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EPA
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Proceedings: National Watershed Water Quality Project Symposium

FOREWORD

The lessons learned from watershed projects addressing nonpoint source problems are recorded in these proceedings of the National Watershed Water Quality Project Symposium, held September 22-26, 1997, in Washington, DC. The Symposium was conducted by the: U.S. Environmental Protection Agency, U.S. Department of Agriculture; Cooperative State Research Education & Extension Service, Natural Resources Conservation Service, ***Maryland Department of Natural Resources*** , and Conservation Technology Information Center (CTIC). The Symposium featured accomplishments of local projects funded under EPA's Section 319 (Clean Water Act) National Monitoring Program and USDA's Demonstration, Hydrologic Unit Area Programs, and Management Systems Evaluation Areas. The symposium also featured lessons learned in the Farm*A*Syst and Home*A*Syst programs.

ACKNOWLEDGMENTS

The success of the symposium and the information transferred from it and the proceedings is due to the expertise and efforts of many individuals. The sum of these are greater than the each individual part and will hopefully be multiplied many times.

Authors

A special thanks goes to the many authors of the papers and abstracts presented in this document. Their efforts in paper preparation and editing made this document possible.

Peer Review

Numerous individuals were involved in the peer review process, too numerous to list, but their invaluable insights and comments ***improved*** the scope and direction of each of the papers that they reviewed.

Program Committee

Appreciation goes out to those individuals on the committee that represented their organizations in planning the program. Their tireless efforts provided insight to the agenda and the tours.

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Monitoring the Effects of Nonpoint-Source Pollution Controls on Sny Magill Creek, Clayton County, Iowa

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The Sny Magill Creek watershed in Clayton County, Iowa (Figure 1), is the location of the Sny Magill Creek Nonpoint Source Pollution Monitoring Project, part of the U.S. EPA's National Monitoring Program. Sny Magill Creek drains a 35.6 mi^2 agricultural watershed, primarily in forest, forested pasture, rowcrop, cover crop, and pasture. The Sny Magill Project, initiated in October 1991, is designed to monitor and assess improvements in water quality from the implementation of best management practices (BMPs) in the watershed. The BMPs are intended to reduce sediment delivery to Sny Magill Creek and to reduce fertilizer and pesticide inputs. A paired watershed approach is being used; Bloody Run Creek, the adjacent watershed to the north, is serving as the control watershed. The objectives of the water-quality project are to show reductions in sediment, nitrate, and pesticide concentrations in Sny Magill Creek relative to Bloody Run Creek, and to document improvements in the biological habitat through a habitat assessment of the stream corridor and monitoring of the benthic macroinvertebrate and fish populations. At this time, results from the monitoring are mixed. Improvements in macroinvertebrates and pesticide detections have been measured, while fish, habitat, and nitrate and sediment loads are unchanged. This paper summarizes the water-quality monitoring results to date. Information on BMPs implemented in the Sny Magill watershed can be found in Palas and Tisl (1997, this volume).

Introduction

Sny Magill Creek is a coldwater stream in northeastern Iowa. Identified water-quality impairments include sediment, nutrients, and pesticides. Sny Magill Creek is managed for "put and take" trout fishing and is one of the more widely used recreational fishery streams in Iowa.

Iowa's State Nonpoint Source Management Report (IDNR, 1989) identified Sny Magill Creek as a priority for project action to improve water quality. The stream was further designated as "high-quality waters" and was to be protected against degradation of water quality. As a result of water quality concerns, the Sny Magill Hydrologic Unit Area land treatment project was implemented in the watershed in 1991 to reduce sediment delivery to Sny Magill Creek and to reduce fertilizer and pesticide inputs (see Palas and Tisl, this volume).

Fish Assessment

An annual fish assessment is conducted at six sites in Sny Magill and Bloody Run watersheds during the fall of each year (Figure 1). The sample date is selected to minimize stocked trout numbers and angler interference with fish sampling personnel, and to sample the streams under baseflow conditions. Two backpack-mounted stream electrofishing units are used to sample a 300-foot stream reach of mixed pool-riffle habitat at each site.

Results of the fish survey from all years show that the streams' forage fish populations are typical of Iowa coldwater streams. Twelve fish species have been identified. For all survey years, the dominant fish is the fantail darter in Sny Magill Creek and the slimy sculpin in Bloody Run Creek. With the exception of 1995 and 1996, year-to-year fluctuations in fish populations appear to be a normal response to variations in precipitation, runoff, water clarity, and water stage. Extremely low numbers were reported for the five Sny Magill sites during 1995 and 1996. The cause of the low numbers is not known. Chemical water-quality data and surveys of the benthic macroinvertebrate populations showed no negative response during this period. An herbicide spill at site SN2 on May 19, 1995, may have impacted the fish populations.

The index of biotic integrity (IBI) is a widely used tool for evaluating the environmental health of a stream or river based on its fish population. The IBI of Lyons and others (1996), developed for coldwater streams in Wisconsin, classified the five Sny Magill sites as "very poor" to "poor" and the Bloody Run site as "poor" to "fair" for any given year. The IBI scores have shown little change and low fish numbers from Sny Magill Creek for 1995 and 1996 prevents an IBI from being calculated for those years. Of the 12 forage fish species identified, only one, slimy sculpin, is classified by Lyons and others (1996) as intolerant to contamination. Slimy sculpin dominate the Bloody Run population (43 to 98% any given year), yet are not found in Sny Magill Creek. It is unlikely that additional fish species, especially intolerant species, will be found in either Bloody Run or Sny Magill creeks unless the species are physically reintroduced. Both Sny Magill and Bloody Run are coldwater streams separated from other coldwater streams by the Mississippi River, a warmwater body. This thermal isolation barrier limits inter-stream movement of coldwater fish species. The IBI of Lyons and others (1996) has its limitations (e.g., one metric is based on the number of intolerant species present), but will continue to be used until a more suitable/appropriate IBI is developed and tested using fish data from Iowa coldwater streams.

Habitat Assessment

The annual habitat assessment, designed to characterize stream habitat conditions, occurs in the fall under low-flow, baseflow conditions at eight water-quality sites (Figure 1; site BRSC was not included). Instream and streamside habitat variables are measured and observed at ten regularly spaced, cross-sectional stream transects within a 100-foot stream reach. Each stream reach includes two or three sets of pools and riffles.

The aquatic habitat characteristics were compared using a simple ranking process and habitat similarity index. The results suggest a relation between the drainage area size and position in the landscape to the habitat variables. Monitoring sites with similar drainage size showed greater habitat similarity to each other than to other sites. The apparent interrelatedness of habitat, drainage area size, and channel slope suggests that physiography and stream morphological processes such as channel erosion and sediment deposition are important determinants of monitoring site habitat character.

An original goal of the habitat assessment was to determine if there were any trends related to implementation of the land treatment changes in the Sny Magill watershed. The annual habitat assessment is good at characterizing habitat but the frequency of the assessment would need to be increased to monitor year-to-year trends attributable to land treatment changes.

Benthic Macroinvertebrate Monitoring

Benthic macroinvertebrate monitoring of Sny Magill and Bloody Run creeks occurs each year on a bi-monthly basis (April, June, August, and October) at eight water-quality sites (Figure 1; site BRSC was not included). Samples are collected in triplicate at each location for each month using a Modified Hess bottom sampler. Laboratory processing and data analysis is performed as described in Plafkin and others (1989).

The benthic community composition for both watersheds is similar. Figure 2 shows the metric results for the HBI values, taxa richness, EPT Index, and the percent dominant taxa. The metric values represent the mean, on an annual basis, for the combined sites of SN1 and SN2, and sites BR1 and BR2. The HBI value is used as a measure of organic pollution. HBI values range from 0 to 5. Lower values indicate streams of high water quality. Taxa richness, a direct measurement of the number of distinct taxa present in a sample, generally increases with increasing water quality, habitat diversity, and/or habitat suitability. The EPT Index measures the more pollution sensitive insect orders of the mayfly, stonefly, and caddisfly. The EPT Index generally increases with increasing water quality. The percent dominant taxa, a measure of the percent contribution of the numerically dominant taxon to the total population sampled, reflects community evenness and redundancy. A high proportion of dominant taxa (>40%) may indicate impairment of water quality.

Metrics that may indicate some discernible trends are the EPT Index and the percent dominant taxa (Figure 2). Both suggest trends of improving water quality in Sny Magill Creek during the monitoring period. The Bloody Run sampling sites have shown slight decreases in EPT Index values each year, suggesting steady to worsening water quality. The Sny Magill Creek sites have shown consistent increases in EPT values since 1992. During the monitoring period, the percent dominant taxon metric has declined for Sny Magill Creek. The percent dominant taxa metric values for Bloody Run Creek have fluctuated but shown no substantial improvements. Until 1995, the HBI values suggested improving water quality at Sny Magill relative to Bloody Run. In 1995, however, the HBI values increased for both creeks. Based on the HBI values for all sites and all years, the water quality is rated as "very good."

Physical/Chemical Water-Quality Data

Stream and suspended-sediment discharge, as well as nitrate and pesticide concentrations and loads, are measured for both Sny Magill and Bloody Run creeks. In spite of just one year of calibration period data, a significant relationship did exist between Sny Magill and Bloody

Run creeks for discharge, sediment, and nitrate load. The pesticide data, however, exhibited no correlation during the calibration period.

From the calibration to the treatment periods, there has been no significant decline in the nitrate loads for Sny Magill Creek relative to Bloody Run Creek. There has been a decline in the frequency of pesticide detections in Sny Magill Creek, from 60% to 25%; the frequency of pesticide detections in Bloody Run Creek has remained above 95%.

For both streams, the majority of a year's total sediment load is delivered during two periods: a spring snowmelt period and a summer storm period. Although BMPs have effectively reduced the sediment delivered from the uplands to Sny Magill Creek by an estimated 35% (see Palas and Tisl, this volume), these reductions in sediment have yet to be reflected in the sediment loads discharged by Sny Magill Creek. It is uncertain whether Sny Magill Creek will show significant reductions in sediment load as a result of BMPs implemented. In spite of their close proximity, some intense rainstorms have affected Sny Magill and not Bloody Run. Data from 1996 illustrate the significance of these rainstorms. In 1996, 14 days accounted for 90% of the year's total sediment load for Sny Magill while 204 days accounted for 90% of Bloody Run's annual total. There also is the concern over the large volume of historical sediment (post-settlement alluvium; Bettis, 1994) in the drainage network. Though implementation of BMPs in the uplands has reduced sediment delivery to Sny Magill Creek, the impact the large quantity of sediment historically stored in the drainage network may have on the sediment loads discharged from Sny Magill Creek is poorly understood.

Conclusion

Results from the Sny Magill Creek Project show some indication of improved water quality in Sny Magill Creek. The frequency of pesticide detections has declined and some of the metrics calculated for the benthic macroinvertebrates do suggest improving water quality for Sny Magill Creek relative to Bloody Run Creek. However, the fish and habitat assessments give no indication of improving water, and nitrate and sediment loads have not declined in Sny Magill.

Acknowledgements

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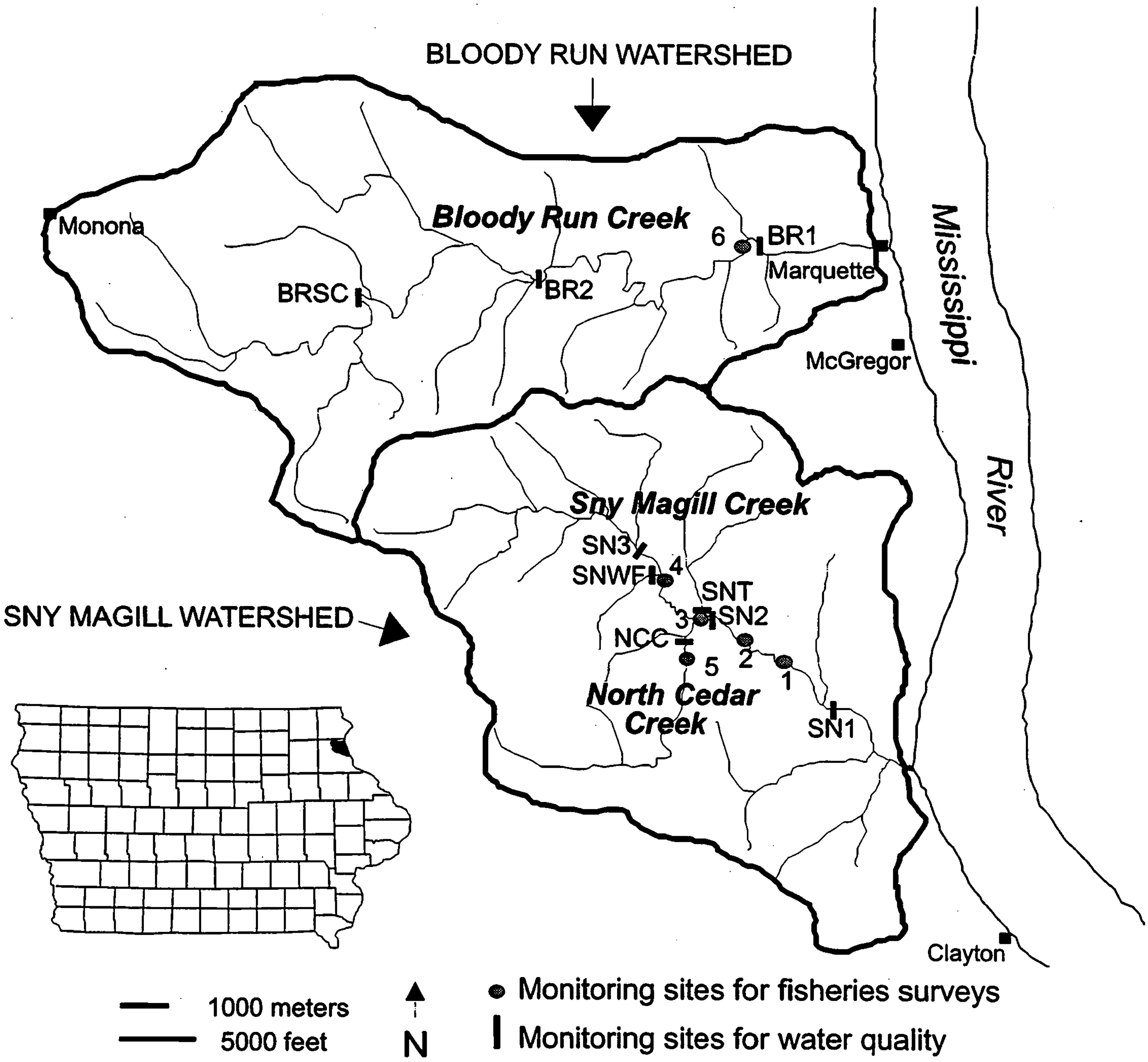
Figure 1. Location of Sny Magill and Bloody Run watersheds.

Figure 2. Benthic macroinvertebrate metrics for Sny Magill and Bloody Run creeks for HBI (A.), taxa richness (B.), EPT Index (C.), and percent dominant taxa (D.).



BLOODY RUN WATERSHED
Bloody Run Creek
Monona
BRSC
BR2
6
BR1
Marquette
McGregor
Mississippi
River
Sny Magill Creek
SN3
SNWF
4
SNT
3
SN2
NCC
5
2
1
North Cedar Creek
SN1
SNY MAGILL WATERSHED
Clayton
1000 meters
5000 feet
N
Monitoring sites for fisheries surveys
Monitoring sites for water quality

Figure 1

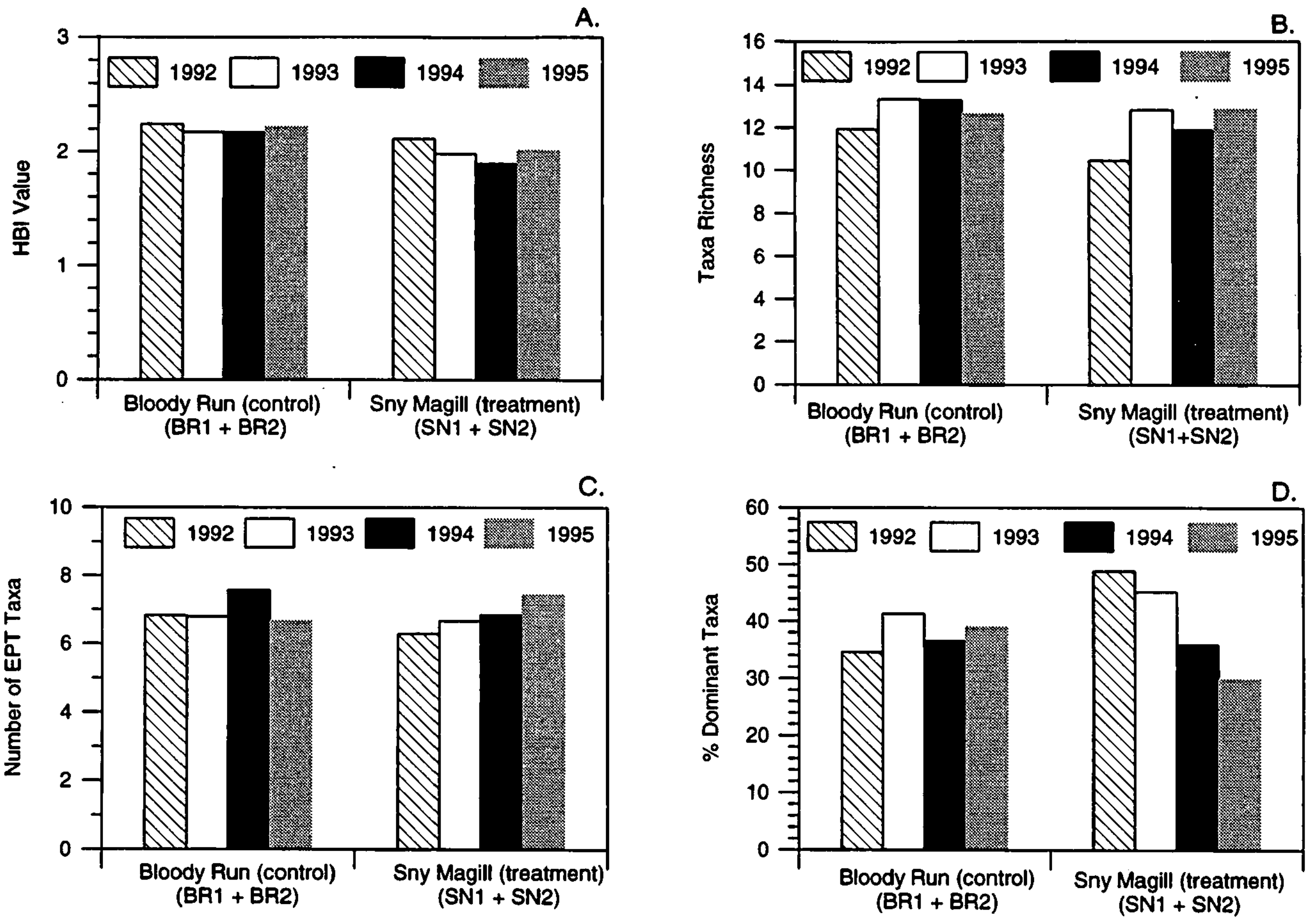

A.
HBI Value
1992
1993
1994
1995
Bloody Run (control)
(BR1 + BR2)
Sny Magill (treatment)
(SN1 + SN2)
B.
Taxa Richness
Bloody Run (control)
(BR1 + BR2)
Sny Magill (treatment)
(SN1+SN2)
C.
Number of EPT Taxa
Bloody Run (control)
(BR1 + BR2)
Sny Magill (treatment)
(SN1 + SN2)
D.
% Dominant Taxa
Bloody Run (control)
(BR1 + BR2)
Sny Magill (treatment)
(SN1 + SN2)

Figure 2

The Missouri MSEA Project:
A Model for "The Partnership Approach" to Water Quality Concerns

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Introduction

Water is one of the most abundant natural resources in Missouri. About 3.2 million Missouri citizens obtain their drinking water directly from the Missouri and Mississippi Rivers. Over 80% of rural Missourians obtain their drinking water from the numerous reservoirs and lakes that dot the state. Both Missourians and non-Missourians alike enjoy the abundant recreational activities associated with these water resources. It is vitally important that the quality of Missouri's water resources be maintained over time.

The objective of the Missouri Management Systems Evaluation Area project (MSEA) is to identify and/or develop agricultural cropping systems and practices that protect water resources from contamination by agricultural chemicals and sediment. The objective of the educational component is to facilitate the transfer of information and technology from all water quality research programs, including the MSEA project, to the end users; in the form of feasible practices that maintain and enhance water quality.

The MSEA projects are unique in their implementation approach, incorporating an extension/ educational component in even the earliest project stages. This allows a vast network of linkages and partnerships to form among research, extension, industry and the ag-community; ensures good communication and movement of information; and facilitates the voluntary adoption by producers of environmentally sound practices.

Setting

Missouri's MSEA project activities have extended throughout northern Missouri. The primary research site, located in a 28 square mile watershed in the north-central part of the state, contains claypan soils representative of the 10 million acre Midwest claypan soil region. One hundred forty surface water sites, representing 95 streams and 14 separate river systems throughout northern Missouri, have also been monitored for herbicide and nutrient contamination over the last four years. Sampling data from other monitoring programs, conducted by industry and other agencies, have been evaluated as well. Demonstration sites, highlighting economically viable low and non-atrazine alternatives and pesticide/nutrient BMPs, have been initiated in six producer's fields in atrazine-sensitive areas. These demonstration sites represent a collaborative effort among MSEA personnel, the Integrated Pest Management Program at the University of Missouri, regional Extension and Natural Resources

Conservation Service (NRCS) personnel, local community watershed committees, industry representatives, and local dealers and producers. (See Figure 1).

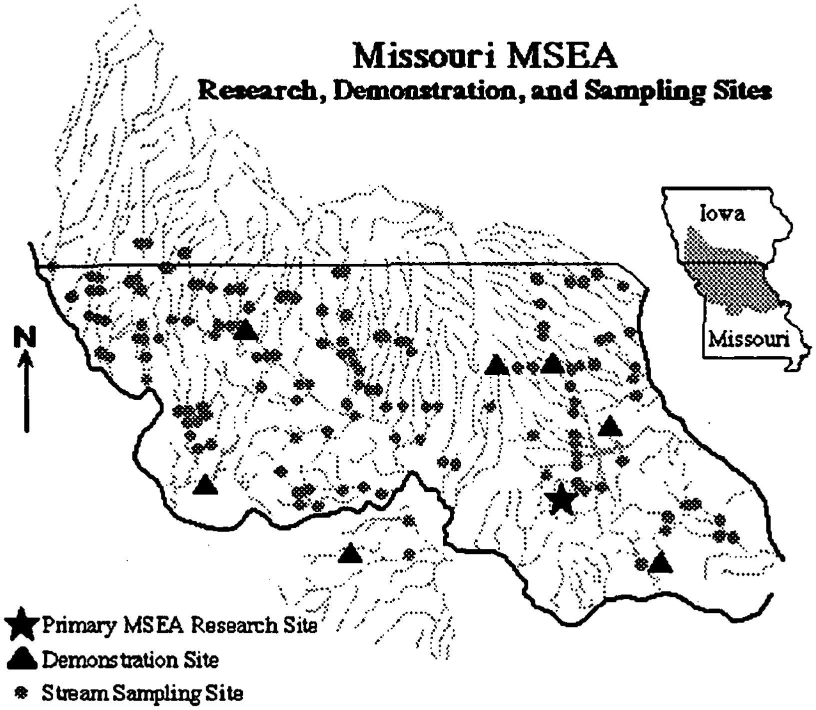

Figure 1. Site map illustrating the extent of Missouri MSEA project activities.

Education and Technology Transfer

Educational efforts have been targeted at groups and individuals with the greatest potential to influence others. Information and technology have been transferred to a diverse customer base through the print media (newsletters, press releases, newspapers, state and national magazine articles), radio, television, field days, tours, demonstrations, workshops, meetings, and conferences. Technology transfer and education programs have increased pesticide use safety, increased awareness of vulnerable water resources (e.g. over 1,300 abandoned wells have been properly sealed and capped), and improved technical advice and recommendations given to producers.

Primary emphasis this year was placed on educating communities regarding their local water quality problems; demonstrating the effectiveness, practicality, and economic viability of various best management practices (BMPs) as solutions to these problems; and providing feedback regarding both the economic and environmental impact of these measures on local surface water quality and agriculture.

Environmental Benefits Measured

No-Till Cropping Practices: The MSEA project was instrumental, and highly successful, in encouraging the adoption of no-till cropping for control of erosion and sedimentation. The use of no-till in Audrain County, the primary location of the Missouri MSEA site, has increased over 8-fold during the 6-year project period; climbing from

14,000 acres in 1990 to 139,500 acres in 1996, an increase from 5.4% to 45.2% of the cropland acreage. For comparison, no-till acres in the state increased from 10% to 30%, and in the Midwest Region from 6% to 18%, over the same time period (CTIC, 1997)B. This success presents an additional water quality challenge, however. Although no-till systems can reduce soil losses by over 80%, mean annual surface runoff from no-till on claypan soils is about 18% higher than from other conservation tillage systems that disturb the entire soil surface ("personal communication", Dr. Eugene Alberts). Higher surface runoff with no-till, coupled with the surface application of herbicides, provide increased opportunities for herbicide movement from farm fields.

Surface Water Quality: The most important water quality problem in Missouri is herbicide contamination of streams, primarily during the critical 45-60 day period following chemical application in the spring. The restrictive layer in many of our soils causes nearly 30% of the total precipitation to be lost as runoff. Excessive runoff usually occurs during the spring when soils become saturated. Of 140 surface water sites monitored throughout northern Missouri in 1994 and 1995; 55% and 42%, respectively, exceeded 3 ppb atrazine in the spring. Sampling was less extensive but much more intensive during 1996 and 1997. During 1996, sampling efforts were focused on the outlets of 20 major drainage basins which were outfitted with USGS flow gages. These sites were monitored 3-7 times during May - early July, with all exceeding 3 ppb until mid May. During 1997, 50 sites were monitored throughout May and June; half on a weekly basis, and the other half (those without flow gages) on a bi-weekly basis.

Atrazine concentrations in surface waters still need to come down. Preliminary data from 1997 show that 85% of these sites exceeded 3 ppb atrazine, 50% exceeded 20 ppb atrazine, over 30% exceeded 30 ppb, and 14 % exceeded 50 ppb. Our sampling over the last four years also reveals that herbicide concentrations in streamflow are not related to the land use patterns of a particular cropping region, but are more related to the hydrologic characteristics of the land resource area (Blanchard, 1995 and 1997). This finding significantly changes how policy makers and regulators must look at the surface water contamination problem.

Implementation of Best Management Practices and Alternatives for Atrazine: Label changes, along with extensive educational efforts, aimed at persuading producers to voluntarily reduce their reliance on this herbicide, have succeeded in decreasing the average use rate from 1.48 lbs/A in 1992 to 1.29 lbs/A in 1995 (Missouri Farm Facts, 1996). However, atrazine use is still widespread (82% of corn acres treated in 1995), and further reductions are necessary. Efforts to expand the voluntary adoption of BMPs which protect surface water quality have been hampered by numerous economic, social, and educational barriers. Identification of these barriers, however, is an important step in overcoming them.

Economic barriers include the increased costs associated with the use of alternative herbicides and the costs associated with creating and maintaining filter/buffer strips and riparian zones. Currently available alternative herbicides require producers and custom applicators to depart from the convenience of prophylactic, broad spectrum, preemerge, one-pass applications. Most of the low or non-atrazine alternatives are significantly more expensive; include a combination of herbicides; require additional applications; and require increased management, due to the narrower spectrum of weeds they control. Many also have a smaller window of application, decreased crop safety, and increased potential liability for both producers and custom applicators. Other BMPs , which encourage applicators to delay applications if fields are saturated or rains are expected, could limit the number of acres they can handle with their current equipment and labor (Johnson, 1996).

Public perceptions represent additional barriers to adoption. In 1994, 10 of Missouri's public water supplies were out of compliance with atrazine levels exceeding the MCL (maximum contaminant level) of 3 ppb for drinking water. But, with all but one of Missouri's public water supplies in compliance throughout 1995, 1996, and 1997, the level of concern has dropped. Extensive educational efforts will be required to inform communities regarding herbicide levels in raw water, how these levels fluctuate throughout the season, the inability of current filtration systems to remove pesticides above certain levels, and the impact that timing of quarterly public water sampling can have on whether or not they remain in compliance.

Overcoming these barriers will require continued educational and demonstration efforts to increase environmental awareness and technical expertise. However, the economic trade-off between production and environmental goals must be recognized, quantified, and addressed. Detailed economic analyses of the various options will help determine the type and amount of incentives required to speed the voluntary adoption of those BMPs with the greatest potential for improving surface water quality. Efforts are underway to conduct these analyses. Identification of areas most in need of implementing BMPs will help in the allocation of limited resources.

Documentation of Basin and Regional Herbicide Losses for Northern Missouri and Southern Iowa Streams: The percentage of applied atrazine lost in a watershed can be determined by monitoring both the atrazine concentration in the river during the critical period following application and the volume of streamflow. It is also necessary to know the number of acres cropped to corn and milo, the percentage of acreage receiving atrazine, and the average atrazine use rate within the basin. Blanchard and Lerch (1997) compiled these figures for 1996 to determine an estimate of the total atrazine applied in each tributary of the Missouri and Mississippi Rivers for northern Missouri and southern Iowa. Using the atrazine concentrations, daily streamflow, and estimated atrazine usage in each river basin, the percent of atrazine lost from each basin was estimated (Figure 2). Atrazine transport from twelve of the largest northern Missouri / southern Iowa river basins comprised 25% of the atrazine discharge in the Mississippi River at Thebes, IL; but represented only 2.6% of the drainage area and 11% of the streamflow. Preliminary data from 1977 show a similar pattern.

Precision Farming: Precision farming technology for automated measurement of soil, site, and yield variability within fields has been evaluated. Strategies to tailor nitrogen fertilizer application to match productivity variations have been developed which show that nitrogen fertilizer applications within a given field can be reduced by 5 to 15% with variable-rate field applications (Kitchen, 1995 and 1996). This could translate into an annual reduction of 14 to 40 million lbs of nitrogen fertilizer for Missouri's 2-million corn acres, and reduce leaching of soil nitrate to groundwater. Several research studies to evaluate the impact of precision farming on herbicide concentrations and losses in surface runoff are being initiated in 1997.

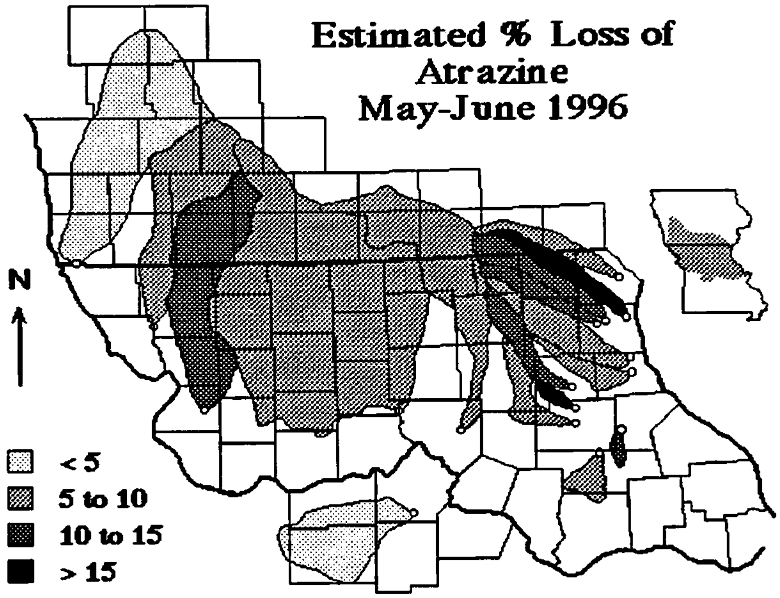

Figure 2. The percent of applied atrazine lost in each drainage basin during May-June 1996.

- **Ground Water Quality:** Herbicide contamination of ground water is not a major problem on claypan soils. Of the more than 1,000 ground water samples analyzed between 1991 and 1994, atrazine was detected in only 66 samples, with concentrations never exceeding 0.12 ppb. Alachlor was detected in only two samples at concentrations near the limit of detection (Blanchard, in press). Nitrate-N contamination, however, appears to be widespread; occurring primarily during the fall and winter. Of the more than 1,000 samples collected from 96 wells, about 25% of the samples exceeded the 10 ppm nitrate-N drinking water standard. In some cases, elevated ground water nitrates are associated with poor nitrogen management on cropped fields (Kitchen, 1997). Farming systems and technologies need to be developed to improve nitrogen crop-use efficiency and to minimize nitrate leaching into ground water.

Lessons Learned

Implementing solutions to water and soil quality problems require clear two-way communication between researchers and end users. While greater awareness regarding water quality issues exists today than a few years ago, adoption lags behind knowledge and technology. Adoption or modification of farming practices generally does not occur as a consequence of any one specific educational program. Change generally occurs in small increments over a period of time. Effective change must also include voluntary solutions to these important environmental issues. It is therefore essential to continue and further develop these ongoing educational programs that not only provide relevant, up-to-date, research-based information on cropping practices and systems that will protect our water resources; but that involve research, extension, government agencies, industry, and the affected communities in a true partnership.

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Lake Pittsfield Watershed Project
- A Cooperative Effort

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The objective of this project is to create of cooperative partnerships in the Blue Creek watershed (watershed) to reduce the sediment delivery to Lake Pittsfield and improve water quality through the implementation of upland cultural, and mechanical best management practices (BMPs).

Lake Pittsfield was constructed in 1961 as a flood control structure and public water supply for the City of Pittsfield located in west central Illinois. Watershed land uses that drain into Lake Pittsfield are dominated by row crop agriculture with small livestock operations (hog production lots) scattered throughout the watershed. Local concern about protecting the watershed's water resources was the catalyst to start the interest in development of a Lake Pittsfield Watershed Project (LPWP). A series of studies to determine the nonpoint source pollution impacts in Lake Pittsfield and cultivation practices within the watershed was the focus of the project's early years (1979-1992). As the result of the studies, sedimentation was determined to be the major water quality problem in Lake Pittsfield. The next phase of the LPWP (1992) was the construction of 29 water and sediment control basins (WASCOBs) and a single large sediment retention basin (SRB) on Blue Creek just prior to the in-flow of Lake Pittsfield.

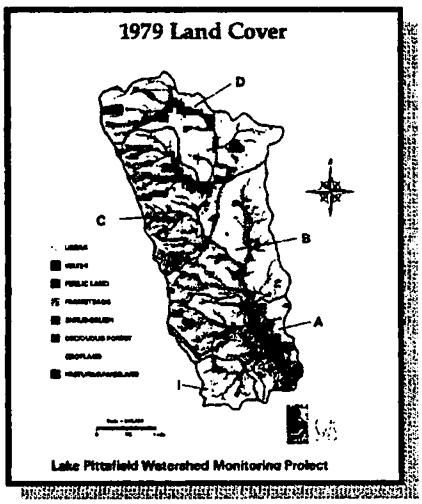

Figure 1

In the Section 319 National Monitoring Program Project (NMPP) land use, land cover and soils determinations generated by the Geographic Information System (GIS) mapping (Figure 1) were used to determine NPS pollution impacts. The GIS is a tool to interpret and then illustrate the data collection, monitoring and BMPs implemented within the watershed and in Lake Pittsfield and its direct ravine tributaries.

INTRODUCTION

Since the construction of Lake Pittsfield in 1961, sedimentation originating from the 7,000-acre watershed has severely reduced the original capacity of the lake. Sediment from farming operations, direct tributaries, and shoreline erosion has decreased the surface area from 262 acres to 222 in the last 33 years. By 1979, 25 percent of Lake Pittsfield's original water storage capacity was lost due to sedimentation. Implementation of agricultural BMPs (no-till conservation tillage/terraces/grass waterways, etc.) Occurred in the late 1970's, through the Agricultural Stabilization and Conservation Service (ASCS) utilizing funding under the United States Department of Agriculture's (USDA) Water Quality Incentive Program (WQIP).

The Lake Pittsfield National Monitoring Program (LPNMP) began in 1992 as a joint responsibility of the Illinois State Water Survey (ISWS), United States Environmental Protection Agency (U.S. EPA), and the Illinois Environmental Protection Agency (Illinois EPA). The goal of the LPNMP is to monitor and evaluate the effectiveness of the installed BMPs and implemented land use cultivation practices (no-till conservation, etc.).

The Pike County Soil and Water Conservation District proposed a series of WASCOBs in the watershed and a SRB constructed on Blue Creek just prior to the inflow of Lake Pittsfield. The funding for the construction of the WSCOBs and the SRB, was obtained through Section 319 Nonpoint Source Pollution Control Program of the Clean Water Act in 1992. Twenty-nine WSCOBs were constructed by the fall of 1995 in the watershed, along with the SRB in the summer of 1996.

DESCRIPTION

Lake Pittsfield sedimentation studies were conducted during the years 1974, 1979, 1985 and in 1992 to access the condition of the lake prior to the proposed WASCOBs and SRB implementations. The purpose of a lake sedimentation survey was to determine the following conditions: 1) the present lake volume, 2) the volume and mass of sediment deposited in a lake, 3) the stage-volume relationship within the lake, and, 4) if there have been prior sedimentation surveys to document the changes in the sedimentation rate over time.

WQIP funding focused on the adoptions of BMPs and cultural practices that will reduce the transportation of sediment, fertilizer, and pesticides within the watershed. These BMPs and cultural practices such as conservation tillage, integrated crop management, livestock exclusions, and wildlife habitat management, are being implemented in the watershed.

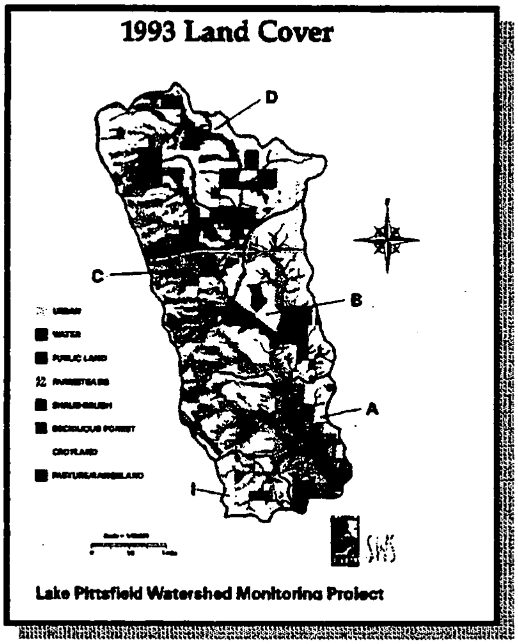

Figure 2

The land uses within the watershed consist of eight different designations including urban, water, public land, farmsteads, shrub-brush, deciduous forest, cropland and pasture/rangeland (Figure 2). The watershed is roughly divided in half between steep woodlands and pasture lands to the southern and western regions and rows crops on flat prairie soils in the northern and eastern regions.

The primary BMPs implementation in the watershed was the construction of the 29 WASCOBs. These WASCOBs have been constructed below some 2,482 acres, or 36 percent of the total watershed size. The construction of the large SRB (423 acre ft) was in the fall of 1996. The SRB is predicted to trap 83 percent of sediment delivery to the watershed prior to the flood water's discharge into Lake Pittsfield.

Locations of the WSCOBs are strategically placed throughout the watershed (Figure 3). The majority of the basins are located in the small tributaries of Blue Creek with other basins located on a western region of the watershed in the direct tributaries. The WASCOB's sizes range from 49.75 acre-ft to 5.02 acre-ft. The mean size of the basins is 24.29 acre-ft. Construction of the SRB (423 acre-ft area) was completed in the summer of 1996.

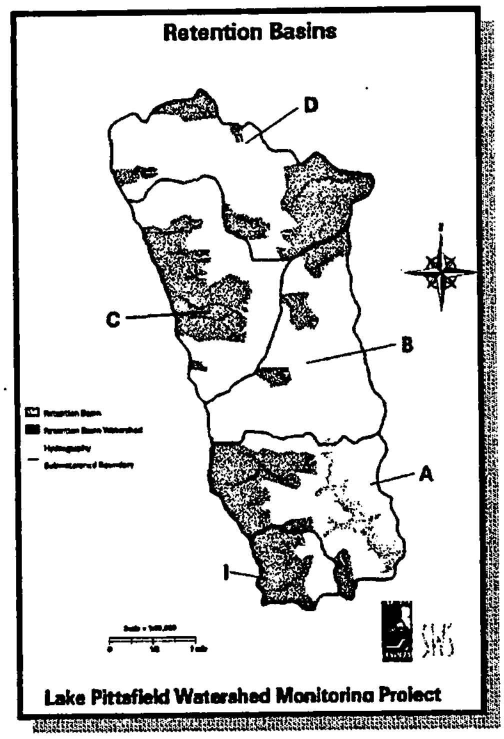

Figure 3

WATERSHED STREAM MONITORING

The stream monitoring strategy was to establish a series of stream sampling and designed flow gaging stations within the watershed. In the fall of 1992, the sampling network was created to collected data in the determined five subbasins (Figure 4). The network consists of automatic samplers and a Doppler flow meter at station B (Lake Pittsfield) to measure stream flow during lake backwater episodes. Five automatic samplers were installed at five separate sampling station locations within the watershed. These locations included the tributaries of Blue Creek, the main channel of Blue Creek, and a large direct tributary to Lake Pittsfield located in the southwestern area of the watershed.

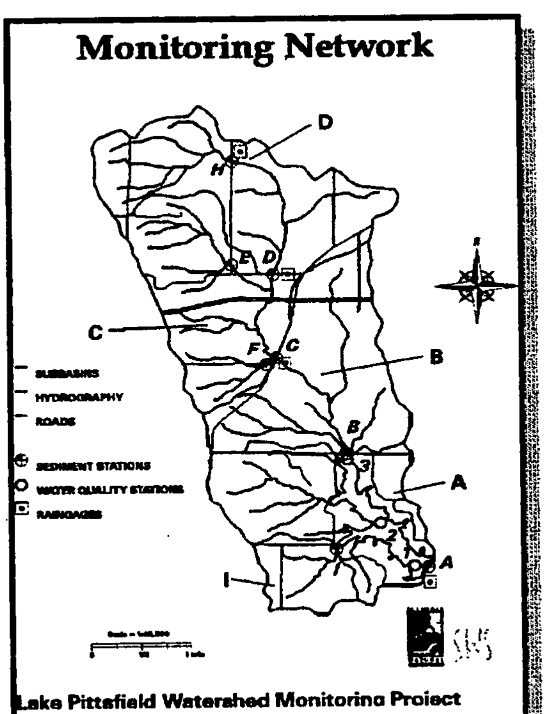

Figure 4

Watershed yields of a sediment baseline were formulated by an intensive sampling schedule during significant flood events during 1993. Normal stream flows were sampled on a biweekly basis to determine the base flow. Stream sampling was intensified during the Spring sampling seasons when the flows' measurements at chosen stream monitoring stations were taken every 3.5 days in accordance with the U.S. EPA National Monitoring Program. All stream samples follow U.S. EPA methodology and flow measurements are performed in accordance with USGS procedures.

MODELING/APPLIED TECHNOLOGIES

Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, updated, manipulate, analyze and display all forms of geographically referenced information.

GIS is being used in the watershed to spatially characterize many of the physical and hydrologic features. GIS has made it possible to construct a high resolution digital model of the land uses/land covers, the hypsography or digital elevation model, hydrology, soils and other physical features needed to properly define a watershed for environmental modeling and assessment. The GIS databases are being used in conjunction with the Agricultural Nonpoint Source Pollution (AGNPS) model to assess the factors affecting the lake's water quality and to characterize physical and environmental activities and their interaction within the watershed. A survey of the extensive ravine stream channel network was conducted in 1978 and was scheduled to be repeated this spring. GIS will be used to develop three-dimensional models of the ravine network which then will be integrated so that physical changes over the two decades can be assessed.

A digital elevation model (DEM) is the digital form of the hypsography in which the data was used to determine the aerial extent of the 29 WSCOBs. With the use of the GIS, the WASCOBs subwatersheds can be characterized for their soil types, slope, slope lengths, land use/land cover and farming practices. Such a determination will allow for an improved assessment of the WSCOB's expected life and for a more comprehensive management of the overall watershed program.

The use of GIS in conjunction with the development of spatial digital databases (SDD), can be utilized for accurate assessments of the stream profiles, streams slope, and to determine areas/shapes of an infinite number of watersheds along a stream reach. These various physical analyses with the integration of the SDD, are making it possible for improvement of the needed assessments/analyses to support management decisions.

RESULTS

The 1992 study, determined that the lake volume was 2,679 acre-feet, which represented a total lake volume loss of 24.8 percent or an average annual volume loss of 0.79 percent since 1961. This compares to the average annual volume loss rate found in the previous studies which varied from a high of 1.19 percent (1974-1979) to a low of 0.32 percent (1985-1992) (Table 1).

Table 1. Comparison of Percent Volume Loss for Different Survey Periods

Survey Period	Years	Lake Volume Loss (Acre-feet)	Lake Volume Loss (Percent)	Average Annual Volume Loss (Percent)
1961-1974	13.5	494	13.9	1.03
1974-1979	4.8	204	5.7	1.19
1979-1985	6.0	105	2.9	0.49
1985-1992	7.2	81	2.3	0.32
1961-1992	31.5	884	24.8	0.79

The study also concluded that 884 acre-ft of sediment has accumulated since 1961. This represents a total of 904,800 tons of sediment deposited from 1961 to 1992, for an average annual deposition of 28,700 tons (Table 2). This represents an average annual sediment yield per acre of watershed of 4.2 tons. The average annual sediment yield per acre of watershed has varied in each sedimentation study conducted. This variation ranged from 5.9 tons (1961-1974) to a low of 0.7 tons (1985-1992).

Table 2. Comparison of Sedimentation Rates (in tons) for Different Survey Periods

	Sediment Deposition (Tons)		Sediment Deposition Per Acre of Watershed Area (Tons)	
Survey Period	Total	Average Annual	Average for Survey Period	Average Annual
1961-1974	545,300	40,400	79.3	5.9
1974-1979	190,100	39,600	27.7	5.8
1979-1985	135,600	22,600	19.7	3.3
1985-1992	33,800	4,700	4.9	0.7
1961-1992	904,800	28,700	131.6	4.2

Table 3. Spring Flood Sediment Yields
Lake Pittsfield Watershed - 1993-1996

	D Subbasin 1756 acres	C Subbasin 1567 acres
1993 7 storms		
Floodwater Discharge (ac-ft)	509	379
Average Sediment Conc. (mg/L)	2,870	7,341
Sediment Yield (tons/acre)	1.1	2.4
1994 4 storms		
Floodwater Discharge (ac-ft)	259	410
Average Sediment Conc. (mg/L)	4,485	8,299
Sediment Yield (tons/acre)	0.9	2.9
1995 7 storms		
Floodwater Discharge (ac-ft)	400	368
Average Sediment Conc. (mg/L)	2,878	4,632
Sediment Yield (tons/acre)	0.9	1.5
1996 7 storms		
Floodwater Discharge (ac-ft)	298	360
Average Sediment Conc. (mg/L)	7,873	6,696

Results of stream monitoring over a four-year time period (1993-1996) revealed that the concentrations of sediment for the first three years were consistently lower (approximately by half) from the watershed's (eastern, Subbasin D) flat former prairie uplands then that of the (western, Subbasin C) steeper pasture and woodlands. The sediment trapping effectiveness of the WASCOBs appears to be influenced by the locations of older established ponds upstream. The WASCOBs in the steeper upland woodland and pasture lands in the watershed's southern and western regions appeared to be more effective in reducing sediment concentrations. During the recorded 1993-1996 "Spring Flood Sediment Yields" (SFSY) revealed an increased sediment in 1996, which was not consist with the previous year's reduction after the construction of the WASCOBs. There is limited evidence that the increase in the 1996 SFSY may be a result of channel streambank instability on Blue Creek in the middle portion of the stream reach (Table 3).

DISCUSSION

The stream monitoring data collected (1993-1996) to fulfil the National Monitoring Program requirements is still being reviewed to determine BMPs effectiveness. The increase sediment delivery rate detected in 1996, may just be a temporary adjustment of the Blue Creek's stream channel to the new hydrologic regime imposted by the WASCOBs. Additional monitoring will determine the extent of any stream channel adjustments. It is hoped that the landowners with WASCOBs located on their land will be able to see the effects of their own farming operations on their basins and give more consideration to conservation farming practices on other areas of their land. Proposed plans are to implement six loose stone weirs on Blue Creek within Subbasin D.

These structures will serve to help reduce the rate and amount of streambank erosion through grade control.

The Farm / Field * A * Syst Decision Support Systems

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The Farm / Field*A*Syst Decision Support Systems (DSS) are user friendly software designed to help assess farm practice impacts (cropland, pastureland, woodland, farmstead, wetland/waterbody, and other resources) on water quality. Pollution potential is evaluated by identifying high risk categories for watersheds or projects. Plan of action to address problems found in farmsteads and fields while preserving data confidentiality is provided.

Results of field tests indicate that the DSS have a high potential to reduce water pollution because they provide a precise list of pollution risks for each farm and recommendations to correct problems. This capability to show and print simple action recommendations for identified high risk categories accelerates the assessment process, and increases farmer participation and implementation.

The Farmstead Assessment System (Farm * A * Syst)

The Farmstead Assessment System (Farm * A * Syst) supports voluntary rural water pollution prevention programs. The program provides unique pollution risk assessment tools for farmsteads and a flexible program implementation framework that has been successful in building interagency and private sector partnerships to support rural pollution prevention efforts. (Jackson, 1995).

The main goals of Farm * A * Syst are to :

- create awareness of farm activities and structures that may cause drinking water contamination and other environmental problems;
- promote an understanding of pollution prevention and clean-up actions;
- identify sources of technical, educational and financial assistance;
- aid in developing personal, voluntary action plans.

This is accomplished by integrating complex national and state environmental policies and programs of numerous agencies into an applied decision-making framework for farmers, ranchers, and rural residents. The framework uses a series of step-by-step worksheets that evaluate rural activities and structures posing risks to groundwater. Information on available financial, technical and educational assistance is also provided through fact sheets developed to coincide with each worksheet. Farmers and rural residents can use Farm * A * Syst on their own, or in consultation with local experts. The system is designed as a confidential service to concerned farmers and rural residents.

The Farm * A * Syst Decision Support System (FADSS)

Description

The Farmstead Assessment Decision Support System (FADSS) is a computer software developed to facilitate the use of the Farm * A Syst worksheets, provide action recommendations to solve problems associated with current farmstead activities, and help identify important issues by watershed or project, so educational programs or efforts can be directed to priority areas.

Major components of the software are:

- user-friendly data entry windows to record farmstead rankings for all assessment worksheets and categories;
- computation of average risk rankings for each worksheet and computation of overall farmstead risk rankings;
- display all high ratings from individual farmstead assessments and action recommendations to reduce high risk factors;
- capability to modify action recommendations for high-risk factors by authorized information managers;
- search capability by sheet categories and risk rankings, computation of risk factor frequency, and display of summary statistics;
- display of fact sheet information;
- printing of action recommendations and summary statistic reports;
- Microsoft Windows based system.

A more detailed description of FADSS is available in Robert and Anderson, 1995.

Implementation and evaluation

The DSS was used by the Stearns County Soil Water and Conservation District, Minnesota, the University of Wisconsin Cooperative Extension of Buffalo county, Waupaca county, and UW -Platteville Extension. It was used on about a total of 100 farms. Visits to each farm were conducted by a trained conservationist or agent. The DSS was also sent upon request to 31 states and 3 Canadian provinces for evaluation.

Benefits and lessons learned

Principal benefits of FADSS reported in the four pilot evaluations are:

- a strong capability to reduce water pollution because the system automatically provides a list of high risks for each farmstead and precise recommendations to correct the problems. This seems to have increased farmer participation. This is also important for educators or others assisting in the evaluations because it reduces the follow up time.

- minimizes the time needed to complete an assessment, a factor very important to farmers and educators. FADDS reduces the time needed for assessment from 2-3 hours to approximately 1 hour.

- very user friendly.

- favors greater consistency of assessments between farms.

- stores all the data in a database while protecting the confidentiality of assessments.

- provides to project managers summary tables of risks and indicates most frequent high risk categories. For example, in southwestern Wisconsin (UW -Platteville Extension), FADSS was used to conduct farmstead assessments on 17 farms. FADSS analysis tools immediately identified that high risks of water pollution were principally in two categories ' Petroleum product storage' (32 cases), followed at a significantly lower frequency by ' Household waste water treatment ' (14), ' Livestock yard management ' (12), and ' milking center waste water treatment ' (11). The ' High Risk Table " indicated that within each of these types of risks, there were 1 or 2 categories with greater risks. For example, in the case of petroleum product storage, high risks most often identified were in the categories ' Spill and tank overfill protection ', and ' Tank enclosure'.

FADSS was preferred over the printed worksheet and fact sheet system but it does require a computer notebook with a good color screen. Agents that used it with farmers have recommended the following improvements:

- capability to display more graphs and print them in color
- more help for the most technical categories
- more explanation or helps indicating why some questions are important and how they relate to pollution prevention.
- prepare a video tape as a complement to the user's guide to make the learning of the software easier.

The Field * A * Syst Decision Support System (FIADSS)

The Field * A * Syst Decision support System (FIADSS) is a complement to Farm * A * Syst, which addresses the management of a whole farm. It is based on a comprehensive and whole farm planning tool - The Whitewater Whole Farm Planning Manual - developed by USDA-NRCS with a team of representatives from the farming community, agencies, commodity groups, and environmental groups, in southeastern Minnesota.

The Basic Conservation Planning - Whole Farm Planning

The goal of the group was to assemble materials that expand environmental awareness, take into account the interactions between many land uses, and help make decisions on the best possible management practices for farm profitability and environmental protection.

> The objective of the system is to provide a method to develop a farm plan that covers all farm natural resource needs while meeting financial and personal goals.

