Feasibility of an On-Farm Water Quality Program in Minnesota

Photo by David Hansen

July 15, 2008
(revised August 27, 2008)

Report prepared by the University of Minnesota Water Resources Center and University of Minnesota Extension

For the Minnesota Department of Agriculture

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Available on-line at http://wrc.umn.edu/outreach/onfarmresearch

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For the Minnesota Department of Agriculture

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Acronyms

AFREC – Agricultural Fertilizer Research and Education Council (State of Minnesota)

ARS – Agricultural Research Service (USDA)

BMP – Best Management Practices (management practices commonly considered to be the most effective and practical means to control nonpoint source pollutants)

BWSR – Board of Water and Soil Resources

CIG – Conservation Innovation Grants (USDA NRCS)

CSREES – Cooperative State Research, Education, and Extension Service (USDA)

DATCP – Wisconsin's Department of Agriculture, Trade and Consumer Protection (similar to Minnesota's Department of Agriculture)

EPA – U.S. Environmental Protection Agency

FSA – Farm Services Agency (USDA)

LCCMR – Legislative-Citizen Commission on Minnesota Resources (State of Minnesota)

MDA – Minnesota Department of Agriculture

MNSCU – Minnesota State Colleges and Universities

MPCA – Minnesota Pollution Control Agency

NRCS – Natural Resources Conservation Service (USDA)

RC&D – Resource Conservation and Development Program (USDA)

ROC – Research and Outreach Centers (UMN)

SWROC – Southwest Research and Outreach Center at Lamberton (UMN)

TMDL – Total Maximum Daily Load 1) a study containing a calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are restored and maintained; 2) the sum of the pollutant load allocations for all sources; 3) loosely used to refer to the entire EPA/MPCA process of identifying and addressing impaired waters.

UMN – University of Minnesota

USDA – U.S. Department of Agriculture

USGS – U.S. Geological Survey

WASI – Wisconsin Agriculture Stewardship Initiative

WMMB – Wisconsin Milk Marketing Board

WRC – Water Resources Center (UMN)

EXECUTIVE SUMMARY

This is the final report of a feasibility study funded by a Minnesota Department of Agriculture Clean Water Legacy FY07 research appropriation. The study examined the potential value, costs, designs, and support for a long-term program aimed at answering questions about the relationship between agricultural land uses and water quality through outreach and water quality monitoring on active commercial Minnesota farms.

The Wisconsin Discovery Farms program inspired discussions of on-farm monitoring in Minnesota and is the primary model for a Minnesota program. The Wisconsin program has been on the ground for seven years – demonstrating substantial and unique impacts, and providing Minnesota with many lessons. The Discovery Farms have clearly affected farmers, rule-makers, and other stakeholders who now expect information from the program to be part of water quality discussions. One of the lessons learned from Wisconsin is the importance of the program directors and the steering committee in ensuring that the program is directed by and relevant to producers.

Minnesota already has a strong research station network and an extensive history of water quality research and monitoring across the state. This report reviews some of those efforts. Any new on-farm water quality program can build upon these strengths while filling the gaps in farm-scale monitoring and outreach.

The Discovery Farms concept was presented to stakeholders at meetings across the state. Participants expressed a mix of enthusiasm and skepticism toward the idea. They were enthusiastic about the potential for a new approach to water quality issues, but concerned about the possibility of creating a program that did nothing new. Many recognized that – depending on the leadership – the program might generate biased, unhelpful results, or would not take advantage of producer-centered problem solving opportunities. Alternatively, some thought the program would duplicate existing monitoring or research approaches, would generate data that is not effectively utilized, or would draw resources away from other water quality efforts. Despite these concerns, support for the program has generally been strong.

Recommendations

Based on the high level of stakeholder interest, Minnesota should pursue a program modeled after the Wisconsin Discovery Farms. The mission should be to create a meaningful way for the agricultural community to be engaged in water quality issues. This will be accomplished by establishing an on-farm monitoring network with the goal of discovering and understanding agricultural water quality issues at the level of the farm system. The program should serve the needs of the impaired waters (Total Maximum Daily Load) process, but should not be constrained by the TMDL approach to addressing water quality.

Outreach is a central component of this program. The first outreach objective is to create an opportunity for producers to learn from each other about the relationship between agriculture and water quality. The second objective is to communicate this understanding to non-farmers including researchers, policy-makers, and the general public. The program should promote open and honest communications among farmers, non-farmers, and government agencies about the problems and possible solutions to environmental and economic issues.

A network of water quality monitoring stations should be established on working commercial farms to assess runoff at the field or multi-field scale. The monitoring should be designed to collect high-quality data that informs policy and management decisions. It should fill the data gap between plot level research and watershed-scale monitoring to improve the empirical understanding of farm-scale agricultural runoff. In addition to water quality data, the program should collect information about farm practices, finances, and crop data such as yield to gain a systems-level

understanding of agricultural water quality. The initial goal at each site should be to observe the hydrology of a farm system. After the observation period, local committees may choose to target monitoring to answer specific questions.

The monitoring network is not meant to be a set of research stations, but should complement existing research programs. It is an opportunity to validate research results, examine the economic implications of recommendations, and to suggest future research directions.

On-farm monitoring sites should be selected to represent major agricultural systems and physiographic regions across the state. Monitoring designs should allow for comparisons with Wisconsin and North Dakota Discovery Farms data. Farmer-cooperators should be selected, in part, for their ability and willingness to contribute to the outreach goals of the program. At least some of the sites should be positioned within monitored watersheds to examine the relationship between farm runoff/drainage and surface water quality. This will be important for testing assumptions about the contributions of upland agriculture to lake and stream water quality.

The effectiveness of the program depends on it being led primarily by producers. The structure of the program should follow the Wisconsin model in which program directors answer to a strong steering committee dominated by members of the major agricultural producer organizations. To facilitate communication, the steering committee should also include representatives of other water quality stakeholders including agencies, researchers, and the environmental community. The institution that houses the program will affect the perceived identity of the program, but the strength of the steering committee will be even more important in ensuring that the program is respected by producers and other diverse interests.

The envisioned program will cost about $500,000 to $1 million per year. Funding should come from diverse sources to avoid being tied to the mission of a single agency or group. Cost estimates should realistically account for the large time commitments needed to do on-farm work, to effectively build relationships and conduct outreach, and to secure funding on an ongoing basis. Start-up may be made easier by taking advantage of existing monitoring infrastructure at sites such as those described in Table 1.

A program should be established as soon as possible to take advantage of the momentum created by the discussions started during this feasibility study. The Wisconsin Discovery Farms program has shared many documents that will be instructive as Minnesota goes through similar steps. If planning activities begin this fall, monitoring equipment could be installed beginning in spring.

INTRODUCTION

In 2007, the MDA Clean Water Legacy research advisory committee identified research spending priorities in relation to impaired waters. One of the priorities was to consider establishment of an on-farm water quality program modeled after the Wisconsin Discovery Farms program. In response, the MDA dedicated CWL funds to study the feasibility of such a program in Minnesota. This report is the outcome of the feasibility study.

The purpose of a monitoring program would be to fill gaps in our empirical understanding of agricultural runoff and to create a meaningful way for the agricultural community to be engaged in water quality issues. Currently in Minnesota, the federal Clean Water Act (the impaired waters and Total Maximum Daily Load process) is driving water quality discussions. A new monitoring program should serve the needs of the impaired waters process but should not be constrained by it.

Do we need another program?

Even the most committed optimists occasionally become discouraged at the prospects of addressing non-point sources of water quality degradation. Doubts are numerous: Do we really understand the relationship between agriculture and water quality? Are we defining realistic water quality goals? Can commonly promoted BMPs be expected to achieve the desired water quality changes? Can current incentives and programs bring about enough changes in agricultural management practices to achieve water quality improvements? Can we reach enough land managers – and the right ones? Is tweaking farm management enough?

Can one more program really address these concerns? We believe the Discovery Farms concept deserves special consideration – it is a fundamentally different approach to addressing agricultural impacts on water quality. First, it is driven by agricultural producers – the people making the land management decisions. Second, it measures water quality at a farm scale under real-world conditions. Third, the goal is to discover and understand the issues at the system scale rather than to research narrow, predefined issues. And finally, it fosters communication among producers and builds new relationships among producers, agency personnel, researchers, conservationists, and the general public. If this unique combination of features can be preserved over time, this program has the potential to achieve something new.

PART I: INFORMATION SOURCES

Three sources of information were examined to determine the feasibility of an on-farm water quality program: 1) on-farm water quality monitoring programs in other states, especially the Wisconsin Discovery Farms; 2) current water quality monitoring activities in Minnesota; and 3) input from stakeholders. These are each discussed below and form the basis of the recommendations in Part II.

I.A. On-Farm Water Quality Monitoring in Other States

Wisconsin Discovery Farms

The Wisconsin Discovery Farms program inspired the discussion of on-farm monitoring in Minnesota and is the primary model for a Minnesota program. The Wisconsin program has been on the ground for seven years – demonstrating substantial and unique impacts, and providing Minnesota with many lessons.

Program development

The Discovery Farms idea was first proposed by faculty members of the University of Wisconsin-Madison College of Agricultural and Life Sciences and UW-Cooperative Extension after they explored farm-based systems research efforts in the Netherlands. Since the initial concept paper was drafted, many other people have had input to the plan, including Wisconsin dairy farmers and farm leaders, other UW System campus faculty members, and representatives of the Department of Natural Resources (DNR), Department of Agriculture Trade and Consumer Protection (DATCP), and USDA's Natural Resource Conservation Service (NRCS).

In 2001, important agricultural organizations were identified and invited to send member representatives to form the steering committee. Monitoring sites were identified by releasing public announcements soliciting farmer cooperators. Thirty-four farmers responded and the steering committee selected six to become the initial Discovery Farms.

Several important guiding principles were established early in the process and are reflected in the mission and vision statements (see Sidebar 1, next page):

- The program is primarily farmer driven.
- The work is done on real commercial farms and addresses a range of types of enterprises and geographical settings.
- Data is collected on both the environmental and economic effects of farm management.
- The program examines the impacts of rules and regulations on environmental indicators and on farm management/profitability.
- Open communication about problems and possible solutions is fostered among farmers, non-farmers, and government agencies.
- The goal of communication is to implement management decisions that are environmentally effective and compatible with profitable agriculture.

A key feature of the program has always been the emphasis on local and producer control. Specifically, representatives from agricultural producer groups dominate the steering committee, which controls the choice of farm sites and other critical decisions about the program mission. Results from each farm site are interpreted by a committee of local farmers and agencies and results are disseminated by the local committee and the steering committee.

Operational structure

Fiscally, Discovery Farms are within the University of Wisconsin system, and the directors are UW Extension faculty. The program offices were deliberately located in the small town of Pigeon Falls rather than in Madison.

The major structural components of the program are:

Directors (Dennis Frame and Fred Madison, UW Extension) – coordinate and manage all operations. (full time staff.)

Steering Committee (11 members from producer groups, 1 from agricultural industry, 1 from an environmental group) – provide oversight and overall direction, help select projects and farm cooperators, provide regional assistance to farm cooperators, and help disseminate information to membership. (Meet 1 to 2 times per year. Directors consult the executive committee between meetings.)

Technical Advisory Committee (about 17 members from research and agencies) – design overall and individual research and monitoring projects.

Farm Advisory Committees (One for each farm. Includes local producers, their advisors, neighbors, agency/education personnel.) – Expand the impact and significance of monitoring activities by providing guidance on the issues that need to be researched and resolved on similar operations, providing support for the farm to identify issues and implement management changes, and helping disseminate information. (Meet 1 to 2 times per year after initial monitoring period.)

Program staff (in addition to the 2 directors)

- Outreach specialists (4 part-time positions)
- Staff (4 part-time positions)

Stakeholder involvement

The most important stakeholders in the Wisconsin Discovery Farms program are the farmers. Representatives from producer groups hold 11 of the 13 seats on the steering committee, which has final word on which farms participate in the program and determines the overall direction of the program. The farmer cooperators and their neighbors are part of each local advisory committee and thus are influential in interpreting monitoring results and determining management responses. One impact of strong producer involvement is that farmers generally have a high level of trust in the program.

DISCOVERY FARMS

Sidebar 1. Wisconsin Discovery Farms

Mission Statement:

The Discovery Farms Program will develop on-farm and related research to determine the economic and environmental effects of Management Practices on a diverse group of Wisconsin farms; and educate and improve communications among the agricultural community, consumers, researchers, and policy-makers to better identify and implement effective environmental management decisions that are compatible with profitable agriculture.

Vision Statement:

To achieve its mission, the Discovery Farms Program needs to:

- Work and communicate with a wide range of agricultural enterprises to determine the environmental impacts of production agriculture and create a reliable database of what different farms contribute in terms of environmental enhancement or degradation;
- Gather baseline information that includes not only environmental information, but management practices and financial conditions that allow for the calculation of the cost of implementing environmentally sound best management practices;
- Determine the affects of environmental rules and regulations on the environment, farm profitability and farm management; and provide accurate information to producers, consumers, policy makers and agency personnel so positive steps can be made to protect both the environment and production agriculture;
- Work and communicate with the agricultural producer groups, environmental groups, consumers, the University of Wisconsin System, the Department of Agriculture, Trade and Consumer Protection, the Department of Natural Resources, the Natural Resources Conservation Service, Environmental Protection Agency, County Land
- Conservation Departments, agricultural businesses and cooperatives; on the importance of maintaining a viable agricultural economy, and identify the impacts, including positive impacts, that agriculture has on Wisconsin.

