1995 Project Abstract
For the Period Ending June 30, 1997
This project was supported by MN Future Resources Fund (MS section 116P.13)

Title: Feedlot and Manure Management Practices Assistance
Project Manager: Gerald F. Heil
Organization: Minnesota Department of Agriculture
Address: 90 West Plato Blvd., St. Paul, MN 55107
Legal Citation: M.L. 95 Chpt. 220, sect. 19, subd. 5h
Appropriation Amount: $200,000.00

Statement Of Objectives
A. Determine the impact of manure integration within a conservation tillage system on water quality. The objective secures baseline data to characterize watershed responses, as measured by nutrient and sediment runoff, to rainfall and snowmelt runoff events. Continued monitoring in the next two biennia will evaluate the response to management changes compared to established baseline data.

B. Evaluation of potential for amelioration of manure effluent utilizing constructed earthen basins.

Overall Project Results
Snowmelt is the major source of runoff, with its associated losses of nutrients (N and P) and oxygen-sink chemicals (COD) entering tile inlets. Sediment loss in the snowmelt is negligible with little practical impact. Annual soil loss in 1996 was much less than the 5.5 Mg per ha tolerable soil loss due to sediment deposition during water ponding around the tile inlets. Baseline data indicates that there were differences between the watersheds for small snowmelt runoff events. During major snowmelt runoff events, however, both watersheds behaved similarly. Baseline data for rainfall runoff between watersheds is pending, since rainfall runoff monitoring continues to this 1997 growing season. A conventional tillage treatment will be imposed on one watershed in the next biennia to capture the response of watershed to tillage change.

Dairy farms in SE Minnesota often have a strong positive nitrogen balance. Nitrogen losses to the atmosphere from manure storage are desirable if they occur through denitrification. Such losses reduce the amount of nitrogen that needs to be land applied, thereby reducing possible excess fertilization which could lead to water pollution. The occurrence and amounts of gaseous nitrogen losses from a liquid manure management system with recycled flush water were investigated on a dairy farm in Winona Co. with 150 to 165 cows. The prevailing mode of nitrogen loss was found to be ammonia volatilization. Denitrification losses were negligible. The average daily loss rate varied from 24.1 kg N per day to 43.3 kg N per day.

Project Results Use and Dissemination
The results of objective "A" will be disseminated to various audiences in the coming Tilney Farm Plot Observation Day (invitation is enclosed). These results will be disseminated along with a results from rainfall simulation study we have recently done at Tilney farm. This rainfall simulation study is treated as a projection of water quality as tillage changes from conservation to conventional tillage during rain storm. The work from this biennium on Objective A will serve as the foundation for work approved for 1998-1999. The objectives "A" and "B" will also be presented in the 1997 American Society of Agronomy meeting in Anaheim, CA (abstracts are enclosed). The results of Objective "B" are published in the Minnesota Agricultural Experiment Station Miscellaneous publication 91-1997 (article enclosed).

YOU ARE INVITED

TILNEY FARMS PLOT OBSERVATION DAY

WEDNESDAY, AUGUST 13, 1997 AT 1:30 P.M.

AT THE FARM PLOT SITE
2 ½ MILES WEST OF LEWISVILLE
ON WATONWAN COUNTY ROAD #10

AGENDA

CORN VARIETY PLOTS

SOYBEAN VARIETY PLOTS

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DISCUSSION TOPICS

JOHN HUNCZAK – PIONEER PLOT

HOG MANURE STUDY

SURFACE/TILE WATER QUALITY,
EROSION, YIELDS AND GPS
AND TILLAGE BY JOHN MONCRIEF

Water Quality of Surface Runoff Entering Tile Inlets in the Minnesota River Basin. D. GINTING*, J.F. MONCRIEF, S.C. GUPTA, Univ of Minnesota.

Direct entry of surface runoff into tile inlets in Southern Minnesota contributes to the non-point source pollution in the Minnesota River. A paired watershed study was undertaken to characterize the impact of tillage system on pollutant loading through surface inlets. In this paper, we report the baseline data on sediment, total P (TP), dissolved molybdate reactive P (DMRP) and Chemical Oxygen Demand (COD) entering tile inlets from 40 and 50-ha watersheds both during snowmelt and rainfall runoff. The watersheds were fall chisel plowed, spring field cultivated and cropped with soybean in 1995 and seed corn in 1996. Snowmelt was the main source of runoff, P and COD in both years. The TP, DMRP and COD concentration in snowmelt runoff ranged from 0.15 to 4.03, 0.001 to 1.17, and 0.35 to 140 mg L^{-1}, respectively. Rainfall runoff entering tile inlets was negligible because of low rainfall amount. Sediment load from both watersheds was small with little practical impact.

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Abstract Form — Agronomy Abstracts

American Society of Agronomy — Crop Science Society of America — Soil Science Society of America

Type one perfect copy following closely the directions below. Title-Summary no. A05003P

Abstracts Sent Via FAX or E-MAIL Are Not Accepted!

Nitrogen Losses from a Liquid Dairy Manure Management System

S.M. BRAUM*, J.F. MONCRIEF, and S.C. GUPTA, Univ. of Minnesota

Dairy farms in the Midwest often have a strongly positive nitrogen balance due to bought feed and N-fixation by alfalfa. The amounts of nitrogen losses from a liquid manure management system with two storage basins and flush water recycling were investigated on the Meyer farm in Winona Co., MN. N-losses to the atmosphere from manure storages reduce the amount of nitrogen that needs to be land applied, thereby reducing possible excess fertilization which could lead to water pollution. Such losses are desirable if they occur through denitrification. The prevailing mode of nitrogen loss was found to be ammonia volatilization. Denitrification losses were negligible, despite aeration of the second basin. The average daily loss rate varied from 24.1kg N d^{-1} to 43.3kg N d^{1}. Volatilization of NH_3 from the storage basins accounted for approximately 50% of the total nitrogen losses from the system.

S. M. Braum, (612) 625-8733, sbraum@soils.umn.edu

Mailing Address of Corresponding Author:

Title and name	Dr. Sebastian M. Braum
Department	Dept. of Soil, Water & Climate
University or other organization	University of Minnesota
Street or P.O. Box if needed	1991 Upper Buford Circle
City, State, ZIP CODE	St. Paul, MN 55108
Country	

Directions:

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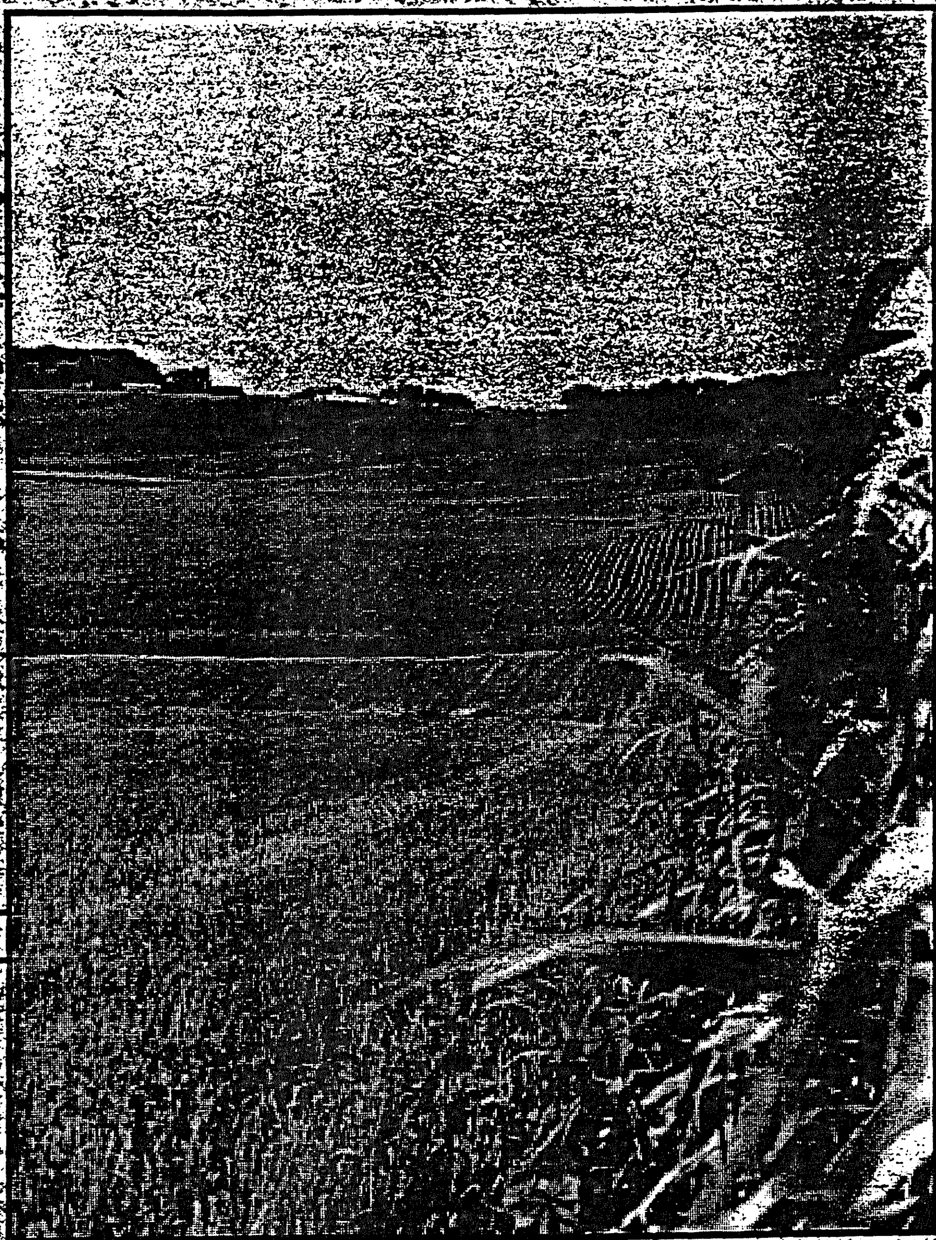
UNIVERSITY OF MINNESOTA

Field Research in Soil Science 1997



Minnesota Agricultural Experiment Station
Miscellaneous Publication 91-1997

NITROGEN CONSERVATION IN A LIQUID DAIRY MANURE MANAGEMENT SYSTEM WITH FLUSH WATER RECYCLING[1]

S. M. Braum and J. F. Moncrief[2]

Abstract:

Dairy farms in SE Minnesota often have a strongly positive nitrogen balance. Nitrogen losses to the atmosphere from manure storages are desirable if they occur through denitrification. Such losses reduce the amount of nitrogen that needs to be land applied, thereby reducing possible excess fertilization which could lead to water pollution. The occurrence and amounts of gaseous nitrogen losses from a liquid manure management system with recycled flush water were investigated on a dairy farm in Winona Co. with 150 to 165 cows. The prevailing mode of nitrogen loss was found to be ammonia volatilization. Denitrification losses were negligible. The average daily loss rate varied from 24.1kg N d^{-1} to 43.3kg N d^{-1}.

Introduction

As they do in all across the U.S., dairy herd sizes on many individual farms are increasing in SE Minnesota to maintain or increase profitability. Along with producing more milk to sell, larger herds also generate larger amounts of wastes. When confined to buildings or small outside lots, the large amounts of wastes generated require proper handling to allow continuous operation of the facilities and to prevent hygienic problems. While the economic value of nutrients in manure for crop production is still worth consideration, the potential for environmental damage from excessive amounts of these nutrients, especially N, becomes increasingly important. In cases where the imbalance between nutrient supply from manure and their removal by crops is particularly big due to excess nutrient influxes from bought feed, fertilizer or N-fixation (alfalfa), the costs of compliance may exceed the benefits derived from the wastes. The problems of nitrogen excess and possible surface and groundwater contamination are magnified for dairy farms in SE Minnesota because of the prevailing crop rotation (alfalfa, corn, soybean), the karst geology with rapid groundwater recharge and the topography of an old, highly dissected erosional land surface with steep slopes and rapid runoff.

Constructed earthen storage basins have become a widespread means of storing animal wastes. In this LCMR-funded project, we are investigating the flow and transformations of nitrogen in a waste management system on a dairy farm in Winona Co. in SE Minnesota over the course of two years. The possibility of gaseous nitrogen losses from the system during storage is of particular interest, since such losses reduce the amount of nitrogen that needs to be disposed of by land application.

Manure management systems can lose nitrogen to the atmosphere as ammonia (NH_3), nitrous oxide (N_2O), and dinitrogen (N_2). Ammonia and ammonium (NH_3, NH_4^+) are always present in manure, commonly comprising 33% of the total N in liquid manure. Several factors influence the volatilization of ammonia. Volatilization can occur anywhere liquid manure is exposed to the atmosphere; scum mats and ice covers consequently reduce ammonia volatilization. It increases with increasing pH and temperature of the liquid manure. N-losses from a manure system as nitrous oxide (N_20) and dinitrogen gas (N_2) require the existence of a nitrification-denitrification cycle. Nitrate (NO_3^-) can be generated under aerobic conditions by microbial oxidation of ammonia. If nitrate then enters into an anaerobic environment, it can be microbially reduced to nitrous oxide or dinitrogen, which are then lost from the manure to the atmosphere.