The process is voluntary and confidential. It is designed to be flexible to meet a wide variety of needs and planning decisions. The planning process is driven by the user to meet personal needs and provides guidance needed to manage all resources. Depending on individual goals, the plan, or parts of the plan, can be shared with others. There are numbers of agencies, private individuals, and groups that can assist the producer.

Whole farm planning materials are organized in a logical and methodical way to help in the planning process and , perhaps, look at farm management in a new way. This may take a while to complete the first time. But once done, the farm plan is easily maintained and modified as needed. Worksheets are organized in distinct sections that should be completed in sequence to get the best benefit from the plan. The sections are:

1. Goal setting: statements of farm management goals within a defined time frame to help focus the planning and the implementation.

2. Inventory: listing of all resources to define current condition, identify basic lacks of certain resources, and to later assess maintenance, improvement, or loss.

3. Evaluation: help define the current state of resources and management. It attempts to identify all resource concerns that may occur on farms in accordance to local standards of resource protection. Worksheets are divided into distinct land uses: cropland, pastureland, woodland, wetland/waterbody, and farmstead. Resource concerns are divided into a four tier evaluation process similar to Farm * A * Syst:

- Rank 4: low potential impact on productivity and probably enhances production. Resource enhancement.
- Rank 3: low-moderate impact on productivity and probably maintain productivity. Resource maintenance.
- Rank 2: moderate-high impact on productivity and may maintain or reduce productivity. Resource degradation with some controls.
- Rank 1: high impact on productivity. Productivity will be reduced. Uncontrolled resource degradation.

4. Alternatives: investigation of alternative actions - what and how - to meet selected needs. Some actions may be evident and others may require more detailed analysis to ensure that they meet financial goals. Guide sheets demonstrate the possible combinations of practices and their interactions.

5. Selection and implementation: selection of steps, actions, and timeline to implement the selected alternative. Blank forms are designed to help the process. They include:

- Action item
- Land use, resource concern
- Goal for resource concern
- Action items needed to achieve goal, priority, responsibility, deadline to complete, and date completed.

6. Follow up: study of impacts of actions and selection of some changes when needed

*Description of the Field * A * Syst Decision System*

The FIADSS software is intentionally very similar to FADSS. The primary goal is to complement and broaden the objectives of FADSS. The look of the software - dialog, data entry, and data processing windows - is also intentionally similar to facilitate its use. Only will the key features be presented, particularly features different from FADSS.

The basic functions of FIADSS are:

- data input
- file and database management
- output of selected action recommendations
- query
- multilevel helps

The principal content additions relate to goal setting, evaluation work sheets, aids in selecting and implementing actions, and notepad for follow-up.

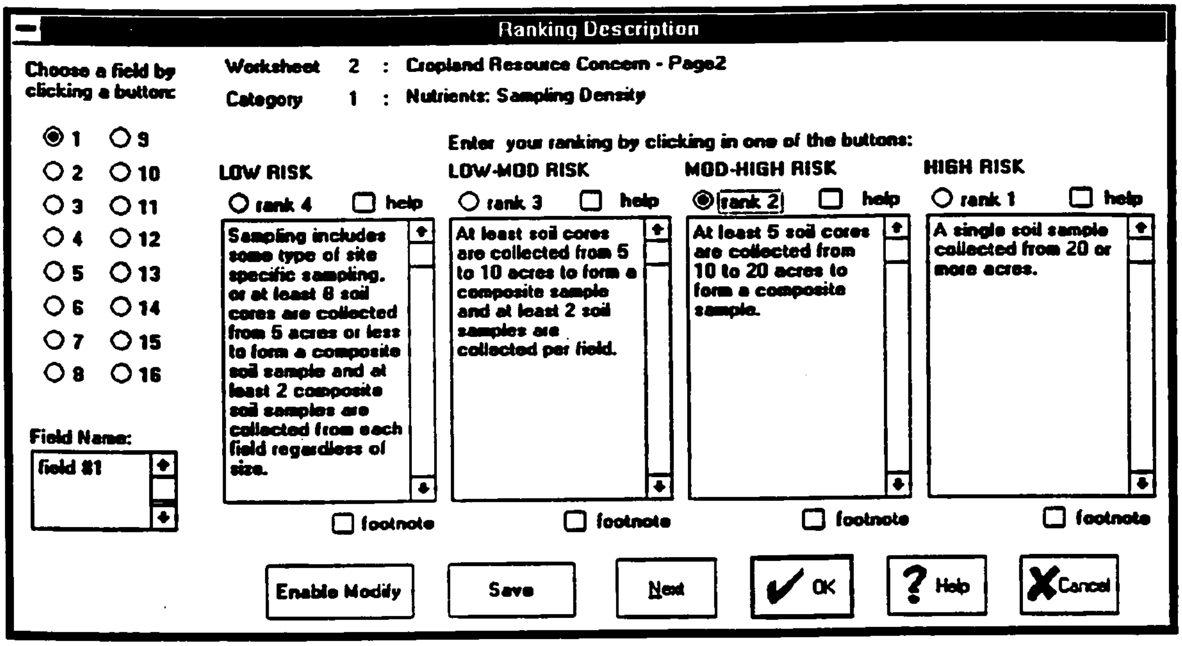

Figure 1. Dialog window for selecting a field and a risk level, and input of a field local name

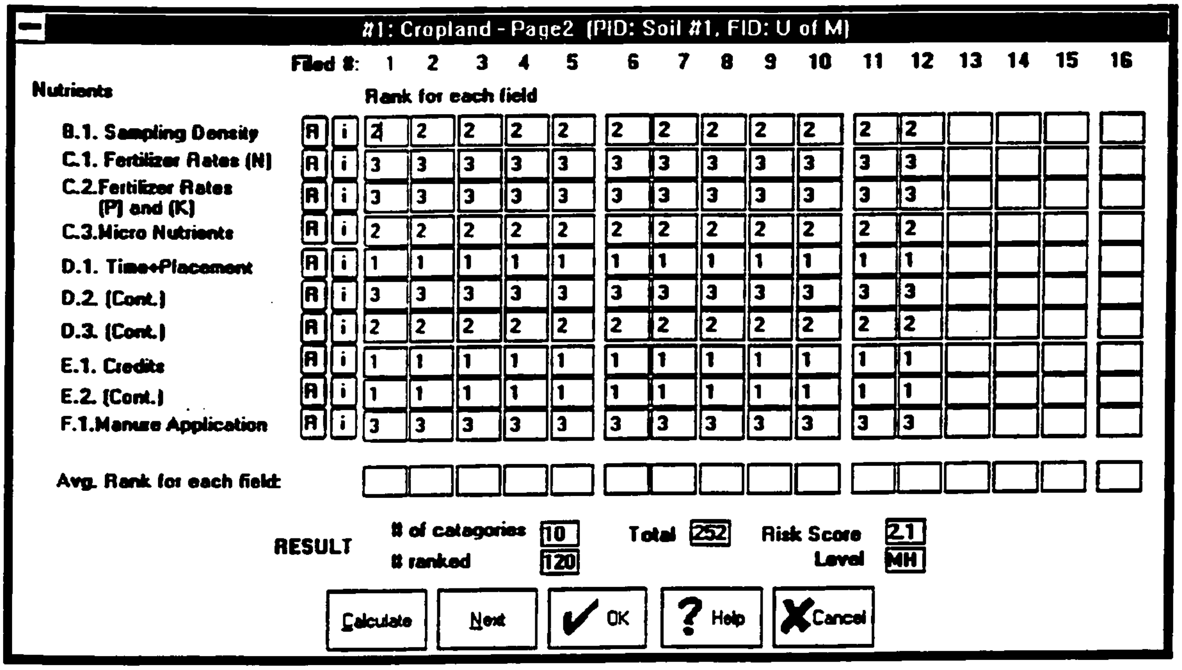

Figure 2. Dialog window for risk level input, access to the ranking description dialog window [i button], and to the action recommendation window [R button]

1. Goal setting. A simple form helps define farm goals and select appropriate actions.

2. Evaluation worksheets. New worksheets help evaluate on-farm resources and management risks:

- cropland
- pastureland
- woodland
- farmstead
- other resources: ground water, urban corridors, recreation
- wetland / waterbody

Worksheets allow for an evaluation of up to 16 fields or parcels. When a farm has more than 16 parcels the farm record can be split into several records identified in the " General Information " worksheet. Each field can receive, in addition to a code number made of the field ID and a number 1 through 16, its usual name (e.g., Todd 80 N) from a dialog window in the ' Ranking Description ' input window (Fig. 1). Each worksheet has several pages grouping into coherent dialog windows all types of categories (Fig. 2).

3. Alternatives. Guide sheets designed to assist in evaluating the effect of potential actions and their impact on agroecosystems.

4. Action Plan. Field * A * Syst provides a list of action recommendations for identified high risk conditions. They are developed regionally and can be eventually modified locally by authorized program managers. They can be accessed at the time of evaluation or summarized and printed by the system after the farm evaluation is finished. In addition, a form is provided to help implement selected actions.

5. Follow-up. An electronic notepad created to record actions and follow-ups.

Hardware and software requirements

FADSS and FIADSS require a PC computer running Windows 3.1 or Windows 95. The system should have a least 4 MB RAM and 1 MB of free hard disk free. More disk space is needed to store farm and field data. A mouse or an equivalent pointer is required.

More information

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Utilizing Voluntary Farmstead Assessments to Encourage Best Management Practice Adoption in the Skaneateles Lake Watershed

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Skaneateles Lake Watershed Agricultural Program

This report provides an illustration of how a voluntary watershed protection program was established through efforts of local farmers, the City of Syracuse, Soil and Water Conservation Districts, Cornell Cooperative Extension associations, the Natural Resources Conservation Service, New York State Department of Health, and New York State Soil and Water Conservation Committee. In addition, the report explains how farmstead assessments were adapted to adequately address priority non point source pollution concerns and serve as an educational tool for farmers.

Program staff developed materials for farm assessments from existing sources such as Farm*A*Syst, the New York City Watershed Program, and Ontario Environmental Plan. Farm assessments are merely one part of a comprehensive planning process utilized to address water quality concerns in the Skaneateles Lake Watershed.

A key component of all plans is that they are consistent with operators' business plans. Moreover, plans cannot negatively impact farm profitability by increasing Best Management Practices' operating and maintenance costs. The net economic effect of all proposed practices on a farm business must be zero or positive.

Introduction

Skaneateles Lake, located in the Finger Lakes region of Central New York, is the primary source of unfiltered drinking water for the City of Syracuse and surrounding communities. Watershed area measures 73 square miles, which is small compared to other Finger Lakes. Approximately 200,000 consumers purchase Skaneateles Lake water from the City of Syracuse.

The City of Syracuse was faced with either constructing a costly filtration plant, or implementing a comprehensive watershed protection program covering all land uses. Agriculture accounts for approximately 48 percent of total watershed area and was the first land use to be examined by the City of Syracuse. Watershed protection is not a new concept for the City of Syracuse. Since the early 1900's, Syracuse has employed watershed inspectors to monitor the public water supply. An example of existing watershed protection efforts is an annual pesticide survey that all watershed farmers fill out.

Legislation, namely the Surface Water Treatment Rule, was the impetus behind commencing a watershed protection program. The Onondaga County Soil and Water Conservation District gathered a group of watershed farmers together to form an Ad Hoc Task Force and make recommendations to the City of Syracuse for an agricultural watershed protection program. Task force members were from three counties comprising the watershed, as well as the City of Syracuse Watershed Control Coordinator. To guide members in formulating their recommendations, a member of the New York State Soil and Water Conservation Committee chaired the group. This chair was also the chairman of the Onondaga County Soil and Water Conservation District.

In 1994, Syracuse Mayor Roy Bernardi endorsed the Ad Hoc Task Force recommendations in a public signing ceremony. Watershed farmers were pleased with the outcome, as they recommended a voluntary program fully funded by the City of Syracuse.

Program Development

Guidance

Upon formalizing the task force recommendations, the Ad Hoc Task Force assumed new duties and changed their name to the Watershed Agricultural Program Review Committee. This group is responsible for providing guidance to program staff, as well as reviewing Whole Farm Plans. Before program staff came on board, the committee developed vision and mission statements to guide the program.

The Skaneateles Lake Watershed vision as described by the group is: *The Skaneateles Lake Watershed will be an environmentally sound region, where a viable agricultural industry and others benefiting from the lake work together harmoniously to improve and maintain a high standard of water quality.*

The program mission is: *To carry out a cost effective, innovative program for the farming community that upholds the high drinking water quality standards of Skaneateles Lake.* This mission has served the program well, as external funding sources, have been used to cover 81 percent of Best Management Practices implementation costs. The USDA Farm Services Agency is one of many outside sources used to fund implementation projects.

Structure

Three existing agencies either assigned or hired staff to carry out various duties in the Skaneateles Lake Watershed Agricultural Program. The Onondaga County Soil and Water Conservation District is responsible for program administration, nutrient management, plan design, and implementation. Cornell Cooperative Extension of Onondaga County provides technical assistance for pathogen management, pesticide risk evaluation, and farm business management. The Natural Resources Conservation Service is responsible for soil management, plan design, and implementation.

Implementation and Evaluation Approaches

Initial Meetings

To promote farmer enrollment in the Skaneateles Lake Watershed Agricultural Program, staff held three informational meetings throughout the watershed. Approximately 67 percent of eligible farmers attended at least one of the three meetings and enrolled over 80 percent of all agricultural land in the protection program. A key factor behind successful program enrollment was the effort of the Watershed Agricultural Program Review Committee. This group encouraged their peers to attend informational meetings and enroll their farms in the program. Another factor was the teamwork between agency directors to promote the protection program to eligible clientele.

Program staff gathered critical data with farmers regarding general environmental conditions on their farms through a "Farmer Affirmation Questionnaire" at each of the three initial meetings. This information indicated specific assessment worksheets that farmers needed to fill out at a later date. After staff interpreted questionnaires, they mailed each farm a "Farmer Affirmation Report" that explained which additional worksheets farmers needed to fill out and why.

Farm Assessments

There are 15 potential farm assessment worksheets that a farmer may have to complete, based on needs identified by the initial questionnaire. The worksheet titles are as follows: 1.) *Pathogens,* 2.) *Manure: Field Application and Storage,* 3.) *Stream Management,* 4.) *Milking Center Wash Water,* 5.) *Silage Storage,* 6.) *Petroleum Product Storage,* 7.) *Fertilizer Management,* 8.) *Pesticide Use,* 9.) *Barnyards,* 10.) *Water Well Evaluation,* 11.) *Waste Disposal,* 12.) *Soil Management,* 13.) *Pasture Management,* 14.) *Forest Management,* and 15.) *Neighbor Relations.* An interdisciplinary group designed the worksheets to address concerns in the Skaneateles Lake Watershed. Since the City of

Syracuse does not filter Skaneateles Lake water, Giardia and Cryptosporidium are the primary concern and many worksheets concentrate on these pathogens.

Farmers and program staff completed farm assessments together to ensure accurate results. Time needed to conduct these assessments ranged from a half hour to two hours, based on complexity of operation and size of business. A visual inspection of all areas of concern gave program staff an opportunity to document positive practices, as well as areas needing improvement.

Following farm visits, team members from Cornell Cooperative Extension, Soil and Water Conservation Districts, and the Natural Resources Conservation Service generated a "Worksheet Report". In this report the team outlined possible Best Management Practices to consider that alleviate potential concerns, as well as positive actions the cooperator may already have in place to reduce non point source pollution.

Environmental Benefits Measured

Cropping Changes

Most program participants had soil conservation plans on file, as required by the Food Security Act, to reduce erosion. However, additional reductions in soil loss were needed to reduce sedimentation concerns in the watershed. Nine farms adopted different crop rotations to reduce soil loss. One farm chose to implement strip cropping, as well as contour farming, while maintaining his existing rotations. All farms appreciated being presented with alternatives in the "Worksheet Report". This gave them time to consider other options prior to working with program staff in developing their Whole Farm Plan.

To measure environmental benefits, the Natural Resources Conservation Service Resource Conservation Specialist utilized the Food Security Act Alternatives model to estimate soil loss. Implementing practices such as strip cropping, contour farming, and alternative crop rotations produced admirable results. These practices reduced annual erosion by 1,369 tons.

Nutrient Management

Cornell University soil test results are the basis for all nutrient management plan recommendations. The Skaneateles Lake Watershed Agricultural Program provides free soil testing for one test recommendation, which is good for three years. Program participants are responsible for taking their own soil samples after three years.

All nutrient management plans account for livestock manure, as well as crop rotations. Dairy and livestock farmers reduced the amount of purchased nutrients the most, while crop farmers altered their commercial nutrients the least. Savings ranged from $180 to $1,911. Average savings per farm amounted to $1,180 annually.

To measure fertilizer savings, the author utilized partial budgets. This method is used to examine specific areas of a farm business and determines the profitability of making changes in one's operation, measured in net farm income. A key component in calculating profitability involves utilizing manure nutrient analysis to place an economic value on manure. By having a quantifiable economic analysis available to illustrate savings from nutrient management, program participants are more likely to continue soil testing, owing to a positive impact on their farms' profitability.

Lessons Learned

Conducting Farm Assessments

Each step in the planning process offers unique educational opportunities. Utilizing a questionnaire to determine appropriate farm assessment worksheets provides farmers with an illustration of why certain areas of their business need closer examination. This is best achieved when a written report accompanies applicable assessment worksheets.

Another educational opportunity occurs when program staff work with a farmer to fill out his or her farm assessment worksheets, referred to in the Skaneateles Lake Watershed Agricultural Program as "Tier II Worksheets". While staff interact with farmers by visually examining farming practices, a two way exchange of ideas and suggestions is facilitated. This visual examination helps reinforce to program participants that no environmental concerns will be reported to regulatory agencies.

Merely conducting environmental assessments does not ensure that operators will change their management practices or be receptive to discussing improvements. However, an environmental performance report can augment assessments by explaining how farm environmental conditions may impact water quality. A report should document positive environmental practices that farmers already have in place, as well as areas needing improvement.

Program Delivery

Agency cooperation is paramount to program success. Staff from the Soil and Water Conservation Districts, Cornell Cooperative Extension, and the Natural

Resources Conservation Service jointly drafted a letter to all watershed farmers endorsing a voluntary watershed protection program. A farmer member of the Watershed Agricultural Program Review Committee was also involved in the program endorsement letter.

All agencies involved should define their roles and describe how they can best contribute to a program's overall success. Teamwork can build upon the strengths of each agency. For example, Cornell Cooperative Extension has research based information on a multitude of areas critical to the Skaneateles Lake Watershed Agricultural Program including nutrient and pathogen management, in addition to pesticide data. Soil and Water Conservation Districts have decades of results in encouraging and assisting producers in adopting conservation practices, as well as securing resources for them to do so. The Natural Resources Conservation Service has extensive experience in providing technical assistance in Best Management Practice design and implementation.

Conclusion

Results obtained in the Skaneateles Lake Watershed Agricultural Program can be replicated elsewhere if certain factors are in place. In fact, the program is a model for New York State's Agricultural Management initiative. Farmer endorsement and promotion are necessary to facilitate program sign-up. A voluntary watershed protection program overseen by a farmer review committee was a key selling point to encourage farmer participation. Moreover, farmer input is crucial in developing effective Whole Farm Plans to reduce environmental concerns.

Multi-year multi-rate demonstrations of manure application for corn fertility in northeast Iowa

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Setting

Livestock is raised on nearly 90% of the farms in the four northeast counties of Iowa. In a manure initiative started in 1987, Iowa State University Extension staff helped area farmers determine the nutrient content of solid manure from dairy, beef, and swine feedlots, and also from dairy barn gutters. With the results of over 1,000 manure samples in hand, a project manure management extension specialist was assigned to assist farmers to optimize use of their manure nutrients. It was soon apparent that one roadblock preventing many farmers from taking appropriate manure credits was that they did not know how much manure they were applying to their fields. A set of wheel scales was purchased with funding by five local banks to calibrate manure spreaders. A common estimated application rate had been 10 tons of manure per acre. Calibrated rates from over 100 spreaders showed the average application was 22 tons per acre.

Still, farmers were reluctant to take manure credits - especially for nitrogen. In most cases manure was surface applied. Farmers were unsure how many nutrients were being lost due to volatilization or runoff before spring tillage. How much nitrogen would be available for the first years crop? What about second year credit? There also was the issue of uniformity of manure application. Without uniformity, manure credits cannot be taken effectively.

Sampling manure for nutrient content so that it can be applied for maximum benefit to crops is difficult. Although a significant amount of manure is handled as a solid in local dairy and cattle feeding operations, increased popularity of confinement feeding has increased liquid manure storage for most swine operations. Liquid handling makes it possible to better manage the time of application, rates and uniformity; but obtaining a representative manure sample from the storage structure can be a problem. The sample is usually taken when the storage structure is being emptied after mixing, the manure has usually been applied before the laboratory results are back.

Considering these management issues and uncertainties about manure crediting, most farmers are not comfortable relying on manure as a consistent nutrient resource.

Introduction

In the karst topography of Northeast Iowa, both ground and surface water resources are threatened if manure nutrients are not properly managed. The USDA Northeast Iowa Water Quality Demonstration Project has established a network of demonstrations to thoroughly document nutrient content of various manures, first-year and carry-over availability, sufficiency of modest rates for corn production, and the effects of excess application.

On-farm manure demonstrations for corn production compare various manure resources, nitrogen fertilizer (with and without manure) and check plots. Measurements on the replicated plots include manure nutrient contribution (through manure analysis and spreader calibration), plot yields and soil and plant nitrate nitrogen analysis. New demonstrations are developed annually throughout the project area, and long-term demonstrations are also maintained. Both long-term and short-term manure application demonstrations are designed specifically to address producer concerns about the concentration of manure nutrients and their seasonal availability, control of spreading rates, and other management issues related to optimizing the use of this on-farm resource.

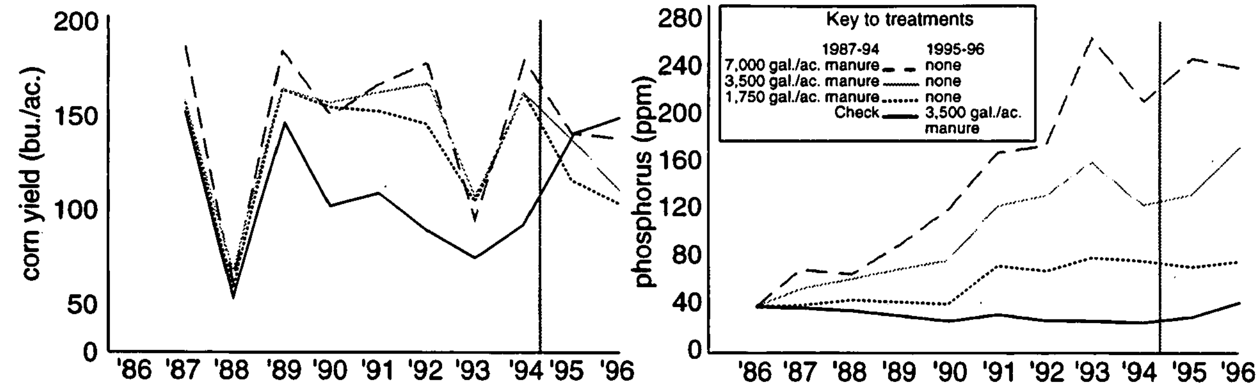
Multi-year demonstration - "Burrack-Kregel Site"

The Burrack-Kregel site was a 10 year manure management demonstration initiated in 1987 by the state-sponsored Big Spring Demonstration Project on continuous corn. Demonstrated was the effect of a fall application of low (1,750 gal.), medium (3,500 gal.), and high (7,000 gal.) rates of swine finishing manure compared to 180 lb./A. applications of commercial N (urea) applied in the fall and spring. A check area had no manure or nitrogen applied. The treatments were replicated three times for eight years (1987-1994). Each treatment area was approximately 30x100 feet. Yields and stalk NO_3 tests were hand harvested from the center rows.

Environmental benefits - results and discussion

The "more is not better" observation was borne out by the demonstration. Average continuous corn yields were identical for 5 years (1989-1994) at 153 bushels per acre on plots receiving 3,500 and 7,000 gallons of manure per acre. The five-year average yield from the 1,750 gallons manure treatment was 145 bushels per acre. The impact of excessive manure application was shown at the end of eight years when the end-of-season cornstalk analysis averaged 8,606 ppm NO_3 -N (4x excessive) in the 7,000 gallons manure treatment, 4,046 ppm (2x excessive) in the 3,500 gallon manure treatment, and 605 ppm (marginal) in the 1,750 gallon treatment. Similar relationships between the manure treatments were present when the soil was analyzed for P and K, however, soil pH test results were lower following increasing rates of manure application (see graphs).

Area producers showed considerable interest in the Burrack-Kregel site demonstration results, which were distributed annually through project newsletters and extension crop meetings. They began to raise additional questions, "How quickly will a field without manure history respond to manure application?", and "How much carryover nutrients are available to the next year's crop?" In fall of 1994 the demonstration design was changed to address their questions. During crop years 1995 and 1996 neither manure nor commercial fertilizer was applied to the areas which had previously received manure. Instead, 3,500 gallons of swine finishing manure was applied to the check areas and to the areas which had previously received 180 lb./A. commercial N in the spring.



Graphs of 1987-1996 Burrack-Kregel manure management corn yield and phosphorus.

The check areas responded immediately to the manure application, producing yields equal to the fall application of 180 pounds of commercial nitrogen. Likewise the manure application on the previous spring urea treatments produced similar yields, indicating that a modest application of manure would provide sufficient N to the crop the first year of application. The areas which had medium and high rates of manure the previous eight years also produced well the first year with no additional N fertilizer, indicating there was carry-over N from the previous manure applications. The late spring soil nitrate and fall cornstalk nitrate tests added information on the environmental impact of various manure application rates.

The cooperators who provided manure for this demonstration site admitted they were skeptical at first about manure nutrient credits, and followed results for three years before starting to make changes in their own crop/manure management practices. Now, however, they have discontinued starter fertilizer and commercial N following manure application on all of their continuous corn fields, and they have asked the Demonstration Project staff to assist with field demonstrations designed to further explore how much commercial fertilizer can be saved on corn the second year following a manure application. They now hire trucks to move manure to more distant farms, and have contracted with another livestock producer to purchase additional manure to apply to a nearby rented farm. They have commented that the work being done by the Northeast Iowa Demonstration Project provides information they cannot get from any other source, and that, without having local manure demonstration data; they would not be treating manure as a resource for their farm.

Multi-site demonstrations

Over the last three years manure demonstrations were established on fifteen additional farms using a design similar to the long-term demonstration. Time of application varied (fall, winter or spring) as well as the type, rate and nutrient content of the manure, according to what was available from the cooperating farmer. Spreading rates for manure applications were calibrated and manure samples analyzed for each demonstration to determine nitrogen credits.

Results and discussion

Average corn yields and end-of-season cornstalk residual nitrate levels from the fifteen sites are shown in table 1. Based on these results, project staff advise local producers that applying 50 lb. N per acre in addition to a typical manure application should provide sufficient nitrogen for their corn crop. Since manure spreading patterns (uniformity) and nutrient concentrations are not always consistent; the 50 lb. N application will compensate for this variability. They can also expect an immediate yield response from moderate manure applications on fields that have not received manure for several years, while high to excessive rates provide carry-over residual nutrients for the next crop year.

Table 1. Average corn yields from 15 manure management demonstrations, 1994-1996.

Treatments	Corn yield (bu./A.)	Stalk nitrate (ppm)
No manure, no nitrogen	124	542
Manure[1], no nitrogen	131	1,850
Manure[1], 50 lb./A. nitrogen	134	2,498
Manure[1], 100 lb./A. nitrogen	133	3,936

[1]The average N credit was 124 lb/A. from all liquid and solid manure sources.

All producers who have cooperated with field demonstrations, spreader calibrations, and manure sampling activities have made adjustments in their manure management and reduced purchases of commercial fertilizer. But the impact of these on-farm demonstrations doesn't stop at the farm gate.

Technology transfer of demonstration results

Methods used to transfer manure management results from demonstrations to local practice have included intensive information marketing, one-on-one assistance, and an innovative incentive education workshop program. Through these efforts, results have reached a large audience.

- Self guided tours of selected demonstrations have allowed farmers to observe manure and nitrogen management options throughout the growing season. Signage plus a mailbox containing brochures with previous demonstration details help visitors understand the manure demonstration.
- A manure management poster has been displayed at more than 25 events attended by over 5,000 people, including 12 locations outside the project area. An average of 250 results brochures and 150 bumper stickers ("Manure Happens – Take Credit") are requested each time the display is used.
- Frequent news releases tailored to the style needed by small community news media, and a project newsletter Water Watch with a bimonthly circulation of 1,700 convey demonstration results to interested local producers.
- A survey conducted by the Demonstration Project in 1995 showed 92 percent of farmers surveyed were aware of the project's Water Watch newsletter and results from N and manure field demonstrations were cited most often as the most useful information it carried.

One-on-one with local farmers

Farm Services Agency (formerly ASCS–FmHA) offices provided referrals to beginning farmers in the project area for a manure utilization/crop fertility planning demonstration. The Iowa Leopold Center for Sustainable Agriculture also provided funding. An extension manure management specialist worked individually with producers to develop a manure nutrient inventory, calibrate spreaders and sample manure. The program had given these young farmers increased management skills and confidence. Of the 17 who completed the program, only three said they were making fertilizer decisions for their own farms when the program began. By the end, this number had increased to 14.

Educational workshops

An innovative incentive education workshop program was designed to reach a large number of producers making more efficient use of staff time and resources. Demonstration results are used to reinforce the technical information provided. Participants learn to analyze and sample their soil resource, set realistic yield goals, develop a manure nutrient inventory, determine manure and legume credits, and prepare nutrient and pest management plans for their own farms. A second-year workshop participants' survey indicates that 92 percent have reduced nitrogen use and 82 percent of those did so by taking manure nitrogen credits. Eighty percent of the surveyed producers indicated they were more involved in soil test interpretation, compared to half before the program began.

Lessons learned

There are legitimate reasons why farmers hesitate to rely on nutrient credits from their manure resource, including uncertainties about nutrient content, application rate, and uniformity of spread patterns as well as the timing of application and cost of moving manure given historically inexpensive commercial fertilizer sources. For areas where improved manure management is both an environmental and economic priority, the Northeast Iowa Demonstration Project has shown the steps needed to effectively cause change in management practices. First, a local database of manure analytical results and spreader calibrations is generated to quantify the potential nutrient resource. Second, a long-term series of local, on-farm demonstrations provides credibility for the economic and environmental benefits of improved manure utilization. Demonstration results enhance education programs, but farmers want to observe the demonstrations firsthand, and may still make changes slowly or on limited acres to build confidence.

As farmers become more environmentally aware of manure and try to refine its use they will in turn expect their fertilizer suppliers, crop consultants and custom manure applicators to recognize manure as a resource. Demonstration Project staff have provided training on spreader calibration and manure crediting to crop consultants and ag businesses as a result of farmer-initiated questions. One farmer relayed that he had requested his custom applicator calibrate his spreading rate. The custom applicator had never thought of doing this but complied with the farmer's wishes. A year later the custom applicator returned to the farm and stated calibrating was the best thing he had ever done for his business and he now lets his other farmer customers know what is applied per acre so they too can take credit.

Another positive outcome of the manure demonstration effort has been the farmer-to-farmer dialogue that takes place as a result of the educational outreach efforts. When farmers meet, either at incentive program meetings or at the local coffee shop, they do talk about what has happened with the manure demonstrations and how they save money by taking manure credits. One farmer even wrote a guest editorial for an area newspaper on how developing a manure management plan reduced his commercial fertilizer needs. This peer reinforcement is ultimately one of the best ways to get manure best management practices established on the land.

Adoption of Best Management Practices (BMPs) to Meet Water Quality Goals in the Granger Drain Hydrologic Unit Area

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This report provides an overview of the Granger Drain Hydrologic Unit Area which has been active since 1991. Implementation and evaluation approaches utilized, environmental benefits measured and lessons learned are reported.

Setting

The Granger Drain Hydrologic Unit Area (Granger HUA) is located in the southern portion of the Yakima River Valley in central Washington State. The Granger Drain is composed of a natural and man-made drainage network that drains approximately 17,000 acres of highly productive irrigated agricultural land. The area within the Granger HUA is part of a desert climatic zone receiving 7-9 inches of precipitation annually. Crop production is dependent upon irrigation water from mountain storage reservoirs. Irrigated soils are predominately silt loams found on rolling topography (2-8%). Irrigation return flows from surface irrigation systems are collected in a series of sub-drains and are returned to the Yakima River via the Granger Drain. This highly productive agricultural system supports a wide variety of crops including: corn, pasture, asparagus, alfalfa, grapes, mint, orchards, hops, wheat and many specialty crops. The Granger HUA has eighteen dairies within its boundaries with cow populations ranging from 100 to over 3,000 and averaging over 600 producing cows.

There are approximately 450 agricultural producers in the project area. This number comprises both commercial operators (275) and noncommercial operators, with outside employment. Most of the small acreages are utilized as pasture. The area surrounds and includes two small communities, Granger and Outlook, with a combined population of 2,000.

Suspended sediment, nutrient and pesticide loads from irrigated agricultural areas of the lower Yakima River basin have long been recognized as serious impairments to water quality. The effects of soil erosion on farmland and the effects of sediment and dichlorodiphenyltrichloroethane (DDT) on the aquatic resource have been the focus of numerous activities by several agencies. Several reaches of the lower Yakima River and several of its tributaries violate numerous state water quality criteria and federal guidelines (Rinella, et al. 1992, Ecology, 1994, 1995). The Granger Drain (WA-37-1024) has been cited by the Washington Department of Ecology (Washington DOE) as exceeding standards in the following parameters: DDT, 4-4'-DDE, 4-4'-DDD, Dieldrin, Endosulfan, fecal coliform, dissolved oxygen, temperature, pH and ammonia. The Washington DOE estimated that the Granger Drain contributed 60 tons/day of suspended solids during the 1995 irrigation season (unpublished data Joe Joy, Washington DOE).

Objectives

The overall project goal is to reduce nutrient, biological and sediment loading from the Granger Drain to the Yakima River mainstream to a level which allows the river to meet its classification as a "Class A" water according to Washington DOE standards. The specific water quality objectives are to accomplish the following: 1. Reduce sediment loading by: a. increasing irrigation use efficiency by improved scheduling; b. decreasing sediment load in tail water by using Best Management Practices (BMPs); c. reducing tail water movement off the field by reuse. 2. Reduce nutrient loading to surface and ground water by: a. proper assessment of yield goals and nutrient needs; b. reducing nitrogen movement by proper timing and placement; c. reducing excess nutrient applications through soil testing and crediting all available nutrient sources. 3. Reduce input of *E. coli* by: a. optimizing waste management and confined feeding operations; b. optimizing waste application methods and timing; c. renovation and management of pastures.

The key to all of the above objectives is the implementation of BMPs at the individual field level as part of a coordinated farm water quality effort.

Implementation and Evaluation Approaches

Project objectives are being met by providing educational materials, demonstrations, technical assistance and developing working partnerships. Implementations of BMPs has been directed at individual producers by using a newsletter and CE publications to provide educational materials, commodity and area meetings and demonstration sites to share technology and follow-up with individual producers to implement BMPs.

A major focus of the project has been directed at dairy operations and associated nutrient management concerns. Many of the eighteen operating dairies in the HUA have increased significantly in cow numbers, with some dairies more than doubling. These increases have placed an additional strain on waste facilities and nutrient loading. The Lower Yakima Conservation District (CD) working with NRCS has worked with fifteen of the eighteen dairies to develop or update dairy waste management plans. This effort has been mainly directed at improvement in handling facilities to prevent movement of waste into surface waters. Approximately 44% of the $300,000 of FSA cost share money spent in the HUA has been spent on dairy waste facilities. Cooperative Extension's role has been to work with dairymen and other producers receiving manure to implement BMPs for nutrient management. Nutrient content of dairy waste, estimation of crop yield and nutrient requirement and the use of soil testing have been stressed as part of nutrient planning. A 1993 survey of dairy storage lagoons in the HUA found that with current management practices lagoons had significantly lower nutrient levels than other Northwest production areas (Table 1.). This information allowed dairymen to modify their application practices and better utilize this resource.

Table 1. A comparison of dairy lagoon nutrient concentration in Pacific Northwest production areas.

	TKN lbs/1000 gal	Inorganic N lbs/1000 gal	Total P lbs/1000 gal	Total K lbs/1000 gal
Granger Drain, WA	2.80	1.56	0.55	2.43
Whatcom County[1], WA	13.60	7.20	3.0	14.10
Willamette Valley[1], OR	4.88	4.46	0.37	5.10

[1] Data collected by Henry Bierlink in Whatcom County CE and by Mike Gangner in the Willamette Valley

Soil sampling to a depth of 4-6 ft in producer fields that have long histories of manure application have shown significant buildup of residual soil nitrate after harvest. These levels which often exceed 300 lbs N/ac have been used to demonstrate that excess nitrogen is being applied thus increasing the potential risk of significant nitrate being leached to ground water. Demonstration plots have been utilized to show that manure applications on these fields can be reduced or eliminated without yield reduction the next year. Phosphorus (P) soil test values in excess of 200 lbs P_2O_5/ac (bicarbonate extractant) have been found indicating long-term build up of P with its potential for movement to surface waters. Current efforts are addressing the potential for manure composting creating a product that can be economically transported greater distances from the dairies.

Since the major mechanism for the movement of nonpoint pollutants to the Granger Drain is through runoff from surface "furrow" irrigation, a major effort of the project was limiting the movement of sediment off the field. Converting surface furrow irrigation to either sprinkler or drip irrigation is the best long-term solution to this problem, because this essentially eliminates surface movement of NPS pollutants. However, this conversion is expensive and, therefore, implementation of this BMP is slow. Approximately 55% of the FSA cost share monies were used to help producers make this conversion and improve delivery systems. With proper management this conversion eliminates surface movement of nonpoint pollutants.

One of the most rapidly adopted BMPs was first introduced by the HUA project in 1994. Researchers had determined that small amounts of polyacrylamide (PAM) added to surface irrigation water could effectively reduce soil erosion under furrow irrigation. Some of Washington's first demonstrations were conducted in the HUA and sediment losses from the end of furrows were reduced by 90-95%. Producers have continued adopting the use of PAM and CE and NRCS personnel continue providing technical assistance to producers desiring to start using this practice. The use of PAM is a cost effective way of improving irrigation infiltration and significantly limiting movement of sediment and attached chemicals.

In 1992 the HUA was selected for a test site of a new field-level P index used to assess the potential for P movement. High P index levels were found associated with irrigated cropping practices where manure applications had been made (Stevens, et.al. 1993). This information is being used to increase producer's awareness of the long-term effects of continuous high rates of manure application.

In 1993 the HUA program utilized the Home*A*Syst program educating rural landowners of potential management practices that may lead to degradation of drinking water supplies and to introduce management practices that can reduce those risks. This was the first application of this tool in the state. Participants were solicited by offering free nitrate testing for domestic wells. Participants reported changes in current practices that would reduce the potential for drinking water contamination and environmental degradation.

To date the success of the project has been based on changes in public and producer's attitudes about water quality and their responsibility as an active part of the problem and the solution. Success has also been based on the successful implementation and continued use of BMPs by producers.

Although the Granger Drain HUA is a joint project with Natural Resource Conservation Service (NRCS), Washington State University Cooperative Extension (CE) and the Farm Service Agency (FSA), the activities of these groups in the HUA has been a catalyst for many working partnerships within the HUA and across the greater Yakima River Watershed. These partnerships are leading to increased efforts towards improving water quality across the Yakima River Watershed.

Environmental Benefits Measured

Although water quality monitoring has not been a part of this project, the Washington DOE has monitored portions of the Yakima River. In 1994 and 1995 the Washington DOE undertook a total maximum daily load (TMDL) evaluation in the lower Yakima River basin including the Granger Drain to control suspended sediments, turbidity and DDT contamination. Preliminary results of this study indicate reduced levels of *E. coli*. However, sediment levels continue to exceed acceptable levels. Washington DOE has established TMDL targets for sediment from the Granger Drain and the HUA is working with producers developing strategies to meet these goals. The TMDL requires return drains to be at 25 ntu or 56 mg/l for total suspended solids, requiring a 85-95% reduction in the Granger Drain discharge.

Based on the effort of the HUA project and the established TMDL, the local irrigation districts have initiated a monitoring program that will be used to evaluate the effectiveness of implemented BMPs and in evaluating future efforts.

Lessons Learned

In 1991 when this project was initiated the general public and producers had not accepted that a water quality problem existed or that they were part of the solution. The HUA over the years has served as an example of how water quality problems should be addressed in other areas in the watershed. During this time a Yakima River Watershed Council (YRWC) has been formed with an active water quality committee using the HUA as a focal point. As a part of the YRWC an interagency group has been formed coordinating efforts and facilitating transfer of technology between agencies and areas of the watershed.

Rate of adoption of BMPs was found to be directly related to cost of BMP implementation. Conversion of irrigation systems often costing $800-1,000/ac are much slower to be implemented than practices such as the use of PAM costing $4-6/ac per application. However, the implementation of expensive BMPs is often the only long-term solution to problems. Therefore, improving water quality in these cases should be considered a long-term effort.

Although the levels of sediment reduction that was initially anticipated have not been reached, producers and other involved parties are actively working on strategies to make things happen. One of the major lessons learned here is that it takes time to lay the groundwork that is often necessary in accomplishing complex goals such as improved water quality.

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DEMONSTRATION AND HYDROLOGIC UNIT PROJECTS IN NORTH CAROLINA: THE TEAM APPROACH TO IMPROVING WATER QUALITY

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Introduction

The Goshen Swamp Watershed, in the southern coastal plain of North Carolina, was selected in 1990 as a site for a Hydrologic Unit Area (HUA) Project. In the same year the Herrings Marsh Run Watershed, which lies within the Goshen Swamp Watershed, was selected as a site for a Demonstration (Demo) Project. This pair of watersheds, with their contiguous relationship on the landscape, provided an excellent opportunity to bring together several federal, state, and local agencies to focus on agricultural land use and its consequential effects on water quality.

The overall objective of both projects, to encourage accelerated, voluntary and widespread adoption of management practices and technologies that cost-effectively reduce impacts on surface and ground water and result in documented water quality benefits, has been achieved. The successful accomplishment of this objective required a collaborative and cooperative team approach to stimulate agricultural producers to adopt best management practices (BMPs).

Setting

The study watersheds are typical of much of the Atlantic Coastal Plain region of the southeastern United States. Soil parent materials are marine and fluvial sediments containing mixed sands and clays. Most of the soils in the watershed are sandy and well drained. The landscape is moderately dissected, consisting of gently undulating uplands and gentle valley slopes.

Two aquifer systems describe the ground water in the project area--the Surficial aquifer and the Cretaceous aquifer. The Surficial aquifer is the saturated portion of the upper layer of sediments, typically 7-17 meters thick. The Surficial aquifer is unconfined, i.e., its upper surface is the water table rather than a confining bed. Thus, it is sometimes called the water table aquifer. Many shallow wells tap the Surficial aquifer, which is particularly vulnerable to contamination.

The 5,000-acre Herrings Marsh Run Watershed (Demo) encompasses a broad mix of rural land uses which includes 120 farms and about 200 residences. Corn and soybeans are the field crops grown on the largest acreage, but there has been a significant shift to cotton production. Area producers also grow at least 10 other crops of significance, including tobacco and vegetable crops. Livestock operations include about 25, 000 hogs, 50, 000 turkeys, 130,000 broilers and 110,000 pullets. The number of swine in the watershed has doubled since 1990, and a continued increase in production is expected.

The Goshen Swamp Watershed (HUA), which covers approximately 130,000 acres, has a crop and livestock production pattern similar to that in the Herrings Marsh Run Watershed. The sandy soils, fluctuating water table, and intensive crop and livestock operations throughout the watershed provide a setting conducive to surface and ground water contamination.

Best Management Practices (BMPs)

Similar BMPs were promoted in both watersheds. Data will be reported for the Goshen Swamp Watershed since it also includes the Herrings Marsh Run Watershed.

Nutrient management was a major thrust because of the natural setting and the agricultural enterprises described previously. Recommended nutrient management practices include soil sampling, plant tissue sampling, waste sampling, crediting for nutrients contained in animal manures, calibration of application equipment, and split applications of fertilizers, especially nitrogen. Nutrient management plans have been developed for over 20,000 acres of cropland. Over 100 animal waste utilization plans have been developed to use more than 280,000 tons of animal manure on 1,700 acres of cropland.

Pest management plans have been developed for producers on 1,700 acres of cropland. The plans include scouting to assess the need for pesticide application, reduced rates of pesticide application, and the use of chemicals that are less persistent in the environment.

Animal waste management practices for water quality protection emphasize good manure handling, collection and storage, off-site transport of manure, and on-site management of manure as a plant nutrient or feed source for livestock. Eighty-five animal waste storage/treatment systems, including three poultry mortality compost facilities, have been installed on farms throughout the Goshen Swamp Watershed. The compost facilities have been a factor contributing to the statewide interest in poultry mortality composting. Permits have been issued for more than 500 mortality composters since the projects began.

The kinds and amounts of BMP implementation were determined through producer surveys designed to track land use and land treatment activities at field and watershed levels. Separate surveys for cropping and animal production systems were used. The BMPs employed in both crop and livestock management were identified and described.

Landscape features, which may be viewed as naturally occurring BMPs, were modified to reduce the amount of nitrogen reaching the streams in the watershed. Beavers constructed a dam near the Site 2 monitoring station which produced an enhanced in-stream wetland. In the upper reaches of the subwatershed above Site 2, a field border between a swine wastewater irrigation field and a small stream was planted to tree seedlings to intercept the nitrogen in the laterally moving ground water before it enters the stream.

Water Quality Evaluation

Methodology

Water quality of streams in the Herrings Marsh Run Watershed has been monitored using four continuous sampling stations. The four continuous monitoring stations for stream discharge and water quality data are located as follows: Site 1 (Red Hill) at the watershed exit; Site 2 (Beaver Dam) along a tributary downstream from intensive swine and poultry operations; Site 3, the background site, along the main stream flowing through woodlands; Site 4 located upstream from Site 1 to monitor the eastern portion of the watershed.

Sample collection has been continuous from October, 1990. Water samples have been collected hourly and combined into three-day composite samples. They are analyzed for nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, ortho-phosphorus, and total phosphorus. Stream discharge is recorded by the U.S. Geological Survey (USGS).

Monitoring wells were strategically placed to evaluate shallow ground water quality throughout the watershed. Well screens were placed at depths ranging from about 2 meters (m) to about 13 m. The wells were monitored monthly for nitrate-nitrogen and selected pesticides. Current well sites include a swine waste irrigation field, pasture field receiving turkey mortality compost, cropped areas for which nutrient and pest management practices are being implemented, and the turkey mortality composter site.

Biological monitoring has been conducted annually at Site 1 by the North Carolina Division of Water Quality (DWQ). Aquatic fauna are inventoried, with the primary output consisting of a species list with indications of relative abundance (rare, common, abundant) for each taxon. Unstressed streams have a diversity of species, while stressed streams have relatively few species. Water quality ratings are assigned based on the abundance and characteristics of the most intolerant invertebrate groups. Streams are classified as *Excellent, Good, Good/Fair,* and *Fair.*

Results

In the first year of the Demonstration Project, mean nitrate-nitrogen concentrations in the surface water leaving the watershed (Site 1) were twice the background concentrations (Site 3). Over the project period, there has been a continued reduction in nitrate-nitrogen and total nitrogen concentrations recorded at the outlet of the Herrings Marsh Run Watershed. This continued reduction indicates the water quality benefits of BMP implementation and landscape modifications.
Stream water from subwatershed 2 has been consistently higher in nitrate nitrogen compared to the other subwatersheds and watershed outlet. In the first year, daily nitrate-nitrogen concentrations at Site 2 sometimes exceeded 10 mg/L. Over-application of animal waste to fields probably contributed to the elevated nitrate concentrations at this sampling station.

Since July, 1991, the maximum nitrate concentration at Site 2 has been 8 mg/L and the mean has been about 5.5 mg/L.

Stream flow data from the USGS gaging stations were integrated with the stream monitoring data to calculate the mass loading of nitrate-nitrogen and ammonium-nitrogen. In 1991 and 1992, the mass nitrate-nitrogen leaving the watershed (Site 1) averaged about 30 pounds/acre/day. The tributary (Site 2) received about 20 pounds/acre/day from its sub-watershed. These levels have decreased slightly with time.

Baseline biological monitoring data indicated a bioclassification of *Fair* at Site 1. Lack of quality stream habitat has limited macroinvertibrate diversity, thus there has been little change in the bioclassification even though nitrate nitrogen concentrations have decreased

Ground water samples were collected monthly from 92 monitoring wells from 1993 to 1995 and quarterly thereafter. Analyses were conducted for three pesticides-- alachlor, atrazine, and metolachlor, the most widely used pesticides in the watersheds. Although the use of these pesticides is high, only two wells out of 92 had confirmed detections for alachlor. Only one well had a detectable level of atrazine and no wells had a metolachlor detection.

Most of the stream samples collected at the watershed outlet were free of pesticides at the analytical detection limits. Although there are large applications of herbicides (700-850 kg annually) in the watershed, current pest management BMPs used by local farmers and applicators appear to be satisfactory for maintaining acceptable ground water quality.

Lessons Learned

Value of small watershed

The small Herrings Marsh Run Watershed (5,000 acres) was deliberately selected for the Demonstration Project with the specific aim of showing, during the project life, measurable water quality changes resulting from land-applied BMPs. Although improvements in water quality were observed during the project period, we concluded that five years is about the minimum time period that one should consider in water quality project planning.

Importance of land use data

Complete and accurate land use data are essential for the proper interpretation of results. The task of obtaining such data was more difficult than we had anticipated. The farmers themselves are the most knowledgeable source of the information but it became increasingly difficult to arrange meetings with farmers to obtain it. It became necessary to complement the farmer surveys with "windshield" surveys and cropping records maintained in county offices.

Modeling constraints

The selection, calibration and verification of models and the development of an interface to link the model with a geographic information system (GIS) has been a significant activity of the Demonstration Project. This effort was undertaken to enable one to predict water quality impacts when a given set of land use characteristics is known. Modeling technology is dynamic and developing, as a result, the calibration and validation of the models has been a slow and painstaking process. The intense data requirements of the model were challenging even for the well defined 5000 acre watershed.

A major modeling goal is to extend water quality findings over space and time. Project modeling has resulted in correlations between modeling and monitoring that range from good for flow, acceptable for long term transport and poor for short term concentration and transport. Continued work is needed to develop coordinated modeling and monitoring techniques for water quality planning and extension of water quality cause and effect relationships over time and space.

Dynamic reference data

The baseline conditions at the conclusion of the projects are quite different from those at the beginning. Several events beyond our control have occurred within the last three years which make quantitative assessment of impacts more difficult.

In the Demonstration Project, the subwatershed for the Site 3 monitoring station was primarily a natural woodland and, thus, it provided a good reference condition. A large swine operation is now in place in the subwatershed which has altered the background conditions. Several new swine operations have been established in other parts of the watershed. It will be interesting to note the effects, if any, of such operations on water quality.

Heavy rains during the summer, 1995 and the damage caused by two hurricanes in 1996 have altered stream channels and hindered the nutrient mass yield determinations.

A development of about 40 manufactured homes has occurred in the Demonstration Project area. On-site waste systems are being employed for the development. There is the potential for water quality impacts, particularly when a septic system malfunctions.

Necessity for team approach

The excellent results from the project would not have been possible without the outstanding cooperation and collaboration among the federal, state, and local agencies and organizations. A single agency could not have carried out the broad range of activities. The Cooperative Extension Service (CES) provided education and information programs. The USDA Natural Resources Conservation Service provided technical assistance. The USDA Farm Services Agency provided cost share assistance to area producers. North Carolina State University (NCSU) scientists have led the modeling efforts to select, calibrate and validate models and evaluate correlation with water quality monitoring date. The USDA Agricultural Research Service (ARS), through its Soil, Plant, and Water Conservation Research Center in Florence, SC, has conducted detailed monitoring of both surface and ground water, and has assisted with the nitrate and pesticide modeling efforts. The North Carolina Division of Water Quality (DWQ) has conducted biological monitoring of selected stream sites in the Herrings Marsh Run Watershed. The US Geological Survey (USGS) has provided cost share assistance for installation of automated sampling and flow measuring stations, maintenance for the flow discharge relationship and flow data management.

Perhaps the most important members of the team are the farmers themselves. The projects proceeded well due to their willingness to cooperate and assist in many ways. We give them our thanks and appreciation.

What Have We Learned About Our Nonpoint Source Pollution Education Programs?

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Educational programming is a common element to most watershed protection projects, but the actual components to an educational strategy vary greatly from project to project and even from educator to educator. These efforts vary mostly in the level of program intensity and in the way information is delivered to the public. In Wisconsin, since 1978, nonpoint source pollution prevention strategies have been targeted to hydrologic units or watersheds in a collaborative effort by the University of Wisconsin Extension, the Wisconsin Department of Natural Resources, the Wisconsin Department of Agriculture, Trade and Consumer Protection, and a number of county agencies. Expanding the watershed-based programs, in 1990 the University of Wisconsin Extension and Wisconsin's Natural Resources Conservation Service began a USDA Demonstration Project under the President's Water Quality Initiative.

Educational programming, often referred to as information and education (I & E) strategies, attempts to provide information to landowners in expectation that it will lead to environmentally beneficial actions such as the adoption of best management practices on the farm. These I & E strategies, especially those that seek to reduce nonpoint source pollution from agriculture, generally rely on a combination of two approaches:

1) Diffuse efforts that involve disseminating, somewhat randomly, information to a wide area - similar to the way a shotgun disperses lead shot by spraying a target indiscriminately. These types of information delivery approaches attempt to reach the largest possible number of the target audience, often through mailings, newsletters and mass media.

2) One-on-one information transfer techniques such as on-farm visits, individual farm trials and individual farmer consultation.