While producers are the primary stakeholders, they do not work alone. The Technical Advisory Committee made of researchers and agency personnel determine the research and monitoring design of the projects. The local advisory committees include local agency/education personnel.

Funding and budget

Discovery Farms' funding has come from diverse state, federal, and private sources (Figure 1).

Of the annual budget of $600,000 to $900,000, over one-third is spent on salaries. Another third goes to USGS to collect and analyze monitoring data. The remainder is spent on travel, office expenses, conferences, and additional monitoring expenses (Figure 2).

USGS annual expenses average about $12,000 per water quality site or about $34,000 per farm to maintain and collect samples. This includes farm visits to maintain equipment (6-33 days/farm), sample handling, data handling and write ups, precipitation data handling, utilities, database management, and equipment costs. Attachment A provides a detailed description of USGS's tasks and costs. USGS matches part of the actual expenses.

In addition to maintenance and data collection, $8,000 to $10,000 per year per farm is spent on sample analysis, and an average of $25,000 worth of time is spent on each farm collecting and organizing detailed management data and working with producers. Thus, the annual total cost per farm is about $75,000. This does not include the average initial installation costs (equipment and labor) of about $25,000 per site.

Figure 1. Wisconsin Discovery Farms Funding Sources

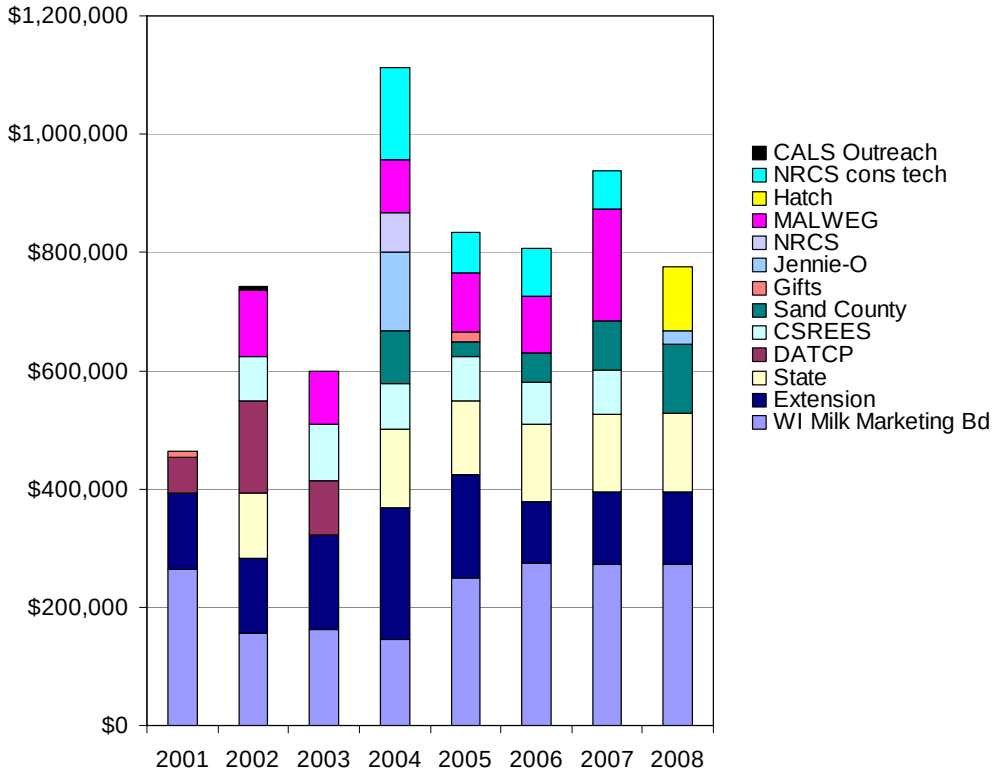
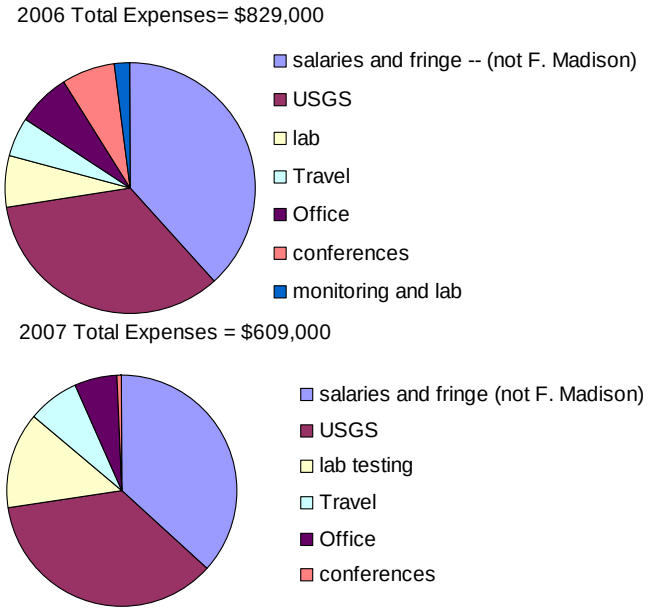


Figure 2. Wisconsin Discovery Farms Expenditures



Data collection and dissemination

Monitoring stations are established on two or three sites on each of eight core farms. The stations have a power source and automatically collect flow data and water samples from all runoff events, including winter and snowmelt events. Water samples are tested for nitrogen, phosphorus, and sediment. Data quality is ensured by using USGS staff to maintain equipment, collect samples, and analyze data. In the future, monitoring will be managed and coordinated by the Pioneer Farm staff (see next section).

Summaries of monitoring results are available on the Discovery Farms web site (http://www.uwdiscoveryfarms.org/) in the form of PowerPoint presentations and write-ups. Much of the monitoring data is available in real time from the USGS web site (accessed through the Discovery Farms site).

The Discovery Farms program gathers extensive data about farm management practices and finances on each core farm. This allows for analysis of economic as well as environmental impacts of decisions. Family dynamics are recognized as an important part of farm management decisions.

In addition to core farms which are monitored without research objectives, the Discovery Farms program includes “special projects” which are established for a limited amount of time to answer a specific question such as the impact of stockpiling of turkey manure.

Results from a variety of farms are combined and interpreted to produce the best recommendations possible. These conclusions are shared at over one hundred agricultural meetings around the state annually – especially at gatherings of participating organizations. Findings are distributed through mass media and other routes that reach farmers and agribusinesses, Extension bulletins, and scientific and technical articles. Field days are held at cooperating Discovery Farms and at the Platteville Pioneer Farm.

To prevent the misuse of data and document the applications of Discovery Farms data, a Data Policy Committee was established to review all requests for data.

Effectiveness

It is difficult to directly attribute behavior or water quality changes to the Discovery Farms program, but several observations suggest that the program is having broad impacts. Field days and outreach events are remarkably well attended. Farmers, legislators, and state agencies have come to expect Discovery Farms data and participants to be part of discussions of policy, rules, and agricultural practices. The program is well-known and well-respected among farmers.

Monitoring data has contributed to understanding of several aspects of agricultural water quality, including:

- Annual patterns of surface water runoff (primarily from January through May).
- Annual patterns of tile line flow (occurs all year in many places).
- Sediment loss in the Driftless Region (it is possible to control runoff from farm fields, even on these steep slopes).
- Impact of soil moisture content in predicting runoff events.
- Impact of single storms on annual sediment losses.
- Impact of runoff during frozen periods on annual nutrient losses (generates a large proportion of losses).
- Practical methods for more effectively managing manure applications to minimize environmental impacts.

Additionally, the program has presented alternative approaches to policy issues. For example:

- Environmental issues include more than water quality. When writing agricultural policy, we must work on multiple issues and not target one source of pollution at the expense of others. (Example: incorporation of manure reduces odors and emissions, but may increase soil erosion and nutrient losses to tile drainage systems.)
- Work with producers to prevent events by focusing on education rather than regulations, increasing understanding of the potential for events, involving producers in designing alternative practices, and moving from prescriptive programs to an adaptive management approach.
- Differentiate between producers who have chronic problems (frequent events) and those with acute problems (one major event based on a series of unpredictable occurrences).

External review recommendations

An external panel reviewed the Discovery Farms program in May of 2007. They observed that the program fills a unique and critical niche in the area of agricultural research/extension. The farmer cooperators have gained a better understanding of researcher's constraints, and most notably, the cooperators "have been an extremely important mouth-piece for change and BMP adoption among other farmers". The following are some of their recommendations for future redirection to keep the program energized and strong.

- Cultivate younger personnel to eventually take leadership of the program.
- Evaluate the scale and intensity of monitoring so the program can reach a wider range of farms (geographically and by operation type and profitability). The current level of accuracy is not necessary to meet some program goals.
- Address the issue of farmer compliance with nutrient management plan implementation in an effort to avoid mandatory compliance efforts.
- Publish monitoring information in peer-reviewed technical journals.
- Collaborate with researchers and experiment stations to investigate issues that require the long-term intense monitoring not feasible on core farms.
- Encourage short-term collaboration with university faculty and graduate students.

- Include greater representation from the environmental community on the steering committee.
- Reduce water and weather analyses costs.

Wisconsin Pioneer Farm

The Pioneer Farm at Platteville, Wisconsin is a UW facility providing opportunities for practical farm experience and farm-scale research.

Program development

The University of Wisconsin-Platteville Farm began operations early in the 1900's and moved to its current location in 1957. The original mission of the farm was to serve as a laboratory for the agricultural students, providing them hands-on real-world agricultural experience. Currently, the farm consists of 430 total acres, of which 340 are cropped. The seven-year crop rotation includes oats, three years of alfalfa, and three years of corn. Livestock enterprises include swine, beef, and dairy. Multiple conservation practices are installed, including contour farming, strip cropping, farm-over terraces, hump-back terraces, and grassed waterways.

In 2001, as a member of the Wisconsin Agriculture Stewardship Initiative, the mission of the College Farm was expanded to place more emphasis on agricultural systems research. The primary focus of this research has been investigating the quality of surface-water runoff from cropland, pasture, and livestock facilities on the farm.

Operational structure

The missions of the Discovery Farms and Pioneer Farm (see sidebars below and on page 10) are meant to complement one another. Discovery Farms monitoring program covers multiple regions of the state and measures environmental loadings associated with particular farming systems. In contrast, Pioneer Farm's monitoring program is designed to collect paired data for evaluating alternative farming practices. The results from Discovery Farms monitoring are used to develop projects at Pioneer Farm. More intensive data collection is possible at the Pioneer Farm and greater risks can be taken than on the commercial Discovery Farms. The Discovery Farms education program is more substantial than that of Pioneer Farm and is directed toward producer education whereas Pioneer Farm education program is focused more on formal classroom instruction for post-secondary education. Discovery Farms and Pioneer Farm are discussing closer coordination of their outreach and monitoring activities.

Pioneer Farm is administered by UW-Platteville School of Agriculture. The Pioneer Farm Research Manager provides oversight for the research program.

Stakeholder involvement

Stakeholders provide input to the Pioneer Farm research program through participation on advisory and technical committees. The groups in the following list currently provide input to Pioneer Farm. Pioneer Farm and Discovery Farms are in the process of modifying stakeholder involvement mechanisms, so the structure described here may soon be obsolete.

1. WASI Coordinating Council- the coordinating council sets research priorities, commissions reports, identifies and cultivates opportunities for financial support,

Sidebar 2. Wisconsin Pioneer Farm

Mission Statement:

UW-Platteville Pioneer Farm supports the vitality of Wisconsin's agriculture. Pioneer Farm's mission is to provide on-farm experiences with students, to evaluate management practices, to conduct systems and applied research, and to communicate education and research to students, agencies, producers, and the public.

provides guidance and oversight on the direction of research and education agendas, and reviews annual reports from WASI parties. Membership composition includes: 2 producers from Pioneer Farm Advisory Committee, 2 producers from Discovery Farms Advisory Committee, 2 producers/ag members selected by Secretary of DATCP, 2 representatives of environmental organizations, and 2 citizens-at-large by invitation of the WASI Coordinating Council. Ex-officio members include one member from each of the following organizations: DATCP, DNR, NRCS, UW Consortium, UW Madison/Extension, UW-Platteville, UW-River Falls, and UW-Stevens Point.

