July 1, 2001
LCMR Final Work Program Report

I. PROJECT TITLE: *Improved Agricultural Systems Overlying Sensitive Aquifers in Southwestern Minnesota*

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Total Biennial Project Budget:

$LCMR:	**$200,000**	**$Match: (No match required)**
-$LCMR Amount Spent:	**$200,000**	**$Match Amount Spent: -------**
$LCMR Balance:	**$ -0-**	**$Match Balance: ----------**

A. Legal Citation: ML 1999, Chap. 231, Sec. 16, Subd. 7 (e).

Appropriation Language: $200,000 is from the future resources fund to the commissioner of agriculture for an agreement with the University of Minnesota, Southwest Experiment Station, to provide technical support, research, systems evaluation and advisory teams to protect sensitive alluvial aquifers threatened by nitrate contamination in southwest Minnesota.

B. Status of Match Requirement:

No match required for this appropriation.

II. and III. PROJECT REPORT SUMMARY

Overall Project Outcome and Results

Water supplies from Lincoln Pipestone Rural Water System District's (LPRWSD) are seriously threatened by elevated nitrate levels. This project was highly successful in bringing various state and federal agencies, UM, area farmers and ag professionals together to develop a response strategy. Local county offices secured EQIP and EPA 319 funds for cost share incentives. LCMR funds provided the technical expertise to develop and coordinate nutrient management plans. Over 40% of the cropland within the Verdi well field enrolled in EQIP. Similar efforts are now taking place in the Holland well field. A grant from LPRWSD will continue plan writing and technical support through 2003.

Current nitrogen recommendations were reexamined in these critical recharge areas. Research found that delaying N applications, using anhydrous ammonia, and/or using band application methods all would be preferred management methods. Continuation of this research, made possible by a grant from LPRWSD, will allow three full cropping seasons to revise existing BMPS.

Public drinking water compliance often requires nitrate removal treatment. An alternative approach for shallow water table aquifers may be phytofiltration. Perennial forages, irrigated with the nitrate-rich ground water during the growing season, remove nitrate and thus reduce nitrate concentrations in recharge water. This research found that this remediation approach has potential in areas where ground water can be readily influenced by leaching. This research will also be continued through 2003. Computer simulation output provided valuable insight into the relationships between management, crop types, and nutrient inputs across soil types in both well fields; this data will be very beneficial in future land use management planning efforts.

Project Results Use and Dissemination

Numerous education events were conducted with local producers, dealerships, and water planners. Local media coverage was excellent. "One-on-one" interaction with producers during the nutrient plan writing and implementation was highly effective.

All of these various components will have a number of publications, revised BMPs, and subsequent Extension bulletins developed upon conclusion in 2003.

IV. OUTLINE OF PROJECT RESULTS:

Result 1: Provide technical assistance to farmers within groundwater sensitive regions including the development and evaluation of NRCS approved nutrient management plans (EQIP cost share), a variety of educational activities such as on-farm demonstration plots, and targeted training programs.

LCMR Budget: $ 117,500 Ending Balance: $ 0.00

PLEASE NOTE: Due to the numerous details, particularly in the research components of Results 2-4, that only the highlights of each result will be supplied in *"IV. Outline of Project Results".* Additional details are provided in the attached Appendix.

Highlights of Result One:

- **"Sign Up" goals were exceeded**: The project's original goal was to enroll 33% of the cropland acres within the Verdi Wellhead Protection Area. Nutrient management plans were developed for more than 40% of the acres (see Figure 1) and these plans will be implemented for the 5-year duration as specified by EQIP requirements. Another 10% of the acreage was enrolled into the Conservation Reserve Program (CRP).
- **Response from local producers was excellent**: Due to the excellent response from farmers willing to participate in the program, all available EQIP funds ($235,540) designated for Lincoln County were quickly exhausted.

Much of this success was due to the fact a nutrient management plan writer was available (due to LCMR funds) which in turn made the federal funds readily available for implementation.

- **Numerous educational events for producers, Ag professionals and water resource staff were provided:** Project funding allowed for the facilitation of many excellent educational events including summer workshops for both Verdi and Holland Wellhead Protection Areas; annual workshops with crop retailers; annual winter meetings with farmers, landowners and interested parties; and the distribution of a quarterly newsletter with a mailing distribution of approximately 250 readers.
- **Additional cost share dollars successfully obtained:** Additional cost share funds (approximately $37,500) through an EPA 319 grant (Wellhead Management for the Holland and Edgerton Wellhead Protection Areas) were successfully obtained by the Pipestone County Conservation and Zoning Office. Initial planning steps with 16 farm operations within the Holland Wellhead Protection Area were made. These plans will be written and implemented for the 2002-2003 crop years;
- **Lincoln Pipestone Rural Water System pledges funds to continue efforts through 2003:** Effective July 1, 2002, additional funding ($25,000) will be provided to the Southwest Research and Outreach Center by the Lincoln Pipestone Rural Water System (LPRWS) for the continuation on nutrient management planning in both the Verdi and Holland Wellhead Protection Areas through the 2003 cropping season. LPRWS also gifted the UM and USDA-ARS to continue field research components in Results 2 and 3.
- **The MN Pollution Control Agency teams up with LCMR cooperators to install a ground water monitoring network**: The emphasis on the LCMR project was to focus on improving agricultural practices within the Holland and Verdi Wellhead Protection Areas. Due to funding limitations, it was not possible to construct a groundwater monitoring network. Fortunately the PCA recognized the need for this type of companion project and established a network in the Verdi wellfield which will allow researchers to evaluate the long-term impacts of agricultural practices on groundwater. See Appendix Seven for additional details and a Web site location.

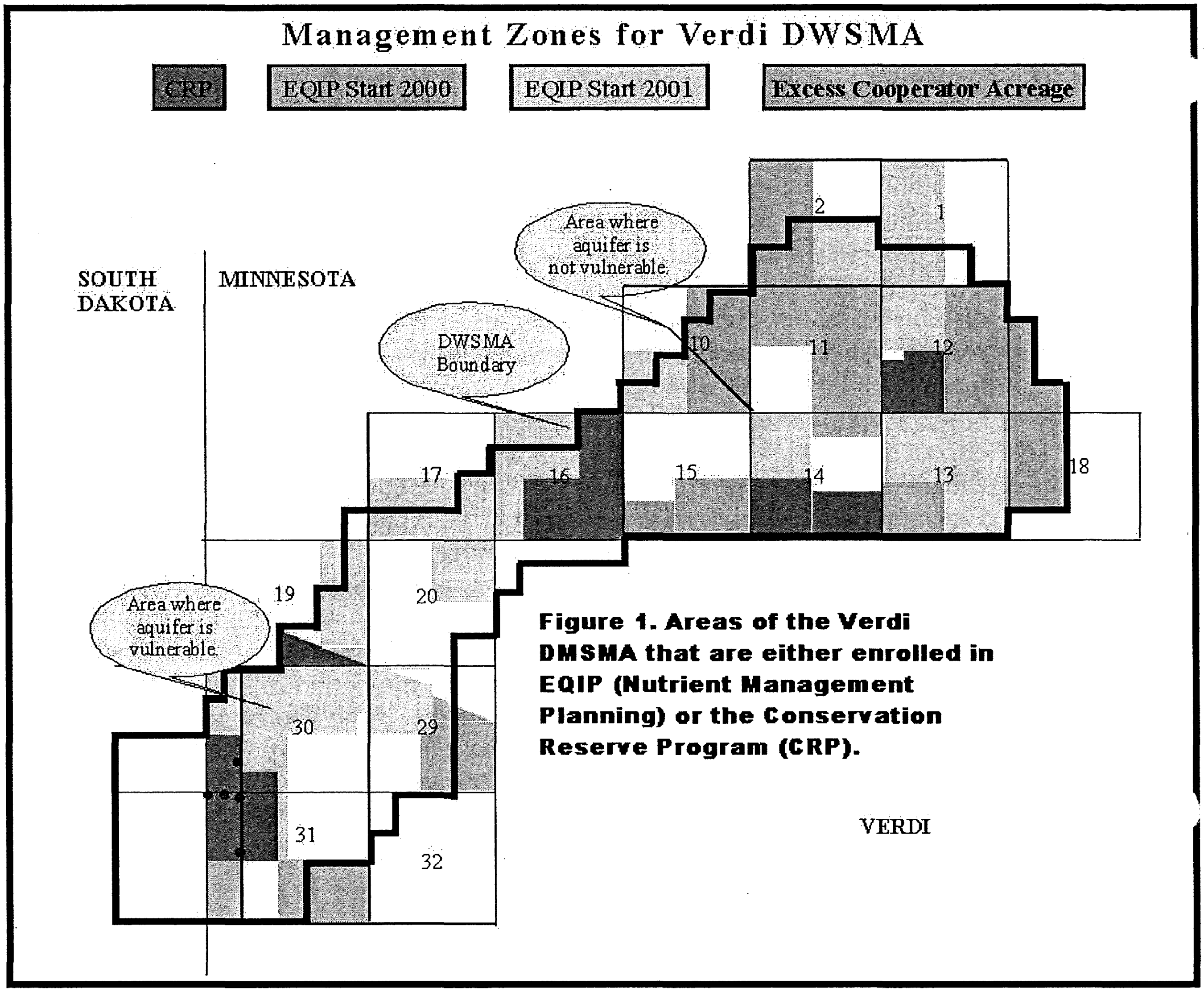

Figure 1. Areas of the Verdi DMSMA that are either enrolled in EQIP (Nutrient Management Planning) or the Conservation Reserve Program (CRP).

Result 2: Conduct research to refine existing Best Management Practices for nitrogen fertilizer and manure management specific for soils, geologic conditions and cropping systems in groundwater sensitive areas.

LCMR Budget: $ 32,500 Estimated Balance: $ 0.00

Highlights:

During the 2000 growing season, field research was done using manure and fertilizer-N at multiple locations. Results at all sites point to some important principles for maximizing agronomic benefits while minimizing economic liabilities. Nitrogen management factors such as time of application, placement, rate, and source of N all played major roles influencing the amount of inorganic soil N during the growing season. These variations in inorganic soil N did not, however, manifest themselves in yield data. This indicates that soil N concentrations for the 2000 growing season on the treated plots were more than sufficient for normal corn growth and development. To prevent application of unneeded N, reducing expense and environmental risk, diagnostic tests during the growing season such as soil sampling for inorganic N and chlorophyll meter readings could be used. These diagnostic tests, along with several others, were used to determine optimum N management practices for sufficient, yet not excessive, N for corn growth and development. Results indicate that delaying N applications, using anhydrous ammonia, and/or using band application methods all would create N situations that maximize N available to plants and minimize N loss potential to the environment.

Effective July 1, 2001, additional funds ($19,250) will be provided by the Lincoln Pipestone Rural Water Board for continuing a portion of research through 2003.

Please see Appendix 2 for a detailed report. An extension publication on the findings of this field research is in progress and will be made available on the web and in hard copy.

Result 3: Determine the effectiveness of "phytofiltration" (filtering contaminated water through plant root systems) of high nitrate ground water by irrigating perennial forages (alfalfa, bromegrass, and orchardgrass) to improve ground water quality.

LCMR Budget: $ 15,000 Est. Balance: $ 0.00

Highlights:

Compliance with the public drinking water standard for nitrate often involves construction and maintenance of a water treatment facility. An alternative approach for shallow water table aquifers may be phytofiltration. Perennial forages, irrigated with the nitrate-rich ground water during the growing season, remove nitrate and thus reduce nitrate concentrations in recharge water. We conducted an experiment at two sites in Minnesota (Pipestone and Sherburne Counties). About 2.5 cm of water was applied 2X weekly during the growing season to 2 or 4 replicates of 3 or 4 species (*Medicago sativa, Bromus inermis, Dactylis glomerata*, and *Glycine max*) at irrigation water concentrations ranging from approx. 15 to 50 mg N/L). Highest yield and N removal were obtained with alfalfa, lowest with smooth bromegrass. Soil solution nitrate concentrations were generally very low under the perennial forages and considerably higher under soybean. Removal of nitrate appears to involve both N uptake and denitrification. This remediation approach has potential in areas where ground water can be readily influenced by leaching. More generally, it appears that perennial forages could be used to remove nitrate from sources such as wastewater or aerobic lagoon water applied through irrigation systems to prevent ground water contamination.

Effective July 1, 2001, additional funds ($15,000) will be provided to USDA-ARS by the Lincoln Pipestone Rural Water Board for continuing this research through 2003.

Please see the Appendix-Result 3 for the detailed report.

Professional Presentation: These findings were presented at the annual joint meeting of the ASA-CSSA-SSSA in Charlotte, NC, October 2001. **Title:** Phytofiltration to remediate high-nitrate ground water: Initial tests of the concept. **Authors:** M.P. Russelle*, D.W. Kelley, M.D. Trojan, E.P. Eid, J.F.S. Lamb, and J.A. Wright. USDA-ARS. Univ. of St. Thomas, Minnesota PCA, and Univ. of Minnesota.

Result 4: Validate existing nitrogen leaching simulation models; predict impacts of improved N management at larger scales (i.e. wellhead recharge area).

LCMR Budget: $ 35,000 Est. Balance: $0.00

A computer simulation model called GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) was used with soil information from the Verdi and Holland Wellhead Protection Areas along with ten years (1989-1998) of local historical weather data. We first calibrated and validated GLEAMS using detailed data from experiments conducted by others at the University of Minnesota Research and Outreach Centers at Morris and Lamberton. We simulated the effects of growing alfalfa, continuous corn at three N rates (100, 130, and 160 lb N/acre), and corn-soybean rotations at one N rate (90 lb N/acre on corn) on all major soils in both WMAs. For the corn-soybean rotation, we ran the simulation with corn in even-numbered years, repeated the simulation with corn in odd-numbered years, and then averaged the results by year over the two crops. Additional details, assumptions and results can be found in the Appendix-Result 4.

GLEAMS predictions supported our hypothesis that nitrate leaching under alfalfa is lower than under annual crops like corn and soybean (Tables 1-4 in the Appendix). The model predicted only rare leaching events under alfalfa, but it predicted high nitrate concentrations in the soil solution. This latter result does not agree with data from Result 3 and many other experiments, which show that soil solution nitrate-N concentrations under alfalfa are typically much lower than 10 ppm. However, the model results confirm that leaching can occur in Minnesota, even under high-producing perennial forage crops. We expect that nitrate leaching losses under native perennial prairie species would be similarly low, although water loss in spring may be higher, since many of these species are warm-season types that do not begin rapid growth until mid-June (e.g., switchgrass, big bluestem, etc.). If water escapes the root zone of perennial forages during spring, it may help improve ground water quality as long as the nitrate concentration of this percolating water is low.

Average predicted corn grain yield increased on some soils with 130 compared to 100 lb N/acre, but little further gain was achieved with 160 lb N/acre. This result also occurred in simulations using a higher yield potential, lending credence to University of Minnesota fertilizer recommendations. The amount of water percolating below the corn root zone did not change with fertilizer N rate, but nitrate concentrations in that water increased rapidly when excessive fertilizer N was applied, leading to very high N losses on some soils. For example, predicted nitrate losses under Kranzburg soils were very small with modest N additions, whereas losses were high under the same conditions on Athelwold, Estelline, Reshaw, and Trosky soils.

Irrigation increased leaching losses, mainly due to increased water percolation during May through August, because of decreased soil water storage capacity when heavy rainfall occurred. In addition, late season irrigation reduces the capacity of soil to store snowmelt and rainfall in spring. Even with the conservative irrigation regime in this simulation, the amount of water percolating below the root zone increased by an average of 30 to 35% on most soils, and nitrate concentration increased to a variable degree.

These results are best visualized in maps of the Holland WMA, which is comprised of several soil types (Figure 2 in Appendix-Result 4), many of which are underlain by a deep sand and gravel deposit that allows percolating water to move quickly into the water table. We applied the model output to each respective soil in the WMA, assuming that a given crop management scenario was being practiced across the entire area. This could be done on a field-by-field basis, but we did not have specific cropping information at that level of detail, nor do we have a GIS layer of field boundaries.

The maps of predicted nitrate leaching loss under different cropping scenarios (Figure 3 in Appendix-Result 4) illustrate the general likelihood that certain soils in the WMA to lose N by this pathway. There is high variability in leaching loss from year to year, which we attempted to capture by using a 10-year weather record. Shallow soils restrict both the amount of water a soil can hold against gravity and the depth of rooting of the crops, resulting in higher probability and amount of nitrate loss. The corn/soybean rotation is the main cropping system used in the area, according to an on-farm survey by the Minnesota Department of Agriculture. Although we did not run simulations with higher N rates in this rotation, one could expect increases in nitrate leaching as was predicted for the continuous corn system with greater fertilizer N.

We estimated the total average annual N loss via leaching by combining the per acre loss and the area of each modeled soil in the Holland WMA (Tables 5 and 6). We modeled losses on soils covering 97% of the WMA. The numbers quickly become quite significant when spread over the 22,213 acres modeled in the Holland WMA. Even when per acre leaching losses were small, total losses were predicted to be over 29,000 lb N if the entire WMA were growing continuous corn under nonirrigated conditions with 100 lb N/acre spring fertilizer applications. Under nonirrigated conditions, total nitrate-N losses under continuous corn tripled as fertilizer N rate increased from 100 to 130 lb N/acre, and doubled again when rate increased to 160 lb/acre. Nitrate losses were similar for a corn/soybean rotation and for continuous corn with modest N rates under dryland conditions, but 40% more nitrate was lost under the corn/soybean rotation than under continuous corn under irrigation. We think this is due to lower water use and lower nitrate uptake by the soybean than by corn, even though more than twice as much fertilizer N is applied in the continuous corn system.

We simulated late fall (October 26) applications of urea fertilizer with immediate incorporation on four soils in the Holland WMA and five soils in the Verdi WMA. Applications of fertilizer N are not recommended before soil temperatures stay below 50 F, because of the risk that fertilizer N will be converted to nitrate and lost before the crop can use it. Averaged over 10 years of weather data, there was no difference in predicted corn yield between late October and late April fertilizer N application times. A slight increase in nitrate leaching (averaging 1 lb N/acre for nonirrigated and 1.4 lb N/acre for irrigated continuous corn) was predicted for fall application compared to spring. This small per acre loss translates into very large amounts of nitrate loss over the entire WMA. As there is rarely a yield benefit, and occasionally a yield loss, due to fall N application, we recommend spring application be used in the WMAs.

It is clear that nonpoint nitrate losses below the root zone of annual crops in the WMA may be contributing to the increasing nitrate concentrations measured in the water table aquifer. It is possible that less diffuse sources (e.g., barnyards with excessive manure deposition, leaky septic systems, surface water affected by tile drainage, etc.) are sources of nitrate as well. This analysis does not include all possible management scenarios, and although results cannot be considered exact, these results should be useful for designing cropping systems to improve and protect future ground water quality in the Holland WMA.

Once we have reviewed all the results and have reviews by other experts, we intend to write technical articles for publication, with appropriate attribution of the funding sources. We are also likely to present this information at scientific meetings, although no abstracts have been written at this time.

V. DISSEMINATION: Short term demonstration plot work and research results will be shared with area farmers and affiliated agency/university staff at the various scheduled field days, potential newsletters, and educational programs listed in "PROJECT RESULTS" section. Additionally portions of the project may be suitable for developing a documentary film for such educational shows as the

Environmental Journal. Near or after project completion, various research components will be presented at state and national professional conferences.

If this type of approach is success, similar programs would be implemented in other wellhead protection areas or areas experiencing elevated nitrate problems.

VI. CONTEXT:

A: Significance: A number of community water supplies in southwest Minnesota, such as the Lincoln-Pipestone Rural Water Supply District, are currently threatened by nitrate contamination. Recent losses of CRP acreage within the recharge areas will intensify existing problems. An interagency technical committee, convened in the fall of 1997, identified several potential ways to reduce nitrogen loading to groundwater. This project will directly deal with many of the major agricultural non-point source issues. Many of the techniques and strategies will be transferable to other source water protection areas throughout the state.

B: Time: Due to the "time lags" involved from the implementation phases to realizing measurable environmental improvements in water quality, it is recommended that a scaled down continuation be considered during the 2001-2003 funding cycle.

C. Budget Context

A. LCMR Budget History:	$ 0
B. Non-LCMR Budget History:	$ 0
C. Total:	$ 0

1. BUDGET

Personnel	$143,860 (72%)
Equipment	$ 6,000 for two computers (3%)
Acquisition	$ 0
Development	$ 0
Other	$ 50,140 (See Attachment A)
Total	$200,000

2. BUDGET-Attachment A

Attachment A Deliverable Products and Related Budget

LCMR Project Biennial Budget

	OBJECTIVES					
Budget Item	Result 1-A Develop nutrient plans; implement demonstrations	Result 1-B "Expert team" formed and evaluations conducted.	Result 2 Refine BMPs thru test plot research.	Result 3 Phytofiltration research on field scale irrigation systems.	Result 4 Validation and prediction of N losses thru simulation models.	
Allocation within Workplan:	$ 100,000	$ 17,500	$ 32,500	$ 15,000	$ 35,000.00	**Subtotals**
Primary Recipient:	**UM-SW Exp. Station**	**UM-Soil, Water and Climate**	**UM-Soil, Water and Climate**	**ARS-USDA**	**ARS-USDA**	
Wages, salaries & benefits	$ 86,360	$ 5,000	$ 18,000	$ 7,500	$ 27,000.00	$ 143,860.00
Space rental, maintenance & utilities						
Printing and Advertising	$ 500					$ 500.00
Communications, telephone, mail, etc.	$ 2,000				$ 1,000.00	$ 3,000.00
Contracts						
Professional/Technic	$ 1,000		$ 7,500			$ 8,500.00
Other contracts						
Local automobile mileage paid	$ 3,500	$ 2,500	$ 1,500	$ 2,000	$ 1,000.00	$ 10,500.00
Other travel expenses in Minnes	$ 1,500	$ 2,000	$ 1,500	$ 1,000	$ 500.00	$ 6,500.00
Travel outside Minnesota						
Office Supplies	$ 1,000				$ 1,000.00	$ 2,000.00
Other Supplies	$ 640	$ 1,000	$ 1,500	$ 2,000	$ 3,000.00	$ 8,140.00
Educational Materials/Supplies		$ 4,000				$ 4,000.00
Tools and equipment	$ 500		$ 2,500	$ 2,500	$ 1,500.00	$ 7,000.00
Office equipment & computers	$ 3,000	$ 3,000				$ 6,000.00
Other Capital equipment						
Other direct operating costs						
Land acquisition						
Land rights acquisition						
Building or other land improvements						
Legal fees						
TOTALS	**$ 100,000**	**$ 17,500**	**$ 32,500**	**$ 15,000**	**$ 35,000.00**	**$ 200,000.00**

VII. COOPERATION:

Cooperator				Affiliation	% Time[1]
Ms.	Pauline	Nickel[2]	Superintendent	U M -Southwest Experiment Station	1%
Dr.	Michael	Russelle[3]	Soil Scientist	Ag Research Service, USDA	5%
Dr.	Mike	Schmitt[4]	Ext Soil Scientist	UM/MES/Soil, Water & Climate	5%
Mr.	Neal	Eash	Soil Scientist	UM -SW Experiment Station	5%
Ms.	Karen	Ostlie	Extension Educator	UM/MES Lincoln Cty Extension Office	1%
Mr.	Robert	Byrnes	Extension Educator	UM/MES Lyon County Extension Office	1%
Mr.	Philip	Berg	Extension Educator	UM/MES Pipestone County Extension Office	5%
Mr.	George	Rehm	Soil Scientist	UM/MES/Dept. of Soil, Water & Climate	1%
Mr.	Don	Evers	Director	Lincoln Pipestone Rural Water Association	5%
Mr.	Russ	Derickson	Advisor	MN Dept. of Agriculture	25%
Mr.	Denton	Bruening	Specialist	MN Dept. of Agriculture	5%
Mr.	Jerry	Purdin	District Conservationist	NRCS-Pipestone Co.	5%
Mr.	John	Biren	Director	Pipestone County Planning and Zoning	5%
Mr.	Dennis	Johnson	District Conservationist	NRCS-Lincoln County	5%
Ms.	Pauline	Moen	District Manager	SWCD-Lincoln County	1%
Mr.	James	Japs	Manager	MN DNR-Waters	1%
Mr.	Bruce	Olsen	Supervisor	MN Dept. of Health	5%
Mr.	David	Wall	Hydrologist	MN PCA/ Water Quality Div.	1%

VIII. LOCATION: Southwest Minnesota including the following counties: Pipestone, Lincoln, Rock, Lyon, Redwood, Murray, Cottonwood, Nobles and Jackson.