This analysis will consider the rate of adoption of nutrient management strategies by farmers in two different Wisconsin watersheds over a five year-period of 1990 to 1995. One watershed, a USDA Water Quality Initiative Demonstration project, used intensive one-on-one information transfer processes. The other, a state funded priority watershed project, relied on more diffuse educational strategies. The educational programming in both watershed-based projects was coordinated by University of Wisconsin Extension educators. This analysis focuses on educational programming, and does not consider the potential differences in additional agency involvement and/or the impacts attributed to other public remediation efforts in the two watersheds.

The comparison in educational program approaches indicates that more intensive one-one-one information transfer strategies are more effective in encouraging farmers to lower rates of nitrogen and phosphorus application on corn ground within the watershed project area.

Introduction

In Wisconsin, nonpoint source pollution has been identified as the greatest cause of water quality problems (Wisconsin Department of Natural Resources, 1992). Over 75 percent of inland lakes, many of the harbors on coastal waters on the Great Lakes, and substantial groundwater resources are affected by nonpoint source pollution. The majority of this problem is attributed to agricultural land uses.

The pervasiveness of these water quality problems are merely symptoms of the more serious causes stemming from failure to implement existing remedial technologies (Lockertz, 1990; Nowak, 1983). While many reports have described the physical dimensions of water quality problems caused by excessive nutrients caused by animal manures, few of these reports provide reliable indicators of remedial technology adoption.

One of the most serious sources of nonpoint pollution are animal manures. These animal manures include organic pollutants, chlorides, nitrogen and phosphorus. Wisconsin has spent much time and money enacting strict and costly limits on municipal and industrial phosphorus dischargers while animal operations remain largely unregulated. Wisconsin Department of Natural Resources (WDNR) estimates show the amount of phosphorus generated from all municipal and industrial sources is approximately six million pounds a year, at least 90 percent of which is treated or otherwise prevented from reaching surface water. The total phosphorus contribution from these sources is less than 600,000 pounds. In contrast, manures associated with the state's livestock industry produces an estimated 143 million pounds of phosphorus per year. WDNR estimates that at least 10 percent of this amount, approximately 14 million pounds, is lost to surface water (Wisconsin Department of Natural Resources, 1992). Consequently, mismanagement of livestock manures in Wisconsin contribute about 25 times as much phosphorus to the state's surface water as all municipal and industrial sources combined. With this in mind, the success of Wisconsin watershed projects in rural areas should be judged on the extent to which manure management practices are used and nutrient management plans are developed and followed.

As stated above, educational programming is a common element to many voluntary watershed protection projects. While those responsible for such projects extol the virtue of strong educational programming, the level of staff commitment varies greatly from project to project. If a project does assign staff to administer educational programs, the role of educator may be intermixed with other job responsibilities that are more technical and bureaucratic. Moreover, approaches that attempt to educate landowners often focus on randomly selected and unconnected activities (Geller, Winett and Evertt, 1982). Carefully designed multi-year strategies that reach landowners who need specific assistance most are rare.

Dedicating an individual staff position to a specific watershed for the purpose of implementing educational programs is also somewhat unique, especially in watersheds less than 300 square miles. When such a staffing commitment does occur, there are often differences in opinion as to how to best provide educational programs that reach farmers. Even professional educators disagree over the benefits associated with reaching the large number of farmers with general information versus a more one-on-one consulting approach with a select farmers in a given area.

Methods

Two watersheds were selected for a comparison of educational programming approaches. Both watersheds were selected in 1989 to begin nonpoint source pollution remediation programs. This designation was due to degraded surface and groundwater quality in conjunction with the impact of sedimentation on aquatic habitat in the watershed's main river system. Both watersheds contained numerous dairy farms, making manure runoff from barnyards and fields a major concern.

In both watersheds, a population of farmers was defined as all farmers who operated at least 40 acres of land and/or have 15 head of dairy cattle. In a northern Wisconsin watershed 101 out of 134 farmers in the project area meeting this criteria responded to an initial questionnaire in 1990 resulting in a 75% response rate. In a southern Wisconsin watershed 208 out of 260 farmers completed a baseline questionnaire, for a response rate of 80%. These surveys measured salient nutrient and pest management behaviors. Among these management behaviors, farmers were asked about their nitrogen and phosphorus application rates in the production of corn. Specifically, the rates of eight different sources of agricultural nitrogen and phosphorus were measured. Nitrogen and phosphorus derived from manure application was also measured by establishing the type of manure applied (dairy, beef, swine, and/or poultry), using estimates of the capacities of various spreaders used and the number of loads applied to the specific corn fields. The survey also measured nitrogen added from legumes.

In 1995, both watersheds conducted follow-up surveys using on-farm interviews. Seventy-five farmers for the detailed "time-two" survey were randomly selected from the each watershed's original list of baseline survey respondents. This number of follow-up interviews was selected to allow a direct comparison of each farmer between how they responded in 1990 and 1995. It also represented an achievable number of on farm visits for a single interviewer during a two month time period when follow-up interviews were in late winter 1996.

In addition to measuring farmer management, this study also asked the local "watershed-based" educator to describe their approach to educational programming. Each educator monitored the amount of time they dedicated to diffuse I & E delivery of information versus the amount of time they spent on face-to-face or direct information delivery to landowners.

Results

Results from the 1990 baseline assessments indicated that over-application of nitrogen and phosphorus could be attributed to the availability of nutrients from field applied livestock manure and prior legume crops in the field rotation. The problem of excess nutrient application can be attributed to a failure of farmers to reduce commercial nutrient purchases to compensate for the availability of on-farm nutrients.

During the ensuing years, each project focused on improving nutrient management practices in their respect watersheds. Each project also relied on a full-time educator to help provide information to farmers. However, an analysis of workload shows how the educators differed substantially in their approach to targeting landowners and delivering information to target audiences. While both educators used similar approaches to delivering water quality information, the degree to which certain techniques and approaches were favored over others distinguished the two educators. Such as in the southern watershed the educator spent more time working through advisory committees and assisting other watershed staff in providing information to landowners. In the northern watershed the educator dedicated nearly three times the number of more working days in direct consultation to landowners that the southern watershed educator.

The educator in the northern watershed began by specifically targeting 120 of the watershed's dairy farmers with personal farm visits. The educator also kept records and strived for multiple farm visits throughout the year. In addition, the northern watershed educator placed more attention on working with local Co-op agronomists from the watershed's three main farm supply dealers. Past research has shown Co-op agronomists and independent crop consultants are the most influential providers of nutrient management information (Shepard, 1993). In this watershed nutrient planning and integrated crop management workshops were offered to the private sector information providers - those entities (i.e., crop consultants) which farmers pay for information. The northern watershed educator followed these approaches between 1992 and 1995.

The educator in the southern watershed gave greater attention to working with influential "peer" farmers in the watershed, often those active in the watershed's citizen advisory committee. The southern watershed educator also dedicated more time to delivering information through the news media, project newsletters and local events such as on-farm demonstrations, tours, farm field days, watershed events, and local schools. In the northern watershed there one local farm Cooperative which dominated the local fertilizer sales market. This Co-op resisted attempts by the watershed educator to work collaborative with on-farm demonstrations and field days. The educator in the southern watershed followed these approaches between 1991 and 1995 (See Table 1).

Other aspects of the projects were very similar in the type of technical and financial assistance provided beyond purely educational information. Regulatory aspects for both projects were also similar because they were administered by a separate WDNR program that was available in both areas if needed.

Changes in critical nutrient management practices that are needed to reduce nonpoint source pollution in both watersheds did occur, and positive benefits were seen in both watersheds. However, the extent of change in nitrogen application was greater in the northern watershed where the educator followed a more targeted information delivery approach (See Figure 1 and Figure 2).

Table 1. The Annual Average Time Dedicated by Watershed Educator on Differing Techniques of Information Dissemination

Educational Approach	Northern Watershed		Southern Watershed	
	Number of Days	Percent Time	Number of Days	Percent Time
1. Human relations skills: counseling, interviewing, conflict resolution and negotiating.	120	46	31	12
2. Conducting demonstration projects and field research.	15	6	15	6
3. Conducting tours and field days.	21	8	26	10
4. Working with small groups and conducting workshops.	32	12	4	2
5. Organizing and maintaining citizen advisory committees.	2	1	36	14
6. Conducting needs assessments and evaluations.	10	4	16	6
7. Making public presentations.	15	6	10	4
8. Staffing booths, exhibits, fairs and public events.	8	3	10	4
9. Writing newsletters and publications.	20	7	34	13
10. Working with the media.	18	7	20	7
11. Writing watershed plans.	0	0	24	9
12. Assisting other watershed staff with technical issues.	0	0	34	13

*Both educators worked full time (40 hours per week), an estimated 260 days per year. The above represent annual estimates of days dedicated to educational approaches.

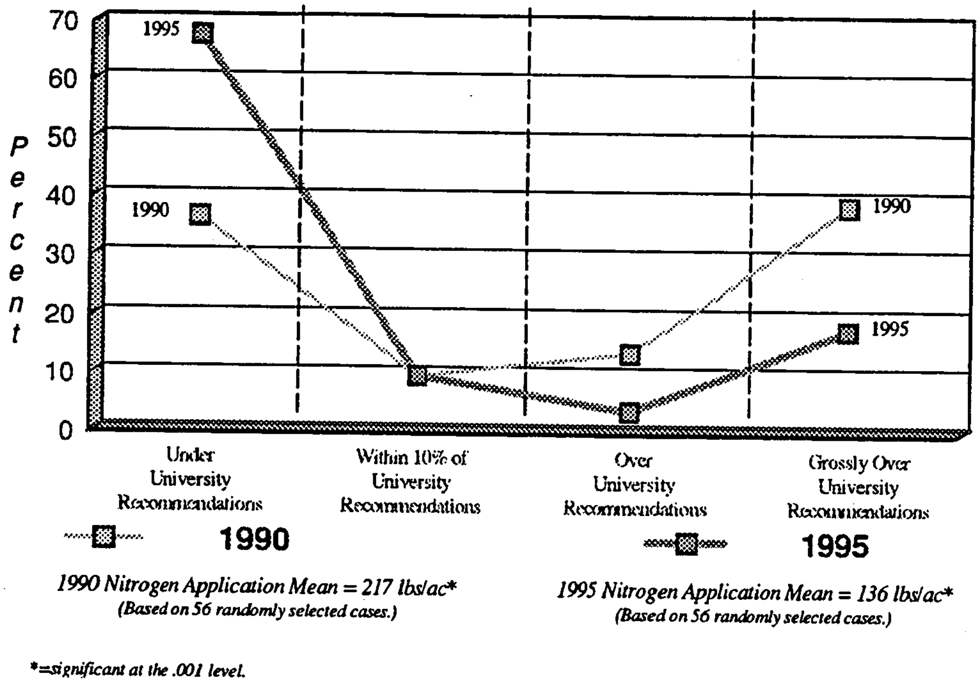

Figure 1. Nitrogen Application Rates of Farmers in The Northern Wisconsin Watershed.

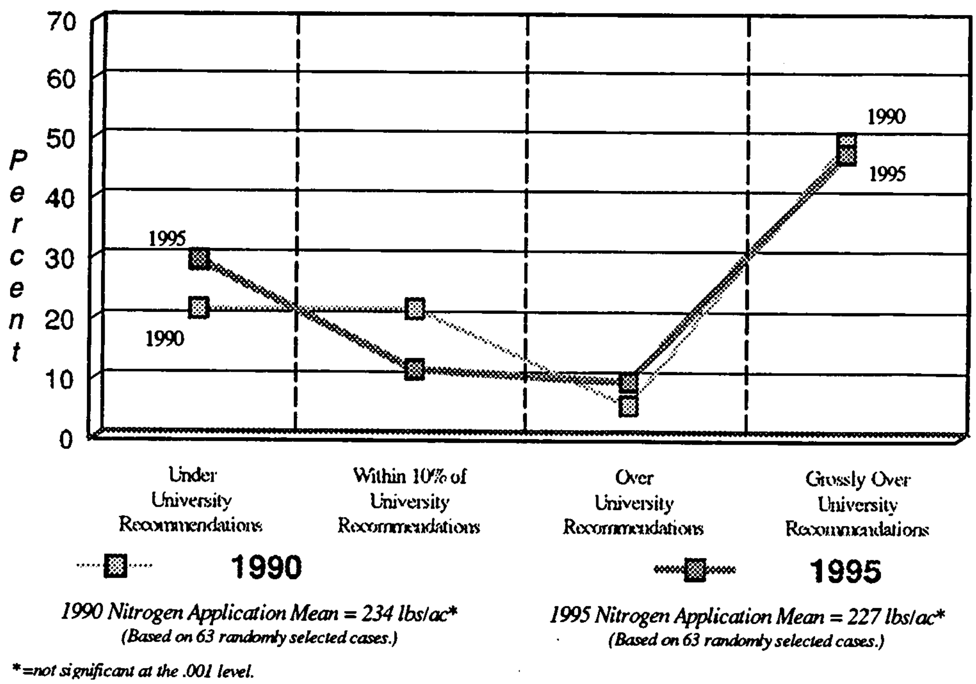

Figure 2. Nitrogen Application Rates of Farmers in The Southern Wisconsin Watershed.

More specifically, farmers in the northern watershed where the educator spent more time conducting one-on-one farm visits and working directly with Co-op agronomists decreased excess nitrogen application rates on corn ground by 80 pounds per acre. In the southern watershed where the educator followed more diffuse information delivery approaches, the rate of decline in excess nitrogen application was not statistically significant even though the average nitrogen application rates showed a slight reduction.

The percent of farmers in the northern watershed who took advantage of on-farm nitrogen in manure and legumes increased from 26 percent to 32 percent during the five year period. In the southern watershed, only 1 percent of the farmers changed their commercial nitrogen rates due to manure sources of nitrogen.

Other positive management changes occurred in both watersheds such as: the percent of farmers reducing commercial nitrogen purchases due to nitrogen from prior legume crops; the percent of farmers using soil tests; and the percent practicing appropriate manure hauling. Both watersheds showed increases in environmentally beneficial practices, but the northern watershed experienced a greater rate of change than the southern watershed.

Conclusions

This comparison of educational approaches shows that greater rates of farm management adoption are found in projects that emphasize direct transfer of information to farmers through one-on-one contacts when contrasted to more diffused-based efforts that rely more heavily on secondary transfer of information to farmers through newsletters, mass media and events.

Other findings include:

Superficial program targeting is insufficient. Target audiences should be identified and then program resources, especially educational programs, should be deployed in ways that ensure that they actually reach those who need them most.

Emphasizing mass dissemination of information more than one-on-one information transfer techniques can diminish the impact of educational programs that encourage farmers to make specific management changes.

Watershed management strategies, annual staff work plans, staff positions and program approaches should acknowledge a commitment to one-on-one information delivery techniques.

Private sector information providers represent a significant influence on farmer behaviors. Educational program design and implementation should utilize public-private sector partnerships in program delivery.

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The Royal River Watershed Education Project

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Given the diffuse nature of non-point source (NPS) pollution, it is often difficult to identify the source. In some areas, agriculture and natural resource industries are significant contributors while in others residential land uses may play a more important role. One solution to this problem is intensive, but broad-based, educational programming in small watershed areas. In 1992, the University of Maine Cooperative Extension began a five-year agricultural and residential watershed education program in the Royal River Watershed area, a sub-watershed of Casco Bay. Since both agriculture and residential sources were assumed to be contributing to NPS pollution, we developed several project goals: 1) producers would adopt practices to reduce NPS pollution; 2) producers would improve pest management practices within the watershed; 3) rural residents would change activities to reduce NPS pollution; 4) a volunteer water monitoring group would identify problem areas within the watershed, and 5) youth awareness of water quality issues would increase. With cooperating farms, we have been able to introduce practices that would minimize water quality impacts such as low input weed control, livestock exclusion from streams, alternative watering systems, stream-bank stabilization, improved nutrient management, and many others. Through a benthic macroinvertebrate study, we documented improved water quality on the dairy farm as a result of implementing BMPs. The residential program has focused on the Safe H2OME program, newsletters, watershed stewards program, youth educational programs, and other demonstration projects. We have seen many successes: growers have fenced out animals from tributary streams; adopted integrated pest management; and improved manure management. Our residential clientele have adopted many home BMPs detailed in the *Streamlines* newsletter. Over 120 people completed our Safe H2ome Program and identified specific areas of improvement. Also, 25% of the wells were found to be polluted with bacteria (15% with E. coli); all were disinfected and retested. From these results, we have demonstrated that broad-based education in focused areas is effective to reduce non-point source pollution.

Introduction

The Royal River watershed covers approximately 197 square miles, spanning 11 towns and two counties. Land uses vary in the watershed. Over 55,000 people live in the watershed area. There are a myriad of business activities including farming, greenhouses, nurseries, fish hatcheries, a shoe factory, summer camps, and other small businesses. These land uses have the potential to produce NPS pollution which can jeopardize fisheries, wildlife, recreation, and the beauty of the river. In fact, the impact of non-point source pollution has been well documented in Casco Bay estuary. Over 40 percent of commercial shellfish beds have been closed due to bacterial contamination; also there has been a notable decline in the abundant marine life in the subtidal zone. In 1992, The University of Maine Cooperative Extension was awarded a grant from USDA-CSREES to begin a non-point source pollution education project in the Royal River watershed.

Given the mixed land uses in the watershed, we divided our educational activities into agricultural and residential focuses. Agriculture is a small but significant interest in the watershed. We also recognized the potentially large NPS pollution contribution from the residential community. Therefore, we proposed several project goals: 1) agricultural producers would adopt practices to reduce NPS pollution; 2) producers would improve pest management practices within the watershed; 3) rural residents would change practices to reduce NPS pollution; 4) a volunteer water monitoring group would identify problem areas within the watershed; and 5) youth awareness of water quality interests would be increased.

Procedure

To reach our agricultural clientele, we identified three demonstration farms (dairy, beef, and fruit/vegetable) to implement/demonstrate BMPs and potential improvements to water quality. We identified key problems on each farm, and corrected them over the period. We used field days, demonstrations, educational programs, video, and others to demonstrate BMPs to producers.

To meet the goals set for our residential audience, we used a variety of mechanisms including focused educational programming, newsletters, volunteer monitoring groups, youth education programs, and other demonstration projects. We have done specific evaluations on demonstration projects, newsletter, and focused educational programs.

Results and Discussion

Agricultural Education Program Activities and Results

On our dairy demonstration farm, we identified two key areas of improvement: livestock access to the stream and poor manure management. Animal access had degraded water quality because of bacteria, nutrients, and stream bank erosion.

Secondly, nutrient management on the farm was inefficient due to poor manure management. As a result, forage quality was poor.

In the fall of 1994, we designed a management plan to address these issues. Before the producer would agree to fence off the brook, we had to demonstrate that livestock influenced stream water quality. We decided to test benthic macroinvertebrate (BMIs) populations in three locations in the stream (above the farm, in the middle, and below the farm). We found significantly different populations and differences in species diversity and feeding groups among sites. These data were convincing to the producer, and he agreed to fence the stream. With the animals fenced out of the stream, a watering system was required. A Ram pump was used to push water to the highest point on the landscape; water was delivered by gravity to each paddock. We also used pasture and solar pumps to show alternative methods. We intensified the rotational grazing to improve efficiency, reduce weeds, and improve manure dispersal over the pasture. At field day presentations, producers showed a great deal of interest in this system. We also planted riparian plant species to show producers which types of plants grow well in eroded environments. We have documented improvements in both forage quality, milk production, and stream bank stabilization. We continued monitoring BMIs in subsequent years and found increases in pollution intolerant families and species diversity. We have used these data in other meetings and presentations and have raised awareness of other producers both inside and outside the watershed.

On the beef demonstration farm, we identified weed management nutrient management, and rotational grazing as focus points. We conducted demonstrations to identify ways to eliminate or reduce atrazine use. We compared atrazine to cultivation or combinations of low-rate herbicides for weed control. We also evaluated narrow-row corn against conventional wide row planting and found that we could cut rates by one third. We successfully showed that a spring-tine cultivator was a viable alternative to pre-emergence herbicides. Cultivation has become the weed control method of choice for the producer. We also demonstrated our computer nutrient management program. Nitrogen fertilizer was reduced with use of the pre-sidedress nitrate test. Rotational grazing system was expanded and intensified as well.

We have worked closely with two fruit and vegetable growers. We focused on improving nutrient management (PSNT in sweet corn), IPM in apples, and weed managment in small fruit production. We helped cut herbicide use with cultivation in strawberries. We improved N efficiency in sweet corn with the PSNT. Apple producers have cut spray applications by a third.

We held field days with the Soil and Water Conservation District to bring producers to see these practices and evaluate their effectiveness. We used grower meetings as well. We seem to have had more success getting producers outside the watershed to adopt these practices than from within. Many of the beef and dairy producers are small, part-time operations with limited income, and do not believe their operations have impact. However, we have used these demonstrations in other educational programs around the state.

Residential Education Program Activities and Results

Our residential education program has been extremely successful. The key features of the program have been the Safe H_2*OME* Program, the *Streamlines* newsletter, volunteer monitoring, and the watershed stewards program.

The Safe H_2*OME* Program has been our most effective educational tool. The program materials consist of five factsheets, each with a worksheet for homeowners to rate the safety of their activities. Homeowners who completed the materials reported the activities that were high to moderately high risk (Table 1). Specific changes resulting from doing the project are reported in Table 2.

Table 1. Results of Targeted Safe H_2*OME* Evaluations

Self Risk Assessments	Percentage with Moderately High to High Risk
Well construction and maintenance	25.8
Household hazardous waste	23.6
Household wastewater	25.8
Lawn and garden care	23.2
Lead in home	24.1

Table 2. Changes made as a result of completing Safe H_2*OME* Program

Areas of intended change	Percentage
Change storage practices of hazardous products	38.9
Have water regularly tested	23.4
Have septic system pumped and maintained	13.7
Improve well construction	10.9
Monitor / decrease water usage	5.7
Increase soil organic matter	2.3

Over 120 residents completed the program materials. When participants returned their evaluations, they were given a water test. We found that 27% of the wells were contaminated with bacteria and 15% with E. coli. We contacted those homeowners and discussed disinfection methods. All wells were sanitized and were retested.

Another way we chose to reach the residential community was through our newsletter *Streamlines*. During the course of the project we had over 1650 residents subscribe to the newsletter. Topics have focused on composting, safe gardening, water testing, wetlands, chlorinating wells, bacteria in water supplies, and many others. Through surveys, residents told us that their understanding of NPS pollution increased (81%), they used educational activities presented in the newsletter (24%), made specific changes in home management(55%) including increased recycling efforts, composting, conserving water, pumped septic systems, used pesticides more safely, and reduced fertilizer use near the river. The newsletter received two awards. We placed second in the national Agricultural Communicators in Education contest; and we won first place in the National Association of County Agricultural Agents/AT&T contest for team newsletters.

We have worked closely with the Friends of the Royal River (a local volunteer monitoring group) to develop a long-lasting monitoring program that will identify problem areas in the river. We have trained volunteers, designed sampling protocols, and established a process such that the group should be able to continue well in the future. Similarly, we have trained 15 individual in the Watershed Stewards Program. Similar to the Master Gardner program, these people received 20 hours of water-based education. In return, they volunteer a minimum of 20 hours of volunteer community service around a project. Some are working with the monitoring program, others with schools, towns, and other water-related programs.

Lastly, we have had a very active youth education program. We have worked with local high school students on the BMI project. Advanced placement biology students visited the dairy demonstration farm, evaluated farm activities, and learned about the dairy industry. On another day, they assisted in sorting the BMIs as well. We worked with the environmental biology classes with data collected by the Friends of the Royal River. They studied chemical data collected by the volunteers, synthesized the data into a report, and presented the material to area residents. We have also had an active program with elementary students as well. Project staff have delivered over 20 programs to area 5^{th} and 6^{th} grade classes on environmental education. We also have assisted with the Southern Maine Children's Water Festival over the past two years. Over 130 students from the watershed attended the program. Children have taken these ideas and done class projects from what they have learned.

Conclusions

Our educational programming efforts have been successful in reducing non-point source pollution within the Royal River watershed. Through our three demonstration farms, we have worked to present to the agricultural community sound production practices that will lessen the impact of farming activities on river and estuary water quality. We have also targeted the residential community and the residents have responded by implementing many pollution-reducing practices. Taken together, we feel that these educational programs have and will continue to help improve water quality in the Royal River, its tributaries, and the Casco Bay estuary.

The Oak Creek 319 (h) National Monitoring Program

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Oak Creek, AZ, which has cut a gorge in the southern rim of the Colorado plateau near Sedona, is a popular recreation area (swimming, hiking, fishing and camping) that is impacted annually by fecal pollution. The goal of this project is to demonstrate that a set of Best Management Practices (BMPs) will reduce the amount of non-point source pollutants (ammonia, nitrate, phosphate and fecal coliforms [FC]) being discharged into the waters of Oak Creek. BMPs at Slide Rock State Park (SRSP), the site most impacted by planktonic fecal pollution, include; an attempt to reduce the number of visitors to the park, improved access to restroom facilities and a public education program. Statistical analysis using pre- and post-BMP data has shown no improvement to water quality in the park. By expanding our watershed monitoring program (during 1995 and 1996) to include interstitial (sediment) FC reservoirs in Oak Creek, we have found that the impact of sediment fecal pollution occurs throughout the length of the canyon and therefore, the problem is more widespread than at just SRSP. During summer months, sediment reservoirs of fecal pollution in Oak Creek can exceed 10,000,000 FC per 100 ml suspended sediment but drop 4 orders of magnitude as winter approaches. This sediment data also contradicts all of the previous water quality studies performed over the past 25 years which have held recreational users responsible for the fecal-related water quality impacts. In Oak Creek, the strong correlation between recreational use and fecal pollution does not prove causation. This study demonstrates the importance of determining whether disrupted sediment reservoirs of fecal pollution are responsible for observed impacts to water quality.

Introduction

Oak Creek has been plagued with an annual, seasonal deterioration in water quality (fecal pollution) during the summer monsoon season (Hansen and White, 1992; Jackson, 1981; Obr *et al.*, 1978; Rose *et al.*, 1987). These studies focused on the recreational day-time users as the primary source of fecal pollution.

During 1995, two major reservoirs of fecal pollution within Oak Creek Canyon were identified: SRSP and the Switchbacks (located at the upper reach of the canyon). These reservoirs averaged 2,200 times more FC than the water column. The large distance (10 km) and the significant reduction in pollution between these two sites is indicative of the existence of more than one source of fecal pollution. Also, the occurrence of sediment bound fecal pollution at SRSP prior to the monsoon season suggested that the source of fecal pollution must be close to the creek because a long-distance transport mechanism i.e., monsoons, is not in place. This implicates a human (recreational and/or residential) source of fecal pollution at SRSP. Contrary to this, the correlation between the summer monsoon rains and the FC build-up at the Switchbacks suggests that fecal material from the abundant elk, deer, and cattle populations on the surrounding uninhabited plateau impact the creek. This study investigates the fecal pollution at SRSP.

Materials and Methods

Sample sites along Oak Creek included Pine Flats Campground (PFC), Slide Rock State Park (SRSP), Mazanita Campground (MZC) and Grasshopper Point (GP). Upstream and downstream samples were taken at each site expect for sediment fecal analysis which for which only downstream samples were taken. Sediment fecal samples were also taken upstream at Pump House Wash.

All samples were collected (Protocol 9060 A.), preserved and stored for analysis (Protocol 9060 B.) as outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1989). Nitrate analyses were done on field filtered (0.45 µm) samples (EPA, 1983). A separate sample was collected for ammonia and phosphate analysis by field filtering and acidifying the samples with sulfuric acid (EPA, 1983). All samples were stored at 4 °C until analyzed.

Water samples were collected using the grab method. Sediment samples were obtained using a hand trowel rinsed with stream water. Sediment samples (500 ml volume) were collected from the upper 10 cm of creek sediment and placed into sterile 1 l plastic bottles. Each sediment sample was taken immediately following water sampling from a location directly beneath the water sample.

FC were enumerated using the Fecal Coliform Membrane Filtration Technique (Protocol 9222 D.; APHA, 1989). For sediments, a suspended sediment (SS) fraction was produced by adding 100 ml of 0.85% (wt./vol.) sterile saline to each sample, vigorously shaking for 30 s and then allowing settlement of the larger stream aggregates. Two 10 ml aliquots of the resultant supernatant (the SS fraction) were collected for analysis. The first aliquot was placed in a graduated centrifuge tube and allowed to settle overnight at 25 °C to measure the sediment load. The second 10 ml SS fraction was added to a Waring® blender containing 90 ml of sterile saline and mixed for 5 min. Appropriate dilutions were then enumerated according to the technique used for water samples.

Results and Discussion

Chemical analyses performed on Oak Creek demonstrated that the water was within acceptable limits and of high quality (Table 1). Nitrate, ammonia and phosphate concentrations were generally well below Oak Creek Unique Water Standards (Mueller, 1984). They are also far below the standards set for total nitrogen (2.5 mg/l) and total phosphorous (0.30 mg/l) set for Oak Creek in the Arizona Administrative Code (Title 18, Ch. 11).

Table 1. Critical Parameters of Oak Creek for Year 1996

	Mean	**Maximum**	**Minimum**
Nitrate (mg/l)	0.066	0.290	0.000
Ammonia (mg/l)	0.013	0.043	0.001
Phosphate (mg/l)	0.020	0.082	0.005
Fecals (cfu/ 100 ml)	160	3,500	0
Sediment Fecals (cfu/100 ml)	1,236,329	74,400,000	0

Fecal levels in the water column most often exceeded the water quality standard of 800 cfu/100 ml (Mueller, 1984) during summer months, and violations of the standard occurred over 50% of the time at the SRSP downstream site. No standard has been set for sediment fecal levels.

In 1996, the sediment populations of FC were on average about 8,000 times greater than the planktonic counts (see Table 1 and Figure 1), suggesting that Oak Creek sediments are receiving a tremendous amount of fecal pollution. Several studies in Arizona (Brickler and Morse, 1979; Brickler *et al.*, 1976; Doyle *et al.*, 1992; Tunnicliff and Brickler, 1984) have also demonstrated that sediment FC populations exceeded water FC populations (but by smaller ratios; 10:1 to 100:1) and impacted water quality.

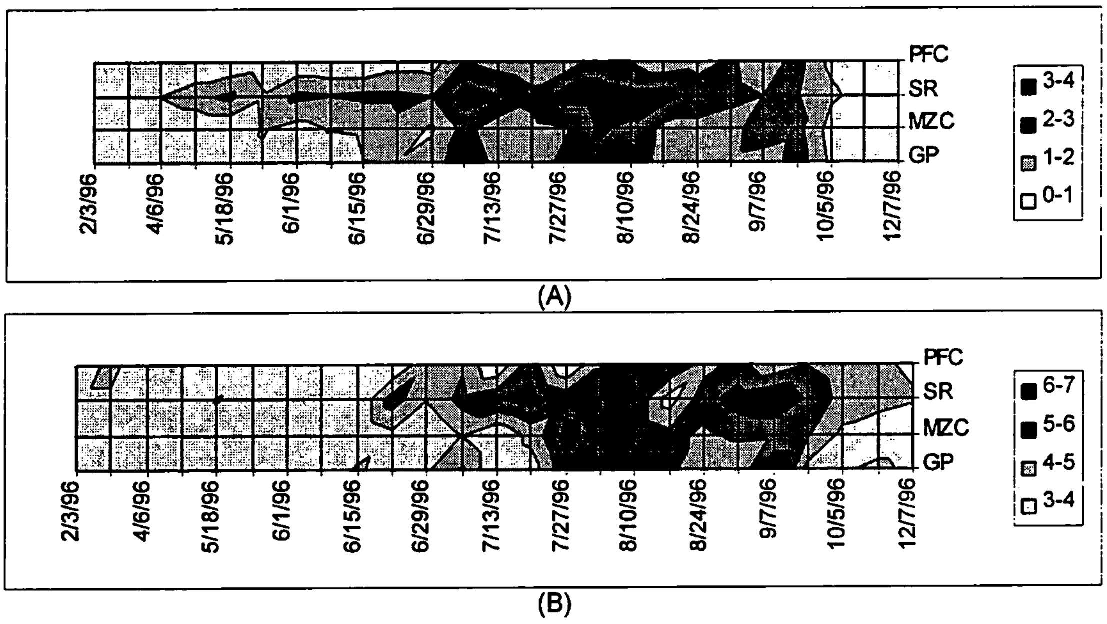

Figure 1. - Sample locations were plotted vs. time to create a category-based spatial and temporal grid. Log_{10} planktonic (A) and sediment (B) FC population/100 ml recovered from Oak Creek were each plotted on this grid to compare water and sediment fecal pollution. In 'B' FC < 1000 cfu/100 ml are included in the lowest log order.

A second sampling regime for FC analysis of water and sediment was undertaken in 1996 encompassing sites within and around Slide Rock State Park. The same correlation between sediment reservoirs and fecal pollution that was observed in the creek-wide study (Figure 1) was also observed within SRSP. While recreational users have been historically held responsible for fecal pollution in Oak Creek, agitation of the sediment through recreational use and by monsoons can cause water quality violations.

During the winter of 1995 a series of BMPs were implemented at SRSP in an attempt to limit the impact of fecal pollution there. BMPs included an attempt to reduce the number of visitors to the park, improved access to restroom facilities and a public education program.

FC data compiled before (1994 and 1995) and after (1996) implementation of BMPs were used for statistical analysis. In order to apply standard regression modeling techniques, transformations of the raw (linear) data are required to strengthen the validity of the analysis. The transformed data for SRSP upstream and SRSP downstream are denoted by LNSRU and LNSRD respectively. The transformation was performed by applying: ln (x + 0.1). Normal probability plots for LNSRU and LNSRD showed linearity except for heavy left tails for each of the transformed data set.

The regression model employed in the analysis is:

$$\text{LNSRD} = b_0 + b_1 \text{ LNSRU} + b_2 \text{ BMP} + b_3 \text{ BMP*LNSRU} + \varepsilon$$

where BMP = 0 if the data were collected prior to BMP implementation and BMP = 1 if the data were collected during BMP implementation. The standard regression assumptions apply in that the error term e is assumed to be normally distributed and independent. The analysis of variance results as well as the coefficient estimates are given in Table 2.

Table 2. Analysis of Variance.

Source	**Sum-of-Squares**	**DF**	**Mean-Square**	**F-Ratio**	**P**
Regression	338.7659	3	112.9220	37.0635	0.0000
Residual	228.5039	75	3.0467		

Effect	**Coefficient**	**Std Error**	**t**	**P-value (2 Tail)**
CONSTANT	1.9905	0.3640	5.4677	0.0000
LNSRU	0.8500	0.1115	7.6235	0.0000
BMP	-0.3320	0.5912	-0.5615	0.5761
LNSRU*BMP	0.1190	0.1736	0.6857	0.4950

The P-value associated with BMP and LNSRU*BMP indicate that H_0: $b_2 = 0$ and H_0: $b_3 = 0$ should not be rejected. This indicates that the BMPs are currently not effective or additional time is needed to further evaluate their effectiveness.

Regression diagnostics showed no blatant violations of the normality distribution except for the residuals vs. time plot. This plot appeared to show three groups of data points; corresponding to the seasonal impact of fecal pollution which occurred during the summer of 1994, 1995 and 1996. This pattern may indicate a correlation between response variables over time which is a violation of one of the regression model assumptions. Future work will focus on selecting the best time series model that fits the data.

Several overall conclusions can be made at this juncture:

1. Sediment reservoirs of FC are a significant factor in the observed fecal pollution in the water column.
2. Recreational use (activity in water) and increased stream flow during monsoonal activity appear to function as a FC distribution system in Oak Creek.

3. BMPs have been ineffective in controlling fecal pollution at SRSP.

During 1997, we will be using random-primer PCR to genotype *Escherichia coli* populations from known human and animal sources as well as those from Oak Creek to determine the source(s) of fecal pollution in the creek. This will enable us to recommend BMPs that will truly enhance water quality in Oak Creek Canyon.

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Communication and Adoption Evaluation of USDA Water Quality Demonstration Projects

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Increasing concern over the Nation's water quality led to a 1988 Presidential Initiative to protect surface water and groundwater from pollution by fertilizers, pesticides and agricultural wastes. Responding to this Initiative, in 1989, the U.S. Department of Agriculture (USDA) and its state and local cooperators launched a Water Quality Program. The Program's goal is to provide farmers and ranchers with the knowledge and technical means to respond independently and voluntarily in addressing on-farm environmental concerns and related state water quality requirements, while maintaining agricultural productivity and profitability.

The Water Quality Program of USDA and state cooperators brings a new focus to the goal of protecting the Nation's water resources from pollution. This new focus emphasizes contaminants from agricultural sources; and it promotes interagency coordination, collaboration and program integration to achieve program objectives.

To achieve its objectives, USDA's Water Quality Program brings together three interrelated components: (1) Education, Technical and Financial Assistance, (2) Research and Development, and (3) Database Development and Evaluation. Water Quality Demonstration Projects in 16 states across the Nation are part of the Education, Technical and Financial Assistance component. This evaluation focuses on the eight demonstration projects established during fiscal year 1990 in California, Florida, Maryland, Minnesota, Nebraska, North Carolina, Texas, and Wisconsin.

The Water Quality Demonstration Projects are designed to accelerate voluntary adoption of agricultural best management practices (BMPs) that protect surface and groundwater, while maintaining farm and ranch productivity and profitability. Objectives are to:

- encourage producers to more quickly adopt cost-effective use of inter-related pesticide, fertilizer, and irrigation BMPs that can substantially reduce agricultural pollutants, and
- show how quickly and effectively farmers and ranchers can voluntarily modify their use of BMPs to prevent or reduce the pollution of surface and ground water.

In line with these objectives, this paper summarizes an evaluation of the ability of the 1990 demonstration projects to accelerate producer adoption of BMPs during 1992-1994, the first two years of full operation of the projects. All of the 1990 projects are scheduled for completion by the close of FY 1998, with two projects already having been concluded.

Evaluation Components
The producer adoption evaluation examines producers':

- changes in awareness of, familiarity with, assessment of, and use of BMPs recommended by the demonstration projects; and
- awareness of, participation in, and reactions to the projects.

Three to four of the several BMPs recommended by each of the demonstration projects were designated for adoption process surveys, resulting in examination of a total of 34 BMP cases. The BMPs sampled from the project-recommended BMPs varied in their requirements for extent of managerial labor, capital investment and risk.

Effectiveness of the projects in the demonstration areas ("watersheds") was evaluated through use of a quasi-experimental design, comparing producer adoption within the eight demonstration project areas with producer adoption within nearby matched comparison areas. Surveys of representative groups of producers were conducted during 1992 and 1994, in both the demonstration areas and the comparison areas. Comparing the adoption rates of the designated BMPs, between the demonstration areas and their respective comparison areas, allows identification of area impacts of the projects. Effectiveness of the projects among project participants was evaluated through use of a simple longitudinal design, examining changes among project participants in the adoption variables measured from 1992 to 1994.

Project effectiveness at the individual producer level was evaluated as well through use of cross-sectional design, examining correlations between individual producers' characteristics and their 1994 status with respect to the adoption variables.

Extensive interviews were conducted with demonstration project staff regarding their project organization, planning and evaluation activities; methods for conducting field demonstrations; and methods for conveying information and education to producers. These interviews help to interpret the findings of the adoption surveys.

Program Effort Findings
The eight projects varied considerably in their organization, planning and evaluation, use of demonstration methods, and in their complementary use of other information and education methods. Most demonstration projects were unable to assess producers' adopter characteristics prior to their initiation, but most did gather feedback from producers once projects were underway. Some projects allocated resources to testing the local applicability of BMPs proven effective elsewhere; and, in some projects, the BMPs initially chosen for evaluation received lower priority emphasis from 1992 to 1994 than initially planned in 1991.

Some projects were more adequately staffed than others with communication professionals, and/or made stronger efforts at targeting their audiences with pertinent information and education strategies. These tended to have more significant increases in BMP awareness, familiarity and adoption, but not without exceptions. Again, the need for local BMP testing and changes in BMP priorities limit the building of inferences about communication impact here. One-on-one communication with producers was the most emphasized method of information transfer, supplemented by local media use.

The demonstration projects appear to have operated in a communication environment loaded perhaps to the point of saturation with agricultural information. It is no small accomplishment for the projects to have gained the producer recognition and impacts indicated. In some cases, the complexity of Federal-State relationships among the collaborating USDA and State Cooperator Agencies made project tasks more difficult to efficiently carry out. USDA funding uncertainties, lags, and late notification of project extensions to varying extents affected all projects, resulting in decreased momentum and personnel losses.

Adoption Findings and Conclusions

The project-area analysis examines the extent to which producers in the demonstration areas--averaging across those who participated directly in the project and those who were non-participants--made gains with respect to the adoption variables. Demonstration area producers as a whole:

- became more aware of most of the BMPs--with statistically significant increases among 21% of the 28 BMP cases examined;
- became more familiar with most of the BMPs--significantly so for 40% of the 28 BMP cases examined;
- did not change their assessments of the BMPs, among the 28 cases examined; and
- increased use of the BMPs in fewer than half of the 26 BMP cases examined--with only 19% of the increases being statistically significant.

Producer awareness of most of the BMPs was already high at the onset of the demonstrations, so the bigger gains in familiarity than in awareness are expected. At the onset of the projects in 1992, an average of about 25 percent of producers were already using the designated BMPs. Thus most of the BMPs examined had already moved through the innovator category of producers and well into the early adopter category. Among the BMP cases where statistically significant gains by 1994 were found, BMP awareness, familiarity, and/or use increased among 5% to 23% of producers, with a median increase of 15%.

These percentages suggest that over the first two years of full operation of the demonstrations projects, overall diffusion spread into the category of early majority adopters. Demonstration area producers' awareness of, familiarity with, and uses of the BMPs made net gains relative to the matched comparison areas in only a few instances. One reason is that there were several occurrences of gains in BMP awareness, familiarity, and use in the comparison area as well. The low frequency of net gains limits a clear inference that the demonstration projects influenced BMP adoption variables at the area level. Several factors could account for these gains, including non-demonstration project coverage of the BMPs and "overflow" of demonstration project information to the comparison areas. The project participant analysis is underway, with findings not yet available.

The analysis for individual producers examined whether their management characteristics reflected their status regarding adoption of the project-recommended BMPs. Producers in the demonstration and comparison areas who indicated that they had received and attended to information about the designated BMPs during 1993 were significantly more familiar with them in 95% of the 19 BMP cases examined, and more likely to be users of them in 53% of these cases. This finding suggests the possibility of demonstration project influences on adoption of project-recommended BMPs.

The evaluation findings suggest that the demonstration projects were a substantial information force within the agricultural information system of the demonstration areas. A strong majority of demonstration area producers were aware of the projects, but adoption of environmentally sound agricultural practices has been previously shown to be a generally slow process. Previous research shows that producer adoption of conservation/environmental practices is apt to occur at a slower rate than for practices that are more clearly economically advantageous.

In addition, two other factors may have attenuated major project impact: (a) the above-noted need for some projects to delay dissemination efforts until they tested the local applicability of BMPs; and (b) the lowering during project implementation of priority accorded by some projects to the BMPs designated for the evaluation. In this context, the increases in BMP awareness, familiarity, and use indicated here during the first two years of project implementation appear encouraging. Increased rates of adoption might be detected by subsequent data-gathering. This evaluation did not examine the separate influences of financial and technical assistance on adoption.

In any case, it does appear that the adoption processes here are slow and deliberate, too much so for conclusive inferences to be drawn over a two-year period. Whether the above results are encouraging enough for subsequent study of these same projects depends greatly upon the conduct of the projects since 1994, current and projected USDA and state-level policies and priorities regarding the BMPs being addressed, and the need for project evaluation for USDA program accountability and improved program management.

Recommendations

Future programs by USDA and its cooperators to accelerate the voluntary adoption of BMPs that focus on water quality should take more advantage of contemporary research on adoption processes and on effective information transfer and communication programs. Also recommended is greater consensus across projects in determining: (1) what constitutes realistic, locally tested BMPs with respect to agronomic, economic and water resource protection advantages; (2) the nature, conduct and effectiveness of field result demonstrations; and (3) the nature and conduct of other information and education strategies. These include use of:

- clearly measurable project goals within a national program framework;
- comprehensive models of information and education strategy and tactics, based upon experience and research in related settings;
- basic communication planning tools in program design and execution, including formative evaluation in order to appropriately segment producers by their existing characteristics and needs;
- adaptive research to assure that the practices being recommended are relevant and economically viable to local producers; and
- justification, integration, and focus of project funding to achieve project objectives.

The above elements require staff trained in information transfer and education, as well as in the technical aspects of practice testing and application. The elements also require project resources committed to information and education program planning, design, production and evaluation. Equally important, these elements require consistency of vision across time and circumstance. This can be quite difficult to achieve in a multi-Agency effort faced with shifting personnel assignments, uncertain budgetary futures, and changing leadership roles. This evaluation also provides recommendations for USDA's management of its future water quality programs, in such a way as to increase effectiveness and administrative efficiency of water quality projects funded by USDA. These recommendations are as follows:

- USDA should emphasize and financially support site-specific, adaptive research as an integral part of projects to accelerate producer adoption of water quality BMPs;
- USDA/CSREES should direct water quality staffs and extramural funding in order to achieve distribution of funds to continuing projects before the midpoint of the Federal Fiscal Year; and
- USDA and its component agencies, including CSREES, should develop and adopt a policy on the duration of Federal funding for future state water quality projects.

This evaluation has been an innovative, complex undertaking. The USDA Water Quality Program, and other national, multi-Agency initiatives will increasingly need sophisticated evaluation strategies. Such future evaluations will require streamlined inter-Agency staff and budget administration, increased interaction between evaluation and project staff, increased precision of project objectives, and reassessment of techniques for evaluating producer adoption.

Gum Creek Water Quality Demonstration Project

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The Gum Creek Water Quality Demonstration Project is located in Crisp and Dooly Counties, Georgia. The watershed is located in the Southern Coastal Plain land resource area. Gum Creek drains into Lake Blackshear which was constructed on the Flint River in 1930 by Crisp County to provide electricity for the County. The 8,250 acre lake is heavily utilized for recreational activities. Ninety percent of the land area in the watershed is utilized in the production of food, fiber or forest products. Most of the city of Cordele is located within the watershed boundaries, and the city's waste treatment plant discharges into Gum Creek.

Lake Blackshear was classified as eutrophic in a 1974 EPA eutrophication survey of Georgia lakes. During the period of 1974 through 1993 the lake was ranked in the top 8 lakes in the state for trophic state index values. In two of these years Lake Blackshear had the highest readings of any tested lake in the state. Gum Creek is identified in the December 1989 *Georgia Nonpoint Source Assessment Report* and the *Georgia Nonpoint Source Management Plan* as an agricultural stream likely to be threatened by agricultural nonpoint sources of pollution.

The watershed is approximately 53,000 acres. Of this, some 25,000 acres are in agricultural production, 23,000 acres are in woodlands and the remainder is in urban/built-up areas including industry, roads and railroads. Major crops grown include cotton, peanuts, corn, small grains , soybeans, watermelons, pecans and pasture. Many of these crops were being grown with high fertilizer and pesticide inputs. The area also has several cattle and hog operations.

The main objective of the project was for farmers to implement cost-shared Best Management Practices (BMP's) designed to reduce pollution and/or the potential of pollution of surface and ground waters in the project area while maintaining farmer productivity and profitability. Other objectives included: increasing landowner knowledge and understanding of agricultural pollution potentials and water quality, increasing crop production efficiency through better management of natural resources, increasing awareness of the general public on surface and groundwater contamination and to initiate a state-administered cost-share program for agricultural BMP's.

The project was designed and supported by some 23 cooperating federal, state, and county governmental agencies. A technical committee was formed representing most of the cooperating agencies. The committee had the charge of designing and approving technical aspects of the project including BMP selection and design and monitoring activities. The committee met regularly for the purpose of project updates and planning. Technical support for BMP's and the education of cooperating farmers was charged to local NRCS and Extension personnel. BMP's were implemented by individual farmers on either a 60% cost-share basis or established payments.

Best Management Practices

Cost-sharing for some 25 separate Best Management Practices was offered to farmers in the project area. These include:

Permanent structures designed to reduce surface water contamination by acting as nutrient or pesticide sinks and settling areas for sediments.

- Shallow Water Impoundments
- Sediment Basins
- Water Impoundment Reservoirs
- Water & Sediment Control Basins (Gully Plugs)

Permanent structures designed to act as physical barriers to prevent contamination of soil, groundwater or surface water from pesticides and/or nutrients.

- Well Head Protection
- Permanent Chemical Mixing/Loading/Storage Facilities
- Portable Chemical Mixing/Loading Systems

Permanent structures designed to reduce sediment, pesticide and nutrient loading of surface water by run-off water management.

- Terraces
- Grassed Waterways
- Riparian Forest Buffer Strips
- Artificial Wetland Construction
- Vegetative Filter Strips
- Conservation Cover Crops
- Forest Road Culverts

Permanent structures designed to prevent access of cattle to streams thus reducing nutrient loading from waste products and sedimentation caused by bank erosion.

- Livestock Fencing
- Alternative Water Sources
- Alternative Water Supplies

Permanent equipment designed to reduce the number of pesticide applications or increase the efficiency of such applications and/or irrigation water applications.

- Envirocaster Peanut Leafspot Advisory & Irrigation Scheduling System Hardware
- Watermark Soil Moisture Blocks and Meters

Management activities designed to reduce the application of pesticides, nutrients, irrigation water and/or increase the efficiency of such applications.

- Integrated Crop Management (ICM) through - soil testing, tissue analysis, nematode sampling, insect scouting, pesticide record keeping, irrigation water management

Management Activities designed to reduce surface water loading of nutrients, pesticides and sediments through cropping systems.

- Crop Residue Use
- Conservation Tillage
- Green Manure Cover Crops

Certain practices were strongly encouraged but did not qualify for cost-share payments or incentives.

- Pesticide Container Recycling
- Contour Farming
- Tree Planting

Monitoring Activities

A monitoring plan was devised by the technical committee that was a compromise between what was desired for good science and what could be afforded under a sparse monitoring budget. Automated sampling devices were desired but were not within the budget constraints. The plan revolved around periodic spot sampling of surface water, shallow test wells, pan collectors, and private wells. Surface water samples were taken primarily after rainfall events. These were taken at 7 established monitoring stations throughout the watershed. Twelve shallow test wells ranging in depth from 10 feet to 20 feet were installed down-slope of row-crop fields and in pecan orchards to monitor shallow groundwater. Samples were withdrawn on a periodic basis. Pan collectors were constructed and placed at the edge of cotton fields to collect runoff exiting fields from furrows. Collectors were placed in both fields being farmed by conventional tillage methods and those being farmed with strip till for comparison purposes. Collectors were emptied after rainfall events. Drinking water and irrigation wells were tested periodically throughout the project period. An effort was made to sample one-quarter of the wells in the watershed. Samples were analyzed at the: University of Georgia Ag Services Lab, Athens, Ga; Georgia Environmental Protection Division, Atlanta, Ga; or the USDA Agricultural Research Lab, Tifton, Ga. Samples were analyzed for both pesticides and nutrients. In addition to laboratory testing, biological sampling and assays also were performed periodically on Gum Creek and several tributaries.

BMP Participation

The main objective of the project was to encourage farmers to voluntarily initiate Best Management Practices. From this standpoint the project was very successful. Cost-share contracts were written with 31 farmers on 12,000 acres in the project area. This represents 98 % of all full time farmers and 48 % of all cropland in the watershed area. Nineteen of the 23 BMP's were initiated on at least one farm. Most were initiated on multiple farms. The highest number of acres were enrolled in management activities. Annual enrollment figures on the most widely adopted practices were as follows: 7980 acres in ICM, 7129 acres in crop residue management, 4168 acres in irrigation water management, 2759 acres in conservation tillage, 1224 acres in green manure cover crop. Permanent structure installation highlights are as follows: 3 water holding facilities (ponds), 200 wellheads curbed, repaired or upgraded, 13 portable chemical mixing stations, 1 permanent chemical mixing/loading/storage facility, 7938 feet of livestock fencing, 1 alternative livestock water source and 1 livestock water supply and 10 miles of terraces.

Monitoring Results

From 1990 until 1996 approximately 1000 water samples were taken. These were analyzed for nutrients, 14 minerals and 46 pesticides.

A total of 275 water samples were analyzed from field pan collectors during 1993 through 1995. Except for water collected during one rainfall event in 1993, chemicals were generally below detection levels for all compounds except fluometuron (Cotoran, etc.) and norflurazon (Zorial). Fluometuron was detected in 41 % of samples. Levels ranged from 0.7 ppb to 78.3 ppb with an average of 14 ppb. Norflurazon was detected in 11 % of samples. Levels ranged from 3 to 114 ppb with an average of 36 ppb. The highest levels of both norflurazon and fluometuron were detected exiting strip-till fields. Runoff accumulated more frequently in conventional tillage fields.

Some 273 water samples were collected from Gum Creek and tributaries for 1990-96. Analysis detected no agricultural chemicals. The fact that fluometuron and norflurazon often were detected at field edges and not in streams indicates an effectiveness of the filtering ability of vegetation between the edge of fields and streams.

Using phosphorous and nitrates as indicators, the overall water quality of samples taken from streams could be classified as fair to good. Phosphorous levels ranged from 0 to 0.38 ppm. Eighty percent of samples were below 0.2 ppm. Nitrate levels ranged from non-detectable to 3.8 ppm. Sample stations in the upper and middle portions or the watershed generally had nitrate levels of 1.0 ppm or below. The highest nitrate and phosphorous levels were consistently detected at two sample stations in the lower portion of Gum Creek. One was located just downstream of the City of Cordele waste treatment facility. The other was downstream from a non-participating hog operation sited by EPD for excessive animal units per acre and subsequently forced to close for economic reasons.

