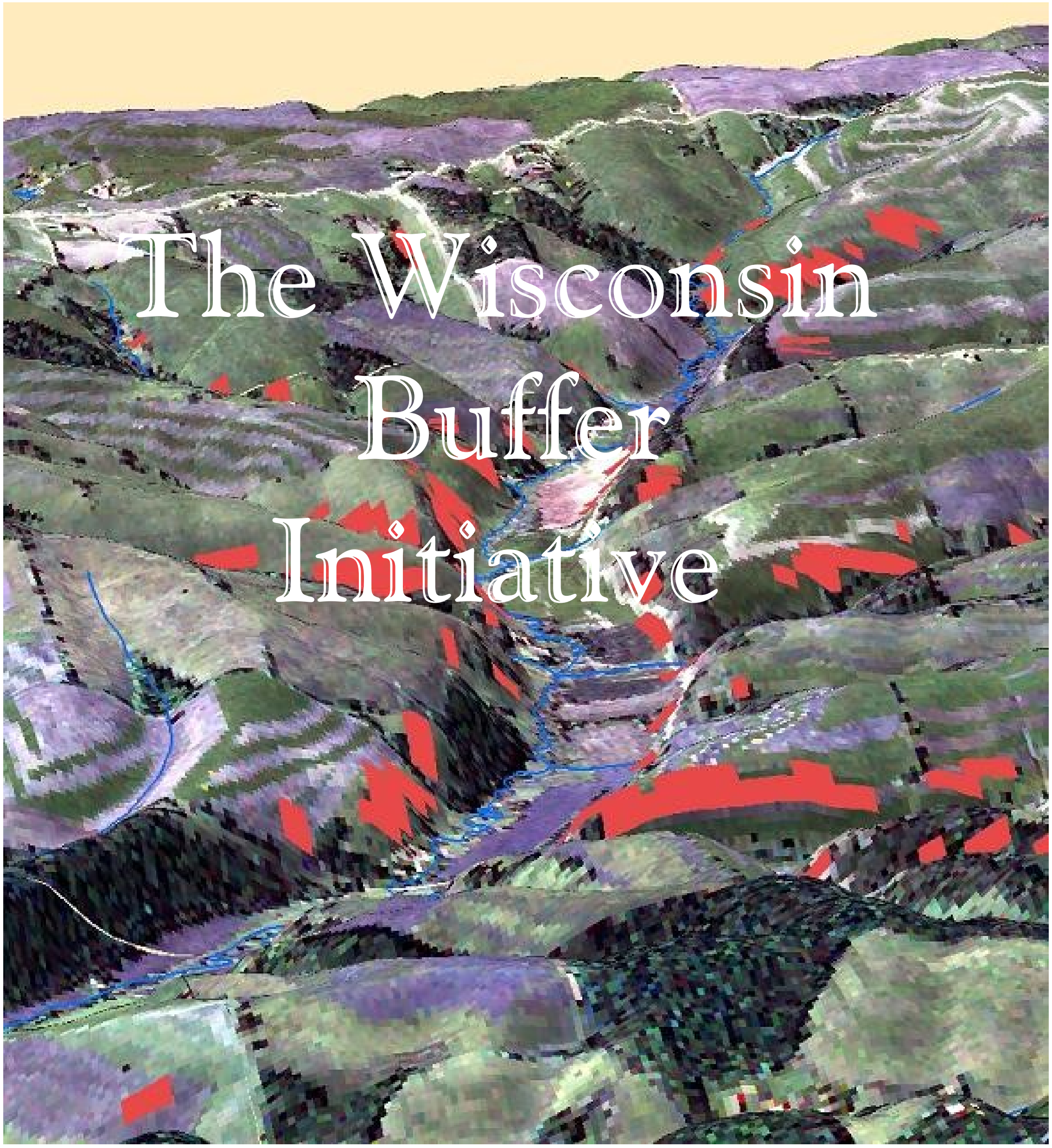



A Report to the Natural Resources Board of the Wisconsin Department of Natural Resources by the University of Wisconsin-Madison, College of Agricultural and Life Sciences.
December 22, 2005

COLLEGE OF AGRICULTURAL & LIFE SCIENCES
UNIVERSITY OF WISCONSIN-MADISON

THE UNIVERSITY of WISCONSIN MADISON

December 29, 2005

To: Secretary P. Scott Hassett, Wisconsin Department of Natural Resources
Members of the Natural Resources Board

From: David Hogg, Interim Dean

Re: Report of the Wisconsin Buffer Initiative

In the spring of 2002 you requested that faculty in the UW-Madison College of Agricultural and Life Sciences (CALS) review the research literature relating to riparian buffer effectiveness as part of your deliberations on the revision of NR 151. The University responded by convening a group of university, agency, environmental and agricultural and natural resources representatives that reviewed the scientific literature and recommended an adaptive management approach to more precisely design and locate buffers in Wisconsin. On the basis of that interim report, the NR Board passed a resolution directing CALS to conduct the necessary research that would help determine effectiveness of buffers under various Wisconsin conditions with a final report delivered to you on or before December 31, 2005.

Over the last 30 months scientists in CALS have collaborated with colleagues in the UW-Madison Center for Limnology to address your charge. The following report reflects the research and analysis that was conducted to examine the potential role of riparian buffers as part of Wisconsin NR 151.

A critical dimension of the work conducted over the last 30 months was the extensive collaboration with agricultural, environmental, natural resource professional associations, and our state and federal agencies. Our faculty worked closely with all these diverse groups to help specify what research needed to be conducted, how this research should be carried out, and the implications of the data that emerged from this research. There is a general agreement by all these diverse groups and interests that the recommendations contained in this report are the best way to use buffers to address the water quality concerns in Wisconsin.

Finally I believe that this report reflects the willingness of UW-Madison to work with state agencies in a cooperative partnership that serves to advance our joint mission of better serving the citizens of Wisconsin.

Office of the Dean
College of Agricultural and Life Sciences
140 Agricultural Hall 1450 Linden Drive Madison, Wisconsin 53706
608/262–1251 Fax: 608/262–4556

# Table of Contents

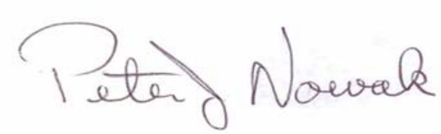
# Acknowledgements

As Chair of the Wisconsin Buffer Initiative I write this acknowledge page with a sense of both humility and optimism. Humility because literally hundreds of Wisconsin citizens contributed to this report and need to be acknowledged. The initial goals, and then the progress toward those goals, were brought to the citizens of Wisconsin in the town halls, schools and other meeting places across Wisconsin. The insights, comments and suggestions of these citizens were then brought back to the Wisconsin Buffer Initiative Advisory Committee. Here citizen and scientist worked side-by-side as equals in trying to determine how to address a complex and contentious issue. In the end, the title of Advisory Committee proved to be a misnomer. This group of citizens, scientists and agency staff provided the leadership and courage to chart a new course for natural resource management in Wisconsin. Representatives from the environmental and agricultural communities of Wisconsin, while acknowledging their differences, also found a higher, common ground. Staff from federal and state agencies, as well as representatives from professional conservation associations, were receptive and supportive of seeking innovative approaches consistent with a challenging fiscal climate. Scientists and staff from the University of Wisconsin-Madison proved through their actions that the core philosophy of the "Wisconsin Idea" is still a vibrant and an invigorating a concept as it was when originally conceived over a hundred years ago. To each and every member of this group I offer my sincere thanks for your commitment to proving the ideal that by working together we can find solutions that were beyond the grasp on any one of us. You have given me a sense of optimism relative to the future of resource management in Wisconsin.

A special acknowledgement is also due to Senator Herb Kohl who helped secure federal funds that allowed this citizen-driven experiment in natural resource management policy to flourish. His faith in creating an opportunity for Wisconsin's Land Grant University to work with the citizens of Wisconsin in charting their own future is especially appreciated.

An effort such as the Wisconsin Buffer Initiative does not occur without the explicit support from the leaders of the University of Wisconsin, agencies and organizations who have been represented in this effort. You have my thanks for allowing your staff to be bold and creative in their thinking and actions. I believe this report demonstrates that your support was justified.

Sincerely,



Pete Nowak, Chair, Wisconsin Buffer Initiative, December 21, 2005

# Executive Summary

> *The Wisconsin reformers have accomplished the extraordinary results for which the whole nation owes them so much…as soon as they decided that a certain object was desirable they at once set to work practically to study how to develop the constructive machinery through which it could be achieved….That state has become literally a laboratory for wise experimental legislation aiming to secure the social and political betterment of the people as a whole.—Teddy Roosevelt 1912*

Wisconsin's water resources are among its most critical economic, ecological, and cultural assets. Although human activities have degraded many of our freshwater resources, progress has been made in addressing many sources of degradation. Agricultural nonpoint-source pollution, however, remains a persistent problem, in part because of its diffuse nature and in part because of the high economic value of agriculture in Wisconsin. Recently, the Wisconsin Natural Resources (NR) Board identified a need for new and innovative strategies for reducing agricultural pollution. The Wisconsin Buffer Initiative (WBI) was formed in response to this need. The goal of the WBI was designing a buffer implementation program to achieve water quality improvements for Wisconsin in the most cost-effective and efficient manner.

The WBI approach differs dramatically from other natural resource management approaches in many ways. The hallmark of WBI is the use of a science-based approach to carefully target conservation efforts, including buffer locations and configurations, so as to maximize water quality improvements. This approach is both effective and efficient. In addition, the WBI advocates for the use of watershed-level adaptive management. Watersheds are the units of program implementation, and water quality is monitored in response to implementation. On-the-ground projects are viewed as opportunities for learning, and are intended to greatly accelerate improvements in policy.

This report is organized into ten chapters. Chapters 1–3 discuss the **genesis and direction of the WBI**. Revisions to the state administrative rules on nonpoint-source pollution (NR151) resulted in an impasse over the issue of mandatory implementation of riparian buffers. In May 2002, the Wisconsin NR Board directed the Wisconsin Department of Natural Resources to collaborate with the University of Wisconsin College of Agricultural and Life Sciences on the development of a scientifically-based agricultural buffer standard. The WBI was formed to facilitate the enhancement and synthesis of the best available research on riparian buffers. A civic science process involving a wide range of stakeholders was driven by addressing the following questions:

1. Where are buffers needed most across the diverse landscapes and land use in Wisconsin?
2. What types of buffers are needed in these specific locations?
3. What are the consequences when buffers are installed in these locations?
4. What will be needed to get these buffers into these specific locations?

The remainder of the report describes how the WBI addressed each of these questions.

Chapter 4 describes the rationale for using an **adaptive management approach** to reducing nonpoint-source pollution. A major goal of the WBI was to *design an efficient and cost-effective statewide program for achieving water quality improvements*. Consequently, the WBI advocates an adaptive management approach whereby policy is designed to learn from implementation experience and is modified on the basis of new knowledge. Management is based on the best available science, but is structured so as to learn from uncertainty and surprises.

Chapter 5 presents the **statewide prioritization of watersheds**. Small watersheds are most likely to provide measurable improvements in stream water quality. Scientists at the University of Wisconsin-Madison ranked 1598 watersheds throughout the state of Wisconsin on their potential to meet three management goals:

- Improve stream water quality
- Protect and enhance aquatic biological communities
- Sustain lake water quality

These management goals were developed by the WBI Advisory Committee and used to guide the statewide analysis. Data from state and federal agencies were used to build statistical models to identify watersheds that are most likely to respond to reductions of phosphorus and sediment through the implementation of conservation practices. The analyses were then used to compile a ranked list of watersheds to be targeted for more intensive conservation efforts. A **poster** (enclosed) displays a map of the ranked watersheds, and also summarizes the WBI targeting approach.

Chapter 6 describes procedures to aid local conservation staff in **planning and implementing conservation systems** in selected WBI watersheds. Local knowledge of watershed conditions can verify that selected watersheds have the capacity to respond effectively to conservation practices. A simple computer model of soil loss can be used to identify subwatershed areas that are most likely to be contributing to water quality impairment. On individual farms, SNAP-Plus software (developed by UW-Madison scientists) can be used to conduct field-level management need analysis. This software can also simulate changes in soil and nutrient losses under different management scenarios, such as changes in crop rotations, tillage, manure application, and buffer implementation.

If buffers are found to be an effective and favorable management practice for an individual field, the **placement and design of riparian buffers** (Chapter 7) should be determined by a contributing area analysis. In this approach, sections of buffer that receive runoff from larger drainage areas are wider than sections with small drainage areas. Allowing for contributing area more effectively removes soil and nutrients from runoff than constant width buffers, and it reduces the amount of land taken out of production.

A **pilot study** (Chapter 8) was conducted in two Wisconsin watersheds to examine the feasibility of the targeting and implementation process proposed by the WBI and to receive feedback from local conservation staff. Farm management and soil information was fed into SNAP-Plus to evaluate the need for management changes and to compare the projected **economic consequences** (Chapter 9) of various management options. Most of the fields had predicted soil and phosphorus losses below current Natural Resources Conservation Service (NRCS) 590 standards. Of those fields that exceeded thresholds, feasible management changes, such as tillage changes, would correct problems. In many instances, these changes would result in increased farm profitability.

The work described in this report is the foundation for the WBI final **recommendations** (Chapter 10) for a statewide program for riparian buffers. Our program carefully targets conservation efforts, thus maximizing efficiency, while simultaneously providing the environmental improvements that the public demands. The WBI feels that adoption of this approach for nonpoint source pollution will elevate Wisconsin to its former position as a national leader in innovative policy and natural resource management. Perhaps more importantly, the civic science approach of the WBI exemplifies the Wisconsin Idea. Our hope is that these efforts will serve as the foundation for far-sighted and innovative policy that will contribute to the betterment of the citizens and the natural resources of the State of Wisconsin.

# 1. Genesis of the Wisconsin Buffer Initiative (WBI)

Wisconsin has a rich and diverse array of water resources; over 15,000 inland lakes are interconnected with 32,000 miles of perennial streams and rivers, which are complemented by another 23,000 miles of intermittent streams. These waters drain into the Mississippi River, Lake Superior, or Lake Michigan while recharging over two quadrillion gallons of groundwater (Wisconsin Academy of Sciences, Arts and Letters 2003). Wisconsin also has a rich and diverse agricultural economy, which is represented by 76,500 farms operating across 15.5 million acres that generate almost $7 billion dollars in receipts (USDA National Agricultural Statistical Service 2005). Besides being the number one producer of cheese in the United States, our agricultural diversity is represented by the fact that Wisconsin is among the top five producers of oats, potatoes, cranberries, tart cherries, carrots, snap beans, sweet corn, and, as would be expected with the dairy industry, corn for silage. Given Wisconsin's diverse agricultural systems and their importance to the state's economy, it is inevitable that farming in some situations and at some times would impair our rich water resources.

Protecting our water resources is a major priority for all the citizens of Wisconsin—urban, suburban, rural, and farm. The Wisconsin Buffer Initiative (WBI) believes that Wisconsin can have both a viable agricultural system and quality water resources. This belief also served as a guiding principle during the genesis of the WBI. The WBI began as a scientific review of riparian buffers[1] in support of potential rule changes for Wisconsin's regulation of nonpoint source pollution. Since its inception, the effort has evolved into a demonstration of how diverse interests can work together to chart a course for protecting the state's waters. Understanding the history that led to the formation of the WBI is necessary to appreciate the recommendations that have emerged from this diverse coalition.

## *Wisconsin's Nonpoint-Source Pollution Programs*

In 1977, the Wisconsin Department of Natural Resources (DNR) created a grant program, then known as NR 418 or the DNR Priority Watershed and Priority Lake Program, to address the issue of nonpoint-source water pollution. From the inception of this program through June 2004, over $187 million was spent on local assistance and cost share grants to protect the state's waters from nonpoint source pollution. On the basis of area-wide water quality plans developed under the requirements of the Federal Water Pollution Control Act, the DNR identified watersheds and lakes in which the need for nonpoint pollution control was most critical. High- or medium-priority watersheds became eligible for funding based on an analysis of DNR district workload, county ability to manage a project, and projected landowner participation. The Wisconsin Legislature in 1997 directed the DNR to re-rank all watersheds in the state based on the level of impairment. Current priority watershed projects (n = 62) that were active were to be terminated under Wisconsin Act 27 unless they were designated a priority by the

[1] The term "buffer" in this report refers to a riparian (along a stream or river) buffer. The WBI acknowledges that the US Department of Agriculture Natural Resources Conservation Service defines at least nine different types of buffers appropriate to Wisconsin. The term "buffer program" in this report refers to an organized effort to implement agricultural conservation practices, including the installation of buffers, for the purpose of improving water quality.

Wisconsin Land and Water Conservation Board. The Land and Water Board subsequently re-designated all 62 projects as priorities. Then, in the 1999–2001 biannual state budget, the Wisconsin Legislature made a number of major modifications to the nonpoint-source pollution-abatement program. The Legislature also revamped the various administrative rules that govern nonpoint source pollution in both rural and urban settings. These revisions included NR 151 through NR 155 and ACTP 50. These changes in the administrative code and administration of the nonpoint program are often referred to as the Redesign of the Nonpoint Pollution Program.

## The Role of Riparian Buffers in Nonpoint-Source Pollution Control

As noted, provisions by the Wisconsin Legislature, Act 27 in 1997 and Act 9 in 1999, directed the DNR to develop performance standards to control polluted runoff from non–agricultural activities, develop performance standards and prohibitions for agricultural activities in cooperation with the Department of Agriculture, Trade and Consumer Protection (DATCP) including four manure management prohibitions developed through a previous advisory committee effort, and to make other changes to address polluted runoff problems from rural and urban sources.

In response to these Legislative directives, a series of technical recommendations and suggested administrative code language were developed. An agency-appointed advisory committee then solicited and generated feedback and public comments as part of the process of developing specific implementation recommendations. Although a broad spectrum of citizens and vested interests participated in this process, consensus was not reached on all issues. In particular, one remaining controversial aspect was associated with the issue of mandatory riparian buffers.

Specifically, the work group developing rules for the implementation of NR 151 recommended a ten-foot vegetated buffer with 50% crop residue on the next ninety feet of cropland adjacent to the riparian area, a twenty-foot vegetated buffer in the riparian zone with 30% residue on the next thirty feet on adjacent cropland, or a thirty-five-foot vegetated buffer in the agricultural riparian areas of the state. Mandating this combination of riparian buffers and conservation tillage in water-quality management areas (i.e., those areas proximate to a river, stream, or lake) proved to be a contentious recommendation. Environmental interests viewed this recommendation as necessary to protect the state's waters, while agricultural interests viewed it as imposing a hardship on the state's agricultural producers.

What emerged in this debate over mandated riparian buffers was the question of scientific justification for this position: both sides, pro and con, appeared to use scientific justifications to support their position. In response to this impasse, DNR Secretary Darrell Bazzell sent a request to Elton Aberle, Dean of the University of Wisconsin-Madison College of Agricultural and Life Sciences (CALS) to review the science on the functioning of riparian buffers.

In response to this request, an ad hoc committee was formed of UW-Madison scientists with expertise in this area. In addition to the scientists, every effort was made to include all of the vested interests that had been involved in the larger discussions with the Wisconsin Legislature and the DNR. Operating under a sixty-day deadline, this group issued a report on April 26, 2002, (*Filter Strips and Buffers on Wisconsin's Private Lands: An Opportunity for Adaptive Management*) and an 890-item scientific bibliography on this topic (Correll 2003). This report was brought before the NR Board in May 2002.

There were several key elements in the ad hoc committee report that had a major influence on the subsequent activities of the WBI. In particular, these elements included:

- Implementing NR 151 relative to riparian buffers should be based on an adaptive management approach. (Chapter 4 of this report discusses this in depth.)
- Research reviewed in this process clearly specified that riparian buffers can have many potential benefits, but the nature and extent to which any of these benefits are achieved is very site specific. Thus, the issue is not whether buffers are good, but where across Wisconsin's diverse landscape can riparian buffers achieve the most benefit for water quality in accord with the intent of NR 151.
- The ad hoc report also noted that riparian buffers by themselves would be unlikely to induce significant changes in the quality of the state's waters. Riparian buffers need to be part of a larger conservation system.
- Due to the potential to take land out of production as part of the process of installing conservation systems and riparian buffers, the ad hoc report emphasized the importance of the private landowner on whose land riparian buffers are needed being an integral part of the overall process.

The NR Board accepted this ad hoc report and asked the UW-Madison CALS to carry out the necessary research and activities to address the recommendations contained in the April 2002 report. The UW-Madison CALS was to submit a final report containing their research and activities to the NR Board on or before December 31, 2005.

## *The Charge of the Wisconsin Buffer Initiative*

The WBI was officially developed in response to this charge from the NR Board:

> **Based on the best available science, where across the diverse Wisconsin agricultural landscape would conservation systems and riparian buffers enhance the quality of the state's waters?**

The Dean of UW-Madison CALS appointed a committee of scientists to work with the agencies, organizations, and citizens of Wisconsin. This group formed the WBI and was made up of an executive committee and an advisory committee. The WBI Executive Committee consisted of representatives from state and federal natural resource agencies and UW scientists. The WBI Advisory Committee operated under an open door policy in that any vested interest was welcome to participate. Meetings of the WBI Advisory Committee have been held approximately every quarter since its formation in 2002. The WBI Executive Committee met during the first year of the WBI to establish the direction and decision protocols but has been relatively inactive since that time.

It is important to note that although UW scientists composed a significant part of the WBI Advisory Committee, the WBI was not intended as a top-down process. Rather than beginning with scientific facts and asking for commentary on those facts, the WBI process purposively began with a blank agenda other than the initial charge from the NR Board. This civic science strategy allowed for an initial, open exchange between all vested interests on what research questions needed to be addressed and what type of research would have credibility for all WBI participants and the landowners of Wisconsin.

**References**

Correll, D. 2003. Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances (Thirteenth Edition). Available at http://www.unl.edu/nac/ripzone03.htm.

USDA National Agricultural Statistical Service. 2005. Wisconsin Annual Statistical Bulletin. Available at: http://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Annual_Statistical_Bulletin/index.asp

Wisconsin Academy of Sciences, Arts and Letters. 2003. Wisconsin's Waters: A Confluence of Perspectives. *Transactions* 30.

## 2. Establishing the Course for the WBI

The WBI used the process of civic science to meet the charge of the NR Board. Civic science occurs when citizen and scientist work together, with neither viewed as superior or subordinate, to develop an agenda, determine appropriate methodology, and agree on a desired outcome to this agenda. Both citizen and scientist are recognized as having valuable contributions to make to meet the mutually desirable outcome. Each group gains from participation in this process. Scientists begin to understand both the concerns and knowledge of participating citizens. In turn, these citizens begin to understand the complexity and challenges associated with conducting robust and valid research.

### *WBI Participants*

In addition to the UW scientists, representatives from the River Alliance of Wisconsin, Trout Unlimited, Wisconsin's Environmental Decade (Clean Wisconsin), The Nature Conservancy, Farm Bureau Federation, Wisconsin Corn Growers Association, and Professional Dairy Producers of Wisconsin participated in this process. Professional associations such as the Wisconsin Association of Land Conservation Employees (WALCE) and the Wisconsin Land and Water Conservation Association (WLWCA) were also active participants, as were representatives from both state and federal conservation agencies that included the DNR, DATCP, US Department of Agriculture Natural Resources Conservation Service (NRCS), US Department of Agriculture Farm Services Agency (FSA), and US Geological Survey (USGS). Input was also sought from constituencies from outside the WBI on a regular basis; several dozen presentations were made each year at meetings ranging from local town meetings to statewide association conferences. Ideas and comments from these meetings were then brought before the WBI Advisory Committee for consideration.

### *Addressing the Question of Buffers*

Many of the initial WBI Advisory Committee meetings were spent gauging positions and commitment from those participants who had been involved in the earlier Redesign of the Nonpoint Pollution Program debates. Early discussions at these meetings vacillated between "buffers are good" arguments to "protect private property rights" positions. Rather than debating the merits of these two contrasting positions, both of which have merit, the discussion was refocused on the type of research necessary to begin to address underlying commonalities. Consensus was finally reached on four basic questions that needed to be addressed by the WBI.

- Where are buffers most needed across the diverse landscapes and land uses found in Wisconsin?
- What *types* of buffers are needed in these specific locations?
- What are the consequences when buffers are installed in these specific locations?
- What will be needed to get these buffers into these specific locations?

Subcommittees were formed to address each of these core questions, with the intention that each subcommittee would meet independently to develop recommendations to submit to the full WBI Advisory Committee.

With these core questions established and a committee structure developed, the WBI discussion turned to what is known about buffers from both a scientific and programmatic viewpoint. Many of the participants in the WBI went on a two-day fact-finding trip to central Iowa. Iowa is often cited as a leader in the Midwest relative to the amount of riparian buffers it has installed during the last decade using federal and state conservation programs. This trip gave WBI participants the opportunity to view some of Iowa's buffer efforts and to discuss buffer programs with local, state, and federal program managers.

As acknowledged in the 2002 ad hoc committee report, buffers can have benefits relative to water quality, wildlife, endangered species, and aesthetic values, among others. However, in keeping with the charge from the NR Board, a decision was made early in the WBI process to focus on the water quality benefits of riparian buffers as part of NR 151.

## WBI Decisions on the Role of Riparian Buffers in Intervention Efforts

The outcome of early discussions—recognizing that buffers need to be part of a larger conservation system and that this system needs to be designed to address water quality concerns—became the foundation for the development of the specific research challenges for UW scientists. This decision implied shifting the intervention effort from trying to stop the water at the stream edge (the focus of the original controversy) to an intervention effort that used an array of conservation practices further up on the landscape to minimize the amount of water reaching the riparian area. Riparian buffers were viewed in subsequent WBI discussions as a measure that would be recommended only if these changes further up in the landscape could not adequately address the water quality concerns.

The WBI further decided that water quality should determine whether assessment of intervention efforts is necessary; if water quality indicates that intervention is needed, then the intervention should begin on the landscape draining into the riparian area of concern. A systems approach should be used in which conservation practices in the upland areas minimize the transport of pollutants into the riparian area.

Much of the scientific literature on buffers examines the design and composition of buffers relative to their effectiveness in isolation or an experimental setting. These buffers were then assessed regarding their ability to remove sediments and nutrients. Yet the systems approach adopted by the WBI asked the question, why allow these sediments and nutrients to move to the riparian area in the first place? Would it not be more effective to retard the movement of sediments and nutrients in the upland area, thereby minimizing the need for large buffers in the riparian area? This broader perspective that buffers are part of conservation systems means that WBI recommendations are cognizant of and compatible with other soil conservation and water quality programs and regulations.

Both the agricultural and environmental interests in the WBI process were interested in protecting water quality. All of those involved recognized that taking a significant amount of land out of production in riparian areas would be both controversial and expensive. <u>Consequently, a conservation systems approach appealed to all sides because water quality would be protected while the amount of land taken out of production would be minimized.</u>

## Using the Best Available Science to Address the Buffer Question

The complementary role of conservation systems and riparian buffers in the WBI recommendations is nothing new as conservationists have been advocating this approach for decades. What is new is how the best available science was used to advance this perspective regarding the four questions underlying the WBI process. In particular, the first question (*Where are buffers most needed across the diverse landscapes and land uses found in Wisconsin?*) is where the WBI scientists made significant advances. As will be explained in the next chapters of this report, two critical qualifications were added to this basic question.

First, contributions of WBI scientists advanced the first question from simply asking *where* to one that asked *where is the greatest probability of getting a meaningful water quality response to the implementation of conservation systems including riparian buffers.* This rephrased question implied the need to rank the diversity of Wisconsin's agricultural landscapes using a common set of criteria. After a significant amount of discussion, the WBI Advisory Committee agreed that the watersheds in the Wisconsin landscape should be ranked on the ability to (1) improve stream water quality, (2) protect and restore aquatic biological communities, and (3) sustain lake water quality. As addressed later in the report, a critical question to this ranking process was the delineation and selection of the watersheds being ranked.

The second, science-based contribution of the WBI was to specify what should happen within the ranked watersheds. Participants agreed that simply identifying priority areas was insufficient, so procedures were developed to identify the specific portions of the landscape that had the greatest probability of contributing to water quality degradation. The conservation systems and riparian buffer approach would initially be advanced in these areas in order to maximize the probability of positive water quality responses.

Ultimately, the WBI began by looking at the state and ended by focusing on specific fields. This focus was achieved by using the best available science to craft a strategic decision that resulted in identifying specific areas where local activities would have the greatest probability of achieving intended water quality outcomes. Besides the inherent effectiveness and efficiency associated with this approach, the WBI collaboration found acceptance to this strategy across a wide spectrum of different interests.

## *Conclusion*

No specific recommendation will be made regarding the civic science process followed by the WBI participants, but it is hoped that those who read this report will recognize that this process should be considered when addressing other natural resource management issues. The civic science philosophy embedded in the WBI bears repeating in other settings because it was much more than simply facilitating public participation. The diverse interests represented in the WBI were equal participants in a process that guided and assessed the scientific contributions of UW-Madison researchers. The contributions of these diverse groups were indispensable to the WBI process, and their efforts have fundamentally strengthened the WBI's final product. The close collaboration between these diverse interests and the University that comprised the WBI process exemplifies the Wisconsin Idea—that our state academic institutions should contribute directly to the betterment of the citizens of Wisconsin.

# 3. Research Questions on Conservation Systems and Riparian Buffers in Wisconsin

The previous chapter described how the WBI used the civic process to focus on specific questions that would become part of the final recommendations. Although the NR Board acknowledged the diversity of the agricultural landscape in its charge to the WBI, it did not specify which watersheds to study. The agricultural land within these watershed units can vary significantly. Moreover, there can be important variation within farms located in these watersheds. Finally, if strategic placement of a conservation system, possibly including riparian buffers, needs to occur, then this implementation may include the subfield, the farm, and possibly portions of neighboring farms. Thus, in response to the earlier "where in Wisconsin" question, it was agreed that WBI research needed to address questions that range from the entire state of Wisconsin down to the subfield. Consequently, the original four basic questions (p.6) evolved into the following four specific questions:

1. How do we develop a buffer implementation strategy based on adaptive management?
2. How do we identify the watersheds that have the greatest probability of showing demonstrable improvements with investment in conservation and buffer systems?
3. What types of tools can be developed that can be employed at the local level to assess watersheds and fields where conservation and buffer systems have the greatest probability of addressing water quality degradation?
4. How do we develop techniques for determining the optimal placement and configuration of conservation and buffer systems on designated landscapes?

Each of these questions was used to solicit additional research from UW scientists that generated information that was then used to develop WBI recommendations. Much of this research was based on cooperative efforts with ongoing research. This included research being conducted by the Wisconsin Agricultural Stewardship Initiative on Discovery Farms, farm systems research being conducted at the UW-Platteville Pioneer Farm, UW-Madison Center for Limnology, and UW-Madison CALS work on related nutrient management and conservation research as part of the Wisconsin Agricultural Experiment Station research agenda. This ability to leverage WBI funds with ongoing research allowed the WBI to develop the impressive and rigorous set of research findings that underlie the WBI recommendations. It should be emphasized that the recommendations developed from this research are based on the best available science at this time in accord with the charge from the NR Board.

# 4. Adaptive Management as a Basis for Natural Resource Management Programs

*Solutions to problems cannot be commanded.*
*They must be discovered.*

*—Lee 1993*

A major goal of the WBI is to set a course for achieving *measurable and substantial* improvements in water quality in the most efficient and cost-effective manner. An early outcome of the WBI process was recognition of the uncertainty associated with predicting the effectiveness of measures intended to protect and improve water quality. There was also recognition that cause-and-effect relationships are often not well-known, and that current knowledge does not provide easy answers as to how to best address Wisconsin's water quality concerns. Finally, unexpected outcomes (surprises) are surprisingly common in natural resource management. WBI participants maintained diverse ideas about the most effective approach for making improvements in water quality. Rather than reaching a stalemate regarding this lack of consensus, the WBI came to realize that this represented an opportunity to embrace these diverse views and employ a resource management approach called *adaptive management*.

What is the WBI's vision of adaptive management? The starting point is the WBI watershed (Chapter 5) as the scientifically appropriate "management unit." The WBI watersheds are large and complex systems. Environmental data are limited and science does not provide adequate theory to allow precise prediction of how in-stream water quality will respond to implementation of the WBI recommendations. Uncertainty comes in two forms: (1) how much and how quickly in-stream water quality will respond to the implementation of buffers, and (2) what are the most effective ways to go about implementing WBI recommendations. The first involves exclusively the response of the natural ecosystem to implementation, and the second involves the broader socio-ecological system.

Implementation of our recommendations in WBI watersheds (Chapter 5) should be viewed as ecosystem experiments and should serve as the primary vehicle for learning and generating new knowledge. Adaptive

### *Natural Resource Management Approaches*

One way to understand adaptive management is to contrast it with other natural resource management approaches. Each has different ways of dealing with the uncertainty and unexpected outcomes.

- Externally prescribed: "thou shalt" regulations from a regulatory agency. This approach largely ignores uncertainty and unanticipated outcomes, resulting in episodic changes to the regulations.
- Error and no trial: based on theories such as how markets work, how people make decisions, or the appropriate role of government. While the theory often attempts to account for uncertainty, unanticipated circumstances often cause error and inefficiency.
- Trial and error: policy is tested on a small scale to assess whether large-scale implementation is feasible and effective. This is dependent on whether conditions of the small-scale test can be extended to the larger area.
- Adaptive management: policy is designed to learn from implementation experience and is adapted on the basis of new knowledge. One goes forward based on current knowledge, but structures the process so as to learn from unexpected outcomes.

management is a formal process for continually improving management policies and practices by learning from the outcomes of implementation. Surprises in ecosystem response are not viewed as failures but, instead, as a source for learning better ways of accomplishing water quality goals. There are four central pillars to the WBI adaptive management approach:

1. Use of reference and treatment watersheds
2. Replication of watersheds
3. Environmental monitoring
4. Adapting the program in response to new knowledge

Use of reference watersheds ensure that changes are not driven by external factors such as weather. Replication is needed because for knowledge to be reliable, it needs to be shown to work on more than one ecosystem. Monitoring is designed to detect ecosystem-level changes, such as sediment-sensitive indicator species and loads of nitrogen, phosphorus, and suspended sediments. These ecosystem experiments accelerate the rate of learning, and new knowledge feeds back into on-the-ground management and allows for constant improvement. Furthermore, the effectiveness of competing or alternative management approaches can be compared within the WBI adaptive management framework.

## *Monitoring in Adaptive Management*

As noted above, monitoring is central to the adaptive management process. Adaptive management is based on learning from current management efforts. The WBI Advisory Committee has developed a set of recommendations for monitoring the implementation of conservation systems and riparian buffers (Appendix A). The recommendations were developed around a series of core questions that emerged from WBI Advisory Committee discussions and are designed to address these core questions:

1. Baseline: What was the status of the watershed before implementation efforts?
2. Implementation: Is the plan being implemented as intended, and is it consistent with the county Land and Water Resource Management Plan?
3. Effectiveness: To what extent is the implementation effort having the desired effect relative to the water quality objectives?
4. Efficiency: What is the cost per unit gain toward the desired water quality objective?
5. Scientific Validation: Are predicted water quality responses to implementation observed?
6. Ownership: Has the management process increased natural resource stewardship?

It is critical to emphasize that monitoring must provide timely feedback concerning program success. This feedback is necessary for agency administrators to make improvements in the implementation process. A relatively small investment in an effective and well-designed monitoring program can vastly improve the effectiveness and efficiency of natural resource management programs. Chapter 1 of this report pointed out that the State of Wisconsin invested $187 million in state funds in nonpoint pollution efforts. One reason cited for abandoning that program was that the effectiveness of this program could not be determined. An adaptive management program will allow the most judicious use of limited funds dedicated to natural resource management. Although the WBI does not prescribe specific water-quality management targets (for example, a 50%

percent reduction in stream phosphorus concentrations), adaptive management provides a roadmap for achieving specific targets and generates the knowledge required to make improvements in water quality. The WBI Advisory Committee encourages our elected leaders and decision makers to take advantage of the benefits of adaptive management.

There is no doubt that adaptive management will require a profound paradigm shift for decision makers, administrators, scientists, and technicians. Integrating adaptive management into Wisconsin's natural resource management efforts will not be a simple task and goes beyond the charge to the WBI. This challenge will likely be taken up by the Wisconsin Legislature, agency administrators, and the citizen boards that advise these agencies. The WBI recommends that the opportunity of specifying the role of riparian buffers within NR 151 be used to begin the process of integrating an adaptive management approach into natural resource management in the state of Wisconsin.

**Reference**

Lee, K. N. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Washington, D.C.: Island Press.

# 5: Targeting Buffer Implementation on a Statewide Scale

The WBI approach differs dramatically from previous buffer implementation programs in that the cornerstone of the WBI process is to install buffers at *carefully selected* sites where *potential* benefits are greatest. Most programs are offered on a first-come, first-served basis, resulting in a highly dispersed distribution of buffers on the landscape. As a result, the extent of buffers in any one watershed tends to be low, and studies at the watershed scale have often indicated marginal effectiveness (Parkyn et al. 2003, Moerke and Lamberti 2003, Nerbonne and Vondracek 2001, Wolf 1995). Although buffers may adequately protect the stream reach closest to where they are implemented, the benefits may be masked by unbuffered areas elsewhere in the watershed. All this indicates that water quality improvements may not be detectable at the watershed scale without careful and extensive placement of conservation and buffer systems within the watershed. Aggregated implementation of buffers is needed to counter this masking effect and create improvements that endure downstream. The water quality benefits of this approach would achieve improvements in water quality at the outlet of the watershed that exceed those of a geographically dispersed, available-to-all approach (Figure 5.1). Benefits of buffers can be further amplified by targeting watersheds based on their potential responsiveness to buffers.