The research site is the Charles Meyer dairy farm in Winona Co. The dairy herd on the Meyer farm was 150 head in 1995, which increased to 165 in 1996. The milk yields (herd average) were 28,000lb or 12,700kg in 1995 and 27,000lb or 12,300kg in 1996. The farm operates an earthen manure storage basin with two cells. The wastes from the dairy barn and the milkhouse enter the first cell through a submerged pipe. Most of the solids are retained in the first cell, either by sinking to the bottom or by forming a floating scum mat on the surface. The liquid under the mat equilibrates with the second cell through a second submerged pipe in the dam separating the two cells. Liquid from the second cell is pumped into a storage tank and used to flush the barn, completing the cycle. The calculated combined maximum volume of the storage cells is 8,400m^3 at the specified depth of 2.44m (8ft). Due to sludge deposition, this depth is no longer available throughout the basins, somewhat reducing the actual storage volume. Twice a year, the contents of cell I are stirred up and pumped out and applied onto cropland with a traveling irrigation gun. This draws down the second basin until its level is below the connecting pipe, leaving approximately 1,054m^3 of liquid in cell II to continue flushing the barn. To avoid an overflow, liquid is pumped occasionally from the second cell for land application.

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[1]This project was funded by the Legislative Commission on Minnesota Resources

[2]S.M. Braum (postdoctoral research associate) and J.F. Moncrief (professor) are in the Dept. of Soil, Water & Climate, Univ. of Minnesota, St. Paul, MN 55108

Experimental Procedure

Manure composition: Manure samples were taken at regular intervals from both cells over the course of two refill periods from 1995 to 1996. The samples were analyzed for total N, ammonia/ammonium, nitrate, total phosphorus, pH, and total, volatile and ash solids content.

System volume determination: After Meyer farms applied manure pumped from the first cell during the first week of May 1996, 2600g of Li was added to the liquid remaining in cell II. The lithium acted as a chemical tracer. By determining the Li-concentrations in both cells over time, the mixing and turnover of cell liquids could be monitored. If complete mixing occurred, a uniform Li-concentration would establish itself. The time it took to reach uniformity throughout the storage basins was the time required for complete mixing. At that point, the Li-concentration was a direct measure of the total volume of liquid circulating through the system. The volume combined with the concentrations of N, P and K gave us the total amounts present of these nutrients. This allows us to evaluate nitrogen losses to the atmosphere as well as planning for the application of the manure as fertilizer. The Li-tracer was useful for the whole period of 167 days from emptying the cells in the spring until the emptying in the fall of 1996, when the storage was again completely full without any freeboard.

Nitrogen budgeting: For comparison with the amount of nitrogen measured in the manure storage, the amounts of nitrogen excreted over the given refill periods were calculated by subtracting the nitrogen in the milk from the nitrogen supplied by the feed ration. Feed ration amounts and analyses were kindly provided by the Meyers. In 1995, the daily ration per cow contained 677g of N and in 1996 it was 771g of N. The nitrogen content of the milk was assumed to be a constant 0.512%.

Results and Discussion

Convergence of the Li-concentration in the two cells of the storage occurred several weeks before the end of the second refill period, indicating uniform mixing (see Fig. 1). At the end of the second refill period, the lithium tracer added at its beginning minus the amount removed from cell II in August allowed us to calculate the liquid volume of the manure storage when it is completely full. The system volume was determined to be 6,711m^3, 3,229m^3 in cell I and 3,482m^3 in cell II. These values were also used in the calculations for the end of the first refill period, since the storage had been completely full then, too.

The amounts and chemical forms of nitrogen in the storage basins were monitored over the two refill periods. For both periods, comparison of the total nitrogen present in the storage at the end of the refill period to the amount that entered the system through feed indicated that substantial losses of nitrogen had occurred. The losses were calculated as follows:

10/18/1995 to 5/1/1996: 195 days of refill	
N added with feed: 150 * 195 * 0.677kg =	19.8t
N removed by milk: (12,712kg / 365) * 150 * 195 * 0.00512 =	5.2t
N excreted by the herd: 19,802kg - 5,216kg =	14.6t
N left in cell II at beginning: 1,054m^3 * 1.149kg m^{-3} =	1.2t
Potential total N in the storage: 14,586kg + 1,211kg =	15.8t
N found in storage at end: 3,229m^3 * 2.014kg m^{-3} + 3,482m^3 * 1.319kg m^{-3} =	11.1t
=> N lost: 15,797kg - 11,096kg =	4.7t

The 4.7t represents a 29.8% loss of nitrogen over the 195 days. This is an average daily loss of 24.11kg N.

5/9/1996 to 10/23/1996: 167 days of refill	
N added with feed: 165 * 167 * 0.771kg =	21.2t
N removed by milk: (12,258kg / 365) * 165 * 167 * 0.00512 =	4.7t
N excreted by the herd: 21,245kg - 4,738kg =	16.5t
N left in cell II at beginning: 1,054m^3 * 1.304kg m^{-3} =	1.4t
N removed from cell II by pumping in 8/96: 499m^3 * 2.111kg m^{-3} =	1.1t
Potential total N in the storage: 16,507kg + 1,374kg - 1,053kg =	16.8t
N found in storage at end: 3,229m^3 * 1.547kg m^{-3} + 3,482m^3 * 1.324kg m^{-3} =	9.6t
=> N lost:16,828kg - 9,605kg =	7.2t

The 7.2t represents a 42.9% loss of nitrogen over the 167 days. This is an average daily loss of 43.25kg N.

Most of the nitrogen in the manure was in the organic form. Ammoniacal nitrogen (NH_3 and NH_4^+) represented between 34% to 50% of the total N. Nitrate was detected only sporadically in very small concentrations. Since nitrification is a prerequisite for denitrification, nitrogen losses by denitrification must be assumed to have been negligible also. The pathway for nitrogen loss from the system must therefor be ammonia volatilization. At the beginning of the study it was hoped that substantial losses would occur by denitrification. Such losses are preferable to losses as ammonia because the nitrogen is then lost primarily as dinitrogen which is not available for plant uptake and therefor non-polluting. Larger amounts of nitrous oxide could be problematic because N_2O is a greenhouse gas, however, it constitutes generally only a small fraction of the nitrogen lost in denitrification. Substantial atmospheric losses as ammonia are a mixed blessing. While they certainly help reduce the amount of environmentally active nitrogen that needs to be disposed of through land application on the farm in question, such losses are actually contributions of available N to the ecosystem. Ammonia in the atmosphere can be taken up directly by plants, or it can enter the soil by precipitation or dry deposition. This leads to increased soil nitrogen and soil acidification, which are especially problematic in poorly buffered and nitrogen-limited natural ecosystems. For these reasons, ammonia in the atmosphere is considered a severe environmental problem in Europe, with emissions from livestock operations being the most important source.

The losses that occurred from the system at the Meyer farm have two possible areas of origin: the livestock buildings and the manure storage cells, because at these two locations, the manure is exposed to the atmosphere. Measurements of the ammonia volatilization from the manure storage will be made in the first half of 1997 to assess its share of the losses. We will also continue to monitor nitrogen in the system to determine if the higher rate of loss for the second refill period was due to climatic factors (summer vs. winter), or if it was caused by the installation of a more efficient aeration system in the spring of 1996in cell II.

Feedlot and Manure Management Practice Assistance

LCMR Final Report - Detailed - Research
M.L. 95, Chapter 220, Section 19, Subdiv. 5h

Department of Soil, Water and Climate
University of Minnesota

and

Minnesota Department of Agriculture

June 30, 1997

Date of Report: June 30, 1997

LCMR FINAL REPORT - Detailed - Research

I. Project Title and Project Number: Feedlot and Manure Management Practices Assistance

Program Manager: Gerald F. Heil
Minnesota Department of Agriculture
90 West Plato Blvd.
St. Paul, MN 55107
Phone: (612) 296-1486 FAX (612) 297-7678

A. Legal Citation: M.L. 95 Chpt.220, Sect.19, Subd.5h

Total Biennial LCMR Budget: $200,000

This appropriation is from the future resources fund to the commissioner of agriculture to accelerate adoption of and changes in feedlot/manure management practices through research, economic analysis and enhanced program design and delivery. $100,000 of this appropriation is for an agreement with the University of Minnesota for evaluation of effluent treatments.

B. LMIC Compatible Data Language: not applicable

C. Status of Match Requirement: not applicable

II. Project Summary: This project mitigates or prevents diffuse source pollution from feedlots/animal manure by accelerating adoption of and changes in feedlot/manure management practices and enhanced program design and delivery. This effort will include: 1) evaluation of crop response and erosive losses of potential contaminants upon integration of manure into crop residue management systems and 2) evaluation of manure handling and storage systems that convert manure nitrogen into environmentally benign forms and allow utilization of phosphorus in an environmentally sound fashion.

III. Six Month Work Program Update Summary:

IV. Statement of Objectives:
A. Impact of manure integration within a conservation tillage system on water quality.
B. Amelioration of manure utilizing constructed lagoons and wetlands.

Timeline for Completion of Objectives:

	7/95	1/96	6/96	1/97	6/97
A					xxxx
B					xxxx

V. Objectives/Outcome:

A. Title of Objective/Outcome: Impact of manure integration within a conservation tillage system on water quality. This objective will secure baseline data to characterize watershed responses to rainfall and snow melt runoff events. Based on LCMR recommendations, this objective is proposed as a six year project with continued monitoring in the next two biennia to capture the response of management changes after gathering baseline data.

A.1. Activity: Impact of manure integration within a conservation tillage system on water quality.

A.1.a. Context within the project: Computer simulations have suggested that management of crop residue will be a prominent part of a "best management practice" for reduction of diffuse source pollution from agricultural sources. Current computer models do not consider manure in the system. When solid sources of manure are incorporated with reduced tillage tools to leave residue on the surface a higher concentration of P is left in the top 8cm. What is the net effect of the P loss when sediment is reduced but the concentration of P in the sediment is higher? This question will be addressed with this objective.

A.1.b. Methods: Two paired watersheds (1-3 ha) will be established on a cooperating farmer's field. This project will be located in a high risk (pollutant loss from farming activity) area of the Minnesota River Basin. The primary criteria for site selection will be farmer cooperator interest, availability of the necessary machinery, and livestock to establish treatments, and the presence of model soils and landscapes which also present a high risk environment (poorly drained, fine textured, and steeply sloping soils). Farmer interest will be the most important criterion. A watershed will be surrounded and be isolated by a berm seeded to a perennial grass. A flume with subsampling apparatus will be positioned at the outlet of each watershed. During runoff events (rainfall and snow melt), runoff data will be collected and hydrographs constructed. Also during runoff events, "grab samples" will be taken incrementally based on runoff volume and retrieved for chemical analysis. During the first two years baseline data will be collected on the watersheds with a conventional cropping system (soluble P, bioavailable P, total P, chemical oxygen demand, and sediment).

A.1.b. Methods: (continued)
In the second and third biennium (based on availability of funds) an improved tillage system with and without manure applied will be established. This will be monitored and compared to the original watershed data.

A.1.c. Materials: Flumes and subsampling apparatus-20,000, a truck will be bought and an existing hydraulic soil sampler will be mounted on it-20,000. This is a specialized vehicle which cannot be leased. As this research needs a total of 4-6 years of data, the vehicle will be used to continue the research for the following two biennia. At the end of total project the vehicle will have little depreciable life remaining. This equipment will be the property of the University of MN after the project.

The flumes will be custom built based on the anticipated rainfall intensity and size of the watersheds chosen for the project. This equipment will be the property of the University of MN after the project for similar future projects.

A.1.d. Budget: Total Biennial LCMR Budget: 100,000

A.1.e. Timeline: **7/95** **1/96** **6/96** **1/97** **6/97**

Identify farmer cooperator xx
Establish paired watershedsxx
Collect baseline data xxxxxxxxxxxxxxxxxxxxxxxxx

B.1. Activity: Amelioration of manure effluent utilizing constructed lagoons. This objective will provide data which evaluates manure amelioration with constructed lagoons.

B.1.a. Context within the project: Due to the N inputs from nitrogen fixation by alfalfa dairy farmers with limited acreage have more N in manure than they can utilize. An alternative strategy to utilization by crops that is environmentally sound is to convert manure N into non polluting forms. This objective will evaluate a series of lagoons to convert N into non polluting forms. This will allow evaluation of cycling of N to non-polluting forms and utilization of P without environmental degradation.

B.1.b. Methods: A farmer with this manure disposal strategy has been identified. The amount and chemical forms of N in each lagoon will be monitored as the manure passes through each stage of the treatment.

The following scenario has been chosen to be evaluated: The first lagoon will be used to separate the fecal material from the urine by settling. It is anticipated that half of the N and most of the P will remain in this lagoon (associated with fecal material). The supernatant that is collected in the second lagoon will be aerated to encourage conversion from ammonium to nitrate by nitrifying bacteria and used to flush the barn daily. After returning to the first lagoon denitrification will occur under anaerobic conditions. The material in either lagoon can be land applied by prescription. Other systems with variations in the above treatment strategy may be evaluated.

B.1.c. Materials:

B.1.d. Budget: Total Biennial LCMR Budget: 100,000

B.1.e. Timeline: **7/95** **1/96** **6/96** **1/97** **6/97**

Farmer cooperator identified xx
Collect Data characterizing system xxxxxxxxxxxxxxxxx
Organized data for interpretation xxxxxxxxxxxxxx

VI. Evaluation: Each individual objective will be evaluated on how well each achieved specific research and educational goals.

VII. Context within Field: This project will coordinate with the MPCA LCMR project titled: "Water Quality Impacts of Feedlot Pollution" (h21) to ensure cooperation and complementary, non-duplicative efforts where possible. This project will also work through the Feedlot and Manure Management Advisory Committee (FMMAC) to coordinate with other manure management and utilization efforts.