178 water samples were analyzed from shallow test wells located at the edge of row crop fields and in pecan orchards. Immunoassay analysis of atrazine and alachlor detected low levels of these chemicals throughout the study. However, these chemicals were applied prior to the beginning of the study. The most common herbicides in the project area, trifluralin, fluometuron and norflurazon were rarely found. Nitrate levels in the test wells often exceeded EPA safe drinking water standards. Wells located in pecan orchards generally had levels of 5 ppm or below. Wells showing highest levels of nitrates (up to 23 ppm) were down slope of large irrigated fields (100 + acres). These fields were in a 2 years of cotton and 1 year of peanuts rotation pattern.

A total of 110 water samples were taken from irrigation, residential and farm wells. None were found to contain any detectable levels of pesticide. Nitrates exceeding EPA guidelines of 10 ppm were found in only 3 of the 110 wells. Two of these were traced to improperly constructed wells and home sewage problems. The third was attributed to an inadequately protected well head and a large fertilizer spill.

Habitat assessment and habitat monitoring was conducted at 5 locations throughout the watershed on 3 different dates from 1992-1994. The conclusions from these studies appear to correlate well with the results of analytical testing. Habitat quality was lowest near the sampling stations showing consistently higher nitrate and phosphorous levels.

Water quality monitoring in the Gum Creek basin did not reveal any components that exceed EPA or Georgia EPD limits. Samples collected at the edge of cotton fields often had low to moderate levels of herbicides, but they were not detected in Gum Creek and tributaries. Water from shallow groundwater test wells often contained nitrate nitrogen levels in excess of 10 ppm. However, these elevated levels were not detected in streams or (with the exceptions noted previously) in drinking water or irrigation wells.

Management Practice Modifications

Significant and measurable reductions in pesticide and nutrient applications occurred during the project period. When the project began cotton farmers averaged spraying for "cotton worms" 6 to 8 times per season. During the project period farmers began to rely on beneficial natural parasites and predators. As a result, during the 1995 and 1996 growing seasons, area farmers sprayed cotton on the average of 2.5 times with no decrease in yield or fiber quality. Pecan growers in the project area are spraying less. Hard lessons have been learned concerning yellow aphid sprays. Improperly timed sprays simply aggravate the problem. Most growers now wait on natural parasites, predators and diseases to crash damaging levels of aphids. Estimates are that due to ICM activities, average nitrogen use decreased by some 6.4 lb/acre and phosphorous applications decreased by some 1.7 lb/acre during the project period.

Spin-off Projects and Lessons Learned

Well surveying in the project area revealed that most of the well heads were not properly protected by grouting and concrete pads (curbs), with over half having cavities around the casing. Curbing was being left to well owners and was not being done. Beginning in July 1996 an educational program was initiated. Gum Creek personnel curbed 40 wells for farmers to generate interest in the program. Technical assistance was then offered to rural homeowners and farmers to help them curb their own wells. Local well drillers were approached to investigate the possibility of incorporating curbing as part of a well drilling package. On April 22, 1997 the 100th well was curbed with either Gum Creek personnel labor or technical assistance. During the same time about 75 additional area wells were curbed and properly protected by local well drillers. Four of the five well drillers in the two county area now routinely curb all wells they drill.

Disposal of plastic pesticide containers is a major problem for many Georgia farmers and local county governments. Because of the Gum Creek project, the Georgia Department of Ag and University of Georgia Extension Service initiated a pilot pesticide container recycling program in Crisp and Dooly counties. To date, more than 90,000 lb of pesticide containers have been collected and recycled. Because of the lessons learned and success of the program in the pilot area, container recycling is now a state-wide program in Georgia. This program had major influence on the initiation of a Georgia Clean Day program that has recovered and disposed of tons of unusable pesticides statewide.

The promise of precision agriculture sparked great interest among Gum Creek personnel and farmers. A Navstar Global Positioning System receiver was purchased with local funds. Soil nutrient mapping was initiated in the project area and selected farms in Crisp County. One acre grids were utilized. During the winter of 1997, 2,200 acres were gridded and maps generated detailing distribution patterns of soil pH, phosphorous, potassium, magnesium, calcium, manganese and zinc. Maps were generated to show the distribution of recommended nutrients as per University of Georgia recommendations. As a result of soil mapping efforts, a long term precision agriculture research project to be conducted by UGA scientist has been initiated.

Perhaps the greatest lesson learned from the project is that profitable South Georgia agricultural enterprises can co-exist with a healthy environment through the use of agricultural Best Management Practices. BMP's can be highly effective in reducing pesticide and nutrient contamination of both surface and groundwater. Farmers are willing to install and implement economically and environmentally sound BMP's.

Another important lesson learned from the Gum Creek Project is the value of inter-agency cooperation and teamwork.

The Implementation of Innovative Best Management Practices in the Sny Magill Watershed

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The Sny Magill Watershed Project is an interagency effort to improve water quality through voluntary changes in farm management practices. The project provides technical assistance, information and education, and cost share assistance to producers within a 22,780 acre agricultural watershed. The project is designed to reduce sediment, nutrient, and pesticide delivery to Sny Magill Creek, a coldwater trout stream located in Clayton County, Iowa.

Background

Since 1991, a diverse selection of Best Management Practices (BMPs) such as Integrated Crop Management (ICM), terraces, water and sediment control basins, and stripcropping have been successfully applied by the majority of landowners within the watershed (Table 1). Iowa State University Extension (ISUE) reports that pesticide and nutrient loading has been reduced on 45% of the cropland acres through the delivery of an ICM assistance program. The Natural Resources Conservation Service (NRCS) estimates that sediment delivery to the stream has been reduced by over 40%. These achievements are significant, but because of the watershed's size, many acres were being left untreated.

Table 1: BMPs Applied 1991-1997

Item	Unit	Amount
Conservation Cropping (Rotations)	ac.	2,957
Conservation Tillage	ac.	1,940
Contour Farming	ac.	1,447
Grade Stabilization Structures	no.	88
Integrated Crop Mgmt.	ac.	3,095
Nutrient & Pest Mgmt.	ac.	2,639
Pasture and Hayland Management	ac.	828
Streambank Protection	ft.	655
Terraces	ft.	249,540
Timber Management Plans	ac.	534
Water & Sediment Control Basins	no.	56

In the mid-1990's, the local project coordinators attempted to identify the barriers preventing additional landowners from adopting the selected BMPs. Through one-on-one inquiries, group meetings, and questionnaires, it became apparent that most of these barriers centered on economic concerns. Many landowners noted the environmental benefits of the selected BMPs, but were reluctant to adopt them due to the direct costs involved.

The agencies worked to develop alternative cost-effective BMPs which would overcome many of the identified barriers, while meeting the overall project objectives of reducing sediment, nutrient, and pesticide delivery to the stream. Primary efforts were focused on the areas of streambank stabilization and nutrient and pest management.

Development of ISUE's Nutrient and Pest Management Incentive Education Program

It is recognized that improving the environmental sustainablility of agriculture will require producers to increase the intensity of their management. For crop nutrient and pest management, there are well established refinements which publicly supported projects in Iowa have documented to reduce excess loading of agricultural chemicals, increase the use of on-farm resources, and maintain or increase profitability.

Existing financial incentives for nutrient and pest management often depend on expert assistance provided to cooperating producers, and lack an educational component. Producers receiving incentives hire crop consultants to "deliver" plans, scouting reports, and recommendations. At the beginning of the Sny Magill project, an integrated crop management (ICM) program was offered. Involved producers enrolled over 3000 acres, and reduced nitrogen applications by nearly 40000 pounds during the 1994 crop year. While successful from a reduction standpoint, in-progress project surveys showed little evidence that this program changed producers' long term attitudes about more sustainable management.

The *Nutrient and Pest Management Incentive Education Program* is a local initiative developed by staff of the Sny Magill Creek HUA and Northeast Iowa Demonstration projects. To enhance long term adoption of practices, it requires participating farmers to learn the basics of managing their own nutrient and pest management programs. The program is targeted to an area where private consultants are either not available or are unwilling to serve small crop acreage farms, including many livestock operations. By moving through the program in a series of workshops with a group of 8 to 10 participants, the program also establishes a peer support mechanism.

Workshop sessions involve reading soil maps and soil test reports, fertilizing for realistic yield goals, as well as determining manure inventories and legume and manure fertility credits. The program allows cooperators to develop, write, and implement their own nutrient, manure utilization, and pest management plans.

Producers receive incentive payments of $1/acre up to a $250 maximum payment for: 1) all crop acres in the management program; 2) all acres covered by their manure distribution plan; and 3) all acres covered by end-of-year field records, according to a record system set up by the project. Additional payments are made at the end of the second and third years for records and for completing an annual survey of nutrient and pest management practices. Pest management planning and basics of field scouting are also introduced. In all, each participant may earn up to $750 in the first year, and $250 in each of years two and three of the program. The maximum payment levels were set high enough to compensate for time spent completing program requirements and to provide some incentive, such as partially offsetting required soil test costs, but low enough not to compete with private crop consultants' fees.

Project staff are available to consult with participants. A biweekly newsletter with useful scouting, field, and pest management information is distributed to participants during the cropping season. Ten to twelve issues are normally provided to participants. An economic evaluation of changes made is part of the end-of-year workshop. This approach is meant to give producers the knowledge and confidence to control their own nutrient and pest management programs, whether they choose to do it themselves or to work with suppliers or consultants in the future.

This program pays incentives for performance of specific program components. A flexible payment source is a critical component of this program, as timing and amounts of payments vary from one producer to another. Traditional agency programs have been set up to provide one payment per year to producers.

Since 1994, sixty-six producers in three northeast Iowa water quality project areas have participated in this program. Ten Sny Magill area producers have been enrolled. Because of the relatively small numbers of participants in this pilot program, evaluation data (baseline and annual post-workshop surveys) have been aggregated for all three water quality projects. The three projects represent different watersheds in the same topography, with a similar mix of producers, farm resources, and environmental concerns.

Comparison of baseline and annual surveys of program participants show increased confidence in their own ability to manage fertility programs (rather than relying on suppliers), reduced use of purchased fertilizers, and improved manure management. Survey responses from 25 producers completing the first year of the NPMI program are as follows:

- 75 percent indicated they reduced nitrogen use.

- 76 percent indicated it was profitable to reduce N use. The improved net income ranged up to $5,500 per farm.

- 67 percent changed manure management. Fifty-six percent of those changing manure management did so by spreading fields that could benefit most from manure. Others noted that they spread manure more uniformly to gain more nutrient credit, or spread more acres when they realized that they were overapplying nutrients.

- 70 percent of the NPMI producers plan to change their insect or weed management programs. Reasons for adjustments include seeking improved weed control with improved timing of spray application, self spraying to avoid custom applicator skips, and seeking increased flexibility with products to match weed problems.

Responses to open-ended survey questions indicate these practices are profitable:

- "Taking credit for the manure application saved $1000 in fertilizer".

- "Continuing to back down nitrogen rates on sod to corn saved $480 on my farm".

- "Changing the rate of manure per acre after calculating crop needs and credits increased the profit on this farm by $1400 to $2000".

The Nutrient and Pest Management Incentive Education program is being evaluated on its effectiveness to: 1) Improve or maintain water quality by refining the use of pesticides and fertilizers, including manure and legume credits; 2) reach the low acreage, diversified young farmers that have the greatest potential to effectively use on farm nutrients, thus reduce off farm fertilizer purchases and as a result, improve farm profit; 3) provide a cost effective incentive program that can be efficiently delivered and evaluated for performance. The goal is to insure that publicly funded management incentives result in sustainable crop management practices that participants will maintain throughout their farming careers.

This program currently represents the primary focus of alternative nutrient and pest management efforts. In order to further reduce sediment load, additional emphasis was placed on innovative streambank stabilization demonstrations.

Alternative Streambank Stabilization Initiative

The Project offers landowners many alternative BMPs for reduction of sedimentation resulting from rill, sheet, and gully erosion. For example, if landowners cannot afford tile outlet terraces, other equally effective sediment reducing BMPs such as contour stripcropping could be offered. When working with streambank erosion problems, however, our available BMP list was limited to effective, albeit expensive, rock rip-rap based technologies. This problem is not isolated to this project. Several projects across the country are faced with this situation. Often landowners with farms along streams simply cannot justify spending their limited income, even with cost share, to benefit and protect such a small area.

Unfortunately, recent studies in Illinois indicate that as much as 60% of the sediment found in small-to-mid size Midwestern streams is derived through streambank erosion. Even though opinions differ on how to resolve streambank erosion problems, few fail to recognize its significance. Everyone involved with the Sny Magill Watershed Project realized that to make significant sediment reductions, the issue of streambank stabilization would have to be addressed. The use of traditional rock rip-rap based technologies was not the answer since so few landowners could afford their use. A more cost effective approach needed to be found.

In 1994, local project coordinators began exploring the use of soil bioengineering. The basis of this technology is the use of plant materials in conjunction with limited structural materials. Together, they provide a sound streambank stabilization installation, but utilize less expensive materials.

Working with NRCS specialists, the local project coordinators invited several federal, state, and county agencies to work together, and have subsequently applied a series of installations to learn more about the uses and limitations of this technology. In the spring of 1995, the first installations using willow posts, fascines, and brush mattresses were installed. More were installed using slightly different combinations in the fall. These installations were completed on a 6 foot high bank and cost approximately $12 per lineal foot, or 1/3 the cost of traditional rock rip-rap based methods, and have been inundated by floods at least 4 times with no apparent damage to the streambank.

In the summer of 1996, an installation using warm season prairie grasses was attempted. Both willows and warm season grasses possess deep penetrating root systems, which hold loose soil in place. Warm season grasses are an alternative for landowners that fear encroachment of willows into cropland. A major problem with warm season grasses, however, is their slow initial growth. Several species take two full growing seasons to become established. Therefore, in this installation, bio-degradable mulch mats were utilized. The mats should hold the loose soil for two to three years, allowing the warm season grasses the time they need to grow and form a dense sod layer. The cost of this installation on a 5 foot high bank was $8 per lineal foot, or 1/7 that of traditional rock rip rap methods.

The use of soil bioengineering technologies does have its limitations. Since the primary stabilizing measures are living, special care must be taken to ensure their survival. Willows and grasses must be frequently scouted for insect, beaver, and ice damage. Failure to conduct periodic inspections and perform required maintenance could lead to failure of the entire installation.

One of the primary instability problems associated with the streambanks is the traffic patterns created by heavy fishing pressure. One of the willow installations failed to survive because anglers simply trampled it. For this reason the use of vegetation was abandoned when the most heavily fished stretch of the stream was stabilized. While surveying, it was noticed that a significant number of anglers using this stretch of the stream were of limited mobility. As a result, handicap accessibility was incorporated into the project designs. Traditional installations would have included concrete and asphalt, which were not used due to high cost and maintenance considerations. Items such as rock gabion baskets and crushed limestone were used which will allow proper access, have fewer maintenance concerns, and remain cost effective.

Plans are underway to install a series of low stone weirs across the stream in the fall of 1997. The weirs will be used to help reestablish a stable pool and riffle sequence, which will not only help stabilize the channel grade and streambanks, but will significantly increase the in-stream habitat potential of the stream.

Lessons learned

The Nutrient and Pest Management Incentive Education Program and the Alternative Streambank Stabilization Initiative represent innovative local efforts to improve water quality.

Providing expert assistance to write crop management plans and recommendations for the producer does not ensure that they will continue practices on their own. By including an educational component, the NPMI program allows cooperators to develop, write, and implement their own nutrient, manure utilization, and pest management plans. This provides for long-term adoption of practices.

The Alternative Streambank Stabilization Initiative is an effort to develop and demonstrate new, lower-cost streambank stabilization technology. The evaluation of these demonstrations is just beginning, as the installations have been in place less than two years. Efforts focus on installations that can be completed with minimum cost and equipment requirements. The sediment load to Sny Magill Creek is directly impacted by these efforts, while indirect results occur from the technical guidance that is applied to watersheds in other areas.

Nitrate Losses Under Various Nitrogen Management Systems

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Nitrate in sub-surface tile flow have been monitored for four years from fields with various tillage and cropping management practices. The effect of the application of large amounts of nitrogen fertilizer, particularly as a pre-plant operation, was shown in the nitrate-N concentrations from tile drains. The pre-plant anhydrous-N application systems with average nitrogen application of 110 kg/ha/yr. had a mean concentration of nitrate-N of 9.4 mg/L. The mean concentration of nitrate-N from a permanent meadow field was 1.0 mg/L.

Introduction

The overall goal of the Little Vermilion River Agricultural Nonpoint Source Hydrologic Unit Area Project is to reduce the levels of nitrate and pesticides entering Georgetown Lake. To accomplish this goal, the Cooperative Extension Service (CES), Natural Resources Conservation Service (NRCS) and Food Security Administration (FSA) are encouraging the adoption of integrated crop management (ICM) practices throughout the watershed. Besides helping improve the quality of water in the lake, these practices should also help prevent degradation in aquifers that serve private wells.

The objective of this research is to determine if selected management practices can eliminate, reduce, or retard the movement of nitrate to ground water and streams. Studies are being conducted in the Little Vermilion River Watershed on several fields that have various practices, including fertilizer and pesticide management systems, buffer strips and wetlands.

Procedures

The Little Vermilion River Agricultural Nonpoint Source Hydrologic Unit Area is located in East Central Illinois and includes 48,900 hectares in parts of Vermilion, Champaign, and Edgar counties. River water quality and sub-surface drain tile flow and water quality, as well as other practices, have been monitored in the watershed. Eight small sub-surface drainage systems were selected that have the exact extent of drainage known. Seven of the sites are in corn-soybean production in various combinations, while an eighth site is permanent meadow. Tillage practices represented by the seven sites under production include no-till, reduced tillage and conventional tillage. Nitrogen applications for the seven sites are listed in Table 1.

Table 1. Annual and Mean Nitrogen Applications, kg/ha.

	Site	Crop Year* 1991-92	1992-93	1993-94	1994-95	Annual Rotation Mean
Pre-Plant Application	Reduced-Till Corn-Beans	0	220	0	224	111
	Reduced-Till Beans-Corn	264	26	237	24	138
	Seed Corn	207	0	186	0	98
	White Corn	190	0	174	0	91
	Mean	165	62	149	62	110
Side Dress or Manure	Conventional Till Beans-Corn	219	0	206	0	106
	No-Till Corn-Beans	0	155	0	183	85
	Corn Silage	125	137	31	125	100**
	Mean	110**	97	79	106	97

*Crop year is defined from harvest to harvest.
**The 1991-92 nitrogen application for Corn Silage is not included in the annual rotation mean because that site has a three year rotation period.

The soils are predominantly Flanagan silt loam and Drummer silty clay loam at a location containing two sub-surface drainage systems of approximately 6.1 and 3.3 ha. Both were in a reduced-till (R-Till) row-crop management system with one field in corn and the other in soybeans and alternating each year. Both fields were tilled using a chisel, field cultivator or disc, and all fertilizer was pre-plant applied (entire field application prior to planting). The R-Till Corn-Beans field received a mean nitrogen application of 111kg/ha/yr. over the four years of record. The R-Till Beans-Corn field received a mean nitrogen application of 138 kg/ha/yr. for the same period (Table 1). A crop year is defined as beginning after harvest.

Three more drainage monitoring sites are located where soils are predominantly Flanagan silt loam and Drummer silty clay loam soils. One site, designated Seed Corn, has a 6.8 ha sub-surface drainage system where high-nitrogen reduced tillage seed corn management was alternated with soybeans. The second site is an 8.4 ha sub-surface drainage system under a corn-soybean reduced tillage management system where white food grade corn was raised; thus, the name White Corn for this site. The third site is a 20.5 ha sub-surface drainage system under a corn-soybean conventional tillage management system, and was named C-Till Beans-Corn. The Seed Corn and White Corn fields were tilled using only discs and field cultivators, and received means of 98 and 91 kg/ha/yr. nitrogen, respectively, in pre-plant applications during the four years of cropping record. The C-Till Beans-Corn field was moldboard plowed after corn production with a field cultivator used as the secondary tillage tool; this field received a mean of 106 kg/ha/yr. nitrogen, with most of that in a side-dress application after corn planting.

At another location where soils are predominately Sabina and Xenia silt loams, a 7.5 ha sub-surface drainage system was under no-till row crop management. This field was named No-Till Corn-Beans because the cropping pattern was alternately corn and soybeans. This field received no tillage except the planting tool. The mean of 85 kg/ha/yr. nitrogen over the four crop years was predominately a side-dress application. A second 6.9 ha sub-surface drainage system outlets from a field in permanent grass, and was named Grass.

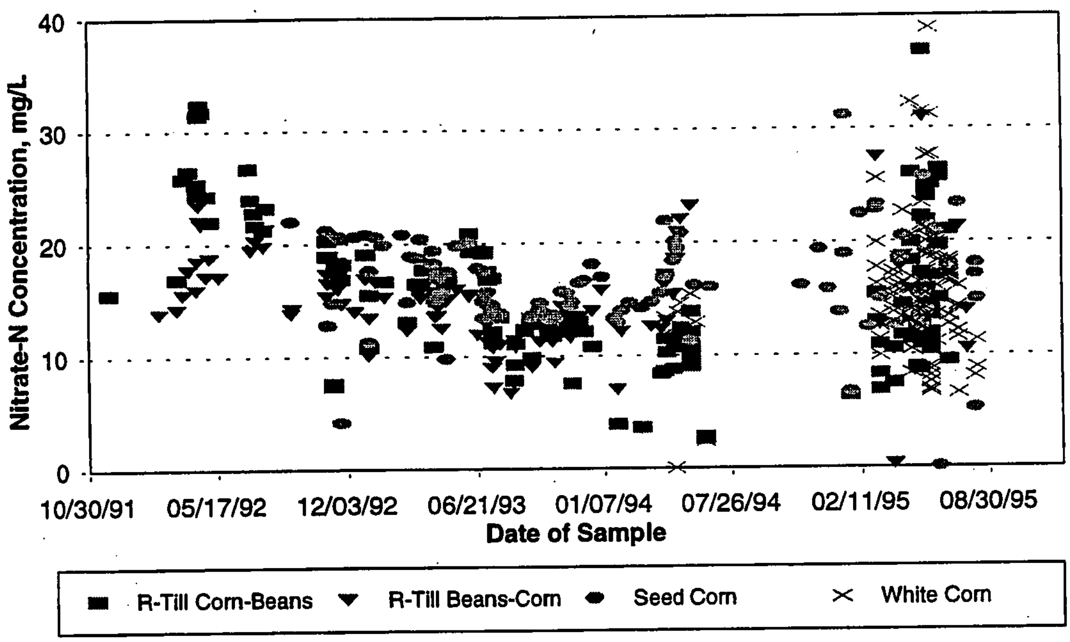
One drainage monitoring site where soils are predominately Birkbeck and Sabina silt loam soils, designated Corn Silage, is a 10.9 ha sub-surface drainage system under soybean-corn-corn reduced tillage management. The second year corn was harvested as silage and the only fertilization over the last four years was cattle manure at the rate of 45 Mg/ha during the winters prior to corn, which was estimated to contain a mean of 100 kg/ha/yr. available nitrogen for the three year crop rotation.

Sub-surface drainage (tile) flow was sampled bi-weekly and additional samples were taken during increased flow following major rainfall events. These samples were analyzed for nitrate as well as pesticides. The sub-surface outflow depth was monitored continuously with a flume and stage recorder. Records of agrichemical application to and tillage on the monitored fields were collected. Soil sampling was performed to provide background and periodic concentration of agrichemicals in the field soil.

Results and Discussion

Results of the nitrate concentrations for the eight tile monitoring stations are presented in Figure 1. Nitrate-N concentrations were above the US EPA Maximum Contaminant Level (MCL) of 10 mg/L NO3-N at all but a few sampling times from the Reduced Till (R-Till), Seed Corn and White Corn locations. Nitrate-N concentrations were generally slightly above and below the MCL from the Conventional Till (C-Till), No-till, and Corn Silage locations. However, nitrate-N concentrations from the corn silage location were quite large in early 1995. Nitrate-N concentrations from the Continuous Meadow location averaged 1.0 mg/L NO3-N for the period of record. As expected, the seasonal pattern of nitrate-N concentrations from the tile stations is similar to, but less pronounced than that found in the river; after all, the tile systems supply the river flow.

Nitrate- N Concentrations At Tile Monitoring Stations



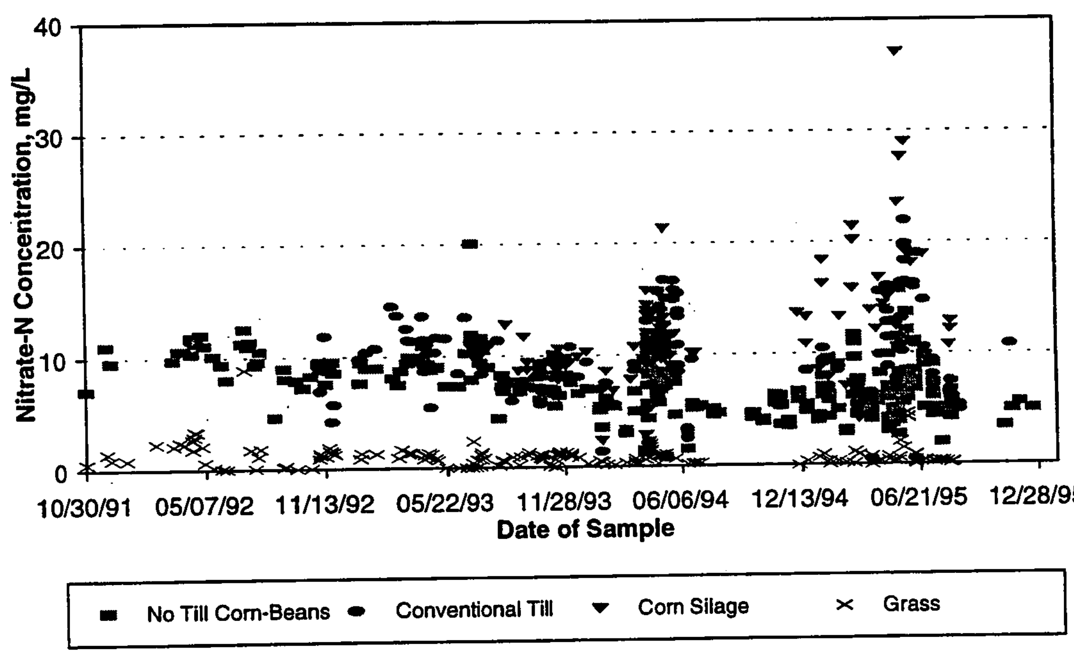


Figure 1. Nitrate-N concentrations at eight tile monitoring sites.

The amount of fertilization, as well as the method and timing of nitrogen application affects the nitrate-N concentrations from field tile. The greatest concentrations were from R-Till Corn-Beans, R-Till Beans-Corn, Seed Corn and White Corn fields where pre-plant broadcast fertilization at somewhat greater nitrogen amounts were applied (Table 1). These four cropping systems received the amount of nitrogen fertilizer for each crop year of record as shown in Table 1. The average nitrogen applied to these four systems was 165 kg/ha in 1991-92, 62 kg/ha in 1992-93, 149 kg/ha in 1993-94, and 62 kg/ha in 1994-95; for an overall average of 110 kg/ha/yr.

The lesser concentrations of NO_3-N in the tile discharge come from the C-Till Beans-Corn and No-Till Corn-Beans fields where side dress application of nitrogen to corn was used, and the Corn Silage field where cattle manure was the only source of nitrogen (Table 1). The average nitrogen applied to these three systems was 110 kg/ha in 1991-92, 97 kg/ha in 1992-93, 79 kg/ha in 1993-94, and 106 kg/ha in 1994-95; for an overall average of 97 kg/ha/yr.

The average nitrate-N concentrations and standard deviation in the tile flow for the periods of record are shown in Table 2. The R-Till Corn-Beans, R-Till Beans-Corn, Seed Corn, and White Corn management systems produced average nitrate-N concentrations of 15.0 mg/L, 14.8 mg/L, 16.5 mg/L, and 15.6 mg/L, respectively, for the period of observation (Table 2). The mean concentration for this management group is 15.5 mg/L. The average nitrate-N concentrations for the C-Till Beans-Corn, No-Till Corn-Beans and the Corn Silage management systems were 9.6 mg/L, 7.3 mg/L, and 11.2 mg/L, respectively. The mean concentration for this management group was 9.4 mg/L which is significantly different than the 15.5 mg/L mean of the other management

Table 2. Mean and Standard Deviation Nitrate-N Concentrations in Tile Outflows.

Management System	Period of Observation	NO_3-N, mg/L	
		Mean	Standard Deviation
R-Till Corn-Beans	12/91 - 12/95	15.0	6.1
R-Till Beans-Corn	2/92 - 12/95	14.8	4.5
Seed Corn	9/92 - 12/95	16.5	4.3
White Corn	4/94 - 12/95	15.6	5.7
Pre-Plant Application Mean		15.5	
C-Till Beans-Corn	11/92 - 12/95	9.6	3.6
No-Till Corn-Beans	10/91 - 12/95	7.3	2.8
Corn Silage	8/93 - 12/95	11.2	4.8
Side-Dress or Manure Mean		9.4	
Grass	10/91 - 12/95	1.0	1.1

group. The lesser concentrations were from fields where nitrogen was usually applied to corn as a side dress application after planting when the corn can immediately utilize the nitrogen and where fertilization was animal manure that is a combination of readily-available and slow-release nitrogen. The pre-plant application treatment means are significantly different from the side-dress and manure application treatment means with an overall difference between the treatments of 6.1 mg/L nitrate - N.

Summary and Conclusions

The objective of this study was to evaluate the effectiveness of tillage and cropping management systems in reducing the movement of nitrate in surface and sub-surface flow. Nitrate in sub-surface tile flow have been monitored for four years from fields with various tillage and cropping management practices. Samples have also been obtained along the mainstream of the watershed for nearly five years.

Concentrations of nitrate differed little among specific sampling locations along the river, but they definitely followed a seasonal cycle. Nitrate concentrations from tile drains varied considerably between fields depending upon the cropping management systems used, with concentrations varying seasonally as in the river.

The effect of the application of broadcast, pre-plant nitrogen fertilizer is clearly shown in the nitrate-N concentrations from tile drains. The pre-plant anhydrous-N application systems with average nitrogen application of 110 kg/ha/yr. had a mean concentration of nitrate-N of 15.5 mg/L while the side-dress and manure application systems with average nitrogen application of 97 kg/ha/yr. had a mean concentration of nitrate-N of 9.4 mg/L. The mean concentration of nitrate-N from a permanent meadow field was 1.0 mg/L.

Results and Lessons Learned from the Beaver Creek Hydrologic Unit Area Project in West Tennessee

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An overview of the major results and some lessons learned from the Beaver Creek Hydrologic Unit Area project in West Tennessee is presented in this paper. Agricultural best-management practices were implemented to improve water quality in the watershed, and an intensive monitoring program was developed to obtain water-quality data.

Data obtained from the monitoring program were used to identify agricultural nonpoint sources of pollutants, to examine the effect of agriculture on surface- and ground-water quality in the watershed, and to evaluate in-field and instream best-management practices. Soil, water, and biological sampling methods were evaluated and new strategies were developed to characterize agricultural nonpoint-source pollutants. Awareness of water-quality issues within the agricultural community was increased through educational and informational activities.

Introduction

Beaver Creek drains about 95,000 acres in Shelby, Tipton, Haywood, and Fayette Counties in West Tennessee and is a major tributary of the Loosahatchie River (fig. 1). Agricultural activities are vital to the local economy. Cropland covers about 70 percent of the watershed; cotton, soybeans, and corn are the principal crops. Many of the streams in the watershed have been channelized to improve drainage. Soils in the watershed consist of highly erodible, well to poorly drained silt loams. Conservation-related measures termed "best-management practices" (BMP's) have been implemented in the Beaver Creek watershed, as in many agricultural areas, to reduce water-quality impairment.

The Beaver Creek watershed project was initiated in 1989, when efforts by the farming community in Tennessee facilitated a cooperative agreement between the U.S. Geological Survey and the Tennessee Department of Agriculture to evaluate agricultural nonpoint-source pollution and BMP's in the watershed. In 1990, the watershed was added to the U.S. Department of Agriculture Hydrologic Unit Area (HUA) program.

As part of the HUA program, the primary goal of the Beaver Creek project was to improve surface- and ground-water quality in the watershed through the implementation of BMP's. An intensive water-quality monitoring program was developed to obtain the information needed by resource management agencies to implement conservation practices and to improve water quality in the watershed. Specific objectives of the monitoring program included determining the extent to which agricultural activities affect water quality in the watershed, evaluating in-field and instream BMP's, and developing and evaluating methodologies for assessing agricultural nonpoint-source (NPS) pollution.

Several government agencies, academic and research institutions, and agricultural organizations were involved in the project (Table 1). A local coordination committee facilitated communication between the various organizations, prevented duplication of efforts by agencies with similar functions, and capitalized on the specialities and resources of all organizations involved. Establishing and maintaining communications, such as those developed during regular meetings of a local coordinating committee, may contribute to the success of other watershed projects.

TABLE 1. Agencies and institutions involved in the Beaver Creek project

U.S. Geological Survey	University of Tennessee Agricultural Extension Service
Tennessee Department of Agriculture	U.S. Department of Agriculture,
Clemson University	Farm Service Agency
University of Memphis	Natural Resources Conservation Service
Tennessee Division of Forestry	Tennessee Department of Environment and Conservation
Water Research Federation	Shelby, Tipton, Fayette, and Haywood County Soil
Tennessee Soybean Promotion Board	Conservation Districts

Technical, financial, and educational assistance was provided to farmers for the implementation of BMP's. BMP's used included structural practices, such as terraces, diversions, and water and sediment control basins; and vegetative and tillage practices, such as permanent vegetative cover, contour strip cropping, conservation tillage, and winter cover crops. Integrated crop management practices, such as nutrient and pesticide management were also used.

Evaluation of Water-Quality Conditions

An intensive monitoring program was used to obtain water-quality data in the watershed (Fig. 1). The monitoring program served several functions such as identifying sources and magnitudes of agricultural NPS pollution, providing information needed to support the selection and implementation of BMP's, and assessing the effectiveness of BMP's in controlling the transport of pollutants from agricultural areas (1).

A ground-water quality reconnaissance was conducted to examine the occurrence and distribution of agricultural chemicals in shallow aquifers in the watershed (2), and a more detailed study was conducted to obtain additional ground-water quality and land-use data (3). An investigation of the movement and degradation of aldicarb and its metabolites in the soil profile was also conducted to examine the potential for the leaching of pesticides into shallow aquifers in the watershed (4).

Nutrient, sediment, and pesticide data were collected at four small streams with drainage areas ranging from 28 to 422 acres (5) and at two larger streams with drainage areas of approximately 8,000 acres each (6). Nutrient, sediment, and pesticide data were also collected at the inlet and outlet of a 0.88-acre constructed wetland cell which received runoff from 47 acres of row crops (7).

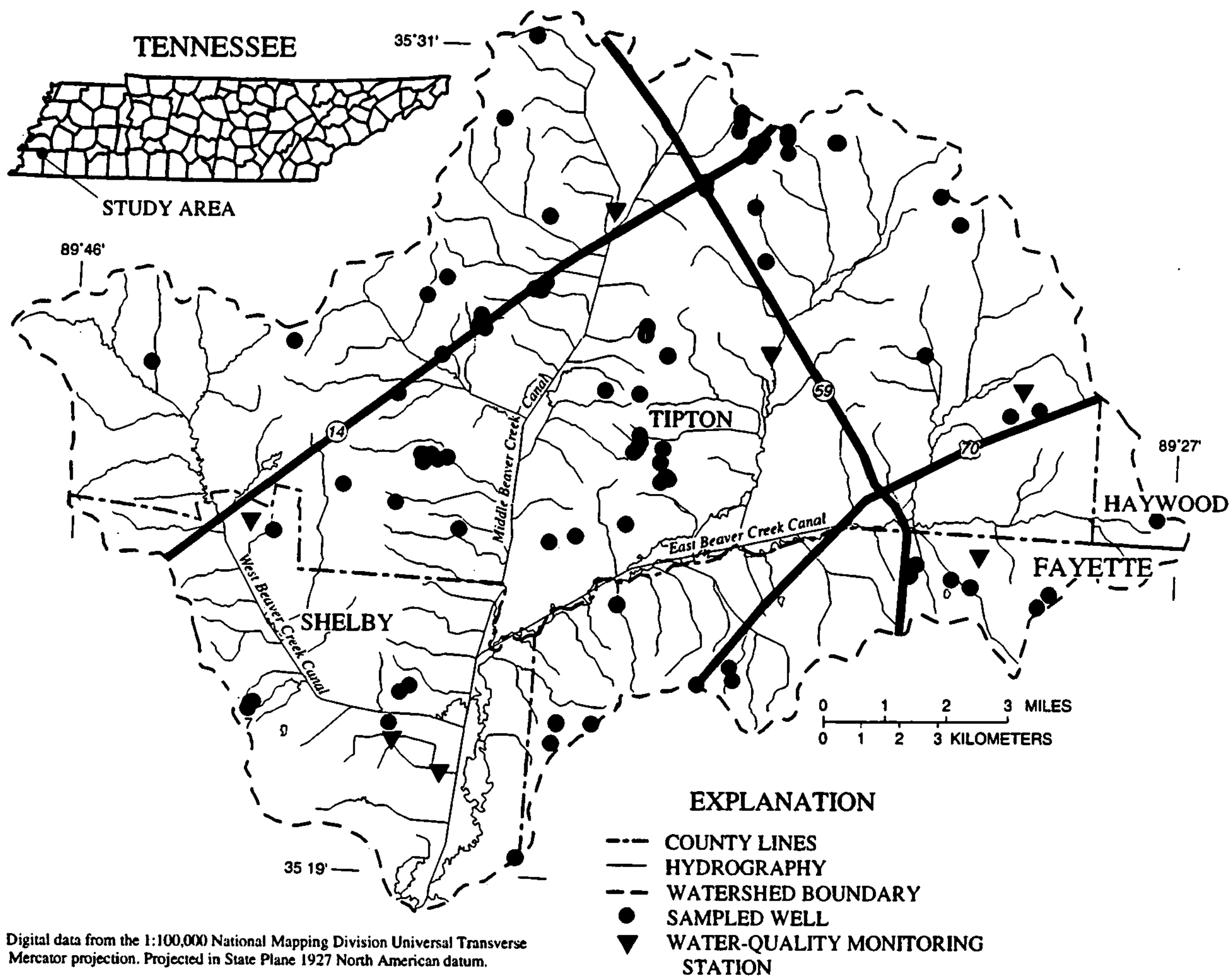

Figure 1. Location of the Beaver Creek watershed study area and monitoring sites.

Summary of Water-Quality Results

Ground Water

Results from the ground-water reconnaissance (2) and the soil sampling study (4) indicate that the potential for the leaching of pesticides such as aldicarb, atrazine, and alachlor into ground water in the watershed is low. The use of no-till and other conservation tillage practices does not appear to increase the leaching of pesticides through the soil profile (4).

Elevated nitrate and fecal bacteria concentrations were detected in samples from several wells indicating the influence of anthropogenic activities (3). Nitrate concentrations were significantly higher in samples from wells near septic tanks and confined animal areas than from wells near fertilized fields. Wells deeper than 150 feet did not appear to be affected by surface or near-surface nitrate sources (8).

Surface Water

Suspended sediment resulting from erosion is a major water-quality problem in the watershed. High sediment concentrations and loads were measured in runoff from agricultural fields (5, 6, 7).

Most of the nitrogen detected in runoff was in the organic form and was transported during late winter and early spring storms (9). Herbicides and carbamate insecticides were detected in surface-water samples collected during storms (5, 7). Most of the transport of pesticides was reported during large storms occurring shortly after pesticide application (10). A natural bottomland hardwood wetlands and a constructed wetland cell were evaluated as instream resource-management systems. The natural bottomland wetland had significantly lower sediment and nutrient loads than a channelized stream draining a basin of the same size and land use (6). The constructed wetland was effective in reducing nitrogen, phosphorus, sediment, and pesticide loads by 40 to 90 percent during a 4-month period (7).

Developments in Sampling Methodologies

A major component of the Beaver Creek study was the evaluation of existing sampling methods and the development of new sampling strategies. The design and implementation of adequate sampling programs for water, soil, and biological samples is critical in assessing agricultural NPS pollution and BMP's.

Monitoring programs must be able to address multiple pollution sources. Differentiating sources of NPS pollution at the watershed level is often difficult. Ground-water studies in the watershed emphasized the use of detailed land-use inventories to identify possible sources of ground-water contamination and the selection of appropriate statistical methods to determine the effect of various land uses on water quality (8).

Surface-water monitoring activities in the watershed indicate that an optimal sampling strategy for characterizing chemicals and sediment in agricultural runoff includes frequent sampling during storm flow. Many monitoring programs include the collection of a relatively small number of samples during storms, when most of the pollutants are transported. A sampling interval equal to 5 percent of the storm flow duration was determined to be adequate in characterizing constituents during storm flow with an error of less than 5 percent (9).

Soil-sampling strategies are needed to accurately characterize the fate and transport of various pesticides in the soil profile. Multiple sampling transects at right angles to crop rows with samples collected at row top, slope, and furrow were used to represent field conditions and describe the spatial and temporal distribution of aldicarb and its metabolites (4).

Many environmental agencies are endorsing the use of biological monitoring in water-quality studies. Evaluations of various biological sampling techniques in the watershed indicate that different sampling methods may produce distinctly different biological assessment results. These results indicate that a variety of methods may need to be used jointly in biomonitoring projects of NPS pollution in streams such as in the Beaver Creek watershed (11).

Educational Activities

Educational activities were used to improve awareness of water-quality issues within the agricultural community and to increase support of HUA activities such as implementation of BMP's and monitoring activities. Pamphlets and short papers (12, 13, 14, 15) were prepared as a cooperative effort between the U.S. Geological Survey and the University of Tennessee Agricultural Extension Service (UTAES) to improve the understanding of water-quality issues in the watershed. A UTAES pamphlet (16) also was prepared to describe ways individuals could protect wells from contamination and improve ground-water quality in the watershed. These publications were distributed through the local offices of UTAES and other cooperating agencies and during annual field days, which also included tours of the watershed, field demonstrations, and presentations.

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Subsurface Drainage Outflow Improvement With Constructed Wetland

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Abstract:

Nonpoint source pollution from agricultural fields is a contributor to the degradation of water quality. In the Little Vermilion River Agricultural Nonpoint Source Hydrologic Unit Area Project, several types of cropping systems and management practices are being studied. One of these practices is the establishment of wetlands which act as possible "sinks" for nitrate nitrogen, phosphorus, and nine commonly used pesticides.

The objectives of this study are to develop a correlation between agricultural effluent flow through the wetland and changes in nutrient and pesticide mass and to quantify how efficiently the wetland can adsorb pollutants.

Subsurface drainage outflow is the only major hydrologic input to a constructed wetland. The inflow and outflow have been monitored and sampled for three years.

The data indicate that 19.8% of the nitrate nitrogen entering the wetland is reduced, or "sunk" within the wetland. The results of this and the analyses of phosphorus and pesticide transport through the wetland will be presented.

Introduction:

Often in central Illinois, nutrient and pesticide concentrations found in ground and surface water exceed the Health Advisory Limit (HAL) set by the US EPA. Most of this contamination is of a diffuse nature (nonpoint source) and attributable to agriculture. Therefore, soluble agrochemicals leached into groundwater or shunted to surface waters through drainage tile are a cause for concern.

A large percentage of land in Illinois, especially Central Illinois, was historically predominated by wetland ecosystems. Due to the effect of acts such as The Swamp Lands Acts of 1849, 1850, and 1860, over 40,000 km^2 of wetlands, 27% of the total state land area, has been converted for agricultural purposes. (Mitsch, 1994; Novotny, 1994) The loss of these ecosystems has delivered a severe blow to the quality of the surface and groundwater of Illinois.

Wetlands occupy transitional niches in the environment. They serve as buffers between dry land and true aquatic environments. The occupation of this unique niche, usually lowland tending toward depressional storage of storm water runoff, lends itself toward collection of water born pollutants. Particularly, agrochemicals used in heavily cultivated areas such as central Illinois eventually appear in surface or ground water. Due to various natural processes, wetland ecosystems delay, contain, or transform nutrients and pollutants entering into their systems. Many studies have shown that wetlands act as "sinks" for nutrients (Kadlec, 1994; Mitsch, 1993; Mitsch, 1994), but few studies have been done concerning pesticide degradation and transport through wetlands (Rodgers et al., 1993). This potential to "sink" nutrients and pesticides could be a valuable property to improve water quality in Central Illinois.

Created or constructed wetlands for nonpoint source pollution abatement function as a relatively inexpensive best management practice (BMP). This study attempts to ascertain the functional value of a small constructed wetland fed by a drainage tile in central Illinois.

Test Site:

The 147 m^3 wetland, located in Vermilion County, has one major hydrologic input, a drainage tile draining 27 acres of farmland in corn soybean rotation. The wetland was constructed by building a dam across the natural outlet of the original depression. Creation of a dam at the site kept the area fully inundated and facilitated measurement of the outflow. The inflow and the outflow were measured with factory calibrated flumes located at the inlet and the outlet of the wetland.

The depth of water in the inlet flume was measured by a calibrated potentiometer attached to a float sitting in a still well situated at the side of the flume. As a backup system for both the inlet and outlet, the depth of water in each flume was also traced by pen on a chart stage gage. The depth in the flume then allowed calculation of the flow rate. The outlet flow rate was measured similarly.

The volume of flow into and out of the wetland was calculated and logged by onsite dataloggers every ten minutes. Rainfall was also logged by an electronic tipping bucket rain gauge. Water samples were taken at equivalent volume amounts by automatic samplers. Samplers were checked after major precipitation events or a minimum of every two weeks.

Water Quality Laboratory Analyses:

Samples were then removed and analyzed for concentrations of nitrate, phosphate, and nine pesticides: atrazine, cyanazine, trifluralin, ethalfluralin, alachlor, metolachlor, butylate, pendimethalin, and clomazone.

Samples were removed from the field, refrigerated at 4° C, and usually analyzed within 24 hours. If analysis was not done within 24 hours, then 2 mL of sulfuric acid was added to the sample to halt microbial activity. The sample was then stored at 4° C until analysis could be performed.

The nutrient concentrations were determined using a Technicon AutoAnalyzer II. The nitrate in the samples was reduced to nitrite, and the concentration of nitrite was determined calorimetrically at the ppm level (mg/L). The significance of the original nitrite concentration was deemed extremely small by previous laboratory analysis. The phosphorus concentration was measured similarly.

Pesticide concentrations were obtained by using Gas Chromatography (GC) techniques. A Hewlett-Packard model 438 gas chromatograph detected pesticide concentrations in samples at the ppb level (ug/L).

Data Analysis:

Rainfall amounts and inflow and outflow volumes were characterized on a daily basis beginning 11-16-93. Concentrations from the analyzed automatic and grab samples were correlated with the appropriate day on which they were taken. Chemical concentrations were related to equal flow volumes. From this relationship, a mass of chemical was calculated on a daily basis for both the inflow and the outflow.

The daily mass values for inflow and outflow were summed to create data sets representing accumulated mass throughout the time of the study. The inflow cumulative mass was plotted against the outflow cumulative mass for each constituent represented in Table 1 to create double mass curves (Figure 1).

Table 1. Linear Regression Values and Statistical Significance of Inflow-Outflow Double Mass Data

	Slope (n)	R^2	t-test value
Flow	0.819	0.993	67.34
Nitrate-Nitrogen	0.727	0.996	149.2
Phosphorus	0.954	0.981	7.86
Atrazine	1.058	0.994	7.78
Cyanazine	0.765	0.972	11.8
Alachlor	0.646	0.664	7.19
Trifluralin	1.694	0.729	7.63
Clomazone	0.087	0.521	115.7
Pendimethalin	1.863	0.826	7.00
Butylate	0.324	0.662	34.7

A linear regression was performed using system software to obtain values for the slope and r-squared listed in Table 1. The slope of the regression line was then tested against a slope of one using a hypothesis test listed in Hogg et al. (1993) for a student's t random variable. T-test values are listed in Table 1.

Results:

Flow

The total flow into and out of the wetland was tested for significance. The slope of the regression was 0.819 ($R^2 = 0.993$). The high t-value (67.34) showed that the outflow was significantly lower than the inflow.

Nutrients

The slope of the regression of the double mass curve for nitrate nitrogen was 0.727 ($R^2 = 0.996$). The results of the hypothesis test concluded that the difference was significant and had a high t value (149.2). The slope of the regression line representing phosphorus was 0.954 ($R^2 = 0.981$) and tested as significantly different (t-value = 7.86). Even though phosphorus tested significantly different from one, the efficiency of the pond at eliminating phosphorus was low and cyclic. At the end of this study, the cumulative phosphorus mass was greater in the outflow than in the inflow.

Pesticides

The regression slope value for atrazine was 1.058 ($R^2 = 0.994$). The t-value, 7.78, represents a high level of significance implying release of atrazine from the pond. A reduction in the net mass of cyanazine entering the pond was noted by the slope of the regression line 0.765 ($R^2 = 0.972$) and corresponding t-value (11.8). The correlation between inflow and outflow, measured by R^2 values, started to worsen with chemical constituents appearing less frequently in samples. Alachlor, clomazone, and butylate showed significant reductions in mass with regression slopes of 0.646 ($R^2 = 0.664$ t-value = 7.19), 0.087 ($R^2 = 0.521$ t-value = 115.7), and 0.324 ($R^2 = 0.662$ t-value = 34.7), respectively. Trifluralin and pendimethalin exhibited similar responses as to that of atrazine. Regression slopes for trifluralin and pendimethalin were, respectively, 1.694 ($R^2 = 0.729$ t-value = 7.63) and 1.863 ($R^2 = 0.826$ t-value = 7.00). The sampled levels of metolachlor and ethalfluralin were not high nor frequent enough to prove significance; therefore, they have been eliminated from the study.

During April and May of 1994 a series of rainfall events created conditions which flooded the stream down grade from the wetland. Water flowed over the dam and flooded the area. High levels of atrazine were then recorded in the outflow. These data were removed from the test. On May 16th of 1995, the outlet weir became clogged. These data were also removed for atrazine and cyanazine. The effect of these events on other chemical constituents appeared negligible.

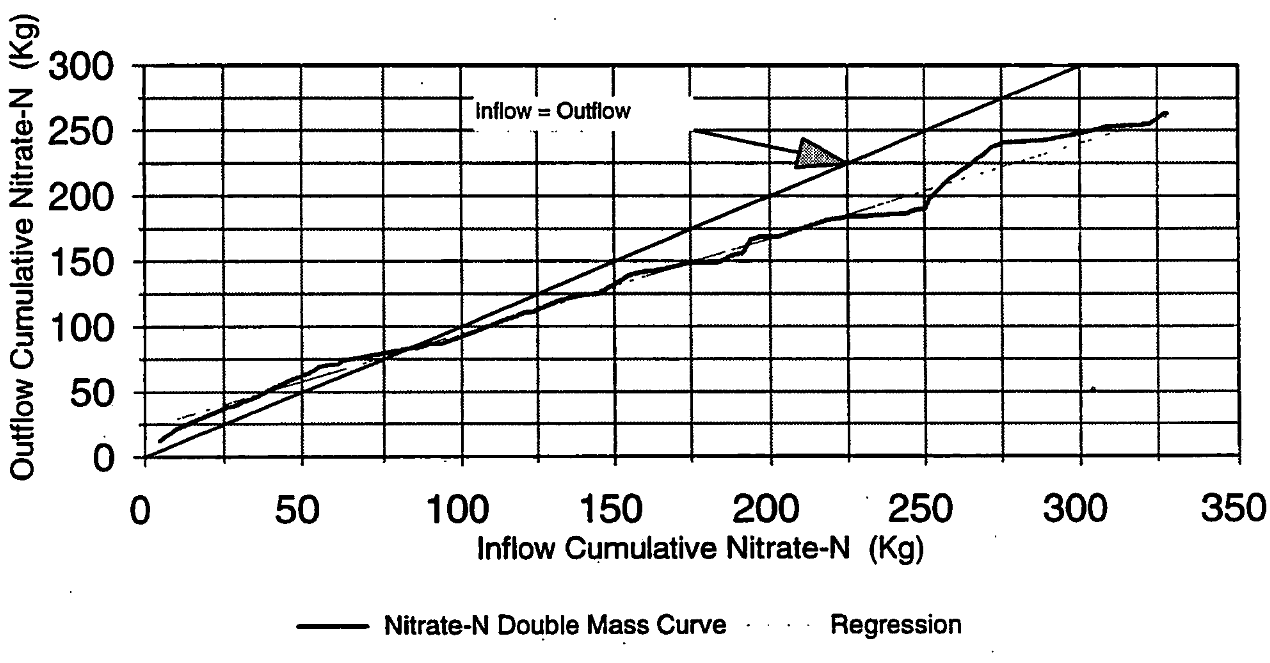

Figure 1. Nitrate-N Double Mass Curve

Removal Efficiency

The results of the efficiency of nutrient and pesticide removal calculated from the cumulative mass difference between the inflow and outflow over the period of the study are presented in Table 2.

Table 2. Cumulative Nutrient and Pesticide Removal Efficiency 11-16-93 - 12-30-95

	Efficiency %
Nitrate-Nitrogen	19.8
Phosphorus	-3.5
Atrazine	-7.75
Cyanazine	20.6
Alachlor	37.0
Trifluralin	-28.4
Clomazone	94.6
Pendimethalin	-22.7
Butylate	27.2

Conclusions:

Differences in chemical mass may be the result of photodegradation, biological uptake, chemical adsorption/desorption, and other processes in addition to leaching through the substrate. Losses due to leaching and evapotranspiration have not been quantified

Though infiltration and evapotranspiration rates are unknown, the slope of the regression for nitrate nitrogen is lower than that of the flow implying that other processes are at work. The main pathways of nitrate nitrogen loss are considered to be through denitrification and leaching.