The WBI strategy is designed to result in a successful nonpoint-source pollution-reduction program that leads to improvements that are measurable and noticed by the public. This approach also uses public funds more efficiently than other programs because directing funds to areas that are most likely to respond to buffers will result in more benefit per dollar spent. All of these benefits would bolster public support for future expenditures.

In this chapter, we explain how we derived a set of watersheds that were used in an analysis of their suitability for conservation system and riparian buffer implementation. We then developed a system for scoring and ranking these watersheds according to the environmental benefits derived from conservation system and riparian buffer implementation. Finally, we combined these rankings to produce a composite list reflective of the potential water quality benefits of buffers.

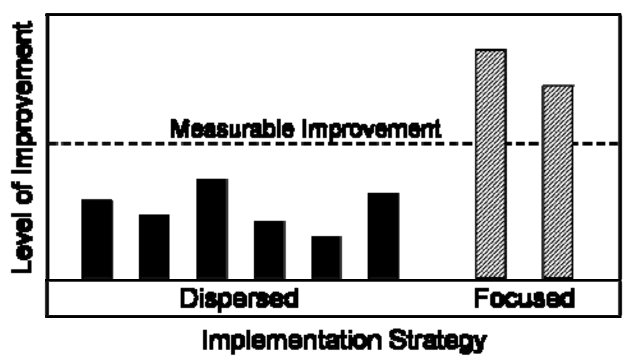



Figure 5.1. The difference between hypothetical focused and dispersed buffer implementation strategies. In both strategies, total improvement (represented by the sum of the heights of the bars) is equal and is the result of equal effort. In the dispersed strategy, a few highly polluting fields in each of six watersheds are buffered, but none of the watersheds improve measurably. In a focused strategy, all highly polluting fields in two watersheds are buffered and both watersheds improve measurably.

## *The Watershed Approach*

The watershed is defined as the area of land that drains to a river or other aquatic system. The watershed is a central concept to the WBI and is the appropriate unit for implementing and monitoring this program for the following reasons:

- Water quality in a stream is a function of *upstream* land use activities.
- The watershed explicitly includes all streams within the watershed area, including small headwater streams. These small streams are critical connections between land use and water quality (Meyer et al. 2003) but are among the least protected of natural resources (Peterson et al. 2001).
- Watersheds are convenient geographic units for implementation because they are stable over time (Bohn and Kershner 2002).
- Changes in water quality at the outlet of the watershed can be easily monitored over time (Bohn and Kershner 2002, McNitt and Kepford 1999), which facilitates the adaptive management process.

## *Choosing an Appropriate Watershed Size*

Choosing an appropriate watershed size is important to the success of a nonpoint-source pollution-reduction program because the costs and benefits of the program are affected by the size of the watershed. As watershed size increases, cumulative environmental benefits increase, but cost is also higher and evaluating the entire area is more difficult and complex. As watershed size decreases, cumulative benefits are smaller; however, on the plus side, costs are lower and evaluating changes induced by an implementation effort is less difficult. Therefore, an intermediate-sized watershed area may be ideal because it allows for improvements in water quality while keeping costs down by concentrating program resources in a limited area (Figure 5.2).

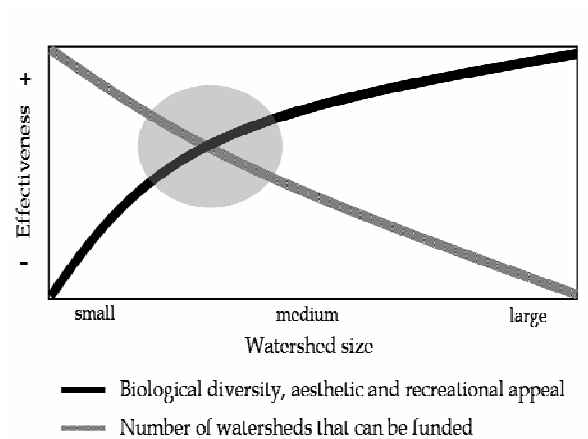



Figure 5.2. Conceptual illustration of tradeoffs in various aspects of program effectiveness across a range of watershed sizes. The gray oval indicates the size that maximizes the average effectiveness across criteria.


Figure 5.3. Three Wisconsin watershed delineations.

We examined two previous Wisconsin watershed delineation efforts by the USGS and the Wisconsin DNR used in the Nonpoint Priority Watershed Program to see if those watersheds would be appropriate for the WBI. After careful consideration, we chose to define a new set because the watersheds delineated by these agencies were too large and were hydrologically incomplete. Figure 5.3 compares these previous efforts with the WBI watersheds. The WBI watersheds were derived from a geographic information system (GIS)-based analysis of stream hydrography and digital elevation models. As such, they should be hydrologically consistent and true watersheds based on ridgeline divides.

The WBI watersheds range from 7.7–38.6 square miles (4,900–24,700 acres, 20–100 square kilometers) in area. Each of these watersheds is a candidate for implementation of riparian buffers and upland management technologies. It is important to note that the WBI watersheds do not include 100% of the land area in Wisconsin; any areas that drain more or less than the targeted size range were not included in the WBI watersheds (shown in white in Figure 5.3).

The best available science indicates that the scale of these WBI watersheds is optimal for identifying and ranking contributions to nonpoint pollution, cost-effective for implementation efforts, and small enough to be meaningful to local conservation staff and landowners.

## *Assessing Watershed Responsiveness to Buffers*

According to the scientific literature (e.g., Wenger 1999) and natural resource management guidelines (Iowa State University 1997, USDA 1998), agricultural conservation practices, including the installation of riparian buffers, are capable of many functions, including filtering sediments and removing nutrients and pesticides from runoff, stabilizing stream banks, promoting biological diversity, regulating stream temperatures, promoting native plant restoration, and serving as dispersal corridors for both aquatic and terrestrial organisms. The WBI Advisory Committee focused on a subset of these functions to develop management goals that can specifically address agricultural nonpoint pollution, can respond meaningfully on the WBI watershed scale, and can be assessed statewide using readily available data.

Following significant discussion and debate, the WBI Advisory Committee reached consensus that the desired management goals should be (in no particular order) (1) improve stream water quality, (2) protect and restore aquatic biological communities, and (3) sustain lake water quality. Each of the 1598 WBI watersheds was rated on its potential responsiveness toward each of these management goals. The following three sections describe the conceptual development for each goal while summarizing the technical procedures used to assign responsiveness ratings to each watershed. The last section describes the combination of individual goal ratings into an overall composite rating.

## Goal 1: Improve Stream Water Quality

Excessive amounts of nutrients and sediment are delivered to streams and downstream water bodies from agricultural land (Carpenter et al. 1998). This pollution impairs the use of these waters by humans for recreation and drinking water and negatively affects aquatic organisms (USEPA 2000). Reducing nutrient and sediment delivery to surface waters through conservation systems and riparian buffers may mitigate these effects.

Research by the USGS (Corsi et al. 1997) reveals considerable variability in the amount of sediments and nutrients delivered by watersheds across the state. This variability is useful from a targeting standpoint because it suggests that changes in land management may produce a much larger benefit in some areas than in others. To quantify this benefit, we built a simple model to estimate the nutrient and sediment reduction potential in each of the 1598 WBI watersheds.

For each constituent (sediment, phosphorus, nitrogen), load reduction potential is equal to the current load minus the sum of unbufferable sources. For the purposes of this analysis, unbufferable sources are defined as those that cannot be attenuated by riparian buffers. These include point sources (e.g., discharges from sewage treatment plants), fine-textured soils that release sediments that are not trapped by buffers, and stream bank erosion. The WBI management goal is to maximize the reduction potential, i.e., to select watersheds that have high loads of sediment and nutrients from agricultural activities, most of which can be substantially attenuated using conservation systems, including riparian buffers.

## Current Loads

To estimate current constituent loads for the WBI watersheds, we first constructed multiple linear regression models. These models relate measured sediment and nutrient loads in streams across Wisconsin (USGS unpublished data) to those streams' watershed characteristics. Average annual loads with at least three years of records were available for 116 sites. We used a GIS and widely available spatial data to calculate characteristics of the streams' watersheds that we expected would influence sediment and nutrient levels. These characteristics included measures of land cover, precipitation, soils, slope, and the stream network. We then used stepwise variable selection to choose models with high explanatory power and whose structure was consistent with our knowledge of landscape processes. In the statistical models, variables measuring land cover in stream riparian zones (Figure 5.4) explained most of the variability in sediment and phosphorus loads. Conversely, total nitrogen and nitrate were primarily driven by the percentage of agriculture in the overall watershed. These results suggest that riparian restoration coupled with upland conservation systems in agricultural watersheds will likely result in greater reductions in phosphorus and sediment than in nitrogen. The ability of conservation systems and riparian buffers to attenuate nitrogen delivery to streams is governed largely by different factors (see sidebar).

We then used the regression equations for each water quality constituent and GIS-derived watershed characteristics to predict annual loads for each of the WBI watersheds. Since annual loads have been measured in only a few of these watersheds, these predictions are the best available estimates of current statewide patterns of nutrient and sediment loads.

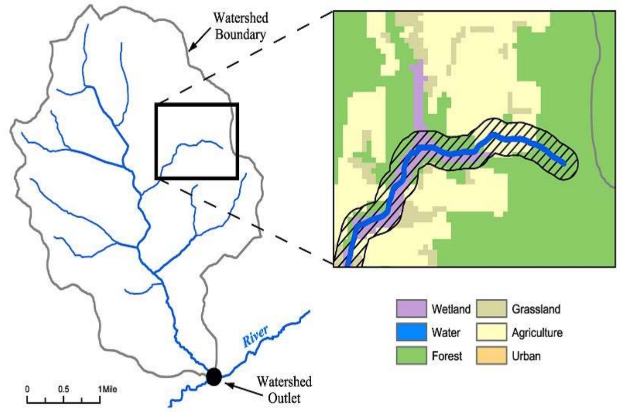



Figure 5.4. An example watershed showing the stream network (blue lines). The inset shows the riparian zone (cross-hatched area) for one stream. To build the models that predict current phosphorus and sediment loads, we analyzed the land use within the riparian zone as well as the land use within the entire watershed. We used a very detailed stream map; in some areas of Wisconsin the smallest streams are intermittent.

### *Unbufferable Sources*

If riparian buffers were capable of eliminating all of the sediment and nutrients that would otherwise be transported to a stream, then rating watersheds for goal one would only require an estimate of the current load. However, some sources are unbufferable. We categorized unbufferable sources of phosphorus and sediment into the following types: meander-belt (stream bank) erosion, fine-textured soils, point-source discharges, and urban stormwater.

***Meander-belt erosion***. The annual sediment load of a stream derives from both upland and channel sources. Channel sources may be divided into two components: that which originates from devegetated banks and that which originates from meander-belt migration. Sediment losses from devegetated banks can be reduced using buffers (Zaimes et al. 2004), particularly if the cause is from cattle grazing and cattle are excluded from the buffer zone. In contrast, meander-belt migration is a natural process whereby streams erode sediments from their floodplains as they adjust their course. In some areas of Wisconsin, the combined effects of poor past land management, steep slopes, and erodible soils have created conditions in which meander-belt erosion is accelerated. This sediment source is for the most part not reducible using buffers (Trimble 1993). We based the estimate of meander-belt erosion on a measure of land form and the amount of agriculture in the stream riparian zone. This estimate was

#### *Buffers and Nitrogen*

Unlike sediment and phosphorus, whose transport from fields to streams is largely driven by surface runoff, nitrogen is transported primarily by subsurface flow. For nitrogen to be removed from groundwater before it reaches surface water, the groundwater must move relatively slowly through the root zone of riparian plants (Mitsch et al. 2001). Therefore, nitrogen load reduction potential is largely driven by local variation in subsurface hydrology. Baker and colleagues (2001) developed a GIS-based model that links nutrient dynamics to riparian hydrology across Michigan. These methods could be applied to Wisconsin in the future to identify watersheds with high nitrogen reduction potential.

converted to a proportion of the total annual sediment load based on measurements at Coon Creek, Wisconsin, where a detailed study was conducted (J.C. Knox, UW-Madison Geography Dept., unpublished data). This equation predicts values ranging from 5% to 36% for the WBI watersheds. In some Lake Superior tributaries in northern Wisconsin, a severe form of meander-belt erosion contributes as much as 90% of the sediment load to streams (Fitzpatrick et al. 2004).

***Fine-textured soils***. Strategically located conservation systems and riparian buffers are capable of trapping a large portion of sediment derived from upland sources. However, in areas with fine-textured soils, such as clay, a larger portion of this sediment remains suspended in runoff as it moves through the buffer and is delivered to the stream. Phosphorus attached to these soil particles is also more likely to pass through the buffer. Therefore, regional variation in soil texture influences the potential for buffers to reduce sediment and phosphorus delivery to streams. We estimated the proportion of sediment and phosphorus that will pass through a buffer as one-fourth of the average proportion of clay in the surface soils within a watershed. Predicted values of soil-texture-related unbufferable phosphorus and sediment range from 0% to 11% for WBI watersheds.

***Point-source discharges***. In some streams, part of the nutrient and sediment load comes from point sources, such as sanitary sewage treatment and industrial facilities. Since these discharges deliver pollutants directly to streams through pipes, buffers are not capable of mitigating against their effects. We estimated the annual load of phosphorus and total suspended solids from all point sources in the Wisconsin Pollutant Discharge Elimination System database using records from 2004. We summed these loads within each WBI watershed to estimate the fraction of the total derived from point sources. Values for suspended solids were generally insignificant relative to nonpoint source estimates, but point sources of phosphorus in a few watersheds exceeded the nonpoint source total.

***Urban stormwater***. Much of the runoff from urban areas is carried directly to receiving waters by stormwater conveyances such as pipes and concrete channels. A recent study in the Chicago area found that buffers of natural vegetation did little to mitigate against the effects of urban areas, presumably because of hydrologic alterations that bypass riparian areas (Fitzpatrick et al. *in press*). We considered the proportion of urban land in each WBI watershed (0% to 82%) to be unbufferable.

### *Sediment and Phosphorus Reduction Potential*

The statewide pattern of sediment and phosphorus reduction potential was similar. Therefore, we combined these ratings into a composite reduction potential, weighing sediment and phosphorus equally (Figure 5.5). Buffer implementation in watersheds that score highly for load reduction potential will contribute most to the goal of improving stream water quality by reducing stream sediment and phosphorus loads. The statewide pattern of load reduction potential is largely driven by variation in current loads. Most watershed ratings were not significantly affected by accounting for unbufferable sources. However, load reduction potential in some watersheds was greatly reduced because of large contributions from one or more unbufferable sources. Accounting for the presence of these sources is important in screening out watersheds where buffers cannot be as effective at improving water quality.

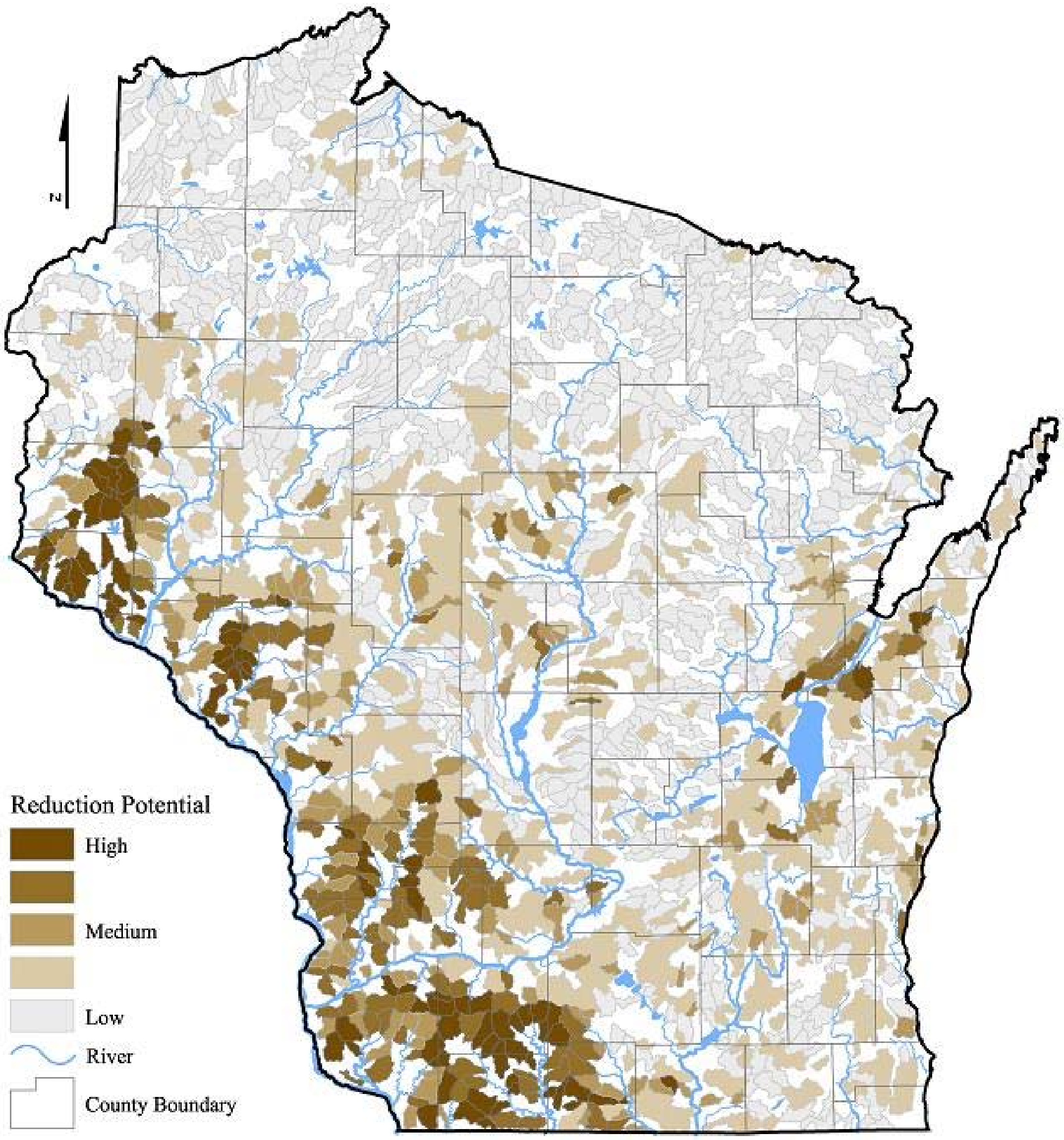



Figure 5.5. Potential for reduction of phosphorus and sediment in WBI watersheds.

## Goal 2: Protect and Restore Aquatic Biological Communities

Aquatic life has been negatively impacted by agriculture (Wang et al 1997). Improving water quality through the methods outlined in nutrient and sediment reduction will certainly help reverse some of these effects. Overall condition of the aquatic biological community has been acknowledged as a useful indicator of stream health and can be even more informative than direct measures of water quality (Wang and Lyons 2003). In this section, we address the following questions: Can conservation systems and riparian buffers correct the most critical, limiting effects of agriculture on aquatic organisms? Will some organisms respond more strongly to improvements? And most importantly, from a geographic targeting standpoint, in what settings can we expect to see the strongest overall biological response to conservation systems and riparian buffer implementation?

Aquatic biological communities typically consist of fish, insects, mussels, crustaceans, and plants. Of these, fish are by far the best known by science in terms of their distributions and habitat needs. They are also useful as an indicator of overall biological conditions because they depend on other organisms for food. Finally, fishing is important recreationally and economically (Wisconsin DNR 2005). For these reasons, we chose to focus on fish as a surrogate for assessing biological community status.

Excessive suspended sediment and siltation have been documented (Wood and Armitage 1997) as having widespread and serious effects on many fish species. Wisconsin fish species vary greatly in their sensitivity to sediment (Becker 1983). Modes of sensitivity include spawning requirements for coarse substrate, sight-dependent feeding, and feeding on other organisms that require coarse substrate. Buffers have been shown to be particularly effective at reducing sediment inputs from runoff, with removal efficiencies as high as 95% in some studies (Peterjohn and Correll 1984).

From among the 150 fish species in Wisconsin, we chose eighteen (Table 5.1) that are particularly sensitive to sediment, live in small- to medium-sized streams, and are common enough to assess their habitat preferences. All of these species are native to Wisconsin except brown trout, which is naturalized. Six fish families are represented. Most of the species are not game fish.

Using fish occurrence and environmental data from the USGS's Aquatic Gap Analysis Project database, we developed habitat models using logistic regression for each of these species and simulated the effect of current human land use. The model predicted the likelihood of a species' presence, which depended both on the sensitivity of the fish to deleterious land uses and on the amount of these land uses present in the watershed. Streams where the likelihood of a species' presence improved significantly under the land-use change simulation and where the potential stream condition was good or excellent were considered good candidates for buffer implementation (red in Figure 5.6). Streams that did not change (green in Figure 5.6) or only improved from poor to marginal (yellow in Figure 5.6) in the simulation were considered poor candidates.

Table 5.1. Wisconsin Stream Fish Species Used in Development of Biological Responsiveness Potential.

| **Common name** | **Family** |
|---|---|
| Chestnut lamprey | Lamprey |
| Northern brook lamprey | Lamprey |
| Silver lamprey | Lamprey |
| American brook lamprey | Lamprey |
| Redside dace | Minnow |
| Blacknose shiner | Minnow |
| Longnose dace | Minnow |
| Northern hog sucker | Sucker |
| Silver redhorse | Sucker |
| River redhorse | Sucker |
| Golden redhorse | Sucker |
| Greater redhorse | Sucker |
| Brown trout | Trout |
| Brook trout | Trout |
| Mottled sculpin | Sculpin |
| Rainbow darter | Perch |
| Banded darter | Perch |
| Logperch | Perch |

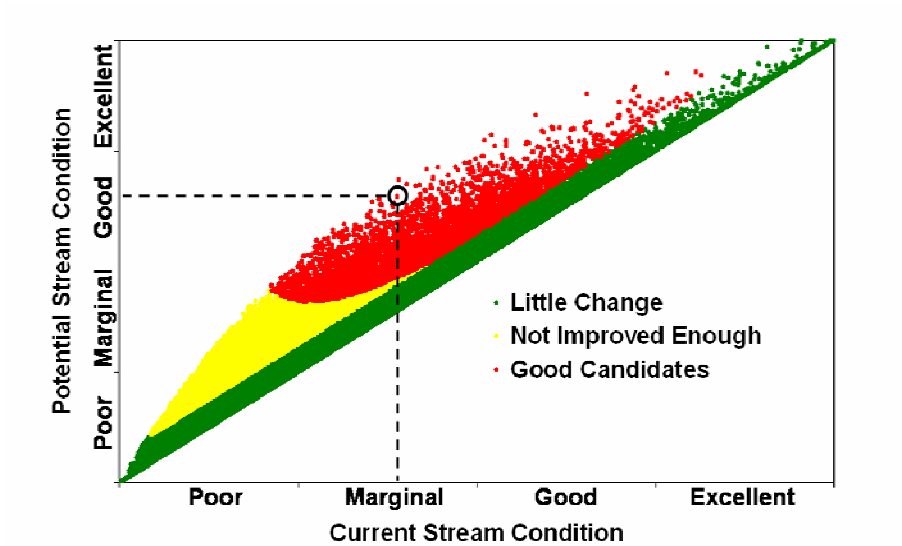



Figure 5.6. Responsiveness scores for one of eighteen sediment-sensitive fish species. Each point on the figure represents a stream (solid areas are tightly clumped points). The stream represented by the circled point is an example of a good candidate for buffer implementation because the predicted habitat improvement (difference between current and potential condition) is large and the potential condition is good.

We repeated this procedure for all eighteen sediment-sensitive species, which produced a responsiveness score for each species for every stream in a given WBI watershed. Next, we took the highest score for each species from among the streams in the watershed and summed those for the biological responsiveness score. This total biological responsiveness score (Figure 5.7) indicates the potential degree of improvement in populations of sediment-sensitive fishes. All of the highly rated watersheds are in areas with significant agricultural land use. However, in some agricultural areas, other environmental characteristics, such as slope and soil type, create stream conditions that are not favorable for most of these species. In these particular watersheds, reductions in sediment would not be as effective at improving conditions for fish because other factors would limit the response.

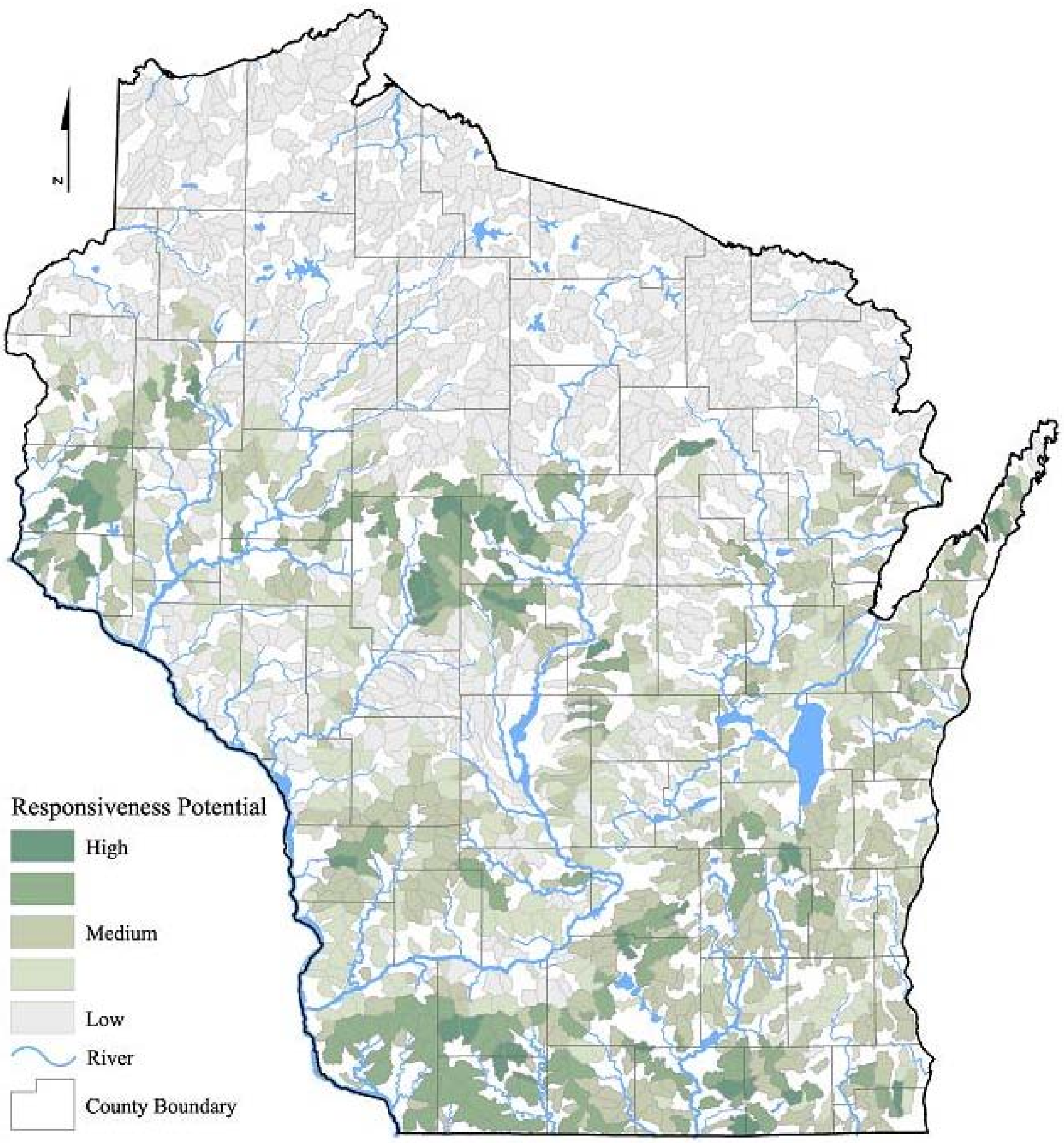



Figure 5.7. Biological responsiveness indicates the potential for improvement in populations of sediment-sensitive fish species.

## Goal 3: Sustain Lake Water Quality

Lakes are one of Wisconsin's most prized natural resources. In addition to providing habitat to a large range of species, they are places for people to recreate. Wisconsin's lakes are a major reason why Wisconsin generated more than $8.4 billion in recreation and tourism revenue in 2004 (Wisconsin Department of Tourism 2005). Clean and clear *oligotrophic* lakes are generally more desirable than *eutrophic* lakes that have poor water clarity due to the presence of weeds and frequent algal blooms.

Weeds and algae demonstrate that a lake has become more "productive" due to an increase in nutrients in the lake water. This increase in production is a process called *eutrophication.* Human activities, however, have greatly increased the rate at which nutrients are added to lakes and, as a result, the water quality in lakes has degraded. Agriculture is one of the activities that contribute excessive nutrients into Wisconsin lakes. When runoff from farmland goes into streams during snowmelt or rainfall, it carries phosphorus into Wisconsin's lakes, where it fuels algal blooms.

Conservation systems and riparian buffers can reduce the amount of phosphorus that enters streams and degrades the quality of Wisconsin lakes. The following describes our effort to identify the upstream watersheds where buffers are most likely to help attenuate eutrophication and sustain good lake water quality.

### *Assessing Phosphorus Reduction Potential for Lakes*

We targeted lakes that were most likely to respond to the implementation of conservation systems and riparian buffers in the WBI watersheds. Specifically, we used the following criteria to select the lakes:

- Drainage lakes: Only some of the lakes in Wisconsin are fed by surface water. Since conservation systems and riparian buffers are primarily intended to remove phosphorus from surface streams, we eliminated seepage and spring lakes from the WBI analysis.
- Watershed area: In order to preserve our efforts to provide the best targeting possible, the lakes used in our analysis are either located within one of the WBI watersheds or downstream from three or fewer WBI watersheds. In addition, we disregarded lakes with less than 75% of their watershed in WBI candidate watersheds.
- Current Trophic State: Shifting a lake from a eutrophic state to an oligotrophic state is far more difficult than slowing the rate of cultural eutrophication. As a result, this analysis only considered lakes that are oligotrophic or marginally eutrophic (i.e., *mesotrophic*) state. All lakes in this analysis have a Trophic State Index value of 55 or less, as calculated by the Satellite Lake Observatory Initiative (SLOI) (Chipman et al. 2004). In addition, only lakes that are large enough to provide a suitable spectral signature were included in the SLOI data set. This limitation eliminates many of Wisconsin's smaller water bodies (e.g., farm ponds) from this analysis.

Three hundred fifty-five lakes satisfied these screening criteria. The phosphorus reduction potential for these lakes was calculated based on the reduction potential in the upstream WBI watersheds. Figure 5.8 shows the final results of this analysis.

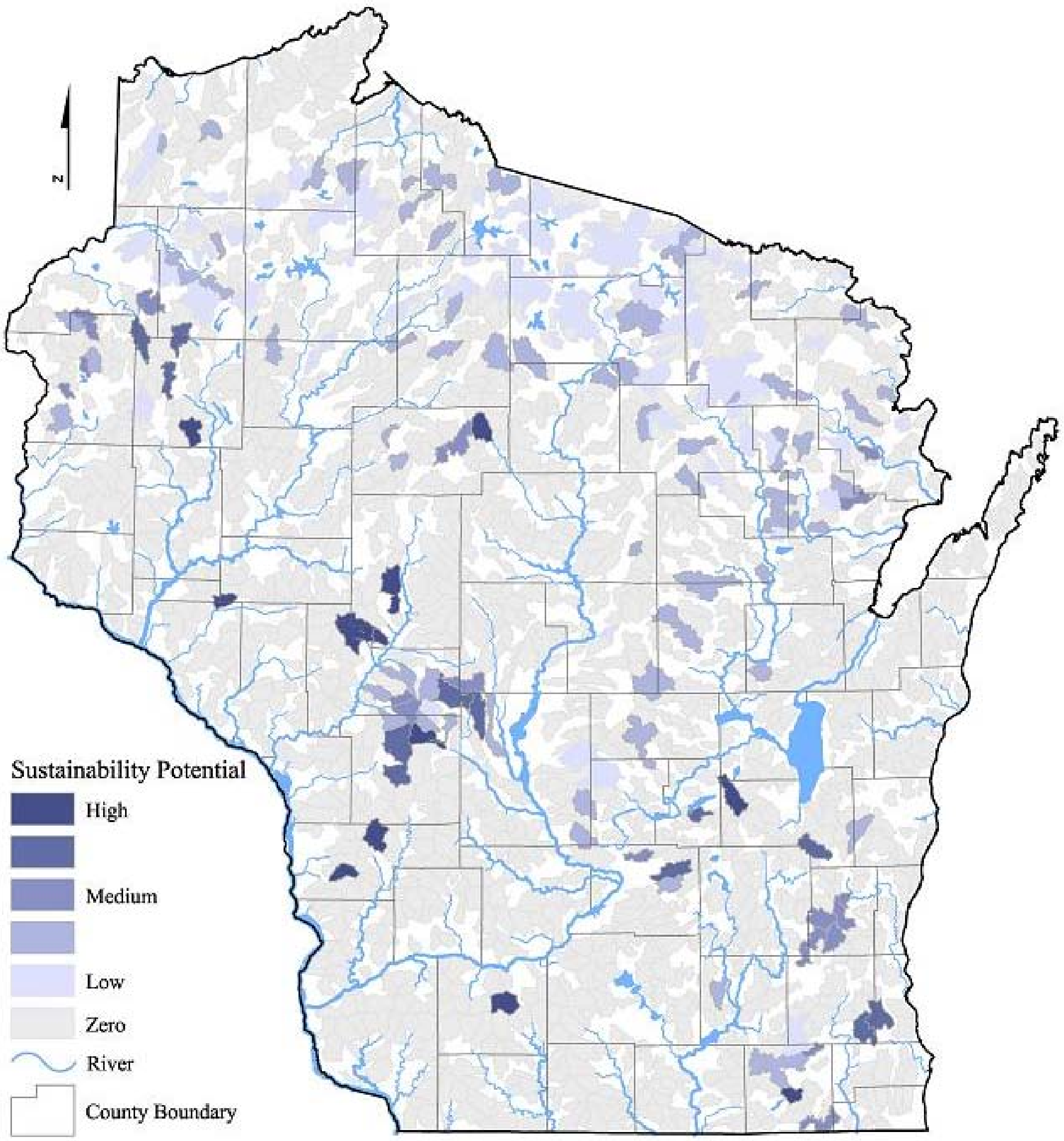



Figure 5.8. The dark watersheds in this map have the most potential to sustain lake water quality through the reduction of phosphorus inputs. The lightest gray WBI watersheds are those that were not included in the lake analysis.

## A Composite Responsiveness Score

The three goals described above were used to identify watersheds that are likely to respond most strongly to implementation of conservation systems and riparian buffers. Each goal focuses on one aspect of what people value in streams and lakes and identifies places where conservation systems and riparian buffers have the greatest probability of having a measurable, positive impact. We used the responsiveness scores from each goal to rank all the 1598 WBI watersheds. If the distribution of these ranks between the three criteria corresponded well with each other (i.e., watersheds that ranked high on one goal also ranked high on the other two goals), then ranking their overall or composite responsiveness would be easy. However, while there is moderate overlap of high ranking watersheds in goals one and two, there is relatively poor overlap of these with high ranking watersheds in goal three. This outcome means that the best places to use conservation systems and riparian buffers to improve stream water quality and to protect and restore aquatic biological communities are not necessarily the best places for sustaining lake water quality.

Since the WBI Advisory Committee agreed that all three of these goals are important, we designed a strategy that (1) selects the highest ranked watersheds in each goal to maximize the likelihood that measurable progress will be made toward each goal; (2) selects the highest composite-ranked watersheds to maximize efficiency by contributing to more than one goal; and (3) can accommodate different levels of program resources (i.e., all goals will be addressed in comparable proportions regardless of the number of watersheds that can be funded).

We used this strategy to create a master ranked list of watersheds (Appendix B) using the following process:

1. Select the watershed with the highest ranking for goal one.
2. Select the watershed with the highest ranking for goal two.
3. Select the watershed with the highest average ranking for the first two goals (i.e., goal one + goal two).
4. Select the watershed (or group of watersheds) with the highest ranking for goal three.
5. Repeat steps one through four, selecting watersheds from those not already chosen, until all watersheds had been added to the list.

This procedure places watersheds into grouped rankings (Appendix B). Each group contains a watershed selected for each one of the first two goals, one selected for its high ranking in both goals one and goal two, and one to three watersheds selected for its high ranking on the goal three. This means that the 1598 watersheds were ranked in a manner that resulted in approximately 350 groups composed of four to six watersheds each (Figure 5.9). When watersheds are selected from this list for NR 151 implementation, they should be selected in these groups so that all of the goals of the WBI Advisory Committee are addressed in comparable proportions.