2. Pioneer Farm Advisory Committee- membership consists of livestock and crop producers, agency personnel, educators, agriculture professionals, and representatives from environmental organizations.
3. Water Science Team- responsible for coordinating projects and consistency in data collection for all of WASI and its components.
4. UW-Platteville School of Agriculture Teams:
    a. Research and Design
    b. Administrative
    c. Data Design Team
    d. Technology Development
    e. Swine
    f. Dairy
    g. Beef
    h. Sampling / Data Collection Team
    i. Water Science Team
    j. Business Development Team
    k. Communications Team

Funding and budget

Over the past 6 years, non-recurring funding for the Pioneer Farm came one-third from the state budget, 60% from UW-Platteville, and the remainder from federal and consortium grants, Wisconsin Milk Marketing Board contracts, and gifts from private non-profits and agencies. Much of these funds were used for facilities not related to the research program.

Financial support that directly relates to the on-farm monitoring program has been provided by UW-Platteville School of Agriculture and the College of Business Industry Life Science and Agriculture, state general program revenue, and the Conservation Technology Earmark. Originally, the level of support was approximately $550,000 per year. However, with reductions in earmark spending at the federal level, current support is approximately $400,000. Continued declining earmark expenditures are expected to result in annual funding of approximately $300,000. Pioneer Farm current annual expenditures are approximately:

Salaries:	$220,000
Water Sample Analysis:	$50,000
USGS:	$90,000
Supplies:	$25,000
Travel:	$15,000

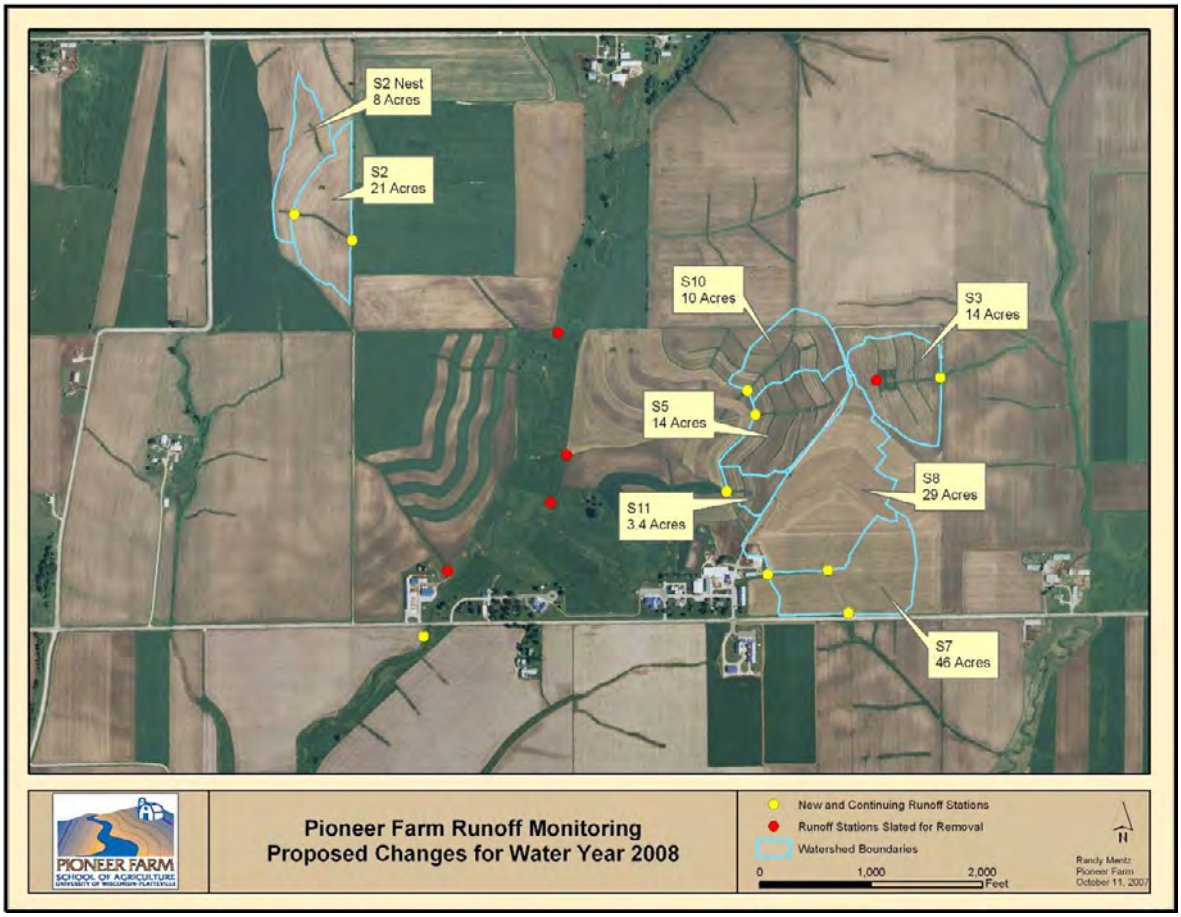
Data collection and dissemination

Monitoring stations are installed and maintained by USGS staff. Day-to-day operation is conducted by Pioneer Farm research staff and collected samples are analyzed by UW-Stevens Point Water

and Environmental Analysis Laboratory. Results of the sample analyses are submitted to USGS personnel who combine the flow and concentration data to generate load sheets for each event. In addition, Pioneer Farm personnel collect related agronomic, photometric, and ancillary data for use in data analysis. Most of the data is archived and available by request through Pioneer Farm. Meteorological data is archived and available for download at the USGS website.

In 2007, Pioneer Farm research staff modified the monitoring infrastructure and crop rotations in order to develop multiple paired basins. Figure 3 illustrates locations of Pioneer Farm surface-water gauging stations. Currently, two basins are calibrated (basins 3 and 5), two basins are nearing the end of their calibration period (basins 10 and 11), and two basins are starting a calibration period (basins 2 and 7). Additionally, sites 2 and 7 are nested which would allow an above-and-below research methodology to collect paired data for evaluation of alternative practices. Staff are examining the monitoring protocols for Discovery Farms and Pioneer Farm and are discussing closer coordination of the two programs.

Figure 3. Pioneer Farm Runoff Monitoring Basins.



Effectiveness

Pioneer Farm outreach efforts have been limited in scope and success. Limited staff with outreach responsibilities makes developing a comprehensive outreach program challenging. In recognition

of this fact, Pioneer Farm and Discovery Farms are collaborating more closely to take advantage of each other's strengths in monitoring and outreach, respectively.

Awareness of Pioneer Farm in the farming community is low. A recent study conducted by the UW-Madison Environmental Resources Center concluded, "The study shows farmers are not aware of Pioneer Farm activities or the implication of those activities for their operations. Generally, knowledge of programs and research is low, and Pioneer Farm is underutilized as a source of information when farmers make management decisions."

North Dakota Discovery Farms

Program development

The development of the North Dakota Discovery Farms program is driven by Ron Wiederholt (NDSU Extension and Ag Research Stations) and committed individuals at the ND Department of Health (DoH). In early 2007, DoH staff learned about the Wisconsin Discovery Farms and asked Wiederholt to help establish a similar program in North Dakota. The DoH committed EPA 319 grant money to program development.

Wiederholt presented the Discovery Farms idea at the April 2007 meeting of the nutrient advisory team (319 watershed advisors, public employees, and producers). The advisory team decided to focus on small- and medium-sized animal feeding operations – sizes that are missed by the regulatory radar. Wiederholt then solicited watershed coordinators for suggestions for farmer cooperators and received four nominations. He and three other staff from DoH and USGS visited and reviewed the four farms.

At that point, Wiederholt formed a steering committee by sending out 60 invitation letters to producer groups and other stakeholders. Thirty-five people responded to the letter and attended the first steering committee meeting on September 7, 2007. The meeting consisted of presentations by Dennis Frame (WISCONSIN Discovery Farms) and Wiederholt, and discussion. By the end of the meeting, the group had selected two of the farms for participation. Monitoring equipment was installed on one farm in November and the other in spring of 2008.

Operational structure

Wiederholt and USGS are the primary hands-on operators of the program.

The steering committee is a loose group that did not want as active of a role as the Wisconsin steering committee. It may become more structured in the future. Wiederholt coordinates, reports, and facilitates the meetings.

They adopted the "Discovery Farms" name with Dennis Frame's encouragement.

The two cooperating farmers are not paid.

Formal program goals are to:

- Encourage responsible development of a diverse livestock industry in the state that will benefit crop and livestock producers while protecting our natural resources.
- Ensure a coordinated approach to the development and management of regulatory practices and policies.
- Document and quantify the environmental benefits and impacts of farming or ranching practices.
- Provide unbiased, reliable information to the general public, agricultural producers, and policymakers concerning the relationship between agricultural production and natural resource management.

- Provide a conduit to enhance communication and information sharing among agricultural producers, researchers, educators, the general public, and regulatory agencies.
- Establish a network of working farms to demonstrate and evaluate the benefits and impacts of existing and new/innovative agricultural land use practices.
- Provide a platform for agricultural systems research through cooperation with interested research institutions.

Stakeholder involvement

Producer groups are supportive and engaged through steering committee activities. Their level of direct involvement is lower than that in Wisconsin.

Funding and budget

As of early 2008, the primary funding source has been EPA 319 grant money through the DoH. Alternate sources need to be identified for the future.

Gaging stations cost about $30,000 to set up.

USGS provides their services at $30,000 per gaging station per year, which is 60% of their costs.

Other major costs include Wiederholt's time, which is covered by ND Extension.

Data collection and dissemination

Each farm has 3 gaging stations with ISCO samplers. Producers make the management decisions.

USGS manages the monitoring station and data.

Effectiveness

The ND Discovery Farms program was established quickly by keeping the establishment process simple, by having a specific focus (small AFO's), and by having eager support from a funder (DoH). It is too early to judge other measures of effectiveness.

Future

The steering committee generated a long list of topics for special projects. High-priority items are pathogens, long-term impacts of manure on soil, and quality of drinking water for cattle.

Arkansas Discovery Farms Project

Program development

Dr. Andrew Sharpley (University of Arkansas) with Dr. Michael Daniels (University of Arkansas Extension) have established on-farm research sites and are in the process of building program support from the agricultural community. Their motivation is to help Extension reach more people and to document the effects of agricultural practices in response to ongoing legal cases. Multiple law suits have been filed over the past several years against Arkansas poultry companies for spreading poultry litter and causing bacterial and phosphorus pollution of surface water. Legally-sound data is needed to help understand agricultural runoff, but producers are hesitant to become formally involved because of potential legal consequences.

Arkansas' agricultural geography includes several significant issues: karst features in the Ozark mountains of the northwest, poultry CAFOs and grazing operations in the northwest, rice production on the Delta and in the southwest, and row crop production in the east.

Operational structure

Research activities are headed by Dr. Sharpley.

A main objective of the program is to help increase the profitable implementation of nutrient management plans while increasing their effectiveness to minimize nutrient losses from livestock operations in Arkansas. This will be achieved through 1) on-farm research, monitoring, and assessment of conservation practice adoption to determine their nutrient loss reduction efficiencies within the given economic constraints of current representative farming systems in Arkansas, 2) on-farm verification and documentation of Nutrient Management Plan (NMP) adoption and implementation, nutrient loss reductions in support of sound environmental farm stewardship, and 3) educational programs developed from information gathered on these farms that will assist agricultural producers in implementing nutrient management plans.

Stakeholder involvement

Involvement from the agricultural community is limited, in part because of concern over legal consequences. Farm Bureau is lobbying for funding. The poultry industry is interested but has not provided funding.

Funding

Two to three years of grants are secured for on-farm monitoring research.

Because of the legal significance of results, there is concern over bias if the poultry industry helps fund the work.

Data collection and dissemination

To reduce costs, they plan to be less dependent on USGS than is Wisconsin.

One of the sites is focused on demonstrating the effects of conversion to a legume-based system.

I.B. Water Quality Monitoring in Minnesota

When using the Wisconsin Discovery Farms as a model, it is important to consider initial differences between the two states. Two significant differences are Minnesota's strong research station programs at the Research and Outreach Centers (ROCs) and the extensive history of water quality research and monitoring across the state. This section summarizes Minnesota's water quality monitoring activities. Any on-farm water quality program should take advantage of these data to provide context for on-farm monitoring.

Watershed Monitoring

The MPCA Environmental Data Access (EDA) system provides access to water (and air) quality data collected and stored by MPCA and other organizations that submit data to the STORET system (http://www.pca.state.mn.us/water/storet.html). Figure 4, Figure 5, and Figure 6 are based on the EDA system and show the distribution of long-term surface water monitoring sites. Figure 7 shows USGS monitoring sites. The sites vary in terms of analytes measured. For example, many of the USGS sites only monitor flow. Figure 8 shows sites that are part of the MDA Agricultural Chemical Monitoring and Assessment Program.

These sites are not on-farm measurements, but they can provide valuable context for on-farm monitoring efforts.