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[1] Time estimates of involvement of related cooperators; No project dollars expended.
[2] Pauline Nickel will oversee activities related to Result 1 and will administer $100,000 of project funds.
[3] Michael Russelle will oversee activities related to Result 3 and 4 and will administer $50,000 of project funds.
[4] Mike Schmitt will oversee activities related to Result 2 and will administer $50,000 of project funds.

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- Appendix Two: Result 2
- Appendix Three: Result 3
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- Appendix Seven: Groundwater Monitoring Network

PCA "Ground Water Monitoring in the Verdi Wellhead Protection Area-2000 Annual Report", March, 2001

- Appendix Eight: Related News Releases

Appendix Result 1

Report submitted by Steve Iverson, Nutrient Management Plan Writer for this project, Southwest Research and Outreach Center

Result 1: Provide technical assistance to farmers within groundwater sensitive regions including the development and evaluation of NRCS approved nutrient management plans (EQIP cost share), a variety of educational activities such as on-farm demonstration plots, and targeted training programs.

1. Nutrient management, pest management and crop residue plans were written by the nutrient management specialist and implemented for the second year for 5 Lincoln County farms and 13 Lincoln County farms for the initial yearly plan

2. The management plans for these 18 farms will be written each year for 3 years with requirement for 2 additional years of follow thru of similar management.

3. The initial goal of the grant was to enroll 33% of the cropland located in the wellhead protection area in this program. The 18 farm operations have approximately 40% of the wellhead cropland enrolled in the EQIP program.

4. Two on farm trial plots have been conducted to provide additional information on nitrogen rates.

5. Educational meetings have been held yearly in July at research plot sites near Holland and Verdi. Researchers presented results of their research and tours of the plots were held.

6. Yearly summer meetings with local fertilizer dealers and crop consultants have been presented to provide information on nutrient management needs special to this area. The meeting also allowed U of M personnel to gather insight on local nutrient management ideas.

7. In July of 2000 a U of M expert panel made 5 on-farm visits to give farmer's additional information and give U of M personnel an opportunity to get first hand knowledge of local farm management concerns.

8. Winter meeting have been held the past 2 years to discuss results of U of M research on Nutrient Management with farmers, land owners and others interested in the conservation needs of the area.

9. The project coordinator assisted U of M research personnel with locating plot sites for 2001, finding a manure source for the plots and giving general updates on the plot conditions. This process is beginning for the 2002 crop year.

10. MPCA personnel were assisted in obtaining easements for development of wells for ground water monitoring sites.

11. Local Extension Educators were given assistance in local farm operator meetings.

12. LPRW was given assistance in developing their wellhead protection plan.

13. A newsletter is being published with distribution to local residents, landowners, local government official and various governmental agencies to provide information about the wellhead protection project and conservation efforts in the area. To date 3 issues have been published with a mailing list of 256.

14. Assistance has been provided to the Pipestone County Environmental and Zoning off ice in making the initial contact with farm operators in Pipestone County for cooperators interested in participating in the MPCA 319 funded program. The critical area of the Holland Well field was the targeted area and 16 farm operators have requested funds from the program. The one additional farm operator with significant acreage in the area has expressed interest as well.

15. The project has not reached its potential in Pipestone County. MPCA 319 funds were not released until the 2001 crop season was in progress. Work will begin with the farmer operators for the 2002 to 2003 crop years to help farm operators adopt the proposed improved management plans.

16. Funding has been provided by the Lincoln Pipestone Rural Water System to continue the work started under funding by the LCMR grant. This funding will allow farm management plans to be written as called for by the EQIP and MPCA 319 grants. Plot research and information meeting will continue thru the 2003 crop years.

Appendix-Result 2

Research conducted and reported by Dr. Michael A. Schmitt, Professor of Soil Science, University of Minnesota

Result 2: Conduct research to refine existing Best Management Practices for nitrogen fertilizer and manure management specific for soils, geologic conditions and cropping systems in groundwater sensitive areas.

Abstract

This project examined a number of nitrogen management strategies in the sensitive aquifer region of southwestern Minnesota. Field research found that delaying N applications, using anhydrous ammonia, and/or using band application methods all would be good management methods for providing maximum N to corn while reducing N loss to the environment. Third, an extension publication on the findings of this field research is in progress and will be made available on the web and in hard copy.

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Executive Summary

The objective of this study was to conduct research evaluating existing Best Management Practices for nitrogen fertilizer and manure management specific to the soils, geologic conditions, and cropping systems in the groundwater sensitive areas of southwestern Minnesota.

During the 2000 growing season, field research was done using manure and fertilizer-N at multiple locations. Results at all sites point to some important principles for maximizing agronomic benefits while minimizing economic liabilities. Nitrogen management factors such as time of application, placement, rate, and source of N all played major roles influencing the amount of inorganic soil N during the growing season. These variations in inorganic soil N did not, however, manifest themselves in yield data. This indicates that soil N concentrations for the 2000 growing season on the treated plots were more than sufficient for normal corn growth and development. To prevent application of unneeded N, reducing expense and environmental risk, diagnostic tests during the growing season such as soil sampling for inorganic N and chlorophyll meter readings could be used. These diagnostic tests, along with several others, were used to determine optimum N management practices for sufficient, yet not excessive, N for corn growth and development. Results indicate that delaying N applications, using anhydrous ammonia, and/or using band application methods all would create N situations that maximize N available to plants and minimize N loss potential to the environment.

Objective 2: Conduct research to refine existing Best Management Practices for nitrogen fertilizer and manure management specific for soils, geologic conditions and cropping systems in groundwater sensitive areas.

Introduction

The Lincoln Pipestone Rural Water Supply District (LPRWSD) operates three main wellfields (Holland, Verdi and Burr) which serve 24 communities (10,000 individuals) and 3,000 farms in southwestern Minnesota. Similar to many distribution systems in this area, the Verdi and Holland wellfields are seriously impacted by elevated nitrate levels. Maintaining acceptable water quality is challenging due to thin permeable soils and shallow water tables. Losses of Conservation Reserve Program (CRP) acres over the last several years have created additional complexities. Additionally, recent studies within these areas indicate that 20-50 lb/N/A/Year from nitrogen inputs could be trimmed without yield reductions.

In 1991, the University of Minnesota released a series of nitrogen Best Management Practices (BMPs) that included statewide and region-specific strategies based on climate, soils and cropping rotations. Due to the unique characteristics of this area, existing N BMPs for SW Minnesota need to be refined. Examination of the efficacy of fall fertilization and the proper timing and rate of hog manure could lead to a set of truer Best Management Practices for this region.

Significance

A number of community water supplies in southwest Minnesota, such as the Lincoln-Pipestone Rural Water Supply District, are currently threatened by nitrate contamination. Recent losses of CRP acreage within the recharge areas will intensify existing problems. An interagency technical committee, convened in the fall of 1997, identified several potential ways to reduce nitrogen loading to groundwater. This project directly deals with many of the major agricultural non-point source issues. Many of the techniques and strategies used here could be transferable to other source water protection areas throughout the state.

Background and Hypothesis

In southwest Minnesota, fall application of manure and fertilizer N is considered a BMP and is commonplace. The actual application rates of N are often greater than recommended because of the lack of confidence in organic N mineralization. The combination of these factors creates a high potential for N losses. Because the soils in these sensitive areas are coarse-textured and relatively shallow (to the water table), leaching of N is an important process in need of control. Our hypothesis is that current N management recommendation for the area as a whole may not be applicable to the sensitive areas and that a refinement of fall N management and education regarding N rates are key to reducing the risk of leaching N.

Description of project, priorities, goals and factors:

- Refine and modify Best Management Practices (BMPs) for nitrogen, including both manure and fertilizer N, for cropping systems specific for the unique soils/geology found in this region of the state;

- Develop replicated small plot research plots at 2 to 4 sites; variables will be timing of application (i.e. early fall, late fall and spring) and a series of N rates;

- Evaluate manure management strategies for preventing negative nitrate impacts;

- Estimate manure and fertilizer N use efficiency of various nutrient and crop management systems for crop systems in this area;

- Integrate plot research/demonstrations and subsequent results with efforts in Result 1, 3 and 4 to form a comprehensive educational package.

Procedures

In-field research/demonstration plots were established in the fall of 1999 at three locations in the Lincoln-Pipestone Wellhead Protection Area. The objective of these plots was two-fold. First, the plots would serve as a demonstration tool for educational programming, such as field tours, and also create visible activity for the project in local areas. Second, these plots provide field data that can be used to emphasize the validity of Best Management Practices for the area.

Manure Management Demonstration Site

One plot site was established in the Holland wellfield to demonstrate the effects of manure application time, method, and rate. Two manure application times were used: early October, when soil temperatures are still above 50 degrees, and late October, when soil temperatures are below 50 degrees. Manure was applied either in injection zones placed 8 inches beneath the soil surface on 30-inch spacing or broadcast on the soil surface. In addition to a control plot, manure rates were 2500, 5000, or 7500 gallons per acre of finishing hog manure. This range in rates was intended to be representative of low and high rates, with the optimum rate in the middle. Table 1 lists the nutrient contents of the manure at each application date.

The approximate 2-acre site was located on a loess-derived soil and had been cropped to soybeans in 1999. Soil nutrient properties are listed in Table 1. No tillage was done prior to manure application and no tillage was done until the spring of 2000—after all the treatments were applied. Manure was applied using a research-plot manure application unit that was equipped with a flow meter to regulate application rate. Plots were 50 feet in length and 20 feet in width. Four replications of the 13 treatments were used.

Corn was grown during the 2000 growing season. All production practices, including pest control management, were done in accordance with the landowners' general practices for the area, by the landowner, with their equipment.

Soil samples were collected from each of the plots in early May after corn had been planted and in mid June when the corn was approximately 12 inches tall. Eight cores were collected and composited from the middle of each plot. A systematic sampling scheme was used. Two random areas were selected and four vertical soil cores taken at 7.5-inch intervals on a transect perpendicular to the direction of the plant rows and possible manure application zones. These soil samples were collected from a 24-inch depth, in 12-inch increments in early

May and a 12-inch depth in mid June. All soil samples were then dried, ground, and analyzed for nitrate nitrogen.

Chlorophyll measurements were taken in mid July to quantify the greenness of the corn plants at this time. These measurements were collected using a hand-held chlorophyll SPAD meter which measured light reflectance of the corn tissue. Readings were collected from the middle of the leaves next to the midrib from the uppermost fully developed leaf. Twenty plants were sampled in each plot. Grain yields were taken at physiological maturity by harvesting the center two rows, which were end-trimmed to a 40-ft length, with a small plot combine. Seed moisture content was also determined and yields were then expressed on a dry matter basis.

After harvest, corn stalks were tested for nitrate content. The amount of nitrate in the base area of corn stalks is a way to tell if excess nitrogen was available to the corn. Corn plants store excess nitrate in the stalk before it is translocated to the leaves and grain. A low stalk nitrate value does not necessarily mean that the corn was nitrogen deficient, but a high nitrate value does indicate sufficient, and in most cases, excessive amounts of N for normal corn growth and yield.

Nitrogen Fertilizer Management Sites

Two plot sites were established to demonstrate the effects of nitrogen fertilizer application time, source, and rate—one in the Holland wellfield and one in the Verdi wellfield. Three N fertilizer application times were used: early October, when soil temperatures are still above 50 degrees, late October, when soil temperatures are below 50 degrees, and mid April, before planting. Nitrogen sources were either anhydrous ammonia, applied in injection zones placed 8 inches beneath the soil surface on 30-inch spacing, or urea, broadcast on the soil surface. In addition to a control plot, N fertilizer rates were 60, 90, 120, and 150 lb N/acre. This range in rates was intended to bracket the predicted optimum rate with insufficient and excessive rates.

Both 2+-acre sites were located on a loess-derived soil and had been cropped to soybeans in 1999. Soil nutrient properties are listed in Table 1. No tillage was done prior to manure application and no tillage was done until the spring of 2000—after all the treatments were applied. Fertilizer application was made using a plot-sized tractor, and for the urea treatments a pneumatic, three-point hitch fertilizer spreader, and for the anhydrous ammonia treatments a 7.5 ft tool bar with a 200 lb self-contained ammonia tank. Plots were 30 feet in length and 10 feet in width. Four replications of the 25 treatments were used.

Corn was grown during the 2000 growing season. All production practices, including pest control management, were done in accordance with the landowners' general practices for the area, by the landowner, with their equipment.

Soil samples were collected from each of the plots in mid June when the corn was approximately 12 inches tall. Eight cores were collected and composited from the middle of each plot. A systematic sampling scheme was used. Two random areas were selected and four vertical soil cores taken at 7.5-inch intervals on a transect perpendicular to the direction of the plant rows and possible fertilizer application zones. These soil samples were collected from a 12-inch depth. All soil samples were then dried, ground and analyzed for nitrate- and ammonium-N.

Chlorophyll measurements were taken in mid July to quantify the greenness of the corn plants at this time. These measurements were collected using a hand-held chlorophyll SPAD meter which measured light reflectance of the corn tissue. Readings were collected from the middle of the leaves next to the midrib from the uppermost fully developed leaf. Twenty plants were sampled in each plot. Grain yields were taken at physiological maturity by harvesting the center two rows, which were end-trimmed to a 40-ft length, with a small plot combine. Seed moisture content was also determined and yields were then expressed on a dry matter basis.

After harvest, corn stalks were tested for nitrate content. The amount of nitrate in the base area of corn stalks is a way to tell if excess nitrogen was available to the corn. Corn plants store excess nitrate in the stalk before it is translocated to the leaves and grain. A low stalk nitrate value does not necessarily mean that the corn was nitrogen deficient, but a high nitrate value does indicate sufficient, and in most cases, excessive amounts of N for normal corn growth and yield.

Results and Discussion

The climatic conditions in the fall of 1999, as well as in the spring and early summer of 2000, were atypical for southwest Minnesota. Fall conditions were dry and very warm, and the soil did not freeze until the third week of December, approximately one month later than normal. Spring weather allowed for very early planting in April that was followed by extremely cold, windy, and rainy conditions through mid June. After the corn emerged, hail, frost, and high winds all stressed the plants at various times. Growing season heat units and precipitation were near normal for all sites. A late season dry spell combined with very high temperatures caused the corn to quickly "shut down" and mature approximately two weeks early.

Manure Management Demonstration Site

Grain yields from this site are listed in Table 2. Mean yields ranged from 104 bu/acre for the control treatment (no manure/N) to 155 bu/acre for the 7500 GPA broadcast and 2500 GPA injected treatments. There was no significant relationship between yield with the two methods of manure application or the two date of manure application—yields averaged 152 bu/acre regardless of these treatment factors (Table 3). There was an effect of manure application rate; however, the effect was only between the control and the lowest application rate as all three manure rates yielded the same. Thus, the amount of N supplied in the 2500 GPA manure rate supplied adequate available such that N was not a limiting factor with all greater rates. There were no interactions between the treatment factors.

Whereas grain yield can provide an indicator of available N when N is below the sufficiency level, soil inorganic N concentrations can provide a more absolute indicator of treatment factors. Soil nitrate-N measured in early May represents the net amount of N released from the manure (and soil organic matter) from the time of application.

Soil nitrate-N concentrations in the top 12 inches of soil in May are listed in Table 4. The control plot had 8.4 ppm nitrate-N. Because no manure was applied to this plot, the nitrate-N present was either carryover from the previous year or nitrate released from organic matter. All other treatments, compared to the control, can provide the net effect of manure N release by subtracting control plot value from the manure treatment's value. Application date had a significant effect on soil nitrate-N (Pr.>F=0.0212, see Table 5), with the earlier application date providing more (27.2 vs. 24.2 ppm) nitrate-N. This would be plausible because the earlier application had a longer period of time to decompose in the soil compared to the later application. The relationship between soil nitrate-N and method of application was highly significant (Pr.>F=0.0001, see Table 5). Injected manure applications averaged 33.2 ppm nitrate-N compared to only 18.3 ppm nitrate-N for broadcast applications. Soil nitrate-N concentrations were correlated to manure application rate (Pr.>F=0.0001, Table 5), although this relationship was not linear. The initial 2500 GPA increment increased nitrate-N by 15.2 ppm whereas the second and third increment increased nitrate-N by 15.8 and 21.9 ppm, respectively.

Soil nitrate-N measurements in the top 24 inches in early May provides an indication of possible nitrate-N leaching occurring, as significant increases in nitrate-N in the second foot combined with the top foot would indicate N movement. Data shown in Table 6 do not provide any evidence of nitrate N movement as the concentrations reflect normal background levels in the second foot combined with the treatment effects in the top foot. Therefore, the effects of the treatment factors are the same as with the top foot's data in Table 4. The dry 1999 fall conditions allowed the spring rains to absorb into the soils with minimal nitrate-N movement.

Soil nitrate-N measurements collected in mid June represent the peak nitrate-N release activity in the soil. After this time, the corn plant starts to uptake N from the soil, generally at a rate greater than the release of N from manure/organic matter. There is no significant difference between application date data (19.0 vs. 18.7 ppm) at this time (Table 7 and Table 8). There still is greater nitrate-N from the injected treatments (21.1 ppm) compared to the broadcast treatments (16.6 ppm), although these differences are less than from the comparable treatment comparisons in early May. The amount of soil nitrates in the 0-12 inch layer in June was less than in May (Table 9). This loss of nitrate over the month time period was most evident with the injected manure in comparison to the broadcast applied. The manure rate effect is still reflected in the in-season nitrate-N measurements. Soil nitrate-N measured at this time from the top foot of soil has been shown to be indicative of grain yield sufficiency/ response in numerous Iowa studies. These Iowa researchers have concluded that if there is approximately 15 ppm nitrate-N in the soil, there will be sufficient N for maximum grain yield response. Our data indicates that, except for the control treatment, nitrate-N concentrations were near or above this 15 ppm threshold. Therefore, the similarity of grain yields measured is not surprising (Table 2).

Similar to grain yield, chlorophyll meter readings in July are also an indicator of plant N sufficiency. Chlorophyll readings were similar (62.0) for all manure treatments (Table 10), with no statistical relationship to any variable (Table 3). Note, however, that the readings were less for the control plot, which also had significantly lower yields.

Measuring the concentration of nitrate in the basal corn stalk is a way to see if adequate N was present for growth, and if that N was excessive. Stalk nitrates on plots applied with manure were much higher than the control, 1992 ppm vs. 119 ppm (Table 11). Basal stalk nitrates were highly related to method of application (Pr.>F=0.0001, Table 3). The stalk nitrates were higher on the injected manure plots in comparison to the broadcast plots, and higher for early application in comparison to late application. These results indicate that more than enough N for normal corn growth and development was present in the soils treated with manure, but that the soils that were injected with manure provided the most N to the corn plant. This agrees with soil nitrate values, where injected soils had higher soil nitrate values than those soils with manure broadcast applied.

Nitrogen Fertilizer Management Sites

Grain yield for the individual sites are listed in Tables 12 and 13. Yields averaged approximately 130 bu/acre at the Holland site while the yields averaged only 85 bu/acre at the Verdi sites. A combination of late planting and the early maturing of the grain contributed to this lower yield. At neither of the sites was there a significant effect on yield from time of fertilizer application (Tables 14 and 15)—the variation in treatment means is from natural variability among the blocks of replicates at each site rather than due to the treatments. Although University of Minnesota Best Management Practices for fertilizer N applications would not recommend fertilizer N applications in early October, the lack of a yield effect this year is not surprising since the lack of fall precipitation greatly reduced the potential for N losses when the spring moisture did arrive.

There was also no significant difference in grain yield due to the effect of N source in our data sets (Tables 12 and 13). University of Minnesota Best Management Practices would recommend either source of N in this area. Again, most likely due to the lack of N loss potential at the sites, no yield differences were realized.

The rate of N application did not have a highly significant effect on grain yield at either of our sites in 2000 (Pr.>F=0.0073, Table 14)(Tables 12 and 13). The yield fluctuations between N rates at both of the sites indicate that there was a great deal of variation between the blocks of treatments. Even with the relatively lower yields at the Verdi site (Table 13), the lack of any response to N rate is surprising. Evaluation of soil N concentrations may be able to explain this.

Soil nitrate-N concentrations in the top 12 inches of soil for the fertilizer management studies are listed in Tables 16 and 17. Soil nitrate-N measurements collected in mid June represent the peak nitrate-N release activity in the soil. After this time the corn plant starts to significantly uptake N from the soil, generally at a rate greater than the release of N from manure/organic matter.

The control plots had 13.2 and 7.0 ppm nitrate-N at Holland and Verdi, respectively. Because no fertilizer was applied to these plots, the nitrate-N present was either from carryover nitrate-N from the previous year or from nitrate released from organic matter. All other treatments, compared to the control, can provide the net effect of fertilizer N release by subtracting control plot value from the fertilizer treatments' value.

At both sites, there was a significant effect of fertilizer N application time on soil nitrate concentrations (Pr.>F=0.0001 for both sites, Tables 18 and 19). At the Holland site, soil nitrate-N averaged 15.8, 18.5, and 28.8 ppm for early October, late October, and April application dates, respectively (Table 16). At the Verdi site, soil nitrate-N averaged 12.5, 13.7, and 28.5 ppm for early October, late October, and April application dates, respectively (Table 17). Note that the difference between the two fall application dates was more pronounced at the Holland site than at the Verdi site. The increase in soil nitrate-N with later application dates is consistent with soil fertility literature—the fall N treatments have probably been subjected to many more N movement and/or loss opportunities, which may or may not have a direct effect on yield.