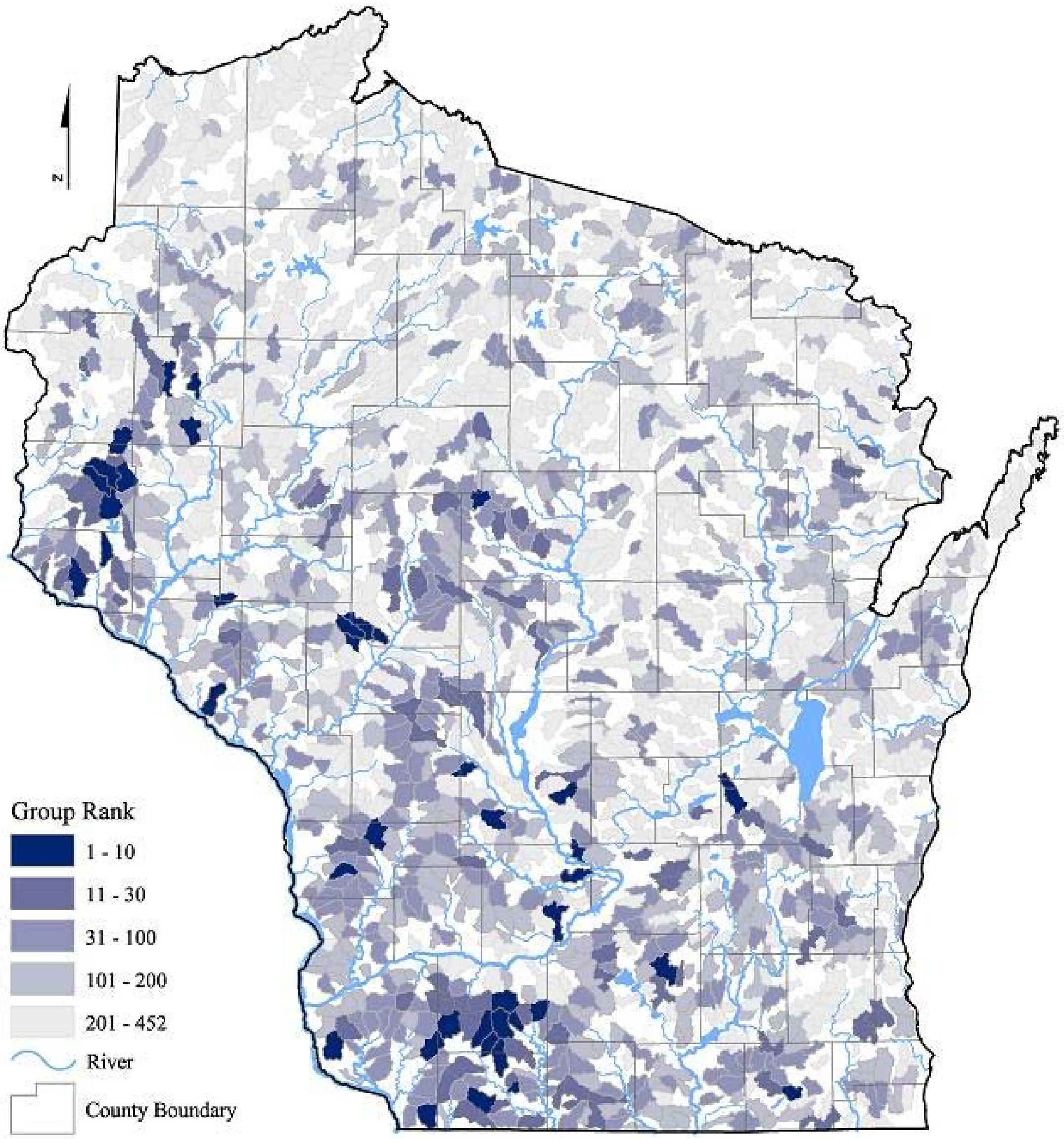



Figure 5.9. Map showing the distribution of ranked watersheds. The ranked list (Appendix B) should be used to select groups of four watersheds for inclusion in the program.

**References**

Baker, M. E., M. J. Wiley, and P. W. Seelbach. 2001. GIS-based hydrologic modeling of riparian areas: Implications for stream water quality. *Journal of the American Water Resources Association* 37:1615–1628.

Becker, G. C. 1983. *Fishes of Wisconsin*. Madison, WI: University of Wisconsin Press.

Bohn, B. A., and J. L. Kershner. 2002. Establishing aquatic restoration priorities using a watershed approach. *Journal of Environmental Management* 64:355–363.

Carpenter, S. R., N. F. Caraco, et al. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications* 8(3): 559-568.

Chipman, J. W., T. M. Lillesand, J. E. Schmaltz, J. E. Leale, and M. J. Nordheim. 2004. Mapping lake water clarity with Landsat images in Wisconsin, U.S.A. *Canadian Journal of Remote Sensing* 30:1–7.

Corsi, S. R., D. J. Graczyk, D. W. Owens, and R. Bannerman. 1997. Unit-area loads of suspended sediment, suspended soils, and total phosphorus from small watersheds in Wisconsin. *U.S. Geological Survey Fact Sheet* FS-195-97.

Fitzpatrick, F. A., M. W. Diebel, M. A. Lutz, T. L. Arnold, and M.A. Harris. In press. Hydrology, geomorphology, and habitat of urbanizing streams, Chicago area, Illinois. *American Fisheries Society Special Publication.*

Fitzpatrick, F. A., M. C. Peppler, H. E. Schwar, J. A. Hoopes, M. W. Diebel. 2004. Monitoring channel morphology and bluff erosion at two installations of flow-deflecting vanes, North Fish Creek, Wisconsin, 2000-03. *U.S. Geological Survey Scientific Investigations Report 2004*:5272.

Iowa State University. 1997. Stewards of our Streams: Riparian buffer systems. *Iowa State University Extension Publication* Pm-1626a.

Meyer, J. L., et al. 2003. Where rivers are born: The scientific imperative for defending small streams and wetlands. *American Rivers and Sierra Club.*

McNitt, J., and R. Kepford. 1999. Developing a new regulatory paradigm to address the impacts of diffuse pollution attributable to agriculture. *Water Science and Technology* 39:299–305.

Mitsch, W. J., J. W. Day Jr., J. W. Gilliam, P. M. Groffman, D. L. Hey, G.W. Randall, and N. Wang. 2001. Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to counter a persistent ecological problem. *Bioscience* 51:373–387.

Moerke, A. H., and G. A. Lamberti. 2003. Responses in fish community structure to restoration of two Indiana streams. *North American Journal of Fisheries Management* 23:748–759.

Nerbonne, B. A., and B. Vondracek. 2001. Effects of local land use on physical habitat, benthic macroinvertebrates, and fish in the Whitewater River, Minnesota, USA. *Environmental Management* 28:87–99.

Parkyn S. M., R. J. Davies-Colley, N. J. Halliday, K. J. Costley, and G. F. Croker. 2003. Planted riparian buffer zones in New Zealand: Do they live up to expectations? *Restoration Ecology* 11:436–447.

Peterjohn, W. T., and D. L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. *Ecology* 65:1466–1475.

Peterson, B. J., et al. 2001. Control of nitrogen export from watersheds by headwater streams. *Science* 292: 86–90.

Trimble, S. W. 1993. The distributed sediment budget model and watershed management in the paleozoic plateau of the upper midwestern United States. *Physical Geography* 14:285–303.

USDA. 1998. Practice code 391: Riparian forest buffer. *U. S. Department of Agriculture, Natural Resources Conservation Service.*

USEPA. 2000. National Water Quality Inventory Report. Office of Water. *EPA* 841/R-02/001.

Wang, L. Z., and J. Lyons. 2003. Fish and benthic macroinvertebrate assemblages as indicators of stream degradation in urbanizing watersheds. In *Biological Signature Responses: Indicating Patterns Using Aquatic Communities*, ed. T. P. Simon. Boca Raton, FL: CRC Press.

Wang, L. Z., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. *Fisheries* 22:6–12.

Wenger, S. 1999. A review of the scientific literature on riparian buffer width, extent and vegetation. Athens, GA: University of Georgia Institute of Ecology, Office of Public Service & Outreach

Wisconsin DNR. 2005. Wisconsin Fishing Report. PUB-FH-506 2005.

Wisconsin Department of Tourism. 2005. The economic impact of expenditures by travelers on Wisconsin: calendar year 2004.

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

Wood, P. J., and P. D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. *Environmental Management* 21:203–217.

Zaimes, G. N., R. C. Schultz, and T. M. Isenhart. 2004. Stream bank erosion adjacent to riparian forest buffers, row-crop fields, and continuously-grazed pastures along Bear Creek in central Iowa. *Journal of Soil and Water Conservation* 59:19–27.

# 6. Planning and Implementation Tools That Can Be Used at the Local Level

How conservation systems and riparian buffers are implemented in response to NR 151 and other programs is a task that will ultimately fall to local conservation staff. County land conservation staff and their local Natural Resources Conservation Service (NRCS) counterparts will need to work with individual farmers and land managers to help them understand what kinds of practices are appropriate, where these are needed, and what is involved in implementation. Because of the variety of agricultural production systems and the complexity of landscapes, conservationists' work will be considerably easier with tools that help assess the situation and convey information in a readily understandable form.

Tools to assist in conservation decisions range from complex computer-based models to simple look-up tables or charts. Regardless of the sophistication, they should share these several common properties:

- Be based on sound science and be representative of local situations.
- Produce understandable and unbiased information.
- Incorporate local knowledge and build on local expertise and experience.
- Be compatible with ongoing conservation and nutrient management efforts.
- Be useable by field staff without extensive training in modeling, GIS, etc.

The WBI developed and evaluated tools to assist in the implementation process. The first tool is actually a decision-making rubric (Figure 6.1) for reviewing the output of information from the watershed ranking process. The second tool includes two approaches for identifying vulnerable areas within a selected watershed, i.e., narrowing the area that will be subjected to more detailed analyses including soil testing and the Soil Nutrient Application Planning (SNAP)-Plus computer program. The evaluation of digital elevation models (DEM), and their role in analyses at multiple scales, is explained in a sidebar on page 31. The last part of this chapter summarizes the development and validation of the SNAP-Plus tool and describes how it can be used to evaluate potential nutrient and sediment losses from individual fields.

## *Local Screening of Statewide Analysis*

Chapter 5 describes a process for ranking the suitability of watersheds across Wisconsin in terms of their potential responsiveness to conservation systems and riparian buffers. Because this is a statewide analysis, it relies on somewhat coarse data. Thus, the analysis does not have the specificity to identify individual farm fields and surrounding land cover or small reaches of streams. It is also based on available data, which may be out-of-date in some areas. Because of these limitations, we recommend that local knowledge be used in the selection of watersheds participating in any state-supported buffer initiative. In Figure 6.1, this is the diamond called *Incorporate local knowledge*.

From the statewide analysis, a selected number of watersheds will be recommended for participation. Local conservation staff in selected areas will be provided the opportunity to review and accept or reject these recommendations on the basis of local knowledge and conditions. Criteria for local review include evaluating the statewide results in light of more detailed or up-to-date local data, existence of other conservation programs and local activities that would influence or interact with a buffer program, likelihood of significant engagement in a program by stakeholders, and knowledge of local conditions that may influence the likelihood of success of a buffer program. Questions related to these criteria can be put into an evaluation form to provide the basis for dialog between local and state staff about the final selection of watersheds.

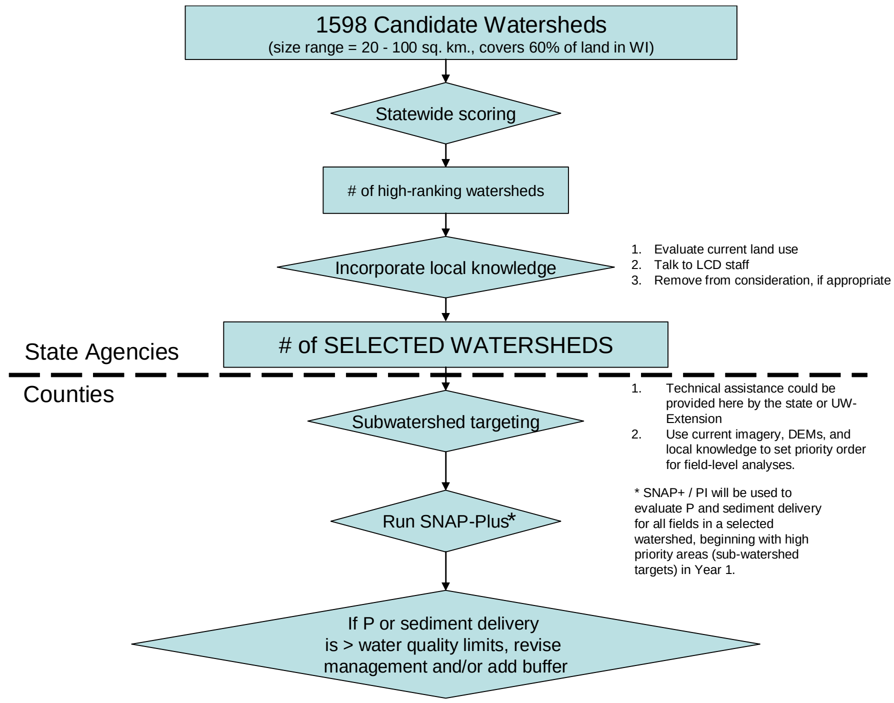



Figure 6.1. Process for evaluating watersheds, subwatershed areas, and fields.

## *Subwatershed Area Priorities*

Once a watershed has been selected for participation in a buffer program, it will be necessary to set priorities for further analysis and implementation. Although the watersheds are relatively small (20–100 square kilometers [7.7–38.6 square miles]), they still typically contain hundreds of farm fields, making it impossible in a single year to do detailed soil testing and SNAP-Plus analyses on every field.

Watershed-wide approaches based on the Universal Soil Loss Equation (USLE) can be used to identify vulnerable areas within watersheds—areas that should receive more immediate attention because they are likely to be contributing disproportionately to water quality impairment. This analysis could be done by GIS staff at a state agency as a technical support function or by local conservation staff.

Numerous watershed-scale models of erosion and nonpoint source pollution exist. Most start with a model of upland erosion based on the USLE or variants. Some models also include delivery, flow routing, and other evaluations of how much and how fast nutrients and sediments end up in receiving bodies of water. In all cases, data about topography, soils, and cropping practices are important factors in detecting areas most likely to be contributing to water quality impairment.

For the purpose of initial identification of areas containing fields where more definitive evaluation should be conducted, it does not matter which model is used as long as the model uses a reliable representation of topography, soils, and cropping practices. (For example, as discussed in Chapter 8, the original, simple version of the USLE was chosen for the WBI pilot study.) With 30 meter-resolution digital elevation models (DEMs), county soils data (obtainable from the Soil Survey Geographic [SSURGO] Database from the US NRCS), and up-to-date land cover data, a GIS-based analysis can show areas where biophysical conditions are likely to be conducive to excessively high erosion rates if appropriate practices are not in place. Individual hotspots can be aggregated to target areas, either by visual inspection of products or through GIS algorithms that identify clusters. An example of this type of analysis is illustrated in Figure 6.2.

Local conservation staff should be most familiar with local conditions and data sets. Some land conservation departments have GIS capabilities in-house or work closely with other county departments that have staff expertise in this area. The preferred option would be for these counties to do the local screening (as discussed earlier in this chapter) followed by a watershed-scale USLE-type analysis to identify vulnerable areas and set priorities for more detailed evaluation. If the time or resources for this do not exist, the analysis could be done by a state agency or UW staff and provided to the county as a map or GIS database.

### *Topographic Data from Digital Elevation Models*

A potential weak link in watershed-scale analysis is topographic data. The only data available throughout the state are 30-meter digital elevation models, a term that refers to data that contain a spot elevation at each point in a grid with 30-meter horizontal spacing and a vertical accuracy specified as plus or minus six feet. Through our case study and evaluation on Discovery Farms sites, we have concluded that these products are adequate for initial screening to indicate high priority areas at a watershed scale in most areas, although in areas with flat or gently undulating terrain more precise information is necessary. Our site-scale research indicates that in all but steep and regular terrain, 30-meter DEMs do not provide reliable information for field-level modeling (e.g., SNAP-Plus) or for determining the locations of concentrated flow with enough accuracy to be of assistance in buffer design and layout. For the SNAP-Plus software, slope information derived from other sources such as soils or topographic maps or from in-field observations will be necessary.

Fine resolution DEMs are necessary for delineation of flow paths and would be quite useful in determining exactly where buffers would be most effective. Unfortunately, production of DEMs with vertical accuracy in the two-foot range may be prohibitively expensive if done for a single purpose such as agricultural land management. However, Wisconsin counties are increasingly investing in such products for multiple purposes, and these products will be increasingly (though spottily) available in the future. At the scale of an individual field, it is also possible to create very accurate elevation data from GPS observations. Receivers can be mounted on four-wheelers and rapidly acquired, although processing the data to generate useful information is technically complex.

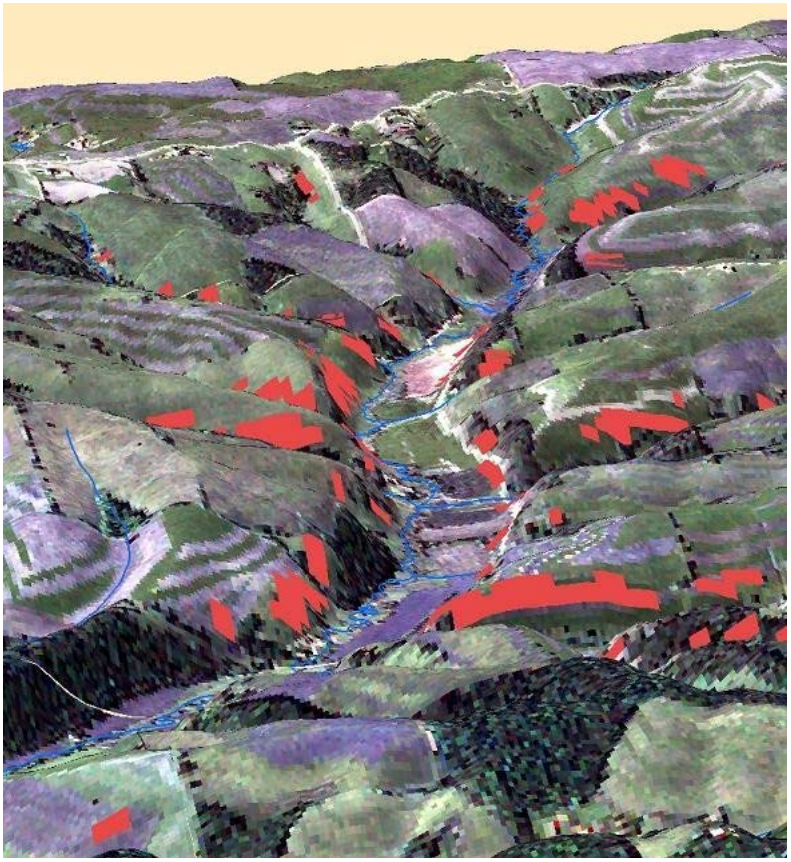


Figure 6.2. An example of how simple and widely available tools and data can be used to show areas (in red) where biophysical conditions are likely to be conducive to excessively high erosion rates if appropriate practices are not in place. (Note: Topography exaggerated for illustration purposes.)

### *Evaluation of Fields In and Around Vulnerable Areas*

Once an area of concern has been established in a watershed, field-level targeting is required to determine where management changes are needed to reduce sediment and nutrient losses. If changes are needed, then appropriate field-specific management options to reduce losses must be found. One tool that is available to assist this process is the SNAP-Plus software program.

SNAP-Plus was originally designed to allow agricultural producers and consultants to prepare nutrient management plans that meet the requirements of the Wisconsin NRCS Field Office Technical Guide (FOTG) Nutrient Management Standard 590 (Wisconsin NRCS 2005). A nutrient management plan indicates the rate, timing, and method of application of crop nutrients, both manure and fertilizer, to a field. The 590 standard requires that producers prepare a nutrient management plan following guidelines intended to protect groundwater and/or surface water. As a result of the limits on soil erosion and runoff phosphorus losses mandated by the 590 standard, the SNAP-Plus software includes both the current national level NRCS erosion calculation program—Revised Universal Soil Loss Equation 2 (RUSLE2)—and an agricultural phosphorus (P) runoff risk estimator—the P Index.

RUSLE2 uses crop management information and readily available soil and topographic data to produce field-specific estimates of erosion in tons per acre per year. For soil conservation planning, the estimated erosion rate is required to be below the tolerable soil loss (T). Values for T have been established by the NRCS for all mapped soils to indicate how much soil can erode from a field without degrading its ability to continue to produce crops. In RUSLE2, a field is considered to be a series of homogeneous planes, each with a specified slope, length, and management. Unlike previous NRCS erosion estimation tools, it can account for the effect of within-field deposition in addition to erosion, so it can provide an edge-of-field sediment delivery estimate. Using RUSLE2, it is possible to assess the effects of changes in type and direction of tillage operations, crop rotations, manure applications, in-field grass buffer strips, and edge-of-field filter strips on sediment delivery to the edge of a field.

The P Index uses routine cropland soil tests and other information to estimate the risk of phosphorus delivery to surface water from a given field with specified management and fertilizer and manure applications. It estimates an annual edge-of-field phosphorus loss taking into account RUSLE2 sediment delivery, rainfall and snowmelt runoff volumes, soil characteristics, soil phosphorus concentration, and manure and fertilizer phosphorus additions. This edge-of-field phosphorus loss is then multiplied by a total phosphorus delivery factor that accounts for the proportion of phosphorus leaving the field in runoff that is actually transported to a stream. The equations used to calculate this factor assume that runoff leaving the field travels to the nearest stream, pond, or lake in a concentrated flow channel, such as a grassed waterway, ditch, or gully.

The P Index in SNAP-Plus was designed specifically for Wisconsin conditions using results from laboratory and field experiments on Wisconsin soils. It can be used to evaluate the effect of varying field management practices on phosphorus delivery. That the P Index can be used to indicate the relative effects of field conditions and management practices on phosphorus loss risks has been verified through in-field runoff monitoring. Annual edge-of-field P Index values correspond well to annual measured runoff phosphorus loads from cropped fields throughout Wisconsin with a range of crops, field characteristics, slopes, tillage types, and manure and fertilizer application practices (Figure 6.3).

The SNAP-Plus program's capabilities to assess field-level sediment and phosphorus runoff potential using locally available information make it a suitable tool for identifying fields in which management changes are needed to reduce runoff losses. Ideally, the maximum allowable sediment delivery or P Index values will be set at levels that address watershed

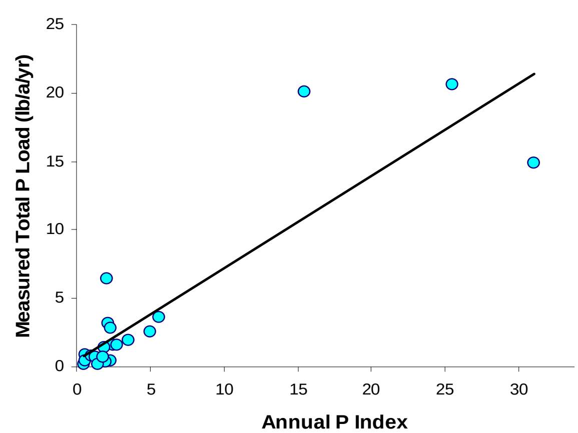


Figure 6.3. The relationship between annual edge-of-field P Index values and measured annual runoff phosphorus losses from 18 cropped fields.

water quality goals and will be modifiable through the adaptive management process. We anticipate that, initially, these maximum levels will correspond to those mandated by the Wisconsin NRCS Nutrient Management Standard 590. Updated guidelines can then be developed on a watershed basis if deemed necessary.

For fields exceeding the established levels, site-appropriate management options will be evaluated with SNAP-Plus to determine their effectiveness in reducing estimated losses below the specified levels. Additional capabilities are being added to SNAP-Plus to allow it to assess the effectiveness of the full suite of management options. It already accounts for those conservation practices that prevent erosion and increase infiltration in the field, such as reduced tillage. In-field and edge-of-field grass buffer strips are being added as management options. The P Index's field-to-stream total phosphorus delivery factor calculations are also being modified to account for other buffers between the edge of the field and the riparian area. The results of in-field monitoring for the WBI project are being used as the basis for developing equations to estimate the effectiveness of grass filter strips for removing phosphorus, as well as sediment, from runoff.

## Using Buffers to Reduce Sediment and Phosphorus Losses

Research for the WBI has helped to identify the conditions where buffers are appropriate management options and where they may not be as beneficial. We monitored parts of two cropped fields with 45-foot grass buffers. Runoff was collected above and below the buffer year-round for two years and analyzed for sediment, dissolved phosphorus, and total phosphorus. The first year of monitoring included extremely large spring and early summer storms at both sites; in the second year there was comparatively little spring and summer runoff, with most of the runoff occurring during the winter. Field A had a sandy loam soil on a steep (10%) slope and was in corn silage for most of the study period. Field B had a clay loam soil on a half as steep (5%) slope and was in corn for grain for most of the study period. Both sites were chisel-plowed in the fall.

Soil phosphorus concentrations were lower on field B than field A. Table 6.1 shows that field A lost more sediment and phosphorus than field B in both years, which

Table 6.1. Annual Sediment and Phosphorus Runoff Losses From Two Cropped Fields Both With and Without a Buffer.

| | Sediment (T/a) | Dissolved P (lb/a) | Total P (lb/a) |
|---|---|---|---|
| Field A | | | |
| Year 1 | | | |
| No buffer | 11.3 | 1.3 | 20.1 |
| With buffer | 3.5 | 0.7 | 17.1 |
| Year 2 | | | |
| No buffer | 0.5 | 0.9 | 1.3 |
| With buffer | 0.1 | 0.2 | 0.4 |
| Total | | | |
| No buffer | 11.8 | 2.2 | 21.4 |
| With buffer | 3.6 | 0.9 | 17.5 |
| Field B | | | |
| Year 1 | | | |
| No buffer | 0.7 | <0.1 | 0.5 |
| With buffer | <0.1 | <0.1 | 0.2 |
| Year 2 | | | |
| No buffer | <0.1 | <0.1 | <0.1 |
| With buffer | 0.1 | 0.1 | 0.3 |
| Total | | | |
| No buffer | 0.7 | <0.1 | 0.5 |
| With buffer | 0.2 | 0.1 | 0.5 |

Abbreviations: P = phosphorus, T = tons

was expected due to field conditions that were more conducive to erosion, along with higher soil phosphorus. The buffer on field A greatly reduced per acre sediment loads; although even with a buffer, the losses were very high, and soil loss exceeded T for that soil. In contrast, runoff losses from field B were low—the buffer was established here for research rather than management purposes. Nonetheless, in year one, the buffer in field B did reduce runoff sediment and phosphorus loads. In the winter of year two, however, there was more runoff from the buffer than from the field itself. On the field, snowmelt was held in depressions resulting from chisel-plowing the clayey soil, while it ran off the comparatively smooth surface of the unplowed buffer, which may have been partially frozen. Consequently, this resulted in more phosphorus and sediment loss from the buffer than the field. In year two, the buffer of field B became a source, rather than a sink, for phosphorus. Over the two-year period, the buffer on field A captured 69% of the sediment but only 18% of phosphorus, while the buffer on field B captured 72% of sediment but only 7% of phosphorus.

SNAP-Plus will be useful for comparing the potential effectiveness of buffers to that of other management options for reducing runoff phosphorus and sediment loads. It cannot, however, be used to design the buffer (i.e., determine the width required at any point) because both RUSLE2 and the P Index assume that fields are homogenous planes without any in-field concentration or channelization of runoff flow. If a buffer is chosen as the preferred management option, its placement and design must take into account runoff flow patterns within the landscape as described in Chapter 7.

**Reference**

Wisconsin NRCS. 2005. Field Office Technical Guide Conservation Practice Standard Nutrient Management Code 590. Available at: http://efotg.nrcs.usda.gov/treemenuFS.aspx?Fips=55025&MenuName=menuWI.zip.

# 7. Placement and Design of Conservation Systems and Riparian Buffers

A buffer is just one component of the entire management system that will be required to meet the state's water quality objectives. Upland practices such as minimal tillage, residue cover, cover crops, and terraces must be in place in order to reduce sediment and water flow to a level that can be handled by the buffer in an environmentally friendly manner. We know that a vegetated buffer's effectiveness depends on the vegetation density and the buffer width. Erosion research (Jin and Römkins 2001) indicates that standing stem density is one of the main measures of the effectiveness of the buffer—many stiff stems slow the water flow, which results in sediment deposition conditions. Current Wisconsin NRCS recommended grass-based buffer mixes have sufficient stem density to produce an effective buffer. For a given vegetation density, the width of the buffer determines the amount of sediment that can be removed without overwhelming, or "blowing out," the buffer (Magette et al. 1989). Therefore, it is important to design the buffer width based on the volume of water that will flow through the buffer cross-section at any point along the riparian buffer.

The design of riparian buffers was one of the main questions posed at the initiation of the WBI. As described in earlier chapters, the need for a riparian buffer is dependent upon a conservation systems approach that includes the ranking of watersheds on their probability of responding to three specific water quality goals, the identification of areas within those watersheds that have the greatest probability of needing conservation systems and riparian buffers, and a decision-making process to determine if upland management changes will mitigate the need for riparian buffers in these areas. If it has been determined that a riparian buffer is necessary, the WBI recommends that, rather than using a uniform width as is currently the recommendation according to Wisconsin NRCS guidelines, the buffer be designed relative to the contributing area.

The science of designing buffers relative to the contributing area has been validated in the emerging scientific area of precision conservation (Delgado et al. 2005). In their article "Establishing Conservation Buffers Using Precision Information," Dosskey et al. (2005) document the importance of considering the topography in designing a riparian buffer (Figure 7.1). They note that "runoff [is] commonly nonuniform, converging on some parts of the field margin and diverging from others because of uneven topography and patterns of soil conditions and farming practices" (Dosskey et al. 2005, 349).

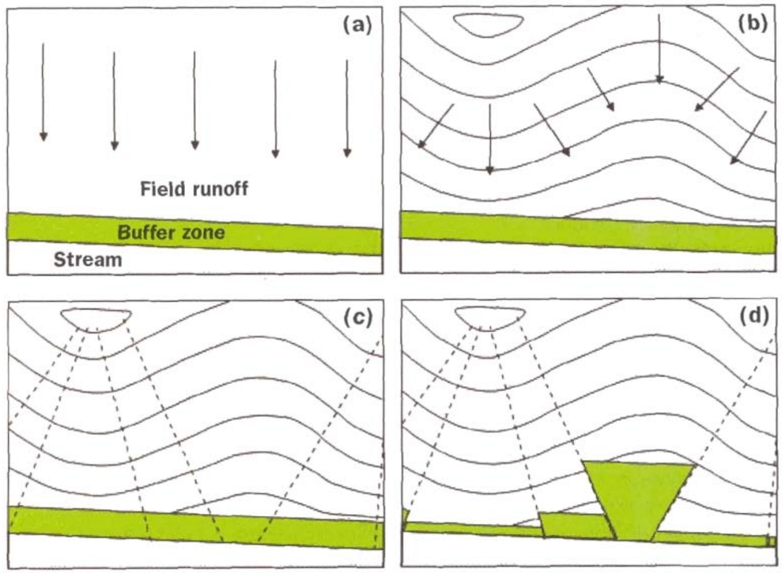


Figure 7.1 Diagrams of crop-field runoff patterns, topographic contours, and alternative buffer designs: (a) uniform runoff flow to a uniform-width buffer; (b) non-uniform runoff flow to a uniform-width buffer, (c) non-uniform runoff areas and the corresponding uniform-width buffer areas to which they flow; (d) non-uniform runoff areas and the corresponding variable-width buffer areas to which they flow. Both (a) and (d) yield an approximately constant level of pollutant filtering along the entire length of the buffer. (Dosskey et al. 2005)

## *Contributing Area*

Relative water-flow volume can be estimated using contributing area calculations and estimates. The contributing area is the area of land from which runoff will flow to any common point. An example of the application of this concept to buffer design follows: if 20% of a ten-acre field drains through a thirty-foot section of field edge while only 5% of the field drains through the adjacent thirty-foot section of field edge, the section of buffer handling the larger contributing area should be wider than the section that handles the smaller contributing area (all else being equal).

When management decisions for agricultural fields are made, it is common to consider the field to be a plane with a single slope or a sequence of planes with one or two slope breaks. In this sort of geometry, each point at the bottom of the field has the same contributing area and the same runoff. However, natural landscapes in Wisconsin are rarely like this. Variations in topography perpendicular to the average slope cause areas of runoff convergence and divergence, resulting in large differences in contributing areas along the bottom of the field. Analyses of several DEMs with contributing area algorithms and a distributed runoff model (Precision Agricultural-Landscape Modeling System or PALMS [Molling et al. 2005]) show a factor of 10 to a factor of over 100 difference between the amount of runoff that would be expected to flow through different sections of an edge-of-field buffer on fields in Wisconsin.

The WBI recommends a modification to the current Wisconsin NRCS Filter Strip Standard 393 (Wisconsin NRCS 2001) that includes contributing area. Current Wisconsin NRCS Standard 393 does not consider contributing area when calculating the width of buffers; however other factors, such as slope and soil characteristics, are part of the design. The proposed modification would not change the current recommendations for buffer dimensions for a field that is a uniform plane with no convergence. Only when convergence occurs would the shape of the buffer change with the modified code. Our recommended changes are in Table 7.1. To incorporate contributing area into buffer design, a unit contributing area factor (UCAF) is used. First the field is assigned a point score according to Table 1 in the Wisconsin NRCS Standard 393 (Wisconsin NRCS 2001). Then the UCAF corresponding to the 393 point score is selected from Table 7.1. The contributing area (CA in square feet/foot) at each location along the edge of the field is then divided by the UCAF to produce the buffer width. For example, if the number of points from the Standard 393 Table 1 is 35 and the contributing area at the edge of the field is 240 square feet /foot from TauDEM (an extension for the ArcGIS computer program), then the buffer-width parallel to the direction of flow should be 40 feet, i.e. CA/UCAF(points = 35) = 240/6 = 40 feet. (See Figure 7.2 for an example of this process computed along an entire field boundary.) If estimated buffer widths exceed 300 feet, then buffers are not likely to be appropriate in those situations without modifications to the landscape; too much contributing area is emptying into too small an area to be effectively aided by a buffer. If most of the runoff is leaving a field as concentrated flow, which is frequently the case in Wisconsin, then the buffer should be integrated with grassed waterways or other structures that are designed to retain maximum sediment.

In our experience with the calculation of contributing area, we have found two software packages that have performed consistently well (TauDEM and Autodesk Land Desktop for AutoCAD) and two software packages that have produced inconsistent results (TOPAZ and the ARC INFO Flow Accumulation Function). To calculate the points in Table 7.1, GIS can be used to determine the average slopes along the incoming flow direction.

Table 7.1. Modified Table to Determine Minimum Buffer Width.

| Total Point Range From Current 393 Standard | Current 393 Standard Buffer Width (ft)[a] | Unit Contributing Area Factor (UCAF) |
|---|---|---|
| 0–10 | 20 | 15 |
| 15–20 | 30 | 10 |
| 25–30 | 40 | 7.5 |
| 35 | 50 | 6 |
| 40 | 60 | 5 |
| 45 | 70 | 4.3 |
| 50 | 80 | 3.8 |
| >50 | 100 | 3 |

[a]The buffer width from the current Wisc. NCRS Standard 393 is shown for reference.

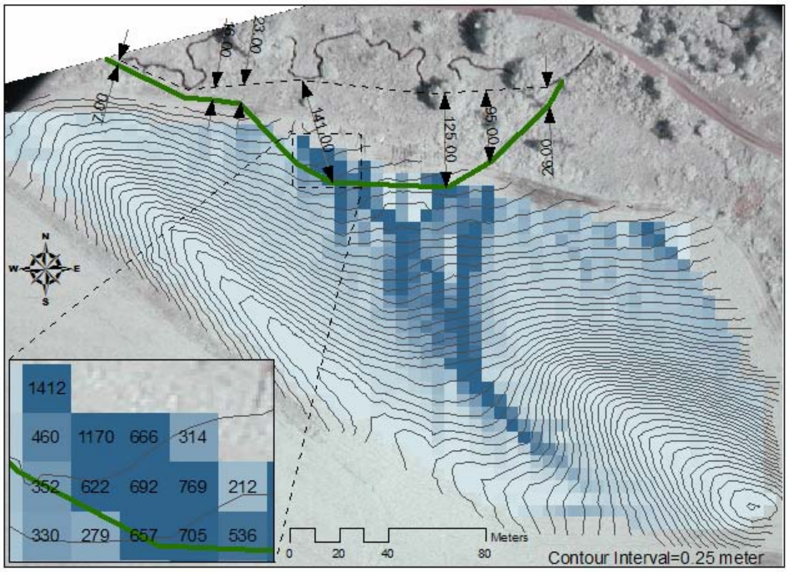



Figure 7.2. A variable-width buffer in a Wisconsin field that was evaluated for appropriate buffer width taking contributing area into account. The background of the figure is an aerial photo of the site, in which a stream appears as a meandering dark line along the top of the image. A natural buffer exists along the stream north of the field. Topographic contour lines (in black) are overlaid on the figure in areas in which a digital elevation model (DEM) was available. The grid in shades of blue is the contributing area; light blue denotes small contributing areas, and dark blue denotes large contributing areas. The contributing area was calculated with TauDEM. The inset shows the actual contributing area values in square feet/foot for a small portion of the DEM. Contributing area values were divided by a unit contributing area factor (UCAF) of 10, which corresponds to the Wisc. NRCS Standard 393 Table 1 point range (15–20) for this location. The green line denotes the minimum buffer width as calculated using contributing area and the UCAF. The buffer was measured from the smoothed stream bank line (dotted line). The numbers on the arrows are the buffer widths (feet) along the direction of overland flow. As this figure shows, the natural buffer is sufficiently wide in most places, so additional buffer would only be required in the center.