Objective A will provide data that can be used to validate computer models currently being used for estimates of pollution losses due to farming activities. These data will be specific to the soil, climate, and landscape conditions of Minnesota. The assessment of the impact of farming activities on contributions of diffuse source pollutants to the River is largely based on these computer models. The data generated by this effort will provide crucial "ground truth" for these models. This effort will be unique in that the evaluation will be on a subwatershed scale rather than conventional small rectangular runoff plots.

VII. Context within Field: (continued)
Objective B will provide data that can be used to assess the effectiveness of constructed lagoons to treat manure from farms with limited land area. It is necessary to do this under the cold conditions of the Minnesota winter since most of the N transformations are the result of bacterial activity. The feasibility of this approach will be evaluation of the final product for further treatment by constructed wetlands, climatic risks, and storage costs.

VIII. Budget context: This project is a continuation of a project funded during the 1993-95 biennium.

VIII. Dissemination: The results from this project will be published in professional and popular journals. There will also be presentations at national and regional professional meetings. Recommendations derived from this project will be utilized in appropriate area of the state.

X. Time: This project will be completed in a one biennium time frame. Objective A will require an additional two to four years of research.

XI. Cooperation: Active participants cooperating include four faculty at the University of Minnesota and three specialists at the Minnesota Department of Agriculture.

A. **Dr. Sebastian M. Braum**, Soil Chemist, will be responsible for the collection of data and the evaluation of manure amelioration with constructed lagoons.

B. **Dr. H.H. Cheng**, Soil Biochemist, Soil Science Department, UM, will participate in the evaluation of treatments on N transformations.

C. **Dr. Satish C. Gupta**, Soil Physicist, Soil Science Department, UM, will provide leadership in the water flow modeling and field validation effort of the project.

D. **Dr. John F. Moncrief**, Extension Soil Scientist, Soil Science Department, UM, will advise on the field demonstrations and provide leadership in the conservation tillage/nutrient management evaluation.
E. **Dr. Mary J. Hanks**, Supervisor, Energy and Sustainable Agriculture Program, Minnesota Department of Agriculture, will have primary responsibility for supervision of the soil quality and value added research components.

F. **Dr. Dave R. Huggins**, Soil Scientist, will aid in the execution of the field research component.

G. **Mr. Gerald F. Heil**, Planning Division Director, Minnesota Department of Agriculture, will have overall project management responsibility.

H. **Mr. Steve H. Olson,** Specialist, Minnesota Department of Agriculture, will be responsible for the customer based research.

I. **Mr. Mark R. Zumwinkle**, Specialist, Minnesota Department of Agriculture, will be responsible for the soil quality investigations.

XI. Reporting Requirements: Semiannual six-month work program update reports will be submitted not later than Jan. 1, 1996, July 1, 1996, Jan. 1, 1997 and a final status report by June 30, 1997.

APPENDIX

Qualifications:

SEBASTIAN M. BRAUM

Postdoctoral Associate
Department of Soil, Water and Climate; University of Minnesota

Education:

Ph.D., May 1995, University of Wisconsin-Madison. Dissertation: Mobilization of Phosphorus and Other Mineral Nutrients by Citrate in the Rhizosphere of *Lupinus albus* L.

Diplom-Agrarbiologe, July 1990, Universität Hohenheim, Stuttgart, Germany. Thesis title: The release of Phosphate from Soils with Acid Phosphatase.

Employment:

4/3/1995 to present: Univ. of Minnesota, Dept. of Soil, Water and Climate

9/1/1990 to 3/31/1995: Graduate Research Assistant, Univ. of Wisconsin-Madison, Soil Science Dept.

Publications:

Braum, S. and P. A. Helmke. 1995. White lupin utilizes soil phosphorus that is unavailable to soybean. Plant and Soil 176, p95-100.

H. H. CHENG

Soil Science, UM
Professor and Head

Education

Berea College, Berea, KY B.A. 1956. Agricultural Science
University of Illinois, Urbana, IL M.S. 1958. Agronomy
University of Illinois, Urbana, IL Ph.D. 1961. Soil Science

Employment History

At University of Minnesota: Professor and Head, Department of Soil Science, 1989-present

At Washington State University: Professor, Department of Agronomy and Soils, 1977-89, Interim Chair 1986-87, Associate Professor 1971-77, Assistant Professor 1965-71; Chair, Program in Environmental Science and Regional Planning, 1988-89,1977-79; Associate Dean, Graduate School, 1982-86.

At Iowa State University: Assistant Professor, Department of Agronomy, 1964-65; Research Associate 1962-64.

Recent Publications (last 5 years)

Roberts, S., and H. H. Cheng. 1988. Estimation of critical nutrient range of petiole nitrate for sprinkler-irrigated potatoes. Am. Potato J. 65:119-124.

Lehmann, R. G., and H. H. Cheng. 1988. Reactivity of phenolic acids in soil and formation of oxidation products. Soil Sci. Soc. Am. J. 52:1304-1309.

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Memberships:

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American Society of Agricultural Engineers
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Selected Publications

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Ph.D., Plant Pathology, Iowa State University, Ames, May, 1980. Dissertation: Alternaria Leaf Spot of Maize. Advisor: Dr. Charlie Martinson.

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Employment History

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Publications

Fox, C.C., M.M. Rekoske, J. Magsam, M.J. Trainor and Bill Knipe. 1989. A rapid seedling test for evaluation of Phytophthora root rot resistance in alfalfa. Proceedings of the 21st Central Alfalfa Improvement Conference, July, 1989.

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Membership in Professional and Honorary Societies (1989)

1. American Society of Agronomy
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Selected Publications

Moncrief, J.F., D.J. Eckert, E.E. Schulte, and D.R. Huggins. 1994. Fertilizer management with residue management systems. 14 pg. In: *In: Surface Crop Residue Management for Soil Conservation and Crop Production* ARS, USDA, W.C. Moldenhauer and W.D. Kemper (eds). Beltville, MD.

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Employment:

1991-present Coordinated development of "Feedlot and Manure Management Directory"

Staff support to 1993 LCMR project Advisory Committee and new Feedlot and Manure Management Advisory Committee (FMMAC).

Coordinating the development of a "Planning Guide for Minnesota Livestock Operators".

A. Title of Objective/Outcome: Impact of manure integration within a conservation tillage system on water quality. This objective will secure baseline data to characterize watershed responses to rainfall and snow melt runoff events. Based on LCMR recommendations, this objective is proposed as a six year project with continued monitoring in the next two biennia to capture the response of management changes after gathering baseline data.

A.1. Activity: Impact of manure integration within a conservation tillage system on water quality.

A.1.a. Context within the project: Computer simulations have suggested that management of crop residue will be a prominent part of a "best management practice" for reduction of diffuse source pollution from agricultural sources. Current computer models do not consider manure in the system. When solid sources of manure are incorporated with reduced tillage tools to leave residue on the surface a higher concentration of P is left in the top 8cm. What is the net effect of the P loss when sediment is reduced but the concentration of P in the sediment is higher? This question will be addressed with this objective.

A.1.b. Methods: Two paired watersheds (40-52 ha) will be established on a cooperating farmer's field. This project will be located in a high risk (pollutant loss from farming activity) area of the Minnesota River Basin. The primary criteria for site selection will be farmer cooperator interest, availability of the necessary machinery, and livestock to establish treatments, and the presence of model soils and landscapes which also present a high risk environment (poorly drained, fine textured, and steeply sloping soils). Farmer interest will be the most important criterion. A flume with subsampling apparatus will be positioned at the tile inlet of each watershed. During runoff events (rainfall and snow melt), runoff data will be collected and hydrographs constructed. Also during runoff events, "grab samples" will be taken incrementally based on runoff volume and retrieved for chemical analysis. During the first two years baseline data will be collected on the watersheds with a conventional cropping system (soluble P, bioavailable P, total P, chemical oxygen demand, and sediment).

In the second and third biennium (based on availability of funds) an improved tillage system with and without manure applied will be established. This will be monitored and compared to the original watershed data.

A.1.c. Materials: Flumes and subsampling apparatus-20,000. The Minnesota Department of Agriculture has provided a truck to be used with this project. We therefore will allocate this money ($20,000) toward electronic technician time and laboratory support for chemical analysis. This will allow implementation of an automated data retrieval system which is necessary to monitor the field sites from remote locations. More than expected snow melt runoff events have occurred than anticipated and it is also necessary to allocate more resources to laboratory support of chemical analysis. Equipment will be the property of the University of MN after the project.

The flumes will be custom built based on the anticipated rainfall intensity and size of the watersheds chosen for the project. This equipment will be the property of the University of MN after the project for similar future projects.

A.1.d. Budget: Total Biennial LCMR Budget : 100,000
Balance : 0

A.1.e. Timeline:	**7/95**	**1/96**	**6/96**	**1/97**	**6/97**
Identify farmer cooperator	xx				
Establish paired watersheds	xx				
Collect baseline data			xxxxxxxxxxxxxxxxxxxxxx		

A.1.f. Final Report

INTRODUCTION

Evaluation of tillage effects on surface water quality of a river needs a watershed scale observations, especially the watershed that drained to a natural waterways or tile inletS. Most investigation on the effects of conservational tillage on quantity and quality of surface runoff from agricultural land have used small plots. The small plot observations are useful for more detail investigation on processes and making treatment comparisons in a more controlled or less spatial variability. However, extrapolating the treatment effects from a small plot to a watershed scale can overestimate the treatment effects. One of the reasons is greater deposition of sediment and retardation of runoff in a depressional landscape in the watershed, and greater soil spatial variability. Paired watershed approach has emerged as a principle means to assume the spatial variabilities. Paired watershed approach uses a control watershed and other one or more watersheds to be treated. Ideally, watersheds are selected on the basis of representativeness of a region, and similarity of size, shape, topography, crop, and land use. The approach consists of two steps. First step is establishing baseline data. In this step, the response of a watershed are calibrated against the other one(s) on varieties of runoff events for a period of time. In the second step, a treatment is imposed on one or more watershed while the control is left undisturbed. The effects of the treatments are measured as departure from the baseline data. If the characteristics of the control watershed have remained unaltered, the changes in the surface water quantity and quality are attributed to the treatment. The objective of this investigation is to establish a baseline data of a paired watershed for use in the next biennium.

BASELINE DATA COLLECTION

Watershed Selection and Characterization:

In July 1995, two watersheds at Tilney Farm were chosen for a paired watershed sites in Lacustrine soil in South Central Minnesota. Tilney farms, a 5,600 acre enterprise, has been associated with the University fertilizer trials in the past. The farm administration, now managed by Thomas Urevig, is very cooperative and receptive to the research ideas. The farm administration has kept historical records of soil organic matter, pH, phosphorus , and potash contents for most of its lands. The soils in the watersheds, identified as Watersheds WS1 and WS2, were developed from glacial till and Lacustrine sediments from Glacial Lake Minnesota in the Watonwan River Watershed which is part of the Blue Earth River sub-basin. These soils comprise roughly 25 percent of the MN River Basin. These soils are also fine textured, have slopes less than 2 percent and are very poorly drained.

Characterization of both watersheds was done by geodetic survey. Topographical and contour map and watershed boundary was generated from the geodetic data. Terrain analysis was also done on the geodetic data using GIS software (ANUDEM and TAPESG). This analysis gives further information to the contour map in the drawing of the approximate watershed boundaries and its corresponding planar surface area.

WS1: This watershed of 44.8 ha is located at Sec 5 T105 N R30. The topography, drainage attribute and the boundary of WS1 was constructed from 889 geodetic points measured in October 1995. This watershed drains to a surface inlet 20.3 cm in diameter. Based on Soil Survey for Watonwan County, the major soil types in the watershed are given in Table 1. A composite soil test taken in fall 1995 showed organic matter was high, pH ranged from 6.3 to 6.8, Olsen P ranged from 22 to 23 ppm, Bray P ranged from 16 to 19 ppm, potassium ranged from 127 to 139 ppm and Zn ranged from 1.8 to 2.2 ppm.

WS2: This watershed of 51.7 ha is located at Watonwan county, section 29 T105 N R30. This watershed drained into two 6-inch surface drain inlets, which divide the watershed into two subwatersheds, East WS1 and West WS1. This division allowed measurement for each inlet separately. The East and West subwatershed is 13.2 and 38.5 ha, respectively. The tile inlets in East and West WS1 were separated by a 50 cm saddle topography between the subwatersheds. If a big runoff event occurs, when water level was high, especially during snowmelting, the West and East WS1 subwatersheds will become one watershed. Based on Watonwan County Soil Survey, major soil types in WS2 are given in Table 2. Soil test taken in fall 1995 showed organic matter as high, pH ranged from 7.5 to 7.6, Olson P ranged from 15 to 27 ppm, Bray-P ranged from 14 to 24 ppm, potassium ranged from 106 to 133 ppm, and Zn ranged from 1.4 to 3.5 ppm.

Table 1. Major soil types in Site 1.

Soil Series	Position in the landform	Area (%)†
Madelia silty clay loam (Typic Haplaquolls)	Low-lying flats on lake plains	35
Spicer silty clay loam (Typic Haplaquolls)	Low-lying areas on lake plains	40
Kingston silty clay loam (Aquic Hapludolls)	Low rises on lake plains	4
Clarion loam (Typic Haplaudolls), 1 to 4 % slopes	Knolls and side slopes on till plains	5
Okoboji silty clay loam (Cumulic Haplaquolls)	Closed depression on till plains	7
Nicollet loam (Aquic Hapludolls)	Low rises on till plains	4
Truman silt loam (Typic Hapludolls), 1 to 4 % slopes	Rises on lake plains	3
Waldorf silty clay loam (Typic Haplaquolls)	Low-lying flats on lake plains	2

†This is rough estimate prior to measurement. Estimate is based on the Soil Survey of Watonwan County, MN (USDA, SCS in cooperation with MN Agricultural Experiment Station, 1992)

Instrumentation:

Runoff volume was determined using an area velocity sensor. This sensor consists of a Doppler Velocity and water depth sensor. This method presents minimal obstruction to the flow and, more importantly, it is capable of measuring bi-directional velocity of runoff, therefore back-flow from the tile drainage can be detected. A Doppler velocity sensor uses the principle of the Doppler effect to measure velocity in a flow stream. The sensor transmits a high frequency sound wave into the flow and then detects the frequencies of the reflected sound waves. These reflected frequencies are related to the velocity in the flow stream at which the reflections occurred. The flow logger connected to the Doppler sensor process the reflected frequencies to determine the average velocity in the flow stream. At the same time, the logger calculated the cross sectional area of the flowing water depth in the pipe. The logger registers the flow rate, which is cross sectional area times flow velocity.

