowered the water table and provided drainage in areas that were previously characterized by ponded conditions. Downstream reaches of Door Creek were transformed into hydraulically-efficient drainage ditches approximately 20 to 30 feet wide and 4 to 8 feet deep, and other reaches of both creeks were turned into smaller, but equally effective, ditches as well (Carnes, 1914).

The ability of the drainage ditches to quickly and effectively move water has had a significant impact on the hydrology of the Door Creek watershed. The lateral drainage ditches that extend from the main streams cause stormwater runoff to reach the Creek much faster during rain events, and the straightened watercourse of the main stem of Door Creek transports water to Lake Kegonsa much more quickly than it would in its natural state. These alterations to Door Creek's hydrology result in higher peak flows, greater erosivity, and increased sediment deposition during flood events (WDNR, 2001).

### 2.4.4 DOOR CREEK WETLAND

The Door Creek Wetland is characterized by several hundred acres of low-lying marsh wetlands that extend from Lake Kegonsa northward to the confluence of Door Creek and Little Door Creek. Expansive wetlands such as this can provide valuable hydrologic functions, such as flood mitigation, that reduce the magnitude of peak discharges while delaying their timing (DCRPC, 2000).

In its natural state, Door Creek followed a meandering watercourse through the wetlands, with overflow from storm events frequently topping the banks of the creek into the surrounding wetland. Subsequent man-made changes to Door Creek have had deleterious impacts on other environmental functions, and conventional wisdom is that extensive ditching of the creek has also negatively impacted the hydrologic functions of the wetlands.

In 1993, the Friends of Lake Kegonsa Society (FOLKS) hired the engineering firm Mead and Hunt of Madison to publish the Door Creek Watershed Feasibility Study. This included an analysis of the impact of man-made changes to Door Creek on the hydrologic functions provided by the Door Creek Wetland. Contrary to what might be expected, they concluded that "the ditching of the wetland had virtually no effect because of the extremely low gradient between the railroad tracks and the mouth and the proximity of Lake Kegonsa, which serves to maintain water levels" (Mead & Hunt, 1993).

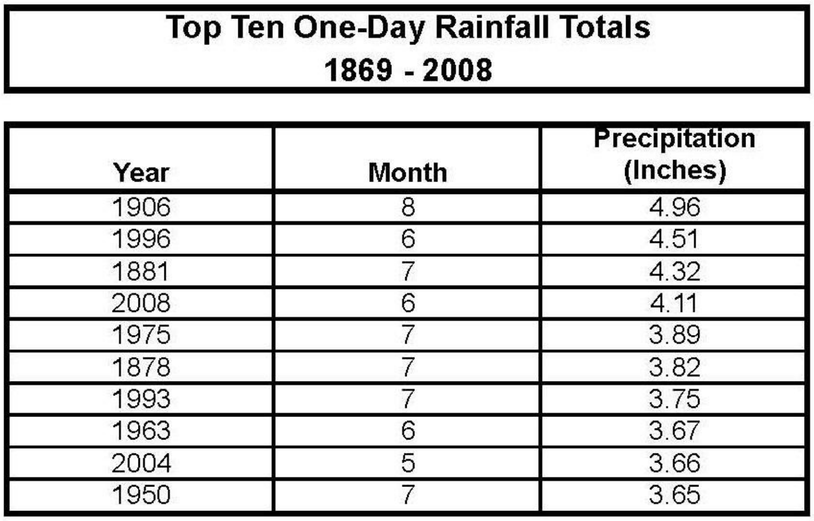
The Door Creek Feasibility Study also addressed the Door Creek Wetland's present ability to provide storm event attenuation. Its study consisted of a rainfall-runoff model that routed storm events of varying recurrence intervals through a storage unit designed to model the Door Creek Wetland. It found that, during these storm events, the wetland reduces Door Creek’s peak discharges to the lake. Mead and Hunt concluded, that "there is a hydrologic benefit provided by the wetland in attenuating watershed runoff. It appears as though a great deal of the wetland area will fill with water during significant rain events" (Mead & Hunt, 2003).

## 2.5 PRECIPITATION AND STREAMFLOW PREDICTIONS

### 2.5.1 OBSERVED AND ESTIMATED PRECIPITATION

The extreme rainfall events that produce flooding in the creek and surrounding watershed are generally caused by summer storm events during the months of June through September (Huff & Angel, 1992). Historical rainfall data is available for the City of Madison dating back to 1869 and the peak recorded one-day rainfall total is 4.96 inches in 1906. The top ten one-day rainfall totals on record are summarized in Table 2.3.

Rainfall amounts during intense storm events in southern Wisconsin have been estimated by two widely-accepted studies. These studies are the National Weather Service's (NWS) Technical Paper 40, which was published in 1961 (Hershfield, 1961), and the Illinois State Water Survey's (ISWS) Bulletin 71, which was published in 1992 (Huff & Angel, 1992). Both reports use a regional analysis of historical rainfall data to estimate rainfall amounts during extreme events.



**Top Ten One-Day Rainfall Totals**
**1869 - 2008**

| Year | Month | Precipitation (Inches) |
|---|---|---|
| 1906 | 8 | 4.96 |
| 1996 | 6 | 4.51 |
| 1881 | 7 | 4.32 |
| 2008 | 6 | 4.11 |
| 1975 | 7 | 3.89 |
| 1878 | 7 | 3.82 |
| 1993 | 7 | 3.75 |
| 1963 | 6 | 3.67 |
| 2004 | 5 | 3.66 |
| 1950 | 7 | 3.65 |

**Table 2.3: Top ten one-day precipitation amounts recorded for Madison, WI.** (Source: Wisconsin State Climatology Office, 2008).

The rainfall depth estimates produced by these studies are primarily used for the design of engineering structures, but they can also provide a rough guide of the total amount of rainfall expected during high intensity, low frequency events, such as the 10-year and 100-year recurrence interval storms. NWS Technical Paper 40 is the design standard currently used by the WDNR. The 10-year, 24-hour and 100-year, 24-hour rainfall depths calculated by Technical Paper 40 are 3.62 and 5.88 inches, respectively (Hershfield, 1961).

### 2.5.2 DOOR CREEK STREAMFLOW

Streamflow data for Door Creek is available from several different sources. Historic daily streamflow data for Door Creek was recorded by the USGS from 1975 to 1979. The USGS also conducted periodic water quality sampling, which included baseflow measurements for Door Creek from 1976 to 2008. Lastly, the previously mentioned Mead and Hunt study used hydrologic modeling based on the design rainfall depth-duration-frequency estimates to predict flow rates in the stream during storm events.

Historic daily streamflow information for Door Creek was recorded from December 1975 to December 1979 at USGS gauging station number 05429580. The gauge is located where Hope Road intersects Door Creek north of US Highway 12-18. The total tributary area for the gauging station is about 15 square miles, which represents approximately one-half of the total tributary area of the watershed. The average annual discharge of Door Creek during the recording period was 7.9 cubic feet per second (cfs), and the daily peak discharges recorded were 178 cfs in March 1976 and 183 cfs in June 1976 (Streamflow data courtesy of United States Geological Survey).

**Door Creek Peak Discharges at Lake Kegonsa**

| Storm Event | 24-Hour Peak Discharge |
|---|---|
| 1-Year | 650 cfs |
| 2-Year | 850 cfs |
| 5-Year | 1,475 cfs |
| 10-Year | 1,900 cfs |
| 25-Year | 2,400 cfs |

**Table 2.4: Peak Discharge Rates.** Modeled peak discharges for Door Creek at its outlet into Lake Kegonsa. Peak discharges were estimated using the TR-20 rainfall-runoff modeling software (Source: Mead and Hunt, 1993).

Baseflow discharge has been recorded at the same site in conjunction with periods of water quality sampling that were conducted roughly every five years from 1976 through 2008. Under the water quality sampling program, three to six samples were taken each year that sampling was conducted. Baseflow measurements were performed simultaneously. The average baseflow for Door Creek estimated during the water quality sampling program was approximately 8 cfs (Water quality and streamflow data courtesy of the United States Geological Survey).

Part of the Door Creek Watershed Feasibility Study included a rainfall-runoff model that estimated peak discharges for Door Creek at its outlet into Lake Kegonsa for storm events ranging from the 1-year, 24-hour event to the 25-year, 24-hour event. Runoff from rainfall events was estimated using the Soil Conservation Service (SCS) TR-20 methodology, with rainfall depths obtained from NOAA Technical Paper 40 and curve numbers estimated using the USGS 7.5-minute Quadrangle maps (Mead and Hunt, 2003).

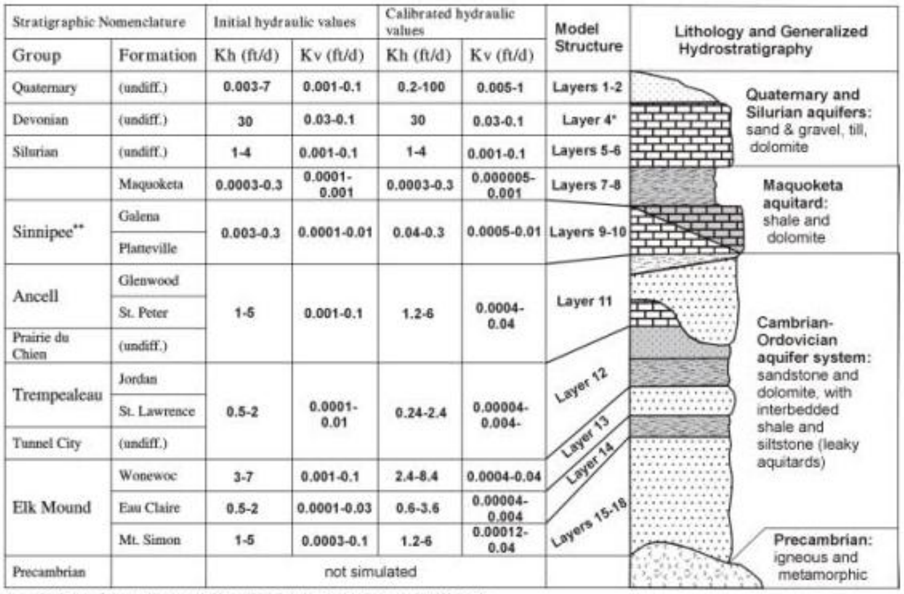
The estimated one-year peak discharge for Door Creek at Lake Kegonsa was roughly 650 cfs, and the estimated peak for the 25-year event was approximately 2,400 cfs. Table 2.4 summarizes the results of the Mead and Hunt study (Mead and Hunt, 1993).

## 2.6 HYDROGEOLOGY

In 1997 the Dane County Regional Planning Commission (DCRPC), now the Capital Area Regional Planning Comission (CARPC), completed a hydrologic planning study called the Dane County Regional Hydrologic Study, and in 1999 the Wisconsin Geological and Natural History Survey (WGNHS) completed an extensive study of Dane County's groundwater conditions and produced a report titled Hydrogeology of Dane County. The DCRPC and WGNHS reports were used as key resources for the Dane County Groundwater Protection Plan, which was published in 1999 by the Dane County Regional Planning Commission. The county groundwater protection plan is a comprehensive study of the potential sources of pollution to and overuse of Dane County's groundwater resources (DCRPC, 1999).

### 2.6.1 DANE COUNTY AQUIFERS

There are three main regional aquifers beneath the Door Creek watershed (Figure 2.7). The deepest of the three, the Mount Simon aquifer, is extremely important for the Dane County region because it is the primary source of municipal water drawn from deep wells (DCRPC, 1999). The Mount Simon aquifer is a regional Paleozoic sandstone formation that is situated between the bedrock and the Eau Claire shale aquitard. The aquitard is an impermeable layer of rock that prevents the movement of groundwater and creates the confined layer below. The average thickness of the confined aquifer beneath the Door Creek watershed is 500 feet (DCRPC, 1999).



| Stratigraphic Nomenclature | | Initial hydraulic values | | Calibrated hydraulic values | | Model Structure |
|---|---|---|---|---|---|---|
| Group | Formation | Kh (ft/d) | Kv (ft/d) | Kh (ft/d) | Kv (ft/d) | |
| Quaternary | (undiff.) | 0.003-7 | 0.001-0.1 | 0.2-100 | 0.005-1 | Layers 1-2 |
| Devonian | (undiff.) | 30 | 0.03-0.1 | 30 | 0.03-0.1 | Layer 4* |
| Silurian | (undiff.) | 1-4 | 0.001-0.1 | 1-4 | 0.001-0.1 | Layers 5-6 |
| | Maquoketa | 0.0003-0.3 | 0.0001-0.001 | 0.0003-0.3 | 0.000005-0.001 | Layers 7-8 |
| Sinnipee** | Galena | 0.003-0.3 | 0.0001-0.01 | 0.04-0.3 | 0.0005-0.01 | Layers 9-10 |
| | Platteville | | | | | |
| Ancell | Glenwood | 1-5 | 0.001-0.1 | 1.2-6 | 0.0004-0.04 | Layer 11 |
| | St. Peter | | | | | |
| Prairie du Chien | (undiff.) | | | | | |
| Trempealeau | Jordan | 0.5-2 | 0.0001-0.01 | 0.24-2.4 | 0.00004-0.004- | Layer 12 |
| | St. Lawrence | | | | | |
| Tunnel City | (undiff.) | | | | | Layer 13 |
| Elk Mound | Wonewoc | 3-7 | 0.001-0.1 | 2.4-8.4 | 0.0004-0.04 | Layer 14 |
| | Eau Claire | 0.5-2 | 0.0001-0.03 | 0.6-3.6 | 0.00004-0.004 | Layers 15-18 |
| | Mt. Simon | 1-5 | 0.0003-0.1 | 1.2-6 | 0.00012-0.04 | |
| Precambrian | | not simulated | | | | |

*Layer 3 not shown because it represents Mesozoic rock that is absent in southeastern Wisconsin
**The Sinnipee is an aquitard below the Maquoketa and an aquifer to the west. Where the Maquoketa is present, the upper layer of the Sinnipee Kh=0.04 and Kz=0.0005 ft/day. Where the Maquoketa is absent, the Sinnipee Kh=0.3 and Kz=0.01 ft/day. For the lower layer of the Sinnipee, Kh and Kz values depend on proximity to the unit's western subcrop.

**Figure 2.7 Stratigraphy Hydrostratigraphy of Southeast Wisconsin.** Major geologic features are shown, including the shallow aquifers, shale aquitard layer, and deep sandstone aquifer Source: Feinstein, 2004.

The middle and upper aquifers are both unconfined by an aquitard. The middle aquifer is another Paleozoic sandstone formation that ranges in thickness from zero feet, below the Yahara Lakes, to 200 feet, beneath the upland areas, and is located above the Eau Claire shale layer. The uppermost aquifer is a shallow, unconfined sand and gravel aquifer deposited during the Quaternary Period. It is between zero and 200 feet thick (DCRPC, 1999).

### 2.6.2 GROUNDWATER PUMPING

The Dane County Groundwater Protection Plan highlights two groundwater quantity issues that are important to the Door Creek watershed: groundwater pumping and groundwater recharge and discharge. Groundwater pumping for municipal and industrial use has the potential to negatively impact the natural processes of recharge and discharge if the rate of pumping is greater than the rate of replenishment (DCRPC, 1999).

Groundwater pumping is the biggest threat to groundwater systems in Dane County. Cones of depression, or areas of significant groundwater drawdown, develop where the rate of groundwater pumping greatly exceeds the rate of groundwater recharge. The most intensive groundwater pumping occurs in urbanized areas that get a majority of their water from high-capacity wells (DCRPC, 1999). Excessive groundwater pumping is important from a hydrologic perspective because it can reduce stream baseflow in surface water and deprive wetlands and springs of their life-giving water by lowering the water table.

Groundwater pumping is not currently a critical issue in the Door Creek watershed, but it has the potential to become more salient if the Village of Cottage Grove continues to grow and the City of Madison continues to expand eastward. At the end of 2008, there were a total of three high-capacity wells in operation in the watershed - all located in Cottage Grove. The total amount of water withdrawn by Cottage Grove for municipal use in 2008 was 172.5 million gallons, or 0.471 million gallons per day. This volume of water withdrawal represents nearly twice the 0.250 million gallons per day withdrawn in 1997. Table 2-5 demonstrates how Cottage Grove's water use has increased between 1997 and 2008 (Public Service Commission, 1997-2008).

### 2.6.3 GROUNDWATER RECHARGE AND DISCHARGE

Controlling groundwater pumping is critical for an ecosystem such as Door Creek because it can have significant impacts on the subsurface flow processes of groundwater recharge and discharge.

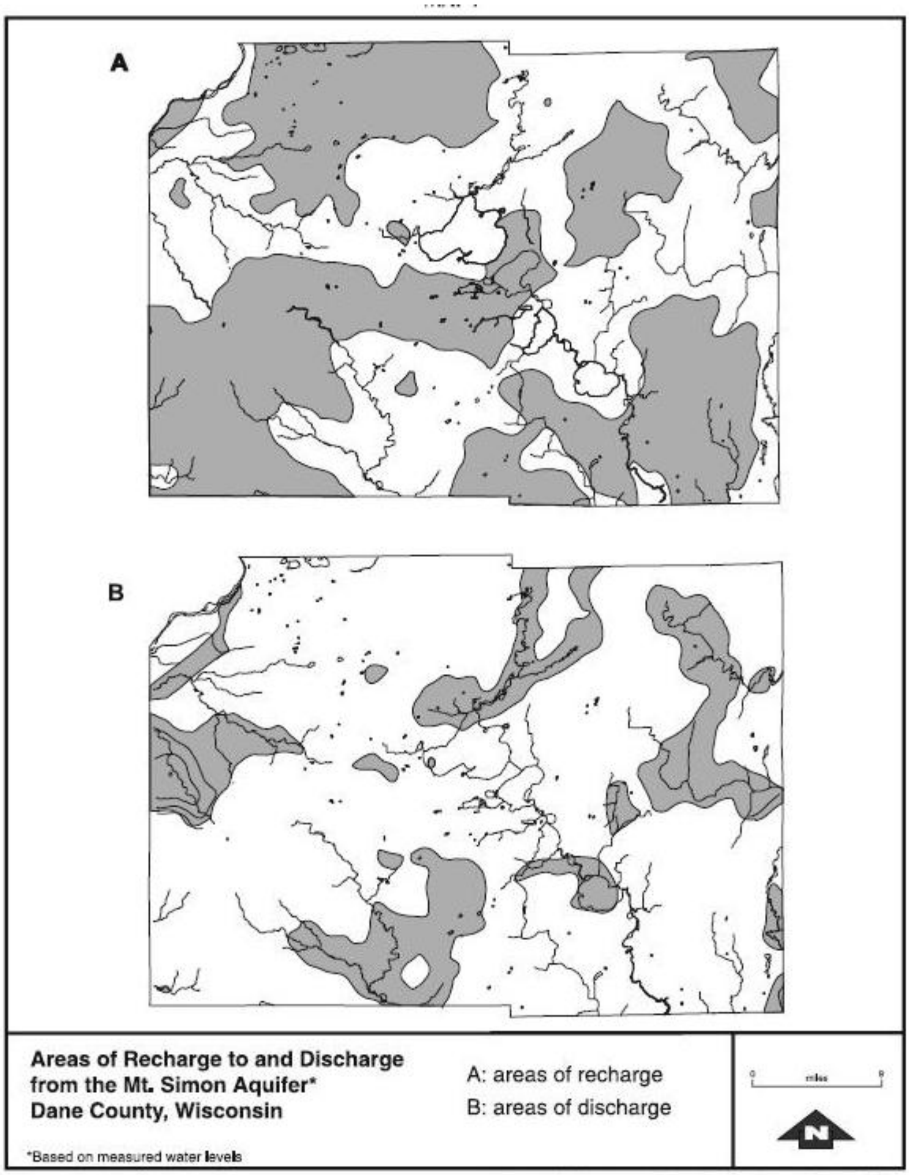
Groundwater recharge is the flow of water from the surface into the subsurface water table. It is important because it replenishes water supplies withdrawn from the underlying aquifers. Groundwater discharge is the opposite of recharge, with water flowing from the water table to the surface. Discharge is also an important process because it helps maintain flows in delicate natural systems such as wetlands and springs (DCRPC, 1999).

The Hydrogeology of Dane County report used a study of the potentiometric (equilibrium pressure) surface of the Mount Simon aquifer to map areas of groundwater recharge and discharge within the county (Figure 2.8).

The recharge and discharge map shows that only the northwest portion of the Door Creek watershed contributes to groundwater recharge. Currently, the recharge process can be negatively-impacted by nitrates from agricultural fertilizers that leach from the surface into the groundwater. In the future, the additional impervious surface added by urbanization could reduce the surface area available for infiltration and recharge of the shallow aquifer.

Two areas within the Door Creek watershed that produce groundwater discharge were also identified. These areas are in the southern portion of the watershed near the Door Creek Wetland and in the northern portion along the main stem of Door Creek. Discharge to the surface in these areas of the watershed occurs at two important locations – springs and the stream. These areas are sensitive to the water table changes that can result from excessive disruptions to the natural groundwater system.

It is common for groundwater to discharge at the surface in springs. In 1989 the DCRPC conducted a reconnaissance of the springs in Dane County. A total of seven springs, or groups of springs, were identified in the Door Creek watershed. These springs coincide with the areas of groundwater discharge, with three clustered near the Door Creek wetland and the other four spread out along the main reach of Door Creek. The DCRPC spring survey is not comprehensive and field observations indicate that additional springs are likely located in the watershed, especially in the upland areas of the watershed where the water table is near the surface (DCRPC, 1999).



Source: *Hydrogeology of Dane County*, Bradbury, et. al., 1999.

**Figure 2.8: Dane County Recharge Discharge.** Areas of groundwater recharge and discharge in Dane County. The Door Creek watershed features areas of recharge in the north portion of the watershed and discharge locations along Door Creek and in the Door Creek Wetland. Source: DCRPC, 1999.

A second common location for groundwater discharge in the Door Creek watershed is into the waterway itself. Groundwater discharge helps maintain baseflow conditions in the stream, which supports various plant and animal communities. The 1997 Regional Hydrologic Modeling and Management Program, coordinated by the DCRPC, used hydrologic and hydraulic modeling programs to estimate current (as of 1995) and future (2020) baseflow conditions in a number of Dane County streams, including Door Creek. The current conditions were estimated using the 80% flow durations obtained from historical USGS data, and the 2020 conditions were estimated by applying the predicted baseflow changes from 1995 to 2020 to the current USGS data (DCRPC, 1999).

The results of the baseflow analysis are as follows:

| | | |
|---|---|---|
| • Current | (1995) | 5.20 cfs |
| • Future | (2020) | 4.33 cfs |

(DCRPC, 1999)

The modeling results show a 17% decrease in Door Creek's baseflow from the 1995 conditions to the projected 2020 conditions. Such a decrease in baseflow conditions has the potential to have a myriad of impacts on the hydrological and biological functions of Door Creek.

### 2.6.4 GROUNDWATER QUALITY

The Dane County Groundwater Protection Plan provides both an overall assessment of the water quality of groundwater in Dane County and also indicates areas of potential concern. "Although good groundwater quality generally exists, it has been affected by certain land use activities in Dane County. The known groundwater quality problems in Dane County have largely resulted from nitrates and bacteria, pesticides, and volatile organic chemicals (VOCs)." (DCRPC, 1999, 39)

The groundwater problems identified in the report are largely absent in water withdrawn via high-capacity municipal wells from the deep, confined aquifer. The US EPA's Safe Drinking Water Act requires that the three municipal wells in Cottage Grove be tested once a year for a wide range of contaminants. Testing results are also required to be published in an annual Consumer Confidence Report (CCR) (DCRPC, 1999). The 2008 Annual Drinking Water Quality Report for Cottage Grove states that the utility "has met or surpassed all State of Wisconsin and Federal drinking water quality standards (Cottage Grove Water Utility, 2009)."

The groundwater quality problems identified in Dane County are usually caused by surface activities: thus, water withdrawn from shallow aquifers by private users are a much bigger concern (DCRPC, 1999). This report will focus on nitrates, bacteria, and pesticides, which are all common problems in a highly agricultural watershed such as Door Creek. VOCs will not be covered in depth because they are usually associated with industrial facilities found in highly urbanized areas (DCRPC, 1999).

The most common bacterial pollutant in Dane County groundwater is the coliform bacteria (DCRPC, 1999). Bacterial pollution of shallow wells usually results when wells are not constructed in accordance with the NR 112 Wisconsin well construction code. Wells with high coliform levels can usually be fixed by treating water with a disinfecting agent or re-constructing them according to the requirements of NR 112 (DCRPC, 1999).

Surface-applied agricultural pesticides that leach into the groundwater system are one major cause of pesticide pollution of groundwater. One harmful chemical of concern in Wisconsin is atrazine, which "has been the most commonly used herbicide in Wisconsin for the past 30 years" (DCRPC, 1999). Atrazine use is regulated by Wisconsin State Administrative Code ATCP

30, which includes a provision that allows DATCP to designate areas where atrazine use is prohibited. Figure 2.9 shows the current atrazine prohibition area for Dane County, which includes much of the Door Creek watershed (Wisconsin State Legislature, 2009).

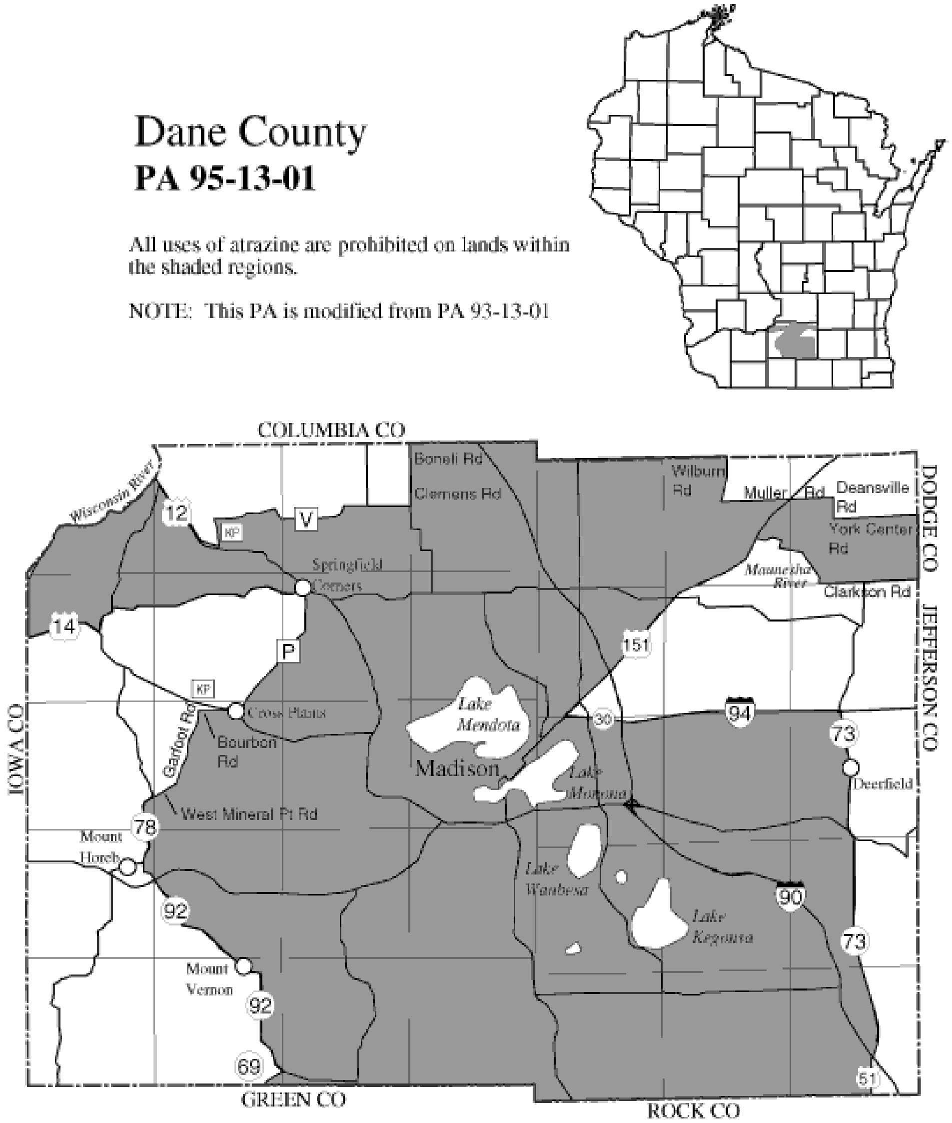


**Figure 2.9: Atrazine Prohibition Areas.** Areas of Dane County where application of atrazine is prohibited. Atrazine application is prohibited throughout nearly the entire Door Creek watershed Source: UW-Extension CLUE and USGS WWSC, 2007.

The biggest groundwater quality issue in the Door Creek watershed is high nitrates. The primary sources of high groundwater nitrates are land applications of nutrients, such as commercial fertilizers, manure, and municipal biosolids (UW-Extension CLUE & USGS WWSC, 2007). Nitrates are highly water-soluble, so they are easily transported from the surface into the groundwater below (DCRPC, 1999). Because of the large groundwater recharge area in the northern portion of the watershed, transport of nitrates into groundwater is a concern in the Door Creek watershed (Figure 2.10).

Recent information on Dane County water quality is available from the Protecting Groundwater in Wisconsin Through Comprehensive Planning website that is maintained by the UW-Extension

Center for Land Use Education and the USGS Wisconsin Water Science Center. It is available online at http://wi.water.usgs.gov/gwcomp.

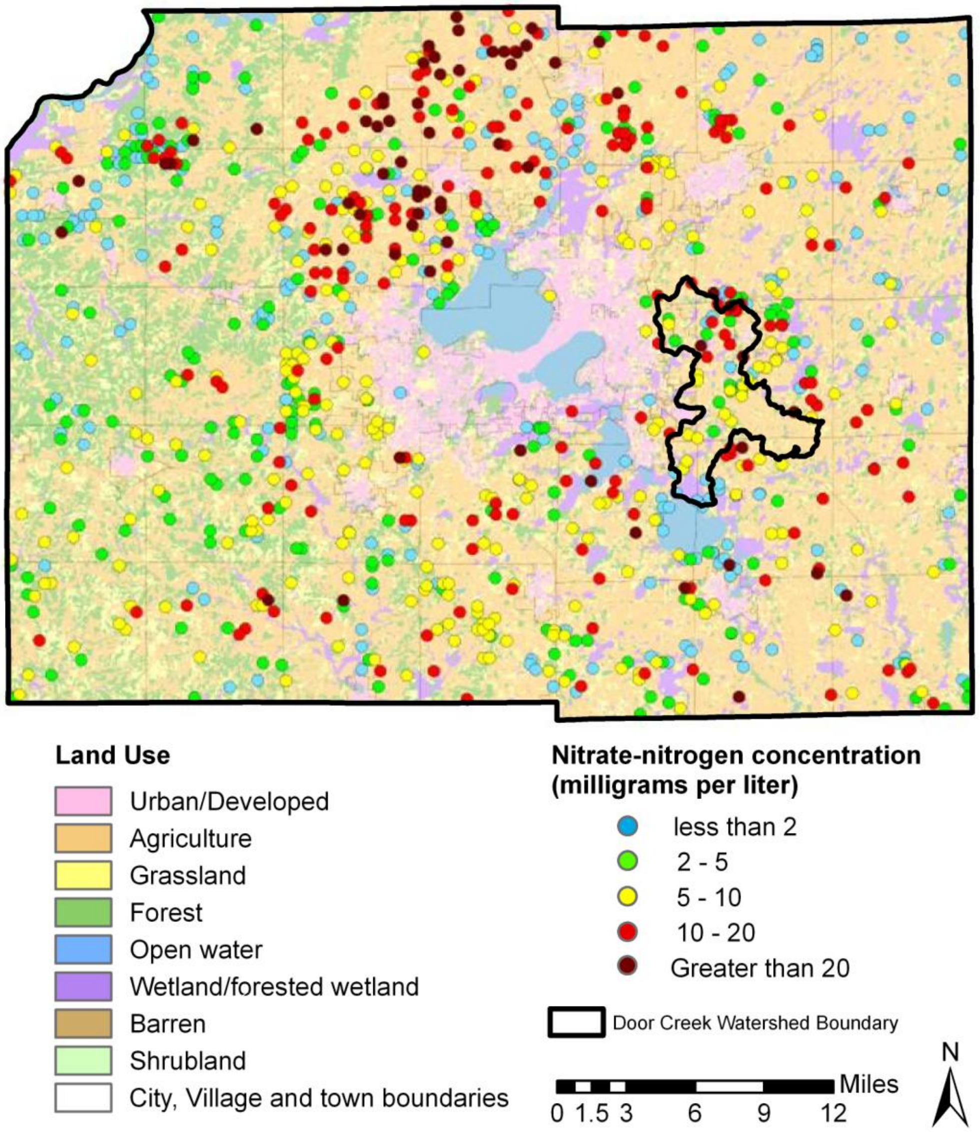


**Figure 2.10: Nitrate-Nitrogen levels in sampled wells in Dane County.** The Door Creek watershed has several wells with nitrate concentrations in excess of 10 mg/l in the northern portion of the watershed. Source: DATCP, 2007 Created Spring 2009 by 2009 WRM Practicum.

The Dane County report states, "In 2006, the WDNR and Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) reported that nitrate-nitrogen (NO3-N) is the most widespread groundwater contaminant in Wisconsin, and that the nitrate problem is increasing both in extent and severity" (UW-Extension CLUE & USGS WWSC, 2007). An extensive well-sampling program conducted from 1990 to 2006 found that 21% (543) of the 2,624 wells sampled in Dane County had nitrate levels that exceed the federal standard of 10 mg/l (UW-Extension CLUE & USGS WWSC, 2007). Figure 2.10 shows the nitrate levels in the wells tested in Dane County.

## 2.7 CONCLUSION

Both natural and man-made features have shaped the character of the present-day Door Creek watershed. The last period of glaciation left a watershed with an extensive network of poorly-drained, low-lying wetlands surrounded by upland hills. Around the turn of the 20th century, farmers took advantage of new excavating and tiling technologies to drain the wetlands and convert those lands into fertile farmlands. Further changes were made the Door Creek landscape as Madison urbanized to the east and Cottage Grove continued to grow around its location in the northeast portion of the watershed. As the Door Creek watershed moves into the 21st century, the proximity of urban growth and farming will create additional burdens on both the surface and sub-surface hydrologic systems that support Door Creek and its watershed's residents.

# CHAPTER 3:

# WATER QUALITY ANALYSIS

## 3.1 INTRODUCTION

Door Creek directly enters Lake Kegonsa, which makes it important to determine what effect Door Creek may have on the lake. This chapter details the water quality data collected to determine the nutrient and physical parameters of Door Creek; observe the base flow concentrations of Door Creek; and to determine the impacts of storm events, pre-fertilizer application and post-fertilizer application, on base flow concentrations.

Data from the US EPA and from independent research studies were used to determine water quality standards for Door Creek. By comparing these standards to current and historical data, we were able to develop a broad sense of what effects Door Creek may have on Lake Kegonsa. Historical data from the USGS provided the framework needed to account for annual variability of water quality and to determine the overall significance of water quality concentrations in Door Creek.

This chapter covers the nutrient and physical samples we took, our analysis of their effects on water quality and our recommendations to improve the water quality in Door Creek.

## 3.2 WATER QUALITY PARAMETERS AND DESCRIPTIONS

Water samples were taken from seven locations on Door Creek extending the entire length of the stream, including the Little Door Creek tributary. These samples were tested for two forms of phosphorus, total dissolved phosphorus (TDP) and total phosphorus (TP), and three forms of nitrogen ammonia, nitrate/nitrite and total Kjeldahl nitrogen (TKN). Also, physical parameters were recorded, including suspended solids (SS), temperature, and dissolved oxygen (DO). These parameters were used to determine how the health and quality of a specific stream, such as Door Creek, contributes positively or negatively to the larger watershed. This section describes each of these nutrients, discusses the sources and effects of each form, and explains the physical parameters.

### 3.2.1 NITROGEN

Nitrogen is a required nutrient for plant growth and can be a limiting nutrient in aquatic systems. The total nitrogen in a waterbody is represented by the concentrations of ammonia, nitrate/nitrite, and TKN. Maintaining safe levels of nitrogen in water is important to human health, and the health of fish and other aquatic flora and fauna. Ammonia ($NH_3$) is found naturally in the atmosphere in small quantities; however, commercial fertilizer and animal waste are now the major contributors of ammonia to aquatic systems, including Door Creek. Ammonia is frequently used in nitrogen fertilizers because it can be directly taken up and utilized by crops. Most of the ammonia that is not used by crops is released to the atmosphere through volatilization. Additionally, ammonia can be released to aquatic systems through the conversion of ammonia to nitrate and nitrite compounds via oxygenation. For these reasons, ammonia typically accounts for a very small portion of the total nitrogen in an aquatic system (Havlin, Beaton, Tisdale, & Nelson, 2005). When ammonia concentration exceeds 0.1mg/L, it can be harmful to fish, causing irritation to gills, eyes, and skin and potentially causing more severe conditions (US EPA, 1999).

Nitrate ($NO_3^-$) and nitrite ($NO_2^-$) are typically formed from oxygenating ammonia. Other sources of nitrate and nitrite include nitrate-containing fertilizer like potassium nitrate, calcium nitrate, and ammonium nitrate; septic tank leaching; and animal and human waste field applications (Havlin et al., 2005). These nitrogen compounds can leach into groundwater, making these compounds a potential threat to groundwater as well as surface water quality. In the Door Creek watershed where nitrogen-based fertilizers are used widely, this is of specific concern. This leaching especially affects wells to unconfined aquifers that are less than 100 feet deep (ATSDR, 2007).

Nitrate in drinking water represents a human health concern. When at risk individuals, including pregnant women and infants, ingest water with high levels of nitrates, it affects their ability to transport oxygen in the blood. This condition is acute and chronic elevated methenmoblobin, also known as blue baby syndrome, can be fatal if it is not treated. (Vitousek et al., 1997). Although rare in the US, the potential for this condition exists whenever nitrate levels exceed 10mg/L, which is the U.S. Public Health Service Standard (Vitousek et. al, 1997).

Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen, ammonia ($NH_3$) and ammonium ($NH_4^+$). TKN is an indicator of eutrophication of water bodies; it provides a measure of the amount of nitrogen that is being used, or is readily available to be used, in primary productivity. For example, during a large algal bloom, the concentration of TKN will increase and can even replace nitrate and nitrite as the primary form of nitrogen in a body of water. As a result, the relationship between TKN and nitrite/nitrate is important in determining the health of a water body. Because TKN is dependent on ammonia, ammonium, and organic nitrogen, the principles that affect these parameters directly affect TKN (Nahm, 2003).

### 3.2.2 PHOSPHORUS

Phosphorus (P) is often considered to be the limiting nutrient in temperate freshwater systems such as Door Creek (Lathrop, 2007). If the limiting nutrient were to increase in concentration in a water body, primary productivity would increase and can lead to eutrophication. Therefore, it is important to assess how much phosphorus is contributed to Lake Kegonsa from the Door Creek watershed. Phosphorus sticks to soil particles and, therefore, predominantly reaches surface waters via soil erosion, where it becomes available to aquatic plants. For these reasons, most agricultural phosphorus control measures have focused on soil erosion to limit transport of particulate phosphorus. However, soils do not have infinite phosphorus adsorption capacity; and with long-term over-application, inorganic phosphorus can eventually enter water systems via runoff even if soil erosion is controlled (US EPA, 2007).

Total dissolved phosphorus (TDP) is a measure of inorganic orthophosphates and organic phosphorous containing compounds, which are forms that are readily available for plant uptake and utilization. Total dissolved phosphorus is also the form of phosphorus typically found in groundwater. Sources of TDP include animal waste, septic tanks, wastewater treatment plants, runoff from construction sites, and commercial fertilizers. Similar to total nitrogen, excess P may lead to massive algal blooms that cause low levels of dissolved oxygen in an aquatic ecosystem (Dodds, Smith, & Lohman, 2006). Low levels of oxygen can be harmful or even fatal to fish and other aquatic species (National Research Council, 1996).

Total phosphorus (TP) consists of TDP along with all other forms of phosphorus, including phosphorus in organic matter, residual plant material, solid waste from manure, and soil disturbances from construction or agricultural practices. Effects of TP are similar to TDP and have the potential to lead to eutrophication of lakes and streams (US EPA, 2006). Total phosphorus is particularly important because it is believed to be the limiting nutrient within the Yahara Lakes system for the majority of the year (Lathrop, 2007).

### 3.2.3 SUSPENDED SOLIDS

Suspended solids (SS) refer to the mass (mg), or concentration (mg/L), of inorganic and organic matter that is held in the water column of a stream, river, lake or reservoir by turbulence. SS are typically comprised of fine particulate matter with a diameter of less than 62 micrometers (μm), though larger aggregated flocculants can occur, especially in the presence of cohesive solids (Waters, 1995). All streams carry some SS under natural conditions due to natural erosion and associated flows. However, any human activity that disrupts soil has the potential to increase SS in a water body (McCaleb & McLaughlin, 2008).

Changes in the loading of SS can affect the physical, chemical, and biological characteristics of a waterbody, including alterations to light penetration, temperature, and sedimentation (Bilotta & Brazier, 2008). Benthic sediments, when disturbed, can also be a direct source of contamination to a lake, contributing heavy metals, pesticides, and nutrients such as phosphorus and nitrogen. Sedimentation can also indirectly affect water quality in a lake. If the sediment is high in organic matter, decomposition can increase in benthic sediments and eventually lead to hypoxia of the bottom substrate and fish kills during low flow (Bilotta & Brazier, 2008).

### 3.2.4 WATER TEMPERATURE

Dissolved oxygen, species presence and distribution, photosynthesis rates, and decomposition rates are affected by water temperature. Changes in water temperature also have a significant impact on lakes by decreasing fish nursery productivity, displacing cool-water fish, increasing primary production, increasing habitat susceptibility to invasive species, and creating a hypoxic zone in the bottom sediment (Boulton, 2009).

Water temperature is altered by changes in bank vegetation and groundwater recharge. Shading of streams by riparian vegetation can reduce the daily and seasonal temperature variation. Temperature variation is particularly important during low flows in summer because streams without shade can heat to the point that many invertebrates and fish are severely stressed or killed. The impact of temperature induced stress can lead to ecological shifts, including the potential for warm-water species to replace cool-water species and allowing invasive species to out-compete native species. (Boulton, 2009).

In addition to the effects of riparian vegetation, groundwater recharge can also act as a natural buffer for water temperature. The temperature of groundwater is influenced by soil and bedrock temperatures, therefore it varies less than that of surface waters and can alleviate surface temperature variations in waterways. This buffering effect typically occurs at stream headwaters, which are primarily fed by groundwater seepage (Boulton, 2009; Kalff, 2002).

Human activities can affect water temperature by altering the bank vegetation, increasing the amount of impervious surfaces draining to the stream, and directly discharging warmer water to streams. Additionally, human activities that affect SS can also indirectly affect temperature. As a stream fills with sediment, it can become wider and shallower, making it more susceptible to extremes in heating and cooling (Boulton, 2009).

### 3.2.5 DISSOLVED OXYGEN

Adequate dissolved oxygen (DO) is necessary to support most aquatic life. As dissolved oxygen levels in water drop below 5.0 mg/L, aquatic organisms suffer. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills. It has also been shown that eutrophication and dissolved oxygen are interrelated. As decomposition rates increase in eutrophic lakes, oxygen levels in benthic habitats drop off, making fish kills in these areas more likely.

Dissolved oxygen levels in a stream or lake are very dynamic, with several interacting factors. For example, moving water, and water that interacts directly with the air, has more oxygen than stationary water or water at depth. Consequently, streams and surfaces of lakes typically have more oxygen. Also, cold water holds more oxygen than warm water, meaning more oxygen is typically present in the winter than in the summer.

## 3.3 WATER QUALITY STANDARDS FOR DOOR CREEK

In order to determine the potential impact of Door Creek's water quality on Lake Kegonsa, recommended or required water quality standards for temperate streams were compared to our findings. While statements about water quality are included in Wisconsin state law, specific numbers are not provided to define what a healthy level would be for each parameter, instead the criteria are specific to each water body and depend on factors including climate, temperature and land use. In order to evaluate the water quality of Door Creek specific numerical standards were developed using EPA recommendations, USGS records, Wisconsin state law recommendations, and scientific studies.

Water quality is highly variable in different climates, land uses, and geographic features. In order to create recommendations to address these variables, the EPA used ecologic and geologic characteristics to develop a regional approach, known as eco-regions. Door Creek falls within the rivers and streams nutrient eco-region VII, subsection 52, defined as the "Southeastern Wisconsin Till Plains." Based on these regions, EPA established Ambient Water Quality Criteria Recommendations to protect human health and water usability. These recommendations are advisory and help meet the water quality standards consistent with section 303(c) of the Clean Water Act (CWA) (See Section 6.2 for full details).

The Ambient Water Quality Criteria Recommendations (AWQCR) were the primary source used in this project because they are designed for southern Wisconsin streams based on scientific data; also, they are frequently referenced in other State and County recommendations and requirements. These recommendations provide the water quality standards used in this report for TKN, TP, and TN (EPA, 2000). It is important to note that the Ambient Water Quality Criteria Recommendations are not enforceable and do not have the effect of law.

In addition to the AWQCR, there are also enforceable water quality recommendations set by either the EPA or the Wisconsin legislature. These standards include total nitrogen, dissolved oxygen, and total suspended solids because they can pose a significant threat to human or ecological health.

In order to protect human health, section 304(a) of the CWA set the drinking water standard for nitrate at 10mg/L and nitrite at 1mg/L (EPA, 2000). This was to prevent adverse health effects, such as blue baby syndrome, caused by ingesting water containing high levels of nitrogen from nitrate/nitrite. In Wisconsin state law, specific numerical water quality standards have also been developed for dissolved oxygen and total suspended solids in order to promote ecological wellbeing. NR 104 defines specific water quality standards for dissolved oxygen and suspended solids. According to NR 104.02(c), dissolved oxygen should be no less than 5mg/L in streams, lakes, and rivers. This standard is developed to prevent fish stress and mortality that occur in low oxygen conditions (Carpenter, 1998). Total suspended solids (TSS) can also have significant adverse effects on macroinvertebrate communities (Packman, 1999). Therefore, NR 104.03(a) states that TSS should not exceed 30mg/L for a 24-hour period.

Not all water quality parameters have recommended or required numerical levels set by governmental agencies. This is due to the site-specific nature of the parameters, or that they are indirectly included in other recommendations. In order to develop numerical standards for these remaining parameters, temperature and total dissolved phosphorus, and supplemental data collected by the USGS for Door Creek and Little Door Creek, are used. To create recommended values for comparison purposes, these data were analyzed in a manner similar to the EPA data.

Table 3.1 illustrates the water quality parameters used, base standards, and their supporting source.

**Table 3.1: Water quality parameters and base standards used in the analysis of Door Creek.**

| Water Quality Parameter | Standard | Source |
|---|---|---|
| Ammonia | 0.039mg/L | Robertson et al., 2006 |
| Total kjehldahl nitrogen (TKN) | 0.24mg/L | EPA, 2000 |
| Nitrate/nitrite | 10mg/L | EPA, 2000 |
| Total nitrogen (TN)* | 1.88mg/L | EPA, 2000 |
| Total dissolved phosphorus (TDP) | 0.033mg/L | Robertson et al., 2006 |
| Total phosphorus (TP) | 0.08mg/L | EPA, 2000 |
| Dissolved oxygen (DO)* | 5mg/L | DNR, 2004 |
| Total suspended solids (TSS)* | 30mg/L | DNR, 2004 |
| Temperature (average) | 13°C (55.4°F) | Robertson et al., 2006 |

*enforceable standard

## 3.4 SAMPLE SITES AND WATER SAMPLING METHODS

### 3.4.1 SAMPLE SITES

Seven sites were chosen for water quality sampling locations. Five sites (A, B, C, D, and G) were located along the length of Door Creek, and two sites (E and F) were located on Little Door Creek, a tributary stream. The sites were chosen to represent different physical characteristics of the creek and were located based on proximity to USGS sample sites and ease of access, including close proximity to roads and landowner access permission (Figure 3.1).

The Door Creek watershed is dominated by an agricultural matrix. Specifically, sites B, C, D, and E, are located on reaches of the creek that are directly adjacent to agricultural fields (Figure 3-2). Of these, site B is located on a reach of Door Creek that has been significantly altered, physically and directionally, and serves as a drainage ditch along several fields. As a result of these alterations, the creek at this site is directly bordered by agricultural fields with a narrow vegetated buffer present along the banks. Site C features a vegetated bank and is located adjacent to farm pasture. Site D also features a vegetated channel and is primarily bordered by agricultural fields. Site E serves to represent the headwaters of Little Door Creek. Lining the creek are thick grasses and herbaceous species, with some woody species, but the surrounding lands are predominantly used for agricultural crops.

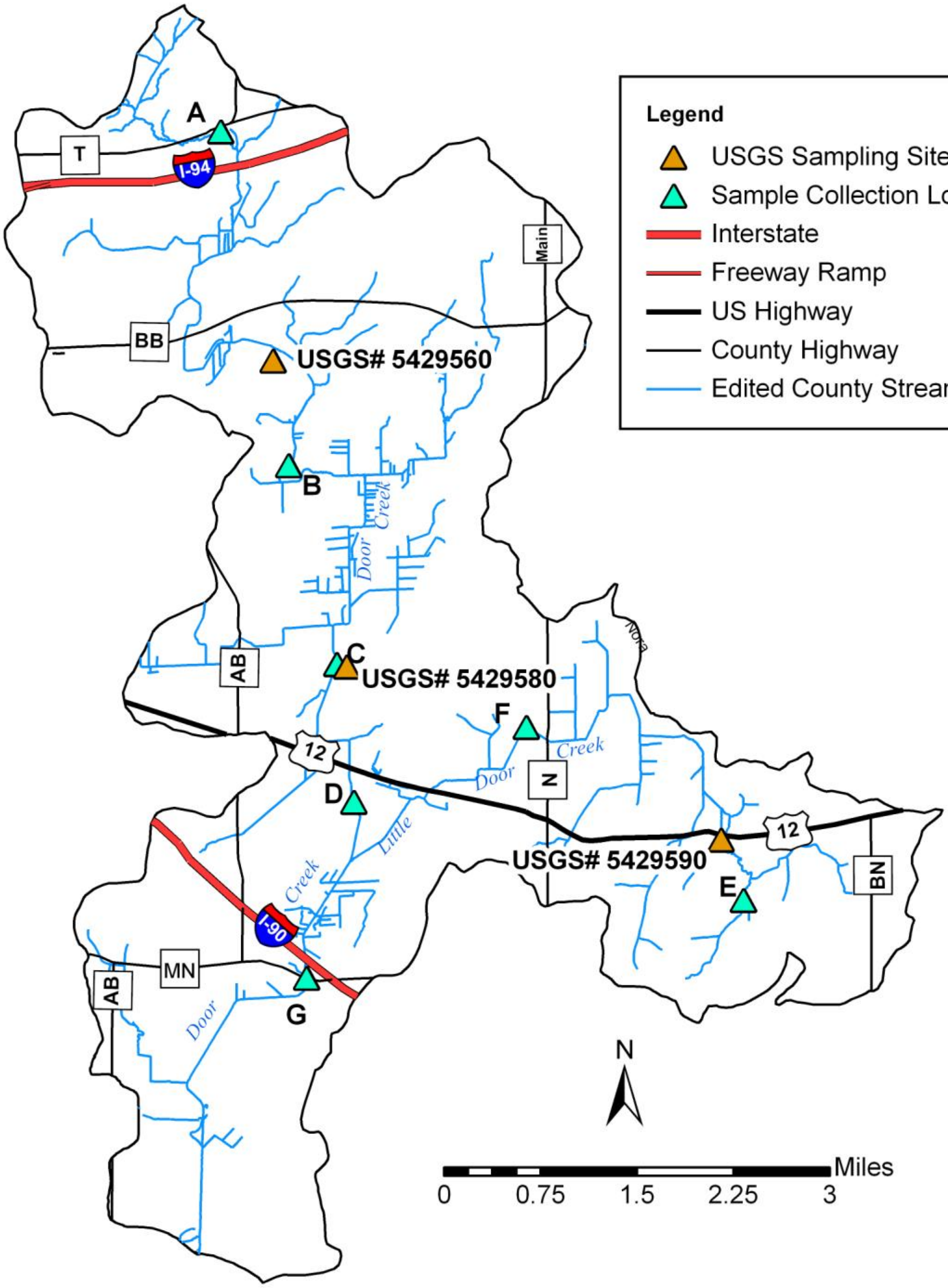


**Figure 3.1: 2009 sample sites and USGS sample sites in the Door Creek watershed.** Source Dane County Streams Layer, 2000, Created August 2009 by WRM practicum.

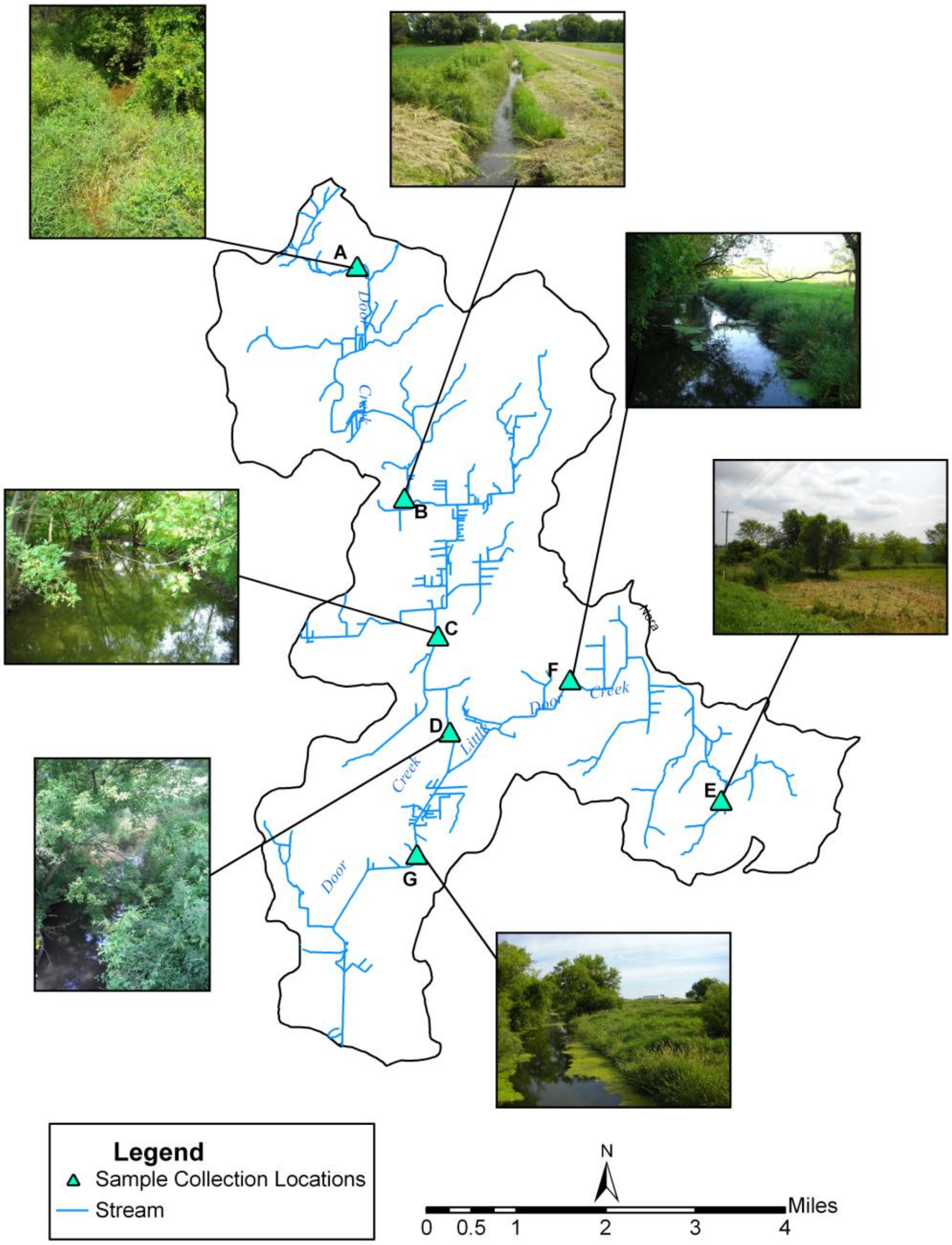


**Figure 3.2: Sample site location and representative photos.** Source: Dane County Streams Layer, 2000, Created February 2010 by the WRM Practicum.

Sites A, F, and G are also impacted by agricultural use, but are located on reaches of the stream that are not flowing directly through agricultural fields (Figure 3.2). Site A, the most northern point of sampling, serves to represent the headwaters of Door Creek. Through GIS analysis, it was determined that at this point of sampling Door Creek drains approximately 787 acres. Site A is located between County Highway T and Seminary Springs Road, and the creek features vegetated banks, with the land surrounding this location primarily wooded and open land. Site F is directly downstream from State Highway 12-18. Similar to site A, it is also surrounded by wooded and open land and has vegetated banks. Lastly, site G represents the most southern point along Door Creek where water samples were taken. This site is adjacent to an Interstate-

90 overpass as well as County Highway MN. The banks are heavily vegetated with grasses and woody species and the surrounding land is primarily open or wooded land cover. It is important to note that sites F and G contain combined flow from Door Creek and Little Door Creek.

### 3.4.2 SAMPLING METHODS

Water samples collected from Door Creek over the period of this study were analyzed by the Wisconsin State Lab of Hygiene. The methods recommended by the State Lab of Hygiene were used for collection and preservation of each sample. Please see Appendix 1 for a full description. For more information or questions on sampling methods please contact the Wisconsin State Lab of Hygiene at (608) 224-6277 or (608) 224-6282.

## 3.5 DOOR CREEK WATER RESULTS AND ANALYSIS

The purpose of this analysis was to determine what concentrations of nutrients and levels of sediment from Door Creek contribute to the current level of eutrophication in Lake Kegonsa. As discussed in Section 3.4, samples were taken from seven different sites along the length of Door Creek and Little Door Creek. Samples were taken to determine baseflow and to observe the effects of storm events before and after fertilizer is applied. Samples were taken in February, March, and May in order to account for temporal variability in water quality. All seven sites were sampled in February and March. and four of the seven sites were sampled in May based on results of nutrient concentrations from the February and March sampling, as well as adjacent land use, geographical location and budget limitations. The results of these samples will be discussed categorically by the type of nutrient or physical parameter that was measured. This allows for trends to be seen spatially at different points in time. All the data presented here are from samples collected by our team between February and May, 2009. Little Door Creek showed the same general trends as Door Creek. Therefore, only Door Creek is represented in the written results. Data from Little Door Creek is available in Appendix 2. Historical data, specifically data collected by the United States Geological Survey (USGS) at USGS Site 05429580, is also available in Appendix 2.

Baseflow concentrations can be defined as specific concentrations of water quality parameters that are maintained by groundwater and exclude human induced inputs (Kalff, 2002). During winter months, cold weather conditions minimize impacts on watersheds from human activities and natural events. As a result, water quality sampling in winter is ideal for determining baseflow concentrations. February typically represents the final month of winter in southern Wisconsin; therefore samples to determine baseflow concentrations were collected at this time. Baseflow concentrations help quantify what effects human activities and natural processes may have on a water system.

To determine what effects human activities have on the Door Creek watershed, we collected samples for rain events occurring prior to and after fertilizer application. These samples were used to quantify the impact of runoff entering Door Creek in the spring, as well as to determine what effect additional nutrients can have on water quality. Our pre-fertilizer sampling occurred March 8th during a 25 year, 12 hour storm event (Huff & Angel, 1992) in which Dane County received approximately 5 inches of a rain, freezing rain, sleet, and snow mixture (NOAA, 2009).

We sampled in March, which is the beginning of spring in southern Wisconsin, because runoff is at or near its peak due to high soil saturation following snowmelt events and because, typically, cropping activities have yet to commence.

Post-fertilizer sampling occurred on May 27th during a 1 year, 2 hour storm event (Huff & Angel, 1992) totaling 1.2 inches of precipitation (NOAA, 2009). May marks the transition from spring to summer and, traditionally, is the first month in which cropping activities can occur because soil moisture has decreased to the point where it can support machinery, thus avoiding rutting and soil compaction. The storm event during which we sampled was the first rain event for a two-week period, indicating that the antecedent moisture condition (AMC) was low and the soil was dry. The AMC is defined as the initial moisture content of the soil prior to a storm event and represents the absorptive capacity of the soil (Mishra, Jain, Surash, Babu, Venugopal & Kaliappan, 2008; Mamedov, Huang & Levy, 2006).

### 3.5.1 NITROGEN

The dominant source of water at baseflow conditions is groundwater. However, some runoff contributions from snowmelt or precipitation may also occur during this time period. In comparing Figure 3.3 to the water quality standards (Table 3.1), all of the nitrogen types exceeded recommended water quality standards at various sample sites during baseflow conditions. Of these, the most startling is the high concentration of nitrate/nitrite at site A. As previously mentioned, the enforceable water quality criterion for nitrate is 10mg/L according to CWA section 304(a). Although there are several potential causes for this high value, the likely culprit is an excessive amount of nitrate-nitrite in the groundwater. Recalling that TN is the summation of nitrate-nitrate and TKN, the high levels of nitrate-nitrate in the groundwater also caused high levels of TN.

High levels of nitrogen in Wisconsin groundwater are not uncommon, particularly in agricultural areas. In fact, 17-26% of wells in agricultural areas of Wisconsin exceed the 10mg/L standard for nitrate (Chern, Kraft, & Postle, 1999). Therefore, in an agricultural setting like the Door Creek watershed, high concentrations of nitrate-nitrite in groundwater are common. Our data confirms that high nitrate-nitrite concentrations were present in the baseflow measurements (Figure 3.3).

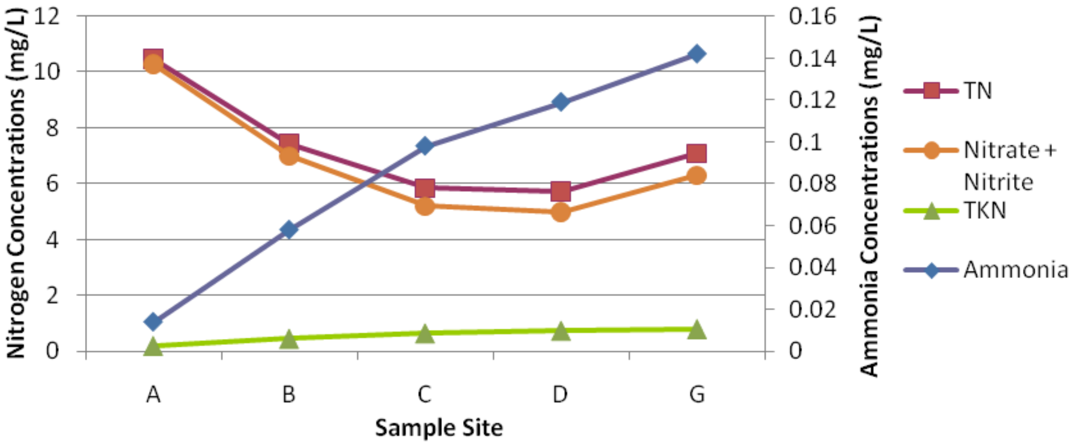


**Figure 3.3: Distribution of nitrogen (N) concentrations of Door Creek during baseflow conditions.** Water Samples collected on February 22, 2009.

As discussed in section 3.2, nitrate-nitrite can easily leach into groundwater. Previous studies have determined that 10% of the total nitrogen added to Wisconsin soils each year leaches to groundwater as nitrate-nitrite (Chern et al., 1999). Over time, the nitrate-nitrite that is leached can build up, which leads to high concentrations of TN in the groundwater. These are the likely reasons that the TN and nitrate-nitrite standards were exceeded.

Spatially speaking, site A yielded the highest TN and nitrate-nitrite concentrations. Of the samples sites, site A was the furthest upstream and drains an area totaling only 787 acres. Proportionally, site A contains the greatest amount of groundwater and is least impacted by snowmelt or runoff. As the drainage area increases, other sources become more significant and can dilute the contribution of groundwater and the inputs of nutrients from groundwater. Therefore, the overall concentration of TN and nitrate-nitrite decreases as the drainage area increases, which can be seen in Figure 3.3. Ammonia and TKN illustrate the opposite trend spatially, meaning they increase as the drainage area increases. This is likely because snowmelt or soil particles entering the stream contain ammonia. This increase in ammonia directly increases the TKN because TKN is the sum of organic nitrogen and ammonia.

To validate the data in Figure 3.3, the nitrogen concentrations collected at sample site C were compared to their respective historic concentrations for Door Creek (see Appendix 2 more information on historic data). Site C was the basis for this comparison because it was the site closest to USGS sample site 05429580. In comparing the data in Table 3.2, all the results found in the baseflow measurements were within their historical ranges.

**Table 3.2: Comparison of nitrogen data collected in 2009 to the respective historical averages provided by the USGS.**

| | 2009 Results, Site C | Historical Average | Historical Range |
|---|---|---|---|
| **Nutrient** | **mg/L** | **mg/L** | **mg/L** |
| TN | 5.84 | 4.83 | 4.0-5.9 |
| TKN | 0.64 | 1 | 0.34-2.0 |
| Nitrate-Nitrite | 5.2 | 3.48 | 3.2-5.2 |
| Ammonia | 0.098 | 0.48 | 0.09-0.97 |

Therefore, the data in this study was authenticated. Nitrogen concentrations and distributions significantly change during a storm event (Figure 3.4).

As mentioned, sampling took place during a 25-year, 12-hour storm event and occurred prior to spring farming activities. Most surprising from the sampling during this storm event is that the concentration of TN was cut in half, decreasing from approximately 10mg/L to 5mg/L. Another difference is that TKN and nitrite-nitrite contribute equally to the concentration of TN.

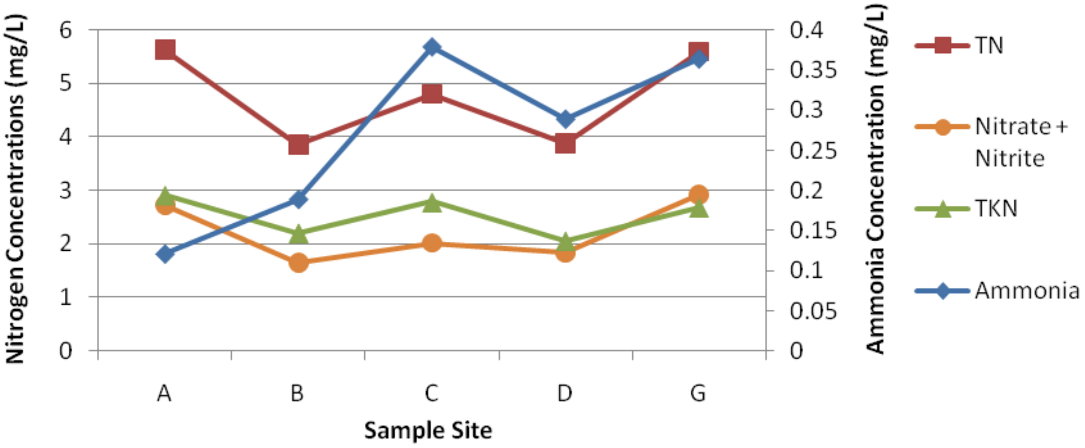


**Figure 3.4: Distribution of nitrogen (N) concentrations during a large storm event prior to farming activities.** Water samples collected on March 8, 2009.

There are two primary explanations for these differences. As mentioned, nitrate-nitrite from groundwater contributes large amounts of TN to Door Creek. However, in a storm event, runoff mitigates the inputs from groundwater, thus decreasing the nitrate/nitrite and TN concentrations. The increased flow volumes resulting from this storm event likely caused this proportionate increase of TKN. Independent research has shown that as flow increases in a stream, sediment loading intensifies, as does the amount of benthic sediment in suspension. Benthic, or bottom, sediment is typically high in organic matter (Cooper, 1983). Therefore, disturbing and releasing this organic, nitrogen-rich benthic sediment likely caused the increase in TKN concentration. The increase seen with TKN was also supported by the doubling concentration of ammonia. Sources of ammonia include atmospheric deposition and land runoff (Srinivasan, Hoffman, Wolfe, & Prcin, 2008); and, because the ammonia concentration increases downstream, land runoff containing ammonia is likely to be the leading cause for this increase. Note that both the baseflow and storm event cases illustrate this trend of increasing downstream ammonia, and further support the conclusion that ammonia concentrations increase with greater drainage area.

In comparing the nitrogen concentrations in Figure 3.4 to their respective standards, TKN and ammonia exceeded their standards, while total nitrogen and nitrate-nitrite did not. It is important to note that the trends found in Figure 3.4 were not supported by historical data. The historical data collected by the USGS in Appendix 2 were taken during low flow periods. Consequently, storm event trends have not been well documented in Door Creek. Therefore, we have collected this data to establish the changes of nitrogen concentrations during storm events.

The nitrogen concentrations from the May storm event, occurring after fertilizer application, demonstrate similar trends to the February sampling (Figure 3.5). These trends include high TN concentrations, particularly at site A; TN dominated by nitrate-nitrite; and lower TKN and ammonia concentrations. There are two possibilities for the similarity in trends between the baseflow and post-fertilizer samples. The primary reason is that the 1.2 inches of precipitation was likely absorbed by the soil. This can be explained by the fact that the storm event during which we sampled was a small one-year event, following two weeks of minimal precipitation. As a result, during the time of this storm event, the antecedent moisture condition (AMC) was probably low, which means the absorptive capacity of the soil was high. For these reasons, the majority of the rainfall was likely to be absorbed by the soil, making land runoff less likely. Since it is probable that minimal runoff reached Door Creek during this storm event, the May samples could reflect those collected in February. This theory is supported by independent research, which shows that when the AMC is low in the soil, runoff from agriculture fields does not make its way to streams (Mishra et al., 2008). Given this theory, applying fertilizer during dry, low AMC soil conditions could prove beneficial in minimizing erosion of nutrient laden soils.

The other possibility to the trends illustrated in Figure 3.5 is that farming practices, fertilizer applications, and manure spreading could have increased the amount of nitrate-nitrite entering the stream. This could account for the large increase in nitrate-nitrite found during this storm event. This is not as likely, however, due to the fact that this was a small-scale rain event. Further research is needed to determine which theory is most likely and to quantify the specific effects of farming practices on the water quality of Door Creek.

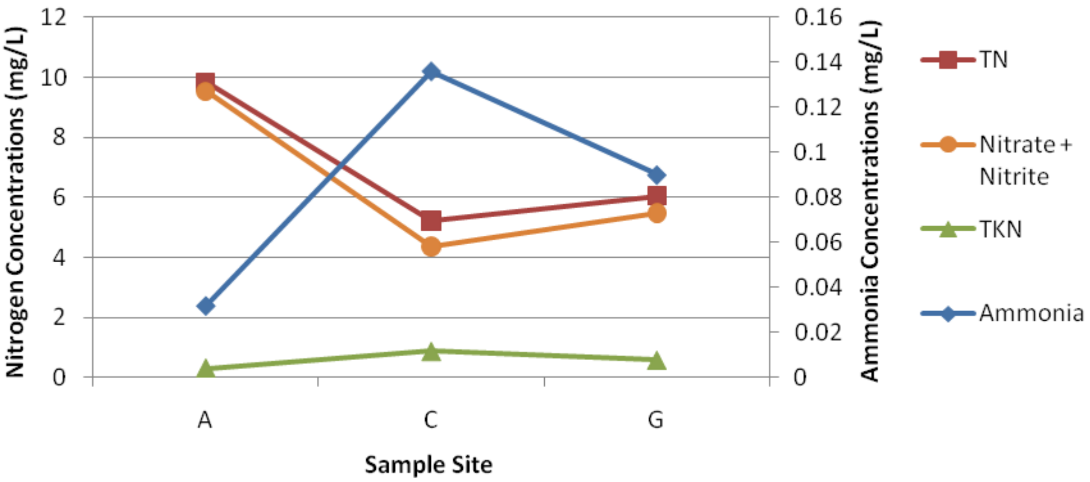


**Figure 3.5: Distribution of nitrogen (N) concentrations during a small storm event after farming practices have occurred.** Water Samples collected on May 27, 2009

### 3.5.2 PHOSPHORUS

As discussed in 3.2, phosphorus is an element that is typically bound to soil, making it difficult to leach into groundwater (Havlin et al., 2005). During baseflow conditions, this study found that total phosphorus typically increased moving downstream. As previously stated, groundwater is the dominant source of water to Door Creek during baseflow conditions. As the drainage area increases, however, additional amounts of snowmelt and runoff, which can carry sediment-bound phosphorus, are more likely to enter the stream. Figure 3.6 illustrates the impact of these inputs to Door Creek by showing that TP increases with drainage area. In addition, a comparison of this distribution to the recommended values for TP shows that site D and G exceed the recommended standard of 0.08mg/L.

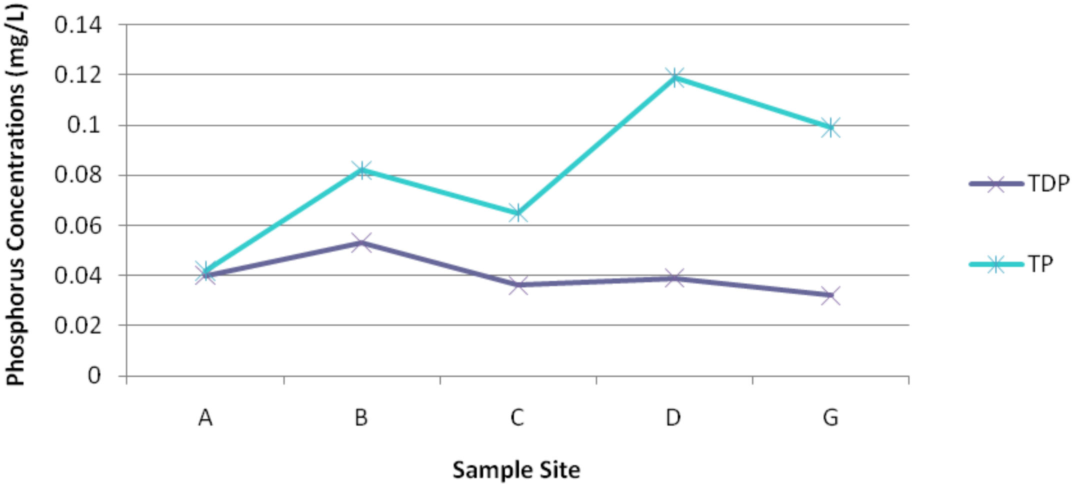


**Figure 3.6: Distribution of phosphorus (P) concentrations of Door Creek during baseflow conditions.** Water Samples collected February 22, 2009.

Although TP increased as the drainage area increased, the concentration of total dissolved phosphorus appeared to be unaffected by drainage area. Total dissolved phosphorus represents the amount of phosphorus that is readily utilized by plants, not the phosphorus that is incorporated in plants or animals. Therefore, one theory is that primary producers are consuming enough dissolved phosphorus to keep the concentration relatively consistent at all seven sample locations. In order to determine the validity of these conclusions and results, the concentrations of total phosphorus and dissolved phosphorus were compared to their respective historical data, provided by the USGS. Based on this comparison, both TP and TDP were within their historical ranges Table 3.3.

**Table 3.3: Comparison of the phosphorus data collected in 2009 to the respective historical averages provided by the USGS.**

| | 2009 Results, Site C | Historical Average | Historical Range |
|---|---|---|---|
| **Nutrient** | **mg/L** | **mg/L** | **mg/L** |
| **Total Phosphorus** | 0.065 | 0.046 | 0.07-0.52 |
| **Total Dissolved Phosphorus** | 0.036 | 0.027 | 0.03-0.38 |

Interestingly, phosphorus concentrations, from samples collected during the pre-fertilizer storm event in March (Figure 3.7), increased ten-fold compared to samples of the February baseflow measurements (Figure 3.6).