The source of N was significant on soil nitrate-N at both sites (Pr.>F=0.0001 for both sites, Tables 18 and 19) (Tables 16 and 17). There was a consistent 25-50% increase in nitrate-N concentrations with anhydrous ammonia compared to urea. Overall nitrate-N concentrations at the Holland site were 23.7 and 18.4 ppm nitrate-N for the anhydrous and urea treatments, respectively, and were 21.8 and 14.6 ppm nitrate-N at the Verdi site for the anhydrous and urea treatments, respectively. Anhydrous ammonia, due to its inherent chemical properties and its banded application method, would naturally slow the nitrification process more than urea. Therefore, anhydrous ammonia provides greater amounts of nitrate-N in the top foot of soil in mid June.

Soil nitrate-N measured at this time from the top foot of soil has been shown to indicate grain yield sufficiency/response in numerous Iowa studies. These Iowa researchers concluded that if there is approximately 15 ppm nitrate-N in the soil, there will be sufficient N for maximum grain yield response. It appears that almost all of the treatments at the Holland site and the majority of treatments at the Verdi site were near or above this threshold. This supports the finding that the grain yields were all similar despite different treatment variables.

Ammonium-N measurements are useful in fertilizer N experiments because they indicate an additional source of plant available nutrients in the soil. When subtracting the control plot's value from any treatment value, the difference is the amount of inorganic N from the additional fertilizer. For both sites, only the treatments with spring applications of fertilizer still had additional ammonium-N available for conversion to nitrate-N (Tables 20 and 21). All fall N treatments—either early or late applications—had undergone full conversion to nitrate N by mid June.

Soil ammonium-N was most significantly related to nitrogen source (Pr.>F=0.0001 for both sites, Tables 18 and 19). Anhydrous ammonia treatments resulted in greater ammonium-N than did urea treatments, especially with increasing N rates and with spring application (Tables 20 and 21). Due to the chemical characteristics of anhydrous ammonia and its application via banding, ammonium conversion to nitrate is naturally slowed. Overall, this is a positive result as ammonium-N is available for plant uptake but is not susceptible to other N loss processes. Although the ammonium-N concentrations were not indicative of yield responses in this study (Tables 12 and 13), management practices that prolong and/or preserve ammonium-N concentrations will have positive agronomic and environmental potential to crop producers.

Similar to grain yield, July chlorophyll meter readings are also an indicator of plant N sufficiency. Chlorophyll readings were similar for all fertilizer treatments (Tables 22 and 23) and were not significantly related to any treatment factor (Tables 14 and 15). Note, however, that chlorophyll readings were significantly different between the two locations. Because factors such as corn hybrid selection, crop growth stage, moisture stress, etc. all affect corn leaf greenness, the differences between sites is not alarming. The significant decrease in chlorophyll readings for the control plot at Verdi (Table 23) was associated with proportional yield decreases (Table 13).

Measuring the concentration of nitrate in the basal corn stalk is a way to see if adequate N was present for growth, and if that N was excessive. Stalk nitrates on plots applied with fertilizer N were higher than the control, 1607 ppm vs. 901 ppm (Tables 24 and 25). Basal stalk nitrates were significantly related to source of fertilizer-N (Pr.>F=0.0001 for both sites, Tables 14 and 15) and time of application (Pr.>F=0.0005 at Holland site, Pr.>F=0.0001 at Verdi site, Tables 14 and 15). The stalk nitrates were higher on the anhydrous ammonia treatments in comparison to the urea treatments, and higher for spring application in comparison to either fall application times. These results indicate that more than enough N for normal corn growth and development was present in the soils treated with fertilizer N, but that the soils that were treated with anhydrous ammonia provided the most N to the corn plant. This makes sense considering that the soils with anhydrous ammonia had higher soil nitrate values than those soils treated with urea. A higher basal stalk nitrate value with spring application also makes sense, since fewer nitrates are lost between application and planting with spring application.

Conclusions

Results from both studies at all sites illustrate some important principles and examples of how crop and livestock producers should be managing their N programs to maximize agronomic benefits while minimizing economic liabilities. Nitrogen management factors (application timing, placement, rate, and source) all played major roles in influencing the amount of inorganic soil N during the growing season. All soil fertility principles regarding these factors were easily justified with soil N measurements. Thus, from this data, conclusions could be reached that would indicate that delaying N applications, using anhydrous ammonia, and/or using band application methods all would create N situations that maximize N available to the plant and minimize N loss potential to the environment.

Soil inorganic N does not necessarily translate to grain yield responsiveness. If N concentrations are less than sufficient, N management scenarios that effect amount of N in the soil will presumably result in yield differences. However, if soil N concentrations are greater than sufficiency thresholds, the effects of N management practices will not be expressed via yield. This is the situation, for the most part, that occurred with the 2000 corn-growing season. The treatments provided a wide range of soil N differences, but due to minimal N losses and normal to low yields, expression of N management was not very evident in yield responses. Determining when yield responds to additional N is therefore very important based on the results of this study so far. What rates of applied N provide sufficient N for optimum yield? Based on the data we have analyzed, it is clear that N diagnostic tests such as soil sampling and analysis for inorganic N (especially during the growing season), as well as chlorophyll meter readings, can contribute to an economically and environmentally sound N management program.

Recognizing N principles associated with N management practices along with N diagnostic practices can be an excellent comprehensive management tool. This strategy would work for the crop producer using commercial N fertilizers or the livestock producers including animal manures in their nutrient programs. Limiting the potential for N loss and quantifying the sufficiency of soil N for optimum grain yield is a workable strategy for corn production in an environmentally sensitive area.

Table 1. Soil chemical/nutrient properties for sites in both wellfields and the manure nutrient characteristics for the manure management study.

Soil Analysis

Location	**pH**	**Bray P1**	**K**	**NO_3-N (0-2 ft)**
		-------------------ppm-------------------		
Holland	6	44	5.3	189
Verdi	6	8	3.9	140

Manure Analysis

Application Date	**Dry Matter**	**N**	**P_2O_5**	**K_2O**	**S**
	------%------	------------------lbs/1000 gal.---------------			
10/05/99	4	51	18	38	3
10/26/99	3	39	10	25	2

Table 2. The effect of manure application method, date, and rate on corn grain yield, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method	---------------------------------bu/acre------------------------------				
Injection	104.2	153.1	149.7	150.0	150.9
Broadcast		146.7	152.9	152.6	150.7
Application Timing					
Early Application		149.1	150.6	153.1	150.9
Late Application		150.6	152.1	149.6	150.8
Method x Timing					
Early--Injection		155.2	148.7	150.9	151.6
Early--Broadcast		143.1	152.5	155.3	150.3
Late--Injection		151.0	150.8	149.2	150.3
Late--Broadcast		150.3	153.4	150.0	151.2
Average		149.9	151.3	151.3	

Table 3. The statistical significance of measured variables as affected by time, method, and rate of manure application, 2000.

Factor	Grain Yield	Basal Stalk NO_3^-	Chlorophyll
		-Pr.>F-	
Rep	0.0316	0.1713	0.0001
Application Time	0.8910	0.0214	0.8465
Method	0.6905	0.0001	0.4322
Time x Method	0.7738	0.3661	0.9139
Rate	0.9403	0.0039	0.5258
Time x Rate	0.6581	0.5991	0.1470
Method x Rate	0.3572	0.7922	0.2579
Time x Rate x Method	0.6841	0.0433	0.4629

Table 4. The effect of manure application method, date, and rate on soil nitrate at soil depth 0-12 inches in May, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method			ppm		
Injection	8.4	28.7	31.8	39.1	33.2
Broadcast		16.6	16.7	21.5	18.3
Application Timing					
Early Application		24.1	26.0	31.5	27.2
Late Application		21.2	22.5	29.1	24.2
Method x Timing					
Early--Injection		29.7	33.1	42.6	35.1
Early--Broadcast		18.5	18.9	20.4	19.3
Late--Injection		27.7	30.4	35.5	31.2
Late--Broadcast		14.8	14.5	22.6	17.3
Average		22.6	24.2	30.3	

Table 5. The statistical significance of May soil variables as affected by time, method, and rate of manure application, 2000.

	May Soil Variables		
Factor	Soil NO_3^-, 0-12"	Soil NO_3^-, 0-24"	Soil NO_3^-, 12-24"
	---------------Pr.>F	-----------------	
Application Time	0.0212	0.0148	0.3292
Method	0.0001	0.0001	0.0001
Time x Method	0.4245	0.1785	0.1287
Rate	0.0001	0.0001	0.0790
Time x Rate	0.9375	0.5378	0.1244
Method x Rate	0.1949	0.0513	0.0934
Time x Rate x Method	0.1188	0.0839	0.5285

Table 6. The effect of manure application method, date, and rate on soil nitrate at soil depth 0-24 inches, May, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method	----------------	------------------	ppm------------	----------------	----------
Injection	7.6	19.6	21.6	26.3	22.5
Broadcast		12.6	12.9	15.1	13.5
Application Timing					
Early Application		16.6	18.6	21.4	18.9
Late Application		15.6	15.9	20.0	17.1
Method x Timing					
Early--Injection		19.9	23.0	28.5	23.8
Early--Broadcast		13.3	14.2	14.3	13.9
Late--Injection		19.3	20.3	24.0	21.2
Late--Broadcast		11.9	11.5	16.0	13.1
Average		16.1	17.2	20.7	

Table 7. The effect of manure application method, date, and rate on soil nitrate at soil depth 0-12 inches, mid-June, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method	ppm				
Injection	9.1	21.6	18.6	23.2	21.1
Broadcast		15.2	15.6	19.0	16.6
Application Timing					
Early Application		18.7	17.4	20.9	19.0
Late Application		18.1	16.8	21.3	18.7
Method x Timing					
Early--Injection		21.5	18.0	22.8	20.8
Early--Broadcast		15.9	16.8	19.0	17.2
Late--Injection		21.6	19.1	23.5	21.4
Late--Broadcast		14.6	14.5	19.1	16.0
Average		18.4	17.1	21.1	

Table 8. The statistical significance of June soil variables as affected by time, method, and rate of manure application, 2000.

	June Soil Variables	
Factor	Soil NO_3^-, 0-12"	(June NO_3^-, 0-12") - (May NO_3^-, 0-12")
	Pr.>F	
Application Time	0.9174	0.0679
Method	0.0030	0.0001
Time x Method	0.4498	0.1936
Rate	0.0513	0.0214
Time x Rate	0.9444	0.9753
Method x Rate	0.5349	0.0672
Time x Rate x Method	0.8595	0.2834

Table 9. The effect of manure application method, date, and rate on difference in soil nitrate at soil depth 0-12 inches from May to June, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method			ppm		
Injection	0.6	-7.1	-12.8	-15.9	-11.9
Broadcast		-1.4	-1.1	-2.5	-1.7
Application Timing					
Early Application		-5.4	-8.2	-10.6	-8.0
Late Application		-3.2	-5.7	-7.8	-5.5
Method x Timing					
Early--Injection		-8.1	-14.2	-19.8	-14.1
Early--Broadcast		-2.6	-2.1	-1.5	-2.0
Late--Injection		-6.1	-11.3	-12.0	-9.8
Late--Broadcast		-0.2	-0.1	-3.5	-1.3
Average		-3.8	-6.1	-8.2	

Table 10. The effect of manure application method, date, and rate on standardized chlorophyll meter readings, mid-June, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method	standardized chlorophyll meter reading				
Injection	59.7	63.0	61.2	62.1	62.1
Broadcast		61.4	61.9	62.4	61.9
Application Timing					
Early Application		62.8	61.3	62.0	62.1
Late Application		61.5	61.9	62.5	61.9
Method x Timing					
Early--Injection		63.1	60.8	62.2	62.0
Early--Broadcast		62.6	61.7	61.9	62.1
Late--Injection		62.9	61.6	61.9	62.1
Late--Broadcast		60.1	62.1	63.0	61.7
Average		62.2	61.6	62.2	

Table 11. The effect of manure application method, date, and rate on basal stalk nitrate, 2000.

	Manure Application Rate (gal./acre)				
	0	2500	5000	7500	average
Application Method	----------basal stalk NO_3^- (ppm)-----------				
Injection	119.5	2210.3	2676.7	3125.8	2670.9
Broadcast		997.0	1320.5	1622.1	1313.2
Application Timing					
Early Application		1702.5	2313.5	2587.3	2201.1
Late Application		1504.9	1683.7	2160.6	1783.1
Method x Timing					
Early--Injection		2133.2	3028.8	3715.8	2959.3
Early--Broadcast		1271.8	1598.3	1458.7	1442.9
Late--Injection		2287.4	2324.7	2535.7	2382.6
Late--Broadcast		722.3	1042.7	1785.6	1183.5
Average		1603.7	1998.6	2374.0	

Table 12. The effect of N application time, source, and rate on corn grain yield at Holland, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	Average
Application Time	---------------	---------------	---------------	---bu/acre---	---------------	---------------
Early October	127.4	127.4	126.5	121.4	132.8	127.0
Late October		131.1	129.1	138.1	136.1	133.6
April		131.2	134.4	113.0	138.4	129.3
N Source						
Anhydrous Ammonia		132.0	135.3	131.5	135.3	133.5
Urea		127.8	123.7	116.8	136.5	126.2
Source x Time						
Early October--AA		130.6	136.9	121.7	134.7	131.0
Early October--Urea		124.2	116.0	121.1	131.4	123.2
Late October--AA		136.0	137.6	148.8	135.1	139.4
Late October--Urea		126.2	117.8	127.5	137.2	127.1
April--AA		129.4	131.4	124.1	136.0	130.2
April--Urea		133.1	137.4	101.9	140.9	128.3
Average		129.9	129.6	124.2	135.9	

Table 13. The effect of N application time, source, and rate on corn grain yield at Verdi, 2000.

	N Application Rate (lb N/acre)					
Application Time	0	60	90	120	150	Average
	bu/acre					
Early October	80.2	91.1	82.0	80.8	99.2	88.3
Late October		96.5	86.3	85.4	78.2	86.6
April		90.8	88.5	86.9	73.3	84.9
N Source						
Anhydrous Ammonia		96.3	86.5	90.2	87.9	90.2
Urea		89.3	85.1	79.1	80.3	83.5
Source x Time						
Early October--AA		89.0	90.3	92.8	99.5	92.9
Early October--Urea		93.3	75.8	71.8	99.0	85.0
Late October--AA		109.3	83.2	89.4	90.1	93.0
Late October--Urea		83.8	89.3	80.0	69.3	80.6
April--AA		90.7	86.0	88.3	74.2	84.8
April--Urea		90.9	90.3	85.5	72.7	84.9
Average		92.8	85.8	84.6	84.0	

Table 14. The statistical significance of measured variables as affected by time, source, and rate of fertilizer-N application, Holland 2000.

Factor	Grain Yield	Basal Stalk NO_3^-	Chlorophyll
	Pr.>F		
Application Time	0.1540	0.0005	0.1459
Source	0.1607	0.0001	0.0592
Time x Source	0.0300	0.6615	0.8951
Rate	0.0073	0.0022	0.1626
Time x Rate	0.1124	0.8965	0.0985
Source x Rate	0.3054	0.0001	0.1505
Time x Rate x Source	0.1619	0.5619	0.4423

Table 15. The statistical significance of measured variables as affected by time, source, and rate of fertilizer-N application, Verdi 2000.

Factor	Grain Yield	Basal Stalk NO_3^-	Chlorophyll
	-Pr.>F-		
Application Time	0.0469	0.0001	0.5537
Source	0.4368	0.0001	0.7302
Time x Source	0.0053	0.0899	0.1766
Rate	0.0078	0.0001	0.8874
Time x Rate	0.6431	0.9834	0.1650
Source x Rate	0.1457	0.0084	0.3945
Time x Rate x Source	0.0689	0.6609	0.0288

Table 16. The effect of N application time, source, and rate on soil nitrate at soil depth 0-12 inches in mid-June, Holland, 2000.

	N Application Rate (lb N/acre)					
Application Time	0	60	90	120	150	average
	ppm					
Early October	13.2	12.9	14.9	16.4	19.0	15.8
Late October		13.3	16.9	17.3	26.3	18.5
April		20.6	25.5	31.0	38.2	28.8
N Source						
Anhydrous Ammonia		17.4	21.8	24.7	30.9	23.7
Urea		13.9	16.4	18.4	24.8	18.4
Source x Time						
Early October--AA		13.3	16.4	13.7	17.7	15.2
Early October--Urea		12.6	13.4	19.0	20.4	16.3
Late October--AA		12.4	15.4	17.6	26.9	18.1
Late October--Urea		14.2	18.4	17.1	25.7	18.8
April--AA		26.4	33.7	42.8	48.0	37.7
April--Urea		14.8	17.4	19.1	28.4	19.9
Average		15.6	19.1	21.5	27.8	

Table 17. The effect of N application time, source, and rate on soil nitrate at soil depth 0-12 inches in mid-June, Verdi, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	average
Application Time	ppm					
Early October	7.0	9.8	10.1	13.1	17.1	12.5
Late October		9.9	13.0	13.3	18.5	13.7
April		16.2	25.2	31.7	40.7	28.5
N Source						
Anhydrous Ammonia		13.6	19.9	22.3	31.4	21.8
Urea		10.4	12.3	16.3	19.6	14.6
Source x Time						
Early October--AA		9.7	11.0	14.2	20.1	13.7
Early October--Urea		9.8	9.1	11.6	14.2	11.2
Late October--AA		10.6	14.5	14.4	19.6	14.8
Late October--Urea		9.2	11.5	12.2	17.5	12.6
April--AA		20.4	34.2	38.3	54.5	36.9
April--Urea		12.1	16.2	25.1	27.0	20.1
Average		12.0	16.1	19.3	25.5	

Table 18. The statistical significance of June soil variables as affected by time, source, and rate of fertilizer-N application, Holland 2000.

	June Soil Variables	
Factor	Soil NO_3^-, 0-12"	Soil NH_4, 0-12"
	Pr.>F	
Application Time	0.0001	0.0352
Source	0.0001	0.0001
Time x Source	0.1919	0.0157
Rate	0.0001	0.0001
Time x Rate	0.8570	0.0087
Source x Rate	0.0001	0.0001
Time x Rate x Source	0.4377	0.0137

Table 19. The statistical significance of June soil variables as affected by time, source, and rate of fertilizer-N application, Verdi 2000.

	June Soil Variables	
Factor	Soil NO_3^-, 0-12"	Soil NH_4, 0-12"
	---------Pr.>F-----------	
Rep	0.6551	0.0004
Application Time	0.0001	0.0001
Source	0.0001	0.0001
Time x Source	0.0004	0.0001
Rate	0.0001	0.0001
Time x Rate	0.0511	0.0001
Source x Rate	0.0001	0.0001
Time x Rate x Source	0.3132	0.0001

Table 20. The effect of N application time, source, and rate on soil ammonium at soil depth 0-12 inches in mid-June, Holland, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	Average
Application Time	---ppm---					
Early October	7.15	8.1	8.5	8.5	9.0	8.5
Late October		8.6	7.7	8.2	7.8	8.1
April		9.1	13.7	17.2	17.9	14.5
N Source						
Anhydrous Ammonia		8.5	11.6	14.2	15.3	12.4
Urea		8.6	8.4	8.5	7.9	8.3
Source x Time						
Early October--AA		7.3	7.6	9.4	9.6	8.5
Early October--Urea		8.9	9.5	7.7	8.4	8.6
Late October--AA		8.7	7.0	8.0	7.7	7.9
Late October--Urea		8.5	8.3	8.4	7.9	8.3
April--AA		9.7	20.1	25.1	28.5	20.8
April--Urea		8.6	7.3	9.3	7.4	8.2
Average		8.6	10.0	11.3	11.6	

Table 21. The effect of N application time, source, and rate on soil ammonium at soil depth 0-12 inches in mid-June, Verdi, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	Average
Application Time	-----------------	----------	ppm	----------	----------	-----------------
Early October	4.6	5.1	5.3	6.8	7.0	6.1
Late October		4.6	6.2	5.2	6.4	5.6
April		6.7	16.4	23.1	38.5	21.2
N Source						
Anhydrous Ammonia		6.3	13.4	18.2	29.1	16.7
Urea		4.7	5.2	5.3	5.5	5.2
Source x Time						
Early October--AA		5.5	6.0	8.8	8.6	7.2
Early October--Urea		4.8	4.7	4.9	5.5	5.0
Late October--AA		5.0	7.0	6.1	7.8	6.5
Late October--Urea		4.1	5.3	4.4	4.9	4.7
April--AA		8.4	27.2	39.7	70.8	36.5
April--Urea		5.1	5.6	6.6	6.3	5.9
Average		5.5	9.3	11.7	17.3	

Table 22. The effect of N application time, source, and rate on standardized chlorophyll meter reading, Holland, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	average
Application Time	-----------------------standardized chlorophyll reading-----------------------					
Early October	61.3	63.8	64.3	64.2	64.2	64.1
Late October		64.1	63.3	64.0	65.3	64.2
April		64.8	64.7	64.5	65.0	64.7
N Source						
Anhydrous Ammonia		63.7	64.3	63.8	64.3	64.0
Urea		64.8	64.0	64.9	65.4	64.8
Source x Time						
Early October--AA		62.5	64.0	62.7	63.4	63.1
Early October--Urea		65.2	64.8	66.2	65.1	65.3
Late October--AA		63.9	63.1	63.7	65.2	64.0
Late October--Urea		64.3	63.6	64.4	65.3	64.4
April--AA		64.6	65.8	65.0	64.2	64.9
April--Urea		64.9	63.6	64.0	65.9	64.6
Average		64.2	64.1	64.3	64.8	

Table 23. The effect of N application time, source, and rate on standardized chlorophyll meter reading, Verdi, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	average
Application Time	----------------------standardized chlorophyll reading----------------------					
Early October	45.2	50.2	50.3	50.8	48.7	50.0
Late October		50.1	48.9	51.7	50.9	50.4
April		49.9	50.9	50.0	50.6	50.4
N Source						
Anhydrous Ammonia		50.5	49.7	51.6	49.5	50.3
Urea		49.7	50.4	50.1	50.7	50.2
Source x Time						
Early October--AA		51.7	51.4	50.0	48.2	50.3
Early October--Urea		48.7	49.2	51.6	49.2	49.7
Late October--AA		49.3	48.2	52.4	50.2	50.0
Late October--Urea		50.9	49.7	51.1	51.7	50.9
April--AA		50.4	49.5	52.4	50.0	50.6
April--Urea		49.5	52.4	47.7	51.2	50.2
Average		50.1	50.1	50.9	50.1	

Table 24. The effect of N application time, source, and rate on basal stalk nitrate values, Holland, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	average
Application Time	-----------------------basal stalk NO_3^- (ppm)-----------------------					
Early October	1097.0	1686.9	1678.7	2282.9	2272.2	1980.2
Late October		1343.2	2367.0	2258.3	2534.2	2125.7
April		2162.6	2896.9	3336.2	3294.6	2922.6
N Source						
Anhydrous Ammonia		2057.1	2582.7	2937.8	2861.3	2609.7
Urea		1410.3	2045.6	2313.8	2539.4	2077.3
Source x Time						
Early October--AA		1823.7	1875.4	2057.4	2393.6	2037.5
Early October--Urea		1550.1	1482.0	2508.5	2150.9	1922.9
Late October--AA		1184.4	2408.4	2268.8	2422.0	2070.9
Late October--Urea		1554.9	2325.5	2247.8	2646.5	2193.7
April--AA		3163.2	3464.5	4487.2	3768.3	3720.8
April--Urea		1162.1	2329.3	2185.1	2820.9	2124.3
Average		1736.2	2314.2	2625.8	2700.3	

Table 25. The effect of N application time, source, and rate on basal stalk nitrate values, Verdi, 2000.