The velocity sensor was secured at the bottom of the pipe about 2 m from surface runoff entrance. This is done to reach a degree of streamline flow at the sensor for better data. Downstream of the sensor, the pipe was connected to a T shape coupling. Through the opening of the T coupling, sensor can be detached from the pipe bottom for cleaning and depth recalibration. The T coupling then connected to a 20.3 cm diameter PVC elbow attached to the tile inlet. The T coupling remained capped to avoid direct entry of rain, except during maintenance. This setup was a modification of an earlier design. In the earlier design, water sealed boxes were made of sheet PVC and the water depth and flow velocity sensor were securely attached in the box. A rectangular opening (about the size of the Doppler sensor) was made on the bottom of a PVC pipe 20.3 cm diameter. The box then was attached to the PVC pipe such that the opening was above the sensor. This will allow the sensor to measure the water depth and velocity through the opening when the water flows in the pipe. This previous design was very tedious in maintenance and troublesome during winter for frequent icing the sensor resulting in erratic data.

During runoff events, runoff samples were taken with a grab sampler connected to the flow logger. Suction line from the sampler was placed at the downstream of the velocity sensor. For a certain volume of runoff water detected by the flow logger, a composite sample will be taken. This allows a more representative sampling with volume and time during the course of a runoff event. The runoff sample will be taken to the lab and analyzed for Sediment, Nitrogen, Phosphorus, COD, and BOD.

The flow logger, batteries and sampler are placed in a custom made housing close to the tile inlets. The housing is made of treated wood and consisted of a platform and enclosure for the sampler and flow logger. The platform was about 125 cm above ground to avoid inundation of equipment during a high rainfall or spring snow-melt. The batteries was continuously charged by a solar panel placed above the housing.

Tillage and Cropping.

Each year during the first two years in the baseline data establishment, both watersheds were fall chisel plowed, followed by a spring field cultivation before planting. In 1995, the watersheds was cropped with soybean. In 1996 the crop was seed corn. In 1997 both WS1 and WS2 were cropped with beans, i.e., the WS1 is cropped with soybean and the WS2 is cropped with navy bean.

Measurements

Soil residue cover was measured diagonally over the interrow area using the line transect procedure (Laflen et al., 1981). We define the interrow area as area between 10-cm wide strips centered over the row. Measurements were made at 20 to 50 points in each watershed after fall plowing, before and after planting.

Snow depth (water equivalent) was measured at 25 to 35 points across a transect in 1997 with a meter stick. Snow density measurements was taken with a steel ring, 3 mm thick, 33 cm in diameter and 35 cm in height. The steel ring was gently pushed into the snow with a turning motion to avoid compaction until it hit the soil surface. At this point, snow was emptied to a pre-weighed plastic bag. The ring was pulled gently out and snow depth was measured. The snow was then weighed in the laboratory for snow density calculations.

Table 2. Major soil types in Site 2

Soil Series	Position in the landscape	Area †(%)
Spicer silty clay loam (Typic Haplaquolls)	Low-lying areas on lake plains	40
Clarion loam (Typic Haplaudolls), 1 to 4 % slopes	Knolls and side slopes on till plains	9
Crippin loam (Aquic Hapludolls)	Low rises on till plains	2
Nicollet loam (Aquic Hapludolls)	Low rises on till plains	4
Okoboji silty clay loam (Cumulic Haplaquolls)	Closed depression on till plains	5
Clarion-Estherville (Typic Hapludolls) complex, 2-6 % slopes, eroded	Knolls and side slopes on till plains	5
Fieldon (Typic Haplaquolls)-Canisteo (Typic Haplaquolls) complex	Rims of depression and low flats on till plains and outwash plains	7
Glencoe clay loam (Cumulic Haplaquolls)	Closed depression on till plain	7
Canisteo-Glenco clay loam	Canisteo-flat areas and rims of depression on till plains; Glenco-closed depressions on till plains	20
Webster clay loam	Low-lying flats on till plains	1

†This is rough estimate prior to measurement. Estimate is based on the Soil Survey of Watonwan County, MN (USDA, SCS in cooperation with MN Agricultural Experiment Station, 1992)

Bottles of runoff samples were collected from the sampler daily during continuous runoff events and brought to laboratory for sediment, P, N, COD and BOD analysis. When possible, BOD analysis was done on 10 to 15 % of the samples. Before any analysis, the runoff suspension was thoroughly stirred and subsampled. Sediment was measured by evaporating 200 mL of runoff suspension at 105°C. Total P (TP) was measured in a 20 mL homogenized runoff suspension using the perchloric acid digestion technique as described by USEPA (1981). Dissolved molybdate reactive P (DMRP) was measured in a 20 mL runoff solution (after filtration of runoff suspension with 0.45 µm membrane). The DMRP was determined without acid predigestion of runoff solution. Particulate P (PP) was determined by the difference between TP and DMRP. All phosphorus fractions were determined with the ascorbic acid method of Murphy and Riley (1962). Nitrogen in the runoff suspension is also measured directly without predigestion. Ammonium-N and nitrate-N were determined using the conductimetric method (Carlson, 1978; and Carlson, 1983). Total N in the runoff suspension was the summation Ammonium-N and nitrate-N. Chemical oxygen demand (COD) was determined by chemical oxidation of runoff suspension as described by USEPA (1979). The BOD was measured by the depletion of oxygen in runoff suspension after five days incubation. BOD is a measure of oxygen needed by microbial degradation of organic material as describe in the Standard Methods for The Examination of Water and Waste Water (1975).

RESULTS

Comparison of Surface residue.

Surface residue cover taken at different times indicated that the statistics of residue cover between watershed WS1 and WS2 were practically similar (Table 3).

Table 3. The statistics of surface residue cover in watershed WS1 and WS2.

Date of Measurement and Description	Surface Residue Cover (%)		
	Statistics	WS1	WS2
25 Apr. 1996. Soybean residue after snowmelt before field cultivation & corn planting.	n Range ave(std Median	50 24 - 48 48.7(15.8) 52	50 24 - 76 44.8(13.6) 48
4 Nov. 1996. Corn residue after chisel plow as primary tillage	n Range ave(std Median	35 8 - 44 22.3(9.4) 20	25 8 - 44 16.6(7.3) 16
7 Apr. 1997. Corn residue after snowmelt, before field cultivation & bean planting	n Range ave(std Median	25 0 - 57.1 19.6(11.5) 19	22 4.8 - 42.9 24.9(9.9) 26.2
26 June 1997. Corn residue after field cultivation and planting	n Range ave(std Median	28 0 - 26.3 7.3(6.5) 5.26	28 0 - 21.1 6.0(5.7) 5.26

This was expected because the tillage system and operation was done with the same machinery on both watersheds. Soybean residue cover was high during over winter until April 1996 because after soybean harvest, no primary tillage was conducted in both watershed. Corn residue was less than 30 % due to the primary tillage after corn harvest in November 1996. The residue cover decreased to less than 10% after spring field cultivation.

Comparison of Snow conditions in 1997.

During winter 1996, snow depth and density were not measured. Snow depth and snow density were measured in 13 December 1996, and 18 February 1997. Snow depth and density at both watershed were not significantly different. On 13 December 1996 snow density (cm water/cm snow) on WS1 and WS2 were 0.26 and 0.24, respectively; the distance-depth weighed average of Snow depth (water equivalent) across a line transect was 4.26 and 3.5 cm in watershed WS1 and WS2, respectively. On 18 February 1997 snow density on WS1 and WS2 were 0.37 and 46, respectively; weighed average of Snow depth (water equivalent) was 5.81 and 7.7 cm in watershed WS1 and WS2, respectively. On both measurements, Snow depth differed less than 1 cm between WS1 and WS2.

Runoff Comparison

Due to differences in characteristics, Snowmelt and rainfall runoff was discussed separately. During snowmelt runoff, snowmelt runoff depth was high and the water flows from subwatershed West WS2 to the subwatershed East WS2. Therefore, during snowmelt runoff events, the subwatersheds joined become one watershed, whereas during rainfall runoff event, the East WS2 and West WS2 subwatershed are separated and each has its characteristics and will be discussed in the next section.

Snowmelt Runoff

<u>Runoff Depth</u>

There are eight comparable snowmelt runoff events, i.e. 4 events from November 1995 to April 2 1996, and 4 events from Nov. 1996 to March 1997 (Table 4). In 1996, total snowmelt runoff in WS1 was 0.33 mm higher than that of WS2 (Table 4). In 1996, Majority of total snowmelt runoff occurred from two snowmelt runoff events, one in February and one in March. Runoff event comparison between WS1 and WS2 varied with years. In 1996, Comparison of snowmelt runoff in WS1 and WS2 is not consistent because snowmelt runoff from WS1 was either greater or smaller compared to the snowmelt runoff in WS2. In 1997, snowmelt runoff from small events in WS2 were consistently higher than those from the WS1. However, for a major runoff event, snowmelt runoff was greater in the WS1 than that in WS2 (Table 7). In 1997, total snowmelt runoff in WS1 was 2.23 mm higher than that in WS2. During 1997, majority of snowmelt runoff was from an event in March (Table 6). Overall on event base, the relationship between WS1 and WS2 is presented in Fig. 1. The positive intercept of regression line and most of points above 1:1 line suggests that in most event, runoff depth in WS2 was greater compared to the WS1. Regression line close to 1:1 line during major events indicated that both WS1 and WS2 behave closely for major snowmelt runoff events.

Sediment Losses

Although there is similar pattern between runoff depth and sediment losses in snowmelt runoff, the quantity of sediment loss is small with very little practical impacts. In 1996, total snowmelt sediment loss in WS1 is lower than that of WS2 (Table 5). On the contrary, in 1997, total snowmelt sediment loss in WS1 was higher compared to that from WS2. Relationships between the WS1 and WS2 is presented in Fig. 2. The positive intercept and slope less than 1 indicated that for small runoff events, WS2 will yield higher sediment loss than the WS1, however, on major events, WS2 likely will result in lower sediment loss.

Phosphorus Losses

In snowmelt runoff, majority of cumulative losses of TP was in DMRP form, particularly in the major runoff events (Table 6). This was due to the runoff volume. The concentration of Phosphorus was not so different from one event to the others compared to runoff volume. Cumulative TP loss in snowmelt was less than 0.1 kg ha^{-1} each year. In 1996, cumulative TP loss from WS2 was 46 g ha^{-1} higher than that in WS1. On the contrary, cumulative TP loss from WS2 was only 9 g ha^{-1} lower than that in WS1 in 1997. Overall on event base, the relationship between WS1 and WS2 is presented in Fig 3. The positive intercept of regression line and most of points above 1:1 line suggests that in most event, TP losses in WS2 was greater compared to the WS1. Regression line close to 1:1 line during major events indicated that both WS2 and WS1 behave closely for major snowmelt runoff events.

Similar pattern is also shown for the DMRP losses. Most of DMRP loss occurred during major snowmelt runoff events. In 1996, cumulative DMRP loss from WS2 was 21 g ha^{-1} higher than that in WS1. On the contrary, cumulative DMRP loss from WS2 was 5 g ha^{-1} lower than that in WS1 in 1997. On event bases, the relationship of DMRP loss between WS2 and WS1 is presented in Fig 4. The positive intercept and slope of less than 1:1 line between the WS2 and WS1 suggested that during small snowmelt runoff events, DMRP loss from WS2 will be higher than those from the WS1. Major snowmelt runoff events were close to the 1:1 line suggesting that both WS1 and WS2 are closely comparable one against the other during major snowmelt runoff.

The relationship of PP losses between WS2 and WS1 (Fig. 5) is somewhat different from that of TP and DMRP losses. The regression line and most points are above 1:1 line. This indicated that both during small and major runoff events, likely PP loss in WS2 will be higher than those in WS1. In 1996 PP losses in WS2 was 24 g ha^{-1} higher than that in WS1 and in 1997, PP losses in WS2 was only 4 g ha^{-1} lower than that in WS1.

Inorganic N Losses.

Cumulative inorganic losses in snowmelt was less than 0.6 kg ha^{-1} in both watershed in 1996 or even less than 0.2 kg ha^{-1} in 1997 (Table 7). Majority of inorganic N loss in snowmelt runoff was during major runoff events. In 1996, total Inorganic N loss in WS2 is 145 g ha^{-1} lower than that in WS1 and in 1997 the inorganic loss in WS2 is only 27 g ha^{-1} higher than that from WS1. On even base, the regression line in Fig. 6 indicated that during small runoff events, total inorganic N loss from WS2 is likely greater than those from WS1. For major runoff events, the regression line and the points were at or under the 1:1 line. Therefore, during major runoff events, inorganic N loss in WS2 will be the same as or smaller than those in WS1.