The wetland undergoes seasonal cycles of growth. This seasonal dependence affects the mass of phosphorus leaving the wetland. The general trend is in reduction of phosphorus, yet, the cumulative mass leaving the wetland had been greater at the end of this study. Uptake by algae and duckweed during cycles of growth is re-released into the system when death and decomposition occurs. The cumulative phosphorus entering the wetland was less than the phosphorus leaving the wetland when vegetation was blooming during the middle of spring. Any phosphorus removed is then released during periods of death and decomposition. Also, natural tree fall litter contributes to the organic pool of the wetland. At its highest, phosphorus retention was 6.7%, but by the end of this study the wetland served as a source of phosphorus.

From analysis of the data, the wetland seemed to serve as a source of atrazine over the period of the study. Adjustments to remove the effects of flooding may not have fully taken into account the true affects on atrazine mass in the wetland.

Results for alachlor, cyanazine, and butylate show similar, approximately 20 to 30 percent, cumulative removal efficiencies. All three chemicals exhibit similar half life decay rates on the order of 10 - 25 days, moderate levels of water solubility, and moderate levels of adsorption (USDA 1991).

Conversely, trifluralin and pendimethalin seemed to collect in the wetland. High levels of adsorption potential and longer half lives tended to work together to keep these chemical constituents from degrading. Also, due to the their high affinity for adsorption, sediment deposited from flooding may have introduced extra quantities of trifluralin and pendimethalin into the system. Desorption and equilibrium processes may have resulted in larger quantities found in the outflow rather than in the inflow.

Clomazone exhibited the highest level of removal efficiency. Clomazone has a rather high half life that is comparable to trifluralin. Of the species tested, though, clomazone had the highest level of water solubility, five to ten times greater than other constituents. This level of water solubility may account for the increased removal efficiency either through microbial breakdown or photodegradation.

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Restoration of the Waukegan River

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The purpose of the project was to reduce the sediment load discharge to Lake Michigan from streambank erosion of the Waukegan River. Erosion was caused by increased urban runoff and channelization, problems common in many urban streams. To address the Waukegan River streambank erosion, a partnership was formed between federal, state and local entities. Innovative streambank restoration techniques were implemented to demonstrate the improvement of water quality by stabilizing eroding streambanks and creating stable stream habitat.

Best management practices (BMPs), such as biotechnical streambank stabilization techniques were implemented on the Waukegan River in Washington Park and Powell Park in the City of Waukegan, Illinois. This project was funded in part with funding from the Section 319 nonpoint pollution program of the Clean Water Act. Monitoring the effectiveness of the implemented BMPs is the responsibility of the Illinois Environmental Protection Agency (Illinois EPA).

At severe streambank erosion sites, biotechnical streambank stabilization techniques (BSST) implementation (structure added to vegetation) was a more cost-effective and environmental sensitive means to reduce nonpoint source (NPS) pollution then the traditional approaches (i.e. rip rap, concrete lining).

INTRODUCTION

In 1991, a partnership between the Waukegan Park District, United States Environmental Protection Agency (U.S. EPA), and the Illinois EPA, utilizing Section 319 funds, was formed to address the severely eroded streambanks of the Waukegan River, which were contributing excessive sediment loading to Lake Michigan.

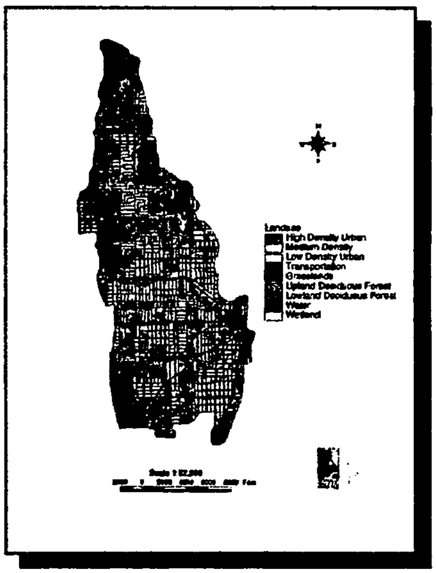

Figure 1

The Waukegan River is located approximately 35 miles northwest of Chicago. The Waukegan River is 12.5 miles long and drains 7,640 acres. Land uses are residential, agricultural, commercial and industrial (Figure 1). The watershed is highly urbanized with most of the urbanized portions of the Waukegan River represented in the reaches that flow through Washington Park and Powell Park in the lower portion of the watershed. Both of these parks are located in the older portion of the City where little or no stormwater detention was constructed. Therefore, little mitigation of stormwater quantity

Figure 2

or quality occurs, resulting in high runoff rates. Sources of water quality impairments also include cross-connections between sanitary and storm sewers, sanitary sewer overflows during wet weather events, severe streambank erosion (Figure 2), and a degraded stream habitat.

In the beginning stages of this project, BSSTs were implemented to protect the City's sanitary sewers and restore the environmental and aesthetics benefits to the park lands. The BSSTs selected combined riparian revegetation (grasses, willows, etc.) with structural stabilization.

The structural elements that were tested in this project included lunkers and interlocking concrete a-jacks structures (Figure 3). These streambank restoration techniques were chosen for their ability to withstand high velocity flow while increasing riparian habitat and in-stream habitats for the fisheries' community.

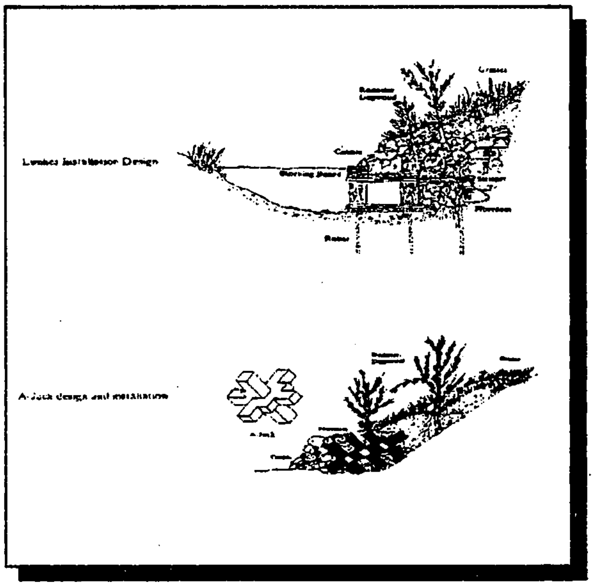

Figure 3

PROJECT DESIGNS

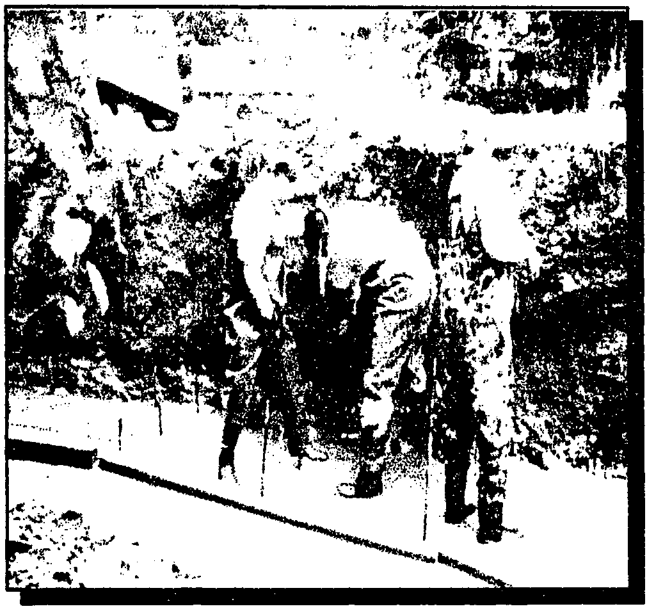

Figure 4

The first installation of the BSSTs occurred on the North Branch of the Waukegan River in Powell Park and Washington Park during the fall of 1991 and 1992. Lunkers and a-jacks were installed in Powell Park while Lunkers with stone were installed in Washington Park (Figure 4). On the two lunker installations, vegetation (willows, dogwoods, grasses, and other wetland plants) were placed into the lower, middle, and upper zones of the lunker structures. The structures utilized were chosen to enhance in-stream habitat and also to provide a structural base for riparian revegetation of the bank.

The next installations of BSSTs were utilized on the South Branch of the Waukegan River in the fall of 1994 to control severely eroded streambanks in Washington Park. The BSSTs installed were lunkers, stone, dogwoods, willows, and grasses (Figure 5). Specific small streambank erosion sites on the South Branch were also stabilized with other BSSTs which included coir coconut fiber rolls, willows, and grasses (Figure 6).

Figure 5

Figure 6

In the winter of 1996, seven low stone weirs (LSWs) formed by granite boulders were installed to create a series of pool/riffle sequences to enhance in-stream habitat on the Waukegan River (Figure 7). These LSWs were constructed to help resolve the lack of water depths, limited cobble substrates, and limited stream aeration needed to enhance the aquatic community in the Waukegan River at Washington Park.

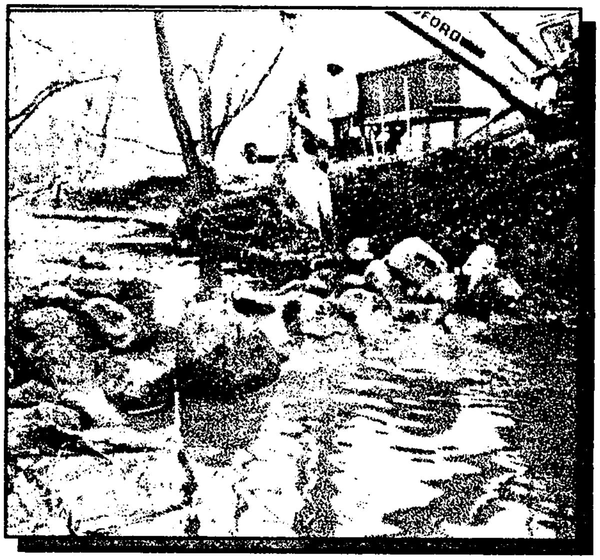

Figure 7

MONITORING

The U.S. EPA's national monitoring program (NMP) is being used to report the effectiveness of the BSSTs implemented the Waukegan River. The NMP incorporates three biological elements. These elements are fisheries, benthos, and in-stream habitats. Stream flow is the other element that is monitored.

National watershed monitoring stations (S1 & S2) on the South Branch of the Waukegan River were located in the downstream treatment reach and on the upstream control reach respectively and followed U.S. EPA's National Watershed Monitoring Protocols (NWMP) (Figure 8). The S2 is the designed upstream control station and is used as a reference condition. These stations based on seasonal sampling are monitored three times (Spring, Summer, and Fall cycles) since 1994. The NWMP requires that a survey of the fisheries and stream habitat be conducted before and after implementation of BSSTs and the LSWs. Macroinverbrate Biotic Index (MBI), Potential Index of Biotic Integrity (PIBI), and Index of Biotic Integrity (IBI) are indexes calculated from the data collected. The monitoring activities are performed by stream Biologists from the Illinois EPA and Illinois Department of National Resources. All the monitoring and related data are entered into the U.S. EPA's Nonpoint Source Management System (NPSMS) and STORET database system on an annual basis.

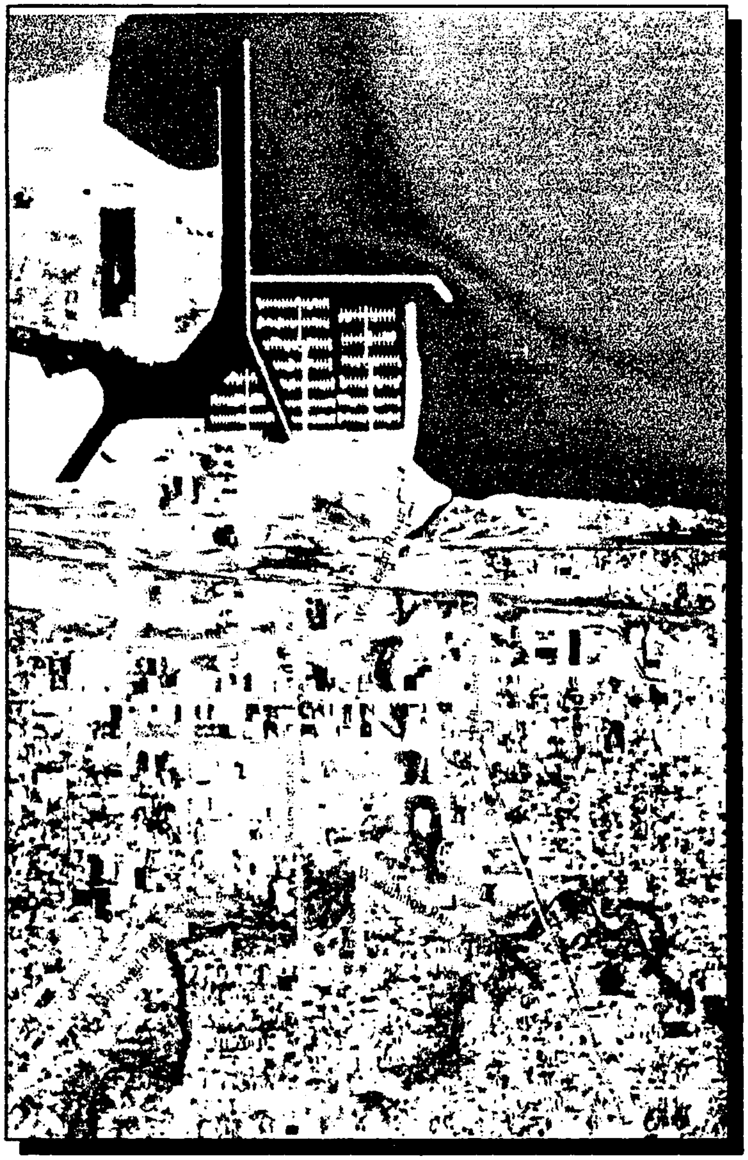

Figure 8

Additional monitoring sites (N1 & N2) are utilized for background data collection on the North Branch of the Waukegan River. At these two stations, the chosen BSSTs were wooden lunker/LSW structures in Washington Park (N1) and recycled plastic lunker and a-jack structures in Powell Park (N2) (Figure 8).

The flow of the Waukegan River is determined by an automatic flow logger (AFL) which incorporates an area velocity sensor which uses the Doppler effect to directly measure the average velocity of stream flow. Springtime stormwater discharges measured in 1996 were 600 to 700 cfs. The meter on the unit calculates the discharge using level to area data points which are inputted by the user. These data points are determined from a cross-sectional survey of the channel at the AFL sensor.

The AFL data collection utilizes three data elements (level, velocity, and flow). This data is recorded in ten minute increments and is downloaded into a computer for analysis monthly.

The AFL is contained in a steel box on a raised platform to minimize vandalism and is located on the South Branch of the Waukegan River approximately 100 feet downstream of S1 (National Monitoring station) and 300 feet upstream of the confluence with the North Branch of the Waukegan River (Figure 9).

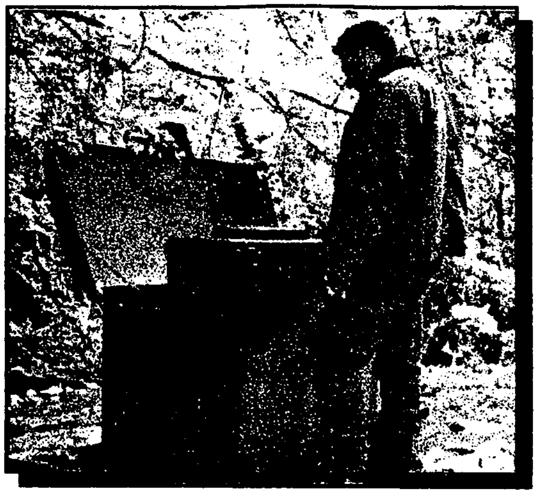

Figure 9

MODELING/APPLIED TECHNOLOGIES

Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information.

GIS is being used in the Waukegan River to spatially characterize many of the physical and hydrologic features of the watershed. GIS has made it possible to construct a high resolution digital model of the land uses/land covers, the hypsography or digital elevation model, hydrology, soils and other physical features needed to properly define a watershed for environmental modeling and assessment.

In the watershed, the digital databases along with flood zone boundaries, storm sewer network, transportation, and zoning areas were used in evaluating the application of BMPs using the AUTO-QI water quality model. These high resolution spatial data bases establish a physical benchmark in time. Since the Waukegan River watershed is now a part of the national monitoring program, the physical changes occurring, spatial assessment/analysis can be done. These activities correlate with the water quality and biological changes taking place within the watershed. The continued updating of the GIS environmental databases, in conjunction with doing change assessments, makes for better management of the overall quality of the watershed and shows how various activities on the watershed impact its environmental quality.

The use of GIS in conjunction with the development of spatial digital databases (SDD), can be utilized for accurate assessments of the stream profiles, streams slope, and determining areas/shapes of an infinite number of watersheds along a stream reach. These various physical analyses with the integration of the SDD, is making it possible for improvement of the needed assessments/analyses to support management decisions.

RESULTS

Implementations of the BSSTs have been successful in reducing streambank erosion, creating and reestablishing a vegetative riparian zone, and protecting the communities public works sanitary sewer infrastructure. However, no significant improvements (i.e. pool depth, instream aeration) to the aquatic communities in terms of aquatic species diversities (MIBI, PIBI) were measured after the installation of the lunkers, a-jack structure and related vegetation practices.

Table 1. Comparison of the Mean Station Values of the Indices for S1 and S2, for 1994 to 1996.

	1994		1995		1996	
	S1	S2	S1 Luncker	S2	S1 Riffles	S2
IBI	25.82	22.18	25.33	26.00	34.67	28.00
MBI	6.64	7.26	6.26	6.31	6.99	8.26
PIBI	41.51	41.93	41.93	41.79	41.34	41.65
FISH SPECIES AND ABUNDANCE						
Coho					2	
Bluegill					9	
Largemouth bass	1				12	
Longnose dace					44	
Mottled sculpin			4		2	
Fathead minnow	4	2	64	4	16	
Creek Chub	1		8		8	
Golden shiner	1	2	17		2	
White sucker			24	7	28	
Black bullhead					3	
Green sunfish					8	
Mosquito fish	27	13	20	4	2	1
Goldfish	1				1	
Brook stickleback			1		1	
Ninespine stickleback	1				3	
Threespine stickleback	1		53	54	84	15
No. of species	8	3	8	4	16	2
Abundacne without stickleback	35	17	138	25	136	1
Abundance with stickleback	35	17	191	69	224	16

After the construction of the seven LSWs in the winter of 1996, improved water quality (i.e. fish species, IBI) was evident in the monitored fishery community. In the 1994 and 1995 years, the number of pollution tolerate species remained at eight. Increased numbers of gamefish and pollution intolerate species raised the IBI to 35. This increased changed the Waukegan River status from degraded aquatic resource to a moderate aquatic resource. At the S1 station, the number of fish species increased from 8 to 16 with the addition of pollution intolerant species. Fisheries abundance increased by 400%, with the lunker/a-jack and LSW habitat enhancement. The upstream control (S2) remained a limited aquatic resource with two to four species with limited population numbers for the entire period. The IBI was 28 or less (Table 1).

The MBI also reflects improving water quality in the LSWs reach on the South Branch. The MBI indicated that water quality did not limit or degrade aquatic resources in 1994 or 1995. In 1996, the MBI score of 8.3 at the S2 station indicated poor water quality. The LSWs at S1 station appeared to moderate the water quality effects since the MBI remained in the non-limited classification at 7.0 (Table 1).

The physical habitat evaluations found deeper pools at the S1 station while the S2 station remained very shallow. The LSWs were designed to transport bedload and scour pools during high flow events. However, PIBI scores remained constant (41-42) for S1 and S2 for all three years (1993-1996) (Table 1). The PIBI scores are predicated on the absence of claypan or silt-mud substrates and the percentage of pools and stream width. The S1 and S2 physical habitat had very little silt or claypan substrates initially, limiting the expected change in the PIBI.

DISCUSSION

This project demonstrated that the BSSTs can be more cost-effective than the traditional approaches in reducing streambank erosion. BSSTs also provide improvements in water quality as well as beneficial in-stream habitats as demonstrated by the IBI and MBI. The incorporation of the LSWs that created the pool/riffles series added to the in-stream physical diversity and to the increase in the biodiversity. In addition to enhancing habitats, LSWs are also effective in reducing erosion of the stream bed, improving streambank stability, and increasing water aeration.

Streambank restoration is only one important step in improving the diversity of the fisheries' community. The other important step is the creation of the in-channel restoration which enhances the entire fisheries' community. LSWs provide the additional pool depth and in stream stone habitat necessary for establishing higher quality fish communities in urban streams.

EVALUATION OF TWO BASINS PRIOR TO STREAMBANK FENCING IN PASTURED AREAS WITHIN THE MILL CREEK BASIN OF LANCASTER COUNTY, PENNSYLVANIA

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Abstract

Streambank fencing within pastured areas is a best-management practice targeted to improve water quality. A cooperative effort between the U.S. Geological Survey and the Pennsylvania Department of Environmental Protection is in the fourth year of a 6- to 10-year study designed to quantify the effect of streambank fencing on surface-water quality in a small basin located within the Mill Creek Basin of Lancaster County, Pa. The paired-basin study was designed to compare control and treatment basins during a 3-year period prior to fence installation and during a 3- to 5-year period following fencing of streambanks located within pasture land in the treatment basin.

Least-squares regression equations developed between the two basins prior to fencing indicated that significant changes in most water-quality constituents could be detected after fence installation. The regressions between basins for nutrients and suspended sediment during base-flow and stormflow conditions showed statistically significant relations for most constituents. To detect significant changes in the mean difference between the treatment and control basins for base flow, a change of 23 percent for suspended-sediment concentrations and an average change of 31 percent for nutrient-species concentrations would be required. Significant changes in the mean difference between basins for stormflow would require changes of 29 and 5 percent for suspended-sediment concentration and yield, respectively, and averages changes for nutrient species of 43 and 31 percent for concentrations and yields, respectively.

Biological metrics indicate that benthic-macroinvertebrate communities are relatively healthy within both basins. Canonical correspondence analysis, used to relate sites, environmental variables, and genera during the pre-fencing period, will be used after the post-fencing period to determine if there was a macroinvertebrate response to changes in the stream habitat caused by streambank fencing.

Introduction

Agriculture is the predominant land use in the Mill Creek Basin of Lancaster County, Pa., and much of the area along streams is used to pasture dairy cattle. Pastured areas within the basin have been identified as nonpoint sources of suspended-sediment and nutrients to streams. Streambank fencing to exclude animal access is a best-management practice that is targeted to reduce suspended-sediment and nutrient inputs to streams by reducing direct nutrient inputs to streams and stopping streambank trampling. A 10-12 foot vegetative buffer along each side of the stream will also help to stabilize streambanks and potentially reduce the input of nutrients to the stream channel by overland or subsurface flow.

A 6- to 10-year study is being conducted in two small paired basins underlain by carbonate bedrock within the Mill Creek Basin to determine the effectiveness of streambank fencing in improving stream-water quality within the treatment basin. The paired basins are located in areas where agriculture accounts for approximately 80 percent of the land use. These basins were chosen for the study because of their similarities in hydrology and geology and because of the presence of a stable agricultural community that has historically not deviated significantly from year-to-year practices for their particular tract of land. This relative constancy is critical to the study because other changes in agricultural activities could make it difficult to detect changes in water quality strictly caused by streambank fencing. The majority of the 2.5-3.0 stream miles within both basins is bordered by land used to pasture dairy cattle (fig. 1).

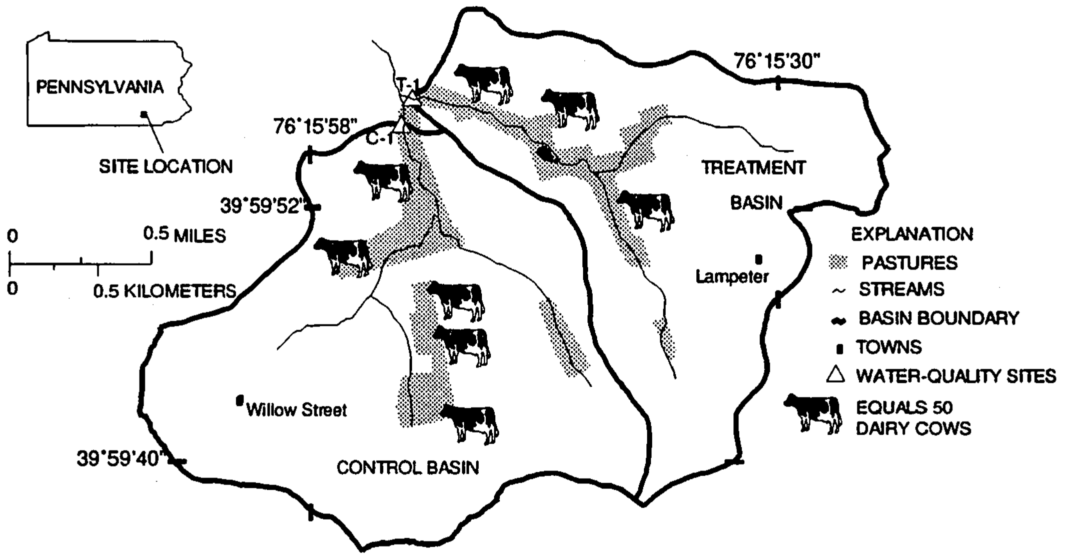

Figure 1. Control and treatment basins.

The study is a cooperative effort between the U.S. Geological Survey and the Pennsylvania Department of Environmental Protection (PaDEP). Funds from PaDEP are provided through the National Monitoring Program (NMP) of the U.S. Environmental Protection Agency.

Study Design

The paired basins, hereafter referred to as the treatment basin and control basin, are similar in size (1.4 and 1.8 square miles, respectively), land use, climate, topography, hydrology, and geology. Three years of pre-fencing (calibration) water-quality data were collected beginning in 1993 to develop relations between the two adjacent basins prior to fencing of streambanks within pastured areas of the treatment basin. Nutrient, sediment, and benthic-macroinvertebrate data were collected at the outlets of the treatment (T-1) and control (C-1) basins. Streamflow was continuously monitored at the outlets of both basins and the physical characteristics of in- and near-stream habitats were documented. Land-use and agricultural-activity data were collected for both basins to determine if activities within the basins changed from the pre-fencing to post-fencing period. For a more detailed description of data being collected in the basins, see Galeone and Koerkle (1996). Fencing within the treatment basin will be installed by July 1997, and post-fencing (treatment) data will be collected for 3 to 5 years after fence installation.

The critical season for this study was defined as the period from April through November. During this time, dairy cows frequently graze in the pastured areas. The critical season is the period when effects of streambank fencing on surface-water quality are most likely to be detected. During the critical season, fixed-time samples were collected by hand every 10 days, and most storm events were sampled. Fixed-time samples were collected regardless of flow conditions; however, only samples collected at or below the 90th percentile of streamflow data for that site were considered base-flow samples. Samples submitted for analysis from storm events were a flow-weighted composite of discrete samples collected throughout the duration of the event. Although base-flow and stormflow samples were collected outside of the critical period, only data collected during critical seasons from April 1994 through November 1996 are presented in this paper.

Constituent concentrations in base-flow and stormflow samples collected at T-1 and C-1 were used to develop relations between the paired basins during the calibration period. Least-squares regression relations developed for water-quality constituents between basins during the calibration period will be compared to the relations developed during the treatment period to determine whether streambank fencing in pastured areas along stream corridors had a significant effect on surface-water quality. Constituent concentrations and yields for T-1 were regressed against corresponding concentrations and yields for C-1 prior to fencing within the treatment basin. Regressions generated between basins for the treatment period will be statistically compared (Clausen and Spooner, 1993) to calibration regressions to determine if the effect of streambank fencing was significant on the water-quality characteristics of the treatment basin. Unless land use and agricultural activity within the basins change significantly from the calibration to treatment period, any significant change in regression relations between basins can be attributed to streambank fencing in the treatment basin. In a paired-basin analysis, the control basin is used to account for any climatic or hydrologic variations during the study. This improves the likelihood of detecting significant changes in water quality caused by the treatment.

Canonical correspondence analysis (CCA) was conducted using the physical characteristics of the stream habitat, water-quality concentrations, and benthic-macroinvertebrate data to determine the relation of physical and chemical characteristics to the biological community within both basins. Biological metrics were calculated from benthic-macroinvertebrate data to characterize the health of the stream. Relative deviations between basins in benthic-macroinvertebrates communities from the calibration to treatment period will be identified using CCA and biological metrics.

Results To Date

Data collected during the calibration period showed elevated nutrient concentrations in base flow and stormflow and elevated suspended-sediment concentrations in stormflow in both the treatment and control basins (fig. 2). Agricultural activities in the basins, such as cows pasturing adjacent to stream channels and nutrient applications to cropland, contribute nutrients and sediment to the stream.

Nutrient and sediment concentrations are similar between basins; however, streamflow at C-1 is nearly twice that of T-1. Streamflow is greater in the control basin because the basin is larger (1.8 square miles compared to 1.4 square miles) and contains greater amounts of impervious surface area associated with residential communities, which increases overland runoff during storms. Ground-water inflow to the control basin from beyond the surface-water basin boundaries may also affect the quantity of surface water measured at C-1. Even though streamflow is different, the streamflow regression relation between basins is highly significant.

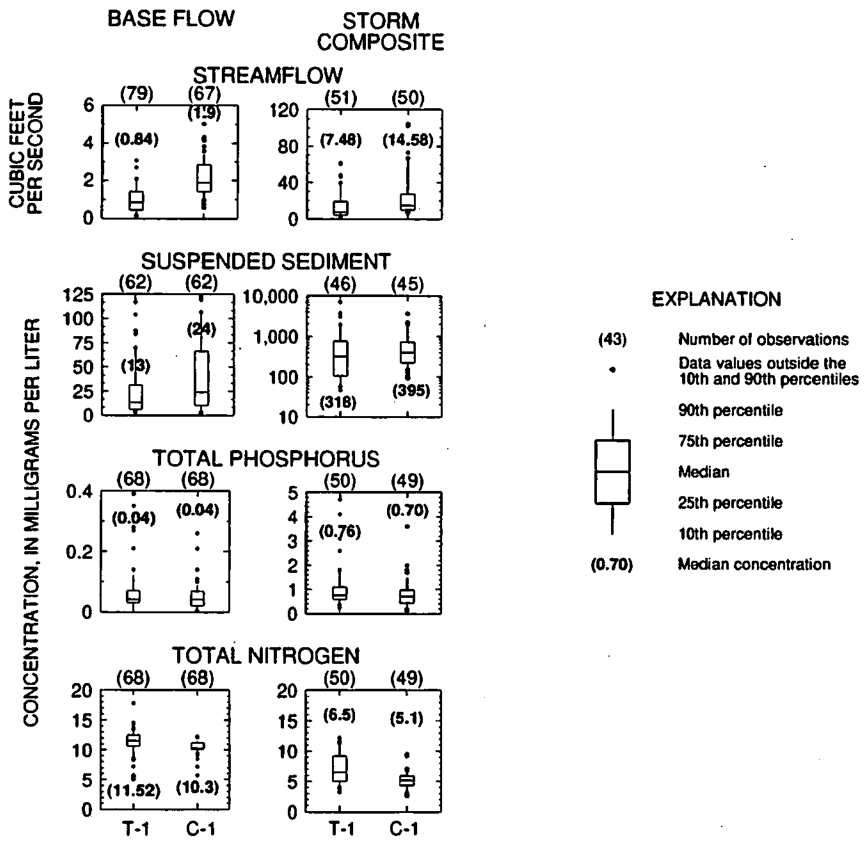

Figure 2. Distribution of streamflow and concentrations of selected nutrients and suspended sediment for base flow and storm-composite samples collected during the critical seasons of 1994 through 1996 at the outlets of the treatment (T-1) and control (C-1) basins.

Least-squares regression equations developed for water-quality constituents and streamflow indicate significant relations between basins for most constituents measured (table 1). That is, the control-basin data for most constituents was a significant predictor of the treatment-basin data based on a 95-percent confidence interval. The significant regressions were used to determine the percentage change (d) required to detect a significant difference in that constituent between basins during the treatment period relative to the calibration period. Techniques for this procedure were derived by Clausen and Spooner (1993). The equation to calculate d requires input of the mean squares error from the regression model, the F value based on degrees of freedom of the model, and the number of samples collected during the calibration and treatment period. The mean square error is directly proportional to the variance, and as the variance of the model increases, so does the value of d required to detect a significant change from the calibration to treatment periods. The value for d is the percent change required to detect a significant difference during the treatment period in the mean for that constituent for T-1 assuming that the mean for that same constituent for C-1 does not change significantly. Values for d were calculated for base-flow and storm-composite samples and for concentration and yield of total and dissolved nutrients, suspended sediment, streamflow, and field constituents. Data indicate that small changes in field constituents (2-4 percent) or streamflow during the treatment period are needed to document significant differences from the pre-fencing period at T-1 (table 1). Large differences in nutrients and suspended sediment are needed to document statistically significant changes from the pre-fencing period at T-1. For example, the regressions for the concentration of total phosphorus indicate a 48-percent change in the base flow and a 32-percent change in stormflow to show a statistically significant change from the pre- to post-fencing period at T-1, assuming the means for C-1 data do not change.

The upper and lower 95-percent confidence intervals for the equations give a graphical indication of the change required in the relation to detect significant effects of fencing. Generally, a significant change will be indicated if the treatment regression relation is outside of the range of the confidence intervals of the pre-fencing relation. For the dissolved ammonia relation for base flow samples, a 20-percent change in the mean concentration for T-1 is required (fig. 3); for the yield of total phosphorus in storm-composite samples, a 31-percent change in the mean for T-1 is required (fig. 4).

Benthic-macroinvertebrate sampling of pools and riffles just above the outlets of the basins indicated that the macroinvertebrate communities are relatively healthy based on biological metrics (table 2). The taxa richness index, the Hilsenhoff biotic index, and the EPT/ Chironomidae abundance ratio indicate that both basins are fully supportive of designated uses for these particular water bodies (see Plafkin and others, 1989, for discussion of the different metrics). Because no reference sites were available for the streams, best professional judgment was used to determine if the designated uses were fully supported or somewhat threatened. The typical four-tiered classification system based on the level of impact as discussed by Bode and others (1993) was used as a guideline for converting the biological data into terms (such as fully supported) that are in accordance with NMP guidelines. It might be difficult to detect any improvements in macroinvertebrate communities caused by streambank fencing in the treatment basin because the metrics for T-1 indicated that the stream is fully supported before the installation of streambank fencing. However, metrics for benthic-macroinvertebrate communities will be compared for calibration and treatments periods to see if significant changes occur in the metrics for the treatment basin relative to the control basin.

Table 1. Percentage change in mean values of constituents for the control and treatment basins that would indicate significant differences in constituents during the critical season (April through November) for the post-fencing period relative to the pre-fencing period.

Constituent	Percentage change required[1,2]	
	Base flow	Stormflow
Streamflow	5	7
Temperature	3	[3]-
Specific conductivity	2	-
Dissolved oxygen	4	-
Suspended sediment - concentration	23	29
Suspended sediment - yield	-	5
Total phosphorus - concentration	48	32
Total phosphorus - yield	-	31
Dissolved phosphorus - concentration	45	23
Dissolved phosphorus - yield	-	16
Dissolved orthophosphorus - concentration	42	22
Dissolved orthophosphorus - yield	-	16
Total ammonia plus organic nitrogen - concentration	[4]NS	NS
Total ammonia plus organic nitrogen - yield	-	36
Dissolved ammonia plus organic nitrogen - concentration	NS	35
Dissolved ammonia plus organic nitrogen - yield	-	29
Dissolved ammonia - concentration	20	83
Dissolved ammonia - yield	-	84
Dissolved nitrite - concentration	26	39
Dissolved nitrite - yield	-	19
Dissolved nitrite plus nitrate - concentration	6	22
Dissolved nitrite plus nitrate - yield	-	18

1. Percent changes are only given for significant regression relations between basins.
2. Percent changes are based on a 95-percent confidence interval and the assumption that post-fencing number of observations will equal pre-fencing number of observations.
3. '-' indicates that data are not available.
4. 'NS' indicates that regression was not significant.

Table 2. Mean biological metrics for benthic-macroinvertebrate sampling from September 1993 through September 1996 (seven samplings events with one in May and September of each year except for 1993) above the outlets of the control (C-1) and treatment (T-1) basins.

Metric	Basin		Metric ranges for levels of impairment[1]		
	C-1	T-1	Fully supported	Fully supported, but threatened	Partially supported
Taxa richness index	23	26	> 20	>10-20	0-10
Hilsenhoff biotic index	5.36	6.44	0-6.50	6.51-8.50	8.51-10.00
EPT/Chironomidae abundance ratio	.61	.67	0.61-2.00	0.21-0.60	0.00-0.20

1. Metric ranges are based on best professional judgment because no references sites were available.

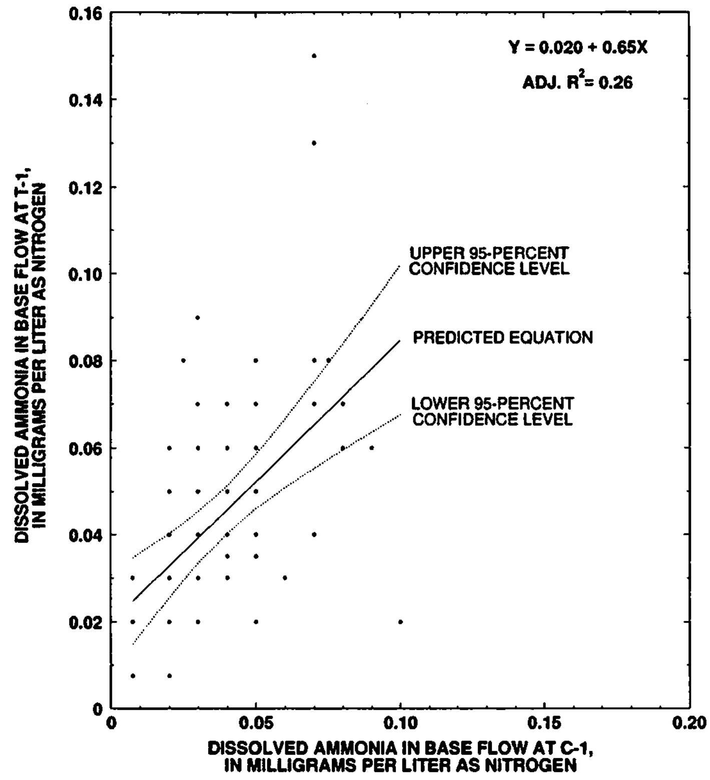

Figure 3. Concentration of dissolved ammonia at the outlet of the treatment basin (T-1) as a function of the concentration of dissolved ammonia at the outlet of the control basin (C-1) for base-flow samples collected during the critical seasons (April through November) from 1994 through 1996.

Changes in biological communities after streambank fencing can be identified through multivariate analysis if the community changes are related to changes in the physical and chemical characteristics of the stream system. One type of multivariate analysis used with biological data is CCA. CCA is used to relate biological species data to many environmental variables such as streamflow, nutrient concentrations, or channel characteristics (Ter Braak, 1987). CCA uses the correlation matrix for species and environmental variables to estimate eigenvalues. The magnitude of the eigenvalue indicates the amount of variability that the eigenvalue explains in the data. CCA generates an ordination plot of species, sites, and environmental variables (fig. 5). To relate species or sites to environmental variables on an ordination plot, a perpendicular line is drawn from the species or site to the vector that represents the environmental variable. The intersection of the perpendicular line to the environmental variable line indicates the relative location of that species or site along the standardized range of the environmental variable. For example, *Gammarus sp.* and *Baetis sp.* were related to relatively high values of specific conductivity. For each environmental variable, the mean response is represented by the origin (0,0) of the diagram.

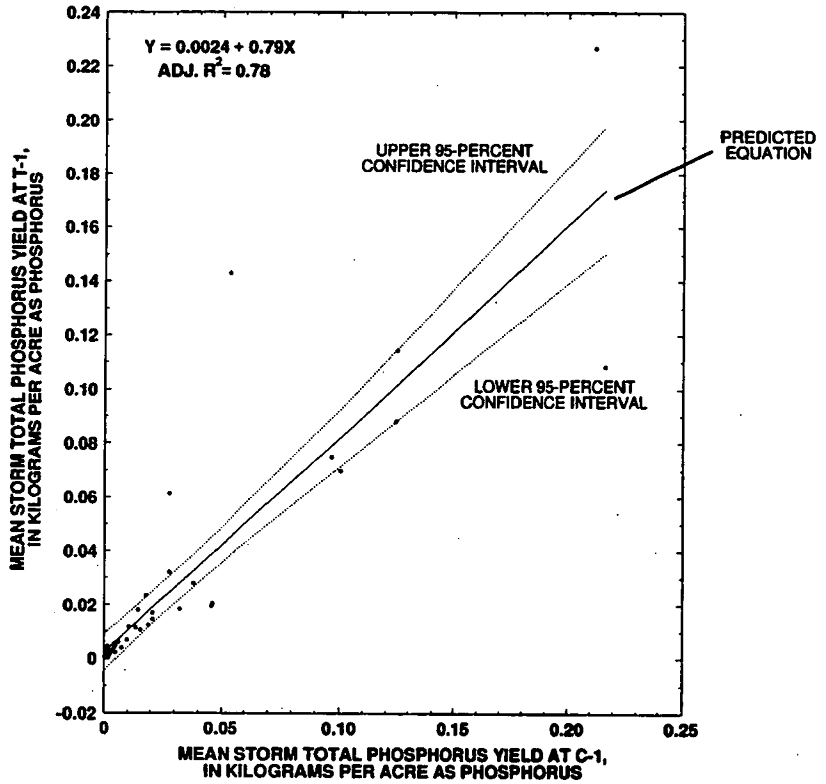

Figure 4. Yield of total phosphorus at the outlet of the treatment basin (T-1) as a function of the yield of total phosphorus at the outlet of the control basin (C-1) for storm-composite samples collected during the critical seasons (April through November) from 1994 through 1996.

The x and y axes of an ordination diagram represent the first and second eigenvalues that explain the most variation in the data. These first two eigenvalues explain 37 percent of the variation in the species-environmental variable data (fig. 5). According to biplot scores, which indicate the correlation of environmental variables to the ordination axes, total phosphorus and dissolved oxygen (in that order of importance) are the variables most highly correlated to the x axis. The pH and relative abundance of macrophytes are the environmental variables most highly correlated to the y axis.The three genera that most influence the ordination diagram are *Gammarus* (amphipods), *Baetis* (mayflies), and *Orthocladius* (midges). This influence is determined from the weighted scores that relate the genus to the different ordination axes. *Gammarus sp.* is the predominant benthic-macroinvertebrate genus identified in the control basin; *Baetis sp.* is the predominant benthic-macroinvertebrate genus identified in the treatment basin; and *Orthocladius sp.* is the most common genus found in both basins. The location of *Gammarus sp.* on the ordination plot relative to the control sampling events (c1 through c7) indicates a strong relation between the genus and the site.

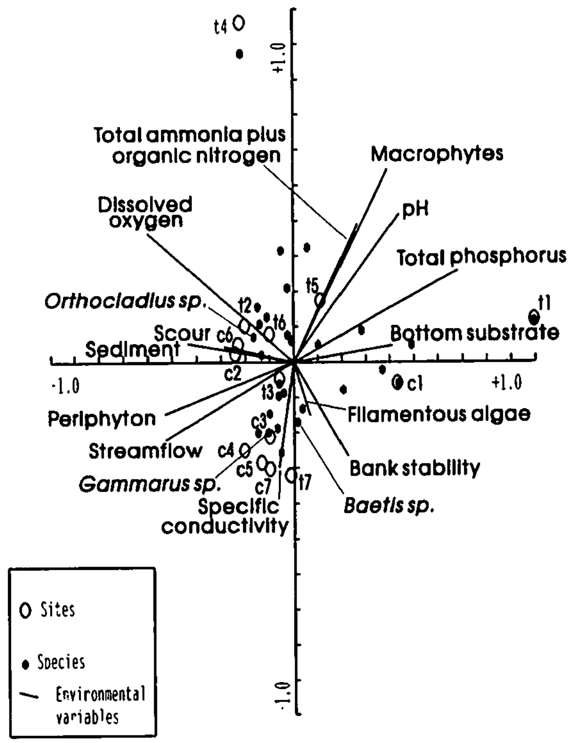

Figure 5. Canonical correspondence analysis ordination plot of 31 species, 13 environmental variables, and 7 sampling events from September 1993 through September 1996 at the outlets of the treatment (labelled t1 through t7) and control (labelled c1 through c7) basins for benthic macroinvertebrates. [Rare taxa were excluded from the analysis.]

Using CCA, changes in species composition at T-1 during the post-fencing period can be related back to any physical and chemical changes in the stream characteristics caused by the fence installation. Any changes in environmental variables will be reflected in the eigenvalues and the correlation of the variables to the ordination axes. These changes along with species composition and abundance data can be used to infer effects of fencing on benthic-macroinvertebrate communities.

Conclusions

Significant relations developed between paired basins using least-squares regression analysis and CCA will be useful in determining the effects of streambank fencing on the chemical, physical, and biological components of the stream system at the outlet of the treatment basin. Post-fencing data will be collected for 3-5 years in both basins. Assuming that the variance and the number of surface-water samples from the calibration to treatment period remain similar and that agricultural activity within the basins remains relatively similar except for the fencing of streambanks, changes of 6 to 84 percent in nutrient species and changes of 5 to 29 percent in suspended sediment between basins from the calibration to treatment period would indicate that streambank fencing had a significant effect on surface-water quality. CCA will be useful in relating changes in the physical and chemical characteristics of the stream to changes in the benthic-macroinvertebrate community. Changes in the benthic-macroinvertebrate community can be attributed to streambank fencing If the biological community responds to changes in the physical and chemical characteristics of the stream channel in the treatment basin and no such response is evident in the control basin during the treatment period. CCA ordination plots would qualitatively identify changes in the relation between benthic-macroinvertebrates and stream characteristics while the eigenvalues and biplot scores associated with CCA could be used to quantify the effect of streambank fencing on the biological community.

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Lessons Learned in the Long Creek Watershed Project

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The Long Creek Watershed Project in Gaston County, North Carolina, was initiated in 1993 as a nine-year EPA 319 Nonpoint Source National Monitoring Program Project. Objectives are to implement and evaluate agricultural and urban nonpoint source pollution control measures for improving surface water quality. This paper describes lessons learned relative to project management, pollution control measures, water quality monitoring, and education activities conducted in the project through 1997.

Pollution control measures include nutrient management, riparian buffers, animal waste management, soil erosion control, and streambank protection. Water quality monitoring consists of physical, chemical, and biological monitoring at: (1) a dairy farm to evaluate waste management and riparian protection practices; (2) cropland to evaluate nutrient and waste management practices; (3) a municipal water supply intake to evaluate sediment control; (4) a municipal biosolids management facility to evaluate nutrients, metals, and pathogen runoff control; and (5) an urban watershed to evaluate urban nonpoint source runoff controls. Education consists of site visits, newsletters, tours, volunteer monitoring, and demonstrations of control measures.

Introduction

The Long Creek Watershed drains 28,000 acres in Gaston County, North Carolina, with major land uses of row crops, dairy, beef, residential, commercial, and recreational facilities. Surface water quality impairments are caused by streambank erosion and runoff of sediment, bacteria, metals, and nutrients from agricultural and urban land uses. The upstream portion of the watershed serves as a municipal water supply for Bessemer City. The intake pool at the water supply intake, located below an agricultural area, is dredged periodically to remove excess sediment.

Objectives of the Long Creek Watershed Project are to measure the water quality benefits of nonpoint source pollution control measures implemented on:

- A dairy farm to evaluate waste management and riparian protection practices to reduce pathogens, sediment, and nutrients;
- Cropland to evaluate nutrient and erosion management practices to reduce sediment and nutrients;
- Land upstream of a water supply intake to evaluate erosion and sediment control measures;
- A biosolids management facility to evaluate municipal biosolids handling and application practices to reduce nutrient and pathogen runoff; and
- An urban watershed to evaluate stormwater and streambank protection measures to reduce nonpoint source runoff.

Project Management

Because of the complexity of this project and large number of agency cooperators, a formal project management structure was established. The project is directed by a Steering Committee that meets bi-monthly. Members of the steering committee include technical experts from North Carolina State University, North Carolina Cooperative Extension Service, USDA - Natural Resources Conservation Service, USDA Consolidated Farm Services Agency, Gaston Soil and Water Conservation District, US Geological Survey, North Carolina Division of Environmental Management, and North Carolina Division of Soil and Water Conservation. The steering committee also includes a cooperating landowner. The steering committee directs and approves all major decisions relating to monitoring objectives and BMP implementation. The Cooperative Extension Service administers the project by providing budget and local project management.

A broader project Advisory Committee consists of representatives from more than 15 government and private organizations. The purpose of this committee is to provide diverse input on project direction and community outreach. Annual workshops provide advisory committee representatives with project updates, tours of monitoring and BMP accomplishments and roundtable discussions. The steering committee and the advisory committee are responsible for setting project goals and objectives, however, the agencies comprising the steering committee are involved with the day-to- day tasks of implementing these objectives. Site specific work plans were created to clarify objectives and assign agency responsibilities and timetables. Also, a "Technician Monitoring Guidebook" was written to provide training and consistent sampling procedures to a project Water Quality Technician.

Lessons learned relative to Project Management include the following:

1. All project stakeholders must be identified at the beginning of the project and provided with the opportunity to have input toward project directions. Team building for this group is essential and requires spending time together learning to understand each other's goals, needs, and limitations.

2. A single lead organization must assume responsibility for project management, including facilitating communication, decision-making, staffing, budgeting, and reporting. Within the lead organization, there must be at least one individual who understands all aspects of the project and coordinates activities.
3. A formal management structure with regular meetings is necessary to ensure that all project stakeholders' needs are being met.
4. Open communications among major project decision-makers must be facilitated through meetings, e-mail, telephone conferences, and newsletters to avoid confusion and misunderstandings.

Pollution Control Measures

Pollution control strategies include educational programs, financial and technical assistance, and regulatory actions. During the two-year baseline water quality monitoring period, implementation plans were developed for critical areas and pollution sources using monitoring and modeling. Project staff designed best management practices (BMPs), including streambank stabilization, livestock exclusion, urban stormwater controls, and agricultural management practices to be installed in 1995-1997. Funding for BMPs is provided by EPA 319 grants, the North Carolina Agriculture Cost-Share Program (ACSP), and a USDA Water Quality Incentive Project (WQIP). Technical and educational assistance is provided through the Gaston Conservation District, USDA-NRCS, and Cooperative Extension Service.

Streambank stabilization BMPs being implemented throughout the watershed include a combination of vegetative and structural controls depending on the condition of the bank and stream flow patterns. Dairy farm BMPs include waste storage and handling, livestock water supplies, riparian area establishment, heavy use and feeding area improvements, stream crossings, and pasture management. Cropland BMPs include erosion control and nutrient management. At the Bessemer City water supply intake, 13 acres of cropland immediately upstream from the intake were converted to permanent wildlife habitat. Also, to comply with the NC Water Supply Watershed Protection Act, development restrictions are enforced one half mile of the area above the intake. At the Gastonia Resource Recovery Farm, municipal biosolids are applied to cropland using recommended rates based on soil and waste analyses. Urban stream protection BMPs being implemented in two subwatersheds include stormwater controls, streambank stabilization, and proper landscaping and lawn maintenance practices.

Lessons learned relative to <u>Pollution Control Measures</u> include the following:

1. All project stakeholders, including landowners and local governments, must be involved in designing BMPs that will be accepted and meet project needs.
2. Project staff must be flexible and patient in working with landowners and municipal officials to meet their needs. Compromise with cooperating landowners is essential in order to meet project needs.
3. BMPs must be designed to directly address identified pollution problems. Systems of BMPs are often required to effectively reduce nonpoint source pollution. These should include combinations of practices that reduce pollution at the source, that slow pollutant transport from the source, and that intercept polluted runoff before entering streams.

4. BMPs that require intensive maintenance are most likely to fail. For example, sediment traps that must be cleaned out following every major storm are likely to be neglected and become ineffective over time. BMPs such as natural forest riparian zones are most likely to remain effective because of low maintenance requirements.
5. Project staff must oversee BMP implementation and often must actually assist in implementation to ensure that BMPs are installed properly and at the correct time in the project monitoring period.
6. Legal, regulatory, and liability issues must be considered in making land use changes on private and public property.

Water Quality Monitoring

Baseline water quality monitoring was initiated in 1993. Physical, chemical, biological, and habitat monitoring are used to determine water quality changes related to implementation of pollution controls. A combination of upstream-downstream, single-station downstream, and paired watershed monitoring is being used to evaluate water quality benefits of BMP implementation. Annual macroinvertebrate and habitat monitoring are conducted by the North Carolina Division of Water Quality at six locations on Long Creek to determine long-term trends in stream health. Following completion of baseline monitoring in 1995, BMP implementation began for a three-year period. Monitoring continues throughout the BMP implementation period and through 2001 to measure long-term impacts of project efforts.

Lessons learned relative to Water Quality Monitoring include the following:

1. Appropriate water quality monitoring designs must be used which allow project staff to statistically evaluate project successes.
2. Appropriate quality assurance and quality control (QA/QC) plans must be developed and followed to ensure valid data.
3. Monitoring must address pollutants of concern that will be controlled through BMP implementation.
4. Monitoring designs must be flexible to meet project conditions and needs.
5. Adequate baseline monitoring is essential to measure success. The high degree of variability measured during the baseline period confirms the need for long-term data records in evaluating water quality changes and also for the need for co-variates such as rainfall and streamflow.
6. Field observations are essential in order to properly interpret monitoring data. Example observations include temperature, land use changes, locations of livestock, recent spills in streams, etc.
7. Adequate training and resources must be provided for sampling technicians to collect samples, maintain sampling equipment, and follow QA/QC plans.

Education

An extensive education and outreach program is being conducted in the watershed. Visuals, tours, newsletters, volunteer monitoring projects, farm visits, and demonstrations of implemented BMPs are used for public education and technology transfer throughout the project. Knowledge gained from BMP implementation and monitoring is transferred throughout the watershed and to other regions.