We recognize that the minimum buffer widths calculated from Table 7.1 will be very wide in some areas and narrow in other areas nearby. This may cause difficulty for equipment operations, so some smoothing or squaring off will probably need to be done. How this is done is entirely up to the landowner or land manager, although the resulting buffer width may not be narrower than the value calculated from the tables.

**References**

Delgado, J. A., C. A. Cox, F. J. Pierce, and M. G. Dosskey. 2005. Precision conservation in North America. *Journal of Soil and Water Conservation* 60:340.

Dosskey, M. G., D. E. Eisenhauer, and M .J. Helmers. 2005. Establishing conservation buffers using precision information. *Journal of Soil and Water Conservation* 60:349–353.

Jin, C.-X., and M. J. M. Römkens. 2001. Experimental studies of factors in determining sediment trapping in vegetative filter strips. *Transactions of the ASAE* 44: 277–288.

Magette, W. L., R. B. Brinsfield, R. E. Palmer, and J. D. Wood. 1989. Nutrient and sediment removal by vegetated filter strips. *Transactions of the ASAE* 32: 663–667.

Molling, C. C., J. C. Strikwerda, J. M. Norman, C. A. Rodgers, R. Wayne, C. L. S. Morgan, G. R. Diak, and J. R. Mecikalski.In press. Distributed runoff formulation designed for a precision agricultural-landscape modeling system. *Journal of the American Water Resources Association*.

Wisconsin NRCS. 2001. Field Office Technical Guide. Section IV Conservation Practices. Filter Strip (393). Available at: http://efotg.nrcs.usda.gov/treemenuFS.aspx?Fips=55025&MenuName=menuWI.zip.

# 8. Pilot Study of the Proposed WBI Implementation Processes

A pilot study of the proposed WBI implementation process was conducted in two watersheds—Hefty Creek in Green County and the Sheboygan River watershed in Fond Du Lac County—during the spring and summer of 2005. Following watershed identification, we followed the implementation steps shown in Figure 6.1: subwatershed targeting, field-scale sediment loss and phosphorus-delivery potential assessment in vulnerable areas using SNAP-Plus, and finally, identifying management alternatives to reduce phosphorus delivery risks from fields exceeding the established limits.

## *Step 1: Subwatershed Area Targeting*

In early May 2005, we met with the Land Conservation Departments of both Green and Fond Du Lac Counties to discuss the usefulness of combining the GIS tool with local knowledge to determine where conservation and buffer practices should be implemented. We explained that the tool is designed to provide a quick, meaningful, and objective evaluation of the landscape within a selected watershed that would assist local staff with their outreach activities. The results of the analysis would then be used as a guide, supplementing—but not replacing—the extensive knowledge that local conservation staff possess.

The GIS-based subwatershed targeting tool uses the USLE to estimate soil erosion within the watershed (Desmet and Govers 1996, Fernandez et. al. 2003) The data required for the tool, which are available to the public free-of-charge, include: 30-meter DEMs, SSURGO Database, Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND), and USGS runoff estimates.

Analysis using the GIS-based subwatershed tool was conducted for both watersheds and yielded results that were, for the most part, consistent with information provided by the local staff. In general, the tool showed that agricultural areas near streams with steep slopes and erodible soils were most likely to lose soil to surface waters. However, local staff suggested that erosion from within the channel was not adequately represented with this tool. This should be taken into consideration when evaluating the entire watershed.

Time constraints dictated that only one watershed could be looked at in great detail, so Green County was chosen as the primary study area because of its closer proximity to UW-Madison. By late May, the Land Conservation Department of Green County had chosen two subregions of the Hefty Creek watershed to be of the most interest. Combined, these areas are 15% of the watershed and include all or part of six farms.

## *Step 2: Identifying High Risk Fields*

First, we collected the information needed to run SNAP-Plus to produce rotation average soil loss estimates and P Index values for all fields. The team met with each of the farmers in the study area. Farmers were asked about their current manure management, fertilizer applications, tillage practices, crop rotations, typical yields, herd sizes, and field names and acreages. Soil and landscape information was either observed in the field or obtained from NRCS soil survey maps provided by the county. All cropped or grazed fields were sampled according to the standard procedure for routine agronomic soil tests. We followed the UW-Extension recommendation of at least one sample per field and no more than 5 acres per sample. Within the pilot area, 274 routine soil samples (six-inch depth) for phosphorus, potassium, pH and organic matter were taken on 1019 acres. This represents an average of 3.7 acres per sample.

*Time and Costs Associated With Snap-Plus*

Collecting the information and running SNAP-Plus requires time and resources. For areas similar to the pilot study area, we estimate that sampling a 200-acre farm would take forty hours. The actual data entry and analysis in SNAP-Plus for this farm would require roughly five hours, but field layouts in the study area are so complicated, with as many as 100 or more fields per farm, that matching the information with the field names used by the farmer will make the process take an additional twenty-five hours. The average cost of routine soil samples is $7.00.

The Hefty Creek watershed pilot areas are characterized by very steep slopes and highly erodible soils. The northwestern pilot area has steeply sloping fields (9% and greater) located within 300 feet of all stream stretches. About a quarter mile of the stream in this area runs through grazed pasture. In the southeastern study area, the fields adjacent to the stream are comparatively broad lowland areas with slopes less than 4%. In this area, fields adjacent to the stream are planted in corn and soybean rotations. Throughout both study areas, all of the fields with slopes of 4% or greater are farmed on the contour and many are in contour strips. Crop rotations on these upland fields were six to eight years with two to three years of row crops and three to four years of established alfalfa hay. Most of the upland fields are hydrologically connected to the lowland areas adjacent to the stream via grassed waterways or tree-lined ravines mapped as intermittent streams.

Soil test P values on the southeastern study area lowland corn and soybean fields ranged from 46 ppm to 344 ppm with the majority above 100 ppm. These values are all “excessively high” meaning that they are well above levels where additional phosphorus is required for crop growth. In contrast, the soil test P range for the upland soils with rotations that included alfalfa hay was 9 ppm to 103 ppm, with the majority of fields below 50 ppm. Although currently little to no manure is applied to the lowland fields, their high soil test P values likely reflect high rates of past manure applications to the flatter, relatively accessible land. The drop in manure applications is a result of a dramatic drop in animal numbers in this area within the last decade.

The current Wisconsin NRCS Nutrient Management Standard 590 target maximum for rotation-average P Index values is 6. Overall, of the 973 cropped acres examined, 19% had P Index values greater than 6, 21% were between 4 and 6, 45% were between 2 and 4, and 15% were less than 2. Erosion and movement of sediment-bound P was the greatest contributor to P loss estimates; all of the fields with P Index values above 6 were upland fields and, except for 1.8 acres, also had estimated soil loss values above the NRCS designated tolerable soil loss value or T. We should note that the percentage (19%) of cropped acres with high P Index values reported above should be considered a maximum. This is because one of the farmers with fields with high P Index values resulting from high soil loss estimates told us that the farm varied between using some tillage and using no-till in parts of the rotations. Where this variation occurred, we used the more erosive management with tillage in our analysis. The majority of the cropped fields adjacent to the creek had P Index values lower than 4 (with one exception of 4.8) despite having comparatively high soil test P values. This is a result of the very low risk of runoff and erosion from these fields. Of the 31 acres of nonrotationally grazed pasture within the two study areas, all had P Index values greater than 6. Fifteen acres were grazed on a monthly rotation, of which 6 acres had P Index values higher than 6.

### *Step 3: Identifying Management Alternatives*

After our initial analysis to identify fields with unacceptable soil loss or P Index values, we reran SNAP-Plus for those fields to evaluate a variety of alternative managements. We found that the P Index values for the cropped fields could always be brought below 6 through adjustments in rotation, tillage, or, on a few fields, shifting the timing of manure applications from winter to spring. In most cases, the necessary adjustments could be made using rotations and managements that the farmers were already using on other fields on their farm. The exceptions were fields that were spring chisel plowed and had with two years of corn silage in the rotation. Switching to no-till would bring the risk of soil loss and phosphorus delivery from almost all of these fields to acceptable levels (Figure 8.1). Some fields had acceptable P Index values but had estimated soil loss levels in excess of T. Figure 8.2 shows an example of a tract with one field that could be brought below T by removing soybeans from the rotation on that field.

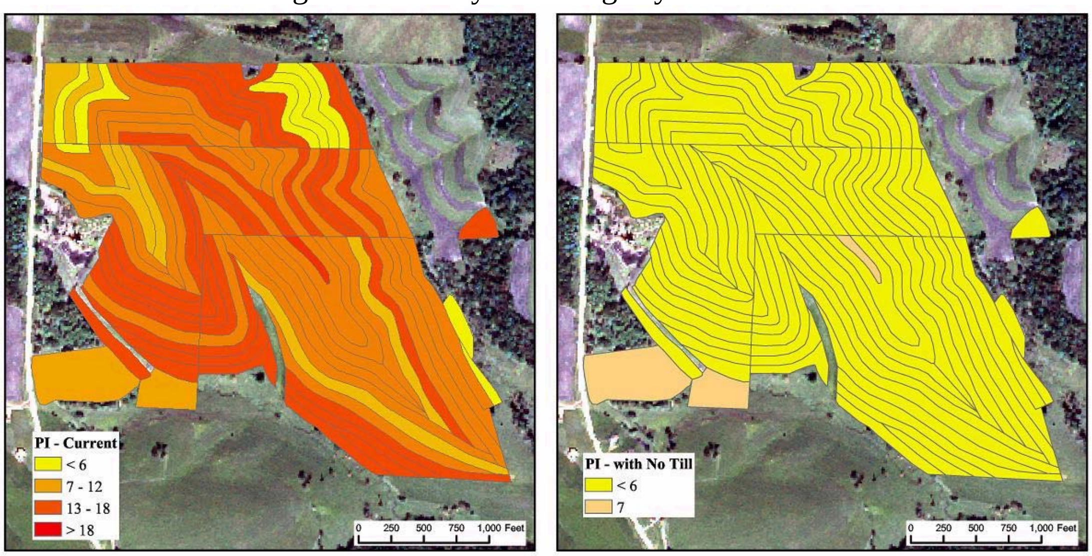



Figure 8.1. Projected P Index (PI) value changes in a farm that is switched from spring chisel-plowing to no-till. The map on the left shows field PI values using the present tillage system, and the one on the right shows that most of the PI values would be brought to acceptable levels (below 6) if a no-till system was adopted without any other management changes.

Figure 8.2 Tract with one field that is losing soil at a rate that exceeds the tolerable soil loss (T), shown in orange on the left. Planting corn instead of soybeans in the rotation would reduce the soil loss to below T (right).

Prior to discussing reducing the P Index values on the pasture lands, we must note that the P Index validation with runoff monitoring data described in Chapter 6 and shown in Figure 6.3 was on cropland. At present, we have no data verifying that the P Index algorithms are appropriate for grazed lands, although some monitoring projects are underway in Wisconsin that should allow us to address this in the future. Most of the pasture in the pilot study area is on very steep and highly erodible land not well-suited to cropland. Using the present P Index algorithms, we found that an ungrazed grass filter strip between the grazed field and waterways appears to be an appropriate way to reduce P Index values below 6. Within the study area, there are also unvegetated paddocks that receive high rates of manure. Since the surface of these paddocks is a permanent covering of manure, not soil, the P Index is not a suitable tool to estimate paddock runoff P loss risks. However, the paddocks are hydrologically connected to the stream via a grassed waterway and probably have a high potential to contribute dissolved phosphorus, if not particulate phosphorus, to the stream.

**References**

Desmet, P. J. J., and G. Govers. 1996. A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *Journal of Soil and Water Conservation* 51:427–433.

Fernandez, C., J. Q. Wu, D. K. McCool, and C. O. Stöckle. 2003. Estimating water erosion and sediment yield with GIS, RUSLE, and SEDD. *Journal of Soil and Water Conservation* 58:128–136.

# 9. Assessing the Economic Impacts of Alternative Management Practices on Selected Wisconsin Farms

This chapter summarizes the results of an economic evaluation of alternative management practices for fields with a high risk of excessive phosphorus and sediment loss. Because the WBI recommendation uses a conservation systems approach to address the contributing area relative to a riparian area, upland management may be required to adopt various remedial practices or best management practices (BMPs). Whether BMPs alone or BMPs in conjunction with a riparian buffer will be required will be determined as part of the assessment process by local conservation staff. Of the initial four questions developed by the WBI Advisory Committee, two addressed this area: what will be required to get conservation and buffer practices in place, and what are the consequences of implementing conservation and buffer practices? Both questions have economic dimensions to them.

In the longer term, the objectives of this economic research are to develop analytical tools (e.g., EXCEL spreadsheets) for whole-farm economic optimization subject to nutrient balance and environmental constraints, such as the NRCS 590 standard. These analytical tools will provide a framework to better assess economic and environmental performance trade-offs over a range of BMPs.

With respect to the WBI project, the specific objectives are to assess the economic impacts of farm/field level adjustments that will meet the NRCS 590 standard. NRCS 590 is used because it is the current standard, but this analysis could be performed using alternative thresholds. While the farm/field adjustments presented here are not the optimal adjustments in that they are not necessarily the profit maximizing and/or cost minimizing adjustments required to meet the 590 standard, they do provide a measure of the cost of compliance. Comparison of alternative BMPs (e.g., tillage practices, changing corn grain for corn silage in a noncompliant field) provides a basis for better understanding the potential economic costs and environmental benefits of alternative management practices on Wisconsin farms.

## *Simulating Field/Farm Level Conditions for Analysis*

In our research approach, representative farms in WBI-targeted watersheds were simulated under alternative farm/field level conditions using SNAP-Plus. The conditions included tillage practices (spring/fall moldboard versus chisel versus no-till) and crop rotations (switching out corn silage for corn grain, alfalfa/brome versus alfalfa). The economic costs of alternative farm/field cropping activities were assessed using standardized crop budgets for corn grain, corn silage, soybeans, alfalfa, wheat, oats, and other small grains. These basic data were obtained from the average production costs/acre observed on several Discovery Farms. These data provide reasonable, ballpark cost of production estimates without revealing the actual costs of production for particular farms. It must be noted, however, that the actual cost of compliance will likely be very situation specific.

The economic assumptions used in the analyses are summarized in Table 9.1. Costs of production/acre were computed for all crops and tillage methods using standard machinery and labor costs and custom rates for particular field operations. Changing tillage, crop rotation, field-level nutrient management, feed/rations (which may change

Table 9.1. Wisconsin Buffer Initiative Economic Assumptions Cost by Crop and Tillage.

| Crop | Fall Chisel | Fall Plow | None | No-Till | Spring Chisel | Spring Plow | 5 Yr Avg FSA Prices | Unit of Measure |
|---|---|---|---|---|---|---|---|---|
| Alfalfa (Hay/Haylage) | $319.00 | $319.00 | $0.00 | $319.00 | $319.00 | $319.00 | $74.00 | Ton |
| Corn Grain | $330.64 | $338.80 | $0.00 | $311.36 | $332.63 | $340.80 | $2.12 | Bushel |
| Corn Silage | $409.28 | $417.44 | $0.00 | $390.00 | $411.27 | $419.44 | $19.08 | Ton |
| Oats w/ Alfalfa Seeding Spring | $214.28 | $222.44 | $0.00 | $195.00 | $216.27 | $224.44 | $1.38 | Bushel |
| Oats w/ Alfalfa/Brome Seeding Spring | $214.28 | $222.44 | $0.00 | $195.00 | $216.27 | $224.44 | $1.38 | Bushel |
| Oatlage w/ Alfalfa Seeding Spring | $214.28 | $222.44 | $0.00 | $195.00 | $216.27 | $224.44 | $48.10 | Ton |
| Pasture (not rotational), Grass | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $48.10 | Ton |
| Pasture Rotational, Grass | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $48.10 | Ton |
| Pasture (not rotational), unimproved | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $48.10 | Ton |
| Soybeans | $249.58 | $269.05 | $0.00 | $241.61 | $249.58 | $271.05 | $5.35 | Bushel |
| Winter Wheat | $252.55 | $260.72 | $0.00 | $233.28 | $254.55 | $262.71 | $3.50 | Bushel |

Abbreviation: FSA = Farm Service Agency

manure composition), among other BMPs, to meet the 590 standard have the potential to change cost of production.

While there is an active debate as to the yield implication of alternative tillage practices, this analysis assumes that crop yields are identical across tillage practices (although the analytical tools allow for this assumption to be changed). In particular, spring or fall chisel plowing is assumed to generate the same yields as no-till. In contrast, changing tillage method or timing can have large impacts on soil loss and the P Index. Crop yields were obtained from participating farms as basic input data to the Snap Plus program. All crops are valued at Farm Service Agency five-year average commodity prices (see Table 9.1).

## *Effectiveness of Alternative BMPs*

Comparing the reductions in the P Index with the associated changes in economic costs provides a partial budgeting tool that may be used by landowners to assess the cost effectiveness of alternative BMPs. Although particular fields are the focus of the Snap-Plus 590 standard compliance simulations, the analysis tracks changes in crop acreage, yields, production, costs, revenues, and profits across *all* fields over the full rotation of the farm being analyzed. This provides an economic assessment that parallels the 590 standard computation of the P Index over the full rotation.

Some BMPs will be more effective (i.e., generate more P Index reductions per dollar of profit and/or cost) compared with others. However, some of these more effective BMPs may not be compatible with the farm's current cropping and/or livestock system. For example, substituting corn grain for corn silage may leave a dairy operation with an on-farm forage deficit, thereby necessitating buying forage. Therefore, in order to better match local conditions and specific farm constraints, it may be necessary to explore a variety of BMPs and their P Index reduction effectiveness when designing 590 standard compliant cropping and livestock systems.

## *Analysis of Three Southwest and South Central Wisconsin Farms*

In all analyses, the BASE simulation is defined as existing management.

### Case 1: WBI-1

This farm uses a dominant rotation comprised of three years alfalfa (plus an establishment year with oatlage followed by two years of corn silage for a six-year rotation on about 140 acres. The dominant tillage is spring chisel. There are multiple fields with winter spreading restrictions under the NRCS 590 standard, due mainly to steep slopes and nearness to Hefty Creek.

The BASE simulation (see Appendix C, Tables1, 2 and 3) for this farm reveals that every field but one is noncompliant with the NRCS 590 standard (i.e., P Index > 6) over the full rotation. The whole-farm acreage weighted-average P Index for the BASE simulation of this farm is 16.6.

Introducing no-till on all fields, while keeping the BASE rotation and winter spreading, generates 590 standard compliance in all but four fields. The whole-farm acreage weighted-average P Index for this simulation is 3.8, a radical reduction in overall average farm P Index due to a change in tillage from spring chisel to no-till. Additional elimination of winter spreading on these four fields generates full 590 standard compliance on all fields over the full six-year rotation. The whole-farm acreage weighted-average P Index for this simulation is 3.5. It should be noted, however, that the elimination of winter spreading on this farm would necessitate additional winter manure-storage strategies. The cost of these strategies is not addressed here.

Changing the BASE rotation to two years of corn grain rather than corn silage, while keeping tillage and winter spreading the same as in the BASE simulation, reduces the P Index in most fields compared to the BASE, but only fourteen fields are 590 compliant. The whole-farm acreage weighted-average P Index for this simulation is 7.1. Introducing no-till while maintaining BASE simulation winter spreading makes all fields 590 compliant and reduces the whole-farm acreage weighted-average P Index to 2.8. Additionally, eliminating winter spreading further reduces the whole-farm acreage weighted-average P Index to 2.5.

These results indicate that three of the simulations would enable this farm to meet 590 P Index standards on all fields: corn silage, no-till, no winter spreading; corn grain, no-till, winter spreading; and corn grain, no-till, no winter spreading. Determining the "best" way to meet the 590 standard is likely to be somewhat subjective because of certain practical crop and livestock considerations and economic and environmental trade-offs. For example, corn grain, as modeled here, leaves more residue than corn silage and generates bigger P Index reductions on this farm's hilly ground, particularly when combined with no-till; however, corn silage better meets the livestock/forage needs of the farm. The economic and environmental trade-offs involved with 590 standard compliance are summarized in Appendix C, Table 3 as the change in profits (i.e., total revenues minus total costs, aggregated to the farm level by field by year, over the six-year rotation) for each BMP scenario compared with the BASE simulation. Since yields were assumed to be constant across tillages, the profit gains due to no-till are mainly due to reduced crop costs/acre. In the case of this farm, no-till corn silage with no winter spreading generates the largest economic return per unit of P Index reduction, whereas no-till corn grain with no winter spreading generates the largest P Index reduction. If managed using no-till corn silage with no winter spreading, this farm could improve profitability by $7,359 over the six-year rotation while becoming 590 standard compliant. Profitability would increase by only $354 with the implementation of no-till corn grain with no winter spreading. Here, the economics reinforce the livestock and forage benefits of no-till corn silage with no winter spreading. Again, however, the potential costs of additional winter manure-storage strategies required by these 590 standard compliant simulations are not addressed here.

### Case 2: On Farmer's Ground (OFG)-14

This farm uses eight different rotations and two tillages (fall chisel and no-till) on 600 plus acres. The longest rotation is six years. The BASE simulation (see Appendix C, Tables 4 and 5) indicates that one 6-acre field (less than 1% of the total farm acreage) is noncompliant with the NRCS 590 standard with a P Index of 10.6. The whole-farm acreage weighted-average P Index for the BASE simulation is 2.8. The noncompliant field has a 7% slope and is in a fall chisel, corn silage/no-till, soybean rotation. Simply swapping this field from corn silage to corn grain with a similar sized field that would go from corn grain to corn silage at a similar point in the rotation generates 590 standard compliance with a field level P Index of 4.5, a 6.1 unit decrease from the BASE simulation. The P Index for the other field involved in this corn silage/corn grain crop swap increases from 2.7 to 3.9, hence remains 590 compliant. Due to the differences in soils and yields between these two fields, this generates $1,172 in profits over the six years of the full farm rotation. The whole-farm acreage weighted-average P Index for this full 590 standard compliance simulation is 2.8, which is a reduction of 0.1 from the BASE simulation.

Another alternative for this noncompliant field is switching the corn silage tillage from fall chisel to no-till, which would reduce tillage costs and, assuming identical yields, increase profits by $347 over the full six-year farm rotation. Of course, this assumes labor and machinery or timely custom hire are available for this shift in tillage practice. In this simulation, the field-level P Index decreases to 4.0, while the whole-farm acreage weighted-average P Index for the simulation is 2.8, an identical P Index to the corn silage/corn grain rotation simulation. The economics in this case suggest that changing the crop rotation would be a better way to go as it generates more farm profits ($1,172 versus $347 over six years) and a bigger return ($3.13 versus $0.85) per unit of P Index reduction.

### Case 3: OFG-16

This farm uses four different seven-year rotations on about 190 acres, all with three years of alfalfa or alfalfa/brome and an establishment year of oats or oatlage. Three of these rotations use three years of continuous corn grain following the alfalfa, and the fourth uses three years of corn silage. Fall chisel is the only tillage practice used. Ten of the twenty-seven fields (32 acres or 16 % of the total farm acreage) are in grazed pasture. Appendix C, Tables 6 and 7 summarize the SNAP-Plus simulations for this farm.

Four of the twenty-seven fields are noncompliant in the BASE simulation. Two of these fields are in crop rotations with P Indexes of 7.1 and 9.8, and two are pastures with P Indexes of 8.5 and 6.4. The two noncompliant crop fields, totaling 15 acres or 8% of the total farm acreage, are in the Oa-A-A-A-Csl-Csl-Csl rotation with fall chisel tillage. The noncompliant pastures total 7 acres or 3.6% of the total farm acreage and about 22% of total pasture acreage. The whole-farm acreage weighted-average P Index for this BASE simulation is 3.5.

Two obvious choices for reducing the P Index in the noncompliant crop fields are to switch to corn grain from corn silage or to switch to no-till corn silage. Switching to corn grain will leave more crop residue, hence reducing the P Index, but could generate livestock forage shortages in several years. This switch reduces field level P Indexes from 7.1 and 9.8 to 3.8 and 3.0, respectively. In addition, the whole-farm acreage weighted-average P Index for this partially compliant—the pasture fields are still not addressed—is 3.1, a reduction of 0.4 units of P Index. The economic analysis indicates that this change will generate an extra $5,256 in profits over the seven-year full-farm rotation.

Addressing the two noncompliant pastures with rotational grazing is assumed to increase harvested forage yield. This increase forage yield, with no assumed increases in costs generates an additional $4,700 over the seven-year full-farm rotation. (Pro-rated fixed costs for paddock establishment and variable labor costs to rotate the cattle are not computed here.) This translates to around $35 per pastured acre per year increase in farm profits due to rotational grazing. This switch also reduces field-level P Indexes from 8.5 and 6.4 to 5.6 and 2.9, respectively. The whole-farm acreage weighted-average P Index for this farm simulation is 3.0, a reduction of 0.4 units of P Index.

## *Summary*

This research provides a snapshot on the economics of meeting NRCS 590 standard compliance for three farms in southwest and south central Wisconsin. Although the particular economics of 590 standard compliance are likely to be highly situation specific due to the local environmental, agronomic, and farm specific (e.g., machinery, labor, management) constraints, these analyses provide a ballpark economic assessment using standardized crop production costs and Farm Service Agency five-year average commodity prices.

In general, for the farms studied here, adoption of NRCS 590 standards would require straightforward management changes on noncompliant fields such as tillage practices (e.g., from chisel to no-till), rotation changes (substituting corn grain for corn silage), and the adoption of managed rotational versus continuous grazing. In many instances, these 590 standard compliance-induced changes were found to be profitable under the economic assumptions used for the analysis. However, several potential costs, such as additional winter manure-storage strategies and the costs of rotational grazing, were not included in this analysis.

In addition, it should be noted that individual farms may be unable to adapt alternative tillage techniques for a variety of reasons. For example, the costs of crop and forage production may be quite different from those assumed here, or perhaps custom hire is more expensive than assumed here or is not available in a timely fashion. Furthermore, while small changes in rotations like swapping corn grain for corn silage on similar sized fields were generally not found to be problematic, these types of changes should be modeled in conjunction with the farm's livestock feed/ forage needs where applicable.

Finally, the economics of 590 standard compliance evaluated here are not optimized. That is, the simulations are not the result of maximizing farm profits subject to field-level environmental constraints. Viewed from a whole farm, nutrient balance, cropping and livestock systems perspective, this economic and environmental optimization context could provide profitable opportunities for rethinking farm management. This systems perspective allows for a better integration and synergy of component farm enterprises: cash grain/forage crops versus on-farm use versus purchased feeds/forage; planting and/or harvesting operations provided on-farm versus custom hire; nutrient management plans to minimize off-farm purchases and maximize returns to on-farm nutrient sources (e.g., manures and legumes); better feed/ration management to better control off-farm nutrient sources; and better management of the number and types of livestock, their feed/forage needs, and their manure volume and composition. Rethinking farm management in this economic and environmental optimization context will require analytical tools to facilitate and quantify the relevant trade-offs. Building on the tools developed for the WBI, further research will be focused in this direction.

# 10. Recommendations of the WBI Advisory Committee

Before listing the individual recommendations, it is important to address the context of the WBI within larger resource management issues. The status and level of understanding of the science underlying the natural resource concerns in the state of Wisconsin is constantly improving. This ever-emerging new knowledge requires us to constantly reexamine the adequacy of yesterday's recommendations for tomorrow's changing policy expectations. The collaboration between UW-Madison and the state and federal agencies, as well as all the other participants in the WBI process, was productive while establishing a framework for future efforts. All involved hope there will be opportunities in the near future when there will be a call for the "best available science" that will facilitate UW-Madison scientists to work with the citizens of Wisconsin in addressing our natural resource management challenges.

Wisconsin does not exist in a natural resource policy vacuum. Landowners, local staff, state agencies, and federal partners are all responding to policy changes made at various levels of government. The WBI cannot be expected to anticipate all the complexities occurring in the natural resource management arena.

Perhaps the most important recommendation emerging from the WBI is the need for an adaptive management approach. Implementation of our recommendations in WBI watersheds should be viewed as opportunities for learning. Adaptive management is designed to foster continual improvement in management practices. Surprises in ecosystem response are not viewed as failures but, instead, as a source for learning better ways of accomplishing water quality goals.

Adaptive management promises more than improved effectiveness and efficiency in resource management. It offers a new paradigm for designing and implementing resource management programs while accelerating our understanding of how to most effectively solve resource management problems.

## *Areas of Agreement*

The WBI was asked to conduct research to determine where riparian buffers are needed to enhance water quality in Wisconsin relative to agricultural runoff. We began by agreeing that riparian buffers by themselves would not allow us to achieve our water quality goals. Instead, a conservation systems perspective is recommended in which riparian buffers are one potential component in this system. Viewing riparian buffers as an integral part of a larger conservation system, however, does not address the "where" question.

There was agreement that the implementation of these conservation systems should occur first in areas where there is the greatest probability of a positive water quality response. To locate these areas, WBI scientists identified and ranked 1598 watersheds in Wisconsin based on criteria agreed to by the entire WBI Advisory Committee. The WBI makes no recommendation on how far down this ranked list any resulting implementation efforts should occur. We recognize that this is a funding decision that needs to be agreed upon by elected officials in the Wisconsin Legislature and agency administrators.

There was also general agreement among WBI participants that simply identifying the boundaries of a set of watersheds would not be sufficient to achieve our water quality goals. The identification of high-priority areas within those watersheds is also important, and spatial analytical tools and widely available digital data, may be used to provide an initial assessment of those subwatershed priority areas. WBI participants also agreed that local staff should have the ability to revise subwatershed priority areas based on additional data or experience. For areas designated as priorities within targeted watersheds, the SNAP-Plus tool can be used to help landowners assess alternative management options for a conservation system. Following this conservation systems approach may result in situations where changes in upland management practices may reduce the need for a riparian buffer.

## *Recommendations*

The following recommendations have to be interpreted in the adaptive management context. Removing the recommendations from this context lessens their value and defeats the very essence of the adaptive management philosophy. Moreover, the recommendations will not solve all our current water quality problems. However, they do focus limited resources on those problems that are causing a disproportionate share of degradation. They also focus efforts on those situations that have the highest probability of responding to remedial efforts. There was general agreement by the participants in the WBI Advisory Committee on the following recommendations.

1. It is recommended that the DNR and UW have the lead responsibility for conducting the data acquisition and analysis necessary to establish and maintain a list of WBI watersheds based on the three agreed upon criteria (1) improve stream water quality, (2) protect and restore aquatic biological communities, and (3) sustain lake water quality), and make this information available to appropriate staffs of the DNR and DATCP on an on-going basis. This data acquisition and analysis activity will also include identifying areas within the WBI watersheds that are especially vulnerable based on soils, topography, land use, and any water quality data available. This activity is to be conducted based on a memorandum of agreement between the DNR and UW-Madison.

2. It is recommended that WBI watersheds receive special consideration for new state funding based on a tiered approach where funds are allocated from the highest ranked to the lowest ranked, with the number funded at any one time based on fiscal considerations. It is also recommended that conservation agencies and organizations in Wisconsin coordinate existing programs to address high-ranked WBI watersheds.

3. A WBI watershed targeted for remediation will be informed of this fact by a letter from the DNR to the appropriate Land Conservation Committee(s) (LCC). The DNR will provide the county with a preliminary map or list of fields/locations that should be subject to priority implementation of the nonpoint and buffer standards. The LCC will review this information in conjunction with their Land and Water Resource Plan and any additional data the county may have to determine which agricultural fields should receive priority treatment based on the estimation that these fields are most likely to yield the greatest water quality benefit in the watershed. Once the nonpoint issues are addressed on the priority fields, the LCC will engage landowners to address other fields that may need appropriate treatment to achieve water quality objectives. The LCC may also

review other nonpoint pollution sources within the watershed. Where these additional sources are found to substantially contribute to water quality problems within the selected watershed, the LCC will work with the DNR and other agencies to address these problems as well. The LCC coordination with other agencies will be especially important when federal programs are targeted as major funding sources.

4. When working on implementation with a landowner in a vulnerable area within a funded WBI watershed, LCCs should formulate a plan based on a conservation systems approach. Each field's contributing area will be identified, and the US Department of Agriculture NRCS conservation planning model will guide the process of determining appropriate upland practices and riparian buffer options. The expectation is that conservation and appropriate management practices will be installed in this contributing area to reduce the impact of concentrated flow areas and runoff of nutrients and sediments moving to the riparian area. If riparian buffers are required, then these will be designed to specifically address the upland contributing area (see recommendation #7). Where sheet and rill erosion are the cause of water quality impairment, appropriate buffers will be installed to achieve water quality goals. As part of this process, it is expected that local conservation professionals will use the US Department of Agriculture NRCS conservation planning model as a basis for making decisions to prohibit agricultural activities from encroaching on the stream. Each LCC will determine if local conservation staff has or should have the capability to employ the SNAP-Plus model. The SNAP-Plus model may be used to determine management options for assessing remedial practices within the contributing area. This determination would be based on the phosphorous (P) Index or soil erosion values, which are components of the SNAP-Plus model. The DNR will work with the UW to ensure that the SNAP-Plus model remains consistent with state nonpoint performance standards and that training and updates to this planning tool occur on a regular basis for those that chose to use it.

5. Local staff will be responsible for coordinating the monitoring of targeted watersheds and reporting those results to the DNR in accordance with a predetermined process. The DNR will work with UW and other salient agencies or organizations to coordinate monitoring efforts in targeted watersheds to the extent feasible (see Appendix A). The DNR is also encouraged to work with UW and any other salient organizations or agencies in interpreting these monitoring results in order to determine what type of changes or adaptation, if any, is needed in the funded WBI watersheds.

6. It is recommended that the need for riparian buffers in any targeted location be determined using a two-step process. First, using the SNAP-Plus model, the landowner will be encouraged to adopt various management practices as part of a larger conservation system that results in meeting existing soil and water conservation standards. If the efficacy of the various conservation and management practices is not capable of meeting these standards, then the second step will be to compliment these upland treatments with a riparian buffer. This riparian buffer will be engineered based on elevation contours so as to specifically address the upland contributing area. If a landowner wants to install a riparian buffer without making any changes to upland

practices, and the buffer is designed to be sufficient to meet the standard as determined by SNAP-Plus calculations, then a buffer alone should be permissible.

7. It is recommended that the US Department of Agriculture NRCS buffer standards be updated to incorporate the knowledge gained through the WBI and Discovery Farm research on buffers in Wisconsin over the past three years. In particular, the NRCS standards should recognize contributing drainage area, in-field soil erosion rates and variations in buffer designs and landscape conditions.

8. It is recommended that the senior staff in the DNR and DATCP work with the Wisconsin Legislature to investigate the type of institutional arrangements that would be required to allow adaptive management to be the foundation of our natural resource management programs.

# Appendix A

## *Recommendations for Monitoring the Effects of WBI Implementation on Nonpoint-Source Pollution Levels*

In order to collect the data required for the adaptive management process, it will be necessary to allocate adequate financial resources for the purpose of monitoring nonpoint-source pollution levels in Wisconsin. The following recommendations have been developed by the WBI-affiliated scientists for monitoring progress towards the three WBI management goals (1) improve stream water quality, (2) protect and restore aquatic biological communities, and (3) sustain lake water quality. All of these recommendations should complement the monitoring of the actual program implementation.

1. Monitoring requires a long-term commitment of *at least* ten years in selected watersheds.

2. The monitoring strategy proposed here is a tiered approach consisting of three levels. These monitoring options were developed based upon the experience of WBI scientists working on these types of projects; however, each situation needs to be independently evaluated and the monitoring may need to be adjusted on the basis of site-specific conditions.

Level 1: A small number of watersheds should be monitored with continuous-flow gages and flow-rate-metered automated samplers located at the watershed outlets. Scheduled biweekly and storm-event driven water sampling should occur at these locations. In addition, event-driven samples of soil and nutrient movement should be collected at field outlets or edges where management changes are made. Annual monitoring of stream biota should also be conducted in these watersheds above and below fields of interest. In the drainage basins of these Level 1 sites, detailed, field-level land cover and management inventories that include cropland and non-cropland should be conducted throughout the monitoring period. Observations on cropland should include crops, tillage, fertilizer, and manure management practices.

Level 2: A moderate number of watersheds should be monitored with biweekly water sampling, including continuous stream flow monitoring at the outlet of the watershed. Biological monitoring should also be conducted in these watersheds. After an initial monitoring period, a comparative analysis will be conducted between the Level 2 and Level 1 sites to evaluate the ability of the Level 2 sampling method to detect water quality changes resulting from changes in known upstream land management. Initial estimates suggest that the cost of implementation and operation of the Level 2 sites is approximately one-fourth the cost of a Level 1 site over a ten-year period.

Level 3: In all other selected watersheds, biological monitoring should be conducted. This can be accomplished by seasonal staff and/or citizens volunteering through the Water Action Volunteers program.

3. Paired watersheds should be monitored where opportunities exist. Reference basins can be monitored with the Level 2 monitoring and volunteers can defray the costs. Reference gages will be located near the gages for a selected watershed, making the additional travel time needed to monitor its paired watershed minimal.

4. Baseline monitoring should begin as soon as possible. We recommend installing water-quality sampling stations and sampling the biota in the top ranked groups of watersheds. To the extent feasible, existing monitoring programs and one-time stream studies should be incorporated into the information base.

5. The Wisconsin DNR should collaborate with the UW system to carry out this monitoring and develop procedures for data integration, analysis, and dissemination, with the goal of creating an open information resource relevant to the ongoing implementation and funding of state nonpoint-source pollution rules.