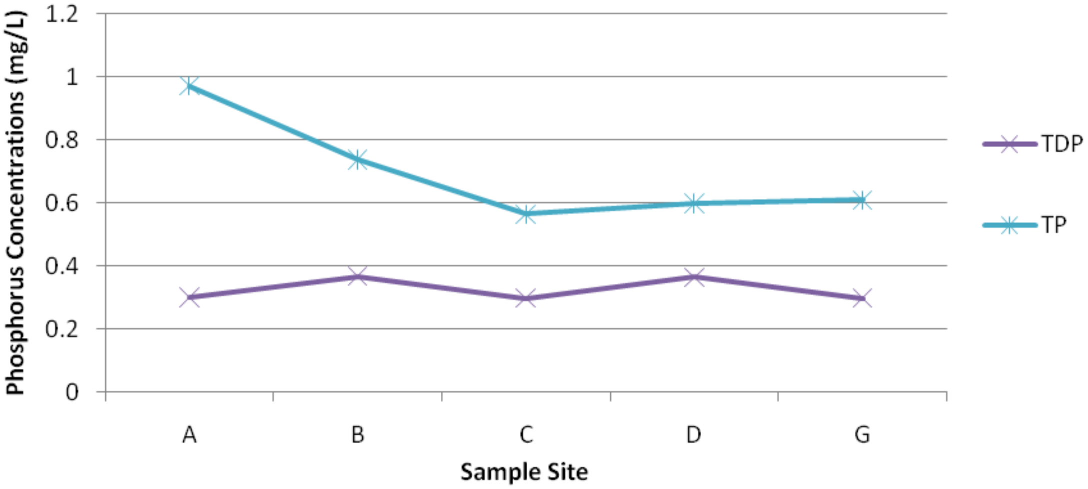


**Figure 3.7: Distribution of phosphorus (P) concentrations during a large storm event prior to farming activities.** Water Samples collected on March 8, 2009**.**

These results are supported by previous studies conducted by Sharpley et al. (2008) and Srinivasan et al. (2008), which have found that storm events significantly increase the amount of phosphorus loading to streams. This research has also found that the amount of soil loss, phosphorus loading, and storm size are directly related. Therefore, as storms become more intense, more phosphorus typically enters a stream. In fact, in some agricultural areas it has been shown that P loading during storm events made up 80% of the total P entering the stream over a 9-year period (Sharpley et al., 2008). Therefore, the high concentrations of TP and TDP during this storm event likely made up the majority of P loading to Door Creek. This loading also has significant implications to the Yahara Lakes, a system that is typically thought to be phosphorus limiting (Lathrop, 2008).

Spatially speaking, TP decreases at Sites A, B, and C before flattening; TDP, on the other hand, remains relatively constant (Figure 3.7). One explanation for this could be that a large flux of phosphorus entered the stream at site C and was diluted as more stormwater entered the stream. Despite this mild dilution, TP and TDP exceeded their standards at all sites. Unfortunately, this data could not be authenticated because the historical data provided by the USGS was only taken during low flow conditions. Therefore, more data should be collected during storm events to determine the concentration of phosphorus during storm events.

Similar to the nitrogen trends, the abundance of phosphorus in Door Creek during the post-fertilizer small storm event in May is similar to the baseflow concentrations from February. This is most likely because the precipitation from this small, one-year event was absorbed due to the low AMC when the storm occurred. As previously discussed, independent studies have shown that when the AMC is low in the soil, runoff from agriculture fields is less likely to make its way into a stream (Mishra et al., 2008). Therefore, the soil and the phosphorus bound to soil particles are also less likely to enter the stream. For these reasons, further research should be conducted in order to better determine what effects farming practices have on P loading during large storm events when P loading is most like to occur.

Although inconclusive, the phosphorus concentration at site C in Figure 3.8 may begin to illustrate some of these effects.

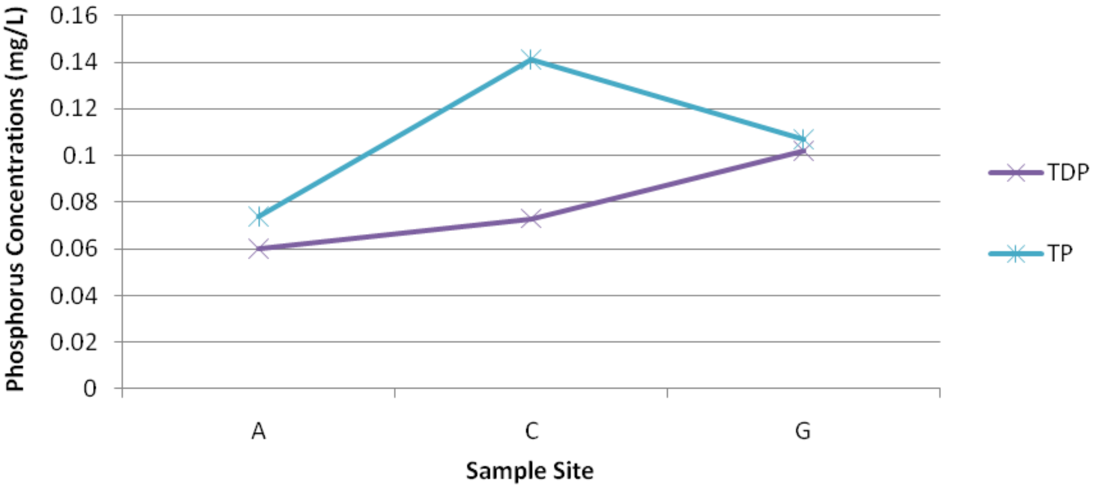


**Figure 3.8: Distribution of phosphorus (P) concentrations during a small storm event after farming activities.** Water samples collected May 27, 2009.

In comparing the trends in Figure 3.8 to Figure 3.6, there is a slight elevation in the TP concentration at site C. Some marginal erosion from an adjacent pasture may have caused this increase. Previous studies have found that areas where soil P levels are allowed to build up, or areas where soil disturbances occur, typically contribute the majority of the phosphorus loading to streams, particularly during storm events (Sharpley et al., 2008, Carpenter et al, 1998). Therefore, areas like pastures, feedlots, and construction sites can be critical areas for phosphorus loss and can lead to serious water quality issues. To help protect Wisconsin waterbodies from these effects, NR 151 (see Chapter 6 for more information on NR 151) was developed to regulate runoff from farming practices, livestock sources, construction activities, and urban sources (WDNR, 2004b). It is important to note that although this legislation is a good tool in helping prevent excessive phosphorus loading, direct runoff from fields and pastures are not addressed.

### 3.5.3 LIMITING NUTRIENT DETERMINATION

The limiting nutrient is that which inhibits the growth of primary productivity. Identifying the limiting nutrient of a waterbody is a key component to developing successful and focused management strategies. In most lakes, phosphorus is the limiting nutrient (Lathrop, 2007). In these cases, management strategies that directly reduce the amount of phosphorus loading will be successful in reducing the amount of primary productivity within these waterbodies.

The N:P ratio is used to determine the limiting nutrient. The N:P ratio is the concentration of total nitrogen divided by the total phosphorus concentration. If the N:P ratio is greater than 10, phosphorus is limiting; if it is less than 10, nitrogen is limiting (Lewis & Wurtsbaugh, 2008). For Door Creek, it appears that both N and P can be limiting, depending on the time of year (Figure 3.9).

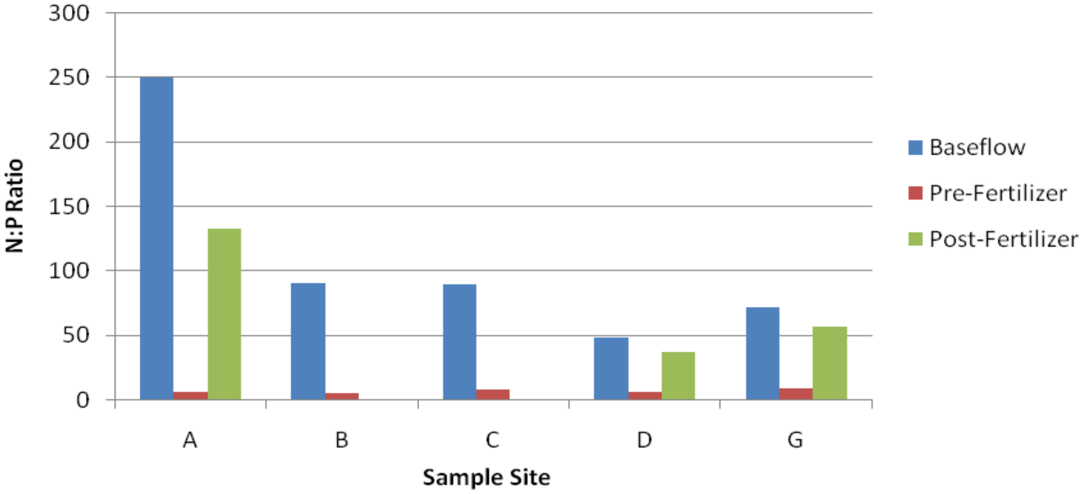


**Figure 3.9: Spatial distribution of the liming nutrient for Door Creek and its fluctuations during the February, March and May samplings**

As mentioned, the February and May samples represented baseflow and small rainfall events, respectively. During these periods, phosphorus is the limiting nutrient. However, in a large storm event, such as the March storm, the influx of phosphorus from soil erosion switches this system to be nitrogen limiting. Based on this analysis, as well as the data described in 3.5.2, it appears that Door Creek can be a source of both nitrogen and phosphorus to Lake Kegonsa.

### 3.5.4 SUSPENDED SOLIDS, TEMPERATURE AND DISSOLVED OXYGEN

Suspended solids (SS), temperature, and dissolved oxygen (DO) are physical parameters that can be used to assess the health and water quality of Door Creek. These three parameters show related trends based on different sampling times and places.

**Table 3.4: Suspended solids from Door Creek during a 25-year rain event in March and a 1-year rain event in May, measured in mg/L.**

| Site | Pre-Fertilizer: March | Post-Fertilizer: May |
|---|---|---|
| **A** | 484 | 7 |
| **B** | 196 | No Data |
| **C** | 35 | No Data |
| **D** | 35 | 26 |
| **G** | 78 | 12 |

Suspended solids, in particular, showed drastic differences between the pre-fertilizer storm event in March and the post-fertilizer storm event in May. As mentioned previously, the storm in March was a 25-year storm event while the storm in May was a 1-year storm event, and was also the first storm event following a two week period of no rain. In comparing the samples from the March and May storm events, the difference in SS in Door Creek is significant (Table 3.4).

NR 104.03(a) states that TSS should not exceed 30mg/L for a 24-hour period (Table 3.1) (WDNR, 2004a). Erosion that can occur during large storm events has potential to contribute large amounts of nutrients and sediment to water systems, such as Door Creek. Consequently, TSS from Door Creek could be leading to sedimentation, contamination, nutrient loading, and decreased oxygen concentrations within Lake Kegonsa. Remember, NR 151 was developed to regulate runoff from farming practices, livestock sources, construction activities, and urban sources (WDNR, 2004b). It is important to note that, although this legislation is a good tool in helping prevent excessive TSS, direct runoff from fields and pastures is not addressed.

Temperature and DO are inversely related. As temperature increases, DO decreases, as can be seen in comparing Figure 3.10 and Figure 3.11.

This can be explained by the fact that colder water is able to hold more DO than warmer water. As air temperatures increase, the water temperature of Door Creek also increases, resulting in lower DO concentrations. Additionally, storm events, land use practices and increased decomposition all contribute to decreased levels of DO (Bilotta & Brazier, 2008).

During baseflow sampling, temperature ranged from 0.8°C (33.4°F) to 6.1°C (43°F). Data were not recorded for the pre-fertilizer storm event in March. In May, temperatures ranged from 11.5°C (52.7°F) to 14.4°C (58°F). Additional temperature readings were taken in August as a way to compare historical summer temperatures to current summer temperatures. Our measurements ranged from 13.4°C (56°F) to 20.8°C (69.4°F) (Figure 3.12).

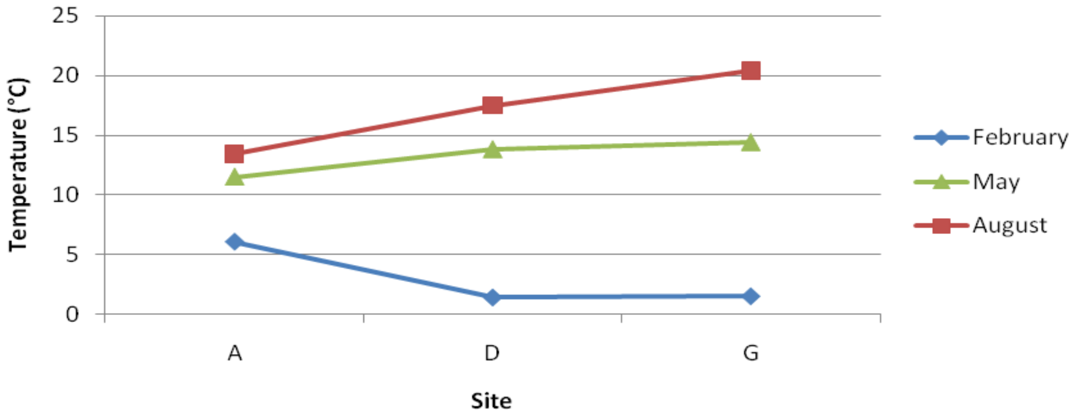


**Figure 3.10: Water temperature measurements for Door Creek, moving downstream; during winter, spring, and summer.**

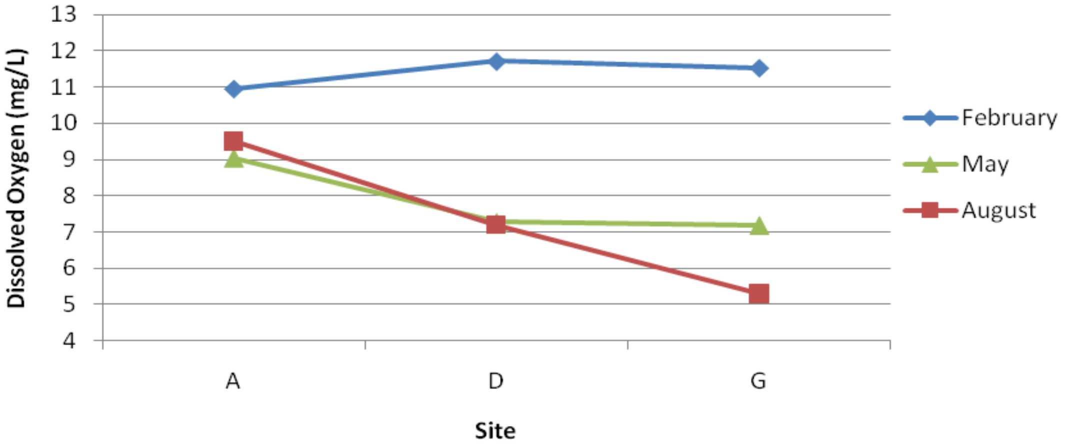


**Figure 3.11: Dissolved Oxygen measurements for Door Creek, moving downstream; during winter, spring and summer.**

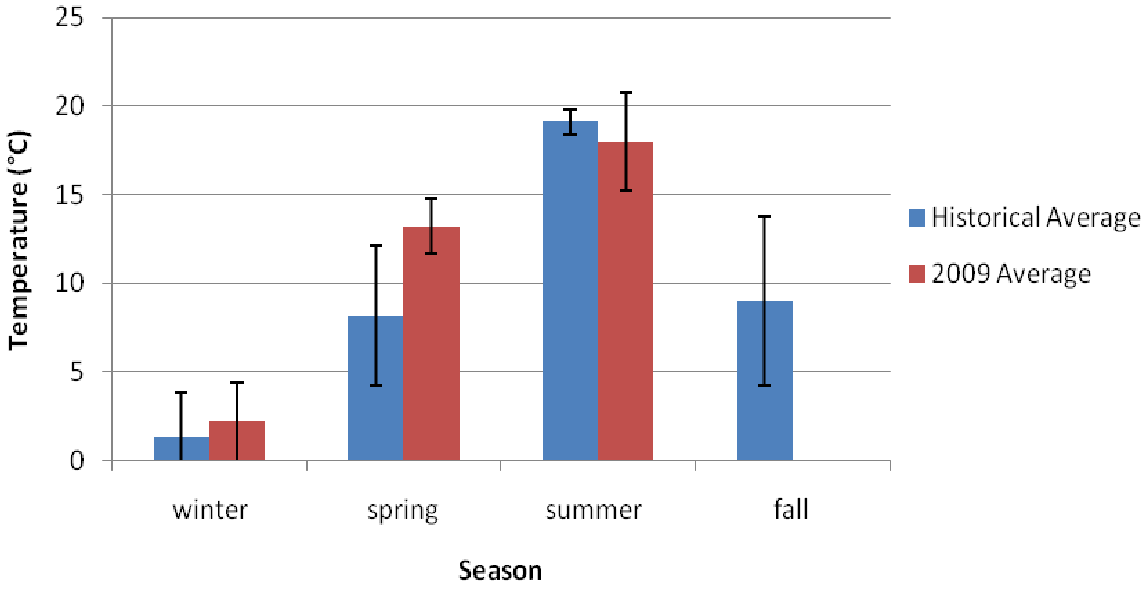


**Figure 3.12: Comparison of Seasonal average temperature in Door Creek.**

Along with seasonal variability, runoff may also contribute to higher temperatures in Door Creek. Although Door Creek is mainly fed by groundwater, water temperatures rise downstream (Figure 3.10) where more land area is contributing to the amount of runoff to Door Creek (Table 3.5).

Dissolved oxygen data we collected during baseflow ranged from 10.95 mg/L to 11.99 mg/L. Data were not recorded for the pre-fertilizer storm event in March. In May, DO ranged from 7.19 mg/L to 9.04 mg/L. We also measured DO in August to compare historical summer DO levels to current levels (Figure 3.13).

**Table 3.5: Approximate land area draining into Door Creek at each sample site.**

| Site | Drainage Area (ac) |
|---|---|
| A | 787 |
| B | 4,525 |
| C | 9,236 |
| D | 10,540 |
| G | 16,133 |

In August, DO dropped as low as 5.3 mg/L and rose as high as 9.5 mg/L. According to the Wisconsin DNR, DO should not drop below 5 mg/L (Table 3.1). The summer average is approximately 5.7 mg/L. Runoff and erosion may also affect DO levels. Moving downstream, DO levels decrease as more runoff is contributed to the stream (Figure 3.13).

In summer, temperatures in Door Creek rise significantly past the average base standard of 13°C (55.4°F) and DO drops surprisingly close to the lowest recommended level of 5 mg/L. Increased temperatures and increased TSS from runoff containing nitrogen and phosphorus may lead to more frequent and more intense algal blooms. These algal blooms increase decomposition, which plays a key role in decreased DO and may lead to fish kills. Reducing direct runoff from fields and pastures may help reduce increasing water temperature and decreased DO, especially in the summer months when these issues pose the largest threat to water quality in Door Creek and Lake Kegonsa.

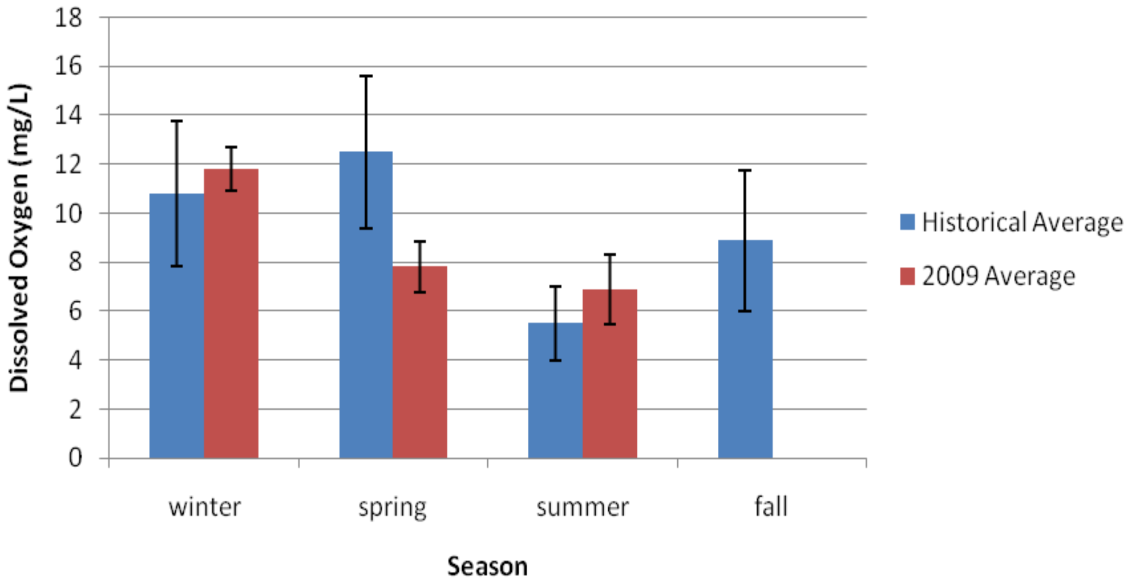


**Figure 3.13: Comparison of Seasonal trends for Dissolved Oxygen in Door Creek.**

## 3.6 CONCLUSIONS AND RECOMMENDATIONS

### 3.6.1 CONCLUSIONS

Our research found that nitrogen is high during baseflow conditions, phosphorus dramatically increases during storm events, and temperature and dissolved oxygen may be problematic during summer months. Based on these findings, we concluded that both nitrogen and phosphorus can be limiting, depending on the time of year. Therefore, both of these nutrients must be managed in order to reduce the amount of primary productivity within Door Creek and, subsequently, Lake Kegonsa.

### 3.6.2 RECOMMENDATIONS

We have come up with three main recommendations based on the results and analysis of our data. These recommendations are:

- Continue monitoring storm events following fertilizer application within the watershed
- Decrease soil erosion entering Door Creek by expanding NR 151-2 to include direct runoff from fields
- Prevent application of fertilizer or manure when the soil is wet or the AMC is high

## CHAPTER 4:

# LAND USE ANALYSES

## OVERVIEW

Land use and management practices have a significant impact on nutrient runoff to Door Creek and Lake Kegonsa. This chapter provides a comprehensive analysis of land use practices in the Door Creek watershed that could potentially impact water quality. Based on their extent, we identified agricultural and urban land use as the two primary categories. These are subdivided into more specific uses in order to provide a complete analysis of potential nutrient sources in the watershed.

Section 4.1 provides a description of common farming practices in the Door Creek watershed and how they impact soil erosion and water quality. This section also includes a discussion of results from our comprehensive study of phosphorus runoff from agricultural lands that was conducted using SNAP-Plus nutrient management software.

Sections 4.2 and 4.3 analyze two agricultural practices that are often overlooked from a nutrient contribution standpoint. Section 4.2 investigates the impacts of pastures where livestock are actively grazed, often on poorly-protected soils with high soil phosphorus content. Section 4.3 summarizes a literature review that was conducted on agricultural drain tiles and their potential for transporting phosphorus and nitrogen to downstream waterways via preferential flow paths.

Section 4.4 provides an analysis of the Madison Metropolitan Sewerage District (MMSD) Metrogro municipal biosolids application program. Through this program, MMSD provides nutrient-rich biosolids from its municipal waste treatment plants to participating farms. The MMSD Metrogro Analysis examines both MMSD's application procedures and potential regulatory changes that could help reduce nutrient runoff.

Section 4.5 investigates nutrient runoff from urban areas and active construction sites. The potential impacts of urban stormwater runoff are identified, and relevant state and local regulatory policies are discussed. For active construction sites, Dane County's erosion control ordinance is assessed in terms of its ability to control nutrients present in the soil prior to construction. Finally, this section also investigates the Rodeville Site 2 landfill, private septic systems, and a golf course located in the watershed.

## 4.1 AGRICULTURAL PRACTICES

### 4.1.1 AGRICULTURAL RUNOFF AND FARMING PRACTICES IN THE DOOR CREEK WATERSHED

Non-point source pollution is one of the major contributing factors to water quality issues in Wisconsin. The US Environmental Protection Agency (US EPA) defines non-point source pollution as pollution that comes from diffuse sources, as opposed to industrial end-of-pipe discharge, and is caused by rainfall or snowmelt moving over and through the ground (US EPA, 2006a). Due to the state's widespread agricultural land use, a variety of applied chemicals, nutrients, and other substances may be discharged into surface and groundwater resources. Some common contaminants from farmed and pastured lands include sediment; pathogens; pesticides; herbicides; and excess nutrients from sources like municipal biosolids, commercial fertilizer and manure (Carpenter et al., 1998; NMS of NPAPR, 1999).

The state governs agricultural runoff primarily through Natural Resource (NR) 151, although there are many other NR rules that are applicable as well (for more information on these laws see Chapter 6). NR 151 sets pollution performance standards and prohibitions for agricultural facilities in order to meet water quality requirements (Wis. Admin. Code § NR 151). Because agricultural land use in the Door Creek watershed amounts to greater than 50% of its total area, it is important to examine the potential effects that agricultural runoff may have on the overall water quality of both Door Creek and the stream's receiving water body, Lake Kegonsa.

#### 4.1.1.1 IMPACTS ON RECEIVING WATER BODIES

According to the Wisconsin Department of Natural Resources (WDNR), non-point source pollution has multiple negative effects on lakes and streams (WDNR, 2009a). For example, when nitrogen and phosphorous enter surface water, they may increase the frequency of algae blooms (Carpenter et al., 1998; Anderson, Glibert, & Burkholder, 2008). Algae blooms decrease the amount of sunlight reaching aquatic plants, which negatively affects aquatic vegetation. The oxygen used by algae as they die and decay reduces the amount available for other aquatic life and can have a devastating impact on fish populations (Anderson, Glibert, & Burkholder, 2008).

Although nitrogen and phosphorous are naturally found in the environment, excess amounts from manure, sludge, or fertilizer spread on farm fields; runoff from barnyards; or runoff from inadequate manure storage facilities can dramatically increase the presence of these nutrients beyond natural levels. In the Door Creek watershed, additional phosphorous, which is found in runoff that enters streams, encourages algae blooms and elevated plant growth (Carpenter et al., 1998; Anderson, Glibert, & Burkholder, 2008). Phosphorous runoff may increase during storm events, especially if flooding occurs (see Chapter 2 for water quality data related to storm events and Chapter 6 for information pertaining to floodplain rules and regulations). Nitrogen, which can come from manure, sludge or commercial fertilizers, is another essential nutrient for plant growth. Nitrogen does not bind to soil particles like phosphorous does, so it can filter down through the soil and contaminate groundwater, which, when ingested, can cause health concerns such as blue baby syndrome, thyroid disease, and, in extreme cases, some cancers (for more information on these health concerns see Chapter 2) (Nolan, Hitt, & Ruddy, 2002; USGS, 2008a). According to the Department of Agricultural, Trade and Consumer Protection

(DATCP), approximately 23% of wells in Dane County do not meet the drinking water standards (DATCP, 2008). The Door Creek watershed has many homeowners that use private wells that can be affected by groundwater contaminated by bacteria, pathogens and high nitrogen levels (Seely, 2009). There are multiple private wells in the Door Creek watershed and Dane County that exceed the nitrate drinking water standard of 10mg/ l (Figure 2.10).

Several of the lakes in the Yahara Chain of Lakes are currently on the US EPA's 303d list of impaired waters, which means that they do not meet Wisconsin’s water quality standards. While multiple components combine to cause the degraded water quality, agriculture plays a significant role (Lathrop, 2007). Due to the number of impaired water bodies in the region, the Wisconsin DNR is currently in the process of considering the creation of a Total Maximum Daily Load (TMDL) for the larger Rock River watershed. If the TMDL were approved, new efforts would need to be employed to reduce nutrient loading from agricultural fields like those found in the Door Creek watershed (WDNR, 2009b). These may include using nutrient management, riparian buffers, and other best management practices. Nutrient management, which will be discussed in more detail below, can play a critical role in reducing nutrient loading in the Door Creek watershed.

#### 4.1.1.2 Managing Agricultural Runoff through Different Management Practices

In Wisconsin, all farmers face the challenge of maintaining maximum crop yields while protecting natural resources. To accomplish this, farmers can modify tillage practices and crop rotations and install best management practices, such as buffers and grassed waterways. Comprehensive nutrient management planning provides an effective tool for developing overall strategies.

*Tillage*

Tilling the soil is done in order to provide weed management, prepare the soil for planting, and to incorporate manure for fertilization. The tillage practice will affect the physical and chemical properties of the soil, which in turn affect plant growth and yield. A common way of defining a tillage method is by describing the amount of residue that is left on the field after planting. Conventional, reduced, and conservation tillage are the three broad categories used in Wisconsin, and the percentage of residue cover determines the category for each practice (Table 4.1) (UW-Extension, 2005).

The primary reasons for leaving crop residue on the field are to protect the soil from erosion and to reduce runoff. In addition to conserving soil and protecting water quality, crop residue also serves to fertilize the soil with the nutrients released as the residue decays. According to soil conservationist Duane Wagner at the Dane County Land Conservation Office, farmers in Door Creek watershed are good soil conservationists. Around 75% of the fields are mulch-tilled, 20% no-tilled, and the remaining 5% are conventionally tilled with a moldboard plow (D. Wagner, personal communication, July 1, 2009).

**Table 4.1: Differences between main categories of tillage practices.**

| Tillage practice | Residue cover after planting (%) | Soil disturbance | Type of equipment |
|---|---|---|---|
| Conventional tillage | < 15 | Intensive | Moldboard plow, tandem disk, field cultivator, harrow |
| Reduced tillage | 15-30 | | Chisel plow |
| Conservation tillage | > 30 | | |
| No-till | | Undisturbed except for planting or nutrient injection, narrow seedbed | Coulters, row cleaners, disk openers |
| Ridge-till | | Undisturbed, except for weed control and planting on seedbed ridges | Sweeps, coulters, disk openers, row cleaners or cultivators |
| Mulch-till | | Full width, before planting and for weed control | Chisels, field cultivator, disk |

There are advantages and disadvantages to each tillage method. From a soil and water conservation perspective, erosion reduction is the main advantage of conservation tillage. It is estimated that this method reduces erosion by 50 percent or more when compared with conventional tillage practices (Uri, 1999). On the other hand, conventional tillage incorporates the applied nutrients into the soil making them readily available for plant uptake and possibly less prone to leach to the groundwater (Gupta, Munyankusi, Moncrief, Zvomuya, Hanewall, 2004). Another benefit of conventional or reduced tillage is weed control. Deeper tillage disturbs and breaks up the root system of unwanted plants keeping the weed pressure down. Conservation tillage, on the other hand, has to rely on herbicides to a greater extent (UW-Extension, 2005).

**Figure 4.1: Example of No-till Tillage practice.** (Photo by Erin Oost).

### *Fertilizer Application*

Supplying growing crops with nutrients, such as phosphorous, nitrogen, and potassium, is necessary to reach desirable yields. To minimize the risk of over-application of nutrients, it is important to regularly test soil nutrient levels. In addition, methods for applying fertilizer and manure to the fields can be modified in order to reduce the amount of nutrients that end up in nearby waters.

Fertilizer is applied at different times during the growing season. Early application helps the crop to get a fast start in the spring and additional applications later in the season may be necessary for maximum yields, depending on the crop. Commercial fertilizer can be applied by different methods. The most frequently used application method in the Door Creek watershed is broadcast application. In this method, fertilizer is evenly distributed to the soil surface. Fertilizer can also be applied under the soil surface or on top of the row.

The application rates are usually based on average soil test levels. Up-to-date soil testing is important in order to avoid over-application. If farmers are participating in a nutrient management program, they are required to test their soils every three years. However, the recommended application rates are based on average soil test levels, which mean that some parts of the field might receive higher amounts of nutrients than needed. An effective, but expensive, method to avoid over-application to fields is to use variable rate spreading technology that adjusts the application rate based on precise soil nutrient levels and GPS positioning (UW-Extension, 2005).

Although in lower quantities, farms with livestock usually spread manure on their field in addition to applying commercial fertilizer. It is difficult to quantify manure application rates in the Door Creek watershed. The Practicum conducted interviews with farmers that revealed inconsistency in spreading patterns and date of application. Manure applications can be flexible but there are both State and County restrictions on application dates and rates (see chapter 6 for more information).

Methods for spreading manure depend on if the manure is in liquid or solid form. Box spreaders are used for solid manure while tanker trucks are used for spraying or injecting liquid manure into the soil. It is important to have the spreader or tank calibrated in order to determine the spreading rate and avoid over-application.

### *Crop Rotations*

Farm fields on which crops are grown can be protected from erosion and nutrient runoff by using crop rotation and residue management. Crop rotation can reduce soil erosion and save fertilizer costs by using nitrogen-fixing legumes. Kanwar, Colvin and Karlen (1995) compared the nutrient losses from different cropping rotations. They found that the losses were greater under continuous corn than under a corn and soybean rotation.

The type of farm ultimately determines what crop rotation the producer might choose. A farm with no livestock usually does not include grass hay or alfalfa in the rotation plan unless there are nearby farms with livestock that would want to buy it. The Door Creek watershed does have some farms that integrate livestock. An example of a rotation for these farms would be four years of continuous alfalfa initially planted with a nurse crop, such as oats used for forage, followed by one year of corn grain and one year of soybeans. Farms with dairy production usually grow winter wheat that is used for feed. In the areas where alfalfa is not grown, the fields typically rotate between corn grain and soybeans, along with occasional winter wheat.

In addition to modifying agricultural practices, other conservation methods are available which can help to achieve better water quality. The following are some of the most common techniques of mitigating agricultural runoff as described in *Farmland Conservation Choices; A guide to Environmentally Sound Practices for Wisconsin Farmers,* produced by the US Department of Agriculture (USDA) in cooperation with others (USDA et al, 1998).

- Contour Buffer Strips: Grass strips that are placed to inhibit runoff flow into streams and decrease its speed in order to reduce erosion.

- Contour Strip Cropping: Strips of alternating crops, for example alfalfa and corn, which follow the land contours and slow runoff and decrease erosion.

- Field Borders/Grass Waterways: Areas around the field or in natural drainage paths where perennial or grass vegetation is planted in order to trap sediments and also to potentially absorb chemicals and nutrients from runoff.

- Water and Sediment Control Basins: Earthen embankments that trap water and sediment. Basins release water slowly, reducing gully erosion and sedimentation to nearby waters.

- Terraces: Man-made ridges to decrease erosion that are built in areas with steep slopes and function like small dams to trap and divert water to a more stable outlet.

### 4.1.2 SNAP-Plus Model Purpose and Methods

The purpose of the general agricultural practice SNAP-Plus model is to identify field conditions and farming practices that have a high potential of contributing excessive nutrient loadings to Door Creek. Dane County has a limited amount of personnel and monetary resources to devote to agricultural land conservation efforts, thus developing a method for identifying areas of high nutrient loading potential would help the County effectively focus its resources.

The SNAP-Plus model was designed to assist producers with their nutrient management on a field-by-field basis (see Appendix 3 - 5 for details on the SNAP-Plus model). Collecting the necessary information to build a field-specific model is a time-consuming effort that is beyond the scope of this study. The goal of the general agricultural practice SNAP-Plus analysis was to model soil conditions and farming practices used in the Door Creek watershed based on generalizations made using the best available information.

Five primary SNAP-Plus parameters were assessed, including:

- Soil Map Units
- Crop Rotations
- Tillage Practices
- Soil Test Phosphorus Levels
- Distance to Nearest Stream

The information used for the model inputs was obtained from several sources, including soil data from NRCS soil surveys; interviews with a handful of producers in the watershed about their practices; and information provided by the Dane County Land Conservation Office. The field conditions and farming practices chosen for the SNAP-Plus model were our best approximation of general agricultural conditions in the Door Creek watershed. The approximations made for each of the SNAP-Plus parameters are described in the following paragraphs.

A total of 73 soil map units were identified in the Door Creek watershed based on the NRCS soil survey. A larger watershed would likely have more than 73 map units, so we attempted to develop a method that would be useful for such a large watershed. We organized the 73 soil map units into 17 groups based on similar physical properties and then selected a representative soil map unit to be used in the SNAP-Plus model.

To choose three cropping rotations that best represent those commonly used in the Door Creek watershed, responses from the producer interviews were aggregated and rotations that best represent those used in the watershed were chosen. Two common trends were identified - the primary crops grown are the cash crops corn grain and soybeans, and some producers also plant non-row crops, such as hay alfalfa and winter wheat. The cropping rotations chosen for the SNAP-Plus model were a two-year rotation of corn grain and soybeans (Cg-Sg15); a five-year rotation of winter wheat, three years of hay alfalfa and corn grain (Ww-3A-Cg); and a three-year rotation of corn grain, soybeans and winter wheat (Cg-Sg15-Ww).

A method similar to that used for the cropping rotations was used to make approximations for the tillage practices. The Dane County Land Conservation Office was also consulted for estimates of the percentage of fields using conventional and conservation tillage methods. Based on this data, two separate tillage conditions were selected for the corn grain crops in the model – a conservation, no-till method and conventional, fall chisel method. The no-till method was also selected for all soybean, winter wheat, and hay alfalfa crops.

Approximations for the soil test phosphorus levels were the most difficult to make. To properly model soil phosphorus levels in SNAP-Plus, field-by-field soil test phosphorus values are necessary. To best determine the impact of soil test phosphorus levels on the calculated P indices, we modeled a range of soil test phosphorus levels that could be expected in the watershed. Our range approximation was based on the SPAL Dane County average soil test phosphorus level of 56 ppm, and the values in the model ranged from 25 ppm to 200 ppm. Additionally, the Dane County average of 3.6% was assumed for the organic content of all soil tests.

Since the SNAP-Plus model was based on the representative soil map units and not individual fields, the distance to stream values could not be calculated. Much of the Door Creek watershed has extensive networks of drainage ditches, so we assumed a conservative 0-300 foot distance to stream for all modeled conditions.

A complete explanation of the methodology and assumptions used for the General Agricultural Practice SNAP-Plus model is located in Appendix 6 of this report.

The potential for phosphorus runoff was estimated by calculating the Phosphorus Index (P index) values for different combinations of the above inputs observed in the Door Creek watershed. The Wisconsin Nutrient Management Standard requirement (NR 590) that prohibits the spreading of manure on fields with a rotational P index greater than 6.0 provided a baseline for identifying conditions that have the potential to contribute high nutrient loads.

#### 4.1.2.1 RESULTS OF THE GENERAL AGRICULTURAL PRACTICE SNAP-PLUS ANALYSIS

This section summarizes the results of the general agricultural practice SNAP-Plus analysis based on the five primary SNAP-Plus model inputs that were analyzed. Complete results of the modeling are located in Appendix 7.

*Soil Test Phosphorus Levels*

One of the primary SNAP-Plus inputs we analyzed was the average soil test phosphorus level of the field. Soil phosphorus levels are unique to individual fields, so generalizations were difficult to make for the entire watershed. To overcome this, the remaining four SNAP-Plus inputs were analyzed over a range of soil test phosphorus levels, including a low estimate of 25 ppm; a value near the Dane County average of 50 ppm; a high estimate of 100 ppm; and extreme values of 150 and 200 ppm. We chose this range of soil test phosphorus values to make trends in the P index calculations more apparent.

*Soil Slope*

Results from the general agricultural practice SNAP-Plus model demonstrate that field slope was the biggest contributor to excessively high P index values within the Door Creek watershed. Figure 4.2 demonstrates the impact of slope on P index values. It plots average P index values, pounds of phosphorous per acre leaving a field and entering surface water, versus soil slope category for varying distances from the stream. The P index values are averaged over all representative soils within a slope category for a scenario that includes: fall chisel tillage; a two-year corn grain and soybean rotation; and a soil test P value of 50 ppm.

The SNAP-Plus modeling results show that for an average soil test phosphorus value of 50 ppm, all slopes steeper than 6% (C slopes and greater) can be expected to have P index values exceeding 6.0. These results are for an average soil test phosphorus value, so phosphorus contributions from fields with higher soil phosphorus levels can be expected to be even higher.

We also analyzed the relationship of P index values to field soil test phosphorus levels and soil slopes. Figure 4.3 shows P index values by soil test phosphorus value averaged over the soil slope categories for a scenario that included the most erosive crop rotation and tillage practices.

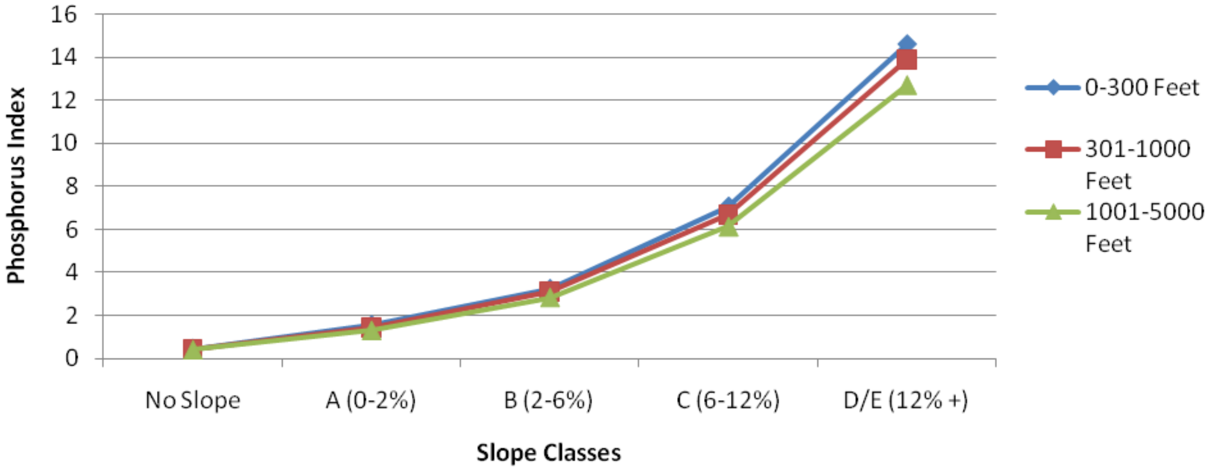


**Figure 4.2: Phosphorus index (P index) values by soil slope and distances to stream for a corn grain and soybean (Cg-Sg) crop rotation under a fall chisel tillage practice and initial soil test phosphorous value of 50 ppm.**

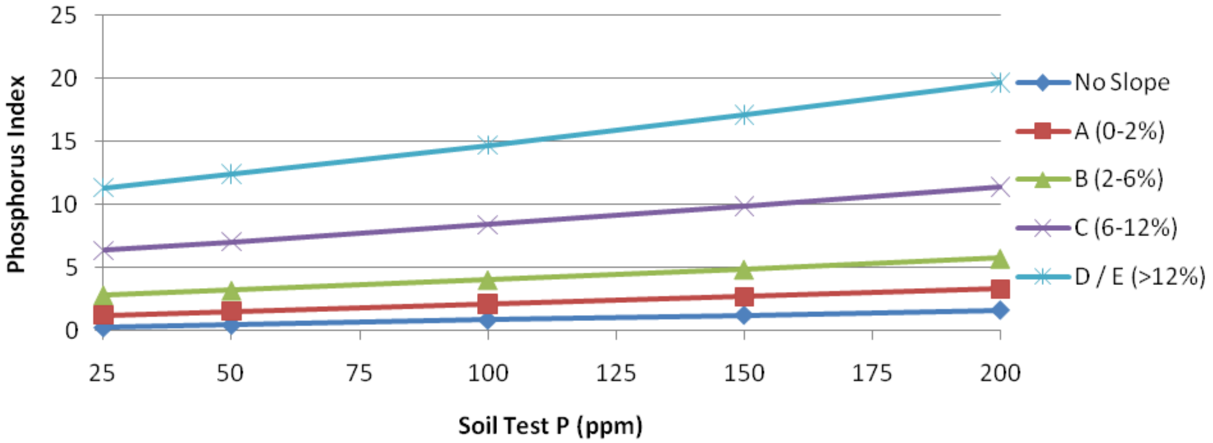


**Figure 4.3: Average Phosphorus Index (P index) values by slope and varying soil test phosphorous values for a corn grain and soybean (Cg-Sg) crop rotation under a fall chisel tillage practice and a distance from surface water of 0-300 feet.**

This scenario demonstrates that fields containing soils with slopes less than 6% are not a primary concern for excessive nutrient runoff. Soils with slopes less than 6% (A and B slopes) have calculated P index values less than 6.0 for the full range of soil test phosphorus levels modeled.

*Tillage Practices*

A third input that we analyzed in the general agricultural practice model was soil tillage. Results of the modeling show that when no-till practices were used, nearly all soil types had P index values below the recommended value of 6.0. This trend was evident across the range of all soil test phosphorus levels, distances to streams, and modeled cropping rotations.

The noticeable impact of no-till practices on P index values is demonstrated by an analysis of a scenario that includes the corn grain and soybean crop rotation, which is the most erosive rotation, and the highest soil test phosphorus level. None of the roughly 13,000 acres of farmland within the Door Creek watershed have calculated P index values above 6.0 for this scenario.

Additionally, when the representative soil groups were modeled with a soil test phosphorus level of 50 ppm, the maximum calculated P index value was 2.1. 11,490 acres, which is 88.5% of the watershed's farmland, have P index values less than or equal to 1.0.

We also analyzed the impacts of tillage based on soil slopes and found that the impacts of conventional tillage on P index values were much greater for steeper slopes than flatter slopes. Figure 4.4 plots P index values versus soil test phosphorus levels and tillage practices for several representative soils of varying slopes. The results show that the P index values for flat soils, such as the Houghton Muck (Ho) or Sable Silty Clay Loam (SaA), are approximately the same whether no-till or conventional tillage is used. However, for soils with slopes greater than 6% (C, D, and E slopes), conventional tillage produces significantly higher P index values than no-till.

These model results indicate that no-till applied to corn grain crops is an effective practice for reducing soil erosion, and fields where the practice is applied in the Door Creek watershed are not a primary concern for nutrient runoff. They also demonstrate that conventional tillage practices become a greater concern for soil erosion and nutrient runoff as field slopes increase.

### *Crop Rotations*

The fourth SNAP-Plus input that was analyzed was cropping rotation. Model results indicate that crop rotations also have a major impact on P index values. The impacts of crop rotations on nutrient runoff are best demonstrated by a scenario that applied fall chisel tillage to the three representative cropping rotations. P index calculations are displayed in Figure 4.6, which plots P index values averaged over all C slope soils for each of the three rotations versus soil test phosphorus levels.

P index values for this scenario are significantly lower when winter wheat and alfalfa are included in a field's cropping rotation. The intensive corn grain and soybean rotation yields an average P index value of 6.5 for a soil test phosphorus value of 50 ppm, while the less intensive rotations that include years of winter wheat or alfalfa have an average P index value of 3.4 for the same soil phosphorus level.

These results indicate that even when conventional tillage methods are applied, P index values for soils with slopes of 6-12% (C slopes) can be kept below the recommended 6.0 if years of winter wheat or hay alfalfa are incorporated into the cropping rotations.

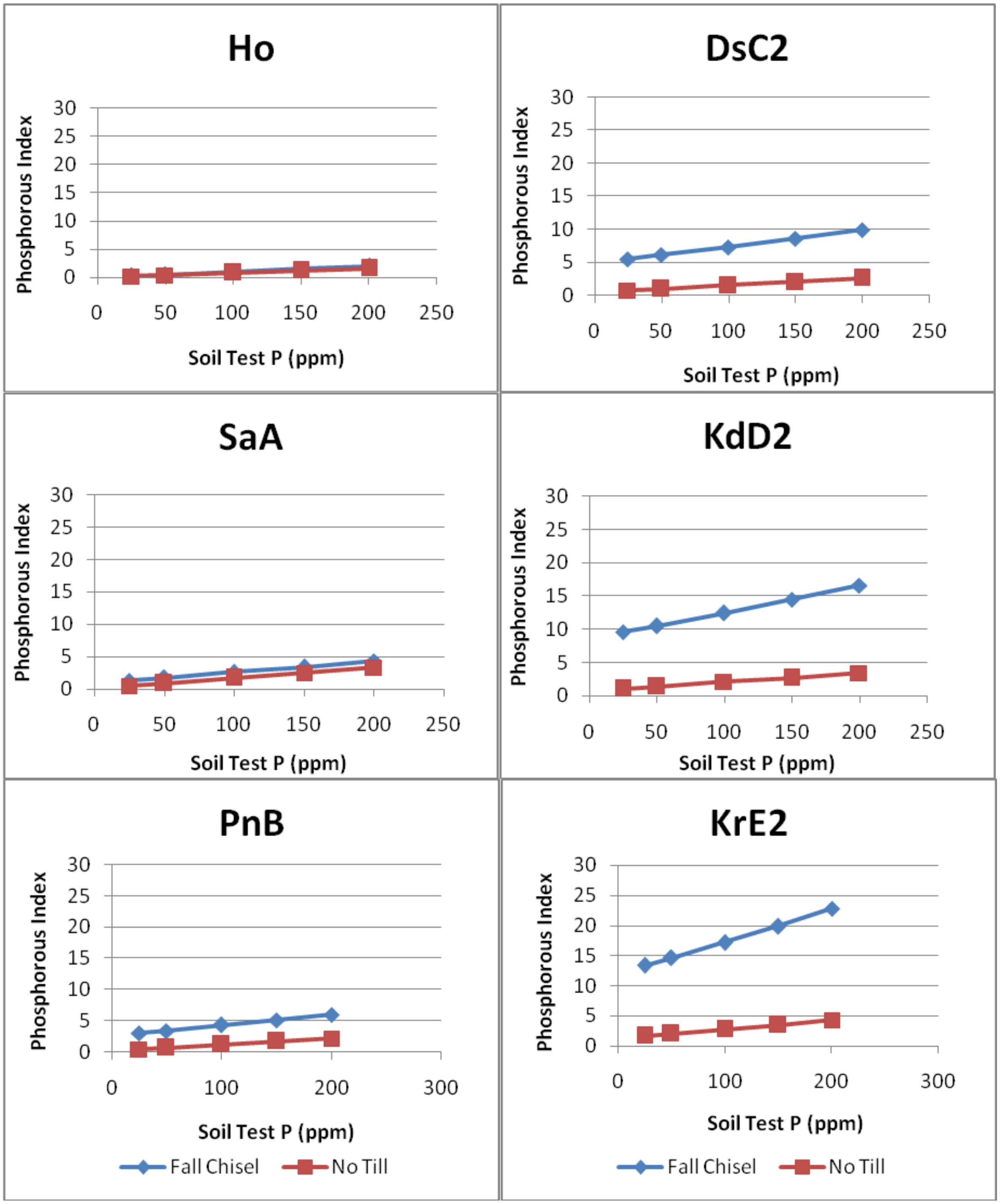


**Figure 4.4: Phosphorous Index (P index) values by varying tillage practices and soil test phosphorous levels.** These are for the most dominant soil types for each slope class within the watershed. Values are plotted for a corn grain and soybean rotation (Cg-Sg15) and a distance of 0-300 feet from surface water.

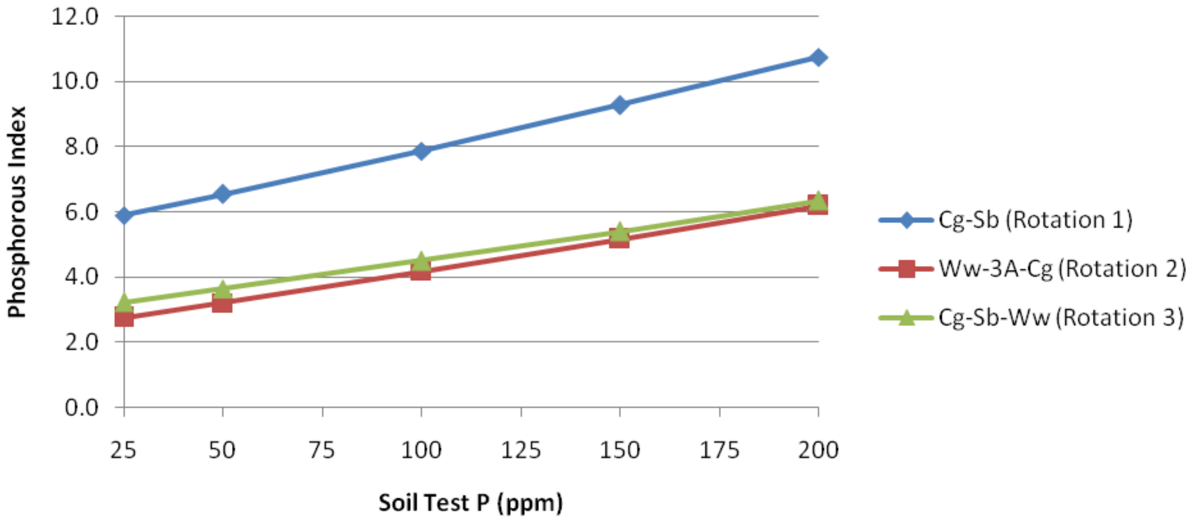


**Figure 4.5: Average Phosphorous Index (P index) values by cropping rotation.** These are for varying soil test phosphorous levels under a fall chisel tillage practice and a distance of 0-300 feet from surface water. Cropping rotations are; corn grain and soybeans (Cg-Sg15); winter wheat, three years of alfalfa and one year of corn grain (Ww-3A-Cg); and corn grain, soybeans, and winter wheat (Cg-Sg15-Ww).

*Distance to Stream*

The final factor in the SNAP-Plus phosphorus index calculations is the distance to stream. Figure 4.2 demonstrates the impact of the distance to stream on P index values. It shows that there is an inverse relationship between the distance to stream and P index value if the other SNAP-Plus inputs are held constant. However, the modeling results also show that the impact of distance to stream on P index values is very small when compared to other factors, and thus is not a main concern from a management standpoint in the Door Creek watershed.

#### 4.1.2.2 CONCLUSIONS AND RECOMMENDATIONS

The original intent of the general agricultural practice SNAP-Plus Model was to develop a method for using SNAP-Plus to identify field conditions and farming practices that are likely to contribute high phosphorus loads to Door Creek. Data obtained from soil surveys, GIS maps, and interviews with producers in the watershed were used to run the SNAP-Plus model and identify these critical areas of concern. The completeness of the model allowed us to add an additional goal of making recommendations for practices that can be implemented in the field to reduce the amount of phosphorus runoff from agricultural fields.

*Watershed Nutrient Management*

Based on the results of the general agricultural practice SNAP-Plus analysis, we can conclude that soil slope is the most important data necessary for phosphorus runoff management at a watershed scale. Model results showed that soils with slopes above 6% (C, D and E slopes) were significantly more likely to have P index values in excess of 6.0 than soils with flatter slopes. This knowledge is important from a watershed nutrient management perspective because it allows potential critical areas to be quickly and easily identified using soil surveys and GIS modeling.

Once potential critical areas of nutrient runoff have been identified, additional field-specific factors can be used to estimate the phosphorus indexes of specific fields. The first of these additional factors is the soil test phosphorus level of the field, which can be determined based on the results of relatively simple and inexpensive soil sampling. There is a direct correlation between the soil test phosphorus level and the P index for a field; the greater the soil phosphorus level is, the greater the expected phosphorus transport from that field.

The second and third additional factors of soil tillage and crop rotations are more difficult to obtain because they require knowledge of the farming practices used on every field within the critical areas. The producer interviews conducted as part of this Practicum were a time-consuming effort that still left uncertainty about the actual practices implemented on specific fields.

However, if resources are available to conduct in-depth surveys, we recommend focusing on fields where conventional tillage is being applied and intensive corn grain and soybean cropping rotations are being used. Fields using no-till for corn grain crops and cropping rotations that include years of winter wheat or alfalfa are much less likely to have critical P index values than fields using more intensive practices.

## 4.2 PASTURES

### 4.2.1 BACKGROUND AND LITERATURE REVIEW

Although agricultural land use in the Door Creek watershed primarily consists of cropland, pastures and rangeland may also contribute significant quantities of nutrients to Door Creek. Over time, grazing animals deposit manure directly to the land’s surface, which without significant nutrient removal through harvest, results in build-up of nutrients. When erosion occurs in grazing areas, large amounts of nutrients can be released. This process increases productivity in Door Creek and might eventually contribute to the eutrophication of Lake Kegonsa (see Chapter 3).

Based on estimation, approximately 570 animals are grazed for at least part of the year within the Door Creek watershed. Pastures vary widely with respect to animal density, slope, distance to surface water, and vegetation cover. Previous studies have shown that soil erosion is more likely to occur as the pasture slope increases, more animals are grazed, and/or the number of years the pasture is grazed increases. This is primarily because grazing can alter, reduce, or eliminate vegetation, which increases erosion processes and agricultural runoff (Hoorman & McCutcheon, 2005).

It is uncommon for animals to be grazed on wetland or to be allowed to enter streams within the watershed. Nevertheless, the practice can have considerable effects on the water quality of the stream. Grazing directly in waterways is typically done to cool off animals in the hot summer months and provide them with drinking water (Pennington et al., 2009). Although this is beneficial for farmers, it can have detrimental effects on the stream, such as an increase in channel sediment from bank and upland erosion, and the introduction of high levels of nutrients due to lack of buffers along the shoreline and bank erosion (Evans, 1998; Pennington et al., 2009).

### 4.2.2 SNAP-PLUS PURPOSE AND METHODS

Because pasturing practices may potentially affect water quality, soil samples were taken to quantify the nutrient concentrations in several typical pastured fields. The SNAP-Plus model was then utilized to determine their respective susceptibility to erosion.

SNAP-Plus has the capacity to predict phosphorous index values (PI values) for a number of pasture types based on animal density, vegetation cover, soil type, and slope. However, this predictive tool has never been scientifically validated for pastures. As a result, it tends to be conservative in its estimation of phosphorus loading and soil loss in pastures. In order to improve the accuracy of this tool, a database of pasture soil tests is needed to help better calibrate the SNAP-Plus model for pastures. The goal of this database is to better account for soil compaction, hoof disturbance, increased pressure on vegetation from grazing practices, and increased annual manure loading (L. Good, personal communication, July 17, 2009; Peppler & Fitzpatrick, 2005). The Natural Resources Conservation Service (NRCS) is also currently improving the RUSLE2 equation, which should further improve the sensitivity of the SNAP-Plus model.

The Practicum soil samples were used in collaboration with studies done by the Department of Soil Science at UW-Madison to contribute to the NRCS database. The sampled pastures were measured in order to help improve the sensitivity of the SNAP-Plus predictability for pastures, obtain soils data for varying pasture types within the Door Creek watershed, and determine what impact these, as well as pastures in general, may have on the water quality of Door Creek.

To meet these objectives, five pastures were sampled on July 2, 2009 for soil nutrient concentrations and other soil parameters, such as pH and organic matter content. The sampled pastures were selected because they were representative of the watershed based on their slope, vegetation cover, and the number of grazed animals. All five pastures were located between 1001 to 5000 feet from Door Creek and were utilized by cattle raised for beef and dairy, as well as a previously grazed, idle beef cattle pasture. The collected data were then used as input parameters in the SNAP-Plus model for a four consecutive one-year grazing rotation (see Appendix 8 for details).

### 4.2.3 SNAP-PLUS PASTURE RESULTS AND DISCUSSION

The compiled data from the sampled pastures and their respective SNAP-Plus analyses can be found in Table 4.2. Our data shows that soil loss increases as slope increases. This trend has been well tested in the agricultural community and is supported by previous research (Hoorman & McCutcheon, 2005).

**Table 4.2: Compiled soil sample test results and SNAP-Plus analysis.**

| **Pasture** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **Soil Slope** | 27% | 2% | 9% | 4% | 4% |
| **Vegetation cover** | High | Medium | Low | Medium | Low |
| **Distance to surface water (ft)** | 1001-5000 | 1001-5000 | 1001-5000 | 1001-5000 | 1001-5000 |
| **Area (ac)** | 8 | 1.5 | 3 | 3 | 5 |
| **Animal Density (animals/acre)** | 1.25 | 6.67 | 10 | 3.33 | 0 |
| **P Concentration (ppm)** | 60 | 175 | 323 | 177 | 343 |
| **K Concentration (ppm)** | 186 | 496 | 1163 | 366 | 934 |
| **Organic Matter (%)** | 4.5 | 4.3 | 7.2 | 4.8 | 7.9 |
| **PI value** | 11.5 | 5.9 | 23.7 | 8.9 | 7.9 |
| **Soil Loss (tons/ac/year)** | 8.6 | 1.2 | 3.1 | 1.7 | 0.9 |

The soil loss calculation provided by SNAP-Plus also illustrates the impact of animal density on pastures. Pasture 5, an idle pasture, had the lowest total soil loss. This is likely due to the modest slope and the fact that the soil was not being disturbed by grazing animals. This indicates that hoof compaction and animal disturbance likely accounts for the discrepancy amongst pastures with similar slopes. It is also likely that the soil loss on the steepest slope (pasture 1) would have increased if the animal density were to increase.

Animals can also indirectly affect soil loss by reducing the quality of areal vegetative cover. Vegetation is a key component in holding soil in place, especially on steeper slopes (Castillo, Martinez-Mena, & Albaladejo, 1997). The factors that affect soil loss also directly affect phosphorus loading and PI values in pastures. This is because phosphorus is typically bound to soil. The vegetation cover for the sampled pastures ranges from low to high where low corresponds to barely any vegetation at all and high corresponds to grass covered surface. Our data shows that slopes with low vegetation cover (pastures 3 and 5) have relatively high PI values compared with steep slopes, such as pasture 1.

Animal density is thought to have the most significant impact on PI values. Increased animal density allows for a build-up of manure in the soil over time. This build-up of manure leads to significantly higher averaged phosphorous concentrations for pastures in this study than averaged soil phosphorous concentrations for Dane County; the average phosphorous concentration for pastures was 240 ppm, while the average for Dane County is only 56 ppm. Because of the high phosphorus concentrations in the soil, most of the PI values for pastures exceeded the recommended level of 6.

Of the sampled pastures, 3 and 5 had the highest concentration of soil P. However, pasture 3 had a P index value three times greater than pasture 5, due to the increase in slope. This result is consistent with previous research (Pennington et al., 2009).

An additional trend highlighted in this study was that phosphorus concentrations in soil remain high even after grazing activities cease, as illustrated at pasture 5. This pasture, which was idle, had the highest P soil concentration, likely caused by the build-up of manure. Once this build-up occurs, phosphorous must be removed by vegetation to reduce P back to acceptable levels. However, this process can be slow, particularly in areas with poor vegetative quality (Castillo, Martinez-Mena, & Albaladejo, 1997). This build-up of high phosphorus would become a concern if the pasture were disturbed, such as would occur with development. (See Chapter 4.5 for further discussion).

### 4.2.4. CONCLUSIONS AND RECOMMENDATIONS

Of the sampled pastures, 1 and 3 had the greatest potential for soil erosion and phosphorus loading, due to their steep slopes. Pasture 3 surpassed 1 as the site with the greatest P index value because of the joint effect of the steep slope and high soil P concentration. These conclusions are supported by previous research, which states that the P index value increases as the pasture slope increases, more animals are grazed, and/or the number of years the pasture is grazed increases (Hoorman & McCutcheon, 2005). These factors also allow for manure to build-up in soil thus causing high P concentrations. These high soil P concentrations may have serious impacts on water quality in Door Creek. Based on the slope, soil P concentration, and vegetation cover, the majority of the pastures exceeded the recommended P index value of 6.

Several management strategies could help reduce the P index value and soil loss in order to protect the water quality in Door Creek. One simple management strategy is to improve vegetation conditions in pastured areas. High quality vegetation not only holds soil in place better but also utilizes nutrients more effectively (Castillo, Martinez-Mena, & Albaladejo, 1997). For example, if the vegetation cover at sample 4 were improved, the P index value would decrease from 8.9 to 8.1. This improvement can typically be accomplished through rotational grazing. Rotational grazing can also be effective at creating a more uniform distribution of manure over an area, rather than having areas of very concentrated, easily erodible manure. With even manure distribution, improved vegetation, and decreased amounts of soil disturbance, a well-managed rotational grazing system can allow more animals to be safely and effectively grazed on a given area, thus maximizing the land-to-livestock ratio. Therefore, implementing this system can be beneficial to maximize yields, while preserving environmental quality.

Another management goal in dealing with pastures is to prevent animals from directly entering streams or waterways. Animal traffic in streams can increase stream temperatures, increase bank and upland erosion, widen channels, and be a source of excess nutrients and coliform bacteria (Evans, 1998). Therefore, creating stream crossing areas and providing water sources for animals, other than the stream, are practices that would greatly assist in preserving water quality.

Based on the literature review for pastures, the results of soil testing, and the SNAP-Plus analysis, the following recommendations are made in order to prevent excessive phosphorus loading and preserve the water quality of Door Creek.

- Prevent overgrazing, soil erosion, and manure build-up by maintaining an adequate land-to-livestock ratio
- Maintain high vegetation cover
- Prevent cattle from directly entering streams
- Promote rotational grazing
- Prevent grazing on steep slopes whenever possible

## 4.3 DRAIN TILES

### 4.3.1 INTRODUCTION

Subsurface drain tiles are an essential part of the agricultural development of the Midwestern United States. They function by removing excess water from farm fields, which allows producers to cultivate fields that were once too wet to grow crops or support farm machinery.

Although drain tile use in Wisconsin is not as common as it is in other Midwest states, drain tiles are still used on approximately 10% of Dane County's cultivated land (Figure 4.6). Determining the extent of drain tile coverage in the Door Creek watershed is difficult because most drain tile maps, if they exist at all, are very primitive. However, we were able to estimate drain tile coverage of approximately 23% of the watershed's agricultural fields based on a geographical analysis of current land use versus the 1920 Door Creek Drainage District boundary.

The impact of drain tiles on water quality has become an increasingly important concern. Subsurface tiles can facilitate the transport of nitrogen and phosphorus from fields to nearby waterways. The ultimate goal of this study is to reduce the amount of phosphorus input into the Yahara Lakes, and thus, this portion of the study will focus on phosphorus and the role drain tiles play in transporting it to the lakes.  Figure 4.7 shows the fields within the watershed that appear to contain subsurface drainage.

### 4.3.2 BACKGROUND INFORMATION

Modern drain tiles are small perforated plastic pipes mechanically installed three to six feet below the surface of an agricultural field (Ruark, Panuska, Cooley & Pagel, 2009). In the past, drain tile systems were constructed of clay tiles that were installed manually. Tile networks branch out into wet areas of a field, with lateral lines joining together to discharge into a drainage ditch, pond or wetland adjacent to the field.

Subsurface tiles work by promoting the downward movement of water from the crop root zone. To accomplish this, they are typically placed at or below the water table in fields where the root zone and water table are insufficiently spaced (Goswami, Kalita, Cooke, & Hirschi, 2008).

Drain tiles in this region of Wisconsin are commonly used in areas with poorly drained soils and when topographic features that retain water are present (Ruark et al., 2009).

Poorly drained soils commonly occur when a medium-grained soil overlies a more restrictive, fine-grained sub-soil. The upper layer becomes constantly saturated, and subsurface drain tiles placed at the interface of the two layers are necessary to remove the excess water from the upper layer (Cooley & Pagel, 2009).

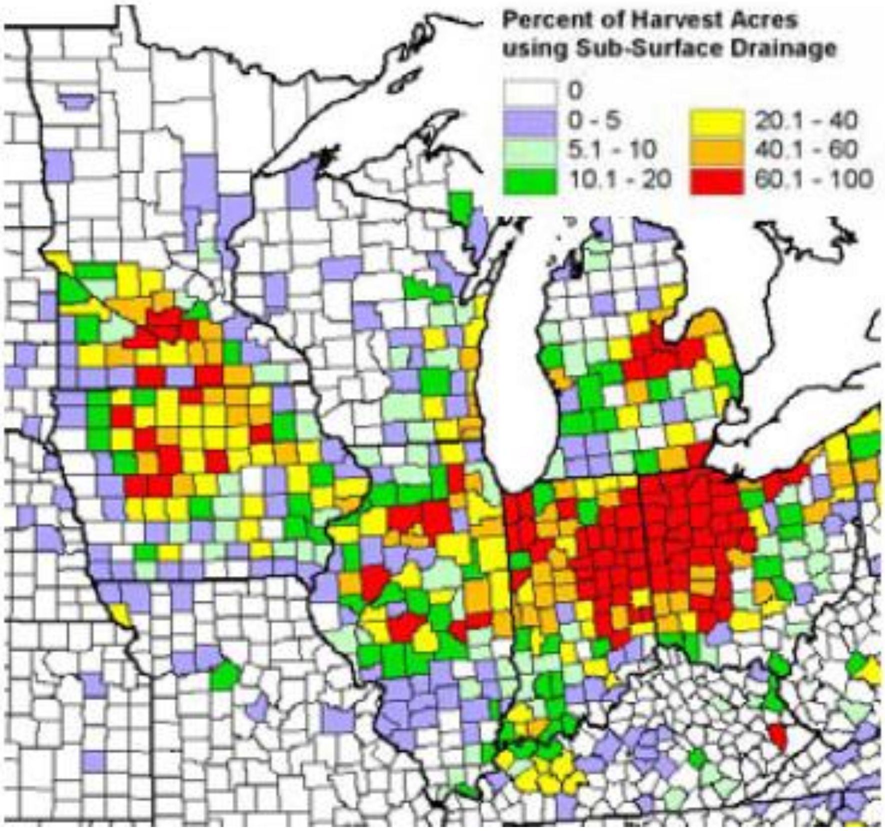


**Figure 4.6: Percent farmland with sub-surface drain tiles in Midwestern states.** Source: 1992 NRI; 1992 Census of Agriculture; Gary Sands, Agricultural Drainage 101.

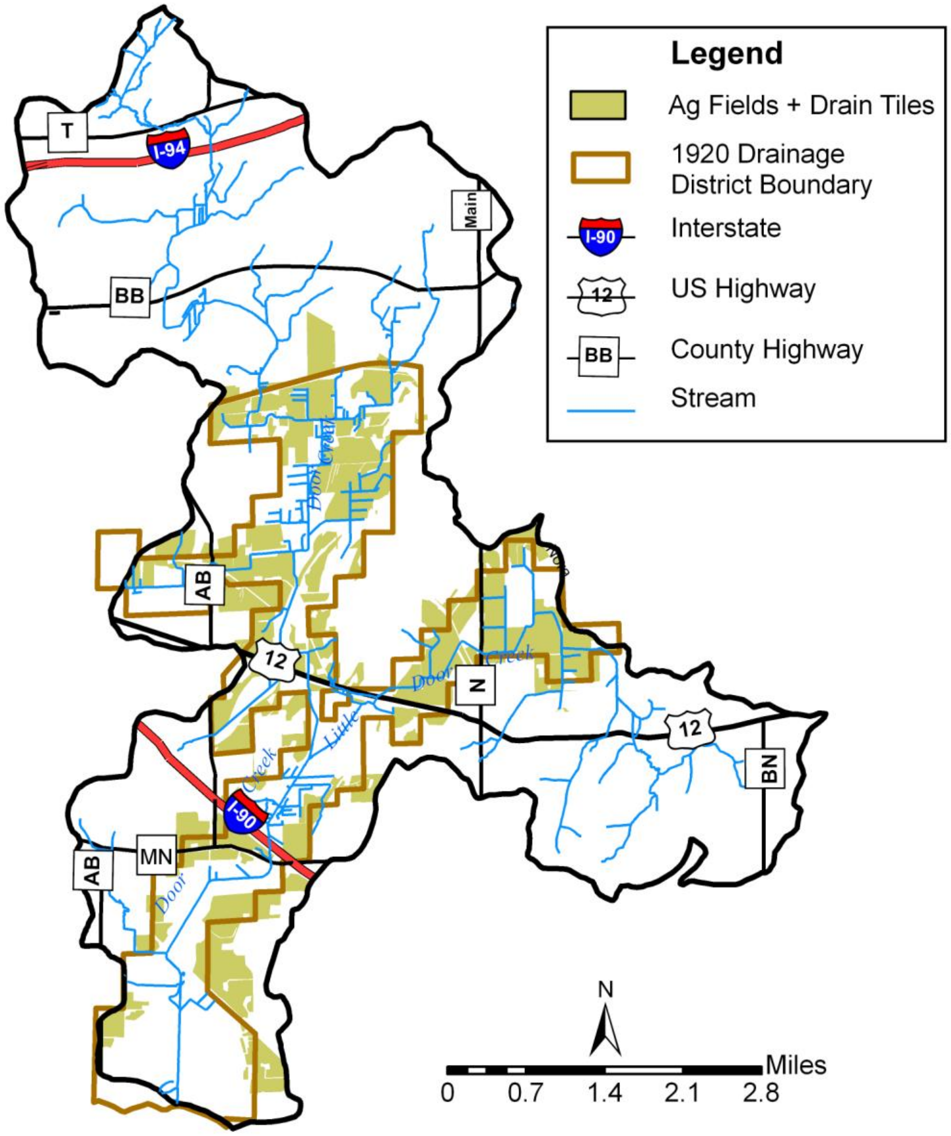


**Figure 4.7: Percent farmland with sub-surface drain tiles in the Door Creek watershed.** Source: Ag Parcels Layer Provided by Cory Anderson, Created July 2009 by 2009 WRM Practicum. Note: All classified agricultural fields (containing farm number) located with the 1920 Drainage District are considered to have drain tiles within the field. CRP, WRP, CREP, wetland and wooded parcels are excluded.

Closed depressions, areas with extensive organic mucks, and areas of high groundwater are the three primary topographic features that promote the retention of water in southern Wisconsin (Cooley & Pagel, 2009). The Door Creek watershed has several of these features that resulted from past glacial activity. Closed depressions feature no natural surface outlet, and thus will remain constantly saturated with water unless a subsurface drainage system provides an artificial outlet. Organic mucks frequently form in low-lying areas that are constantly wet (Ruark et al., 2009). The Door Creek watershed has over 1,700 acres of mucks, a substantial amount of which has been drained for farming purposes (NRCS, 2009).

### 4.3.3 PHOSPHORUS TRANSPORT VIA DRAIN TILES

Phosphorus can naturally exist in both a particulate and dissolved phase. Particulate phosphorus is chemically bound to sediments, and is primarily transported by surface runoff. Conversely, dissolved phosphorus remains in solution and is capable of moving down through the soil to subsurface drains. A more detailed discussion phosphorus transport in runoff is given in Chapter 5 of this report.

Conventional wisdom in the field of agricultural drainage long held that particulate phosphorus transport via surface runoff was a significantly greater concern than subsurface phosphorus transport. Since dissolved phosphorus had to travel through three to six feet of soil to reach the drain tiles below, it was believed that most of the nutrients would enter the particulate phase by binding with soil particles before they reach the tile system (Geohring et al., 2001). However, research over the past several decades has found that there are field conditions where the transport of phosphorus to drain tiles can be a concern.

### 4.3.4 FACTORS AFFECTING DRAIN TILE WATER QUALITY

The factors affecting phosphorus transport via drain tiles include both soil conditions and farming practices. The most important factors are discussed below.

*Macropores*

Macropores are large openings in the soil that provide preferential flow paths for dissolved phosphorus to move down into the soil. Macropores capable of transporting phosphorus can range in diameter from 1 mm (0.04 inches) up to 50 mm (2.0 inches) or more. One of the main sources of macropores in soils is earthworm burrows, especially in fields where no-till practices are used (Shipitalo & Gibbs, 2000). A second source is large cracks in dry soils, which are most prevalent in soils with high clay content (Eastman, Gollamudi & Madramootoo, 2007).

*Soil Type*

Pore size is the fundamental characteristic that controls drainage in soils. Sands and other soils with large pores drain easily and allow rapid leaching of water to occur. In contrast, soils with small pores, compacted soils, and soils with greater than 20% clay content, do not drain easily and have the potential to retain water. Subsurface drain tiles are frequently used to facilitate drainage of these saturated soils.