Ammonium-N is smaller compared to the nitrate N. The cumulative NH_4-N losses in WS2 is consistently lower in both 1996 and in 1997 (Table 7). Also in all major events, NH_4-N losses in WS2 is consistently lower than those in WS1. The regression line (Fig. 7) indicated that that during small runoff events, NH4-N loss from WS2 is likely greater than those from WS1. For major runoff events, the regression line and the points were below the 1:1 line, which indicate that during major runoff events, inorganic N loss in WS2 will be smaller than those in WS1.

Nitrate N loss was the predominant component of inorganic n losses in snowmelt runoff. Therefore the pattern of NO_3-N loss was the same as that in the total inorganic-N loss. In 1996, cumulative NO_3-N loss in WS2 was 126 g ha^{-1} lower than that in WS1 and in 1997, cumulative NO_3-N loss in WS2 was 45 g ha^{-1} lower than that in WS1 (Table 7). On event base, the regression line (Fig. 8) indicated that On even base, NO_3-N loss from WS2 is likely greater than those from WS1. For major runoff events, the regression line and the points were at or under the 1:1 line. Therefore, during major runoff events, inorganic N loss in WS2 will be the same as or smaller than those in WS1.

Biological and Chemical Oxygen Demand

Biological oxygen demand were measured only from 10-15% of the samples, when time allows. In 1996, The BOD of the selected samples from WS1 ranged from 2.8 to 4.1 mg L^{-1}. The BOD of selected samples from the West and East WS2 ranged from 4.23 to 4.80 mg L^{-1} and 5.2 to 7.4 mg L^{-1}, respectively. In 1997 BOD of selected sample from WS1 ranged from 16.8 to 20.2 mg L^{-1}. The BOD of selected samples from West and East WS2 ranged from 5.2 to 7.3 mg L^{-1} and 5.2 to 14.4 mg L^{-1}, respectively. In 1997, with more BOD measurements in snowmelt runoff, on average BOD in WS1 and WS2 was 55 % and 37 % of COD, respectively.

Cumulative COD in snowmelt in WS2 was 1033 g ha^{-1} greater than that in WS1. However, in 1997 cumulative NO_3-N loss in WS2 was 1056 g ha^{-1} lower than that in WS1. On event base, the relationship of COD between WS1 and WS2 is presented in Fig 9. The positive intercept of regression line and most of points above 1:1 line suggests that in most small events, TP losses in WS2 was greater compared to the WS1. Regression line close to 1:1 line during major events indicated that both COD in WS1 and WS2 behave closely during major events

Rainfall Runoff

The relationship of rainfall runoff event between WS2 against WS1 has not been established because there has no rainfall runoff occurred in the watershed WS1. There were three rainfall runoff events in WS2, one in June and two in August 1996. Since the subwatersheds was separated during rainfall runoff and the behavior of flow in West WS1 and in WS2 are significantly different, the west and east WS2 is regarded as different units during rainfall events. The difference in flow behavior between the East and West WS2 was due to tile network in the watershed. In East WS2, back flow occurred frequently. This is shown by negative values of runoff or some associated pollutant in the East WS2 (Table 8 and 9).

Summary and Conclusion

In both WS1 and WS2 watershed, snowmelt is the major source of runoff, and associated losses of N, P and COD. Sediment loss in the snowmelt is negligible with little practical impact. Sediment loss due to rainfall is commonly greater than that due to snowmelt runoff. Rainfall runoff in the West WS1 resulted in 0.6 Mg ha-1 in 1996, much less than the tolerable soil loss. One reasons of lack of soil loss is sediment deposition. Ponding due to greater surface runoff flow than flow into the tile inlet resulted in sediment deposition, especially the coarse sediments. Majority of sediments going in to the tile inlets is the fine sediments that stays in suspension for a day or longer. The pair comparison of watershed WS1 and WS2 is better during snowmelt runoff events. Particularly, the range of runoff covers both small and major runoff events. Therefore the relationships between watersheds for snomelt runoff has been established in this first biennium. The regression line relating both watersheds indicated that for small snowmelt runoff events, the WS2 resulted in greater surface runoff and its associated N, P and COD compared to those from WS1. On the other hand, during major snowmelt runoff events, the WS2 behave closely against the WS1. However, since comparison between watershed is not established for rainfall runoff, it is recommended that the treatment that will be imposed on one watershed be postponed until fall 1997. It is recommended to impose a treatment on WS2. By doing this, the treatment effects during snowmelt can be inferred across watershed WS2 and WS1, i.e., from the previously established baseline data. At the same time, to cope for the lack of rainfall runoff events in WS1, the treatment effects during rainfall runoff events can be inferred from the changing of rainfall runoff pattern within the subwatershed West WS2. This is done by comparing the rainfall runoff event in the first biennium (1996 and 1997) against the next biennium solely within the West WS2 subwatershed.

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Table 4. Runoff events and their associated depth in 1996 and 1997.

1996 Event	Runoff		1997 Event	Runoff	
		mm			mm
2/8-2/27	WS1	6.78	11/6-11/17	WS1	0.0
	WS2	7.63	'96	WS2	0.22
3/10-3/13	WS1	0.06	2/28-3/04	WS1	0.09
	WS2	0.0		WS2	0.94
3/27-3/31	WS1	2.95	3/08-3/12	WS1	8.23
	WS2	1.75		WS2	4.89
4/01-4/02	WS1	0	3/19-3/20	WS1	0.05
	WS2	0.08		WS2	0.08
Total	WS1	9.78	Total	WS1	8.37
	WS2	9.45		WS2	6.13

Fig. 1. Paired comparison of snowmelt runoff depth between WS1 and WS2

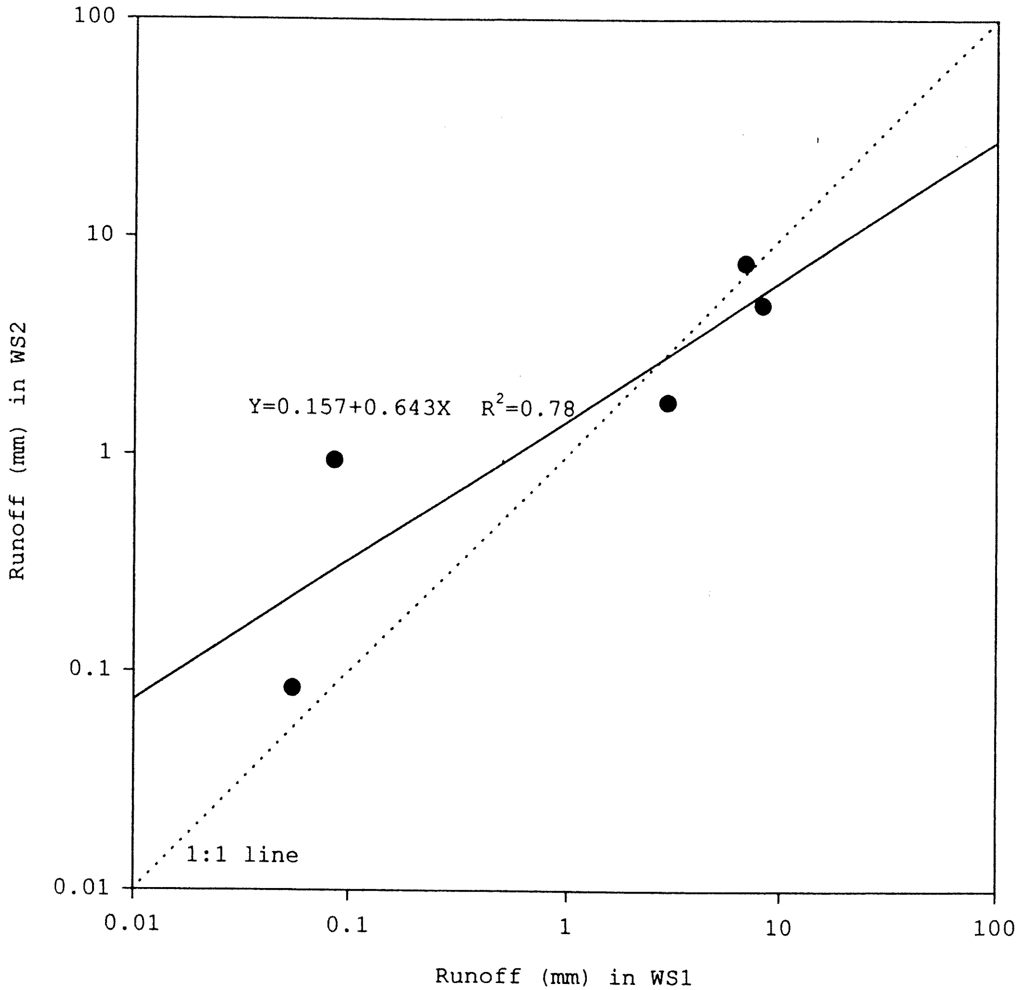

Table 5. Runoff events and their associated sediment losses in 1996 and 1997.

1996 Event	Sediment		1997 Event	Sediment	
		kg ha^{-1}			kg ha^{-1}
2/8-2/27	WS1	11.5	11/6-11/17	WS1	0.0
	WS2	37.1	'96	WS2	1.30
3/10-3/13	WS1	0.18	2/28-3/04	WS1	0.07
	WS2	0.0		WS2	0.60
3/27-3/31	WS1	6.83	3/08-3/12	WS1	33.4
	WS2	2.67		WS2	2.63
4/01-4/02	WS1	0	3/19-3/20	WS1	0.11
	WS2	0.21		WS2	0.16
Total	WS1	18.5	Total	WS1	33.6
	WS2	39.9		WS2	4.69

Fig. 2. Paired comparison of sediment losses in snowmelt runoff between WS1 and WS2

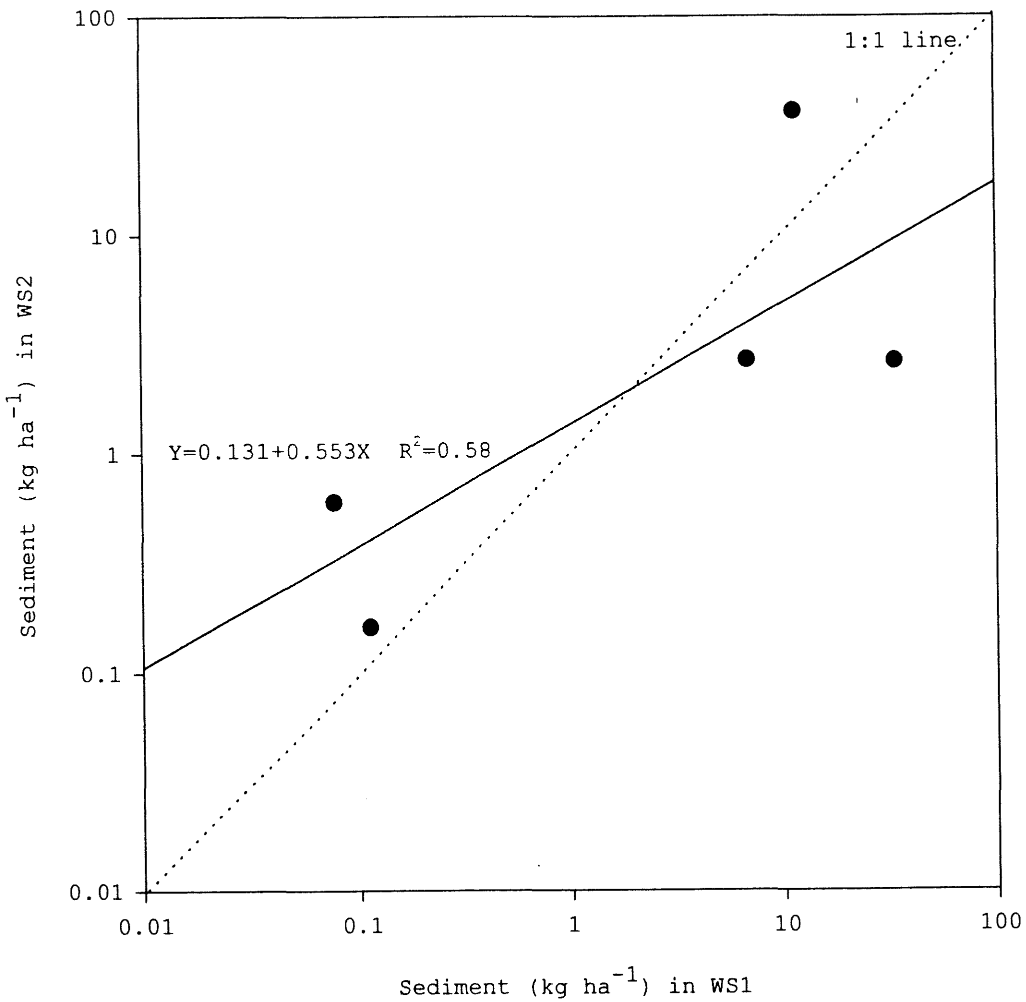

Table 6. Runoff events and their associated P losses in 1996 and 1997.