We encourage the careful monitoring of management changes within the watershed, landowner participation rates, and the time necessary for staff to complete analyses recommended by the WBI process. This information can be collected through surveying landowners and local staff in addition to the use of available remotely-sensed imagery. We also encourage using multiple approaches to program implementation where feasible, as long as these approaches are capable of generating information about the efficacy of nonpoint-source control measures. For example, one variation might be the use of an auction to allocate program dollars within a subwatershed. Finally, we recommend incorporating the research conducted at the Discovery Farms and Pioneer Farm when program changes are considered. All of this information should be open and easily accessible through Web-based resources.

# Appendix B

Appendix B: Ranked list of WBI watersheds. In the "ID" field, the number indicates the group rank and the letter indicates the goal(s) in which that watershed ranked the highest (W, improve stream water quality; F, protect and restore aquatic biological communities; C, composite of W and F; L, sustain lake water quality). The "Description" field contains the name of the stream at the outlet of the watershed (Unnamed streams were named "Trib. to [first named stream downstream]"). The "County" field is the county the contains the outlet of the watershed (Note that many watersheds cross county boundaries). The "Area" field is the area of the watershed in square kilometers.

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 1-W | Tiffany Creek | Dunn | 89 |
| 1-F | Trib. to Lemonweir River | Juneau | 44 |
| 1-C | Willow River | St Croix | 96 |
| 1-L | Brownlee Creek | Buffalo | 48 |
| 2-W | Mineral Point Branch | Iowa | 86 |
| 2-F | Vermillion River | Barron | 65 |
| 2-C | Eau Galle River | St Croix | 99 |
| 2-L | Mill Creek | Iowa | 94 |
| 3-W | Lovett Creek | Lafayette | 21 |
| 3-F | Leech Creek | Columbia | 60 |
| 3-C | Ames Branch | Lafayette | 92 |
| 3-L | Upper Pine Creek | Barron | 81 |
| 4-W | Dodge Branch | Iowa | 95 |
| 4-F | Campbell Creek | Adams | 72 |
| 4-C | Dry Run | St Croix | 74 |
| 4-L | Silver Creek | Fond du Lac | 72 |
| 5-W | East Branch Pecatonica River | Iowa | 65 |
| 5-F | Otter Creek | Sauk | 96 |
| 5-C | South Fork Willow River | St Croix | 95 |
| 5-L | South Fork Bad Axe River | Vernon | 60 |
| 6-W | Furnace Creek | Lafayette | 54 |
| 6-F | Onemile Creek | Juneau | 81 |
| 6-C | Isabelle Creek | Pierce | 99 |
| 6-L | West Fork Kickapoo River | Vernon | 98 |
| 7-W | Conley Lewis Creek | Iowa | 38 |
| 7-F | East Branch Big Eau Plein River | Marathon | 56 |
| 7-C | Pecatonica River | Iowa | 99 |
| 7-L | Arnold Creek | Clark | 33 |
| 8-W | Cave Creek | Pierce | 57 |
| 8-F | Trib. to Wisconsin River | Columbia | 44 |
| 8-C | Rattlesnake Creek | Grant | 90 |
| 8-L | Jackson Creek | Walworth | 47 |
| 9-W | Eagle Creek | Buffalo | 80 |
| 9-F | Koshkonong Creek | Dane | 98 |
| 9-C | Otter Creek | Lafayette | 79 |
| 9-L | Halls Creek | Jackson | 70 |
| 9-L | South Fork Halls Creek | Jackson | 35 |
| 9-L | East Fork Halls Creek | Jackson | 71 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 10-W | Sinsinawa River | Grant | 78 |
| 10-F | Barker Creek | Barron | 44 |
| 10-C | Little Platte River | Grant | 86 |
| 10-L | Trib. to Silver Creek | Fond du Lac | 31 |
| 11-W | Wind River | Pierce | 24 |
| 11-F | Koshkonong Creek | Dane | 26 |
| 11-C | North Fork Bad Axe River | Vernon | 85 |
| 11-L | Mill Creek | Monroe | 66 |
| 11-L | Brandy Creek | Monroe | 23 |
| 12-W | Cady Creek | Dunn | 60 |
| 12-F | North Branch Nippersink Creek | Walworth | 86 |
| 12-C | Yellowstone River | Lafayette | 75 |
| 12-L | Big Rib River | Taylor | 85 |
| 13-W | Silver Creek | Barron | 20 |
| 13-F | Scotch Creek | Marathon | 69 |
| 13-C | Shullsburg Branch | Lafayette | 85 |
| 13-L | Wedges Creek | Clark | 88 |
| 13-L | Meadows Creek | Clark | 31 |
| 14-W | Lost Creek | Pierce | 67 |
| 14-F | Freeman Creek | Marathon | 71 |
| 14-C | Galena River | Lafayette | 88 |
| 14-L | Roy Creek | Green Lake | 40 |
| 15-W | Parker Creek | St Croix | 39 |
| 15-F | Steel Brook | Jefferson | 71 |
| 15-C | Rush River | St Croix | 98 |
| 15-L | Trib. to Fox River | Waukesha | 90 |
| 16-W | Little Trimbelle Creek | Pierce | 51 |
| 16-F | Cawley Creek | Clark | 99 |
| 16-C | Fennimore Fork | Grant | 61 |
| 16-L | Beaver Creek | Juneau | 56 |
| 17-W | South Fork Elk Creek | Buffalo | 66 |
| 17-F | Kinnickinnic River | St Croix | 99 |
| 17-C | Sudah Branch | Iowa | 89 |
| 17-L | Little Yellow River | Juneau | 99 |
| 18-W | Otter Creek | Iowa | 50 |
| 18-F | West Branch Rock River | Fond du Lac | 80 |
| 18-C | Blake Fork | Grant | 89 |
| 18-L | West Branch Beaver Creek | Jackson | 51 |
| 18-L | West Branch Beaver Creek | Jackson | 21 |
| 19-W | Plum Creek | Pierce | 84 |
| 19-F | Turtle Creek | Walworth | 81 |
| 19-C | Little Baraboo River | Sauk | 66 |
| 19-L | Sand Creek | Burnett | 90 |
| 20-W | Smock Creek | Green | 20 |
| 20-F | Mill Creek | Wood | 95 |
| 20-C | Spafford Creek | Lafayette | 59 |
| 20-L | Root River | Milwaukee | 99 |
| 21-W | Kittleson Valley Creek | Iowa | 85 |
| 21-F | Hay River | Barron | 86 |
| 21-C | Moccasin Creek | Wood | 75 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 21-L | North Branch Duck Creek | Columbia | 88 |
| 21-L | Middle Branch Duck Creek | Columbia | 59 |
| 22-W | Trib. to Willow River | St Croix | 28 |
| 22-F | South Branch Beaver Creek | Marinette | 78 |
| 22-C | Bonner Branch | Lafayette | 89 |
| 22-L | Ashippun River | Waukesha | 91 |
| 23-C | Apple River | Lafayette | 28 |
| 23-W | Big Rock Branch | Grant | 26 |
| 23-F | Door Creek | Dane | 81 |
| 23-L | Trib. to Yellow River | Barron | 21 |
| 23-L | Boyer Creek | Washburn | 33 |
| 23-L | Trib. to Boyer Creek | Washburn | 24 |
| 24-W | Jordan Creek | Green | 42 |
| 24-F | South Branch Yellow River | Wood | 93 |
| 24-C | Little Richard Creek | Green | 73 |
| 24-L | Spring Creek | Columbia | 46 |
| 25-W | Copper Creek | Lafayette | 31 |
| 25-F | North Fork Popple River | Clark | 99 |
| 25-C | Blue River | Grant | 86 |
| 25-L | West Branch Milwaukee River | Fond du Lac | 85 |
| 26-W | Trib. to Otter Creek | Lafayette | 25 |
| 26-F | Duck Creek | Adams | 98 |
| 26-C | Hamann Creek | Marathon | 68 |
| 26-L | Robinson Creek | Jackson | 83 |
| 27-W | Smith Conley Creek | Iowa | 49 |
| 27-F | Hay Creek | Eau Claire | 87 |
| 27-C | Sylvester Creek | Green | 64 |
| 27-L | Left Foot Creek | Marinette | 42 |
| 28-W | McClintock Creek | Lafayette | 22 |
| 28-F | Sixmile Creek | Dane | 86 |
| 28-C | Seas Branch | Vernon | 36 |
| 28-L | Wood River | Burnett | 60 |
| 29-W | Trib. to Plum Creek | Pierce | 27 |
| 29-F | Pheasant Branch | Dane | 61 |
| 29-C | Skinner Creek | Green | 77 |
| 29-L | Harder Creek | Polk | 27 |
| 30-W | Flint Creek | Iowa | 77 |
| 30-F | Big Drywood Creek | Chippewa | 96 |
| 30-C | Sixmile Branch | Grant | 64 |
| 30-L | Cedar Creek | Washington | 70 |
| 31-W | Pine Creek | Pierce | 41 |
| 31-F | Spring Brook | Langlade | 81 |
| 31-C | Mounds Branch | Grant | 44 |
| 31-L | Rock Creek | Polk | 28 |
| 32-W | Trempealeau River | Buffalo | 40 |
| 32-F | Blackhawk Creek | Rock | 91 |
| 32-C | South Fork Hay River | Dunn | 85 |
| 32-L | Tarr Creek | Monroe | 58 |
| 32-L | Tarr Creek | Monroe | 100 |
| 32-L | Silver Creek | Monroe | 82 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 33-C | Artus Creek | Marathon | 22 |
| 33-L | Washington Creek | Taylor | 34 |
| 34-W | Fennimore Fork | Grant | 29 |
| 34-F | Cunningham Creek | Clark | 99 |
| 34-C | Narrows Creek | Sauk | 84 |
| 34-L | Oconomowoc River | Washington | 76 |
| 35-W | Stevens Creek | Rock | 37 |
| 35-F | Lightning Creek | Barron | 55 |
| 35-C | Blockhouse Creek | Grant | 94 |
| 35-L | Sand Creek | Monroe | 55 |
| 36-W | Kinnickinnic River | Pierce | 27 |
| 36-F | Koshkonong Creek | Dane | 73 |
| 36-C | Wolf Creek | Lafayette | 74 |
| 36-L | Bashaw Brook | Burnett | 93 |
| 37-W | Rush River | Pierce | 28 |
| 37-F | Rubicon River | Dodge | 85 |
| 37-C | Springville Branch Bad Axe River | Vernon | 57 |
| 37-L | North Branch Little River | Oconto | 69 |
| 38-W | Little Plum Creek | Pepin | 26 |
| 38-F | South Branch Rock River | Fond du Lac | 100 |
| 38-C | Neshota River | Brown | 87 |
| 38-L | Mukwonago River | Waukesha | 29 |
| 39-W | Beaver Creek | Dunn | 46 |
| 39-F | Little Tamarack Creek | Trempealeau | 37 |
| 39-C | Silver Creek | Dodge | 59 |
| 39-L | Hartman Creek | Waupaca | 21 |
| 40-W | Mud Creek | Winnebago | 66 |
| 40-F | Turtle Creek | Barron | 95 |
| 40-C | Big River | Pierce | 54 |
| 40-L | Glenn Creek | Jackson | 42 |
| 41-W | Reads Creek | Vernon | 50 |
| 41-F | Spring Brook | Rock | 50 |
| 41-C | Boice Creek | Grant | 94 |
| 41-L | Black River | Taylor | 92 |
| 42-W | Kittleson Valley Creek | Iowa | 86 |
| 42-F | Wolf River | Chippewa | 98 |
| 42-C | East River | Brown | 98 |
| 42-L | Trib. to Yellow River | Wood | 98 |
| 43-W | Bear Creek | Vernon | 62 |
| 43-F | Mill Creek | Dodge | 58 |
| 43-C | Cazenovia Branch | Sauk | 87 |
| 43-L | Silver Creek | Washington | 24 |
| 44-W | Camp Creek | Richland | 42 |
| 44-F | Pine Creek | Taylor | 96 |
| 44-C | Moore Creek | Monroe | 94 |
| 44-L | Beaver Creek | Taylor | 44 |
| 45-W | Waumandee Creek | Buffalo | 52 |
| 45-F | North Branch O'Neill Creek | Clark | 91 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 45-C | Jack Creek | Clark | 39 |
| 45-L | Tyler Forks | Iron | 100 |
| 46-L | Trib to Morrison Creek | Jackson | 22 |
| 46-W | Traverse Valley Creek | Trempealeau | 58 |
| 46-F | South Fork Eau Claire River | Clark | 98 |
| 46-C | Whiteside Creek | Lafayette | 52 |
| 47-W | Spring Creek | Pierce | 21 |
| 47-F | Meadows Creek | Barron | 84 |
| 47-C | Rock River | Rock | 37 |
| 47-L | Rock Creek | Jefferson | 61 |
| 48-W | Trib. to Trempealeau River | Trempealeau | 22 |
| 48-F | Rocky Run | Columbia | 84 |
| 48-C | Soda Creek | Marathon | 23 |
| 48-L | Waupee Creek | Oconto | 66 |
| 49-W | Neshonoc Creek | La Crosse | 35 |
| 49-F | Plum Creek | Dodge | 61 |
| 49-C | Platte River | Grant | 98 |
| 49-L | Marengo River | Bayfield | 92 |
| 49-L | Morgan Creek | Bayfield | 32 |
| 50-W | Trib. to Mississippi River | Pierce | 25 |
| 50-F | Dill Creek | Marathon | 96 |
| 50-C | Bishop Branch | Vernon | 52 |
| 50-L | Deerskin River | Vilas | 75 |
| 51-W | Trib. to Trempealeau River | Trempealeau | 21 |
| 51-F | Trib. to West Branch Rock River | Dodge | 55 |
| 51-C | Madden Branch | Lafayette | 58 |
| 51-L | Horse Creek | Polk | 91 |
| 52-W | Porcupine Creek | Pepin | 30 |
| 52-F | Jambo Creek | Manitowoc | 56 |
| 52-C | Lotz Creek | Chippewa | 21 |
| 52-L | Black Otter Creek | Outagamie | 55 |
| 53-W | Hackett Branch | Grant | 25 |
| 53-F | Bear Creek | Portage | 51 |
| 53-C | Spring Creek | Green | 45 |
| 53-L | Schoenick Creek | Shawano | 38 |
| 54-W | Elk Creek | Buffalo | 46 |
| 54-F | West Branch Big Eau Pleine River | Marathon | 89 |
| 54-C | Pigeon Creek | Grant | 57 |
| 54-L | Clear Creek | Jackson | 65 |
| 55-W | Kickapoo River | Monroe | 97 |
| 55-F | Rocky Run | Marathon | 41 |
| 55-C | Tenmile Creek | St Croix | 55 |
| 55-L | Somo River | Lincoln | 71 |
| 55-L | Trib. to South Fork Jump River | Price | 23 |
| 55-L | South Fork Jump River | Price | 46 |
| 56-W | Crooked Creek | Grant | 45 |
| 56-F | Bear Creek | Marathon | 94 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 56-C | Dougherty Creek | Lafayette | 72 |
| 56-L | Perry Creek | Jackson | 52 |
| 57-W | Vance Creek | Dunn | 42 |
| 57-F | Sugar Creek | Walworth | 71 |
| 57-C | Little Hemlock Creek | Wood | 49 |
| 57-L | Spirit Creek | Burnett | 65 |
| 57-L | Trib. to Wood River | Burnett | 20 |
| 58-W | Pine Creek | Trempealeau | 28 |
| 58-F | Randall Creek | Marathon | 81 |
| 58-C | Rountree Branch | Grant | 36 |
| 58-L | East Branch Milwaukee River | Fond du Lac | 87 |
| 59-W | Trib. to Fennimore Fork | Grant | 41 |
| 59-F | Honey Creek | Green | 86 |
| 59-C | Trib. to Mississippi River | Pierce | 34 |
| 59-L | South Branch Little Wolf | Waupaca | 72 |
| 60-W | Mill Creek | Richland | 72 |
| 60-F | Yahara River | Dane | 93 |
| 60-C | Searles Creek | Green | 52 |
| 60-L | White River | Waushara | 49 |
| 60-L | White River | Waushara | 48 |
| 61-W | Trib. to Coon Creek | Vernon | 32 |
| 61-F | North Branch Tenmile Creek | Portage | 85 |
| 61-C | West Branch Sugar River | Dane | 85 |
| 61-L | Trib. to Morrison Creek | Jackson | 22 |
| 62-W | Barr Creek | Sheboygan | 24 |
| 62-F | Taylor Creek | Rock | 80 |
| 62-C | Wood Branch | Lafayette | 48 |
| 62-L | North Branch Little Wolf | Waupaca | 89 |
| 63-W | Trib. to Trempealeau River | Buffalo | 26 |
| 63-F | Des Plaines River | Kenosha | 55 |
| 63-C | Rocky Run | Clark | 38 |
| 63-L | South Branch Pigeon River | Waupaca | 98 |
| 63-L | North Branch Pigeon River | Waupaca | 65 |
| 64-W | East Branch Pecatonica River | Lafayette | 22 |
| 64-F | Spring Creek | Columbia | 92 |
| 64-C | Big Green River | Grant | 89 |
| 64-L | Minnow Creek | Ashland | 27 |
| 65-W | Trib. to Waumandee Creek | Buffalo | 37 |
| 65-F | East Twin River | Kewaunee | 84 |
| 65-C | Tainter Creek | Crawford | 99 |
| 65-L | Starks Creek | Oneida | 26 |
| 66-W | East Branch Mill Creek | Richland | 26 |
| 66-F | Dorn Creek | Dane | 32 |
| 66-C | Trib. to Fourteenmile Creek | Adams | 28 |
| 66-L | Brant Creek | Lincoln | 41 |
| 66-L | Little Somo River | Lincoln | 100 |
| 67-W | Trib. to Rush Creek | Crawford | 36 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 67-F | East Branch Rock River | Washington | 81 |
| 67-C | Little Rib River | Marathon | 57 |
| 67-L | Whitewater Creek | Walworth | 62 |
| 68-W | North Creek | Trempealeau | 28 |
| 68-F | Mullet River | Sheboygan | 83 |
| 68-C | No Name Creek | Washington | 42 |
| 68-L | Montreal River | Iron | 51 |
| 69-W | Richland Creek | Crawford | 66 |
| 69-F | Drewek Creek | Marathon | 22 |
| 69-C | South Branch O'Neill Creek | Clark | 61 |
| 69-L | Linzy Creek | Oconto | 59 |
| 70-W | Trib. to Tainter Creek | Crawford | 29 |
| 70-F | Token Creek | Dane | 71 |
| 70-C | Hornby Creek | Vernon | 53 |
| 70-L | Little Peshtigo River | Marinette | 80 |
| 71-W | Sand Creek | Crawford | 25 |
| 71-F | Nelson Creek | Clark | 72 |
| 71-C | Trimbelle River | Pierce | 92 |
| 71-L | North Fork Jump River | Price | 70 |
| 72-W | West Branch Mill Creek | Richland | 35 |
| 72-F | Rock Creek | Clark | 66 |
| 72-C | McAdam Branch | Grant | 35 |
| 72-L | Pine Lake Creek | Oneida | 87 |
| 73-W | Borst Valley Creek | Trempealeau | 53 |
| 73-F | Sevenmile Creek | Juneau | 54 |
| 73-C | Engle Creek | Barron | 25 |
| 73-L | Honey Creek | Walworth | 84 |
| 74-W | Van Dyne Creek | Winnebago | 24 |
| 74-F | Rowan Creek | Columbia | 77 |
| 74-C | Bower Creek | Brown | 92 |
| 74-L | South Branch Yellow River | Juneau | 79 |
| 75-W | Trib. to Milwaukee River | Ozaukee | 33 |
| 75-F | Brighton Creek | Kenosha | 73 |
| 75-C | De Neveu Creek | Fond du Lac | 58 |
| 75-L | Hawkins Creek | Jackson | 61 |
| 75-L | Morrison Creek | Jackson | 39 |
| 76-W | Trib to Kickapoo River | Crawford | 27 |
| 76-F | Spring Brook | Walworth | 41 |
| 76-C | Brush Creek | Vernon | 82 |
| 76-L | Red River | Menominee | 78 |
| 77-W | Trout Run Creek | Buffalo | 21 |
| 77-F | Little Plover River | Portage | 33 |
| 77-C | Menominee River | Grant | 53 |
| 77-L | Squaw Creek | Forest | 26 |
| 78-W | Elk Creek | Vernon | 37 |
| 78-F | Potato Creek | Marathon | 30 |
| 78-C | Rogers Branch | Grant | 67 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 78-L | Dickey Creek | Jackson | 36 |
| 79-W | Sawmill Creek | Lafayette | 59 |
| 79-F | Hemlock Creek | Wood | 57 |
| 79-C | West Branch Little Sugar | Green | 89 |
| 79-L | Lunch Creek | Marquette | 58 |
| 80-W | Cherry Branch | Lafayette | 24 |
| 80-F | Trib. to Cedar Creek | Washington | 60 |
| 80-C | Borah Creek | Grant | 45 |
| 80-L | West Branch Eau Claire River | Langlade | 85 |
| 80-L | Sucker Creek | Langlade | 20 |
| 81-W | Gran Grae Creek | Crawford | 46 |
| 81-F | Otter Creek | Rock | 99 |
| 81-C | Sugar River | Green | 56 |
| 81-L | South Branch Neenah Creek | Marquette | 81 |
| 82-W | Coon Creek | Vernon | 21 |
| 82-F | Sugar River | Dane | 94 |
| 82-C | Big Sandy Creek | Marathon | 47 |
| 82-L | Jay Creek | Monroe | 59 |
| 83-W | Sawyer Creek | Winnebago | 37 |
| 83-F | Little Drywood Creek | Chippewa | 88 |
| 83-C | OK Creek | Green | 23 |
| 83-L | Little Mackay Creek | Washburn | 92 |
| 84-W | Halls Branch | Crawford | 34 |
| 84-F | Hoosier Creek | Racine | 54 |
| 84-C | Squaw Creek | Marathon | 53 |
| 84-L | Pecore Creek | Oconto | 87 |
| 85-W | Ash Creek | Richland | 48 |
| 85-F | Ore Creek | Walworth | 49 |
| 85-C | Porky Creek | Marathon | 21 |
| 85-L | Otter Creek | Marinette | 84 |
| 85-L | Colburn Creek | Forest | 25 |
| 86-W | Turton Creek | Trempealeau | 62 |
| 86-F | Maunesha River | Dane | 95 |
| 86-C | Bears Grass Creek | Eau Claire | 73 |
| 86-L | Long Lake Creek | Iron | 61 |
| 87-W | Halfway Creek | La Crosse | 85 |
| 87-F | Fourmile Creek | Marathon | 64 |
| 87-C | Rush Creek | Crawford | 79 |
| 87-L | Christie Brook | Oconto | 36 |
| 88-W | Trib. to Platte River | Grant | 36 |
| 88-F | Little Turtle Creek | Walworth | 98 |
| 88-C | Wildcat Creek | Dodge | 74 |
| 88-L | Gudegast Creek | Oneida | 49 |
| 88-L | Jennie Webber Creek | Oneida | 64 |
| 89-W | Harvey Creek | Buffalo | 95 |
| 89-F | Fenwood Creek | Marathon | 53 |
| 89-C | Little Grant River | Grant | 52 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 89-L | Neenah Creek | Marquette | 89 |
| 90-W | Arkansaw Creek | Pepin | 59 |
| 90-F | Scarboro Creek | Kewaunee | 56 |
| 90-C | Bear Creek | Clark | 30 |
| 90-L | Hay Creek | Washburn | 35 |
| 91-W | Hardies Creek | Trempealeau | 21 |
| 91-F | Kummel Creek | Dodge | 79 |
| 91-C | East Branch Fond Du Lac River | Fond du Lac | 65 |
| 91-L | Bear Creek | Taylor | 27 |
| 92-W | Cleaver Creek | Juneau | 62 |
| 92-F | Allen Creek | Rock | 92 |
| 92-C | Martin Branch | Grant | 57 |
| 92-L | Butternut Creek | Ashland | 69 |
| 93-W | Pigeon Creek | Trempealeau | 97 |
| 93-F | South Fork Lemonweir River | Monroe | 93 |
| 93-C | West Branch Baraboo River | Vernon | 95 |
| 93-L | Wolf Creek | Marinette | 38 |
| 94-W | Warner Creek | Vernon | 64 |
| 94-F | Seeley Creek | Sauk | 85 |
| 94-C | Wild Creek | Marathon | 28 |
| 94-L | Trib. to Wolf River | Menominee | 64 |
| 95-W | Trib. to Apple Creek | Outagamie | 26 |
| 95-F | Little Bear Creek | Barron | 42 |
| 95-C | Bear Creek | Juneau | 95 |
| 95-L | Big Weirgor Creek | Rusk | 79 |
| 96-W | Pompey Pillar Creek | Iowa | 51 |
| 96-F | Trib. to Red Cedar River | Barron | 67 |
| 96-C | Norwegian Creek | Clark | 35 |
| 96-L | Casey Creek | Washburn | 84 |
| 97-W | Trib. to Mormon Creek | Vernon | 40 |
| 97-F | Duck Creek | Jefferson | 81 |
| 97-C | Prahl Creek | Marathon | 35 |
| 97-L | Middle Inlet | Marinette | 85 |
| 98-W | Bruce Valley Creek | Trempealeau | 29 |
| 98-F | Shaw Brook | Dodge | 91 |
| 98-C | Timber Coulee Creek | Vernon | 91 |
| 98-L | Pike Lake Creek | Marathon | 26 |
| 99-W | Sugar Creek | Crawford | 66 |
| 99-F | Trib. to Buena Vista Creek | Portage | 47 |
| 99-C | Mosquito Creek | Wood | 52 |
| 99-L | Fox Creek | Polk | 57 |
| 100-W | Bogus Creek | Pepin | 29 |
| 100-F | Brewer Creek | Juneau | 35 |
| 100-C | Hickey Creek | Barron | 27 |
| 100-L | Bog Brook | Forest | 27 |
| 101-W | Otter Creek | Vernon | 29 |
| 101-F | Silver Creek | Manitowoc | 64 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 101-C | Billings Creek | Vernon | 94 |
| 101-L | Radley Creek | Waupaca | 81 |
| 101-L | Emmons Creek | Waupaca | 70 |
| 102-W | Hawkins Creek | Richland | 40 |
| 102-F | East Fork Hemlock Creek | Wood | 33 |
| 102-C | Trib. to Sugar River | Rock | 31 |
| 102-L | Hydes Creek | Waupaca | 32 |
| 103-W | Trib to Chippewa River | Pepin | 29 |
| 103-F | Lower Pine Creek | Dunn | 94 |
| 103-C | Roxbury Creek | Dane | 67 |
| 103-L | Dead Creek | Monroe | 37 |
| 104-W | Trout Creek | Buffalo | 31 |
| 104-F | North Branch Honey Creek | Sauk | 94 |
| 104-C | Coon Branch | Lafayette | 23 |
| 104-L | Eighteenmile Creek | Bayfield | 81 |
| 105-W | Trib to Lake Michigan | Kewaunee | 25 |
| 105-F | Noisy Creek | Marathon | 33 |
| 105-C | Roger Creek | Chippewa | 27 |
| 105-L | Little Deerskin River | Vilas | 27 |
| 105-L | Blackjack Creek | Vilas | 37 |
| 106-W | Annis Creek | Dunn | 55 |
| 106-F | Black Creek | Marathon | 73 |
| 106-C | Markham Creek | Rock | 27 |
| 106-L | Minnesuing Creek | Douglas | 56 |
| 107-W | Cook Creek | Monroe | 23 |
| 107-F | Trib. to Des Plaines River | Kenosha | 61 |
| 107-C | Mormon Creek | La Crosse | 96 |
| 107-L | Squaw Creek | Price | 63 |
| 108-W | Willow Branch | Grant | 21 |
| 108-F | Cold Spring Creek | Dodge | 37 |
| 108-C | East Branch Shioc River | Shawano | 45 |
| 108-L | First South Branch Oconto | Menominee | 82 |
| 109-W | Wilson Creek | Dunn | 97 |
| 109-F | South Fork Popple River | Clark | 64 |
| 109-C | West Fork Little Rib River | Marathon | 61 |
| 109-L | North Branch Pemebonwon River | Marinette | 92 |
| 110-W | Trib to S. Fork Bad Axe River | Vernon | 24 |
| 110-F | North Fork Bob Creek | Chippewa | 93 |
| 110-C | Burgy Creek | Green | 65 |
| 110-L | North Fork Skinner Creek | Rusk | 52 |
| 111-W | Pine Creek | Sauk | 39 |
| 111-F | Marsh Creek | Rock | 90 |
| 111-C | Plum Creek | Brown | 94 |
| 111-L | Big Pine Creek | Lincoln | 70 |
| 112-W | Little Willow Creek | Richland | 36 |
| 112-F | Duncan Creek | Chippewa | 90 |
| 112-C | County Line Creek | Marathon | 34 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 112-L | Noisy Creek | Oneida | 96 |
| 113-W | Ashwaubenon Creek | Brown | 76 |
| 113-F | Trout Creek | Dunn | 82 |
| 113-C | Trib. to Little Eau Pleine River | Marathon | 35 |
| 113-L | Weso Creek | Oconto | 29 |
| 114-W | Chimney Rock Creek | Trempealeau | 62 |
| 114-F | Saunders Creek | Rock | 69 |
| 114-C | Little Richard Creek | Green | 25 |
| 114-L | Fay Lake Outlet | Florence | 55 |
| 115-W | Weister Creek | Vernon | 55 |
| 115-F | Spring Brook | Dodge | 66 |
| 115-C | Knapp Creek | Richland | 94 |
| 115-L | Dryden Creek | Ashland | 64 |
| 116-W | McCartney Branch | Grant | 20 |
| 116-F | Big Roche a Cri Creek | Adams | 69 |
| 116-C | Dorrity Creek | Barron | 22 |
| 116-L | Murphy Creek | Marinette | 25 |
| 117-W | Melancthon Creek | Richland | 38 |
| 117-F | Dead Creek | Dodge | 81 |
| 117-C | Beaver Creek | Wood | 28 |
| 117-L | Swamsauger Creek | Oneida | 44 |
| 118-W | French Creek | Trempealeau | 58 |
| 118-F | Trib. to Little Eau Pleine River | Portage | 52 |
| 118-C | Thompson Valley Creek | Eau Claire | 34 |
| 118-L | Little Thornapple River | Rusk | 94 |
| 119-W | Davis Creek | Jackson | 21 |
| 119-F | Yellow River | Wood | 96 |
| 119-C | Silver Creek | Marathon | 20 |
| 119-L | Yellow River | Washburn | 86 |
| 120-W | Harrison Creek | Vernon | 31 |
| 120-F | East Fork Popple River | Clark | 53 |
| 120-C | East Branch Yellow River | Wood | 41 |
| 120-L | Kelly Brook | Oconto | 72 |
| 121-W | Millville Creek | Grant | 61 |
| 121-F | North Fork Eau Claire River | Clark | 99 |
| 121-C | Mud Creek | Dodge | 36 |
| 121-L | Chippanazie Creek | Washburn | 78 |
| 122-W | Elk Creek | Trempealeau | 92 |
| 122-F | Tisch Mills Creek | Manitowoc | 33 |
| 122-C | Coon Creek | Vernon | 49 |
| 122-L | North Branch Oconto River | Forest | 96 |
| 123-W | Rowley Creek | Sauk | 34 |
| 123-F | Mud Creek | Jefferson | 38 |
| 123-C | Apple Creek | Outagamie | 93 |
| 123-L | Ericson Creek | Douglas | 29 |
| 123-L | Amnicon River | Douglas | 73 |
| 124-W | Willow Creek | Richland | 95 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 124-F | Starkweather Creek | Dane | 55 |
| 124-C | West Branch Pine River | Richland | 99 |
| 124-L | Stevens Creek | Florence | 76 |
| 125-W | Little Sugar River | Green | 100 |
| 125-F | Crawfish River | Columbia | 65 |
| 125-C | Devil Creek | Lincoln | 71 |
| 125-L | Upper Tamarack River | Douglas | 60 |
| 125-L | Toad Creek | Douglas | 27 |
| 126-W | Mud Branch | Lafayette | 25 |
| 126-F | Paint Creek | Chippewa | 92 |
| 126-C | Sherman Creek | Eau Claire | 60 |
| 126-L | Squirrel River | Oneida | 88 |
| 127-W | Plum Creek | Crawford | 43 |
| 127-F | Calamus Creek | Dodge | 61 |
| 127-C | Trib. to Koshkonong Creek | Dane | 21 |
| 127-L | Twin Lakes Creek | Oneida | 54 |
| 128-W | Picatee Creek | Crawford | 27 |
| 128-F | Lomira Creek | Dodge | 54 |
| 128-C | Seymour Creek | Juneau | 56 |
| 128-L | Beaver Brook | Washburn | 63 |
| 129-W | Trib. to Waumandee Creek | Buffalo | 31 |
| 129-F | North Branch Pensaukee River | Oconto | 92 |
| 129-C | Beaver Creek | Eau Claire | 33 |
| 129-L | Papoose Creek | Vilas | 21 |
| 130-W | South Fork Kinnickinnic River | Pierce | 46 |
| 130-F | Mud Creek | Dane | 61 |
| 130-C | Trout Creek | Brown | 40 |
| 130-L | Second South Branch Oconto River | Oconto | 68 |
| 131-W | Lane Creek | Grant | 48 |
| 131-F | Badger Mill Creek | Dane | 87 |
| 131-C | Leggett Creek | Grant | 49 |
| 131-L | Pioneer Creek | Vilas | 93 |
| 132-W | Big Creek | Trempealeau | 45 |
| 132-F | North Branch Milwaukee River | Sheboygan | 97 |
| 132-C | Plum Creek | Sauk | 39 |
| 132-L | Nixon Creek | Vilas | 36 |
| 133-W | Trib. to De Neveu Creek | Winnebago | 30 |
| 133-F | Muskrat Creek | Eau Claire | 87 |
| 133-C | Hay Creek | Chippewa | 45 |
| 133-L | Brule Creek | Forest | 97 |
| 134-W | Garners Creek | Outagamie | 30 |
| 134-F | Town Drain | Green Lake | 40 |
| 134-C | Robbins Creek | Columbia | 22 |
| 134-L | Tom Doyle Creek | Oneida | 26 |
| 135-W | Lowery Creek | Iowa | 35 |
| 135-F | West Branch Shioc | Shawano | 77 |
| 135-C | Butler Creek | Dodge | 48 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 135-L | Brunsweiler River | Ashland | 67 |
| 136-W | Hutchinson Creek | Buffalo | 21 |
| 136-F | Ahnapee River | Door | 93 |
| 136-C | East Branch Big Sandy Creek | Marathon | 26 |
| 136-L | Sailor Creek | Price | 96 |
| 137-W | Trib. to South Fork Bad Axe River | Vernon | 27 |
| 137-F | Oldens Creek | Marathon | 48 |
| 137-C | Mount Vernon Creek | Dane | 43 |
| 137-L | Ghost Creek | Sawyer | 31 |
| 137-L | Christy Creek | Sawyer | 27 |
| 138-W | Little Suamico River | Oconto | 68 |
| 138-F | Kewaunee River | Kewaunee | 85 |
| 138-C | Sterling Creek | Clark | 20 |
| 138-L | Trib. to Bear River | Vilas | 50 |
| 139-W | Little Waumandee Creek | Buffalo | 93 |
| 139-F | North Fork Trade River | Burnett | 48 |
| 139-C | Dutchman Creek | Brown | 78 |
| 139-L | Squaw Creek | Price | 109 |
| 140-W | Fall Creek | Dunn | 29 |
| 140-F | Mud Creek | Monroe | 47 |
| 140-C | East Fork Raccoon Creek | Rock | 43 |
| 140-L | Swamp Creek | Forest | 94 |
| 141-W | Trib. to Fennimore Creek | Grant | 21 |
| 141-F | South Branch Manitowoc River | Calumet | 73 |
| 141-C | Pensaukee River | Shawano | 91 |
| 141-L | Price Creek | Sawyer | 56 |
| 142-W | Pine Creek | Crawford | 70 |
| 142-F | Fordham Creek | Adams | 72 |
| 142-C | Willow Creek | Rock | 60 |
| 142-L | East Branch Lily River | Langlade | 52 |
| 143-W | Trib. to Wisconsin River | Crawford | 21 |
| 143-F | Black Creek | Manitowoc | 62 |
| 143-C | Gilbert Creek | Dunn | 95 |
| 143-L | Gull Creek | Washburn | 26 |
| 144-F | Piscasaw Creek | Walworth | 35 |
| 144-W | Sandy Creek | Grant | 53 |
| 144-C | Pine River | Richland | 97 |
| 144-L | Turtle River | Iron | 74 |
| 145-W | Rossman Creek | Buffalo | 22 |
| 145-F | Spring Creek | Calumet | 52 |
| 145-C | Fancy Creek | Richland | 75 |
| 145-L | Little Roche a Cri Creek | Adams | 68 |
| 146-W | Taycheedah Creek | Fond du Lac | 42 |
| 146-F | Pumpkinseed Creek | Waushara | 56 |
| 146-C | Otter Creek | Eau Claire | 66 |
| 146-L | Sand Creek | Sawyer | 73 |
| 147-W | Trib. to Sugar River | Dane | 22 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 147-F | Klawitter Creek | Marquette | 82 |
| 147-C | Trout Run | Jackson | 44 |
| 147-L | Totagatic River | Sawyer | 73 |
| 148-W | Du Charme Creek | Crawford | 35 |
| 148-F | Pratt Creek | Dodge | 73 |
| 148-C | Fisher Creek | Sheboygan | 31 |
| 148-L | Springstead Creek | Price | 42 |
| 149-W | West Fork Knapp Creek | Richland | 48 |
| 149-F | Mole Brook | Marathon | 34 |
| 149-C | Sevenmile Creek | Fond du Lac | 59 |