Draining compacted soils or soils with a high clay content can increase phosphorus loading and soil erosion. Clays have a high surface area to volume ratio, which creates a high potential for phosphorus to bind to sediments and then be transported via runoff (Penn, Mullins & Zelazny, 2005). Additionally, as clays dry they develop waxy, hydrophobic coatings that can cause cracks and fissures to form in the soil. These openings can create a direct mechanism for sediments and dissolved nutrients to be transported to subsurface drain tiles (Eastman, Gollamudi & Madramootoo, 2007).

Loam and sandy loam soils typically do not develop cracks and fissures as they dry, and thus sediment and dissolved nutrient loading to drain tiles is more likely to occur in soils with higher clay contents (Eastman, Gollamudi & Madramootoo, 2007). This is an important water quality issue because subsurface drain tiles installed to drain waterlogged soils for agricultural purposes may transport excessive amounts of phosphorus-rich sediments and dissolved phosphorus to nearby streams.

### *Nutrient Application Methods*

Another important contributing factor to phosphorus transport through agricultural drain tiles is the composition and amount of nutrients applied to the soils and the method of application. Metrogro municipal biosolids, manure, and commercial fertilizer are the main sources of agricultural phosphorus in the Door Creek watershed.

The Madison Metropolitan Sewerage District's (MMSD) procedures for Metrogro application on fields with subsurface drainage are discussed in detail in Section 4.4 of this report and will not be addressed in this section.

The composition of manure can vary greatly from farm to farm, with the percent solid and percent liquid of the manure heavily impacting the amount of spreadable manure that can leach to subsurface drain tiles. Liquid in the manure allows dissolved phosphorus to leach downward through macropores, while solids create a more viscous (thick) manure that inhibits flow and increases the opportunities for soil to adsorb phosphorus (Cooley & Pagel, 2009).

In contrast to manures, the chemical compositions of commercial fertilizers are carefully formulated to provide the right amount of nutrients at the right time during the growing season. Plants primarily use phosphorus that is dissolved in water, so phosphorus-containing fertilizers are formulated to contain upwards of 90% water-soluble phosphorus (Whitney, 1988). The dissolved phosphorus is essential for growing crops, but it is also frequently present in high amounts in drain tile discharge (Gentry, David, Royer, Mitchell & Starks, 2007).

Rates at which both manure and commercial fertilizers are applied also play an important role in the amount of phosphorus that reaches drain tiles. Application of excess nutrients in areas with extensive macropores can overwhelm the soil's ability to adsorb phosphorus and lead to preferential flow to subsurface drains (Geohring et al., 2001). Studies have also shown that both excess dissolved and particulate phosphorus can be carried away by surface runoff (Kleinman & Sharpley, 2003).

### *Tillage Practices*

The final factor in controlling phosphorus transport via drain tiles is the tillage practice being used. One of the key impacts of tillage practices on phosphorus transport is the control of macropores in agricultural fields. Soil tillage, such as a chisel or disk method, disturbs the soil and closes many of the macropore openings. Conditions in no till fields, on the other hand, promote the preservation of subsurface macropores. In no-till fields, the nutrients provided by crop residue and the lack of disturbance by plowing provide a favorable environment for earthworms to thrive. Accompanying the earthworms are extensive networks of burrow macropores that provide preferential flow paths to the drain tiles below (Shipitalo & Gibbs, 2000).

A second key impact of soil tillage is its ability to increase the phosphorus sorptivity of the soil by increasing the amount of surface area that the phosphorus can adsorb to (Lapen et al., 2008). Drainage studies performed in the Midwest have demonstrated that incorporation of nutrients can reduce both subsurface and surface phosphorus transport. A study conducted by

Geohring et al. (2001) in central Illinois found that manure incorporation reduced total phosphorus loads to drain tiles. Correspondingly, a study by Tabbara (2003) in Iowa found that incorporation reduces surface nutrient runoff by moving phosphorus into the soil column and out of the "mixing zone" found in the first two inches below the surface.

### 4.3.5 RECOMMENDATIONS

Agricultural drain tiles are an important tool for draining fields and increasing crop yields, but if they are not carefully managed, they can have negative impacts on downstream water quality (Cooley & Pagel, 2009). Just as there is no one best way to farm, there is not a universal solution for managing phosphorus transport by subsurface drain tiles. The most effective management is done on a field-by-field basis.

The conditions described in the previous section provide an excellent framework for developing nutrient management techniques for fields that are drained by subsurface drain tiles. The following recommendations suggest practices that can be implemented to prevent subsurface phosphorus runoff during field application of nutrients.

1. Nutrient application on no-till fields should be avoided due to the large numbers of macropores present (Shipitalo & Gibbs, 2000).
2. The timing of manure spreading should be monitored based on field soil types. Spreading on dry soils with high clay contents should be avoided because of the large cracks that form during dry conditions (Eastman, Gollamudi & Madramootoo, 2007). Spreading on wet soils should also be avoided because the moisture reduces the water-holding and nutrient adsorption capacity of the soil (Cooley & Pagel, 2009).
3. Manures that are spread should have a minimum solid content of 5%, or treatments that decrease moisture content should be applied before field spreading (Cooley & Pagel, 2009).
4. Application of commercial fertilizer and manure should be matched with crop requirements to avoided excessive application. This can be done using a simple method such as soil test P level thresholds or a more advanced tool such as Wisconsin's SNAP Plus nutrient management model (Sharpley, McDowell & Kleinman, 2001).
5. Manure and fertilizer should be incorporated into the soil as they are being spread. Water with dissolved nutrients can be transported to drain tiles within 15 minutes, so incorporation needs to occur as close to application as possible (Lapen et al., 2008).

## 4.4 MMSD METROGRO BIOSOLIDS RECYCLING REPORT PROGRAM ANALYSIS

### 4.4.1 MOTIVATION

In addition to runoff from agricultural activities, two other land uses that may contribute excess nutrients to the Door Creek watershed include municipal biosolid application and industry. The focal point of this analysis was the Madison Metropolitan Sewerage District's (MMSD) biosolids recycling and Metrogro program (MMSD Metrogro). However, it also included an examination of local municipalities, industries, and private septic haulers. Based on the results of this examination and by incorporating professional input from Wisconsin Department of Natural Resources (WDNR) Waste Water Specialist Robert Liska, we were able to eliminate local municipalities, industries and private septic haulers as major nutrient sources and, instead, focus our efforts on providing an in-depth assessment of the MMSD Metrogro program (R. Liska, personal communication, July 10, 2009).

The main factors contributing to excessive nutrient and pathogen export from fields that receive municipal biosolids applications are topography and soil phosphorous levels. Critical topographic features include steep slopes, wetlands, waterways, and fractured bedrock, all of which exist in the Door Creek watershed. Wisconsin Administrative Code NR 204 restricts the application or injection of municipal liquid biosolids on these topographic features (Wisconsin State Legislature, 1996). The Door Creek watershed also contains several agricultural parcels known to have elevated soil phosphorus levels. Frequent large volume injections of municipal liquid biosolids into soils with excessive phosphorus levels can create a greater risk for phosphorus runoff from these fields.

#### 4.4.1.1 BACKGROUND: MMSD METROGRO BIOSOLIDS PROGRAM

MMSD collects and treats wastewater from municipalities in the Madison area, and also accepts private septage from independent sewerage contactors that collect it from homes outside MMSD's sewer collection network. The septage is taken to the Nine Springs Wastewater Treatment Plant, where it undergoes several physical and biological treatment processes that produce treated effluent and municipal liquid biosolids (Taylor, 2008). Treated effluent is water that has undergone both primary and secondary treatment processes. MMSD discharges its treated effluent back into the environment at either Badfish Creek or Badger Mill Creek.

Liquid biosolids are the highly-treated biosolids that are separated from the treated effluent during the biological filtering process and injected into agricultural parcels across Dane County via the MMSD Metrogro program. After treatment, the Metrogro liquid biosolid contains approximately 5% solids. These solids primarily consist of the nutrients phosphorus, nitrogen, and potassium, as well as trace amounts of heavy metals such as mercury, copper, and lead (a list of all components of the 2007 Metrogro biosolid are found in Appendix 9). The Metrogro biosolid meets the United States Environmental Protection Agency (US EPA) and the WDNR criteria for a high quality liquid biosolid based on metal concentrations as well as bacteria and pathogen content (Taylor, 2008). In order to meet the US EPA/WDNR quality guidelines, MMSD must analyze the liquid biosolid daily for nutrients and trace elements to assure the biosolids quality during the recycling season (Taylor, 2008). With quality assurance, the Metrogro program can attract landowners willing to accept the injection of Metrogro biosolid.

The MMSD Metrogro Program is a voluntary program wherein agricultural landowners allow MMSD Metrogro to inject liquid biosolids on their land (Taylor, 2008). As of February 2009, the MMSD Metrogro program has injected municipal liquid biosolids into 53 (3.5%) of the 1,495 agricultural fields within the Door Creek watershed (Figure 4.8). In terms of acres, MMSD Metrogro has injected municipal biosolids into 1,219 (10%) of the 13,272 acres of agricultural fields (J. Post, personal communication, February 6, 2009).

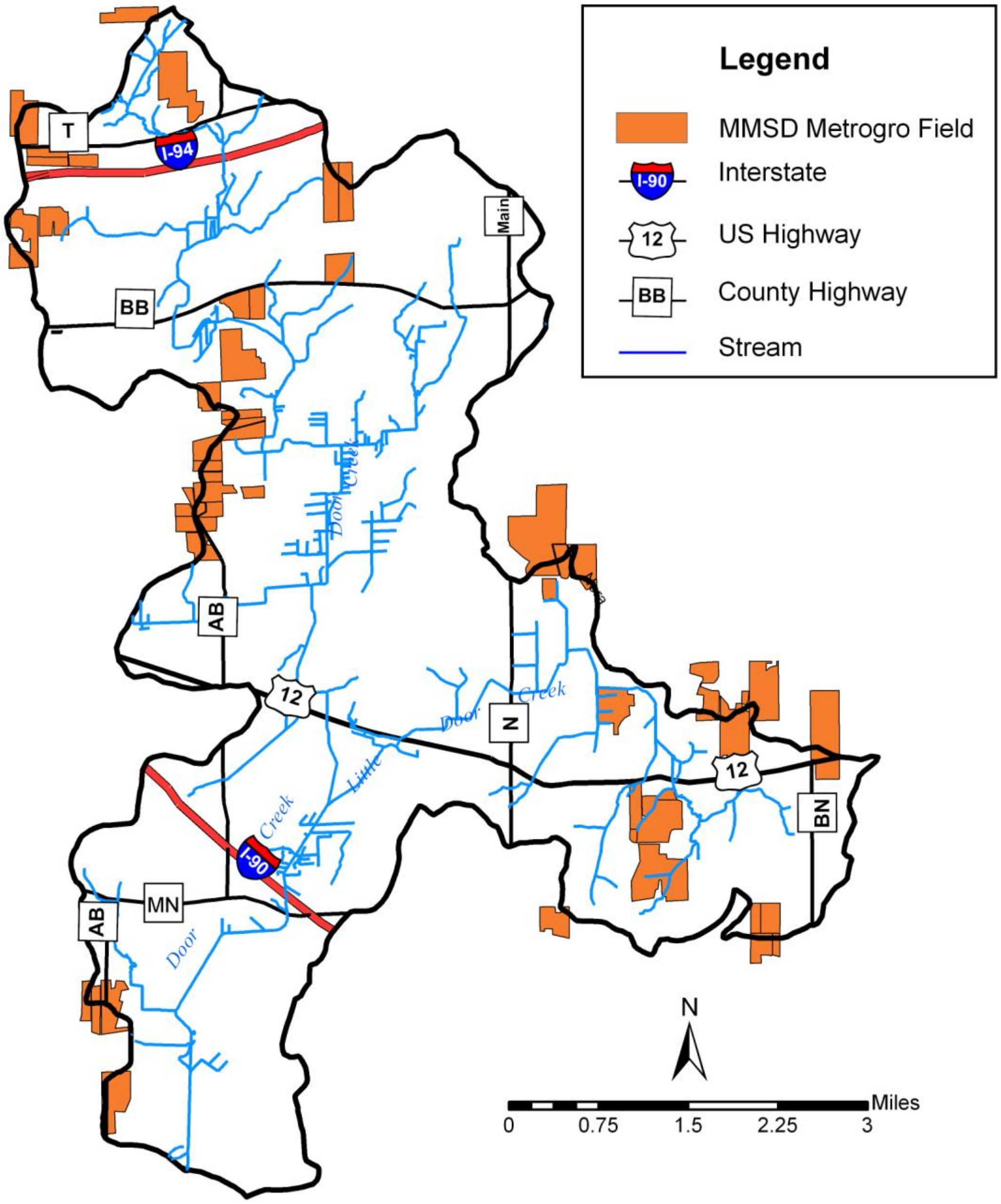


**Figure 4.8: Madison Metropolitan Sewerage District "Metrogro" Fields.** MMSD Metrogro currently is or previously has injected the Metrogro biosolid into 53 (3.5%) of the 1495 agricultural fields indicated on this map. In terms of acres, MMSD Metrogro has injected on 1,219 (10%) of the 13,272 acres of agricultural fields. Source: Jim Post, MMSD, 2009, Created August 2009 by 2009 WRM Practicum.

This program is mutuality beneficial to both MMSD and the volunteer agricultural land owners because MMSD is able to efficiently dispose of the liquid biosolids in a place other than a landfill and the agricultural landowners receive free fertilizer and soil conditioner. Potential sites for MMSD Metrogro injection are subjected to an in-depth inspection process before any application can occur. The agricultural landowner must first complete a site inspection and must go through an approval process administered by the WDNR (Taylor, 2008). As part of the WDNR approval process, environmentally sensitive areas restricted by NR 204, including steep slopes, water bodies, wells, home setbacks, and certain soils are identified. In this manner, environmentally sensitive areas are flagged and prohibited from receiving biosolids injection. Once the acceptable fields are identified, MMSD then determines the biosolid application rate for the field using WDNR guidelines that are based on nitrogen requirements for each crop type (Wisconsin State Legislature, 1996). The application rate is also adjusted to account for other nitrogen sources that are being simultaneously applied to the field, such as manure or commercial fertilizer (Taylor, 2008). This is an effective method for nitrogen accounting; however, one potential problem with the application rate is that phosphorus and other nutrients are not considered.

The Metrogro liquid biosolid is injected eight inches deep with a four inch buffer of tillage below the injection depth (Taylor, 2008). For many biosolid injections, the landowner will follow directly behind a Metrogro injection implement with a tillage implement (M. Northouse, personal communication, July 30, 2009). This immediate tillage further incorporates the Metrogro biosolid into the field by disrupting the soil matrix and increasing the soil's contact with the biosolid. Tillage also disrupts macropores in the field, thus slowing the movement of the biosolid through soil horizons (Watson & Luxmoore, 1986).

#### 4.4.1.2 LAWS REGULATING BIOSOLIDS APPLICATION

Municipal liquid biosolids programs such as MMSD Metrogro are regulated by both the US EPA 40 CFR 503 and WDNR Wisconsin Administrative Code NR 204 regulations. US EPA 40 CFR 503 sets the minimum federal requirements for municipal biosolids management. The US EPA may also delegate regulation to the state, as long as the state meets the minimum requirements established under 40 CFR 503. , Wisconsin has been delegated to regulate municipal biosolids under WDNR Wisconsin Administrative Code NR 204. NR 204 was originally based on US EPA 40 CFR 503, but now contains several requirements that extend beyond those required by the Federal regulations. These include identification of potential environmental pathways that may put human, plant or animal life in contact with the biosolid; general site management requirements; and restrictions and recordkeeping requirements (Wisconsin State Legislature, 1996). An in-depth discussion of NR 204 is provided in Chapter 6 of this report.

### 4.4.2 ASSESSMENT OF THE MMSD METROGRO PROGRAM

The examination of MMSD Metrogro consists of two parts: a SNAP-Plus analysis to determine the impact of MMSD Metrogro application within the watershed based on the Wisconsin recommended phosphorous index (PI) values, and an assessment of MMSD Metrogro operations and WDNR regulations.

Additionally, the Practicum performed a topographic analysis of Door Creek using ArcGIS 9.2. The analysis shows that the Door Creek watershed does have topographic areas that restrict the application of municipal liquid biosolids under NR 204. The topographic restrictions in NR 204 do not entirely prevent the Metrogro program from injecting liquid biosolids on a field with topographic restrictions. The restrictions do however prevent the Metrogro program from injection on the specific areas that are subject to the topographic restrictions. As discussed earlier, the WDNR and MMSD mark, or flag, those restricted areas and MMSD Metrogro will not inject liquid biosolids there.

#### 4.4.2.1 SNAP-PLUS ANALYSIS

The goal of this analysis was to determine the percentage of fields within the watershed that receive the Metrogro applications and have Wisconsin PI values greater than the recommended value of 6.0 ppm. The results also allowed us to assess which of the primary SNAP-Plus parameters were causing these high PI values. By analyzing the impact of several critical parameters, we were able to determine the overall risk of nutrient loading based on Metrogro application.

*Methods*

There are 53 fields within the watershed that are receiving Metrogro applications. Of these, 50 were entered into the MMSD SNAP-Plus model. Three fields were not used due to unavailable soil test data. The same model parameters as the general agricultural practice SNAP-Plus model (Section 4.1.2) had to be determined for each field, in addition to a new parameter representing nutrient application. The field-by-field information was gathered from historical data that was provided by MMSD.

Soil map units, field sizes, and distances to the nearest stream were determined for each field using a combination of the documentation provided by MMSD and a series of spatial analyses using ArcGIS 9.2. Soil map units were obtained from the most recent National Resources Conservation Service (NRCS) Soil Survey, and field sizes were calculated using ArcGIS tools and then compared to the MMSD data to check for consistency. Distances to the nearest stream were determined by creating distance buffers in ArcGIS and identifying those fields receiving Metrogro that lie within these buffers.

Tillage practices were selected based on interviews with producers within the watershed that were previously described in Section 4.1.2. For this analysis, we assumed that no tillage was used for soybean or winter wheat production, and that fall chisel and no disking was used for corn grain.

Crop rotations were assumed to be a three year rotation of corn grain, soybeans, and winter wheat. This was based on information obtained from MMSD on typical farming practices in the Door Creek watershed, and it also supports MMSD's internal practice of only applying to fields every three years. Soil test phosphorus levels as well as Metrogro application rates for the model were also obtained from MMSD documentation. This data was recorded from 2000-2008; but due to time constraints and model limitations, it was assumed that all fields received Metrogro applications starting in 2009.

Complete details on how the parameters were obtained and entered in to the SNAP Plus model are located in Appendix 10.

*MMSD SNAP-Plus Analysis Results*

The SNAP-Plus model results indicate that only 95 (8%) of the 1,219 acres within the watershed that are receiving Metrogro applications have an average P index greater than 6.0 (Table 4.3). Of the 95 acres that exceed the P index of 6.0, all have soils with slopes ranging from 6 to 12%. These same fields also have P index values ranging from 6.1 to 7.1 with a total average value of 6.5 (Table 4.4). When considering that there are approximately 13,000 acres of agricultural land within the watershed, the 95 acres that have a P index value above 6.0 is relatively insignificant.

**Table 4.3: Breakdown of acreage in the Door Creek Watershed receiving Metrogro based on Phosphorous Index values.**

| | Acres of Watershed | Percent of Agricultural Lands |
|---|---|---|
| P Index >6 | 95 | 8 |
| P Index <6 | 1124 | 92 |
| Total Analyzed | 1219 | 100 |

**Table 4.4: Analysis of field slopes within the Door Creek Watershed that have P index values greater than 6.0.**

| Slope (%) | Area (ac) | % of Fields with > 6 PI | PI value for a three year rotation | | |
|---|---|---|---|---|---|
| | | | Min | Max | Avg. |
| 12-Jun | 95 | 100 | 6.1 | 7.1 | 6.5 |

Even though the SNAP-Plus model indicated that P Index values would decrease over the three year rotation, it is important to note that the amount of phosphorous being applied to the field following the Metrogro application is not fully removed from the field given the current crop rotation. This results in an increase in soil P levels after multiple applications of Metrogro.

The general agricultural practice SNAP-Plus method in Section 4.1.2 indicated that soils with slopes exceeding 6% are areas of concern for the contribution of phosphorus to surface waters. Since all of the 95 acres with P index values greater than 6.0 have slopes exceeding 6%, attention should be given to these areas because of their high potential for contributing phosphorous to the watershed. MMSD does apply special practices to fields with slopes exceeding 6%, which may reduce P index values.

*SNAP-Plus Conclusions*

Based on the results of the MMSD SNAP-Plus analyses, we conclude that the key parameter analyzed within the model is soil slope. This is supported by model results that show that 100% of the Metrogro fields with a modeled P index greater than 6.0 have slopes exceeding 6%. These fields are of most critical concern because if they are not managed carefully, they have the potential of contributing to high phosphorous loadings to nearby streams.

Even though soil slope was identified as the most important field parameter, concern should also be given to the remaining parameters as well. Since soil type and distance to nearest stream cannot be changed on the landscape, there is little worry that these parameters will significantly increase the P index. However, changes in tillage practice, crop rotation, and nutrient application (Metrogro) could significantly alter these results. Thus, it is also our conclusion that it is very important that MMSD keep detailed up-to-date records and incorporate the data into SNAP-Plus models to ensure that surface waters are not receiving excessive amounts of phosphorous.

#### 4.4.2.2 ASSESSMENT OF WDNR REGULATIONS AND MMSD METROGRO OPERATIONS

The assessment of MMSD Metrogro operations and WDNR regulations consists of a review of Metrogro's operating procedures and the requirements in NR 204 as they apply to subsurface drain tile and nutrient restrictions. If either of these aspects is improperly handled or under-regulated there is a potential for the release of liquids biosolids into the broader Door Creek environment. The assessment of how MMSD and the WDNR regulations manage these two vital aspects of liquid biosolids application supports the goal of the Practicum by investigating potential sources of nutrient pollution that may be overlooked.

*Drain Tile Restrictions*

The Practicum conducted a literature review, which is located in Section 4.3 of this report, on the potential hazards of injecting liquid nutrients into fields containing subsurface drain tiles. Watson and Luxmoore (1986) found that liquid nutrients can travel directly into subsurface drain tiles via soil macropores such as worm burrows, soil cracks, and abandoned root channels. Macropores allow the liquid biosolid to effectively bypass the soil matrix, which would otherwise slow down its movement (Watson & Luxmoore, 1986). This is a concern because once liquid biosolids have reached subsurface drain tiles they are able to easily move from the subsurface drainage system into a receiving water body.

Our review of NR 204 found it does not restrict the injection of municipal liquid biosolids in fields containing subsurface drain tiles. Robert Liska, a WDNR Wastewater Specialist who oversees the land application of MMSD Metrogro, was contacted to provide clarification on the regulations in place for municipal liquid biosolids injection into these types of fields. Mr. Liska stated that drain tile regulation is one "soft spot" of NR 204. He elaborated that the law contains no explicit provisions that prohibit municipal biosolid application programs from injecting into fields containing subsurface drainage, and it also does not require monitoring of injection into those fields (R. Liska, personal communication, June 30, 2009).

A lack of drain tile regulation is also present in other liquid material injection regulations, such as NR 113 (private septage and grease interceptors), and NR 214 (industrial liquids, sludges and byproducts). (A more complete discussion of NR 214 is provided in Chapter 6) Our examination of industrial and private septage application within the Door Creek watershed was based on industrial and private septage application permits. The examination found no active industrial and private septage application sites within our study area (R. Liska, personal communication, July 3, 2009). While we did not find any industrial and private septage liquid material application sites within Door Creek, we did find several sites near the watershed that receive industrial liquid materials. Based on their close proximity, we believe the lack of drain tile regulation in NR 214 has the potential to cause future nutrient transport problems for the Door Creek watershed if industrial liquid application sites are permitted.

During an interview, MMSD Metrogro indicated that it is aware of the potential hazards associated with injecting liquid biosolids into fields with subsurface drainage and has implemented voluntary procedures to prevent liquid biosolids from leaching into drain tiles. Mike Northouse, MMSD Biosolids and Land Application Manager, stated that MMSD Metrogro does not inject into fields that are drained by subsurface tiles. This is primarily due to concerns that field injection equipment could damage the drain tiles (M. Northouse, personal communication, June 6, 2009). When asked his opinion on MMSD's self-imposed policies that prohibit injection into drain tiled fields, WDNR's Robert Liska expressed his confidence in their ability to enforce that restriction (R. Liska, personal communication, June 30, 2009).

*Nutrient Restrictions*

The MMSD Metrogro and other municipal programs do have to comply with nutrient restrictions under NR 204. However, these only restrict the amount of nitrogen that can be applied with a municipal liquid biosolid. This nitrogen restriction is based on crop requirement.

Dave Taylor, MMSD Director of Special Projects, maintains that MMSD Metrogro is fully compliant with all nitrogen application regulations in NR 204 and has even taken extra voluntary steps to control phosphorus loading. Mr. Taylor says that the MMSD Metrogro phosphorus policy aims "to bring [phosphorus] rates more in line with [phosphorus] removal over the crop rotation" (D. Taylor, personal communication, December 8, 2008). In a follow-up interview, Mr. Taylor indicated that MMSD Metrogro imposes a voluntary, self-regulated restriction on the length of time between reapplication of liquid biosolids. MMSD Metrogro will not return to the same field for a minimum of three years in an effort to bring the soil phosphorus level in line with crop phosphorus removal. In some cases, they may not return for even longer periods based on the rotational practices of the crops being grown (D. Taylor, personal communication, April 6, 2009).

MMSD Metrogro also maintains detailed records for each field that receives liquid biosolids. These records contain information on important measurements, such as biosolids quality, well water quality, site hauling and application history, metal loading information, and soil nutrient testing data (Taylor, 2008). The detailed records help them determine the required liquid biosolids application rates by accounting for all sources of nitrogen, including what is already in the soil. Additionally, if the records indicate that the metal content of the field reaches the EPA restrictive limits, MMSD Metrogro will stop liquid biosolid injection (D. Taylor, personal communication, April 6, 2009).

Additionally, there are two other Wisconsin laws that regulate the application and management of liquid biosolids and other liquid materials, which are Wisconsin Agriculture, Trade, and Consumer Protection Chapter 50 (ATCP 50), and Natural Resources Conservation Service Conservation Practice Standard 590 (NRCS 590). ATCP 50 combines a series of regulatory tools, which include grants, cost sharing, and management regulations, into a broad soil and water resource management program (ATCP, 2009). NRCS 590 is a regulation that creates acceptable criteria for managing the amount, source, placement, form, and timing of nutrient application (NRCS, 2005). Each of these laws contains specific measures that overlap with NR 204 and may cause regulatory conflicts.

The primary regulatory measure in ATCP 50 that may conflict with NR 204 is section ATCP 50.78, Nutrient Management (ATCP, 2009). ATCP 50.78 requires a nutrient management plan for any field that receives any amount, source, and form of plant nutrient application by soil nutrient reserves, commercial fertilizers, and organic wastes (ATCP, 2009). NR 204 does not require a nutrient management plan, and liquid biosolids applied under NR 204 receive an exemption from the ATCP 50 nutrient management plan requirement (ATCP, 2009; Wisconsin State Legislature, 1996). However, if the field received an application of a nutrient source that was regulated by ATCP 50 in the year prior to or following the biosolids application, a nutrient management plan that included the biosolids would be required (ATCP, 2009).

In this situation the conflict between NR 204 and ATCP 50 regarding the nutrient management plan can cause confusion on the part of the landowner, or publicly owned treatment works (POTW). This conflict may even open the door for mishandling or mismanagement of nutrients. If the POTW is unaware of prior or future applications of other nutrients, or the land owner believes the biosolid applied by the POTW is exempt from a nutrient management plan, nutrients may be mishandled. This conflict could ultimately defeat the purpose of the law, which is to minimize excessive nutrient applications in order to protect water quality (ATCP, 2009).

NRCS 590 contains two regulatory measures that may conflict with NR 204. The first is NRCS 590 site restrictions for the application of manure and fertilizers. NRCS 590 contains site restrictions based on frozen or snow covered ground; slope; setback from surface waters; depth to groundwater and bedrock; setback from community and private wells; setback from residences, businesses, schools, and recreation areas; maximum loading restrictions, etc., that are similar to NR 204 (NRCS, 2005; Wisconsin State Legislature, 1996). However, NR 204 slope restrictions, as well as water and property setbacks, are stricter than NRCS 590 (NRCS, 2005; WI Legislature, 1996). Having these two different sets of site restrictions is one hindrance to applying the SNAP-Plus model to a POTW's application of municipal biosolids. Currently, SNAP-Plus is set up to model liquid material applications under NRCS 590 restrictions, not NR 204.

A second set of NRCS 590 regulatory measures that conflict with NR 204 are the nutrient criteria regulations. NRCS 590 regulates the source, rate, timing, form, and method of application for all major nutrients, including nitrogen, phosphorus, and potassium (N, P, K), if the landowner has a NRCS 590 nutrient management plan (NRCS, 2005). In comparison, NR 204 only regulates the amount of N applied to the field according to the N needs of the current crop, with no broad nutrient management plan requirement (Wisconsin State Legislature, 1996). This is where conflict can arise.

In NRCS 590, organic byproducts like municipal biosolids are applied in accordance with applicable regulations, meaning NR 204 (NRCS, 2005). NRCS 590 exempts liquid biosolid and other liquid material because they are already regulated by NR 204 or similar liquid material regulation. If the landowner does not have a NRCS 590 nutrient management plan, they do not need to account for the P load of municipal biosolid applied to the field, only the N, according to NR 204. If the landowner does have a NRCS 590 nutrient management plan, the landowner will need to include the N of the biosolid in the NRCS 590 nutrient management plan and in NR

204, but not the P. The phosphorus needs of the plants are only regulated by the specific requirements of the NRCS 590 nutrient management plan, thus NR 204 exempts the P load of a municipal biosolid (NRCS, 2005). To further exacerbate the situation, liquid biosolids contain P levels that are approximately three times the average P concentration in manure, by dry weight (Taylor, 2007; NRCS, 2005). This regulatory conflict may allow the landowner to bypass the NRCS 590 nutrient management plan for municipal biosolids and apply P at a higher concentration without accounting for it.

## 4.4.3 POTENTIAL FUTURE NUTRIENT REGULATION AND DRAIN TILE CHANGES

After assessing the current regulations and their shortcomings, we sought the WDNR's opinion on areas where regulations could be refined or improved. In an interview, Fred Hegeman, WDNR Wastewater Engineer, elaborated on the WDNR's current position on NR 204 regulations. Mr. Hegeman indicated that the WDNR is aware that NR 204 lacks nutrient and drain tile regulation and is also aware of the shortcomings of two similar liquid material laws, NR 113 and NR 214 (F. Hegeman, personal communication, July 13, 2009). The following sections discuss this in more detail.

### 4.4.3.1 NUTRIENT REGULATIONS

In order to address the lack of nutrient regulation in NR 113, NR 204, and NR 214 the WDNR would need to amend all three liquid material laws. The WDNR is considering this approach; however, it does not have anything drafted at this time. Based on conversations with Mr. Hegeman, potential amendments with respect to these laws may include (F. Hegeman, personal communication, July 13, 2009):

- Adding or modifing soil testing and monitoring for phosphorus and other agriculture nutrients.
- Requiring nutrient management plans for phosphorus and other agriculture nutrients that are similar to the Department of Trade and Consumer Protection (DATCP) nutrient management plans.
- Implementing a phosphorus index or developing a phosphorus strategy, which may include a mandatory time interval for reapplication of liquid materials based on the phosphorus index of the field.
- Implementing soil loss strategies.

Note: Amendments or modifications of laws may be done in a manner comparable to current NRCS 590 regulations.

A follow-up interview with MMSD indicates concern regarding a potential phosphorus restriction in NR 204 that is similar to the one for nitrogen. Mike Northouse of MMSD stated that if the amount of phosphorus is limited to the requirement of the current crop being grown, MMSD "Metrogro will go out of business." (M. Northouse, personal communication, July 30, 2009).

MMSD has two primary concerns that must be overcome to make this phosphorus limitation work (M. Northouse, personal communication, July 30, 2009). The concerns are:

- Some of the fields receiving Metrogro biosolid have a high level of soil phosphorus but are not a concern for excessive phosphorus transport. MMSD is currently restricted from applying biosolids to erosive areas, and it feels that excess phosphorus applied to non-erosive areas will largely remain on the fields.
- Removing phosphorus from the Metrogro biosolid is very expensive and would require technology upgrades.

#### 4.4.3.2 DRAIN TILE REGULATIONS

Subsurface drain tile regulation is currently receiving less emphasis by the WDNR. Mr. Hegeman is unsure if and how drain tile regulations will be drafted into the new liquid material regulations for each law. He explained that Wisconsin currently has no other laws regulating drain tiles, and that any new law would be difficult to enforce because regulatory agencies have inadequate, if any, maps locating drain-tiled fields (F. Hegeman, personal communication, July 13, 2009).

To complete our investigation of potential municipal biosolid application regulatory changes, we contacted Dr. Dick Wolkowski, a UW Madison-Extension Soil Scientist. Dr. Wolkowski offered his opinion that liquid municipal biosolid runoff via drain tiles may be a relatively small issue. The factors that determine whether liquid biosolids can reach subsurface drain tiles and thus be released into the downstream waterbodies include percent solids of the liquid biosolids, tillage practice, and liquid biosolid injection rate. Compared to other materials such as certain industrial liquids, municipal liquid biosolids have a higher percentage of solids and do not pose as large a risk of transported being downstream via subsurface drain tiles (D. Wolkowski, personal communication, July 14, 2009).

Dr. Wolkowski suggested the following best management practices to prevent liquid materials from leaching into drain tiles (D. Wolkowski, personal communication, July 14, 2009):

- Injection or application of liquid biosolids with immediate incorporation (on the same implement)
- Reduction of liquid biosolid application rate to prevent ponding
- Performing light tillage with a disk or similar implement to disrupt the macropore continuity prior to application

#### 4.4.3.3 SNAP-PLUS FOR NR 204 MANAGEMENT

During our interview, Mike Northouse of the WDNR commented on the possibility that his agency would incorporate SNAP-Plus modeling into new NR 204 regulations. Mr. Northouse is concerned about how the WDNR would regulate SNAP-Plus nutrient indexing of potential injection fields. His primary concerns focused on model preparation and the methodology that would be used when preparing the model. If the MMSD Metrogro program can prepare a

SNAP-Plus model for the specific areas of the fields that they are going to apply liquid biosolids to, then SNAP-Plus should be a viable tool for managing their nutrient applications. However, if the SNAP-Plus models used by Metrogro are the ones prepared by the landowners to meet NRCS 590 requirements, then MMSD Metrogro's ability to inject liquid biosolids will be severely limited (M. Northouse, personal communication, July 6, 2009).

The issue with the SNAP-Plus methodology required by NRCS 590 for landowners is that it classifies the soils for the entire field based on a limiting soil condition that is defined as the most erosive soil covering a minimum of 10% of the field (DATCP, 2008). The MMSD Metrogro program is already restricted from injecting in these limiting soil areas, and thus the SNAP-Plus models prepared by landowners would eliminate the possibility of injecting liquid biosolids into the other areas of the field that are not restricted by a limiting soil condition (M. Northouse, personal communication, July 6, 2009).

### 4.4.4 CONCLUSIONS

The main goal of this examination was to investigate potential sources of nutrient pollution currently being overlooked by the MMSD Metrogro program and the laws governing municipal waste application. Our assessment of municipal liquid biosolid application within the Door Creek watershed included a SNAP-Plus analysis of MMSD Metrogro fields and an assessment of the MMSD Metrogro operations and WDNR regulations, which included interviews with key persons who manage, oversee, and regulate Metrogro applications.

After this extensive examination of the MMSD Metrogro program, it is our conclusion that this program is not likely to be a primary contributing source of nutrient pollution to the Door Creek watershed. MMSD follows all current NR 204 regulations and has gone beyond what is required of them by implementing their own stricter procedures. MMSD has also developed practices for prohibiting the injection of liquid biosolids on fields drained by subsurface tiles; these practice could provide an effective model for other liquid biosolid applicators to follow.

However, our assessment did find two areas of concern. The SNAP-Plus modeling of the MMSD Metrogro fields indicated that approximately 8% of the fields receiving the Metrogro application have P index values in excess of 6.0. We do not suspect, however, that these fields constitute high levels of nutrient contribution, because they only represent approximately <1.0% of the agricultural land within the watershed. However, long-term SNAP-Plus modeling indicates that Metrogro soil phosphorus levels will increase over time, so it will still be important to properly manage the Metrogro applications by continuing to avoid application on fields with high erosivity. Without proper management even this small proportion of agricultural lands could be a contributor to downstream nutrient pollution within the Door Creek watershed.

The Practicum has consulted MMSD about these two areas of concerns and we are hopeful that they will address them in the future. It would be premature to ask the MMSD Metrogro program to use the current SNAP-Plus program to model field P index values. This model needs to be modified to be compatible with the practices of a publicly owned treatment work such as MMSD. The Practicum recommends that upon the modification of SNAP-Plus, MMSD Metrogro should use it as a best management practice to identify and exclude those field areas with a P index above 6.0. MMSD Metrogro is aware of the possibility of increasing P indices in their fields. They are currently looking into processes and technologies to reduce phosphorus in their biosolids and changing rotational practices to further limit the application of phosphorus on their fields (D. Taylor and M. Northouse, personal communication, September 15, 2009).

Our review of state laws regulating biosolids and liquid materials has indicated two potentially large sources of nutrient pollution, nutrient and drain tile restrictions. State municipal liquid biosolids law, NR 204, lacks several key provisions, including soil testing and record keeping, phosphorus management and re-application time intervals, and soil loss strategies. Without these key regulatory provisions in NR 204, the potential will remain for nutrients to be released unnecessarily into the Door Creek watershed and downstream waterways.

The review of Wisconsin State laws, ATCP 50 and NRCS 590, which contain regulations with NR 204, found three primary areas of possible conflict with NR 204. Liquid biosolids applied under NR 204 receive an exemption from the ATCP 50 nutrient management plan that may lead to the mishandling of nutrients. NRCS 590 and NR 204 contain two different, and possibly conflicting, sets of site restrictions that have delayed the SNAP Plus model's ability to model P indeces for POTWs. Lastly, NRCS 590 nutrient criteria regulations conflict with NR 204. NR 204 exempts the P load of a municipal biosolid from the NRCS nutrient management plan, which may allow the landowner to possibly bypass the NRCS 590 nutrient management plan. If these conflicts are properly addressed and revised, it should reduce the possibility of unnecessary nutrient runoff and improper nutrient management.

The WDNR's proposed amendments to the NR 204, NR 113, and NR 214 regulations would enhance nutrient management requirements already in place in Wisconsin and create continuity between laws that are related to nutrient management. These proposed amendments would alleviate many of the main concerns regarding liquid material nutrient regulation. However, a lack of subsurface drain tile regulation could leave some waterbodies at risk for nutrient pollution. The science behind nutrient transport to downstream waterbodies via subsurface drain tiles is well-established, especially for highly liquid materials, such as certain industrial liquids.

Our examination of industrial application within the Door Creek watershed found that there were no active sites receiving industrial liquid materials. There are, however, several sites near the watershed receiving industrial liquid materials. Based on the close proximity of these industrial sites to the Door Creek watershed, we believe that it is plausible that the watershed may receive industrial liquid materials in the future. The high liquid content of many these materials makes them the most likely to be leached to subsurface drain tiles and transported to downstream waterbodies. Thus, the addition of a drain tile prohibition to NR 214 would be effective in limiting pollution due to industrial liquid materials in the Door Creek watershed and the rest of the state of Wisconsin.

### 4.4.5 RECOMMENDATIONS

1. Wisconsin's liquid biosolid application laws lack several key regulatory measures needed to prevent the release of liquid biosolid into Door Creek and Lake Kegonsa. To account for these nutrient management shortcomings, the NR 204 regulations should be amended based on the following recommendations:

   *These recommendations should also be considered for NR 113 and NR 214*

   1.1. Require soil testing and monitoring for phosphorus and other nutrients.

   1.2. Require nutrient management plans for phosphorus and other agricultural nutrients similar to the Department of Trade and Consumer Protection (DATCP) nutrient management plans.

   1.3. Implement a phosphorus index or phosphorus management strategy, which may include a mandatory time interval between reapplication of liquid materials based on the phosphorus index of the field.

   1.4. Implement soil loss strategies that may include tilling soil below the depth of liquid biosolids injection at the time of application.

   1.5. Require injection equipment to be calibrated for each field so that the liquid biosolid application rate does not create ponding.

   1.6. Require drain tile mapping on all new fields proposed to receive municipal biosolids.

   If it proves infeasible to make changes to NR 204, we recommend that the County enact an ordinance that incorporates one or more of the above recommendations.

2. Amendments to NR 214

   2.1. Prohibit the injection of industrial liquid materials into fields containing subsurface drain tiles.

## 4.5. URBAN STORMWATER AND CONSTRUCTION SITE EROSION ANALYSIS

### 4.5.1 OVERVIEW

Urban stormwater is produced by rainfall and snowmelt runoff from developed landscapes. It is different than runoff from rural or natural landscapes because it flows across concentrated areas of impervious surfaces, such as parking lots, streets and rooftops. As stormwater flows across these impervious surfaces, it picks up and carries increased loads of contaminants to downstream lakes and streams. Carefully managing urban stormwater is important because, according to the US EPA, "as little as 10% impervious cover in a watershed can result in stream degradation" (US EPA, 2003).

Within the Door Creek watershed approximately 4,235 acres (22%) of the land is covered by urban and transportation development (Table 4.5). The Practicum used geographical data obtained from the Capital Area Regional Planning Commission to produce a GIS analysis of land cover.

**Table 4.5: Approximate land use/cover in acres and percent of the total Door Creek watershed land area.**

| Land Use Classification | Acres | % of Watershed |
|---|---|---|
| Agriculture | 10,312 | 53 |
| Urban | 2,770 | 14 |
| Transportation | 1,465 | 8 |
| Wetland | 1,684 | 9 |
| Forest | 1,668 | 9 |
| Open Land | 1,342 | 7 |
| Open Water | 69 | 0.5 |

Residential developments are scattered throughout the watershed, with concentrated areas of development located in the northern portion and along the western edge of the watershed. These areas include the City of Madison in the northwest, the Village of Cottage Grove in the northeast, and the village of McFarland along the western boundary. Important transportation corridors include Interstates 90 and 94, State Highway 12-18, and several County highways. The developed areas within the watershed are shown on Figure 4.9.

In addition to stormwater runoff from developed urban areas, new developments under construction also produce soil erosion that can enter stormwater systems. Construction activities significantly disturb the soil, making it vulnerable to erosion during snowmelt and rain events. Runoff from construction sites can carry large loads of eroded sediment, soil nutrients, and contaminants that degrade water quality into nearby water bodies.

Stormwater discharge from urban areas and erosion runoff from construction sites can have significant water quality impacts on Door Creek and Lake Kegonsa if they are not properly managed. The potential water quality effects associated with these developments will become more important as urbanization increases in the Door Creek watershed.

Enforcement of the current State and Federal water quality standards will be an important part of managing future stormwater and construction site runoff. Wisconsin manages water degradation threats by following federal mandates for water quality protection through the US EPA Clean Water Act, and the State and Dane County have implemented additional regulations to control and manage stormwater runoff, land erosion, and water degradation.

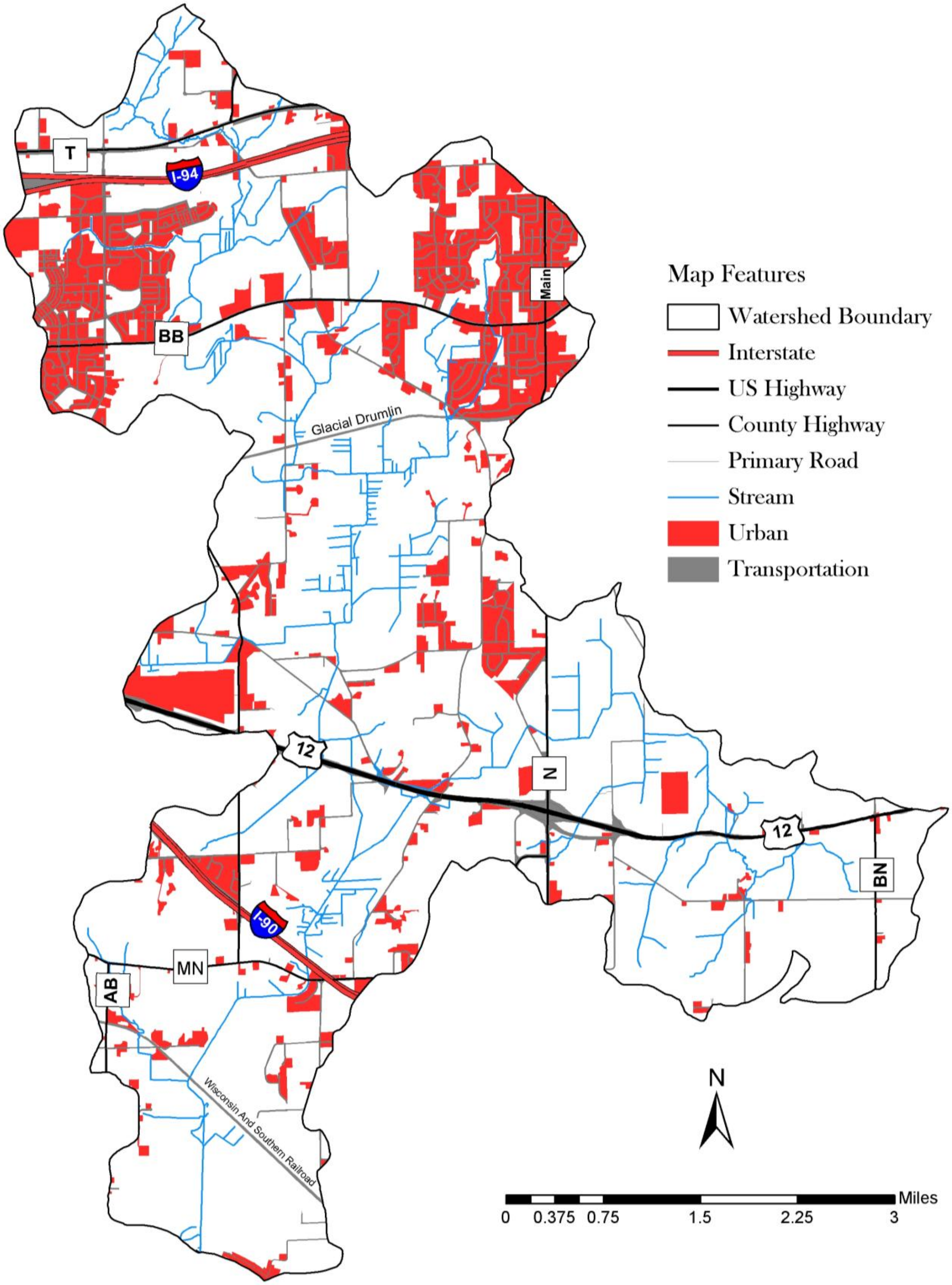


**Figure 4.9: Major municipalities and development within and surrounding the Door Creek watershed.** Source: Capital Area Regional Planning Commission 2007, Dane County Land Use Polygons 2005, Created June 2009 by 2009 WRM Practicum

### 4.5.2 Urban Areas

#### 4.5.2.1 IMPACTS

The US EPA has identified urban stormwater as one of the leading sources of water degradation in the United Sates (US EPA, 2002). The landscape changes that accompany urbanization have important impacts on water quality, water quantity, and groundwater flow. These impacts include more diverse pollutants, reduced pollutant removal, reduced infiltration, and increased peak flow during storm events (Davis, 2005).

**Table 4.6: The effects of impervious surfaces and resulting impacts.**

| | Flooding | Erosion | Channel Widening | Streambed Alteration | Water Quality Degradation | Habitat Loss |
|---|---|---|---|---|---|---|
| **Increased Volume** | ● | ● | ● | ● | | ● |
| **Increased Peak Flow** | ● | ● | ● | ● | | ● |
| **Increased Peak Flow Duration** | ● | ● | ● | ● | | ● |
| **Decreased Base Flow** | | | | | ● | ● |
| **Changes in Sediment Loading** | ● | ● | ● | ● | ● | ● |
| **Increased Pollutant Loading** | | | | | ● | ● |

Source: Dane County Erosion Control and Stormwater Management Manual, Chapter 3, Stormwater Management, January, 2007.

From a water quality standpoint, the urban environment can contribute a variety of pollutants to stormwater runoff, including: oil, grease, and toxic chemicals from automobiles; pesticides and nutrients from lawns and fields; viruses, bacteria and nutrients from pet waste and leaking septic systems; and road salts, sediments, heavy metals, and thermal pollution from roads (US EPA 2003). Since stormwater carries these pollutants downstream, receiving waters typically experience negative impacts, which can include decreases in fish density, species richness, and diversity (USGS, 2008b).

Urbanization also has significant impacts on water quantity and groundwater flow. The impervious surfaces that accompany urbanization increase the volume of stormwater runoff during rainfall events (Figure 4.6). The efficient means of transport, such as streets, ditches, and sewers, also quickly transport the increased volume of water downstream. Groundwater flow is changed as increased impervious surfaces reduce infiltration and the residence time of water during rain and snowmelt events. Loss of infiltration decreases groundwater recharge and can result in lower stream flows during dry periods or increased flooding directly following rain events (US EPA, 2003).

#### 4.5.2.2 REQUIREMENTS AND MANAGEMENT PRACTICES

Urban stormwater runoff in Wisconsin is currently regulated under Wisconsin's Runoff Management Rule as established in Wisconsin Administrative Code (Wis. Admin. Code) NR 151, Subchapters III and IV. Subchapters III and IV set forth non-agricultural performance standards and transportation performance standards, respectively, to reduce the amount of sediments and non-point source pollutants and to achieve water quality standards (WDNR, 2005). In order to achieve state water quality standards, urban areas with population densities of 1,000 or more people per square mile, were responsible for developing and implementing stormwater management plans as of March 10, 2008 (WDNR, 2005).

Additionally, the requirements of the National Pollution Discharge Elimination System (NPDES) are administered under the Wisconsin Pollutant Discharge Elimination System (WPDES) Permit Program. The WPDES is regulated under the authority of Wis. Admin. Code NR 216 (WDNR, 2009c) and requires communities throughout the state to obtain state permits before discharging stormwater into lakes or streams.

The goal of NR 216 is to minimize the release of pollutants carried by stormwater runoff by establishing minimum discharge standards for WPDES permits. The current NR 216 standards were adopted in August, 2004, and they set required performance standards for municipalities subject to NR 216 municipal stormwater permits. These municipalities were required to reduce total suspended solids by 20% as of March 10, 2008 and reduce total suspended solids by 40% as of March 10, 2013 (WDNR, 2005).

Water quality improvements through the WPDES permit program are achieved by a range of measures that include best management practices (BMPs), stormwater monitoring, and public outreach and education (City of Madison, 2006b). The most appropriate BMPs are addressed in Wis. Admin. Code NR 154, and include such practices as street sweeping and leaf collection to help reduce loading of important nutrients, such as phosphorus, in stormwater runoff.

In addition to State requirements, the Dane County Code of Ordinances has implemented more stringent guidelines for stormwater runoff management that all municipalities must meet under Subchapter II of Chapter 14: Manure Management, Erosion Control and Stormwater Management. Stormwater management plans must be submitted prior to construction for all urban developments. Design requirements include maintaining the predevelopment peak runoff rates for the 2-year and 10-year, 24-hour storms; safely discharging the 100-year flood; and trapping particles greater than or equal to 5 microns in diameter in order to achieve 75% trap efficiency (LWRD, 2007b; Figure 4.10).

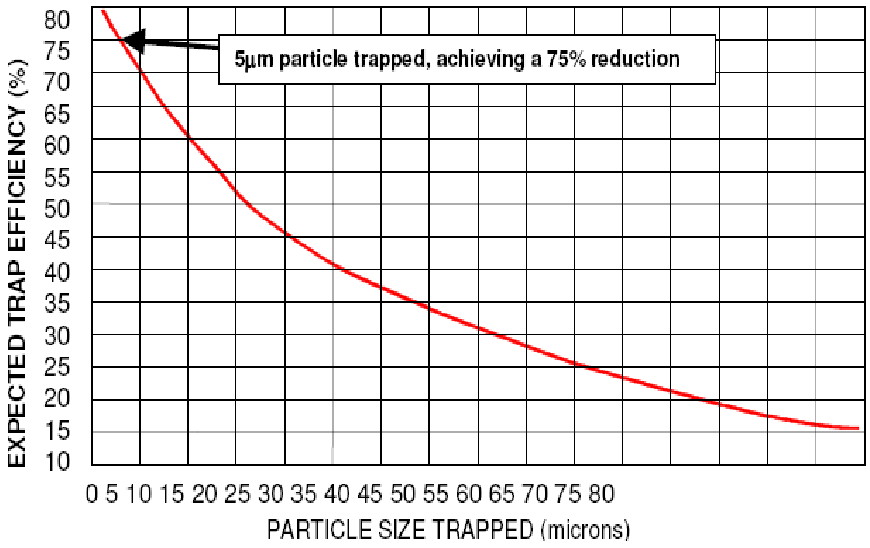


**Figure 4.10: A 75% reduction in soil loss from uncontrolled construction sites can be achieved by limiting soil loss to a maximum of 7.5 tons/ acre/year (t/ac/yr).** For the majority of Dane County soils, in order to achieve trapping efficiency of 75%, soil particles down to 5 microns need to be trapped, as illustrated. SOURCE: Dane County Erosion Control and Stormwater Management Manual, Chapter 2 – Erosion Control, January, 2007.

Additionally, stormwater flow must be discharged to a stable outlet at non-erosive velocities; directed from impervious to pervious areas; and controlled for water temperature (USGS, 2004). In order to promote groundwater recharge, residential developments are required to achieve infiltration rates equal to 90% of pre-development rates, and non-residential developments must achieve a 60% rate (LWRD, 2007b). Wisconsin's Urban Storm Water Regulations are also discussed in more detail in Chapter 6.

### 4.5.2.3 Potential Issues

While development within the Door Creek watershed has been relatively slow since 2002 (Table 4.7), expanded development over the next decade could have significant stormwater impacts.

**Table 4.7: Land developed and under construction within the watershed.**

| Door Creek Watershed Area | 19,310ac |
|---|---|
| Total Developed Since 2002 | 39.4ac |
| Under construction as of May 1, 2009 | 20.8ac |

The Village of Cottage Grove is predicted to have the greatest growth, and municipalities located around the edge of the Door Creek watershed are expected to expand into the watershed. Taking the year 2000 as a baseline, the population of Cottage Grove is estimated to grow by 95% by 2020 (Village of Cottage Grove, 2009a). The Village of McFarland, located along the western edge of the watershed, is expected to grow by 36% by 2020, and the population of the City of Madison is projected to grow by 18% by 2020 (City of Madison, 2006a; Village of McFarland, 2006).

The expansion of these urban communities will create more impervious surfaces within the watershed. The impacts of urbanization on water quality, water quantity and groundwater flow that are currently being experienced in the watershed would only increase as urban areas expand. Dane County and the State both have set requirements for stormwater management from urban areas. Future management planning and decision making must account for the impacts of future growth in order to minimize the potential watershed degradation that can be caused by increasing urbanization.

## 4.5.3 CONSTRUCTION SITE EROSION CONTROL

### 4.5.3.1 IMPACTS OF CONSTRUCTION RUNOFF

Soil erosion produced by active construction sites in urban areas is another important concern associated with urbanization. Construction disturbs the soil considerably, making soil erosion and runoff problems more likely to occur. In Wisconsin, construction sites are the largest source of sediments polluting waterways. This is due to a combination of a lack of vegetation, which leads to high erosion rates; graded land surfaces; and efficient ditches and storm sewers that promote high delivery rates (UWEX & WDNR, 1997). Soil erosion from construction sites is a water quality concern in the Yahara Lakes region because the eroded soil can directly contribute high levels of nutrients, such as phosphorus and suspended solids, to nearby waterbodies.

### 4.5.3.2 REQUIREMENTS AND MANAGEMENT PRACTICES

Construction sites are also regulated under the NR 216 WPDES permit program and Wis. Admin. Code NR 151. Enforcement of construction site standards under NR 216 began on August 1, 2004. The regulation requires all landowners of construction sites that disturb one acre or more of land to obtain a construction permit prior to beginning work on a site (WDNR, 2006).

NR 151 sets forth construction site standards that require the implementation of an erosion and sediment control plan and is enforced through the NR 216 WPDES permit program. Erosion and sediment control plans are required to utilize BMPs to reduce, to the maximum extent possible (MEP), annual average sediment loads by 80% (WDNR, 2005).

A separate set of erosion and sediment control standards has been developed to limit further pollution after construction has been completed and stabilization has occurred. These standards are similar to those set forth for established urban areas. According to NR 151, a written storm water management plan must be developed for new urban areas and include performance standards that will address total suspended solids (TSS), peak discharge rate, infiltration, protective areas, and fueling and maintenance areas (WDNR, 2005).

The Dane County Stormwater and Erosion Control Ordinance, which was implemented in 2002, has erosion control standards that are equivalent to those required by NR 151 and NR 216. As with the State requirements, the County requires an 80% reduction in sediments from a newly developed site, and a 40% reduction in sediments from redeveloped sites (LWDR, 2002). Dane County administers the ordinance in unincorporated areas and grants administrative authority to municipalities with an adopted a stormwater management plan that meets the County requirements (LWDR, 2002).

The WDNR estimates that 30 tons of sediment per acre per year can be eroded from an uncontrolled construction site (UW-Ext & WDNR 1997). Based on the WDNR estimate, Dane County has mandated a maximum allowable soil loss rate from construction sites of 7.5

tons/acre/year, which reduces soil loss by 75% (LWDR, 2007a). In order to achieve 75% trapping efficiency on site, construction sites are required to trap sediments down to the 5 micron particle size (Fig. 4.11) (LWDR, 2007a).

Both the County and State outline a variety of structural and non-structural practices that can minimize soil erosion from construction sites. Dane County's *Erosion Control and Stormwater Management Manual* and WDNR's Construction Site Erosion and Sediment Control standards provide guidance for implementing effective construction site erosion control practices. These can include such practices as silt fences, stone track pads, vegetated buffer strips, and sediment basins; and they are implemented based on the topography and local features of a site (LWDR, 2007a; WDNR, 2009d).

Requirements for erosion control permit compliance are in place for Dane County, but its ability to enforce those standards is relatively limited. The permittee is to inspect the site once a week and after every, rain event that is 0.5 inches or greater. Inspections by Dane County are also to take place at least once every 30 days to ensure compliance. If a lack of effective controls is noted during an inspection, the permittee is notified and given a deadline to apply the necessary sediment and erosion controls (J. Harder personal communication, July 27, 2009). The County can also require site inspections based on complaints received from the public. However, the reality in the field is that compliance with erosion standards is often left to the judgment of the permittee, due to limited resources at the County and State level.

#### 4.5.3.3 POTENTIAL ISSUES

The allowable soil loss requirements of the Dane County Erosion Control and Stormwater Management Ordinance are based upon the Universal Soil Loss Equation (USLE) tolerable soil loss (LWDR, 2007a), which does not account for phosphorus concentrations in the soil. In Dane County, soils have been tested and averaged by the University of Wisconsin Soil and Plant Analysis Lab (UW SPAL) to have a phosphorus concentration of 56 ppm, which exceeds the recommended level of 30 ppm per acre (UW SPAL, 2004). Soil phosphorus levels are known to vary between farm fields, with some areas having soil test phosphorus levels several times that of the County and State averages. For example, samples taken by the Practicum from six pasture areas in the Door Creek watershed had an average soil phosphorus level of 190 ppm.

Assuming Dane County's average soil phosphorus levels, and using Dane County's 7.5 tons/acre/year maximum allowable soil loss from construction sites, soil information from UW SPAL, and equations provided by The Wisconsin Phosphorus Index website (http://wpindex.soils.wisc.edu), the potential phosphorus loading from a one acre construction site would be 8.98 lbs/year. By comparison, potential phosphorus loading from a one acre construction site would be 18 lbs/ac/yr using the average soil phosphorus levels measured in the pastures of the Door Creek watershed. This level of phosphorus loading is double the level that would be assumed under the Dane County estimate of average soil phosphorus, and more than double the recommended levels.

The projected future urban growth of Madison, Cottage Grove, and McFarland outlined in Section 4.5.2.3 would directly impact the amount of construction occurring within the watershed. Considering the amount of sediment that can run off of a construction site; the high level of phosphorus in the soils of the Door Creek watershed; and the detrimental effects that phosphorus can have on aquatic ecosystems, the testing of soil phosphorus levels could prove useful in limiting excess phosphorus inputs into waterbodies (Table 4.8). By addressing phosphorus levels that may be present in soils prior to construction activities, appropriate measures could be put into place to limit the levels of phosphorus loading that could occur.

**Table 4.8: Possible Phosphorous Loading.**

| **Maximum Allowable Soil Loss, 7.5 tons/ac/yr** | | |
|---|---|---|
| | **Soil test P levels (ppm)** | **P loading lbs/ac/yr** |
| **SPAL Recommended** | 30 | 7.62 |
| **Dane County (ave)** | 56 | 8.98 |
| **Pasture (ave)** | 190 | 18.08 |

Phosphorous loading that could occur in runoff based on soil phosphorus levels and the maximum allowable soil loss level of 7.5 tons/ac/yr.

If pre-construction soil phosphorus levels that are several times greater than the recommended levels are present on a site, one way to control phosphorus loadings is to lower the allowable soil loss below 7.5 tons/ac/yr. For example, a 25% reduction in the allowable soil loss to 5.5 tons/ac/yr would result in an approximate 25% reduction in phosphorus loading. A 50% reduction to 3.75 tons/ac/yr allowable soil loss would lead to an approximate 50% reduction in phosphorus loading (Table 4.9).

**Table 4.9: Phosphorus loading reductions.**

| | **Soil test P levels** (ppm) | **25% reduction Soil loss, 5.5 t/ac/yr P loading** lbs/ac/yr | **50% reduction Soil loss, 3.5 t/ac/yr P loading** lbs/ac/yr |
|---|---|---|---|
| **SPAL Recommended** | 30 | 5.59 | 3.56 |
| **Dane County (ave)** | 56 | 6.58 | 4.19 |
| **Pasture (ave)** | 190 | 13.26 | 8.44 |

Potential phosphorous loading reductions following an approximate 25% and 50% reduction in allowable soil loss, from 7.5 tons/ac/yr to 5.5 tons/ac/yr and 3.5 tons/ac/yr, respectively.

As can be seen in table 4.8 and table 4.9 phosphorus loading can be quite high where elevated soil phosphorus levels exist, and consequently, if soil loss levels can be reduced, phosphorus loading can also be reduced. Where elevated phosphorus levels exist, it could take at least a 50% reduction in allowable soil loss to obtain phosphorus loading levels that would be comparable to fields with soil test phosphorus levels closer to Dane County's average or the State recommended levels. For an expanded table showing the range of soil test phosphorus levels obtained by the Practicum, the resulting phosphorus loading based on allowable soil loss, reductions in allowable soil loss, and the equations utilized, please see Appendix 11.

Discussions among County planners, municipalities, and developers will need to take place to determine reasonable and attainable increases in erosion control standards that will address excessive phosphorus loading. Given the known effects of phosphorus on aquatic systems in the Yahara Lakes watershed, addressing excessive phosphorus loadings from construction sites can be a key component in minimizing future water degradation.

#### 4.5.3.4 RECOMMENDATIONS

- Require soil phosphorus testing before construction occurs.
- Require more stringent erosion control measures for construction sites that contain excessively high soil phosphorus levels.
- Monitor active construction sites on a consistent basis, particularly in areas with high phosphorus concentrations.

### 4.5.4 DOOR CREEK WATERSHED AREAS OF CONCERN

#### 4.5.4.1 DANE COUNTY LANDFILL RODEFELD SITE #2

The Rodefeld Site 2 landfill was investigated as a potential source of nutrients and pathogens to Door Creek. The Dane County Landfill Rodefeld Site 2 landfill is located on Highway 12 & 18, east of Interstate 90 and west of County Road AB, across from the Yahara Hills Golf Course. The landfill was opened in 1987 and is currently in its last of seven total phases, which cover a total surface area of 79 acres. Administration of the landfill is the responsibility of the Dane County Department of Public Works, Highway and Transportation, Solid Waste Division.

Solid waste disposal facilities in Wisconsin are regulated under the WDNR NR 500 Administrative Code series, and groundwater monitoring in the vicinity of landfills is regulated by Wisconsin Act 410 of the 1983 Wisconsin groundwater law. Landfills are required to install monitoring wells at a maximum distance of 492 feet from the edge of the area storing waste and to submit monitoring data to the WDNR four times a year. (WDNR, 2008) Environmental monitoring data is publicly available online at the WDNR's Groundwater and Environmental Monitoring System (GEMS) website, which can be accessed at the following location: http://dnr.wi.gov/org/aw/wm/monitor/gemsweb/index.htm.

There are two potential sources of harmful landfill runoff: leachate, which is water that infiltrates toward the groundwater, and surface runoff, which is water that travels overland into stormwater management facilities.

During a meeting with the engineering staff of Dane County's Solid Waste Division, the County provided background information, documentation of the site's strormwater management, and overall site plans. The engineering plans for the landfill site address the two sources of potentially harmful runoff in the following ways.

Leachate is kept within the landfill facility by a four-foot clay layer that is covered with an impermeable geosynthetic (plastic) membrane under the entire landfill. The subsurface of the landfill is designed to transport leachate that reaches this impermeable layer to sump basins, where it then pumped into the MMSD wastewater system. (A. Younes, personal communication, April 17, 2009)

Overland stormwater runoff is managed by two sedimentation basins that are located at the east and west ends of the landfill site and connected to the landfill by a series of transport ditches. The phasing plan of the landfill is designed such that only one of the seven phases is actively filled with solid waste at any given time. When a phase is completed, it is covered with dirt, seeded and maintained without the use of fertilizer. Runoff from active phases is kept within the facility via a berm around the perimeter of the facility. This water is allowed to infiltrate through the solid waste to the leachate disposal system. (A. Younes, personal communication, April 17, 2009)

Based on the information provided by Dane County as well as the WDNR statutory requirements for landfill water quality monitoring, we can conclude that the Rodefeld Site 2 landfill is not a significant contributor of nutrients and pathogens to Door Creek.

#### 4.5.4.2 PRIVATE SEPTIC SYSTEMS

The Practicum investigated the possibility that onsite sewage treatment systems, or private septic systems, are a major source of nutrient and bacteria pollution within the Door Creek watershed. Most of the Door Creek watershed is without a central municipal sewerage service, as a result there are a large number of private septic systems within the watershed.

Private septic systems are a viable alternative to a central municipal service that provides reliable waste treatment for home owners and commercial properties. The septic tank provides primary waste treatment by separating and retaining the solids and FOGs (fats, oils and greases), thus allowing the liquids to pass through to the leaching field (Tchobanoglous, Burton & Stensel, 2002). Periodically, a private septic contractor will remove and transport the solids and FOGs to a publicly owned treatment works (POTW) for further treatment. Once the liquid arrives in the leaching field, it undergoes further treatment as the liquid is physically dispersed over the broad leaching field. The nutrients and bacteria are both filtered by the soil and processed by bacteria present in the soil (Tchobanoglous, Burton & Stensel, 2002).

A properly functioning septic system removes the majority of solids and nutrients from the effluent before it is released back into the environment (Tchobanoglous, Burton & Stensel, 2002). A typical four-person septic system produces a treated effluent with a five-day biochemical oxygen demand (BOD) between 120 and 200 mg/l, total suspended solids (TSS) between 70 and 150 mg/l, and FOG of 30 mg/l or less (Tchobanoglous, Burton & Stensel, 2002). Septic systems may also have secondary treatments processes to further reduce nutrients and solids in the treated effluent, such as filters, aerobic treatment systems (ATUs), or raised bed filtration (mound systems).

The Door Creek watershed has a large number of mound systems. Mound systems are typically used in the presence of a high water table, fractured bedrock, or other limiting condition where the wastewater needs to receive further treatment before being released into the environment (Converse & Tyler, 2000). Mound systems are a concern in the Door Creek watershed because the limiting site conditions increase the possibility that untreated or partially treated sewerage will contaminate surface and ground waters if mound systems are not properly treating the wastewater.

We used three basic approaches to assess possible nutrient and bacteria pollution caused by private septic systems within the Door Creek watershed. The first of these was a geographical analysis using ArcGIS to determine the approximate number of septic systems in the watershed. The amount and distribution of septic systems in the watershed might indicate possible areas of concern based on the sheer volume of treated effluent being released. The second part of our analysis was to collect historical water quality data for Door Creek and perform our own water quality sampling during the spring and summer of 2009. Understanding the nutrient loads and bacteria content in Door Creek could indicate possible releases of untreated or partially-treated waste. Lastly, we researched the history of Lake Kegonsa's beaches for any beach closings due to bacteria. Beach closings due to fecal coliform contamination are a major indicator of the release of untreated or partially-treated waste.

One caveat about these assessment processes is that they might also indicate the release of animal waste, not septic waste into the watershed. All waste releases were related to the timing of rain storm events because large storm events are a major factor in the release of animal wastes from agricultural fields. For us to conclude that untreated or partially treated septic effluent was released, there needs to be elevated nutrients and high bacteria concentrations in the water independent of any storm event, and a beach closing due to fecal coliform. If probable septic effluent releases are identified, GIS mapping of the septic tank locations could then be used to indicate a possible source location.

#### 4.5.4.2.1 ESTIMATE OF PRIVATE SEPTIC SYSTEMS

The Dane County Public Health Department maintains records of private septic system locations in the Door Creek watershed; however, we were unable to gain access to these highly-restricted data. To estimate the number of private septic systems in the watershed, we obtained data collected by Dr. Dolores Severtson, UW-Madison Assistant Professor of Nursing and Environmental Studies, that include all parcels in Dane County that are not connected to a municipal waste treatment system (D. Severtson, personal communication, April 27, 2009). The parcel data was analyzed using the ArcGIS 9.2 geographical modeling software, and a total of 1,231 parcels without a connection to a municipal waste treatment system were counted in the watershed. These parcels are shown on Figure 4.11. Based on the assumption that there is one family-sized septic system per indentified parcel, there are an estimated 1,231 private septic systems within the Door Creek watershed.

This estimate is biased because it assumes each individual parcel has one septic tank. Clusters of residential parcels may have one central septic tank, which would cause the estimate to inflate the number of septic tanks. Additionally, the estimate is based on a septic tank unit that is equal to one family-sized tank per parcel. Large apartment complexes and central septic tanks for clusters of residential parcels have a much larger septic tank. In this situation the one parcel-one tank assumption deflates the estimated number of septic systems in the watershed. The Practicum has not corrected its estimate of septic systems for this bias due to time and information limitations.

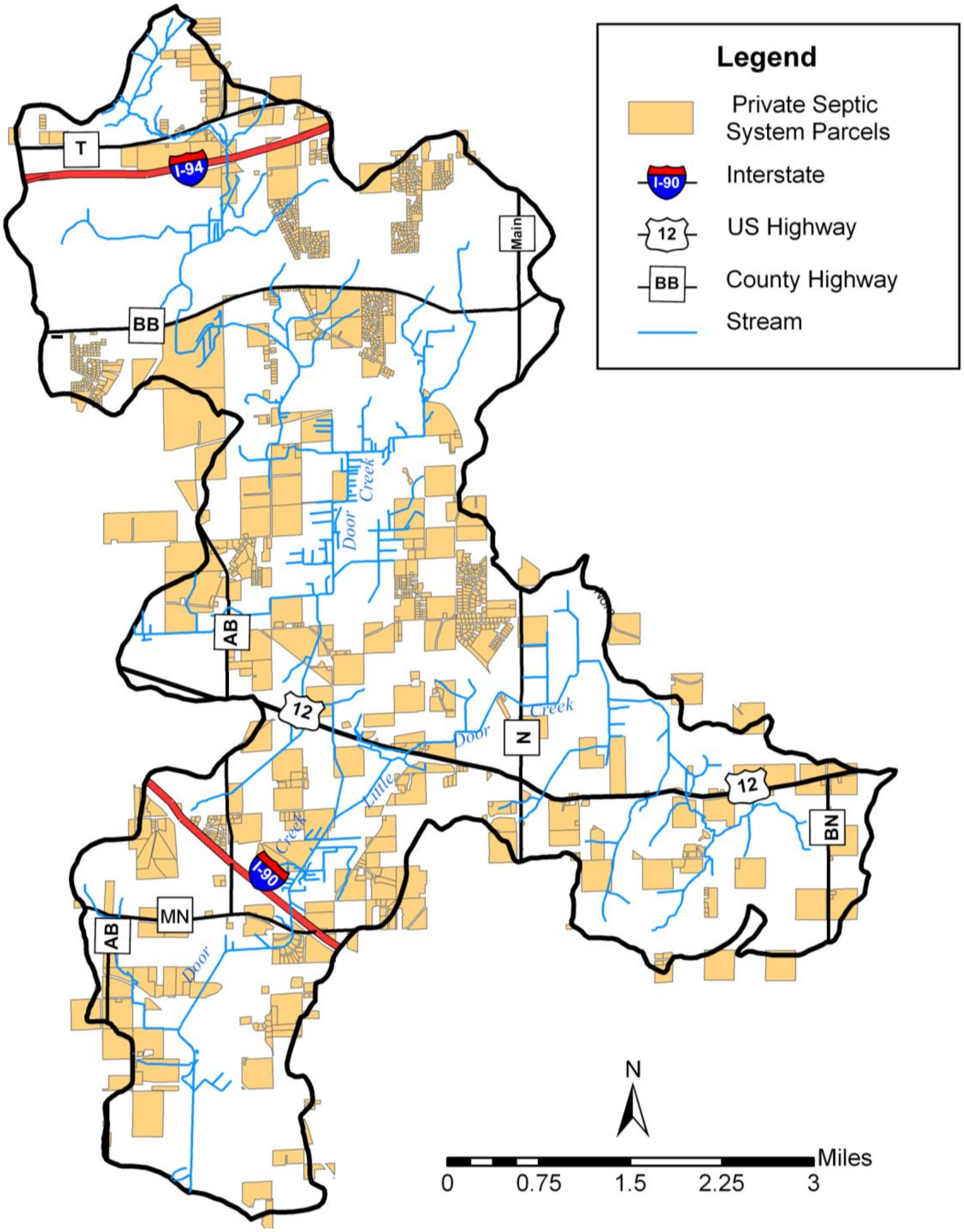


**Figure 4.11: Location of private septic systems within the Door Creek watershed.** There are approximately 1,231 private septic systems in the Door Creek Watershed. Based on active parcels that are not connected to municipal sewerage systems information received from Professor Lori Severtson. Source: Dr. Lori Severtson, UW Madison. Created August 2009 by the WRM Practicum.

#### 4.5.4.2.2 POSSIBLE WATER QUALITY IMPACTS

The nutrients nitrogen and phosphorus, and the bacteria fecal coliform are the three primary concerns regarding the release of septic effluent. Each has its own set of potential problems and impacts on receiving waterbodies, such as the Door Creek or Lake Kegonsa.

Denitrification, as well as adsorption, plant uptake, and volatilization are the major ways in which nitrogen is removed from the system (Hantzsche & Finnemore, 1992). If untreated or partially treated septic effluent is released, these processes may not occur. As a result high levels of nitrogen may enter the groundwater or surface water. Large releases of nitrogen could lead to algae blooms, eutrophication, and human illnesses, such blue baby syndrome (US EPA, 2006b; 2008). It should be noted that even if the denitrification process occurs, up to approximately half of the original nitrogen content within the septic effluent may still be exposed to the ground or surface water (Brown, 2003).

Phosphorus enters septic tanks primarily from organic wastes and phosphates. Anaerobic digestion processes in the septic tank convert phosphorus into soluble orthophosphates that can react with and attach to other solid particles. Thus, the phosphorus either attaches to solids in the septic tank or to soil particles after the effluent is released into the soil. Phosphorus that attaches to solids in the septic tanks is removed by private septic contractors and treated by a POTW. The systems are designed such that phosphorus that is released via effluent is also removed from the soil by adsorption, precipitation, plant uptake, and biological immobilization. (Brown, 2003).