	N Application Rate (lb N/acre)					
	0	60	90	120	150	average
Application Time	basal stalk NO_3^- (ppm)					
Early October	901.8	746.8	836.9	2007.2	1602.8	1298.4
Late October		761.8	774.3	1756.4	1694.1	1246.7
April		1499.6	2211.8	2419.5	3001.3	2283.0
N Source						
Anhydrous Ammonia		1266.4	1529.7	2267.3	2340.3	1850.9
Urea		739.0	1018.9	1854.7	1858.5	1367.8
Source x Time						
Early October--AA		945.6	1107.6	2138.3	1903.8	1523.8
Early October--Urea		548.1	566.2	1876.1	1301.7	1073.0
Late October--AA		725.3	797.2	1709.1	1900.3	1282.9
Late October--Urea		798.3	751.4	1803.8	1488.0	1210.4
April--AA		2128.4	2684.4	2954.7	3216.8	2746.1
April--Urea		870.7	1739.2	1884.3	2785.8	1820.0
Average		1002.7	1274.3	2061.0	2099.4	

Appendix-Result 3

Result 3: Determine the effectiveness of "phytofiltration" (filtering contaminated water through plant root systems) of high nitrate ground water by irrigating perennial forages (alfalfa, bromegrass, and orchardgrass) to improve ground water quality.

Report submitted by Drs. Michael Russelle, USDA-ARS, St. Paul, MN, and David Kelley, University of St. Thomas (formerly USDA-ARS), St. Paul, MN

A) Sherburne County – Drip Irrigation System:

This experiment continued on plots established in 1999 at the Sand Plain Irrigation Farm in Sherburne County, MN, to contrast the effectiveness of phytofiltration by perennial and annual crops in the "worst-case scenario" of a coarse-textured (loamy sand) soil. Such soils are prone to large losses of nitrate by leaching, increasing the risk of ground water contamination under these soils.

Suction cup samplers have been used to sample soil solution at the base of the root zone (about 40 inches deep in this soil). We inserted additional suction cup samplers in May 2001 to improve estimates of nitrate concentration in the drainage water. In this experiment, we have used stable tracers for nitrate, which allow us to estimate nitrate uptake by the crops. Both ^{15}N-labeled nitrate, a stable isotope of N, and bromide (Br), a chemical analog of nitrate, were used in 2000 and 2001. Results from the 2000 cropping system suggest that alfalfa and orchardgrass recovered about 55% of the applied nitrate, whereas bromegrass and soybean recovered only 25%. Bromegrass stands have been poorer than desirable throughout this experiment at both sites. Soybean does not begin rapid growth until early June, but irrigation began in May to maximize the amount of N applied during the growing season.

The 2001 growing season is not complete at the time of writing, so we report yield results from the first two forage harvests from Sherburne Co. Only the first harvest has been analyzed for total N at this time; tracer analyses are underway. As was seen in the first two cropping seasons, alfalfa yielded the most forage dry matter (DM), 4500 lb DM/acre at first harvest and 3100 lb DM/acre at the second. Orchardgrass was second most productive, 3000 lb DM/acre at first and 1900 lb DM/acre at the second harvest, and bromegrass was least productive, 2100 and 900 lb DM/acre for the first and second harvest, respectively. Plots did not receive fertilizer N during the experiment, and the grasses had to rely on N applied in irrigation water and N mineralized from soil organic matter. There was no effect of nitrate concentration in the irrigation water on yield, so it is unlikely the grasses would have responded to additional fertilizer N.

The consistency of yield differences among these three cool season forage species over the course of this experiment suggests that alfalfa would be the best choice for a farmer wishing to utilize or sell the forage produced under these conditions. Alfalfa typically has much higher value in the market, making this species the best choice of these three.

First harvest forage contained 3.2% N in alfalfa, 1.7% N in orchardgrass, and 1.9% N in bromegrass. Total N removal from the plots averaged 145 lb N/acre for alfalfa, 50 lb N/acre for orchardgrass, and 40 lb N/acre for bromegrass. This relationship confirms results from 1999 and 2000. As we have not completed the tracer analyses, we cannot evaluate the proportion of N derived from the added nitrate in 2001 at this time.

During the 2000 cropping season, difficulties were experienced in collection of soil solution from the ceramic suction cup samplers. The most reliable samples were obtained in September. All crop species maintained the soil solution below 10 ppm nitrate-N at the bottom of the root zone in the 24.4 ppm treatment, but solution concentrations exceeded the drinking water limit under all species in the 42.7 ppm treatment in September (Figure 1). Both water and N use decline in autumn as annual crops mature and as growth of winterhardy perennial crops slows. This implies that the potential for phytofiltration will be limited during the last weeks of the growing season.

Results from the first two regrowth periods of the perennial crops in 2001 showed that all three maintained soil solution concentrations below 10 ppm nitrate-N, but that leachate water under soybean was consistently at or above the public drinking water limit, regardless of the nitrate concentration of the irrigation water. These results suggest that perennial forage grasses and alfalfa may be able to reduce nitrate concentration in the soil solution, even under conditions when excess water is applied to the crop.

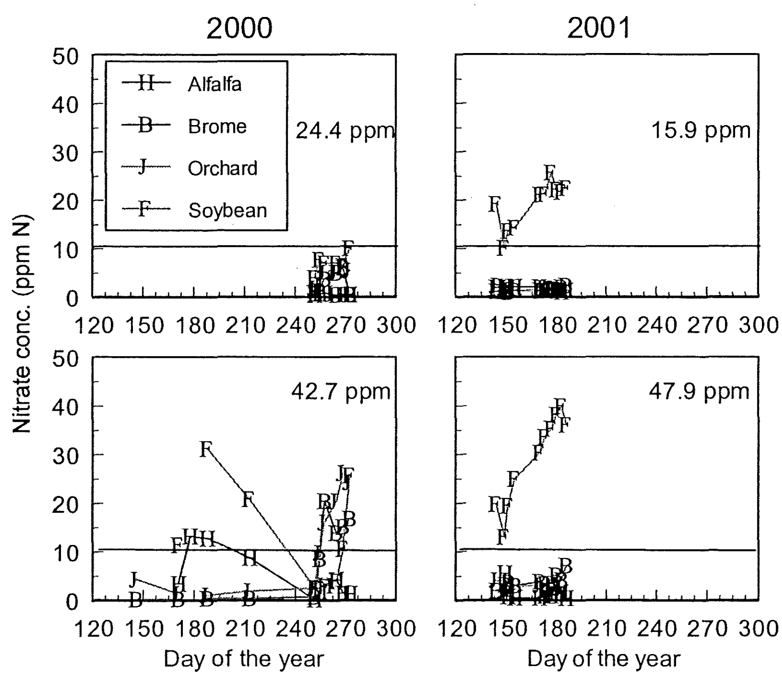

Figure 1. Average soil solution nitrate concentrations in plots of alfalfa, bromegrass, orchardgrass, and soybean on a loamy sand in Sherburne Co., MN, when overirrigated with water containing about 16 to 48 ppm nitrate-N. Data points are averages of all ceramic suction cup samplers that yielded solution on the indicated date, ranging from one to 7 samplers.

Within the context of a two-year grant funding cycle that encompasses only one complete cropping season, we cannot conclude with assurance which species would be the best in recovering nitrate applied in irrigation water. Although soybean and alfalfa accumulated similar amounts of aboveground N in 2000, alfalfa and orchardgrass removed twice as much of the applied N in the harvested forage than either bromegrass or soybean. The disparity between the uptake estimates using ^{15}N and Br tracers and the disappearance of nitrate from the soil solution under all the perennial forages implies that nitrate may also be removed by denitrification as well as by uptake by the plants. Both mechanisms would help protect the water table aquifer from nitrate influx in recharge water.

B) Pipestone County – Overhead Sprinkler System:

This experiment was established outside the Holland wellhead protection zone to test the concept of phytofiltration on plots large enough to directly assess effects on the shallow water table aquifer. Plots had been established using other funds on the farm of Keith and Pearl Pritchett in Pipestone Co. in 1999, aligned with the presumed ground water flow direction. Push-probe samples of ground water in January 2000 indicated that flow direction was perpendicular to expectations, probably due to water inflow from the North Branch of Pipestone Creek, about one quarter mile to the NW of the plots. Plots alfalfa, bromegrass, and orchardgrass were reestablished in May 2000 in the new orientation. Plots were irrigated twice weekly through a solid-set sprinkler system when the Pritchett's schedule allowed beginning in August 2000, with about 1 inch of water applied each time at a concentration of 22.7 ppm nitrate-N. Results from the 2000 cropping season were reported previously.

The first harvest in 2001 was delayed by more than three weeks due to rain. Alfalfa yielded 4300 lb DM/acre, orchardgrass yielded 2700 lb DM/acre, and bromegrass yielded 2500 lb DM/acre. Alfalfa forage contained the highest N concentration (3.2%) and bromegrass contained more N (1.5%) than orchardgrass (1.3%).Total N harvested was higher in alfalfa (140 lb N/acre) than in the two grasses (40 lb N/acre).

The delayed harvest also delayed onset of irrigation with nitrate-containing water until late June 2001. We installed both stainless steel suction cup samplers and tension lysimeters in 2000, but these have not performed satisfactorily. New ceramic suction cup samplers were installed in spring 2001. Soil solution concentrations were determined on July 2, 10, and 17, 2001. These averaged 5.7 ppm nitrate-N. Too few samples were available for valid statistical comparisons, but all concentrations were less than the public health standard of 10 ppm nitrate-N.

In May 2001, personnel from the Minnesota Pollution Control Agency obtained water samples from the aquifer under the plot area. Three upgradient sites were probed and samples were obtained from a downgradient position in each plot with a push probe. The water table was between 22 and 26 feet below the soil surface. The aquifer was sampled at three depths in most locations and water was analyzed for nitrate-N. No differences between upgradient and downgradient sites were detected, nor were there differences among treatments. Nitrate concentration declined with depth in the aquifer from about 16 ppm nitrate-N at the top of the water table to about 9 ppm nitrate-N 10 feet below the water table (Figure 2). If the ground water in the area contains about 16 ppm nitrate and the water leaching from the plots is less than 10 ppm, one would expect dilution of the ground water beginning at the water table. The lack of change in nitrate concentration may be due to insufficient water influx, which means we would need to add more irrigation water during the season to promote more leaching. The plots were newly established in 2000 and irrigation was more limited than would occur in most production years. Thus, both the flux of recharge water and nitrate removal were limited in 2000.

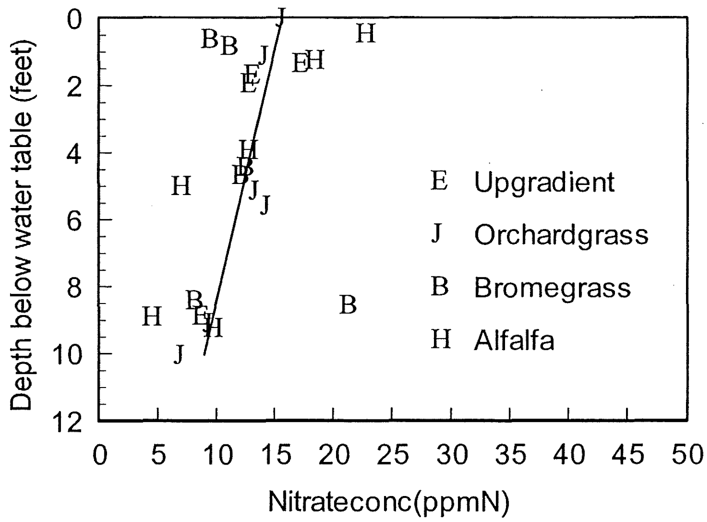

Figure 2. Nitrate concentrations in ground water under the Pipestone Co. experimental site, May 14-16, 2001. Each data point is a single measurement of water collected at the indicated depth and location. Nitrate concentration was affected by depth only.

Two processes must occur for phytofiltration to be successful. These initial tests of the phytofiltration concept at two field locations in Minnesota indicate that the first of these processes does occur, that is, nitrate concentrations decline substantially as water passes through the root zone of perennial forages in particular, due to both nitrate uptake and perhaps denitrification. However, we did not detect a change in ground water nitrate concentration at the Pipestone Co. site after one partial growing season of treatment. In these experiments, we applied 2 acre-inches of water per week. Future research should evaluate higher water application rates. Clearly, phytofiltration would be applicable only on sites with rather shallow water table aquifers that are readily affected by percolating water. Although this potential water treatment strategy shows promise, it should not be used until further research demonstrates its effectiveness in reducing ground water nitrate concentrations.

Dr. Russelle will report on these findings at the annual joint meeting of the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America in October in Charlotte, NC. A copy of the abstract is attached to this final report. In addition, as data are finalized, we will write technical articles reporting these results, with attribution of this funding source.

Appendix-Result 4

Result 4: Validate existing nitrogen leaching simulation models; predict impacts of improved N management at larger scales (i.e., wellhead recharge area).

Report submitted by Drs. Michael Russelle, USDA-ARS, St. Paul, MN, and David Kelley, University of St. Thomas (formerly USDA-ARS), St. Paul, MN

To predict effects of crop management on nitrate leaching in the Verdi and Holland Wellhead Management Areas (WMA), we used a computer simulation model called GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) with soils information from the area and ten years (1989-1998) of local historical weather data. We first calibrated and validated GLEAMS using detailed data from experiments conducted by others at the University of Minnesota Research and Outreach Centers at Morris and Lamberton. We simulated the effects of growing alfalfa, continuous corn at three N rates (100, 130, and 160 lb N/acre), and corn-soybean rotations at one N rate (90 lb N/acre on corn) on all major soils in both WMAs. For the corn-soybean rotation, we ran the simulation with corn in even-numbered years, repeated the simulation with corn in odd-numbered years, and then averaged the results by year over the two crops.

We assumed maximum yields were 140 bu/acre for corn, 65 bu/acre for soybean, and 4 tons dry matter/acre for alfalfa. We recently learned that local farmers attain higher corn yields in many years and especially under irrigation, and that yields of alfalfa can attain 5 tons/acre. We have checked the model output using higher maximum corn yields on three diverse soils, but found little effect on predicted nitrate leaching, even though predicted yields were generally higher. This result is important, because it indicates that long-term average nitrate leaching losses are not regulated as much by crop yield potential than by the amount of N added to the field and the amount of excess water received. Running and compiling the results of these simulations is quite labor-intensive, and we did not revise the modeled output for this report. Readers should, however, be aware that the yield predictions are likely lower than good farmers can achieve, so economic comparisons among cropping scenarios should be avoided.

Urea was the assumed N source, and was applied and immediately incorporated in the model in late April, one week before planting corn. In addition, we evaluated the effects of fall versus spring application of fertilizer N. Simulations were conducted twice, once using precipitation only and once with supplemental irrigation. The modeled irrigation regime was conservative; water was not applied until the soil dried to 25% of the available soil water holding capacity, and water was added only to 90% of the water holding capacity, so irrigation *per se* did not exacerbate leaching. Applied water was assumed to contain 5 ppm nitrate-N. No attempt was made to delay irrigation if precipitation would occur within a day or two, and thus, the model reflected the reality farmers face in needing to irrigate when precipitation is not a certainty.

Because the soil survey in Pipestone Co. has been digitized, we were able to produce maps of predicted nitrate leaching in the Holland WMA based on the results for each major soil. We understand that the soil survey in Lincoln Co. is likely to be digitized by the end of 2001. After we get this GIS data layer, we plan to produce similar maps of the Verdi WMA.

Perennial crops can help reduce nitrate leaching by reducing both nitrate concentrations in the soil solution (see Result 3) and water flux during spring, when leaching losses are usually highest in the North Central Region. An example comparing alfalfa and corn water use is shown in Figure 1. Spring growth of alfalfa and other cool season perennial forages results in higher water use through evapotranspiration than with corn (evaporation only), and reduces the amount of water loss by gravity through the soil. Nitrate leaching on fine-textured soils is uncommon during late summer, when crop water use is high, so neither corn nor alfalfa are likely to lose nitrate via leaching during this time.

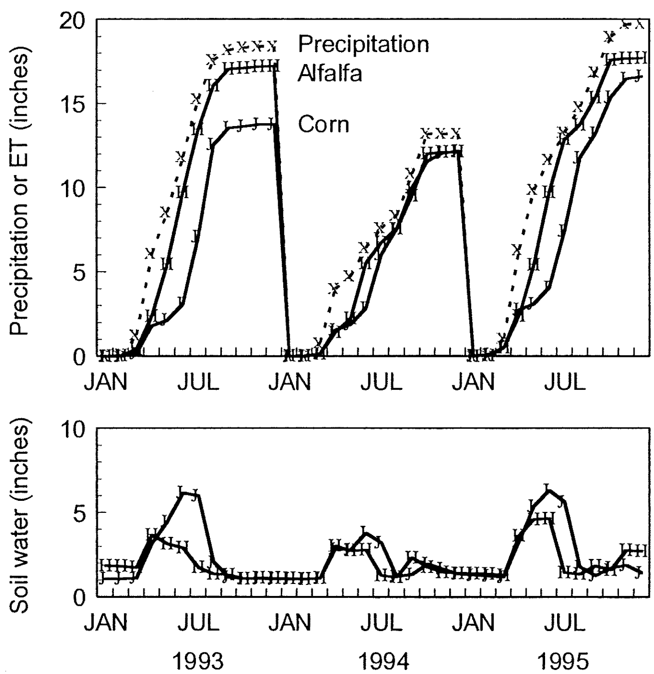

Figure 1. GLEAMS simulation results of water use and soil water storage under alfalfa (triangles) and corn (circles) using three consecutive years of weather data. The water use and precipitation curves are cumulative by calendar year, whereas the soil data are continuous from January 1, 1993.

GLEAMS predictions supported our hypothesis that nitrate leaching under alfalfa is lower than under annual crops like corn and soybean (Tables 1-4). The model predicted only rare leaching events under alfalfa, but it predicted high nitrate concentrations in the soil solution. This latter result does not agree with data from Result 3 and many other experiments, which show that soil solution nitrate-N concentrations under alfalfa are typically much lower than 10 ppm. However, the model results confirm that leaching can occur in Minnesota, even under high-producing perennial forage crops. We expect that nitrate leaching losses under native perennial prairie species would be similarly low, although water loss in spring may be higher, since many of these species are warm-season types that do not begin rapid growth until mid-June (e.g., switchgrass, big bluestem, etc.). If water escapes the root zone of perennial forages during spring, it may help improve ground water quality as long as the nitrate concentration of this percolating water is low.

Average predicted corn grain yield increased on some soils with 130 compared to 100 lb N/acre, but little further gain was achieved with 160 lb N/acre. This result also occurred in simulations using a higher yield potential, lending credence to University of Minnesota fertilizer recommendations. The amount of water percolating below the corn root zone did not change with fertilizer N rate, but nitrate concentrations in that water increased rapidly when excessive fertilizer N was applied, leading to very high N losses on some soils. For example, predicted nitrate losses under Kranzburg soils were very small with modest N additions, whereas losses were high under the same conditions on Athelwold, Estelline, Reshaw, and Trosky soils.

Irrigation increased leaching losses, mainly due to increased water percolation during May through August, because of decreased soil water storage capacity when heavy rainfall occurred. In addition, late season irrigation reduces the capacity of soil to store snowmelt and rainfall in spring. Even with the conservative irrigation regime in this simulation, the amount of water percolating below the root zone increased by an average of 30 to 35% on most soils, and nitrate concentration increased to a variable degree.

These results are best visualized in maps of the Holland WMA, which is comprised of several soil types (Figure 2), many of which are underlain by a deep sand and gravel deposit that allows percolating water to move quickly into the water table. We applied the model output to each respective soil in the WMA, assuming that a given crop management scenario was being practiced across the entire area. This could be done on a field-by-field basis, but we did not have specific cropping information at that level of detail, nor do we have a GIS layer of field boundaries.

The maps of predicted nitrate leaching loss under different cropping scenarios (Figure 3) illustrate the general likelihood that certain soils in the WMA to lose N by this pathway. There is high variability in leaching loss from year to year, which we attempted to capture by using a 10-year weather record. Shallow soils restrict both the amount of water a soil can hold against gravity and the depth of rooting of the crops, resulting in higher probability and amount of nitrate loss. The corn/soybean rotation is the main cropping system used in the area, according to an on-farm survey by the Minnesota Department of Agriculture. Although we did not run simulations with higher N rates in this rotation, one could expect increases in nitrate leaching as was predicted for the continuous corn system with greater fertilizer N.

We estimated the total average annual N loss via leaching by combining the per acre loss and the area of each modeled soil in the Holland WMA (Tables 5 and 6). We modeled losses on soils covering 97% of the WMA. The numbers quickly become quite significant when spread over the 22,213 acres modeled in the Holland WMA. Even when per acre leaching losses were small, total losses were predicted to be over 29,000 lb N if the entire WMA were growing continuous corn under nonirrigated conditions with 100 lb N/acre spring fertilizer applications. Under nonirrigated conditions, total nitrate-N losses under continuous corn tripled as fertilizer N rate increased from 100 to 130 lb N/acre, and doubled again when rate increased to 160 lb/acre. Nitrate losses were similar for a corn/soybean rotation and for continuous corn with modest N rates under dryland conditions, but 40% more nitrate was lost under the corn/soybean rotation than under continuous corn under irrigation. We think this is due to lower water use and lower nitrate uptake by the soybean than by corn, even though more than twice as much fertilizer N is applied in the continuous corn system.

We simulated late fall (October 26) applications of urea fertilizer with immediate incorporation on four soils in the Holland WMA and five soils in the Verdi WMA. Applications of fertilizer N are not recommended before soil temperatures stay below 50 F, because of the risk that fertilizer N will be converted to nitrate and lost before the crop can use it. Averaged over 10 years of weather data, there was no difference in predicted corn yield between late October and late April fertilizer N application times. A slight increase in nitrate leaching (averaging 1 lb N/acre for nonirrigated and 1.4 lb N/acre for irrigated continuous corn) was predicted for fall application compared to spring. This small per acre loss translates into very large amounts of nitrate loss over the entire WMA. As there is rarely a yield benefit, and occasionally a yield loss, due to fall N application, we recommend spring application be used in the WMAs.

It is clear that nonpoint nitrate losses below the root zone of annual crops in the WMA may be contributing to the increasing nitrate concentrations measured in the water table aquifer. It is possible that less diffuse sources (e.g., barnyards with excessive manure deposition, leaky septic systems, surface water affected by tile drainage, etc.) are sources of nitrate as well. This analysis does not include all possible management scenarios, and although results cannot be considered exact, these results should be useful for designing cropping systems to improve and protect future ground water quality in the Holland WMA.