Figure 4

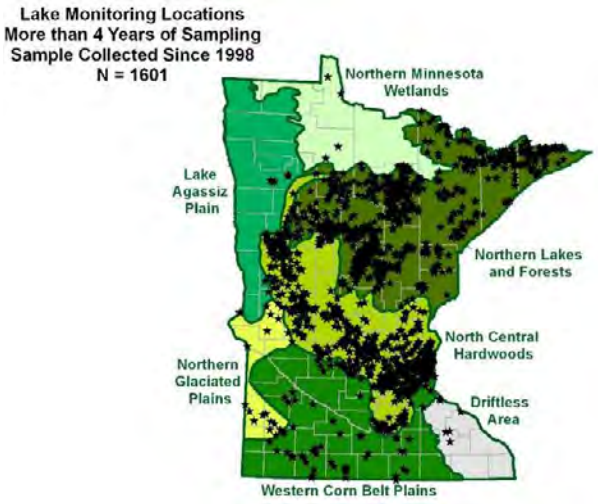


Figure 5

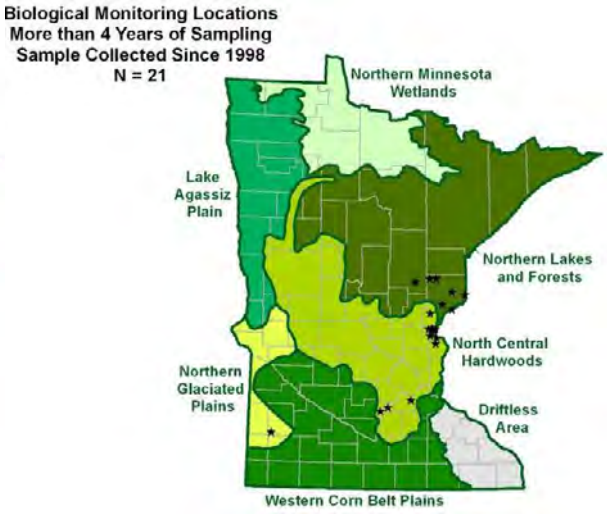


Figure 6

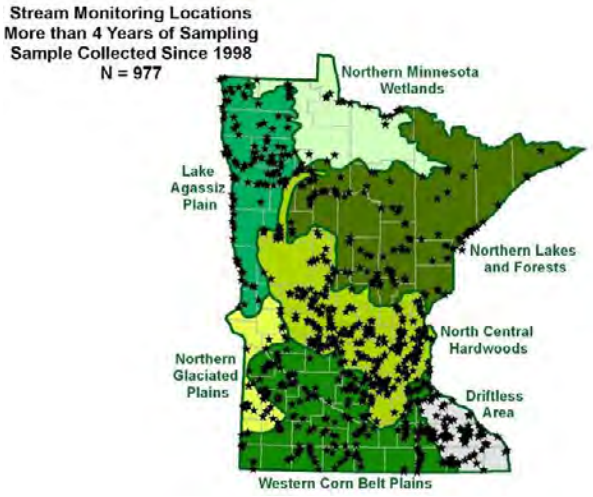


Figure 7

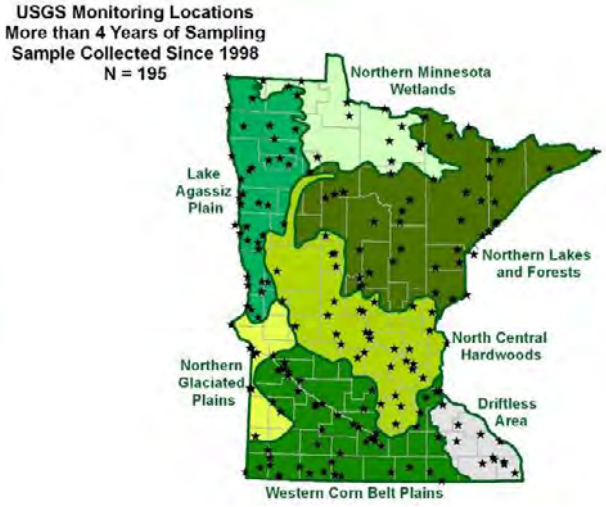
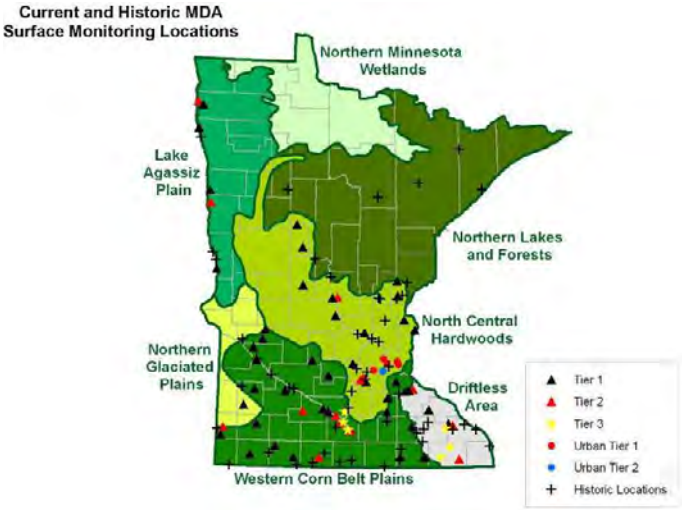


Figure 8



On-farm Research

Over the years, Minnesota researchers have conducted on-farm studies of surface runoff, leaching, and tile flow. These studies were generally short-term and the results may or may not be easily accessible. The data may be available only in "gray literature" such as LCCMR reports or the "Blue Book" from the UMN Department of Soil, Water, and Climate.

A few examples of the numerous research studies conducted on commercial farms include:

- A current study of runoff from fields with turkey manure applications (John Moncrief, Kandiyohi County).
- Nutrient losses associated with surface tile inlets vs. gravel inlets (LeSueur and Wantonwan Counties).
- Effects of slow release fertilizer on potato yield and nitrate leaching potential (Otter Tail, Todd, Sherburne Counties)
- Nitrate leaching associated with fertilizer BMPs (Olmsted County. Randall, G.; Schmitt, M. 1998. Best Management Practices for Nitrogen Use in Southeastern Minnesota. UM Extension 06126.)

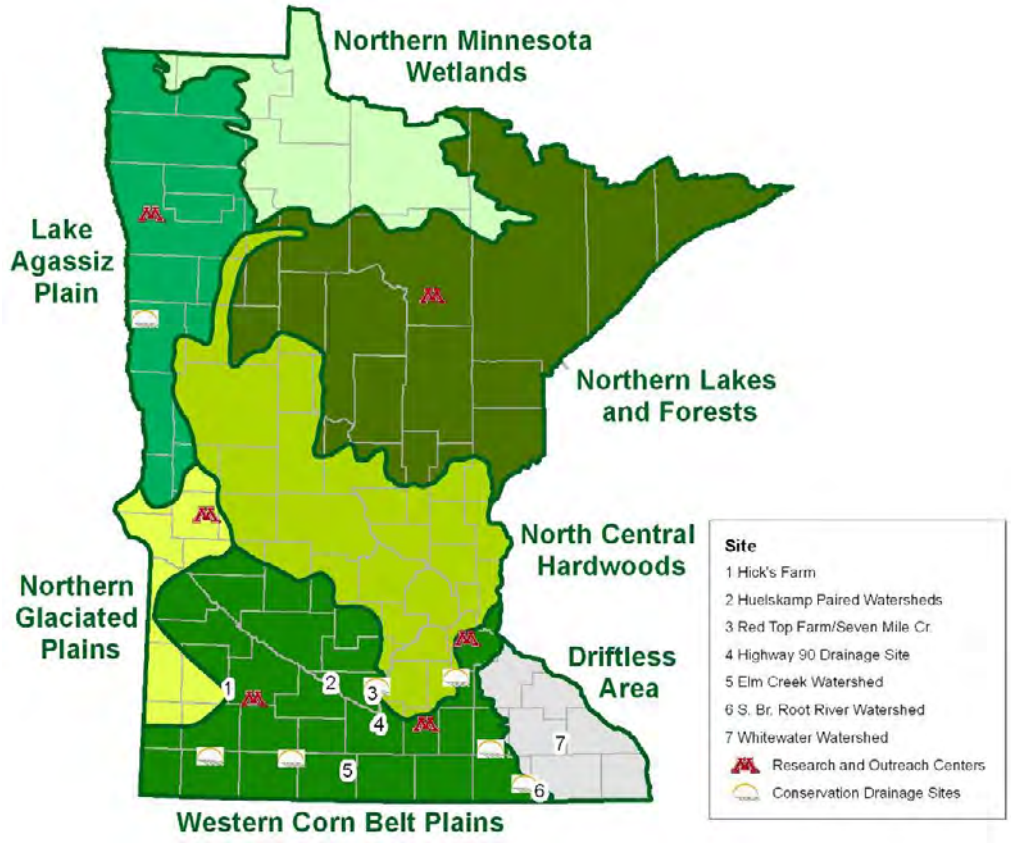
On-farm research generally aims to answer a specific question and is often associated with plot work at a research station. An on-farm water quality program could strengthen on-farm research by providing suggestions for needed research, by creating research sites that have farm-scale baseline information, and by helping to communicate research results.

Comprehensive Water Quality Monitoring

Minnesota has many monitoring sites that deserve special attention for their potential to contribute to an on-farm water quality monitoring network (Table 1 and Figure 9). They are called "comprehensive water quality monitoring" sites because they combine water quality monitoring with land use assessments and other studies to help provide a broad picture of water quality issues in a watershed. Some of these locations may be suitable for establishing an on-farm monitoring site. Other programs are valuable because they provide examples of how to build collaboration among producers, researchers, and other stakeholders. All of the sites provide a wealth of historical data that can be used to interpret new data. This is not a complete list of "comprehensive monitoring" sites, but it represents the data resources available in Minnesota.

Table 1 was created to help assess whether these sites should be incorporated into an on-farm monitoring network. Each site is rated for its potential to contribute to research and outreach objectives, based on criteria listed in Table 2. The outreach rating is based on the degree of current public participation and awareness, local outreach support, site accessibility, available historic data, and the participation offered by the landowner. The research rating is based on each site's ability to meet water quality system design recommendations detailed in Table 3 "Surface-water monitoring design alternatives."

Figure 9. Comprehensive Water Quality Monitoring Projects



I.C. Stakeholder Perspectives

The success of an on-farm water quality program depends on meaningful engagement from multiple stakeholder groups. Groups that have a stake in a monitoring program include:

- Agricultural producers;
- Agricultural producer groups and business organizations;
- Local and regional crop production retailers;
- State agencies (MPCA, MDA, BWSR);
- Soil and Water Conservation Districts;
- Watershed organizations;
- Non-governmental environmental and conservation organizations;
- Federal agencies (NRCS, RC&D, EPA, ARS, USGS, FSA, Army Corps of Engineers);
- Research and outreach entities (UMN, ROC, UMN Extension, MNSCU).

On October 29th, 2007, MDA staff took an initial exploratory tour of Wisconsin Discovery Farms along with representatives of UMN and USGS. Participants were impressed with the influence of the program on farmers as well as policy- and rule-makers, but some thought it would benefit from stronger relationships with the University and DATCP. Generally, people were enthused about the potential of the program to foster dialog among producers and harness their energy and knowledge, but were left with many questions about how to find the right leadership, and whether it can generate data that is useful in policy making.

The primary method of gathering stakeholder input was through four public forums in February and March 2008 and a fifth summary forum in April attended by a sample of participants from the previous forums (Table 4). Groups and individuals were also invited to submit written comments. During the first half of each program, Dennis Frame described the Wisconsin Discovery Farms Program. Then participants discussed two questions: Should Minnesota pursue an on-farm water quality monitoring network? If so, what are the most important objectives it should address? As time allowed, we discussed specific design features such as how to administer a monitoring program, sources of funding, and others.

Summary of Feedback

The following summary is based on forum discussions, anonymous evaluation forms submitted at the forums, written comments, and especially the April summary forum attended by a mixed group of stakeholders.

Should Minnesota pursue an on-farm water quality monitoring network?

Overwhelmingly, people supported emulating the Wisconsin Discovery Farms program, but only if the program were producer-driven and led by one or more people who are broadly respected and trusted by the agriculture community as well as other stakeholders. Other key concerns were that the program have long-term support and that it would be a "useful" effort that didn't duplicate existing work or generate data of limited value.

Dissenters voiced several concerns. First, some did not want to commit support without knowing more about what was being proposed. Others feared that a monitoring program would take resources away from cost-share, technical assistance, and one-on-one work with land owners – all of which are key to implementing water quality changes. Finally, some were concerned that a monitoring program could not be effective because of political or institutional biases, limited impact on water quality because there will always be key people or sites that are not reached, limited impact on water quality because important water quality issues cannot be addressed at the farm scale, or because it would not teach us anything new.

What are the most important objectives a monitoring network should address?

The first objective should be to create a bottom-up program that earns farmers' trust.

Secondly, the network should measure actual farm-scale runoff. Like the Wisconsin Discovery Farms program, monitoring should begin without a pre-conceived research objective. Issues should not be defined until after a couple years of baseline data are collected.

Third, communication is key. Communicate results among producers by creating opportunities for producers to help interpret and share the information. Communicate results to rule-makers, legislators, researchers, and the general public.

Fourth (and related to communication), generate quality data that all parties can agree on so data can speak for itself to either confirm or refute commonly held assumptions.