1996		TP	DMRP	PP	1997		TP	DMRP	PP
		$g\ ha^{-1}$					$g\ ha^{-1}$		
2/8-2/27	WS1	31.1	17.3	13.8	11/6-11/17	WS1	0.0	0.0	0.0
	WS2	74.3	40.5	33.9	'96	WS2	1.68	1.29	0.39
3/10-3/13	WS1	0.10	0.02	0.08	2/28-3/04	WS1	0.53	0.22	0.31
	WS2	0.02	0.0	.0		WS2	5.10	3.04	2.07
3/27-3/31	WS1	7.78	5.27	2.51	3/08-3/12	WS1	51.3	33.7	17.7
	WS2	9.74	3.28	6.46		WS2	35.8	23.8	12.0
4/01-4/02	WS1	0	0	0	3/19-3/20	WS1	0.34	0.22	0.12
	WS2	0.49	0.29	0.20		WS2	0.94	0.75	0.19
Total	WS1	38.9	22.6	16.4	Total	WS1	52.2	34.1	18.1
	WS2	84.6	44.0	40.5		WS2	43.5	28.9	14.6

Fig 3. Paired comparison of TP losses in snowmelt runoff between WS1 and WS2

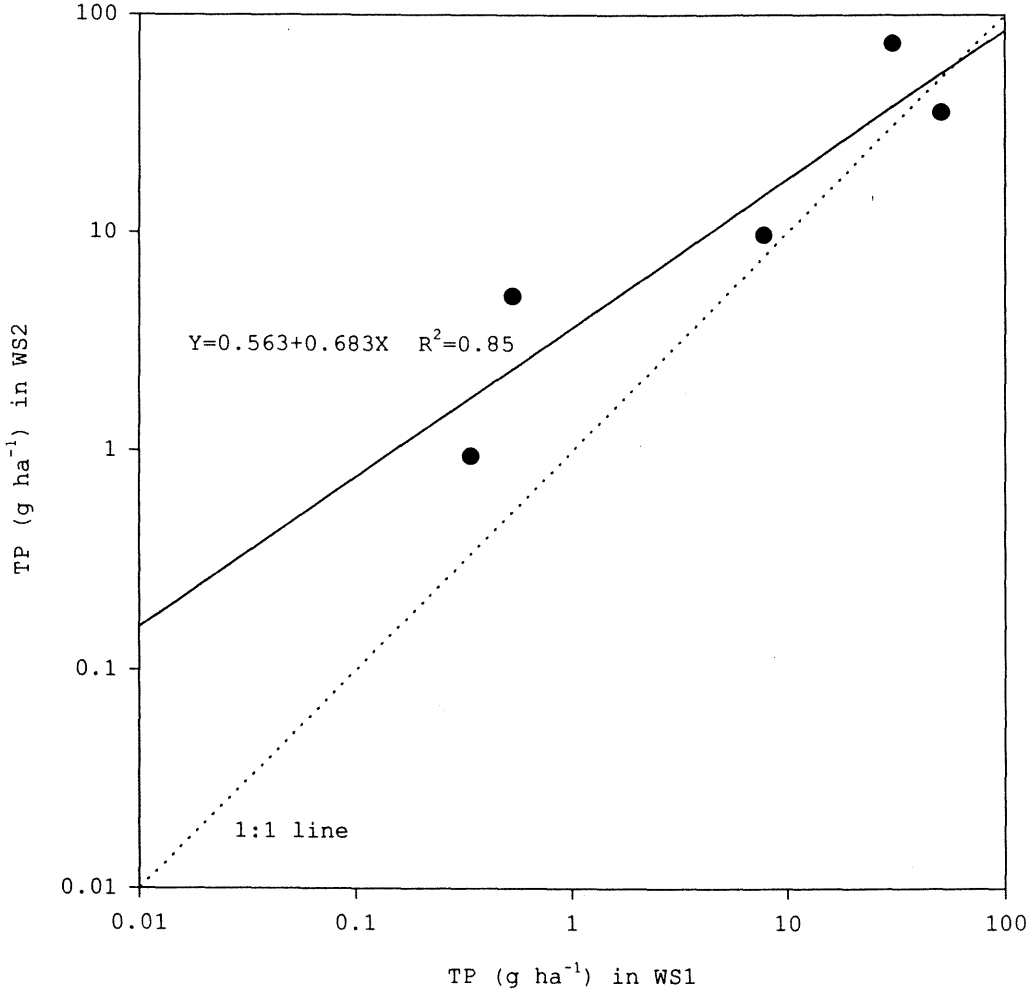

Fig 4. Paired comparison of DMRP losses in snowmelt runoff between WS1 and WS2.

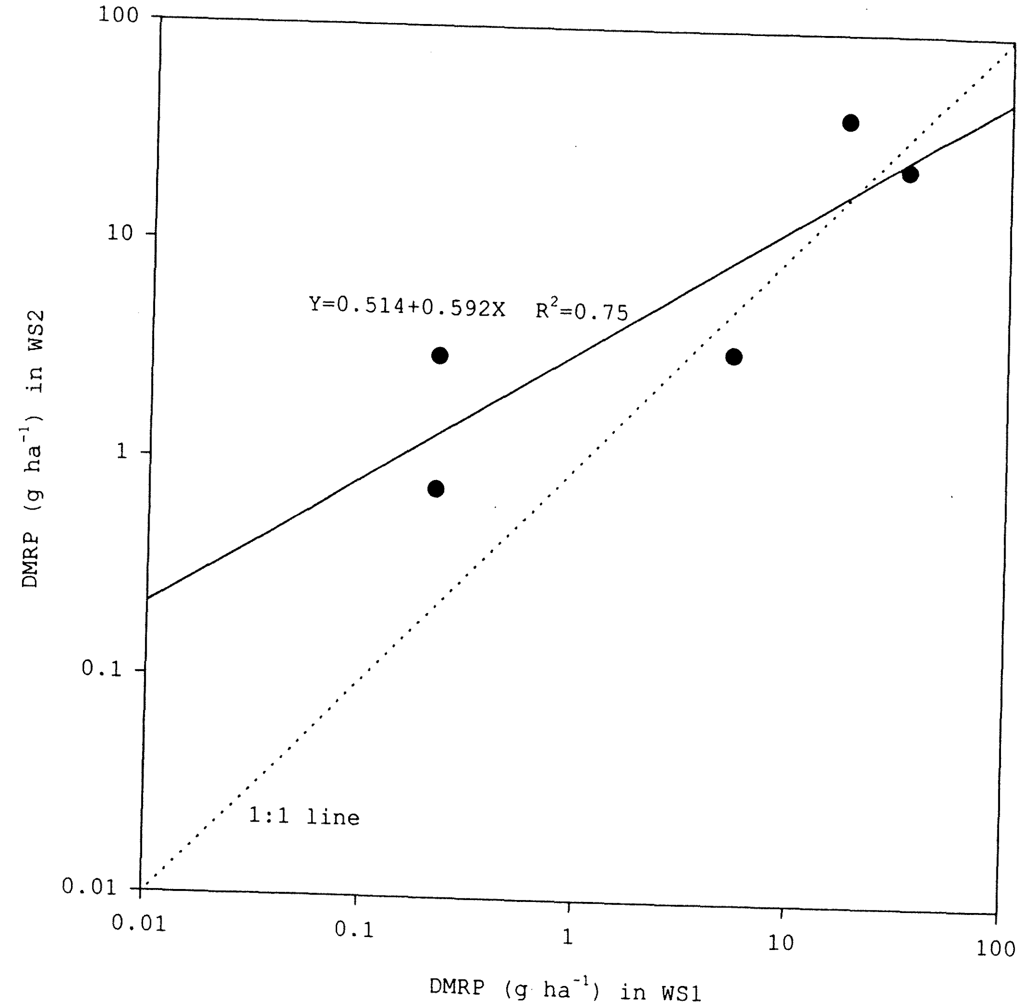

Fig. 5. Paired comparison of PP losses in snowmelt runoff between WS1 and WS2.

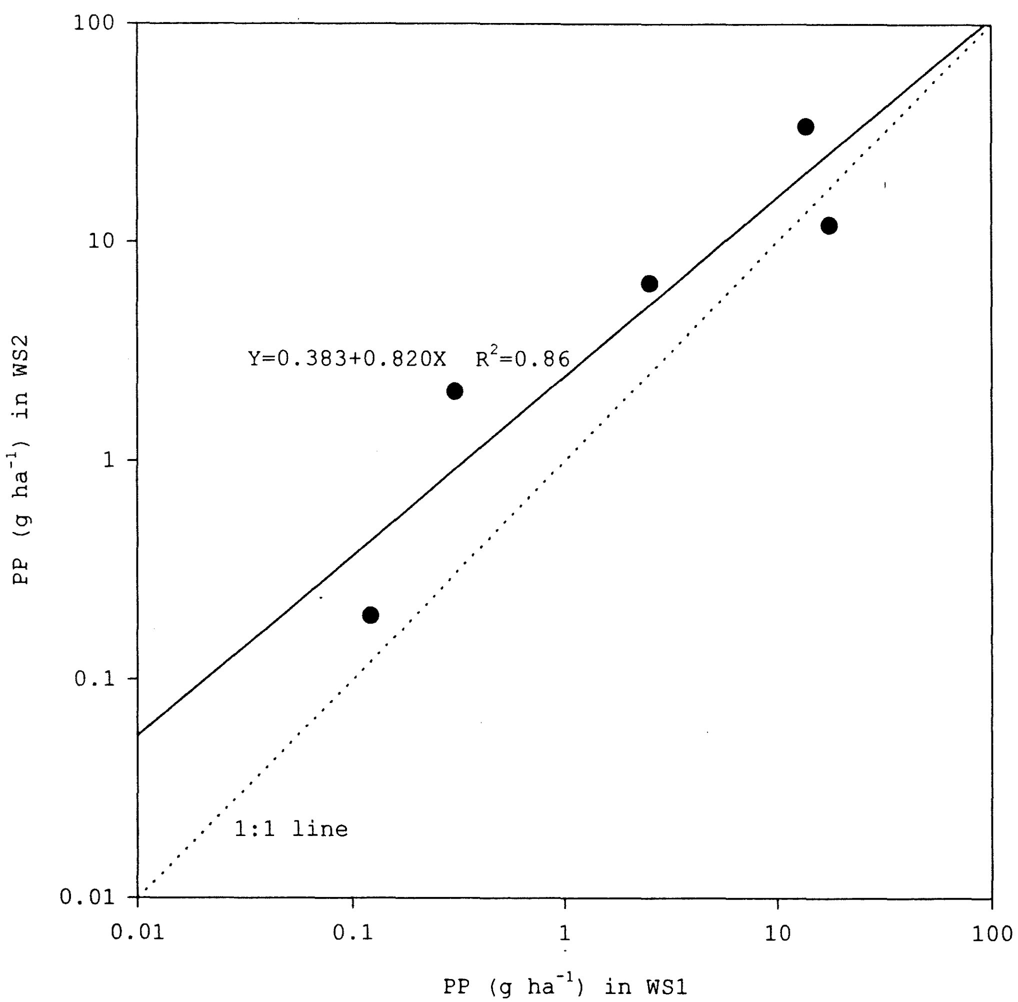

Table 7. Runoff events and their associated N losses in 1996 and 1997.

1996		NH_4-N	NO_3-N	Total	1997		NH_4-N	NO_3-N	Total
		---- g ha^{-1}		----			------g ha^{-1}		-----
2/8-2/27	WS1	85.5	127	213	11/6-11/17	WS1	0	0.0	0.0
	WS2	75.3	155	230	*96	WS2	0.09	69.7	69.7
3/10-3/13	WS1	0.29	4.51	4.80	2/28-3/04	WS1	0.13	1.53	1.66
	WS2	0.0	0.0	0.0		WS2	3.34	13.0	16.3
3/27-3/31	WS1	19.2	274	293	3/08-3/12	WS1	36.3	84.4	121
	WS2	10.4	11.9	126		WS2	14.9	46.6	61.4
4/01-4/02	WS1	0.0	0.0	0.0	3/19-3/20	WS1	0.12	1.68	1.80
	WS2	0.66	8.43	9.1		WS2	0.23	3.85	4.07
Total	WS1	105	405	510	Total	WS1	36.5	87.6	124
	WS2	86.4	279	365		WS2	18.6	133	152

Fig 6. Paired comparison of Total N losses in snowmelt runoff between WS1 and WS2.

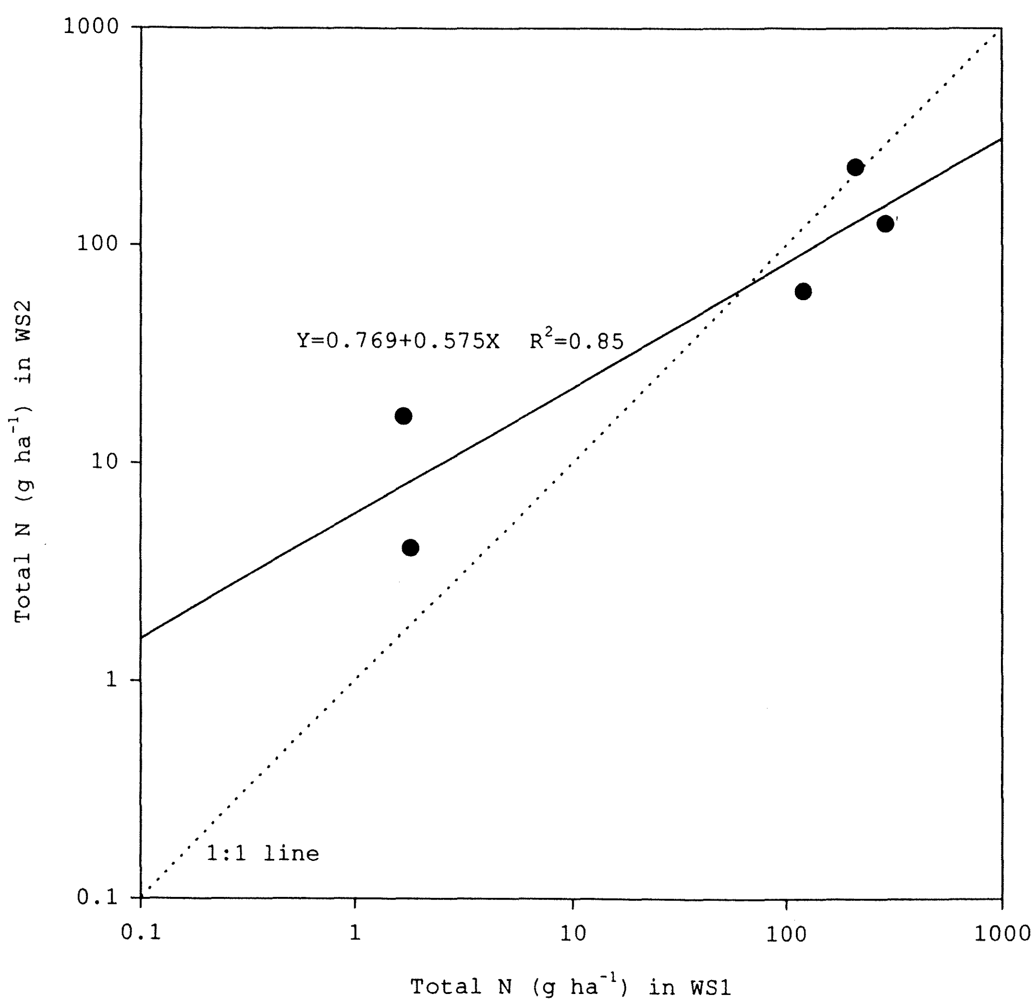

Fig 7. Paired comparison of NH_4-N losses in snowmelt runoff between WS1 and WS2.