While the phosphorus in the effluent may attach to soil particles, the phosphorus can still be transported to ground or surface water via soil particle movement. Soil particle movement can occur for a variety of reasons, including soil erosion, physical disturbances, and storm events (Brown, 2003). In addition, if the septic tank is leaking, large amounts of phosphorus may be released. Once released into aquatic environments, phosphorus may cause algae blooms and eutrophication (US EPA, 2008).

Fecal coliform is present in places containing human or animal wastes. The purpose of a septic tank is to treat and store human waste and all of the associated nutrients, bacteria, and pathogens, including fecal coliform (Tchobanoglous, Burton & Stensel, 2002). If a septic tank is leaking or improperly treating human waste, bacteria and pathogens can be released into ground and surface waters. The presence of fecal coliform in ground and surface water is a strong indicator of a human or animal waste release.

Fecal coliform is a public health concern because if it is ingested by humans it can cause a variety of illness such as diarrhea, abdominal cramps, and Hemolytic uremic syndrome (US EPA, 2006c). If fecal coliform is indentified in groundwater monitoring wells or surface waters such as Lake Kegonsa, WDNR officials would likely take preventative measures, such as beach closings or private household water boiling warnings to prevent human exposure (US EPA, 2006c).

#### 4.5.4.2.3 RESULTS OF NUTRIENT AND PATHOGEN DETECTION ANALYSIS

Baseflow water quality samples are the best indicator of untreated effluent coming from a private septic system. Baseflow samples represent the ambient water quality of a water body and reflect the base load on nutrient pollution coming into it. They are not influenced or diluted by storm water non-point runoff.

A review of historical Door Creek stream baseflow water quality measurements recorded by the USGS did not indicate elevated phosphorus or fecal coliform (USGS, 2008c). Also, the beach at Lake Kegonsa State Park has never reported a beach closing due to fecal coliform contamination. Only one beach closing has occurred since 2004, and that was a result of a blue-green algae bloom.

Recent baseflow water samples taken by the Practicum in the spring and summer of 2009 also did not indicate elevated phosphorus levels. However, the historical USGS and 2009 Practicum baseflow water quality measurements did indicate higher than normal levels of nitrates in the Door Creek stream (USGS, 2008c).

#### 4.5.4.2.4 DISCUSSION AND CONCLUSIONS

Our analysis of indicators of septic system pollution failed to indicate the presence of elevated phosphorus or fecal coliform levels in baseflow water samples or beach closing due to fecal coliform. Therefore, we cannot conclude that private septic systems are releasing untreated or partially-treated septic effluent into the Door Creek stream or watershed. As a result of this conclusion, we did not further pursue the identification of possible of septic tank sources.

Additionally, we are able to conclude that private septic systems are not a source of either phosphorus or fecal coliform to Door Creek for three reasons. First, historical USGS sampling results and 2009 Practicum baseflow water quality sampling results for Door Creek do not indicate the presence of phosphorous at a level of concern. Second, the USGS has a long record of analyzing Door Creek for fecal coliform, which is highly related to the occurrence of an untreated human or animal waste release and the associated sewage nutrient pollution. The USGS has only once found excessively high levels of fecal coliform in Door Creek during a large storm event (USGS, 2008c). If that fecal coliform was coming from private septic systems it would have been detected in the USGS water samples, regardless of whether the samples were taken at baseflow or at storm events. Thus, as there is no fecal coliform indicated by a baseflow sample, we can assume there are no major waste releases or nutrient pollution coming from private septic systems. Third, there is no known beach closing at Lake Kegonsa State Park associated with fecal coliform. Only one beach closing has occurred since 2004, and it was a result of a Blue-Green algae bloom.

Our review of water quality sampling data did indicate higher than normal nitrate levels in Door Creek. It is still unclear if the combined nitrate releases of the estimated 1,231 septic systems in the Door Creek watershed are making a significant contribution to the elevated baseflow nitrate levels of Door Creek. Even properly functioning septic system may release nitrates, and other potential sources of nitrates, such as commercial fertilizer, are widely applied to land throughout the watershed. Thus, we cannot unequivocally state that private septic systems are not a contributing source of nitrates to Door Creek.

#### 4.5.4.3 GOLF COURSES

There are two active golf courses within the Door Creek watershed, the Yahara Hills Golf Course and the Door Creek Golf Course. The Yahara Hills Golf Course is owned by the City of Madison and is located south of US Highway 12/18 and west of County Highway AB. This course was opened in 1967, with 36 holes covering 450 acres (Ekren 2009). The Door Creek Golf Course is a privately owned course which is located south of County Highway BB, between Vilas Hope Road and Vilas Road. Door Creek runs directly through this course, crossing holes 12 and 13 (Door Creek Golf Course, 2009). Each of the courses were contacted for interviews, the Yahara Hills Golf Course responded to our request, the Door Creek Golf Course did not.

The Yahara Hills Golf Course is a municipal course, so it is subject to more stringent regulations than a privately owned course. Since 2005, municipal courses are required have a current nutrient management plan that meets the 590 standard (T. Ekern, personal communication, August 25, 2009). Fertilizer is applied to meet the strictest guidelines required by NR151. All fertilizer that is applied is slow release because maintenance prefers to have a constant, steady growth of the grass so they can mow at regular intervals. No phosphorus is applied to the course except when Milorganite is applied, which meets all phosphorus requirements. (Ekern 2009)

Multiple water quality areas of concern are addressed in the nutrient management plan. The course has five bodies of water and multiple locations of the course are less than 25 cm to groundwater (Ekren 2009). Frequent flooding is a problem at this course due to its proximity to groundwater and lack of drainage. Currently there are no drain tile networks leaving the course, but this may change in the upcoming years. Trygve Ekern, head of grounds maintenance, explained that golf is slowly transitioning from a walking sport to a riding sport, which requires adequate drainage for travel (T. Ekern, personal communication, August 25, 2009). When flooding occurs, revenue is lost, as golfing with carts is delayed much longer than golfing on foot.

There is reason to believe that the Yahara Hills Golf Course is of no significant threat to the Door Creek watershed, based on the information collected. Practices at the Door Creek Golf Course were undetermined, so no conclusion can be made pertaining to this course.

This chapter describes the different land use practices in the non-agricultural areas of the Door Creek watershed. There are reasons to believe that increased urbanization will also cause an increase in phosphorous loading to Door Creek. Other areas of concern such as landfills, septic systems and golf courses are probably of less significance for the water quality in the watershed, but need further investigation in order to draw final conclusions.

## CHAPTER 5:

# DOOR CREEK WETLANDS ANALYSIS

## 5.1 INTRODUCTION

Once regarded as "wastelands" and "barriers to progress," wetlands are now understood as unique and critically important features on the landscape. Wetlands provide a suite of ecosystem services such as flood attenuation, water quality improvement, and biodiversity support. Though it is well known that the health of wetlands and watersheds are inextricably linked (Mitsch & Gosselink, 2000), the science of wetland ecosystem services, and the understanding of how these services benefit specific watersheds, like those along Door Creek, is still evolving.

The capacity of wetlands to provide natural and cost-effective water quality improvement is integral to the efforts of Yahara CLEAN as it addresses the water quality problems of the Door Creek watershed. In order to gain a better understanding of how the wetlands benefit the Door Creek watershed, this chapter evaluates the watershed's wetland resources and focuses on how these wetlands reduce phosphorous and nitrogen loads to Door Creek and Lake Kegonsa.

First, the chapter outlines the existing wetland resources, briefly reviews the functions and values of wetlands, and describes current threats to the quantity and quality of wetlands. Next, the Door Creek wetlands are evaluated to determine whether and how they help improve water quality in the watershed. Lastly, the framework of protecting and restoring wetlands is assessed to identify strategies for sustaining and increasing wetland ecosystem services.

## 5.2 CONTEXTUAL OVERVIEW OF THE DOOR CREEK WETLANDS

Wetlands are defined as areas where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which has soils indicative of wet conditions (Wis. Stats 23.32(1)). Due to geology, hydrology, and climate, the Door Creek watershed has a large diversity and abundance of wetland ecosystems.

Wetlands greater than 2 acres were mapped in 1986 by the Wisconsin Wetland Inventory (WWI), providing a graphic representation of wetland location, size, and community type. Approximately 2,014 acres (9%) of the watershed is currently mapped as wetland (Figure 5.1). Much of this acreage, 1,407 acres (70%), is found to be connected hydrologically to Door Creek and is predominately located in the 100-year floodplain, as indicated by the Federal Emergency Management Agency (FEMA) and are considered floodplain wetlands (Figure 5.2). The watershed has four distinct wetland plant community types: shallow marsh, sedge meadow, wet prairie, and shrub-carr (WWA, 2009c). Shallow marsh and sedge meadow are the most dominant (77%).

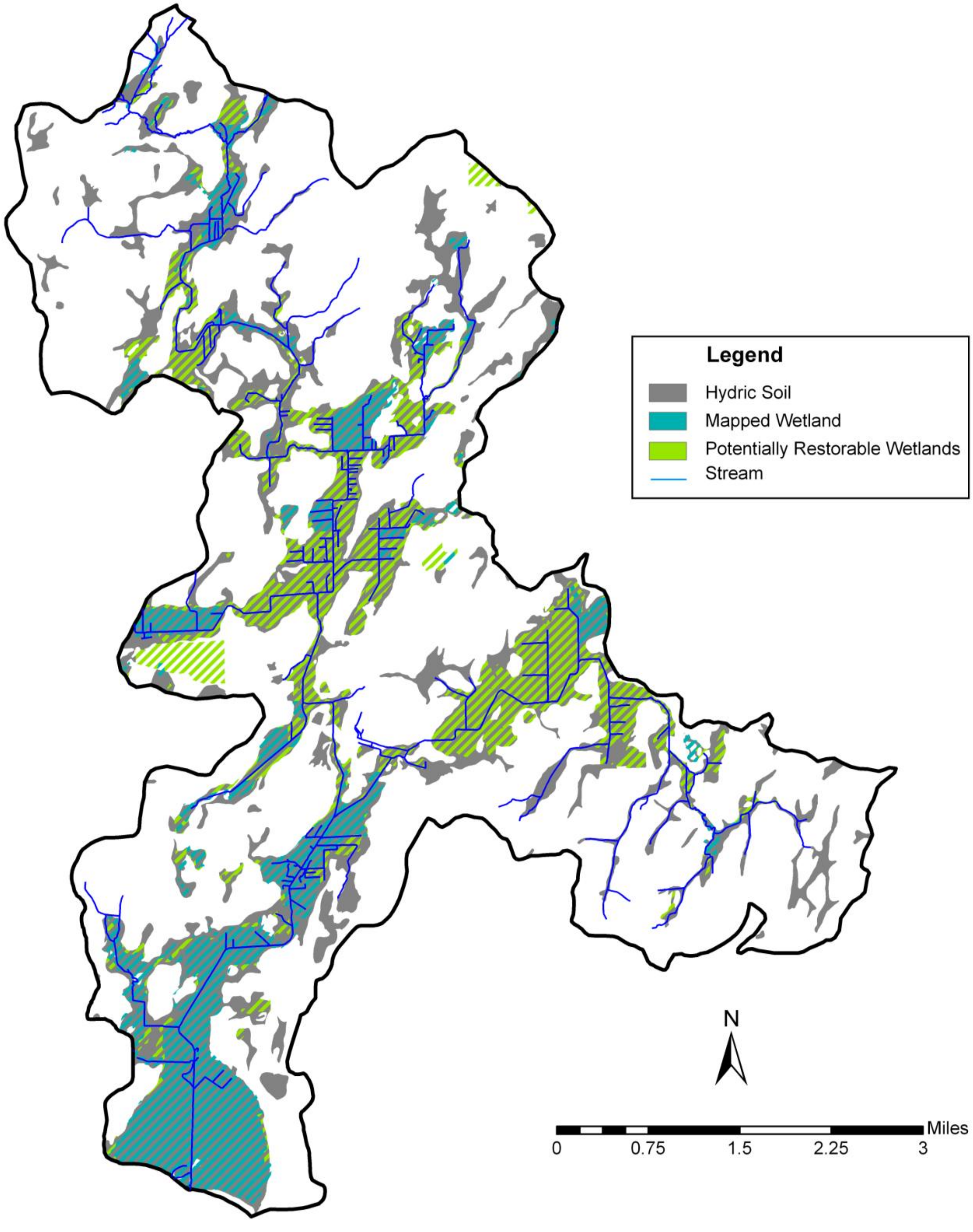


**Figure 5.1: Mapped Wetlands and Comparison of Hydric Soils, Wetlands, and Potentially Restorable Wetlands.** The Door Creek watershed contains 6,071 acres of hydric soil (31% of watershed), 2,274 acres of potentially restorable wetlands (12% of watershed), and 2,014 acres of mapped wetlands (10% of watershed). Source: Dane County, Soils Layer, 2005 and WDNR, Dane County Wetlands, 1994. Created on September 25, 2009 by 2009 WRM Practicum.

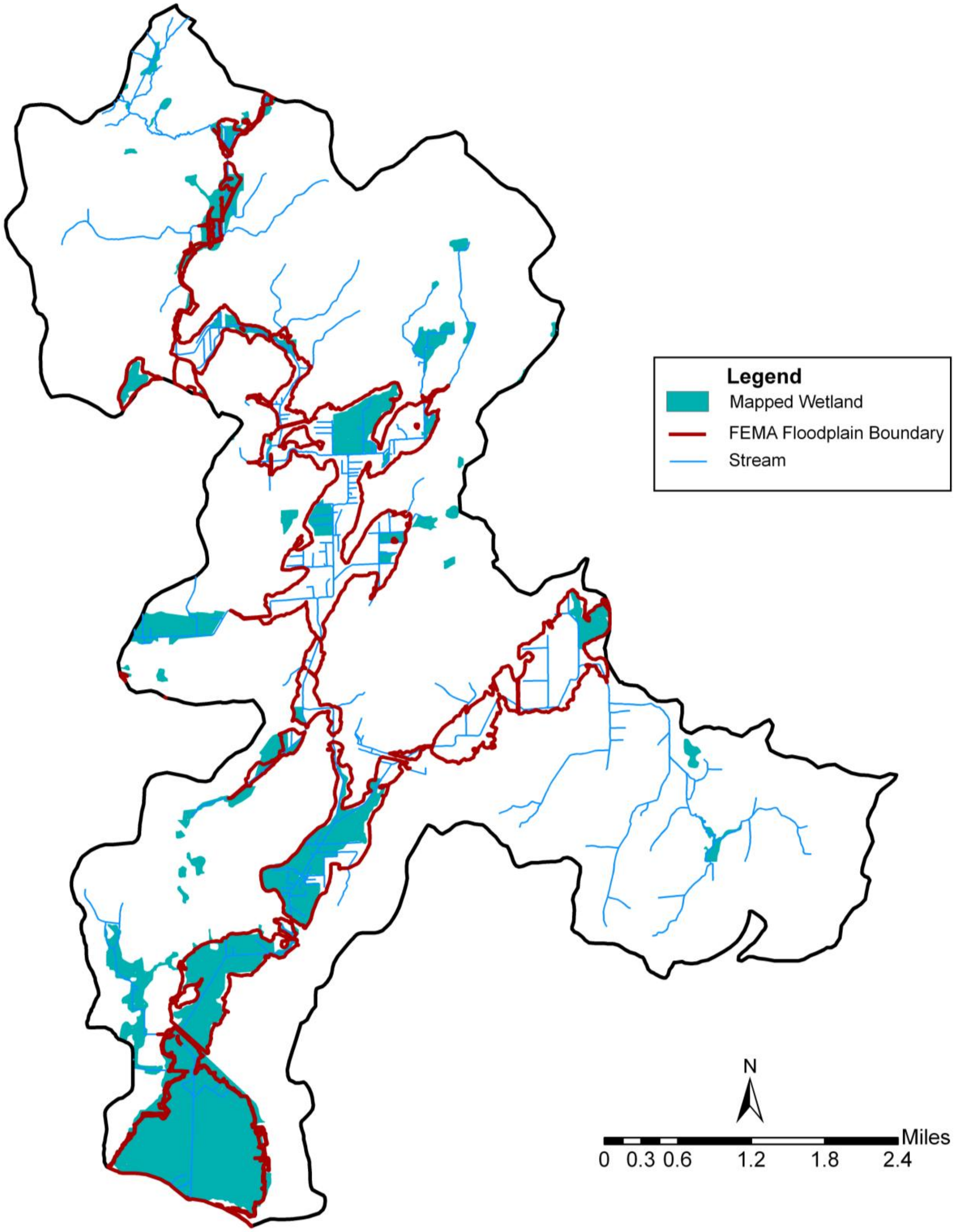


**Figure 5.2: Wetlands Contained Within Floodplain Boundaries.** Door Creek mapped wetlands shown in relation to FEMA floodplain boundary. Source: WDNR, Dane County Wetlands, 1994 and FEMA Floodplain data. Created on December 15, 2009 by 2009 WRM Practicum.

Although 2,014 acres of wetland are mapped, wetlands under 2 acres are not mapped in this process, so there is a strong possibility that the total wetland acreage is underrepresented. The Wisconsin Wetland Inventory (WWI) provides a comprehensive documentation, but it is not a precise inventory of the watershed's wetland resources, and, furthermore, does not always correspond with all the wetlands that may exist and that are protected under federal and state wetland laws.

To gain a better understanding of wetlands not illustrated by the WWI, the presence of hydric soils is evaluated. Wetlands are defined as having hydric soils and hydrophytic vegetation present (Wis. Stats 23.32(1)) and each are key indicators of current and former wetlands. In the Door Creek watershed, 6,071 acres are mapped as having hydric soil (Figure 5.1). However, only 1,938 (32%) acres are actually mapped as wetland. The high proportion of hydric soils not mapped as wetland suggests that the total mapped wetlands are an underrepresentation. However, the 4,133 acres of hydric soils not mapped as wetland may be cases where these hydric soils have been drained or filled for agricultural purposes and no longer have sufficient hydrology to support hydrophytic (wetland) vegetation.

## 5.3 WETLAND ECOSYSTEM SERVICES: WATER QUALITY IMPROVEMENT

Wetlands contribute to the ecological, economic, and social well-being of the Door Creek watershed and the Yahara Chain of Lakes in numerous ways. They provide valuable fish and wildlife habitat, minimize flood damages, and provide recreational opportunities 1. Though numerous wetland ecosystem services exist, this section highlights how wetlands are capable of improving water quality and focuses specifically on how floodplain wetlands, the majority of the Door Creek wetlands, perform this service.

Commonly likened to the "kidneys of the landscape," (WWA, 2009a) wetlands trap, transform, and store nutrients, contaminants, and sediment that cause common water quality problems, such as algal blooms and fish kills. Nutrients of particular water quality concern are phosphorous (P) and nitrogen (N). Wetlands have been shown to be effective agents in moderating the introduction of P and N to streams and rivers. Past studies reveal that the percent reduction of pollutants varies depending on the wetland type (CWP, 2006).

The effectiveness of wetlands to improve water quality depends on two key factors, location and size (Crumpton et al., 2008). Wetlands need to be located to intercept significant nutrient loads and large enough to allow sufficient residence times in order to treat the intercepted nutrient loads. Load reductions and residence times can be increased by increasing the total wetland acreage relative to the area of the contributing watershed, also known as the wetland to watershed ratio (w/w). In addition, Mitsch and Gosselink (2000) conclude that, on average, 5% of temperate-zone watersheds need to be wetland in order to optimize ecosystem services, such as water quality improvement.

---

[1] Further details about wetland ecosystem services and how wetlands benefit Wisconsin's communities are available at: http://www.wisconsinwetlands.org/localgovbenefits.htm

Nitrogen is principally removed by an ecological process known as denitrification. This occurs when wetlands are flooded and under anaerobic soil conditions. During denitrification, soil microorganisms transform nitrate (NO3) and release it as gaseous nitrous oxide (N2O) or mineral nitrogen (N2) (Crumpton et al., 2008).

All wetlands provide varying rates of denitrification, yet floodplain wetlands are noted for their high denitrification capacity (Woltemade, 2000; Gergel et al., 2005; Forshay & Stanley, 2005). High rates of denitrification are made possible by the lateral hydrologic connectivity between the stream and wetlands – mainly when flood pulses facilitate the transition to anaerobic conditions. Conversely, where floodplain wetlands dry intermittently and shift to aerobic conditions, $NO_3$ can leach and cause these wetlands to become a source of NO3. During this time, plant uptake of N is known to limit the extent of NO3 flushing downstream (King et al., 2009).

Adsorption, sediment accumulation, and plant uptake are the primary mechanisms that allow wetlands to function as phosphorous (P) sinks. Under aerobic conditions, sediment-bound P accumulates as sediments are deposited from upstream runoff and surface water. In turn, this P is stored as the sediment accumulates in the wetland. Wetland vegetation plays an integral role in this process by slowing the velocity of sediment-rich water so that soil particles are able to settle out of the water column (Zedler & Kercher, 2005). In addition, wetland vegetation consumes P through plant uptake and eventually deposits the P in the soils once the plants die (Mitsch & Gosselink, 2007).

Floodplain wetlands have been shown to provide high rates of sediment accretion and P adsorption due to the larger water, sediment, and nutrient loads that occur in floodplain wetlands as compared to depressional wetlands. Craft and Casey (2000) indicated that phosphorous retention is 1.5 times greater in floodplain wetlands. Furthermore, their research suggests that high total P accumulations correlate with increasing clay content in the soil.

Wetlands can also be sources of P to downstream waters. Under aerobic conditions, P availability is typically low (Brady & Weil, 2007; Schramm et al., 2009) and P is filtered and stored through sediment accretion and adsorption. As wetlands become flooded, the soils shift from aerobic to anaerobic conditions, and, consequently, P availability increases. P availability takes place due to the reduction and dissolution of iron phosphates, the hydrolysis and dissolution of iron and aluminum phosphates, and the release of the clay-bound phosphates (Schramm et al., 2009). Wetlands that dry intermittently, or restored wetlands on former agriculture lands, are documented as being more prone to oxidation and are characterized by higher P availability (Reddy et al., 1999, 2005; Crumpton et al., 2008).

Though P availability generally increases under anaerobic soil conditions, wetland vegetation moderates the amount of P that may flush downstream. Depending on vegetation density and plant uptake capacity, significant portions of the available P may be neutralized. Thus, wetland vegetation plays a critical role in buffering the likelihood of available P flushing downstream, as well as mitigating the transformation of wetlands from P sinks to sources (Schramm et al., 2009).

In sum, the existing scientific literature highlights the capacity of wetlands to reduce the harmful effects of sediment and nutrient loads. This service can be overwhelmed, though, when wetlands receive significant stormwater flows and pollutants from upland development, and they are hydrologically modified due to human activities. The following section identifies the human disturbances that impair and threaten the natural functions (i.e. chemical processes) which wetlands use to assimilate and store nutrients and sediment.

## 5.4 HUMAN DISTURBANCES AND IMPLICATIONS FOR WETLAND HEALTH

While it is clear that wetlands benefit the Door Creek watershed, the wetland ecosystem services are limited by the severe destruction and degradation that has historically occurred in the watershed. Since 1919, only 16% of the original 5,000 wetland acres remain in the watershed (WDNR, 2001). Moreover, extensive ditching and wetland draining disrupts the hydrologic connectivity between the stream and wetlands and is one of the largest factors decreasing the provisioning of water quality improvement and other ecosystem services. Upland development and stormwater runoff also contribute to the degradation of wetland functions and ecosystem services.

### 5.4.1 ALTERING HYDROLOGIC CONNECTIVITY

Hydrologic connectivity ensures the “water mediated transfer of matter, energy, and organisms within or between elements of the hydrological cycle” (Pringle, 2003, p. 2685). Riverine ecosystems, such as Door Creek, are spatially and temporally variable, with phases of hydrologic connectivity and disconnectivity. Under natural conditions, for example, floodplain wetlands may be disconnected from Door Creek most of the year, but, during storm events or flood pulses, the floodplain wetlands and stream become biophysically linked and water, sediment, organic matter, and nutrients are transferred between both units (Hillman et al., 2008).

This hydrologic connectivity forms the basis for how floodplain wetlands are able to provide ecosystem services, such as water quality improvement. Hydrologic connectivity can be subdivided into three distinct categories: lateral (channel-floodplain), longitudinal (upstream-downstream), and vertical (surface-subsurface). Each plays an important role in providing ecosystem services, yet lateral connectivity is the most important for floodplain wetlands to enhance water quality.

Lateral connectivity facilitates flood pulses and allows nutrient-rich sediments and organic matter to be deposited. In turn, denitrification, sediment accretion, adsorption, and plant uptake activate as the flood pulse recedes, water and sediment are stored, and water quality is improved (Hillman et al., 2008; King et al., 2009). For example, P accumulation was shown to be higher in floodplain wetlands as result of hydrologic connectivity (Craft & Casey, 2000). Kaushal et al. (2008) also found that denitrification increased following the reestablishment of hydrologic connectivity.

Hydrologic variability shapes the ecological integrity of floodplain wetland ecosystems, but it has been largely altered by human disturbances in the Door Creek watershed, including wetland draining and filling. Present-day Door Creek exists as a man-made straightened channel with few natural meanders, and large portions of the stream–wetland interface have been degraded by berming activities. Figure 5.3 shows how the stream has been altered from its natural state.

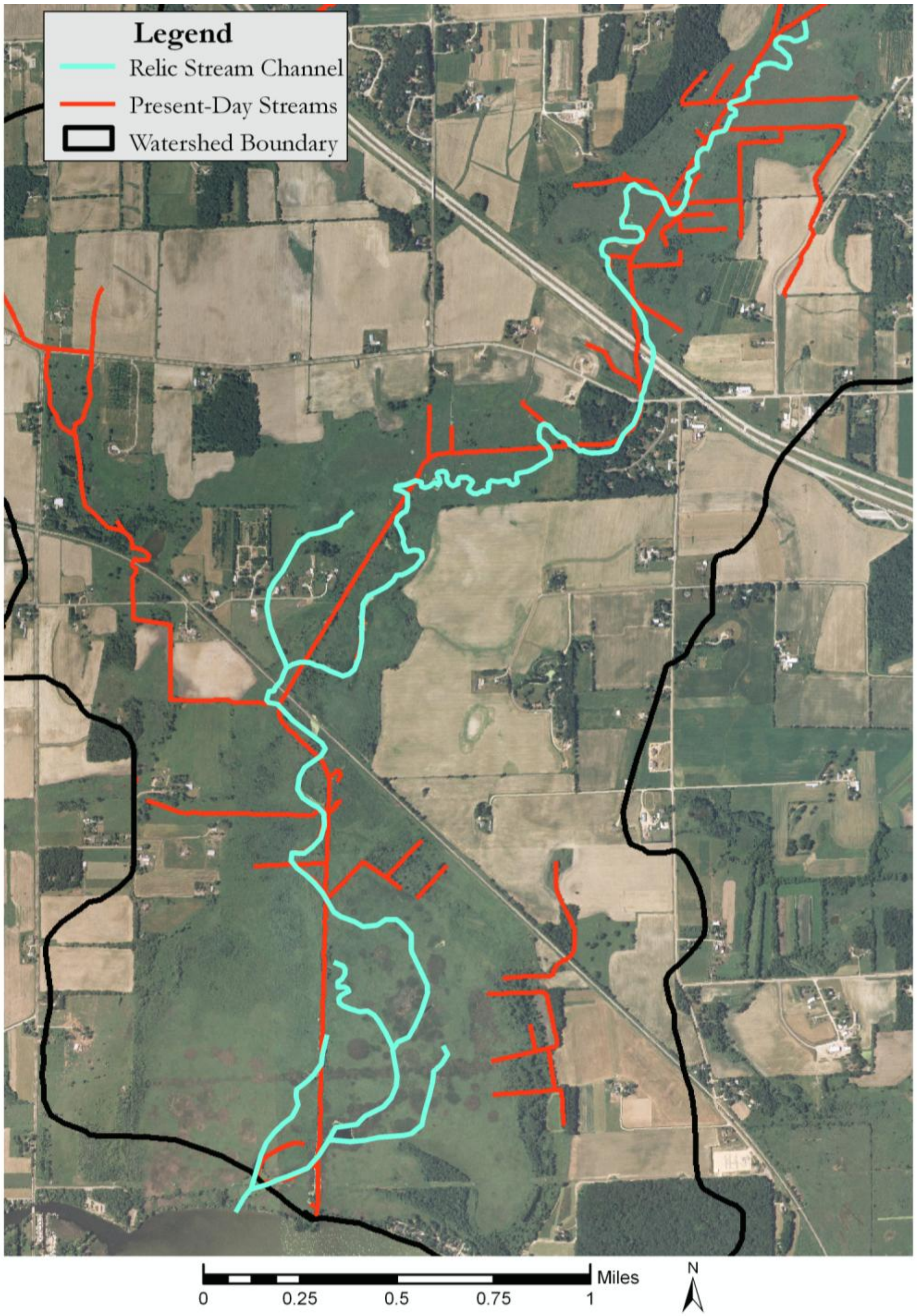


**Figure 5.3: Relic Stream Channel.** The Relic Stream channel was identified from aerial photos pre- ditching and berming of the lower Door Creek. The present day stream channel was identified from current aerial photos. Created on March 4, 2010 by 2009 WRM Practicum.

The shallow marshes along the northern shore of Lake Kegonsa are also degraded by the construction of a series of embankments. These embankments not only limit lateral connectivity between the lake and wetlands, they have also eliminated valuable fish habitat (CARPC, 2008).

Although adverse effects are widely imposed by human disturbances, ecological benefits can also arise from them. Hydrologic dis-connectivity created by draining and filling wetlands can contribute to the establishment of high quality vegetation by limiting nutrient-rich conditions that lead to the formation of non-native, invasive, and aggressive species monotypes (Zedler and Kercher, 2004). As Mika et al. (2008, p. 92) notes, "spatial and temporal disconnections can enhance genetic diversity by isolating populations, and prevent [pollutants and sediment] from moving through the ecosystem." The positive effects of isolating populations are evident in the Door Creek watershed where native, diverse stands of grasses and forbs have developed adjacent to the embankments.

### 5.4.2 Indirect Threats

The direct draining and filling of wetlands will continue to be a threat, activities surrounding the wetlands may have greater impacts. Residing in the low points of the watershed, wetlands are extremely vulnerable to land use activity and land development in the surrounding uplands. Runoff from agriculture or urban areas eventually ends up in wetlands and can shift vegetative structure and function. For example, monotypes of invasive species are observed throughout the watershed where Bedford and Zimmerman (1974) and Mead and Hunt (1993) once documented diverse stands of native wetland vegetation. In addition, changes in overland flow and impervious cover from roads, homes, and so on can influence the natural hydrology and, alter the hydroperiod. As a result, succession may occur from one wetland community type to another (CWP, 2006).

The health of the Door Creek wetlands are greatly influenced by stormwater runoff, hydrological alterations, and other indirect impacts from urban, suburban, and rural land use in the surrounding uplands. As urbanization increases, it increases areas of impervious surfaces, decreases groundwater infiltration and ground water discharge, and increases stormwater runoff.

## 5.5 Do the Door Creek Wetlands Improve Water Quality?

The Door Creek wetlands have been impacted by direct alterations (e.g. draining) and indirect impacts from land use activities in the uplands. While wetland quantity and quality has declined, the wetlands may still be providing critical ecosystem services to the watershed. Thus, the Practicum collected soil and water samples from wetlands located in the Door Creek Wildlife Area (DCWA) and privately owned wetlands adjacent to the DCWA in order to determine whether the Door Creek wetlands are providing any water quality benefits. Data was subsequently generated from analyses performed by the Wisconsin State Laboratory of Hygiene and the University of Wisconsin Soil and Plant Analysis Laboratories (SPAL). This data was used to determine whether the wetlands were functioning as nutrient sources or sinks.

### 5.5.1 Soil Analysis

Determining phosphorous (P) concentrations was the principal focus of the soil sampling and analyses. We collected surface soil samples and vertical solid profiles within the wetlands to obtain data on the total phosphorus (TP) concentration, available P concentration, and percent organic matter.

We used three basic criteria to determine surface soil sample locations: proximity to Door Creek, access to land, and wetland vegetation community type. We selected lands that were physically adjacent to Door Creek, because these areas are most frequently affected by fluctuations of the main channel of Door Creek. Public, or private lands where approval from private landowners had been acquired, were selected as sample locations to represent areas with a variety of vegetative communities. Figure 5.4 illustrates where each surface sample was taken and shows its representative vegetative cover. Surface soil samples taken from these locations were analyzed for a dry weight TP concentration by SPAL.

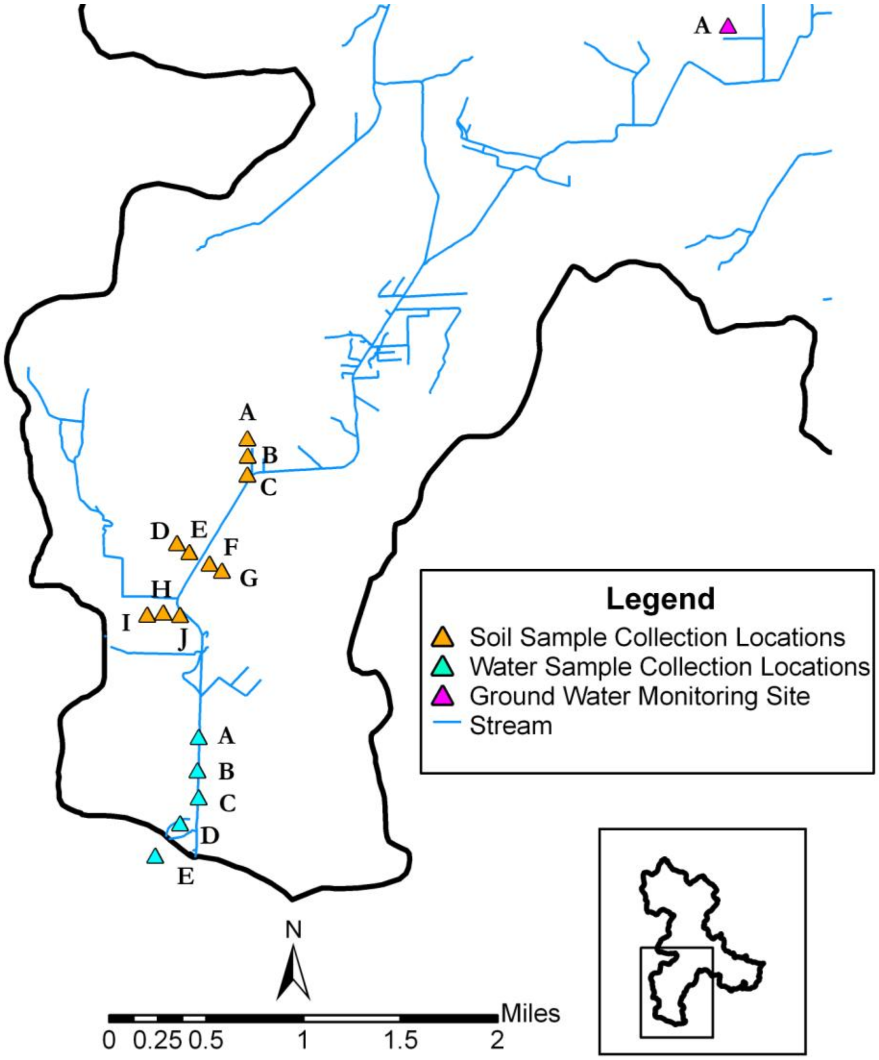


**Figure 5.4: Wetland Soil & Water Sampling Locations.** WRM Practicum wetland soil sampling sites A-J are shown in orange. Door Creek wetland, stream, and Lake Kegonsa water sampling sites A-E are shown in blue. Ground water monitoring site A is shown in purple. Created on February 28, 2010 by 2009 WRM Practicum.

The surface soils sampled within the wetlands were primarily organic or clay soils, or a combination mixture of both. Two samples, I and A, were taken from upland soils to represent a gradient of soils from uplands, to wetlands, to the Creek. These soils were comprised of a silt and sand mixture and are not considered to be wetland soils. The vertical profile soil samples were similar to the other wetland soil samples. However, the vertical profile at site H did contain two distinct sand layers, one from 40 to 46 centimeters (cm), and the other from 89 to at least 100 cm deep.

Two surface locations were chosen for further vertical profile soil sampling. A vertical profile was conducted to provide insight to the source, either groundwater or surface water, of the increased levels of phosphorous in the surface soil. Sites F and H were chosen because each had moderately high surface concentrations of phosphorus. Vertical profile soil samples were taken from the surface to a depth of one meter (39 inches) using a Vibrocore soil sampler. The soil profile cores were then separated by natural breaks of soil composite for analysis. Ten centimeters (4 inches) of the profile were analyzed for a dry weight TP concentration by SPAL.

#### 5.5.1.2 RESULTS

The TP results for the wetland soils (excluding sites A and I) range from 668 parts per million (ppm) to 1,664 ppm, with six of eight samples testing above 1,000 ppm, and with an average of 1,286 ppm. The TP results for the vertical profile soil samples also have a broad range. The site H vertical profile has a TP concentration of 1,308 ppm at the surface and a TP concentration of 267 ppm at the deepest portion of the sample, from 76-86 cm. The complete TP results for the surface and vertical profile soil samples are shown in Tables 5.1 and 5.2.

**Table 5.1: Upland and Wetland Surface Soil Characteristics to Determine Phosphorous Loading Capacity.**

| SURFACE SOIL SAMPLE | COMMUNITY TYPE | TP (PPM) | AVAILABLE P (PPM) | ORGANIC MATTER (%) | RUNOFF DP (MG/L) |
|---|---|---|---|---|---|
| A | Upland | 346 | 39 | 1.7 | 0.429 |
| B | Sedge Meadow / Shrub Carr | 1,497 | 24 | 26.7 | 0.264 |
| C | Sedge Meadow | 1,135 | 32 | 23.7 | 0.352 |
| D | Sedge Meadow (restored) | 767 | 29 | 9.9 | 0.319 |
| E | Sedge Meadow (restored) | 688 | 28 | 9.4 | 0.308 |
| F | Wet prairie | 1,613 | 28 | 43 | 0.308 |
| G | Shrub Carr | 1,637 | 27 | 47.4 | 0.297 |
| H | Sedge meadow | 1,664 | 18 | 39.2 | 0.198 |
| I | Upland | 400 | 21 | 3.3 | 0.231 |
| J | Marsh / Sedge Meadow | 1,294 | 13 | 49.7 | 0.143 |

The SPAL TP (ppm), available P (ppm), and percent organic matter results for the Practicum surface soil sampling of Door Creek wetlands and terrestrial lands. Runoff dissolved phosphorus (Runoff DP) was calculated from the formula, [Runoff DP = 0.011 x available P concentration] for soil types A, B, C, O (Good & Panuska, 2008).

The available P results for the all surface soil samples range from 13 ppm to 39 ppm. The average available P for wetlands soils (excluding site A and I) equaled approximately 25 ppm. The percent organic matter results for all surface soil samples ranged from 1.7% to 49.7%. The average percent organic matter for wetland soil samples (excluding sites A and I) equaled approximately 31%, with the highest percentages occurring nearest to the Door Creek stream.

**Table 5.2: Vertical Profile of Wetland Soils.**

| Soil Profile Sample | Depth (cm) | TP (ppm) |
|---|---|---|
| H - 1 | 0-10 | 1308 |
| H - 2 | 23-33 | 647 |
| H - 3 | 51-61 | 623 |
| H - 4 | 76-86 | 267 |
| F - 1 | 0-10 | 1894 |
| F - 2 | 31-41 | 1375 |

The SPAL TP results for the vertical profile soil sampling of Door Creek wetlands. The profile soil samples were taken from the surface to a depth of one meter with a Vibrocore soil sampler

Runoff of dissolved phosphorus (runoff DP) was calculated using the available P data and the formula [runoff dissolved P = 0.011 x available P] (Good & Panuska, 2008). This formula applies to soil types A, B, C, and O. Type O soils contain mucks and peaks (i.e. wetland soils) and type A, B, C, soil types contain many southern Wisconsin medium to fine textured soils (i.e. agriculture and upland soils) (Good & Panuska, 2008). The runoff DP for the wetland soil samples range from 0.143 to 0.352 milligrams per liter (mg/L) with an average of 0.274 mg/L.

#### 5.5.1.3 DISCUSSION

The initial results of the surface and vertical profile soil sampling suggest that the Door Creek wetland soils contain: relatively high concentrations of TP, a high percentage of organic matter, and a low concentration of available P. From these initial results, the primary source of phosphorous was used to determine the function of the wetland as a source or a sink, based on the soil's capacity to hold phosphorous.

The vertical profile soil sampling indicates the primary source of P into the wetlands is from surface water, not groundwater, because the amount of TP decreases as the distance from the surface increases. This is explained more completely in Chapter 3. During storm events that over top the embankments, there are likely to be higher levels of P in the water column. When the water tops the embankments, the water velocity decreases and the sediments, which carry phosphorus, settle into the wetlands. In addition, the embankment may trap water in the wetland complex after the flood waters recede. The dissolved P in the trapped water remains in the wetland until it slowly filters through the soils or evaporates.

The high level of TP, which is at the lowest depth of the vertical profile, raises a concern that P will enter via groundwater inputs. However, the higher levels of TP found in the surface soils, and the immediate impact that storm events produce, make managing surface water inputs more important for water quality. In order to determine if the wetlands are acting as a source or a sink for P, it is necessary to understand the amount of P which is currently bound to the soils and the soil's capacity to bind to P. The relativity high TP in the surface wetland soil concentrations (Tables 5.1 and 5.2) support research that wetlands store P and act as P sinks (Crumpton et al, 2008, Mitsch & Gosselink, 2000, Rogers et al., 2009).

The amount of P that is able to bind to sediment is related to the amount of organic matter in the soil. By definition, a wetland soil needs to have at least 10% organic matter (L. Good, personal communication, October 29, 2009). Based on the percent organic matter values seen in Table 5.1, locations B – H and J are contain wetlands soils. Sites D and E, with 9.9% and 9.4% organic matter respectively, are on the cusp of the defined amount of organic matter. It is important to note that samples D and E were taken from a location that was used as a pasture for a number of years and was restored by Dane County in 2007-2008. The recent restoration of wetland functions is the likely cause for lower organic matter content in comparison to the other wetland soils.

The percent organic matter in soil dictates how much TP the soil will hold. Thus, the concentration of available P and the TP concentration is a function of the percent organic matter. Generally, the higher the organic matter value, the lower the available P concentration, and the larger the TP storage capacity. Based on the data in Table 5.1 and comparisons to other wetland soils, Door Creek wetlands have moderate to high percent organic matter content, low available P concentration, and moderate to high TP concentration. The moderate to high percent organic matter is an indication that the Door Creek wetland soils can hold larger amounts of TP while having a low available P concentration; therefore the wetlands are a probable P sink (L. Good, personal communication, October 29, 2009).

Using the runoff DP data contained in Table 5.1, there are two probable nutrient flux scenarios for the Door Creek wetlands (L. Good, personal communication, October 29, 2009). One scenario is that stream water, containing a higher Dissolved Reactive Phosphorous (DRP) concentration than the wetland soil, floods and saturates the wetlands. When the wetland soil comes in contact with the DRP saturated flood waters, the wetland soil absorbs P because they have a higher relative capacity to hold P compared to storm water. This would happen during a typical storm event, or spring snow melt, in the Door Creek watershed in which the stream floods over the wetland embankment and saturates the wetlands. This scenario reinforces initial indications that the Door Creek wetlands are indeed a P sink, especially when the wetlands are flooded by P rich storm or snowmelt waters (L. Good, personal communication, October 29, 2009).

A second possibility is that stream water that contains a lower DRP concentration then the wetland soils' runoff DP concentration saturates the wetlands. When the wetland soil comes in contact with the low concentration DRP water, the wetland soils will likely release P into the water. The wetland soil releases P because the water now has the higher relative capacity to hold P, compared to the wetland soil. This situation is typical of the natural interactions between the Door Creek wetlands and the stream, but it could also be caused by the removal of the Door Creek embankments. This possibility does not support the initial finding that the wetlands are a P sink, and it may suggest that the Door Creek wetlands could become a P source, under the requisite conditions (L. Good, personal communication, October 29, 2009).

Further testing is needed to conclusively state that the Door Creek wetlands are a source, a sink, or a combination of both. However, there is enough preliminary data to strongly suggest that the Door Creek wetlands are a P sink, especially in situations where high DRP concentrations overtop the wetland embankments during spring snowmelt or storm water events. In addition, the wetlands may become a P source if large amounts of low DRP concentration waters break into and disturb the wetlands.

## 5.5.2 WATER SAMPLING METHODS

Wetlands are capable of filtering nutrients and providing water quality benefits through both physical filtering/deposition, and several biogeochemical processes (Mitsch and Gosselink, 2007). In order to determine whether the Door Creek wetlands provide these benefits, water samples, taken in the stream channel and from both shallow and deep-water marsh communities, were compared. The marsh communities in the wetland complex have limited connections to the stream due to the embankment, which was created when the stream was straightened. The Wisconsin State Lab of Hygiene (SLOH) performed the water nutrient analyses on each water sample. The water analysis methods used by the SLOH can be found in Appendix 1.

### 5.5.2.1 WATER ANALYSIS METHODS

To detect nutrient differences, sampling sites were selected based on landscape position within the Door Creek wetlands. A total of three sites were selected in the upper (site A), middle (site B), and lower (site C) wetlands (Figure 5.4). Samples were collected from each wetland location by entering approximately 15-20 feet from the stream edge, while also collecting samples, along the same gradient, from within the main channel of Door Creek. Supplement samples were conducted to distinguish between the surface and the groundwater residing in the Door Creek wetlands and Door Creek itself.

A complete data set of two samples at each location was generated for each site within the Door Creek wetlands. This data included nutrient concentrations of ammonia, nitrate/nitrite, total Kjeldahl nitrogen (TKN), total dissolved phosphorus (TDP), and total phosphorus (TP), and facilitated an analysis of changes and trends between each location.

In addition, water samples were taken from two monitoring wells located at ground water monitoring site A (Figure 5.5). The monitoring wells were created at two depths, 16 and 9 feet,(ft), by Dr. Jean Barr, of the University of Wisconsin-Madison Department of Geology, and the Practicum using a vibrocore soil sampler. PVC pipe was installed to reinforce the soil and create a monitoring well. A water sample was taken from each well and analyzed for nitrate/nitrite concentration. Taking water samples from these two wells allowed us to sample two different depths of the water table, 9 ft and 16 ft.

Lastly, a near shore Lake Kegonsa water sample (site E) and an inland wetland water sample (site D) were taken. The near shore Lake Kegonsa water sample was taken approximately 75 ft off shore and to the west of the mouth of Door Creek. The inland wetland sample was taken approximately 200 ft inland of the shore and west of the mouth of Door Creek.

### 5.5.2.2 RESULTS

On average, the concentration of ammonia, TKN, TDP and TP was lower in the stream in comparison to the adjacent wetland. However, nitrate/nitrite levels were higher in the stream than in the wetland. The average concentrations of ammonia, nitrate/nitrite, TKN, TDP and TP in Door Creek and the wetland are shown in Table 5.3. The complete results of the SLOH water analyses, for both Door Creek, the Door Creek wetland and near shore Lake Kegonsa, are shown in Tables 5.4 and 5.5. Ground water monitoring site A samples had no detectable nitrate/nitrite concentrations for surface water and 5.87 mg/L for bottom water.

**Table 5.3: Averaged nutrient analysis of stream and wetland water samples.**

| Door creek location | Ammonia (mg/l) | Nitrate/nitrite (mg/l) | TKN (mg/l) | TDP (mg/l) | TP (mg/l) |
|---|---|---|---|---|---|
| Stream | 0.042 | 4.353 | 0.822 | 0.048 | 0.095 |
| Wetland | 0.253 | 0.149 | 9.852 | 0.268 | 1.463 |

The average concentrations of ammonia, nitrate/nitrite, TKN, TDP, and TP for Door Creek and Door Creek wetland water samples (sites A – C). Samples were averaged from two separate Practicum sampling dates of 4/19/2009 and 7/3/2009, with water analysis performed by the SLOH.

**Table 5.4: Nutrient Analysis of Lake Kegonsa and wetland water sampling.**

| Door Creek Location | Ammonia (mg/L) | Nitrate/Nitrite (mg/L) | TKN (mg/L) | TDP (mg/L) | TP (mg/L) |
|---|---|---|---|---|---|
| Near Shore Lake Kegonsa | ND | ND | 1.05 | 0.026 | 0.068 |
| Door Creek Inland Wetland | 0.332 | ND | 67.3 | 0.298 | 4.78 |

The results of the near shore Lake Kegonsa and Door Creek inland wetland water samples, taken on 7/29/2009. The SLOH performed the water analyses on the samples. ND is none detected.

**Table 5.5: Nutrient Analysis of wetland and stream water samples.**

| DATE | NUTRIENT ANALYSIS | UPSTREAM | | MIDSTREAM | | DOWNSTREAM | |
|---|---|---|---|---|---|---|---|
| | | Stream Water | Wetland Water | Stream Water | Wetland Water | Stream Water | Wetland Water |
| 4/19/2009 | Ammonia (mg/L) | 0.071 | 0.145 | 0.069 | 0.025 | 0.08 | ND |
| | Nitrate/Nitrite (mg/L) | 5.42 | ND | 5.34 | ND | 5.15 | ND |
| | TKN (mg/L) | 1.18 | 2.78 | 0.8 | 4.03 | 0.9 | 1.18 |
| | TDP (mg/L) | 0.043 | 0.228 | 0.042 | 0.075 | 0.04 | 0.111 |
| | TP (mg/L) | 0.151 | 1.21 | 0.091 | 0.349 | 0.102 | 0.18 |
| 7/3/2009 | Ammonia (mg/L) | ND | 0.86 | ND | 0.249 | 0.031 | 0.239 |
| | Nitrate/Nitrite (mg/L) | 3.44 | ND | 3.4 | 0.893 | 3.37 | ND |
| | TKN (mg/L) | 0.66 | 9.55 | 0.69 | 34 | 0.7 | 7.57 |
| | TDP (mg/L) | 0.056 | 0.408 | 0.055 | 0.136 | 0.053 | 0.65 |
| | TP (mg/L) | 0.075 | 2.26 | 0.076 | 3.35 | 0.073 | 1.43 |

#### 5.5.2.3. DISCUSSION

Based on the sampling results, from Door Creek and the wetland, the near shore Lake Kegonsa, and the ground water monitoring site, the Practicum is able to make firm conclusions about possible water quality benefits coming from the Door Creek wetlands. Foremost, the Practicum has concluded that the Door Creek wetlands are providing water quality benefits by removing nitrogen from the water through denitrification. While it is clear that the wetlands are removing nitrogen, it is unclear at what rate or magnitude the nitrogen is being removed. Further studies are needed to make that determination, as well as to indicate what factors in the Door Creek wetlands are influencing the denitrification process.

A comparison of data from Door Creek and the adjoining wetlands shows that denitrification is occurring in the Door Creek wetlands. Door Creek had an average nitrate/nitrite concentration of 4.353 mg/L, while the Door Creek wetlands had an average nitrate/nitrite concentration of 0.149 mg/L (Table 5.3). The total amount of nitrate/nitrite is 97% lower in the wetland as compared to the surface water of Door Creek. Therefore, nitrate/nitrite reduction is occurring as surface water enters the adjacent wetlands.

The comparison of the nitrate/nitrate data collected from ground water monitoring site A reaffirms the conclusion that denitrification is occurring in areas with hydric soils. A comparison of the surface to bottom water nitrate/nitrite concentrations indicates that nitrate/nitrite was completely removed from the water as it approached the surface. The close proximity of the monitoring well to Door Creek and the wetland hydric soil where the well is located leads to the assumption that this represents what is actually occurring in the Door Creek wetlands.

The Door Creek wetlands do have higher concentrations of ammonia and TKN, however, those elevated concentrations may be attributed to the transformation of nitrogen during the denitrification process. In addition, the Practicum cannot be sure of the origin of the water in the wetland. The water may be from either current base flow in the stream or stranded waters from a storm event. Stranded water from a storm event would also likely contain higher concentrations of ammonia and TKN due to surface runoff (See Chapter 3 for additional water quality data and analysis).

The Practicum also reaffirms the conclusion that the Door Creek wetlands are a major phosphorus sink in the Door Creek watershed. This conclusion is based on a comparison of TDP and TP data taken from Door Creek and the Door Creek wetland. Door Creek wetlands have concentrations of TDP and TP upwards of 10 times greater than Door Creek. The relativity high wetland soil TP results and the high wetland water TDP and TP concentrations strengthen the conclusion that the wetlands are acting as a phosphorus sink for Door Creek watershed.

While the high levels of TDP and TP in the water of the wetlands may be attributed to variety of sources and fluxes, as discussed in the soil analysis conclusions and discussion, the Practicum believes the primary source of the TDP and TP in the water is runoff from upland soils with elevated P levels and fertilizers within the watershed. In addition, the main P flux to the wetland is from storm events and spring snowmelt that cause flood conditions, where water overtops the Creek embankments and traps large amounts of DRP rich water in the wetlands.

The removal and storage of P in the Door Creek wetlands can prevent the large algae blooms and eutrophication that result from excessive P entering Lake Kegonsa. Thus, removal of P from Door Creek waters via the Door Creek wetlands is an important part of improving water quality in Door Creek and downstream Lake Kegonsa.

### 5.5.3 SOIL AND WATER ANALYSIS CONCLUSION

Our research did not have the resources to determine the specific effectiveness of wetlands in improving water quality, yet there is strong evidence that the wetlands are contributing water quality benefits to the watershed. The wetlands are reducing nitrogen loads via denitrification and appear to be functioning as nutrient sinks through the storage of phosphorous. The removal and storage of these nutrients improve the quality of water by reducing eutrophication and algal blooms within Door Creek, Lake Kegonsa, and the broader Yahara watershed.

Water quality improvements exist; however, current watershed conditions undermine the extent to which the wetlands can provide this service. With the channelization and berming of Door Creek, and the extensive draining and ditching of wetlands, the collective ability of the wetlands to store and remove pollutants is limited. Nonetheless, there are many opportunities to restore wetlands and optimize the conditions that facilitate the improvement of water quality. Restoration, therefore, is one plausible best management practice to improve water quality.

Though restoration is a potential strategy for increasing water quality in the future, the current wetlands are an asset not only for the water quality gains, but also for ecosystem services such as flood attenuation and fish and wildlife habitat. Protecting and restoring wetlands may not be the definitive solution to reversing water quality problems, but soil and water analysis shows that wetlands are providing a natural means of reducing poor water quality. An effective strategy may be to utilize wetland conservation in tandem with watershed-based initiatives that address the source of excessive sediments and nutrients.

## 5.6 WETLAND RESTORATION AND WATER QUALITY IMPROVEMENT

Though protection is the most effective strategy for sustaining wetland ecosystem services, many wetlands have been completely destroyed and degraded in the watershed. Given that there are several opportunities to reverse this destruction and degradation and that the Practicum's research is indicating wetlands help improve water quality, wetland restoration will be evaluated to determine its role in improving the health of the Door Creek watershed.

### 5.6.1 RESTORATION OPPORTUNITIES

The Door Creek watershed has a myriad of conditions that affect the health of wetlands (see Section 5.4). The straightened man-made channel now functioning as Door Creek has few natural meanders. Much of the floodplain wetlands are hydrologically disconnected due to channelization and berming. In addition, nearly 80% of the original wetlands have been drained and filled since channelization began in the early 1920s (WDNR, 2001).

Restored wetlands provide varying degrees of water quality benefits, however, the restoration of riparian and floodplain wetlands will likely generate the greatest benefits due to their capacity to treat incoming surface water and runoff. Floodplain wetlands comprise the majority of the wetlands in the watershed and offer the most opportunities to initiate restoration efforts. Therefore, a stream corridor or floodplain wetland restoration will be evaluated for use in the Door Creek watershed.

A stream corridor restoration is the most promising restoration approach for water quality improvement because it involves restoring natural dynamics, such as hydrologic connectivity, throughout the entire system rather than in isolation (King et al., 2009). In our view, restoring the natural flow and hydrologic connectivity would increase the overall capacity of floodplain wetlands to improve water quality, more so than restoring wetlands that have no lateral connectivity with Door Creek. Moreover, since approximately 70% of the total wetlands in the watershed fall within the floodplain and are disconnected from Door Creek, they present the greatest opportunity for restoration.

Restoration activities will not only improve water quality but can also deliver multiple other benefits to the watershed. For example, a secondary benefit of stream corridor restoration is to improve fish habitat, mainly for northern pike (M. Kakuska, personal communication, June 3, 2009).

In practice, re-meandering Door Creek would be a substantial undertaking, which will require significant engineering, construction, and monitoring. Re-meandering large portions of the stream would require a thorough analysis of the stream hydrology and costs associated with the necessary engineering. Given the low velocity of the lower reaches of the stream, it is plausible that many of the desired water quality effects of re-meandering could be accomplished by simply breaching embankments in targeted locations.

Irrespective of the restoration technique pursued, there is a certain degree of uncertainty in managing and restoring riverine and floodplain ecosystems (King et al., 2009). Thus, it is common to have an incomplete understanding of how the natural dynamics and variability will change following a restoration. The following section evaluates both the promise of restoring Door Creek and its floodplain wetlands, and the uncertainty about how the system will respond to a stream corridor restoration that reestablishes the natural meanders and lateral hydrologic connectivity between the floodplain wetlands and Door Creek.

## 5.6.2 UNCERTAINTY AND MOVING FORWARD WITH RESTORATION

While uncertainty exists in many conservation efforts, the potential restoration of Door Creek and its wetlands includes the prospect of adverse impacts, rather than ecological benefits, occurring. The following section highlights the factors that need to be considered prior to committing to a large-scale stream corridor or other floodplain wetland restoration.

### 5.6.2.1 EFFECTS ON NUTRIENT PROCESSING

In restorations that re-establish hydrologic connectivity, the hydroperiod can be expected to increase in the adjacent wetlands. Increased flooding may lead to longer durations of anaerobic conditions that, in consequence, can lead wetlands to become sources of P, as revealed in Section 5.2.1.2., A caveat to this, however, is that although P availability increases under anaerobic conditions, wetlands with dense vegetation can moderate the extent of P release using plant uptake mechanisms and filtering effects.

In contrast to P retention, where P becomes available under anaerobic conditions, the opposite transpires with nitrogen (nitrate/nitrite), because anaerobic conditions facilitate the gaseous release of N to the atmosphere through denitrification. A preponderance of research shows that reconnecting the stream and wetlands will increase the rate of denitrification, particularly when restored hydrological conditions mirror the historical hydrograph (Forshay & Stanley, 2005; Gergel et al., 2005; King et al., 2009; Schramm et al., 2009). Thus, restoration would lead to several benefits in terms of reducing the effects of N as a limiting nutrient.

The scientific literature supports the Practicum's hypothesis that restoring the hydrologic connectivity in Door Creek would lead to net increases in the amount of N removed and marginal gains in the amount of P stored and removed. Because P availability is likely to increase following restoration, it may diminish the amount of P that is accreted and adsorbed. The ability of wetland vegetation to minimize the prospect of P leaching downstream is unknown, however, that ability may eliminate concern that the wetlands will become a P source. In spite of the role of wetland vegetation, restoring the Door Creek wetlands will probably contribute more to the buffering of N rather than to P impacts.

### 5.6.2.2 EFFECTS ON VEGETATIVE STRUCTURE AND FUNCTION

Even without conducting a comprehensive vegetation inventory of the wetlands, it is clear that non-native, invasive, and aggressive species have degraded native plant diversity and resilience in many of the watershed's wetlands. Mead and Hunt (1993) note the invasion of noxious species in their evaluation of the Door Creek wetlands and it should be expected that this problem has worsened since that time. Many wetlands have become monotypes of reed canary grass (*Phalaris arundinacea)* or hybrid cat-tail (*Typha X glauca)*. Other wetlands have interspersed stands of these, or additional, undesirable species.

Due to the already impaired wetland vegetation composition, there is concern that restoring hydrologic connectivity will exacerbate existing stands of invasive species or expose new areas to invasion. With restored hydrologic connectivity, there is a greater exchange of nutrients and seeds. Thus, invasive species that thrive in soils with enriched nutrients may find more conducive growing conditions following a restoration (Vercoutere, Honnay, and Hermy, 2007).

A carefully crafted and implemented management program would prevent encroachment and further invasion of invasive species. For example, embankment breaching adjacent to a wetland with diverse or high-quality native vegetation would require the complete removal and containment of any invasive species. Otherwise, high-quality vegetation would be threatened as invasive propagules are dispersed via the restored hydrologic connectivity. Restoration site selection should avoid areas with adjacent stands of high quality vegetation and target lands that are already degraded by invasive species. This reduces the prospects of extirpating native species from certain wetlands while still achieving water quality benefits. Because native vegetation may become degraded following restored connectivity, future restoration efforts ought to consider the utility of incorporating novel ecosystems (J.B. Zedler, personal communication, July 21, 2009).

## 5.6.3 DEALING WITH UNCERTAINTY – UTILIZING AN ADAPTIVE RESTORATION FRAMEWORK

Uncertainty will exist with any restoration project. It is impossible to know definitively how an ecosystem will respond to complex natural processes and interactions. One way to minimize this uncertainty, and develop a knowledge base about the ecosystem in question, is to develop and implement an Adaptive Restoration framework.

Adaptive Restoration, an ecological restoration approach, combines scientific research with restoration techniques that foster continued learning about a site's ecosystems while accommodating for unknown factors (Zedler, 2005). As we continue to learn about the complex interaction that occurs within a watershed, and specifically within wetlands, it is important to consider this new information when developing management options. The incremental approach of adaptive restoration is well suited for complex systems, including the Door Creek wetland, which has sensitive hydrological, biological, chemical, and socio-cultural relationships.

An adaptive restoration approach to restoring wetlands in the Door Creek Watershed could have a number of benefits compared with more conventional techniques. The outcomes of subsequent phases can reveal the most effective tactics and provide valuable data for further restoration activity in similar ecosystems. Under adaptive restoration, it would be possible to isolate the causal relationship between actions and their effects, as well as the efficacy of restoration in environments with different biotic communities, physical characteristics, and degrees of impairment. For example, an adaptive experiment could compare the capacity of a restored wetland to filter nutrients to a wetland left disconnected from the stream.

In contrast, if a uniform, conventional restoration approach were pursued across the watershed and the benefits were found to be short lived, or less than desired, it would be difficult to establish the reasons for the failure of the strategy.  Thus, an adaptive framework can isolate shortcomings or adverse impacts so that they can be avoided in the future.

### 5.6.4 Use a Targeted Restoration Approach

Much of the discussion on restoration has focused on restoring hydrologic connectivity between the stream and wetlands. Such restorations deliver water quality benefits, but other steps can be taken to increase the restoration benefits.

Zedler (2003), for example, promotes the concept of strategically prioritizing restoration sites based on the ecosystem service desired and the ability of that site to be restored.  Middle and downstream wetlands are cited for their greater ability to improve water quality.  Thus, restoring wetlands in these reaches of the watershed is likely to deliver more water quality benefits than restoring a wetland in the upper reaches.  Therefore, a targeted water quality wetland restoration approach will consist of restoring sites beginning downstream and working further up in the watershed.  The targeted approach provides a range of ecological benefits, such as fish and wildlife habitat and flood attenuation.

## 5.7 Improving Wetland Protection

Though wetlands purify water before it enters downstream waterways, this important function, and others, such as flood attenuation and fish and wildlife habitat, are only delivered when wetlands are effectively protected.  Wetland protection facilitates the continued supply of ecosystem services and is more reliable than the uncertainty associated with the restoration of complex natural dynamics and processes in degraded wetlands.

The state of Wisconsin has implemented various wetland regulations with the aim of enhanced protection now, and into the future, for our wetland resources.  Dane County has voluntarily expanded state-mandated shoreland-wetland zoning requirements to inland wetlands. Coupled with the Section 404 permitting program of the federal Clean Water Act, U.S. Department of Agriculture conservation programs (i.e. Swampbuster), and other federal programs, the Door Creek wetlands receive a relatively high degree of protection.

In spite of the mosaic of regulations and policies established for wetland protection, there are gaps that threaten the health of wetlands, which are further discussed in Chapter 6.5.  These gaps provide opportunities at the local level to more effectively preserve the natural functions and ecosystem services of wetlands (CWP, 2007; ASWM, 2007; WWA, 2009b).  The following sections identify practical steps for securing improved wetland protection in the watershed and for the greater Dane County area.

### 5.7.1 DEVELOP A DANE COUNTY WETLAND CONSERVATION ORDINANCE

Wetlands smaller than 2 acres and many activities that indirectly impact wetlands are either loosely regulated or unregulated at the county level. Remedying these wetland protection gaps can be accomplished by strengthening Chapter 11 of the Dane County Zoning Ordinance; however, we promote the concept of developing a stand-alone wetland conservation ordinance.

Regardless of the approach taken, all wetlands need to be protected without exception to their size, type, and location. Adding protection for small wetlands (< 2 acres) and those that are unmapped will foster a more comprehensive approach and protect a higher percentage of wetlands in the County. Since the current framework at the County is working, the creation of a wetland conservation ordinance will bolster the program, and facilitate more effective wetland protection, by comprehensively including all the land use controls that affect wetland functions and ecosystem services under one umbrella. Rather than having a series of land use controls in place, the wetland conservation ordinance would drive the regulatory requirements in the county.

Adopting a stand-alone ordinance would also provide the County with more authority to control indirect impacts, such as stormwater runoff, and hydrological modifications from upland development. Crafting a new ordinance would also allow the placement of more effective wetland buffers. Buffers can substantially minimize the indirect impacts occurring in the watershed. Effective buffers range from 30 to 1,000 feet, depending on the purpose, such as removing sediment, phosphorous, or nitrogen, or providing wildlife habitat (Environmental Law Institute, 2008). For example, Mayer et al. (2005) suggest that buffers of approximately 90 feet and 370 feet can remove 75% and 90% of nitrogen loads, respectively, from entering the wetlands.

As currently written, Chapter 11 incorporates buffer standards via the 75-foot setback requirement. Since much of the Door Creek wetlands are sited adjacent to agricultural lands, they have the potential to be encroached upon by urbanization patterns and lose the capacity to trap and remove sediment and pollutants. Considering the moderate to high level of nutrients in the wetlands, buffer standards should facilitate their ability to withstand nutrient overloads and continue to offer water quality improvement functions. Increasing the 75-foot setback, requiring “no-mow” areas, and creating maintenance standards are strategies to include in a County wetland buffer program.

Beyond wetland buffers, a wetland conservation ordinance, which includes project review requirements that mirror state and federal protocols, could add a layer of review that allows local governments to apply land use policy and planning tools to land development and land use activities with wetland impacts. Furthermore, wetland permitting decisions could be made in context of how a project fits into comprehensive, or other, planning documents and initiatives.

Since incorporated regions (cities and villages) of the County operate their own land use policy and planning programs and are not required to implement County standards, there are limits to regulating all wetlands in the County. To overcome this gap, the County can collaborate and coordinate with cities and villages to adopt similar wetland conservation measures. Alternatively, the County could develop a model wetland conservation ordinance that cities and villages can adopt into their own land use regulations.

### 5.7.2 Implement a Mechanism for Limiting Impacts to Hydric Soils

Currently, there are minimal controls in place to steer development away from placement in hydric soils. As a result, the potential for historic wetlands to revert back (if conditions are correct), is lost, ensuing development becomes prone to groundwater-induced flood damages, and most notably, denitrification is lost from these areas.

Revisions to Chapter 75 (Land Division and Subdivision) of the Dane County Code of Ordinances and the definition of "land suitability" can serve as a mechanism for controlling development in hydric soils. Chapter 75.13 currently reads "no land shall be divided or subdivided for a use which is held unsuitable by the committee for reason of flooding or potential flooding, soil limitations, inadequate drainage, incompatible surrounding land use or any other condition likely to be harmful to the health, safety or welfare of the future residents or users of the area, or harmful to the community or the county." As written, there is marginal authority for the Land Development Committee to restrict development explicitly based on hydric soils.

A simple resolution could be to include the words, "hydric soils and other," prior to the codified language "soil limitations." By doing so, the Land Development Committee would have the authority to review for the presence of hydric soils and steer development away from these sites. Since there is currently a loophole that allows developers to maintain farming and drainage systems as a way around regulatory protections, limiting the use of hydric soils sites for development will help bring these lands into regulation (See Chapter 6 for more details about this issue).

### 5.7.3 Land and Easement Acquisition and Voluntary Conservation Practices to Preserve Wetlands and their Upland Buffers

In addition to legal means of securing effective wetland protection, non-regulatory approaches can supplement regulatory mandates at the federal, state, and local level. In the Door Creek watershed, Dane County has been active in the purchase of contiguous private lands to include in the Door Creek Wildlife Area. However, there have not been acquisitions of upland buffers for the wetlands.

Establishing upland buffers around wetlands facilitates the preservation and optimization of the natural functions and public benefits of wetlands. Purchasing lands and easements around existing wetlands establishes these buffers. The size of an effective wetland buffer varies depending on the intended purpose, but the functionality of wetlands generally improves as the surrounding matrix of upland habitats is preserved (Environmental Law Institute, 2008). A buffer approach will help increase the capacity of wetlands to offer water quality improvement services for Door Creek and Lake Kegonsa.

## 5.8 CONCLUSIONS AND RECOMMENDATIONS

Based on the scientific literature on wetland ecosystem services and the role of wetlands in improving water quality, as well as the data presented in this chapter, it is clear wetlands are part of the equation for addressing water quality problems at the watershed scale. While we are unaware of the precise percent reduction of phosphorous and nitrogen provided by the Door Creek wetlands, protecting and restoring them is a practical and cost-effective means of reducing nutrient loads. When coupled with eliminating and minimizing the source of these nutrients, wetland conservation is likely to produce valuable rewards in terms of not only the reduction of cultural eutrophication, such as fish kills, and algal blooms, but also ecosystem services, such as flood attenuation and fish and wildlife habitat, along with water quality improvements.

The following summarizes the Practicum's overall wetland recommendations for the Door Creek watershed. These recommendations can be implemented across the entire Yahara Lakes Chain and the state of Wisconsin.

- Federal and State wetland laws should be complemented with an effective local wetland protection program.
- An Adaptive Restoration Framework should be used for stream corridor and floodplain wetland restoration.
- A targeted wetland restoration approach should be used when selecting sites to be restored.

# CHAPTER 6:

# LEGAL FRAMEWORK GOVERNING DOOR CREEK

## 6.1 INTRODUCTION

The Door Creek watershed includes several growing towns, cities, and villages within Dane County, Wisconsin. Due to the geographic location of the watershed, land use practices within the watershed are regulated by a complex legal framework of federal, state and local rules and regulations. In order to understand how these rules and regulations affect water quality within the Door Creek watershed, and ultimately Lake Kegonsa, this chapter highlights the water quality regulations of greatest relevance. This chapter also provides an introduction to proposed legislative changes being considered by various levels of government.

As many of these regulations are based on how the land is used, the chapter is divided into sections, beginning with an overview of laws that affect *all land uses* and ending with a discussion of the laws that focus exclusively on water quality concerns, for specific land use management practices within the Door Creek watershed. The discussion of these regulations provides a context for the final recommendations of this report.

### ALL LAND USE PRACTICES

Four major water quality regulatory areas apply to all land uses: Surface Water Quality, Groundwater Quality, Riparian Zoning and Public Trust Doctrine. These rules and regulations acknowledge that the hydrosphere is a combination of surface water, groundwater and riparian zones that are connected, but are distinct enough from each other so as to require unique regulations (Ritter, 2006; Kent, 2001).

### SPECIFIC LAND USE MANAGEMENT PRACTICES

Within the Door Creek watershed, the land use practices that are of particular concern are wetland development, agricultural practices, sludge application and urban development. Each of these different types of land use is regulated separately by a number of federal, state and local statutes.

## 6.2 CLEAN WATER ACT

The Federal Water Pollution Control Act, more commonly known as the Clean Water Act (CWA), is the primary federal surface water quality legislation. Over the years, the implementation of the Clean Water Act (CWA) by the United States Environmental Protection Agency (US EPA) has evolved from focusing solely on point sources of pollution into a more holistic watershed approach (US EPA, 2009a; Kent, 2001).

The current version of the CWA regulates surface water pollution within the Door Creek watershed in two primary ways. First, it gives the US EPA the authority to set water quality standards for priority and conventional surface water contaminants[2] and, second, it makes it "unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit is obtained under its provisions (US EPA, 2009b)."

### 6.2.1 WATER QUALITY STANDARDS

The first provision of the CWA regulates water pollution by ensuring that waterways meet certain minimum surface water quality standards. Like many regulations administered by the US EPA, the Wisconsin Department of Natural Resources (WDNR) sought and received approval from the US EPA to implement and enforce several provisions of the CWA, including the ability to set the water quality standards for waterbodies within Wisconsin (US EPA, 2007; WDNR, 2009a).

Some of these water quality standards, such as NR 105, are associated with toxic substances and apply to all waterbodies (Wis. Admin. Code § NR 105). However, most of these water quality standards are based on the designated use of a waterbody (WDNR, 2004a; Wis. Admin Code § NR 102). The WDNR established use designations for each navigable waterbody within Wisconsin[3] based on ecological and hydrological data collected for that waterbody. WDNR established approximately five use-based categories for implementing water quality standards. These include, but are not limited to:

- Fish and Aquatic Life
- Recreation
- Fish Consumption
- Public Health and Welfare
- Wildlife (WDNR, 2004a)

The Door Creek has been designated as a Limited Aquatic Life (LAL) waterbody, which is a sub-designation of the Fish and Aquatic Life category. LAL waterbodies, also known as marginal surface waters, have such poor water quality that it limits the capacity of the waterbody to support fish and other aquatic life (WDNR, 2004a). On the other hand, all four of the Yahara Lakes, including Lake Kegonsa, have been designated as Areas of Special Natural Resource

---

[2] Pesticides, insecticides and herbicides are not regulated under the CWA, but rather are regulated under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA).

[3] **"Waters of the State"** includes "those portions of Lake Michigan and Lake Superior within the boundaries of this state, and all lakes, bays, rivers, streams, springs, ponds, wells, impounding reservoirs, marshes, watercourses, drainage systems and other surface water or groundwater, natural or artificial, public or private, within this state or its jurisdiction." Wis. Admin. Code § NR 102

Interest (ASNRI) and as Priority Navigable Waters (PNW) (WDNR, 2009c).

When a waterway fails to meet the water quality standards established for it, that waterbody is officially classified as impaired. Section 303(d) of the Clean Water Act requires that each state provide a list of all their impaired waterbodies. In Wisconsin, the Impaired Waters List, as it is commonly referred to, is created by the state legislature in conjunction with the WDNR and the US EPA. As of 2010, two of Fthe four Yahara Lakes, and the outlet to Lake Kegonsa, were classified as impaired (Figure 6.1) (US EPA, 2007; WDNR, 2010a).Lake Waubesa was recently delisted with the release of the 2010 impaired waters list.

The WDNR identified three major impairments of the Yahara River Chain of Lakes:

- Nutrient and sediment enrichment[4]
- Oxygen depletion
- Habitat loss (WDNR, 2010a; US EPA, 2008)

Door Creek has not been classified as impaired to date despite the fact that the Door Creek watershed has experienced relatively similar nutrient loading and habitat loss as was seen across the Yahara Lakes. As described in Chapters 1-5, parts of Door Creek were dredged and straightened, which led to habitat loss, and agricultural and urban land use management practices have contributed to excess nutrient loading.