Lessons learned relative to Education include the following:

1. Project participants must develop an education plan that addresses targeted audiences.
2. The education plan must be flexible and adaptable to new opportunities to meet educational needs.
3. Project staff must develop strong working relationships with local media to provide continuing news coverage of watershed activities. The Long Creek project is covered regularly by the local newspaper in addition to magazines and other media outlets.
4. A project logo is helpful in providing a visual identity for the project. This logo can be used on displays, stationary, signs, newsletters, rain gauges, magnets, and other materials to create awareness of the project.
5. Roadside signs should be placed throughout the watershed to identify project cooperators.
6. Citizen advisory committees provide an outlet for informing local citizens of project activities and for collecting input on how best to meet local citizen needs. The Long Creek Watershed Watch citizen advisory committee keeps informed about water quality and agency activities and participates in citizen monitoring.
7. Regular tours of project sites and hands-on workshops are very effective in transferring knowledge to project cooperators and others. More than 40 tours have been conducted in Long Creek for Congressional Staff, local elected officials, students, state and federal agencies, water quality scientists, media, and citizen groups.

CONCLUSIONS

The Long Creek Watershed Project has been successful in creating awareness of nonpoint source pollution concerns and in implementing BMPs to address problems. Water quality monitoring has documented specific problems and will be used to measure project successes. Project stakeholders have developed a systematic management approach that is being copied in other watershed projects. Results from this project will be used to more effectively manage watersheds in other regions.

The Monocacy River Watershed Water Quality Demonstration Project: A Commitment to Water Quality

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Monocacy River Watershed Water Quality Demonstration Project
Frederick, Maryland

Setting

The Monocacy River watershed covers 899 square miles in the Maryland and Pennsylvania piedmont (Figure 1). The Monocacy River, a major tributary to the upper Potomac River and, ultimately, the Chesapeake Bay, was identified as a priority watershed for nonpoint source (NPS) pollution. Maryland's 208 Water Quality Management Plan for the Middle Potomac River watershed (1985) noted impairment of surface water beneficial uses due to livestock operations, lack of compliance with state standards at several wastewater treatment plants, and failing septic systems. Additionally, the report recommended implementation of an accelerated NPS control program for nutrients, sediments, and animal waste from agricultural operations in Frederick and Carroll counties.

In 1990, the University of Maryland System's Cooperative Extension Service (CES), the United States Department of Agriculture's Natural Resources Conservation Service (NRCS), and the Farm Services Agency (FSA), in cooperation with the Frederick Soil Conservation District (FSCD) and the Carroll Soil Conservation District (CSCD), launched the Monocacy River Watershed Water Quality Demonstration Project (the Monocacy Project). The Monocacy Project is involved in several large interagency projects combining nutrient management planning and education by CES, conservation planning by NRCS and the Districts, and water quality monitoring by the Maryland Department of Natural Resources and the University of Maryland. While individual agency roles are well-defined, overlap is often necessary to meet the project goals. Emphasis is placed in individual service and community involvement to gain and maintain producer trust and support.

Objectives

The primary project goal is to improve surface and ground water resources in the watershed by accelerating the widespread, voluntary adoption of best management practices (BMPs).

Implementation and Evaluation Approaches

Due to the size of the watershed, three subwatersheds, Linganore Creek, Israel Creek, and Piney Run-Alloway Creek, were chosen as target areas. These areas have both agricultural and suburban land uses typical of the watershed. Night meetings were held in each of the

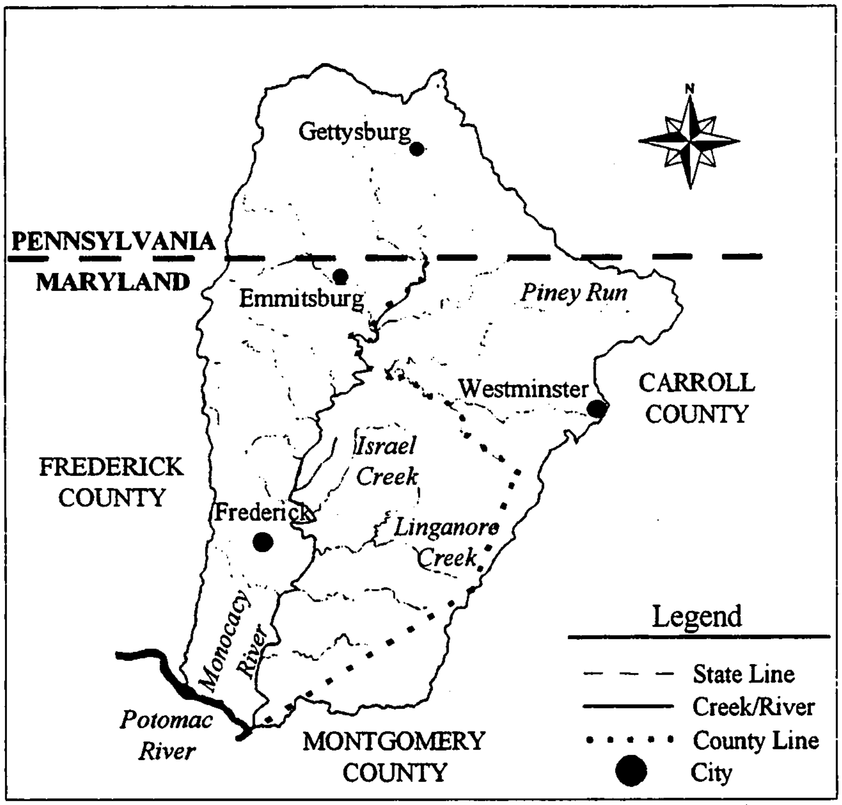

Figure 1. Monocacy River Watershed

original subwatersheds to introduce the Monocacy Project to the community. The Monocacy Project initially focused on the agricultural community, but as suburban areas grew, the Monocacy Project included this new audience. In 1995, the Glade Creek subwatershed was added to the targeted areas, in response to problems with surface contamination of groundwater that threatens the growing population's drinking water supply. As the demand for services outside the targeted watersheds increased further, the Monocacy Project ultimately expanded to include the rest of the watershed.

Information and education activities are of primary importance to the Monocacy Project. The Monocacy Project promotes BMPs to the agricultural and suburban communities through the *Monocacy Farmer*, a quarterly newsletter, presentations to local schools and civic groups, displays at agricultural field days and county fairs, and tours for both the agricultural community and non-farm residents of the watershed. The Project often serves as a liaison to the agricultural community for regulatory officials, foreign visitors, and university researchers. Several "Understand Agriculture" tours have been conducted to provide an informal forum for communication, and discussion of agricultural and natural resource policies between farmers and regulatory agency staff.

The Monocacy Project's Nutrient Management Consultant promotes, develops, and updates nutrient management plans. This often involves challenging the farmer to a test: A field is split in half, one half uses nutrient management, and the other uses traditional fertilization practices. At the end of the growing season, the crop yields are equivalent. The Pre-sidedress Nitrogen-Nitrate Soil Test (PSNT), a check for soil N during the growing season, is also used to convince farmers to cut back on initial fertilizer applications. If the PSNT indicates the field needs additional nitrogen, after following the recommended nutrient management plan, the Monocacy

Project commits to covering the costs of the needed fertilizer. These types of "show-me" tools are very successful at getting farmers to try new practices.

As BMPs became more recognized, the Project took on the challenge of drinking water education. A groundwater model, which uses dye to show groundwater and pollutant movement, provides a highly effective visual tool to teach citizens about groundwater pollution. A well water testing program was also implemented. Workshops on topics such as well and septic maintenance, lawn and garden care, water conservation, and water quality around the home were held.

The success of the Monocacy Project's efforts is traced quantitatively by practices implemented through the SCDs and by responses to program surveys. Project impact is also evaluated qualitatively by the increased awareness of water quality, and management options in the agricultural and suburban communities. Ongoing water quality monitoring efforts will ultimately provide a scientific evaluation of Project efforts.

Environmental Benefits Measured

Changes in Water Quality

A separate 319 National Monitoring Program Watershed project has collected water chemistry data since 1993 and is developing a quantitative evaluation of BMP implementation in the Warner Creek. The most recent quantitative evaluation is found in Shrimohammadi and Felton (1997). The paired watershed component of this project indicated animal waste management is still a major concern in the Monocacy Watershed. The upstream-downstream component of the project indicated nitrate-laden ground water flow was a major vehicle for pollution from animal waste.

Watershed-scale improvements in water chemistry were not statistically significant between 1993 and 1996. Variations of hydrology were extreme and probably overshadowed any variations due to BMPs implemented in 1994 or 1995. Also, it is not unreasonable to expect time lags, such as those classically illustrated in Libra et al. (1987), in water quality response to BMPs.

BMP Implementation

While water quality monitoring continues, water quality benefits can also be evaluated through reductions in fertilizer applications and the implementation of management practices. Nutrient management planning resulted in reduced application of nutrients, usually commercial fertilizer. Between 1990 and 1996, nutrient applications were reduced by 2.9 million pounds (30.8 lbs./ac.) of nitrogen and 3.5 million pounds (39.9 lbs/ac.) of phosphorus. Conservation tillage, conservation cropping sequence and crop residue management continue to be implemented throughout the watershed, reducing soil losses. Table 1 shows the practices implemented within the watershed during the last 7 years.

Qualitative Measures

Much of the success of the Monocacy Project is anecdotal. Recent surveys from a series of residential environmental workshops indicate these programs provide valuable information and increase participants' awareness of their impact on water quality. The average change in their knowledge is indicated in Table 2. This environmental awareness often results in more environmentally conscious decisions on a daily basis.

Table 1. Application of All Erosion & Sediment Control Practices/Activities

Practice / Activity	Units	1990-1996 Summary
Soil Conservation and Water Quality Plans	Acres	51,003
Conservation Crop Sequence	Acres	28,405
Conservation Tillage	Acres	24,815
Cover Crop	Acres	8,766
Crop Residue Management	Acres	17,947
Contour Farming	Acres	1,497
Stripcropping	Acres	2,769
Critical Area Planting	Acres	149
Grassed Waterway	Acres	52
Diversion / Terrace	Feet	2,188
Pasture / Hayland Management	Acres	4,262
Pasture / Hayland Planting	Acres	572
Livestock Stream Crossing	Each	5
Spring Development / Watering Trough	Each	67

The Project always receives a good response at workshops, presentations, and displays. Requests for repeat performances at other events are common. Additionally, working relationships with other agencies, as well as local businesses, such as fertilizer dealers and biosolids applicators, continue to improve.

Table 2. Survey Results

Topics	Knowledge Before	Knowledge After
Household Hazards	average	above average
Alternative Household Cleaners	average	above average
Ground and Surface Water Movement	below average	above average
Well Maintenance	below average	above average
Septic System Maintenance	below average	above average
Lawn & Garden Care	below average	above average
Spreader Calibration	none	above average

Lessons Learned

The Monocacy Project has worked closely with watershed citizens for seven years, helping implement conservation and water quality programs and apply innovative technologies. During this time, many lessons were learned about interagency cooperation and successfully promoting BMPs.

The first, most important lesson learned was, to make dramatic changes, community support is a must. This can be gained by working with local citizens and agencies from the beginning. Starting a new project without local input and initiation can imply current programs are inadequate, leading to resentment and antagonism from local agencies.

Trust, name recognition and community involvement are necessary for participation in workshops and field demonstrations. The short-term nature of the project has made these difficult to achieve. Citizens do not want to rely on an agency that will not exist in a few years. Also, the temporary nature of the staff positions has caused tremendous staff turnover. This also can jeopardize community relationships and reduced the effectiveness of the project.

Targeting just one sector of the population can also cause friction. After a few years of targeting the agricultural community, farmers began to feel they were being singled out. By expanding the educational programs to suburban and urban communities, the Monocacy Project emphasized that all citizens play a role in water quality, not just farmers. Additionally, introducing residents to agriculture through tours and presentations promoted mutual understanding and cooperation.

Getting BMPs on the ground requires individual assistance, flexibility, creativity, and money. Many agricultural operations are family farms. It often takes individual attention and perseverance to change traditions in a family business. Because each farm and farmer are different, BMPs need to be custom-fit. BMPs must be simple and low maintenance. Achieving this requires flexibility and creativity on the part of agency personnel and programs. Often, institutional guidelines and agency restrictions make it difficult to implement innovative, common-sense solutions.

Lastly, change usually has a price tag attached. Many BMPs do not benefit the farmer directly or do not yield short-term returns. Because of this, public funding for the protection of public resources is required. Cost-share programs need continued support and increased flexibility. New, innovative management practices are not funded by traditional cost-share programs. This lack of funding often impedes the adoption of new technology.

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Environmental Assessment For Real Estate Professionals

by Bob Broz
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ABSTRACT:

Much of the agricultural land surrounding cities and towns has been subdivided for urbanization and development. Real estate professionals and land appraisers can learn to recognize possible environmental hazards associated with agricultural practices by using an assessment tool such as the Farmstead Assessment System (Farm-A-Syst). A course was offered to inform real estate professionals about potential environmental hazards, present regulations and the importance of an environmental audit when buying or selling agricultural land.

INTRODUCTION:

Agricultural land surrounding cities and towns are being divided into smaller parcels for individual home sites, subdivisions and industrial development. Many of the activities that took place on farmsteads were exempt from certain regulations or were considered as acceptable practices.

Representatives from the real estate profession, land appraisers, lending institutions, Department of Health, Missouri Department of Natural Resources, University Outreach and Extension, and the Mark Twain Water Quality Initiative worked cooperatively to develop a course that would increase awareness of regulations and environmental concerns in Missouri. The Farmstead Assessment System, Farm-A-Syst, was used as a model to identify specific areas of potential environmental concern on agricultural property.

The Farm-A-Syst is an assessment tool used to identify potential environmental problem areas that may occur from practices on a farmstead. The Farm-A-Syst assesses wellhead protection practices, pesticide storage and handling practices, petroleum storage and handling practices, fertilizer storage and handling practices, on-site sewage systems, hazardous waste disposal, livestock manure management practices and farmstead site evaluation.

The course, Environmental Assessment for Real Estate Professionals, is approved through the Missouri Real Estate commission and the Missouri Land Appraisers commission for six hours of certification credit. The class provides real-estate professionals and their clientele with the ability to identify pollution risks on properties and to have some indication of how those risks may affect land values. The materials included in the course notebook offer cost-effective, voluntary action to prevent pollution, reduce potential liability and protect personal health. The course also develops awareness of environmental issues when assessing, buying and selling rural properties.

The course was sponsored by University Outreach and Extension in support of the Mark Twain Water Quality Initiative (MTWQI). MTWQI is a multi-agency organization that combines the talents and efforts of the Missouri Department of Natural Resources, the Natural Resources Conservation Service, the Missouri Department of Conservation and University Extension.

METHODS/EDUCATIONAL CURRICULUM:

Several factors influenced the development of the "realtors" course: 1.) the number of rural landowners selling property for agricultural production, 2.) the selling of rural property in small parcels for an expanding urban population, 3.) the expansion of urbanization and industrialization into rural property surrounding cities, and 4.) the change in attitude of where people want to live.

The course curriculum was developed to go from general state regulations to more specific areas of concern. The class curriculum is as follows:

1. Overview and Pre-Test - 20 minutes

Class participants are given a pre-test containing questions from each of the major areas. This prepares participants for the types of information the course will offer. An overview of the course content and notebook allows participants some hands-on activities in using the notebook.

2. Federal and State Regulations - 50 minutes DNR and DoH

The Missouri Department of Natural Resources and Missouri Department of Health officials give an overview of regulations that affect water and environmental quality. A regulatory directory has been developed listing areas of concern, action required, agencies of authority, telephone numbers and environmental and health considerations. The directory is a summary of those activities associated with agricultural and rural housing development that can be harmful to water and environmental quality.

3. Site Evaluation - 45 minutes

By using the USDA pamphlet "Making a Solid Investment" and county soil survey reports developed by the Natural Resources Conservation Service (NRCS), class participants are asked to determine if a section of agricultural land located on the soil survey map is suited for subdivision development. By determining the soil characteristics and answering the questions in the pamphlet, class participants can determine if the land is suited for development.

4. Private Drinking Water Wells - 45 minutes, presented by DNR and DoH

Public drinking water supplies are not always readily accessible to rural locations. The Missouri Department of Natural Resources and the Department of Health go through the regulations that are applicable to homeowners with private wells. The Department of Health discusses recommendations on wellhead protection, location and water testing that should be considered when buying or selling rural property.

5. On-Site Sewage Systems - 40 minutes, presented by DoH

Missouri's on-site sewage regulations are discussed by local Department of Health officials. Class participants are shown examples of working and non-working on-site systems. Guidesheets produced by University Outreach and Extension and technical bulletins by the Missouri

Department of Health explain the correct construction, maintenance and care of conventional on-site sewage systems. By being able to identify potential problems with on-site sewage systems, real estate professionals can determine if costly repairs or installation costs are needed on the property.

6. On-Site Sewage System Alternatives - 20 minutes, presented by University Extension
Much of Missouri's soil profile does not meet the minimum percolation standards for conventional on-site sewage systems. Basic information on alternative systems is reviewed for building requirements, availability of systems, maintenance and cost. Approved alternatives covered in the class are: drip irrigation systems, mound systems, sand filter systems, low-pressure pipe systems and submerged flow wetlands. Many older homes being sold with 1 or 2 acre lots may require the use of an aeration septic system with an alternative drainage field to meet state guidelines. Technical bulletins developed by the Missouri Department of Health are included in the participants' packet of materials.

7. Solid and Hazardous Waste - 40 minutes, presented by University Extension
The two most common means of disposal of solid waste in rural areas has been burning and dumping. As rural agricultural property has been subdivided, new owners may find themselves with an unwanted farm dump or burn pile on their property. Property values can be greatly hindered by the existence of a farm dump or burn pile. The correct procedure for cleaning up or closing a farm dump is discussed. Information on recycling and hauling refuse to local dumps is discussed as alternatives to burning or on-site dumping.

Another area associated with rural ownership is illegal dumping by others. The legal responsibility for cleaning up solid waste that is illegally dumped by others is discussed. Even though the property owner may not be at fault, they must shoulder the burden of clean up and proper disposal of unwanted trash.

Many areas now have refuse hauling available, but for those areas where it is not available, participants will look at ways of correctly disposing of hazardous materials that are generated or found on rural properties. A pamphlet on household hazardous waste is included in the notebook to help identify common household products that can be detrimental to the environment.

8. Hot Spots - 40 minutes, presented by University Extension
Practices that were generally considered acceptable on farmsteads may create costly environmental problems. The "hot spots" section of the class looks at four basic areas that are common on many rural farmsteads and can be potentially costly to correct.

In the past, most farming operations had on-farm fuel storage for convenience. These areas, if not contained in secondary containment structures, could have an accumulation of petroleum spills and leaks in the surrounding soil. Petroleum laden soil can be environmentally dangerous and very costly to correct. Knowing what to look for and where to look for on-farm fuel storage may save a real estate client from costly environmental clean up.

Livestock lagoons were commonly used on farms for storing animal waste. Once the livestock operation was discontinued, most lagoons were left in place and not properly closed. Participants are made aware of the regulation affecting new Confined Animal Feedlot Operations and the procedures for closing a lagoon that is no longer in use.

The storage and handling of pesticides and fertilizers were a common practice on many farms. Participants can follow the questions in the Farm-A-Syst to determine if there was proper handling of pesticides and fertilizers at the farmstead or if some environmental damage may have been done. Improper mixing of pesticides, without using some form of well protection device, may have contaminated farm deep wells and ponds.

Many rural homesteads had drilled or hand dug wells or cisterns that have been replaced with deep wells or rural water supplies. Many of these wells have been left abandoned and can create environmental and safety concerns. Class participants are given information on the environmental concerns, liability, safety and health concerns of abandoned wells. Information concerning the proper method of closure and the estimated cost are reviewed.

9. Using the Farm-A-Syst - 20 minutes, presented by University Extension
The purpose of the class is to create awareness of hidden concerns or environmental problems that can affect the value of rural property. By using an assessment tool, the Farm-A-Syst, real estate professional can identify areas of concern that may decrease the market value of rural properties. Class participants are introduced to the Farm-A-Syst packet of information and work through one section to get an understanding of how to use the assessment form. The Farm-A-Syst is divided into seven areas with worksheets and accompanying fact sheets to help class participants ask the right questions when assessing rural properties. The site assessment and overall assessment make up the complete Farm-A-Syst packet.

10. Summary, Post Test and Evaluation - 25 minutes

RESULTS:

The course has been offered three times with a total of 68 people having attended the class. Evaluations have ranked very high in determining the usefulness of the program.

Of those attending the course, 45 attended the course for professional certification, 30 attended for personal/professional development, and 3 attended for other reasons.

The professional roles of those attending were as follows:

Appraisers - 30	Educator - 1
Bankers - 5	Broker - 17
Commissioner - 1	Investor - 2
Health Professional - 3	Regulator - 3
Realtors - 12	Ag Related Profession - 1

A pre and post test was given to participants to determine the level of knowledge on environmental regulations and issues they had before and after the course was conducted. Pre-test scores ranged from 44 percent to 89 percent with an average of 69.14 percent. Post-test scores ranged from 56 percent to 100 percent and had an average of 82.92 percent.

When ranking the course, using a scale of 1 being very low satisfaction to 5 being very high, the participants gave the class an average of 4.35 for overall quality of the course compared to past and/or comparable experiences.

When asked if the program should be repeated for others, 66% of those responding to the evaluation strongly agreed, and 34% agreed. Other information indicated that 75% felt a more in-depth program should be offered on the subject areas, and 30% felt a more basic program should be developed.

The nature of the course is to heighten awareness of environmental concerns and regulations about rural properties. Test scores from the class indicate that increased awareness has occurred. The direct effect the information will have on improving environmental problems on rural property has not been documented at this time. But by increasing the knowledge level and showing the correlation between land values, liability issues and environmental concerns, we hope to see a strong voluntary action to correct some environmental problems when assessing property for loans or sales.

A follow-up survey is being sent to those attending to see how the subject matter covered in the program will be used and if the information on the Farm-A-Syst will be helpful in determining the marketability of rural properties. The survey will also ask for information concerning the most common areas of concern when doing an environmental assessment on rural property.

SUMMARY:

Agricultural properties are being sold in smaller sections for rural homes, subdivisions and industrial development. Real estate professionals and appraisers need to be aware of potential environmental problems that are associated with agricultural properties and farmsteads. These problem areas may affect land vales. The use of an assessment tool, such as the Farm-A-Syst, to help identify these areas of concern is very useful.

Though designed to be done by rural land owners, the Farm-A-Syst can be used as an environmental assessment tool by real estate professionals and land appraisers. The assessment worksheets walk the user through the different areas of the farmstead that generally have been known to be at risk of causing environmental problems. The fact sheets for the Farm-A-Syst can be used to review state and federal regulations and to list contact names and numbers if you have questions concerning specific situations. The need for public education for environmental and regulatory concerns of rural property is in great demand. Programs developed and presented by local agency people give credibility to courses like the Environmental Assessment for Real Estate Professionals and offer needed information to the public.

Sand Mountain-Lake Guntersville Hydrologic Unit Area Progress Report: 1990-1996

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Background

The Sand Mountain-Lake Guntersville Watershed covers approximately 400,800 acres in Northeast Alabama. Major land uses include cropland, pastureland, and forestland. Principal crops include corn, soybeans, and wheat. Minor crops include hay, grain sorghum, and commercial vegetables. Approximately 75% of the cropland is subject to excessive erosion. In addition to row crop production, broilers, eggs, cattle, and hogs are produced in large numbers.

Surface drainage in the watershed flows north-westward into Guntersville Lake on the Tennessee River. Guntersville Lake is the major source of water-based recreation in the area.

Baseline Water Quality Problems

High nutrient concentrations, bacterial pollution, and excessive sediment were the primary water quality problems at the inception of this project. These problems were affecting Lake Guntersville, the streams of the watershed, and the area's ground water. Studies by the U.S. Geological Survey (USGS) revealed that more than ten tons of nitrogen (N) per day were discharged from Town Creek during high flows. Bacterial pollution of ground water was a growing problem with more than half of all the well water tested showing pollution by fecal coliform bacteria,and more than 30% of the wells tested had nitrate levels exceeding the EPA limit for drinking water. The total sediment load (suspended sediment plus bedload) of the tributary streams was estimated to be 550,000 tons per year. Studies showed that 90% of the estimated soil erosion occurred on cropland.

The Sand Mountain-Lake Guntersville Hydrologic Unit Area, a USDA water quality protection project, began in 1990. The project promoted environmentally and economically sound agricultural practices by offering a combination of educational, technical, and financial assistance to producers. Participation is voluntary.

Accomplishments

Community Outreach

The Alabama Cooperative Extension System (ACES) county staff have held 123 tours and or special water quality training sessions to educate 17134 attendees on water quality issues during the project period (1990-1996). In addition, ACES staff generated 628 news articles and have held 6082 direct county agent consultations with clients on water quality issues or conflicts during the project period.

The Alabama Cooperative Extension System State staff developed 148 water quality publications that were used in this project and provided leadership to maximize the success of the educational effort.

Nutrient Management

This effort has led to an estimated 90 % of all row crop producers having currently developed farm level nutrient management plans.

Animal Waste Management and Pollution Prevention

An estimated 25% of all livestock producers in the watershed now have pollution prevention plans for animal waste management and an estimated 17% currently have animal waste management systems in place. Approximately 49% of all poultry producers installed new or upgraded dead bird disposal facilities, representing an estimated 38% of the total production in the project area.

Erosion and Sediment Control

Erosion and sediment control practices placed on more than 3771 acres include conservation cropping sequence, conservation tillage, contour farming, cover and green manure crop, crop residue use, and pasture and hayland planting. There have been over 9940 feet of terrace installed to control erosion.

Project Impacts

With approximately 79% of total planned nutrient management applied, current improvements have led to a 40% reduction in nitrogen and phosphorus entering surface and ground water.

Technical assistance from the Natural Resource Conservation Service (NRCS), financial assistance from the Farm Service Agency (FSA) and educational assistance from the Alabama Cooperative Extension System have helped farmers and citizens decrease nutrient runoff by approximately 202 tons of nitrogen and 38 tons of phosphorus on 21,300 acres of crop and pastureland, annually.

Overflow from all animal waste lagoons has been significantly reduced.

There has been a significant increase in public recognition of farmers' efforts to protect water quality.

An Executive Report issued in November 1996 by the Watershed Monitoring and Evaluation Committee shows that overall water quality of streams is improving.

This report documents improvements in the key water quality parameters such as increasing pH values, decreasing total organic nitrogen levels, and increasing dissolved oxygen levels.

The water quality also has improved significantly in Lake Guntersville. State health standards for body contact recreation have consistently been met at the major swimming areas of Town, Short, and South Sauty Creek embayments. Overall fish population dynamics have increased or remained stable, with no fish consumption advisories issued.

While water quality improvements have occurred, there remain some major areas of concern. Increasing phosphate levels in all monitored surface water streams in the watershed have been noted. Bacterial levels monitored in surface water streams remain too variable to establish a trend. Private well water monitoring continues to indicate significant contamination by fecal coliform bacteria. Sedimentation entering Lake Guntersville continues to cause concern. Rates of sedimentation have increased for the period 1961 to 1996 compared to the period 1940 to 1961. Currently the total reservoir storage volume losses are at approximately five percent.

The Sand Mountain-Lake Guntersville Hydrologic Unit Area project has made considerable progress since it officially began in 1990. Goals to be met include:

- Determine the source of phosphate levels increasing in surface water streams and reduce levels.
- Delineate the source of fecal coliform bacteria in area well water. If the bacteria are coming from local septic systems, corrections can be made. If the bacteria are originating from animal waste, a concentrated effort to reduce levels must be made.
- Set a goal of reducing sedimentation loading in Lake Guntersville of 5% per year, compared to 1996 monitoring results, through the year 2000 or 20% reduction over the period. This goal can be met by continuing to emphasize reduced tillage in agriculture, utilization of best management practices to reduce sedimentation on construction sites and practicing best management practices in timber harvesting.

All Federal and Alabama state agencies participating in this watershed project have helped make this project successful while the local farmers and citizens have made it happen. Continued success in reaching goals above can only occur through local participation. All federal and state personnel are fully committed to providing support for the project. We all look forward to the day that monitoring activity shows that this watershed is pristine clean!

The 1996 Monitoring and Evaluation Committee Members

SM-LG Conservancy District
- Raymond Hamilton
- Stanley McClendon

Jackson County SWCD
- John Brown

Alabama A&M University
- David Mays
- Karamat Sistani

Marshall County Health Department
- Freeman Smith

Natural Resources Conservation Services
- Jim McCullough
- Jerry Wisener

Alabama Dept of Environmental Management
- Steve Foster
- Charles Sweatt

Alabama Division of Game and Fish
- Keith Floyd

Auburn University
- Cliff Webber

Tennessee Valley Authority
- Doug Murphy
- Charlie Saylor
- Frank Sagona

Federal and State Organizations participating in the Sand Mountain-Lake Guntersville Watershed Project

- USDA Agricultural Stabilization and Conservation Service
- Alabama Department of Conservation and Natural Resources
- Geological Survey of Alabama
- The Alabama Department of Public Health
- Alabama Association of Conservation Districts
- Top of Alabama Regional Council of Government
- USDA Soil Conservation Service
- USDA Extension Service
- United States Geological Survey
- The United States Environmental Protection Agency - Region IV
- DeKalb, Etowah, Jackson, and Marshall Counties Soil and Water Conservation Districts
- The Alabama Department of Environmental Management

- Sand Mountain-Lake Guntersville Watershed Conservancy District
- The Alabama Cooperative Extension System
- The Alabama Forestry Commission
- The Tennessee Valley Authority
- Alabama Department of Agriculture and Industries
- Alabama Soil and Water Conservation Committee

This project is based upon work supported by the Extension Service, U.S. Department of Agriculture (CSREES).

The Muddy Fork HUA - A Water Quality Success Story

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Introduction

The rolling hills of the Ozarks in Northwest Arkansas are known for their scenic beauty and abundant ground and surface water resources. Vast groundwater aquifers supply drinking water to a majority of the rural population while lakes provide municipal drinking water for urban residents. In addition, networks of streams and lakes provide superb fishing, boating, and swimming opportunities for local residents as well as tourists. Ground and surface water in the Illinois River watershed, occupying portions of four counties in Arkansas and Oklahoma, serve these purposes.

Due to aesthetic values and the demand for drinking water and recreational water activities, improvement and protection of water quality along the Illinois River has been a priority for both states in recent decades. In the late-1980's, Lincoln Lake, a reservoir constructed on one of the Arkansas tributaries to the Illinois River, began demonstrating signs of eutrophication. Residents of the town of Lincoln complained that the water had a peculiar taste and odor. Water data collected by the United States Geological Survey on Lincoln lake during the years of 1988-1989 suggested that the lake was receiving high nutrient loads. Elevated levels of nitrogen and phosphorus were also found in other nearby lakes and streams.

Lincoln Lake is located in the Moore's Creek sub-basin of the Illinois River watershed. Numerous confined poultry, swine, dairy, and beef cattle operations are on the land surrounding the lake. Because animal waste produced in the basin is land-applied almost exclusively to pastureland, runoff from these pastures was thought to be a major source of the nutrient and bacterial loads reaching surface water supplies. In an effort to restore beneficial uses of water resources in this sub-basin, the USDA funded the Moore's Creek Water Quality Project in 1990.

The Project

The Moore's Creek Water Quality project began as a joint effort among the University of Arkansas Cooperative Extension Service (CES), the Natural Resource Conservation Service (NRCS), and the Farm Services Agency (FSA) in cooperation with other state and federal agencies. The project area initially covered approximately 15,000 acres and included Lincoln Lake and two of its tributaries, Moore's Creek and Beatty Branch. After the first year, however, the project area was expanded to encompass a 47,122-acre area known as the Muddy Fork of the Illinois River Hydrologic Unit Area (HUA) and included three reservoirs and a network of small tributaries to the Illinois River.

The primary objectives of the project were to reduce nutrient, bacterial, and sediment transport to ground and surface water supplies while maintaining the economic viability of local agricultural operations. These objectives were to be accomplished through the voluntary adoption of nutrient management, waste utilization, and conservation Best Management Practices (BMPs).

Project Methods

One-on-One Farm Visits

Because the Muddy Fork HUA Water Quality Project has been executed through non-regulatory agencies such as the CES, there has been strong interest and participation from landowners. Most farmers welcome one-on-one visits from NRCS and CES staff who assess land use and make recommendations on animal production systems. Local CES personnel relay results of BMP research conducted at the University of Arkansas and State Specialists provide additional support in answering questions and providing publications on proven BMPs. The BMPs that are emphasized involve small management changes that reduce the impact of agriculture with little cost to the farmer in terms of time and money. NRCS staff offer technical assistance in the form of nutrient management, waste utilization, and conservation plans that are tailored to each farmer's operations. In years when cost-share funding was available, FSA has provided financial assistance to producers who commit to Long Term Agreements.

On-Farm Demonstrations

Although BMP awareness has been growing, many landowners are often reluctant to try new management strategies. Some feel that because BMPs were developed on University research plots, the geology, soil type, and slope may be quite different from those on their own land in the watershed. In this respect, on-farm demonstrations have been extremely successful in promoting the effectiveness of BMPs as residents witness the results on land and operations similar to their own. When a farmer hears his neighbor speak of high yields or monetary savings due to the adoption of a BMP, he is often ready and willing to implement the management practice on his own farm.

Educational Programs, Publications, and Media Attention

Many residents of the watershed are willing to take an active role in the protection of their water supplies, but are not sure what to do. Information has been disseminated to the general public through fact sheets, videos, newspaper articles, and television spots on how water quality can be improved and preserved in the karst terrain of Northwest Arkansas. Educational programs on the water cycle, water conservation, and water quality have been presented to civic groups, community leaders, school children, and 4-H clubs. For those directly involved in agriculture, field tours of on-farm demonstrations, annual meetings, newsletters, and presentations at Farm Bureau and Cattleman's Association meetings have been most effective. Presentations using a groundwater simulator have been well received in elementary schools as a valuable teaching tool. As "contaminants" move through the model, students take home the message that activities in one area can have an impact on other seemingly distant water supplies which are all connected through the water cycle.

To reach more diverse audiences, display boards have been used effectively at county fairs, local festivals, banks, and libraries to promote the Muddy Fork of the Illinois River HUA Water Quality Project and general water quality awareness.

Project Accomplishments

Over the past seven years, the Muddy Fork HUA Water Quality Project has been a success. The impact of this project is evident in the numbers of BMPs installed, the size of the soil and water database generated from intensive sampling efforts, and the overall increase in public water quality awareness.

BMP Implementation

Since 1990, nearly 250 farm conservation plans have been completed within the project area. The voluntary adoption of BMPs which emphasize nutrient management, waste utilization, and conservation was the primary method to improve and protect ground and surface water supplies in the HUA. Over the past seven years, whole-farm nutrient management plans were established on more than 32,000 acres. To better identify the fertility status of their pastures, farmers have been encouraged to take advantage of free soil testing services through the University of Arkansas. With this management tool, fertilizer recommendations were based on forage uptake and were used to supplement nutrients contributed from land-applied animal manures.

At the start of the project, manure handling may have been the most neglected component of agricultural production. But, through the cooperative efforts of USDA agencies, 134 waste management systems, including 35 waste storage structures (concrete lagoons and dry stacking sheds) have been installed. Previously, most waste management decisions were based on convenience and cost, with little consideration for their impact on water quality. However, through educational efforts, producers learned that by reducing waste application rates or splitting applications, utilizing alternative forages, and installing vegetative grass filter strips, nutrient leaching and runoff from land-applied wastes could be reduced. Producers were also pleased to realize that BMPs such as these resulted in greater forage yields, higher feed conversions, and substantial economic savings. In much the same way, chicken house and litter truck calibrations highlighted the importance of knowing the quantity and quality of animal manures that were applied to pastures.

The most successful BMP demonstrations may have been the replacement of dead bird pits with composting units. Although dead bird pits were an accepted method of carcass disposal since the 1950's, many pits failed to properly decompose the birds. At a study site located in the Muddy Fork HUA, University of Arkansas researchers found that groundwater moving through a typical pit transported pollutants such as ammonium, nitrate, phosphate, organic carbon, and pathogens such as *Salmonella* to aquifers. At the same time, dead bird composting units were found to consistently convert the birds into a valuable organic fertilizer in dry, above-ground bins so that groundwater was protected. Today, disposal pits are no longer being installed in Arkansas and more than 30 composters have been constructed in the Muddy Fork HUA.

Database Development

One of *the* primary reasons that the Muddy Fork HUA Water Quality Project was proposed was that there was insufficient ground truth data to help verify sources for water quality degradation. Without this type of information, it was difficult to determine the magnitude of nutrient, sediment, and bacterial contributions from agricultural operations in the HUA. In order to begin gathering data, the project budget included funding for water, soil, manure, and forage sampling and analyses.

As the project progressed, a substantial database has accumulated. More than 21,000 acres within the HUA have been soil tested and more than 400 water samples have been collected from streams, springs, ponds, and wells. Because the results of these analyses have been stored in DataPerfect, it has been difficult to identify and interpret water quality trends. However, by using IDRISI, a Geographical Information Systems software, and GeoExplorer, a hand-held Global Positioning System, we are in the process of converting the data into digital maps on computer that will depict the impact of BMP implementation on water quality within the HUA over time.

Water Quality Awareness

Perhaps the greatest benefit of the Muddy Fork HUA Water Quality Project was an increase in public awareness of water quality, specifically the role of waste utilization and nutrient management in watershed-scale water quality improvement and protection efforts. Several thousand individuals have participated in tours, annual meetings, and educational programs while more than a 100 publications have been developed and distributed to residents in the HUA. Four videos of BMP demonstrations and one which highlights the Muddy Fork project have been taped and used in presentations to diverse audiences. Additional outreach through television news spots and regular news articles has also helped to promote interest in the project and water quality protection.

Water Quality Monitoring

While consistent water quality monitoring may help define the impact of BMP implementation, regularly scheduled, site-specific stream, lake, or well monitoring was not a component of this project. It was decided that the best use of funds for our purposes was to alleviate the cost of well, pond, stream and spring water analyses as they were requested by landowners in the watershed.

Coincidentally, an on-going USEPA-funded 319 grant project has evaluated the impact of BMPs on water quality in Moore's Creek and Beatty Branch. Monitoring results from five sites along these two streams in the HUA indicate that concentrations of NH_3-N and Total N have decreased significantly over time. Other parameters such as NO_3-N, PO_4-P, and TSS have remained fairly stable. Data indicate that concentrations of Total N decreased by 50 to 75% from 1991-1994 and continued to decrease by 50 to 73% during 1995 to 1996. These results seem to indicate that progress has been made from implementation of BMPs.

Lessons Learned

As this project has progressed, it has gained momentum. One of the key reasons that farmer involvement and participation has been so great is that from the start, the project was promoted as *theirs*. Although the ultimate goal may have been to improve ground and surface water quality, the methodology was to teach and train residents in ways that they could protect their own resources.

When positive comments and recognition were offered, credit was always given to the producers. Ruth Parker, the Mayor of Lincoln, wrote a letter stating her appreciation of the HUA project and credited the project efforts for contributing to the improvements in the city's drinking water quality. Letters such as these and certificates of appreciation were always shared with HUA residents so that they realized that their voluntary efforts were noticed and valued. Several landowners in the watershed, including Hollis and Vera Barker, State Representative Jerry Hunton, Alan and Robin Reed, and Brian Weaver, have received Environmental Excellence Awards from the EPA - Region 6. In fact, Brian Weaver went on to win a National Conservation Award for his role in environmental management.

Initial planning and promotion of the project was designed to include key agricultural leaders and prominent members of the community as well as local city officials, policy-makers, and representatives from the three USDA agencies.

Continual input and feedback are essential to effectively addressing dynamic needs of watershed residents. Consequently, a willingness to modify and adjust objectives as the project progresses is critical to the continued success of the project.

Conclusions

Now that many of the agricultural non-point sources have been identified and are being addressed through BMPs, as the project continues, the focus may broaden to include some of the smaller, less apparent sources of water quality degradation. Currently, a demonstration is underway that will use GIS and a Global Positioning System (GPS) as tools for whole-farm nutrient management planning. In addition, future demonstrations may include the stabilization of stream banks to reduce erosion, especially along areas where cattle have direct access to the waterways. Other areas of focus will include the impact of septic systems, gravel roads and urban runoff in the cities of Lincoln and Prairie Grove. The Muddy Fork of the Illinois River HUA Water Quality Project has been one of the most successful of its type due to the combined efforts of area residents, state and federal agencies, local government, and the University of Arkansas. With continued cooperation, promotion, and information exchange, the project will further demonstrate that individual efforts can combine to improve water quality within an entire HUA.

Effectiveness of Barnyard Best Management Practices in Wisconsin

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A study has been designed to (1) compute the loads of selected constituents coming from a single critical barnyard in each of two watersheds in Wisconsin and (2) determine whether implementation of barnyard Best Management Practices (BMPs) at each site improves water quality in the receiving streams. Using an upstream-downstream experimental design, investigators are analyzing data for discrete water samples collected automatically during storm-runoff periods before and after implementation of barnyard BMPs at Otter Creek and Halfway Prairie Creek. Before BMPs were implemented, downstream loads of total phosphorus, ammonia nitrogen, biochemical oxygen demand (BOD), and microbial loads of fecal coliform bacteria were statistically greater than upstream at each site. Downstream loads of suspended solids were statistically greater than upstream loads only at Otter Creek. Data collected after implementation of the barnyard BMPs indicate improvements in water quality at both sites. The barnyard BMP at Otter Creek has reduced loads of suspended solids by 81 percent, total phosphorus by 88 percent, ammonia nitrogen by 97 percent, BOD by 80 percent, and microbial loads of fecal coliform bacteria by 84 percent; the barnyard BMP at Halfway Prairie Creek has resulted in 67-, 89-, 94-, 91-, and 24-percent reductions, respectively.

Introduction

The Nonpoint Source Water Pollution Abatement Program was created in 1978 by the Wisconsin Legislature. The program goal is to improve and protect the water quality of lakes, streams, wetlands, and ground water within selected priority watersheds by controlling sources of nonpoint pollution. For each selected watershed, the Wisconsin Department of Natural Resources and county Land Conservation Departments draft management plans that guide the implementation of pollution-control strategies known as Best Management Practices (BMPs). These plans summarize land-use inventories, describe the results of pollution-source modeling, and suggest pollution-reduction goals. The U.S. Geological Survey, through a cooperative effort with the Wisconsin Department of Natural Resources, is studying changes in water quality that result from the implementation of BMPs. State and county officials are then comparing the results to the watershed plans to assess progress and determine whether goals are being realized. Information gained from these studies will help managers make informed decisions regarding BMP implementation in other priority watersheds.

As part of this monitoring program, an upstream-downstream (above-and-below) experimental design is being used to (1) compute the loads of selected constituents coming from a single critical barnyard in each of two watersheds and (2) determine whether implementation of BMPs at each site improves water quality in the receiving streams. This paper focuses on the methods used to collect data, the magnitude of the differences in constituent loads between upstream and downstream sites before implementation of BMPs, and the degree to which the investigated barnyard BMPs reduced constituent loads to the stream.

Study Areas and Data Collection

Two sampling stations were established on each stream (fig. 1). One station is upstream from a single barnyard-runoff source, and the other station is downstream from that same source. Station locations were chosen to minimize inflows other than runoff from each barnyard. The barnyards investigated were identified by each watershed plan as critical nonpoint sources based on herd size, lot size, proximity to the stream, and downslope overland flow characteristics.

Otter Creek, one of the Section 319 National Monitoring Program projects, is within the Sheboygan River Priority Watershed, 15 miles west of Lake Michigan, in east-central Wisconsin (fig. 1). The drainage area of Otter Creek is 9.2 square miles at the downstream sampling station, and land use in the watershed is 67 percent agricultural (Bachhuber and Foye, 1993). The stream is typified by reduced aquatic habitat due to excessive sediment and nutrient loading from nonpoint sources—mainly cropland and dairy operations—and recreation is limited by degraded fisheries and by high fecal coliform counts. The investigated barnyard on Otter Creek is a dairy operation with approximately 50 cows. Upstream and downstream sampling stations, each equipped to continuously monitor streamwater levels and to collect discrete water

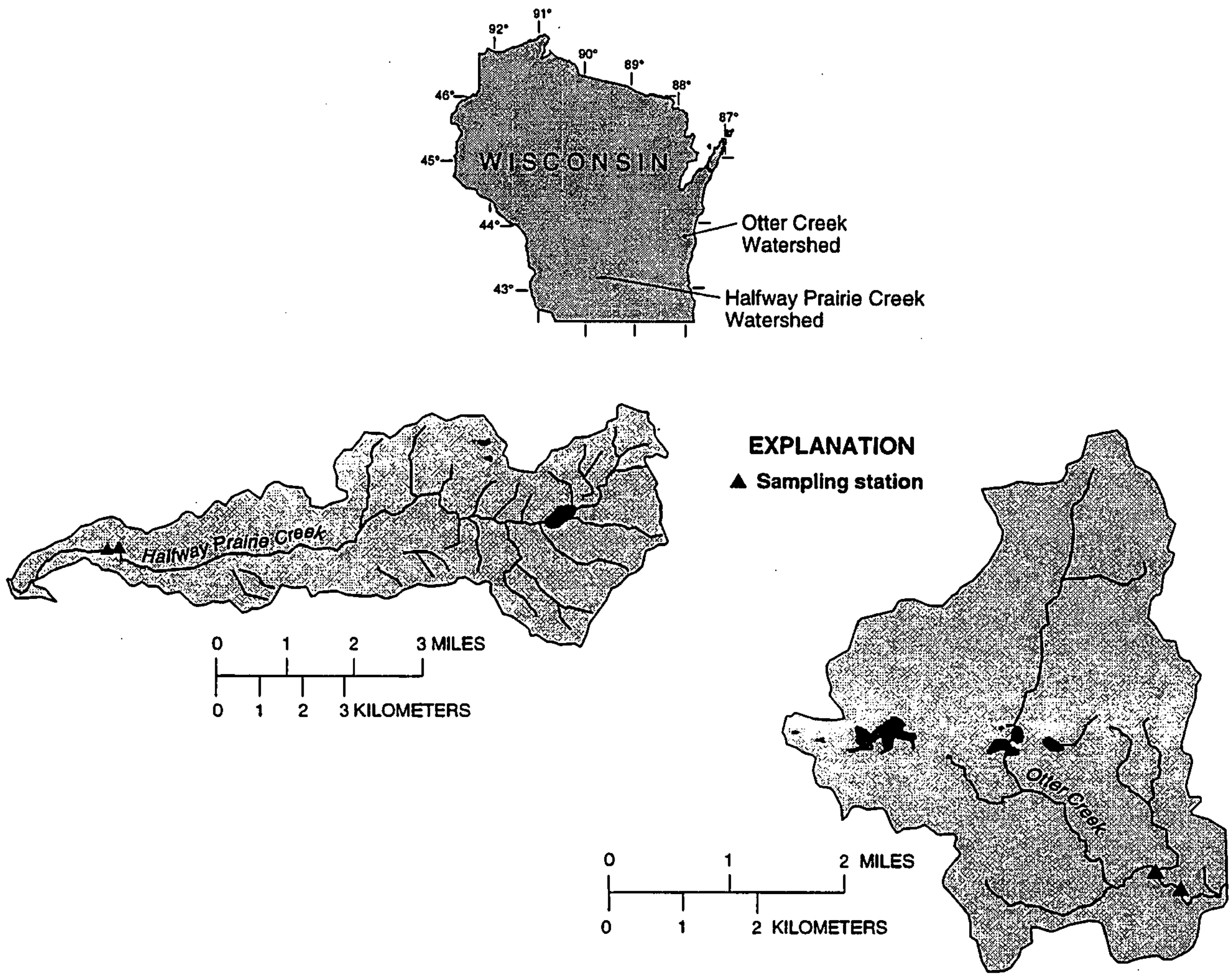

Figure 1. Location of upstream and downstream sampling stations for Otter Creek (right) and Halfway Prairie Creek (above).

samples, were established on Otter Creek in March 1994. Water samples are collected by means of a refrigerated water-quality sampler, which is activated by the rise and fall of streamwater levels.

Halfway Prairie Creek is within the Black Earth Creek Priority Watershed, 20 miles northwest of Madison, in south-central Wisconsin (fig. 1). The drainage area of Halfway Prairie Creek is 16.1 square miles at the downstream sampling station, and land use in the watershed is 60 percent agricultural (Eagan and Morton, 1989). Like Otter Creek, this stream is typified by reduced aquatic habitat due to excessive sediment and nutrient loading and by high fecal coliform counts. The investigated barnyard on Halfway Prairie Creek also is a dairy operation, with approximately 100 cows on site. Upstream and downstream sampling stations were established on Halfway Prairie Creek in April 1995. At the upstream sampling station, streamwater levels and precipitation are continuously monitored, and discrete water samples are collected by means of a refrigerated water-quality sampler. The downstream station is equipped to collect water samples only.

Upstream-downstream sampling designs have the inherent potential for upstream loading sources to mask the effects of the investigated source, because individual inputs from the investigated source are often small compared to the cumulative inputs from upstream drainage areas (Spooner and others, 1985). To reduce the potential for this problem, two enhancements were added to the sampling design at Halfway Prairie Creek. First, the water-quality samplers were activated by precipitation and were programmed to collect time-integrated samples for an initial period. (This enhancement was also added to the Otter Creek sampling design for the post-BMP monitoring period.) After the initial period, samples were collected in response to the rise and fall of streamwater levels, as in the pre-BMP setup at the Otter Creek stations. Two benefits of the enhanced approach are that (1) it allows for sampling of barnyard runoff in the receiving stream before streamwater-level increases can be sensed, thereby helping to isolate the barnyard runoff from sources upstream, and (2) it allows sampling during small runoff periods in which local inputs from the barnyard are apparent, but little runoff from the upstream areas of the watershed is observed. A second enhancement at Halfway Prairie Creek is that the upstream and downstream stations were close enough together to allow a direct electronic connection between automatic samplers and, hence, the collection of concurrent samples from both water-quality samplers. This design allows for statistical comparisons between concurrent individual upstream and downstream concentrations in water samples.

The types of barnyard BMPs implemented at Otter Creek and Halfway Prairie Creek are similar. Clean rainwater is diverted away from the concrete areas of each barnyard to minimize the amount of water flushing thorough the system. Direct precipitation is conveyed by a sloped concrete surface and retaining wall to a screened collection box where most of the large solids are trapped. The remaining liquid is then gravity piped to a concrete pad, which evenly distributes the liquid on to a grass filter strip. The filter strip at Otter Creek gently slopes downwards toward the stream, whereas the filter strip at Halfway Prairie Creek is a substantial distance from the stream. Cows, which were previously allowed to roam the stream and banks at each site, have been fenced in, and a gravel-lined channel crossing now allows them access to the stream. Although sampling sites were chosen to minimize inflows other than that from the barnyard, a field near the investigated barnyard at Otter Creek could have potentially contributed to the stream loading between the upstream and downstream stations in the pre-BMP phase, especially during periods of heavy storm runoff. As part of the barnyard BMP, a grassed swale was installed to help minimize runoff from this field.

Water samples from 12 storm-runoff periods were collected for the pre-BMP period of April 1994–October 1995 at Otter Creek. The clean-water diversion and concrete work were completed in October 1994; however, runoff from the collection box was not conveyed to the filter strip until October 1995. With the exception of one snowmelt period, all the pre-BMP samples for Otter Creek were collected for storm-runoff periods between April and October. Water samples from 11 storm-runoff periods were collected for the pre-BMP period of April–July 1995 at Halfway Prairie Creek. All the barnyard BMP components at Halfway Prairie Creek were implemented by October 1995. All samples from both streams were analyzed for suspended solids, total phosphorus, and ammonia nitrogen. Due to holding time and budget constraints, samples from some storms were not analyzed for biochemical oxygen demand (BOD) and fecal coliform bacteria.

To date (August 1997), water samples from 12 storm-runoff periods have been collected for the post-BMP period at Otter Creek, and water samples from 11 storm-runoff periods have been collected for the post-BMP period at Halfway Prairie Creek. (The post-BMP period began April 1996 at both streams.) The sample collection portion of the study is complete; however, analysis of water samples and constituent load computations have only been completed for seven storm-runoff periods at Otter Creek and eight storm-runoff periods at Halfway Prairie Creek.

The continuous streamflow and instantaneous water-quality data were used to estimate loads for individual storm-runoff periods. Loads were computed—in pounds—for suspended solids, total phosphorus, ammonia nitrogen, and BOD, by summing the product of instantaneous concentration and streamflow rate for each storm-runoff period (Porterfield, 1972). Microbial loads of fecal coliform bacteria were computed similarly, however, the units are in total colony forming units (in the volume of water that occurred during a storm-runoff period).

Runoff volumes for the downstream sites at Otter Creek and Halfway Prairie Creek were assumed to be equal to the volumes computed for each upstream site. In reality, this is generally not the case because some amount of water is contributed by the barnyard during a runoff period. However, for the pre-BMP period at Otter Creek, meaningful differences in streamflow between the upstream and downstream stations were difficult to detect, primarily because the drainage area of the barnyard is small compared to the drainage area of the entire watershed. Because of the assumption of equal volumes, the loads computed for the downstream stations for Otter Creek and Halfway Prairie Creek are slightly conservative.

Results and Discussion

Testing of Experimental Design

A critical aspect of validating conclusions for an upstream-downstream experimental design is determining whether downstream loads are significantly greater than the upstream loads before BMPs are implemented. At both streams, loads of suspended solids, total phosphorus, ammonia nitrogen, BOD, and microbial loads of fecal coliform bacteria were greater at the downstream station than at the upstream station for most periods of pre-BMP runoff (figs. 2 and 3). Using the Wilcoxon signed ranks test to find differences between paired data sets, study investigators determined that downstream loads were significantly greater than upstream loads (at the 95-percent confidence level) for all constituents except suspended solids at Halfway Prairie Creek. These significant differences indicate that the investigated barnyard-runoff sources are important contributors to the loading of total phosphorus, ammonia nitrogen, BOD, and fecal coliform bacteria for the storms monitored; in addition, the barnyard on Otter Creek is also an important source of suspended solids.