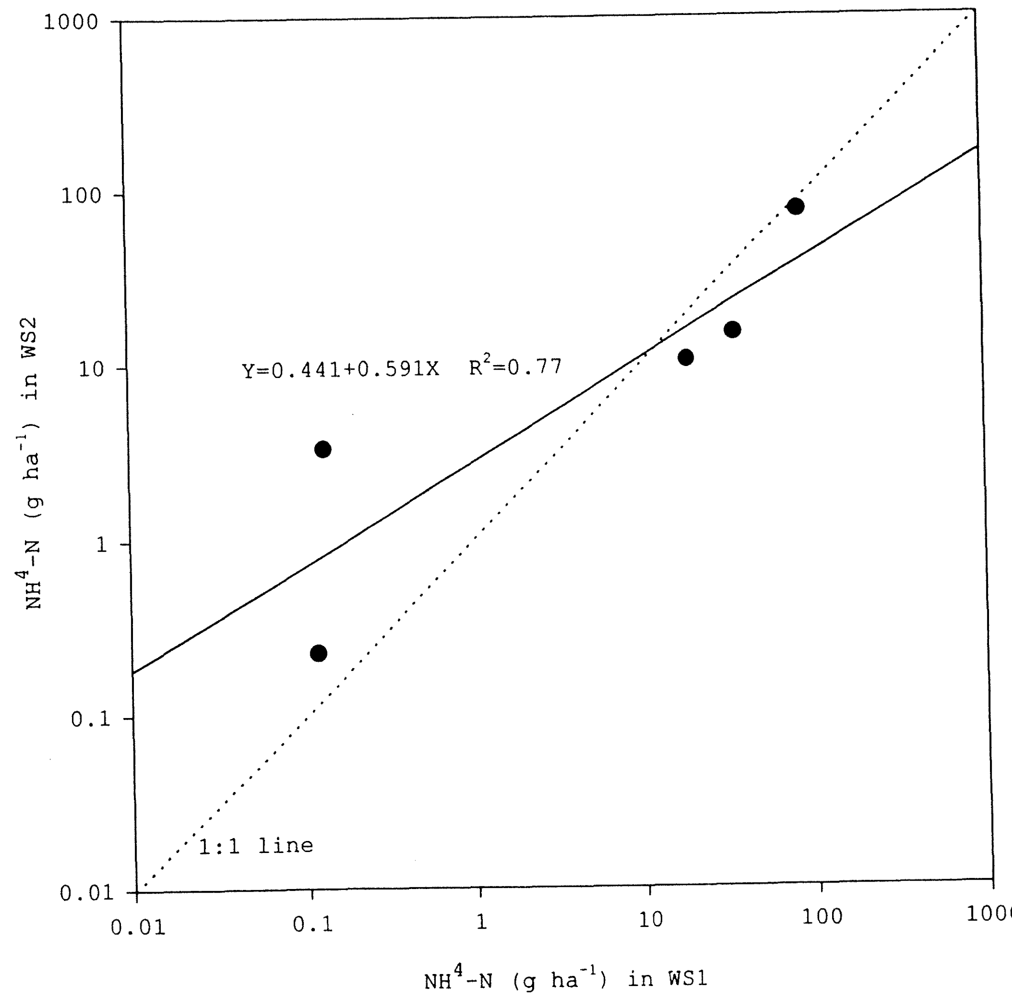

Fig 8. Paired comparison of NO_3-N losses in snowmelt runoff between WS1 and WS2.

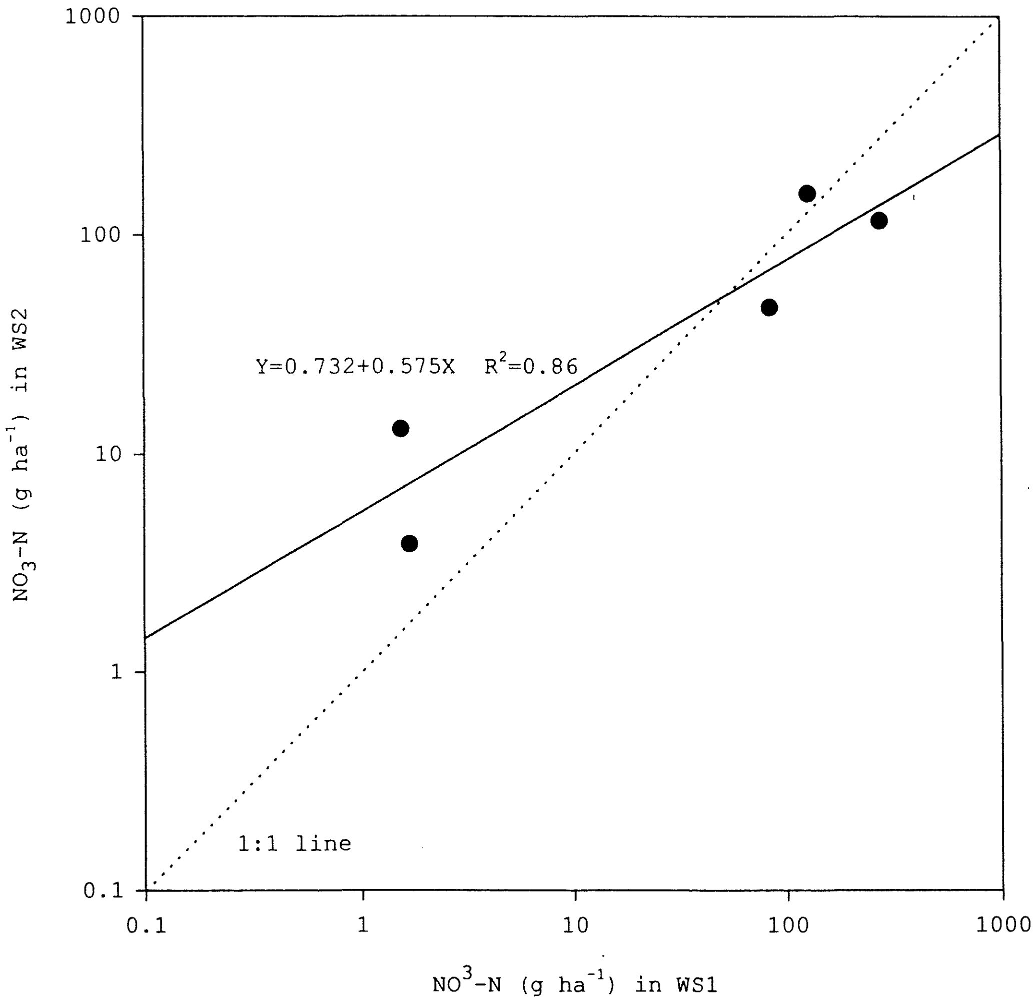

Table 8. Runoff events and their associated COD in 1996 and 1997.

1996 Event	COD		1997 Event	COD	
	g ha^{-1}			g ha^{-1}	
2/8-2/27	WS1	1776	11/6-11/17	WS1	0.0
	WS2	3125	"96	WS2	60.3
3/10-3/13	WS1	18.5	2/28-3/04	WS1	33.6
	WS2	0.0		WS2	24.9
3/27-3/31	WS1	945	3/08-3/12	WS1	2515
	WS2	618		WS2	1175
4/01-4/02	WS1	0.0	3/19-3/20	WS1	31.9
	WS2	28.2		WS2	38.3
Total	WS1	2739	Total	WS1	2581
	WS2	3772		WS2	1524

Fig. 9. Paired comparison of COD in snowmelt runoff between WS1 and WS2

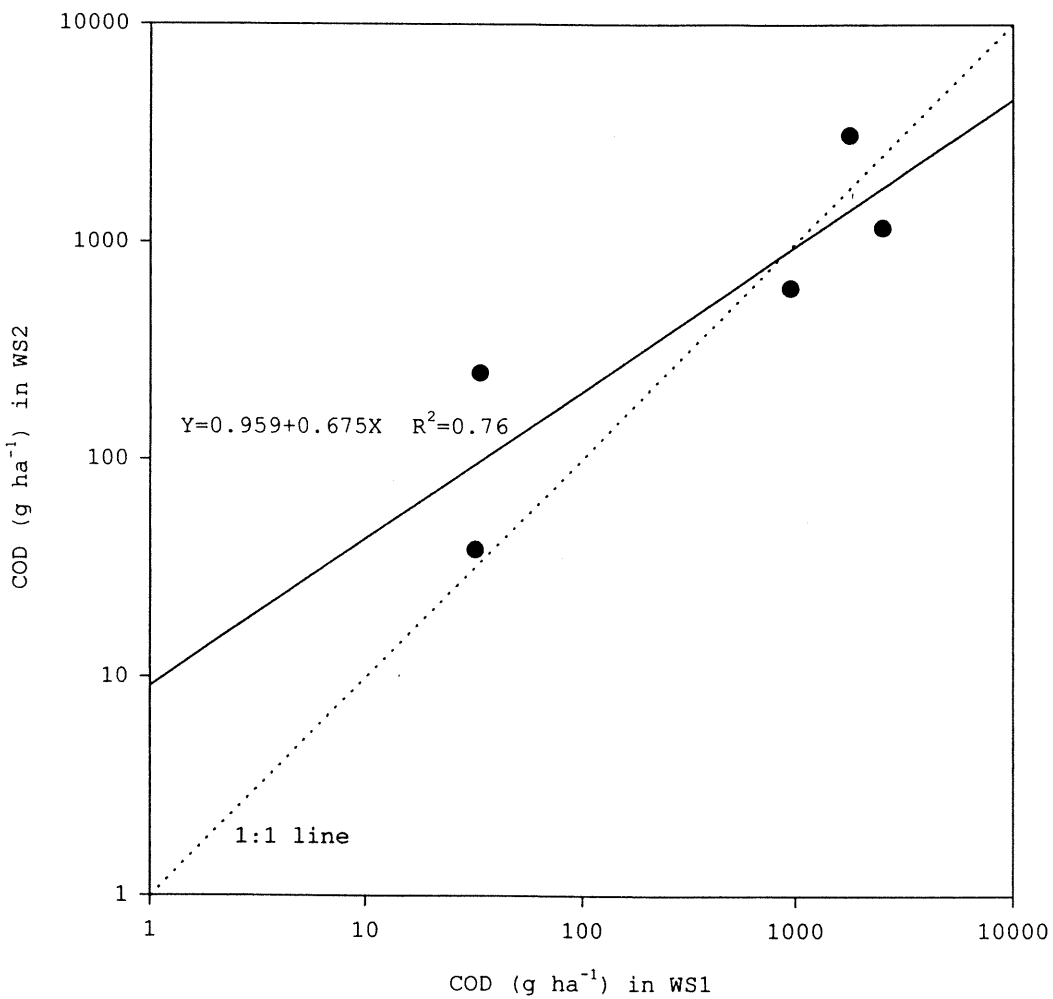

Table 9. Rainfall runoff events and their associated depth and losses of sediment, and Phosphorus in watershed WS2 in 1996.

Date Event	Watershed WS1	Runoff depth	sediment	TP	DMRP	PP
		mm	kg/ha	g/ha	g/ha	g/ha
6/15-6/21	West	0.02	2.16	1.0	0.06	0.94
	East	-4.01	-15.5	-36.0	-22.1	-13.9
8/22-8/25	West	0.92	43.4	23.3	4.80	18.5
	East	-0.41	-2.17	2.66	2.49	0.17
8/25-8/28	West	0.89	534	5.95	4.14	1.81
	East	0.29	0.08	12.9	8.74	4.13
Total	West	1.83	580.1	30.3	8.99	21.3
	East	-4.12	-17.6	-20.5	-10.9	-9.62

Table 10. Rainfall runoff events and their associated losses of Nitrogen and COD in watershed WS2 in 1996.

Date Event	Water-shed	Inorganic N			COD
		NH4-N	NO3-N	Total N	
				g/ha	g/ha
6/15-6/21	West	0.01	4.13	4.12	79.8
	East	-3.26	-866	-870	-775
8/22-8/25	West	0.42	56.4	56.8	1675
	East	-0.17	-90.5	-90.7	0.001
8/25-8/28	West	1.55	23.0	24.6	108.3
	East	0.68	-59.9	-59.3	170.6
Total	West	1.98	83.5	85.5	1863
	East	-2.74	-1017	-1019	605.2

B.1. Activity: Amelioration of manure effluent utilizing constructed earthen basins. This objective will provide data which evaluates manure amelioration with constructed basins.