#### 6.2.1.1 TOTAL MAXIMUM DAILY LOAD (TMDL)

The US EPA generally classifies runoff from urban and agricultural fields as non-point source pollution (US EPA; 2009a). One of the primary means of managing non-point source pollution under the CWA is through the creation of Total Maximum Daily Loads (TMDL). Typically, waterbodies listed on a state's 303(d) list are formally considered for the creation of a TMDL by the WDNR and the EPA. It is important to note that formal consideration for the creation of a TMDL does not mean that a TMDL and associated pollution regulations will be implemented. This is because TMDLs are not mandatory for impaired waters on the 303(d) list, unless they are required by a judge under specific litigation (US EPA, 2009c).

---

[4] The WDNR estimated that as of 2006 the total phosphorous loading from the Door Creek watershed was roughly between 0.617 and 0.923 lbs/acre/year (Congdon, 2006).

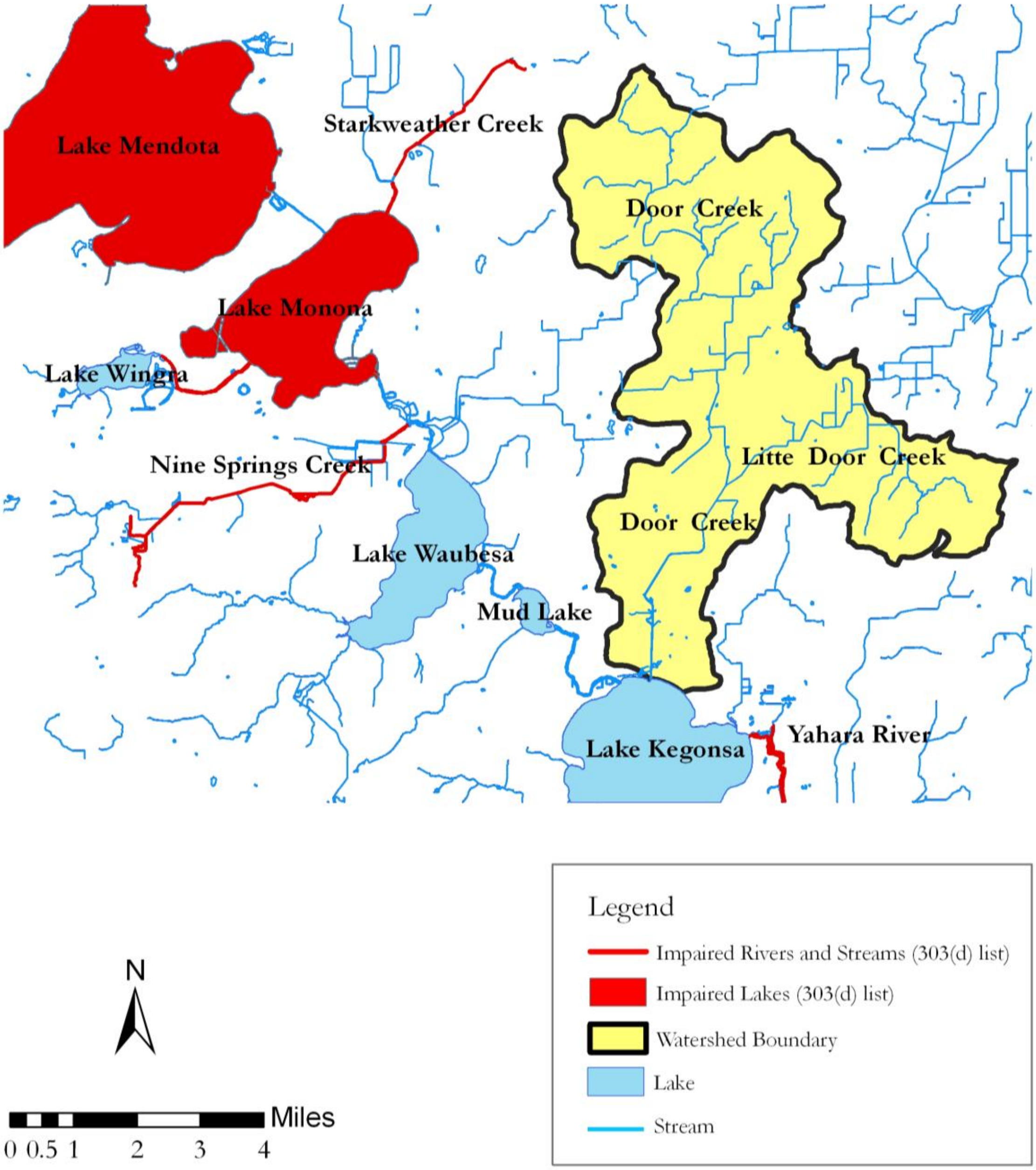


**Figure 6.1: Yahara River Impaired Waterbodies.** Source: Dane County Streams Land Information Office; Streams Layer 2000, and WDNR, 2009c. Created: March 2010 by the WRM practicum.

For a particular waterbody or watershed, TMDLs establish the maximum waste load allocations (WLA) for point source pollution and load allocations (LA) for non-point source pollution, while still allowing for a margin of error within these calculations (US EPA, 2009c). The load allocations are based on a state's water quality standards for the designated use of that waterbody (US EPA, 2007). The WDNR currently does not generally regulate agricultural runoff within a TMDL as part of the waste load allocations, unless they are classified as a Confined Animal Feeding Operation (CAFO), but rather uses voluntary programs to help reduce pollution loading from agricultural fields.

To address non-point pollution, communities or individuals can request the WDNR and the US EPA to create a TMDL for an impaired waterbody or watershed (WDNR, 2009a). Approved TMDLs may place an uneven burden for improving water quality on the stakeholders who adversely impact the waterbody. Because of this, TMDLs can lead to disagreements between the various stakeholder groups over who should bear the burden of improving the water quality (Boese, 2002). To reduce potential conflicts between the various stakeholder groups, the WDNR works with the public throughout the process of creating and implementing a TMDL (Lehmann, 2006).

#### 6.2.1.2 PROPOSED ROCK RIVER WATERSHED TMDL

The Rock River watershed is currently under review by the WDNR for the creation of a TMDL to address phosphorous loading. Many TMDL limits are determined by using the average nutrient level for a US EPA eco-region (EPA, 2001). However, due to the natural variability of soil types and the nutrient loading within southern Wisconsin, the WDNR has proposed that the Rock River TMDL use limitations based on wadeable and non-wadeable stream nutrient averages (Robertson, 2006a; Robertson, 2006b). The WDNR has proposed a phosphorous limitation of 0.08 mg/l for wadeable streams and of 0.125 mg/l for non-wadeable streams (Baumann, 2006).

If the Rock River TMDL is approved, the WDNR could require that all impaired rivers and streams within the Rock River watershed meet these wadeable and non-wadeable water quality standards. Since Door Creek is not currently listed as impaired (Figure 6.2), the wadeable and non-wadeable stream standards would not apply.

If, in the future, Door Creek were to be classified as impaired, and these standards were applied, Door Creek would only meet the non-wadeable stream standards during baseflow conditions. However, because Door Creek is upstream of an impaired waterbody, and it contributes to the pollutant loading of that waterbody, Door Creek could be targeted to implement voluntary programs to reduce non-point source pollution loading.

When addressing non-point source pollution in areas that have an approved TMDL, the state has primarily focused on using Conservation Reserve Enhancement Program (CREP)[5] funds for contributory waterways, even though there are many other programs that also address non-point source pollution runoff. The WDNR and DATCP hope to use CREP funds to establish vegetated, riparian buffers along more than 95% of any impaired waters that suffer predominately from non-point source pollution and for which a TMDL has been created. Within the Rock River, this program is estimated to have removed 69.0 lbs of phosphorous and 38.1 lbs of nitrogen per mile of riparian buffer. If a TMDL were approved for the larger Rock River

---

[5] The Conservation Reserve Enhancement Program (CREP) is a Farm Bill program administered in Wisconsin by cooperation with the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP), the USDA Farm Service Agency (FSA), the Natural Resources Conservation Service (NRCS) and the Wisconsin Department of Natural Resources (WDNR) (DATCP, 2005).

watershed, programs like CREP could be used to help reduce the phosphorus loading from the Door Creek watershed (WI DATCP, 2005).

The WDNR is also considering changing how TMDLs are regulated under NR 151. Currently, runoff from non-CAFO agricultural fields is not regulated within an approved TMDL. However, the WDNR is considering amending NR 151 to include the regulation of non-CAFO agricultural land in order to address soil loss and phosphorous runoff to impaired waterbodies, if a TMDL has been approved. If the proposed changes are approved, it is possible that a TMDL could be used to place restrictions on nutrient runoff from upstream agricultural fields and require cost-sharing. Thus, if both the Rock River TMDL and this proposed change to NR 151 were approved, increased restrictions might be placed on non-point source nutrient pollution loading in the Door Creek watershed on a case by case basis by the WDNR.

### 6.2.2 POINT-SOURCE POLLUTION

Water quality-based standards are only one way the Clean Water Act (CWA) regulates surface water pollutants. Point source pollution standards are the second. EPA's NEPDS program, established under the CWA, regulates point-source pollution through permitting and litigation processes. Under the provisions of CWA, states may seek approval from the EPA to implement point source pollution regulation. Within Wisconsin, the WDNR has been approved by the EPA to administer several of these point source provisions using Wisconsin's Wastewater Pollutant Discharge Elimination System (WPDES) permit program. The land application of manure, biosolids, private septic sludge, and urban stormwater runoff are all classified as different types of point source pollution in Wisconsin. Each of these types of point sources is treated differently within the permitting program. As such, the regulations used to address each type of land use management practice will be addressed separately in the following sections of this chapter.

## 6.3 GROUNDWATER

When surface water enters groundwater systems, impurities in the surface water can contaminate the groundwater (Ally, 1994; Waller, 1994). This becomes increasingly problematic when the groundwater is the primary source for drinking supplies, as is true for most Wisconsin residents (Groundwater Coordinating Council, 2009; WDNR, 2007). In order to protect the public from impurities, such as nitrates, regulations and standards have been set at the federal, state, and local levels (Nolan, 2002; NMS of NPAPR, 1999).

### 6.3.1 FEDERAL

The United States Congress passed the Safe Drinking Water Act (SDWA) in 1972. Under the provisions of this Act, the US EPA is required to set national limits for several pollutants in public drinking water supplies. These limits, known as Maximum Contaminant Levels (MCLs), are based on the health effects caused by each pollutant and. As with many other regulations administered by the US EPA, states may, and routinely do, seek approval to implement and enforce various provisions of the SDWA (US EPA, 2009e).

### 6.3.2 STATE

Within Wisconsin, the Wisconsin Department of Natural Resources implements and enforces many of the provisions of the SWDA, including:

- Collecting ground water samples
- Analyzing the results of sampling
- Ensuring that water supply systems meet regulatory requirements
- Providing technical assistance for public and private water supplies
- Regulating MCLs for drinking water
- Requiring the creation of wellhead protection plans (WDNR, 2009d)

The US EPA and the WDNR define public water systems as those that "provide drinking water for human consumption via piping to at least 15 service connections or regularly serving an average of at least 25 people a day for at least 60 days per year" (WDNR, 2007). These public wells can be publicly or privately owned (WDNR, 2007). The WDNR regulates four types of public supply systems that range from large municipal owned systems to small, transient non-community systems, such as a tavern wells (See Table 6.1).

Within the Door Creek watershed, local municipalities serve as the primary provider of public water supplies for two communities: the Village of McFarland and the Village of Cottage Grove (Village of McFarland, 2007; Village of Cottage Grove, 2009). Under the SDWA, such public drinking water supplies must be monitored, and records kept, that detail the types and levels of pollutants found in the publicly maintained wells.

In Wisconsin, nitrates are the most common groundwater contaminant (Groundwater Coordinating Council, 2009). Several wells in the Door Creek watershed have elevated levels of nitrates (See Figure 2.10). The effects of such elevated levels of nitrates on human health are described in Section 3.2.1. Water quality standards for drinking water contaminants are usually set so that only one person in one million would face an increased risk of developing cancer as a result of drinking two liters of such water every day for 70 consecutive years (WDNR, 2007).

**Table 6.1: Types and Locations of Public Drinking Water Systems.**

| Public Drinking Water Systems | | Examples |
|---|---|---|
| **Municipal Community (MC)** | Systems are owned by public entities such as a city, village, town or sanitary district and serve at least 25 residents on a year-round basis. | Municipal water |
| **Other than Municipal Community** | Systems are the same as MC systems except that they are not publicly owned. | Mobile home parks, apartment buildings, and condo complex |
| **Nontrainsient Noncounty** | Systems regularly serve at least 25 of the same people at least six months out of the year and often include schools and factories. | Schools, factories, mid-to – large sized commercial buildings |
| **Transient Noncommunity** | Systems that serve at least 25 people for at least 60 days a year. | Restaurants, taverns, churches, motels, and campgrounds |

Source: WDNR, 2007a

The Maximum Contaminant Level (MCL) for nitrate is 10 milligrams per liter (mg/L) and for nitrite is 1 mg/L (US EPA, 2009f). The MCL for nitrate and nitrite is 10 mg/L. According to the Department of Agricultural, Trade and Consumer Protection (DATCP), approximately 23% of wells in Dane County violate nitrate/nitrite drinking water standards (WI DATCP, 2008a). Nitrates of around 0.003 mg/l have been found in the confined aquifer, while nitrates higher than 20 mg/l have been found in the unconfined aquifer (Village of McFarland, 2009; USGS, 2008a). Many groundwater wells throughout the Door Creek watershed have nitrate levels of 10 mg/L and several are greater than 20 mg/L (Figure 2.10). When a public well is found to have exceeded the drinking water standard for a pollutant, such as nitrate, the well water is either treated, or the well is closed (WDNR, 2007). Therefore, most of the municipal wells in Dane County comply with these drinking water standards (CARPC, 2004a; Village of McFarland, 2009). However, public water supplies only provide a small portion of the total drinking water in the Door Creek watershed (CARPC, 2004a: CARPC, 2004b). The remainder of the watershed obtains drinking water from private groundwater wells.

Private groundwater wells that serve less than 25 people at least 60 days a year are not regulated by the Safe Drinking Water Act (WDNR, 2007). Therefore, most rural private landowners have the sole responsibility for monitoring their drinking water supply (Kent, 2001). However, as will be described later, the part of the Door Creek watershed within the City of Madison is an exception to this general rule. Since only approximately 10% of private well owners in Wisconsin have their wells tested, there is very little information regarding potential water quality problems for private wells (Groundwater Coordinating Council, 2009). If an existing private well is tested and the contaminant is found to be above the water quality standards implemented by the State (under NR 812) or Dane County (under Chapter 45), and the results are reported to the WDNR or Dane County regulatory agency, only then does the WDNR or Dane County have the authority to require treatment or abandonment of the well (WDNR, 2007; Wis. Admin. Code § NR 812; Dane County Code of Ordinances § Chapter 45).

WELLHEAD PROTECTION - In addition to setting water quality standards for drinking water, the Safe Drinking Water Act (SDWA) also requires that states develop a wellhead protection program. Wisconsin's program involves an inventory of public water supply wellheads, delineation of wellhead protection areas (WHPAs), enumeration of potential contaminant sources within the WHPAs, and a requirement for wellhead protection plans for new public wells. Required wellhead protection plans must identify the recharge area, groundwater flow, and existing contamination sources within one half mile of the well. The plan must then establish a wellhead protection area and an education program based on this information. Wellhead protection ordinances are often also used to provide wells with addition protection against contamination. (WDNR, 2009d; Wis. Admin. Code § NR 811).

### 6.3.3 LOCAL

Groundwater contamination, and the potential legal ramifications for landowners, is an issue of concern in Dane County. A recent Wisconsin court case, Tremls vs. Stahl Farms, shows that land spreading of manure can lead to legal actions and liability (Seely, 2009). "The Tremls sued Stahl Farms, and in January 2006, a federal judge ruled the family was entitled to $80,000 in damages because studies showed the manure had contaminated their groundwater (Seely, 2009)." Given the potential for groundwater contamination from agricultural practices, it is a good ides for agricultural landowners should manage their lands in a manner that reduces their liability, by reducing the potential for excess nutrients to leach into groundwater (WI DATCP, 2008a).

Local regulations, designed to protect against the types of groundwater contamination mentioned above, focus primarily on wellhead protection. Local wellhead protection ordinances are intended to regulate surface water activities in order to protect groundwater quality within a community. These regulations also help to ensure that wells are sited in locations less susceptible to contamination in the first place. As of 2008, three communities within the Door Creek watershed had wellhead protection programs: the Town of Burke, the Town of Sun Prairie, and the Village of Cottage Grove (WDNR, 2008). Each of these wellhead protection ordinances have been tailored to their community and are therefore slightly different from each other.

Whereas most local groundwater regulations focus on wellhead protection, the City of Madison regulations require testing private groundwater wells once every five years. Such testing is designed to ensure that private landowners are not being harmed by drinking water containing toxic levels of pollutants, including nitrates and nitrites. Only a very small part of the Door Creek watershed is currently in the City of Madison. However, as was discussed in Section 4.5, the City of Madison anticipates annexing several areas within the watershed.

In conclusion, regulations designed to help protect the public from groundwater contamination exist at the federal, state and local levels. Within the Door Creek watershed, there is growing concern that agriculture may be contributing to nitrate and nitrate groundwater contamination. It is possible that some of the nitrate/nitrite levels found in the watershed came from past agricultural land management practices and that these levels may remain high until diluted with uncontaminated water. More research at the watershed level would be needed to confirm this assertion. Many agricultural land management practices already in place are intended to reduce surface water and groundwater contamination (see Section 6.6 for more detail). The ongoing evolution of groundwater regulation reflects the recognition that groundwater contamination remains a challenging problem.

## 6.4 RIPARIAN ZONING

A riparian zone is defined as an area adjacent to a river, stream, wetland, or lake (Anderson, 1987; Gregory, 1991). Because various rural and urban land uses are found in riparian zones, regulations for riparian zones apply to many different land uses (Kent, 2001; Salton, 1959). In the Door Creek watershed, land use within the riparian zone is primarily agricultural, with some residential areas located in the northern portion of the watershed.

Riparian zones are hydrologically connected to a waterway through flooding, movement of a stream through time, or ponding adjacent to the waterway (Anderson, 1987; Gregory, 1991). Due to this connection, riparian zones provide habitat for aquatic and amphibious wildlife (Anderson, 1987; Gregory, 1991). Because riparian zones are often subject to flooding, improper management could harm the health, safety and welfare of the general public (Banner, 2009; Hulse, 2004). To ensure effective management of these areas, Federal and Wisconsin State policies manage riparian zones based on their location relative to an adjacent waterbody (Kent, 2001; FEMA, 2005).

Riparian zones are defined by the Ordinary High Water Mark (OHWM) of the lake or stream in question. For purposes of water quality management in Wisconsin, Riparian zones above the OHWM fall into two categories: floodplains and shorelands[6]. Riparian zones below the OWHM are held in public trust and are regulated separately under Wisconsin State Statute 30 (Kent, 2001).

### 6.4.1 FLOODPLAIN ZONING

Floodplains are the first of three types of riparian zones that are regulated for water quality and public health purposes within the Door Creek watershed.

---

[6] Although these two categories share some of the same water quality and public health concerns and in many cases geographically overlap, they are each managed separately.

### 6.4.1.1 Impacts of Flooding

During the severe storms and flooding of 2008, the county reported approximately $13.5 million dollars of property damage and $64.4 million dollars of crop losses (Dane County, 2009a). Flooding can also cause nutrients to be carried downstream (Banner, 2009; Monaghan, 2009; FEMA, 2009d; Gurnell, 2003). This is especially true for agricultural fields with recent applications of manure, fertilizers or biosolids (Banner, 2009; Monaghan, 2009). During the 2008 flooding, agricultural fields in Southern Wisconsin suffered significant soil erosion and lost nutrient value (WI DATCP, 2008b). Floodplain regulations and conservation programs, administered by federal, state and local levels of government, can have a dramatic impact on the effects of a flood (Burns, 2005; Ku, 1992; White, 1940). For example, during the recent 2008 flooding, agricultural landowners who had implemented USDA programs, such as the Environmental Quality Incentives Program (EQIP) to reduce soil erosion, experienced less soil and nutrient losses then those who did not (WI DATCP, 2008b).

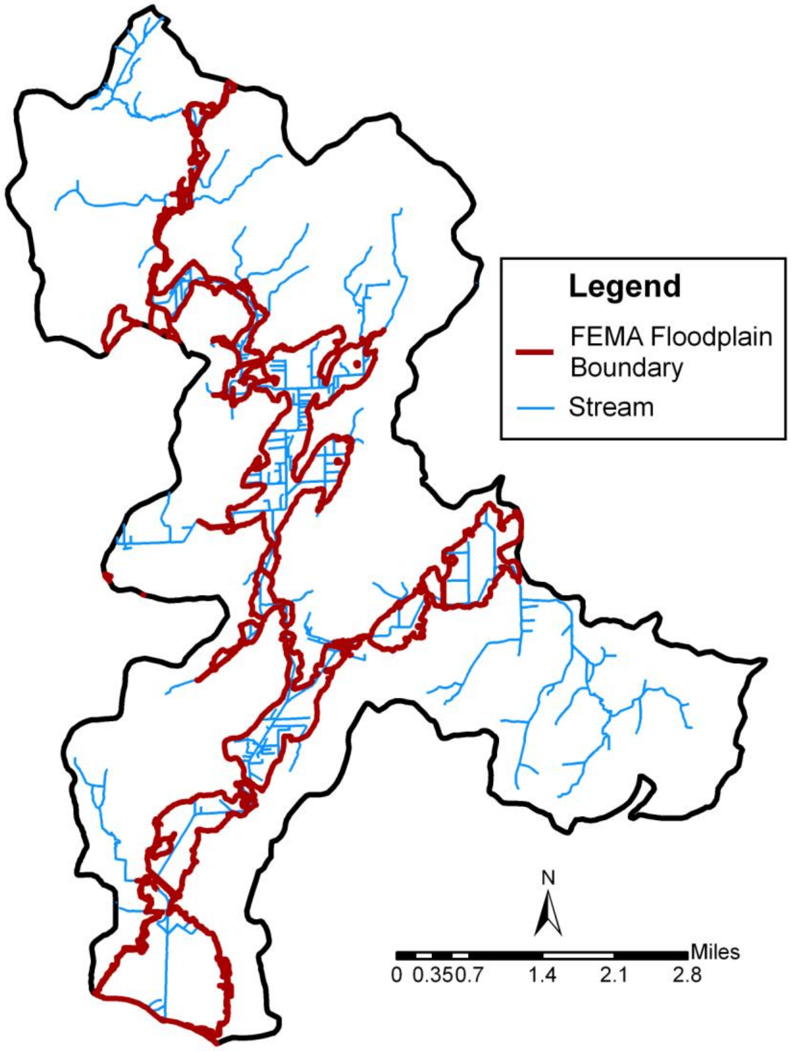


**Figure 6.2: Floodplains within the Door Creek Watershed.**
Source: FEMA, Flood Hazard Zones, 2009, Created: December 2009 by the WRM Practiucm

The Door Creek watershed, with its extensive floodplains and wetland complex, also experienced the negative effects of flooding in 2008 (Figure 6.2). Flooding within the Door Creek watershed damaged agricultural fields, backed up culverts, and filled basements (TGCa, 2008; TGCb, 2008; USGS, 2008b).

### 6.4.1.2 Federal Floodplain Regulation

The National Flood Insurance Act of 1968 created the National Flood Insurance Program (NFIP). Communities participate in the NFIP by adopting official Flood Insurance Rate Maps (FIRM) and by creating an approved floodplain ordinance for new development, and are eligible for government flood insurance (NFIA, 1973).

The legal definition of a floodplain is an area inundated by water during a flood event that would otherwise be dry, or in other words, an area above the Ordinary High Water Mark (OHWM). A floodplain includes a floodway, a flood fringe, and a flood storage district (Figure 6.3).

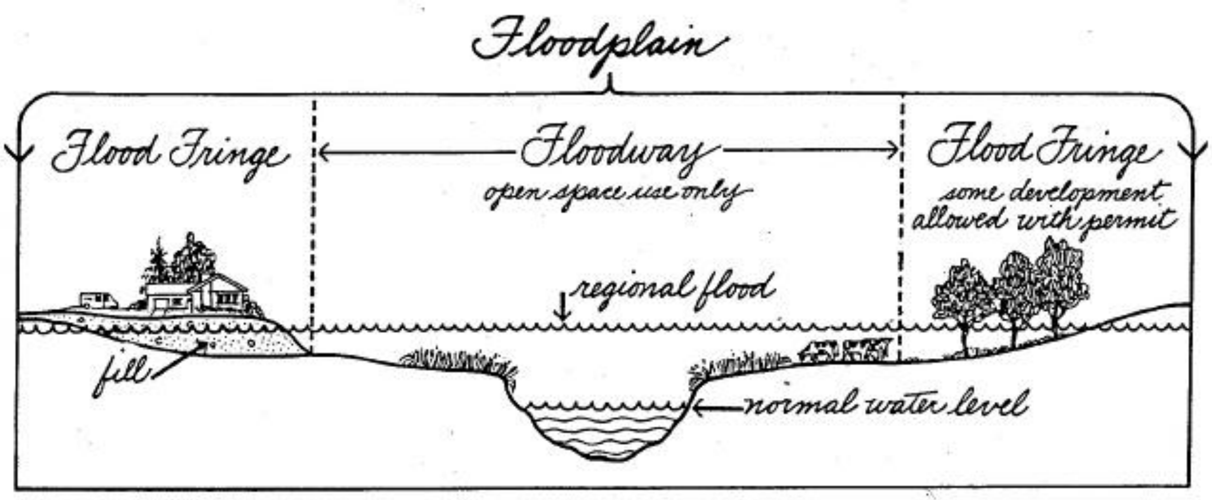


**Figure 6.3: Floodplain, Floodway, and Flood Fringe.** (WDNR, 2010b)

The floodway includes the river or stream channel and the adjoining land needed to carry the 100-year flood. Within an area defined as the 100-year floodplain, there is a one percent chance of a flood occurring during any given year, on average. However, actual flooding can occur more frequently (Kent, 2001, FEMA, 2005; FEMA, 2009a).

### 6.4.1.3 State Floodplain Regulations

The WDNR established NR 116, Wisconsin's Floodplain Management Program, to meet the requirements of NFIP. The program creates a partnership between state and local governments by requiring the adoption of local zoning ordinances that meet the minimum standards of NR 116. Many communities within Dane County participate in NFIP under NR 116 (Dane County, 2009a). Local governments are free to make more restrictive floodplain ordinances as long as they do not conflict with NR 116 (FEMA, 2009b; Kent, 2001).

The broad goals of Wisconsin's floodplain management program include:

- Protecting human life and property
- Minimizing the costs of flood control by state and local agencies
- Reducing tax dollars spent on flood damage and other relief efforts
- Preventing victimization of land and home buyers
- Preventing the increase of the floodplain (and associated damages) caused by poor development decisions

(FEMA, 2005)

The Federal Emergency Management Agency (FEMA) creates and distributes official maps that designate the locations of floodplains. FEMA recently provided updated maps to Dane County and to all of the municipalities within the county (WDNR, 2009e). Local governments are now in the process of adopting these updated maps as part of their floodplain zoning ordinances (FEMA, 2005).

Development within the floodplain is not allowed to increase the 100-year flood elevation by 0.01 feet. The floodplain is divided into the floodway and the flood fringe (Figure 6.4). The flood fringe includes areas up to two feet above the floodway, that is, two feet above the 100-year floodplain. Development within the flood fringe is generally allowed as long as the development meets certain standards, such as flood proofing basements. Development within a floodway, such as most residential buildings, sewage systems, drinking water wells, wastewater treatment ponds or facilities, is generally prohibited, although cropland, pastures, orchards, and forestry are generally allowed. Because these agricultural areas could be subjected to frequent flooding, they are regulated under a number of other provisions discussed in more detail in Section 6.6, including provisions to encourage protection of agricultural lands subject to frequent flooding (FEMA, 2005; Kent, 2001).

### 6.4.1.4 Recent Changes to Floodplain Regulations

The WDNR recently amended NR 116 by adding a new floodplain district called a flood storage district. This new type of floodplain district is intended to provide floodplain storage that helps reduce downstream flood volumes. Development in a flood storage district is regulated so that the overall flood storage capacity of the district is not reduced. This can be done in a number of ways, including excavating other locations to provide compensatory flood storage (WDNR, 2009f).

To help communities create ordinances that meet the standards of NR 116, the WDNR created a model ordinance that communities can adopt. Communities can modify the model ordinance to meet their needs as long as the adopted ordinance is as least restrictive as NR 116. Within the Door Creek watershed, the Village of Cottage Grove, the City of Madison, and the Village of McFarland have all adopted floodplain ordinances. Unincorporated areas within the Door Creek watershed are regulated under Dane County's Chapter 17 floodplain ordinance, which was recently updated in the summer of 2009 to include Flood Storage Districts (Dane County, 2009b).

The recent changes to NR 116 could affect proposed development projects within the Door Creek watershed. As Figure 6.3 shows, there are extensive floodplains within the watershed. The proposed changes to NR116 would require that no increase in the floodplain result from any development within a floodplain or a flood storage district. The changes to NR 116 could reduce or change development plans within the watershed.

In conclusion, floodplain regulations are intended to protect the health, safety, and welfare of the public. This includes not only protecting property from damage, but also protecting waterbodies from pollution during a flood. Floodplain regulations are important factors in controlling the nitrate and phosphorous levels of Door Creek.

## 6.4.2 SHORELAND

Development in areas adjacent to waterbodies can affect both water quality and aquatic life (Stein, 2005; Elias, 2003; Jennings, 1999); however, no federal statue requires shoreland zoning to protect shorelands from the potential impacts of development. States, however, may choose to regulate land uses adjacent to navigable waterbodies through shoreland zoning. (Kent, 2001)

### 6.4.2.1 STATE SHORELAND REGULATIONS

Wisconsin's Shoreland Management Program, created under NR 115, defines shorelands as all areas within 1,000 feet from the ordinary high water mark (OHWM) of a navigable lake, pond or flowage, 300 feet from a navigable river or stream, or the navigable stream reaches of floodplains (officially listed as such by the WDNR) (Figure 6.4) (Wis. Admin. Code § NR 115).

Under NR 115, county shoreland zoning is required for unincorporated shoreland areas above the OHWM. Areas under the OHWM are not regulated under Wisconsin's shoreland zoning statutes; however municipalities may voluntarily adopt ordinances to include areas below the OHWM. Even if a municipality chooses not to adopt local shoreland zoning, they are still required to continue county shoreland zoning in areas annexed from unincorporated areas that were formerly regulated by the county (Wis. Admin. Code § NR 115).

### 6.4.2.2 COUNTY SHORELAND REGULATIONS

Shoreland areas adjacent to Door Creek and Lake Kegonsa have the potential to contribute excessive nutrients to these waterbodies, if they are poorly managed (Markham, 2003). Most shoreland areas in the Door Creek watershed are in unincorporated areas that are covered under Dane County's shorelands ordinance, Chapter 11: Shoreland, Shoreland-Wetland and Inland Wetland Regulations. Chapter 11 requires new development and some redeveloped areas to meet certain development standards (Dane County Code Ordinance § Chap. 11).

The building setbacks and shoreland erosion control measures required by Chapter 11 are of particular importance to the Door Creek watershed. These requirements help protect waterways from the increased soil erosion and nutrient runoff that can result from an increase in impervious surfaces and/or the clearing of native vegetation. Also relevant to the Door Creek watershed is the fact that, like floodplain zoning, most normal agricultural activities such as crop fields and gardening are exempt from shoreland zoning requirements. However, agricultural areas are regulated under a number of other provisions, discussed in more detail in Section 6.6, including provisions to encourage protection of agricultural shorelands.

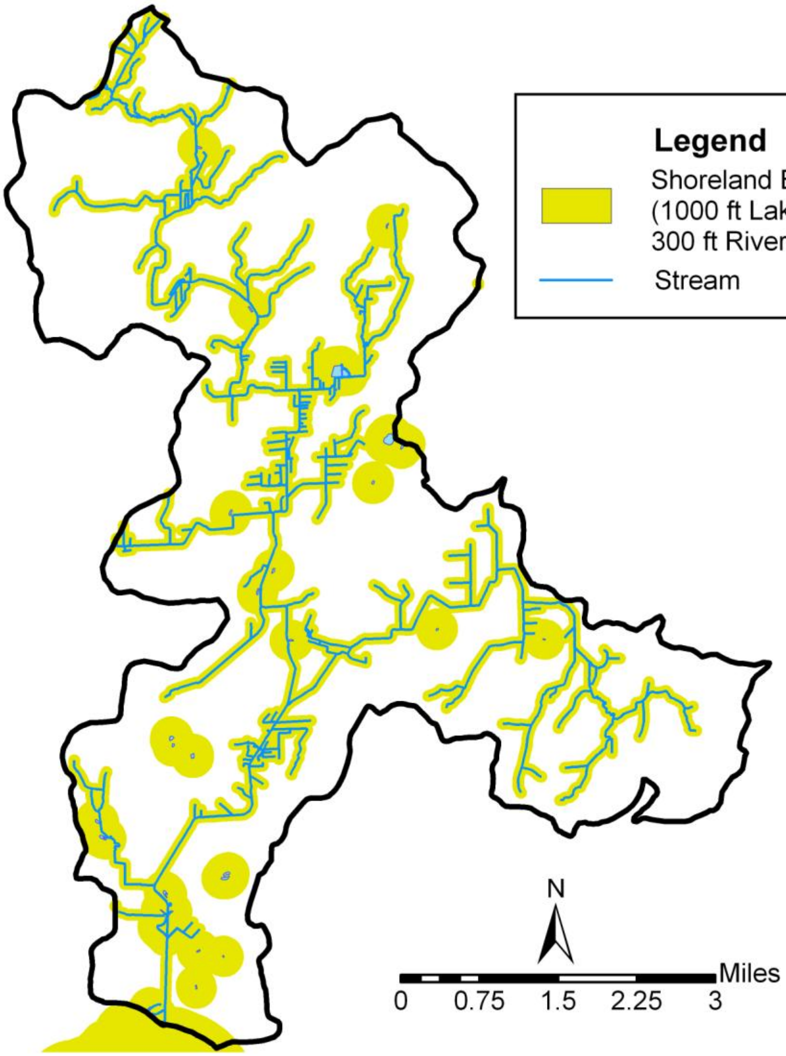


**Figure 6.4: Door Creek Watershed Shorelands.**
Source: Dane County Planning and Development, 2009 Created: April 2010 by the WRM Practicum.

### 6.4.2.3 Proposed Shoreland Zoning Changes

Several changes have been proposed for both NR 115 and Chapter 11. At the state level, the WDNR is considering revisions to NR 115 that would reduce runoff and restore habitat within shorelands. The proposed changes include limiting the amount of impervious surface on a property in a shoreland zone to no more than 15 percent of the total property area, unless the impervious surface is offset using best management practices such as rain gardens or native vegetation restoration (Dane County, 2009c).

As part of this revision process, the WDNR has created the Lake Classification Grant program, which provides funding to counties for the targeted management of waterbodies based on a classification system. Dane County received a Lake Classification grant to assess their current shoreland ordinance. The Dane County Waterbody Classification Project Team has determined that the current Shoreland Zoning Ordinance: "does not adequately protect more sensitive waterbodies in the Developing and Rural categories (Dane County, 2009c)."

As of March 2009, Dane County solicited and received public comment on the objectives and strategies that could be used to regulate waterbodies based on a waterbody classification system. Dane County's current proposal is a hybrid between "traditional shoreland zoning standards, based on setbacks and designated buffer areas, and; performance-based standards, based on the designs that meet objective, and measurable engineering criteria (Dane County, 2009c)." The proposal by Dane County would allow a developer to choose the standard under which they would be regulated for a particular development (Dane County, 2009c).

**Table 6.2: Proposed Amendments to County Shoreland Zoning.**

| Water Quality Standards | Developing Waters (Proposed Door Creek Classification ) |
|---|---|
| Applies to: | All shoreland lots with new development or redevelopment |
| **1)** Install stormwater practices to meet sediment retention and infiltration targets | Achieve 80% reduction in sediment, compared with no controls |
| | Infiltrate 90% of predevelopment infiltration volumes |
| **2)** If Residential use, development has an approved Dane County or Municipal stormwater permit compliant with current standards of chapter 14, Dane County Code | Applicable |
| **3)** Comply with specific lot design and setback standards for each class | Min. Lot Width: 200 feet |
| | Min Structure Setbacks: 100 feet |
| | Min. Vegetative Buffer Depth: 75 feet |
| | Max. Impervious Surface: 15% |
| | Min Lot Area: 2 acres |

Note: Generally, the stormwater management regulations within NR 151 require a reduction by 80% of total suspended solids (TSS) compared with no controls for new development and 40 % reduction for redevelopment. Furthermore, residential development shall infiltrate 90% pre-development infiltration volumes and for non-residential development, 40% of infiltration volumes. (Dane County, 2009c)

Under the proposed lake classification standard, new building and vegetative setbacks would be increased for rural waters, while the current setbacks would be maintained for urban waters (Table 6.2). The proposed performance standard would require development to be mitigated through the use of sediment and infiltration best management practices (Table 6.2). These proposed changes to county shoreland zoning, if approved, would be comparable to the proposed changes to NR 115 (Dane County, 2009c).

Door Creek is exactly the kind of waterbody that the proposed regulations are intended to protect. The proposal classifies Door Creek as a developing waterbody, and, if approved, development near Door Creek would have to meet either the new performance standards or the new setback standards shown in Table 6.2. Either way, the proposed changes to county shoreland zoning would require increased setbacks or stormwater requirements for development within a shoreland adjacent to Door Creek.

### 6.4.3 WISCONSIN'S PUBLIC TRUST DOCTRINE (DREDGING AND FILLING OF STREAM BEDS)

Article IX, Section 1 of the Wisconsin State Constitution states that navigable waters "shall be common highways and forever free …" This provision of the constitution is the basis for the Public Trust Doctrine. Although Wisconsin's Public Trust Doctrine has evolved over the years, its main purpose has always been to preserve navigable waters for travel, recreation, and the enjoyment of Wisconsin citizens (WDNR, 2009g).

The Public Trust Doctrine also plays an important role in the issuing of permits to dredge, fill or straighten waters of the state (Quick, 1994). Dredging and filling of rivers and streams can have a significant impact on water quality and hydrology (Johnston, 2005). Therefore, the WDNR requires a permit under Wisconsin State Statue 30.20 for removing or adding fill material to a navigable stream. Permits required under Wisconsin State Statue 30.20 are generally granted, as long as doing so would be consistent with the public interest and the cumulative impacts of granting such a permit are considered (Michael Cain, Personal Communication, October 6th, 2009).

Activities, such as the straightening or re-meandering a navigable river or stream, also impact the hydrology of a waterbody and require a permit under Wisconsin State Statute 30.195. The owner of the land, a private owner or government entity, is not allowed to change the course of a waterbody if it will negatively affect the flood flow capacity of the stream, hurt public rights, or impact the rights of other riparian land owners. It is important to note, however, that the scope of the Public Trust Doctrine does not cover groundwater or wetlands above the OHWM. (Kent, 2001)

As was discussed in Chapter 2, Door Creek has been extensively dredged and straightened, thereby changing the stream flow location, width and depth. Chapter 5 recommended the restoration of the creek within the Door Creek Wildlife Area and discussed the pros and cons of remeandering the stream for water quality purposes. If the Door Creek original stream meanderings were restored by removing material from the bed of the stream, a permit would be required under Wisconsin State statue 30.20. If Door Creek were re-meandered it would require a permit under 30.195. Federal permits are also required for dredging and filling in navigable waterways and are discussed in section 6.5.

## 6.5 WETLANDS

The Door Creek watershed contains vast areas of both riparian and isolated wetlands (Figures 5.1 and 5.2). Riparian wetlands are directly connected to or are within the nexus of a navigable waterway, while isolated wetlands are not.

Wetlands are officially defined as areas that are inundated by surface or groundwater for durations long enough to support vegetation adapted for life in saturated soil conditions. The anaerobic, saturated conditions in wetland soils result in slow decomposition of the vegetation and, thereby, the creation of a soil that is high in organic material, known as a hydric soil. Because of the fertile soils found in wetlands, these lands are often drained and used for agriculture. In some cases, these drained wetlands are used for other purposes, such as residential housing. There are many federal, state, and local laws and policies that are intended to discourage or prevent dredging, draining, and filling of wetlands (US Army Corps of Engineers, 2009; and Brady, 2006). They are covered in detail in the following sections.

### 6.5.1 FEDERAL WETLAND REGULATIONS

There are two main approaches to preventing the dredging, draining and filling of wetlands at the federal level: Section 404 of the Clean Water Act (CWA) and the Swampbusters Provision of the USDA Farm Bill.

#### 6.5.1.1 CLEAN WATER ACT WETLAND REGULATIONS (AND EXEMPTIONS FOR AGRICULTURAL WETLANDS)

Section 404 of the CWA requires a landowner who wishes to place any dredged or fill materials in waters of the United States, including wetlands with or without a nexus to a navigable waterway, to obtain a permit from the US Army Corps of Engineers. Many agricultural activities are exempt from such permit requirements (US Army Corps of Engineers, 2009).

Wetlands converted to agricultural lands before December 23, 1985 are classified as Prior Converted (PC) croplands as long as agricultural operations continue (US EPA, 2009g). PC wetlands are not regulated under the CWA (Table 6.3). However, if the PC croplands are not farmed with an agricultural commodity for more than five consecutive years, and wetlands characteristics return, then the land is once again considered to be a wetland subject to regulation under the CWA. As of December 23, 1985, activities associated with converting a wetland to agricultural land, or converting an agricultural wetland to a non-wetland area, were no longer exempt from dredge and fill permit requirements (Army Corps of Engineers, 2009). However, ongoing agricultural activities, such as “normal” farming, ranching and forestry, continue to be exempt as long as they do not change the use of the land (US EPA, 2009g; Kent, 2001). Normal farming includes “cultivation, harvesting, minor drainage, plowing, and seeding.” (US EPA, 2009g; Zinn, 2001)

An additional type of agricultural wetland, called Farmed Wetlands (FW), is very similar to PC croplands, in that they are wetlands brought into production before 1985. However, unlike PC wetlands, FW lands continue to be wet enough to be “valuable wetland habitat subject to CWA. FW lands are considered to be wet at least 14 days a year and are often not farmed every year due wetness or flooding.” (Thomson, 2004) If agricultural use of a FW area ceases for 5 years, then such an area may lose its FW classification and may be reclassified as a wetland (US EPA, 2009g; Zinn, 2001).

**Table 6.3: Natural Resource Conservation Service CWA Wetland Types.**

1. Non-Wetland (NW) – Those lands that do not exhibit the characteristics of wetlands.
2. Prior Converted (PC)—Areas that were converted from wetlands to non-wetlands prior to December 23, 1985, produced a commodity crop at least once since December 23, 1985 and, as of that date, did not support woody vegetation
3. Farmed Wetland (FW)—Wetlands that were manipulated (e.g., ditched, tiled, cleared of woody vegetation) prior to December 23, 1985; produced a commodity crop before December 23, 1985; wetland hydrology was not eliminated; and the area had not been abandoned (five years with no management unless in a set-aside program)
4. Wetland – Those areas with wetlands subject to the Clean Water Act

Source: US EPA, 2009g

### 6.5.1.2 USDA Farm Bill Wetland Policies

The Farm Bill not only shapes federal agricultural policy, but also has a significant impact on the environmental management of wetlands. The 1987 Farm Bill, also known as the National Food Security Act, prevents federal payment for any commodity produced on a "converted wetland" or to any person who converts a wetland after November 28, 1990. These provisions, known as the Swampbuster provisions, have been included in every subsequent Farm Bill. Wetlands converted prior to December 23, 1985, Prior Converted (PC) wetlands, are exempt from the Swampbuster prohibitions. Generally, to maintain this exemption status, water must not cover the PC wetland for more than 14 consecutive days during the growing season. (Kent, 2001)

In some ways, the Swampbuster provisions under the Farm Bill protect agricultural wetlands to a greater extent than the CWA. While a permit can be obtained under section 404 of the CWA to allow wetland to be dredged or filled, the Swampbuster provisions of the Farm Bill may still impose penalties for such a wetland conversion. That is, even if a permit has been obtained under the CWA to dredge or fill the wetland, the Swampbuster provisions will still apply (unless mitigation can be shown for the loss of wetland value and function) (Kent, 2001).

### 6.5.1.3 Inconsistencies in Federal Regulatory Wetland Determinations

While two distinct federal programs regulate wetlands, the various wetland definitions, e.g. prior converted cropland and farmed wetland, pose problems for how the regulations are implemented. The primary gap relates to how and when the CWA Section 404 permit program is applied to a wetland that is changing from an agricultural use, which is predominately under the jurisdiction of USDA programs, to a non-agricultural use, which is predominately under the jurisdiction of CWA. The gap between how and when wetlands are classified for regulation by agricultural and non-agricultural programs presents a potential threat for the protection of many wetlands. This is especially true for wetlands within the Door Creek watershed, as many of these wetlands are adjacent to anticipated future development (Zinn, 2001).

In 1994 and 2005, agreements were made to address the overlap of wetland conservation responsibilities between USACE and NRCS. The most recent agreement, called the Joint Guidance (JG) document, changed the handling of wetland determinations. NRCS determinations (NW, PC, and FW) are now used solely for Farm Service Agency purposes, while USACE determinations are used strictly for CWA purposes. This removed the loophole that allowed PCs to be considered non-wetlands, (in other words, wetlands that exhibited the hydrologic and soil conditions of wetlands and where farming practices had ceased) (Zinn, 2001).

### 6.5.1.4 Most Indirect Wetland Impacts are not Federally Regulated

Negative indirect wetland impacts are defined as adverse responses by a wetland to one or more stress factors. Examples of such impacts include:

- Alterations to natural hydrology
- Increase in non-native, exotic species
- Decline in biological diversity

Direct impacts result from activities occurring within the wetland, whereas indirect impacts originate outside a wetland. For example, an indirect impact can result from inputs of stormwater and pollutants generated by land development, or other activities in the upland areas surrounding the wetland, also known as the contributing drainage area (CDA). The CDA is defined as the total area that contributes pollutant and sediment runoff to the site of interest, in this case a wetland. Under Section 404 of the CWA, direct impacts to wetlands, such as dredging and filling, are clearly regulated. However, negative indirect impacts to wetlands, such as alterations to hydrology, vegetation and soil structure, are often not regulated. For additional information concerning such indirect wetland impacts, see the Center for Watershed Protection (CWP, 2006).

Although indirect impacts to wetlands are not regulated by federal statutes, some direct and indirect impacts are regulated for federally registered endangered species that live in wetlands. Since many plant species endemic to wetlands are endangered, it is possible that indirect impacts on wetlands would be covered by federal endangered species statutes for plants located on federal or state owned property (Lisie Kitchel - WDNR, Personal Communication, March 8th, 2010). Also, federal law does not prohibit state and local statutes from regulating indirect impacts on wetlands. Therefore, this gap in the federal wetland regulatory framework is often covered at the state or local level of government.

### 6.5.2 STATE WETLAND REGULATIONS

#### 6.5.2.1 State Implementation of the Clean Water Act (CWA)

Individual states may seek approval from the EPA to administer the provisions of the CWA that pertain to wetland dredge and fill permits or wetland water quality certification. The EPA also allows states to make more restrictive regulations.

In the early 1980's, Wisconsin adopted NR 103, Water Quality Standards for Wetlands, which requires that "all practicable alternatives be taken to avoid and minimize impacts to wetlands, and that permitted actions produce no significant adverse impacts to wetland functions and value." This means that, unlike the federal legislation, "reasonably foreseeable" indirect impacts may be regulated by the State of Wisconsin. NR 103 also prohibits non-water dependent activities from harming the value or function of wetlands greater than 0.10 acres in size, if practical alternatives exist. (CARPC, 2008; WDNR, 1992)

In 2000, Wisconsin implemented a Statewide Programmatic General Permit program to implement sections 404 and 401 of the CWA (under NR 299). The program requires compliance with NR 103. Since the adoption of the program, the average annual development of wetlands dropped from 1440 acres per year in the 1990's to less than 100 acres per year since 2002 (Wis. Admin. Code § NR 299; Wis. Admin. Code § NR 103).

Both NR 103 and NR 299 were passed when isolated wetlands were regulated under the CWA by the USACE. However, on January 8th of 2001, the U.S. Supreme Court restricted the USACE from protecting isolated wetlands in non-navigable, intrastate waters (Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers, No. 99–1178). Only those wetlands with a significant connection to a navigable waterway were kept under the protection of the CWA. In response to this ruling, in 2001, the Wisconsin State Legislature passed Wisconsin Act 6 to restore protection of isolated wetlands in Wisconsin (administered by the WDNR under NR 352). The language and exemptions of this act are roughly the same as the federal CWA pertaining to navigable wetlands. However, some wetlands that are less than one acre in size and that meet other stipulations of Wisconsin Act 6 may be dredged or filled without submitting a permit application to the WDNR (Wis. Admin. Code § NR 352; Wis. Admin. Code § NR 299; Wis. Admin. Code § NR 103).

Wisconsin Act 6 also helped set the WDNR policy of avoidance and mitigation in reviewing wetland permits. Specifically, Wis. Stats. 281.37 states that:

> The department [of natural resources] may not consider a mitigation project in reviewing an application … unless the applicant demonstrates that all appropriate and practicable measures will be taken to avoid and minimize adverse impacts on the wetland.

#### 6.5.2.2 NR 115 and NR 117

The WDNR also administers two other state administrative rules that govern wetlands, NR 117: Wisconsin's City and Village Shoreland-Wetland Protection Program, and NR 115: Wisconsin's

Shoreland Management Program. Both administrative rules govern the type of activities that are allowed on or within the shoreland zone, which includes all areas within 1,000 feet from the OHWM of a navigable lake, pond or flowage, or 300 feet from a navigable river or stream, or the navigable stream reaches of floodplains. Both administrative rules require communities to adopt shoreland-zoning ordinances that meet the minimum requirements stipulated in the rule, while also allowing communities to enact stricter requirements if they so choose. NR 117 specifically relates to shoreland-wetlands within cites and villages, while NR 115 pertains to shoreland wetlands within towns. NR 117 allows certain uses and prohibiting others within a certain distance of a shoreland-wetland of a certain size. The protected shoreland wetlands include "all wetlands of 5 acres or more and all portions of wetlands of 5 acres or more, which are shown on the final wetland inventory maps." The following types of uses are generally allowed in a shoreland-wetland zone under NR 117: recreational activities, agricultural land use, limited construction, and development of parks and recreational areas. NR 115 protects all wetlands shown on the Wisconsin Wetland Inventory (WWI) and has similar permitted uses to NR 117 (Wis. Admin. Code § NR 115; Wis. Admin. Code § NR 117).

Uses not expressly permitted by NR 117 and NR 115 are prohibited. Although many agricultural practices are exempt, draining, dredging, filling and flooding are generally not permitted in shoreland-wetlands. However, NR 117.4 outlines procedures to rezone areas zoned as shoreland-wetland to another use designation. If rezoning of the shoreland wetland occurs, and the wetland still falls within the regulatory definition of a wetland, it *may* still be regulated under other applicable federal, state and local land use regulations (Wis. Admin. Code § NR 115; Wis. Admin. Code § NR 117).

### 6.5.3 OTHER STATE LAWS

There are many state laws whose primary focus is not to regulate wetlands but still have provisions to protect wetlands by creating a protective area around them. For example, NR 151 establishes a protective area within 75 feet of wetlands within special natural resource interest areas, within 50 feet of highly susceptible wetlands, and within 30-10 feet of less susceptible wetlands (WDNR, 2004b). NR 204 and NR 113, which are discussed in more detail in Section 6.7, both have provisions that prevent spreading of sludge within a certain distance of a wetland. NR 243, which pertains to Confined Animal Feeding Operations, also has a provision pertaining to the protection of wetlands. However, these administrative rules do not always protect Prior Converted (PC) and Farmed Wetlands (FW) (Wis. Admin. Code § NR 204; Wis. Admin. Code § NR 113; Wis. Admin. Code § NR 243).

## 6.5.4 County and Local Wetland Regulations

Dane County and its municipalities have voluntarily expanded upon the state requirements by regulating inland wetlands as if they were shoreland wetlands. All mapped inland and shoreland-wetlands receive the protections outlined in Chapter 11 of the Dane County zoning ordinance. Chapter 11, Shoreland, Shoreland-Wetland and Inland-Wetland Regulations, protects wetlands of two acres or more that are shown on the Wisconsin Wetland Inventory Maps in unincorporated areas in Dane County. For all wetlands that are regulated, all new buildings must be set back at least 75 feet from the mapped shoreland-wetland district. The permitted and prohibited uses within inland and shoreland-wetlands generally follow the uses described under state law. This includes permitting many agricultural practices such as silviculture, pasturing livestock, cultivating agricultural crops and harvesting wild crops (Dane County Code Ordinance § Chap. 11).

Although Chapter 11 provides regulatory protections for both shoreland and inland wetlands, some wetlands are still left unprotected. Wetlands smaller than two acres do not have regulatory protection because Chapter 11 only regulates wetlands depicted by the Wisconsin Wetland Inventory (WWI) process. There has been a proposal by Representative John Hendricks to protect hydric soils from development. The implementation of this proposal could conceivable protect wetlands of less than 2 acres from development, if approved. (Dane County Code Ordinance § Chap. 11)

Several local municipalities regulate direct and indirect impacts on wetlands by adopting wetland ordinances that comply with or exceed the requirements of NR 117, NR 151 or Chapter 11. The City of Madison, the Village of Cottage Grove, and the Village of McFarland all require stormwater and/or erosion control permits, if a development project might impact a wetland. The City of Madison has a wetland zoning ordinance, and both the Village of Cottage Grove and the Village of McFarland have adopted shoreland-wetland ordinances (Wis. Admin. Code § NR 115; Wis. Admin. Code § NR 117).

### 6.5.4 CONCLUSION

Because the wetlands in the Door Creek watershed are in Dane County, Wisconsin, they are protected better than they would be in many other states. Wisconsin's regulatory protections extend beyond the federal requirements and Dane County's wetland regulations provide valuable, additional protections. However, the exemptions within state and county wetland regulations may still leave some wetlands at risk.

As will be discussed in Section 6.6, development trends within the Door Creek watershed, including the pressure to build new homes and commercial or industrial buildings, have increased the pressure on lands that were once wetlands, such as Prior Converted (PC) and Farmed Wetlands (FW). However, PC wetlands often retain the ability to re-establish themselves as functioning wetlands because they retain a wetland vegetative seed bank and hydric soil characteristics.

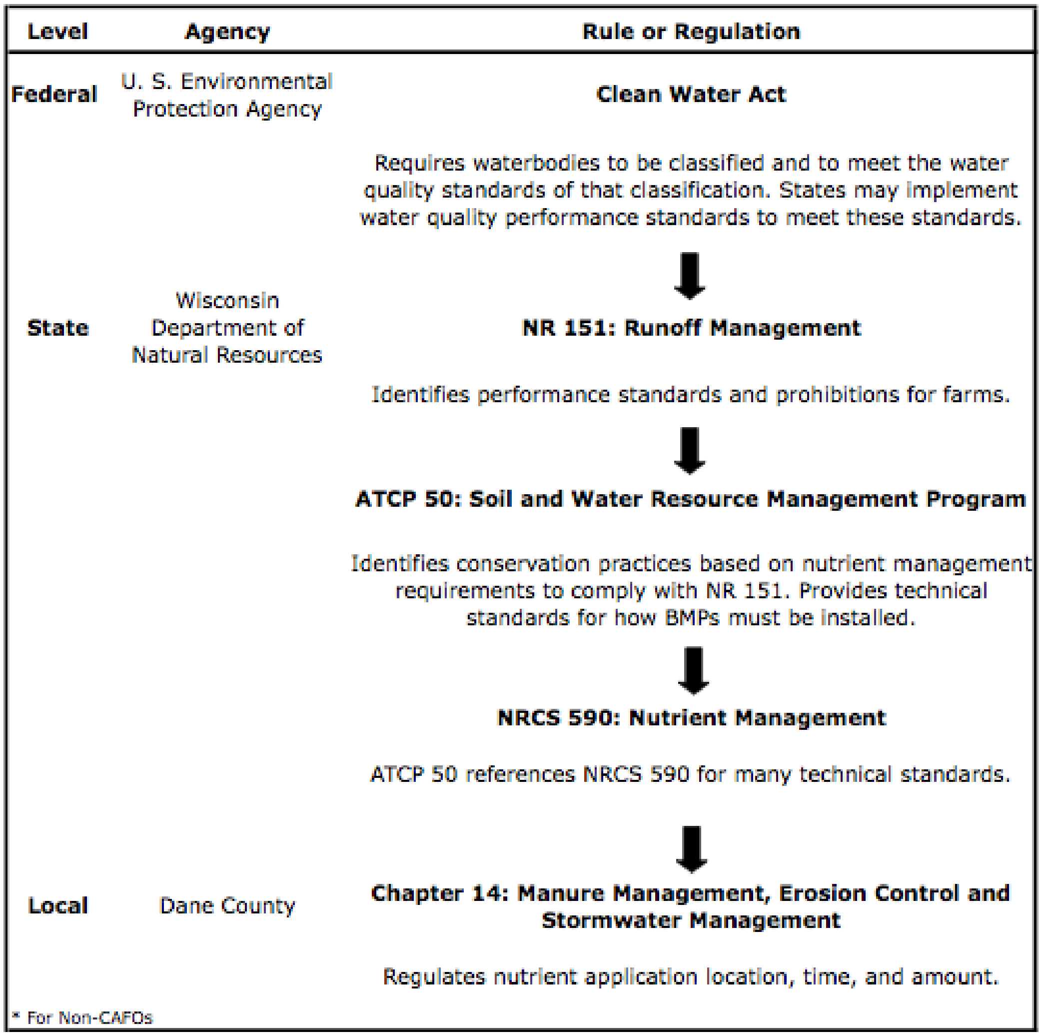
Regulatory loopholes concerning Prior Converted and Farmed Wetlands may allow these former wetlands to be developed. Therefore, the desire to develop such areas needs to be weighed against the value of restoring them. Under the current regulatory structure, the opportunity to restore such areas is generally only available if agricultural practices end and the sites gain a protective status.

Many areas within the Door Creek watershed with current or former wetlands, as indicated by the present of hydric soils, are already recommended for protection or restoration within Dane County's long range planning documents such as Dane County's Comprehensive Plan (See

Section 6.6). However, absent funding for wetland acquisition or restoration, many of these areas may be lost to development in the coming years. Since areas directly adjacent to a river or stream represent the best locations for wetland restoration to yield improvements in water quality it is recommended that these should receive priority if there is limited funding.

## 6.6 AGRICULTURE

Agricultural lands in Dane County are classified as some of the most productive land within Wisconsin (CARPC, 2009). Agricultural working lands comprise 63 percent of the Door Creek watershed and are a vital component of the local economy (Figure 2.2) (Town of Cottage Grove, 2002; Village of Cottage Grove, 2009; Village of McFarland, 2006; CARPC, 2009). However, agricultural landowners are facing two growing concerns: water quality pollution and development pressures. In this section, the legal framework guiding these two agricultural impacts will be discussed, while highlighting some proposed changes to these regulations.



| Level | Agency | Rule or Regulation |
|---|---|---|
| **Federal** | U. S. Environmental Protection Agency | **Clean Water Act** |
| | | Requires waterbodies to be classified and to meet the water quality standards of that classification. States may implement water quality performance standards to meet these standards. |
| | | ⬇ |
| **State** | Wisconsin Department of Natural Resources | **NR 151: Runoff Management** |
| | | Identifies performance standards and prohibitions for farms. |
| | | ⬇ |
| | | **ATCP 50: Soil and Water Resource Management Program** |
| | | Identifies conservation practices based on nutrient management requirements to comply with NR 151. Provides technical standards for how BMPs must be installed. |
| | | ⬇ |
| | | **NRCS 590: Nutrient Management** |
| | | ATCP 50 references NRCS 590 for many technical standards. |
| | | ⬇ |
| **Local** | Dane County | **Chapter 14: Manure Management, Erosion Control and Stormwater Management** |
| | | Regulates nutrient application location, time, and amount. |

* For Non-CAFOs

**Figure 6.5: Flow Chart of Wisconsin's Agricultural Water Quality Rules.**

## 6.6.1 AGRICULTURAL WATER QUALITY REGULATIONS

Due to the loss of agricultural lands to development, there is increasing pressure on the remaining agricultural lands to not only increase productivity, but also to provide habitat for wildlife and create buffers between various land uses, while also protecting surface water and groundwater from pollution (Shortle, 2001; WLSC-DATCP, 2006; WI DATCP, 2009a). Several federal, state and local regulations and policies have been developed to help control agricultural impacts on the environment in the face of increased development pressures (Figure 6.5).

### 6.6.1.1. FEDERAL AGRICULTURAL LAWS AND POLICIES

The Farm Bill is the primary agriculture policy tool of the Federal government. The Farm Bill was most recently reauthorized under the Food, Conservation, and Energy Act of 2008. The Farm Bill impacts international trade, food safety, rural communities, and environmental conservation, through the use of subsidies such as price supports, insurance, and loans (Herszenhorn, 2008; AFT, 2009a). The distribution of funds to various programs supported by the Farm Bill changed with the most recent adoption of the bill (AFT, 2009a: AFT, 2009b). Less money is available for the Conservation Reserve Program (CRP), while additional funds were allocated for programs focused on wetlands and wildlife habitat, such as the Wetlands Reserve Program (WRP) and the Working Lands Program (USDA, 2009; NRCS, 2009a). Since Farm bill subsidies have been provided to various agricultural landowners within the Door Creek watershed in the past decade, these changes in funding could affect agricultural land management practices in the watershed (Environmental Working Group, 2009).

The most important change in the 2008 Farm Bill that could affect the Door Creek watershed is the increased funding for the Environmental Quality Incentives Program (EQIP), which is part of the Working Lands Programs. Funding for EQIP increased by roughly fifty percent to total $7.325 billion overall (USDA, 2009). EQIP provides agricultural producers with financial and technical assistance to implement best management practices relating to irrigation and water management, nutrient management, erosion control, and wildlife habitat enhancement.Before this increase in funding, the Wisconsin EQIP was only able to fund approximately 60 percent of applicants (NRCS, 2009d). It is possible that this increase in funding at the national level may increase funding for the Wisconsin EQIP. The 2009 list of eligible practices for funding within Wisconsin was just posted by the Natural Resource Conservation Service (NRCS). In the Door Creek watershed, the Wisconsin EQIP could provide funding for:

- Riparian buffers
- Streambank stabilization
- Contour farming
- Sedimentation basins
- Well decommissioning
- Comprehensive nutrient management plans
- Other Best Management Practices (USDA and NRCS, 2009)

Since EQIP is a voluntary program, it is important that farmers both learn that funding is available and then actively choose to implement the best management practices on their land. Most farmers are directed to this funding through their local land conservation offices, as the land conservation and federal NRCS agents work together, county by county. EQIP projects require cost sharing, in which a set portion of the costs of a program or project is paid for by the government agency, while the rest of the costs are covered by either the applicant or other governmental agencies (Figure 6.6).

Another Federal agricultural policy tool is the Clean Water Act (CWA). The Environmental Protection Agency (EPA) has delegated much of the implementation and enforcement of the CWA to the states. In Wisconsin, the Department of Natural Resources (WDNR) enforces several of the provisions of the CWA that regulate agricultural practices.

**Figure 6.6: Cost Sharing in Wisconsin.**

Cost Sharing became a Wisconsin State Law in 1977 as a means to provide private landowners with financial assistance to implement conservation practices (NRCS 2009b). The Natural Resource Conservation Service (NRCS) pays up to 75% of the conservation practice cost in its contracts. Local government may contribute additional funds to reach 90% or more of the cost. The shared funding gives private landowners the ability to stay in compliance when it is not economical to do so independently (NRCS 2009c). Laws that include required cost sharing, such as NR 151, also require that producers be offered cost sharing funds in order to require compliance. Unfortunately, when government funding is low and no cost share funds are available, little can be done to enforce such laws (Susan Josheff - WDNR, Personal Communication, February 23, 2010).

### 6.6.1.2. Agricultural State Laws and Policies

There are many Natural Resource (NR) Administrative Rules in Wisconsin that regulate management of agricultural lands to protect water quality, including NR 151, NR 243, NR 204, NR 214, and NR 113. Of these, NR 151, and the associated ACTP 50 and NRCS 590, is the foremost NR Administrative Rule used to implement the agricultural provisions of the CWA in Wisconsin (Wis. Admin. Code § NR 151).

NR 151 sets performance standards and prohibitions for farms to minimize the amount of soil erosion, nutrient runoff from land-applied manure, fertilizers, and other non-point source pollutants that may affect water quality.

There are four main performance standards outlined in NR 151. These are:

- Sheet, rill, and wind erosion
- Manure storage facilities
- Clean water diversions
- Nutrient management

The sheet, rill, and wind erosion standards within NR 151 require all cropped fields to meet the tolerable soil loss rate (“T”), which sets the maximum rate of erosion allowable for a particular soil and site location that will still maintain soil productivity (see Chapter 4.2). These calculated values can then be used to prepare nutrient management plans that control field application of nutrients. NR 151 also includes requirements for maintaining new and altered manure storage facilities. However, some nutrients are exempt from NR 151, including municipal, industrial or private septic sludge, if they are the only source of nutrients applied to the field (Wis. Admin. Code § NR 151.07 (2)). Those three sources of nutrients are regulated by their own WDNR municipal, industrial or private septic tank sludge provisions, which are found in NR 204, NR 214, and NR 113, respectively. These regulations are discussed in more detail in Section 6.6. (Wis. Admin. Code § NR 151)

NR 151 includes provisions that require all runoff to be diverted away from feedlots, manure storage areas, and barnyards that are within Surface Water Quality Management Areas (Table 6.4). These rules and regulations are intended to limit sediment and nitrogen runoff from agricultural fields into surface water or groundwater. To assist producers in meeting runoff requirements of NR 151, the state may assist them with cost sharing (Wis. Admin. Code § NR 151).

**Table 6.4: Agriculture NR 151 Site Restrictions.**

**The Clean Water Divesion protections within NR 151.015(2)** state that runoff shall be "diverted away form contacting feedlot manure storage areas and barnyard areas within water quality management areas except that a diversion to protect a private well under s NR 151.015(18)(a) is required only when the feedlot manure storage area or barnyard area is located upslope from a private well."

**Water quality management area (NR 151.015 (24))**
**1.** "Within 1,000 feet from the ordinary high water mark of navigable waters (lake, pond, or flowage)"
**2.** "Within 300 feet from the ordinary high water mark"
**3**. "A site that is susceptiable to groundwater contamination"
**Sites Susceptable to Groundwater Contamination (NR 151.015 (18))**
"**(a)** An area within 250 feet of a private well.
**(b)** An area within 1000 feet of a municipal well.
**(c)** An area within 300 feet upslope or 100 feet downslope of karst features.
**(d)** A channel with a cross−sectional area equal to or greater than 3 square feet that flows to a karst feature.
**(e)** An area where the soil depth to groundwater or bedrock is less than 2 feet.
**(f)** An area where the soil does not exhibit one of the following soil characteristics:

  **1.** At least a 2−foot soil layer with 40% fines or greater abovegroundwater and bedrock.

  **2.** At least a 3−foot soil layer with 20% fines or greater above groundwater and bedrock.

  **3**. At least a 5−foot soil layer with 10% fines, or greater above groundwater and bedrock."

There are two important exceptions to this general rule: when the producer "changes the management of a livestock facility in a manner that results in noncompliance with a livestock performance standard or prohibition (NR 151)," or if they are participating in the newly adopted Wisconsin Working Lands Initiative (WWLI) tax credit program. The WWLI is described in more detail in Section 6.6.2. In either of these two cases, the producer must bring the livestock facility into compliance whether or not cost-sharing available (Wis. Admin. Code § NR 151).

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) recently adopted ATCP 50 to implement pollution runoff standards associated with NR 151. ATCP 50 establishes nutrient management standards based on the nitrogen needs of the crop, which are then used to create nutrient management plans. Like NR 151, ATCP 50 does not apply to lands where only municipal, industrial or private septic tank sludge is applied. Nutrient management plans created with cost-share funds provided under ATCP 50 must meet the standards established in Natural Resources Conservation Service (NRCS) 590 (Wis. Admin. Code § NR 151; Wis. Admin. Code § ATCP 50).

NRCS Nutrient Management Standard Code 590 is intended to guide the management of nutrient application and soil nutrient levels by accounting for the amount, source, placement, form, and timing of nutrient applications. The Nutrient Management Plan must be compiled by a qualified nutrient planner and include all parts of every field on which the producer mechanically applies nutrients. This program is intended to minimize impacts of nitrogen on surface and ground water quality, while improving crop production for the farmer (NRCS, 2005).

NRCS generally requires that agricultural land use managers test their soil every four years for pH, phosphorus, potassium, and organic matter. This information is used to help ensure that phosphorus and potassium applications do not exceed the total nutrient application recommendation for a given crop rotation. Despite the advantages provided by nutrient management plans, only 16% of Dane County farmers had a NRCS 590 Nutrient Management Plan as of 2008; and no farmers in the Door Creek watershed had submitted plans to the Dane

County Conservation Offices as of June of 2009 (WI DATCP, 2008a; Duane Wagner, Personal Communication, June 2009). If a plan is established by a certified crop advisor (CCA), then the plan must follow the 590 standard. However, producers are able to develop their own nutrient management plans without the guidance of a consultant. These plans would not need to follow the guidelines established by NRCS 590, nor would they need to be reported to the county (Duane Wagner, Personal Communication, June 2009) (Wis. Admin. Code § NRCS 590).

NRCS 590 also contains provisions that are intended to minimize the entry of phosphorous (P) to surface waterbodies. P is regulated in a very different manner than nitrogen under NRCS 590. NRCS 590 requires an agricultural land manager to develop a P management strategy for applying manure or organic by-products to agricultural fields. This strategy may be based either on not exceeding an average Phosphorous Index (PI) of 6 for a crop rotation (as described in Chapter 4.2), or on a Soil Test Phosphorous Strategy, which includes installing and maintaining contour, buffer, or filter strips; maintaining 30% crop residue or vegetative cover; or establishing fall crops; *and* managing phosphorous applications from all sources based on a soil test P value. Commercial P fertilizers are generally prohibited from being applied when there is a "P test in the non-responsive range for the crops being grown." NRCS 590 provisions also recommend that when manure, organic byproducts or fertilizers are applied, agricultural land managers should establish perennial vegetative cover in all areas where concentrated flow results in reoccurring gullies. They should also avoid the build up of soil P beyond the responsiveness of the plants, which is generally over 30-50 parts per million (ppm).

Several proposed changes to NR 151 could impact both water quality and agricultural land use management (WDNR, 2009h). The WDNR is currently working to amend NR 151 and, as part of this process, has held several public meetings over the past three years (WDNR, 2007b; WDNR, 2009a). The proposed changes to NR 151 are intended to discourage tillage on steep slopes and within riparian areas directly adjacent to water bodies (WDNR, 2007d; WDNR, 2010c). It is important to note that, as of the spring of 2010, these changes have not in any way been finalized by the WDNR and the final version brought to the legislature for approval may be different (John Pfender, Personal Communication, August 6, 2009).

The following is a list of proposed changes to NR 151 that are relevant to the Door Creek watershed:

1. Currently NR 151 regulates nitrogen application, but not phosphorous application. The most recent proposed draft legislation would change this by prohibiting phosphorous application based on an average phosphorous index (PI), which would be calculated using the SNAP-Plus model (described in Chapter 4.1.2) (WDNR, 2010). Also, PI levels are not to exceed 10 for any individual year, and not to exceed 6 for an "accounting period" of 8 years (WDNR, 2010; WDNR, 2007c). For areas with designated TMDLs, stricter phosphorous and soil loss rates may be warranted (WDNR, 2010; JAC for NR 151 and NR 153, 2008).

2. To protect riparian areas, tillage would be set-back at least 20 feet from riparian areas (WDNR, 2010). Harvesting would still be allowed in this area as long as self-sustaining vegetative cover is maintained and harvesting does not require tilling (WDNR, 2010).

3. Several changes to NR 151 are aimed at how construction site and urban runoff are regulated. These proposed changes will be discussed in Sections 6.8

In light of the WDNR's proposed changes to NR 151, DATCP is also considering revising ATCP 50 (WI DATCP, 2009b). The proposed changes to ATCP 50 include farmland conservation standards and requirements, and farmland cost-share standards and requirements. However, no draft language has been presented to the public as of the spring of 2010.

Drain tiles are not currently regulated by NR 151, ATCP 50, or NRCS 590. There are no proposals to change this tradition in the currently proposed amendments to NR 151 or ATCP 50 (Wis. Admin. Code § NR 151; Wis. Admin. Code § NRCS 590; Wis. Admin. Code § ATCP 50).

The manner in which NR 151 and ATCP 50 regulate manure and fertilizer application does not coincide with the NR 204 regulations for the land application of municipal biosolids. This can cause confusion for those landowners who wish to apply more than one type of nutrient source to their fields. However, bringing these different administrative rules in alignment with each other is not currently the primary focus of any proposed regulation changes. A more detailed description of these differences between ATCP 50 and NR 204 was provided in Chapter 4.2 and a detailed explanation of how the WDNR regulates fields with multiple types of nutrient applications is provided in section 6.7 (Wis. Admin. Code § NR 151; Wis. Admin. Code § NR 204;

Wis. Admin. Code § ATCP 50).

The final agricultural law of importance for water quality is NR 243. The primary purpose of NR 243 is to regulate how large farms, farms with over a 1,000 animal units, which are known as Confined Animal Feeding Operations (CAFOs), manage their manure in order to protect water quality (WDNR, 2009i). A detailed description of this law will not be provided because there are currently no CAFOs in the Door Creek watershed (WDNR, 2009j; WDNR, 2009k). The siting of a large animal feeding operation is regulated under ATCP 51, which prevents the siting of large animal feeding operations without local approval. This regulation will be described in more detail in the local laws and policies of this section (Wis. Admin. Code § ATCP 51) (Wis. Admin. Code § NR 243).

### 6.6.1.3. Agricultural Local Laws and Policies

Local county conservation offices may enforce agriculture land use regulations that go beyond those of state regulations. For example, within Dane County's ordinance, Chapter 14 requires more stringent manure management than the state. The ordinance encourages proper utilization of manure, and provides guidelines for unused manure pits and manure storage facility installation.

The most important part of Chapter 14 is the requirement to obtain a permit to spread liquid manure in the winter. Liquid manure is defined as anything containing less than 12% solid substance. The winter spreading permit is available at no cost to the producer. When a permit is issued, the county supplies the producer with a map of acceptable locations for spreading during winter months (Table 6.5 shows the winter spreading restrictions imposed by Chapter 14). These regulations do not apply to solid manure spreading. Twenty percent of the permittees undergo a status review to ensure all guidelines are being followed. As of 2009, no permits have been issued for winter spreading of liquid manure within the Door Creek watershed (Dane County Code of Ordinances Ch.14; Duane Wagner, Personal Communication, June 2009).

Local communities in Dane County occasionally establish their own agricultural regulations. Within the Door Creek Watershed, only one community, the Town of Cottage Grove, has implemented Wisconsin's agricultural siting rule. This rule, also known as ATCP 51, sets odor and water quality siting standards for livestock facilities planning to expand or build a facility that will contain 500 animal units or greater. Producers regulated under ATCP 51 must compile an 'odor score' to assess the impacts of expansion on surrounding neighbors. If expansion by the operation is approved locally, it gives the producer a 'right to farm' protection against encroaching development. This rule not only helps ensure appropriate siting of large livestock facilities in a manner that helps protect surface water, but also protects the agricultural producer against odor complaints that may result after additional livestock siting has been approved. ATCP 51 also requires animal operations to comply with NR 151 and ATCP 50 regardless of the availability of cost sharing (if ATCP 51 applies to the new or expanded animal livestock facility) (Wis. Admin. Code § ATCP 51; Wis. Admin. Code § NR 151).