Once we have reviewed all the results and have reviews by other experts, we intend to write technical articles for publication, with appropriate attribution of the funding sources. We are also likely to present this information at scientific meetings, although no abstracts have been written at this time.

Figure 2. Soils map of the Holland Wellhead Management Area. Lincoln Pipestone Rural Water District wells are shown as teal-colored circles in the lower SW corner of the area.

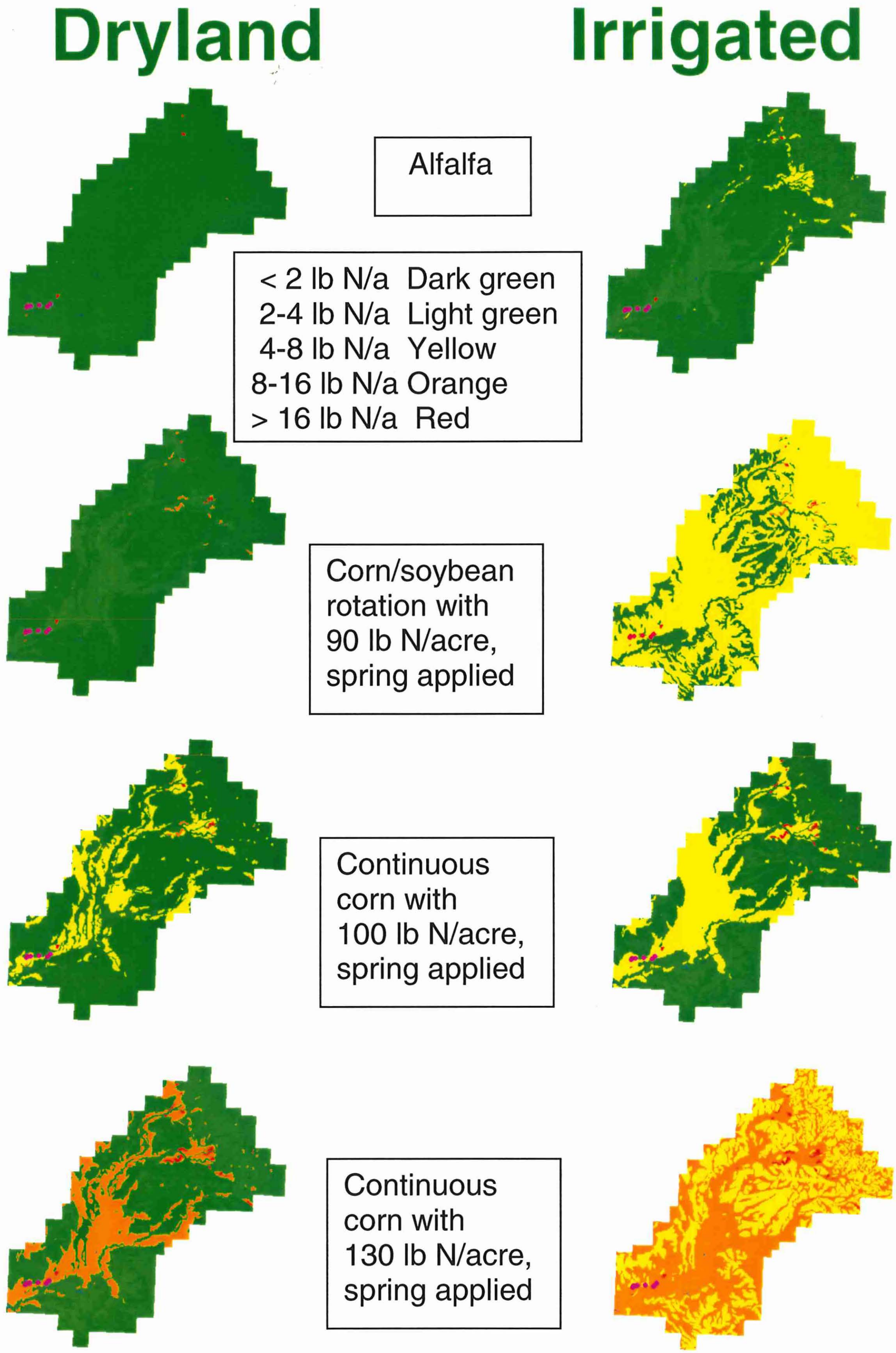

Figure 3. Predicted nitrate leaching in the Holland Wellhead Management Area.

Table 1. Holland WMA, nonirrigated scenario: annual crop yield, nitrate leaching losses, water percolation below the root zone, and flow-weighted concentration of leachate water, as predicted by GLEAMS on the indicated soils using local weather data from 1989 through 1998.

Cropping system and management	Soil series													
	Athelwold	Barnes	Brookings	Estelline	Estelline deep	Flom	Hidewood	Kranzburg	Lamoure	Renshaw	Svea	Trosky	Vienna	Whitewood
Alfalfa														
Yield (dry tons/acre)	1.6	1.5	1.5	1.6	2.0	1.5	1.5	1.5	1.5	1.7	1.5	1.6	1.5	1.5
Percolation (inches)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Concentration (ppm)	28.0	0.0	0.0	25.5	0.0	0.0	0.0	0.0	0.0	22.3	0.0	0.0	0.0	0.0
Nitrate loss (lb N/acre)	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Continuous corn - 160 lb N/acre														
Yield (bu/acre)	127.1	137.4	137.5	127.1	137.7	137.5	137.5	137.6	137.6	126.9	137.6	127.8	137.9	137.5
Percolation (inches)	1.0	0.9	0.7	1.0	0.6	0.7	0.7	0.5	0.6	1.1	0.9	0.8	0.6	0.7
Concentration (ppm)	86.4	33.6	40.1	83.4	39.6	45.1	43.3	41.4	43.8	79.0	34.8	84.6	39.6	47.2
Nitrate loss (lb N/acre)	19.1	6.6	6.4	18.5	5.0	7.5	6.6	4.2	6.1	20.5	6.7	15.9	5.1	7.1
Continuous corn - 130 lb N/acre														
Yield (bu/acre)	127.1	137.2	136.6	127.1	137.6	137.4	137.4	137.4	137.5	126.9	136.8	127.8	137.8	137.4
Percolation (inches)	1.0	0.9	1.0	1.0	0.6	0.7	0.7	0.5	0.6	1.1	0.9	0.8	0.6	0.7
Concentration (ppm)	37.6	10.7	14.6	43.2	11.7	15.8	15.2	38.7	15.8	35.3	9.5	43.4	13.1	6.4
Nitrate loss (lb N/acre)	8.3	2.1	2.3	9.6	1.5	2.6	2.3	1.3	2.2	9.2	1.8	8.2	1.8	1.0
Continuous corn - 100 lb N/acre														
Yield (bu/acre)	125.1	132.2	136.6	125.7	134.0	133.8	133.8	132.9	134.4	124.8	132.4	126.4	133.7	133.8
Percolation (inches)	1.0	0.9	1.0	1.0	0.6	0.7	0.7	0.5	0.6	1.1	0.9	0.8	0.6	0.7
Concentration (ppm)	20.2	4.3	2.7	19.6	2.1	2.5	2.5	11.4	3.8	18.5	3.8	19.0	3.7	2.6
Nitrate loss (lb N/acre)	4.5	0.8	0.4	4.3	0.3	0.4	0.4	0.2	0.5	4.8	0.7	3.6	0.5	0.4
Corn/Soybean - 90 lb N/acre on corn														
Corn yield (bu/acre)	126.9	137.2	136.7	126.8	136.8	137.2	137.1	136.7	137.1	127.0	137.1	127.7	137.3	136.7
Soybean yield (bu/acre)	50.8	63.5	63.2	50.8	62.5	63.2	63.1	62.2	62.8	51.1	63.5	50.7	62.7	64.2
Percolation (inches)	0.6	0.4	0.3	0.6	0.2	0.3	0.3	0.2	0.3	0.7	0.4	0.5	0.2	0.3
Concentration (ppm)	22.5	13.0	12.4	25.1	16.4	16.7	15.4	2.2	13.6	22.7	13.1	21.4	17.3	15.8
Nitrate loss (lb N/acre)	2.9	1.2	0.9	3.3	0.8	1.2	1.0	0.6	0.8	3.5	1.2	2.4	1.0	1.0

. Holland WMA, irrigated scenario: annual crop yield, nitrate leaching losses, water percolation below the root zone, and flow-weighted concentration of leachate water, as predicted by GLEAMS on the indicated soils using local weather data from 1989 through 1998.

Cropping system and management	Soil series													
	Athelwold	Barnes	Brookings	Estelline	Estelline deep	Flom	Hidewood	Kranzburg	Lamoure	Renshaw	Svea	Trosky	Vienna	Whitewood
Alfalfa														
Yield (dry tons/acre)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Percolation (inches)	0.5	0.2	0.1	0.6	0.2	0.1	0.1	0.1	0.1	0.8	0.1	0.4	0.0	0.0
Concentration (ppm)	26.4	44.3	49.4	27.2	45.9	52.3	44.2	49.9	42.2	34.1	44.4	29.2	0.0	48.5
Nitrate loss (lb N/acre)	3.2	1.9	1.2	3.5	1.9	0.8	1.5	0.8	0.8	6.4	0.8	2.7	0.0	0.1
Continuous corn - 160 lb N/acre														
Yield (bu/acre)	127.1	137.4	136.6	136.2	138.8	136.2	136.8	138.3	137.2	137.5	138.1	138.2	137.4	137.6
Percolation (inches)	1.0	1.1	1.0	1.3	0.8	1.1	1.0	0.7	0.8	1.4	1.1	1.0	0.9	0.9
Concentration (ppm)	86.4	45.6	65.0	96.6	61.6	67.7	66.4	61.3	68.7	82.1	54.9	97.5	57.0	63.7
Nitrate loss (lb N/acre)	19.1	11.7	14.2	27.3	11.2	16.1	14.5	10.4	13.0	26.5	13.6	22.4	11.1	14.4
Continuous corn - 130 lb N/acre														
Yield (bu/acre)	136.4	137.4	136.6	135.7	138.4	136.2	136.8	137.9	137.2	137.5	138.0	138.2	137.4	137.5
Percolation (inches)	1.2	1.1	1.0	1.3	0.8	1.1	1.0	0.7	0.8	1.4	1.1	1.0	0.9	0.9
Concentration (ppm)	49.8	27.6	48.5	51.8	38.1	41.8	41.8	34.2	43.2	39.6	34.5	49.6	36.3	43.3
Nitrate loss (lb N/acre)	13.2	7.1	10.6	14.6	6.9	9.9	9.1	5.8	8.1	12.8	8.6	11.4	7.0	8.8
Continuous corn - 100 lb N/acre														
Yield (bu/acre)	135.9	136.9	136.0	135.2	138.3	135.8	136.3	137.4	136.7	136.9	137.5	137.3	137.3	137.5
Percolation (inches)	1.2	1.1	1.0	1.3	0.8	1.1	1.0	0.7	0.8	1.4	1.1	1.0	0.9	0.9
Concentration (ppm)	21.1	6.7	11.9	24.6	8.5	10.5	9.7	7.3	11.1	17.3	7.2	19.6	8.2	11.7
Nitrate loss (lb N/acre)	5.6	1.7	2.6	7.0	1.5	2.5	2.1	1.2	2.1	5.6	1.8	4.5	1.6	2.4
Corn/Soybean - 90 lb N/acre on corn														
Corn yield (bu/acre)	136.5	137.4	135.7	135.8	138.4	135.0	136.4	137.4	136.8	137.2	137.9	137.8	137.6	137.7
Soybean yield (bu/acre)	63.9	64.7	64.6	63.8	64.7	64.7	64.7	64.7	64.7	64.2	64.8	64.0	64.8	64.7
...olation (inches)	0.9	1.0	0.7	0.9	0.6	0.7	0.8	0.6	0.6	1.1	0.9	0.8	0.9	0.8
Concentration (ppm)	26.5	20.3	28.0	31.1	28.8	32.9	27.8	24.6	30.5	21.2	21.1	27.5	30.0	28.2
Nitrate loss (lb N/acre)	5.3	4.4	4.5	6.4	4.0	5.5	4.7	3.5	3.9	5.2	4.1	5.1	5.8	4.8

Table 3. Verdi WMA, nonirrigated scenario: annual crop yield, nitrate leaching losses, water percolation below the root zone, and flow-weighted concentration of leachate water, as predicted by GLEAMS on the indicated soils using local weather data from 1989 through 1998.

Cropping system and management	Soil series and slope (%)												
	Arvilla	Arvilla 2-6	Beotia	Beotia 2-4	Brookings	Dickey 2-6	Estelline	Flandreau	Fordville 2-6	Hidewood	Kranzburg	Kranzburg 2-6	LaPrairie
Alfalfa													
Yield (dry tons/acre)	2.0	2.0	1.5	1.5	1.5	1.7	1.6	1.5	1.7	1.5	1.4	1.4	1.5
Percolation (inches)	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	0.0
Concentration (ppm)	11.4	11.4	0.0	0.0	0.0	0.0	25.2	0.0	10.5	0.0	0.0	0.0	0.0
Nitrate loss (lb N/acre)	0.4	0.4	0.0	0.0	0.0	0.0	0.2	0.0	0.7	0.0	0.0	0.0	0.0
Continuous corn - 160 lb N/acre													
Yield (bu/acre)	126.1	126.1	137.0	137.0	137.5	139.0	125.0	137.2	110.1	137.5	137.4	137.4	137.1
Percolation (inches)	1.9	1.9	0.8	0.8	0.7	0.1	1.0	0.5	2.3	0.7	0.6	0.6	0.7
Concentration (ppm)	96.4	96.4	37.5	37.5	40.1	42.4	80.1	31.7	71.4	43.3	30.1	30.1	37.5
Nitrate loss (lb N/acre)	42.5	42.5	7.1	7.1	6.4	1.4	18.4	3.7	36.8	6.6	3.7	3.7	6.3
Continuous corn - 130 lb N/acre													
Yield (bu/acre)	126.0	126.0	136.9	136.9	137.4	138.9	125.0	137.0	108.6	137.4	137.2	137.2	137.0
Percolation (inches)	1.9	1.9	0.8	0.8	0.7	0.1	1.0	0.5	2.3	0.7	0.6	0.6	0.7
Concentration (ppm)	74.8	74.8	13.5	13.5	14.6	35.3	37.8	8.2	44.2	15.2	7.9	7.9	14.7
Nitrate loss (lb N/acre)	32.9	32.9	2.6	2.6	2.3	1.2	8.7	1.0	22.8	2.3	1.0	1.0	2.5
Continuous corn - 100 lb N/acre													
Yield (bu/acre)	125.9	125.9	131.0	131.0	133.0	138.7	122.6	131.3	108.0	133.8	130.2	130.2	131.8
Percolation (inches)	1.9	1.9	0.8	0.8	0.7	0.1	1.0	0.5	2.3	0.7	0.6	0.6	0.7
Concentration (ppm)	55.8	55.8	4.4	4.4	2.7	2.2	18.6	3.9	29.9	2.5	3.7	3.7	4.7
Nitrate loss (lb N/acre)	24.6	24.6	0.8	0.8	0.4	0.1	4.3	0.5	15.4	0.4	0.5	0.5	0.8
Corn/Soybean - 90 lb N/acre on corn													
Corn yield (bu/acre)	123.4	123.4	135.9	135.9	136.7	138.4	124.5	136.6	109.4	137.1	136.3	136.3	135.2
Soybean yield (bu/acre)	55.8	55.8	67.8	67.8	67.7	67.8	53.3	66.8	51.5	67.6	66.7	66.7	67.6
Percolation (inches)	1.2	1.2	0.4	0.4	0.3	0.0	0.6	0.2	1.5	0.3	0.2	0.2	0.3
Concentration (ppm)	49.1	49.1	16.0	16.0	12.4	14.8	23.8	24.2	27.4	14.8	12.3	12.3	18.2
Nitrate loss (lb N/acre)	13.4	13.4	1.4	1.4	0.9	0.1	3.1	0.7	9.3	1.0	0.6	0.6	1.4

4. Verdi WMA, irrigated scenario: annual crop yield, nitrate leaching losses, water percolation below the root zone, and flow-weighted concentration of leachate water, as predicted by GLEAMS on the indicated soils using local weather data from 1989 through 1998.

Cropping system and management	Soil series and slope (%)												
	Arvilla	Arvilla 2-6	Beotia	Beotia 2-4	Brookings	Dickey 2-6	Estelline	Flandreau	Fordville 2-6	Hidewood	Kranzburg	Kranzburg 2-6	LaPrairie
Alfalfa													
Yield (dry tons/acre)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Percolation (inches)	1.1	1.1	0.0	0.0	0.1	0.0	0.7	0.1	2.0	0.1	0.2	0.2	0.0
Concentration (ppm)	21.0	21.0	0.0	0.0	49.4	0.0	25.7	49.4	14.2	44.2	53.5	53.5	43.4
Nitrate loss (lb N/acre)	5.3	5.3	0.0	0.0	1.2	0.0	3.9	1.0	6.5	1.5	2.3	2.3	0.1
Continuous corn - 160 lb N/acre													
Yield (bu/acre)	136.4	136.4	137.9	137.9	136.6	139.6	136.9	137.5	136.4	136.8	139.2	139.2	137.5
Percolation (inches)	2.2	2.2	1.1	1.1	1.0	0.2	1.3	1.5	2.9	1.0	0.8	0.8	1.0
Concentration (ppm)	96.1	96.1	55.7	55.7	65.0	45.5	85.1	72.7	58.0	66.4	51.8	51.8	54.8
Nitrate loss (lb N/acre)	48.8	48.8	14.3	14.3	14.2	2.4	25.0	24.7	37.8	14.5	9.3	9.3	12.3
Continuous corn - 130 lb N/acre													
Yield (bu/acre)	135.9	135.9	137.9	137.9	136.6	139.6	136.8	137.5	136.3	136.8	139.2	139.2	137.5
Percolation (inches)	2.2	2.2	1.1	1.1	1.0	0.2	1.3	1.5	2.9	1.0	0.8	0.8	1.0
Concentration (ppm)	73.6	73.6	36.7	36.7	48.5	40.3	41.4	35.8	40.3	41.8	25.6	25.6	37.2
Nitrate loss (lb N/acre)	37.4	37.4	9.4	9.4	10.6	2.1	12.2	12.1	26.3	9.1	4.6	4.6	8.3
Continuous corn - 100 lb N/acre													
Yield (bu/acre)	136.2	136.2	137.9	137.9	136.0	139.6	135.5	136.9	136.3	136.3	138.2	138.2	137.5
Percolation (inches)	2.2	2.2	1.1	1.1	1.0	0.2	1.3	1.5	2.9	1.0	0.8	0.8	1.0
Concentration (ppm)	54.8	54.8	9.5	9.5	11.9	8.1	20.4	16.7	28.3	9.7	8.8	8.8	11.1
Nitrate loss (lb N/acre)	27.9	27.9	2.4	2.4	2.6	0.4	6.0	5.6	18.4	2.1	1.6	1.6	2.5
Corn/Soybean - 90 lb N/acre on corn													
Corn yield (bu/acre)	137.2	137.2	137.9	137.9	135.7	139.7	137.5	136.9	137.4	136.4	137.9	137.9	137.6
Soybean yield (bu/acre)	64.5	64.5	64.6	64.6	64.6	65.0	63.7	64.2	64.2	64.7	64.5	64.5	64.5
Percolation (inches)	1.5	1.5	0.8	0.8	0.7	0.4	0.9	1.2	2.0	0.8	0.6	0.6	0.8
Concentration (ppm)	51.1	51.1	22.6	22.6	28.0	27.7	14.1	75.9	155.1	129.4	19.0	19.0	24.6
Nitrate loss (lb N/acre)	16.8	16.8	4.0	4.0	4.5	2.4	3.0	5.3	12.2	4.7	2.7	2.7	4.3

Table 5. Holland Wellfield Management Area, nonirrigated scenario: Total predicted annual nitrate leaching by soil type based on GLEAMS simulations and local weather data from 1989 through 1998. Modeled soil series (>200 acres) are indicated in bold face. For mapping, we estimated that nitrate leaching for non-modeled soils was the same as for modeled soils with similar properties.

							Continuous corn				Corn/soybean rotation		Alfalfa	
					160 lb N/acre		130 lb N/acre		100 lb N/acre		90 lb N/acre on corn			
Map Unit symbol	Series	Area (acres)	Series total (acres)	Depth (inches)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)
At	Athelwold	1103	1103	36	19.1	21093	8.3	9179	4.5	4927	2.9	3224	0.2	169
BaB	Barnes	517												
BaB2		1682												
BaC2		201	2400	60	6.6	15806	2.1	5017	0.8	2027	1.2	2947	0.0	0
BrA	Brookings	3295	3295	60	6.4	21047	2.3	7686	0.4	1397	0.9	2817	0.0	0
BwC2	Buse-Barnes	381												
BwD		83	463	60	6.6	3052	2.1	969	0.8	391	1.2	569	0.0	0
ByC2	Buse-Vienna	12												
ByD		12												
DaB	Darnen	18												
EsA	Estelline	1776												
EsB		184												
EsB2		186	2146	36	18.5	39631	18.5	39631	4.3	9317	3.3	6996	0.1	305
EtA	Estelline deep	1141	1141	60	5.0	5657	5.0	5657	0.3	294	0.8	899	0.0	0
FaB, B2	Flandreau	16												
Fm	Flom and Roliss	1046	1046	60	7.5	7888	2.6	2759	0.4	444	1.2	1265	0.0	0
FoA	Fordville	42												
Gravel Pit		17												
Hd	Hidewood	975	975	60	6.6	6436	2.3	2257	0.4	365	1.0	972	0.0	0
KrA	Kranzburg	1030												
KrB		1707												
KrB2		1626	4362	60	4.2	18495	1.3	5452	0.2	1055	0.6	2561	0.0	0
La	Lamoure	509											0.0	0
Lb	Lamoure, freq. flooded	790	1299	60	6.1	7973	2.2	2885	0.5	691	0.8	1052		
Lc		83												
LsA	Lismore	152												
Qu	Quam	27												
Ra	Rauville	154												
ReA	Renshaw	243												
ReB		200												
ReC		29	475	15	20.5	9742	9.2	4357	4.8	2278	3.5	1680	0.3	133
RnB2, C2	Renshaw-Vienna-Buse	32												
SoE	Sioux	12												
SvA	Svea	338	338	60	6.7	2263	1.8	616	0.7	247	1.2	404	0.0	0
TrA	Trent	55												
Ts	Trosky	1426	1426	38	15.9	22697	8.2	11646	3.6	5086	2.4	3352	0.0	0
VaC	Vienna	14												
VaC2		19												
VbA		25												
VbB		126												
VbB2		769	920	60	5.1	4726	1.8	1620	0.5	457	1.0	897	0.0	0
Water		5												
Wh	Whitewood	824	824	60	7.1	5851	1.0	807	0.4	322	1.0	843	0.0	0
	Totals:	**22,896**	**22,213**			**192,355**		**100,539**		**29,300**		**30,476**		**607**

5. Holland Wellfield Management Area, irrigated scenario: Total predicted annual nitrate leaching by soil type based on GLEAMS simulations and local weather data from 1989 through 1998. ed soil series (>200 acres) are indicated in bold face. For mapping, we estimated that nitrate leaching for non-modeled soils was the same as for modeled soils with similar properties.