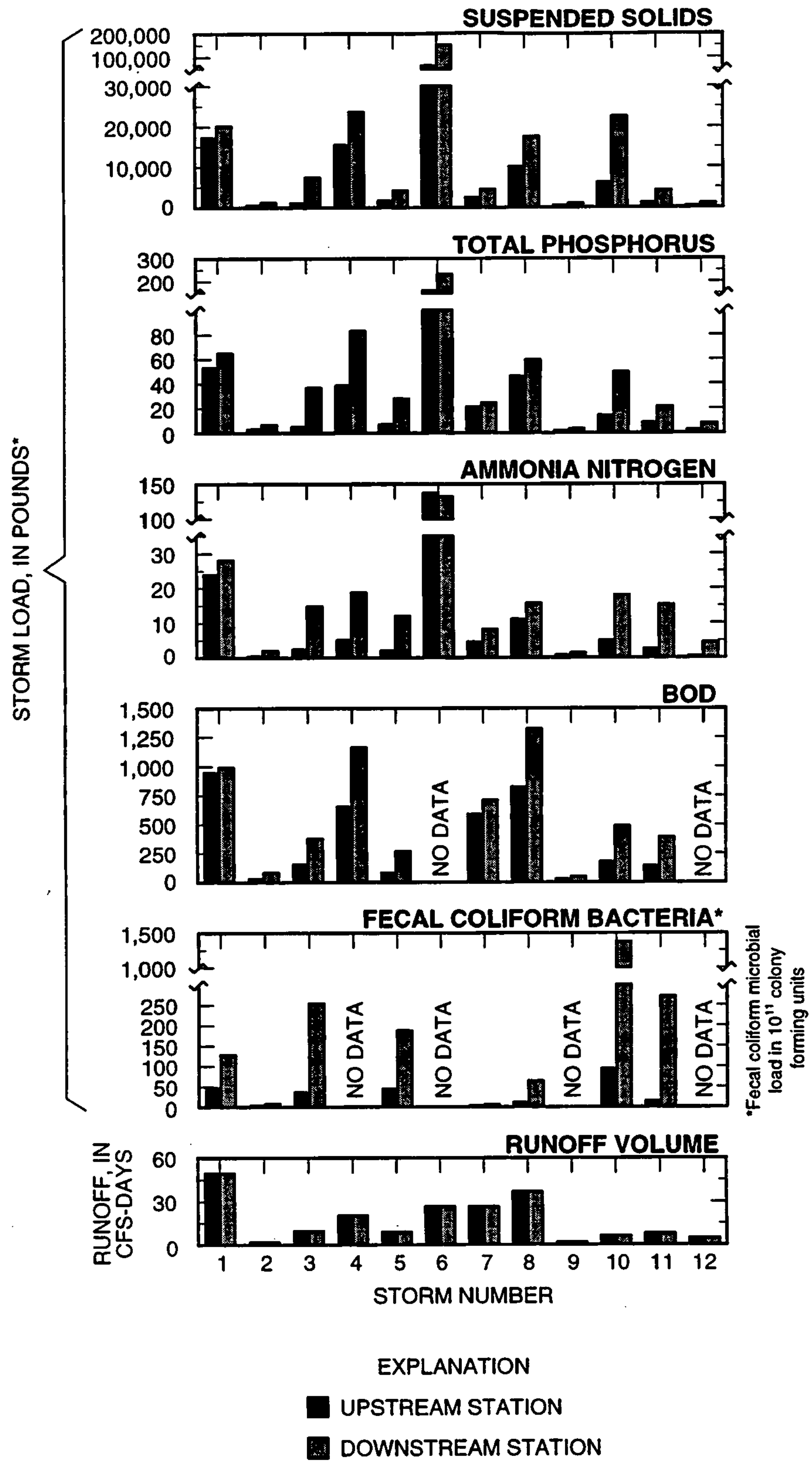

Figure 2. Loadings and runoff volumes for pre-BMP storm-runoff periods at Otter Creek.

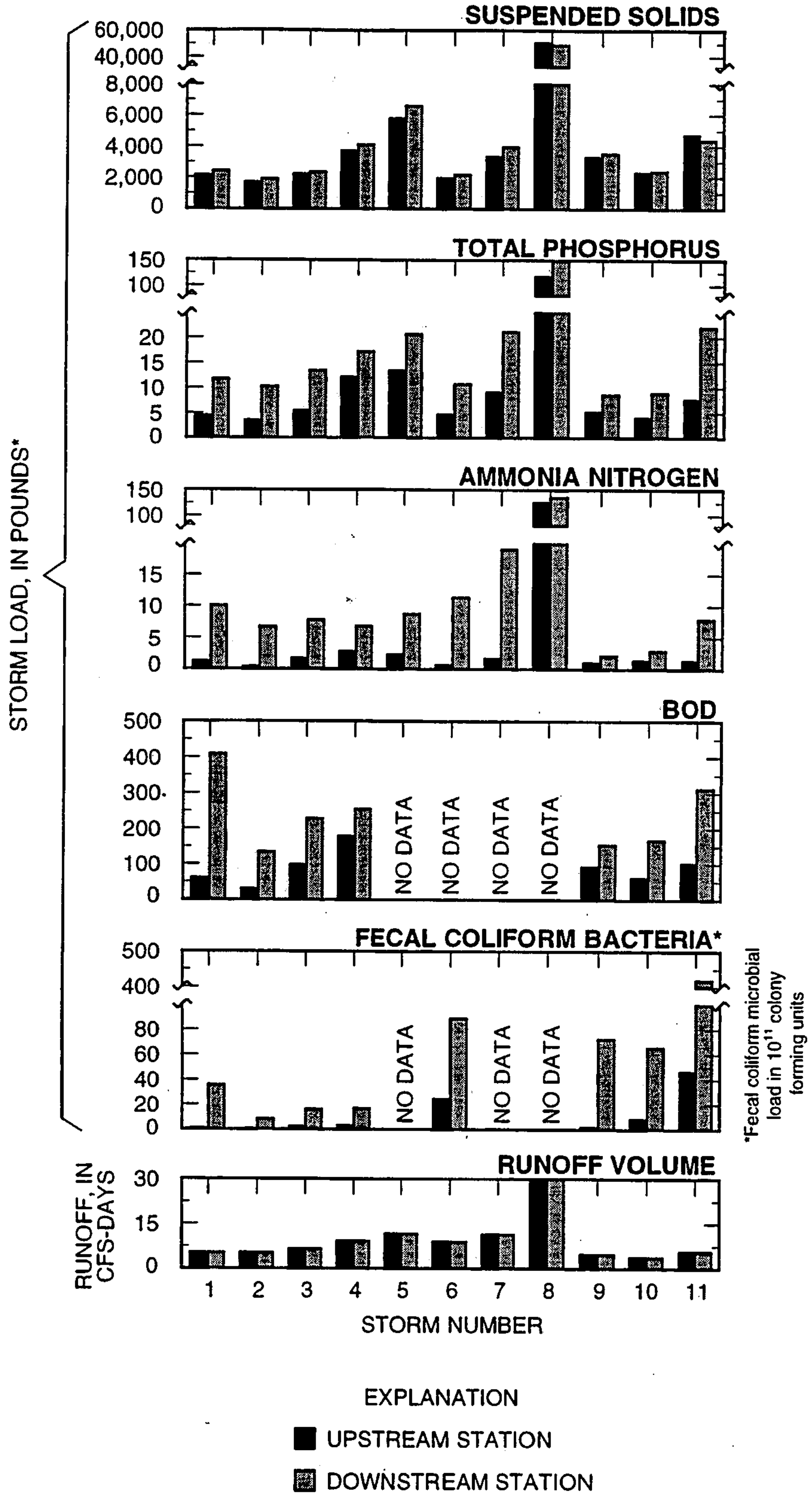

Figure 3. Loadings and runoff volumes for pre-BMP storm-runoff periods at Halfway Prairie Creek.

Large variations in meteorological data, such as rainfall, could affect comparisons of pre- and post-BMP load data. For example, a post-BMP period with much larger rainfalls than the pre-BMP period could show a reduction in loads simply because the barnyard loads could be masked by much larger contributions from upstream sources. The median runoff volume, rainfall, maximum 30-minute rainfall intensity, and rainfall-runoff ratio for the pre- and post-BMP runoff periods were compared to see whether meteorologic conditions differed. The Wilcoxon-Mann-Whitney rank sum test was used to find differences between pre- and post-BMP data sets. Results show no significant difference between pre- and post-BMP data for either Otter or Halfway Prairie Creek. Any decrease in load contributed by each barnyard is therefore most likely due to the implementation of the barnyard BMPs and not to changes in meteorological variables. Rainfall-runoff relations for the pre- and post-BMP storm-runoff periods at Otter Creek and Halfway Prairie Creek are shown in figure 4. Boxplots comparing pre- and post-BMP storm-runoff volumes are shown in figure 5.

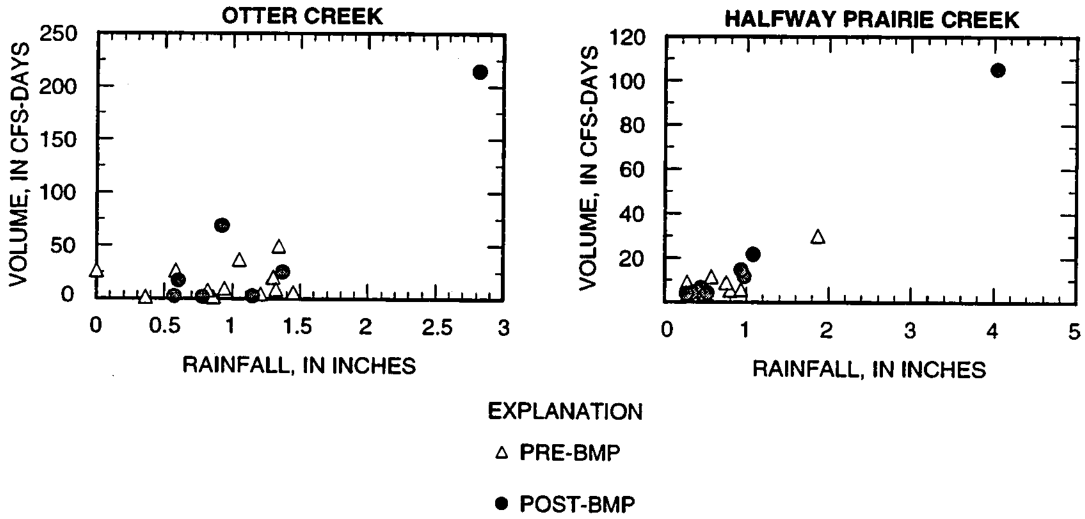

Figure 4. Rainfall depth versus storm-runoff volume for pre- and post-BMP storms at Otter Creek and Halfway Prairie Creek.

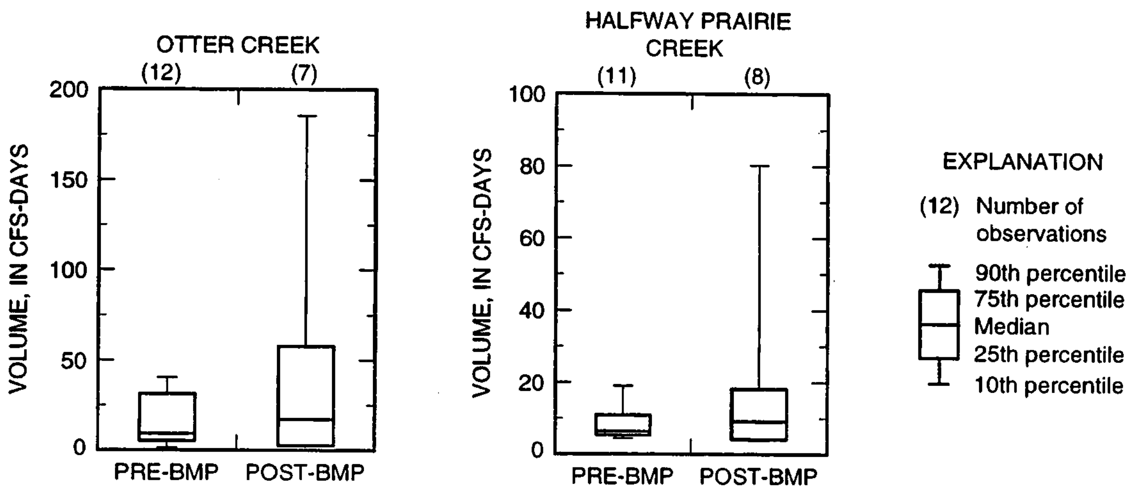

Figure 5. Boxplots of storm-runoff volume, by pre- and post-BMP period, at Otter Creek and Halfway Prairie Creek.

Differences Between Pre- and Post-BMP Barnyard Loads

The difference between upstream and downstream load was computed for each constituent and each runoff period for pre- and post-BMP conditions. These differences are considered to be the loads contributed by each barnyard (figs. 6 and 7). The Wilcoxon-Mann-Whitney rank sum test was used to determine whether the contribution of each barnyard decreased significantly after implementation of barnyard BMPs.

At Otter Creek, post-BMP loads of suspended solids, total phosphorus, ammonia nitrogen, BOD, and microbial loads of fecal coliform bacteria contributed by the barnyard were significantly less than the pre-BMP loads (at the 95-percent confidence level). At Halfway Prairie Creek, post-BMP loads of total phosphorus, ammonia nitrogen and BOD contributed by the barnyard were also significantly less than pre-BMP loads. Because the pre-BMP data analysis at Halfway Prairie Creek showed no significant difference between upstream and downstream loads of suspended solids, a statistically significant decrease in post-BMP suspended solids was not detected. Although statistically significant differences were observed between upstream and downstream microbial loads of fecal coliform bacteria for the pre-BMP period at Halfway Prairie Creek, high variability in the available data have made it difficult to observe significant differences between pre- and post-BMP periods. Analysis of samples from the remaining post-BMP runoff periods may help reduce variability and allow investigators to detect significant differences between pre- and post-BMP periods.

Effectiveness of Barnyard Best Management Practices

The Hodges-Lehmann estimator is the median of all possible pairwise differences between two independent data sets (Helsel and Hirsch, 1992). This estimator was used to determine the decrease in loads contributed by each barnyard between the pre- and post-BMP periods. This difference was then divided by the pre-BMP median barnyard contribution, resulting in a percentage decrease. At Otter Creek, implementation of the barnyard BMP has reduced the loads of suspended solids by 81 percent, total phosphorus by 88 percent, ammonia nitrogen by 97 percent, BOD by 80 percent, and microbial loads of fecal coliform bacteria by 84 percent; the barnyard BMP at Halfway Prairie Creek has resulted in 67-, 89-, 94-, 91-, and 24-percent reductions, respectively (Table 1). Watershed planners for Otter Creek and Halfway Prairie Creek had expected that implementation of the designed barnyard BMPs would result in phosphorus load

Table 1. Difference in constituent loads between upstream and downstream sites at Otter Creek and Halfway Prairie Creek barnyards before and after installation of BMPs, and percentage reduction in constituent loads achieved by barnyard BMP.

	Median load difference between upstream and downstream stations, in pounds*				Median percent decrease**	
	Otter Creek		Halfway Prairie Creek			
Constituent	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP	Otter Creek	Halfway Prairie Creek
Suspended solids	2,960	470	230	-19	81	67
Total phosphorus	13.0	0.8	7.2	0.7	88	89
Ammonia nitrogen	4.5	0.3	6.4	0.2	97	94
BOD	205	11	107	10	80	91
Fecal coliform bacteria*	112.2	8.3	46.2	20.5	84	24

*Fecal coliform microbial load in 10^{11} colony forming units.
**Computed by dividing the Hodges-Lehmann estimator for pre- and post-BMP barnyard loads by the pre-BMP median barnyard load.

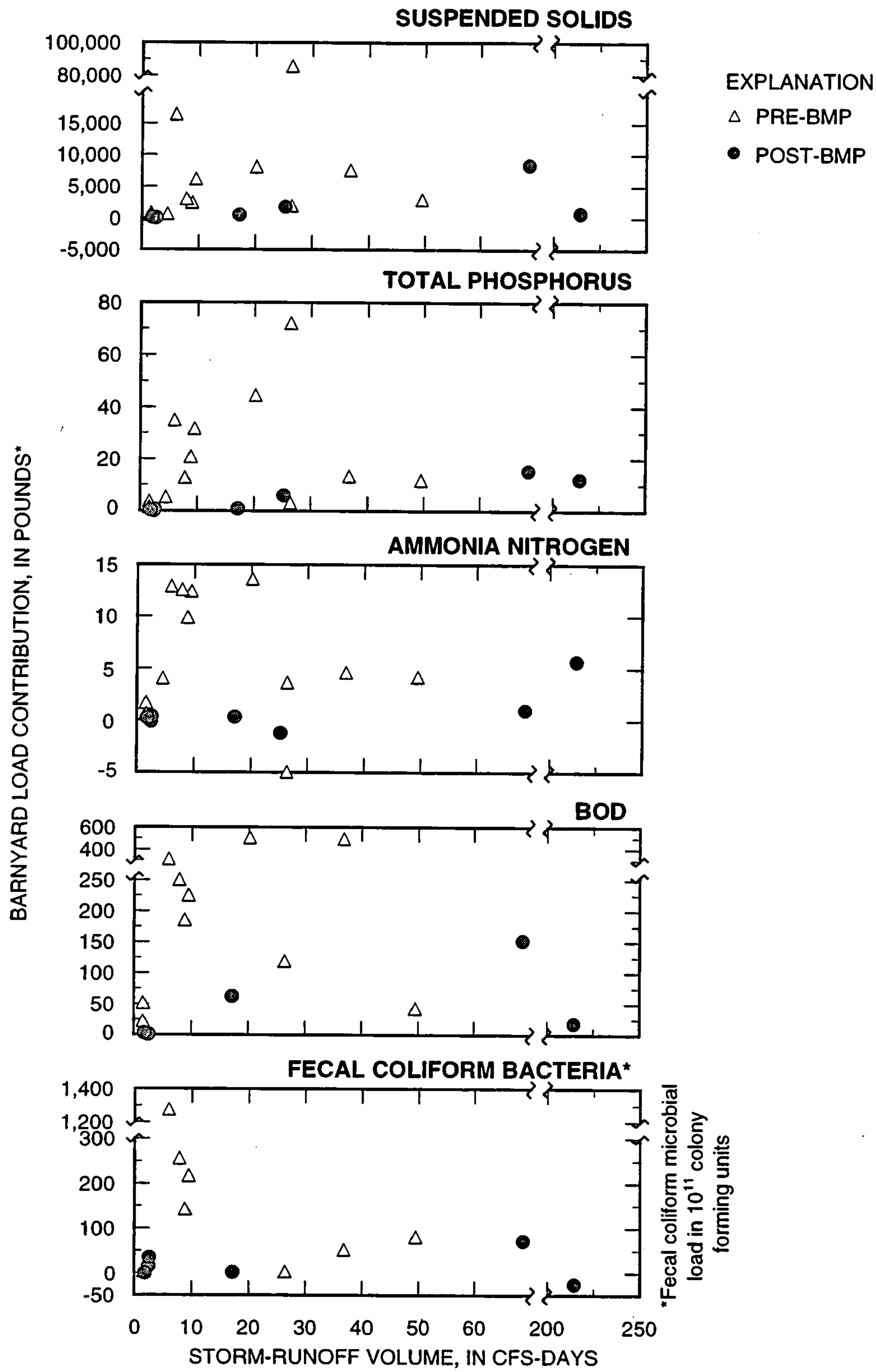

Figure 6. Storm-runoff volume versus load contributed by the barnyard for pre- and post-BMP storm-runoff periods at Otter Creek.

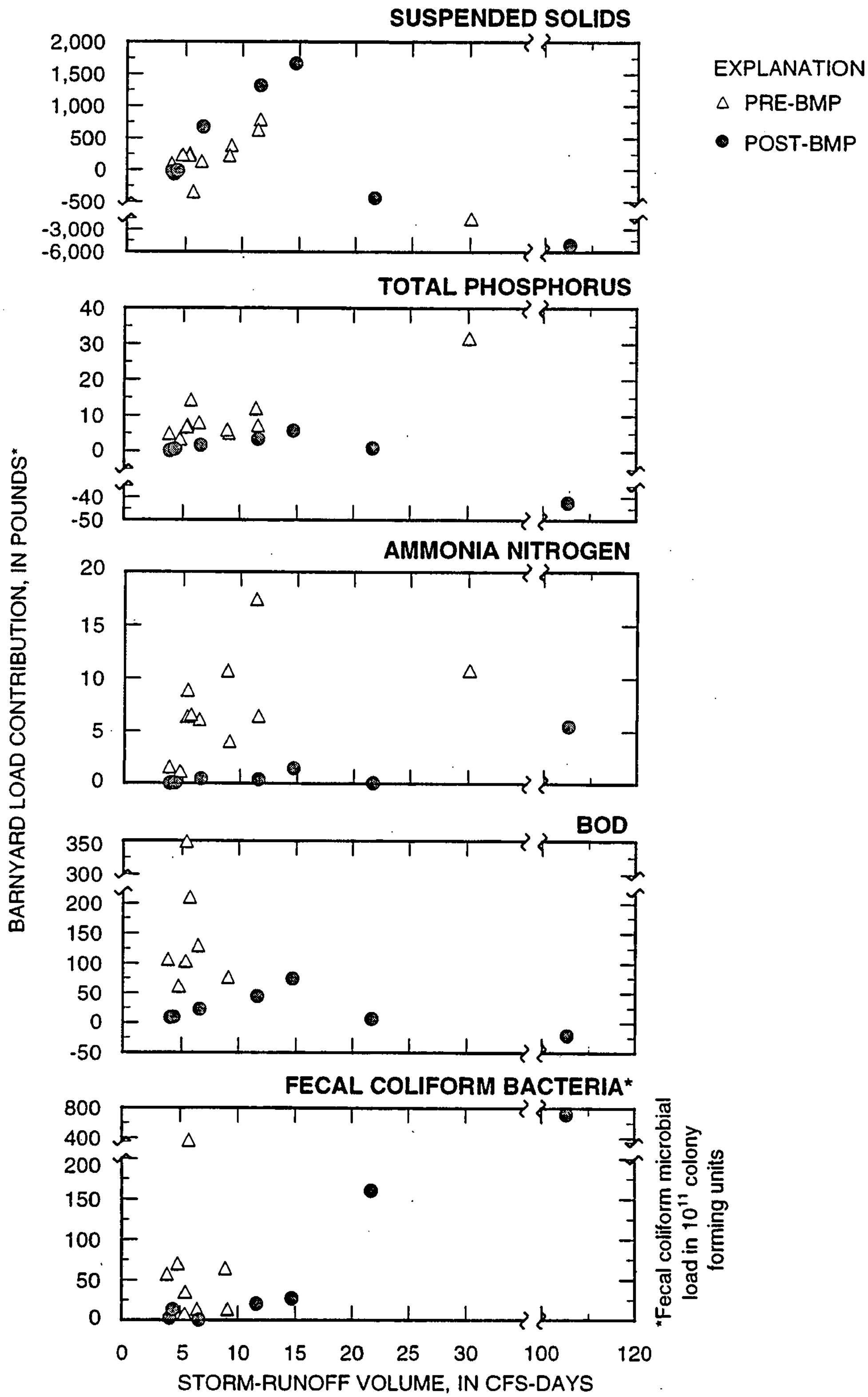

Figure 7. Storm-runoff volume versus load contributed by the barnyard for pre- and post-BMP storm-runoff periods at Halfway Prairie Creek.

reductions of approximately 95 percent for each barnyard (Pat Sutter, Dane County Land Conservation Department, written commun. 1997). The reductions in phosphorus found in this study—nearly 90 percent for both barnyards investigated—indicate that this assumption is not unreasonable.

Summary

The implemented barnyard BMPs at Otter Creek and at Halfway Prairie Creek have significantly reduced the contributions of total phosphorus, ammonia nitrogen, and BOD to the stream. At Otter Creek, loads of suspended solids and microbial loads of fecal coliform bacteria have been significantly reduced as well. Although statistically significant differences were observed between upstream and downstream microbial loads of fecal coliform bacteria for the pre-BMP period at Halfway Prairie Creek, high variability in the available data have made it difficult to observe statistically significant differences between pre- and post-BMP periods. Analysis of samples from the remaining post-BMP runoff periods may help reduce variability and allow investigators to detect significant differences between pre- and post-BMP periods.

Watershed planners for Otter Creek and Halfway Prairie Creek had expected that implementation of the designed barnyard BMPs would result in phosphorus load reductions of approximately 95 percent for each barnyard. The reductions in phosphorus found in this study—nearly 90 percent for both barnyards investigated—indicate that this assumption is not unreasonable.

Finally, the upstream-downstream experimental design appears to have worked well, not only for measuring the magnitude of the barnyard BMP sources but also for documenting the magnitude of the load reductions due to BMP implementation. This technique will most likely have merits in studies of other rural nonpoint BMPs, such as streambank erosion, rotational grazing, and buffer strips.

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The Nebraska MSEA Project
Management of Irrigated Corn and Soybeans to Minimize Ground Water Contamination

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Background

There is a clear need to reduce the contribution of production agriculture to the contamination of both ground and surface waters by nitrate-nitrogen. The USDA sponsored Management Systems Evaluation Areas (MSEA) projects have concentrated on two major aspects of the problem across the cornbelt: 1) gaining a better understanding of how contamination occurs, including the challenges and limitations faced by farmers in managing production systems, and 2) developing and improving practical technologies that will enable the producer to continue to operate at a profit, with lower overall environmental impact. The Nebraska MSEA has focussed on irrigated corn and soybean production in a zone having high levels of ground water nitrate.

Project Setting

The project area in Nebraska's Central Platte Valley (Figure 1) contains over 200,000 ha of irrigated land underlain by shallow ground water having nitrate-N concentrations above 10 mg/L. Some areas, such as the one around the MSEA site, have concentrations between 30 and 40 mg/L. While there are a number of contributors to the problem, the greatest single source of contamination is nitrogen (N) fertilizer applied to irrigated corn, which dominates the production system in the area.

Factors contributing to ground water contamination include overestimation by corn producers of N and water requirements, their inability to uniformly distribute water using conventional furrow irrigation, limitations in timing and form of N application, and the lack of a rapid and reliable technique for programming supplemental N applications. Furthermore, there are no efficient means to apply additional nitrogen on furrow irrigated corn after the crop exceeds about 80 cm in height.

A typical conventional furrow irrigation may apply 2 - 3 times the amount of water needed. Irrigation runoff is controlled by diking the lower end of the field from the end of June until mid September, instead of installing a tailwater reuse system. During the irrigation season all runoff from both irrigation and precipitation soaks into the ground within the field. The combined effects of management, terrain and good infiltration rate contribute greatly to the potential for leaching of agrichemicals, particularly nitrate-nitrogen.

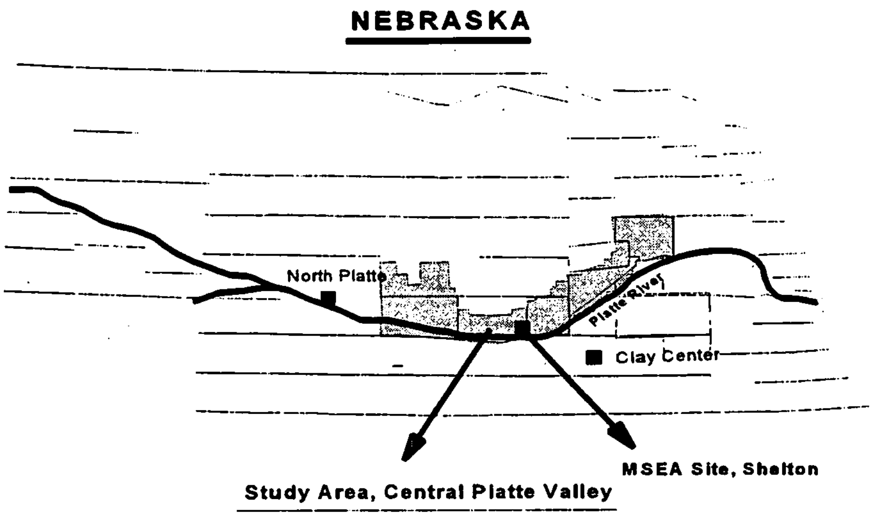

Figure 1. **Principal site and satellite locations for the Nebraska MSEA project.**

Project Objectives

1. Evaluate the impact on water quality of conventional and improved management systems that employ available technologies.

2. Improve existing "best management practices" and develop new practices and technologies that are both environmentally friendly and cost effective.

Implementation and Evaluation Approaches

Field research was established in 1990 at a principal site near the town of Shelton and at satellite locations, both in the Central Platte Valley and at Research and Extension Centers near Clay Center and North Platte. The field work has dealt primarily with the evaluation and demonstration of available technology packages and the development of new technologies for water, nitrogen, and pesticide management on irrigated, monoculture corn and corn-soybean rotations. This work has been complemented by a program of socio-economic research and an active extension program. This report will focus primarily on results from the field scale management block research/demonstration area, and some of their implications.

Direct evaluation of the impact of management systems on ground water quality has been made on four 13.6 ha management blocks (Figure 2). The management blocks include conventional farmer practice for furrow irrigation and nitrogen management, improved furrow irrigation and nitrogen management, and center pivot sprinkler irrigation with fertigation, all on corn. In addition, the fourth block is seeded to sprinkler irrigated alfalfa to evaluate the ability of this scavenger crop to remove nitrate from the high nitrate ground water which is pumped for irrigation. The improved technologies are designed to be managed by producers.

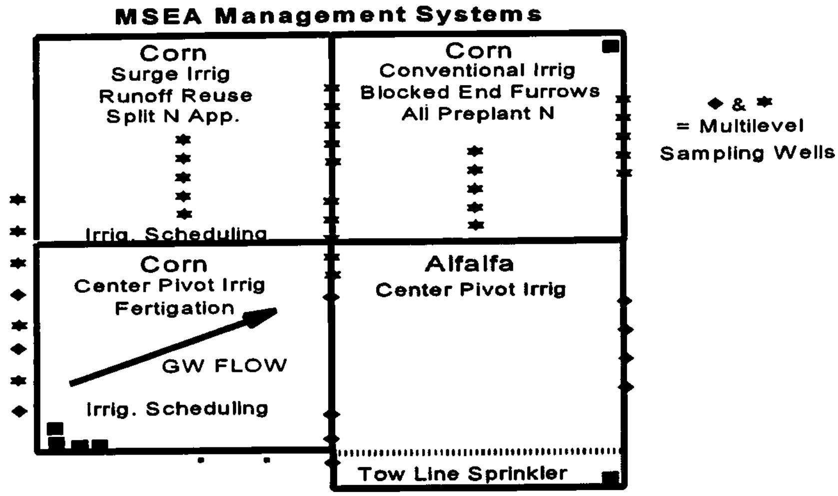

Figure 2. **Layout for field scale evaluation of management systems employing available technology.**

Each technology package is established as a single treatment, providing enough land area for a full-scale demonstration and evaluation while ensuring that treatment associated changes in ground water quality can be detected. The impact of these management systems on water quality is being evaluated directly through the use of multi-level samplers placed in wells around and within the management blocks. Indirect assessment of system impact on water quality is being made through the use of banks of suction lysimeters to sample the quality of drainage water leaving the root zone, and by means of tracers applied at the land surface. The amounts of water and N fertilizer applied to each system, and the resulting crop yields are direct measures of input changes and their impacts on production.

From the outset we assumed that three steps would be required to have any significant impact on ground water nitrate concentrations:

1. Reduce N fertilizer. Do this by assuming a reasonable yield goal, while including several important items in the calculation of N requirement: a) residual mineral N, b) an estimate of the contribution from mineralization, and c) the amount of N supplied to the crop by the high-nitrate ground water pumped for irrigation.

2. Time N applications to better coincide with crop uptake. Use a small, handheld chlorophyll meter on both surge flow and sprinkler irrigated fields to guide decisions to delay or eliminate N applications by fertigation, thereby decreasing N fertilizer amount below that computed as "recommended".

3. Improve water management. Schedule irrigations according to soil water content and weather conditions; control irrigation amounts to minimize leaching of applied N during the growing season; let the crop deplete more of the soil water at the end of the season, thereby retaining more of the winter and spring precipitation and reducing off-season leaching.

Environmental Benefits Measured

Within the strictures imposed by weather, soil variability, equipment and our knowledge of the system, we were reasonably successful in accomplishing what we set out to do. Table 1 presents the mean water and N inputs and resultant crop yields for the three MSEA management systems during five years of field evaluation. The prime input-output values of Table 1 are summarized in Table 2 as a percentage of the conventional system.

Table 1. Average Irrigation, Rainfall, Soil Nitrogen, Fertilizer, and Yield Data over Five Years.

Year/ Irrig.	Irrig. Applied (mm)	Rainfall 5/1-9/30 (mm)	Rain + Irrig. (mm)	Residual N* (kg/ha)	Starter N (kg/ha)	N Fertilizer (kg/ha)	Irrig. NO_3-N (ppm)	Irrig. N (kg/ha)	Grain Yield (Mg/ha)
Conventional	606	445	1051	100	24	196	30.8	228	11.91
Surge-Flow	211	445	656	107	24	135	28.9	78	11.49
Center-Pivot	175	445	620	75	24	122	29.4	57	11.18

* Total residual N (nitrate-N) to a depth of 0.9 m.

Table 2. Average Management Block Irrigation, Fertilizer, and Yield as Percent of Conventional Practice.

	Irrig. Applied (% of Conv)	Total Fertilizer (% of Conv)	Grain Yield (% of Conv)
Conventional	100	100	100
Surge-Flow	40	69	96
Center-Pivot	33	63	94

The two tables collectively show that improving management systems by using readily available technologies can substantially reduce the excess applications of irrigation water and nitrogen fertilizer that contribute to nitrate leaching from the crop root zone in the central Platte Valley.

Suction samplers installed at a depth of 135 cm under the management systems showed average soil water nitrate concentrations over project life as shown below.

Conventional Management	53.7 mg/L
Surge Flow Irrigation	28.5 mg/L
Center Pivot Irrigation	12.0 mg/L

These numbers by themselves do not indicate the amount of nitrate moving to the water table. They only represent measurements during the active growing season and provide no information on the volume of leachate. However, they clearly indicate the overall quality of the water leaving the root zone during the indicated period. We do not believe that the concentration of drainage from the pivot irrigated field can be maintained at 12 mg/L and also maintain full production.

Better management <u>can</u> improve ground water quality. When the project began in 1991, the nitrate-nitrogen concentration was essentially 30 mg/L through the entire 14 meter depth of saturated thickness of the aquifer. At present under the center pivot, water quality has improved in the upper 5 meters of the ground water, with nitrate-nitrogen concentrations in the range of 22-25 mg/L. There is a lesser improvement under the surge system, and none under the conventional system. The deeper ground water remains at the original high concentration. Improvement literally comes from the top down. As water of lower nitrate concentration enters the upper tier of the ground water and the water of higher concentration is pumped from below, water quality will gradually improve, up to a point.

Lessons Learned

1. The most important lesson learned from this work is that it is not only possible, but quite feasible to reduce ground water nitrate concentration through careful application of currently available technologies and BMPs.

   Use of surge irrigation, an "intermediate" technology, together with improved nitrogen management reduced applications of nitrogen and water, resulting in lower in-season losses of both. Results would have been better if we had not tried supplemental nitrogen applications by adding N fertilizer to the irrigation water in 1993 and 1994. While "fertigation" results in a uniform N application under center pivot irrigation, the row to row and point to point variability of water intake under furrow irrigation resulted in an unsatisfactory N distribution across the field. The problem was exacerbated both years by adverse weather phenomena.

   Conversion to center pivot irrigation offers the greatest opportunity to improve water quality. This system permits close control of water quantity applications during the growing season, and makes it easy to leave the soil profile relatively dry at the end of the season. The latter practice will allow the soil to store more of the winter and spring precipitation, reducing the amount of water available to leach residual nitrogen. Use of the chlorophyll meter to schedule supplemental "spoon feeding" of the crop through fertigation can increase nitrogen use efficiency and further decrease nitrate loss.

2. Reducing water and nitrogen very close to the minimum levels for full production leaves little room for error and may entail significant risk or increased cost for the producer when unexpected weather conditions or other management problems arise. Our experience with the center pivot is a good example. Errors in placement of "full fertilizer" calibration rows for chlorophyll application in 1992 resulted in an erroneous decision to withhold N fertilizer. This resulted in a 12 percent yield loss in that year and had some continuing impact in the following years.

3. Our MSEA extension program has shown that targeted educational programs can move producers toward more reasonable levels of fertilizer and water application. However, they are highly reluctant to voluntarily move to application levels that they perceive to significantly increase the risk of yield loss. Successful voluntary conversion of large areas to more environmentally friendly management systems must, at a minimum, be cost neutral and must address farmers' perceptions of risk resulting from reduced inputs of water and nitrogen.

North Carolina Agricultural Systems For Environmental Quality (ASEQ) Project

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Introduction

The North Carolina/South Carolina Agricultural Systems for Environmental Quality Project is being conducted in Duplin County, North Carolina, and Florence County, South Carolina, by a team that has successfully implemented a USDA Water Quality Demonstration Project in the Herrings Marsh Run Watershed in North Carolina, location of the highest swine producing county in the country. This area is typical of land utilized for crop and livestock production in the southeastern U.S., where rapid growth is occurring in the swine, poultry, cotton and truck-crop industries. Water quality improvements have already been measured in the Water Quality Demonstration Project area as a result of best management practice (BMP) implementation. The ASEQ Project offers the additional opportunity to develop, implement and evaluate innovative BMPs as well as to refine those currently in existence.

Major objectives of the ASEQ project are to:

1) evaluate the capacity of riparian and in-stream wetland systems to protect water quality
2) increase functionality and adoption of site specific farming as a BMP to improve production cost effectiveness and protect water quality
3) enhance the efficiency of a constructed wetland treatment system to remove nitrogen and phosphorus from swine wastewater and thus minimize the amount of land required for terminal treatment and protect soil, air and water quality.

The following agencies are providing leadership for the ASEQ effort:

- Cooperative Extension Service in the College of Agriculture and Life Sciences at North Carolina State University

- USDA Agriculture Research Service - Soil, Water and Plant Research Center in Florence, South Carolina

- USDA Natural Resources Conservation Service

Other agencies involved include the United States Geological Survey, which has cost shared the installation and maintenance of automated sampling and stream gaging stations; and the North Carolina Department of Environment, Health and Natural Resources, Division of Water Quality which conducts biological sampling to support project water quality evaluations. This cooperative effort has allowed the Demonstration Project to go beyond the initial charge of voluntary, accelerated and widespread adoption of BMPs.

An initial goal of the Demonstration Project was to measure water quality changes. A relatively small 5,000-acre watershed was selected to facilitate surface and ground water monitoring and tracking of land use activities. ARS was also interested in documenting water quality changes and agreed to run surface and ground water analyses. A cooperative arrangement was established with USGS for installation and maintenance of automated sampling stations and the North Carolina Department of Environmental, Health and Natural Resources for biological sampling to support water quality evaluations. These provisions for monitoring water quality and land use set an excellent basis for development and evaluation of models to determine water quality changes in the study watershed and to extend project results over time and space.

Riparian and In-stream Wetland Systems

A riparian area has been replanted between a spray field for swine lagoon liquid and an adjacent stream. Lagoon liquid was over applied to the spray field which did not maintain vegetative cover resulting in ground water nitrate levels averaging 60 mg/l with some wells exceeding 300 mg/l. Recommended practices are now being implemented for lagoon liquid irrigation, and ground water levels are decreasing. To minimize the impact of surface and ground water flows from the spray field, the riparian zone was replanted in 1992 with five species of trees.

Soil samples for denitrification and enzyme assay (DEA) and Phosphorus (P) fractionation will be collected from four locations along two transects of the experimental area. These locations will be 1) at the edge of the spray field, 2) at the midpoint of the riparian zone, 3) at the stream edge, and 4) in the non-treated edge across the stream from the spray field. Sampling sites are

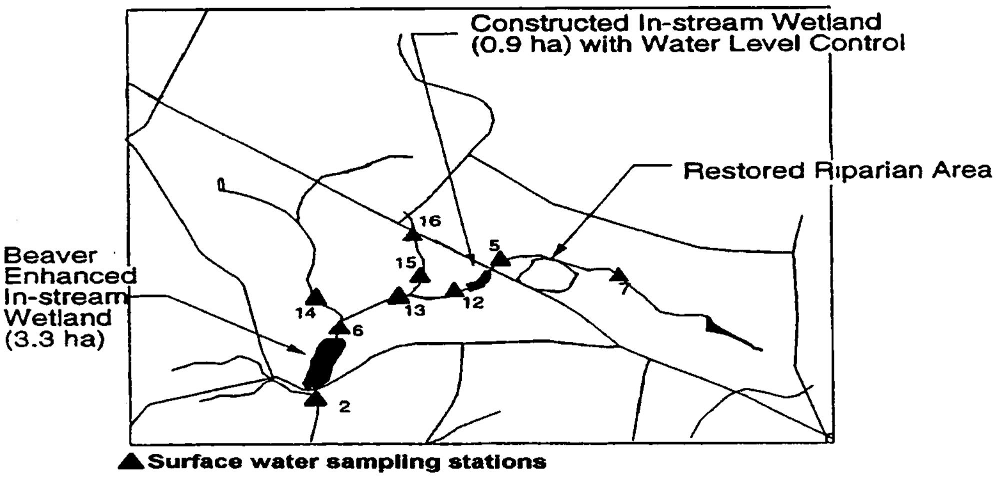

Figure 1: Riparian and In-stream Wetland System

located within 2-5 meters of each of eight ground water monitoring wells. Soil samples will be collected from the upper 15 cm of the soil profile, at a point midway between the soil surface and the water table, and 15 cm below the top of the water table. DEA analyses will determine the limiting factors for denitrification (i.e. NO_3 or C source).

Stream water nitrate concentrations are still higher downstream of the restored wooded riparian zone than upstream by about 10 mg/l after two years' growth of the replanted trees. The stream nitrate concentrations in the restored riparian area have been 12-14 mg/l.

In-stream Wetlands. A beaver enhanced in-stream wetland that was developed during the Demonstration Project is reported on in the Demonstration Project paper. An in-stream wetland with water level control was constructed in a dry, one hectare pond (dam had been breached) that receives flow from the restored riparian area but is above the enhanced in-stream wetland (Figure 1). This allows the evaluation of three landscape features in series along a stream reach being 1) the restored riparian area, 2) constructed in-stream wetland, and 3) beaver-enhanced in-stream wetland. The constructed in-stream wetland will be evaluated for its capacity to reduce nitrogen at various water levels. Inflow and outflow volume, wetland depth and concentration of nitrogen and phosphorus will be measured. Vegetation will be surveyed annually for composition, biomass and nutrient accumulation in three transects. One annual sediment transect with four sampling points will be taken from the 0-15 cm depth for DEA. One annual sampling of sediment pore water will be made with diffusion-controlled pore water samplers placed in duplicate at 0-15 cm depths into the sediment at three points on a transect that parallels the stream direction.

Constructed Wetland Treatment Systems

Constructed wetland studies funded through an Environmental Protection Agency grant, "Evaluation of Alternative Constructed Wetland Systems for Swine Wastewater Treatment," will be continued to determine the most effective use of constructed wetlands in an overall treatment system to minimize land required for terminal treatment and protect soil, air and water quality. The research site has a nursery operation with 2600 pigs (average weight equals 13 kg) that uses a flushing system to recirculate lagoon liquid for house cleaning from a single stage lagoon.

Wetlands with two 3.6 x 36 m cells in series were constructed in 1992. Initially, a total Kjeldahl nitrogen (TKN) loading rate of 3 kg/ha/day was used but a dischargeable effluent was not achieved, so it was increased to 10 kg N/ha/day during the second year. Mass removal of nitrogen was 94% at the loading rate of 3 kg TKN/ha/day and decreased to 68% at the higher rate of 10 kg TKN/ha/day. Total phosphorus (T.P.) mass removal efficiencies ranged from 40 to 100 percent at T.P. loading rates less than 1 kg TP/ha/day and varied from 20-80% when TP loading rates were 1-4 kg/ha/day.

Pilot overland flow and media filter processes are being evaluated as possible wetland system components to achieve a treatment train which provides higher removals and results in less land for terminal treatment. The overland flow treatment unit consists of a 4 x 20 m plot with a 2% slope. The overland flow system had an hydraulic loading of 2.5 cm/day which resulted in an ammonia application of 54 kg/ha/day. Total mass nitrogen removal efficiency was 59%, total phosphorus removal efficiencies varied from 40-80% at loading rates as high as 38 kg TP/ha/day. Average inflow total Kjeldahl nitrogen was 250 mg/l, outflow total Kjeldahl nitrogen was about 78 mg/l and nitrate nitrogen was about 30 mg/l. The overland flow plot resulted in good nitrogen removal and cost effective oxidation to nitrate for subsequent denitrification and removal of nitrogen as nitrogen gas rather than ammonia which has environmental impacts.

The media filter which was a 1.8 m-diameter x 0.9 m high tank filled with marl gravel received lagoon wastewater as a fine spray onto surface at hydraulic loading rates of 75 $L/m^2/hr$ and total nitrogen loading rate of 147 g/m^2. About 50% of total suspended solids and chemical oxygen demand were removed from wastewater with just one cycle, and losses of total nitrogen were 11% with one cycle and 22% with four cycles. With four cycles 24-32% of the influent TKN was converted to nitrate. Media filters can provide a very cost effective unit process for removal of carbon and suspended solids as well as nitrification for use as a unit process before denitrification for additional nitrogen removal.

Precision Agriculture

Current precision agriculture or site specific farming activities directed at more efficient production, energy savings and reduced chemical use which emphasize and document water quality benefits will be complemented and expanded. Three commercial combine-mounted yield monitor systems will be used: two for retrofitting farmer cooperator combines and one for retrofitting a research combine. Yield mapping will be conducted on as large an area as possible so that farmers will have multiple case studies to set a basis for evaluating precision agriculture.

Spatial yield research will be conducted with the acquired data by 1) simulating crop growth and yield for comparison to the mapped yield, 2) identifying correlated parameters that can be used to determine important cause-and-effect relationships resulting in the variable yield, and 3) developing and implementing variable nitrogen management using the mapped yield. First, mechanistic models of crop growth and yield, nutrient removal, water quality and nitrogen transformations will be used along with corresponding soil and crop parameters to simulate the effects of variable soils on yield. Second, recent developments in statistical theory, including innovative techniques to exploit spatial data will be used to extract causal relationships from data collected at different spatial intensities. Mapped yield, which is taken at high frequency, can be used to develop strategies for more time-consuming sampling such as soil fertility, soil characteristics, crop characteristics, etc. The resulting data sets will be examined using state-space models to narrow the choice to important variables. Third, measurements of nitrogen availability such as with the chlorophyll meter will be used with mapped yield, mapped soil tests and experience with mineralizeable soil nitrogen factions to guide sidedress nitrogen recommendations.

Water quality benefits. Work is underway to develop paired fields to evaluate differences in surface and ground water resulting from contemporary farming and precision agricultural recommendations. Two 3-acre fields have been obtained at the new Center for Environmental Farming at the North Carolina Department operated Cherry Farm in Goldsboro, North Carolina. Six wells ranging from 300 cm to 450 cm have been established in each three-acre field. Preliminary data shows nitrate concentrations of 20 to 25 mg/l in these fields. These wells will be sampled every two weeks during the cropping season from about April to October and about once every month from November to March for nitrate, ammonia and ortho-phosphate. Surface drainage will be collected from about a one-acre sub-watershed in each field for flow through a sampling station with an automated sampler and flow meter. Sampling will be initiated by flow stage and flow proportion samples will be taken at given stage increments so that yield can be calculated based upon concentration and flow for a given sample. Surface runoff samples will be analyzed for total suspended solids, nitrates, total Kjeldahl nitrogen and ortho-phosphate. Ground water concentration differences and surface water yield differences between the study plots will be determined to evaluate the water quality benefits of precision agriculture at this site with sandy clay loam soils which are typical of the middle Coastal Plain.

Decision Support System

WATERSHEDSS, is a decision-support system (DSS) that is available electronically has been developed through an EPA grant, "Understanding the Role of Agricultural Landscape Feature, Function and Position in Achieving Environmental Endpoints." The purpose of the DSS is to help watershed managers determine appropriate management and/or BMP systems and their placement on the landscape for particular water quality problems. Effectiveness data collected from the riparian and wetland system studies will be included in a BMP database that is part of WATERSHEDSS. The decision support system is accessible at the following universal resource locators (URLs):

http://www.bae.ncsu.edu/bae/programs/extension/wqg *or*
http://h2osparc.wq.ncsu.edu

Technology Transfer

Educational workshops on Precision Agriculture; Landscape Features to Protect Water Quality; and Constructed Wetlands for Wastewater Treatment are to be conducted in conjunction with this grant.

A site specific farming workshop was held during the first year because we had the opportunity to cooperate with North Carolina State University College of Agriculture and Life Sciences, North Carolina Agricultural Research Service and North Carolina Cooperative Extension Service, and North Carolina Department of Agriculture for a "Precision Agricultural Field Day at the Center for Environmental Farming Systems, Cherry Farm, Goldsboro, North Carolina. The field day was judged a success on the basis of the approximately 200 who participated and the number and quality of industrial and educational displays. There was about 55 farmers and 15 county extension agents in attendance. The ARS Coastal Plains Soil, Water and Plant Research Center had an educational display on their yield monitoring and site specific irrigation work which led to the CSREES grant objective on site specific farming.

Assessing the Impacts of Voluntary Pollution Prevention Programs in Agriculture: Lessons Learned from a Cost-Benefit Evaluation of Farm *A* Syst

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Abstract
With the passage of the Government Performance and Results Act (GPRA) of 1993, national budget balancing efforts for both voluntary and regulatory programs must address the costs and benefits of pollution-prevention efforts as well as other traditional agricultural programs. However, cost-benefit and other similar impact assessment data have been historically difficult to obtain--and are indeed sparse for voluntary pollution prevention programs--mainly due to the intrinsic problems associated with measuring environmental benefits. This paper presents research that provides decision makers with a model comprehensive impact assessment technique for evaluating voluntary pollution prevention programs in the agricultural and rural home-owner sector in a manner that is relatively easy and inexpensive.

A case study is presented in which both economic and non-economic impacts of the Farm Assessment System (Farm *A* Syst) program in Louisiana were measured. Results show farmers spent an average of approximately $700--in at least one-time expenditures--on making changes in their practices and structures. Extrapolation to the one-third of those farmers who are estimated to participate in programs such as Farm *A* Syst (approximately 8,551 farmers) produce estimated net economic benefits of at least $2.4 million, as well as other benefits related to educational and attitudinal impacts on farmers, all of which are statistically significant. Farmers may very well make additional changes throughout their lives (as opposed to one-time changes only).

Cash incentives have shown to increase participants' actions to reduce environmental risks, although the sample size here is very small. Data from the Louisiana study has been used as a basis for estimating national impacts of the program. It is estimated that the 42,000 farmers who have undergone farm assessments throughout the US have spent approximately $30 million in pollution prevention expenditures since late 1989. This methodology may have direct application to other rural environmental management programs. That potential is briefly explored.

Introduction
Since Congress is now requesting accountability of government funded programs, such evaluation--or impact assessment--should become a cornerstone of any new program's design. The most recent law that addresses this issue is the Government Performance

and Results Act (GPRA) of 1993, in which comprehensive impact evaluations of programs and policies are to be conducted, primarily in the form of cost-benefit analyses. At the same time, economic data on the impact of programs in agriculture--especially those programs which are voluntary and pollution-preventive in nature, have been historically difficult to obtain. The primary reason for this is the fundamental difficulty in measuring the economic and non-economic benefits (or impacts) that these programs have on its participants and to society in general.

In meeting this standard, and in addressing the need to develop and conduct such an evaluation of its own program, the National Farm *A* Syst/Home *A* Syst Office undertook such an evaluation on Louisiana's version of Farm *A* Syst. This evaluation was conducted during the course of a two year pilot implementation ending in October 1996 (Moreau, 1996, and Moreau, et. al., 1997). Farm *A* Syst is a voluntary pollution-prevention program that enables farmers to quantitatively identify--and perhaps reduce--the risks their farming practices and structures pose to groundwater quality. In many states this assessment also addresses risks to surface water. A home assessment program of parallel design is also available in most states, addressing environmental concerns around the home.

This impact assessment methodology is currently being refined and proposed to Farm *A* Syst and Home *A* Syst coordinators on the state level as a way of evaluating their own programs. If Farm *A* Syst is integrated into other programs such as NRCS's Resource Conservation Planning initiative, or community source water protection programs, then the methodology can be useful in evaluating those broader programs as well.The Resource Conservation Planning process has many characteristics that are similar to Farm *A* Syst, as it places the emphasis of environmental protection activities in the hands of the farmer or rancher, in the form of flexible, voluntary and confidential plans that address a broad array of environmental and crop management activities.

This paper details the results from the Louisiana study, and the information gained and lessons learned. We propose that the methodology be considered for evaluating the impacts of similar programs. Such analyses should aid many aspects of the decision-making process, especially as it relates to the long-term funding of programs.

Methods for Measuring Costs and Benefits

Measuring the economic costs and benefits of environmental-related programs such as Farm *A* Syst has been historically difficult, mainly due to the difficulty in assigning values to environmental benefits. Fields (1994), Freeman (1993), and Mitchell and Carson (1989) provide excellent summaries of the different direct and indirect ways in which environmental benefits can be measured, under both observed and hypothetical situations. Each of these valuation techniques has pro's and con's related to issues such as standing (whose benefits and whose costs count?) and parameters of the type of benefit being measured (e.g., avoided cost of some regulatory action, willingness-to-pay for a desired outcome, etc.).