**Table 6.5: Winter Manure Application Restrictions within Chapter 14 or Dane County's Code of Ordinances (Section 14.20).**

**1.** On frozen, snow-covered or ice covered cropland, the application of stored pumpable liquid manure is prohibited in the following areas:

- **a)** "on a waterway or other channelized flow"
- **b)** "on non-harvested vegetation"
- **c)** "within 30 feet on either side of a waterway"
- **d)** "within 200 feet upslope of a well, tile inlet, sinkhole, gravel pit or fractured bedrock at the surface"
- **e)** "within 300 feet of a stream or drainage ditch"
- **f)** "within 1,000 feet of a lake"
- **g)** "on slopes of greater than 12%"

**2.** Such manure may not be applied on either frozen, snow-covered, or ice-covered cropland unless it is incorporated (unless allowed to do so within an approved liquid manure winter application plan).

Agricultural practices may also be subject to county or local municipal zoning and thus are affected by the overall comprehensive planning process. This is discussed in more detail in the following section.

### 6.6.2 GROWTH AND DEVELOPMENT

Agricultural lands are often the first to be developed because they are near the urban fringe and have relatively low costs of construction when compared to already developed sites (UW-Extension and WI DATCP, 2002). Dane County anticipates that, between the years 2000 and 2030, approximately 15,700 acres of rural land will be developed (CARPC, 2009). In the Door Creek watershed, there is considerable pressure to develop the land surrounding urban centers such as Madison, McFarland, and Cottage Grove (CARPC, 2009). Although development can be a considerable economic driver, unplanned or haphazard development can negatively impact water quality and wildlife habitat by changing the rates of soil erosion and stormwater runoff (See Chapter 4.5).

Planning and zoning has been used to address development in Wisconsin since the 1920s. Zoning is a type of land use regulation that allows local governments to restrict development at particular locations. Planning is used to help direct how zoning ordinances and other ordinances should be changed in the future based on the values of the community (Schilling, J. 2008).

#### 6.6.2.1 SMART GROWTH LAW

To address concerns associated with haphazard and unplanned development, the State of Wisconsin passed the Wisconsin Act 9, also known as the Smart Growth Law, in October of 1999 (DOA, 2008; Wis. Stats. 66.1001). The law requires that, beginning on January 1, 2010, all communities that wish to regulate land use must do so in accordance with an adopted comprehensive plan that meets the standards established within Wis. Stats. 66.1001. However, Wisconsin courts have yet to rule on the scope of the law or how the law will be applied to a community (Schilling, 2008). Therefore, the extent to which the state can require compliance of land use regulations with a community's comprehensive plan is still unknown.

Comprehensive plans are intended to guide a community's land use decisions on a wide range of issues. Although the law gives a community considerable freedom to shape their comprehensive plan to meet the needs of their citizens, it does require that the certain topics, called elements, must be addressed. Of particular importance to the Door Creek watershed is the Agricultural, Natural and Cultural Resources element. The goals, objectives and policies concerning streams, floodplains, wetlands, surface water, and groundwater are discussed within this element. Although there is no requirement that comprehensive plans address water quality and quantity, many plans, such as Dane County's Comprehensive Plan, often do.

#### 6.6.2.2 DANE COUNTY COMPREHENSIVE PLAN

Most communities within the Door Creek watershed have adopted a comprehensive plan. Since much of the Door Creek watershed is located in unincorporated areas, a large part of the watershed is regulated under Dane County's Comprehensive Plan. The Towns of Cottage Grove and Blooming Grove have their own plans that have been incorporated into Dane County's plan by reference. If the problems identified in the Dane County comprehensive plan are not satisfactorily addressed by voluntary programs or funding, they will likely be addressed by formal legislation at some time in the future. Thus, the recommendations, goals, objectives, and policies within the Dane County Comprehensive Plan will likely play a key role in how Door Creek watershed will be developed in the coming years (Dane County, 2007).

Dane County has established the broad goal "to protect, improve, and preserve the quality and quantity of water resources," within their comprehensive plan. Specific water resource objectives and policies relevant to the Door Creek watershed include the following:

- Improve at least 80% of 303(d) impaired water bodies to the point that they are no longer listed as impaired by 2045 at the rate of at least 20% per decade, and prevent any new water bodies from becoming impaired
- Prevent development from increasing the potential for flood-related problems
- Discourage farmers from spreading manure on frozen land and help them establish alternatives such as cooperative manure handling (Dane County, 2007)

Dane County recommended a number of methods to help meet these water quality objectives, including:

- Encouraging producers to enroll in financial assistance programs such as Purchase of Agricultural Conservation Easements (PACE), Purchase of Development Rights (PDR), Transfer of Development Rights (TDR), and public easements
- Encouraging farmers to take part in voluntary programs offered by the USDA that provide farmers with support for protecting and restoring surface water, ground water and environmentally sensitive areas, such as the Conservation Reserve Program

(CRP), the Conservation Reserve Enhancement Program, and the Wetland Reserve Program (WRP)

- Restoring wetlands on public properties and willing private properties
- Using zoning to protect agriculture and environmentally sensitive areas

Dane County effectively extended the Comprehensive Plan by adopting, via reference, the planning goals and objectives of the Park and Open Space Plan, the Water Quality Plan, the Groundwater Protection Plan and the Farmland Preservation Plan. These plans will be addressed in more detail in the following sections.

### 6.6.2.3 PARK AND OPEN SPACE PLAN

One of the primary goals of Dane County's Park and Open Space Plan is to "protect lakes, rivers, and streams, including shorelines, wetlands, high infiltration areas and associated vegetative buffers to maintain high water quality, manage water quantity and sustain water-related recreation throughout Dane County." To accomplish this goal, the plan recommends buying or otherwise protecting areas directly adjacent to waterbodies to reduce flooding and erosion, prevent bank destabilization and help enhance water quality (Dane County Parks Department, 2006). As Figure 6.7 shows, considerable portions of the Door Creek watershed are recommended for future parkland.

Of particular importance to the Door Creek watershed is the recommendation to use the conservation fund to acquire land, as it becomes available, to expand the Door Creek Wetlands Natural Resource Area both to the north and east so that it meets up with the Blooming Grove Drumlin Natural Resource Area. Although water quality protection is not the main priority of the Parks and Open Space Plan, the protection of the wetlands via acquisition may indirectly prevent water quality degradation in the Door Creek watershed (Dane County Parks Department, 2006).

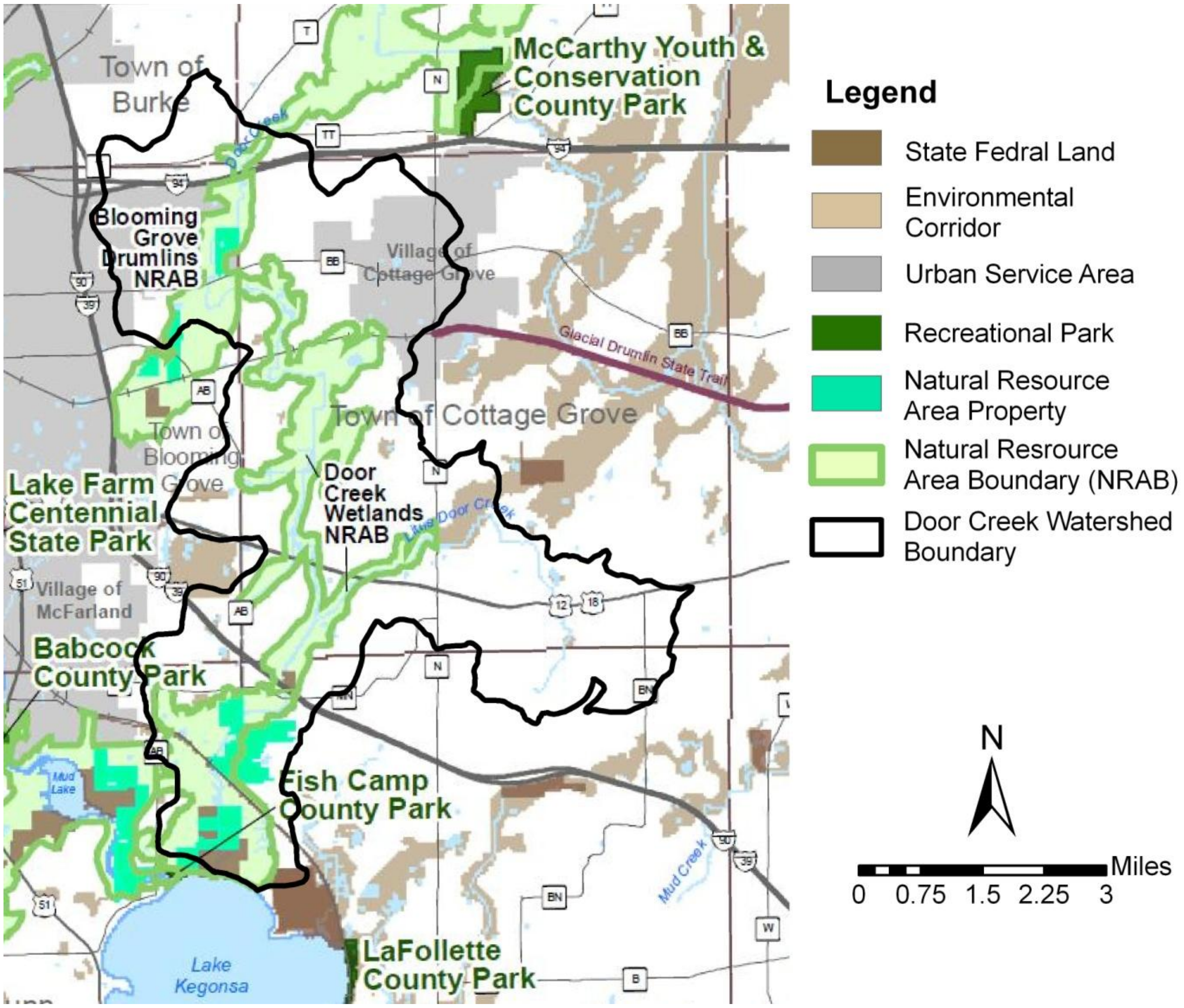


**Figure 6.7: Proposed Parkland within the Door Creek Watershed.** Source: Dane County Parks Department, 2006, Created: March 2010 by WRM Practicum.

### 6.6.2.4 WATER QUALITY PLAN

The Dane County Water Quality Plan identifies agricultural lands as the largest source of sediment and nutrient runoff to the county’s lakes and streams. To address agricultural runoff concerns, the plan recommends implementing Chapter 14 in conjunction with NR 151. Dane County also recommends encouraging agricultural producers to employ protective measures, such as conservation tillage practices, integrated pest management, stream buffers, biosolids application to meet crop needs, and subsurface injection or incorporation of biosolids (CARPC, 2004c).

For urban communities, the plan recommends the adoption of comprehensive erosion and storm water runoff ordinances that require use of best management practices to reduce untreated urban and rural stormwater runoff, practices such as detention and infiltration ponds. Furthermore, they recommend using “easements, land acquisitions, and voluntary cooperation from landowners” to protect shoreline and stream corridor functions, maintain groundwater recharge areas and springs, and educate landowners about the vulnerability of groundwater to contamination (Figure 6.8) (CARPC, 2004c).

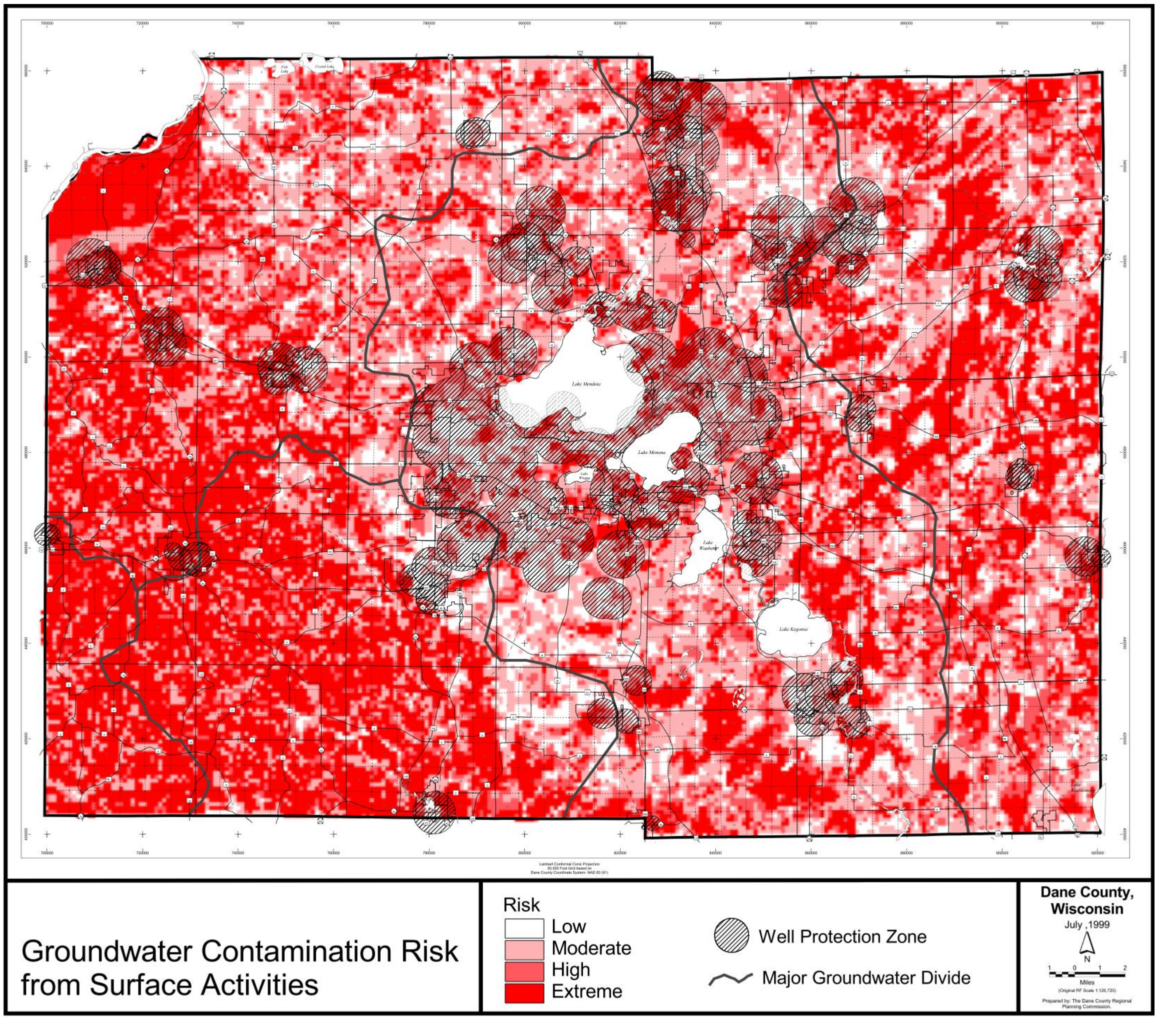


**Figure 6.8: Groundwater Contamination Susceptibility.** (CARPC, 1999b).

### 6.6.2.5 GROUNDWATER PROTECTION PLAN

One of the main concerns of Dane County's Groundwater Protection Plan, adopted as an appendix to the Water Quality Plan, is that, as of 1999, between 25 to 35 percent of private wells are contaminated with high nitrate-nitrogen levels. High nitrates in groundwater can come from a variety of sources, such as nitrogen fertilizers, manure spreading, municipal biosolids application and failing septic tanks and landfills. To help ensure that nutrients do not leach into the groundwater, Dane County recommends creating wellhead protection plans, ensuring that on-site septic systems are regularly maintained, checking sanitary sewer lines and underground storage tanks for leaks, and applying nutrients only to meet the needs of the crop. For areas like the Door Creek watershed that have high groundwater nitrate levels, Dane County recommends increasing, or at least maintaining, groundwater infiltration because dilution is the primary mechanism to control nitrate levels in groundwater once they are introduced (CARPC, 1999a).

#### 6.6.2.6 WISCONSIN WORKING LANDS INITIATIVE/FARMLAND PRESERVATION PLAN

One of the many constraints of enforcing agricultural laws is the requirement of cost-sharing. When cost-sharing is not available, many of the laws cannot be enforced. Wisconsin Working Lands Initiative (WWLI) is an exception to this as it rewards producers with a tax credit. If a farmer chooses to take advantage of the available tax credit, certain guidelines must be followed, whether or not cost sharing is available.

This initiative has the potential to drastically change the number of individuals with nutrient management plans as well as the number of individuals abiding by soil and water conservation requirements in Wisconsin laws, such as NR 151, NR 204, and NR 216. This is because those wishing to receive any of the WWLI tax credits must comply with Wisconsin's runoff rules for agriculture, including meeting tolerable soil loss and manure storage requirements, and creating a nutrient management plan.

The WWLI was passed as part of the Wisconsin 2009-2011 biennial budget. The WWLI is part of Chapter 91 of the Wisconsin State Statue that expands and modernizes the existing Wisconsin Farmland Preservation Program by setting new zoning standards, establishing agricultural enterprise areas (AEA), and allowing the purchase of agricultural conservation easements through a matching grant program (PACE). The goal of both the WWLI and PACE is to preserve prime agricultural land now and into the future (WI DATCP 2009c).

Because of the change from the Farmland Preservation Program to the Working Lands Initiative, counties must update their agricultural conservation plans to meet the new program guidelines. All counties with high population growth, including Dane County, must update and certify their conservation plans by 2011 in order for farmers to be eligible to receive to receive a tax credit for the 2011 fiscal year. In order to be eligible for WWLI tax credits, the county agricultural conservation plan must identify farmland that is worthy of agricultural protection, and such land must be either zoned for farmland preservation and/or be included in part of an individual farmland preservation agreement. The last agricultural conservation plan was adopted by Dane County in 1981, but it is currently being updated (WI DATCP 2009d).

Elected officials within county or municipal governments may then choose whether or not to zone areas identified within the county agricultural conservation plan according to the new WWLI standards (under Chapter 91). The new standards provide flexibility by allowing local governments to apply more specific standards, if desired. The WWLI also allows local governments to purchase agricultural conservation easements from willing landowners

If a given piece of land is not zoned for agricultural preservation, than a landowner wishing to participate in the WWLI must be in an Agriculture Enterprise Area (AEA) and enter into a Farmland Preservation Program Agreement. An AEA is defined as a contiguous land area devoted primarily to agricultural use, as designated by the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP), and is created in response to a local application. Local applications can be submitted by local government or landowners (WI DATCP

2009d).

WWLI Tax credits are given as a flat rate credit per acre, as long as the producer makes at least $6,000 gross farm revenue. Tax credits range from $5 to $10 per acre, depending on location and whether a farmland preservation agreement exists. In order to receive the $10 per acre tax credit, the land must be in a farmland preservation zoning district and must be covered by an individual farmland preservation agreement. To qualify for the middle range tax credit, $7.50 per acre, the land must be in a farmland preservation zoning district, but does not need to be covered by an individual farmland preservation agreement in an AEA. The lowest tax credit of $5 per acre is available if the land is not in a farmland preservation zoning district but is covered by an individual farmland preservation agreement in an AEA (WI DATCP, 2009d).

After January 1, 2010, an agricultural landowner who wishes to rezone their land from a certified farmland preservation district to a non-agricultural use must pay a conversion fee to the local government. This fee must be at least three times greater than the highest per acre value of tillable cropland within the community at the date the rezoning occurs. Communities are allowed to collect additional fees and use this money to buy farmland conservation easements.

The new agricultural conservation plan, local farmland preservation zoning, tax credits and conversion fees in the WWLI may all help to protect valuable farmland within the Door Creek watershed from development. The WWLI may also help protect Door Creek from runoff from current agricultural fields and from future development. This protection is especially important if the soil phosphorous levels are high within these fields, as was found in several parts of the Door Creek watershed (see Chapter 4.2).

### 6.6.3. Conclusion

Planning and zoning can help reduce land use conflicts that often occur when a community has multiple goals, such as protecting farmland, ensuring economic growth and protecting water quality. Considerable changes in land use management have and will continue to occur in the Door Creek watershed. With proper planning and stakeholder involvement, the communities within the Door Creek watershed may be able to achieve common goals and objectives, like improving water quality, by working together to overcome challenges. Dane County's Comprehensive Plan, Water Quality Plan, Groundwater Protection Plan, and Farmland Preservation Plan are good steps toward regional planning within the Door Creek watershed. Only time will tell how well Dane County and the municipalities within the Door Creek watershed will be able to implement the goals and objectives of these plans.

## 6.7 LAND USE PRACTICE: LAND APPLICATION OF SLUDGE

Sludge is created when solids are separated from wastewater during the treatment process. Sludge can be placed in a landfill or incinerated, but it is frequently applied on land so that the nutrients in the sludge can be utilized. Several types of sludge are applied on land in or near the Door Creek Watershed, including municipal, industrial and private septic tank sludge (Chapter 4.4).

The land application of sludge can have negative side effects, including contributing to the runoff of phosphorous, nitrogen, potassium, PCBs, bacteria and heavy metals. The impact of the runoff of these nutrients and chemicals depend on the type of pre-application treatment and the method of application. To safely manage runoff caused by sludge, the US Environmental Protection Agency (EPA) and the Wisconsin Department of Natural Resources (WDNR) have established several rules and regulations that govern the application of municipal, industrial, and septic tank sludge (US EPA, 1994) (Gerba, 2002; Epstein, 2002; Wang, 2004).

### 6.7.1 LAND APPLICATION OF MUNICIPAL BIOSOLIDS

The Madison Metropolitan Sewerage District (MMSD) currently applies liquid biosolids, via injection, in the Door Creek watershed as part of the Metrogro program. Both the land application of biosolids and the discharge of the remaining wastewater treatment effluent are regulated by the US EPA and the WDNR. In Wisconsin, discharging to a waterbody and applying biosolids to land, which are classified as point sources of pollution, require a WPDES permit from the WDNR. The rules and regulations that govern WPDES permits are described in more detail in Section 6.8.2. This section of the chapter, however, focuses exclusively on the rules and regulations that govern land spreading and injection of municipal biosolids (WDNR, 2009; Wis. Admin. Code § NR 204, US EPA, 1994).

The US Environmental Protection Agency (EPA) classifies sewage sludge as solid, semi-solid, or liquid residue created during the treatment of domestic sewage (NRC, 2002). The land application of biosolids from publicly-owned treatment works is primarily regulated under NR 204: Domestic Sewage Sludge Management. Like NR 151, NR 204 is part of the Clean Water Act and is implemented by the WDNR (US EPA, 1994). NR 204 requires that any publicly-owned treatment works (POTW) that wish to apply sludge to the land, such as MMSD Metrogro, must first apply for a permit to discharge to waters of the state (Wis. Admin. Code § NR 204).

In order for the WDNR to approve the permit, several standards must be met. One standard is to ensure that pathogen levels in biosolids are reduced or treated before being applied to the land. Biosolids are classified as Class A or B based on their pathogenic levels. MMSD applies type B solids and meets all site restrictions and testing standards required under NR 204 (and Part 503) (US EPA, 1994; Wis. Admin. Code § NR 204).

A second standard within NR 204 restricts the location where land application is allowed. Application of biosolids is restricted around environmentally sensitive areas, such as those areas that are highly susceptible to surface water and groundwater contamination (Tables 6.6 and 6.7). This means that individual sites might have several areas where land application is prohibited, while allowing the application of biosolids at non-prohibited areas (Wis. Admin. Code § NR 204; Fred Hageman, personal communication, July 13th, 2009).

**Table 6.6: NR 204 Restrictions for Sludge Applied to the Land in Bulk.**

| Site Criteria * | Surface | Incorporation | Injection |
|---|---|---|---|
| Depth to Bedrock | 3 ft. | 3 ft. | 3 ft. |
| Depth to High Groundwater | 3 ft. | 3 ft. | 3 ft. |
| Allowable Slopes | 0-6% | 0-12% | 0-12% |
| Distance to Wells | | | |
| Community water supply or school | 1,000 ft. | 1,000 ft. | 1,000 ft. |
| Other | 250 ft. | 250 ft. | 250 ft. |
| Minimum Distance to Residence, Business or Recreation Area | 500 ft. | 200 ft. | 200 ft. |
| Minimum Distance to Residence or Business with Permission | 250 ft. | 100 ft. | 100 ft. |
| Distance to Rural Schools and Health Care Facilities | 1,000 ft. | 1000 ft. | 500 ft. |
| Distance to Property Line | | | |
| Minimum Distance to Streams, Lakes, Ponds, Wetlands or Channelized Waterways connected to a Stream, Lake, Pond or Wetland. | | | |
| Slope 0 to <6 | 200 ft. | 150 ft. | 100 ft. |
| Slope 6 to <12 | Not Allowed | 200 ft. | 150 ft. |
| Minimum Distance to grass waterways, or dry run with a 50 foot range grass strip. | | | |
| Slope 0 to <6 | 100 ft. | 50 ft. | 25 ft. |
| Slope 6 to <12 | Not Allowed | 100 ft. | 50 ft. |
| Soil permeability range (in/hr) | 0.2-6.0 | 0-6.0 | 0-6.0 |

* Municipal application of sludge is also prohibited when the metal content of the sludge reaches unacceptable levels. The administrative rule contains specific levels and requirements regarding additional prohibitions (such as pH, soil characteristics, radium contamination, oxygen content, etc.) and additional exceptions/variances. For a complete list of site restrictions, please see the full rule (Wis. Admin. Code § NR 204).

Although NR 204 restricts the application of biosolids in channelized waterways directly connected to a steam, lake, pond or wetland, subsurface drain tiles are not classified as a direct conduit to water. Thus, drain tiles are not regulated under NR 204 (Fred Hageman, personal communication, July 13, 2009). Although no state administrative rules are currently interpreted to classify subsurface drain tiles as direct conduits to water, it should be noted that MMSD voluntarily avoids such drain-tiled fields (Chapter 4.4.2.2).

The frequency of biosolid application to a particular site is also restricted, under NR 204, based on the nitrogen needs of the crop being grown on that particular site. Phosphorus in biosolids is regulated separately from nitrogen. NR 204 requires that the soil be tested for total phosphorous at least once every four years, but does not regulate the amount of phosphorous applied (Wis. Admin. Code § NR 204).

**Table 6.7: NR 204 Minimum Durations Between Application And Harvest/Grazing/Access for Class B Sludge Applied to the Land.**

| Criteria * | Surface | Incorporation | Injection |
|---|---|---|---|
| Food Crops Whose Harvested Part May Touch the Soil/Sludge Mixture (beans, melons, squash, etc.) | 14 months | 14 months | 14 months |
| Food Crops Whose Harvested Parts Grow in the Soil (potatoes, carrots, etc.) | 20/38 months | 20/38 months | 20/38 months |
| Feed or Other Food Crops (field corn, hay, sweet corn, etc.) | 30 days | 30 days | 30 days |
| Grazing of Animals | 30 days | 30 days | 30 days |
| Public Access Restriction | | | |
| High Potential | 1 year | 1 year | 1 year |
| Low Potential | 30 days | 30 days | 30 days |

* There are additional exceptions and variances for the application of Class B Sludge. For a complete list of site restriction, please see the full rule (Wis. Admin. Code § NR 204).

It is also important to note that fields that *only* receive municipal biosolids, industrial solids, or private septic solids do not have to create a nutrient management plan, as required under NR 151, ATCP 50 and NRCS 590, because NR 151 specifically exempts fields where these products are spread. :

> …This performance standard does not apply to industrial waste and byproduct solids regulated under ch. NR 214, municipal sludge regulated under ch. NR 204, septage regulated under ch. NR 113, or manure directly deposited by pasturing or grazing animals on fields dedicated to pasturing or grazing (Wis. Admin. Code § NR 204).

While nutrient management plans are not required, all sources of nitrogen must still be taken into account by the agricultural landowner when setting application rates for a crop. If a field is subject to regulation under NR 151 *and* additional phosphorous, such as sludge, is applied to the field, under either NR 204, 113, or 214, the phosphorous in the sludge would not be limited by NR 151. Instead, only additions *of manure or commercial fertilizer* would be limited by NR 151. It is also important to note that the requirements of NR 204, 113, and 214 must be met whether or not there is cost-sharing, unlike NR 151 (Rasmussen, 2004).

The WDNR is in the initial stages of considering amending NR 204. For more information about these proposed changes see Chapter 4.4.3.

### 6.7.2 LAND APPLICATION OF INDUSTRIAL SLUDGE

Industrial food processing and aquiculture sludge, such as corn by-product, often contain beneficial nutrients. When this sludge is applied to an agricultural field, the industrial company, the agricultural landowner, and the public may benefit. That is, the industrial company avoids paying to landfill or incinerate the byproduct, the agricultural landowner gets free or inexpensive nutrients, and the public benefits from landfills filling more slowly and by potential reductions in air pollution (Personal Communication R. Wolkowski, November 23rd 2009).

Currently, no land application of industrial sludge occurs in the Door Creek watershed (Chapter 4). However, industrial sludge is applied near the Door Creek watershed. As land is developed, open areas in the Door Creek watershed will experience more pressure to allow the land application of industrial sludge. Given the potential surface and groundwater contamination that is possible from the land application of industrial sludge, the following section gives a brief discussion of regulations regarding the land application of industrial sludge (Elliott, 1991; Gerba, 2002).

Regulation of industrial sludge is either exempt from or not covered by many of the federal regulations that govern municipal sludge application, such as 40 CFR Part 503 or Section 405 of the Clean Water Act. However, provisions in both the Clean Water Act and the Resource Conservation Recovery Act (RCRA) that pertain to the application or disposal of industrial wastes are administered by the WDNR under NR 214: Land Treatment of Industrial Liquid Wastes, By-Product Solids and Sludges. Table 6.8 provides a general overview of the restrictions on land application of industrial sludge. As with municipal biosolids, the current law has no restrictions with respect to subsurface drain tiles or nutrient management plans under NRCS 590 (see Section 6.5) (Wis. Admin. Code § NR 214; WDNR, 2007d).

## Table 6.8: Major Restrictions for Industrial Sludge Applications in NR 214.

| | **Landspreading Systems** | **Subsurface Absorption** | **Absorption Ponds** | **Ridge and Furrow** | **Spray Irrigation** | **Overland Flow** | **Sludge Spreading** |
|---|---|---|---|---|---|---|---|
| Depth to groundwater or bedrock | 36 inches* | 5 Feet | 5 Feet (including mound height) | 5 Feet | 5 Feet | 5 Feet | 36 inches* |
| Allowable slopes | >12% when ground unfrozen, >2% when ground is frozen or snow covered | | | | | 2-8% | >12% when ground unfrozen, >2% when ground is frozen or snow covered |
| Distance to potable well | 250 Feet | 250 Feet | 250 Feet | 250 Feet | 250 Feet | 250 Feet | 250 Feet |
| Distance to community public well without vegetative buffer | 1000 Feet | 1000 Feet | 1000 Feet | 1000 Feet | 1000 Feet | 1000 Feet | 1000 Feet |
| Distance to surface water without a vegetative buffer | 200 feet (may be reduced to 50 feet if incorporated) | | | | | | 200 feet (may be reduced to 50 feet if incorporated) |
| Distance to surface water with a maintained vegetative buffer at least 20 feet wide | 100 feet (may be reduced to 50 feet if incorporated) | | | | | | 100 feet (may be reduced to 50 feet if incorporated) |
| Within a floodplain during a flood | NP | NP | NP | NP | NP | NP | NP |
| Within floodway | NP | NP | NP | NP | NP | NP | NP |
| Within a wetland | | | | | | | NP |
| Distance to nearest inhabited dwelling (unless reduced with consent of owner) | 500 Feet | 25 Feet | 500 feet | 500 feet | 500 Feet | 500 Feet | 500 Feet |
| Distance to Property Line | | 5 Feet | | | | | |

* May be reduced on a case-by-case bases (Wis. Admin. Code § NR 214)

NP = Not Permitted

The permit now requires:

- Nitrogen loading limits of 165 pounds per year, unless the permittee justifies, through the use of a management plan, the application of additional nutrients (WDNR, 2007). Such a management plan requires approval by the WDNR (WDNR, 2007). No management plan is required to apply less than 165 pounds of nitrogen per year.
- The calculation of per acre loading of phosphorous (WDNR, 2007d)
- The soil at each individual spray irrigation field be tested annually for available nitrogen, phosphorous, potassium, and pH. The results of these analyses are used by the WDNR to determine if the applied nutrients are meeting the agronomic needs of the cover crop (Wis. Admin. Code § NR 214).

These provisions may have the potential to limit phosphorous applications based on soil testing and the agronomic needs of the crop cover, but have not been used as such to date.

There have been recent changes to NR 214 permits that pertain to how nutrients are regulated.

### 6.7.3 LAND APPLICATION OF PRIVATE LIQUID SEPTAGE

Private on-site sewage treatment systems include “septic and holding tanks, dosing chambers, grease interceptors, seepage beds, seepage pits, seepage trenches, privies and portable restrooms (Wis. Admin. Code § NR 113).” Servicing of private sewage systems is regulated under NR 113: Servicing Septic or Holding Tanks, Pumping Chambers, Grease Interceptors, Seepage Beds, Seepage Pits, Seepage Trenches, Privies, or Portable Restrooms. NR 113 generally requires septage from private systems to be taken to a publicly owned treatment work (POTW), like MMSD, unless emergency situations arise that require land application of the liquid septage.

If private septage needs to be applied, the following guidelines apply:

- Only on sites with less than or equal to 2% slopes (in the winter)
- Less than 10,000 gallons of liquid septage per acre
- At least 750 feet from surface water or wetlands
- Not in a floodplain
- Approval from landowner
- Fields that received POTW sludge in the last crop year are prohibited

There are also additional restrictions based on the method of land application: spreading, incorporation, or injection. Restrictions for spreading, incorporation and injection are summarized in Table 6.9. There are also restrictions in place that are intended to reduce food borne pathogens, such as prohibiting the harvesting of food crops for a certain period of time after liquid septage has been applied (Wis. Admin. Code § NR 214).

**Table 6.9: NR 113 Restriction for Sludge Applied to the Land in Bulk.**

| Site Criteria * | Surface | Incorporation | Injection |
|---|---|---|---|
| Minimum Depth to Surface to Bedrock and Groundwater | 3 ft. | 3 ft. | 3 ft. |
| Maximum Allowable Slopes (non-winter) (3) | 6% | 12% | 12% |
| Maximum Allowable Slopes (winter) | 2% | N/A | N/A |
| Minimum Distance to Community Well (3) | 1000 ft. | 1000 ft. | 1000 ft. |
| Minimum Distance to Other Well | 250 ft. | 250 ft. | 250 ft. |
| Distance to Distance to Residence, Business or Recreational Area without Permission from the Owner or Occupant | 500 ft. | 500 ft. (1) -200 ft.(2) | 500 ft. |
| Distance to Distance to Residence or Business with written permission from the Owner or Occupant | 250 ft. | 200 ft. (1) - 100 ft. (2) | 100 ft. |
| Minimum Distance to a Stream, River, Ponds, Lake, Sinkhole, Flowage, Ditch, or Wetland | | | |
| Slope 6 to 12 | N/A | 200 ft. | 150 ft. |
| Slope 6 to <12 non-winter | 200 ft. | 150 ft. | 100 ft. |
| Slope 0 to 2 winter (3) | 750 ft. | N/A | N/A |
| Minimum Distance to a dry run | | | |
| Slope 0 to 6 | 100 ft. | 50 ft. | 25 ft. |
| Slope 6 to 12 | N/A | 100 ft. | 50 ft. |
| Minimum Distance to a property line (3) | 50 ft. | 25 ft. | 25 ft. |

(1) If not lime established, but incorporated within 6 hours
(2) If lime established and incorporated within 6 hours.
(3) See full law for further limitations or exceptions on winter applications (Wis. Admin. Code § NR 213)

The WRM Practicum investigation found no current permits for liquid septage land application within the Door Creek watershed boundaries (Chapter 4.4.2.2). In addition, the Practicum analyzed the Door Creek stream for indications of nutrient or pathogen contamination from private septic system treated effluent. The Practicum found no indication of nutrients or pathogens coming from the effluent and concluded private septic system effluent was not a major contributor of pathogens or nutrient contamination to Door Creek (Chapter 4.4).

### 6.7.4 COMPARISON OF THE RULES THAT GOVERN LAND APPLICATION OF SLUDGE

Tables 6.6, 6.7, 6.8, and 6.9 illustrate the extensive restrictions found in NR 204, 214 and 113 on the land application of sludge. These three land spreading administrative rules have many similarities. For example, all three administrative rules prohibit spreading of sludge within 1000 ft of a community well, within 250 ft from a potable drinking well, and on slopes of greater than 12 degrees. But they also have many differences. For example, only NR 214 allows the WDNR to require groundwater well monitoring. Many of these differences exist to address the different impacts of each type of land spreading activity. However, such differences can cause confusion for landowners who must abide by more than one regulation.

This confusion can also arise with the differences between the land spreading regulations discussed in this chapter and the manure and fertilizer spreading regulations under NR 151 (and the associated ATCP 50 and NRCS 590). Some recommendations to reconcile the differences between these various laws were discussed in detail in Chapter 4.4.2.2.

## 6.8 URBAN

All the cities, villages and towns in the vicinity of the Door Creek watershed anticipate increased development over the next 20 years (see Chapter 4.5). The development that accompanies urban growth can have a wide range of negative impacts on waterbodies, such as Door Creek, due to changes in hydrology and pollutant levels. (See Chapter 4.5 for a description of the potential impacts and their causes).

The impact of urban growth on water quality in a watershed is commonly mitigated via the management of stormwater runoff. Rules and regulations have been established at all levels of government to address the potential impact of changes in stormwater flow. Increases in point sources of water pollution also accompany urban development, but are regulated differently than non-point source stormwater runoff. An overview of both stormwater and point source rules and regulations will be provided in this section of the report. These regulations often require the implementation of Best Management Practices (BMPs) to meet performance standards, such as not exceeding the pre-development stormwater flow. Figure 6.9 shows an idealized example of such a standard, where, post-development, the peak storm flow would have increased in volume and occurred earlier in time, if not for the implementation of a BMP.

Throughout the following discussion it is important to note proposed changes to many of the rules and regulations presented in this Chapter may affect the implementation of these rules. For example, the Wisconsin Department of Natural Resources (WDNR) recently proposed requiring land areas that contribute non-point source pollution, such as stormwater runoff to an impaired waterbody with an approved TMDL, to implement Best Management Practices (BMPs) to control this pollution (Section 6.2.1).

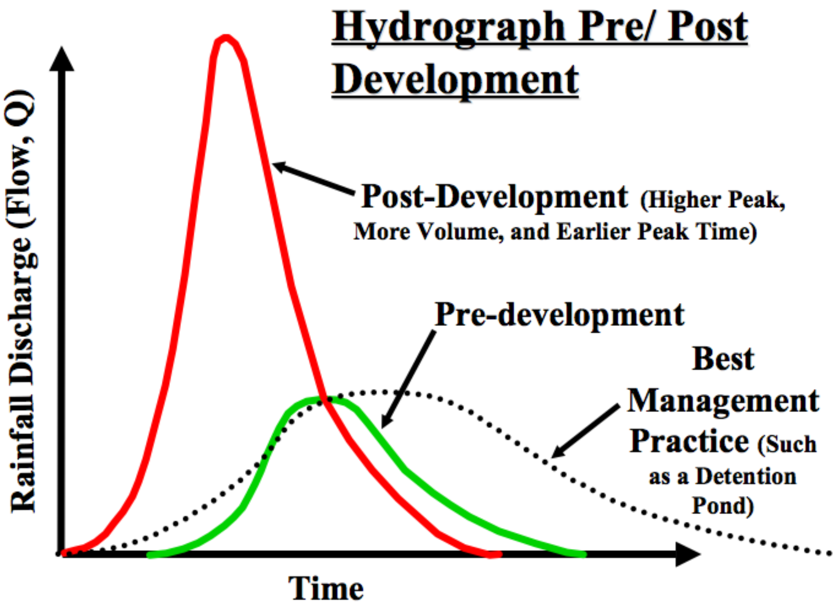


**Figure 6.9: Idealized Stormwater Hydrograph.** (Bannerman, 2010).

### 6.8.1 STORMWATER AND CONSTRUCTION RUNOFF

Urban stormwater runoff from construction sites and developed areas is often directed towards municipal sewer systems. This stormwater runoff is then redirected either to a waterbody untreated (in uncombined sewer system), or to a municipal treatment facility and then to a waterbody (in a combined sewer system) (US EPA, 2010a).

Most of the Door Creek watershed is not covered by an urban service area (USA). This means a majority of the Door Creek watershed's stormwater is not directed towards a municipal sewer system. However, a few portions of the watershed are within a USA near the City of Madison and the Village of Cottage Grove (CARPC, 2009). Both of these communities use a separate municipal stormwater system (MS4), which keeps human wastes separate from stormwater runoff. Keeping human wastes separate from stormwater can reduce stormwater overflows, which happen when untreated human waste flows into nearby waterbodies because the municipal treatment plant cannot treat or hold all of the water it receives during a storm event[7]. However, this also means that the stormwater is usually not treated before it is directed towards a waterbody. This is the case within both the City of Madison and the Village of Cottage Grove. The Village of Cottage Grove directs untreated stormwater and construction site runoff in urban areas towards Door Creek, while the City of Madison directs untreated stormwater and construction site runoff towards the Yahara Chain of Lakes (Village of Cottage

---

[7] All human wastes within USAs in the Door Creek watershed are directed towards the Nine Springs Wastewater Treatment Facility, which then sends treated wastewater to Badfish Creek and ultimately into the Yahara Chain of Lakes (Madison Metropolitan Sewerage District, 2008).

Grove, 2010; MMSD, 2008).

### 6.8.1.1 FEDERAL RULES AND REGULATIONS

The US EPA administers several provisions of the Clean Water Act (CWA) pertaining to stormwater runoff under the National Pollutant Discharge Elimination System (NPDES) stormwater program. The NPDES stormwater program regulates three types of stormwater: MS4s (municipal separate stormwater systems), construction sites and industrial activities. As there are only limited industrial stormwater activities in the Door Creek watershed, this section of Chapter 6 will only address the rules and regulations pertaining to municipal stormwater and construction site runoff (US EPA, 2010b).

The NPDES program has been implemented in two separate phases. Phase I requires medium or large cities to obtain a NPDES permit from the US EPA for their municipal stormwater discharges into a navigable waterway. Based on the population of communities in 2000, the entire Door Creek watershed was outside of the Urbanized Areas, as defined by the US EPA under Phase I of the NPDES permit program Figure 6.11 (US EPA, 2000a).

Phase II requires that smaller MS4s, in urbanized areas as defined by the US EPA, to also obtain a NPDES permit. Many areas within the Door Creek watershed fall within Madison’s Urbanized Area and thus are subject to Phase II of the NPDES Permit Program including:

- Village of Cottage Grove,
- Village of McFarland
- Village of Maple Bluff
- Town of Blooming Grove
- Town of Burke
- Town of Cottage Grove
- Town of Maple Bluff
- Town of Pleasant Springs

(US EPA, 2000b)

In order for the EPA to approve a Phase II NPDES permit, the operator(s) of the municipal separate storm sewer system (MS4s) must: reduce pollutants to the maximum extent practicable (MEP), protect water quality, and meet the requirements of the Clean Water Act (US EPA, 2010). Furthermore, the NPDES permit requires several management programs be implemented by the municipality with respect to stormwater, which will be discussed within the context of implementation of NR 216 at the state level.

### 6.8.1.2 STATE STORMWATER AND CONSTRUCTION SITE RULES AND REGULATIONS

Like many of the provisions of the Clean Water Act (CWA), states are allowed to seek approval from the US EPA to administer the urban stormwater and construction site permit programs. The WDNR has created several administrative rules to regulate urban non-point source pollution such as construction site and stormwater runoff. Of these urban water quality rules, NR 151 and NR 216 will play a key role in regulating stormwater runoff as development increases in the Door Creek watershed.

The intent of NR 151 is to prevent fish kills, protect drinking water supplies, and reduce post-construction storm flows. To do this, NR 151 regulates runoff from agricultural, non-agricultural, and transportation land uses (Personal Communication, Roger Bannerman, WDNR, February 8, 2010). Subchapter III of NR 151 contains the non-agricultural (i.e. urban) performance standards pertaining to construction sites (NR151.11), post-construction sites (NR 151.12), and existing urban centers (NR 151.13) (Table 6.10) (Wis. Admin. Code § NR 151).

NR 151.11 and NR 151.12 require a construction site and/or stormwater plan be created for all development projects that are subject to the performance standards of those statutes. The construction site and/or stormwater plan must use Best Management Practices (BMPs) to ensure that the development meets certain performance standards to the maximum extent practicable (Table 6.10). Examples of these BMPs include silt fences, vegetative buffers, infiltration basins, detention ponds, retention ponds, grass-swales, rain gardens, and so on. The WDNR has provided information about the performance requirements of these BMPs at the following website: http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm.

The performance standards of NR 151.11 and NR 151.13 require that stormwater and/or construction site plans prove that the BMP employed will meet the required performance standards. Models such as RUSLE2 or SLAMM can be used to assure the effectiveness of a given BMP. These models use site and climate variables to predict the performance of a given BMP and to determine what BMPs are needed to meet the performance standards required of a given project (Table 6.10) (Wis. Admin. Code § NR 151).

NR 151.13 contains the performance requirements for municipalities under Phase 1 and Phase 2 of the EPA’s NPDES permit program (Table 6.10). In Wisconsin, this program is administered by the WDNR under the WPDES permit program. During Phase 1, those communities with 1,000 or more people per square mile must reduce the current TSS coming from their community by 20%, based on the 2-year 24-hour storm.

## Table 6.10: NR 151 Non-Agricultural Stormwater and Construction Site Standards.

| | | | |
|---|---|---|---|
| These standards are based on achieving these results as compared to no controls. Best Management Practices (BMPs) are to be used to the maximum extent practicable to meet these results. | | | |
| **NR 151.11 Construction Site Performance Standard for New Development and Redevelopment *** | | | |
| | **Acreage** | **Reduction of Total Suspended Solids** | **Based on:** |
| **Construction Sites** | 1 or more | 80% | average annual rainfall |
| **NR 151.12 Post Construction Standards for New Development and Redevelopment *** | | | |
| **Post-Construction Type** | **Acreage** | **<u>Based on Per Annual Rainfall</u>** | **<u>Maintain or reduce:</u>** |
| | | **Reduction of Total Suspended Solids**[1] | **Peak Discharge**[1] |
| New Development | 1 or more | 80% | 2-year 24-hour storm |
| Redevelopment | 1 or more | 40% | 2-year 24-hour storm |
| Infill Development (years 2002 - 2012) | Under 5 acres | 40% | 2-year 24-hour storm |
| Infill Development (after year 2012) | | 40% | 2-year 24-hour storm |
| **Land Use Type** | **Infiltration** | **Based on:** | **Maximum Area Required to Meet Standard** |
| Residential | 25% | 2-year 24-hour storm | 1% of project area |
| | 90% | average annual rainfall | 1% of project area |
| Non-Residential | 10% | 2-year 24-hour storm | 2% of project area |
| | 60% | average annual rainfall | 2% of project area |
| **NR 151.13 Developed Urban Area Performance Standard *** | | | |
| **Existing Urban Areas** | **Population** | **Reduction of Total Suspended Solids** | **Based on:** |
| Phase 1 | 1,000 or more people per mile$^2$ | 20% | 2-year 24-hour storm |
| Phase 2 | Urbanized Areas | 40% | 2-year 24-hour storm |

* There are exceptions and additional requirements. See full law for complete information. (Wis. Admin. Code § NR 151)

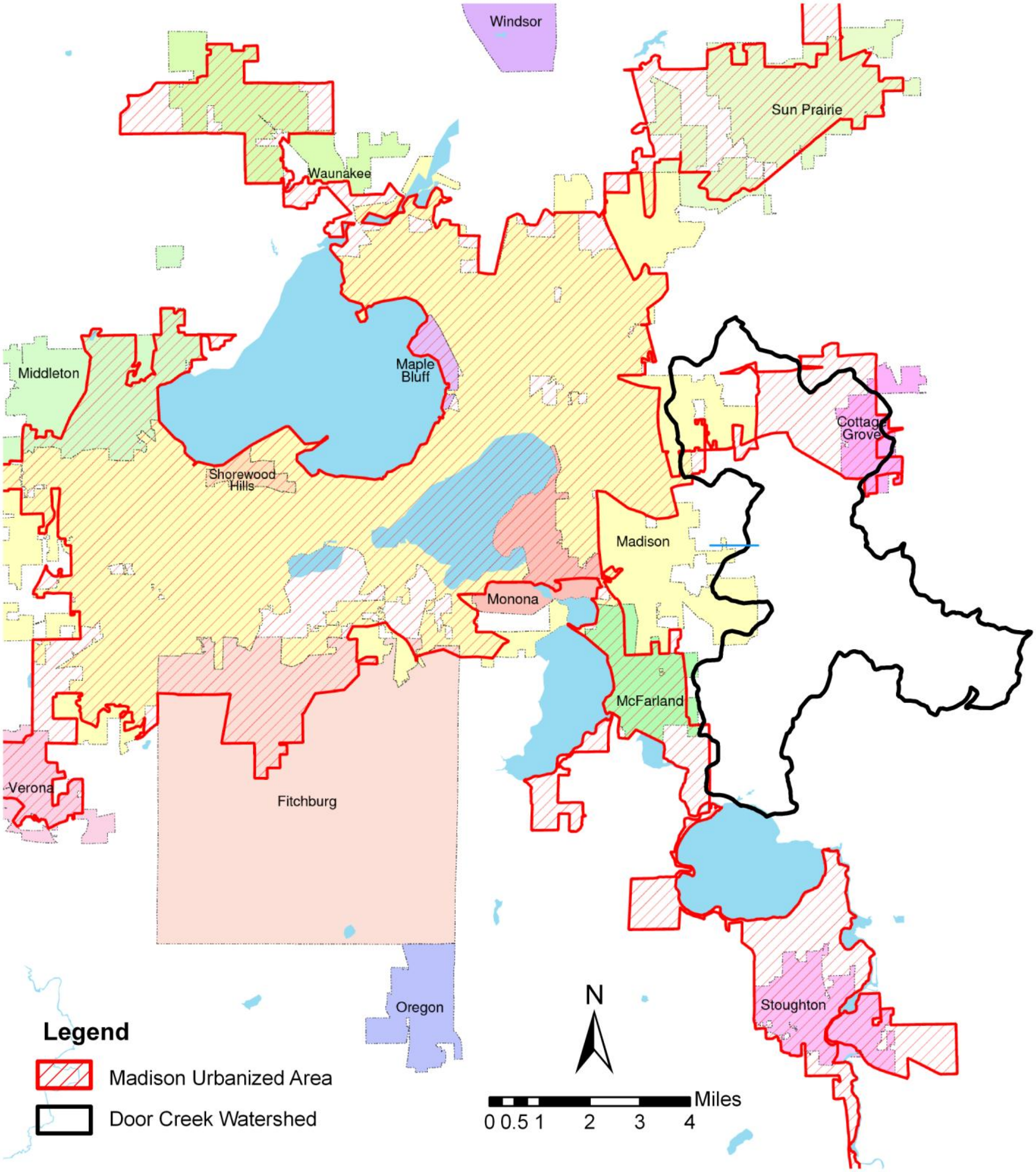


**Figure 6.10: US EPA Urbanized Areas as of 2000.** Source: US EPA, 2000a, Created April 2010 by WRM Practicum.

As of the 2000 census, only two communities within the Door Creek watershed fell under Phase 1 of the WPDES permit program, the Village of Cottage Grove and the City of Madison (Figure 6.10). As development occurs, parts of the Door Creek watershed may become subject to these requirements especially the areas near the City of Madison.

Under the Phase 2 requirements, urbanized areas (as defined by the US EPA) must reduce their TSS by 40%, based on the 2-year 24-hour storm. Several towns and villages in the Door Creek watershed are subject to this permit, such as the Village of McFarland (US EPA, 2000b). These provisions are further implemented by NR 216 (Wis. Admin. Code § NR 151).

The WDNR has proposed changing several NR 151 standards. As Table 6.10 shows, all construction sites must currently reduce TSS by 80%. The new proposal by the WDNR would:

- Require all construction sites, regardless of size, to ensure that no more than 5 tons per acre per year of sediment are allowed to runoff from any given site (This proposal would be in line with the new Total Maximum Daily Load (TMDL) requirements that were described in Section 6.2.1.)
- Remove the exemption for road and parking lots from the post-construction standards and instead require a 50% reduction of TSS for proposed parking areas and internal roads
- Require a post-construction peak flow control performance standard to model the 1-year 24-hour storm, in addition to the 2-year 24-hour storm
- Establish infiltrations based on the percentage of connected impervious surfaces, instead of on the current requirement of 90% and 60% of stormwater to be infiltrated for residential and non-residential development respectively (WDNR, 2010d)

### 6.8.1.2.2 NR 216

NR 216 implements several provisions within NR 151 that pertain to Phase I and Phase II of the WDPES permit program. NR 216 stipulates the requirements for the following provisions for Phase I and Phase II sized communities:

- Public Involvement and Participation
- Public Education and Outreach
- Elicit Discharge and Detection and Elimination
- Construction Site Pollution Control
- Storm Water Management
- Pollution Prevention

NR 216 requires that these provisions be implemented in a manner that helps the community meet the 20% reduction of TSS required for Phase I and the 40% reduction of TSS required for Phase II. Also under NR 216, cities and villages “may assume administration and regulation of soil erosion and stormwater control programs if they have adopted stormwater and erosion control ordinances that include standards at least as restrictive [as the provisions within NR 216].” Counties may also seek approval to administer soil erosion and stormwater control programs that regulate unincorporated areas. Regardless of whether or not a community has their own stormwater and construction site ordinances, WPDES permits are still required by the WDNR (Wis. Admin. Code § NR 216).

#### 6.8.1.3 LOCAL

Within Dane County, twenty-one municipalities around the City of Madison have joined together to apply for one group WPDES permit application under NR 216. Of these communities, Dane County, the City of Madison, the Villages of Cottage Grove, and McFarland, and the Town of Cottage Grove are either within the Door Creek watershed or have extraterritorial zoning within part of the Door Creek watershed. As part of the outreach and education programs associated with the group municipal stormwater permit, the Madison Area Municipal Storm Water Partnership (MAMSWaP) has created the My Fair Lakes campaign to promote better stormwater management practices. For more information about this campaign see the following website: <www.myfairlakes.com>. All communities have also affirmed that they meet the requirements of Phase I and Phase II within NR 216 and NR 151. Under those construction site and post-construction site requirements, municipalities are often required to enforce an ordinance(s) (MAMSWaP, 2009).

Additionally, Dane County, the City of Madison, the Village of Cottage Grove, the Village of McFarland and the Town of Cottage Grove have all adopted their own stormwater and/or construction site management ordinances. Dane County’s ordinance (Chapter 14) is unusual in that it applies to all areas within the county. City and villages are required to adopt their own ordinances that must meet the standards of Chapter 14, while Dane County enforces the ordinances for unincorporated areas (Dane County Code Ordinance § Chap. 14).

The stormwater portion of Chapter 14 requires that any development must apply for a stormwater permit, if it has 20,000 or more square feet of impervious surface. The erosion control portion of this ordinance requires that any land disturbing activity have an erosion control permit: if it disturbs 4000 square feet or more, is located on a slope of more than 12%, or meets one of the other minimum requirements. Performance standards include a TSS reduction of 80% for new development and 40% for redevelopment, treating the first half inch of rain for oil and grease, and insuring that there is no increase in the rate of runoff for both the 2-year and 10-year 24-hour storm events (Dane County, 2002).

Even if a municipality has adopted their own stormwater and/ or erosion control ordinance in line with Chapter 14, stormwater may be further managed by the Capital Area Regional Planning Commission (CARPC). Development outside the current Urban Sewer and Water Service Area (USA) in Dane County requires review by the CARPC before public services will be provided to the development. As part of the application process, CARPC reviews a municipality’s application for consistency with comprehensive plans, including associated stormwater provisions, proposed environmental corridors, and other applicable laws. They also review the municipality's application to ensure that stormwater management mitigates, to the "maximum extent practicable," the adverse impact of development on surface water and ground water quality. Applications for urban service area (USA) extensions, reviewed by CARPC, are then ultimately approved or denied by the Wisconsin Department of Natural Resources (CARPC, 2010b).

### 6.8.2 URBAN POINT SOURCES

Point sources present the second category of urban water pollution. Point source pollution is pollution that can be linked back to a single identifiable location, such as a landfill. All point sources that discharge to navigable waters require a NPDES permit from the EPA. In Wisconsin, this program is administered by the WDNR under the WPDES permit program. A detailed description of the rules and regulations pertaining to point sources will not be provided, as point sources have not been considered a major source of pollutants in the Door Creek watershed (See Chapter 4.5.2). This is largely due to the absence of municipal effluent discharges in the Door Creek watershed; instead the effluent is discharged into the Badfish creek. For more information concerning point source pollution regulation in Wisconsin, please see the following WDNR website: http://www.dnr.state.wi.us/ORG/water/wm/ww/. Urban point sources might become more of a concern as more of the Door Creek watershed is developed over the coming years.

### 6.8.3 STORMWATER AND CONSTRUCTION CONCLUSION

Stormwater and construction site runoff can have a major impact on water quality. This is especially true in the Door Creek watershed since portions of the watershed are known to have high levels of soil phosphorous. Improperly managed stormwater runoff from such high phosphorous locations could lead to large flushes of nutrients into Door Creek during storm events. Dane County's approach to stormwater is already more comprehensive than current state statutes and has helped to ensure a higher level of uniform management for the watershed. The County's ordinance will likely be updated once the NR 151 amendments have been approved. During this amendment process, an opportunity may exist for the county to target high impact locations that have excess phosphorous, as was recommend in Chapter 4.5.

## 6.9 CONCLUSION

The earlier chapters of this report (1 through 5) identified the sources and impacts of nutrient loading in the Door Creek watershed. Specifically, both agricultural and urban runoff contributes to elevated phosphorous and nitrogen loads in Door Creek. Each of these nutrient sources are regulated by numerous existing laws that, both directly and indirectly, address phosphorous and nitrogen loading. However, as indicated by the levels of the nutrients in Door Creek, problems remain.

A brief overview of the laws, in the context of the Door Creek watershed, which relate not only to nutrient loading specifically, but to water quality in general, has been provided in Chapter 6. The chapter has covered the regulation of designated uses, groundwater, shorelands, floodplains, wetlands, farmland, comprehensive planning, sludge application, urban stormwater runoff and construction site runoff. Even with the considerable regulations that already exist for nitrogen and phosphorous, the Door Creek watershed remains challenged by the levels of nutrient pollution. As such, the legislative and regulatory bodies with responsibility for addressing such water quality issues have an opportunity to continue to both improve existing regulations and to address gaps in such regulations.

Several proposed changes in the regulatory framework, of importance to the Door Creek watershed, have been recommended at the state and local levels (See Table 6.11).

**Table 6.11: Proposed changes in the regulatory framework that may affect the Door Creek watershed.**

| | | |
|---|---|---|
| **WDNR/ US EPA** | **Rock River Watershed Total Maximum Daily Load (TMDL)** | Limit phosphorous for wadable streams to 0.08 mg/l and for non-wadeable streams to 0.125 mg/l. |
| **WDNR** | **Nr 151**, Agriculture | Phosphorous application shall not exceed an average PI index 10 for an individual year or 6 on average for an 8-year accounting period. |
| | | Requires a tillage set back of 20 feet from riparian areas. |
| | **NR 151**, Urban | Requires all construction sites regardless of size to ensure that no more than 5 tons per acre per year of sediment are allowed to runoff from any given site. |
| | | Removes some of the exemptions for parking lots and internal roads. |
| | | Adds a performance standard for peak flow of the 1-year 24hour storm. |
| | **NR 151** TMDLs | Requires regulation of soil loss and phosphorous runoff from agricultural fields to impaired waterbodies |
| **WDNR and Dane County** | **Shoreland Zoning** (Both NR 115 and Dane County Chapter 11) | May require either an additional setbacks and/or performance standards for new development within shorelands. |
| **WDNR** | **NR 204** | Initiated initial stages of considering amendments. |
| | | Actively seeking research the impacts of land spreading of biosolids within the state. |

It is important to note that if the Rock River Watershed TMDL is approved, and if the proposed changes to NR 151 are approved, only then could agricultural non-point runoff from the Door Creek watershed be regulated to meet the standards of the TMDL. If the proposed amendments to NR 151 concerning TMDLs are not approved, then the wadeable and non-wadeable stream requirements would not apply to Door Creek, as it is not currently officially classified as impaired on the state's 303(d) list of impaired waterbodies. These proposed changes address many, but not all, of the regulatory gaps in current legislation. However, the enforcement of the current regulations and these potential changes, if and when they are approved, face additional challenges.

In some cases, improving water quality relative to nutrient loading isn't just a matter of amending current, or adding new, regulations. Rather, the issue is funding and enforcement. The main challenge with enforcement is that many agricultural rules and regulations require cost-sharing before they can be enforced. This means that if the state or local government cannot provide financial assistance to a farmer that is in violation of a rule or regulation, then they cannot be required to come into compliance. Therefore, it will help state and county governmental bodies to identify the worst sources of agricultural pollution through the use of soil tests, water quality monitoring and models such as SNAP Plus. This will help state and county governments optimize how they allocate and target funding when it comes to enforcing water quality rules and regulations that affect agricultural activities in the Door Creek watershed.

Even with the proposed amendments and proper enforcement, there are a few gaps in water quality regulation that remain. Such gaps, and their associated impacts, have been identified in the various chapters of this report and will be highlighted once again in the final chapter.

## CHAPTER 7:

# RECOMMENDATIONS FOR THE FUTURE OF DOOR CREEK

The systems of Door Creek and the Yahara Chain of Lakes System, including Lake Kegonsa, are in continual flux. As such, the future of these systems is dependent upon how the lands within the watershed are used and the impacts of those actions. This project has assessed the water quality of Door Creek, as well as assessed a number of ways in which land use practices in both urban and rural areas may affect the water quality.

Throughout the previous chapters recommendations have been made to address each specific issue. Here, the recommendations are organized under three primary goals. For each goal, the recommendations are formulated using objectives and implementation strategies or outcomes. Some of these implementation strategies are already implemented within the watershed, listing them here emphasizes the need to continue such actions into the future.

These recommendations are meant to be used in context of the future projected uses within the watershed. The forecasts for the future of the watershed include expansion of urban development into the Door Creek watershed. As such it is ever more important to plan for these changes and implement strategies that will protect the vital services which the natural systems provide to the community.

## GOAL: MANAGE NUTRIENT RUNOFF AND SOIL EROSION SO THAT THE ENVIRONMENTAL INTEGRITY OF DOOR CREEK IS MAINTAINED OR IMPROVED FROM ITS CURRENT CONDITION.

### OBJECTIVE: MANAGE NUTRIENT SPREADING WITHIN THE DOOR CREEK WATERSHED.

OUTCOMES:

- Eliminate regulatory conflicts between NRCS 590, ATCP 50, and NR 204 the proceeding recommendations should be integrated into NR 204, as well as, NRCS 590 and ATCP 50, via amendments.
- ▪ Perform regular soil tests for phosphorous before re-application of nutrients to adequately track the level of phosphorous in the soil, and adjust management practices accordingly.
- ▪ Require nutrient management plans for phosphorus and other agricultural nutrients that are similar to the Department of Trade and Consumer Protection (DATCP) nutrient management plans for lands receiving municipal, industrial or private septic spreading.
- ▪ Require mapping of drain tiles on all new fields proposed to receive municipal biosolids.

- Prohibit the injection of industrial, municipal or septic tank liquid materials on areas with drain tiles.
- Prevent ponding conditions by reducing fertilizer or manure application when the soil is wet or the AMC is high.

### OBJECTIVE: REDUCE SOIL EROSION IN AREAS OF URBAN DEVELOPMENT

OUTCOMES:

- Require Soil Phosphorous testing prior to construction.
- Adjust erosion control measures for construction sites to correspond to the levels of phosphorous in the soil; the higher the phosphorous soil level the more stringent the standards.
- Increase monitoring of erosion control practices for construction sites.

### OBJECTIVE: REDUCE SOIL EROSION USING CURRENT AGRICULTURAL PRACTICES

OUTCOMES:

- Identify critical areas within the watershed that are most likely to be of concern: areas with slopes above 12 percent, areas where a corn and soybean rotation is implemented, and areas with high soil phosphorous levels.
- Restrict use spreading of municipal, industrial or private septic products on critical areas.
- Prevent pasturing or disturbance of the soil on excessively steep slopes.
- Promote conservation programs and easement for critical areas.
- Promote Best Management Practices, such as rotational grazing, reduction of overgrazing, maintenance of high quality vegetation on pastures, incorporatation of a non-row crop into the rotation.
- Continue to promote no till practices.

## GOAL: ASSESS THE EFFECTIVENESS OF WATER QUALITY MANAGEMENT AND IMPROVEMENT STRATEGIES

### OBJECTIVE: MONITOR WATER QUALITY OF DOOR CREEK

OUTCOMES:

- Continue current USGS water quality monitoring.
- Expand water quality monitoring to include a location at the mouth of Door Creek in order to monitor the effects of the wetland complex on water quality.
- Expand water quality monitoring to include sampling time, pre and post agricultural activities, to determine the effect of these on water quality.

### OBJECTIVE: COORDINATE WATER QUALITY IMPROVEMENT EFFORTS ACROSS AGENCIES

AND COMMUNITY GROUPS

OUTCOME:

- Develop a centralized database containing water quality data.

## GOAL: MAINTAIN AND IMPROVE ECOSYSTEM SERVICES TO PROVIDE WATER QUALITY BENEFITS

### OBJECTIVE: PROTECT CURRENT ECOSYSTEM FUNCTIONS

OUTCOMES:

- Develop a Dane County Wetland Conservation Ordinance.
- Implement a mechanism for reviewing and controlling land development and land use activities in hydric soils.
- Pursue and encourage land and easement acquisition and voluntary conservation practices to preserve wetlands and their upland buffers.

### OBJECTIVE: ASSESS OPTIONS TO RESTORE WETLANDS

OUTCOME:

- Use an Adaptive Restoration Framework to address stream corridor and floodplain wetland restoration.

# GLOSSARY:

**Aquitard:** An impervious layer of rock that prevents the movement of groundwater and creates a confined layer beneath it.

**Ammonia:** A gaseous, highly water-soluble compound made up of hydrogen and nitrogen ($NH_3$) that is associated with nitrogen-containing fertilizers.

**Antecedent Moisture Condition (AMC):** The relative wetness or dryness of soil. Antecedent moisture conditions change continuously and can have a very significant effect on the infiltration or runoff of precipitation during wet weather.

**Baseflow:** Water flow that is maintained by groundwater and excludes human induced inputs.

**Benthic sediments:** Sediments on the bottom of a lake or stream.

**Coliform Bacteria:** Relatively benign organisms present in the environment and the feces of animals that are usually used as an indicator for the presence of more harmful bacteria species. http://www.doh.wa.gov/ehp/dw/programs/coliform.htm

**Cone of Depression:** A lowering of groundwater levels near a well that is caused by significant groundwater pumping.

**Confined Aquifer:** A layer of permeable rock that holds water where movement toward the surface is prevented by an aquitard.

**Dissolved Oxygen (DO):** Gaseous oxygen ($O_2$) dissolved in water. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Dissolved oxygen is probably the single most important water quality factor that pond managers need to understand.

**Ecoregion:** Areas of similar ecosystem type, quality and quantity of an environmental resource.

**Effluent:** Water, wastewater, or other liquid (raw, partially or completely treated) flowing from a basin, treatment process, or treatment plant.

**Erosion:** The removal or loss of soil, rock, and sediment in the natural environment usually due flowing water, glaciers, and wind. This may be increased by human processes.

**Eutrophication:** High primary productivity due to excessive nutrient input; water is subject to algal blooms, often resulting in poor water quality, especially because of the lack of oxygen. Generally the result of human land use impacts.

**Flocculants:** Containing, consisting of, or occurring in the form of loosely aggregated particles.

**Hypoxia:** Low oxygen in waterbodies; usually less than 2 mg/L. In many cases hypoxic waters do not have enough oxygen to support fish and other aquatic animals. Hypoxia can be caused by the presence of excess nutrients in water.

**Index of Biotic Integrity (IBI) Score:** Based on a combination of metrics used to score different aspects of stream ecosystems and used to assess the overall health of the system. See http://www.epa.gov/bioiweb1/html/ibi-hist.html for further information.

**Land-to-livestock ratio:** the maximum number of livestock that can be grazed on a given parcel of land.

**Limiting Nutrient:** A nutrient (usually nitrogen or phosphorous) that is low in proportion to other nutrients and will be exhausted first, therefore limiting growth of plants.

**Macroinvertebrates:** Animals that have no backbone and are visible without magnification. Stream-bottom macroinvertebrates include such animals as crayfish, mussels, aquatic snails, aquatic worms, and the larvae of aquatic insects.

**Macropores:** Large openings in the soil ranging from 1mm to 50mm in diameter that create preferential flowpaths for water to flow downward through a soil column. They are frequently created from earthworm burrows, plant roots, and cracks in dry soil.

**Nutrient management plan (NMP):** a written plan that specifies the utilization of fertilizer, animal manures, and other biosolids.

**Oxygenated:** Enriched with oxygen.

**Potentiometric Surface:** The potential elevation level the groundwater in a confined aquifer would reach if it had a free surface.

**Primary Productivity:** The growth rate of algae and other plants.

**Recurrence Interval:** A term that indicates the probability of a given hydrologic event occurring. An X-year recurrence interval event has a 1/X probability of occurring in any given year.

**Residue management:** plant material remaining in the field after harvest

**Riparian:** Anything pertaining to or situated on the bank of a river or lake.

**Runoff:** Excess water, rain, or snowmelt that runs off impervious surfaces, or fields when the soil is fully saturated. Runoff carrying nutrients or other pollutants may contribute to poor water quality in streams and lakes.

**Soil Map Unit:** Unique identifier used within the Natural Resources Conservation Services Soil Survey that can be linked to a soils name and slope.

**Soil Surveys:** Describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and makes predictions about the behavior of soils.

**Total Dissolved Phosphorus (TDP):** The sum of organic and inorganic phosphorous (P). This nutrient is readily taken up by plants and is the main contributor to algal blooms.

**Total Kjehldahl Nitrogen (TKN):** The sum of organic nitrogen which includes ammonia ($NH_3$) and ammonium ($NH_4^+$).

**Total Nitrogen (TN):** Comprised of dissolved inorganic and organic nitrogen and particulate organic and inorganic nitrogen. Decomposed algae contribute to organic nitrogen while sewage, runoff and erosion are main contributors of inorganic nitrogen.

**Total Phosphorus (TP):** Total phosphorous is a measure of all the various forms of phosphorus (dissolved and particulate) found in water.

**Total Suspended Solids (TSS):** Solid materials, including organic and inorganic, that are suspended in the water and affect its clarity. This includes silt, plankton and industrial wastes. Suspended solids can result from erosion from urban runoff and agricultural land, industrial wastes, bank erosion, bottom feeders (such as carp), algae growth, or wastewater discharges.

**Unconfined Aquifer:**A layer of permeable rock that holds water whose upper boundary is not restricted by an aquitard.

**Wisconsin Phosphorus Index (P index):** A value calculated using the RUSLE2 soil loss equation and empirical factors that quantifies the average amount of phosphorus eroded from agricultural fields in pounds of phosphorus per acre per year.

# CHAPTER REFERENCES:

## CHAPTER 1

Carnes, W. E. (1914). *The reclamation of fifteen hundred acres of swamp land in the Township of Blooming Grove*. Dane County, Wisconsin: University of Wisconsin - Madison.

Cassidy, F. (1968). *Place names of Dane County, Wisconsin* (p. 255). Tuscaloosa, AL: University of Alabama Press.

Lathrop, R.C. (2007). Perspectives on the eutrophication of the Yahara lakes. *Lake and Reservoir Management*, *23*, 345-365.

Lathrop, R.C., Nehls, S.B., Brynildson, C.L., & Plass, K.R. (1992). *The fishery of the Yahara lakes* [Technical Bulletin, 181]. Madison, WI: Wisconsin Department of Natural Resources.

Northern Prairie Wildlife Research Center, United States Geological Survey. (2006, August 3). *Wetlands of the United States: Their extent and their value to waterfowl and other wildlife, a century of wetland exploitation*. http://www.npwrc.usgs.gov/resource/wetlands/uswetlan/century.htm#swamp

Sherwood, H.H., Coddington, W.B., Willard, A.C., & Jones, E.R. (1915). *Proceedings of the first annual convention of the Wisconsin State Drainage Association. Madison, Wisconsin, December: 9-11, 1914*. Madison, Wisconsin: The Association, 1914. http://digital.library.wisc.edu/1711.dl/WI.ACWSDA01

Wisconsin Department of Natural Resources (WDNR). (2009, July 10). In Prep. DRAFT Ecological landscapes of Wisconsin [Handbook 1805.1]. Madison, WI: Wisconsin Department. of Natural Resources. http://www.dnr.state.wi.us/landscapes/

## CHAPTER 2

Carnes, W. E. (1914). *The reclamation of fifteen hundred acres of swamp land in the Township of Blooming Grove, Dane County, Wisconsin.* Madison, Wisconsin: University of Wisconsin.

City of Madison. (2006). *Background Information: City of Madison Comprehensive Plan, Volume 1* (Chapter 1, Population and Demographics). Madison,WI: City of Madison. Retrieved on July 1, 2009 from http://www.cityofmadison.com/planning/comp/dplan/v1/chapter1/v1c1.pdf

Clayton, L., & Attig, J.W. (1997). *Pleistocene geology of Dane County, Wisconsin*. (WGNHS Bulletin 95). Madison, Wisconsin: Wisconsin Geological and Natural History Survey.

Cottage Grove Water Utility. (2009). *2008 Annual drinking water quality report.* Cottage Grove, WI. Retrieved on August 26, 2009 from http://www.village.cottage-grove.wi.us/utilities/09waterreport.pdf

Dane County Regional Planning Commission. (2005). *Dane County Water Quality Plan: Summary Plan 2004*. Madison, Wisconsin. Retrieved on June 4, 2009 from http://danedocs.countyofdane.com/webdocs/PDF/capd/waterq/WaterQPlan_appendix.pdf

Dane County Regional Planning Commission. (1999). *Dane County Groundwater Protection Plan* (Appendix G of Dane County Water Quality Plan). Madison, Wisconsin.

Dane County Regional Planning Commission. (2000). *Dane County Wetlands Resource Protection Plan*. Madison, Wisconsin.

Feinstein, D.T., Hart, D.G., Eaton, T.T., Krohelski, J.T., & Bradbury, K.R. (2004). *Simulation of regional groundwater flow in Southeastern Wisconsin* (Open File Report 2004-01). Wisconsin Geologic and Natural History Survey.

Fullerton, D.S., & Bush, C.A. (2004). *Glacial Limits.* U.S. Geological Service: National Atlas.gov. Retrieved on August 25, 2009, from http://nationalatlas.gov/articles/geology/a_glacial.html

Hershfield, D.M. (1961). *Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years* (Technical Paper No. 40). Washington D.C.: Weather Bureau, U.S. Department of Commerce. Accessed on June 21, 2009 from: http://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf

Huff, F.A., & Angel, J.R. (1992). *Rainfall Frequency Atlas for the Midwest* (Illinois State Water Survey Bulletin 71, MCC Research Report 92-03). Champaign, Illinois: Midwestern Climate Center. Retrieved on June 21, 2009 from http://w ww.isws.illinois.edu/pubdoc/B/ISWSB-71.pdf

Mead & Hunt, Inc. (1993). *Door Creek Watershed Feasibility Study*. Madison,Wisconsin.

Mitsch, W. J., & Gosselink, J.G. (2007). *Wetlands* (4th ed.). Hoboken: John Wiley & Sons.