Table 4. Number of Participants at Stakeholder Forums

	Producers	County and SWCD staff	Env. groups & watershed districts	State and federal agency staff	University and Extension
St. Cloud, Feb 19		6	3*	2	
Eagan, Feb 20	9				
Lamberton, Mar 18	8	1	1		1
Rochester, Mar 19	7	2	4	5	
St. Paul, Apr 4	10	2	2	7	3

** Watershed district representatives, including one producer.*

Several other points were made during the discussion of objectives:

- Farm-scale costs and cost effectiveness must be part of the assessments.
- Don't attempt to do rigorous research. Leave that to the research stations. This program should be measuring impacts of what farmers are actually doing.
- On the other hand, there is a need to learn the actual impacts of farming systems and specific practices.
- The program should address the TMDL process: What's coming off the land? How do we improve load allocations? How do we fix any problems?
- The program should be coordinated with the multitude of existing water quality monitoring and research efforts, but coordination activities should not overload the program to the point that its major objectives suffer.
- Coordinate with similar programs in Wisconsin and other states.
- Control data dissemination so pieces are not used out of context.
- Water analysis should focus on TMDL priorities: sediment, phosphorus, nitrogen, and bacteria. Pesticides may also be an important issue, but any value of assessment must be weighed against the cost of analysis and potential reluctance among farmer cooperators.
- It is essential to protect cooperators from regulatory risk.
- Watershed-scale monitoring should be included to learn about the impact of farm scale activities on the small watershed scale.
- Data from this program could be used to validate and fine-tune models.
- Results could help identify critical time periods for water quality impacts.
- Groundwater should be considered along with surface water.

How should the program be structured?

Regardless where the program is housed, it is critical that the program be run by managers that are broadly trusted and respected.

The steering committee approach used by the Wisconsin Discovery Farms program was strongly supported. Respondents liked that it was heavily dominated by producer groups and that it determined the overall direction of the program. Program managers answer to the steering committee.

While many viewed the University of Minnesota or UMN Extension as the preferred home for this program, there was also significant distrust of University policy among some producer group leaders. For this reason, the MNSCU system may be a more palatable home. The MDA was also suggested as the preferred administrator. Another suggestion was for the University to do the monitoring and analysis, but to assign outreach activities to another entity.

People repeatedly mentioned the importance of taking advantage of existing institutions, especially the University Research and Outreach Centers. Other county and regional institutions were also mentioned.

PART II: RECOMMENDATIONS

The recommendations in Part II are made by the authors of the report and reflect an evaluation of stakeholder comments and assessment of existing programs in Wisconsin, Minnesota and other states. Based on stakeholder support, Minnesota partners should pursue an on-farm water quality program modeled after Wisconsin's Discovery Farms program.

II.A. Mission and Objectives

For this project to be successful, a clear mission must be defined. Upland water quality monitoring is expensive and can take many forms. Monitoring design decisions made at the beginning of the project will restrict what information and outcomes are possible, and so must be thoughtfully matched to the mission.

Based on stakeholder comments, the following components should be considered as part of the mission statement.

- Generate farm-scale water quality information.
- Provide an opportunity for producers to impact monitoring priorities and to learn from each other how to address water quality issues.
- Examine economic and environmental impacts of agricultural management alternatives and of regulatory alternatives.
- Address the range of farm types and landscape types in Minnesota.
- Improve communication among the agricultural community, consumers, researchers, and policy-makers to better identify and implement effective environmental management decisions that are compatible with profitable agriculture. (quoted from the Wisconsin Discovery Farms mission statement)

The primary objective for monitoring should be to generate "baseline" field- and farm-scale runoff data – data of high enough quality to provide an empirical understanding of the range of flow and constituent concentrations in farmland runoff. TMDL studies and other watershed-based projects need realistic estimates of loading from various types of agricultural systems, but commonly get loading estimates from models based on data measured at scales much smaller or larger than a field or farm.

In addition to baseline data, the monitoring program should aim to contribute to our understanding of the farm- and watershed-scale effects of specific agricultural practices and the effectiveness of BMPs.

Given the current importance of the impaired waters/TMDL framework in addressing water quality issues, this monitoring program should serve the needs of the impaired waters process, without being constrained by it. The program should be designed to help determine what is actually coming off the land, improve estimates of load allocations, and more effectively fix any problems that are identified.

The effectiveness of the program can be tracked through evaluations of stakeholder knowledge and attitudes, quantifying available data quality, and noting levels of participation in agricultural water quality events.

II.B. Structure

Name

The Minnesota on-farm water quality program should adopt the "Discovery Farms" name used by the Wisconsin program. The name is used in Wisconsin and North Dakota and is gaining recognition regionally. Its use in Minnesota would help people quickly understand the program and would strengthen recognition of all three programs. "Discovery Farms" means something different in each state, but implies two common features: producer leadership and primary monitoring objectives of supporting outreach and "discovering" issues. As long as the Minnesota program shares those features, using the "Discovery Farms" name would enhance communication.

Direction by a Steering Committee

Like the Wisconsin program, the primary advisory role should be held by a steering committee dominated by representatives of producer group membership. This group should determine major objectives, direction of the program, and budget allocations. In Wisconsin, the steering committee meets at least annually to review progress and decide objectives for the coming year. Between meetings, individual members of the committee are consulted by the program directors. An equally important role of committee members is to communicate program information back to their constituents. In Wisconsin, the committee members mostly represent the membership rather than the leadership of the producer groups and only one of the 13 members is from outside the agriculture community. While retaining the dominance of the producer groups, Minnesota should consider adding seats for representatives of conservation (e.g. environmental, wildlife, and watershed groups), research (e.g. UMN ROC and Extension researchers), and state agencies. These non-agricultural members will be critical for communicating program results back to their respective organizations and ensuring wide acceptance of the data. The MDAs Agricultural Fertilizer Research and Education Council is a good example of a producer-led steering committee.

Directors/Administrators

The individuals who administer the day-to-day operations of this program are critical to its success. They must be trusted and respected by the agricultural community as well as other stakeholder groups, and they must be willing to follow the direction of the steering committee. Because of the diversity of audiences to be reached, the program should have more than one director, each with different outreach strengths. Between them, they must have strong relationships with the producer organizations, the research community, agencies, and the environmental community.

The directors must also be in a position to answer primarily to the steering committee. In Wisconsin, this is accomplished by using tenured Extension faculty as program directors.

Administrative Home

The choice of a fiscal and administrative home for this program has several implications. Some considerations in choosing that home are:

- **Fiscal flexibility**. Can the organization easily receive and disperse funds from and to a variety of entities?
- **Fiscal burden**. What are the costs of establishing the program? What are the ongoing costs of maintaining the program and are they justified by the benefits received?
- **Relationship to stakeholders**. How will various stakeholder groups perceive the work of the organization?

- **Relationship to related programs.** Does the organization facilitate networking with other water quality monitoring efforts, researchers, other states' efforts, and potential funders?
- **Outreach capacity.** Related to the previous two items, does the organization have inherent strengths or barriers for communicating results to producers, industry, the general public, researchers, policy makers, local government units, and private organizations.

One option is to follow Wisconsin's example and house the program within the UMN Extension Service and experiment stations. The benefits would be:

- a strong connection to technical expertise at the University of Minnesota, the Research and Outreach Centers (ROCs), and Regional Extension Educators (REE);
- an established outreach network through the ROCs, REEs, and their local connections;
- an established infrastructure that would streamline the process of establishing a program;
- access to regional technical and funding resources through the CSREES structure;

The weaknesses that would have to be addressed are:

- Outreach networks would have to be expanded to reach non-traditional audiences;
- The University extracts a percentage of grant funds to cover overhead charges. On the other hand, the University provides physical and organizational support.
- The program would have to be positioned within a unit that can be trusted by major stakeholders, and must be structured to ensure that producers maintain primary direction over the program direction and especially the outreach component.

The Minnesota Department of Agriculture is another potential administrative home that may address some of the drawbacks of the University, and may have easier access to state funding. However, MDA may not be as well trusted by stakeholders outside of the agriculture community. Another possibility would be to base the program at one of the MNSCU units, such as Minnesota State University, Mankato. A MNSCU home would have to put extra effort into building and maintaining statewide and regional connections. A third alternative would be to use an existing non-profit organization or to create a new organization.

The most effective approach may be to combine multiple institutions. For example, the program could be placed fiscally within UMN Extension, with one of the directors employed by MDA or another non-University entity. Alternatively, the MDA could be the fiscal agent and implement activities through contracts with UMN and other entities. The newly created Minnesota Agricultural Water Resources Coalition could be another important entity in the structure of the program.

Multi-State Collaboration

An on-farm water quality program should be Minnesota-specific, and direction and interpretations should be locally led. At the same time, the program should collaborate with similar programs in other Midwestern states to gain access to additional funding and expertise. Benefits of regional collaboration include:

- Expanding funding opportunities by improving access to regional Extension experiment station funds and federal funds.
- Sharing and comparing relevant data, such as those from southwest Wisconsin and southeast Minnesota.
- Allowing each state to focus on different concerns. For example, North Dakota's focus on medium-sized livestock operations frees Minnesota to emphasize other issues.
- Learning from each others program experiences.

The CSREES Great Lakes Water Quality Program is proposing a five-state Discovery Farms effort that would help support and coordinate efforts across state boundaries. Outcome of the proposal should be determined by mid-summer.

Farmer Cooperators

Good farmer cooperators are a key part of a successful on-farm water quality program. Wisconsin's method of selecting cooperators has been effective and should be used as a model. Public announcements were used to solicit applications. The steering committee narrowed the list of applicants based on predetermined criteria including how well the location and type of operation fits project goals, how well the operator will be able to support outreach efforts, and how well the physical site is suited for monitoring. After site visits to each of the farms, the steering committee prioritized the farms and invited participation.

Relationships with farmers will be strengthened by a contract that clearly states responsibilities and expectations of both the farmer and the program. Important expectations are that the farmer must be willing to make all water quality data public, to cooperate in the process of evaluating data, and to cooperate in presenting the information at field days and other events. The program must provide the farmer cooperators some privacy protection by limiting information collected about the farm operation, specifying ahead of time what information will be needed and how it will be used, and arranging all contact with the farmer through a program liaison rather than directly through the farmer.

The Wisconsin Discovery Farms cooperators signed a contract with the University of Wisconsin that defined the expectations and rights of the University and the farmer. (Contract is in section 6.h. of Attachment B.) The following are some of the issues addressed by the contract.

- Term of contract (up to 7 years) and conditions for early termination.
- Obligations of both parties
    - Work together to evaluate the farm and the data (University retains ultimate approval over scientific methodologies)
    - Cooperate to implement security measures to protect the operation from disease and to protect University equipment and personnel from harm.
    - Provide liability protection.
- University obligations:
    - Pay the cooperator an annual stipend plus expenses
    - Provide equipment and collect data in conformance with project procedures
    - Ensure that monitoring does not result in unreasonable interference with the farm operation
    - University reserves the right to share the data and evaluation, except that it must keep financial information confidential
    - Provide any software, hardware, and assistance needed for record keeping and data entry
- Cooperator obligations:
    - Allow University access to the farm at reasonable times for implementing program activities. The cooperator retains approval over who may access the farm where safety, animal health, or biosecurity are concerns.
    - Provide access to records and information necessary to the program activities including sufficient information to develop partial budgets.
    - Implement best management practices identified cooperatively by the advisory committee and the farmer.
    - Work with the University to host educational and other events on the farm related to the program.

An issue raised repeatedly at the public forums was concern that participation in the program will expose cooperators to regulatory risk. Wisconsin Discovery Farms addressed this concern by working with the Wisconsin DNR (which has regulatory roles similar to the MPCA) to develop a

contract with producers stating in part that "the DNR does not intend to seek monetary penalties through formal enforcement actions against the University or the farmer for violations of state statutes, regulations or permits that the department determines occurred as a result of actions performed in accordance with the terms of the Discovery Farms contract, unless there is significant damage to the environment, as determined by the DNR, such as fish kill or contamination of a public or private water supply or groundwater." (Contract is shown in section 6.h. of Attachment B.) Minnesota should take a similar approach.

Staff

Staffing levels should be adequate to support multiple types of outreach, facilitate advisory group activities, support farmer-cooperators, and to sufficiently analyze and publish monitoring results. Inadequate analysis or outreach would severely reduce the value of expensive monitoring data.

II.C. Outreach

Outreach is critical to the usefulness of an on-farm water quality program, so adequate staff and planning must be dedicated to outreach from the beginning.

Over the past year, Dennis Frame gave more than 70 presentations about Wisconsin Discovery Farms (some of those to audiences in other states). This level of outreach requires willingness to travel and an effective rapport with varied audiences. The Wisconsin farmer-cooperators are also frequent and influential presenters. In fact, one of the criteria for selecting farmer-cooperators is their willingness and ability to speak to groups. Another effective communication route is through steering committee members back to their constituencies. For example, during a critical runoff period, Wisconsin Discovery Farms released a notice based on program data urging farmers not to spread manure. This message was delivered by the steering committee members to their respective groups rather than directly by the Discovery Farms program. Minnesota should consider this outreach role of the group when designing the make-up of the steering committee.