					Continuous corn						Corn/soybean rotation		Alfalfa	
					160 lb N/acre		130 lb N/acre		100 lb N/acre		90 lb N/acre on corn			
Map Unit symbol	Series	Area (acres)	Series total (acres)	Depth (inches)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)	N leached (lb N/acre)	Total for series (lb)
At	Athelwold	1103	1103	36	19.1	21093	13.2	14514	5.6	6161	5.3	5869	3.2	3573
BaB	Barnes	517												
BaB2		1682												
BaC2		201	2400	60	11.7	28105	7.1	17006	1.7	4102	4.4	10604	1.9	4490
BrA	Brookings	3295	3295	60	14.2	46736	10.6	34928	2.6	8545	4.5	14889	1.2	3803
BwC2	Buse-Barnes	381												
BwD		83	463	60	11.7	5426	7.1	3283	1.7	792	4.4	2047	1.9	867
ByC2	Buse-Vienna	12												
ByD		12												
DaB	Darnen	18												
EsA	Estelline	1776												
EsB		184												
EsB2		186	2146	36	27.3	58607	14.6	31427	7.0	14944	6.4	13767	3.5	7566
EtA	Estelline deep	1141	1141	60	11.2	12761	6.9	7890	1.5	1755	4.0	4519	1.9	2113
FaB, B2	Flandreau	16												
Fm	Flom and Roliss	1046	1046	60	16.1	16796	9.9	10377	2.5	2614	5.5	5787	0.8	793
FoA	Fordville	42												
Gravel Pit		17												
Hd	Hidewood	975	975	60	14.5	14117	9.1	8886	2.1	2070	4.7	4610	1.5	1417
KrA	Kranzburg	1030												
KrB		1707												
KrB2		1626	4362	60	10.4	45164	5.8	25205	1.2	5250	3.5	15373	0.8	3466
La	Lamoure	509											0.8	0
Lb	Lamoure, freq. flooded	790	1299	60	13.0	16835	8.1	10582	2.1	2730	3.9	5114		
Lc		83												
LsA	Lismore	152												
	Quam	27												
	Rauville	154												
ReA	Renshaw	243												
ReB		200												
ReC		29	475	15	26.5	12559	12.8	4357	5.6	2278	5.2	1680	6.4	133
RnB2, C2	Renshaw-Vienna-Buse	32												
SoE	Sioux	12												
SvA	Svea	338	338	60	13.6	4601	8.6	2889	1.8	600	4.1	1378	0.8	277
TrA	Trent	55												
Ts	Trosky	1426	1426	38	22.4	31890	11.4	16223	4.5	6407	5.1	7209	2.7	3815
VaC	Vienna	14												
VaC2		19												
VbA		25												
VbB		126												
VbB2		769	920	60	11.1	10183	7.0	6484	1.6	1472	5.8	5348	0.0	0
Water		5												
Wh	Whitewood	824	824	60	12.9	10634	8.8	7238	2.4	1951	4.8	3989	0.1	88
	Totals:	**22,896**	**22,213**			**335,508**		**201,291**		**61,671**		**102,184**		**32,400**

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Appendix 5- Related News Releases and Educational Event Announcements

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Looking out for the land

Ag department field tour highlights land-use practices

BY JIM MUCHLINSKI
Independent Staff Writer

LAKE BENTON — Farmers, a rural water system, researchers and government agencies are all partners in groundwater protection in the Buffalo Ridge area near Lake Benton.

A field tour Tuesday afternoon sponsored by the Minnesota Department of Agriculture highlighted field management practices that help to prevent nitrate contamination in drinking water. Many of the projects also prevent soil erosion and lead to efficient farm chemical costs.

Michael Russelle, a Minnesota Department of Agriculture soil scientist, said field management steps such as alfalfa plantings, manure and nutrient management programs, and reduced tillage that leaves crop residue on fields can serve as an alternative to costly nitrate-related water treatment systems.

Nitrates, a by-product of nutrients such as manure and fertilizer, are potentially fatal groundwater contaminants if extremely high levels go undetected in drinking water.

"It makes sense to try to address nitrate concerns with natural approaches," Russelle said. "We're seeing that it can be done in ways that still allow for farm profitability."

Many of the improvements can occur through grant programs available to interested landowners.

He said the interest among landowners near the Buffalo Ridge serves as a model for other agricultural areas that need for groundwater protection.

"We looked into it because of concerns for rural water system wells in the local area," Russelle said. "It's a good place for demonstration projects. We're showing that there could be a role in the future for approaches such as multi-year alfalfa crops."

He said one of the newer possibilities is a process called "phytofiltration," in which nitrate- contaminated water is used for irrigation and fertilizer on alfalfa. Because of the well-established alfalfa root systems, nitrates are naturally used by the crop without filtering back into groundwater reserves.

Duane Vahl, who farms near Verdi in southwestern Lincoln County, said grant opportunities and groundwater conservation work has co-existed well with his farm operation.

He's participated in both nutrient management and crop residue incentive programs.

"For me, it's been practical," Vahl said. "It's a good thing to have research and financial incentives that make it possible for farmers to participate."

Lyle Trautman of rural Lake Benton said the program has been helpful as he decides how to manage his farmland.

Besides field management programs, Trautman has sponsored construction of earth berms designed to prevent runoff. He said the structures have helped to protect fields after heavy rains such as those that occurred this month.

"It's a win-win situation," Trautman said. "We've had gulleys in the past that aren't a problem anymore. Landowners are sometimes concerned that this kind of program could mean more government regulation, but in this case it's just been a good resource. I haven't had to make any big, costly changes to work with it."

Tuesday afternoon's field tour near Lake Benton was the first of two tours, along with an event Tuesday evening in Pipestone County near Holland.

Lincoln-Pipestone Rural Water administrator Dennis Healy said the water system installed reverse osmosis treatment equipment several years ago to treat water at its Holland area well-field to prevent nitrate contamination.

So far, the same treatment equipment hasn't been needed at LPRW's deeper Verdi area wells. Healy said land management projects could help to prevent more costly water treatment in the future.

"It's a good investment," he said. "We won't be able to see all of the advantages right away. It's likely to have positive results over the long term."

Photo by Jim Muchlinski

Southwest Research and Outreach Center agronomist Jeff Strock spoke about soil management Tuesday during a field tour near Lake Benton.

Staff from the Southwest Research and Outreach Center have assisted area conservation staff in the Lincoln County and Pipestone County demonstration projects.

"It was a good opportunity for our staff to work with the balance between farm profits and natural resources," said SWROC Director Pauline Nickel. "All of the indicatations suggest that these kinds of partnerships can make a difference."

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Agri News

YOUR OPINION?
What would you like to see in the new farm bill? Send us your comments.

Farmers, agencies cooperate to protect region's water supply

Tuesday, August 7, 2001

By Carol Stender

Agri News staff writer

VERDI, Minn. -- When the Holland well shed in the Lincoln-Pipestone Rural Water district tested above the standard 10 parts-per-billion for nitrates, the district took action.

The district built a $3.5 billion treatment plant near Pipestone to clean the water and staff brought together farmers and local, state and federal agencies to find ways to stop nitrate leaching into the aquifer LPRW uses.

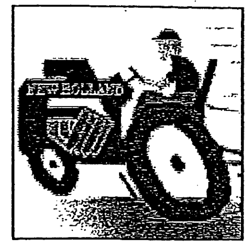
Last week, more than 30 farmers and area residents heard about the research project being conducted in both the Verdi and Holland well sheds. While Don Evers of the LPRW said there isn't enough history yet to draw conclusions, the cooperation of the various agencies and producers has "really turned things around."

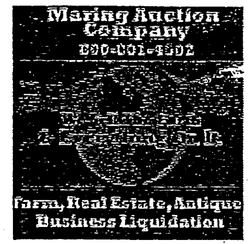
After all, prevention is cheaper than the cure, he said.

The challenge is the soil system that water goes through before it joins the shallow aquifer.

"It's good soil the top three to four feet," said Conrad Schardin, Verdi township chairman and farmer. "But underneath it's coarse-textured sand and gravel. In most areas of ground water there is a clay layer above the aquifer, but here there isn't, to stop the leaching."

Farmers taking part in the research have applied nitrogen at rates of 0, 60, 90, 120 and 150 pounds per acre. The N is applied at three different times -- early October, late fall and early spring. So far the results have supported what Jeff Strock, Southwest Research





and Outreach Center soil scientist has found in other trials: 90 pounds of N is sufficient to produce a good crop without over applying chemical and risking nitrogen leaching.

"We have to put something on but not a lot," said Lester Otkin, who hosted one of the field day events at his test corn plots. "We can see were we didn't put anything on in this trial and that doesn't pay the rent. I know that N pays but what's feasible and at what rates? I don't think we have to put on as much as we do."

Phytofiltration is one way to filter nitrogen before water reaches an aquifer. Michael Russelle, USDA soil scientist, told the group that using perennial forages is beneficial, especially for municipal systems with shallow aquifers. Under phytofiltration, nitrate-contaminated water is used to irrigate perennial forage fields. As the water leaches through the soil, the forage will retain the nitrates. Leftover water that leaches into underground aquifers will contain reduced levels of nitrates and be safe for drinking water.

A LCMR grant ended July 1, but Denton Bruening of the Minnesota Department of Agriculture said agencies involved in the research and local government units are supplying funds. It's hoped that the project can continue for at least another three years.

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Urgent Alert
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Top Stories

Field day to highlight water quality improvement practices

By: Mike Nowatzki, Daily Globe July 31, 2001

HOLLAND - A series of water quality improvement programs, spawned from the discovery of high nitrate levels in drinking water in Pipestone and Lincoln counties, will be highlighted during two presentations today at test plots near Holland and Verdi.

Using state and federal grants, dozens of farmers around the two towns have worked with the Minnesota and U.S. departments of agriculture and the University of Minnesota to implement best management practices.

Steve Iverson, a nutrient management specialist with the U of M Extension Service, said the primary goal is to get farmers to use the correct amount of nitrogen fertilizer recommended by Extension, thereby decreasing groundwater contamination and reducing the amount of excess fertilizer.

The other goal is to convince farmers to leave 30 percent of the crop residue - the leftover stubble from corn and soybean harvest - on their fields after planting next spring.

"It reduces the amount of runoff and erosion in the field so you don't get the runoff flowing into shallow streams that can affect the aquifer," Iverson said.

Aquifers around Holland and Verdi are extremely susceptible to groundwater contamination, Iverson said. There is no clay layer between the soil and gravel above the Holland aquifer, "so any nitrogen that seeps through the top three to four feet can move pretty fast" into the groundwater supply, he said.

In 1997, the Minnesota Department of Health found that in certain communities in Pipestone and Lincoln counties, drinking water from rural supplies was unsafe due to high levels of nitrates. Lincoln-Pipestone Rural Water later installed a treatment plant near Pipestone to filter out contaminants.

Around the same time as the health department study, a survey by the Minnesota Department of Agriculture found concern among local farmers that the U of M's nitrogen recommendations were too low, said Pipestone County Conservation Zoning Administrator John Biren. The university recommends roughly 60 pounds of nitrogen per acre for a 120-bushel corn yield, and most area farmers were 30 pounds on either side of that figure, he said.

To address farmers' concerns, the U of M decided to test the effectiveness of the different nitrogen types - anhydrous ammonia, urea and a 28 percent-nitrogen liquid mixture - and rates on plots near Holland and Verdi. The goal is to get farmers working with the university, local and state agencies and the USDA to maximize the return on their fertilizer, and to show that farmers use fertilizer responsibly, Biren said.

Gordon Moeller provided land for two such plots last year on his farm 11 miles northeast of Pipestone. He planted corn on the test plots and will see the results this fall. If the test works correctly, it will make it easier for him to decide how much nitrogen to apply.

"We ourselves try to figure it out, because you're wasting it if that crop out there doesn't utilize it," Moeller said.

Grants have played a large role in the water quality effort. Ninety percent of a $96,000 grant from the Minnesota Pollution Control Agency will be paid out to Pipestone County farmers implementing best management practices, said Biren, who distributes the funds as manager of the Pipestone County Soil and Water Conservation District.

The most popular incentive program so far, Biren said, is the continuous Conservation Reserve Program signup program. Farmers have enrolled about 600 acres of land into CRP within 2,000 feet of the Holland and Edgerton well fields. Upstream, 17 farmers are being paid to plant grass buffer strips on both sides of intermittent streams. Similar efforts are under way in Lincoln County, made possible by grant funding from the Natural Resources Conservation Service.

Although the official test results aren't in yet, the director of operations for Lincoln-Pipestone Rural Water said the practices appear to be working at the Holland well field.

"We have basically seen the nitrates drop 10 parts (per million) because of the well head protection program," Don Evers said.

Nitrate levels higher than 10 parts per million are considered unsafe and must be made public by water suppliers. One well at the Holland field has dropped from 26 to 16 parts per million, Evers said.

Lincoln-Pipestone Rural Water's grant from the Minnesota Department of Agriculture expired July 1, but Evers said board members voted to continue funding water quality programs until other sources are found.

"Myself, I feel we're on the right track with this, because nitrates are man-made," he said.

The Verdi field day will start at 3 p.m. today. The site is located seven miles west of the junction of U.S. 14 and U.S. 75 in Lake Benton, three miles south on Lincoln County 1 and half a mile west. In case of inclement weather, discussions will take place at the Lake Benton Community Center.

The Holland field day will start at 7 p.m. The site is located nine miles north of junction of Minnesota 30 and U.S. 75 in Pipestone, or 10 miles south of Lake Benton. Go two miles east on 191st Street and half a mile north on 100th Avenue. In case of inclement weather, the event will be at the Fountain Prairie Town Hall, 2092 110th Ave.

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Reader Opinions

Southwest Research and Outreach Center
College of Agricultural, Food, and Environmental Sciences

Box 428
Lamberton, MN 56152
507-752-7372
Fax: 507-752-7374

UNIVERSITY OF MINNESOTA FIELD DAYS

The University of Minnesota along with the Pipestone and Lincoln County Extension Services, the Legislative Commission on Minnesota Resources (LCMR), and the Minnesota Department of Agriculture will be holding field days to discuss the U of M's fertilizer recommendations and current nitrogen management research in Lincoln and Pipestone counties. Information on water quality programs in Lincoln and Pipestone counties will also be presented. The field days will be held at the following locations:

VERDI PLOT

July 31st at 3:00 pm

PLOT LOCATED: 7 miles West of the Junction of 14 & 75 in Lake Benton, 3 miles South on Lincoln Co 1 and ½ mile West

Verdi inclement weather site:
Lake Benton Community Center

HOLLAND PLOT

July 31st at 7:00 pm

PLOT LOCATED: 9 miles North of the Junction of 30 & 75 in Pipestone or 10 miles South or the Junction of 14 & 75 in Lake Benton to 191st Street, 2 miles East on 191st St and ½ mile North on 100th Ave

Holland inclement weather site:
Fountain Prairie Town Hall 2092 110th Ave

PROGRAM

Welcome with refreshments

- **Jeff Strock** – Soil Scientist Southwest Research and Outreach Center
  Results of Research in the Holland and Verdi area on Nitrogen Best Management Practices

- **Michael Russell** - USDA Soil Scientist & U of M Adjunct Professor
  Results of current research on efforts to improve ground water quality using perennial forage

- **Lincoln and Pipestone County Program Updates**

A credits applied for

WATER QUALITY PROTECTION MEETING

The University of Minnesota along with the Pipestone and Lincoln County Extension Service, the Legislative Commission on Minnesota Resources (LCMR) and the Minnesota Department of Agriculture will hold an afternoon meeting to discuss results of research and other projects conducted in the Verdi and Holland areas in 2000. Topics covered will be results of the U of M nitrogen management research, MPCA groundwater monitoring and assement program in the Verdi area, and Lincoln and Pipestone County programs to protect groundwater and surface water quality in the area.

WEDNESDAY MARCH 14, 2001 1:30 PM

LAKE BENTON COMMUNITY CENTER: Benton St. Downtown Lake Benton

1:30 WELCOME: KAREN OSTLIE: Lincoln County Extension Educator

1:35 MIKE SCHMITT: U OF M EXTENSION SOIL SCIENTIST, SOIL FERTILITY

Results of research in the Holland and Verdi areas in 2000 on Nitrogen Best Management Practices

2:20 JEFF STROCK: Soil Scientist, Southwest Research and Outreach Center

SWROC Research results in the Holland and Verdi Well field protection area

2:40 MICHAEL RUSSELLE: USDA Soil Scientist and U of M Adjunct Professor

Results of current research on efforts to improve ground water quality using perennial forages.

3:00 Coffee break

3:10 MODERATOR PHILLIP BERG: Pipestone County Extension Educator

3:10 ERIN EID: MPCA Ground Water Monitoring and Assessment Program

Results of ground and surface water monitoring in the Verdi Wellhead Protection area

3:30 JERRY PURDIN: NRCS PIPESTONE COUNTY

Pipestone County 319 grant program in the Holland Wellfield Protection area

3:40 LINCOLN COUNTY UPDATE

Appendix 6- Affiliated Grants

- Continued Funding Support from the Lincoln Pipestone Rural Water System

- Lincoln County-EQIP Funding Proposal for the Verdi Wellhead Protection Area Project

- 319 Funding: Wellhead Management for the Holland and Edgerton Wellhead Protection Areas

6-15-01 As presented to LPRWS

Lincoln Pipestone Wellhead Protection Research, Education and Nutrient Management Project Agreement between Lincoln Pipestone Rural Water System and University of Minnesota partners (SWROC; Mike Schmitt-Department of Soil, Water and Climate; and Michael Russelle-USDA-ARS through Dept. of Soil, Water, and Climate)

General Project Efforts:

UNIVERSITY OF MINNESOTA--Southwest Research and Outreach Center (SWROC): Provide technical assistance to farmers in the Verdi and Holland Wellhead Protection Areas including the development and evaluation of approved nutrient management plans, educational programs and targeted training programs.

University of Minnesota – Department Of Soil, Water, And Climate (Mike Schmitt, contact/coordinator): Conduct research to validate and/or refine existing Best Management Practices for nitrogen fertilizer and manure management specific for soils, geologic conditions and cropping systems in groundwater sensitive areas of Southwest Minnesota.

United States Department of Agriculture - Agricultural Research Service – (Michael Russelle, contact/coordinator): Determine the effectiveness of "phytofiltration" of high nitrate groundwater by irrigating perennial forages (alfalfa, bromegrass and orchardgrass) to improve groundwater quality and of perennial CRP plantings to prevent water quality degradation.

Work Plans:

__Southwest Research and Outreach Center:__

1. Design and implement whole-farm nutrient management plans for farms within the Verdi and Holland wellhead protection areas (NRCS will provide EQIP cost share incentives in Lincoln County and a 319 grant will provide the cost share incentive for the Pipestone County program). It is anticipated a total of 35 plans will be completed for farmers in the Holland and Verdi wellhead protection areas. Currently there are 18 plans in progress in Lincoln County.

2. As needed coordinate with and assist other agencies in the wellhead protection effort.

3. Assist in the communication, coordination, implementation, and data collection for Dept. of Soil, Water, and Climate and USDA-ARS personnel with their research projects.

4. Organize education efforts on Nitrogen management and related topics for producers and agricultural professionals in Pipestone and Lincoln Counties though educational meetings and news articles.

University of Minnesota - Mike Schmitt:

Objective/Result 1:

Increase N management educational activities in the sensitive areas of southwest Minnesota. By using outreach methods such as demonstration sites, field days, grower meetings, and farm visits, awareness of the concerns and learning of possible alternative strategies will be conveyed. These outreach efforts will occur throughout the duration of this extended project.

Objective/Result 2:

Conduct continued research to evaluate existing Best Management Practices for nitrogen fertilizer and manure management specific for soils, geologic conditions and cropping systems in groundwater sensitive areas. This will entail plotwork at three locations each growing season in the area. Factors such as N sources, rates, and time of application will be continued and measuring soil factors such as inorganic N levels and crop factors such as yield and nutrient recovery as dependent variables. Plotwork will continue for an additional two growing seasons. Soil sampling will occur through the growing season of 2003; at which time plant N uptake and yields will be measured. Data will be compiled and summarized at the end of the project.

USDA-ARS (through the University of Minnesota Dept. of Soil, Water, and Climate)- Michael Russelle:

1. Conduct field research near Pipestone to evaluate use of phytofiltration to remediate water that contains excessive nitrate. Field research involves irrigating three perennial forage species with water containing about 25 mg nitrate-N per liter (25 ppm), measurement of forage yield, total-N and nitrate-N content, inorganic N distribution in the soil, soil solution nitrate concentrations, and ground water quality. These results will help the water system evaluate whether phytofiltration can be used to reduce maintenance costs at the treatment facility in the Holland wellfield and to prevent the need for such a facility in the Verdi wellhead protection zone.

2. Evaluate the likely effects of CRP acres on nitrate losses in parts of the Holland and Verdi wellfields using computer simulation modeling and GIS (geographic information systems) mapping. This research will help target plantings of perennials like switchgrass to soils in the wellhead protection zones that will produce the best water quality outcome.

3. Participate in local educational activities, including presentations at winter meetings to relate results of research and submission of articles for the project newsletter.

Project timeline: July 1, 2001 to September 1, 2003

Project cost:

Southwest Research and Outreach Center: $25,000.00 total cost to be gifted to the Southwest Research and Outreach Center as an unrestricted gift for these expenses.

University of Minnesota - Mike Schmitt: $19,250 total cost to be gifted to the Southwest Research and Outreach Center as an unrestricted gift for expenses associated with the plotwork (treatment implementation, sampling, analysis, supplies, travel) to be conducted.

United States Department of Agriculture - Agricultural Research Service - Michael Russelle: $15,000 total cost to be gifted to the Southwest Research and Outreach Center as an unrestricted gift for these expenses.

Funding Logistics:

LPRWS can gift these funds quarterly. SWROC will handle funds for all project components.

JOINT VENTURE BETWEEN THE NATURAL RESOURCES CONSERVATION SERVICE AND THE LINCOLN SOIL AND WATER CONSERVATION DISTRICT

DATE: June 25, 1998

TO: William Hunt, NRCS, Chief

FROM: Dennis Johnson, NRCS and Pauline Moen, Lincoln SWCD

RE: EQIP Grant Proposal-Verdi Wellhead Protection Area Project

Enclosed please find the EQIP Grant Proposal for the Verdi Wellhead Protection Area Project. This grant proposal is being submitted as a joint venture between the NRCS and the Lincoln SWCD. Along with the grant application are letters of support from the Local Work Group (4 agencies), Lincoln-Pipestone Rural Water System and the Minnesota Department of Agriculture. Also attached to the grant proposal is a map showing the location of our project.