National Climatic Data Center. (2003). *Monthly Station Climate Summaries* (Climatography of the United States No. 20 1971-2000). Asheville, North Carolina. Retrieved on June 4, 2009 from http://cdo.ncdc.noaa.gov/climatenormals/clim20/wi/474961.pdf

Public Service Commission of Wisconsin. (1997-2008). *Annual Report of Cottage Grove Water Utility*. Madison, Wisconsin: author. Retrieved on June 4, 2009 from http://psc.wi.gov/pdffiles/annlrpts/wegs/WEGS_2008_1390.PDF

USDA Natural Resources Conservation Service, & University of Wisconsin-Extension. (2000). *Residue management choices: A guide to managing crop residues in corn and soybeans* (UWEX Publication No. GWQ029). Madison, WI: Extension Publications.

UW-Extension Center for Land Use Education (CLUE), & USGS Wisconsin Water Science Center (WWSC). (2007). *Protecting Groundwater in Wisconsin Through Comprehensive Planning: Groundwater Findings for Dane County.* Retrieved from http://wi.water.usgs.gov/gwcomp/find/dane/index_full.html

Village of Cottage Grove. (2009). *Village of Cottage Grove Comprehensive Plan* (Chapter 1: Issues and Opportunities). Retreived July 1, 2009 from http://village.cottage-grove.wi.us/master_plan/pdfs/master/page02.pdf

Village of McFarland. (2006). . *Village of McFarland Comprehensive Plan* (Chapter 1: Population trends and projections, issues and opportunities). Retrieved on August 8, 2009 from http://www.mcfarland.wi.us/CommunityDevelopment/ComprehensivePlan/tabid/513/Default.aspx

Wisconsin Department of Natural Resources (WDNR). (2001). *Yahara Kegonsa focus watershed report* (WDNR Publication PUBL-WT-711 2001). Madison, Wisconsin. Retrieved on June 4, 2009 from http://www.dnr.state.wi.us/org/gmu/lowerrock/surfacewaterfiles/watersheds/yaharakegonsa.pdf

Wisconsin State Legislature. (2009). *Agriculture, Trade and Consumer Protection Administrative Code,* Chapter ATCP 30: Pesticide Product Restrictions (Register April, 2009, No. 640). . Retrieved on August 26, 2009 from http://www.legis.state.wi.us/rsb/code/atcp/atcp030.pdf

Zedler, J. B. (2003). Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment, 1*(2), 65-72. doi: 10.1890/1540-9295(2003)001[0065:WAYSRI]2.0.CO;2

# CHAPTER 3

Agency for Toxic Substances and Disease Registry (ASTDR). (2007). Nitrate/Nitrite Toxicity. In *Case studies in environmental medicine* (CSEM). Retrieved on June 29, 2009 from http://www.atsdr.cdc.gov/csem/nitrate/nitrate.html.

Bilotta, G. S., & Brazier, R. E. (2008). Understanding the influence of suspended solids on water quality and aquatic biota. *Water Research, 42*(12), 2849-2861.

Boulton, A. J. (2009). Stream ecology, temperature impacts on. *Water Encyclopedia*. Retrieved on July 13, 2009 from http://www.waterencyclopedia.com/Re-St/Stream-Ecology-Temperature-Impacts-on.html

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

Chern, L., Kraft, G., & Postle, J. (1999). Nitrate in groundwater - A continuing issue for Wisconsin citizens. *The Nutrient Management Subcommittee of the Nonpoint Source Pollution Abatement Program*. Retrieved on August 3, 2009 from http://dnr.wi.gov/org/water/dwg/gw/pubs/nitrate.pdf

Cooper, A. (1983). Effect of storm events on benthic nitrifying activity. *Applied and Environmental Microbiology, 46*(4), 957-960. Retrieved on August 11, 2009 from http://aem.asm.org/cgi/reprint/46/4/957.pdf

Dodds, W. K., Smith, V. H., & Lohman, K. (2006). Nitrogen and phosphorus relationships to benthic algal biomass in temperate stream. *Canadian Journal of Fisheries and Aquatic Sciences, 63(*5), 1190-1191.

Havlin, J. L., Beaton, J. D., Tisdale, S. L., & Nelson, W. L. (2005). *Soil fertility and fertilizers: An introduction to nutrient management* (7th ed.). New Jersey: Pearson.

Huff, F., & Angel, J. (1992). *Rainfall frequency atlas of the Midwest*. Midwestern Climate Center. Retreived on July 26, 2009 from http://www.iga.uiuc.edu/pubdoc/B/ISWSB-71.pdf.

Kalff, J. (2002). *Limnology.* Upper Saddle River, New Jersey: Prentice Hall.

Lathrop, R.C. (2007). Perspectives on the eutrophication of the Yahara lakes. *Lake and Reservior Management, 23*, 345-365. Retreived on July 15, 2009 from http://www.dnr.state.wi.us/org/water/fhp/lakes/Lathrop2007LakeandReservManageVol23p345-365.pdf.

Lewis, W., & Wurtsbaugh, W. (2008). Control of lacustrine phytoplankton by nutrients: Erosion of the phosphorus paradigm. *International Review Hydrobiology*, *93*(4-5), 446-465.

Mamedov, A., Huang, C., & Levy, G. (2006). *Antecedent moisture content and soil texture effects on infiltration and erosion* (abstract #H34C-08). American Geophysical Union. Retrieved on August 7, 2009 from http://adsabs.harvard.edu/abs/2006AGUFM.H34C..08M.

McCaleb, M. M., & McLaughlin, R. A. (2008). Sediment trapping by five different sediment detention devices on construction sites. *Transactions of the Asabe, 51*(5)*,* 1613-1621.

Mishra, S., Jain, M., Surash Babu, P., Venugopal, K., & Kaliappan, S. (2008). Comparison of AMC-dependent CN-conversion formulae. *Water Resource Management, 22*, 1409-1420.

Nahm, K. H. (2003). Influences of fermentable carbohydrates on shifting nitrogen excretion and reducing ammonia emission of pigs [Review]. *Critical Reviews in Environmental Science and Technology, 33*(2), 165-186.

National Oceanic and Atmospheric Administration (NOAA). (2009). Event Record Details. National Climatic Data Center. Retrieved on July 26, 2009 from http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~ShowEvent~752611

National Research Council: Committee on Inland Aquatic Ecosystems, Water Science and Technology Board, Commission on Geosciences, Environment, and Resources. (1996). *Freshwater ecosystems: Revitalizing educational programs in limnology*. Washington D.C.: National Acadamy Press.

Packman, J. J. (1999, October). Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands. *Annual meeting of the Canadian Water Resources Association, Center for Urban Water Resources Management.* Vancouver, BC.

Robertson, D. D., Graczyk, D.J., Garrison, P.J., Wang, L., LaLiberte, G., & Bannerman, R. (2006). *Nutrient concentrations and their relations to the biotic integrety of wadeable streams in Wisconsin* (Professional paper 1722, USGS). Retrieved March 21, 2009, from http://pubs.usgs.gov/pp/pp1722/.

Sharpley, A., Kleinman, P., Heathwaite, A., Gburek, W., Folmer, G., & Schmidt, P. (2008). Phosphorus loss from an agricultural watershed as a function of storm size. *Journal of Environmental Quality*, *37*, 362-368. Retrieved on August 26, 2009 from http://jeq.scijournals.org/cgi/content/abstract/37/2/362.

Srinivasan, R., Hoffman, D., Wolfe, J., & Prcin, L. (2008). Evaluation of removal of orthophosphate and ammonia from rainfall runoff using aboveground permeable reactive barrier composed of limestone and zeolite. *Journal of Environmental Science and Health, 43*(12), 1441-1450. Retrieved August 26, 2009, from http://www.informaworld.com/smpp/content~content=a902329253.

U.S. Environmental Protection Agency (US EPA), Health and Ecological Criteria Division. (1999). *Ambient water quality criteria recommendations updates: Ammonia.* Retrieved on June 2, 2009 from http://www.epa.gov/waterscience/criteria/ammonia/technical.html.

U.S. Environmental Protection Agency (US EPA), Health and Ecological Criteria Division. (2000). *Ambient water quality criteria recommendations*. . Retrieved on March 16, 2009 from http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_7.pdf.

U.S. Environmental Protection Agency (US EPA). (2006). *Phosphorus*. Retrieved on July 24, 2009 from http://www.epa.gov/volunteer/stream/vms56.html

U.S. Environmental Protection Agency (US EPA). (2007). *Phosphorus*. Retrieved on July 9, 2009 from http://www.epa.gov/agriculture/ag101/impactphosphorus.html

Vitousek, P. M., Aber, J. D., Howarth, R. W., Likens, G. E., Matson, P. A., Schindler, D. W., Schlesinger, W. H., & Tilman, G. D. (1997). Human alteration of the global nitrogen cycle: Sources and consequences. *Ecological Applications, 7*(3), 737-750.

Waters, T. F. (1995). *Sediment in streams: Sources, biological effects and control*. Bethesda, MD: American Fisheries Society. .

Wisconsin Department of Natural Resources (WDNR). (2004a). *Chapter NR 104: Uses and defined standards*. Retrieved on May 27, 2009 from http://www.dnr.state.wi.us/org/water/wm/wqs/codes/nr104.pdf.

Wisconsin Department of Natural Resources (WDNR). (2004b). *Chapter NR 151: Runoff management.* Retrieved on August 26, 2009 from http://www.legis.state.wi.us/rsb/code/nr/nr151.PDF

Wisconsin Department of Natural Resources (WDNR). (2008). *Nitrate in drinking water* (Division of Water, WS-001). Retrieved on June 16, 2009 from http://www.dnr.state.wi.us/org/water/dwg/nitrate.htm

## CHAPTER 4

Anderson, D. M., Glibert, P. M., & Burkholder, J. M. (2008). Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries and Coasts, 25*(4)*,* 1559-2731*.*

Brown, R. B. (2003). *Soils and Septic Systems.* University of Florida Institute of Food and Agricultural Sciences: . Retrieved on September 16, 2009 from http://edis.ifas.ufl.edu/SS114

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

Castillo, V., Martinez-Mena, M., & Albaladejo, J. (1997). Runoff and soil loss response to vegetation removal in a semiarid environment. *Journal of Soil Science Society of America, 61,* 1116-1121. Retrieved on August 26, 2009 from http://www.britannica.com/EBchecked/topic-art/552611/19387/Soil-loss-versus-vegetative-cover-The-amount-of-topsoil-lost.

City of Madison. (2006a). Population and demographics. In *City of Madison Comprehensive Plan* (Chapter 1). Retrieved on July 16, 2009 from http://www.cityofmadison.com/planning/comp/dplan/v1/chapter1/v1c1.pdf.

City of Madison. (2006b). Utilities. In *City of Madison Comprehensive Plan* (Chapter 10). Retrieved on July 16, 2009 from http://www.cityofmadison.com/planning/comp/dplan/v1/Chapter10/v1c10.pdf.

Converse, C. J., & Tyler, E. T. (2000). *Wisconsin mound soil absorption system: Siting, design, and construction manual.* Retrieved on June 28,2009 from http://www.soils.wisc.edu/sswmp/SSWMP_15.24.pdf

Cooley, E., & Pagel, J. (2009) *Tile drainage in Wisconsin*. Madison, WI: University of Wisconsin Extension Discovery Farms.

Dane County Land and Water Resources Department (LWRD). (2002). *Dane County's erosion control and stormwater management ordinance: A summary.* Retrieved on August 8, 2009 from http://www.danewaters.com/pdf/summaryaug2002.pdf.

Dane County Land and Water Resources Department (LWRD). (2007a). Erosion control. In *Dane County Erosion Control and Stormwater Management Manual* (Chapter 2). Retrieved on August 8, 2009 from http://www.danewaters.com/pdf/manual/ecsmm2revfinal.pdf.

Dane County Land and Water Resources Department (LWRD). (2007b). Stormwater. In *Dane County Erosion and Stormwater Management Manual* (Chapter 3). Retrieved on August 8, 2009 from http://www.danewaters.com/pdf/manual/ecsmm3revfinal.pdf.

Davis, A. (2005). Green engineering principles promote low-impact development. *Environmental Science and Technology, 39*(16), 338A-344A.

Door Creek Golf Course. (2009). [map]. Retrieved on September 11, 2009 from www.doorcreekgolfcourse.com.

Eastman, M., Gollamudi, A., & Madramootoo, C. (2007). *Role of phosphorus drains in subsurface transport*. Ste. Anne-de-Bellvue, Quebec, CA: McGill University.

Ekern, T. (2009). *Nutrient management plan: Yahara Hills Golf Course*. City of Madison, Wisconsin.

Evans, R. (1998). The erosional impacts of grazing impacts. *Physical Geography, 22*(2), 251-268.

Gentry, L., David, M., Royer, T., Mitchell, C. & Starks, K. (2007). Phosphorus transport pathways to streams in tile-drained agricultural watersheds. *Journal of Environmental Quality, 36,* 408-415.

Geohring, L., McHugh, O., Walter, M.T., Steenhuis, T., Akhtar, M.S., & Walter, M. (2001). Phosphorus transport into subsurface drains by macropores after manure applications: Implications for best manure management practices. *Soil Science, 166*(12), 896-909.

Goswami, D., Kalita, P. K., Cooke, R. A., & Hirschi, M. C. (2008). Estimation and analysis of baseflow in drainage channels in two tile-drained watersheds in Illinois. *Transactions of the ASABE, 51*(4), 1201-1213.

Goswami, D., Kalita, P. K., Cooke, R. A. C., & McIsaac, G. F. (2009). Nitrate-N loadings through subsurface environment to agricultural drainage ditches in two flat Midwestern (USA) watersheds. *Agricultural Water Management, 96*(6)*,* 1021-1030.

Gupta, S., Munyankusi, E., Moncrief, J., Zvomuya F., Hanewall, M. (2004). Tillage and manure application effects on mineral nitrogen leaching from seasonally frozen soils. *Journal of Environmental Quality, 33,* 1238-1246.

Hantzsche, N. N., & Finnemore, E. J. (1992). Predicting ground-water nitrate-nitrogen impacts. *Ground Water, 30*, 490-499. Retrieved on June 28, 2009 from http://www3.interscience.wiley.com/cgi-bin/fulltext/119318239/PDFSTART

Hoorman, J., & McCutcheon, J. (2005). *Negative effects of livestock grazing riparian areas* (Ohio State University Extension Fact Sheet, LS-2-05). Retrieved on July 25, 2009 from http://ohioline.osu.edu/ls-fact/pdf/0002.pdf.

Kanwar, R.S., Colvin, T.S., Karlen, D.L. (1995). Tillage and crop rotation effects on drainage water quality. In *Clean water - clean environment - 21st century: Team agriculture - working to protect water resources* (Volume 3: Practices, systems & adoption) (pp. 163-166). Kansas City, Missouri, 5-8 March 1995.

Kleinman, P., & Sharpley, A. (2003). Effect of broadcast manure on runoff phosphorus concentrations over successive rainfall events. *Journal of Environmental Quality, 32*, 1072-1081.

Lapen, D.R., Topp, E., Edwards, M., Sabourin, L., Curnoe, W., Gottschall, N., (2008). Effect of liquid municipal biosolid application method on tile and groundwater quality. *Journal of Environmental Quality, 37,* 925-936.

Lathrop, R.C. (2007). Perspectives on the eutrophication of the Yahara Lakes. *Lake and Reservoir Management, 23*, 345-365.

Nolan, B. T., Hitt, K.J., & Ruddy, B. C. (2002). Probability of nitrate contamination of recently recharged groundwaters in the conterminous United States. *Environmental Science & Technology, 36*(10), 2138-2145.

Nutrient Management Subcommittee of the Non-point Pollution Abatement Program Redesign (NMS of NPAPR). (1999). *Nitrate in groundwater – a continuing issue for Wisconsin citizens.* Retrieved from http://www.dnr.state.wi.us/org/water/dwg/gw/pubs/nitrate.pdf

Penn, C., Mullins, G., & Zelazny, L. (2005). Mineralogy in relation to phosphorus sorption and dissolved phosphorus losses in runoff. *Soil Science of America Journal, 69*, *1532-1540.*

Pennington, J., Sharpley A., Jennings J., Daniels, M., Moore, P., & Daniel, T. (2009). Grazing management affects runoff water quality and forage yield (University of Arkansas, FSA9530). Retrieved on July 25, 2009 from http://www.uaex.edu/Other_Areas/publications/PDF/FSA-9530.pdf.

Peppler, M., & Fitzpatrick, F. (2005). Monitoring the effects of riparian intensive rotational grazing on bank erosion [booklet]. Pioneer Farm Research Synopsis - UW Platville. Retrieved on July 26, 2009 from http://www.uwplatt.edu/pioneerfarm/symposium/2005/files/booklet_session2.pdf.

Porter, P. A., Barry, J., Samson, R., & Doudlah, M. (June 2008). *Growing Wisconsin energy: A native grass pellet bio-heat roadmap for Wisconsin*. Retrieved on September 16,2009 from http://www.agrecol.com/images/news/_AgrecolADDReport.pdf

Ruark, M., Panuska, J., Cooley, E. & Pagel, J. (2009). Tile drainage in Wisconsin: Understanding and locating tile drainage systems (Fact Sheet No. 1). Madison, WI: University of Wisconsin Extension Discovery Farms. Retrieved from http://www.uwdiscoveryfarms.org/newpubs/publications/DF-TD1.pdf

Seely, R. (2009, July 26). Many private rural wells in Wisconsin not tested for contamination.

*Wisconsin State Journal.* Retrieved from: http://www.madison.com/wsj/topstories/459580

Sharpley, A., McDowell, R., & Kleinman, P. (2001). Phosphorus loss from land to water: Integrating agricultural and environmental management. *Plant and Soil, 237,* 287-307.

Shipitalo, M., & Gibbs, F. (2000). Potential of earthworm burrows to transmit injected animal wastes to tile drains. *Soil Science Society of America Journal, 64,* 2103-2109.

Tabbara, H. (2003). Phosphorus loss to runoff water twenty-four hours after application of liquid swine manure or fertilizer. *Journal of Environmental Quality, 32,* 1044-1052.

Taylor, D. (2008). *Biosolids recycling and the Metrogro Program*. Retrieved on June 6, 2009 from http://www.madsewer.org/Metrogro.htm

Taylor, D. (2007). *Metrogro biosolids quality - 2007 average values*. Retrieved on June 6, 2009 from http://www.madsewer.org/Metrogro.htm

Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2002). *Wastewater engineering: Treatment and reuse*. Metcalf & Eddy (Eds.). New York: McGraw-Hill.

U.S. Department of Agriculture. (2005). *Natural Resource Conservation Service Conservation Practice Standard, Code 590: Nutrient Management.* Retrieved on September12, 2009 from http://efotg.nrcs.usda.gov/references/public/WI/590.pdf

U. S. Department of Agriculture, Natural Resources Conservation Service (NRCS). (2009). Web Soil Survey. Retrieved July 16, 2009, from http://websoilsurvey.nrcs.usda.gov/.

U.S. Department of Agriculture, UWEX, WDNR, DTCAP, Wisconsin County Land Conservation Departments, & Commitees. (1998). *Farmland conservation choices: A guide to environmentally sound practices for Wisconsin's farmers* (UWEX: GWQ025).

U.S. Environmental Protection Agency (US EPA), Office of Water. (2002). *National water-quality inventory, 2000 report* (EPA 841–R–02–001, 207). . Retrieved on July 26, 2009 from http://www.epa.gov/305b/2000report/.

U.S. Environmental Protection Agency (US EPA). (2003). *Protecting water quality from urban runoff* (US EPA Publication No. EPA 841-F-03-003). Retrieved on July 22, 2009 from http://www.epa.gov/owow/nps/toolbox/other/epa_nps_urban_facts.pdf

U.S. Environmental Protection Agency (US EPA). (2006a). *Terms of environment: Glossary, abbreviations and acronyms*. Retrieved on October 3, 2009 from http://www.epa.gov/OCEPAterms/nterms.html

U.S. Environmental Protection Agency (US EPA). (2006b). *Ground water and drinking water: Consumer fact sheet on nitrates and nitrites*. Retrieved on September 19, 2009 from http://www.epa.gov/ogwdw000/contaminants/dw_contamfs/nitrates.html

U.S. Environmental Protection Agency (US EPA). (2006c). *Drinking water contaminants: Basic information about* ***E. coli*** *0157:H7 in drinking water*. Retrieved on September 19, 2009 from http://www.epa.gov/safewater/contaminants/ecoli.html#four

U.S. Environmental Protection Agency (US EPA). (2008). *Water quality criteria for nitrogen and phosphorus pollution: Basic information*. Retrieved on September 19, 2009 from http://www.epa.gov/waterscience/criteria/nutrient/basic.htm

U.S. Geological Survey (USGS). (2004). *Hydrologic, ecologic, and geomorphic responses of Brewery Creek to construction of a residential subdivision: Dane County, Wisconsin, 1999–2002* (Scientific Investigations Report 2004–5156). Retrieved on July 26, 2009 from http://pubs.usgs.gov/sir/2004/5156/.

U.S. Geological Survey (USGS). (2008a). *Protection of Wisconsin's groundwater through comprehensive planning: Dane County - nitrate-nitrogen concentrations*. Retrieved from http://wi.water.usgs.gov/gwcomp/find/dane/nitrate.html

U.S. Geological Survey (USGS). (2008b). *A comparison of runoff quantity and quality from two small basins undergoing implementation of conventional- and low-impact-development (LID) strategies: Cross Plains, Wisconsin, water years 1999–2005* (Scientific Investigations Report 2008–5008). Retreived on July 26, 2009 from http://pubs.er.usgs.gov/usgspubs/sir/sir20085008

U.S. Geologic Survey (USGS). (2008c). *National water information system: Web interface* [Data file]. Retrieved on November 12, 2008 from http://nwis.waterdata.usgs.gov/usa/nwis/qwdata

University of Wisconsin-Extension (UWEX), & Wisconsin Department of Natural Resources (WDNR). (1997). *Polluted urban runoff - A* *source of concern* (UW-Ext Publication No. GWQ020, WDNR Publication No. WT-483-97). Madison, WI: Extension Publications.

University of Wisconsin Extension (UWEX). (2005). *Management of Wisconsin soils* (A3588). Retrieved from http://learningstore.uwex.edu/pdf/A3588.pdf 6/30/2009

University of Wisconsin Soil Plant and Analysis Lab (UW SPAL). (2004). *Wisconsin soil test summary: 2000-2004*. Retrieved on July 27, 2009 from http://uwlab.soils.wisc.edu/madison/

Uri, N.D. (1999). *Conservation tillage in U.S agriculture: Environmental, economic, and policy issues*. Binghamton, New York: Haworth Press.

Village of Cottage Grove. (2009a). Population trends and forecasts. In *Village of Cottage Grove Comprehensive Plan* (Chapter 1: Issues and Opportunities). Retrieved on July 22, 2009 from http://village.cottage-grove.wi.us/master_plan/pdfs/master/page02.pdf.

Village of Cottage Grove. (2009b). Utilities. In *Village of Cottage Grove Comprehensive Plan* (Chapter 7: Community Facilities and Utilities). Retrieved on July 22, 2009 from http://village.cottage-grove.wi.us/master_plan/pdfs/master/page33.pdf.

Village of McFarland. (2006). Population trends and projections. In *Village of McFarland Comprehensive Plan* (Chapter 1: Issues and Opportunities). Retrieved on August 8, 2009 from http://www.mcfarland.wi.us/CommunityDevelopment/ComprehensivePlan/tabid/513/Default.aspx.

Watson, K.W., & Luxmoore, R.J. (1986). Estimating macroporosity in a forest watershed by use of a tension infiltrometer. *Soil Science Society of American Journal*, *50*, 578–582.

Whitney, D. (1988). *Phosphorus facts: Soil, plant and fertilizer* (C-655). Manhattan, KS: Kansas State University Cooperative Extension Service.

Winter, T.C., Judson, W., Harvey, O., Franke, L., & Alley, W.M. (1998). *Ground water and surface water a single resource* (U.S. Geological Survey Circular 1139). Retrieved from http://pubs.usgs.gov/circ/circ1139/

Wisconsin Department of Agriculture, Trade, and Consumer Protection. *Chapter 50: Soil and Water Resource Management Program* (Register, April, 2009, No. 640). Retrieved on September 12, 2009,from http://www.legis.state.wi.us/rsb/code/atcp/atcp050.pdf

Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP). (2005). *2004 Annual Report.* Conservation Reserve Enhancement Program (CREP). Retrieved from http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/crep/news/ANNUAL_REPORT_1-5-2005.pdf

Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP). (2008). *Water quality protection: Features of the "580" nutrient management standards*. Retrieved from http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/nutrient-mngmt/pdf/WaterQualityProtectionFeaturesOf590.pdf

Wisconsin Department of Natural Resources (WDNR), Runoff Management Division. (2005). *Wisconsin's runoff management rules: Non-agricultural performance standards for construction erosion control and stormwater management, NR 151 Subchapter III.* Retrieved on July 20, 2009 from http://www.dnr.state.wi.us/runoff/pdf/rules/NR151SubchapterIIIFactSheet.pdf.

Wisconsin Department of Natural Resources (WDNR), Runoff Management Division. (2006). *Does your construction site need a stormwater permit? A guide to Wisconsin erosion control and stormwater management permit requirements* (WDNR Publication No. WT-881). Madison, WI: Wisconsin Department of Natural Resources.

Wisconsin Department of Natural Resources . (2008). *Summary of Wisconsin's solid waste landfill program*. Retrieved on June 8, 2009 from http://dnr.wi.gov/org/aw/wm/solid/landfill/

Wisconsin Department of Natural Resources (WDNR). (2009a). *Manure management and water quality*. Retrieved on July 21, 2009 from http://dnr.wi.gov/runoff/ag/waterquality.htm

Wisconsin Department of Natural Resources (WDNR). (2009b). *Rock River Total Maximum Daily Load (TMDL).* Retrieved on October, 9, 2009 from: http://dnr.wi.gov/org/water/wm/wqs/303d/RockRiverTMDL/

Wisconsin Department of Natural Resources (WDNR), Runoff Management Division. (2009c). *Stormwater management.* Retrieved on July 21, 2009 from http://www.dnr.state.wi.us/runoff/stormwater.htm.

Wisconsin Department of Natural Resources (WDNR), Runoff Management Division. (2009d). *Storm water management technical standards*. Retrieved on September 2, 2009 from http://dnr.wi.gov/runoff/stormwater/techstds.htm

Wisconsin State Legislature. (1996). *Wisconsin Department of Natural Resources Administrative Code, Chapter NR 204: Domestic sewage sludge management* (Register, November, 1996, No 491). Retrieved on June 20, 2009 from http://www.legis.state.wi.us/rsb/code/nr/nr204.pdf

Wolf, A. T. (2007). Rural Nonpoint Source Pollution Control in Wisconsin: The limits of the program. *Journal of the American Water Resources Association, 31*(6), 1009-1022.

## CHAPTER 5

Association of State Wetland Managers (ASWM). (2007). ***P**rotecting and restoring wetlands: Strengthening the role of local government*. Retrieved on July 24, 2009 from http://www.aswm.org/propub/jon_kusler/local_government_051507.pdf

Bedford, R.L., Zimmerman E.H., & Zimmerman, J.H. (1974). *The Wetlands of Dane County, Wisconsin for the Dane County Regional Planning Commission*. Madison, WI.

Brady, N.C., & Weil, R.C. (2007). *Nature and properties of soils*. Upper Saddle River, NJ: Prentice Hall.

Capital Area Regional Planning Commission (CARPC). (2008). *Dane County wetlands resource management guide*. Madison, WI: Dane County. Retrieved on July 24, 2009 from http://danedocs.countyofdane.com/webdocs/.../Wetland_Guide_web.pdf

Center for Watershed Protection (CWP). (2006). *Direct and indirect impacts of urbanization on wetland quality*. Elliot City, Maryland. Retrieved from http://www.cwp.org/Resource_Library/Center_Docs/special/wetlands/articles/WetlandsArticle1.pdf

Center for Watershed Protection (CWP). (2007). *A Local Ordinance to Protect Wetland Functions*. Elliot City, Maryland. Retrieved from http://www.cwp.org/Resource_Library/Center_Docs/special/wetlands/articles/WetlandsArticle4.pdf.

Craft, C.B, & Casey, W.P. (2000). Sediment and nutrient accumulation in floodplain and depressional freshwater wetlands of Georgia, USA, *Wetlands*, *20*, 323-332.

Crumpton, W. G., & Goldsborough, L. G. (1998). Nitrogen transformation and fate in prairie wetlands. *Great Plains Research*, *8*, 57-72.

Crumpton, W.G., Kovacic, D.A., Hey, D.L., & Kostel, J.A. (2008). Potential of restored and constructed wetlands to reduce nutrient export from agricultural watersheds in the Corn Belt. In *Final Report of the Upper Mississippi River Sub-Basin Hypoxia Nutrient Committee: Gulf hypoxia and local water quality concerns workshop*. St. Joseph, Michigan: American Society of Agricultural and Biological Engineers. Retrieved from http://www.umrshnc.org/index.php?option=com_docman&task=doc_view&gid=27&Itemid=74.

Dane County Regional Planning Commission. (2000). *Door Creek wetlands resource protection plan*. Madison, WI: author.

Environmental Law Institute. (2008). *Planner's guide to wetland buffers for local governments*. Retrieved on July 24, 2009 from http://www.elistore.org/Data/products/d18_01.pdf

Forshay, K.J., & Stanley, E.H. (2005). Rapid nitrate loss and denitrification in a temperate river floodplain. *Biogeochemistry*, *75*, 43-64.

Gergel, S.E., Carpenter S.R., and Stanley E.H. (2005). Do dams and levees impact nitrogen cycling? Simulating the effects of flood alterations on floodplain denitrification. *Global Change Biology*, *11*, 1352-1367.

Good, L., & Panuska, J. (2008). *Current calculations in the Wisconsin P index*. Retrieved on November, 2, 2009 from http://wpindex.soils.wisc.edu/assets/PIndexCalculationsDec08.pdf

Hillman, M., Brierley, G.J., & Fryirs, F.A. (2008). Social and biophysical connectivity of river systems. In Brierley, G.J., & Fryirs, K.A. (Eds.), *River futures – An integrative scientific approach to river repair* (pp. 125-146). Washington, DC: Island Press.

Kaushal, S.S., Groffman, P.M., Mayer, P.M., Striz, E.S., & Gold, A.J. (2008). Effects of stream restoration on denitrification in an urbanizing watershed. *Ecological Applications*, *18*, 789-804.

King, S.L., Sharitz, R.R., Groninger, J.W., & Battaglia, L.L. (2009). The Ecology, restoration, and management of southeastern floodplain ecosystems: A synthesis. *Wetlands*, *29*, 624-634.

Mayer, P.M., Reynolds Jr., S.K., Canfield, T.J., & McCutchen, M.D. (2005). *Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: a review of current science and regulations*. Ada, OK: U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory. http://www.epa.gov/nrmrl/pubs/600R05118/600R05118.pdf. Retrieved July 30, 2009.

Mead & Hunt, Inc. (1993). *Door Creek Watershed Feasibility Study*. Madison,Wisconsin.

Mika, S., Boulton, A., Ryder, D., & Keating, D. (2008). Ecological function in rivers: Insights from crossdisciplinary science. In Brierley, G.J. & Fryirs, K.A. (Eds.), *River futures – an integrative scientific approach to river repair* (pp. 125-146). Washington, DC: Island Press.

Mitsch, W. J., & Gosselink, J.G. (2000). The value of wetlands: Importance of scale and landscape setting. *Ecological Economics*, *35*(1), 25-33.

Mitsch, W. J., & Gosselink, J.G. (2007). *Wetlands* (4th ed.). Hoboken: John Wiley & Sons.

Pringle, C. (2003). What is hydrologic connectivity and why is it ecologically important? *Hydrological Processes*, *17*, 2685–2689.

Reddy, K. R., Kadlec, R. H., & Flaig, E. (1999). Phosphorous retention in streams and wetlands: A review. *Critical Reviews in Environmental Science and Technology*, *29*(1), 83-146.

Reddy, K. R., Wetzel, R. G., & Kadlec, R. H. (2005). Biogeochemistry of phosphorous in wetlands (Agronomy Monograph No. 46, ASA-CSSA-SSSA). *Phosphorous: Agriculture and the Environment* (pp. 263-316). Madison, WI.

Rogers, S. J., Potter, K. W., Hoffman, A. R., Hoopes, J. A., Wu, C. H., & Armstrong, D. E. (2009). Hydrologic and water quality functions of a disturbed wetland in an agricultural setting. *Journal of the American Water Resource Association*, *45*(3), 628-638.

Schramm, H.L., Cox, M.S., Tietjen, T.E., & Ezell, A.W. (2009) Nutrient dynamics in the Lower Mississippi River Floodplain: Comparing present and historic hydrologic conditions. *Wetlands, 29*(2), 476-487.

Vercoutere, B., Honnay, O., & Hermy, M. (2007). Vegetation response after restoring the connectivity between a river channel and its floodplain. *Applied Vegetation Science*, *10*, 271-278.

Wisconsin Department of Natural Resources (WDNR). (2001). *Yahara Kegonsa focus watershed report* (PUBL-WT-711 2001). Madison, Wisconsin. Retrieved on June 4, 2009 from http://www.dnr.state.wi.us/org/gmu/lowerrock/surfacewaterfiles/watersheds/yaharakegonsa.pdf

Wisconsin Department of Natural Resources (WDNR). (2008). *Wetland mapping*. Madison, Wisconsin. Retrieved on July 15, 2009 from http://dnr.wi.gov/wetlands/mapping.html

Wisconsin Statutes, § Chapter 23. Retrieved on August 12, 2009 from http://www.legis.state.wi.us/statutes/Stat0023.pdf

Wisconsin Wetlands Association (WWA). (2009a). *Halfway Creek Marsh – workhorse wetland function water quality protection*. Madison, Wisconsin. Retrieved on July 18, 2009 from http://wisconsinwetlands.org/Gems/WH4_Halfway_Creek_Marsh.pdf.

Wisconsin Wetlands Association (WWA). (2009b). *Land use and wetlands*. Madison, Wisconsin. Retrieved on July 18, 2009 from http://wisconsinwetlands.org/localgovs.htm.

Wisconsin Wetlands Association (WWA). (2009c). *Wetland communities of Wisconsin*. Madison, Wisconsin. Retrieved on July 18, 2009 from http://wisconsinwetlands.org/wetlofwisc.htm

Woltemade, C. (2000). Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water. *Journal of Soil and Water Conservation 55*(3), 303-309.

Woltemade, C., & Woodward, J. (2008). Nitrate removal in a restored spring-fed wetland

Pennsylvania, USA. *Journal of the American Water Resources Association (JAWRA), 44*(1), 222-234.

Zedler, J. B. (2003). Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment, 1*(2), 65-72.

Zedler, J. B. (2005). Restoring wetland plant diversity: A comparison of existing and adaptive approaches. *Wetlands Ecology and Management, 13,* 5-14.

Zedler, J. B., & Kercher, S. (2004). Causes and consequences of invasive plants in wetlands: Opportunities, opportunists, and outcomes. *Critical Reviews in Plant Sciences, 23*(5), 431–452.

Zedler, J. B., & Kercher, S. (2005). Wetland resources: Status, trends, ecosystem services and restorability. *Annual Review of Environment and Resources, 30*, 39-74. doi:10.1146/annurev.energy.30.050504.144248

# CHAPTER 6

## SECTION 6.2

Anderson, T. (2004). *Biodiversity and Ecosystem Services* (Casuio, no: 109-111). University of Oslo..

Baumann, J. (2006). *Water Quality Targets for Rock River TMDL* [Agenda item from the public information meeting held by the Wisconsin Department of Natural Resources December 12, 2006]. Retrieved from: http://dnr.wi.gov/org/water/wm/wqs/303d/RockRiverTMDL/Rock%20River%20Basin%20Targets.pdf

Bennett, E., Carpenter, S.R. & Clayton, M.K.. (2004). Soil phosphorous variability: Scale-dependence in an urbanizing agricultural landscape. *Landscape Ecology*, *20*, 389-400. Retrieved from: http://www.springerlink.com/content/qq1l2715661wu130/fulltext.pdf

Bennett, E.M. (2005). Soil phosphorous concentrations in Dane County Wisconsin, USA: An evaluation of the urban-rural gradient paradigm. *Environmental Management*, *32*(4), 476-487. Retrieved from http://www.springerlink.com/content/w7jj5qtgnkw558cp/fulltext.pdf

Boesse, G.W. (2002). Approaches to the allocation of loads in TMDLS. *National TMDL Science and Policy*, 24, 930-953.

Buda, A. R. & DeWalle, D. R. (2009). Dynamics of stream nitrate sources and flow pathways during stormflows on urban forest and agricultural watersheds in central Pennsylvania, USA. *Hydrological Processes, 23*(23), 3292-3305.

Capital Area Regional Planning Commission (CARPC). (2004). *Dane County Water Quality Plan: Chapter 2*. Retrieved from http://danedocs.countyofdane.com/webdocs/PDF/capd/waterq/WaterQPlan_chap2.pdf

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

Carpenter, S., R. Lathrop, P., Nowak, D., Armstrong, E., Bennett, K., Brasier, B., Kahn, & Reed-Anderson, T. (2006). The ongoing experiment: The restoration of Lake Mendota. In Magnuson, J. J., Kratz, T. K., & Benson, B. J. (Eds), *Long-term dynamics of lakes in the landscape* (pp. 236-257). Oxford University Press.

Congdon, J. (2006). *The Rock River Basin: An overview*. [Agenda item from the public information meeting held by the Wisconsin Department of Natural Resources on December 12th, 2006]. Retrieved from: http://dnr.wi.gov/org/water/wm/wqs/303d/RockRiverTMDL/Congdon%20TMDL%20mtg-Rock%20River%20Basin%20Overview.pdf

Dane County. (2007). *Yahara Waterways*. [Trail guide]. Retrieved from http://danedocs.countyofdane.com/webdocs/PDF/lwrd/lakes/yaharaTrailGuide.pdf

Department of Agriculture, Trade and Consumer Protection. (2005). *2004 Annual Report: Wisconsin's Conservation Reserve Enhancement Program (CREP).* Retrieved from: http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/crep/news/ANNUAL_REPORT_1-5-2005.pdf

Dzurik, A. A. (2003). *Water resource planning* (Third Addition). Oxford, UK: Rowman and Littlefield Publishers, Inc.

Lathrop, R.C. (1988). *Phosphorus trends in the Yahara Lakes since the Mid-1960s* (Research Management Findings No 11. Publ-RS-711 1988). Retrieved from: http://dnr.wi.gov/org/es/science/publications/PUBL_RS_711_88.pdf

Lehmann, L. (2006). *Overview of impaired waters and TMDLs*. [Agenda item from the public information meeting held by the Wisconsin Department of Natural Resources on December 12, 2006]. Retrieved from http://dnr.wi.gov/org/water/wm/wqs/303d/RockRiverTMDL/RockRiverTMDL%20-%20Lehmann%20-%20Dec12-2006.pdf

Omernik, J.M., & Bailey, R.G. (1997). Distinguishing between watersheds and ecoregions. *Journal of the American Water Resources Association*, 33(5), 935- 949. Retrieved from:

Robertson, D. (2006a). *Nutrients on the biological integrity of streams and rivers: Information to help refine nutrient criteria for Wisconsin*. [Agenda item from the public information meeting held by the Wisconsin Department of Natural Resources on December 12, 2006]. Retrieved from http://dnr.wi.gov/org/water/wm/wqs/303d/RockRiverTMDL/Robertson_Rock_River_presentation.pdf

Robertson, D., Graczyk, D.J., Garrison, P.J., Wang, L., LaLiberte, G., & Bannerman, R. (2006b). *Nutrient concentrations and their relations to the biological integrity of wadeable streams in Wisconsin* (Professional Paper: 1722). United States Geological Survey & Wisconsin Department of Natural Resources. Retrieved from http://pubs.usgs.gov/pp/pp1722/

Stumborg, B.E., Baerenklau, K.A., & Bishop, R.C. (2001). Nonpoint source pollution and present values: A contingent valuation study of Lake Mendota. *Review of Agricultural Economics, 23*(1), 120-132. Retrieved from http://www.jstor.org/stable/1349910?seq=1

Winter, T.C., Harvey, J.W., Lehn Franke, O., & Alley, W.M. (1998). Ground water and surface water: A single resource. (U.S. Geological Survey Circular 1139). Retrieved from http://pubs.usgs.gov/circ/circ1139/

Wis. Admin. Code § NR 102.

Wis. Admin. Code § NR 105.

Wisconsin Department of Natural Resources (WDNR). (2010). *2010 List of Impaired Waters*. Retrieved on January 2, 2010 from http://dnr.wi.gov/org/water/wm/wqs/303d/303d.html

Wisconsin Department of Natural Resource (WDNR) (2009a). *Water Evaluation Section*. Retrieved on August 3, 2009. from http://www.dnr.state.wi.us/org/water/wm/wqs/

Wisconsin Department of Natural Resources (WDNR). (2009b). *2009 List of Impaired Waters*. Retrieved on August 3, 2009 from http://www.dnr.state.wi.us/org/water/wm/wqs/303d/2008/2008Updates.htm

Wisconsin Department of Natural Resources (WDNR). (2009c). *Surface water viewer: Designated waters*. Retrieved on September 13, 2009 from http://dnrmaps.wisconsin.gov/imf/imf.jsp?site=SurfaceWaterViewer

Wisconsin Department of Natural Resources (WDNR). (2004). *State of Wisconsin: Guidelines for Designating Fish and Aquatic Like Uses for Wisconsin Surface Waters* (PUBL-WT-807-04). Retrieved from http://www.dnr.state.wi.us/org/water/wm/wqs/wbud/UDG_FINAL_2004.pdf

Wisconsin Department of Natural Resources (WDNR). (2001). *Lower Rock River Water Quality Management Plan*. Retrieved from http://www.dnr.state.wi.us/org/gmu/lowerrock/surfacewaterfiles/watersheds/lr09.pdf

Wisconsin Department of Natural Resources (WDNR), Joint & Non-Agricultural NR 151/153 Advisory Committee. (2009). *Proposed NR 151 Language Pertaining to TMDLs*.

U.S. Environmental Protection Agency (US EPA). (2009a). *Introduction to the Clean Water Act*. Retrieved September 14, 2009 from http://www.epa.gov/watertrain/cwa/

U.S. Environmental Protection Agency (US EPA). (2009b). Clean Water Act. Retrieved on September 14, 2009 from http://www.thecre.com/fedlaw/legal14water/cwa.htm

U.S. Environmental Protection Agency (US EPA). (2009c). *Overview of Impaired Waters and Total Maximum Daily Loads Program*. Retrieved on September 13, 2009 from http://www.epa.gov/owow/tmdl/intro.html

U.S. Environmental Protection Agency (US EPA). (2009d). *Ecoregions of the United States*. Retrieved on September, 09, 2009 from http://www.epa.gov/bioindicators/html/usecoregions.html

U.S. Environmental Protection Agency (US EPA). (2007*). Title 33- Navigation and Navigable Waters. Chapter 26 – Water Pollution Prevention and Control. Subchapter III – Standards and enforcement*. Retrieved from http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cit

e:+33USC1313

U.S. Environmental Protection Agency (US EPA). (2001). *Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion VIII* (EPA 822-B-01-015). Retrieved from http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_8.pdf

## SECTION 6.3

Alley, W.M., Reily, T.E., & Lehn Franke, O. (1999). *Sustainability of Ground-Water Resources* (U.S. Geological Survey Circular 1186). Retrieved from http://pubs.usgs.gov/circ/circ1186/pdf/circ1186.pdf

Congressional Research Service (CRS). (2006). *CRS Issue Brief for Congress: Safe Water Drinking Act: Implementation and Issues* (Order Code: IB10118). Library of Congress.. Retrieved from http://ncseonline.org/nle/crsreports/06Apr/IB10118.pdf

Duhigg, C. (2009). Health ills abound as farm runoff fouls wells. *New York Times,* September17, 2009. Retrieved from http://www.nytimes.com/2009/09/18/us/18dairy.html?_r=1

Dane County Regional Planning Commission (CARPC). (2004b). *Dane County Water Quality Plan. Chapter 2: Water Quality Conditions.*

Dane County Regional Planning Commission (CARPC). (2004a). *MPO and Urban Service Area Boundaries.*

Groundwater Coordinating Council. (2009). *Report to the Legislature: Groundwater Wisconsin's buried treasure*. Retrieved from http://www.dnr.state.wi.us/org/water/dwg/gcc/rtl/2009fullreport.pdf

Nolan, B. T., Ruddy, B. C., Hitt, K. J., & Helsel, D. R. (1998). A national look at nitrate contamination of ground water. *Water Condition and Purification, 39*(12), 76-79.

Nolan, B. T., Hitt, K.J., & Ruddy, B. C. (2002). Probability of nitrate contamination of recently recharged groundwaters in the conterminous United States. *Environmental Science & Technology*, *36*(10), 2138-2145.

Nutrient Management Subcommittee of the Non-point Pollution Abatement Program Redesign (NMS of NPAPR). (1999). *Nitrate in Groundwater – A Continuing Issue for Wisconsin Citizens.* Retrieved from http://www.dnr.state.wi.us/org/water/dwg/gw/pubs/nitrate.pdf

Pye, V., & Patrick, R. (1983). Ground water contamination in the United States. *Science*, *221*(4612), 713-718.

Seely, R. (2009, July 26). Many private rural wells in Wisconsin not tested for contamination. *Wisconsin State Journal.* Retrieved from http://www.madison.com/wsj/topstories/459580

Village of Cottage Grove. (2009). *Village of Cottage Grove Comprehensive Plan: Natural Resources Inventory –Water Resources* (May 2009 Draft, Adopted April 17th, 2000). Retrieved from http://www.village.cottage-grove.wi.us/master_plan/pdfs/master/page15.pdf

Village of McFarland. (2009). *Services Available to McFarland Residents: Water Supply.* Retrieved on July 21, 2009 from http://www.villageofmcfarland.net/McFarlandHome/VillageServices/tabid/541/Default.aspx

U.S. Geological Survey (USGS). (2009). *Ground water use in the United States.* Retrieved on September 13, 2009 from http://ga.water.usgs.gov/edu/wugw.html

U.S. Environmental Protection Agency (US EPA). (2009a). *Safe Drinking Water Act* (SDWA). Retrieved on September 13, 2009 from http://www.epa.gov/OGWDW/sdwa/basicinformation.html

U.S. Environmental Protection Agency (US EPA). (2009b). *Drinking Water Contaminates*. Retrieved on September 13, 2009 from http://www.epa.gov/OGWDW/contaminants/index.html

U.S. Geological Survey (USGS). (2008). *Protection of Wisconsin's groundwater through comprehensive planning: Dane County- nitrate-nitrogen concentrations.*. Retrieved from http://wi.water.usgs.gov/gwcomp/find/dane/nitrate.html

Vidon, P. G. F., & Hill, A.R. (2004). Landscape controls on the hydrology of stream riparian zones. *Journal of Hydrology*, *292*, 210-228.

Waller, R.M. (1994). *Ground water and the rural homeowner.* United States Geological Survey and the United States Department of the Interior (1994-380-615). Retrieved from http://pubs.usgs.gov/gip/gw_ruralhomeowner/

Winter, T.C., Harvey, J.W., Lehn Franke, O., & Alley, W.M. (1998). *Ground water and surface water a single resource* (U.S. Geological Survey Circular 1139). Retrieved from http://pubs.usgs.gov/circ/circ1139/

Wisconsin Department of Natural Resources (WDNR). (1993). *State of Wisconsin wellhead protection program plan for public water supplies.* Retrieved from http://dnr.wi.gov/org/water/dwg/gw/pubs/whpp_plan.pdf

Wisconsin Department of Natural Resources (WDNR). (2007). *Safe Water on Tap 2007 Annual Drinking Water Report.*

Wisconsin Department of Natural Resources (WDNR). ( 2008). *List of communities in Wisconsin with wellhead protection plans* (updated July 8th, 2008). Retrieved from http://dnr.wi.gov/org/water/dwg/gw/whp/communities.pdf

Wisconsin Department of Natural Resources (WDNR). (2009). *Wisconsin Wellhead Protection Program Summary.* Retrieved on September 16, 2009 from http://dnr.wi.gov/org/water/dwg/gw/whp/WHP-sum.html

Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCAP). (2008). *Water Quality Protection: Features of the "580" Nutrient Management Standards.* Retrieved from http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/nutrient-mngmt/pdf/WaterQualityProtectionFeaturesOf590.pdf

## SECTION 6.4.1

Anderson, E. W. (1987) . Riparian area definition: A viewpoint. Rangelands, 9(2), 70.

Anderson, D. G. (1968). Effects of urban development on floods in Northern Virginia. (Geol Surv. 26 P, 5 FIG, 5 TAB, 9 REF).

Banner, E., Stahl, A., & Dodds W. (2009). Stream discharge and riparian land use influence in-stream connections and loading phosphorous from Central Plains Watersheds. Environmental Management, 44(3), 552-565.

Burns, D., Vitvar, T., McDonnell, J., Hassett, J., Duncan, J., & Kendall, C.. (2005). Effects of suburban development on runoff generation in the Croton River basin, New York, USA. Journal of Hydrology, 311(1-4), 266-281.

Dane County. (2009a). Dane County Natural Hazard Mitigation Plan (Public Review Draft. July 17, 2009). Retrieved from http://im.na.amec.com/DaneCo_HazardMitigation/functionality/admin/

Dane County. (2009b). Letter from Dane County Planning and Development "To Town Clerks, Town Chairs, and County Board Supervisors" pertaining to Flood Storage District Maps. [August 3, 2009 Letter]. Retrieved from http://danedocs.countyofdane.com/webdocs/pdf/plandev/zoning/Flood_Storage_Information.pdf

Federal Emergency Management Agency (FEMA). (2005). Floodplain and shoreland zoning: A guidebook for local officials. Dam Safety, Floodplain and Shoreland Management (2005 Edition). Retrieved from http://dnr.wi.gov/org/water/wm/dsfm/Documents/FloodplainShorelandZoningGuidebook.pdf

Federal Emergency Management Agency Region 10 (FEMA). (2009a). The 100 Year Flood Myth. Retrieved on September 16, 2009 from http://training.fema.gov/EMIWeb/edu/docs/hazrm/Handout%203-5.pdf

Federal Emergency Management Agency (FEMA). (2009b). National Flood Insurance Program (NFIP): Floodplain Management Requirements – A Study Guide and Desk Reference for Local Officials. Retrieved from http://www.fema.gov/plan/prevent/floodplain/fm_sg.shtm

Federal Emergency Management Agency (FEMA). (2009c). Floodway. Retrieved on October 6th, 2009 from http://www.fema.gov/plan/prevent/floodplain/nfipkeywords/floodway.shtm

Federal Emergency Management Agency (FEMA). (2009d). Flood plain management criteria for flood-related erosion-prone areas. Retrieved on October 6, 2009 from http://edocket.access.gpo.gov/cfr_2002/octqtr/pdf/44cfr60.5.pdf

Gregory, S. V., Swanson, F. J., McKee, W. A., & Cummins, K. W. (1991). An ecosystem perspective of riparian zones: Focus on links between land and water. Bioscience, 41(8), 540-551.

Gurnell, S. J. (2003). Spatial hydorgeomorphological influences on sediment and nutrient deposition in riparian zones: Observations from the Garonne River, France. Geomorphology, 49(1-2), 1-23.

Hammer, T.R. (2005). Stream channel enlargement due to urbanization. Water Resources Research, 8(6), 1530-1540.

Hollis, G. E. (1975). The effects of urbanization on floods of different recurrence intervals. Water Resources Research, 11, 431-435

Hulse, D. W., Branscomb, A., &. Payne, S. G. (2004). Envisioning alternatives: Using citizen guidance to map future land and water use. Ecological Applications, 14(2), 325-341.

Kent, P. G., &. Dudiak, T. A. (2001). Wisconsin water law: A guide to water rights and regulations. University of Wisconsin-Extension. Retrieved from http://learningstore.uwex.edu/pdf/g3622.pdf

Ku, H.F.H., Hagelin, N.W., Buxton, H.T. (1992). Effects of urban storm-runoff control on groundwater recharge in Nassau County, New York. Ground Water, 30(4), 507-514.

Kusler, J. A. (2003). Common legal questions about floodplain regulations in the courts: 2003 Update. Retrieved on October, 6th, 2009 from http://www.floods.org/NoAdverseImpact/FLOODPLAIN_REG_IN_COURTS_050604.pdf

Monaghan, R.M., Carey, P. L., Wilcock, R. J., Drewry, J. J. , Houlbrooke, D. J., Quinn, J. M., & Thorrold B. S. (2009). Linkages between land management activities and stream water quality in a boarder dyke irrigated pastoral catchment. Agricultural Ecosystems and Environment, 129(1-3) 201-211.

National Flood Insurance Act of 1968, § 42 U.S.C. 4001 et seq. (NFIA). (1973). Retrieved from http://www.fema.gov/pdf/fhm/frm_acts.pdf

Salton, A.. (1959). Role of Local Government in Water Law. Wisconsin Law Review, January 1959, p. 25.

Sax, J. L. (1970). The Public Trust Doctrine in Natural Resource Law: Effective judicial intervention. Michigan Law Review, 68(3), 471-566. DOI: 10.2307/1287556. Retrieved from http://www.bepress.com/ils/iss4/sax.pdf

Stein, E. D. (2005). Effect of increases in peak flows and imperviousness on stream morphology of ephemeral streams in Southern California. North American Benthological Society (NB21F-05).

Swanson, F. J., Gregory, S.V., Sedell, J.R., & Campbell A.G.. (1982). Land-water interactions: The riparian zone. In Edmonds, R. L. (Ed.), Analysis of Coniferous Forest Ecosystems in the Western United States (US/IBP Synthesis Series 14). Stroudsburg, PA: Hutchinson Ross Publishing Co.

Tanka, K., Kodama, M., Sawanda, T., Tsuzuki, M., Yamamoto, Y., & Yanagisawa, T. (2009). Flood evenlLoadings of nitrogen and phosphorous from the Yahagi River to Chita Bay, Japan. Jarq-Japan Agricultural Research Quarterly, 43(1), 55-61.

Town of Cottage Grove (TCGa). (2008). Town Board Meeting Minutes,. June 16th, 2008. Retrieved from http://www.tn.cottagegrove.wi.gov/docview.asp?docid=1277&locid=143

Town of Cottage Grove (TCGb). (2008). Town Board Meeting Minutes, July 21, 2008. Retrieved from http://www.tn.cottagegrove.wi.gov/docview.asp?docid=1279&locid=143

United States Geological Survey (USGS). (2008). Flood of June 2008 in Southern Wisconsin. Retrieved from http://pubs.usgs.gov/sir/2008/5235/pdf/sir20085235.pdf

White, G. F. (1940). State regulation of flood-plain use. Journal of Land & Public Utility Economics, 16(3): 352-357.

Wisconsin Department of Natural Resources (WDNR). (2009b). Letter from WDNR “To All Dane County Communities With Flood Storage Areas” concerning Flood Insurance Rate Maps (FIRMS) and Flood Storage Districts (FSD). [Letter dated July 1, 2009].

Wisconsin Department of Natural Resources (WDNR). (2009a). The ordinary high water mark- What is it? Retrieved on October 5, 2009 from http://dnr.wi.gov/org/water/wm/dsfm/shore/ohwm.htm

Wisconsin Legislative Reference Bureau (WLRB). (2004). Wisconsin Constitution Article IX, Section 1: The Public Trust Doctrine. October 2004, 4(4). Retrieved from http://www.legis.state.wi.us/lrb/pubs/consthi/04consthiIV4.htm

## SECTION 6.4.2

Dane County. (2009). Dane County Waterbody Classification Project: Phase II: Shoreland and Riparian Management Plan (WBC Policy Document Public Hearing Draft 11-5-09). Retrieved from http://danedocs.countyofdane.com/webdocs/pdf/lwrd/lakes/Shoreland_Management_Plan_Draft_11-5-09.pdf

Garrison, P.J. & Wakeman, R. S. (2000). Use of paleolimnology to document the effects of lake shoreland development on water quality. Journal of Paleolimnology, 24(4), 369-393.

Markham, L. (2003). Shoreland development density and impervious surfaces: How do they affect water resources? How much is too much for our lakes and streams? Center for Land Use Education. Retrieved from http://www.uwsp.edu/cnr/landcenter/pdffiles/Imp_Surf_Shoreland_Dev_Density.pdf

Panuska, J.C., & Lillie, R.A. (1995). Phosphorus loading from Wisconsin watersheds: Recommended phosphorous export coefficients for agricultural and forest watersheds (Research Management Findings, No 38). Bureau of Research, Wisconsin Department of Natural Resources. (p. 8).

Wisconsin Department of Natural Resources (WDNR). (2009). Lake protection and classification grants. Retrieved on June 13, 2010 from http://dnr.wi.gov/org/caer/cfa/grants/Lakes/lakeprotection.html

## SECTION 6.4.3

DeGaynor and Co., Inc. v. DNR, 70 Wis. 2d 936 (1975)

Johnston, Jr, S. A.. (2005). Estuarine dredge and fill activities: A review of impacts. Environmental Management, 5(5): 427-440.

Quick, J. (1994). The Public Trust Doctrine in Wisconsin. Wisconsin Environmental Law Journal, 1(1), 105-116.

Sax, J. L. (1970). The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention. Michigan Law Review, 68:, 471-566. Retrieved from http://www.bepress.com/ils/iss4/sax.pdf

Wisconsin Department of Natural Resources (WDNR). (2009a). Public Trust Doctrine. Retrieved on October 6, 2009 from http://dnr.wi.gov/org/water/wm/dsfm/shore/doctrine.htm

Wisconsin Department of Natural Resources (WDNR). (2009a). What are Wisconsin's stream access laws? Do they apply to lakes? Retrieved on October 6, 2009 from http://dnr.wi.gov/fish/faq/access.htm

# APPENDIX 1:

## WATER SAMPLING PROTOCOLS

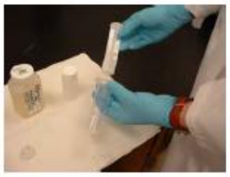
Procedure for Field Filtering Samples for Dissolved Ortho Phosphorus or Total Dissolved Phosphorus (7/20/04) from the Wisconsin State Lab of Hygiene.

60 mL bottle

50 mL syringe, disk or capsule filter.

1. Items needed to field filter water samples for dissolved ortho-phosphorus (ortho-P) or total dissolved phosphorus (TDP): 1-60 mL bottle and, 1-50 mL syringe *(Norm-ject)*, and 1-0.45µm cartridge filter ***(Whatman GD/XP, #S6970-2504 or Millipore Sterivex, #SVHV01015).***

2. Collect the sample in a clean bailer sampler. Transfer the sample directly to the quart bottle.

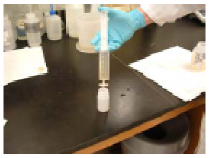


3. Remove the plunger from the 50 mL syringe **prior** to attaching the filter.

4. Attach the filter by pushing it onto the syringe tip. Note that it will only fit one correct way.

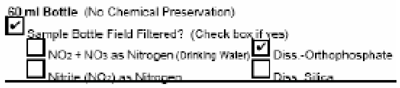
5. Pour **unpreserved** sample from the sampling device into the syringe and fill to the top of the barrel.

6. It is important to filter a known amount so it can be properly acidified. 50mL is recommended



7. Re-insert the plunger, slowly push the plunger down and discard about 5 mL of solution. Place the filter over the bottle opening and push plunger down. It may seem difficult, but most samples will only required 30-45 seconds to filter 50mL. **<u>CAUTION:</u>** Filter may rupture if too much pressure is applied. Discard the filter and syringe.

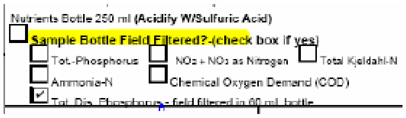
8. If TDP is desired, add one special small (reduced volume) vial of sulfuric acid to the 60 mL bottle. DO NOT add acid if ortho-P is desired.



**60 ml Bottle** (No Chemical Preservation)
☑ Sample Bottle Field Filtered? (Check box if yes)
☐ $NO_2$ + $NO_3$ as Nitrogen (Drinking Water) ☑ Diss.-Orthophosphate
☐ Nitrite ($NO_2$) as Nitrogen ☐ Diss. Silica

Field #: ___________
FIELD FILTERED
Total Dissolved Phosphorus

☐ Preserved with: $H_2SO_4$



Nutrients Bottle 250 ml **(Acidify W/Sulfuric Acid)**
☐ **Sample Bottle Field Filtered?-(check** box if yes)
☐ Tot.-Phosphorus ☐ $NO_2$ + $NO_3$ as Nitrogen ☐ Total Kjeldahl-N
☐ Ammonia-N ☐ Chemical Oxygen Demand (COD)
☑ Tot. Dis. Phosphorus - field filtered in 60 ml. bottle

9. Write "field filtered" on the label on the 60 mL bottle or use special labels provided by the lab. If ortho-P is desired, check the "Sample Bottle Field Filtered" box on the test request form. If TDP is desired, check the $H_2SO_4$ box on the side of the bottle and indicate note on the 60 mL bottle is field filtered on the test request form (see example).

10. Promptly ship samples to the laboratory on ice.

General Preservation and Shipping Requirements for water samples (6/28/07) for the Wisconsin State Lab of Hygiene.

***Note: Fill all bottles just below the neck***

2-Quart: For TSS. Preserve with Ice only.

1-250 mL: For nitrogen and Total Phosphorus. Preserve with 1-vial $H_2SO4$ & ice.

Dissolved reactive (ortho) P. Ice only.

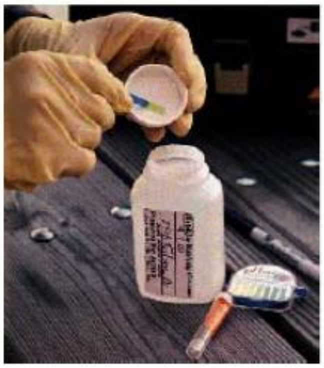
Complete 1-test request form for each sampling point. Remember to note that you preserved the sample on the bottom left corner of the form.

1. **Collect samples** according to sampling protocol (1-250 mL 1-60 mL bottle and 2-quart bottle for TSS & chlorophyll).

2. **Preserve the 250 mL bottle** by adding a vial of sulfuric acid ($H_2SO_4$). Circle the word "nutrients" and check the $H_2SO_4$ box. **DO NOT preserve the quart bottles** for TSS-only use ice.

3. **Example** of circling properly labeled bottle.

4. **Securely cap the 250 mL bottles and mix** by inverting several times.



5. **Verify sample pH (250 ml bottles).** Remove cap from sample bottle and check pH pouring a drop of sample onto the pH paper. Add additional acid if correct pH has not been achieved. Note: No more acid should be needed for lake or river water.

Packing and Shipping Instructions for Water Samples to the Wisconsin State Lab of Hygiene.

1. Place sample bottles in **separate** plastic zip-lock bags and securely close. **DO NOT** place quart and 250 mL bottles in the same bag.

Put quart for TSS & chlorophyll in gallon zip-lock bags. You may also put the 60 mL bottle in this bag as well

Put sulfuric acid preserved bottles in small zip-lock bags.

2. Line cooler with the large plastic bag provided.

3. Place bagged bottles inside cooler.

4. Pour ice over and between bagged sample bottles. Please make sure ice completely fills cooler. **DO NOT USE "blue ice"** or other freezer packs.

5. Twist plastic liner bag closed.

6. Securely seal the bag with a plastic cable lie to prevent leakage during shipping.

7. Place the test request forms in a gallon zip-lock bag and place on top of the bag containing the ice.

8. Close the cooler lid and wrap with reinforced shipping tape completely around the cooler on both ends.

9. Remove the mailing label card from the plastic envelope, flip-over so the WSLH address is exposed and reinsert into envelope.

10. Check the appropriate box on the "contents" label located on the left of the address.

11. Ship the samples to the laboratory by UPS or other suitable carrier. Use the address pre-printed on the "red" State Lab of Hygiene shipping label.

NOT FOR U.S. MAIL

**State Lab. of Hygiene**
**2601 Agriculture Drive**
**Madison, WI 53718-6780**

***Samples must be received by the laboratory with 24 hours of collection if dissolve ortho-P or chlorophyll a are desired.***

**Questions?** Contact one of the below individuals at the State Lab of Hygiene

- Kit Bruehl or George Bowman (608-224-6277) or Graham Anderson, Chris McSweeny or Lori Edwards (608-224-6282)

# APPENDIX 2:

# WATER QUALITY - LITTLE DOOR CREEK RESULTS AND HISTORICAL USGS DATA

## A2.1 LITTLE DOOR CREEK RESULTS

Little Door Creek, as a tributary, has a smaller drainage area and smaller flows than that of Door Creek. These small flows make it unlikely that Little Door Creek will have a significant impact on Lake Kegonsa, or the other Yahara Lakes. However, Little Door Creek may cause significant localized water quality problems for Door Creek.  Because of these potential impacts, water quality samples were collected at the headwaters of Little Door Creek (site E), the main channel prior to entering Door Creek (site F), and Door Creek after Little Door enters the stream (site G). For consistency, these sites were sampled on the same days that Door Creek was sampled. This section will contain the data results and a brief analysis of the data collected for Little Door Creek.

### NITROGEN:

The baseflow nitrogen levels for Little Door Creek revealed that the majority of TN was made up of nitrate-nitrite, ammonia increased downstream, and TKN remained relatively constant throughout (Figure A2-1). These trends were likely caused by high levels of nitrate-nitrite in groundwater and by inputs of ammonia from erosion or runoff. It is important to note that these trends were present in the Door Creek results as well. In both cases, all nitrogen forms exceeded their standards. Despite these similarities, the distribution of TN and nitrate-nitrite at site F was significantly higher than concentrations at the Door Creek sites. Although this trend has been observed, it is unclear why this is occurring. One possible explanation is the nearness of the 12-18 overpass. However, the mechanisms for this increase need to be further investigated before concrete conclusions can be made.

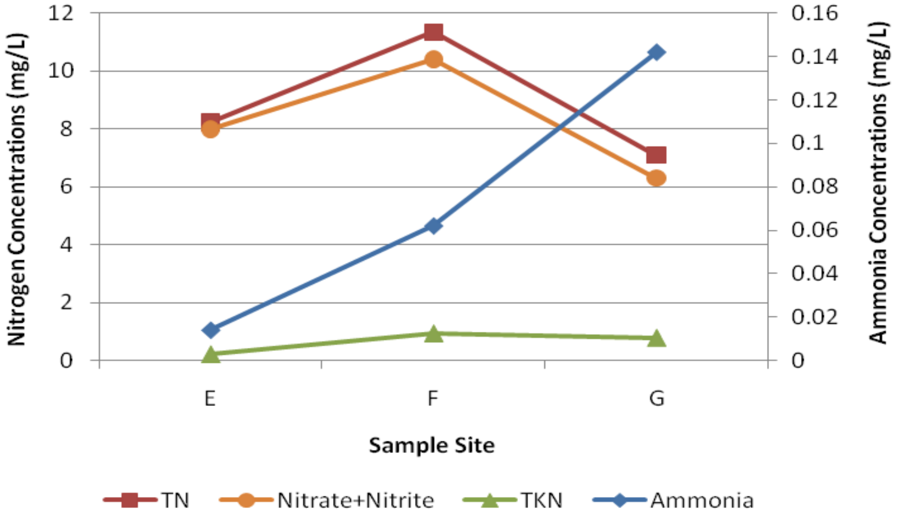


**Figure A2-1: Distribution of nitrogen concentrations of Little Door Creek during baseflow conditions on February 22, 2009.**

Little Door Creek had roughly the same distributional trends as Door Creek in the storm events sampled in March (Figure A2-2). Those trends were (1) ammonia approximately increased downstream, (2) TKN and nitrate-nitrite had roughly the same concentrations, and (3) TKN and nitrate-nitrite equally contributed to the TN concentration. These trends are likely the result of rainwater diluting groundwater nitrate-nitrite and disturbing benthic sediment due to increased flows from the storm event. As in the baseflow sample, the concentration of TN and nitrate-nitrite at site F were significantly higher than concentrations at Door Creek. Again, the mechanism(s) causing this increase is not well understood and needs to be further investigated. Although this increase existed, it did not push nitrate-nitrite and TN to exceed their standards. As in Door Creek, all forms of nitrogen, besides TN and nitrate-nitrite, exceeded their standards.

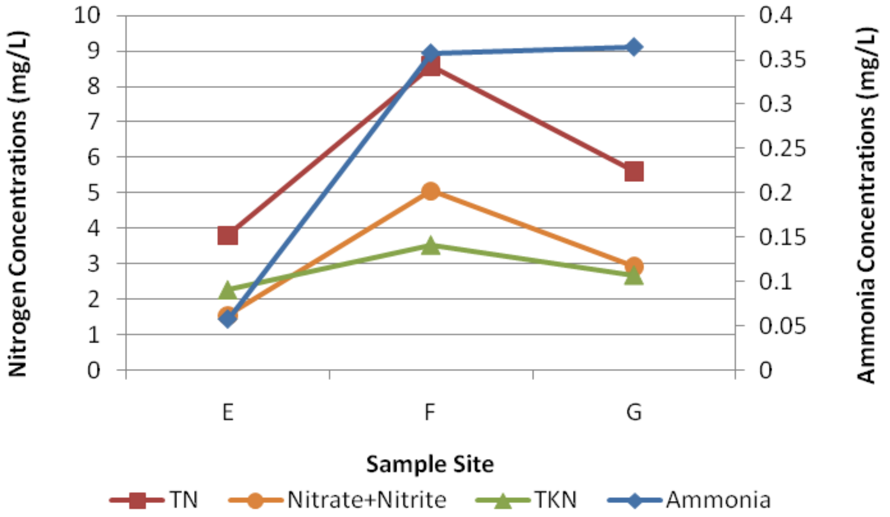


**Figure A2-2: Distribution of nitrogen concentrations in Little Door Creek during a large storm event prior to farming activities on March 8, 2009.**

The distribution of nitrogen concentrations during the May sampling was similar to the sample results from the February baseflow conditions (Figure A2-3). There was a slight variation in the ammonia concentration during the May sampling, but this did not significantly change the overall concentration of ammonia in Little Door Creek. This was likely because the storm event sampled in May was a small-scale event and occurred when the soil was dry, or the AMC was low. Therefore, more research needs to be gathered to determine what inputs agricultural practices add to storm events in Little Door Creek.

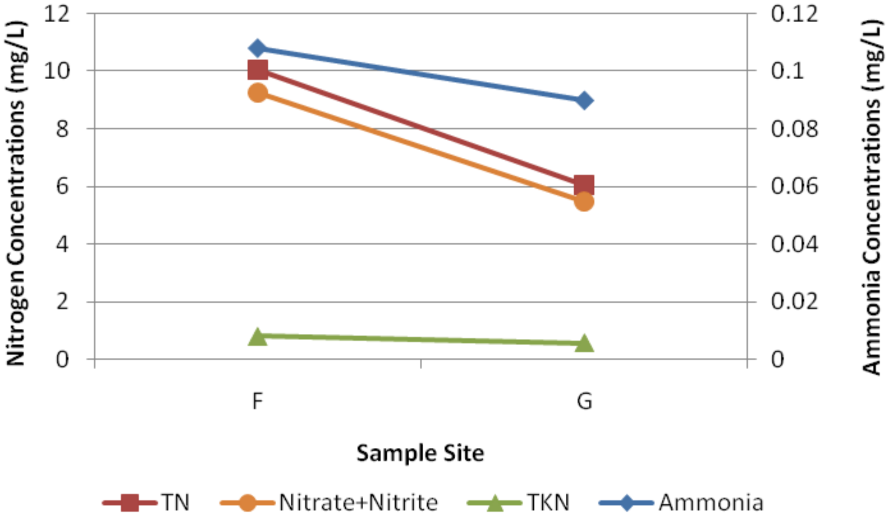


**Figure A2-3: Distribution of Nitrogen concentrations in Little Door Creek during a small storm event after farming activities on May 27, 2009.**

## PHOSPHORUS:

Generally speaking, TP increases moving downstream during baseflow conditions (Figure A2-4). Because of this increase, TP exceeded its standard at site G. TDP, however, remained relatively unaffected moving downstream and did not exceed its standard. These trends were very similar to those found in Door Creek and were believed to be caused by snowmelt and runoff, which can carry sediment-bound phosphorus, entering the stream as the drainage area increases.

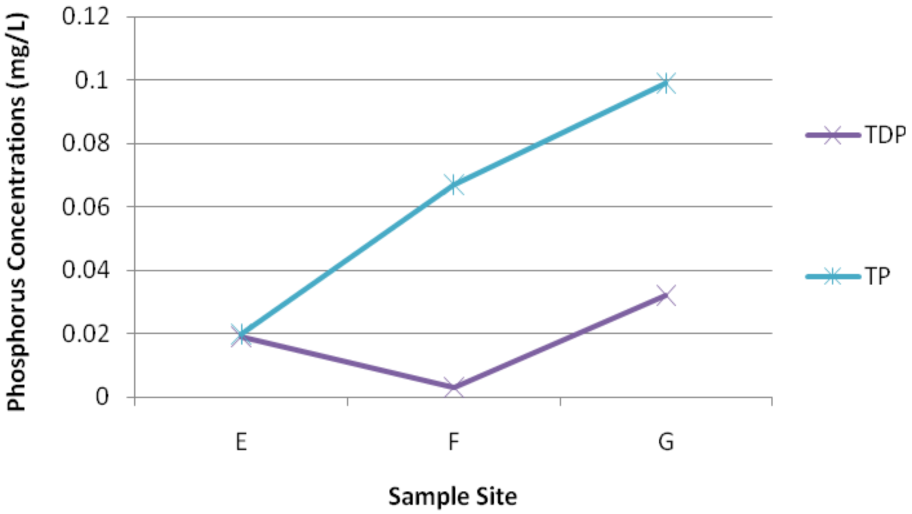


**Figure A2-4: Distribution of phosphorus concentrations of Little Door Creek during baseflow conditions on February 22, 2009.**

In the large storm event sampled in March, the most significant trend seen is that the concentration of TP and TDP increased almost 10-fold compared to baseflow concentrations (Figure A2-5). This increase is likely caused by an increase in soil erosion that may occur during a storm event, which was also seen in the Door Creek results. Because of this large increase, TP and TDP exceeded their standards at all locations.

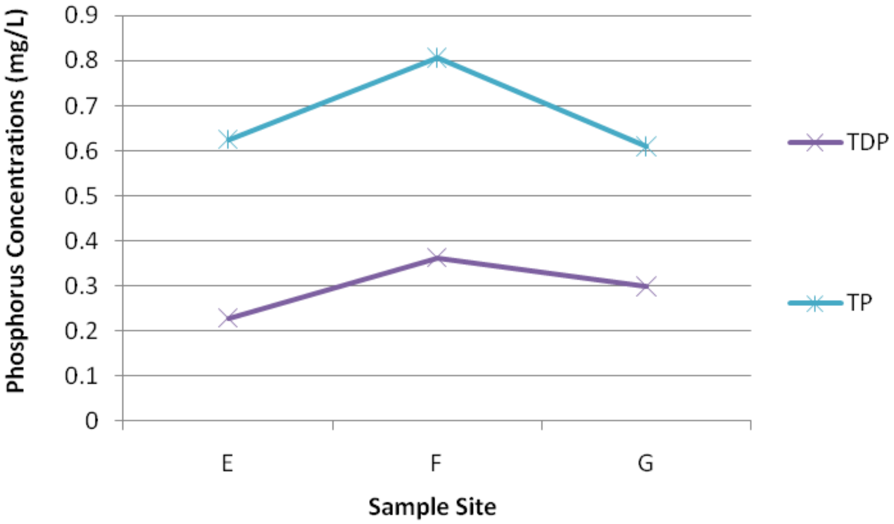


**Figure A2-5: Distribution of phosphorus concentrations of Little Door Creek during a large storm event prior to farming activities on March 8, 2009.**

As with the Door Creek results, the abundance of phosphorus in Little Door Creek during the post-fertilizer small storm event in May was similar to the baseflow concentrations from February (Figure A2-6). In May, the sampled storm event was a small-scale event and occurred when the AMC was low. Therefore it is likely that the precipitation was absorbed by the soil, rather than entering the stream as runoff. As in the case with the baseflow results, all of the concentrations met their recommended values except for TP at site G.