Outreach activities should be designed for several audiences:

- Producers – One of the main goals of the program should be to facilitate mutual learning among farmers.
- General public – Stakeholders often mentioned the need to help the public gain a more accurate and nuanced understanding of the relationship between agriculture and water quality.
- Researchers – Outreach to researchers can help them gain a "reality check" of research results, and to gather input on future research priorities. In turn, researchers can help interpret monitoring data.
- Policy makers – Like the general public, legislators need a regular and reliable source of information about agriculture and water quality issues.
- Agencies – This program can be a source of high-quality, state-specific data to support the work of public employees who make and implement rules and provide technical assistance.
- Local organizations – SWCDs, county water planners, watershed districts, and other local government and non-governmental organizations need locally relevant, on-farm data, and in turn, have local information that can be used by the on-farm monitoring program.

One valuable message this program could deliver to all audiences is the level of variability among farm operations and the variability of risks and benefits of specific practices as implemented on different farms.

II.D. Monitoring and Research Design

Potential purposes, scopes, and design of a monitoring program are described in this section to help planners define needs. Recommendations are summarized on page 32.

Uses for Monitoring Data

A monitoring network designed for one purpose will not necessarily serve another purpose, so it is essential to clarify the uses of the resulting data before designing a monitoring program. The many potential purposes of monitoring generally fit into one of three categories: collecting baseline data, demonstrating land management practices, or evaluating practices.

Collecting baseline data. Monitoring can be established to learn how much and what type of runoff occurs from a particular land use. A "problem" does not need to be identified beforehand. Baseline data can be used for trend analysis, exploratory work to define issues for further study, allocation of pollutant loads to various sources, model validation, studying the fate and transport of water components, or identifying critical areas within a watershed. The scale of monitoring must match the scale of the purpose. In Minnesota, baseline data is commonly collected at the scale of large watersheds to assess and monitor lake and stream water quality. Plot scale data is also available. However, very little farm scale baseline monitoring data has been collected. Farm system-level data could provide information about runoff from common farm operations, and about the relationships between farm-scale runoff and baseline data collected at the plot and watershed scales. It could also document variation within and between seasons.

Demonstrating practices. Monitoring may be associated with demonstration projects aimed at reducing the risk for new adopters by working out the logistics of a practice and promoting implementation. Like baseline data, data from demonstration project monitoring are generally exploratory and help define issues for further study.

Evaluating practices. To quantify the effectiveness and impacts of a land management practice or a conservation program, the practice or program must be compared to an alternative. Thus, this type of monitoring must be set up with a well-controlled research design. Results can be used to generate efficiency factors for models, or to estimate the cost and effectiveness of implementing a practice. Many practices have been evaluated at the plot scale or edge-of-field. Far less information is available at the farm system or watershed scales. Data from research studies at these large scales could be used to evaluate the environmental and economic impacts of implementing practices across a watershed.

Scale and Scope: What to Measure

Each of the three purposes above may be addressed at several scales: (a) a field with homogenous land management, (b) a system, i.e., a group of fields (or other land uses) under a dynamic set of management practices examined as a whole, or (c) a watershed. In addition, each purpose can be examined at several temporal scales: variation over the course of the seasons, variation between years with different weather patterns, or long term average conditions.

An on-farm water quality program can help fill the gap between the plot and watershed scale by focusing on runoff and drainage at the edge of a field or a small group of fields. It can also help link the three scales by nesting one inside of another. For example, data from drainage tiles on Red Top Farms have been compared to data at the outlet of Seven Mile Creek watershed (personal communication, Bill VanRyswyk, MDA). This showed how patterns for nitrogen and phosphorus movement differed between the two scales.

A monitoring program should at a minimum measure flow, nutrients, and sediment. These are relatively easy to measure and most relevant to impaired waters/TMDL issues. Bacteria and

pesticides are important issues that may need to be addressed, but are more expensive and difficult to analyze.

Agronomic and economic measures are equally important as measures of environmental impact. Water quality questions are at the center of this program, but agricultural water quality can only be understood in the context of farm-scale economics and decision-making processes.

Data Quality and Costs

Generally, there is a trade-off between cost of monitoring and the level of certainty in the data – higher precision and accuracy require more labor and/or more expensive equipment than lower precision data. For a given budget, an on-farm monitoring program may be able to maximize information generated by tolerating somewhat lower data certainty and freeing resources to monitor more sites. For example, the Wisconsin Discovery Farms spent about $35,000 to install high-end, fully automated monitoring equipment on three sites on a single farm and $50,000 per year to collect and analyze the data. A system with lower accuracy – perhaps ±50% uncertainty – may have only one-tenth the cost and thus would allow for monitoring on ten times the farms. The Wisconsin Pioneer Farm is analyzing these tradeoffs in detail and should be consulted when designing a Minnesota program.

To ensure data consistency and quality, Wisconsin has contracted with USGS to manage the monitoring sites, sample collection, and data management. Minnesota stakeholders had few comments on this arrangement. USGS staff in Minnesota have expressed a strong interest in collaborating with an on-farm project and should be consulted in planning the monitoring.

Links to Research

Many stakeholders stressed that an on-farm water quality program should not aim to do research – this should be left to the ROCs and other University researchers. The first priority is to monitor full-scale commercial farms under real-world management. "Real-world management" is not compatible with research designs in which a control and treatment system must be maintained for multiple seasons. Still, strong links to research activities are important to the value of an on-farm program. First, an on-farm program is a chance to examine research results in a real application. Second, attention to experimental design will increase the credibility and usefulness of monitoring data by helping determine whether irregularities in monitoring data are flukes or meaningful patterns that are relevant to other sites.

Sidebar 3. Unreplicated Research Methodology References

Crop Science, volume 46, issue 6 (2006) includes several papers from a symposium on unreplicated experiments. In particular, see Roger W. Payne. 2006. "New and traditional methods for the analysis of unreplicated experiments." *Crop Science* 46:2476.
And see article by Doug Johnson who has an office in St. Paul.

Stephen Carpenter has conducted ecological experiments on Wisconsin lakes. E.g., see Carpenter et al. 1995. "Ecosystem experiments." *Science* 269:324;
Carpenter et al. 1998. "Evaluating alternative explanations in ecosystem experiments." *Ecosystems* 1:335.

The BA-CI method is described by:
Stewart-Oaten et al. 1986. "Environmental impact assessment: 'Pseudoreplication' in time?" *Ecology* 67:929.
Stewart-Oaten et al. 1992. "Assessing effects of unreplicated perturbations: No simple solutions." *Ecology* 73:1396.

Stewart-Oaten is responding to this classic article:
Hurlbert. 1984. "Pseudoreplication and the design of ecological field experiments." *Ecological Monographs* 54:187.

Other references:

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Finally, it is possible to conduct research without controlling the farmer's management practices by using statistical methods developed for studying systems such as lakes or large land areas where land treatments cannot be controlled. (See sidebar for literature references.)

A strong relationship between an on-farm water quality program and existing research programs such as the Research and Outreach Centers would be mutually beneficial. A current example is the Southwest Research and Outreach Center's installation of precisely designed and paired drainage basins to test the treatment of drainage water before it enters ditches or streams. At the same time, drainage basins are being built on farms in the South Branch of the Root River watershed in southeast Minnesota. The controlled conditions at SWROC will allow for the quantification of impacts and will help interpret observations at the farm sites. The on-farm sites will examine the practicality and real-life impacts of the basins, will help validate the research site results, and will generate meaningful research topics for SWROC.

Engaging the research community in an on-farm water quality program will help attract additional financial and intellectual resources and will encourage researchers to address the practical issues raised by the monitoring program.

Summary of Monitoring Recommendations

All three purposes (baseline data, demonstrations, and evaluation) can be addressed by a Minnesota water quality program. Initially, the focus should be on systems-level, baseline data to learn about the hydrology of particular farm types. After an observation period, a local committee can decide the value of demonstrating or evaluating the impacts of specific practices, or of nesting plot research within a farm.

At least some of the farm monitoring sites should be located within monitored watersheds to allow comparisons between patterns of farm-scale hydrology and patterns of watershed hydrology.

The monitoring sites should be chosen and analysis methods designed to generate data with relevance beyond the very local situation. A monitoring program should be developed in collaboration with external research efforts to increase the value of both. The initial team designing the monitoring program should include expertise with unreplicated experimental methods.

Monitoring should focus on analytes relevant to the impaired waters/TMDL program – nitrogen, phosphorus, bacteria and sediment. Pesticides and other issues could be considered as funds and interest allow. Both surface water and subsurface drainage may be measured. Monitoring should go beyond water quality to include yield, farm costs, and other measures that help explain the economics and decision-making processes behind land management alternatives.

USGS should be consulted as a potential collaborator to take advantage of their monitoring and data management expertise. Their transparency and quality assurance skills will help ensure the program generates data that is respected by all parties. Ultimately, data quality and usefulness will depend on a well-defined protocol and plan for the whole process from monitoring to data presentation.

Designers of the monitoring program should consult Appendix A: "Designing a Monitoring Program," and "USGS Budget Summary" (Part 12 of the attached "History and Experiences of UW-Discovery Farms"), and should work with Dennis Busch (Wisconsin Pioneer Farm) who is doing a detailed assessment of the same issues for the Discovery Farms Program. Monitoring protocols in the two states should be coordinated enough to allow comparisons.

II.E. Funding and Budgets

Funding Sources

The success of this program depends on pursuing diverse funding sources. In the absence of a single, permanent funding source, the use of diverse sources can provide some long-term security. This approach also can give the steering committee more freedom to define objectives than if they were constrained by the missions of one agency or group. The drawback of multiple funders is the amount of time that has to be spent on fundraising.

At the state level, the 2006 Minnesota Clean Water Legacy Act and LCCMR are appropriate funding sources. At the federal level, e.g., federal earmarks and USDA CSREES grants, funding priorities increasingly lean toward multi-state programs. This is a strong incentive for regional collaboration.

Other potential funding sources are listed in the sidebar. In addition to direct funding, some program costs may be met or reduced through collaborations. For example, data storage and management could be incorporated into existing MPCA, DNR, or USGS database management systems.

Sidebar 4. Potential Funding Sources

- Clean Water Legacy Act
- LCCMR
- Agricultural industry corporations and organizations
- Agricultural producer groups
- Non-governmental organizations, including conservation groups
- USDA Conservation Innovation Grants
- USDA CSREES National Research Initiative Competitive Grants Program
- USGS Cooperative Water Program
- University of Minnesota and UMN Extension
- AFREC (MDA research and education grants)
- Other state funds
- Research grants
- Federal earmarks

Program Costs

The cost estimates in Table 5 are based on the programs in Wisconsin and North Dakota. For the same cost, the program could establish either a few sites with high-precision monitoring (like the Wisconsin program), or many sites with lower-precision. In either case, only a few pilot sites should be established in the first year, with more sites added in subsequent years. It may be easier to start the program at sites with existing monitoring efforts such as those listed in Table 1.

Table 5. Projected Program Costs

	Oct. '08 – Mar. '09	Apr. '09 – Sep. '09	Oct '09 – Sep. '10
Staff	1 FTE to facilitate program development $40,000	2 FTE directors @$90,000, 2 FTE staff @ $60,000 $150,000	2 FTE directors @$90,000, 4 FTE staff @ $60,000 $420,000
Installation	$0	Installation of 2 high-end monitoring sites, or 4 or more lower precision sites $70,000	Installation of 2 high-end monitoring sites, or 4 or more lower precision sites $70,000
Monitoring	$0	Sampling, analysis, and farm survey for 2 high-end monitoring sites, or 4 or more lower precision sites $50,000	Sampling, analysis, and farm survey for 4 high-end monitoring sites, or 8 or more lower precision sites $160,000
Outreach, travel	$10,000	$20,000	$50,000
Office	In-kind	$25,000	$50,000
TOTALS	(six months) $50,000	(six months) $315,000	(one year) $750,000

Program goals must be realistic and matched to the funding available. Wisconsin staff have pointed out that they cannot manage more than the current eight core farms. Each farm requires a lot of ongoing support and regular personal contact. Effective outreach also requires a large time commitment, and the ongoing time needed to secure funding should not be underestimated.

II.F. Next Steps

Stakeholders strongly support the establishment of an on-farm water quality program that is producer-led and addresses the missions described in previous sections. A program should be established as soon as possible to take advantage of the momentum created by the discussions started during this feasibility study.

Minnesota can take advantage of the experience of the Wisconsin Discovery Farms program. They have shared many documents that will be instructive as Minnesota goes through similar steps. Documents include steering committee job description and meeting minutes, mission and vision statements, the contract used with farmer cooperators, work plans, monitoring protocol, methods for data interpretation, and others. A binder of these materials will be submitted with this report.

The immediate need is for one full-time equivalent to procure initial funding, facilitate the establishment of a steering committee and hiring of permanent program directors, and to begin designing a monitoring program. This job should be split among at least two people who together have the needed technical expertise, and have the ability to reach across boundaries within and outside the agricultural community and the University.