| 149-L | Fishtrap Creek | Sawyer | 45 |
| 150-W | Big Slough | Trempealeau | 22 |
| 150-F | East Branch Little Black | Taylor | 58 |
| 150-C | Trib. to South Fork Eau Claire | Clark | 24 |
| 150-L | Wolf River | Forest | 84 |
| 151-W | Trib. to Trempealeau River | Jackson | 25 |
| 151-F | Eagle Creek | Racine | 43 |
| 151-C | Johnson Creek | Jefferson | 83 |
| 151-L | Rice Creek | Vilas | 70 |
| 152-W | Citron Creek | Crawford | 41 |
| 152-F | Beaver Creek | Dodge | 76 |
| 152-C | Sheboygan River | Fond du Lac | 76 |
| 152-L | Wilson Creek | Sawyer | 56 |
| 153-W | Weedons Creek | Sheboygan | 23 |
| 153-F | Soft Maple Creek | Rusk | 96 |
| 153-C | Gill Creek | Dodge | 31 |
| 153-L | Enterprise Creek | Oneida | 73 |
| 154-W | Trout Creek | Iowa | 44 |
| 154-F | Casco Creek | Kewaunee | 44 |
| 154-C | Twomile Creek | Wood | 45 |
| 154-L | Nixon Creek | Vilas | 30 |
| 155-W | Parsons Creek | Fond du Lac | 20 |
| 155-F | Little Kickapoo Creek | Crawford | 35 |
| 155-C | Trib. to Baraboo River | Sauk | 28 |
| 155-L | East Branch Eau Claire River | Langlade | 63 |
| 156-W | Squaw Creek | Jackson | 54 |
| 156-F | Rocky Creek | Wood | 60 |
| 156-C | Hills Creek | Juneau | 44 |
| 156-L | Mud Creek | Oneida | 91 |
| 157-W | North Fork Buffalo River | Trempealeau | 78 |
| 157-F | Kohlsville River | Washington | 52 |
| 157-C | Puff Creek | Wood | 34 |
| 157-L | Little Turtle River | Iron | 45 |
| 158-W | Big Creek | Sauk | 75 |
| 158-F | Dunlap Creek | Dane | 36 |
| 158-C | Bull Branch | Grant | 30 |
| 158-L | Johnson Creek | Vilas | 31 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 159-W | Trib. to Mississippi River | Crawford | 20 |
| 159-F | Daly Creek | Oconto | 72 |
| 159-C | Kankapot Creek | Outagamie | 69 |
| 159-L | Little Bear Creek | Iron | 95 |
| 160-W | Copper Creek | Crawford | 70 |
| 160-F | Casper Creek | Dodge | 36 |
| 160-C | Cameron Creek | Clark | 40 |
| 160-L | Spread Eagle Outfit | Florence | 24 |
| 161-W | Pine Creek | Trempealeau | 34 |
| 161-F | Lyndon Creek | Juneau | 55 |
| 161-C | Goggle-Eye Creek | Clark | 24 |
| 161-L | West Branch Wolf River | Menominee | 90 |
| 162-W | Sucker Creek | Ozaukee | 36 |
| 162-F | Silver Creek | Kewaunee | 64 |
| 162-C | West Creek | Eau Claire | 50 |
| 162-L | West Fork Chippewa River | Sawyer | 72 |
| 163-W | Spring Creek | Buffalo | 40 |
| 163-F | Little Eau Pleine River | Marathon | 77 |
| 163-C | Bolen Creek | Dunn | 38 |
| 163-L | South Branch Oconto | Langlade | 92 |
| 164-W | Mill Creek | Jackson | 21 |
| 164-F | Shoulder Creek | Rusk | 69 |
| 164-C | Juda Branch | Green | 48 |
| 164-L | West Torch River | Ashland | 74 |
| 165-W | North Fork Beaver Creek | Trempealeau | 87 |
| 165-F | Honey Creek | Sauk | 63 |
| 165-C | Bass Creek | Rock | 45 |
| 165-L | Hay Creek | Price | 70 |
| 166-L | Trib to Yellow River | Burnett | 81 |
| 166-W | Trib. to Duck Creek | Outagamie | 21 |
| 166-F | Onion River | Sheboygan | 72 |
| 166-C | Trib. to Root River | Racine | 99 |
| 167-W | Little Green River | Grant | 43 |
| 167-F | Bark River | Waukesha | 71 |
| 167-C | Spring Brook | Rock | 24 |
| 167-L | Lynch Creek | Sawyer | 31 |
| 168-W | Bostwick Creek | La Crosse | 96 |
| 168-F | Milwaukee River | Fond du Lac | 78 |
| 168-C | Trib. to Wisconsin River | Wood | 26 |
| 168-L | Lily River | Forest | 80 |
| 169-W | Trib. to Fox River | Winnebago | 22 |
| 169-F | Trib. to Rock River | Rock | 32 |
| 169-C | Douglas Creek | Jackson | 63 |
| 169-L | Connors Creek | Sawyer | 38 |
| 170-W | Sand Branch | Grant | 22 |
| 170-F | White River | Walworth | 79 |
| 170-C | Bridge Creek | Eau Claire | 93 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 170-L | Sevenmile Creek | Oneida | 39 |
| 171-W | Mill Creek | Buffalo | 38 |
| 171-F | Trib. to Little Turtle Creek | Rock | 58 |
| 171-C | Jim Creek | Chippewa | 31 |
| 171-L | Tamarack Creek | Vilas | 72 |
| 172-W | Trib. to Kickapoo River | Monroe | 26 |
| 172-F | Tomorrow River | Portage | 98 |
| 172-C | Trib. to Rock River | Jefferson | 41 |
| 172-L | Rice Creek | Vilas | 65 |
| 173-W | Sioux Creek | Barron | 28 |
| 173-F | Raccoon Creek | Rock | 66 |
| 173-C | Trib. to Little River | Oconto | 22 |
| 173-L | Mukwonago River | Waukesha | 70 |
| 174-W | Trib. to Honey Creek | Sauk | 28 |
| 174-F | North Branch Crawfish River | Columbia | 77 |
| 174-C | Trib. to Fox River | Racine | 40 |
| 174-L | McKenzie Creek | Washburn | 38 |
| 175-W | Reynolds Coulee Creek | Trempealeau | 21 |
| 175-F | Sweeny Pond | Barron | 24 |
| 175-C | Crawfish River | Dodge | 31 |
| 175-L | Portage Creek | Vilas | 47 |
| 176-W | North Fork Clam River | Burnett | 69 |
| 176-F | Root River | Kenosha | 27 |
| 176-C | Little Trappe River | Marathon | 24 |
| 176-L | Muskellunge Creek | Oneida | 38 |
| 177-W | North Branch Manitowoc River | Calumet | 28 |
| 177-F | Brick Creek | Clark | 47 |
| 177-C | Dawson Creek | Dodge | 25 |
| 177-L | Caves Creek | Marquette | 26 |
| 177-L | Westfield Creek | Marquette | 91 |
| 177-L | Tagatz Creek | Marquette | 58 |
| 178-W | Oak Creek | Milwaukee | 73 |
| 178-F | Deer Tail Creek | Rusk | 97 |
| 178-C | McGinnis Creek | Marathon | 62 |
| 178-L | Rocky Run | Oneida | 77 |
| 179-W | West Branch Fond Du Lac River | Fond du Lac | 20 |
| 179-F | Mill Creek | Shawano | 83 |
| 179-C | Fall Creek | Eau Claire | 46 |
| 179-L | Pickerel Creek | Langlade | 110 |
| 180-W | Potter Creek | Brown | 28 |
| 180-F | Rat River | Winnebago | 83 |
| 180-C | Little Elk Creek | Dunn | 42 |
| 180-L | Ninemile Creek | Vilas | 20 |
| 181-W | Missouri Creek | Pepin | 82 |
| 181-F | Little River | Marinette | 39 |
| 181-C | Trib. to Rock River | Jefferson | 32 |
| 181-L | Foulds Creek | Price | 51 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 182-W | Pine Creek | Manitowoc | 29 |
| 182-F | Fourmile Creek | Barron | 43 |
| 182-C | Spring Creek | Dane | 21 |
| 182-L | Upper Inlet | Marinette | 41 |
| 183-W | Pensaukee River | Shawano | 21 |
| 183-F | Maple Creek | Outagamie | 69 |
| 183-C | Big Slough | Columbia | 91 |
| 183-L | Scuppernong River | Jefferson | 93 |
| 184-W | Onion River | Sheboygan | 45 |
| 184-F | Little Menomonee River | Milwaukee | 73 |
| 184-C | Soper Creek | Monroe | 97 |
| 184-L | Loon Creek | Shawano | 36 |
| 185-W | Trib to Cranberry Creek | Juneau | 45 |
| 185-F | Quaderer Creek | Barron | 29 |
| 185-C | Baraboo River | Juneau | 90 |
| 185-L | Kaubashine Creek | Oneida | 27 |
| 186-W | Babb Creek | Sauk | 25 |
| 186-F | Saunders Creek | Rock | 29 |
| 186-C | North Branch Trempealeau River | Jackson | 56 |
| 186-L | Rat River | Forest | 92 |
| 187-W | Irving Creek | Dunn | 30 |
| 187-F | Grand River | Green Lake | 50 |
| 187-C | Sauk Creek | Ozaukee | 81 |
| 187-L | South Branch Pike River | Marinette | 53 |
| 188-W | Twin Creek | Sauk | 31 |
| 188-F | Stony Brook | Dodge | 70 |
| 188-C | Pike River | Kenosha | 47 |
| 188-L | Rice Creek | Price | 64 |
| 189-W | Sanders Creek | Grant | 44 |
| 189-F | McCann Creek | Chippewa | 71 |
| 189-C | Little Sandy Creek | Marathon | 31 |
| 189-L | Neptune Creek | Oneida | 27 |
| 190-W | Prentice Creek | Columbia | 32 |
| 190-F | Spring Creek | Jefferson | 25 |
| 190-C | Ninemile Creek | Eau Claire | 22 |
| 190-L | Shell Creek | Washburn | 49 |
| 191-W | Trib. to Apple River | St Croix | 51 |
| 191-F | Fisher River | Chippewa | 94 |
| 191-C | Suamico River | Brown | 76 |
| 191-L | Lost Creek | Vilas | 57 |
| 192-W | Willow River | St Croix | 35 |
| 192-F | Kinnickinnic River | Milwaukee | 70 |
| 192-C | Arrowhead River | Winnebago | 80 |
| 192-L | Trib. to Brill River | Washburn | 46 |
| 193-W | Fly Creek | Trempealeau | 26 |
| 193-F | Spring Brook | Rock | 31 |
| 193-C | Deer Creek | Jefferson | 27 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 193-L | Moose Creek | Iron | 38 |
| 194-W | Daggets Creek | Winnebago | 30 |
| 194-F | Potters Creek | Waupaca | 70 |
| 194-C | Black River | Jackson | 24 |
| 194-L | Julia Creek | Oneida | 45 |
| 195-W | Little Bear Creek | Buffalo | 94 |
| 195-F | Spring Creek | Portage | 47 |
| 195-C | Black River | Sheboygan | 39 |
| 195-L | Randall Creek | Iron | 23 |
| 196-W | Mill Creek | Richland | 25 |
| 196-F | Dry Creek | Adams | 33 |
| 196-C | Elk Creek | Chippewa | 86 |
| 196-L | Whalen Creek | Washburn | 21 |
| 197-W | Trib. to Little LaCrosse River | Monroe | 23 |
| 197-F | Menomonee River | Waukesha | 90 |
| 197-C | Ross Crossing Creek | Green | 28 |
| 197-L | Indian Chain Creek | Oneida | 23 |
| 197-L | Kathan Creek | Oneida | 21 |
| 198-W | Halfway Prairie Creek | Dane | 71 |
| 198-F | Mud Creek | Manitowoc | 73 |
| 198-C | Bear Creek | Richland | 91 |
| 198-L | Tomahawk Creek | Oneida | 21 |
| 199-W | Trout Creek | Crawford | 23 |
| 199-F | Story Creek | Green | 59 |
| 199-C | Jim Moore Creek | Marathon | 21 |
| 199-L | Long Lake Branch | Bayfield | 87 |
| 200-W | Council Creek | Monroe | 36 |
| 200-F | Trib. to North Branch Crawfish River | Columbia | 28 |
| 200-C | Black Earth Creek | Dane | 86 |
| 200-L | Slim Creek | Washburn | 38 |
| 201-W | Fish Creek | La Crosse | 39 |
| 201-F | Sawyer Creek | Washburn | 88 |
| 201-C | Fourmile Creek | Portage | 97 |
| 201-L | Buckaton Creek | Vilas | 45 |
| 202-W | East Branch Blue Mounds Creek | Dane | 83 |
| 202-F | Elm Creek | Wood | 95 |
| 202-C | Little LaCrosse River | Monroe | 75 |
| 202-L | Pelican River | Oneida | 66 |
| 203-W | Trib. to Hemlock Creek | Wood | 25 |
| 203-F | Hog Creek | Marathon | 42 |
| 203-C | Pewaukee River | Waukesha | 99 |
| 203-L | Loon Creek | Burnett | 74 |
| 204-W | Onion River | Sheboygan | 22 |
| 204-F | Fox River | Marquette | 39 |
| 204-C | Devils River | Manitowoc | 88 |
| 204-L | North Branch Peshtigo Brook | Oconto | 72 |
| 205-W | North Fork Beaver Creek | Trempealeau | 89 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 205-F | Carter Creek | Adams | 83 |
| 205-C | South Branch Trempealeau | Jackson | 57 |
| 205-L | Webb Creek | Burnett | 63 |
| 206-W | Trib. to De Neveu Creek | Winnebago | 31 |
| 206-F | Fountain Creek | Juneau | 28 |
| 206-C | Chippewa River | Dunn | 39 |
| 206-L | Snake Creek | Douglas | 33 |
| 207-W | Trump Coulee Creek | Trempealeau | 27 |
| 207-F | Eightmile Creek | Winnebago | 82 |
| 207-C | Knights Creek | Dunn | 84 |
| 207-L | Swamp Creek | Oneida | 29 |
| 208-W | Johns Creek | Dunn | 22 |
| 208-F | East Branch Honey Creek | Sauk | 63 |
| 208-C | Trib. to Rock River | Jefferson | 21 |
| 208-L | Fourmile Creek | Oneida | 24 |
| 209-W | Trib. to East Twin River | Kewaunee | 22 |
| 209-F | Trib. to O'Neil Creek | Chippewa | 49 |
| 209-C | Duck Creek | Outagamie | 94 |
| 209-L | Denomie Creek | Ashland | 48 |
| 210-W | Trib. to Mississippi River | Crawford | 23 |
| 210-F | Muddy Creek | Dunn | 78 |
| 210-C | Francis Creek | Manitowoc | 35 |
| 210-L | Rice Creek | Oneida | 48 |
| 211-W | Tamarack Creek | Trempealeau | 96 |
| 211-F | Brown Creek | Barron | 26 |
| 211-C | Allen Creek | Marquette | 26 |
| 211-L | Eagle River | Oneida | 82 |
| 212-F | Dutch Gap Canal | Kenosha | 32 |
| 212-L | Trib to Manitowish River | Iron | 61 |
| 212-W | Sneed Creek | Iowa | 75 |
| 212-C | Trib. to Bass Creek | Rock | 38 |
| 213-W | West Branch Blue Mounds Creek | Iowa | 50 |
| 213-F | Trib. to Rock River | Jefferson | 32 |
| 213-C | Trib. to Kinnickinnic River | St Croix | 37 |
| 213-L | Trib. to Link Creek | Oneida | 78 |
| 214-W | Dutch Creek | La Crosse | 50 |
| 214-F | South Branch Beaver Brook | Polk | 61 |
| 214-C | Trib. to Alto Creek | Dodge | 20 |
| 214-L | Plum Creek | Vilas | 92 |
| 215-W | Little Manitowoc River | Manitowoc | 35 |
| 215-F | Trib. to Wolf River | Outagamie | 48 |
| 215-C | Trib. to Rock River | Jefferson | 22 |
| 215-L | Trib. to Fox River | Racine | 20 |
| 216-W | Marsh Creek | Iowa | 92 |
| 216-F | Web Creek | Price | 83 |
| 216-C | Pigeon River | Manitowoc | 53 |
| 217-W | Trib. to Baraboo River | Sauk | 21 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 217-F | Galloway Creek | Jefferson | 44 |
| 217-C | Little River | Oconto | 32 |
| 218-W | Trib. to Hemlock Creek | Wood | 20 |
| 218-F | Stillson Creek | Chippewa | 20 |
| 218-C | Lowes Creek | Eau Claire | 93 |
| 219-W | Fleming Creek | La Crosse | 92 |
| 219-F | Iron Creek | Dunn | 51 |
| 219-C | Kriwanek Creek | Manitowoc | 31 |
| 220-W | Trib. to Blue Mounds Creek | Iowa | 20 |
| 220-F | Trib. to Crawfish River | Columbia | 40 |
| 220-C | Dell Creek | Sauk | 92 |
| 221-W | Rocky Run | Portage | 24 |
| 221-F | Trib. to Turtle Creek | Walworth | 40 |
| 221-C | Fourteenmile Creek | Adams | 85 |
| 222-W | Wilson Creek | Sauk | 41 |
| 222-F | Potato Creek | Rusk | 76 |
| 222-C | Point Creek | Manitowoc | 57 |
| 223-W | Corning Creek | Adams | 38 |
| 223-F | Deer Creek | Jefferson | 41 |
| 223-C | Black Creek | Outagamie | 93 |
| 224-W | Johnson Creek | Marathon | 79 |
| 224-F | Stony Creek | Kewaunee | 62 |
| 224-C | Nolan Creek | Dodge | 23 |
| 225-W | Taylor Creek | Eau Claire | 20 |
| 225-F | Fox River | Columbia | 90 |
| 225-C | Wildcat Creek | Dodge | 22 |
| 226-W | Fischer Creek | Manitowoc | 30 |
| 226-F | Beaver Creek | Marathon | 21 |
| 226-C | Eighteenmile Creek | Dunn | 75 |
| 227-W | Little Lemonweir River | Juneau | 91 |
| 227-F | Mud Creek | Manitowoc | 76 |
| 227-C | Beaver Creek | Eau Claire | 47 |
| 228-W | Big Cain Creek | Marathon | 28 |
| 228-F | West Branch Fond Du Lac River | Fond du Lac | 75 |
| 228-C | Como Creek | Walworth | 43 |
| 229-W | Spencer Creek | Monroe | 26 |
| 229-F | Bundy Creek | Marinette | 88 |
| 229-C | Branch River | Brown | 88 |
| 230-W | Devils Creek | Ashland | 40 |
| 230-F | Alto Creek | Dodge | 39 |
| 230-C | Hulburt Creek | Sauk | 37 |
| 231-W | Big Beaver Creek | Dunn | 50 |
| 231-F | Pickerel Creek | Shawano | 36 |
| 231-C | Baker Creek | Dodge | 36 |
| 232-W | Rajek Creek | Lincoln | 24 |
| 232-F | Trib. to Fox River | Green Lake | 76 |
| 232-C | Spring Brook | Winnebago | 57 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 233-F | Trib to Channel Lake | Kenosha | 26 |
| 233-W | Trib. to West Branch Fond Du Lac River | Fond du Lac | 27 |
| 233-C | Mud Run | Dodge | 27 |
| 234-W | Barnes Creek | Lincoln | 24 |
| 234-F | Bear Creek | Outagamie | 77 |
| 234-C | Trib. to Alto Creek | Dodge | 41 |
| 235-W | Indian Creek | Burnett | 38 |
| 235-F | Babit Creek | Taylor | 24 |
| 235-C | Trib. to Duck Creek | Outagamie | 45 |
| 236-W | Trib to Wisconsin River | Sauk | 34 |
| 236-F | Nine Springs Creek | Dane | 32 |
| 236-C | Cranberry Creek | Dunn | 81 |
| 237-W | King Creek | Trempealeau | 33 |
| 237-F | Little Eau Claire River | Marathon | 100 |
| 237-C | Pebble Creek | Waukesha | 48 |
| 238-W | Trib. to Wisconsin River | Grant | 26 |
| 238-F | East Fork Black River | Wood | 99 |
| 238-C | Molash Creek | Manitowoc | 45 |
| 239-W | Tamarack Creek | Buffalo | 46 |
| 239-F | Hay Creek | Chippewa | 89 |
| 239-C | Spring Creek | Walworth | 24 |
| 240-C | Trib to Green Bay | Brown | 31 |
| 240-W | Pony Creek | Shawano | 32 |
| 240-F | Whitefish Bay Creek | Door | 67 |
| 241-W | Trib. to Little LaCrosse River | Monroe | 29 |
| 241-F | Elder Creek | Chippewa | 51 |
| 241-C | Kinnickinnic River | St Croix | 25 |
| 242-W | Byrds Creek | Richland | 29 |
| 242-F | Duck Creek | Brown | 32 |
| 242-C | Yellow River | Wood | 20 |
| 243-W | Pike Creek | Kenosha | 46 |
| 243-F | Walla Walla Creek | Waupaca | 54 |
| 243-C | Liberty Creek | Green | 33 |
| 244-W | South Fork Paint Creek | Chippewa | 27 |
| 244-F | Shivering Sands Creek | Door | 31 |
| 244-C | Duck Creek | Brown | 20 |
| 245-W | Sevenmile Creek | Sheboygan | 30 |
| 245-F | Trib. to Henderson Creek | Winnebago | 36 |
| 245-C | Trib. to Bear Creek | Outagamie | 60 |
| 246-W | Horse Creek | Richland | 23 |
| 246-F | Blake Creek | Waupaca | 97 |
| 246-C | Hoods Creek | Racine | 40 |
| 247-W | Trappers Creek | Taylor | 32 |
| 247-F | School Section Creek | Shawano | 37 |
| 247-C | Como Creek | Chippewa | 27 |
| 248-W | Baird Creek | Brown | 49 |
| 248-F | Meeme River | Manitowoc | 55 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 248-C | Kirchner Creek | Oconto | 27 |
| 249-W | Kennedy Creek | Marathon | 25 |
| 249-F | Trib. to Milwaukee River | Fond du Lac | 41 |
| 249-C | Trib. to Kinnickinnic River | Pierce | 22 |
| 250-W | Trib. to Mississippi River | Buffalo | 39 |
| 250-F | Black Creek | Eau Claire | 96 |
| 250-C | Tibbet Creek | Oconto | 38 |
| 251-W | South Fork Buffalo River | Trempealeau | 81 |
| 251-F | Fox River | Waukesha | 61 |
| 251-C | Herman Creek | Outagamie | 63 |
| 252-W | French Creek | Jackson | 71 |
| 252-F | Shaw Creek | Waupaca | 40 |
| 252-C | North Branch Manitowoc River | Calumet | 78 |
| 253-W | Pine Creek | Jackson | 28 |
| 253-F | Silver Creek | Sheboygan | 51 |
| 253-C | Otter Creek | Sheboygan | 30 |
| 254-W | Rocky Run | Wood | 91 |
| 254-F | Grand River | Green Lake | 83 |
| 254-C | Thomas Slough | Oconto | 37 |
| 255-C | Trib to Lake Michigan | Door | 26 |
| 255-W | Little Bear Creek | Richland | 37 |
| 255-F | Alder Creek | Winnebago | 38 |
| 256-W | Clear Creek | Rusk | 31 |
| 256-F | Red River | Kewaunee | 43 |
| 256-C | Bear Creek | Pepin | 86 |
| 257-W | Town Line Creek | Jackson | 22 |
| 257-F | Keyes Creek | Door | 30 |
| 257-C | Sand Creek | Dunn | 53 |
| 258-W | Conlan Creek | Clark | 22 |
| 258-F | Willow Creek | Fond du Lac | 21 |
| 258-C | Pokegama Creek | Barron | 95 |
| 259-W | Vosse Coulee Creek | Jackson | 25 |
| 259-F | Hinkson Creek | Columbia | 49 |
| 259-C | Grand River | Marquette | 31 |
| 260-W | Popple Creek | Dunn | 21 |
| 260-F | Lincoln Creek | Milwaukee | 56 |
| 260-C | Irish Creek | Dodge | 24 |
| 261-W | Little Suamico River | Oconto | 30 |
| 261-F | Trib. to Rock River | Jefferson | 31 |
| 261-C | Roaring Creek | Jackson | 24 |
| 262-W | Sand Creek | Monroe | 31 |
| 262-F | Levitt Creek | Taylor | 81 |
| 262-C | Trib. to Branch River | Manitowoc | 31 |
| 263-W | Lakes Coulee Creek | Trempealeau | 33 |
| 263-F | Hatton Creek | Waupaca | 78 |
| 263-C | New Channel | La Crosse | 41 |
| 264-W | Three Springs Creek | Door | 22 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 264-F | Whitcomb Creek | Waupaca | 67 |
| 264-C | Stony Creek | Jackson | 44 |
| 265-W | Tank Creek | Jackson | 33 |
| 265-F | Cedar Creek | Calumet | 65 |
| 265-C | Trib. to Milwaukee River | Washington | 31 |
| 266-W | North Branch Pine River | Lincoln | 62 |
| 266-F | Trib. to Sheboygan River | Fond du Lac | 51 |
| 266-C | Becky Creek | Rusk | 26 |
| 267-W | La Crosse River | La Crosse | 72 |
| 267-F | Rio Creek | Kewaunee | 63 |
| 267-C | Killsnake River | Calumet | 83 |
| 268-F | Trib to Sheboygan River | Manitowoc | 42 |
| 268-W | Trib. to Cedar Creek | Washington | 21 |
| 268-C | Mink Creek | Sheboygan | 50 |
| 269-W | Twentymile Creek | Bayfield | 47 |
| 269-F | Bear Creek | Portage | 56 |
| 269-C | Trib. to Badfish Creek | Dane | 26 |
| 270-W | Pine River | Langlade | 66 |
| 270-F | Hayes Creek | Oconto | 38 |
| 270-C | Trib. to Fourteenmile Creek | Adams | 28 |
| 271-W | Stony Creek | Jackson | 25 |
| 271-F | Little Black River | Taylor | 58 |
| 271-C | Black Brook | St Croix | 43 |
| 272-W | Trib. to Plover River | Portage | 34 |
| 272-F | Rat River | Winnebago | 33 |
| 272-C | Trib. to Duck Creek | Outagamie | 59 |
| 273-W | German Creek | Barron | 22 |
| 273-F | Lilly Bay Creek | Door | 44 |
| 273-C | Trib. to Fox River | Winnebago | 57 |
| 274-F | Trib to Green Bay | Oconto | 26 |
| 274-W | Devils Creek | Ashland | 27 |
| 274-C | Crossman Creek | Sauk | 53 |
| 275-W | Cramer Creek | Price | 20 |
| 275-F | Belle Fountain Creek | Green Lake | 89 |
| 275-C | Trib. to North Branch Milwaukee River | Washington | 36 |
| 276-W | Spring Brook | Ashland | 27 |
| 276-F | Rice Creek | Polk | 22 |
| 276-C | Big Creek | La Crosse | 49 |
| 277-W | Wood Creek | Taylor | 81 |
| 277-F | Black Creek | Green Lake | 61 |
| 277-C | Little West Branch Wolf River | Menominee | 88 |
| 278-C | Trib to Fox River | Green Lake | 29 |
| 278-W | Boomer Creek | Iron | 42 |
| 278-F | Trib. to Yahara River | Dane | 71 |
| 279-W | Knuteson Creek | Sawyer | 67 |
| 279-F | Trib to Beaver Creek | Dodge | 27 |
| 279-C | Trib to S. Branch Manitowoc River | Calumet | 22 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 280-F | Trib to Green Bay | Brown | 28 |
| 280-W | Yellow River | Barron | 98 |
| 280-C | Beaver Creek | Monroe | 45 |
| 281-W | Trib to Little LaCrosse River | Monroe | 20 |
| 281-C | Trib to West Branch Milwaukee River | Fond du Lac | 31 |
| 281-F | Pine Creek | Calumet | 74 |
| 282-F | Trib to Pine River | Waushara | 42 |
| 282-W | Vermont Creek | Dane | 39 |
| 282-C | Poplar Creek | Waukesha | 66 |
| 283-W | Trib to Oconto River | Oconto | 21 |
| 283-C | Trib to Wolf River | Winnebago | 22 |
| 283-F | Peplin Creek | Marathon | 49 |
| 284-W | Klein Creek | Adams | 47 |
| 284-F | Trib to Wisconsin River | Portage | 28 |
| 284-C | Big Rock Creek | Polk | 29 |
| 285-W | Devils Creek | Rusk | 65 |
| 285-C | Trib to Milwaukee River | Ozaukee | 23 |
| 285-F | Lost Creek | Portage | 37 |
| 286-W | Jader Creek | Bayfield | 21 |
| 286-F | Little Creek | Waupaca | 34 |
| 286-C | Sugar Creek | Door | 38 |
| 287-F | Peterson Creek | Kenosha | 25 |
| 287-W | Rock Creek | Jackson | 89 |
| 287-C | Farmers Valley Creek | Monroe | 61 |
| 288-F | Rose Brook | Shawano | 33 |
| 288-C | Copper Creek | Sauk | 21 |
| 288-W | Lawrence Creek | Iron | 35 |
| 289-F | Trib to Bear Creek | Outagamie | 33 |
| 289-C | Trib to Branch River | Manitowoc | 23 |
| 289-W | Baldwin Creek | Lincoln | 31 |
| 290-F | Trib to Wisconsin River | Adams | 48 |
| 290-C | Trib to Little River | Oconto | 21 |
| 290-W | Schramm Creek | Bayfield | 49 |
| 291-W | Spirit River | Lincoln | 99 |
| 291-F | Underwood Creek | Milwaukee | 55 |
| 291-C | Black Creek | Clark | 40 |
| 292-F | Trib to Sheboygan River | Sheboygan | 25 |
| 292-C | Trib to Trout Creek | Marinette | 23 |
| 292-W | Tiger Creek | Shawano | 49 |
| 293-W | Dent Creek | Shawano | 20 |
| 293-F | Pine River | Waushara | 97 |
| 293-C | Hay Creek | Sauk | 24 |
| 294-C | Trib to Cedar Creek | Washington | 20 |
| 294-W | Potato River | Iron | 83 |
| 294-F | Bull Brook | Polk | 66 |
| 295-W | Fisher Creek | Florence | 31 |
| 295-F | Kroenke Creek | Shawano | 31 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 295-C | Trib to Onion River | Sheboygan | 30 |
| 296-W | Silver Creek | Taylor | 81 |
| 296-C | Trib to Little River | Oconto | 22 |
| 296-F | Husher Creek | Racine | 29 |
| 297-W | Rock Creek | Dunn | 95 |
| 297-F | Toad Creek | Outagamie | 42 |
| 297-C | Webster Creek | Juneau | 41 |
| 298-F | O'Keefe Creek | Marquette | 61 |
| 298-C | Apple River | Polk | 84 |
| 298-W | Joe Snow Creek | Lincoln | 29 |
| 299-F | Trib to Yahara River | Dane | 26 |
| 299-C | Hibbard Creek | Door | 54 |
| 299-W | McCloud Creek | Langlade | 43 |
| 300-C | Trib to Mud Creek | Manitowoc | 28 |
| 300-W | Little Elk River | Price | 79 |
| 300-F | Bear Creek | Outagamie | 42 |
| 301-F | Trib to Balsam Branch | Polk | 50 |
| 301-C | Stony Creek | Washington | 54 |
| 301-W | Coon Creek | Dunn | 40 |
| 302-W | N. Branch Beaver Creek | Marinette | 49 |
| 302-C | Trib to Sheboygan River | Fond du Lac | 25 |
| 302-F | Mouse Creek | Waupaca | 21 |
| 303-C | Trib to Grand River | Green Lake | 22 |
| 303-W | Holt Creek | Marathon | 41 |
| 303-F | North Branch Beaver Brook | Polk | 64 |
| 304-W | Silver Creek | Shawano | 44 |
| 304-F | Lau Creek | Dodge | 23 |
| 304-C | Turner Creek | Wood | 68 |
| 305-W | Trib to Wisconsin River | Juneau | 22 |
| 305-F | Trib to Fox River | Green Lake | 48 |
| 305-C | Alder Creek | Rusk | 31 |
| 306-W | McKenzie Creek | Taylor | 63 |
| 306-F | Willow Creek | Waushara | 21 |
| 306-C | Otter Creek | Chippewa | 88 |
| 307-F | Trib to Fox River | Winnebago | 33 |
| 307-W | Owl Creek | Wood | 21 |
| 307-C | Fivemile Creek | Clark | 95 |
| 308-W | South Fish Creek | Bayfield | 77 |
| 308-F | Beaver Creek | Barron | 76 |
| 308-C | Mink Creek | Taylor | 39 |
| 309-C | Mukwonago River | Waukesha | 40 |
| 309-W | Lambs Creek | Dunn | 47 |
| 309-F | Tenmile Creek | Barron | 77 |
| 310-F | Trib to White River | Walworth | 43 |
| 310-W | Hay Creek | Dunn | 44 |
| 310-C | Allen Creek | Jefferson | 30 |
| 311-W | Moose Ear Creek | Barron | 83 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 311-F | Genesee Creek | Waukesha | 82 |
| 311-C | Trade River | Polk | 70 |
| 312-W | Trib to South Fish Creek | Bayfield | 24 |
| 312-C | Bradley Creek | Waupaca | 26 |
| 312-F | Battle Creek | Jefferson | 24 |
| 313-W | Blueberry Creek | Douglas | 47 |
| 313-F | Mud Brook | Marinette | 26 |
| 313-C | Comet Creek | Waupaca | 89 |
| 314-W | Sevenmile Creeek | Wood | 39 |
| 314-F | Gilson Creek | Brown | 23 |
| 314-C | Pebble Brook | Waukesha | 47 |
| 315-F | Yahara River | Dane | 30 |
| 315-C | Little Oconomowoc River | Waukesha | 29 |
| 315-W | Twin Creek | Marinette | 41 |
| 316-F | Heins Creek | Door | 40 |
| 316-C | Cedar Creek | Washington | 35 |
| 316-W | Hay Creek | Rusk | 27 |
| 317-W | North Fork Copper River | Lincoln | 95 |
| 317-F | Trib to Sheboygan River | Sheboygan | 41 |
| 317-C | Fairbanks Creek | Adams | 51 |
| 318-F | Skunk Creek | Rusk | 29 |
| 318-W | Skulen Creek | Marathon | 32 |
| 318-C | Butternut Creek | Polk | 47 |
| 319-W | Bingham Creek | Adams | 32 |
| 319-F | Hay Creek | Taylor | 70 |
| 319-C | Browns Creek | Eau Claire | 31 |
| 320-W | Trib to East Branch Eau Claire River | Langlade | 30 |
| 320-C | Mecan River | Waushara | 93 |
| 320-F | Larson Creek | Door | 24 |
| 321-C | Trib to Montello River | Marquette | 25 |
| 321-W | Carpenter Creek | Waushara | 32 |
| 321-F | Straight River | Polk | 82 |
| 322-W | Holmes Creek | Price | 51 |
| 322-F | Trib to Otter Creek | Jefferson | 25 |
| 322-C | Wolf Creek | Polk | 90 |
| 323-W | Oxbo Creek | Lincoln | 21 |
| 323-F | Trib to Little Peshtigo River | Marinette | 23 |
| 323-C | Middle Branch Embarass River | Shawano | 86 |
| 324-W | Trib to Clam River | Burnett | 29 |
| 324-F | South Fork Main Creek | Rusk | 93 |
| 324-C | West Branch Red River | Shawano | 79 |
| 325-W | Dead Horse Creek | Adams | 84 |
| 325-F | Trib to Muddy Creek | Dunn | 23 |
| 325-C | North Branch Embarrass River | Shawano | 79 |
| 326-W | Silver Creek | Ashland | 24 |
| 326-F | Rice Creek | Barron | 56 |
| 326-C | Otter Creek | Dunn | 95 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 327-C | Spranger Creek | Shawano | 37 |
| 327-W | Squaw Creek | Lincoln | 48 |
| 327-F | Tank Creek | La Crosse | 23 |
| 328-F | Stony Brook | Calumet | 28 |
| 328-W | Joe Creek | Taylor | 22 |
| 328-C | Sinking Creek | Dunn | 32 |
| 329-W | Trib to Lemonweir River | Juneau | 49 |
| 329-F | Clam River | Polk | 93 |
| 329-C | Paradise Creek | Taylor | 47 |
| 330-W | Spaulding Creek | Waupaca | 26 |
| 330-F | Willow Creek | Waushara | 20 |
| 330-C | Flume Creek | Portage | 96 |
| 331-F | Little Jump River | Rusk | 20 |
| 331-C | South Branch Embarrass River | Shawano | 79 |
| 331-W | Allen Creek | Forest | 50 |
| 332-W | Spring Creek | Douglas | 29 |
| 332-F | Hay Creek | Wood | 88 |
| 332-C | Auburn Lake Creek | Fond du Lac | 35 |
| 333-W | Spring Lake Creek | Sawyer | 38 |
| 333-F | Trib to Puckaway Lake | Green Lake | 25 |
| 333-C | Dandy Creek | Monroe | 28 |
| 334-W | Little Weirgor Creek | Sawyer | 99 |
| 334-F | Bassett Creek | Kenosha | 23 |
| 334-C | Peterson Creek | Waupaca | 70 |
| 335-W | Levis Creek | Jackson | 97 |
| 335-F | Johnson Creek | Manitowoc | 23 |
| 335-C | Knapp Creek | Polk | 25 |
| 336-W | Saint Croix River | Douglas | 92 |
| 336-F | Trib to Cedar Creek | Ozaukee | 26 |
| 336-C | South Fork Clam River | Burnett | 47 |
| 337-W | Evergreen River | Menominee | 79 |
| 337-C | Trib to Mud Creek | Manitowoc | 24 |
| 337-F | Duchess Creek | Shawano | 28 |
| 338-W | Little Hay Meadow Creek | Lincoln | 64 |
| 338-F | Trib to Bark River | Jefferson | 29 |
| 338-C | Gardner Creek | Shawano | 23 |
| 339-F | Trib to Mecan River | Marquette | 23 |
| 339-W | Nichol Creek | Waupaca | 27 |
| 339-C | Sucker Creek | Green Lake | 54 |
| 340-F | Trib to Grand River | Green Lake | 20 |
| 340-C | Trib to Branch River | Manitowoc | 25 |
| 340-W | North Fork Spirit River | Lincoln | 93 |
| 341-W | Douglas Creek | Price | 74 |
| 341-F | Mud Creek | Rusk | 90 |
| 341-C | Nace Creek | Waupaca | 30 |
| 342-W | Kurt Creek | Wood | 41 |
| 342-F | Ox Creek | Marquette | 36 |