The Lincoln County Local Work Group has discussed the importance of protecting our Rural Water System. By developing specific plans and implementing conservation practices, nitrate levels would be improved in our drinking water supply by reducing the nutrients and sediments that enter the aquifer area from the watershed that flows into the Verdi Wellhead Protection Area. This project is important not only to those in Lincoln County, but to all those individuals, communities, and towns that the Rural Water System supplies water. We are concerned with the condition of our natural resources and would like to see this proposed area treated to enhance and protect our valuable water resources.

If you have any questions, please feel free to give either Dennis or Pauline a call at 507/694-1630. Thank you for your consideration in this matter.

Sincerely,

Dennis Johnson
Dennis Johnson,
District Conservationist
NRCS

Pauline Moen
Pauline Moen,
District Manager
Lincoln SWCD

Attachments and Enclosures

cc/Tim Koehler, NRCS, St. Paul
cc/Mike Nienabar, NRCS, Marshall

LINCOLN COUNTY-EQIP FUNDING PROPOSAL VERDI WELLHEAD PROTECTION AREA PROJECT

1. **Proposal Definition:** Our proposal area is the watershed that flows into the Verdi Wellhead Protection Area (one of three wells which supply water to the Lincoln-Pipestone Rural Water System). The proposal area is 10,240 acres in total size which includes approximately 640 acres in Pipestone County. The Verdi Well Field Area is located in the southwest part of Lincoln County in the Big Sioux Watershed. The aquifer which the Verdi well fields are located on is Spring Creek which drains to the Big Sioux River and thence to the Missouri River. We will focus on the entire watershed of this aquifer. It is the intent to protect the Spring Creek Aquifer by which the Lincoln-Pipestone Rural Water System is located in Lincoln County. The aquifer itself occurs near the land surface in a band about one quarter of a mile on either side of Spring Creek in an area that begins about one mile east of the well field to several miles up stream. Near the well field, this area is much broader and extends to about one mile south of Spring Creek. Data provided by the South Dakota Geological Survey indicate that the aquifer occurs as a sand plain (termed the Big Sioux Aquifer) to the west although locally, it is covered by loess or a thin cover of clay-rich till.

   Proposal Name: Verdi Wellhead Protection Area Project
   Lincoln County, Minnesota

   Proposal Contact (s): Pauline Moen, Lincoln SWCD and/or Dennis Johnson, NRCS
   P.O. Box 32, Ivanhoe, MN 56142 Phone: 507/694-1630 FAX: 507/694-1850

2. **EXECUTIVE SUMMARY:**

a. Name of proposal area: Verdi Well Field Area.

b. Problems and opportunities within the proposal area: Water quality in Southwest Minnesota is of significant concern to both private well users and public water suppliers. Aquifers in this region are often shallow and have a high potential of contamination from nitrate leaching. Deeper aquifers in this area may not be suitable for water supplies due to other contaminants such as sulfur or because of slow well recharge. Agricultural practices can be a source of contamination and adoption of environmentally sound practices can be highly beneficial in reducing contamination of the area's aquifers. Lincoln-Pipestone Rural Water pumps water from three major well fields (Verdi, Holland, and Burr). The Lincoln-Pipestone Rural Water System supplies water to over 10,000 individuals in Southwest Minnesota. During the summer of 1997, water supplied to some of its customers exceeded 10 parts per million nitrate level (the U.S. Environmental Protection Agency recommended allowable limit for nitrate in drinking water).[1] The dependence on the rural water system is partially related to the elevated mineral content of the region's ground water and to historically high nitrate levels in many private wells. The shallow depth of the wells of the Verdi Well Field makes them extremely susceptible to contamination from land use activities occurring outside as well as within the County's boundaries. Additionally, most individuals served by the water system lack a dependable backup source of drinking water. This makes protection of the system's well field and recharge zone of critical importance. Land use that effect the quality of water in ground water recharge areas should be controlled to minimize detrimental effects to the ground water. The ground water used as potable water and its recharge area should be considered highly sensitive and protected areas. Surface water that recharges the ground water should be kept as pollution free as possible, and buried contaminants should be kept away from current and potential future water supplies.

c. Objectives of the proposal: Provide cost-share incentive payments to develop and follow through with sound nutrient management and pest management plans. By installing and adopting environmentally sound best management practices in this wellhead area, the benefits will enhance and protect the rural water system for all involved.

d. Natural resource synopsis (appropriate soil, water, air, plant, and animal current conditions in the proposal area): The Lincoln-Pipestone Rural Water System District operates five wells in the Verdi Well Field which range in depth from 57 to 69 feet and pump from a sand and gravel aquifer that may exhibit semi-confined to unconfined hydraulic conditions depending on the local geological setting. Construction records for wells 1 through 4 report that between 9 to 35 feet of "clay" overly the aquifer. Some of this cover is likely to be loess rather than clay-rich till. Also, the water table occurs near the stratigraphic base of this "clay" so any till layer present has little ability to serve as a confined layer because it is dewatered and likely to be highly fractured. The aquifer is reportedly covered by 40 feet of "clay" at the site of well number 5. Here, there may be a greater thickness of water saturated clay-rich till because

[1] This information is taken from the Technical Committee Report to The Interagency Steering Committee-Regarding Management of Nitrate Nitrogen Sources for the Holland and Verdi Well Fields, Dated December 9, 1997.

the water table occurs at a higher elevation. As a result, the aquifer may be exhibit a greater degree of hydraulic confinement.[2]

e. Economic and social factors (appropriate in the proposal area): Approximately 80% of Lincoln County residents rely on this Verdi well system for their water supplies along with 14 towns surrounding Lincoln County. This water system is a full, partial or backup source for eight counties (Lincoln, Pipestone, Lyon, Yellow Medicine, Rock, Nobles, Murray and Lac qui Parle) and ten other towns. All of the municipalities in Lincoln County are served by this rural water system. There has been a rapid expansion of intensive livestock production facilities in the region. Spreading the manure is of great concern. Currently, some of the fields were manure is to be applied are within a mile of the Verdi well field. MDA indicates that commercial forms of fertilizer are being over applied. Proper nutrient management is a primary goal for this proposal.

f. Proposed solutions of the proposal: Apply agronomic rates of fertilizers by designing whole farm nutrient management plans and pest management plans for all farms within the wellhead protection zone and begin implementation of these plans. Disseminate educational materials to improve the understanding of nutrient management planning.

g. Expected results of the proposal: A combination of best management practices would reduce the nitrate levels in the drinking water produced at the Verdi well field to safe standards.

3. Natural Resource Concerns:
Our primary resource concerns are as follows: 1) Water - Ground Water Quality - Nutrients; and 2) WATER - Ground Water Quality - Pesticides.

Our secondary concerns are as follows: 1) WATER - Surface Water Quality - Nutrients; 2) WATER - Surface Water Quality - Pesticides; and 3) SOILS - Soil Quality - Excessive sheet/rill erosion.

Water quality in Southwest Minnesota is of significant concern to both private well users and public water suppliers. Aquifers in this region are often shallow and have a high potential of contamination from nitrate leaching. Deeper aquifers in this area may not be suitable for water supplies due to other contaminants such as sulfur or because of slow well recharge. Agricultural practices can be a source of contamination and adoption of environmentally sound practices can be high beneficial in reducing contamination of the area's aquifers. In September of 1997 a steering committee was formed to address water quality problems in Southwest Minnesota. Agencies involved in the steering committee included the Department of Health, Department of Natural resources, Board of Water and Soil Resources, Pollution Control Agency and the Department of Agriculture. The steering committee then brought together a technical committee to determine sources of pollution in ground water, specifically nitrate, and to determine possible solutions or preventive actions. One of the first actions of the technical committee was to address nitrate problems of a specific public water supplier. Lincoln-Pipestone Rural Water supplies water to over 10,000 individuals in Southwest Minnesota. During the summer of 1997, water supplied to some of its customers exceeded 10 parts per million (the U.S. Environmental Protection Agency recommended allowable limit for nitrate in drinking water). Nitrate levels in the Verdi well fields have been over 5 parts per million during the past year. One of the first actions taken by the technical committee was to interview farmers in the potential recharge area of the well fields.

Twenty-two farmers were interviewed in the Spring Creek Watershed in September of 1997, in which a total of 6,364 acres of farmland were inventoried. Farm interviews covered over 80% of all agricultural acres in the watershed. A total of 264,000 lbs of nitrogen were applied to the crops in the form of commercial fertilizer for the 1997 crop season. Corn acres received 255,000 lbs of commercial fertilizer or 96% of all fertilizer nitrogen. An additional 7,000 lbs of nitrogen were contributed through manure for a total of 262,000 lbs of nitrogen applied to all corn acres. All acres received nitrogen either in the form of commercial nitrogen or manure. Most corn acres, 2,020 (87%), were corn following soybeans. Timing of N fertilizer applications is an important consideration in maximizing fertilizer use efficiency and minimizing environmental effects. The corn yield goal across all farms was 133 bushels per acre on an average field. University of Minnesota N recommendations (based on yield goal, crop history, and soil organic matter level) were compared to actual amounts of fertilizer and manure applied to each field. Approximately 1,350 acres had soil tests with soil organic matter data. The average field had 3.8% organic matter and 88% of all fields were in the medium to high range (greater than 3%) in regard to organic matter. University of Minnesota N recommendations to fulfill this goal averaged 92 lb/N/A. Actual amounts of N applied from commercial fertilizer and manure averaged 109 lb N/A and 3 lb/A respectively across all corn acres. Factoring in all appropriate credits from

[2] This information is taken from the Technical Committee Report to The Interagency Steering Committee-Regarding Management of Nitrate Nitrogen Sources for the Holland and Verdi Well Fields, Dated December 9, 1997.

fertilizer, legumes and manures, there was an over-application of 20 lb/N/A.[3] Considering a new swine feedlot was built on aquifer area, the amount of N from manure could very easily increase.

4. Natural Resource Goals:
The following information is taken from Technical Committee Report to The Interagency Steering Committee-Regarding Management of Nitrate Nitrogen Sources for the Holland and Verdi Well Fields:

Factoring in legume N credits and manure N inputs into the process on a field-by-field basis, the amounts in excess of 1997 UM recommendations are illustrated below. One of the huge advantages of the technique developed through the nutrient assessment process is the ability to examine in great detain the nutrient balances and make some inferences on where the biggest gains in water quality can be obtained through focused educational programs.

Excess Nitrogen on Corn Acres

Crop Rotation	Total Acres	Excess Acres	Excess N Average lb/A	Excess N Total lb
Corn/Soybeans	1,990	1,984	20	40,219
Continuos Corn	195	195	45	7,900
Other	135	46	49	2,178
Totals	2,320	2,225	23 Avg.	50,297

Ninety-five (95%) of the total corn acres were classified into the Excess category. Over-application of N averaged 23 lb/A across all acres in this category. However, only 789 (34%) acres of corn were applied with N in excess of 30 lbs/A of the UM recommendations. Reduction of nitrogen on all acres to the maximum recommended by the UM would reduce 50,000 of lbs nitrogen from the farmers interviewed and including 650 acres of corn not in the survey process, an additional 13,000 lbs of nitrogen could be reduced for a total of 63,000 lb reduction of nitrogen for Spring Creek watershed. UM recommendations are based on economic factors, so the reductions in N should lead to substantial savings with little or no yield loss to many of the farmers in the Spring Creek watershed.

Below are the selected goals for this watershed:

<u>The goals for protecting the primary resource concerns includes:</u>

1. Develop and complete nutrient management on 3,380 acres (33% of cropland within the wellhead area). 3,380 acres @ $4.50/ac. = $15,210.00/yr. Figuring $15,210.00 over a three year period would be a total request of $45,630.00 (for three years). We plan on working with 1/3 of the acres (landowners) per year for three years.

2. Develop and complete waste utilization plans on 3,380 acres (33% of cropland within the wellhead area). 3,380 acres @ $4.50/ac. = $15,210.00/yr. Figuring $15,210.00 over a three year period would be a total request of $45,630.00 (for three years). We plan on working with 1/3 of the acres (landowners) per year for three years.

3. Develop and complete pest management plans on 1,024 acres (10% cropland within the wellhead area). 1,024 acres @ $5.50/ac. = $5,632.00. Figuring $5,632.00 over a three year period would be a total request of $16,896.00 (for three years). We plan on working with 1/3 of the acres (landowners) per year for three years.

<u>The goals for protecting the secondary concerns includes:</u>

1. Enroll 40,000 feet of Conservation Reserve Program filter-strips within the area. No EQIP dollars will need to be requested to complete this goal. For 40,000 feet of filter strips the cost is $6,400.00/yr. Over a 10 year period the total cost is $64,000.00.

2. Develop and complete residue management plans on 1,024 acres. At $7.00/ac. = $7,168.00. Figuring $7,168.00 over a three year period would be a total request of $21,504.00 (for three years). We plan on working with 1/3 of the acres (landowners) per year for three years. We will also work with the landowners on crop rotation.

3. Develop and complete 10 acres of grassed waterways. (9,000 feet @ $3.50/ft.) = $31,500.00. $31,500.00 @ 75% = $23,625.00.

4. Install 10 water and sediment control basins. (average cost is $2,500/basin). $2,500 @ 10 basins = $25,000.00 @ 75% = $18,750.00.

[3] This information is taken from the Technical Committee Report to The Interagency Steering Committee-Regarding Management of Nitrate Nitrogen Sources for the Holland and Verdi Well Fields, Dated December 9, 1997.

5. Monitoring and Evaluation Plan:
By developing the specific plans and installing the conservation practices with individual landowners as listed above will reduce the nitrate level in our drinking water supply. Installing the conservation practices will initially reduce the sediment and nutrient load going into surface water. Samples will continue to be collected by the Lincoln-Pipestone Rural Water System for accurate nitrate levels in the Verdi Well Field wells. The Technical Committee will also evaluate the likelihood of success regarding nitrogen management strategies for the well field.

6. SIZE AND SCOPE:
The Verdi Wellhead Protection Area is 12,160 acres in total size.
Total Area of Federal Portion of Proposal: 0 acres
Total Area of Nonfederal Portion of Proposal: 12,160 acres
Total Area of Tribal Portion of Proposal: 0 acres
Cultivated Cropland: 10,800 acres
Pastureland: 1,100 acres
Other Non Urban Land: 260 acres

7. LOCATION:
The Verdi Well Field Protection Area is located in Lincoln County, Minnesota.
The congressional district number is 21B.
Hydrologic unit delineation number is 10170202.
FIP Code number is 27081.

8. EQIP RESOURCES REQUESTED BY YEAR:
We are requesting the following to be encumbered in 1999:
Financial Assistance: ~~$93,710.00~~ ← I called change third 85595.02
Education Assistance: $ 4,000.00
Technical Assistance: $ 0

The Financial Assistance breakdown over the three years providing the funds are encumbered the first year (1999) are as follows:
FY1999-~~$93,710.00~~ 85595.02
FY2000-$51,335.00 43220
FY2001-$51,335.00 43220

9. PARTNERSHIP CONTRIBUTION AND PARTICIPATION INFORMATION:
A Technical Committee was formed to develop a Wellhead Protection Plan. This Technical Committee met to 1) review technical information and assess the potential sources of nitrogen and 2) develop a methodology for addressing nitrogen sources that impact drinking water supplies in the Holland and Verdi well fields operated by the Lincoln-Pipestone Rural Water Supply District. They expanded there charge to 1) characterize the hydrogeology and nitrate concentrations in surface and groundwater for the two well fields (Verdi and Holland), 2) assess the sources of nitrogen which may be impacting water supply wells, 3) assess management tools for reducing nitrate levels, and 4) evaluate the likelihood of success regarding nitrogen management strategies for the two well fields. The following agency staff served on this Technical Committee: Denton Bruening, MDA; Jay Frischman, MN DNR; Elizabeth Gelbmann, MPCA; James Japps, MN DNR; Eric Mohring, BWSR; Bruce Montgomery, MDA; Arthur Persons, MDH; Michael Trojan, MPCA and David Wall, MPCA.

A Lincoln-Pipestone Wellhead Protection Committee was formed in January 12, 1998. This committee was set up to develop the Well Protection Plan for the Verdi Wellhead Protection Area. The following agencies/people serve on this committee: Marlin Thompson, Mayor of Lake Benton; Glenn Krog, Farmer; Dennis Johnson, NRCS-Lincoln County; Dale Sterzinger, Lincoln SWCD; J. David Fruechte, Farmer; John Biren, Pipestone Planning and Zoning & SWCD; Jerry Purdin, NRCS-Pipestone County; Eric Petersen, Pipestone County Commissioner; Donald Evers, Director-Lincoln Pipestone Rural Water; Bruce Olsen, MDH; David Norgaard, Lincoln County Commissioner; Jay Gilbertson, East Dakota Water Development District (SD); Conrad Schardin, Verdi Township Chairman; Willie Langholz, Pipestone Vet Clinic; Joe Weber, Chairman-Lincoln Pipestone Rural Water and Rod Spronk, Lincoln-Pipestone Rural Water.

An important partnership is the Minnesota Department of Agriculture. Department of Agriculture has submitted an LCMR request to the state legislature for $400,000. Part of this request includes providing $50,000 to hire an employee to assist the NRCS with nutrient management plans in both Lincoln and Pipestone Counties beginning in FY99. Our contact person on this information is Denton Bruening and Bruce Montgomery of the Minnesota Department of Agriculture. Bruce Montgomery can be reached at 612-297-7178 and Denton Bruening can be reached at 612-297-4400. If the LCMR proposal fails, MDA has a backup person (recently hired-out of the Marshall, MN area) who may be able to work with the management plans.

Other agencies involvement includes:

- NRCS-will provide technical assistance to install and design best management practices as needed, provide education of ecological practices such as Integrated Crop Management and Ag Waste Utilization, and implementation of CRP filter strips.
- Lincoln Soil and Water Conservation District-will provide technical assistance to install and design best management practices along with education, promotion and landowner contact.
- Farm Service Agency-will administer cost-share funds and participate in the Local Work Group meetings.
- Extension Office-will provide education and promotion.

10. LOCAL WORKGROUP AND PRODUCER PARTICIPATION:

Local Work Group-consists of the following agencies: NRCS, Lincoln SWCD, FSA, Lac qui Parle River Watershed District, Redwood Cottonwood Rivers Control Area, Yellow Medicine River Watershed District, Lincoln-Pipestone Rural Water System, Lincoln County Water Management Task Force, USFWS, and the Lincoln County Commissioners-decided on priority areas in the County. Each representative listed above also serves on other committees in which the EQIP projects have been discussed and approved. The four agencies: FSA, NRCS, MN Extension Service, and the Lincoln SWCD were all involved in the development of this grant proposal.

As listed above, the Lincoln-Pipestone Wellhead Protection Committee will help in the application process. The local work group will continue to discuss future EQIP proposals.

Local producers serve on the Lincoln-Pipestone Wellhead Protection Committee and have indicated a need for management practices that would reduce nutrients and pesticides in ground water.

11. PROPOSAL OUTCOMES:

The top five outcomes for this proposal will be the following (from the OLPS entry option list):
WATER-Surface Water Quality-Nutrients
WATER-Surface Water Quality-Pesticides
WATER-Ground Water Quality-Nutrients
WATER-Ground Water Quality-Pesticides
SOILS-Soil Quality-Excessive sheet/rill erosion

12. CONSERVATION PRACTICES:

Resource Management System:	Amount	Total Cost	Amount Requested
Nutrient Management Plans	3,380 acres	$45,630.00	$15,210.00
Waste Utilization Plans	3,380 acres	$45,630.00	$15,210.00
Pest Management Plans	1,024 acres	$16,896.00	$5,632.00
CRP Filter Strips/buffers (10 years)	40,000 feet	$64,000.00	$0.00
Residue Management Plans	1,216 acres	$21,504.00	$7,168.00
Grassed Waterways	10 acres	$31,000.00	$23,625.00
Water & Sediment Control Basins	10 basins	$25,000.00	$18,750.00
TOTALS		**$249,660.00**	**$85,595.00**

The Nutrient Management Plans, Waste Utilization Plans, Pest Management Plans and Residue Management Plans will be done over a three year period. We will work with 1/3 of the total acres per year over the three year period.

Technical assistance will be available through the MDA, NRCS and SWCD.

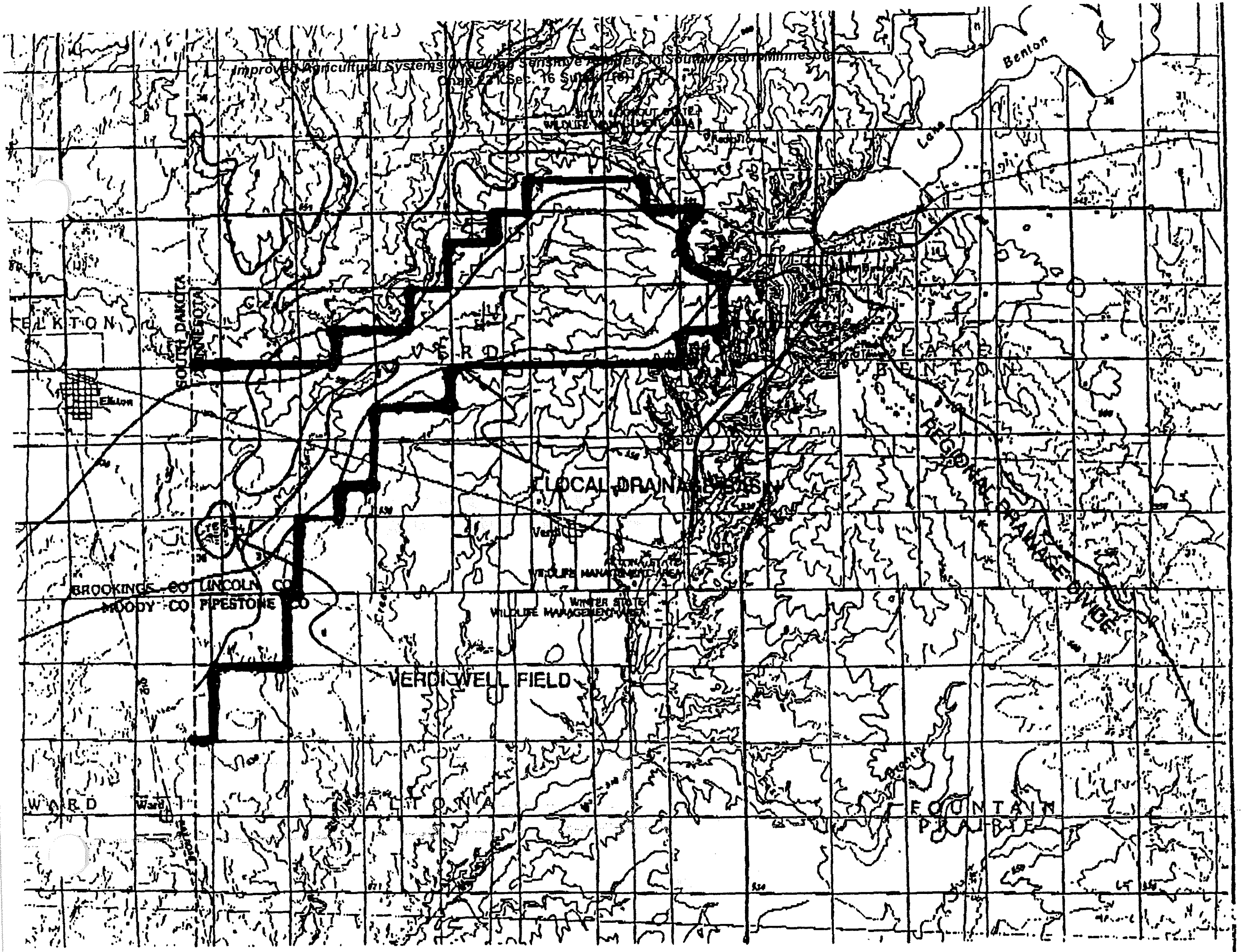
13. LANDUSER PARTICIPATION AND CIVIL RIGHTS IMPACTS:

Landuser Participation in the Proposal Area:
Our landusers consist of 100% white American, with approximately 85% being of male gender and 15% female gender.