Steps for Program Development

Establish steering committee

Who: Temporary facilitator.

Tasks: Propose size of committee and organizations to be represented. When consensus is reached among stakeholders, invite each organization to send their representative to an initial meeting. Elect an executive committee and define committee's duties.

Define mission

Who: Steering committee

Tasks: Write mission statement to guide the program.

Define structure

Who: Steering committee

Tasks:

- Define role of steering committee
- Define make-up and roles of local research/advisory committees (See WI model)
- Indentify and define roles of other players
- Identify potential local liaisons for farms
- Determine formal outreach mechanisms
- Determine relationship to "special projects" or other on-farm research activities.
- Begin building outreach network with agricultural consultants, REE, and others.

Solicit initial funding and collaborators

Who: Temporary facilitator.

Tasks: Identify funding sources and in-kind collaborators. With approval of the steering committee, pursue funding.

Establish a technical workgroup

Who: Temporary facilitator and steering committee.

Tasks: Identify expertise needed to develop the monitoring system. Establish a workgroup composed largely of researchers and agency personnel familiar with developing research and monitoring projects. Define goals of the workgroup. (See Wisconsin model.)

Develop monitoring program

Who: Technical workgroup, with advising and approval from steering committee.

Tasks: Considering both the long and short-term goals of the program, design the overall and individual site monitoring projects including determining number of sites, general characteristics and locations of sites, analytes to be monitored, monitoring equipment, how and when to collect samples, sampling personnel, sampling and storage protocol, data to collect about the farm operation and landscape (see WI model), and planning for the dissemination of information.

Hire program directors

Who: Steering committee and temporary facilitator

Tasks: Determine who will employ the director(s). Work with employer to write and post job description, interview, and select.

Identify physical headquarters

Who: Directors

Tasks: Find and secure office space.

Define and begin to fill staffing needs

Who: Directors and temporary facilitator

Tasks: Write job descriptions and hiring plan.

Establish regulatory protection for cooperators

Who: Facilitators and directors

Tasks: Identify relevant regulations. Work with regulators to prepare contracts between regulators and farmer-cooperators.

Identify monitoring sites

Who: Steering committee and directors

Tasks: Determine procedure for soliciting cooperators and criteria for selecting sites.

Install monitoring

Timeline

The following timeline is targeted at installing the first monitoring equipment in summer of 2009. Time commitments are

- Full-time facilitator
- Steering committee would meet once every 4 to 8 weeks for the first 6 to 12 months.
- Technical workgroup would meet once every 4 to 8 weeks for 3 to 4 months.

Table 6. Timeline for Program Development

	’08 O	N	D	‘09 J	F	M	A	M	J	J	A
Establish steering committee	■	■	■								
Solicit initial funding, collaborators, advisors	■	■	■	■	■	■	■				
Determine monitoring design				■	■	■	■				
Hire directors and determine physical headquarters				■	■	■					
Identify monitoring sites						■	■	■	■		
Begin installing monitoring equipment									■	■	■

Appendix A: Tables

Tables 1, 2, and 3 were developed by Dennis Busch (Director, UW Plattville Pioneer Farm), Adam Birr (Minnesota Department of Agriculture), and Ann Lewandowski (UM Water Resources Center)

Table 1. Comprehensive Water Quality Monitoring Sites (Sites are mapped in Figure 9)

Site **contact** *Ecoregion*	**Scale** (size)	**Issues and Outcomes**	**Capacity for integration into on on-farm water quality monitoring network** *=Fair, **=Good, ***=Excellent Ratings based on advantages and disadvantages described in Table 2.		**Funding**
			Research Capacity	**Outreach Capacity**	
Drainage Network **Mark Dittrich (MDA)** *47. Western Corn Belt Plains* *b. Des Moines Lobe* *c. E. IA and MN Drift Plains* *48. Lake Agassiz Plain* *a. Glacial Lake Agassiz Basin* *51. N. Central Hardwoods* *i. Big Woods*	Field	Purpose is to test and promote new drainage technology including controlled drainage, woodchip bioreactors, and infiltration basins and buffers.	*** + Research design: Two Phases: Phase 1: 3 sets of paired drainage sites Phase 2: Control versus conventional without replication at each site; instead, all sites included in analysis as replicates. Sites currently monitor nitrate-N using grab samples. + Nicollet site is located partially within Seven Mile Creek- a monitored watershed + Mower site is within the S. Branch of Root River. + Newly installed systems, so high confidence in the location of the drainage areas. Potential topics: Pollutant leaching, drainage practices	** + The list of participants is extensive, and could be used to develop a considerable outreach effort. + Multiple sites. + Part of the multi-state Agricultural Drainage Management Coalition.	MN Legislature LCMR (2) Conservation Innovation Grants
Map site #1 **Hicks Farm** **Jeff Strock (UM)** *47. Western Corn Belt* *b. Des Moines Lobe*	Field (37 and 54 ac)	Examine nutrient and pesticide losses associated with controlled drainage systems.	** + Research design: Paired tile drainage system totaling 91 acres. Also, an undrained field and managed prairie. The sites were calibrated in 2006 and 2007. Very well instrumented (CR10x, ISCO, pressure transducer, rain gauge, eight observation wells). Combination grab and storm activated composite and discrete samples. Monitoring pesticides, N, P, soil, crop yield and quality, water table. - The project is located on a producer's farm and is large in scale; therefore, it could be difficult to ask the producer	** + The farm owner/operator, Mr. Hicks, if willing to participate, would be an excellent addition to an outreach program- in the same manner that DF owner/operators participate in the DF outreach program. - Only one location. Other projects offer multiple sites.	Current funding is limited (SWROC & ARS). Potential for research grants.

			to maintain research that is less productive without substantial compensation to make up for lost revenue. Potential topics: Drainage management, simultaneous projects such as greenhouse gas emissions.		
Map site #2 **Huelskamp Creek** **Adam Birr, David Mulla (UM)** *47. Western Corn Belt* *b. Des Moines Lobe*	Sub-watershed (2 watersheds of 2500 ac)	Objective was to accelerate BMP adoption, improve water quality, and evaluate the effect of farmer-selected BMPs on down-stream water quality. No change in water quality was measurable after 2 years of BMP implementation. (BMPs were conservation tillage, CRP filter strips, replacing open inlets with risers or gravel inlets, and miscellaneous nutrient management diagnostic tests.)	*** + Research design: Paired basins. Monitored TSS, DP, TP, Nitrate-N, flow, at watershed outlets. + Monitoring equipment is still available at the watershed outlets (CR10x, ISCO, nitrogen gas bubbler system, and rain gauge). + Good relations with producers due to previous research projects. + Good location for conducting edge-of-field in conjunction with sub-watershed monitoring. + Extensive management data available resulting from one-on-one surveys conducted from 2001 to 2003 crop years. Potential topics: impact of watershed-scale BMP implementation, edge-of-field issues related to manure management, pesticide losses, nutrient management, and tillage.	*** + Good relations with producers due to previous research projects. + Contacted producers in spring of 2008. Much interest in continuing the research including edge-of-field monitoring and addressing additional research priorities.	Previously funded by a USDA-CSREES section 406 grant Not currently funded or monitored.
Map site #3 **Seven Mile Creek** **Brown Nicollet Cottonwood Water Board** *47. Western Corn Belt Plains* *b. Des Moines Lobe* *51. N. Central Hardwoods* *i. Big Woods*	Sub-watershed (20,000 ac)	Purpose is to demonstrate cost-effective modeling techniques and land management practices suitable for other Minnesota River Basin watersheds. Includes the St. Peter wellhead protection area and a county park. TMDL listings for fecal coliform and turbidity.	** -/+ Research design: Potential for paired data? (Need to analyze existing data collected above ditches 13 and 46 to determine if they are acting as pairs. Otherwise, may be possible to conduct paired analysis using above-and-below treatment area design) Nine monitoring sites of varying duration. Two of the sites are one-time biological sites where fish and macroinvertebrates were sampled. The remaining sites are stream chemistry sites. Four of the sites are long-term sites with sampling beginning in two of the sites in 1996, one of the sites in 2000, and the remaining site in 2003. Sampling frequency consists of baseflow and stormflow. Sample frequency is adequate for load calculations from April to September since approximately 2000. Samples are analyzed for	*** + Local interest. + Local technical capacity. + Long history of outreach activities within the watershed. + Accessible (Seven Mile Creek Park).	• MPCA: Water Resource Investigation Grant • Local Funding: Nicollet Environmental Services, Nicollet SWCD • DNR: Environmental Partnerships Program

			transparency, dissolved oxygen, nitrate-nitrogen, pH, total phosphorus, total suspended solids, temperature, turbidity, fecal coliform, and E. coli. Pesticide sampling occurs at the watershed outlet in the park. The park station is equipped with Campbell dataloggers, pressure transducers, rain gauge, and ISCO samplers. Continuous flow information is collected at all four sites. ISCO samplers were used at two of the sites from 2001 to 2003. There are a number of secondary sites located throughout the watershed that have been established for special projects and short-term duration. + Substantial historic data is available. Could be beneficial to continue monitoring if research sites are located within the Seven Mile Creek Watershed. + Includes Red Top Farms and an MDA Drainage Network site. + Substantial land use information including RUSLE2 modeling, ADAPT modeling, FANMAP survey, and LiDAR survey. Potential topics: Restored wetland, field vs. watershed wq trends, direct pipe septic systems, large dairy, ditch and inlet management, groundwater		
Map site #3 **Red Top Farm** **Brian Williams (MDA)** *47. Western Corn Belt Plains* *b. Des Moines Lobe*	Field (25 to 30 ac)	Evaluate long-term field scale tile drainage flow, and nutrient and pesticide losses. Evaluate and promote BMPs. Provide an educational opportunity Use results to validate DRAINMOD and ADAPT models	* - Research design: Three fields with monitored tile systems – not paired or replicated. Monitoring discharge, N, P, and pesticides. Very well instrumented (CR10x, ISCO, pressure transducer, rain gauge). Sampling consists of a combination of baseflow grabs and storm activated composites. + Substantial historic monitoring and field management data is available. Data has been collected since 1998. + Located within Seven Mile Creek - a monitored watershed - Located on producer owned site; therefore, control may be an issue for research projects without compensation. Potential topics: N fertilizer, pesticides, fecal coliform, manure management, and model validation	** + The Red Top farm has been conducting research and outreach for many years. + It is well known in the agricultural community and could, therefore, be an asset to the MWQRFN outreach program. - Only one location. Other projects offer multiple sites.	Current funding for the project is limited. Without the extra-ordinary efforts of MDA staff, current research objectives would not be achieved.

Map site #4 **Hwy 90 site** **Brian Williams (MDA)** *47. Western Corn Belt* *b. Des Moines Lobe*	Sub-Field (6 to 9.5 ac)	*Same as Red Top Farm.*	*** + Research design: Four tile-drained plots (2 treatments, 2 replications) ranging from 6.0 - 9.5 acres in size. Currently comparing discharge, nutrient, and pesticide losses from two fertility strategies (U of M Recommendations with industry N and P (variable rate) application rates). Also evaluating the effect of drainage spacing on hydrology and pesticide and nutrient losses. Very well instrumented (CR10x, ISCO, pressure transducer, rain gauge). Sampling consists of a combination of baseflow grabs and storm activated composites. + The size of the research area is small enough to make it more feasible to compensate owner/operators for conducting research that reduces profitability. Potential topics: Drainage management, N and P fertilizer, pesticides, fecal coliform, manure management, and model validation	* + The site is in its infancy so outreach efforts have been limited thus far but is a primary component of this site. + Multiple partners from industry and research have been brought together to form an advisory group. + Site is located adjacent to Pioneer research plots which offers unique outreach opportunities.	MPCA 319 Funds
Map site #5 **Elm Creek** **Ken Brooks (UM Dept of Forest Resources)** *47. Western Corn Belt* *b. Des Moines Lobe*	Sub-watersheds (700 ac sub watersheds within 270 sq. mile watershed)	Original purpose was to examine the effect of perennials and "third" crops.	Research design: Seven nested monitoring sites. Compared perennial vegetation to corn-soybeans. Surface and tile line monitoring. Monitored sediment, N, P, OM. Potential topics: restored wetland	- Limited outreach activity	LCMR Excel Energy grant to CINRAM
Map site #6 **South Branch Root River** **Donna Rasmussen (Fillmore SWCD)** *52. Driftless Area* *b. Blufflands and*	Watershed (74,330 ac)	Karst topography and springs complicate the hydrology. Goals are to reduce bacteria and sediment loading.	*** + Projects delineating springsheds have begun in this basin. Groundwater flow in karst topography is difficult to determine. + Historic data available: Citizen Monitoring, stage-discharge data, fish and invertebrate surveys conducted, feedlot surveys, crop residue transect surveys, water quality data. + Research design: One sampling site monitored since 1999 at watershed outlet. Flow continuously monitored	*** + Available local capability demonstrated through numerous previous activities such as newsletter, open houses, and presentations.	MPCA Clean Water Partnership Fillmore County Fillmore SWCD Mower SWCD