| ID | Description | County | Area (sq. km.) |
| --- | --- | --- | --- |
| 342-C | Black Brook | Langlade | 78 |
| 343-F | Friday Creek | Polk | 28 |
| 343-W | North Fork Thunder River | Marinette | 78 |
| 343-C | Copper River | Lincoln | 97 |
| 344-F | Little Pine Creek | Marquette | 26 |
| 344-W | South Fork Thunder River | Marinette | 57 |
| 344-C | Lower Middle Inlet | Marinette | 78 |
| 345-W | Holmes Creek | Marinette | 41 |
| 345-C | Packard Creek | Shawano | 54 |
| 345-F | O'Neil Creek | Chippewa | 44 |
| 346-W | Hanson Creek | Bayfield | 27 |
| 346-F | Scuppernong Creek | Waukesha | 52 |
| 346-C | Manley Creek | Sauk | 34 |
| 347-C | Wedde Creek | Marquette | 63 |
| 347-W | Miscauno Creek | Marinette | 60 |
| 347-F | McKenzie Creek | Polk | 44 |
| 348-W | Medicine Brook | Marinette | 28 |
| 348-F | Hay Meadow Creek | Portage | 72 |
| 348-C | Little Wolf River | Marathon | 64 |
| 349-W | Montagne Creek | Florence | 39 |
| 349-F | Rice Creek | Rusk | 108 |
| 349-C | Christmas Creek | Chippewa | 31 |
| 350-C | Pammel Creek | Vernon | 41 |
| 350-W | Deer Creek | Ashland | 28 |
| 350-F | Mosquito Creek | Waupaca | 41 |
| 351-W | Black Alder Creek | Lincoln | 30 |
| 351-F | Bull Junior Creek | Marathon | 98 |
| 351-C | Cedar Creek | Marathon | 21 |
| 352-F | Osceola Creek | Polk | 34 |
| 352-W | Eddy Creek | Sawyer | 31 |
| 352-C | Pigeon Creek | Barron | 24 |
| 353-W | Trib to Robinson Creek | Jackson | 29 |
| 353-C | Plover River | Marathon | 52 |
| 353-F | Snake Creek | Green Lake | 28 |
| 354-W | Big Hay Meadow Creek | Lincoln | 77 |
| 354-C | Little Jump River | Rusk | 51 |
| 354-F | Trappe River | Marathon | 79 |
| 355-F | Trib to Grand River | Green Lake | 21 |
| 355-W | Lemke Creek | Taylor | 52 |
| 355-C | Mollies Creek | Jackson | 35 |
| 356-W | Mondeaux Creek | Price | 38 |
| 356-F | French Creek | Columbia | 62 |
| 356-C | Indian Creek | Jackson | 37 |
| 357-W | Hines Creek | Oconto | 23 |
| 357-F | Black Creek | Marathon | 35 |
| 357-C | Upper Middle Inlet | Marinette | 73 |
| 358-F | Hay Creek | Clark | 95 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 358-W | Little Bois Brule River | Douglas | 96 |
| 358-C | Gravelly Brook | Marinette | 40 |
| 359-F | Stuntz Brook | Washburn | 53 |
| 359-C | Clearwater Creek | Langlade | 30 |
| 359-W | Green Meadow Creek | Lincoln | 52 |
| 360-F | Trib to Mud Lake | Door | 25 |
| 360-W | Alder Creek | Iron | 58 |
| 360-C | North Fork Main Creek | Rusk | 55 |
| 361-W | Clemens Creek | Burnett | 24 |
| 361-F | Trib to Apple River | Polk | 24 |
| 361-C | Trib to Lemonweir River | Juneau | 46 |
| 362-F | Trib. to Waupaca River | Portage | 54 |
| 362-C | Bruce Creek | Waushara | 38 |
| 362-W | Little Wausaukee Creek | Marinette | 30 |
| 363-C | Horse Creek | Eau Claire | 34 |
| 363-W | Sullivan Creek | Marinette | 27 |
| 363-F | Middle Fork Main Creek | Rusk | 60 |
| 364-F | Cedar Springs Creek | Waushara | 29 |
| 364-C | Trib. to Wisconsin River | Juneau | 54 |
| 364-W | Hay Creek | Sawyer | 44 |
| 365-F | Trib. to South Branch Little Wolf River | Waupaca | 25 |
| 365-C | Willow Creek | Waushara | 78 |
| 365-W | Spring Creek | Washburn | 29 |
| 366-W | Bad River | Ashland | 21 |
| 366-F | Skinner Creek | Rusk | 83 |
| 366-C | Sucker Creek | Barron | 33 |
| 367-W | Trib. to Marengo River | Bayfield | 23 |
| 367-F | Rice Bed Creek | Polk | 42 |
| 367-C | Godfrey Creek | Washburn | 38 |
| 368-F | Peshtigo Brook | Oconto | 33 |
| 368-C | Little Silver Creek | Waushara | 43 |
| 368-W | Rock Creek | Sawyer | 26 |
| 369-C | Smith Lake Creek | Sawyer | 32 |
| 369-W | Cap Creek | Bayfield | 29 |
| 369-F | Twin Creek | Rusk | 51 |
| 370-C | Trib. to Menominee River | Marinette | 40 |
| 370-W | Frog Creek | Washburn | 75 |
| 370-F | Kenyon Creek | Sawyer | 64 |
| 371-W | Trib. to Eau Claire River | Douglas | 39 |
| 371-F | South Branch Peshtigo River | Forest | 53 |
| 371-C | Logemanns Creek | Shawano | 26 |
| 372-W | Wausaukee River | Marinette | 92 |
| 372-F | Trib. to Mecan River | Marquette | 26 |
| 372-C | Oshkosh Creek | Menominee | 28 |
| 373-C | Smith Creek | Price | 28 |
| 373-W | Oronto Creek | Iron | 45 |
| 373-F | Middle Branch Peshtigo River | Forest | 42 |

| ID | Description | County | Area (sq. km.) |
| --- | --- | --- | --- |
| 374-W | Dalles Creek | Menominee | 22 |
| 374-F | Needle Creek | Price | 39 |
| 374-C | Murray Creek | Price | 28 |
| 375-W | LeRoy Creek | Florence | 31 |
| 375-F | Little Popple River | Florence | 92 |
| 375-C | Summit Creek | Sawyer | 37 |
| 376-W | Jackson Creek | Waupaca | 21 |
| 376-F | North Fork Yellow River | Taylor | 98 |
| 376-C | Crescent Creek | Lincoln | 44 |
| 377-F | Page Creek | Marquette | 25 |
| 377-W | Kakagon River | Ashland | 87 |
| 377-C | Little Frog Creek | Washburn | 45 |
| 378-W | North Branch Pike River | Marinette | 96 |
| 378-F | North Fork Clam River | Burnett | 36 |
| 378-C | Silver Creek | Juneau | 29 |
| 379-W | Squaw Creek | Marinette | 23 |
| 379-F | White Creek | Adams | 20 |
| 379-C | Hemlock Creek | Barron | 68 |
| 380-W | Swift Creek | Sawyer | 23 |
| 380-F | Little Eau Claire River | Portage | 24 |
| 380-C | Miller Creek | Shawano | 66 |
| 381-C | Mondeaux River | Taylor | 77 |
| 381-W | Slough Creek | Marinette | 28 |
| 381-F | Mackay Creek | Washburn | 50 |
| 382-W | New Wood River | Lincoln | 100 |
| 382-F | Crawford Creek | Douglas | 21 |
| 382-C | White Creek | Jackson | 27 |
| 383-F | Alder Creek | Rusk | 46 |
| 383-C | Crazy Horse Creek | Rusk | 51 |
| 383-W | Spikehorn Creek | Marinette | 35 |
| 384-W | Handsaw Creek | Marinette | 25 |
| 384-F | Armstrong Creek | Forest | 95 |
| 384-C | Hunting River | Langlade | 93 |
| 385-W | Little West Branch Creek | Menominee | 100 |
| 385-F | Logging Creek | Polk | 81 |
| 385-C | South Fork Yellow River | Taylor | 58 |
| 386-F | Bean Brook | Washburn | 70 |
| 386-W | Chases Brook | Burnett | 95 |
| 386-C | Lepage Creek | Florence | 30 |
| 387-F | Squaw Lake Creek | Sawyer | 67 |
| 387-W | Miller Creek | Douglas | 22 |
| 387-C | Pine Creek | Bayfield | 45 |
| 388-F | Trib. to Yellow River | Burnett | 22 |
| 388-W | North Branch Prairie River | Lincoln | 98 |
| 388-C | Hay Creek | Price | 27 |
| 389-F | Deer Creek | Price | 26 |
| 389-C | Spring Creek | Taylor | 20 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 389-W | Little Waupee Creek | Oconto | 34 |
| 390-W | Trib. to Wolf River | Langlade | 26 |
| 390-F | Beaver Creek | Price | 27 |
| 390-C | Hay Creek | Price | 76 |
| 391-W | Elk River | Price | 87 |
| 391-F | Carpenter Creek | Price | 32 |
| 391-C | Bearskin Creek | Oneida | 71 |
| 392-W | Trib. to Little Yellow River | Juneau | 24 |
| 392-F | Patterson Creek | Price | 21 |
| 392-C | Pine Creek | Price | 66 |
| 393-F | Black Brook | Burnett | 66 |
| 393-C | South Branch Pemebonwon | Marinette | 99 |
| 393-W | Trout Brook | Ashland | 29 |
| 394-W | Trib. to North Fork Jump River | Price | 20 |
| 394-F | Schraum Creek | Ashland | 38 |
| 394-C | Little Pine Creek | Lincoln | 90 |
| 395-W | Scott Creek | Lincoln | 31 |
| 395-F | Crooked Creek | Rusk | 24 |
| 395-C | Musser Creek | Price | 27 |
| 396-F | Bosner Creek | Ashland | 28 |
| 396-C | Mosquito Brook | Sawyer | 39 |
| 396-W | Big Brook | Bayfield | 70 |
| 397-F | Trib. to Namekagon River | Washburn | 39 |
| 397-C | Trib. to Pine River | Florence | 25 |
| 397-W | Castle Creek | Bayfield | 28 |
| 398-W | Sheosh Creek | Douglas | 35 |
| 398-F | Nail Creek | Rusk | 67 |
| 398-C | Hobbles Creek | Price | 76 |
| 399-C | Chicog Creek | Washburn | 63 |
| 399-W | Averill Creek | Lincoln | 45 |
| 399-F | Little Mondeaux Creek | Price | 58 |
| 400-W | Little South Branch Pike | Marinette | 73 |
| 400-F | Lamon Tangue Creek | Florence | 63 |
| 400-C | Copper Creek | Douglas | 46 |
| 401-W | Buckley Creek | Douglas | 22 |
| 401-F | Iron River | Bayfield | 83 |
| 401-C | Elvoy Creek | Forest | 50 |
| 402-W | Pipestone Creek | Sawyer | 21 |
| 402-C | Trib. to East Branch Eau Claire River | Langlade | 23 |
| 402-F | Pokegama River | Douglas | 84 |
| 403-W | Little Thornapple River | Sawyer | 32 |
| 403-F | Section Twenty Creek | Sawyer | 22 |
| 403-C | Ounce River | Douglas | 97 |
| 404-C | Thornapple River | Sawyer | 85 |
| 404-W | Landwehr Creek | Lincoln | 23 |
| 404-F | Poplar River | Douglas | 94 |
| 405-F | Trib. to North Fork Wood River | Burnett | 77 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 405-W | Davidson Creek | Jackson | 21 |
| 405-C | Weasel Creek | Sawyer | 62 |
| 406-C | Smith Creek | Price | 30 |
| 406-W | Eagle Creek | Marinette | 80 |
| 406-F | Bluff Creek | Douglas | 52 |
| 407-W | Chase Creek | Price | 31 |
| 407-F | Mishonagon Creek | Vilas | 46 |
| 407-C | Knowles Creek | Oconto | 22 |
| 408-F | Hoffman Creek | Ashland | 24 |
| 408-C | Hay Creek | Burnett | 38 |
| 408-W | Hendricks Creek | Florence | 33 |
| 409-F | Nelson Creek | Price | 25 |
| 409-W | Camp F Creek | Marinette | 71 |
| 409-C | North Branch Peshtigo River | Forest | 90 |
| 410-W | Wisconsin Creek | Florence | 30 |
| 410-F | Swamp Creek | Iron | 78 |
| 410-C | Larson Creek | Bayfield | 28 |
| 411-F | Steve Creek | Price | 29 |
| 411-W | Otter Creek | Forest | 75 |
| 411-C | Popple Creek | Price | 48 |
| 412-W | Deer Creek | Ashland | 24 |
| 412-F | Rock Creek | Price | 26 |
| 412-C | Dead Creel | Sawyer | 78 |
| 413-W | Crotte Creek | Douglas | 52 |
| 413-F | Bardon Creek | Douglas | 35 |
| 413-C | Vaughn Creek | Ashland | 71 |
| 414-W | Middle River | Douglas | 92 |
| 414-C | Johnson Creek | Florence | 22 |
| 414-F | Camp Eight Creek | Forest | 43 |
| 415-W | Woods Creek | Florence | 85 |
| 415-F | Fivemile Creek | Washburn | 57 |
| 415-C | Torpee Creek | Forest | 34 |
| 416-W | Halley Creek | Forest | 26 |
| 416-F | Bear Creek | Douglas | 24 |
| 416-C | South Branch Popple River | Florence | 88 |
| 417-W | South Branch Presque Isle River | Vilas | 42 |
| 417-F | Hill Creek | Bayfield | 90 |
| 417-C | Iron River | Ashland | 78 |
| 418-W | George Ladd Creek | Sawyer | 23 |
| 418-F | Monico Creek | Oneida | 67 |
| 418-C | Magee Creek | Ashland | 48 |
| 419-W | West Fork Montreal River | Iron | 89 |
| 419-F | Muskeg Creek | Bayfield | 63 |
| 419-C | Ninemile Creek | Langlade | 58 |
| 420-F | Bear Creek | Oneida | 21 |
| 420-W | Tupper Creek | Sawyer | 70 |
| 420-C | Thompson Creek | Douglas | 51 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 421-W | Raspberry River | Bayfield | 29 |
| 421-F | Pearson Creek | Douglas | 29 |
| 421-C | Laymans Creek | Iron | 51 |
| 422-F | Halls Creek | Florence | 23 |
| 422-W | Bois Brule River | Douglas | 138 |
| 422-C | Log Creek | Sawyer | 57 |
| 423-W | Hay Creek | Burnett | 35 |
| 423-F | Hay Creek | Lincoln | 21 |
| 423-C | Haymeadow Creek | Oneida | 57 |
| 424-C | Lauterman Creek | Florence | 25 |
| 424-W | K C Creek | Marinette | 46 |
| 424-F | Whittlesey Creek | Bayfield | 63 |
| 425-W | Muskrat Creek | Vilas | 26 |
| 425-F | Little George Creek | Oneida | 22 |
| 425-C | Weber Creek | Iron | 21 |
| 426-C | Little Popple River | Florence | 32 |
| 426-W | Coffee Creek | Lincoln | 25 |
| 426-F | North Branch Pine River | Forest | 93 |
| 427-F | Cole Creek | Douglas | 21 |
| 427-C | Balsam Creek | Douglas | 79 |
| 427-W | Squaw Creek | Sawyer | 23 |
| 428-W | Berry Creek | Lincoln | 23 |
| 428-F | Kingstone Creek | Forest | 21 |
| 428-C | Little Willow Creek | Oneida | 67 |
| 429-F | Muskellunge Creek | Ashland | 26 |
| 429-W | Armstrong Creek | Lincoln | 31 |
| 429-C | Jones Creek | Forest | 51 |
| 430-W | East Fork Chippewa River | Ashland | 77 |
| 430-F | Indian Creek | Oneida | 26 |
| 430-C | Skanawan Creek | Lincoln | 24 |
| 431-W | Hoffman Creek | Price | 28 |
| 431-F | Flag River | Bayfield | 90 |
| 431-C | Fourmile Creek | Bayfield | 27 |
| 432-W | Trib. to South Branch Presque Isle River | Vilas | 55 |
| 432-F | McCaslin Brook | Oconto | 37 |
| 432-C | Prairie River | Langlade | 66 |
| 433-W | Cranberry Creek | Douglas | 26 |
| 433-F | East Branch Presque Isle River | Vilas | 48 |
| 433-C | McDonald Creek | Forest | 33 |
| 434-W | Brown Creek | Oneida | 28 |
| 434-F | Beecher Creek | Marinette | 26 |
| 434-C | Brunet River | Sawyer | 35 |
| 435-W | East Torch River | Ashland | 37 |
| 435-F | Mud Creek | Forest | 30 |
| 435-C | Threemile Creek | Price | 21 |
| 436-W | Deer Creek | Sawyer | 23 |
| 436-F | Silver Creek | Douglas | 39 |

| ID | Description | County | Area (sq. km.) |
|---|---|---|---|
| 436-C | Bad River | Ashland | 91 |
| 437-W | Devils Creek | Sawyer | 21 |
| 437-F | South Fork White River | Bayfield | 73 |
| 437-C | Rocky Run | Ashland | 34 |
| 438-W | Cowan Creek | Polk | 28 |
| 438-F | Sioux River | Bayfield | 86 |
| 438-C | Popple River | Forest | 72 |
| 439-W | Moose River | Douglas | 84 |
| 439-F | Hungry Run | Ashland | 32 |
| 439-C | Moose River | Ashland | 60 |
| 440-W | Siphon Creek | Vilas | 22 |
| 440-C | North Fish Creek | Bayfield | 37 |
| 440-F | Smith Creek | Douglas | 21 |
| 441-F | East Fork Iron River | Bayfield | 72 |
| 441-C | Spider Creek | Langlade | 25 |
| 441-W | Hackett Creek | Rusk | 29 |
| 442-W | Allequash Creek | Vilas | 22 |
| 442-F | Kolin Creek | Bayfield | 29 |
| 442-C | Fish Creek | Bayfield | 39 |
| 443-W | Riley Creek | Price | 24 |
| 443-F | Reefer Creek | Bayfield | 30 |
| 443-C | Meadow Creek | Ashland | 50 |
| 444-F | Trib. to Johnson Creek | Vilas | 25 |
| 444-W | Red Cliff Creek | Bayfield | 21 |
| 444-C | Little Amnicon River | Douglas | 55 |
| 445-F | Johnson Creek | Oneida | 27 |
| 445-W | Bergen Creek | Washburn | 79 |
| 445-C | Pine River | Forest | 76 |
| 446-W | Spruce River | Douglas | 71 |
| 446-F | South Branch Pike River | Marinette | 30 |
| 446-C | Haymeadow Creek | Vilas | 37 |
| 447-W | Upper Ox Creek | Douglas | 31 |
| 447-F | Elm Creek | Ashland | 21 |
| 447-C | Little Sioux River | Bayfield | 55 |
| 448-W | Bootjack Creek | Oneida | 27 |
| 448-F | Stevenson Creek | Vilas | 21 |
| 448-C | Sand River | Bayfield | 79 |
| 449-W | Trib. to Moose River | Sawyer | 20 |
| 449-F | Lenawee Creek | Bayfield | 24 |
| 449-C | Siskiwit River | Bayfield | 63 |
| 450-W | Garland Creek | Vilas | 20 |
| 450-F | Bark River | Bayfield | 28 |
| 450-C | Pikes Creek | Bayfield | 84 |
| 451-W | Trib. to Saint Croix River | Douglas | 24 |
| 451-F | Lost Creek Number One | Bayfield | 25 |
| 451-C | Trib. to East Fork Cranberry River | Bayfield | 21 |
| 452-W | East Fork Cranberry River | Bayfield | 97 |

# Appendix C

## *Tables—Economic Impacts of Alternative Management Practices on Selected Wisconsin Farms*

Table 1. BASE and Two No-Till SNAP-Plus Simulations for Case 1.

| Corn Silage, Spring Chisel, Avg Yields, Winter Spreading | | | | | Corn Silage, No-Till, Avg Yields, Winter Spreading | | | | | Corn Silage, No-Till, Avg Yields, No Winter Spreading | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BASE Scenario | | | | | NT/WinterSpreading: Ola-A-A-A-Csl-Csl | | | | | NT/NoWinterSpreading: Ola-A-A-A-Csl-Csl | | | | |
| Costs | Revenues | Profits | Soil Loss | P-Index | Costs | Revenues | Profits | Soil Loss | P-Index | Costs | Revenues | Profits | Soil Loss | P-Index |
| $1,996 | $2,153 | $157 | 7.7 | 21.4 | $1,932 | $2,153 | $221 | 1 | 3.4 | $1,932 | $2,153 | $221 | 1.0 | 3.4 |
| $3,559 | $3,968 | $409 | 7.5 | 18.8 | $3,474 | $3,968 | $494 | 1 | 4.1 | $3,474 | $3,968 | $494 | 1.0 | 4.1 |
| $7,983 | $8,610 | $627 | 7.5 | 21.3 | $7,728 | $8,610 | $882 | 1 | 4.6 | $7,728 | $8,610 | $882 | 1.0 | 4.6 |
| $7,983 | $8,610 | $627 | 7.6 | 17.8 | $7,728 | $8,610 | $882 | 1 | 2.8 | $7,728 | $8,610 | $882 | 1.0 | 2.8 |
| $7,983 | $8,610 | $627 | 7.6 | 21.7 | $7,728 | $8,610 | $882 | 1 | 4.6 | $7,728 | $8,610 | $882 | 1.0 | 4.6 |
| $7,983 | $8,610 | $627 | 7.6 | 22.6 | $7,728 | $8,610 | $882 | 1 | 3.5 | $7,728 | $8,610 | $882 | 1.0 | 3.5 |
| $7,983 | $8,610 | $627 | 7.5 | 23.4 | $7,728 | $8,610 | $882 | 1 | 5.0 | $7,728 | $8,610 | $882 | 1.0 | 5.0 |
| $3,992 | $4,305 | $313 | 7.6 | 19.5 | $3,864 | $4,305 | $441 | 1 | 3.0 | $3,864 | $4,305 | $441 | 1.0 | 3.0 |
| $3,559 | $3,968 | $409 | 5.1 | 16.8 | $3,474 | $3,968 | $494 | 0.6 | 6.0 | $3,474 | $3,968 | $494 | 0.6 | 2.4 |
| $3,992 | $4,305 | $313 | 5.0 | 17.4 | $3,864 | $4,305 | $441 | 0.6 | 6.2 | $3,864 | $4,305 | $441 | 0.6 | 2.5 |
| $3,992 | $4,305 | $313 | 5.0 | 16.5 | $3,864 | $4,305 | $441 | 0.6 | 6.2 | $3,864 | $4,305 | $441 | 0.6 | 3.1 |
| $3,559 | $3,968 | $409 | 2.1 | 7.3 | $3,474 | $3,968 | $494 | 0.3 | 2.9 | $3,474 | $3,968 | $494 | 0.3 | 2.1 |
| $3,992 | $4,305 | $313 | 5.0 | 20.8 | $3,864 | $4,305 | $441 | 0.6 | 5.4 | $3,864 | $4,305 | $441 | 0.6 | 3.5 |
| $1,780 | $1,984 | $205 | 5.1 | 20.8 | $1,737 | $1,984 | $247 | 0.6 | 6.5 | $1,737 | $1,984 | $247 | 0.6 | 3.4 |
| $3,992 | $4,305 | $313 | 5.0 | 16.5 | $3,864 | $4,305 | $441 | 0.6 | 6.1 | $3,864 | $4,305 | $441 | 0.6 | 2.5 |
| $5,987 | $6,458 | $470 | 2.1 | 7.5 | $5,796 | $6,458 | $662 | 0.3 | 3.1 | $5,796 | $6,458 | $662 | 0.3 | 1.8 |
| $3,992 | $4,305 | $313 | 2.1 | 6.7 | $3,864 | $4,305 | $441 | 0.3 | 2.9 | $3,864 | $4,305 | $441 | 0.3 | 2.1 |
| $3,992 | $4,305 | $313 | 4.9 | 15.4 | $3,864 | $4,305 | $441 | 0.6 | 3.6 | $3,864 | $4,305 | $441 | 0.6 | 3.6 |
| $5,987 | $6,458 | $470 | 5.0 | 15.7 | $5,796 | $6,458 | $662 | 0.6 | 2.8 | $5,796 | $6,458 | $662 | 0.6 | 2.8 |
| $3,992 | $4,305 | $313 | 5.0 | 14.6 | $3,864 | $4,305 | $441 | 0.6 | 3.6 | $3,864 | $4,305 | $441 | 0.6 | 3.6 |
| $3,992 | $4,305 | $313 | 7.6 | 21.1 | $3,864 | $4,305 | $441 | 1 | 3.1 | $3,864 | $4,305 | $441 | 1.0 | 3.1 |
| $8,898 | $9,921 | $1,023 | 7.6 | 17.7 | $8,685 | $9,921 | $1,236 | 1 | 3.0 | $8,685 | $9,921 | $1,236 | 1.0 | 3.0 |
| $1,996 | $2,153 | $157 | 9.1 | 22.7 | $1,932 | $2,153 | $221 | 1.6 | 4.3 | $1,932 | $2,153 | $221 | 1.6 | 4.3 |
| $3,992 | $4,305 | $313 | 7.4 | 22.2 | $3,864 | $4,305 | $441 | 1 | 4.5 | $3,864 | $4,305 | $441 | 1.0 | 4.5 |
| $5,987 | $6,458 | $470 | 7.6 | 16.8 | $5,796 | $6,458 | $662 | 1 | 2.5 | $5,796 | $6,458 | $662 | 1.0 | 2.5 |
| $5,339 | $5,953 | $614 | 5.0 | 12.9 | $5,211 | $5,953 | $742 | 0.6 | 3.1 | $5,211 | $5,953 | $742 | 0.6 | 3.1 |
| $1,996 | $2,153 | $157 | 7.8 | 16.7 | $1,932 | $2,153 | $221 | 1.6 | 3.7 | $1,932 | $2,153 | $221 | 1.6 | 3.7 |
| $12,457 | $13,889 | $1,433 | 7.6 | 15.7 | $12,159 | $13,889 | $1,730 | 1 | 2.3 | $12,159 | $13,889 | $1,730 | 1.0 | 2.3 |
| $5,987 | $6,458 | $470 | 5.0 | 11.5 | $5,796 | $6,458 | $662 | 0.6 | 2.7 | $5,796 | $6,458 | $662 | 0.6 | 2.7 |
| $1,996 | $2,153 | $157 | 7.8 | 20.5 | $1,932 | $2,153 | $221 | 1.6 | 5.3 | $1,932 | $2,153 | $221 | 1.6 | 5.3 |
| $15,966 | $17,220 | $1,254 | 7.6 | 15.1 | $15,456 | $17,220 | $1,764 | 1 | 2.3 | $15,456 | $17,220 | $1,764 | 1.0 | 2.3 |
| $3,992 | $4,305 | $313 | 8.0 | 20.0 | $3,864 | $4,305 | $441 | 1.6 | 4.4 | $3,864 | $4,305 | $441 | 1.6 | 4.4 |
| $7,983 | $8,610 | $627 | 7.6 | 17.4 | $7,728 | $8,610 | $882 | 1 | 2.9 | $7,728 | $8,610 | $882 | 1.0 | 2.9 |
| $7,118 | $7,937 | $819 | 7.5 | 17.0 | $6,948 | $7,937 | $989 | 1 | 3.8 | $6,948 | $7,937 | $989 | 1.0 | 3.8 |
| $7,983 | $8,610 | $627 | 5.1 | 9.8 | $7,728 | $8,610 | $882 | 0.6 | 1.6 | $7,728 | $8,610 | $882 | 0.6 | 1.6 |
| $5,987 | $6,458 | $470 | 7.8 | 18.8 | $5,796 | $6,458 | $662 | 1.6 | 4.8 | $5,796 | $6,458 | $662 | 1.6 | 4.8 |
| $7,983 | $8,610 | $627 | 7.6 | 15.7 | $7,728 | $8,610 | $882 | 1 | 2.4 | $7,728 | $8,610 | $882 | 1.0 | 2.4 |
| $7,983 | $8,610 | $627 | 11.4 | 25.6 | $7,728 | $8,610 | $882 | 2.1 | 5.2 | $7,728 | $8,610 | $882 | 2.1 | 5.2 |
| $5,339 | $5,953 | $614 | 11.5 | 24.9 | $5,211 | $5,953 | $742 | 2.2 | 5.1 | $5,211 | $5,953 | $742 | 2.2 | 5.1 |
| $3,559 | $3,968 | $409 | 11.2 | 25.2 | $3,474 | $3,968 | $494 | 2.2 | 5.8 | $3,474 | $3,968 | $494 | 2.2 | 5.8 |
| $1,780 | $1,984 | $205 | 11.5 | 24.9 | $1,737 | $1,984 | $247 | 2.2 | 5.0 | $1,737 | $1,984 | $247 | 2.2 | 5.0 |
| $5,339 | $5,953 | $614 | 7.6 | 17.8 | $5,211 | $5,953 | $742 | 1 | 4.0 | $5,211 | $5,953 | $742 | 1.0 | 4.0 |
| $5,987 | $6,458 | $470 | 7.8 | 12.5 | $5,796 | $6,458 | $662 | 1 | 2.0 | $5,796 | $6,458 | $662 | 1.0 | 2.0 |
| $3,992 | $4,305 | $313 | 7.7 | 13.8 | $3,864 | $4,305 | $441 | 1 | 3.5 | $3,864 | $4,305 | $441 | 1.0 | 3.5 |
| $1,780 | $1,984 | $205 | 1.8 | 3.0 | $1,737 | $1,984 | $247 | 0.2 | 0.9 | $1,737 | $1,984 | $247 | 0.2 | 0.9 |
| $3,559 | $3,968 | $409 | 7.9 | 23.2 | $3,474 | $3,968 | $494 | 1.6 | 5.8 | $3,474 | $3,968 | $494 | 1.6 | 5.8 |
| $0 | $4,440 | $4,440 | 1.9 | 6.7 | $0 | $4,440 | $4,440 | 2.1 | 5.4 | $0 | $4,440 | $4,440 | 2.1 | 5.4 |
| $0 | $5,328 | $5,328 | 1.9 | 7.0 | $0 | $5,328 | $5,328 | 2.1 | 5.7 | $0 | $5,328 | $5,328 | 2.1 | 5.7 |
| $247,245 | $278,897 | $31,652 | 6.6 | 16.6 | $239,886 | $278,897 | $39,011 | 1.1 | 3.8 | $239,886 | $278,897 | $39,011 | 1.1 | 3.5 |

Abbreviations: A = alfalfa, Cg = corn grain, NT = no-till, Ola = Oatlage with alfalfa seeding spring.

Table 2. Comparison of Corn Grain SNAP-Plus Simulations for Case 1.

| Corn Grain, Spring Chisel, Avg Yields | | | | Corn Grain, No-Till, Avg Yields, Winter Spreading | | | | Corn Grain, No-Till, Avg Yields, No Winter Spreading | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SC/WinterSpreading: Ola-A-A-A-Cg-Cg | | | | NT/WinterSpreading: Ola-A-A-A-Cg-Cg | | | | NT/NoWinterSpreading: Ola-A-A-A-Cg-Cg | | | |
| Costs | Revenues | Profits | P-Index | Costs | Revenues | Profits | P-Index | Costs | Revenues | Profits | P-Index |
| $1,839 | $1,941 | $102 | 8.1 | $1,775 | $1,941 | $166 | 2.2 | $1,775 | $1,941 | $166 | 2.2 |
| $3,245 | $3,544 | $300 | 8.3 | $3,159 | $3,544 | $385 | 3.1 | $3,159 | $3,544 | $385 | 3.1 |
| $7,354 | $7,762 | $408 | 9.4 | $7,099 | $7,762 | $663 | 3.6 | $7,099 | $7,762 | $663 | 3.6 |
| $7,354 | $7,762 | $408 | 6.8 | $7,099 | $7,762 | $663 | 1.8 | $7,099 | $7,762 | $663 | 1.8 |
| $7,354 | $7,762 | $408 | 9.5 | $7,099 | $7,762 | $663 | 3.5 | $7,099 | $7,762 | $663 | 3.5 |
| $7,354 | $7,762 | $408 | 8.6 | $7,099 | $7,762 | $663 | 2.3 | $7,099 | $7,762 | $663 | 2.3 |
| $7,354 | $7,762 | $408 | 10.2 | $7,099 | $7,762 | $663 | 3.8 | $7,099 | $7,762 | $663 | 3.8 |
| $3,677 | $3,881 | $204 | 7.5 | $3,549 | $3,881 | $332 | 2.0 | $3,549 | $3,881 | $332 | 2.0 |
| $3,245 | $3,544 | $300 | 8.9 | $3,159 | $3,544 | $385 | 5.4 | $3,159 | $3,544 | $385 | 2.3 |
| $3,677 | $3,881 | $204 | 9.1 | $3,549 | $3,881 | $332 | 5.5 | $3,549 | $3,881 | $332 | 2.4 |
| $3,677 | $3,881 | $204 | 9.0 | $3,549 | $3,881 | $332 | 5.6 | $3,549 | $3,881 | $332 | 2.5 |
| $3,245 | $3,544 | $300 | 4.2 | $3,159 | $3,544 | $385 | 2.7 | $3,159 | $3,544 | $385 | 1.9 |
| $3,677 | $3,881 | $204 | 9.7 | $3,549 | $3,881 | $332 | 5.0 | $3,549 | $3,881 | $332 | 2.2 |
| $1,622 | $1,772 | $150 | 10.3 | $1,580 | $1,772 | $192 | 5.7 | $1,580 | $1,772 | $192 | 3.0 |
| $3,677 | $3,881 | $204 | 8.9 | $3,549 | $3,881 | $332 | 5.5 | $3,549 | $3,881 | $332 | 2.4 |
| $5,516 | $5,822 | $306 | 4.4 | $5,324 | $5,822 | $497 | 2.8 | $5,324 | $5,822 | $497 | 1.5 |
| $3,677 | $3,881 | $204 | 4.0 | $3,549 | $3,881 | $332 | 2.7 | $3,549 | $3,881 | $332 | 1.3 |
| $3,677 | $3,881 | $204 | 7.0 | $3,549 | $3,881 | $332 | 2.9 | $3,549 | $3,881 | $332 | 2.9 |
| $5,516 | $5,822 | $306 | 6.3 | $5,324 | $5,822 | $497 | 2.0 | $5,324 | $5,822 | $497 | 2.0 |
| $3,677 | $3,881 | $204 | 6.8 | $3,549 | $3,881 | $332 | 3.0 | $3,549 | $3,881 | $332 | 3.0 |
| $3,677 | $3,881 | $204 | 7.9 | $3,549 | $3,881 | $332 | 2.0 | $3,549 | $3,881 | $332 | 2.0 |
| $8,111 | $8,861 | $750 | 7.0 | $7,899 | $8,861 | $962 | 2.0 | $7,899 | $8,861 | $962 | 2.0 |
| $1,839 | $1,941 | $102 | 7.6 | $1,775 | $1,941 | $166 | 2.0 | $1,775 | $1,941 | $166 | 2.0 |
| $3,677 | $3,881 | $204 | 9.6 | $3,549 | $3,881 | $332 | 3.4 | $3,549 | $3,881 | $332 | 3.4 |
| $5,516 | $5,822 | $306 | 4.3 | $5,324 | $5,822 | $497 | 1.6 | $5,324 | $5,822 | $497 | 1.6 |
| $4,867 | $5,317 | $450 | 5.9 | $4,739 | $5,317 | $577 | 2.5 | $4,739 | $5,317 | $577 | 2.5 |
| $1,839 | $1,941 | $102 | 6.5 | $1,775 | $1,941 | $166 | 1.8 | $1,775 | $1,941 | $166 | 1.8 |
| $11,356 | $12,405 | $1,050 | 5.8 | $11,058 | $12,405 | $1,347 | 1.4 | $11,058 | $12,405 | $1,347 | 1.4 |
| $5,516 | $5,822 | $306 | 5.1 | $5,324 | $5,822 | $497 | 2.2 | $5,324 | $5,822 | $497 | 2.2 |
| $1,839 | $1,941 | $102 | 8.6 | $1,775 | $1,941 | $166 | 3.1 | $1,775 | $1,941 | $166 | 3.1 |
| $14,708 | $15,524 | $816 | 5.7 | $14,198 | $15,524 | $1,327 | 1.5 | $14,198 | $15,524 | $1,327 | 1.5 |
| $3,677 | $3,881 | $204 | 7.6 | $3,549 | $3,881 | $332 | 2.1 | $3,549 | $3,881 | $332 | 2.1 |
| $7,354 | $7,762 | $408 | 6.7 | $7,099 | $7,762 | $663 | 2.0 | $7,099 | $7,762 | $663 | 2.0 |
| $6,489 | $7,089 | $600 | 7.5 | $6,319 | $7,089 | $770 | 2.9 | $6,319 | $7,089 | $770 | 2.9 |
| $7,354 | $7,762 | $408 | 3.8 | $7,099 | $7,762 | $663 | 1.1 | $7,099 | $7,762 | $663 | 1.1 |
| $5,516 | $5,822 | $306 | 7.9 | $5,324 | $5,822 | $497 | 2.8 | $5,324 | $5,822 | $497 | 2.8 |
| $7,354 | $7,762 | $408 | 6.0 | $7,099 | $7,762 | $663 | 1.6 | $7,099 | $7,762 | $663 | 1.6 |
| $7,354 | $7,762 | $408 | 9.3 | $7,099 | $7,762 | $663 | 2.3 | $7,099 | $7,762 | $663 | 2.3 |
| $4,867 | $5,317 | $450 | 8.9 | $4,739 | $5,317 | $577 | 2.1 | $4,739 | $5,317 | $577 | 2.1 |
| $3,245 | $3,544 | $300 | 9.9 | $3,159 | $3,544 | $385 | 2.9 | $3,159 | $3,544 | $385 | 2.9 |
| $1,622 | $1,772 | $150 | 8.9 | $1,580 | $1,772 | $192 | 2.1 | $1,580 | $1,772 | $192 | 2.1 |
| $4,867 | $5,317 | $450 | 7.9 | $4,739 | $5,317 | $577 | 3.1 | $4,739 | $5,317 | $577 | 3.1 |
| $5,516 | $5,822 | $306 | 4.8 | $5,324 | $5,822 | $497 | 1.3 | $5,324 | $5,822 | $497 | 1.3 |
| $3,677 | $3,881 | $204 | 6.5 | $3,549 | $3,881 | $332 | 2.9 | $3,549 | $3,881 | $332 | 2.9 |
| $1,622 | $1,772 | $150 | 1.5 | $1,580 | $1,772 | $192 | 0.7 | $1,580 | $1,772 | $192 | 0.7 |
| $3,245 | $3,544 | $300 | 9.5 | $3,159 | $3,544 | $385 | 3.2 | $3,159 | $3,544 | $385 | 3.2 |
| $0 | $4,440 | $4,440 | 5.4 | $0 | $4,440 | $4,440 | 5.4 | $0 | $4,440 | $4,440 | 5.4 |
| $0 | $5,328 | $5,328 | 5.7 | $0 | $5,328 | $5,328 | 5.7 | $0 | $5,328 | $5,328 | 5.7 |
| $227,114 | $251,761 | $24,647 | 7.1 | $219,755 | $251,761 | $32,006 | 2.8 | $219,755 | $251,761 | $32,006 | 2.5 |

Abbreviations: A = alfalfa, Cg = corn grain, NT = no-till, Ola = Oatlage with alfalfa seeding spring.