By Race and Ethnic Group	Total Customers		Total Expected Participants	
	Male	Female	Male	Female
White (and not of Hispanic origin)	102	24	21	4

This is our only race and ethnic Group

There were some very positive findings from the interviews done by the MDA. There is strong evidence that producers are voluntarily adopting the educational materials and strategies developed by the UM. It is also evident that promotional activities need to continue and be specifically targeted to deliver the most recent technology and recommendations. Soybeans crediting is an area where there is a strong need for more education in this study area. Strong similarities exist in all existing FANMAP projects; producers are generally managing commercial N inputs successfully (although frequently using outdated recommendations) but continually under-estimate the N credits associated with manure and legume inputs.



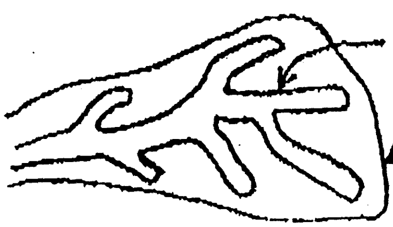
VERDI WELL FIELD

AQUIFER TYPE: WATER TABLE
AQUIFER MATERIAL: SAND AND GRAVEL

Verdi Wellhead Protection Area

EXPLANATION

LOCATION OF THE VERDI WELL FIELD



APPROXIMATE EXTENT OF THE AQUIFER MATERIALS

APPROXIMATE SIZE OF THE LOCAL DRAINAGE BASIN

SOURCES

BASE MAP USGS 1:100,000 scale topographic map, contour interval is [illegible]
DATA Files of LPRW and B.A. Liesch Associates
Various publications, reports and test hole logs provided by the USGS, MGS, MN DNR, SD DENR

B. A. LIESCH ASSOCIATES, INC.	LINCOLN PIPESTONE RURAL WATER
	VERDI WELL FIELD

TOTAL P.09

319 Grant Application

April 27, 1999

Part 1

1. Name of Project

Wellhead Management for the Holland and Edgerton Wellhead Protection Areas

If funded this proposal will control identified nonpoint sources of ground and surface water pollution over the sensitive wellhead protection areas of the Holland well field and the Edgerton well field.

2. Responsible Party

John Biren
Conservation and Zoning Administrator
Pipestone County
119 2nd Ave SW Suite 13
Pipestone MN 56164
(507) 825-6765

3. Cooperating organizations: (Feel free to call any of the following to discuss their role with the project.)

Pipestone Soil and Water
Conservation District
LeRoy Stensgaard (507) 658-3681

City of Edgerton
Public Works Director
William Vanderby (507) 442 4361

University MN Extension Service
Pipestone County
Philip Berg (507) 825-6715

MN Department of Agriculture
Soil Scientist
Bruce Montgomery (651) 297-7178

Lincoln Pipestone Rural Water
Director/Manager
Don Evers (507) 368-4248

Natural Resources Conservation Service
District Conservationist
Jerry Purdin (507) 825 5881

MN Department of Health
Special Services
Bruce Olson (651) 215-0796

University of MN Southwest State University
Soil Scientist
Neal Eash (507) 537-7380

(3. Cooperating organization continued)

MN Pollution Control Agency
Regional Basin Coordinator
Mark Hanson (507) 537-7146

MN Department of Health
Public Health Engineer
Jon Blomme (507) 537-7151

Simplot Soil Builders
Hatfield MN
Rich Sowieralski (507) 825-3311

U.S. Fish and Wildlife Services
Biological Techician
Marty Baker (507) 831-2220

Pipestone Comprehensive Water Plan
Pipestone County
Eric Peterson (507) 658-3973

MN Board of Water and Soil Resources
Board Conversationalist
Tabor Hoek (507) 537-7260

University of MN Southwest Experiment Station
Soil Scientist
Jeffrey S. Strock (507) 752-7372

Pipestone Hog Systems
Environmental Assurance Director
Willie Langholz (507) 825-4211

Mycogen Seeds
District Sales Manager
Peter A DeGreff (507) 836-6302

MN Department of Health
Source Water Protection
Terry Bovee (507) 389-6597

MN Department of DNR
Area Hydrologist
Cliff Bentley (507) 537-7258

4. Brief narrative description of project objectives

This proposal considers the wellhead protection areas of the Holland well field and the Edgerton well field. (See Attachment A) The Holland well field is one of three well fields operated by the Lincoln Pipestone Rural Water System. The Lincoln Pipestone Rural Water System supplies drinking water to 24 communities, and 2,830 farms. The Edgerton well field supplies the community of Edgerton, MN with water. Elevated nitrate levels, fecal coliform bacteria levels, ammonia levels, and a degradation of habitat to the Endangered Topeka Shiner indicate the severity of poor water quality in these areas. Documentation for these water quality problems is as follows: Testing of Nitrate levels has been on going in the Edgerton and Holland well fields. Incidentally, this testing indicates that both well fields have exceeded federal standards of ten parts per million nitrate-nitrogen. In addition, the MN Pollution Control Agency has listed Pipestone Creek and the Rock River on the final Minnesota 1998 CWA section 303(d) list. This list indicates that the Pipestone Creek exceeds the Total Maximum Daily Loading (TMDL) for fecal coliform bacteria. Intern the Rock River exceeds the Total Maximum Daily Loading for fecal coliform bacteria levels and ammonia levels. Finally, habitat degradation in these streams are impacting the Topeka Shiner which is now on the endangered list as specified under the federal Endangered Species Act. (See attachment B)

(4. Brief narrative description of project objectives continued)

In the Holland and Edgerton wellhead protection areas maintaining acceptable water quality is challenging due to thin permeable soils and shallow water tables as well as a strong surface water ground water connection. Recent studies conducted by the MN Department of Agriculture within theses areas indicate that 20-50 LB/N/A/Year from nitrogen inputs could be trimmed without yield reduction. In addition runoff from feedlots, septic systems, and farmland is suspected by initial sampling and inventory work to be a major contributor toward non-point source pollution. To control these sources of non-point pollution this grant proposes to use a combination of education and incentive payments to implement Best Management Practices (BMP's).

5. Proposed work plan

There are three components to the work plan. 1a. Acceleration of implementing Best Management Practices (BMP's). 2b.Utilize incentives to obtain proper land use changes. This will include the upgrading of Individual Onsite Sewage Treatment Systems, (ISTS) upgrading the non complying feedlots, improved residue management, and improved nutrient management. 3c. Educate the farmers in the well head protection area by continuing to involve them in sound research and demonstration plots that use proper nitrogen best management practices.

1a. Acceleration of implementing BMP's

There are many programs and initiatives that already exist which could help reduce nonpoint source pollution. These programs include the Conservation Reserve Program, in particular the buffer strip program, special Ag waste cost share, Ag BMP revolving loan fund, Pipestone County's level three feedlot inventory, LCMR work plan of Improved Agriculture Systems Overlying Sensitive Aquifers In Southwestern Minnesota, Pipestone County Comprehensive Water Plans local abandoned well sealing program, MN Pork Producers quality assurance programs, and the Environmental Quality Incentive Program. These programs are all in place and active in Pipestone County, however, to best utilize them it would be necessary to acquire additional technical assistance to make one on one contact with landowners and operators to explain and sell these existing programs. This additional assistance would result in more implementation work being completed. By hiring agronomy interns the Holland and Edgerton well fields would benefit and in addition the interns would learn how to work with BMP's during future endeavors.

1b. Milestones

By the time the 319 grant dollars are available for the 2001 cropping and construction year the Pipestone Soil and Water Conversation District (SWCD) will have hired interns to promote BMP's for the cropping and construction years of 1999 and 2000. This additional help over the course of the next three years will result in more extensive BMP implementation.

1c. Results

The results will be seen in the higher levels of participation in the fore mentioned programs. Denton Bruening at the MN Department of Agriculture in February 1998 conducted an initial Farm Nutrient Management Assessment Program (FANMAP). By conducting another FANMAP survey the hope is to see a significant increase of BMP participation that was directly promoted by the interns. Further more, progress reporting by the Pipestone SWCD and the NRCS will indicate increase in BMP participation.

2a. Utilize incentives to obtain proper land use changes This will include the upgrading of ISTS, non-complying feedlots, improved residue management, and improved nutrient management.

There are several types of land use changes and BMP's that will take more than one on one land operator contact to sell More specifically changing residue management techniques, nutrient management techniques, and upgrading non complying ISTS and non-complying feedlots presents a costly hardship that is seen by the farmers as having few guarantees concerning economic efficiency. During several wellhead protection public meetings, landowners have indicated that incentive payments are needed to reduce the risk of changing to a different residue management system or changing nutrient application amounts. In terms ISTS farmers indicated that the financial burden of installing an onsite sewage treatment system would be too much of a cost for the environmental benefit they will receive. In addition Pipestone County has adopted its first septic ordinance to address an eighty-five plus percent non-compliance rate. In the wellhead protection areas there are 75 non-complying ISTS. This grant proposal is offering incentives to bring 15 ISTS into compliance. In terms of feedlots the Pipestone County feedlot inventory has indicated 48 feedlots in the well head protection areas. 7 of these feedlots have runoff control problems. This grant will help with engineering and design costs on these seven feedlots.

2b Milestones

The incentive payment will be made available for the 2001 cropping year and construction season.

2c Results

The FANMAP survey suggests 59% of the corn acres have 30lb/A nitrogen or more applied above the University of Minnesota Recommendations. It is the hope of this project to reduce this over application on 3,000 acres or 50% of those acres over applying nitrogen by 30lb/A or more. In terms of residue management the Pipestone County residue transect survey indicate 78% of 15,000 acres in this watershed are below 30% residue cover. A realistic goal of increasing residue management on 1500 acres has been set. Although Pipestone County and the MN Pollution Control Agency have set guidelines and goals of upgrading the non complying feedlots and ISTS this grant will enhance the existing programs by focusing on these vulnerable areas of the Holland and Edgerton well head protection areas. The level 3-feedlot inventory will be completed by the year 2003. The level 3-feedlot inventory is the one that brings all feedlots in these areas into compliance. If funded this grant will help with the engineer and design cost on all feedlots that have runoff problems. The availability of ISTS professionals will dictate the number of systems

(2c Results continued)

that can be upgraded per year. A realistic goal of upgrading an additional 20% of the non-complying septic systems in these two watersheds would mean the upgrading of 15 systems during the 2001 construction season.

3a. Educate the farmers in the well head protection area by continuing to involve them in sound research and demonstration plots that use proper nitrogen BMP's. These plots will add validity for the farmers on what proper nitrogen application is to maximize economic potential while protecting the groundwater.

3b. Milestones

To build on a successful locally driven program to involve local farmers, the University of Minnesota Extension Service, and local fertilizer dealers with nitrogen based test plots that all parties involved can relate to. We have commitment from three local farmers, (Gordon Moeller, Ken Christensen, and Ron Francis), Simplot Soil Builders, The University Extension Service and the Pipestone SWCD to continue these plots for a period of up to ten years. In addition the purchase of a soil probe to be used for proper soil sampling to base nutrient management plans on will benefit many area farmers. This soil probe would be mounted on a Pipestone SWCD vehicle.

3c. Results

Will be self-evident by the participation of all parties, the knowledge that is gained, and the relationship that is built between government, farmer, and private business.

6. Budget:

Task	319 Cash	Local Cash	Local Inkind	Total
Component 1 Acceleration of implementing BMPs				
Hire Intern	$ 8,960	$ 8,960		$ 17,920

Component 2. Utilize incentives to obtain proper land use changes. This will include the upgrading of Individual Onsite Sewage Treatment Systems, (ISTS) upgrading the non complying feedlots, improved residue management, and improved nutrient management.

Task	319 Cash	Local Cash	Local Inkind	Total
Incentive Payments				
Nutrient Planning $9.00/Acre	$27,000		$5,000	$32,000
Conservation Tillage 7/Acre	$10,500		$1,500	$12,000
Feedlot (7 upgrades)	$10,000	$25,000	$25,000	$65,000
ISTS (15 upgrades)	$30,000	$30,000	$5,000	$65,000

Measuring Results

(6. Budget continued)

Transect Survey		$2,000	$2,000
Feedlot Inventory		$4,000	$4,000
City Of Edgerton Water Sampling		$500	$500
Lincoln Pipestone Water Sapling	$5,000	$2,000	$7,000
SWCD Sampling	$1,500	$4,000	$5,500

Component 3. Educate the farmers in the well head protection area by continuing to involve them in sound research and demonstration plots that use pro per nitrogen BMP's.

Task	319 Cash	Local Cash	Local Inkind	Total
Purchase Soil Probe	$ 4,000	$ 1,500	$ 1,000	$ 6,500
Test Plots	$ 2,000	$ 1,500	$ 6,000	$ 9,500
Analysis of soil samples			$5,000	$5,000

Total amount requested under this grant source $92,960.00

7. Measures of Success
In terms of the Holland wellhead protection area Lincoln Pipestone Rural Water is working with the MN Pollution Control Agency and the MN Department of Health to insure a proper sampling plan is followed. This sampling includes both surface waters of Pipestone Creek and the actual wells. This information can be compared with past histories of sampling to measure success. (See attachment B and C)

The City of Edgerton has been and will continue sampling nitrates in their well fields. These results are shared with the MN Department of Health.

In conjunction with the MN Department of Agriculture the Pipestone SWCD will continue well sampling of private wells in the two well head protection areas on at least an annual basis.

The MN Department of Agriculture will again conduct FANMAP Surveying in both well head protection areas to see changes in fertilizer application.
Property owner participation will be indicated on progress reporting that is done by both the Pipestone SWCD and the NRCS field office.

8. Yes, these are comprehensive watershed projects that have been delineated by the MN Department of Health.

9. Minnesota's Nonpoint Source Management Plan contains two chapters, which address the contents of this proposal. Chapter 4. Groundwater and Chapter 10, Agriculture Nutrients, specific recommendations can be found on these pages:

Chap 4, pg 2-5	(Role of local government, protection and management approaches, if contamination is detected)
Chap 4, pg 16	Goal 3 - Identification of geological sensitive areas Goal 4 - Increase emphasis on prevention; use several strategies Goal 5 - Evaluate impacts of contaminate source
pg 17	Goal 6 - Enhance & promote hydrologic unit-based management Goal 7 - Assist local governments with developing Wellhead Protection Goal 8 - Improve pesticide and fertilizer management
pg 18	Goal 11 - Develop methods for identifying NPS controls to project groundwater on a project-specific basis.
Chapter 10. pg 10	"The commissioner of health shallow adopt rule including establishment of wellhead protection measures for wells serving public water supplies.
pg 15	Goal 1: "Enhance the education delivery system for nutrient and crop residue best management practices and the sensitivity of water resources to nutrient contamination. Target audiences for education should include agricultural dealers, consultants, local resource managers and farmers"
pg 16	Goal 2: "Further develop and improve best management practices that minimize nutrient losses from agricultural fields and obtain information needed to understand nutrient transport to water resources and ways of reducing such losses".
pg 18	Goal 3: "To improve our understanding of the adoption of BMP's effectiveness of BMP's, and to identify priority areas through monitoring of BMP implementation and soil, surface, and ground water nutrient levels."

Part 2

10. The Holland Wellhead Protection Area is a sub watershed of the Pipestone Creek Watershed; which is in the Missouri River Basin. The Edgerton Wellhead Protection Area is a sub watershed of the Rock River Watershed; which is also part of the Missouri River Basin.

11. The Holland Wellhead Protection Area covers approximately 19,800 acres. The Edgerton Wellhead Protection Area covers approximately 900 acres.

12. The Holland Wellhead Protection Area is located at latitude; 44 07 30 longitude; 96 20 30
The Edgerton Wellhead Protection Area is located at latitude; 43 52 30 longitude; 96 07 30

13. Both the Holland Wellhead Protection Area and the Edgerton Wellhead Protection Area are priorities with the Pipestone County Comprehensive Local Water Plan. The watersheds as well as the aquifers that supply water to the wells are mentioned throughout the Comprehensive Local Water Plan. Specifics can be found from page13 through page 21.

14. Yes, diagnostic and planning work has been ongoing for many years. The Lincoln Pipestone Rural Water System, City of Edgerton, and the MN Department of Health have been sampling the wells for nitrate contamination for more than the past 10 years. In addition, the City of Edgerton has competed a Well Head Protection Plan as defined by the MN Department of Health, and the Lincoln Pipestone Rural Water System is very close to completing their plan. Other diagnostic work which has been completed includes: The MN Department of Agriculture has conducted an FANMAP survey, tillage transect surveys, feedlot inventories, random well sampling for nitrate, DNR water monitoring for water table levels, and The Department of Health facilitated scientific delineation of the well head protection areas.

15. 100 percent of the land use is agricultural.

16. There are more than 40 miles of intermitted streams found in these watersheds.

17. There are no lakes in these areas.

18. There is no coastal acreage.

19. The impaired uses are as follows: Drinking water supplied by these two well fields for communities and individuals has exceeded the national drinking water standards of 10ppm nitrate nitrogen. In addition Pipestone Creek and the Rock River have made the Total Maximum Daily Load (TMDL) for fecal coliform bacteria impairing swimming. More over, ammonia levels in the Rock River are at high enough levels to have aquatic life listed as an affected use. Both of these river systems have degradation of habitat that will impact the endangered Topeka Shiner.

20. Water quality standards violated include both surface and ground water. Concerning ground water is the federal 10ppm-nitrate nitrogen level. And for surface water are the fecal coliform and ammonia standards. (See attachment b).

21. Nitrate-nitrogen and fecal coliform will be addressed along with other pollutants that are present in surface water runoff of agricultural lands.

22. Sources of Pollutants have been identified as feedlots, ISTS, runoff of agricultural nutrients.

23. Yes, this information has been gathered by monitoring data. This monitoring data has been gathered through wellhead assessments, FANMAP surveys of the Holland and Edgerton well fields, and Pipestone County feedlot inventories, and tillage transect surveys. MPCA has gathered sufficient information for listed TMDL. The MN Department of Health has monitored the ground water of both wells to indicate nitrate problems.

24. Yes, the impairment has been documented in wellhead data for both the Edgerton and Holland Well fields.

25. Estimate of pollution control to achieve water quality goals.
3000 acres of nutrient management plans
1500 acres of conservation tillage
7 feedlot upgrades
15 ISTS upgrades
900 acres of CRP Bufferstrip and Continuos

26. The following BMP's will be implemented:
1. All State wide BMP's that address compliance to the MPCA 7020 feedlot rules, and MPCA 7080 septic rules:
2. Applicable NRCS Technical Standards Including:
   a) 590-Nutrient Management
   b) 633-Ag Waste Utilization
   c) 595-Pest Management
   d) 329-Residue Management
   e) 638-Water and Sediment Control Basins
   f) 412-Grass Waterways

27. Estimated cost for BMP's $77,500.00.

28. There will be several types of on going monitoring. Most significant indicator of success will be ground water monitoring as required by the MN Department of Health.

29. Monitoring program elements to be used include:
Biological - Fecal Coliform (Surface Water)
Chemical/Physical-Nitrate - (Surface Ground \water)

30. Funding requested from 319 Grant Program:

BMP Implementation	$78,000
Monitoring	$0
Project Management	$0
Public Education	$2,000
Soil Probe	$4,000
Interns Technical Assistance	$8,960

Total 319 contribution $92,960.00

Appendix 7-Groundwater Monitoring Network

MN Pollution Control Agency "Ground Water Monitoring in the Verdi Wellhead Protection Area-2000 Annual Report", March, 2001

GROUND WATER MONITORING IN THE VERDI WELLHEAD PROTECTION AREA – 2000 ANNUAL REPORT

Minnesota Pollution Control Agency

Prepared by the Ground Water Monitoring and Assessment Program

March, 2001

Abstract

The Verdi well field, in Lincoln County, Minnesota, supplies drinking water to a large area in Southwestern Minnesota. The aquifer in which the well field is completed has a history of elevated nitrate concentrations. Unfortunately, there is insufficient information to determine time trends in concentration, making it impossible to evaluate potential health risks to people consuming water from the aquifer.

In 1999 and 2000, the Minnesota Pollution Control Agency established a ground water monitoring network in the Verdi Wellhead Protection Area. The primary objective of the study is to evaluate long-term impacts of agricultural management practices on ground water quality. The monitoring network includes ten monitoring wells, five public supply wells, and five surface water sampling locations. Sampling included discharge measurements in Spring Creek, water level measurements in monitoring wells, measurement of stable isotope concentrations in monitoring wells, and sampling for nitrate, chloride, pesticides, and other inorganic chemicals.

The Southwest Research and Outreach Center, University of Minnesota, Agricultural Research Service, Natural Resource Conservation Service, and the Soil and Water Conservation District offices have launched an aggressive education program to modify farmer behavior related to nutrient management. The Minnesota Department of Agriculture has coordinated the project through a grant provided by the Legislative Commission on Minnesota Resources.

This report summarizes monitoring efforts for 2000. We include recommendations for long-term monitoring in an Appendix. Long-term monitoring is critical for establishing baseline water quality conditions and evaluating the effectiveness of voluntary nutrient management programs.

Discharge measurements during 2000 indicate about 8 million cubic feet (60 million gallons) of water seeped through Spring Creek and presumably into underlying aquifers. Seepage primarily occurred during May and June. Seepage appeared to contribute to aquifer recharge, as indicated by changes in chloride and organic carbon concentrations in the aquifer in response to stream discharge. Results for stable isotopes indicate that recharge to the aquifer may be rapid since there was no evidence of fractionation of ground water and there were distinctly different temperature signatures in ground water for the spring and summer sampling events.

Nitrate concentrations in the aquifer increased from north to south. Nitrate concentrations were correlated with Eh and chloride in monitoring wells but not in public supply wells. Two wells contained detectable concentrations of pesticides. The source of pesticide may be surface water seepage, since pesticides were detected in samples from Spring Creek.

Based upon results from sampling in 2000, we recommend the following activities:

- consolidate the monitoring network;
- continue sampling monitoring wells;
- continue monitoring stream discharge; and
- identify mechanisms of recharge.
-

We recommend quarterly sampling for nitrate, chloride, dissolved oxygen, Eh, and dissolved iron.

For more information, please see the following Website:

http://www.pca.state.mn.us/water/groundwater/gwmap/gw-verdi.pdf