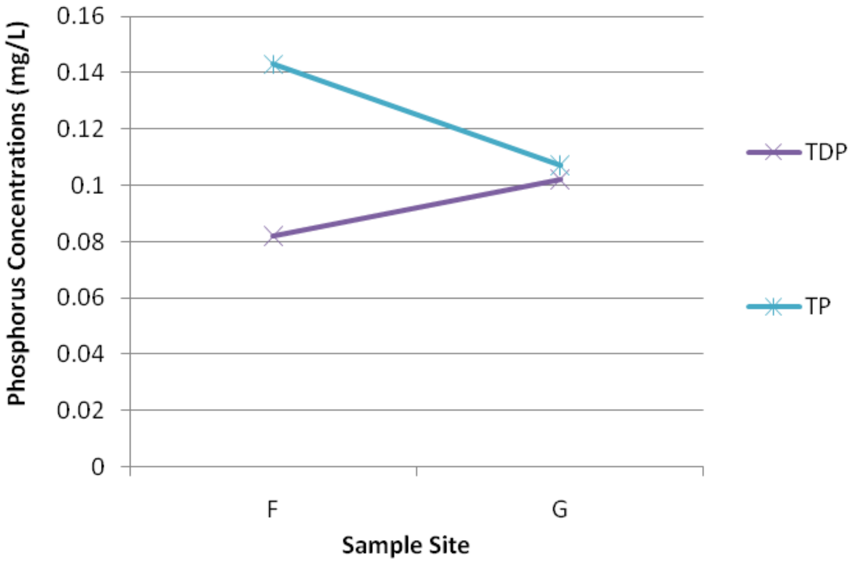


**Figure A2-6: Distribution of phosphorus concentrations of Little Door Creek during a small storm event after farming activities on May 27, 2009.**

## SUSPENDED SOLIDS:

Suspended solids were also measured in Little Door Creek on the same dates in March and May as was Door Creek. In March, TSS in Door Creek averaged approximately 190 mg/L while Little Door Creek averaged 175 mg/L. In May TSS in Door Creek averaged 15 mg/L and 23 mg/L in Little Door Creek (Figure A2-7). Runoff caused by the large, 25-year storm event sampled in March is the likely cause for the influx of TSS during this sampling event. On the contrary, the low level of TSS seen in May is expected because this was a small 1-year storm event and the antecedent moisture content was low at the time of the storm. Therefore, runoff was not as significant and did not contribute to large TSS loading to Door and Little Door Creek. Overall, the TSS trends for Little Door Creek matched those of Door Creek.

**Table A2-1: Suspended solids from Little Door Creek during a 25-year rain event in March and a 1-year rain event in May, measured in mg/L.**

| Site | Pre-Fertilizer: March | Post-Fertilizer: May |
|---|---|---|
| **E** | 259 | No data |
| **F** | 188 | 34 |
| **G** | 78 | 12 |

## TEMPERATURE:

Water temperature in Little Door Creek also followed the same trends as Door Creek. From winter sampling done in February, we saw that water temperature at the headwaters of Little Door Creek was higher than downstream as this reach of the creek is primarily groundwater fed. The same trend can be seen in temperature results from Door Creek, since both headwaters of Door and Little Door are fed by groundwater. Spring sampling in March and summer sampling in May illustrated a rise in water temperature moving downstream. The ambient temperature was almost exactly the same in both Little Door and Door Creek for all three seasons sampled. Figures illustrating these trends can be found in Chapter 3, Figures 3.10 and 3.12.

## DISSOLVED OXYGEN:

Dissolved oxygen in Little Door Creek dropped proportionately from winter to spring to summer, again following the same trend as Door Creek. Average DO for Little Door Creek in winter was approximately 10.8 mg/L then dropped to approximately 7.5 mg/L in spring and finally to 6.5 mg/L in summer. As outlined in section 4.6, two main reasons for this seasonal drop in DO are rising ambient water temperatures and decomposing algae. Warmer water inherently holds less DO than colder water, and as decomposition rates increase, DO levels drop because oxygen is consumed during decomposition processes. The figure illustrating this trend can be found in Chapter 3, Figure 3.13.

## A2.2. HISTORICAL DATA

Within the Door Creek watershed there are three USGS water quality sampling locations, identified as USGS sites 05429580, 05429560 and 05429590, as illustrated in Figure 3.1, Chapter 3.1. At these sites, water quality measurements were collected sporadically starting in 1979. These measurements included physical parameters such as temperature, dissolved oxygen, flow, pH, and coliform, while nutrient data included total phosphorus (TP), total dissolved phosphorus (TDP), total nitrogen (TN), total Kjehldahl nitrogen (TKN), ammonia, nitrite and nitrate. Of the three sites, USGS site 05429580 was the most studied, meaning more samples were taken at more frequent time intervals at this site than at the others. This site also fell very close to sample site C. For these reasons site 05429580 is a good basis for comparison to illustrate if the data collected in this report was typical for Door Creek in an historical context (See Chapter 3.4). The purpose of this appendix is to graphically represent all measurements collected at USGS site 05429580 for comparative purposes. The raw data collected by the USGS can be found at http://nwis.waterdata.usgs.gov/wi/nwis/qwdata. It is important to note that only the USGS data that was deemed pertinent to our project was utilized. Therefore, not all of the parameters illustrated in this appendix were collected in this project or utilized in the discussion of our results.

# APPENDIX 3:

# SNAP-PLUS

The SNAP-Plus model was developed in a collaborative effort between the Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP), Wisconsin Department of Natural Resources (WDNR), United States Department of Agriculture Natural Resources Conservation Service (NRCS), UW Discovery Farms Program, and the University of Wisconsin College of Agriculture and Life Sciences. It is a Microsoft Windows® Nutrient Management Planning software program and was developed as an upgrade from its predecessor SNAP2000. Its purpose is to provide agricultural managers with a tool that allows them to comprehensively manage nutrients within agricultural systems in accordance with Wisconsin's Nutrient Management Standard NR 590 (Pearson et al, 2004). SNAP-Plus gives farmers and consultants the opportunity to input many different types of agricultural practices and accurately forecasts the results of those practices, making it easier to adjust management strategies in order to meet NR 590 standards. Not only does the model provide for flexibility, but it also allows for the extrapolation of these strategies over long periods of time. This makes it easier to analyze changes in agricultural practices.

The program is designed to allow users to integrate five major components: a conservation plan, a nutrient management plan, a record keeping program, manure/wastewater management, and a feed management program (Pearson et al, 2004). The following results can be calculated by the model: crop nutrient recommendations for nitrogen, phosphorous, and potassium, according to University of Wisconsin recommendations; a RUSLE2 based soil loss assessment to determine if allowable soil loss values (tons/acre/year) are being met; a rotational Wisconsin Phosphorous Index (WPI); and a rotational phosphorous balance for using soil test phosphorous (Figure A3-1).

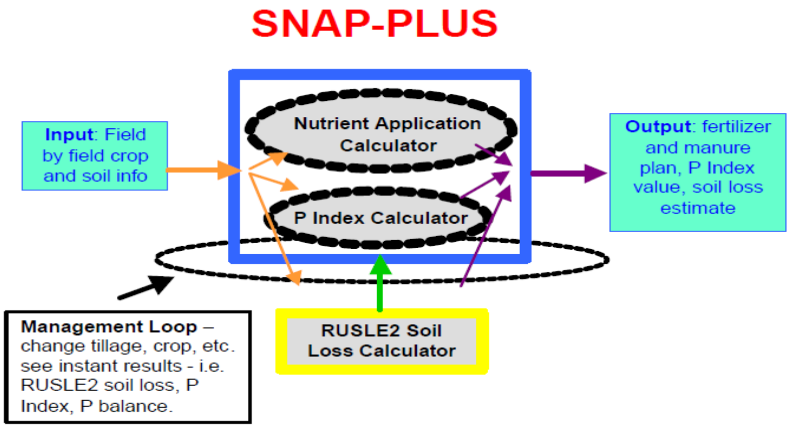


**Figure A3-1: Diagram of the Inputs, Outputs, and Interactions of the SNAP-Plus model** (Pearson et al, 2004).

## APPENDIX 4:

# RUSLE2

RUSLE2 is the major driving force within the SNAP-Plus model. It was developed by the USDA - NRCS, the USDA - Agricultural Research Service and the University of Tennessee in 1993. RUSLE2 is a scientifically based prediction of soil loss and is an update from its predecessor, the USLE (Universal Soil Loss Equation). It uses mathematical equations along with scientific knowledge from test plots and technical judgments to estimate the loss of soil through rill and interrill erosion (USDA, 2005)

The driving mathematical equation for RUSLE2 can be written as $a = r * k * l * S * c * p$ where:

a = the net detachment (mass/unit area)
r = erosivity factor
k = soil erodibility factor
l = dimensionless length factor
S = dimensionless slope steepness factor
c = dimensionless cover factor
p = dimensionless conservation practice.

Rainfall erosivity (r) values are gathered from datasets already compiled and built into the program from actual climactic and simulated rain events. Soil erodibility (k) values are already compiled as datasets and built into the model. These values were gathered from test plots that were located on many different soil types. Each plot was identical in size, slope, and practice. Length and slope factors (l & S) are computed using actual field measurements. Cover and practice factors (c & p) are also obtained from datasets already built into the program based on crop and agricultural practices being implemented. All of these values are calculated on a daily time scale based on long term averages from the datasets. Length (l), slope (S), cover (c), and practice (p) factors are also directly entered into the SNAP-Plus interface which allows managers to change crops and agricultural practices to meet desired goals, since the landscape's slope and length cannot be changed. The most highly weighted component of the equation is the product of rk. This is what produces the estimated daily soil loss for unit plot conditions. The other factors in the equation are responsible for adjusting this estimate to the site-specific conditions (USDA, 2005).

One major advantage that RUSLE2 has over earlier versions such as USLE and RUSLE is its ability to compute and account for deposition.

This is represented by the equation $D= ( Vf/ q) * ( Tc - g)$ where:

D = deposition rate (mass/unit area)
Vf = fall velocity of the sediment
q = runoff rate
Tc = transport capacity of the runoff
g = sediment load (mass/ unit width).

RUSLE2 is able to divide the soil into five major classes (primary clay, silt, sand, small aggregates, and large aggregates) based on soil texture and the amount of upslope deposition (USDA, 2005). This is extremely important because as soil is deposited larger particles will settle out first, leaving smaller particles behind. These finer particles are able to bond with other substances such as nutrients and chemicals due to their relatively high Cation Exchange Capacity (CEC). Therefore, as the concentration of smaller sized soil particles increases, so does the concentration of nutrients and chemicals.

Since RUSLE2 is based on mathematical relationships from previously collected datasets, it is important to note that these datasets are constantly being updated within the model. However, RUSLE2 has an advantage over its predecessors in that it uses additional modeling to predict erosion rates for management practices that are not well represented within the datasets. This is called “process-based erosion science” (Foster, Yoder, Weesies & Toy, 2001). The combination and integration of both available updated tables and advanced modeling is what makes RUSLE2 such a robust and successful tool.

# APPENDIX 5:

# WISCONSIN PHOSPHOROUS INDEX (WPI)

The Wisconsin Phosphorous Index (WPI) was developed for the purpose of providing a relative indication, in pounds per acre per year, of the amount of annual runoff phosphorous that could be contributing to the contamination of nearby surface water from a particular field (Good & Panuska, 2008). By monitoring the phosphorous being lost from a field, managers are able to change land use practices to reduce the amount of contamination. The WPI is also important for maintaining compliance with Wisconsin's Nutrient Management Standard NR 590. In order to stay in compliance with the NR 590 standard fields cannot contribute more then 6.0 lbs/acre/year of phosphorous (Good, 2005, Figure A5-1).

**Table A5-1: Ranges of WPI and potential for phosphorous delivery to nearby surface water (Good, 2005).**

| P Index Range | Potential for P delivery to nearby surface water |
|---|---|
| 0-2 | Low to medium |
| 2-4 | Medium to high |
| 4-6 | High to excessive |
| Over 6 | Excessive |

The WPI is mathematically derived using two primary components: a particulate P index that estimates annual delivery of sediment-bound phosphorous, and a soluble P index that estimates the annual runoff dissolved phosphorous loads, which includes dissolved phosphorous losses from unincorporated manure or fertilizer applications (Good, 2005). Note that the WPI does not account for phosphorous losses due to subsurface flow and tile drainage, and is also designed to err on the side of *over-estimating phosphorous* delivery for parameters that do not yet have an extensive research base (Good & Panuska, 2008).

To validate the model, field data has been collected throughout the state of Wisconsin to determine actual edge of field phosphorous contribution to surface water (Stuntebeck, Komiskey, Owens & Hall, 2008). These results have been compared to the WPI predictions for the same test areas and the two appear to be well correlated (r2 = 0.79) (Bundy, Mallarino & Good, 2008).

Particulate P is calculated by determining the mass of three size-classes of eroded particles that include clay, silt, and other large particles, using RUSLE2, and then multiplying these particle sizes by soil test P values for each particle size along with an appropriate enrichment ratio (Good & Panuska, 2008). The Soluble P is much more difficult to compute. It incorporates a number of different sub-calculations to derive a final value. To summarize, it calculates dissolved P runoff accounting for winter runoff, non-frozen soil period runoff, and direct dissolved P losses from manure or fertilizer applications (Good & Panuska, 2008). Once both the particulate P and soluble P are calculated and summed they are multiplied by a total phosphorous delivery ratio to account for P deposition or infiltration as runoff travels from the edge of the field to the surface water (Figure A5-1).

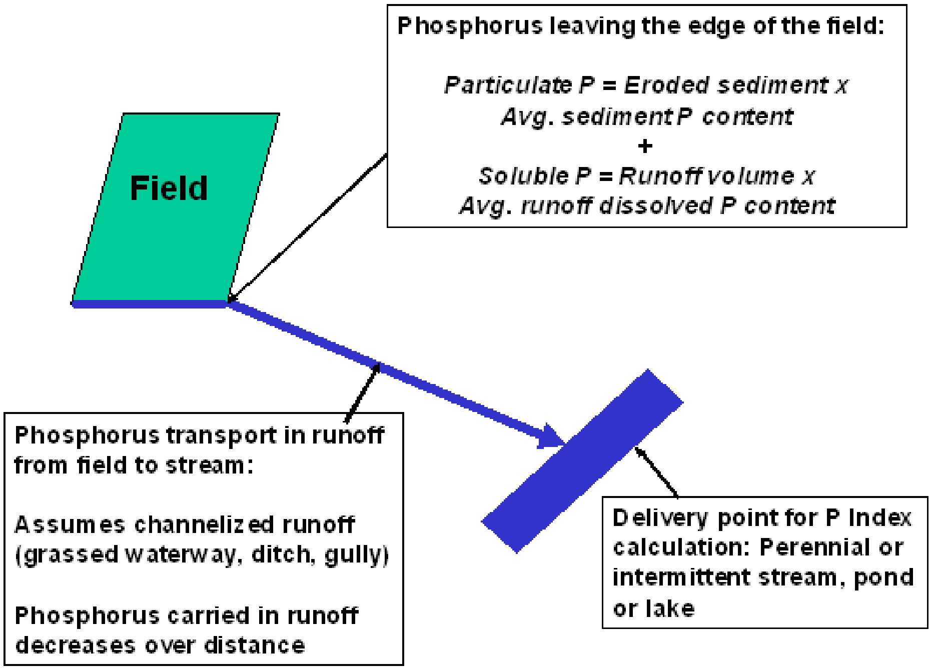


**Figure A5-1: Movement of Phosphorous from the edge of field to surface water (Good, 2005).**

# APPENDIX 6:

# SNAP-PLUS METHODOLOGY

## SOIL GROUPINGS

The most recent Dane County soil survey was published by the National Resources Conservation Service (NRCS) in 2009 (NRCS, 2009). The Dane County GIS Soils layer identifies 73 different soil map units in the Door Creek watershed. In order to simplify the SNAP-Plus analysis, these 73 soil map units were organized into groups of similar soil properties based on RUSLE2 soil erosion equation inputs and other soil characteristics. Each group was then assigned a representative soil map unit that best represented the group's characteristics.

The RUSLE2 equation inputs used for the soil groupings were: soil erodibility factor (k), soil slope (S) and soil erodibility index (EI). The k, or soil erodibilty factor, was the first criteria used to sort the soil map units. The k values for soils in the Door Creek watershed varied from 0.05 for a Granby Loamy Sand (Gn) to 0.43 for several different soils (NRCS, 2009). Since the k values are empirically-determined, they are stratified into value levels that provide a good basis for the first level of grouping (ARS, 2007).

Soils were then sorted by their EI value, which is defined by the equation $EI = (r * k * S * l) / T$. Variables in this equation are defined above (Appendix 4: RUSLE2). Soils with an EI value less than 8 are defined as "Not-Highly Erodible," and soils with an EI greater than or equal to 8 are defined as "Highly Erodible" (NRCS, 2006). Soil map units were sorted within each k-value grouping based on whether they are classified as Not-Highly Erodible or Highly Erodible.

The final level of RUSLE2-based soil map unit sorting was done using soil slopes. Each soil map unit has a slope range associated with it that can be quickly identified based on the A-E letter following the two letter soil group abbreviation (ie: Griswold: Gw**B**, Gw**C**, Gw**D**, etc.). Soil slope ranges are:

A = 0-2 %
B = 2-6 %
C = 6-12 %
D = 12-20 %
E = >20 %

Soils already sorted by k and EI values were then grouped based on common slopes where necessary.

To complete the process, additional soil map unit groupings were made based on soil drainage – well-drained and poorly drained – and physical soil properties – mucks and loamy sands.

Once the full array of soils in the Door Creek watershed were sorted and grouped, a representative soil was chosen for each of proposed groupings. These representative soils were chosen based on their area within the watershed and how well they represent the average properties of the given group. They were then used as the soil map unit inputs in the SNAP-Plus model.

A total of 17 representative soil map units were chosen to represent these 73 soil map units in the watershed. Final soil groupings used in the SNAP-Plus analysis are summarized in the Table A6-1.

**Table A6-1: Soil groupings and representative soil type for the SNAP-Plus analysis.**

| Representative Soil | Area (Acres) | Kf | Representative Slope | Map Units Included |
|---|---|---|---|---|
| Ho | 1704 | ---- | ---- | Ad, Ho, Pa |
| Gn | 253 | ---- | ---- | Gn, Gp, Wt |
| GwB | 221 | 0.24 | 4% | BoB, GwB, KcB, SeB, ShA |
| GwC | 278 | 0.24 | 9% | BoC2, GwC |
| GwD2 | 122 | 0.24 | 16% | BoD2, DrD2, GwD2, RpE |
| DsC2 | 843 | 0.32 | 9% | DsC2, KdC2, MhC2, PnC2, RnC2, RoC2, WrC2 |
| KdD2 | 303 | 0.32 | 16% | KdD2, KrD2, MhD2 |
| KrE2 | 126 | 0.32 | 28% | KrE2 |
| SaA | 1817 | 0.32 | 2% | EfB, EgA, Mc, Os, Ot, RaA, SaA, VrB, VwA, Wa |
| PnB | 3953 | 0.32 | 4% | Cu, DsB, GsB, HaA, KeA, KeB, Ma, PnA, PnB, PoA, PoB, RnB, RoB, TrB, WrB |
| ScC2 | 96 | 0.37 | 9% | BbC2, PeC2, ScC2, ScD2 |
| DnB | 2312 | 0.37 | 4% | BbA, BbB, Co, DnB, Ev, MdB, ScA, ScB, WvB, SfA, DnC2, DoC2, MdC2, DuD2, DuE2, MdD2 |
| SfA | 13 | 0.43 | 2% | SfA |
| DnC2 | 225 | 0.43 | 9% | DnC2 |
| MdC2 | 613 | 0.43 | 9% | MdC2 |
| DuD2 | 30 | 0.43 | 16% | DuD2, DuE2 |
| MdD2 | 76 | 0.43 | 16% | MdD2 |

## TILLAGE PRACTICES AND CROP ROTATION

In order to calculate soil P index, we needed to obtain the information about the farming practices such as tillage, nutrient application method, nutrient application rate, and crop rotation. Crop rotation influence both soil erodibility and nutrient application. Several different crops are grown in the Door Creek watershed, such as corn grain, soybean, hay , alfalfa crops,

**Table A6-2: Door Creek Crop Rotations used within SNAP-Plus.**

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Rotation 1 | Hay Alfalfa | Hay Alfalfa | Hay Alfalfa | Corn | Soybeans |
| Rotation 2 | Hay Alfalfa | Hay Alfalfa | Wheat | Corn | Back to Year 1 |
| Rotation 3 | Corn | Soybean | Corn | Soybean | Back to Year 1 |

**Table A6-3: Door Creek Tillage Practices used within SNAP-Plus.**

| | | Hay | Wheat | Soybean | Corn grain |
|---|---|---|---|---|---|
| Yield goal | | 3.5-4 tons/yr | 75 bu/ac | 50 bu/ac | 150 bu/ac |
| Fertilizer (lbs/ac) | $K_2SO_4$ | 40 | 100-150 | 200 (Spring) | 200-300 (Fall) |
| | Urea | 160 | 100-150 | - | 170 (Spring) |
| Tillage | | None | No-till | No-till,<br>Fall chisel (no disk)*, Spring chisel (disk)* | No-till,<br>Fall chisel (no disk), Spring chisel (disk) |

* = Only for the 5 year rotation pattern

and wheat. Based on our interviews with several farmland owners in the Door Creek watershed, we chose corn grain, soybean, mixed grass hay, and wheat as the representative crops for our watershed. Four or five-year rotation patterns of the crops were made for the SNAP-Plus model input (Table A6-2).

Different tillage practices will change soil erodibility and thus influence calculated soil P index. Based on our interviews, we chose three major tillage practices, including no-till, fall chisel (no disk) and spring chisel (disk), and applied these practices to different rotation patterns to see the impact of different scenarios on soil P index values (Table A6-3).

## SOIL PHOSPHORUS DATA

In order to estimate the P index value, it is necessary to obtain the soil phosphorus data as a parameter in SNAP-Plus. However, soil test phosphorous levels differ from field to field due to different soil types and management practices. As a result, we needed to determine a range of soil test phosphorous levels to estimate the possible soil P index. We obtained soil test phosphorous data from two different sources. An average of 56 ppm soil test phosphorous for Dane County was reported by the Department of Soil Science at the University of Wisconsin-Madison. We also obtained soil sample data from different farms in the watershed and acquired a range of soil phosphorous data from 20 to more than 200 ppm. We ran SNAP-Plus with 25, 50, 100, 150 and 200 ppm of soil test phosphorous values in order to cover the range of sampled soil test phosphorous values within the watershed.

## DISTANCE TO STREAM

Because of the shape of the watershed, no fields are greater than 5,000 ft to Door Creek. The SNAP-Plus allows you to choose from a range of distance to stream parameters. These distances were 0-300 ft, 301-1,000 ft, and 1,001-5,000 ft. All rotations and scenarios were run at all three distance parameters.

# APPENDIX 7:

# RESULTS OF THE GENERAL AGRICULTURAL PRACTICE SNAP-PLUS ANALYSIS

| | |
|---|---|
| **Rotation:** | Varied |
| **Tillage:** | No-Till |
| **Distance to Stream:** | 0 - 300 Feet |

* Dane County Average Soil Test P Value is 56 ppm

** Wisconsin NR590 Maximum Recommended PI Value is 6.0

*** Values in RED exceed the Recommended PI Value of 6.0

**Summary By Representative Soil**

| | | | | **Cg-Sb** | | | | | **Ww-3A-Cg** | | | | | **Cg-Sb-Ww** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
| **Soil Group** | **Slope** | **Area (Ac.)** | **Percentage** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| Gn | ----- | 253 | 2.00% | 0.1 | 0.2 | 0.5 | 0.7 | 0.9 | 0.1 | 0.2 | 0.4 | 0.7 | 0.9 | 0.1 | 0.2 | 0.5 | 0.7 | 1 |
| Ho | ------ | 1704 | 13.10% | 0.2 | 0.4 | 0.8 | 1.2 | 1.6 | 0.1 | 0.4 | 0.8 | 1.2 | 1.7 | 0.2 | 0.4 | 0.9 | 1.3 | 1.7 |
| SaA | A | 1817 | 14.00% | 0.5 | 0.9 | 1.7 | 2.5 | 3.3 | 0.4 | 0.8 | 1.7 | 2.5 | 3.4 | 0.5 | 0.9 | 1.7 | 2.6 | 3.4 |
| SfA | A | 13 | 0.10% | 0.2 | 0.2 | 0.3 | 0.5 | 0.6 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 0.2 | 0.2 | 0.4 | 0.5 | 0.5 |
| DnB | B | 2312 | 17.80% | 0.5 | 0.7 | 1.2 | 1.7 | 2.2 | 0.4 | 0.6 | 1.2 | 1.7 | 2.2 | 0.5 | 0.7 | 1.2 | 1.7 | 2.3 |
| GwB | B | 221 | 1.70% | 0.4 | 0.6 | 1.1 | 1.6 | 2.1 | 0.3 | 0.6 | 1.1 | 1.6 | 2.1 | 0.4 | 0.6 | 1.1 | 1.7 | 2.2 |
| PnB | B | 3953 | 30.50% | 0.4 | 0.7 | 1.2 | 1.7 | 2.2 | 0.4 | 0.6 | 1.1 | 1.7 | 2.2 | 0.4 | 0.7 | 1.2 | 1.7 | 2.2 |
| DnC2 | C | 225 | 1.70% | 0.8 | 1.1 | 1.6 | 2.2 | 2.8 | 0.6 | 0.9 | 1.5 | 2.1 | 2.7 | 0.7 | 1 | 1.6 | 2.2 | 2.7 |
| DsC2 | C | 843 | 6.50% | 0.7 | 1 | 1.5 | 2 | 2.6 | 0.6 | 0.8 | 1.4 | 2 | 2.6 | 0.7 | 0.9 | 1.5 | 2.1 | 2.6 |
| GwC | C | 278 | 2.10% | 0.6 | 0.8 | 1.4 | 1.9 | 2.4 | 0.5 | 0.7 | 1.3 | 1.8 | 2.4 | 0.6 | 0.8 | 1.4 | 1.9 | 2.4 |
| MdC2 | C | 613 | 4.70% | 0.8 | 1.1 | 1.7 | 2.3 | 2.9 | 0.7 | 1 | 1.6 | 2.2 | 2.8 | 0.8 | 1.1 | 1.7 | 2.3 | 2.9 |
| ScC2 | C | 96 | 0.70% | 0.7 | 1 | 1.6 | 2.1 | 2.7 | 0.6 | 0.9 | 1.4 | 2 | 2.6 | 0.7 | 1 | 1.5 | 2.1 | 2.7 |
| DuD2 | D | 30 | 0.20% | 1.6 | 2.1 | 3.2 | 4.2 | 5.3 | 1.3 | 1.8 | 2.9 | 4 | 5.1 | 1.5 | 2 | 3.1 | 4.2 | 5.3 |
| GwD2 | D | 122 | 0.90% | 0.9 | 1.2 | 1.8 | 2.4 | 3 | 0.8 | 1.1 | 1.7 | 2.3 | 2.9 | 0.9 | 1.2 | 1.8 | 2.4 | 3 |
| KdD2 | D | 303 | 2.30% | 1.1 | 1.4 | 2.1 | 2.7 | 3.4 | 0.9 | 1.2 | 1.9 | 2.5 | 3.2 | 1.1 | 1.4 | 2 | 2.7 | 3.3 |
| MdD2 | D | 76 | 0.60% | 1.4 | 1.8 | 2.4 | 3.2 | 3.9 | 1.2 | 1.5 | 2.2 | 2.9 | 3.6 | 1.3 | 1.7 | 2.3 | 3 | 3.8 |
| KrE2 | E | 126 | 1.00% | 1.7 | 2 | 2.8 | 3.5 | 4.3 | 1.3 | 1.7 | 2.4 | 3.1 | 3.9 | 1.5 | 1.9 | 2.6 | 3.3 | 4.1 |

**Summary By Slope**

| **Slope Group** | **Area (Ac.)** | **Percentage** | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| ------ | 1957 | 15.10% | 0.2 | 0.3 | 0.7 | 1.0 | 1.3 | 0.1 | 0.3 | 0.6 | 1.0 | 1.3 | 0.2 | 0.3 | 0.7 | 1.0 | 1.4 |
| A | 1830 | 14.10% | 0.4 | 0.6 | 1.0 | 1.5 | 2.0 | 0.3 | 0.5 | 1.0 | 1.5 | 1.9 | 0.4 | 0.6 | 1.1 | 1.6 | 2.0 |
| B | 6486 | 49.90% | 0.4 | 0.7 | 1.2 | 1.7 | 2.2 | 0.4 | 0.6 | 1.1 | 1.7 | 2.2 | 0.4 | 0.7 | 1.2 | 1.7 | 2.2 |
| C | 2056 | 15.80% | 0.7 | 1.0 | 1.6 | 2.1 | 2.7 | 0.6 | 0.9 | 1.4 | 2.0 | 2.6 | 0.7 | 1.0 | 1.5 | 2.1 | 2.7 |
| D / E | 658 | 5.10% | 1.3 | 1.7 | 2.5 | 3.2 | 4.0 | 1.1 | 1.5 | 2.2 | 3.0 | 3.7 | 1.3 | 1.6 | 2.4 | 3.1 | 3.9 |

| | |
|---|---|
| **Rotation:** | Varied |
| **Tillage:** | No-Till |
| **Distance to Stream:** | 301-1000 Feet |

* Dane County Average Soil Test P Value is 56 ppm

** Wisconsin NR590 Maximum Recommended PI Value is 6.0

*** Values in RED exceed the Recommended PI Value of 6.0

### Summary By Representative Soil

| | | | | **Cg-Sb** | | | | | **Ww-3A-Cg** | | | | | **Cg-Sb-Ww** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
| **Soil Group** | **Slope** | **Area (Ac.)** | **Percentage** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| Gn | ----- | 253 | 2.00% | 0.1 | 0.2 | 0.4 | 0.6 | 0.9 | 0.1 | 0.2 | 0.4 | 0.6 | 0.9 | 0.1 | 0.2 | 0.4 | 0.7 | 0.9 |
| Ho | ------ | 1704 | 13.10% | 0.2 | 0.4 | 0.8 | 1.2 | 1.5 | 0.1 | 0.3 | 0.8 | 1.2 | 1.6 | 0.2 | 0.4 | 0.8 | 1.2 | 1.6 |
| SaA | A | 1817 | 14.00% | 0.4 | 0.8 | 1.6 | 2.3 | 3.1 | 0.3 | 0.8 | 1.6 | 2.4 | 3.2 | 0.5 | 0.9 | 1.7 | 2.5 | 3.3 |
| SfA | A | 13 | 0.10% | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 0.2 | 0.2 | 0.3 | 0.5 | 0.5 |
| DnB | B | 2312 | 17.80% | 0.4 | 0.7 | 1.2 | 1.6 | 2.1 | 0.4 | 0.6 | 1.1 | 1.6 | 2.1 | 0.4 | 0.7 | 1.2 | 1.7 | 2.2 |
| GwB | B | 221 | 1.70% | 0.4 | 0.6 | 1.1 | 1.5 | 2 | 0.3 | 0.5 | 1 | 1.5 | 2 | 0.4 | 0.6 | 1.1 | 1.6 | 2.1 |
| PnB | B | 3953 | 30.50% | 0.4 | 0.7 | 1.1 | 1.6 | 2.1 | 0.3 | 0.6 | 1.1 | 1.6 | 2.1 | 0.4 | 0.7 | 1.1 | 1.6 | 2.1 |
| DnC2 | C | 225 | 1.70% | 0.8 | 1 | 1.6 | 2.1 | 2.6 | 0.6 | 0.9 | 1.4 | 2 | 2.6 | 0.7 | 1 | 1.5 | 2.1 | 2.6 |
| DsC2 | C | 843 | 6.50% | 0.7 | 0.9 | 1.4 | 1.9 | 2.5 | 0.5 | 0.8 | 1.3 | 1.9 | 2.4 | 0.6 | 0.9 | 1.4 | 2 | 2.5 |
| GwC | C | 278 | 2.10% | 0.6 | 0.8 | 1.3 | 1.8 | 2.3 | 0.4 | 0.7 | 1.2 | 1.7 | 2.3 | 0.5 | 0.8 | 1.3 | 1.8 | 2.3 |
| MdC2 | C | 613 | 4.70% | 0.8 | 1.1 | 1.6 | 2.2 | 2.7 | 0.7 | 0.9 | 1.5 | 2.1 | 2.6 | 0.8 | 1 | 1.6 | 2.1 | 2.7 |
| ScC2 | C | 96 | 0.70% | 0.7 | 1 | 1.5 | 2 | 2.5 | 0.6 | 0.8 | 1.4 | 1.9 | 2.5 | 0.7 | 0.9 | 1.4 | 2 | 2.5 |
| DuD2 | D | 30 | 0.20% | 1.5 | 2 | 3 | 4 | 5 | 1.2 | 1.7 | 2.7 | 3.8 | 4.8 | 1.5 | 1.9 | 2.9 | 4 | 5 |
| GwD2 | D | 122 | 0.90% | 0.9 | 1.2 | 1.7 | 2.3 | 2.9 | 0.7 | 1 | 1.6 | 2.2 | 2.8 | 0.9 | 1.1 | 1.7 | 2.3 | 2.9 |
| KdD2 | D | 303 | 2.30% | 1.1 | 1.4 | 2 | 2.6 | 3.2 | 0.9 | 1.2 | 1.8 | 2.4 | 3 | 1 | 1.3 | 1.9 | 2.5 | 3.1 |
| MdD2 | D | 76 | 0.60% | 1.4 | 1.7 | 2.3 | 3 | 3.7 | 1.1 | 1.4 | 2.1 | 2.7 | 3.4 | 1.3 | 1.6 | 2.2 | 2.9 | 3.6 |
| KrE2 | E | 126 | 1.00% | 1.6 | 1.9 | 2.6 | 3.3 | 4.1 | 1.3 | 1.6 | 2.3 | 3 | 3.7 | 1.5 | 1.8 | 2.5 | 3.2 | 3.9 |

### Summary By Slope

| **Slope Group** | **Area (Ac.)** | **Percentage** | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| ------ | 1957 | 15.10% | 0.2 | 0.3 | 0.6 | 0.9 | 1.2 | 0.1 | 0.3 | 0.6 | 0.9 | 1.3 | 0.2 | 0.3 | 0.6 | 1.0 | 1.3 |
| A | 1830 | 14.10% | 0.3 | 0.5 | 1.0 | 1.4 | 1.8 | 0.2 | 0.5 | 1.0 | 1.4 | 1.8 | 0.4 | 0.6 | 1.0 | 1.5 | 1.9 |
| B | 6486 | 49.90% | 0.4 | 0.7 | 1.1 | 1.6 | 2.1 | 0.3 | 0.6 | 1.1 | 1.6 | 2.1 | 0.4 | 0.7 | 1.1 | 1.6 | 2.1 |
| C | 2056 | 15.80% | 0.7 | 1.0 | 1.5 | 2.0 | 2.5 | 0.6 | 0.8 | 1.4 | 1.9 | 2.5 | 0.7 | 0.9 | 1.4 | 2.0 | 2.5 |
| D / E | 658 | 5.10% | 1.3 | 1.6 | 2.3 | 3.0 | 3.8 | 1.0 | 1.4 | 2.1 | 2.8 | 3.5 | 1.2 | 1.5 | 2.2 | 3.0 | 3.7 |

| | |
|---|---|
| **Rotation:** | Varied |
| **Tillage:** | No-Till |
| **Distance to Stream:** | 1001-5000 Feet |

* Dane County Average Soil Test P Value is 56 ppm

** Wisconsin NR590 Maximum Recommended PI Value is 6.0

*** Values in RED exceed the Recommended PI Value of 6.0

**Summary By Representative Soil**

| | | | | **Cg-Sb** | | | | | **Ww-3A-Cg** | | | | | **Cg-Sb-Ww** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
| **Soil Group** | **Slope** | **Area (Ac.)** | **Percentage** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| Gn | ----- | 253 | 2.00% | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 0.1 | 0.1 | 0.4 | 0.6 | 0.8 |
| Ho | ------ | 1704 | 13.10% | 0.2 | 0.3 | 0.7 | 1.1 | 1.4 | 0.1 | 0.3 | 0.7 | 1.1 | 1.5 | 0.2 | 0.2 | 0.7 | 1.1 | 1.5 |
| SaA | A | 1817 | 14.00% | 0.4 | 0.8 | 1.4 | 2.1 | 2.8 | 0.3 | 0.7 | 1.4 | 2.2 | 3 | 0.4 | 0.5 | 1.5 | 2.3 | 3 |
| SfA | A | 13 | 0.10% | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 0.2 | 0.2 | 0.3 | 0.4 | 0.4 |
| DnB | B | 2312 | 17.80% | 0.4 | 0.6 | 1.1 | 1.5 | 1.9 | 0.3 | 0.6 | 1 | 1.5 | 2 | 0.4 | 0.5 | 1.1 | 1.5 | 2 |
| GwB | B | 221 | 1.70% | 0.4 | 0.6 | 1 | 1.4 | 1.8 | 0.3 | 0.5 | 0.9 | 1.4 | 1.9 | 0.3 | 0.4 | 1 | 1.4 | 1.9 |
| PnB | B | 3953 | 30.50% | 0.9 | 0.6 | 1 | 1.5 | 1.9 | 0.3 | 0.5 | 1 | 1.4 | 1.9 | 1.1 | 1.2 | 1 | 1.5 | 1.9 |
| DnC2 | C | 225 | 1.70% | 0.7 | 0.9 | 1.4 | 1.9 | 2.4 | 0.6 | 0.8 | 1.3 | 1.8 | 2.4 | 0.6 | 0.7 | 1.4 | 1.9 | 2.4 |
| DsC2 | C | 843 | 6.50% | 0.6 | 0.8 | 1.3 | 1.8 | 2.3 | 0.5 | 0.7 | 1.2 | 1.7 | 2.2 | 0.6 | 0.7 | 1.3 | 1.8 | 2.3 |
| GwC | C | 278 | 2.10% | 0.5 | 0.7 | 1.2 | 1.6 | 2.1 | 0.4 | 0.6 | 1.1 | 1.6 | 2.1 | 0.5 | 0.6 | 1.2 | 1.7 | 2.1 |
| MdC2 | C | 613 | 4.70% | 0.7 | 1 | 1.5 | 2 | 2.5 | 0.6 | 0.8 | 1.4 | 1.9 | 2.4 | 0.7 | 0.8 | 1.5 | 2 | 2.5 |
| ScC2 | C | 96 | 0.70% | 0.6 | 0.9 | 1.3 | 1.8 | 2.3 | 0.5 | 0.8 | 1.3 | 1.8 | 2.3 | 0.6 | 0.7 | 1.3 | 1.8 | 2.3 |
| DuD2 | D | 30 | 0.20% | 1.4 | 1.9 | 2.7 | 3.7 | 4.6 | 1.1 | 1.6 | 2.5 | 3.5 | 4.4 | 1.3 | 1.5 | 2.7 | 3.6 | 4.6 |
| GwD2 | D | 122 | 0.90% | 0.8 | 1.1 | 1.6 | 2.1 | 2.6 | 0.7 | 0.9 | 1.4 | 2 | 2.5 | 0.8 | 0.9 | 1.6 | 2.1 | 2.6 |
| KdD2 | D | 303 | 2.30% | 1 | 1.3 | 1.8 | 2.4 | 2.9 | 0.8 | 1.1 | 1.6 | 2.2 | 2.8 | 0.9 | 1 | 1.7 | 2.3 | 2.9 |
| MdD2 | D | 76 | 0.60% | 1.2 | 1.5 | 2.1 | 2.7 | 3.4 | 1 | 1.3 | 1.9 | 2.5 | 3.1 | 1.1 | 1.3 | 2 | 2.6 | 3.3 |
| KrE2 | E | 126 | 1.00% | 1.5 | 1.8 | 2.4 | 3.1 | 3.7 | 1.2 | 1.5 | 2.1 | 2.7 | 3.4 | 1.3 | 1.4 | 2.3 | 2.9 | 3.6 |

**Summary By Slope**

| **Slope Group** | **Area (Ac.)** | **Percentage** | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| ------ | 1957 | 15.10% | 0.2 | 0.3 | 0.6 | 0.9 | 1.1 | 0.1 | 0.3 | 0.6 | 0.9 | 1.2 | 0.2 | 0.2 | 0.6 | 0.9 | 1.2 |
| A | 1830 | 14.10% | 0.3 | 0.5 | 0.8 | 1.2 | 1.6 | 0.2 | 0.5 | 0.9 | 1.3 | 1.7 | 0.3 | 0.4 | 0.9 | 1.4 | 1.7 |
| B | 6486 | 49.90% | 0.6 | 0.6 | 1.0 | 1.5 | 1.9 | 0.3 | 0.5 | 1.0 | 1.4 | 1.9 | 0.6 | 0.7 | 1.0 | 1.5 | 1.9 |
| C | 2056 | 15.80% | 0.6 | 0.9 | 1.3 | 1.8 | 2.3 | 0.5 | 0.7 | 1.3 | 1.8 | 2.3 | 0.6 | 0.7 | 1.3 | 1.8 | 2.3 |
| D / E | 658 | 5.10% | 1.2 | 1.5 | 2.1 | 2.8 | 3.4 | 1.0 | 1.3 | 1.9 | 2.6 | 3.2 | 1.1 | 1.2 | 2.1 | 2.7 | 3.4 |

| | |
|---|---|
| **Rotation:** | Varied |
| **Tillage:** | Fall Chisel |
| **Distance to Stream:** | 0-300 Feet |

* Dane County Average Soil Test P Value is 56 ppm

** Wisconsin NR590 Maximum Recommended PI Value is 6.0

*** Values in RED exceed the Recommended PI Value of 6.0

## Summary By Representative Soil

| | | | | Cg-Sb | | | | | Ww-3A-Cg | | | | | Cg-Sb-Ww | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Rotation 1 | | | | | Rotation 2 | | | | | Rotation 3 | | | | |
| **Soil Group** | **Slope** | **Area (Ac.)** | **Percentage** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| Gn | ----- | 253 | 2.00% | 0.2 | 0.4 | 0.7 | 1 | 1.3 | 0.1 | 0.2 | 0.5 | 0.8 | 1.1 | 0.2 | 0.3 | 0.5 | 0.8 | 1.1 |
| Ho | ------ | 1704 | 13.10% | 0.3 | 0.5 | 1 | 1.5 | 2 | 0.2 | 0.4 | 0.9 | 1.4 | 1.9 | 0.2 | 0.4 | 0.9 | 1.3 | 1.7 |
| SaA | A | 1817 | 14.00% | 1.3 | 1.7 | 2.6 | 3.4 | 4.3 | 0.7 | 1.1 | 2.1 | 3 | 3.9 | 0.8 | 1.2 | 1.9 | 2.7 | 3.4 |
| SfA | A | 13 | 0.10% | 1.2 | 1.4 | 1.6 | 2 | 2.3 | 0.5 | 0.6 | 0.9 | 1.1 | 1.3 | 0.7 | 0.8 | 1 | 1.2 | 1.5 |
| DnB | B | 2312 | 17.80% | 3.6 | 4 | 4.9 | 5.9 | 6.9 | 1.6 | 2 | 2.7 | 3.5 | 4.2 | 1.9 | 2.2 | 2.8 | 3.5 | 4.1 |
| GwB | B | 221 | 1.70% | 2 | 2.3 | 3 | 3.7 | 4.4 | 1 | 1.3 | 1.9 | 2.6 | 3.2 | 1.2 | 1.4 | 1.9 | 2.4 | 2.9 |
| PnB | B | 3953 | 30.50% | 3 | 3.4 | 4.3 | 5.1 | 6 | 1.4 | 1.7 | 2.4 | 3.1 | 3.9 | 1.7 | 1.9 | 2.5 | 3.1 | 3.7 |
| DnC2 | C | 225 | 1.70% | 8.1 | 8.9 | 10.6 | 12.4 | 14.2 | 3.6 | 4.1 | 5.2 | 6.3 | 7.5 | 4.2 | 4.7 | 5.7 | 6.7 | 7.8 |
| DsC2 | C | 843 | 6.50% | 5.5 | 6.1 | 7.3 | 8.6 | 9.9 | 2.5 | 2.9 | 3.8 | 4.8 | 5.7 | 3 | 3.4 | 4.2 | 5 | 5.8 |
| GwC | C | 278 | 2.10% | 4 | 4.5 | 5.4 | 6.5 | 7.6 | 1.9 | 2.2 | 3 | 3.8 | 4.7 | 2.2 | 2.5 | 3.2 | 3.9 | 4.6 |
| MdC2 | C | 613 | 4.70% | 7.5 | 8.3 | 9.9 | 11.5 | 13.3 | 3.4 | 3.9 | 5 | 6.1 | 7.2 | 4 | 4.5 | 5.5 | 6.5 | 7.6 |
| ScC2 | C | 96 | 0.70% | 6.8 | 7.5 | 8.9 | 10.4 | 12.1 | 3 | 3.5 | 4.5 | 5.5 | 6.6 | 3.6 | 4 | 4.9 | 5.8 | 6.8 |
| DuD2 | D | 30 | 0.20% | 13.2 | 14.6 | 17.4 | 20.4 | 23.6 | 6.2 | 7.2 | 9.1 | 11.1 | 13.2 | 7.3 | 8.1 | 9.9 | 11.8 | 13.8 |
| GwD2 | D | 122 | 0.90% | 7.2 | 8 | 9.5 | 11.1 | 12.8 | 3.5 | 4 | 5.1 | 6.2 | 7.3 | 4 | 4.5 | 5.4 | 6.5 | 7.5 |
| KdD2 | D | 303 | 2.30% | 9.6 | 10.5 | 12.4 | 14.5 | 16.6 | 4.5 | 5.1 | 6.4 | 7.7 | 9.1 | 5.2 | 5.8 | 7 | 8.2 | 9.5 |
| MdD2 | D | 76 | 0.60% | 13.3 | 14.5 | 17.1 | 19.8 | 22.7 | 6.2 | 6.9 | 8.5 | 10.2 | 11.9 | 7.2 | 7.9 | 9.4 | 11 | 12.7 |
| KrE2 | E | 126 | 1.00% | 13.4 | 14.6 | 17.2 | 19.9 | 22.8 | 6.6 | 7.4 | 9 | 10.7 | 12.6 | 7.5 | 8.3 | 9.8 | 11.5 | 13.2 |

## Summary By Slope

| **Slope Group** | **Area (Ac.)** | **Percentage** | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| ------ | 1957 | 15.10% | 0.3 | 0.5 | 0.9 | 1.3 | 1.7 | 0.2 | 0.3 | 0.7 | 1.1 | 1.5 | 0.2 | 0.4 | 0.7 | 1.1 | 1.4 |
| A | 1830 | 14.10% | 1.3 | 1.6 | 2.1 | 2.7 | 3.3 | 0.6 | 0.9 | 1.5 | 2.1 | 2.6 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 |
| B | 6486 | 49.90% | 2.9 | 3.2 | 4.1 | 4.9 | 5.8 | 1.3 | 1.7 | 2.3 | 3.1 | 3.8 | 1.6 | 1.8 | 2.4 | 3.0 | 3.6 |
| C | 2056 | 15.80% | 6.4 | 7.1 | 8.4 | 9.9 | 11.4 | 2.9 | 3.3 | 4.3 | 5.3 | 6.3 | 3.4 | 3.8 | 4.7 | 5.6 | 6.5 |
| D / E | 658 | 5.10% | 11.3 | 12.4 | 14.7 | 17.1 | 19.7 | 5.4 | 6.1 | 7.6 | 9.2 | 10.8 | 6.2 | 6.9 | 8.3 | 9.8 | 11.3 |

| | |
|---|---|
| **Rotation:** | Varied |
| **Tillage:** | Fall Chisel |
| **Distance to Stream:** | 301-1001 Feet |

* Dane County Average Soil Test P Value is 56 ppm
** Wisconsin NR590 Maximum Recommended PI Value is 6.0
*** Values in RED exceed the Recommended PI Value of 6.0

**Summary By Representative Soil**

| | | | | Cg-Sb | | | | | Ww-3A-Cg | | | | | Cg-Sb-Ww | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Rotation 1 | | | | | Rotation 2 | | | | | Rotation 3 | | | | |
| **Soil Group** | **Slope** | **Area (Ac.)** | **Percentage** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| Gn | ----- | 253 | 2.00% | 0.1 | 0.4 | 0.6 | 0.9 | 1.2 | 0.1 | 0.2 | 0.5 | 0.8 | 1 | 0.1 | 0.3 | 0.5 | 0.8 | 1 |
| Ho | ------ | 1704 | 13.10% | 0 | 0.5 | 1 | 1.4 | 1.9 | 0.2 | 0.4 | 0.9 | 1.3 | 1.8 | 0.2 | 0.4 | 0.8 | 1.2 | 1.7 |
| SaA | A | 1817 | 14.00% | 0.7 | 1.6 | 2.4 | 3.3 | 4.1 | 0.7 | 1.1 | 2 | 2.8 | 3.7 | 0.8 | 1.1 | 1.8 | 2.5 | 3.3 |
| SfA | A | 13 | 0.10% | 1 | 1.3 | 1.6 | 1.9 | 2.2 | 0.5 | 0.6 | 0.8 | 1 | 1.2 | 0.7 | 0.8 | 1 | 1.2 | 1.4 |
| DnB | B | 2312 | 17.80% | 3.2 | 3.8 | 4.7 | 5.6 | 6.5 | 1.5 | 1.9 | 2.6 | 3.3 | 4 | 1.8 | 2.1 | 2.7 | 3.3 | 3.9 |
| GwB | B | 221 | 1.70% | 1.9 | 2.2 | 2.9 | 3.5 | 4.2 | 0.9 | 1.2 | 1.8 | 2.4 | 3 | 1.1 | 1.3 | 1.8 | 2.3 | 2.8 |
| PnB | B | 3953 | 30.50% | 2.7 | 3.3 | 4 | 4.9 | 5.7 | 1.3 | 1.6 | 2.3 | 3 | 3.7 | 1.6 | 1.8 | 2.4 | 2.9 | 3.5 |
| DnC2 | C | 225 | 1.70% | 7.7 | 8.5 | 10.1 | 11.7 | 13.5 | 3.4 | 3.9 | 4.9 | 6 | 7.1 | 4 | 4.4 | 5.4 | 6.4 | 7.4 |
| DsC2 | C | 843 | 6.50% | 5.5 | 5.7 | 6.9 | 8.2 | 9.5 | 2.4 | 2.8 | 3.6 | 4.5 | 5.5 | 2.8 | 3.2 | 3.9 | 4.7 | 5.5 |
| GwC | C | 278 | 2.10% | 4.1 | 4.2 | 5.2 | 6.2 | 7.2 | 1.8 | 2.1 | 2.9 | 3.7 | 4.4 | 2.1 | 2.4 | 3 | 3.7 | 4.3 |
| MdC2 | C | 613 | 4.70% | 7.6 | 7.9 | 9.4 | 11 | 12.6 | 3.2 | 3.7 | 4.7 | 5.8 | 6.9 | 3.8 | 4.3 | 5.2 | 6.2 | 7.2 |
| ScC2 | C | 96 | 0.70% | 6.5 | 7.1 | 8.5 | 9.9 | 11.4 | 2.9 | 3.3 | 4.3 | 5.3 | 6.3 | 3.4 | 3.8 | 4.6 | 5.5 | 6.4 |
| DuD2 | D | 30 | 0.20% | 13.6 | 13.8 | 16.5 | 19.4 | 22.4 | 5.9 | 6.8 | 8.6 | 10.5 | 12.5 | 6.9 | 7.7 | 9.4 | 11.2 | 13.1 |
| GwD2 | D | 122 | 0.90% | 7.7 | 7.6 | 9 | 10.6 | 12.2 | 3.3 | 3.8 | 4.8 | 5.9 | 7 | 3.8 | 4.3 | 5.2 | 6.1 | 7.1 |
| KdD2 | D | 303 | 2.30% | 10.4 | 10 | 11.8 | 13.7 | 15.8 | 4.3 | 4.8 | 6.1 | 7.3 | 8.6 | 5 | 5.5 | 6.6 | 7.8 | 9 |
| MdD2 | D | 76 | 0.60% | 13.7 | 13.8 | 16.2 | 18.8 | 21.5 | 5.9 | 6.6 | 8.1 | 9.6 | 11.3 | 6.9 | 7.5 | 9 | 10.5 | 12 |
| KrE2 | E | 126 | 1.00% | 14.6 | 13.9 | 16.3 | 18.9 | 21.6 | 6.2 | 7 | 8.6 | 10.2 | 11.9 | 7.1 | 7.8 | 9.3 | 10.9 | 12.5 |

**Summary By Slope**

| **Slope Group** | **Area (Ac.)** | **Percentage** | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| ------ | 1957 | 15.10% | 0.1 | 0.5 | 0.8 | 1.2 | 1.6 | 0.2 | 0.3 | 0.7 | 1.1 | 1.4 | 0.2 | 0.4 | 0.7 | 1.0 | 1.4 |
| A | 1830 | 14.10% | 0.9 | 1.5 | 2.0 | 2.6 | 3.2 | 0.6 | 0.9 | 1.4 | 1.9 | 2.5 | 0.8 | 1.0 | 1.4 | 1.9 | 2.4 |
| B | 6486 | 49.90% | 2.6 | 3.1 | 3.9 | 4.7 | 5.5 | 1.2 | 1.6 | 2.2 | 2.9 | 3.6 | 1.5 | 1.7 | 2.3 | 2.8 | 3.4 |
| C | 2056 | 15.80% | 6.3 | 6.7 | 8.0 | 9.4 | 10.8 | 2.7 | 3.2 | 4.1 | 5.1 | 6.0 | 3.2 | 3.6 | 4.4 | 5.3 | 6.2 |
| D / E | 658 | 5.10% | 12.0 | 11.8 | 14.0 | 16.3 | 18.7 | 5.1 | 5.8 | 7.2 | 8.7 | 10.3 | 5.9 | 6.6 | 7.9 | 9.3 | 10.7 |

| | |
|---|---|
| **Rotation:** | Varied |
| **Tillage:** | Fall Chisel |
| **Distance to Stream:** | 1001-5000 Feet |

* Dane County Average Soil Test P Value is 56 ppm

** Wisconsin NR590 Maximum Recommended PI Value is 6.0

*** Values in RED exceed the Recommended PI Value of 6.0

## Summary By Representative Soil

| | | | | **Cg-Sb** | | | | | **Ww-3A-Cg** | | | | | **Cg-Sb-Ww** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
| **Soil Group** | **Slope** | **Area (Ac.)** | **Percentage** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| Gn | ----- | 253 | 2.00% | 0.2 | 0.3 | 0.6 | 0.9 | 1.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.5 | 0.7 | 0.6 |
| Ho | ------ | 1704 | 13.10% | 0.2 | 0.5 | 0.9 | 1.3 | 1.8 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.8 | 1.1 | 1 |
| SaA | A | 1817 | 14.00% | 1.1 | 1.5 | 2.2 | 3 | 3.8 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 0.9 | 1.7 | 2.3 | 2.1 |
| SfA | A | 13 | 0.10% | 1.1 | 1.1 | 1.3 | 1.5 | 2 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 |
| DnB | B | 2312 | 17.80% | 3.1 | 3.5 | 4.3 | 5.1 | 6 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.7 | 1.8 | 2.5 | 3 | 2.9 |
| GwB | B | 221 | 1.70% | 1.8 | 2 | 2.6 | 3.2 | 3.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1 | 1.2 | 1.7 | 2.1 | 2 |
| PnB | B | 3953 | 30.50% | 2.6 | 3 | 3.7 | 4.5 | 4.4 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.4 | 1.6 | 2.2 | 2.7 | 2.6 |
| DnC2 | C | 225 | 1.70% | 7 | 7.7 | 9.2 | 10.7 | 12.4 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.6 | 3.9 | 4.9 | 5.8 | 5.8 |
| DsC2 | C | 843 | 6.50% | 4.7 | 5.3 | 6.3 | 7.5 | 8.7 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.6 | 2.8 | 3.6 | 4.3 | 4.3 |
| GwC | C | 278 | 2.10% | 3.5 | 3.9 | 4.7 | 5.6 | 6.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.9 | 2.1 | 2.8 | 3.4 | 3.3 |
| MdC2 | C | 613 | 4.70% | 6.6 | 7.2 | 8.6 | 10 | 11.6 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.5 | 3.8 | 4.8 | 5.7 | 5.6 |
| ScC2 | C | 96 | 0.70% | 5.9 | 6.5 | 7.8 | 9.1 | 10.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 3.1 | 3.4 | 4.2 | 5.1 | 5 |
| DuD2 | D | 30 | 0.20% | 11.5 | 12.7 | 15.1 | 17.8 | 20.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 6.3 | 6.8 | 8.7 | 10.3 | 10.2 |
| GwD2 | D | 122 | 0.90% | 6.3 | 6.9 | 8.3 | 9.7 | 11.2 | 3 | 3 | 3 | 3 | 3 | 3.5 | 3.8 | 4.7 | 5.6 | 5.6 |
| KdD2 | D | 303 | 2.30% | 8.3 | 9.1 | 10.8 | 12.6 | 14.4 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 4.6 | 4.9 | 6.1 | 7.1 | 7.1 |
| MdD2 | D | 76 | 0.60% | 11.6 | 12.7 | 14.9 | 17.2 | 19.7 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 6.3 | 6.7 | 8.2 | 9.6 | 9.6 |
| KrE2 | E | 126 | 1.00% | 11.6 | 12.7 | 14.9 | 17.3 | 19.8 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 6.5 | 7 | 8.5 | 10 | 10 |

## Summary By Slope

| **Slope Group** | **Area (Ac.)** | **Percentage** | **Rotation 1** | | | | | **Rotation 2** | | | | | **Rotation 3** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** | **25** | **50** | **100** | **150** | **200** |
| ------ | 1957 | 15.10% | 0.2 | 0.4 | 0.8 | 1.1 | 1.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.7 | 0.9 | 0.8 |
| A | 1830 | 14.10% | 1.1 | 1.3 | 1.8 | 2.3 | 2.9 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 0.8 | 1.3 | 1.7 | 1.7 |
| B | 6486 | 49.90% | 2.5 | 2.8 | 3.5 | 4.3 | 4.7 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.4 | 1.5 | 2.1 | 2.6 | 2.5 |
| C | 2056 | 15.80% | 5.5 | 6.1 | 7.3 | 8.6 | 10.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.9 | 3.2 | 4.1 | 4.9 | 4.8 |
| D / E | 658 | 5.10% | 9.9 | 10.8 | 12.8 | 14.9 | 17.1 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 5.4 | 5.8 | 7.2 | 8.5 | 8.5 |

# APPENDIX 8:

# PASTURES SNAP-PLUS METHODOLOGY

Table A8-1 summarizes the soil mapping unit, pasture type, area, distance to stream, animal density, and soil test results from the five sampling locations (3 farms) that were used as input parameters in the SNAP-Plus model. The grazing calculator, within the SNAP-Plus model, was used in conjunction with herd sizes and estimated pasturing durations (length of time animals were on the pasture) to determine the nutrient contributions to the soil from manure. These durations are specified below along with corresponding animal herd size.

**Table A8-1: Door Creek site specific input data and results for the pasture SNAP-Plus model.**

| **Pasture** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| **Soil Slope** | 27% | 2% | 9% | 4% | 4% |
| **Vegetation cover** | High | Medium | Low | Medium | Low |
| **Distance to surface water (ft)** | 1,001-5,000 | 1,001-5,000 | 1,001-5,000 | 1,001-5,000 | 1,001-5,000 |
| **Area (ac)** | 8 | 1.5 | 3 | 3 | 5 |
| **Animal Density (animals/acre)** | 1.25 | 6.67 | 10 | 3.33 | 0 |
| **P Concentration (ppm)** | 60 | 175 | 323 | 177 | 343 |
| **K Concentration (ppm)** | 186 | 496 | 1163 | 366 | 934 |
| **Organic Matter (%)** | 4.5 | 4.3 | 7.2 | 4.8 | 7.9 |
| **PI value** * | 11.5 | 5.9 | 23.7 | 8.9 | 7.9 |
| **Soil Loss (tons/ac/year)** * | 8.6 | 1.2 | 3.1 | 1.7 | 0.9 |

* = Actual results generated from the SNAP-Plus model

Pastures 1 and 2 (Farm 1):

Both pastures 1 and 2 have approximately 20 3-5 month old beef animals that are being grazed on two pastures 8.5 and 1.5 acres in size, respectively. In order to run the model, it was assumed that these steers were pastured 210 days out of the year (spring to fall) on both the KrE and VrB soils. This is a typical grazing pattern for cattle in southern Wisconsin. It is of note that pasture 1 had well-established grass on it, while pasture 2 had a poorer standing crop of grasses with intermittent exposed soil.

Pastures 3 and 4 (Farm 2)

Pastures 3 and 4 have approximately 40 Holstein milk cows grazing on them. Each pasture is approximately 3 acres in size. The vegetation in these two locations is of poor quality, with copious amounts of exposed, bare soil. It was assumed that these dairy cows occupied pasture 4 25% of the time for 210 days and pasture 3 50% of the time for 210 days. The remaining time the cows were assumed to be on a concrete feedlot. This was based on data collected from observations of animal activity and soil disturbance within the watershed.

Pasture 5 (Farm 3)

The idle pasture 5, is approximately 5 acres in size and was previously used to graze both yearling beef cattle and older steers. Although this pasture is no longer utilized, the vegetation in it is of poor quality, with areas of exposed soil. Since no animals are using the pasture, nutrient inputs for this field were 0.

# APPENDIX 9:

# MMSD METROGRO NUTRIENT CONTENT

**Table A9-1: Madison Metropolitan Sewerage District's Metrogro biosolids 2007 index of nutrients, metals, and other parameters.**

| Parameter | Concentration | EPA EQ Limit* | EPA Ceiling Limit | Units (Dry Weight) |
|---|---|---|---|---|
| **Total Solids** | 4.7 | NA | NA | % |
| **TKN** | 7.7 | NA | NA | % |
| **NH3-N** | 3.6 | NA | NA | % |
| **Total-K** | 0.9 | NA | NA | % |
| **Total-P** | 4.6 | NA | NA | % |
| **Arsenic** | 5.1 | 41 | 75 | mg/kg |
| **Cadmium** | 1.9 | 39 | 85 | mg/kg |
| **Chromium** | 44.0 | NA | NA | mg/kg |
| **Copper** | 681 | 1.5 | 4.3 | mg/kg |
| **Lead** | 45.3 | 300 | 840 | mg/kg |
| **Mercury** | 1.5 | 17 | 57 | mg/kg |
| **Molybdenum** | 24.7 | NA | 75 | mg/kg |
| **Nickel** | 26.0 | 420 | 420 | mg/kg |
| **Selenium** | 6.2 | 100 | 100 | mg/kg |
| **Zinc** | 820 | 2.8 | 7.5 | mg/kg |
| **PCB** | <0.013 | NA | NA | mg/kg |

The yearly index is averaged from weekly or monthly data. (Taylor, 2007).

# APPENDIX 10:

# MMSD SNAP-PLUS METHODOLOGY

A total of 53 fields that have had Metrogro applications at one time were identified within the Door Creek watershed. Of these 53 fields, 50 were entered into the SNAP-Plus model for analysis. The remaining three fields were not used because initial pre-Metrogro soil phosphorous values were not available. The areas of the 50 fields were obtained from both spatial data and application documentation obtained from MMSD. These values were compared for consistency before being entered into the SNAP-Plus model.

## SOILS, AREA, AND DISTANCE TO NEAREST STREAM

Once the field tracts to be modeled were located, the ArcGIS 9.2 geographical modeling software was used to determine the NRCS Soil Survey soil map units underlying each field. The GIS software was then used to calculate the areas for each soil mapping unit within the field tracts. In order to select the most susceptible soil map unit to enter into the SNAP-Plus model, the most susceptible soil to erosion that comprised at least 10% of the total field area was selected. This method was used in order to be in compliance with the NR590 standard (See Chapter 6).

GIS was also used in determining how far away each field was from surface water (Door Creek). A 300 ft, 1000 ft, and 5000 ft buffer was created around Door Creek and each of the 50 fields were evaluated and placed into one of these categories. This was done using a buffering tool which is just one of the many tools that GIS 9.2 has built into it. If a field was located within multiple buffers the lower (closer to the stream) category was chosen as the designation. Since the model is based on edge of field calculations the field edge closest to the stream should be evaluated to insure the accuracy of the model. This information was then entered into the SNAP-Plus interface for evaluation.

## SOIL PHOSPHORUS DATA

Soil test phosphorous data was entered into the model based on data obtained from MMSD. The range of sampling dates for this data is from 2000 to 2008 and the model was run with the most current soil test data that was available. However, this data was not complete in that we only had soil test phosphorous levels. In order to have the model run to completion we used Dane County averages for pH, organic matter, and potassium which were obtained from the UW-Madison's Soil and Plant Analysis Lab (UW-SPAL). These values were 6.6, 3.5%, 149 ppm respectively. These average values were then combined with the field-specific soil test phosphorous values and entered into the model.

## NUTRIENTS

Nutrient sources included within this model were both the conventional fertilizers applied during the years between Metrogro applications and the Metrogro applications themselves. Assumptions for the conventional fertilizer applications were made based on information obtained from agricultural surveys conducted within the watershed. The conventional fertilizers applied in the model were potassium sulfate and urea, which were selected to represent the potassium and nitrogen applications to the soybeans and wheat during the 3 year rotation.

The Metrogro applications were applied at the start of the three-year rotation to fields planted with corn grain. The exact application of phosphorous varied from field to field based on the nutrient content of the Metrogro product when it was applied. The primary goal of the product is to meet the nitrogen demands for the corn crop and is managed accordingly. Since the nutrient content of Metrogro for each application could not be obtained the amount of phosphorus applied to each field had to be estimated based on the average nutrient content of the Metrogro product in 2007.

The MMSD provided data on the amount of phosphorous applied to the fields during each application along with the 2007 average nutrient content of Metrogro. This allowed us to back-calculate the volumetric rate of Metrogro that was applied to the fields. SNAP-Plus contains a routine that calculates the mass of phosphorus per gallon of Metrogro based on the input parameters: percent solids, total phosphorus as a percentage of dry matter, and density. The 2007 average values of 4.70%, 4.60%, and 8.34 lbs/gallon, respectively, for these parameters were obtained from MMSD's website (MMSD, 2007). The density of phosphorus in Metrogro calculated by SNAP-Plus was 0.025 lbs of phosphorus per gallon of Metrogro. The amount of phosphorous (lbs/acre) applied to each field was then divided by the calculated density (0.025 lbs/gallon) to obtain an application rate of gallons of Metrogro per acre that was applied.

## CROPPING AND TILLAGE PRACTICES

A three-year cropping rotation of corn grain, soybeans, and winter wheat was assumed for all fields based on the typical rotations that MMSD applies Metrogro (M. Northouse, personal communication, July 30, 2009).

Tillage practices were assumed to be a spring chisel for corn followed by no-tillage for soybeans and wheat. These were selected for two reasons. The first is that according to MMSD, most farmers follow behind the Metrogro trucks with some sort of tillage practice before seeding. The second reason is that according to interviews conducted in the watershed these are the most common tillage practices for these crops. Crop yields of 150 bu/acre for corn, 50 bu/acre for soybeans, and 75 bu/acre for wheat were also assumed for the model based on the same interviews.

# APPENDIX 11:

# ALLOWABLE SOIL LOSS AND SOIL PHOSPHOROUS LEVELS

The following tables are expanded versions of those tables presented in Chapter 4.5.

**Table A11-1: Soil Test Phosphorus Levels from Door Creek Pasture Samples.**

| Door Creek Pasture Samples | OM<br>% | Bray P level<br>ppm | Initial suface Bray P1<br>ppm | Initial surface total P<br>mg/kg, ppm | Initial surface total P<br>lbs | **Allowable Soil loss, 7.5 t/ac/yr**<br>P loading lbs/ac/yr | **25% reduction Soil loss, 5.5 t/ac/yr**<br>P loading lbs/ac/yr | **50% reduction Soil loss, 3.5 t/ac/yr**<br>P loading lbs/ac/yr | **75% reduction Soil loss, 1.9 t/ac/yr**<br>P loading lbs/ac/yr |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.2 | 323 | 387.60 | 1941.99 | 0.001942 | 29.13 | 21.36 | 13.59 | 7.38 |
| 2 | 4.8 | 177 | 212.40 | 1045.36 | 0.001045 | 15.68 | 11.50 | 7.32 | 3.97 |
| 3 | 4.5 | 59 | 70.80 | 743.87 | 0.000744 | 11.16 | 8.18 | 5.21 | 2.83 |
| 4 | 4.4 | 60 | 72.00 | 731.16 | 0.000731 | 10.97 | 8.04 | 5.12 | 2.78 |
| 5 | 4.3 | 175 | 210.00 | 955.43 | 0.000955 | 14.33 | 10.51 | 6.69 | 3.63 |
| 6 | 7.9 | 343 | 411.60 | 2178.84 | 0.002179 | 32.68 | 23.97 | 15.25 | 8.28 |
| **Pasture Ave** | **5.5** | **190** | **227.40** | **1205.27** | **0.001205** | **18.08** | **13.26** | **8.44** | **4.58** |

These levels illustrate the range of soil test phosphorus levels attained by the Practicum and the resulting phosphorus loading that could be expected based on the USLE allowable soil loss level and 25%, 50%, and 75% reductions to the allowable soil loss level. OM = Organic Matter

**Table A11-2: Soil Test Phosphorus Levels based on 25%, 50% and 75% reductions to the allowable soil loss level in Dane County and the state of Wisconsin.**

|  | **OM**<br>% | **Bray P level**<br>ppm | **Initial surface Bray P1**<br>ppm | **Initial surface total P**<br>ppm | **Initial surface total P**<br>lbs | **Allowable Soil loss, 7.5 t/ac/yr**<br>**P loading** lbs/ac/yr | **25% reduction Soil loss, 5.5 t/ac/yr**<br>**P loading** lbs/ac/yr | **50% reduction Soil loss, 3.5 t/ac/yr**<br>**P loading** lbs/ac/yr | **75% reduction Soil loss, 1.9 t/ac/yr**<br>**P loading** lbs/ac/yr |
|---|---|---|---|---|---|---|---|---|---|
| **Dane County** | 3.5 | 56 | 67.2 | 598.59 | 0.000599 | 8.98 | 6.58 | 4.19 | 2.27 |
| **WI State** | 3.2[*] | 30[+] | 36 | 508.05 | 0.000508 | 7.62 | 5.59 | 3.56 | 1.93 |

[*] = State average.

[+] = Recommended levels.

OM = Organic Matter. (Panuska, 2008)

**Initial Surface Bray P1**: Soil test P level * stratification factor. Here, a stratification factor of 1.2 was used, representing fall chisel tillage.

**Initial Surface Total P**: (13+(2.7*%OM)+(0.03*initial surface Bray P1))^2. Conversion to pounds: divide by 10^6

**Determining Phosphorus Loading**:(Soil loss (tons)*2000)* Initial surface total P (lbs)

# APPENDIX REFERENCES:

Agricultural Resource Service (ARS). (2007). *Revised Universal Soil Loss Equation 2 – How RUSLE2 Computes Rill and Interrill Erosion*. Oxford, MS: United States Department of Agriculture. Retrieved on July 13, 2009 from http://www.ars.usda.gov/Research/docs.htm?docid=6014

Bundy, L. G., Mallarino, A. P., & Good, L. W. (2008). Field-Scale Tools for Reducing Nutrient Losses to Water Resources. In *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop* (pp. 159-170). September 26-28, 2005, Ames, Iowa. Sponsored by Iowa State University and EPA. Organized by the MRSHNC, Upper Mississippi River Sub-basin Hypoxia Nutrient Committee. St. Joseph,Michigan. Retrieved on July 5, 2009 from http://www.epa.gov/msbasin/pdf/symposia_ia_session12.pdf

Foster, G.R., Yoder, D.C., Weesies, G.A., & Toy, T.J. (2001). The Design Philosophy Behind RUSLE2: Evolution of an Empirical Model. In J.C. Ascough II & D.C. Flanagan (Eds.), *Soil Erosion Research for the 21st Century* (pp. 95-98). (Proc. Int. Symp. 3-5 January 2001, Honolulu, HI, USA). St. Joseph, MI: ASAE. 701P0007.

Good, L. W., & Panuska, J. (2008). *Current Calculations in the Wisconsin P Index*. Retrieved on July 5, 2009, from http://wpindex.soils.wisc.edu/assets/PIndexCalculationsDec08.pdf

Good, L. W. (2005). *The Wisconsin Phosphorus Index.* Retrieved on July 5, 2009 from http://wpindex.soils.wisc.edu/pi.php

Madison Metropolitan Sewage District (MMSD). (2007). *Metrogro Biosolids Quality-2007 Average Values*. Retrieved on July 5, 2009 from http://www.madsewer.org/ProgramsAndInitiatives/BiosolidsAndEMS/Metrogro/MetrogroBiosolidsQuality.pdf

National Resources Conservation Service. (2006). *National Food Security Act Manual, Fourth Edition: Highly Erodible Land Determinations* (Electronic Directives System M_180_511 – Fourth Edition Amendment 1). Washington, D.C.: United States Department of Agriculture. Retrieved on July 13, 2009 from http://policy.nrcs.usda.gov/Default.aspx

National Resources Conservation Service. (2009). *Soil Survey Geographic (SSURGO) database for Dane County, Wisconsin.* (wi025). Fort Worth, TX: United States.Department of Agriculture. Retrieved on July 13, 2009 from http://www.ftw.nrcs.usda.gov/ssur_data.html

Pearson, B., Good, L. W., Kaarakka, P., Bundy, L., Erb, K., & Jarrell, W. (2004). *SNAP-Plus – Nutrient Management Software for Wisconsin* [PDF document]. Retrieved on July 5, 2009 from http://www.soils.wisc.edu/extension/wcmc/2004proceedings/Pearson.pdf

Stuntebeck, T D., Komiskey, M. J., Owens, D. W., & Hall, D. W. (2008). *Methods of Data Collection, Sample Processing, and Data Analysis for Edge-of-Field, Streamgaging, Subsurface-Tile, and Meteorological Stations at Discovery Farms and Pioneer Farm in Wisconsin, 2001-7.* (U.S. Geological Survey Open-File Report 2008-1015, 60 p.)

Taylor, D. (2007). *Metrogro Biosolids Quality-2007 Average Values*. Retrieved on June 6, 2009 from http://www.madsewer.org/Metrogro.htm

University of Wisconsin Soil and Plant Analysis Lab (UW-SPAL). *Wisconsin Soil Test Summer 2000-2004.* Retrieved on July 5, 2009 from http://uwlab.soils.wisc.edu/madison/

USDA-Agricultural Research Service. (2005). *Revised Universal Soil Loss Equation 2 – Overview of RUSLE2.* Retrieved on July 5, 2009 from http://www.ars.usda.gov/research/docs.htm?docid=6010

Yoder, D.C., Foster, G.R., Weesies, G.A., Renard, K.G., McCool, D.K., & Lown, J.B. *Evaluation of the RUSLE Soil Erosion Model*. Article within AGRICULTURAL NON-POINT SOURCE WATER QUALITY MODELS: THEIR USE AND APPLICATION (Southern Cooperative Series Bulletin #398, July, 2001, updated July, 2004). http://www.bae.ncsu.edu/www3/acad/Regional-Bulletins/Modeling-Bulletin/rusle-yoder-001016.html

THE NELSON INSTITUTE
FOR ENVIRONMENTAL STUDIES
University of Wisconsin-Madison

TOGETHER. FOR THE PLANET.