Coulees *c. Rochester / Paleozoic Plateau Upland*			with grab samples. Sampling is adequate for load calculations beginning with the 2004 data. Autosamplers will be installed for the 2008 monitoring season at the watershed outlet near Forestville State Park. Two sites added in subwatersheds in the western portion of the watershed during the 2007 monitoring season continuously monitoring flow and turbidity and equipped with autosamplers. Need to analyze data to determine if paired basins or above-below treatment research designs can be used. Monitoring sediment, nutrients, bacteria, pesticides (2002), transparency, turbidity, pH, temperature, and dissolved oxygen. + Local technical assistance available. + The SWAT model is currently being applied to the watershed to evaluate nutrient, sediment, and pesticide transport. + Turbidity TMDL studies beginning in spring of 2008 with additional water quality monitoring. Turbidity probes are being installed in additional subwatersheds as part of the study. Potential topics: karst hydrology, impact of watershed-scale BMP implementation.		
Map site #7 **Whitewater River** **Greg Johnson (MPCA), John Nieber (UM Bioproducts & Biosys. Eng.)** *52. Driftless Area* *c. Rochester/ Paleozoic Plateau Upland*	Field (25 and 60 ac watersheds)	Mission was to measure effectiveness of ag BMPs. Learned about karst hydrology.	Research design: Paired watersheds have been calibrated and monitored from 1996 to 2006. Continuous flow monitoring and automatic sampling. Tested TSS, P, and N. Watersheds differ in proportion of surface to groundwater runoff. Potential topics: Karst hydrology impacts on BMP effectiveness.	- Limited outreach activity	MPCA 319 grants

Table 2. Research and Outreach Criteria for Rating Water Quality Monitoring Sites

	Advantages (Indicated with a "+" in Table 1)	**Disadvantages** (Indicated with a "-" in Table 1)
RESEARCH CRITERIA		
Experimental Design (Paired Data)	+ Paired data collection- evaluating BMP effectiveness is possible	
Scale	+ Edge-of-field site is (or can be) nested within watershed monitoring.	- No edge-of-field monitoring
Sample Collection	+ Automated Sampling	- Passive sampling- low precision - Grab sampling- low precision
Discharge Measurement	+ Pre-calibrated structures + Good stage-discharge relationship	- Poor stage-discharge relationship
Historical Data Collection	+ Historical data available.	
Degree of Control	+ If evaluation of BMP's is an option, a degree of control over the site would be beneficial.	- Lack of control over site management
Site Characteristics / location	+ All weather vehicle access possible. + AC power available + Vandal protection. + Single, homogeneous land use + Definable watershed	- Poor access to site - No AC power - No protection - Multiple land uses - Watershed boundaries unclear
Local Technical Support	+ Local technical support is available.	- No local support
Physiographic Region	+ Site located in region where there is little other monitoring	- Site located in region with multiple projects
OUTREACH CRITERIA		
Public Participation / Awareness	+ Program has demonstrated local public participation	- Local participation is limited
Local Outreach Support	+ Local technical support is available.	- No local support
Accessibility	+ Site is accessible for education events	- Poor site accessibility
Historical Data	+ Historic data is available	- No historic data available
Cooperative / Participatory Landowner	+ Land owner is willing participant in education and outreach	- Land owner has limited interest in participating in outreach efforts

Table 3. Surface-Water Monitoring Design Program Components

		Suggested designs for two monitoring objectives	
Components	**Alternatives**	**Baseline**	**Evaluate Practice**
1. Experimental Design			
Paired Data	1. Multiple Plots		
	2. Above-and-Below Watersheds		**X**
	3. Paired Watersheds		**X**
	4. Multiple Watersheds		**X**
Unpaired Data	1. Single Plot		
	2. Single Field	**X**	**X**
	3. Single Watershed		
2. Sample Frequency	1. Time Interval (e.g. 1/month)		
	2. Composite Multiple Events	**X**	
	3. Sample Selected Events	**X**	
	4. Sample All Single Events		**X**
	5. Multiple Discrete Samples per Event		
	6. Continuous		
3. Sample Collection	1. Grab Sample		
	2. Depth Integrated Composite Grab Sample		
	3. Passive (e.g. Flow Splitter)	**X**	
	4. Time/Flow Based Composite		**X**
	5. Time/Flow Based Discrete		
	6. Continuous (in-situ)		
	7. Automated sampler, telemetry, real-time monitoring		
4. Sample Preservation	1. None	**X**	
	2. Refrigerated		**X**
	3. Acidified		
5. Variables Analyzed	Dependant on Objective	**TS**	**TP**
6. Analysis Method	Dependant on Variable		
7. Volume Quantification	1. Collect all Runoff		
	2. Tipping Bucket with Counter		
	3. Passive Flow Splitter		
	4. Flume with Stage Recorder		**X**
	5. Natural Chanel with Staff Gauge		
	6. Natural Chanel with Stage Recorder	**X**	
8. Study Duration	1. Months	**X**	
	2. Years		**X**
	3. Years to Decades		
9. Land Use Monitoring	1. Personal Observations	**X**	**X**
	2. Field Logs	**X**	**X**
	3. Personal Interviews	**X**	**X**
	4. Remote Sensing		
10. Data Management	1. Ad hoc Files		
	2. Spreadsheets / Data base	**X**	**X**
	3. Geographic Information System		

Table 3. Surface-Water Monitoring Design Program Components. (cont.)

Additional considerations for site locations:
- accessibility during runoff events
- AC power
- cooperative landowner
- protection from vandals
- proximity to problem area
- homogenous land use
- definable watershed boundaries
- homogenous soil type

Appendix B: Designing a Monitoring Program

There are several reasons why surface-water quality and quantity are measured. The National Water Quality Handbook (NRCS 2003) lists the following purposes for monitoring:

1. **Analyze Trends** – How does water quality and quantity change over time?
2. **Determine Fate and Transport of Pollutants** – How and where do pollutants move in the environment?
3. **Define Critical Areas** (a.k.a. Reconnaissance Monitoring) – Are areas of the landscape contributing more pollutant load than others?
4. **Assess Compliance** – Does water quality meet standards?
5. **Evaluate Practices** – Do conservation practices improve water quality?
6. **Evaluate Program Effectiveness** – Can water quality programs improve water quality?
7. **Make Wasteload Allocations** – How much pollutant load is produced by specific land use activities within the basin?
8. **Model Calibration and Validation** – Do models accurately predict runoff water quality and quantity?
9. **Conduct research** – Address specific research questions.
10. **Define Water Quality Problem** – Why are water bodies are impaired? What is causing the impairment?

While, the above list of monitoring purposes answers the question of *why* the monitoring program is being undertaken, it is not particularly useful in determining *how* the monitoring program will be designed. The design of the monitoring program (experimental design, sample collection, sample frequency, etc.) is based on the monitoring objective and the acceptable level of uncertainty in the data.

Surface-Water Monitoring Objectives

Perhaps the most important part of a monitoring program is the development of a clear, concise monitoring objective. The objective should clearly articulate what is being monitored, where monitoring will occur, and what are the constraints of the monitoring program. The objective is critical because it will heavily influence the monitoring design components: experimental design, station location, variables monitored, sample collection methods, sampling frequency, sample preservation, sample analysis, method for determining discharge volume, study duration, land use monitoring, and data management.

The following is an example of a monitoring objective:

To determine the effect of conservation tillage in continuous corn rotations on edge-of-field total phosphorus loading to surface-water during snow-melt in southeast Minnesota.

This objective clearly states what is being monitored, where the monitoring is taking place, and when the monitoring occurs. From this objective and a desired level of uncertainty in the data set, the monitoring design can be developed.

Data Uncertainty

The activities undertaken in determining quality and quantity of surface-water runoff, including stage measurement, stage-discharge relationship, sample collection, sample storage/preservation, and sample analysis) introduce uncertainty in the final data that is generated. Within each activity,

such as sample collection, there are several alternatives- each with an associated level of uncertainty. Harmel et al. (2006) address data uncertainty in surface-water monitoring programs and discuss the root mean square error propagation method as a way to estimate the uncertainty of the overall monitoring program.

Monitoring Design Components

Monitoring surface-water quality seems like a simple proposition: determine the volume of water that runs off the land and collect a sample for analysis. However, there are multiple conditions that make what seems to be a simple proposition a logistical challenge. For example, for ephemeral streams, such as waterways, runoff events are short duration and often occur in the evening, on weekends, or are accompanied with dangerous lightening conditions; making it difficult to collect grab samples. Concentration of contaminants varies within a single runoff event; therefore, multiple samples need to be collected to accurately estimate loads. In order to determine discharge volume, depth (stage) of runoff must be recorded throughout the event and the dimensions of the flow channel must be known. Much of the contaminant load can be delivered during snowmelt conditions- freezing temperatures impose many additional challenges to sample collection and discharge measurements (e.g. frozen sample lines, frozen water in flumes, erroneous stage measurements).

While the challenges to surface-water monitoring are substantial, options are available to help overcome these challenges. Automated and passive samplers and stage recorders can be deployed to capture samples and flow data for events that occur during non-business hours and during conditions too dangerous for site visits. Moreover, the automated equipment is capable of collecting multiple samples per event based on time or flow intervals. Challenges related to winter runoff can be overcome with remote power generators or frequent site visits. Table 3 lists major components to consider when designing a surface-water monitoring program (NRCS 2003); and, several alternatives are provided for each component. While this list is not all inclusive, it does include standard equipment options most often utilized for surface-water monitoring.

Alternative sampling and volume quantification strategies can be broken down into three general categories:

1) site visits during events,

(grab samples, depth integrated composites / staff gauge readings)

2) passive monitoring, and

(flow splitters, single-stage samplers / tipping bucket, flow splitter)

3) automated methods.

(flow and time-based composites, discrete sampling, continuous)

While site visits require little expenditure on equipment, they can require significant labor resources. Technicians will need to be on call 24 hours per day 7 days per week and travel to the sites whenever there is potential for a runoff event. Furthermore, in order to collect precise data, they will need to stay on site for the duration on the event to collect samples and record stage.

Passive monitoring techniques can eliminate the need for site visits during events. Flow splitting techniques can produce flow-weighted composite samples as well discharge estimates. In comparison, single-stage samplers sample only the rising limb of the hydrograph and, consequently, may be less accurate at estimating loads. While site visits during events may not be required, passive samplers still must be maintained and prepped before potential runoff events- a

significant use of labor. However, one additional benefit of passive techniques is that they do not require power to operate. This can be an advantage when sites are located in remote locations.

Automated sampling and stage recording equipment can be deployed to collect samples and record stage without site visits during events. Moreover, if telemetry is added, operators can monitor sites remotely to determine if runoff has occurred or samples have been collected. The telemetry option also allows technicians to change sampling interval or turn samplers off and on without having to travel to the site. These capabilities can greatly enhance efficient use of labor resources, but they come at a price- literally. Fully automated sites with telemetry and real-time monitoring require high investments in equipment and labor. They can, however, produce very precise estimates of discharge, concentration, and load in surface-waters.

Ultimately, the design that works best for a specific objective will depend heavily on available labor and funding. High quality data can be collected if labor and/or financial resources are adequate, since one resource can often be substituted for another.

Potential Program Designs

Given the number of alternatives available, monitoring programs can be designed several different ways. For illustration purposes, potential designs for the two specific monitoring objectives listed below are included in Table 3.

Monitoring Objectives:

1. To determine baseline total solids load in surface-water from a field growing organic soybeans; and,

2. To determine the effect of conservation tillage in continuous corn rotations on edge-of-field total phosphorus loading to surface-water during snow-melt in southeast Minnesota.

The recommended monitoring designs detailed in Table 3 differ for the two objectives for two reasons. First, because the evaluation of a practice (objective 2) requires the determination if a treatment is significant, paired data will need to be collected. At the field scale paired data can be collected with any one of the following options: above-and-below watersheds, paired watersheds, and multiple watersheds. If, on the other hand, the objective is to determine baseline annual sediment load in runoff from a specific field, the design is less complicated and paired data is not needed.

Second, the precision required for collecting baseline data is substantially lower than evaluating a practice; therefore, sample collection, volume quantification, and sampling frequency can be more lax. Generally there is a trade-off between cost and precision. That is to say, the higher the level of precision in the data, the more costly the monitoring design. This is true for our example objectives. Single-stage samplers are inexpensive but only collect samples during the rising limb of the hydrograph and, for that reason, are not as precise as the more costly automated sampling equipment at producing load estimates. The cost of installation of a pre-calibrated flume and stage recorder may not be justified for collecting baseline data, but it may be necessary for the evaluation of practices. Also, costs can be reduced by compositing multiple events or sampling only selected events when collecting baseline data; however, precision may be reduced. Using the root mean square error propagation method, the estimated data uncertain for the monitoring designed outlined for objective 1 was ± 50% and ± 10% for objective 2.

Resources for planning a monitoring program

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Attachment

History and Experiences of UW-Discovery Farms

This 3-inch binder and electronic files were provided by Dennis Frame. They include many of the documents created during the establishment of the Wisconsin Discovery Farms, and will be invaluable as Minnesota goes through many of the same steps.