Table 3. Aggregate Farm Results Over Full Rotation for Case 1.

| **Weighted Farm Averages Over Full Rotation (six years)** | **Change in Profits (Loss)** | **Change in P Index** | **Profit (Loss) per Change in P Index** |
|---|---|---|---|
| Corn Silage, No-Till, Average Yields, Winter Spreading | $7,359 | (12.7) | $15.05 |
| Corn Silage, No-Till, Average Yields, No Winter Spreading | $7,359 | (13.0) | $14.54 |
| Corn Grain, Spring Chisel, Average Yields | ($7,005) | (9.5) | ($19.63) |
| Corn Grain, No-Till, Average Yields, Winter Spreading | $355 | (13.7) | $0.64 |
| Corn Grain, No-Till, Average Yields, No Winter Spreading | $355 | (14.0) | $0.59 |

Table 4. Comparison of BASE and Two SNAP-Plus Simulations for Case 2.

| OFG 14: BASE | | | | OFG 14: Cg-43 and Csl-11 | | | | OFG 14: NoTill-43 (Csl) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Costs | Revenues | Profits | P-Index | Costs | Revenues | Profits | P-Index | Costs | Revenues | Profits | P-Index |
| $12,017 | $11,848 | -$169 | 2.6 | $12,017 | $11,848 | -$169 | 2.9 | $12,017 | $11,848 | -$169 | 2.6 |
| $4,604 | $9,507 | $4,903 | 1.5 | $4,604 | $9,507 | $4,903 | 1.5 | $4,604 | $9,507 | $4,903 | 1.5 |
| $10,301 | $10,156 | -$145 | 3.3 | $10,301 | $10,156 | -$145 | 3.3 | $10,301 | $10,156 | -$145 | 3.3 |
| $32,504 | $30,996 | -$1,508 | 4.0 | $32,504 | $30,996 | -$1,508 | 4.0 | $32,504 | $30,996 | -$1,508 | 4.0 |
| $4,604 | $9,507 | $4,903 | 1.4 | $4,604 | $9,507 | $4,903 | 1.4 | $4,604 | $9,507 | $4,903 | 1.4 |
| $12,888 | $11,855 | -$1,033 | 2.0 | $12,888 | $11,855 | -$1,033 | 2.0 | $12,888 | $11,855 | -$1,033 | 2.0 |
| $20,601 | $20,311 | -$290 | 3.8 | $20,601 | $20,311 | -$290 | 3.8 | $20,601 | $20,311 | -$290 | 3.8 |
| $2,302 | $4,753 | $2,452 | 2.6 | $2,302 | $4,753 | $2,452 | 2.6 | $2,302 | $4,753 | $2,452 | 2.6 |
| $4,604 | $9,507 | $4,903 | 0.9 | $4,604 | $9,507 | $4,903 | 0.9 | $4,604 | $9,507 | $4,903 | 0.9 |
| $41,202 | $40,622 | -$580 | 2.9 | $41,202 | $40,622 | -$580 | 2.9 | $41,202 | $40,622 | -$580 | 2.9 |
| $4,604 | $9,507 | $4,903 | 1.2 | $4,604 | $9,507 | $4,903 | 1.2 | $4,604 | $9,507 | $4,903 | 1.2 |
| $10,735 | $9,244 | -$1,490 | 3.6 | $10,735 | $9,244 | -$1,490 | 3.6 | $10,735 | $9,244 | -$1,490 | 3.6 |
| $14,578 | $30,105 | $15,527 | 1.6 | $14,578 | $30,105 | $15,527 | 1.6 | $14,578 | $30,105 | $15,527 | 1.6 |
| $8,946 | $7,704 | -$1,242 | 2.7 | $8,055 | $7,410 | -$646 | 3.9 | $8,946 | $7,704 | -$1,242 | 2.7 |
| $6,444 | $5,928 | -$517 | 2.3 | $6,444 | $5,928 | -$517 | 2.3 | $6,444 | $5,928 | -$517 | 2.3 |
| $12,888 | $11,855 | -$1,033 | 5.4 | $12,888 | $11,855 | -$1,033 | 5.4 | $12,888 | $11,855 | -$1,033 | 5.4 |
| $18,884 | $18,619 | -$266 | 3.1 | $18,884 | $18,619 | -$266 | 3.1 | $18,884 | $18,619 | -$266 | 3.1 |
| $20,601 | $20,311 | -$290 | 1.7 | $20,601 | $20,311 | -$290 | 1.7 | $20,601 | $20,311 | -$290 | 1.7 |
| $5,951 | $5,342 | -$609 | 2.1 | $5,951 | $5,342 | -$609 | 2.1 | $5,951 | $5,342 | -$609 | 2.1 |
| $7,673 | $15,845 | $8,172 | 1.2 | $7,673 | $15,845 | $8,172 | 1.2 | $7,673 | $15,845 | $8,172 | 1.2 |
| $8,946 | $7,704 | -$1,242 | 1.8 | $8,946 | $7,704 | -$1,242 | 1.8 | $8,946 | $7,704 | -$1,242 | 1.8 |
| $7,786 | $6,536 | -$1,250 | 2.2 | $7,786 | $6,536 | -$1,250 | 2.2 | $7,786 | $6,536 | -$1,250 | 2.2 |
| $17,854 | $16,027 | -$1,827 | 3.1 | $17,854 | $16,027 | -$1,827 | 3.1 | $17,854 | $16,027 | -$1,827 | 3.1 |
| $11,509 | $23,767 | $12,258 | 1.5 | $11,509 | $23,767 | $12,258 | 1.5 | $11,509 | $23,767 | $12,258 | 1.5 |
| $44,636 | $44,008 | -$628 | 2.4 | $44,636 | $44,008 | -$628 | 2.4 | $44,636 | $44,008 | -$628 | 2.4 |
| $15,451 | $15,233 | -$217 | 1.6 | $15,451 | $15,233 | -$217 | 1.6 | $15,451 | $15,233 | -$217 | 1.6 |
| $18,884 | $18,619 | -$266 | 1.7 | $18,884 | $18,619 | -$266 | 1.7 | $18,884 | $18,619 | -$266 | 1.7 |
| $58,370 | $57,548 | -$821 | 2.0 | $58,370 | $57,548 | -$821 | 2.0 | $58,370 | $57,548 | -$821 | 2.0 |
| $18,884 | $18,619 | -$266 | 3.7 | $18,884 | $18,619 | -$266 | 3.7 | $18,884 | $18,619 | -$266 | 3.7 |
| $10,301 | $10,156 | -$145 | 2.5 | $10,301 | $10,156 | -$145 | 2.5 | $10,301 | $10,156 | -$145 | 2.5 |
| $23,357 | $19,608 | -$3,749 | 2.3 | $23,357 | $19,608 | -$3,749 | 2.3 | $23,357 | $19,608 | -$3,749 | 2.3 |
| $15,871 | $14,246 | -$1,624 | 4.0 | $15,871 | $14,246 | -$1,624 | 4.0 | $15,871 | $14,246 | -$1,624 | 4.0 |
| $128,210 | $122,262 | -$5,948 | 2.9 | $128,210 | $122,262 | -$5,948 | 2.9 | $128,210 | $122,262 | -$5,948 | 2.9 |
| $18,058 | $17,220 | -$838 | 2.4 | $18,058 | $17,220 | -$838 | 2.4 | $18,058 | $17,220 | -$838 | 2.4 |
| $23,357 | $19,608 | -$3,749 | 4.8 | $23,357 | $19,608 | -$3,749 | 4.8 | $23,357 | $19,608 | -$3,749 | 4.8 |
| $3,069 | $6,338 | $3,269 | 0.9 | $3,069 | $6,338 | $3,269 | 0.9 | $3,069 | $6,338 | $3,269 | 0.9 |
| $14,499 | $13,337 | -$1,162 | 1.7 | $14,499 | $13,337 | -$1,162 | 1.7 | $14,499 | $13,337 | -$1,162 | 1.7 |
| $13,734 | $13,541 | -$193 | 4.3 | $13,734 | $13,541 | -$193 | 4.3 | $13,734 | $13,541 | -$193 | 4.3 |
| $13,734 | $13,541 | -$193 | 3.3 | $13,734 | $13,541 | -$193 | 3.3 | $13,734 | $13,541 | -$193 | 3.3 |
| $14,499 | $13,337 | -$1,162 | 2.7 | $14,499 | $13,337 | -$1,162 | 2.7 | $14,499 | $13,337 | -$1,162 | 2.7 |
| $5,150 | $5,078 | -$72 | 3.2 | $5,150 | $5,078 | -$72 | 3.2 | $5,150 | $5,078 | -$72 | 3.2 |
| $32,618 | $32,159 | -$459 | 3.0 | $32,618 | $32,159 | -$459 | 3.0 | $32,618 | $32,159 | -$459 | 3.0 |
| $17,854 | $16,027 | -$1,827 | 3.1 | $17,854 | $16,027 | -$1,827 | 3.1 | $17,854 | $16,027 | -$1,827 | 3.1 |
| $41,202 | $40,622 | -$580 | 3.5 | $41,202 | $40,622 | -$580 | 3.5 | $41,202 | $40,622 | -$580 | 3.5 |
| $54,173 | $51,660 | -$2,513 | 2.8 | $54,173 | $51,660 | -$2,513 | 2.8 | $54,173 | $51,660 | -$2,513 | 2.8 |
| $11,716 | $10,995 | -$721 | 10.6 | $10,301 | $10,156 | -$145 | 4.5 | $11,369 | $10,995 | -$374 | 4.0 |
| $25,777 | $23,710 | -$2,066 | 4.3 | $25,777 | $23,710 | -$2,066 | 4.3 | $25,777 | $23,710 | -$2,066 | 4.3 |
| $29,185 | $28,774 | -$411 | 5.7 | $29,185 | $28,774 | -$411 | 5.5 | $29,185 | $28,774 | -$411 | 5.7 |
| $22,250 | $45,950 | $23,700 | 2.6 | $22,250 | $45,950 | $23,700 | 2.6 | $22,250 | $45,950 | $23,700 | 2.6 |
| $977,861 | $1,019,752 | $41,891 | 2.9 | $975,555 | $1,018,618 | $43,063 | 2.8 | $977,514 | $1,019,752 | $42,238 | 2.8 |

Abbreviations: Cg = corn grain, Csl = corn silage, OFG = on farmer's ground.

Table 5. Aggregate Farm Results Over Full Rotation for Case 2.

| **Weighted Farm Averages Over Full Rotation (six years)** | **Change in Profits (Loss)** | **Change in P Index** | **Profit (Loss) per Change in P Index** |
|---|---|---|---|
| OFG 14: Cg-43 and Csl-11 | $1,172 | (0.1) | $3.12 |
| OFG 14: No-Till-43 (Csl) | $347 | (0.1) | $0.51 |

Abbreviations: Cg = corn grain, Csl = corn silage, OFG = on farmer's ground.

Table 6. Comparison of BASE and Two SNAP–Plus Simulations for Case 3.

| OFG 16: BASE | | | | OFG 16: 10&16, Csl==>Cg | | | | OFG 16: + 9b&11&13, Pg ==> PRg | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Costs | Revenues | Profits | P-Index | Costs | Revenues | Profits | P-Index | Costs | Revenues | Profits | P-Index |
| $21,711 | $38,453 | $16,742 | 3.7 | $21,711 | $38,453 | $16,742 | 3.7 | $21,711 | $38,453 | $16,742 | 3.7 |
| $0 | $5,051 | $5,051 | 1.4 | $0 | $5,051 | $5,051 | 1.4 | $0 | $5,051 | $5,051 | 1.8 |
| $0 | $6,734 | $6,734 | 1.4 | $0 | $6,734 | $6,734 | 1.4 | $0 | $6,734 | $6,734 | 1.8 |
| $0 | $5,051 | $5,051 | 1.4 | $0 | $5,051 | $5,051 | 1.4 | $0 | $5,051 | $5,051 | 1.4 |
| $0 | $1,684 | $1,684 | 3.9 | $0 | $1,684 | $1,684 | 3.9 | $0 | $1,684 | $1,684 | 4.1 |
| $0 | $842 | $842 | 4.6 | $0 | $842 | $842 | 4.6 | $0 | $842 | $842 | 4.8 |
| $0 | $842 | $842 | 0.4 | $0 | $842 | $842 | 0.4 | $0 | $842 | $842 | 0.6 |
| $0 | $842 | $842 | 3.9 | $0 | $842 | $842 | 3.9 | $0 | $842 | $842 | 4.1 |
| $25,958 | $36,393 | $10,435 | 5.9 | $25,958 | $36,393 | $10,435 | 5.9 | $25,958 | $36,393 | $10,435 | 5.9 |
| $12,979 | $18,196 | $5,217 | 7.1 | $10,856 | $19,227 | $8,371 | 3.8 | $10,856 | $19,227 | $8,371 | 3.8 |
| $0 | $2,525 | $2,525 | 8.5 | $0 | $2,525 | $2,525 | 8.5 | $0 | $4,545 | $4,545 | 5.6 |
| $9,650 | $17,090 | $7,441 | 2.4 | $9,650 | $17,090 | $7,441 | 2.4 | $9,650 | $17,090 | $7,441 | 2.4 |
| $0 | $3,367 | $3,367 | 6.4 | $0 | $3,367 | $3,367 | 6.4 | $0 | $6,061 | $6,061 | 2.9 |
| $18,093 | $32,045 | $13,952 | 3.5 | $18,093 | $32,045 | $13,952 | 3.5 | $18,093 | $32,045 | $13,952 | 3.5 |
| $8,653 | $12,131 | $3,478 | 9.8 | $7,237 | $12,818 | $5,581 | 3.0 | $7,237 | $12,818 | $5,581 | 3.0 |
| $8,443 | $14,954 | $6,511 | 2.7 | $8,443 | $14,954 | $6,511 | 2.7 | $8,443 | $14,954 | $6,511 | 2.7 |
| $12,062 | $21,363 | $9,301 | 2.5 | $12,062 | $21,363 | $9,301 | 2.5 | $12,062 | $21,363 | $9,301 | 2.5 |
| $9,650 | $17,090 | $7,441 | 2.3 | $9,650 | $17,090 | $7,441 | 2.3 | $9,650 | $17,090 | $7,441 | 2.3 |
| $6,031 | $10,682 | $4,651 | 4.5 | $6,031 | $10,682 | $4,651 | 4.5 | $6,031 | $10,682 | $4,651 | 4.5 |
| $2,412 | $4,273 | $1,860 | 3.0 | $2,412 | $4,273 | $1,860 | 3.0 | $2,412 | $4,273 | $1,860 | 3.0 |
| $2,412 | $4,273 | $1,860 | 3.8 | $2,412 | $4,273 | $1,860 | 3.8 | $2,412 | $4,273 | $1,860 | 3.8 |
| $4,825 | $8,545 | $3,720 | 3.4 | $4,825 | $8,545 | $3,720 | 3.4 | $4,825 | $8,545 | $3,720 | 3.4 |
| $3,619 | $6,409 | $2,790 | 3.6 | $3,619 | $6,409 | $2,790 | 3.6 | $3,619 | $6,409 | $2,790 | 3.6 |
| $4,825 | $8,545 | $3,720 | 2.6 | $4,825 | $8,545 | $3,720 | 2.6 | $4,825 | $8,545 | $3,720 | 2.6 |
| $9,650 | $17,321 | $7,671 | 2.4 | $9,650 | $17,321 | $7,671 | 2.4 | $9,650 | $17,321 | $7,671 | 2.4 |
| $38,598 | $68,362 | $29,764 | 1.4 | $38,598 | $68,362 | $29,764 | 1.4 | $38,598 | $68,362 | $29,764 | 1.4 |
| $3,619 | $6,409 | $2,790 | 4.0 | $3,619 | $6,409 | $2,790 | 4.0 | $3,619 | $6,409 | $2,790 | 4.0 |
| $203,187 | $369,469 | $166,281 | 3.5 | $199,649 | $371,186 | $171,537 | 3.1 | $199,649 | $375,900 | $176,251 | 3.0 |

Abbreviations: Cg = corn grain, Csl = corn silage, OFG= on farmer's ground, PRg = pasture rotational, grass.

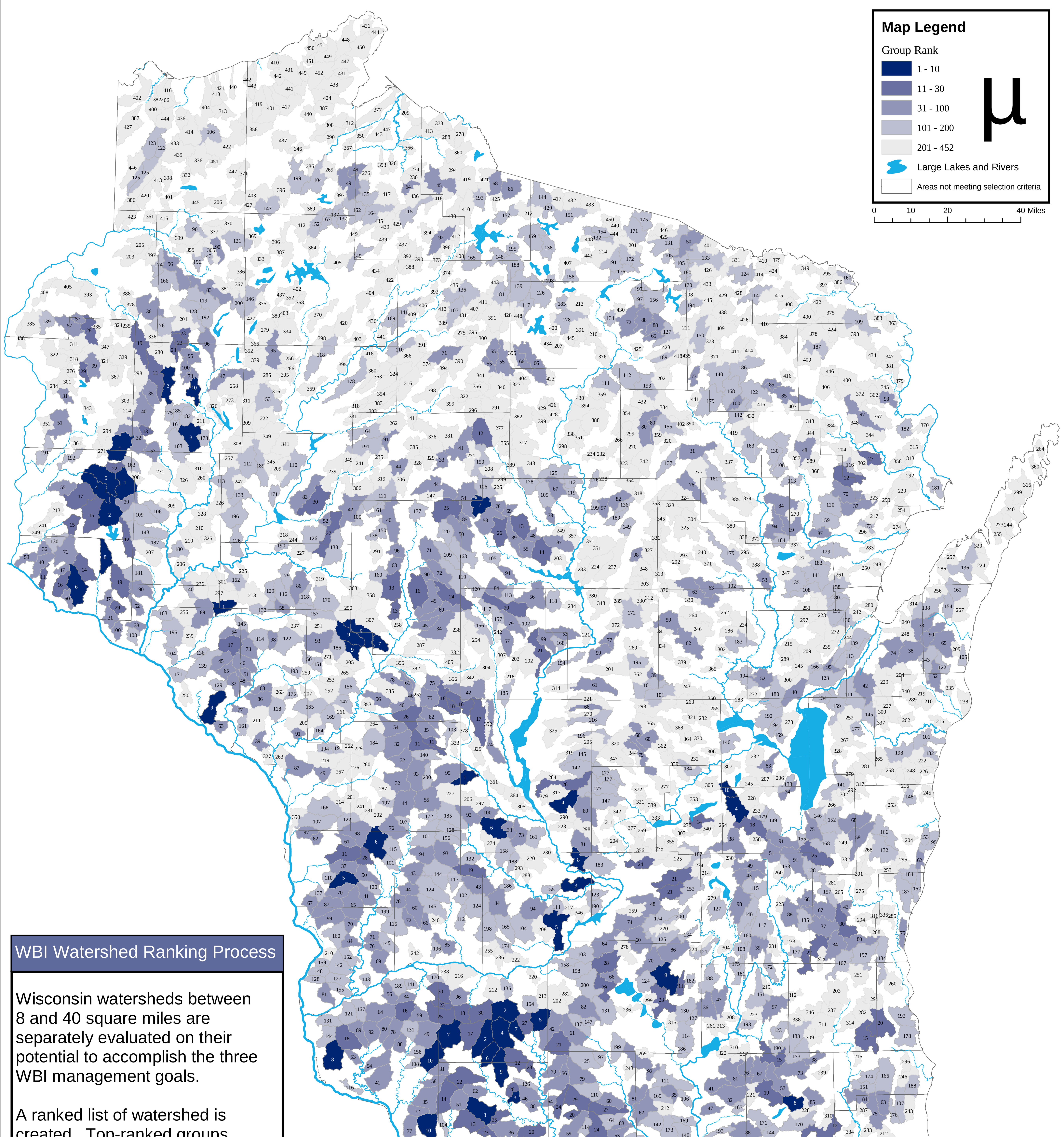
Table 7. Aggregate Farm Results Over Full Rotation for Case 3.

| **Weighted Farm Averages Over Full Rotation (seven years)** | **Change in Profits (Loss)** | **Change in P Index** | **Profit (Loss) per Change in P Index** |
|---|---|---|---|
| OFG 16: 10&16, Csl==>Cg | $5,256 | (0.4) | $53.89 |
| OFG 16: +9b&ll&13, Pg==>PRg | $9,970 | (0.4) | $80.54 |

Abbreviations: Cg = corn grain, Csl = corn silage, OFG= on farmer's ground, PRg = pasture rotational, grass.

# Wisconsin Buffer Initiative

## WBI Statewide Watershed Ranking




### WBI Watershed Ranking Process

Wisconsin watersheds between 8 and 40 square miles are separately evaluated on their potential to accomplish the three WBI management goals.

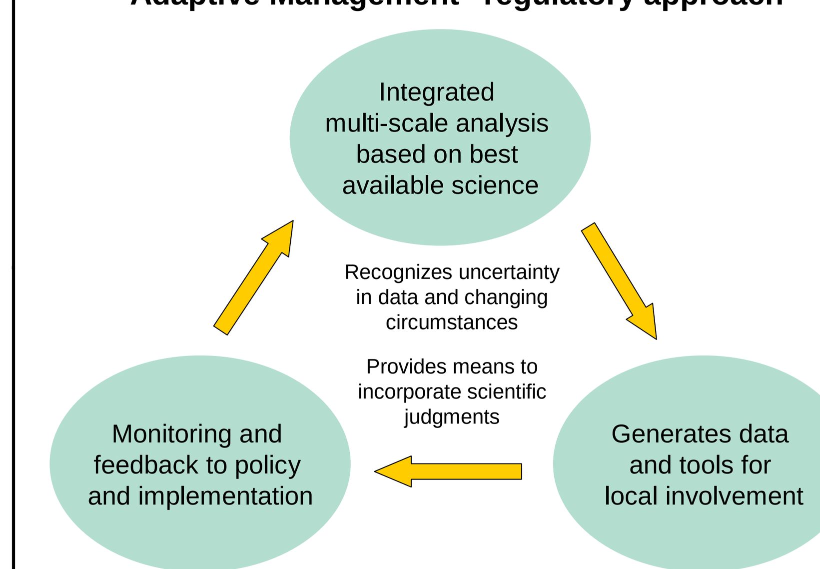
A ranked list of watershed is created. Top-ranked groups of watersheds have the greatest likelihood of responding to buffers and related conservation practices.

## Wisconsin Buffer Initiative Project Description

The Wisconsin Buffer Initiative (WBI) is an effort to make science-based recommendations to the Wisconsin Department of Natural Resources for the development of state rules governing agricultural pollution. Under the guidance of a broadly representative advisory committee, researchers at the University of Wisconsin-Madison provide ideas and approaches at four scales. The overall goal is to identify areas where buffers, in conjunction with other conservation practices, have the greatest likelihood of reducing water quality degradation.

### Adaptive Management

**Science-based recommendations leading to "Adaptive Management" regulatory approach**



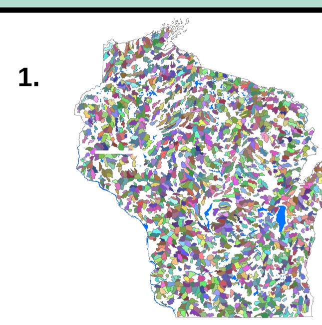

### Management Goals

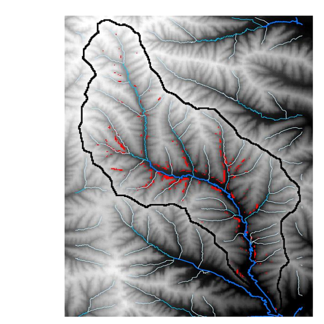
***1. Improve stream water quality***
- reduce loads of sediment and nutrients

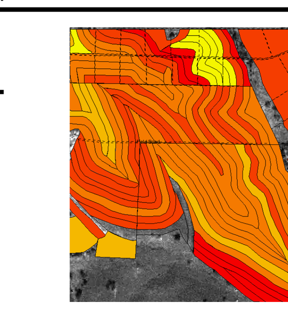
***2. Protect and enhance native biological communities***
- use sediment-sensitive fish species as indicators

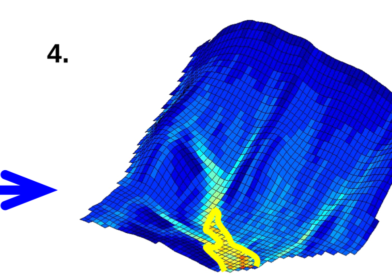
***3. Sustain lake water quality***
- reduce phosphorus loads to lakes to prevent eutrophication

### Analysis Process

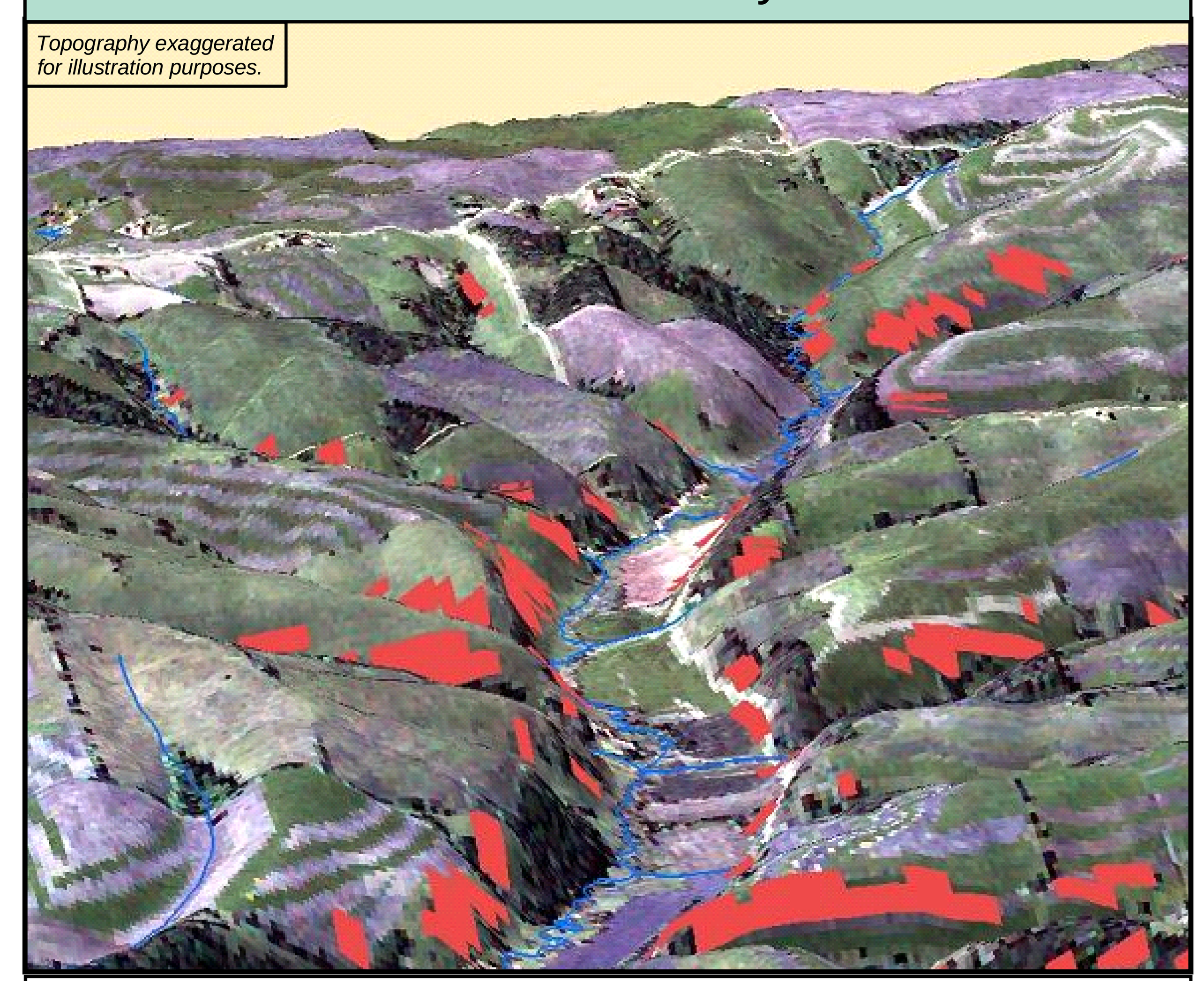
1.

Identifying watersheds most likely to show improvements with investment in buffers

2.

Identifying high priority areas within a watershed for detailed analysis

3.

Evaluating phosphorus and sediment loss and determining conservation alternatives for individual fields

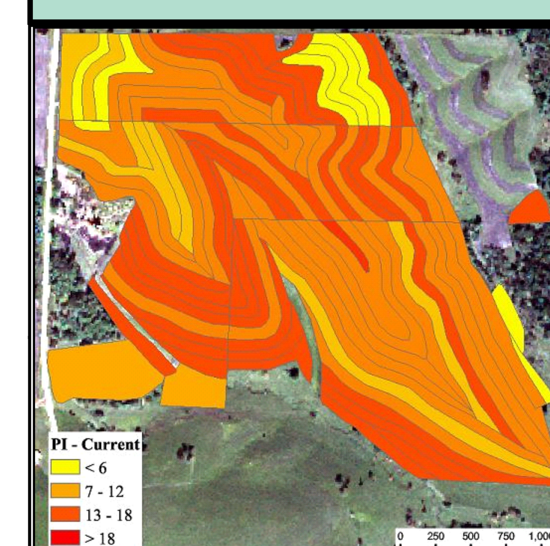
4.

Determining optimal placement and configuration of buffers within fields

### Watershed Analysis



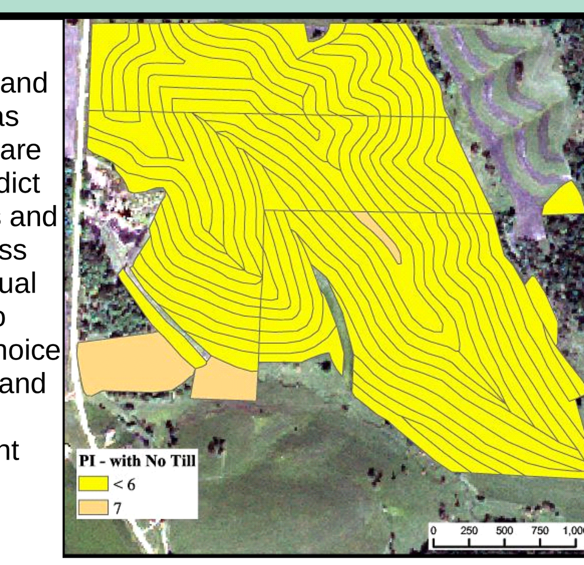

Soil and phosphorus delivery are calculated for all fields in a selected watershed, beginning with the areas that are most vulnerable to erosion (shown above in red) according to a GIS-based USLE analysis.

### Field Analysis




Spring-chisel plow

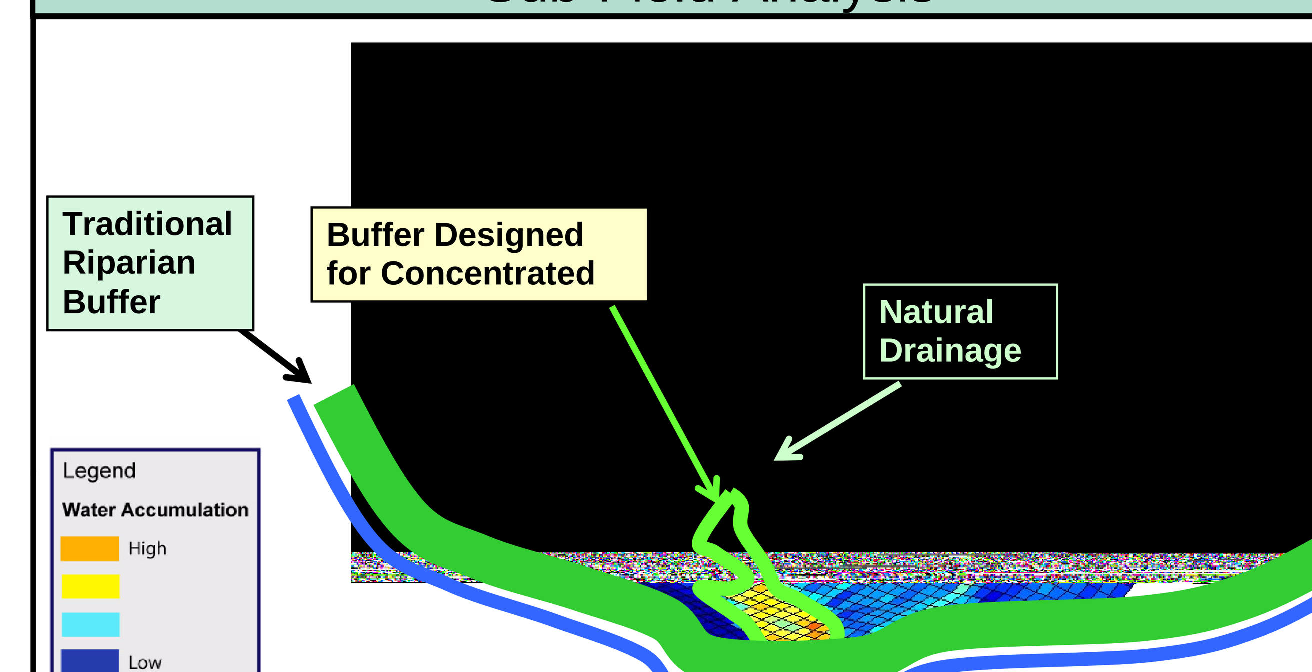
Soil testing and tools such as SNAP-plus are used to predict phosphorus and sediment loss from individual fields and to guide the choice of effective and economical management practices.




No-till

**Example: Field P Index values for a dairy farm**
**Rotation: 2 Yrs Corn silage – Oats – 3 Yrs Alfalfa**

### Sub-Field Analysis




Topographic data from detailed digital elevation models provides the basis for identifying areas of convergent flow and locating buffers for greatest affect. Grass waterways and buffers in these areas are more effective and may be more economical than simple "ribbons" of grass between fields and streams (riparian buffers).

### Credits and Contacts


- *WBI Principal Investigator:* Pete Nowak, University of Wisconsin-Madison
- *WBI Researchers:* Laura Good, John Norman, Larry Bundy, Jake Vander Zanden, Jeff Maxted, Matt Diebel, Christine Molling – University of Wisconsin-Madison
- *Map Design and Development:* Steve Ventura and Ben Webb, University of Wisconsin-Madison



This research was funding in part through a grant from the USDA Natural Resource Conservation Service

*Website:* http://www.drs.wisc.edu/wbi/

November, 2005