B.1.a. Context within the project: Due to the N inputs from nitrogen fixation by alfalfa dairy farmers with limited acreage have more N in manure than they can utilize. An alternative strategy to utilization by crops that is environmentally sound is to convert manure N into non polluting forms. This objective will evaluate a series of basins to convert N into non polluting forms. This will allow evaluation of cycling of N to non-polluting forms and utilization of P without environmental degradation.

B.1.b. Methods: A farmer with this manure disposal strategy has been identified. The amount and chemical forms of N in each basin will be monitored as the manure passes through each stage of the treatment. The following scenario has been chosen to be evaluated: The first basin will be used to separate the fecal material from the urine by settling. It is anticipated that half of the N and most of the P will remain in this basin (associated with fecal material). The supernatant that is collected in the second basin will be aerated to encourage conversion from ammonium to nitrate by nitrifying bacteria and used to flush the barn daily. After returning to the first basin denitrification will occur under anaerobic conditions. The material in either basin can be land applied by prescription. Other systems with variations in the above treatment strategy may be evaluated.

B.1.c. Materials:

B.1.d. Budget: Total Biennial LCMR Budget :$100,000
Balance :$0

B.1.e. Timeline:	**7/95**	**1/96**	**6/96**	**1/97**	**6/97**
Farmer cooperator identified	xx				
Collect Data characterizing system	xxxxxxxxxxxxxxx				
Organized data for interpretation			xxxxxxxxxxxx		

B.1.f. Final Report

The objective of this study was to investigate the forms and transformations of nitrogen in a dairy farm waste management system in SE Minnesota. Manure management systems can lose nitrogen to the atmosphere as ammonia (NH_3), nitrous oxide (N_2O), and dinitrogen (N_2). Ammonia and ammonium (NH_3, NH_4^+) are always present in manure, commonly comprising 33% of the total N in liquid manure. The volatilization of ammonia is influenced by several factors. It increases with increasing pH and temperature of the liquid manure. Ammonia volatilization can occur anywhere the manure is exposed to the atmosphere. A floating scum mat and an ice cover in the winter can therefor reduce these losses. N-losses from a manure system as nitrous oxide (N_2O) and dinitrogen gas (N_2) require the existence of a nitrification-denitrification cycle. Nitrate (NO_3^-) can be generated under aerobic conditions by microbial oxidation of ammonia. If nitrate enters into an anaerobic environment, it can be microbially reduced to nitrous oxide or dinitrogen, which are then lost to the atmosphere.

Constructed earthen basins have become a widespread means of storing liquid animal wastes. In this LCMR-funded project, we have been investigating the possibility of gaseous nitrogen losses from liquid dairy manure in an earthen storage. Such losses would increase the amount of manure that could be disposed of by land application without risking pollution.

Detailed information provided by the cooperating farm on manure applications, the numbers of cows and the feed rations has allowed a final evaluation of the manure management system. As a result, some conclusions had to be changed from the previous status reports.

Materials and Methods

The research site was the Charles Meyer dairy farm in Winona Co., Minnesota. The dairy herd on the Meyer farm was 150 Holstein cows in 1995, which increased to 165 in 1996 and to 231 in 1997. The milk yields (herd average) were 28,000 lb or 12,700kg in 1995 and 27,000lb or 12,300kg in 1996 and 1997. The wastes from the dairy barn and the milkhouse enter the first cell of the earthen storage basin through a submerged pipe. Most of the solids are retained in the first cell, either because they sink to the bottom or they form floating scum mat on the surface. The liquid under the mat equilibrates with the second cell through a second submerged pipe in the dam separating the two cells. Liquid from the second cell is pumped into a storage tank and used to flush the barn, thus completing the cycle. The maximum design volume of the two storage cells is 8,400m^3 when filled to the maximum depth of 2.44m (8ft). Due to sludge deposition, the operating depth is somewhat smaller, thus reducing the actual volume for storage . The actual dimensions of the storage basins were established by surveying in March of 1997. Twice a year, the contents of cell I are stirred up, pumped out and applied onto cropland with a traveling irrigation gun. Manure is pumped out until its level is below the pipe connecting cells I and II, leaving approximately 1,054m^3 of liquid in cell II so that flushing the barn can continue. To prevent the storage from overflowing, liquid is pumped occasionally from the second cell for land application. The amounts of these mid-term applications were taken into account in calculating nitrogen budgets.

Two modern aerators of 2hp each (Aeromix "Tornado") have been in use in basin #2 since June 12., 1996. This equipment and its installation was kindly provided by Aeromix Systems Inc. of Minneapolis. It enabled us to study the effect of enhanced aeration on the nitrogen chemistry of the manure system.

Manure composition: Manure samples were taken at regular intervals from both cells over the course of three refill periods from 1995 to 1997. The samples were analyzed for total N, ammonia/ammonium, nitrate, total phosphorus, pH, total and volatile solids, and ash content.

Determination of actual liquid volume in the system: After the manure had been pumped out of the first cell during the first week of May 1996, 2600g of Li was added to the liquid remaining in cell II. The lithium acted as a chemical tracer. The concentration of Li was measured by flame emission using ashed manure samples dissolved in 1-M HCl. By determining the concentrations in both cells over time, the mixing and turnover of cell liquids could be monitored. After mixing is complete, a uniform Li-concentration should occur. The time it takes to reach a uniform Li-concentraion in the storage cells is defined as the time required for complete mixing. At that time, the Li-concentration can be used to calculate the total volume of liquid circulating through the system. This volume and the concentrations of N, P and K in the cells were used to calculate the total amounts of these nutrients in the system. This allowed the estimation of nitrogen losses to the atmosphere as well as planning for the application of the manure as fertilizer. The Li-tracer was used for a period of 167 days from emptying the cells in the spring until the emptying in the fall of 1996, when the storage was again completely full without any freeboard.

Nitrogen budget: Nitrogen losses were calculated as the difference between the amount of nitrogen measured in the manure storage and the amounts of nitrogen excreted over the refill period. The excreted nitrogen was calculated by subtracting the nitrogen in the milk from the nitrogen supplied by the feed ration. Feed ration amounts and analyses were kindly provided by the Meyers. The daily feed ration per cow contained 677g of N in 1995, and in 1996 and 1997 it contained 771g of N. The nitrogen content of the milk was assumed to be 0.512% (van Horn et al., 1994).

Ammonia volatilization: Direct measurement of ammonia volatilization from the manure storage basin was done on five occasions in 1997 to corroborate the nitrogen loss estimates obtained with the above method.

Results and Discussion

Convergence of the Li-concentration in the two cells of the storage occurred several weeks before the end of the second refill period, indicating uniform mixing (see Fig. 1). At the end of the second refill period, the lithium tracer added at its beginning minus the amount removed from cell II in August allowed us to calculate the liquid volume of the manure storage when it is completely full. The storage volume was determined to be 6,711 m^3, 3,229 m^3 in cell I and 3,482 m^3 in cell II. These values were also used in the calculations for the end of the first refill period, since the storage was completely full then, too.

The amounts and chemical forms of nitrogen in the storage basins were monitored over the three refill periods. For both periods, comparison of the total nitrogen present in the storage at the end of the refill period to the amount that entered the system through feed indicated that substantial losses of nitrogen had occurred. Throughout the data collection period, analyses of KCl-extracts only yielded erratic readings of trace amounts of nitrate, regardless of aeration. The losses were calculated as follows:

10/18/1995 to 5/1/1996: 195 days of refill

N added with feed: 150 * 195 * 0.677kg =	19.8t
N removed by milk: (12,712kg / 365) * 150 * 195 * 0.00512 =	5.2t
N excreted by the herd: 19,802kg - 5,216kg =	14.6t
N left in cell II at beginning: 1,054m^3 * 1.149kg m^{-3} =	1.2t
Potential total N in the storage: 14,586kg + 1,211kg =	15.8t
N found in storage at end: 3,229m^3 * 2.014kg m^{-3} + 3,482m^3 * 1.319kg m^{-3} =	11.1t
=> N lost: 15,797kg - 11,096kg =	4.7t

The 4.7t represents a 29.8% loss of nitrogen over the 195 days. This is an average daily loss of 24.11kg N.

5/9/1996 to 10/23/1996: 167 days of refill

N added with feed: 165 * 167 * 0.771kg =	21.2t
N removed by milk: (12,258kg / 365) * 165 * 167 * 0.00512 =	4.7t
N excreted by the herd: 21,245kg - 4,738kg =	16.5t
N left in cell II at beginning: 1,054m^3 * 1.304kg m^{-3} =	1.4t
N removed from cell II by pumping in 8/96: 499m^3 * 2.111kg m^{-3} =	1.1t
Potential total N in the storage: 16,507kg + 1,374kg - 1,053kg =	16.8t
N found in storage at end: 3,229m^3 * 1.547kg m^{-3} + 3,482m^3 * 1.324kg m^{-3} =	9.6t
=> N lost:16,828kg - 9,605kg =	7.2t

The 7.2t represents a 42.9% loss of nitrogen over the 167 days. This is an average daily loss of 43.25kg N.

11/15/1996 to 4/15/1997: 151 days of refill

N added with feed: 214 * 151 * 0.771kg =	24.9t
N removed by milk: (12,258kg/365) * 214 * 151 * 0.00512 =	5.6t
N excreted by the herd: 24914kg - 5556kg =	19.4t
N left in cell II at beginning: 1,054m^3 * 1.323kg m^{-3} =	1.4t
Potential total N in the storage: 19358kg + 1394kg =	20.8t
N found in storage at end: 3,229m^3 * 2.816kg m^{-3} + 3,482m^3 * 1.627kg m^{-3} =	14.8t
=> N lost: 20752kg - 14758kg =	6.0t

The 6.0t represents a 28.9% loss of nitrogen over the 151 days. This is an average daily loss of 39.69 kg N.

Measurement of ammonia volatilization from the manure storage basin:

Date	Loss rate	Weather conditions
April 15	14.54 kg N d^{-1}	cool, light wind
May 16	24.11 kg N d^{-1}	cool, very windy
June 3	16.54 kg N d^{-1}	warm, sunny, breezy
June 10	19.34 kg N d^{-1}	hot, sunny, breezy

Comparison of the loss rates calculated from the inputs and manure analyses with the directly measured volatilization shows a difference of approximately 50%. This indicates that volatilization from the storage basin is not the only pathway for N-loss. The balance is most likely due to ammonia volatilization occurring in the barn.

At the beginning of the study it was hoped that substantial losses would occur by denitrification. Such losses are preferable to losses as ammonia because the nitrogen is then lost primarily as dinitrogen which is not available for plant uptake and therefor non-polluting. Larger amounts of nitrous oxide could be problematic because N_2O is a greenhouse gas, however, it constitutes generally only a small fraction of the nitrogen lost in denitrification. In order to confirm the occurrence of significant nitrification, higher and more consistent amounts of nitrate or nitrite would have to be present. Also, the pH never changed in the basins from an average of pH 7.4; a significant drop below pH 6.0 would have indicated nitrification. Since nitrification is a prerequisite for denitrification, nitrogen losses by denitrification must be assumed to have been negligible.

The pathway for nitrogen loss from the system must therefor be ammonia volatilization. The nitrogen loss rate increased during the winter refill period 1996/1997 compared to the winter 1995/1996. This suggests that the use of the two "Aeromix" aerators since the spring of 1996 has led to an increase in ammonia volatilization by "airstripping". In swine manure, aeration has been found to be an effective method for reducing NH_3.

Most of the nitrogen in the manure was in the organic form. Ammoniacal nitrogen (NH_3 and NH_4^+) represented between 34% to 50% of the total N. Even though the losses did occur as ammonia, the affected N-pool is the organically bound Nitrogen. As can be seen from figures 2-4, the mineral N-pool (NH_3 + NH_4^+) remains basically constant. This would require increased ammonification of organically bound N to replenish the NH_3 + NH_4^+-pool if NH_3 is removed to the atmosphere. Substantial atmospheric losses as ammonia are a mixed blessing. While they certainly help reduce the amount of environmentally active nitrogen that needs to be disposed of through land application on the farm in question, such losses are actually contributions of available N to the ecosystem. Ammonia emissions to the atmosphere are contribute to eutrophication and acidification of adjacent areas by atmospheric deposition. Ammonia in the atmosphere can be taken up directly by plants, or it can enter the soil by precipitation or dry deposition. This increases bioavailable soil nitrogen. Nitrification of ammonia to nitrate causes soil acidification. These two processes are especially problematic in poorly buffered and nitrogen-limited natural ecosystems such as surface freshwater and boreal forests, which are both extensive in Minnesota. For these reasons, ammonia in the atmosphere is considered a severe environmental problem in Europe, with emissions from livestock operations having been identified as the most important source.

Conclusions

Monitoring of the chemical forms of nitrogen in the manure has found no evidence for nitrogen losses by denitrification. The substantial losses that occurred from the system at the Meyer farm have two possible areas of origin: the livestock buildings and the manure storage cells, because at these two locations, the manure is exposed to the atmosphere. Measurements of the ammonia volatilization from the manure storage has shown that approximately 50% of the total nitrogen losses from the manure management system happen there. There is no environmentally neutral nitrogen loss from the system; all nitrogen lost contributes to the eutrophication and acidification of the local and regional ecosystem. Increasing ammonia losses from manure storages is therefor not a desirable management practice for reducing manure nitrogen for land application.