With regard to agricultural-based programs, many economists believe that the contingent valuation method that asks people "what they are willing-to-pay" (WTP) for some environmental benefit is one of the more appropriate measures. This is due to the fact that WTP questions take into account a more theoretically acceptable approach to obtaining values that address the traditional consumer and producer surplus (CS and PS) measures which are the basis for cost-benefit calculations (Boyle, 1997). However, contingent valuation techniques can be costly and are highly debated because of their hypothetical nature and wide variation in response rates (Johnson and Johnson, et. al., 1990).

Valuation is perhaps even more difficult in pollution prevention programs, where risk and outcome parameters have a certain degree of subjectivity associated with them. For example, nitrate passage from the land surface to the underground aquifer, and its accumulation there to dangerous levels, is a process that can take decades (Ryding, 1992). Not only is it difficult to understand what impact current farming practices are having on the underlying groundwater, but it is nearly impossible to determine the effectiveness (and corresponding economic benefit)--in the short term--that a pollution prevention program has on such practices if a water test is the primary measuring stick. Such lag-effects would out-live the researchers!

Due to time and budget constraints, and in order to utilize more than one method of valuation for comparison purposes, the researchers of the cost-benefit study on Louisiana's Farm *A* Syst focused on two of the more "applied" methods of economic valuation of environmental benefits noted in the literature. First, the fairly recent concept of *averting expenditures* (Abdalla, et. al., 1993, and Laughland, et. al., 1993, among others) was applied. This approach estimates the lower bound of benefits as those monies actually spent (or planned to be spent) by farmers who make substantive changes in their practices due to information gained through the farm assessment process. These figures can be easily attained from participants through pre- and post-program surveys. In this study, this amount averaged about $700 per farmer, conservatively assumed as a one-time expenditure over a 10 year period.

The second method--termed *avoided cost of clean-up and/or change in water supply* --looks at the $700 as a sort of "insurance premium" against the future and higher cost of environmental clean-up. This cost was conservatively estimated at approximately $80,000 (Shaw, 1995) for a typical petroleum or farmstead hazardous waste type problem. In order to compare the above two methods to the traditional technique of *contingent valuation* (what one is "willing-to-pay" to reduce the risk to groundwater contamination), figures from an existing and similar WTP study were used. Here, the lower-bound median monthly willingness-to-pay figure of $6.44--which was documented by Jordan and Elnagheeb (1993) in a previous study on Georgia households--was utilized (the figure is conservative because the mean was nearly double that amount). The three methods are summarized mathematically below.

NB=AE-GC (averting expenditures - Method #1)
NB=CU-AE-GC (avoided cost of environmental clean-up - Method #2)
NB=WTP-AE-GC (contingent valuation questions - Method #3)

(where, NB=Net Benefits, AE=farmers' Averting Expenditures, GC=federal, state, and local Governmental Costs of administering the program, CU=Clean-Up and alternative water supply costs associated with different contaminants, and WTP=Willingness-To-Pay from contingent valuation questions in Jordan & Elnagheeb study)

Impact Results from the Louisiana Case Study

Participation -- Overall, 134 assessments and accompanying pre- and post-assessment surveys were completed. The one-on-one visits produced a 61% (n=85) response rate in Phase 1 (the first year of the study), and a 98% (n=49) response rate in Phase 2--the second year of the study. The "workshop" delivery also utilized in Phase 1 produced a low 7.5% (approximate n=400) response rate. Here, concern for confidentiality required anonymity of participants, which prevented follow-up, and which we judge to be the primary reason for the low response rate under this type of delivery. As one would expect, one-on-one delivery provides a much more effective delivery (benefit), although more inputs (costs) are required in terms of resources than other delivery methods.

High Risk Areas Noted -- The most common high risk areas noted were in petroleum product storage, well condition and/or location, and pesticide storage and handling. Table 1 below lists the percentage of high risk cases noted by the 134 participants.

Table 1:

Areas of High Risk in Louisiana Case Study
Identified during the Farm Assessment Process

Area (Worksheet)	High Risk Cases (n=134)
Petroleum product storage	23.3%
Well condition and/or location	17.3
Pesticide storage and handling	12.0
Household waste water treatment	11.3
Farmstead hazardous waste management	9.8
Livestock waste management	7.5
Fertilizer storage and handling	5.3
Poultry litter and carcass management	5.

3

Changes Made and Planned and their Associated Costs -- Results show that 43 (32%) of the 134 farmers made, or planned to make, 66 individual changes in their farming practices after undergoing the assessment. These changes were specified by the participants to have been made "due to information provided by the Farm *A* Syst materials," and totaled $91,437 ($682 per farmer based on 134 participants). Farmers' time, which respondents valued at an average (median) of $12.00 per hour, constituted approximately one-third of this total.

Changes that farmers either made or planned to reduce their risk to groundwater contamination as a result of undergoing Farm *A* Syst ranged from strictly "management type" decisions which required no direct outlay of cash (such as mixing pesticides in the field away from the well, or properly recycling used oil and antifreeze), to changes that required low to high out-of-pocket expenditures (such as putting back-flow valves in well pumps, or pulling a leaking underground storage tank). Figure 1 below shows a summary of these actions. Please note that the "management type only" changes have a cost that is in terms of farmers' time only, and do not have any out-of-pocket cost component.

Figure 1:

Types of Changes Made and Planned by Louisiana Farmers due to Information Gained from Undergoing Farm *A* Syst

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Expenditures and Risk -- One of the issues addressed in the study was whether or not farmers were making changes to those areas where they needed to the most--or more specifically where they noted a high risk. Analysis of the data collected shows that this was indeed the case. For example, nitrate and/or bacteria problems were noted as a high risk by 47% of the farmers surveyed, and 44% of the monies spent by farmers was allocated to changes involving nitrate and/or bacteria issues. A graphical representation of this analysis is shown in Figure 2 below.

Figure 2:

Comparison of High Risks Noted and Expenditures on Changes

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Economic (Cost-Benefit) Measurements -- The methods of *averting expenditures, avoided cost of clean-up and/or change in water supply*, and *contingent valuation* produced present value estimates of net benefits (over an assumed ten-year period) of $2.7 million, $2.4 million and $15 million, respectively. Details are presented in Table 2 below. All figures are in present value terms (PV). As discussed in the previous section, the methods of *averting expenditures* and *avoided cost* are lower bound estimates of net benefits in that benefits are a function on the observed behavior of expenditures noted. For instance, farmers may be willing to spend much more to reduce their risk. The method of *contingent valuation* takes this into account, and therefore produces a much higher willingness-to-pay. In addition, the latter method utilizes all farming households in the state as a base for extrapolation, whereas the first two methods utilize only that portionof the farming community (approximately one-third of all farming houselhods) that is estimated to participate in an environmental program such as Farm *A* Syst.

The discount rate used for government costs and farmers costs were the average T-Bill rate (5.2%) and farm-borrowing rate (7.5625%), respectively, for the time period in which the study occurred.

Table 2:

Comparison of Net Benefits of Farm *A* Syst Estimated Under Three Methods

Method of Benefit Estimation	PV Benefits (over 10 yrs)	PV Cost (over 10 yrs)	PV Net Benefits (over 10 yrs)	PV Net Benefits per Year
#1-Avert. Expend.'s: (8,551 farmers)	$3,993,691	$1,262,261	$2,731,430	$273,143
#2-Avoided Cost (8,551 farmers)	7,615,555*	5,255,951	2,360,604	236,060
#3-Contingent Value Q's:				
-all farm h.hold's (25,653)*	20,409,713	5,255,951	15,153,762	1,515,376

* In this study, and due to the methodology of the Jordan and Elnagheeb study from which the WTP figures are derived, the contingent valuation method incorporates both users and non-users of the resource (all farming households), whereas the other two methods incorporate only users (one-third of all farming households, or only those households expected to be similar to the volunteer sample). It should be noted that this estimate is a conservative one, as the contingent valuation method could theoretically incorporate other rural and even non-rural households as well, which would produce estimates in net benefits of over $1 billion.

Possible Effects of Economic Incentives to Qualifying Farmers -- Providing farmers with a cash incentive to undergo a voluntary pollution prevention program such as Farm *A* Syst may help to spur participation as well as increase the amount of changes the farmer will make. A small portion of participants (5 out of 134) qualified for a $150 cash incentive under the NRCS's Water Quality Incentive Program (WQIP). Of this amount, $75 was required to be used towards a water test. Three (60%) of these participants made or planned to make six changes estimated at a total cost of $16,850, compared to the other 129 participants (termed as the primary sample) which made/planned $74,587 in changes. Table 3 below details the comparisons between the groups. Note that WQIP has recently changed to EQIP, or Environmental Quality Incentive Program. It should be stressed that caution is warranted here with regard to the small sample size. However, the authors felt the information should be presented so that consideration be given to incentive-based delivery methods for other state programs.

Table 3:

Comparisons Between WQIP Farmers and Other Farmers

	Primary Sample (n=129)	WQIP Farmers (n=5)	% Difference (of %'s)
% Farmers Making/Planning Changes	30.2%	60.0%	99%
Expenditures per Farmer	$578	3,370	483%
Number of Changes Per Farmer	.46	1.2	161%
Expenditures per Change	$1,243	$2,808	126%

*Non-Economic (Educational) Benefits of Farm *A* Syst* -- There may be many other benefits that farmers can gain by undergoing a program like Farm *A* Syst in addition to those that are measured in economic terms only. For example, it is clear that many farmers in the study had a "positive" experience with Farm *A* Syst. They showed significant gains in knowledge and a positive change in attitude after having gone through the process.

In order to test for these educational benefits, comparisons of means in response rates of the 21 questions asked both before and after a farmer underwent his/her risk assessment showed, in most every instance, a positive change in knowledge, attitude, perception or awareness regarding the potential effects of farming practices on groundwater quality. Many of these changes were statistically significant. For example 73% of the respondents changed **away from** a "Don't Know" response (as opposed to changing **to** a "Don't Know" response) in the post-survey to the question "What is the most common source of nitrate found in well water in your area?" Similar statistics were noted in the question "what extent is pollution of well water as a result of farming practices a problem in your area?"

Another example is that a significant number of respondents (at 95% confidence level) in the post-assessment survey said they would "Find source of nitrates and correct the problem" if they found out their "water supply was polluted with a high level of nitrates," as compared to their answers given in the pre-assessment survey (their other choices were "install water-treatment system" or "find a new water supply").

Use or Worth of the Program -- It is also very important to have an understanding of what farmers felt about the program in general. For instance, did they think Farm *A* Syst was worth doing, or would they recommend it to their neighbors? And how difficult did they think the materials were and how long did it take to go through the assessment process? These questions were asked in the surveys and tested for significance, and all had positive results.

Of hose who changed their answers (to either "yes" or "no") after undergoing the assessment, 75% of those respondents thought the assessment was worth doing ("yes") after they had done it as compared to 25% who changed in the other direction (to "no")--significant at 99%. Nearly all respondents thought the worksheets were easy to complete, and that all of the questions were understandable. Approximately 75% of the respondents were assisted (through a "one-on-one" delivery) by either an Extension, NRCS, or USDA AmeriCorp member. This sort of delivery system is very common for Farm *A* Syst--and programs like it--on a state-by-state basis. The average time needed to complete the assessment was about 1.8 hours.

Implications for Program Coordinators

Impact evaluation is now a key component of any government-funded program, and program coordinators should build-in evaluation procedures early on in program development, and especially prior to program implementation. One of the major findings of this research is that the methodology can be used to quickly evaluate the costs and benefits of similar programs. Likewise, environmental programs that are designed for non-farm entities (such as the Home *A* Syst program) can also benefit from the design.

The cost-benefit information otained in this study is the first of its kind for Farm *A* Syst, and is the only information currently available to help estimate the economic impact of the program on a national basis. It is estimated that 42,000 farm assessments have been conducted throughout the US to date. By applying our best estimate of economic impact--$700 per farming household due to inforation gained by Farm *A* Syst--the result is nearly $30 million in pollution prevention expenditures. This type of impact evaluation data is extremely important in terms of maintaining or increasing support for the program.

Other programs that are based on the Farm *A* Syst approach, such as the new Resource Conservation Planning initiative--as described in the recent NRCS Materials Development Team Report--could also benefit from this cost-benefit evaluation methodology. This report recommends placing the responsibility of these flexible, voluntary and confidential planning exercises in the hands of the farmer or rancher, including issues such as: crop management, erosion control, water quality, recreational opportunities, fish and wildlife habitat protection/enhancement, and other community concerns.

If that approach is taken, cost-benefit information--provided in layman terms relating to monies saved or costs avoided--could help foster participation. This planning process is much broader than the Farm *A* Syst program which was evaluated in Louisiana. Thus, additional cost-benefit indicators would need to be identified.

One of the recommendations by the NRCS Development Team was to "monitor the performance and outcomes of programs," thus changing the emphasis from individual employee performance monitoring to program-based-monitoring. The methods utilized in this study could help to reach this goal, as each of the planning components will undoubtedly be evaluated in terms of economic and non-economic costs and benefits. Continued or increased funding of these programs could depend in part on such impact evaluations.

Lessons Learned

The following recommendations should help policy makers and decision makers who wish to evaluate--in both a social (cost-benefit) and physical (environmental) manner--voluntary pollution prevention programs in agriculture.

Recommendation #1: The impact evaluation process is one that should be built-in at the fore-front of the overall planning of new programs so that accurate and timely information can be documented to evaluate the program once implementation takes place.

Recommendation #2: Decision makers should analyze the economic impacts--in addition to non-economic impacts--of policies and programs in order to gain a more comprehensive understanding of the holistic effect of the program. Documentation of such economic impacts will help to make a case for continued or increased funding of programs that are effective.

*<u>Recommendation #3</u>: The "model methodology" and set of "model surveys" designed for the Louisiana Farm *A* Syst study should be utilized as a starting point for evaluators and decision makers when conducting cost-benefit studies on voluntary pollution prevention programs in the agricultural sector.*

*<u>Recommendation #4</u>: Program evaluators should consider measuring the economic costs and benefits of government programs and policies under more than one method, in order to provide a better understanding of benefit estimations and limitations, and the ranges of which such calculations can vary. Three methods that are recommended as a starting point in programs similar to Farm *A* Syst are: (1) averting expenditures; (2) avoided cost of clean-up and/or change in water supply, and; (3) contingent valuation.*

<u>Recommendation #5</u>: One method that should be considered to statistically test for the non-economic benefits of voluntary pollution prevention programs is to measure the changes (from pre- to post-program participation) that participants have regarding inquiries to their knowledge, perceptions and attitudes about how their farming practices can affect the quality of their water resources.

<u>Recommendation #6</u>: Decision makers should conduct further testing on the impacts of providing economic incentives to potential users to increase program participation in voluntary pollution prevention programs.

<u>Recommendation #7</u>: Program evaluators should, whenever possible, conduct similar evaluations by using a stratified and randomly selected sample of participants. Additionally, evaluators should maintain proper control over the survey delivery and follow-up procedures in accordance with such standards recognized in the literature.

*<u>Recommendation #8</u>: Data collection of impacts of programs such as Farm *A* Syst should continue and be on-going. Data collection and analysis of delivery methods other than one-on-one (such as the group workshop method, for instance) is especially encouraged, as comparisons could then be made with regard to the net-benefits of each. This would help to determine which type of delivery yields the highest net-benefit and net-benefit ratio.*

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Figure 1. Types of Changes Made and Planned by Louisiana Farmers due to Information Gained from Undergoing Farm *A* Syst

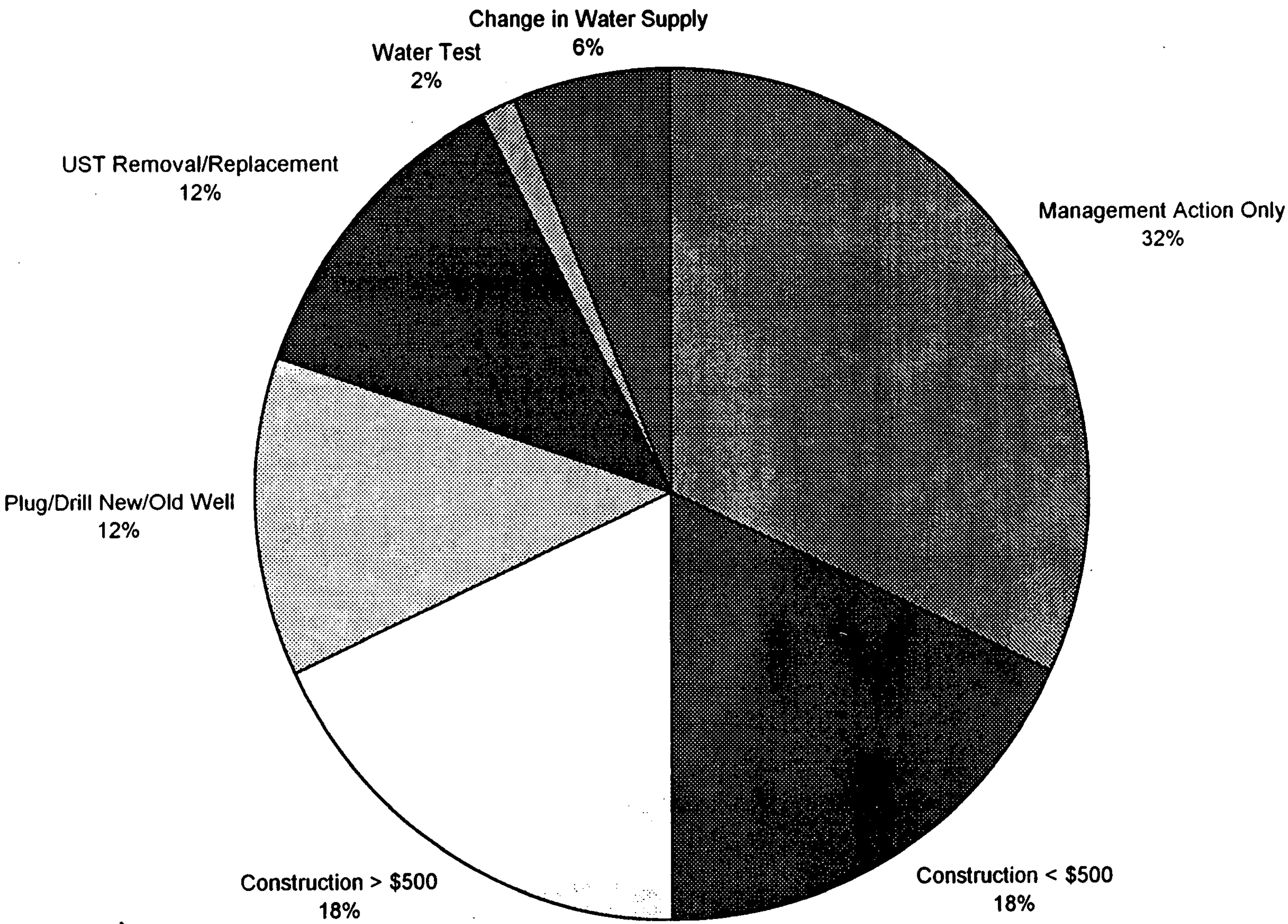
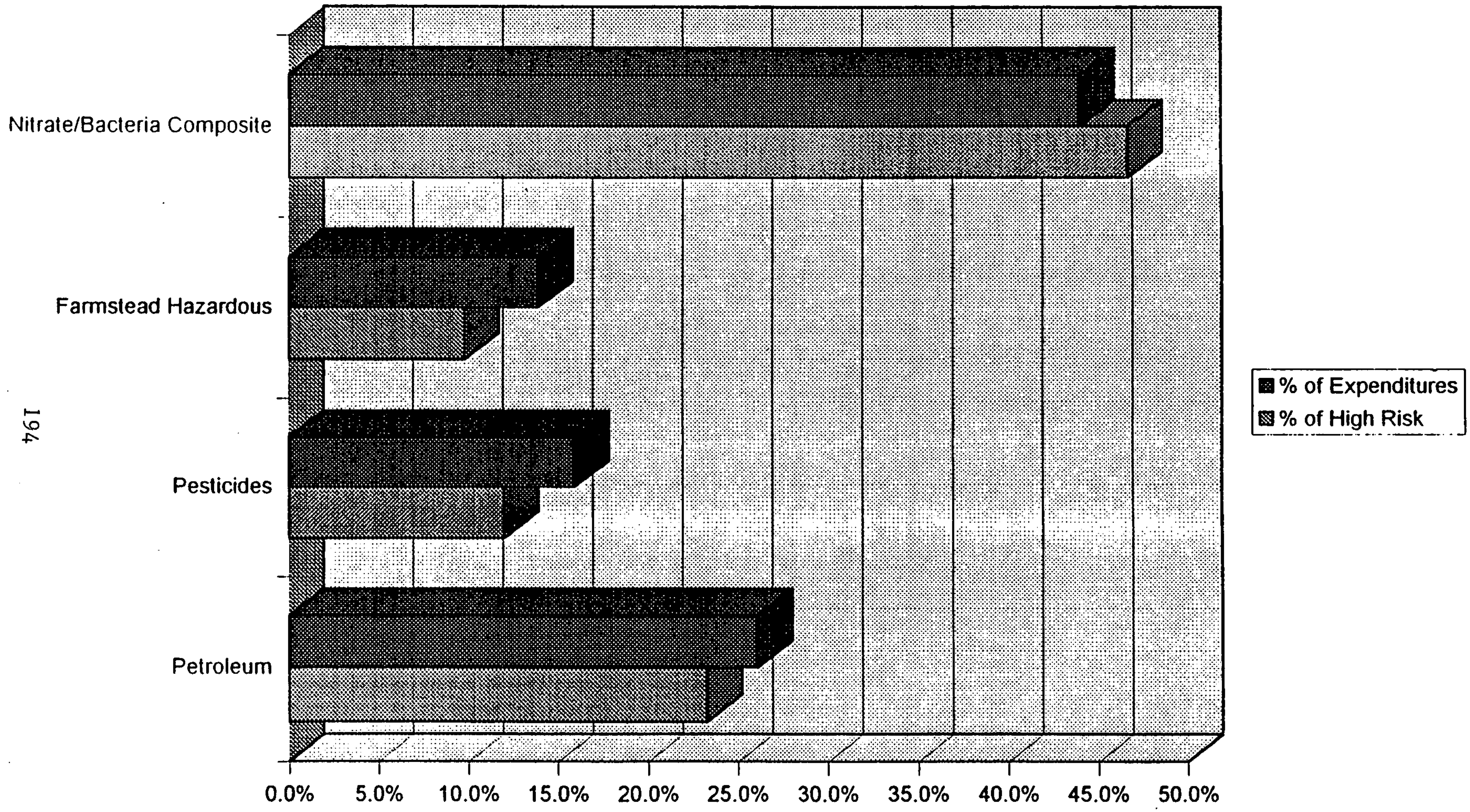


Figure 2. Comparison of High Risks Noted and Expenditures on Changes



Analysis of Long Creek Watershed Monitoring Data

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Nutrient and solids concentrations in streamflow were monitored during a three-year period in a 56.6-ha, mostly agricultural, watershed located in southwestern North Carolina. Nutrient and solids concentrations in weekly grab samples were significantly greater downstream of an overgrazed cow holding and feeding area compared to upstream during a two-year period prior to the implementation of best management practices (BMPs). During the year of monitoring after installing livestock exclusion fencing nutrient and sediment concentrations decreased significantly, especially downstream of the cow holding area. Both parametric and nonparametric analysis of nitrogen, phosphorus, and solids monitoring data indicated statistically significant reductions in the concentrations of pollutants after BMP implementation

Introduction

The Long Creek watershed is the site of a nine-year comprehensive watershed project initiated in 1993 to improve stream water quality while documenting the effectiveness of nonpoint source pollution controls. The project is one of 20 comprehensive watershed monitoring projects in the U.S. EPA National Monitoring Program (Osmond et al., 1995). The Long Creek drains a 11,530-ha Piedmont watershed in Gaston County, North Carolina. It has documented water quality degradation caused by sediment, bacteria, and nutrients (NC DEM, 1989). Potential pollution sources include agriculture (livestock and crop production), mining, forestry, urban runoff, septic system outflow, streambank erosion, and discharges from industries and wastewater treatment plants. Approximately 20,060 m^3 of animal waste and 21,950 m^3 of municipal sludge is applied to agricultural land in the watershed annually.

The project watershed contains five management or study areas. The most intensively monitored study area is a dairy farm pasture and heavy use area which is the focus of this paper. Land use in the monitored watershed (fig. 1) is mostly pasture with areas of residential houses, small business, woods, and farm buildings along the watershed boundary. The 42-ha area upstream of site D contains mostly pasture which provides supplemental forage to between 50 and 100 replacement heifers. Several homes, a small apartment complex, and a small business are located along the periphery of the upstream (site D) drainage area. The 14.6-ha area between sites D and E is grazed regularly by between 50 and 100 adult dry cows and occasionally by another 50 to 100 milking cows. Due to the increased stocking density, grass in the area between sites D and E is sparse overall, with relatively large denuded areas in places where the cows are fed. Additionally, the streambanks between sites D and E are eroding at an accelerated rate due, at least partially, to unlimited access of the cows to the stream.

The average annual rainfall in the monitored area is about 1090 mm. The watershed geology is typical of the western Piedmont with a saprolite layer of varying thickness overlaying fractured igneous and metamorphic rock. Soils in the drainage area are generally well-drained and have a loamy surface layer underlain by a clay subsoil. Both upstream and downstream drainage areas are hilly with land slopes of 5 to 15 percent.

The small stream draining the watershed flow continuously with discharges ranging from 1.4 L/s to more than 2800 L/s during large storm events. Several normally dry channels enter the stream between the upstream and downstream monitoring sites; thus, the discharge at sites D and E are nearly equal during baseflow conditions, but, because of the heavy use areas and large building roofs, can be quite different during storm events.

Land treatment in the monitored drainage was focused on treating the area between monitoring sites D and E. The only BMP installed upstream of site D was an alternate watering system for the 50 plus heifers grazing in the drainage area. BMPs implemented between sites D and E include an alternate watering system, livestock exclusion fencing, improved stock trails, heavy use area stabilization, a runoff spreader, and a cattle stream crossing. The fencing excluded the cows from a corridor ranging from 18 to 31 meters wide along the stream. Grass has been established on streambank areas with severe erosion and hardwood trees have been planted along the entire 330 meters of the riparian corridor. Additionally, volunteer vegetation in the riparian corridor has helped to stabilize streambanks and channels leading to the stream.

Procedure

Grab samples from the overfall of a v-notch weir at site D and a large culvert at site E were collected weekly since April of 1993. The grab samples were collected within 20 minutes of each other, iced immediately, and transported to a nearby laboratory within five hours where they were preserved using approved methods. Samples were analyzed for nitrite+nitrate nitrogen (NO_{2+3}), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total suspended solids (TSS), and total solids (TS) concentrations by a U.S. EPA certified laboratory. Samples were analyzed using methods 353.1, 351.2, 365.4 from U.S. EPA (1983) for NO_{2+3}, TKN, and TP and 2540D and 2540B from APHA et al. (1989) for TSS and TS. Split, blank, and spiked samples were prepared and analyzed to verify the quality and representativeness of the samples.

Results and Discussion

Documenting an effect of a BMP using the upstream-downstream monitoring design can be accomplished in several ways including regression analysis and parametric or nonparametric analysis of variance. The regression analysis requires a relationship between upstream and downstream pollutant concentrations that is different before compared to after BMP implementation. Due to the large, random influence of cows in the stream, a relationship between pollutant concentrations at D and E before BMP implementation was weak to nonexistent; therefore, this method was not used. Three analysis of variance methods were used on the differences between concentrations at sites D and E.

Figure 2 shows the differences in TSS concentrations at sites D and E with positive differences indicating concentrations greater at E. For the pre-BMP period (4/3/93 to 2/6/96), observation of bars suggests that TSS concentrations are generally greater at site E than at D while after BMP implementation differences are nearly zero. Trends were similar, although the magnitude of the differences in concentrations after BMP implementation were greater for NO_{2+3},TKN, TP, and TS or in other words, the BMPs were not quite as effective at reducing concentrations of the other pollutants.

Univariate analysis (SAS Institute, 1985) of the concentration differences between D and E indicated that the data were not normally distributed; therefore, the data was log-transformed before performing an analysis of variance (ANOVA). Additionally, nonparametric statistical analyses were used to assess the data. The average difference between D and E pre- and post-BMP implementation along with probabilities of exceeding the computed test statistic for ANOVA, the Wilcoxin Rank Sum test, and the Kolmogrov-Smirnov test (SAS Institute, 1985) are shown in Table 1. The tests were used to compare the differences in concentrations before BMP implementation to after implementation. Because only one year of monitoring data has been collected since implementation, fewer (43 versus 143) data exist for the post-BMP period.

Table 1. Probabilities of Exceeding the Test Statistic for Comparisons Between Differences in Concentrations at Sites D and E Before and After BMPs.

Pollutant	Mean at D Pre-BMP mg/L	Mean of Differences[1] Pre-BMP mg/L	Post-BMP mg/L	ANOVA[2] Pr > F	Wilcoxin Rank Sum Pr > Z	Kolmogorov-Smirnov Pr > KSa
NO_{2+3}		0.25	0.59	0.0174	0.0030	0.0082
TKN		7.61	0.50	0.0001	0.0001	0.0001
TP		1.42	0.28	0.0961	0.0001	0.0001
TSS		70.4	0.17	0.0001	0.0001	0.0001
TS		153.0	27.9	0.0055	0.0004	0.0003

[1] average of concentrations at site E minus D for 143 pre- and 49 post-BMP samples.
[2] analysis of variance was conducted on the logarithms of the concentrations.

A general indication of the level of pollutants in the stream is given by the pre-BMP concentrations of pollutants shown in column two of Table 1. These mean levels are also a rough estimate of post-BMP concentrations considering that the only BMP implemented upstream of site D was the alternate drinking water supply. Columns three and four show that the increase in concentrations from upstream to downstream is reduced by the implementation of BMPs with the exception of NO_{2+3}. The concentration of NO_{2+3} increases downstream relative to upstream with the implementation of BMPs.

This seemingly negative effect of the BMPs can be explained by an increasing trend in NO_{2+3} concentrations throughout the duration of the project and the realization that the riparian area may increase infiltration and shallow ground water movement thereby increasing NO_{2+3} movement to the stream.

The ANOVA on the log-transformed data indicates that there is sufficient evidence of a significant reduction in TKN, TP, TSS, and TS at the 0.10 level of significance and TKN, TSS, and TS at the 0.05 level of significance. The results from nonparametric Wilcoxin Rank Sum and Kolmogorov-Smirnov tests indicate relatively strong differences in pre- and post-implementation data. The nonparametric tests indicate stronger differences than the parametric ANOVA test, especially for TP. This may be due, at least partly, to the magnitude of the variability in differences in TP concentrations which ranged from -0.23 to 33.8 mg/L.

Thus, statistical analyses of the pre- and post-BMP implementation concentration data indicates that the BMPs are having a significant effect on levels of pollutants in the stream. Observation of a greater diversity and intensity of aquatic life in the stream has also indicated improved water quality since the implementation of BMPs.

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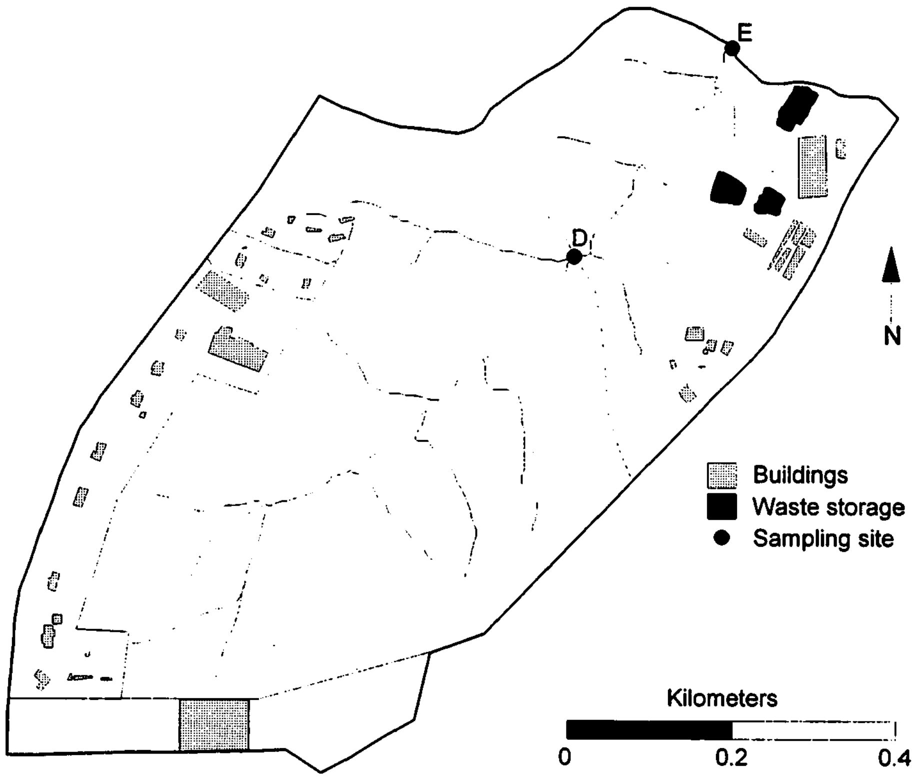

Figure 1. Map of watershed area.

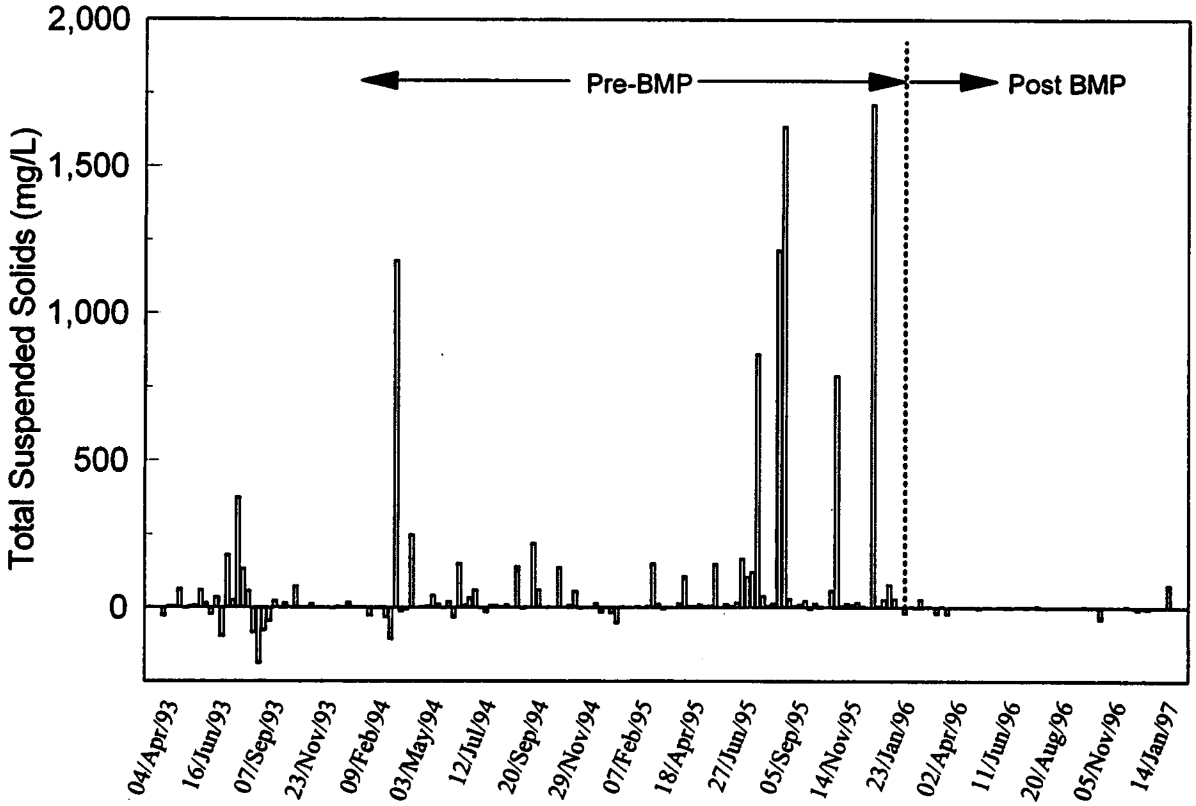

Figure 2. Differences in concentrations of suspended solids in grab samples from sites D and E.

Jordan Cove Urban Watershed Section 319 National Monitoring Program Project

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Introduction

Runoff from urban areas is the second leading cause of nonpoint source pollution behind agriculture in the U. S. (USEPA, 1994). In CT, MA, RI, and TX, urban runoff is the major source of nonpoint pollution. The major types of pollutants found in urban runoff are more varied than from agricultural areas and include suspended solids, nutrients, oxygen-demanding substances, pathogens, road salts, hydrocarbons, heavy metals, and other toxins (USEPA, 1993a). Urban runoff sources also dominate nonpoint loading to Long Island Sound, an estuary impaired by hypoxia and pathogen contamination (LISS, 1994).

The Nationwide Urban Runoff Program (NURP) evaluated runoff from 28 urban areas around the U. S. (USEPA, 1983). Among the study's main conclusions were that concentrations of pollutants did not vary significantly in runoff among differing types of urban land uses, such as residential versus commercial (USEPA, 1983). However, open/non-urban areas had lower concentrations than urban areas. A few best management practices (BMPs) were studied during NURP, such as wet detention basins, recharge devices, and street sweeping. Since that time there have been additional studies of BMPs to reduce nonpoint sources of pollutants from urban areas. Most of these studies have been related to the effectiveness of individual BMPs, such as detention basins. Excellent summaries of urban BMP effectiveness can be found in Schueler (1992) and USEPA (1993b). To date, however, there has not been an attempt to investigate the effectiveness of an entire suite of BMPs applied to an urban development.

The objectives of this study are to determine the water quantity and water quality benefits from developing an urban subdivision using pollution prevention BMPs. Site design and landowner education are major BMPs. Two residential areas will be developed beginning July 1997; one using traditional subdivision requirements and one using BMPs. Runoff from these two areas is being compared to an existing residential control watershed. The purpose of this paper is to describe the study design, the BMPs that will be used, and provide preliminary results from watershed calibration.

Study Area
The project is located in Waterford, CT near Long Island Sound. The existing control is a 13.9-acre residential watershed containing 43 lots ranging from 0.3 to 0.5 acre developed in 1988 (Figure 1). The traditional subdivision is a 10.6-acre residential/commercial/poultry farm being developed into 18 0.3-acre lots (Figure 2). The BMP subdivision is a 6.9-acre gravel pit being developed into 12 0.25-acre lots following cluster guidelines (Figure 3). The control watershed has 30 % imperviousness while the treatment area is at 9.1% imperviousness.

Methods
The overall study design is based on a paired watershed approach (Clausen and Spooner, 1993) using one control and two treatment watersheds. This approach uses a calibration period and treatment period. During a calibration period of 1.5 years, no land use changes in the watersheds occurred. The treatment period includes two intervals: a 18-month construction period, and a long-term post implementation monitoring period. During calibration, regressions are developed between paired observations from the control and treatment watersheds, such as paired concentrations. A new regression is developed following treatment. Analysis of covariance is used to test the difference between the two regression slopes and intercepts.

Overland flow is being monitored using H-flumes at the treatment sites and a combination V-notch and rectangular weir in the stormwater pipe at the control site. During stormflow periods, samples are automatically taken of overland flow using ISCO samplers using flow proportional sampling and a weekly composite. Samples are analyzed for total suspended solids, total phosphorus, total Kjeldahl, ammonia, and nitrate nitrogen, copper, lead, and zinc. Grab samples are analyzed for fecal coliform bacteria and BOD_5. Analyses are by EPA approved methods (USEPA, 1983b). Monitoring costs about $50,000/yr.

Results and Discussion

BMP Design

The BMP watershed incorporates several pollution prevention measures as part of its design. A main feature is the replacement of curb-and-gutter and stormwater collection methods with bioretention swales (Table 1, Figure 3). The traditional 28 ft wide asphalt road is being replaced with a 20ft wide concrete paver road that allows 12 % infiltration (UNI Eco-Stone®). A bioretention cul-de-sac that allows for detention and infiltration of runoff will be constructed in lieu of a conventional paved area. Individual bioretention gardens are incorporated into each lot to detain roof and lot runoff (Prince George's County, 1993). Several alternative driveway surfaces are being installed including traditional asphalt, concrete pavers, porous concrete, concrete two-track, and gravel. Finally, the lawns will be reduced and replaced with no-mowing and low-mowing zones including native and other low maintenance vegetation. During construction additional BMPs will be used, such as phased grading, seeding stockpiles, and post storm maintenance. Following construction, additional BMPs will be employed over the long-term (Table 1). Deed convenants will restrict imperviousness, obstructions in the swales and will require maintenance of vegetation and driveways. Ongoing education programs will be devoted to lawn nutrient and pesticide management, pet waste management, and general good housekeeping practices. Costs of BMPs will be tracked. Planning costs have been about double for the BMP lots ($808/lot) as compared to the traditional lots ($407/lot).

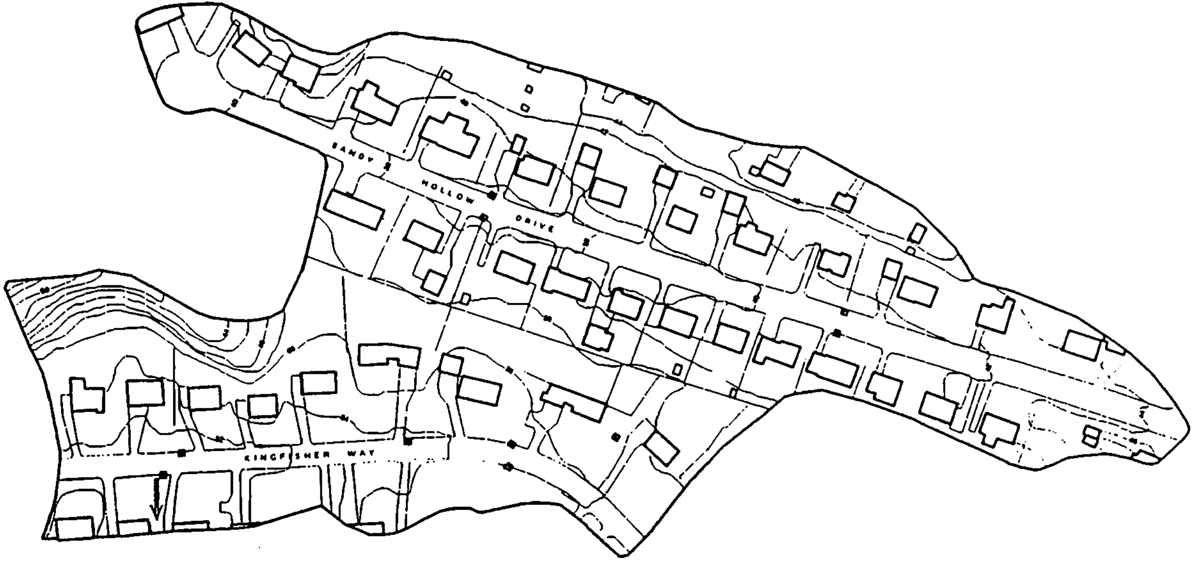

Figure 1. Existing Residential Control Watershed with contours, Waterford, CT

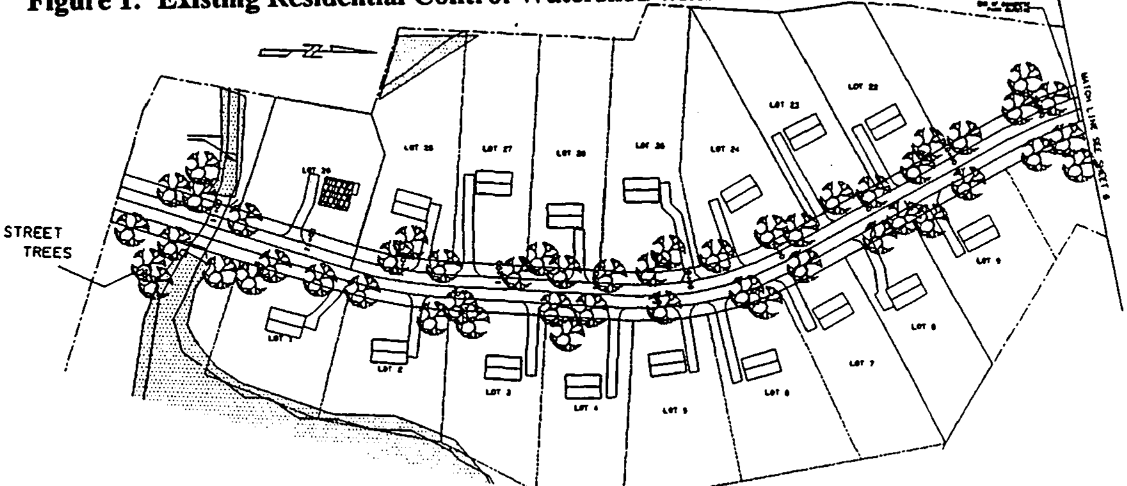

Figure 2. Traditional subdivision watershed, Waterford, CT

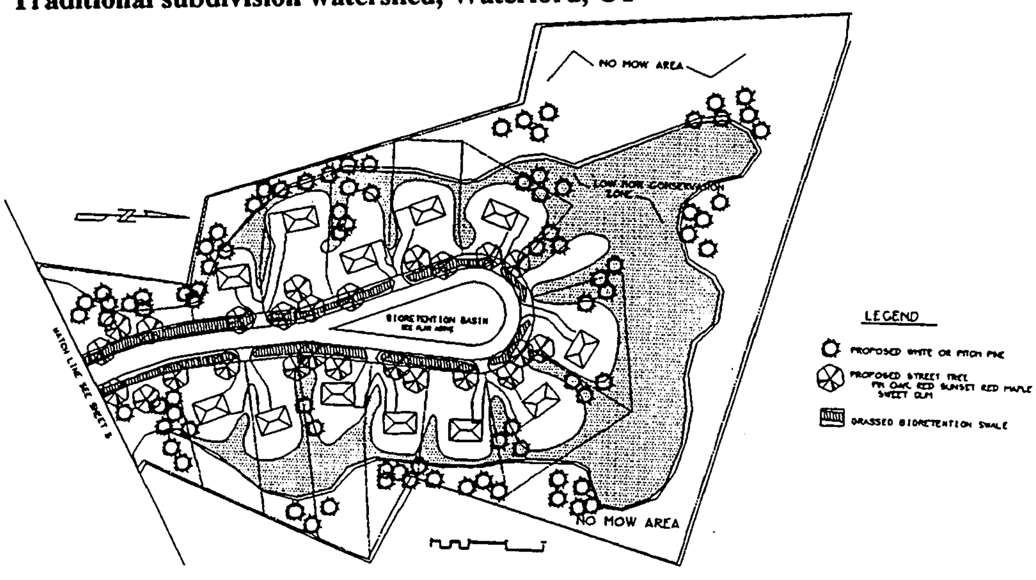

Figure 3. BMP subdivision watershed, Waterford, CT

Table 1. BMPs used in BMP subdivision watershed, Waterford, CT

Pollution Prevention Design BMPs	Long-term Maintenance
Bioretention swales	Deed restrictions
Narrow road surface	Impervious controls
Infiltrating road surface	Swale obstructions
Bioretention cul-de-sac	Driveway maintenance
Small 2-story house footprint	Education efforts
Roof/lot runoff bioretention gardens	lawn nutrient management
Low-mow and no-mow areas	pet waste management
Reduced lawn area mowed	good housekeeping
Driveway treatments	
Shared driveway entrances	
Cluster subdivision	

Table 2. Median Concentrations in stormwater runoff from the Jordan Cove, CT monitoring sites (11/95-5/97) and the Nationwide Urban Runoff Program (NURP)

Variable (mg/L)	Control	BMP	Traditional	NURP
Total suspended solids	22.0	3.5	41.0	100.0
Total phosphorus	0.152	0.020	1.4	0.330
Total Kjeldahl nitrogen	1.2	0.6	4.4	1.5
Ammonia nitrogen	0.30	0.10	<0.01	0.17
Nitrate-nitrogen	0.40	0.22	0.1	0.68
Biochemical oxygen demand	2	2	—	9
Fecal Coliform bacteria	18	20	—	14,700
Copper	0.014	0.009	0.006	0.034
Lead	0.009	0.004	0.009	0.144
Zinc	0.062	0.044	0.057	0.160
Discharge (ft^3/wk)	5001	526	0.38	—

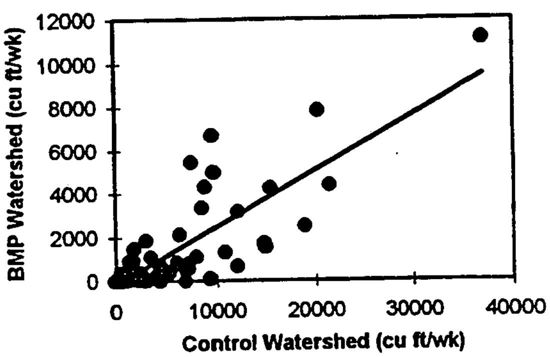

Figure 4. Stormflow calibration regression for existing control and BMP sites, Waterford, CT

Calibration Monitoring

Concentrations of pollutants in runoff from the existing residential control are somewhat lower when compared to event mean concentrations from the NURP studies (Table 2). Runoff from the BMP site exhibits lower concentrations of most water quality variables than the control site. At times the flow at the BMP site is dominated by ground water flow from a seep in the old gravel pit.

Calibration for flow has been conducted between the control and BMP watershed. In order to develop the regression between runoff from the two sites, hydrograph separation (recession baseflow back projection) of stormflow and baseflow was necessary for the BMP site due to the ground water inputs. The regression between the two sites (Figure 4) is significant ($F=83.0$, $p=<0.001$, $R^2=0.62$). The median runoff from the existing residential control is about 10 times that from the BMP site. Significant ($p=0.05$) calibration regressions have also been establish for total suspended solids, total phosphorus, BOD, fecal coliform bacteria, copper, and lead concentrations; and the mass export of ammonia, total Kjeldahl – N, total suspended solids, and total phosphorus. Calibration of the control and traditional site is underway.

Conclusions

Several pollution prevention BMPs have been arranged in a residential neighborhood to reduce runoff of nonpoint source pollutants from urban areas. Calibration of the BMP site has been achieved for discharge but only after hydrograph separation of stormflow from baseflow. Calibration has also been achieved for most water quality variables.

Acknowledgments

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Partnerships in Puget Sound Watershed Remediation: Linking Water Quality to Pollution Controls

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Mid-project water quality data and pollution control information from the Totten and Eld Inlet Clean Water Projects are examined to determine if the installation of nonpoint source pollution controls have decreased the concentrations of fecal coliform (FC) bacteria entering shellfish harvest areas. Sources of bacterial contamination include poor livestock keeping practices at recreational farms and failing on-site sewage systems. Farm plans were developed on 9 of 22 targeted sites in three study basins and 78 of 88 planned best management practices were installed. Preliminary analyses of water quality data suggest that FC concentrations: decreased 31% in one creek, did not change in a second creek, and increased 600% in a third creek.

Introduction

Totten and Eld Inlets, in southern Puget Sound, (Figure 1) are highly productive shellfish growing areas where harvest is threatened or restricted by nonpoint source pollution. More than 30% of the shellfish harvest areas in Puget Sound have been closed or restricted to shellfish harvest (PSWQA, 1991). Sources of bacterial contamination to these shellfish growing waters include failing on-site sewage systems and poor livestock keeping practices on small, mostly recreational farms. Three streams in the study area fail to meet state water quality standards for FC (Schneider, Burns, and Pierre) and are included on Washington's (303(d)) list of impaired waterbodies.

Watershed management plans were developed for the Totten Inlet (44,320 acres) and Eld Inlet (23,220 acres) watersheds in 1989. Implementation of pollution management actions has occured only when funding allowed. In 1993 and 1995, nearly $1.8 million in grant funded projects enabled the Thurston County Environmental Health Division (TCEHD) and the Thurston Conservation District (TCD) to focus efforts on nonpoint pollution controls in these two watersheds through 1999. Much of the effort has focused on working with landowners to repair failing on-site sewage systems (OSSS) and mitigate pollution from small farm livestock keeping practices. The goal of these clean water projects has been to to reopen harvest-restricted shellfish growing areas and protect threatened areas within a relatively short time frame.

Washington's Department of Ecology is studying the effectiveness of nonpoint pollution control programs in six sub-basins within these watersheds under EPA's National Monitoring Program (NMP) guidance (EPA, 1991) and funding (approximately $0.5 million over 10 years). The goal of the monitoring program is to detect trends in water quality and pollution controls and associate these trends to each other. Water quality is monitored before, during, and after (1992-2001) pollution controls are installed. Data on the initial installation of pollution controls are collected. However, data are not available regarding their continued operation and maintenance. Historical water quality data (1986-1992) generated by TCEHD were also used in project design and evaluation. The paired watershed and single site over time monitoring strategies are used.

Fecal coliform bacteria is the major water quality parameter of interest, other parameters include: total suspended solids, turbidity, streamflow, conductivity, temperature, and precipitation. Water quality is monitored during the wet season on a weekly basis from mid-November through mid-April (n=23). Information about potential sources of pollution and the management of those sources are collected and examined for the extent of coverage in each basin and possible effects on water quality.

Implementation and Evaluation Approach

Farms in the Totten and Eld watersheds, and those in the study basins, were inventoried and prioritized by TCD and TCEHD according to their potential to degrade water quality. TCD then contacted priority farms and, where landowners were willing, developed farm plans and helped the landowner implement the recommended Best Management Practices (BMPs). Livestock commonly found on these farms include horses, beef cattle, llamas, donkeys, goats, sheep, and chickens. In order to compare animal types and numbers, animal types were converted to animal units (1 AU=1000 pounds). Farm animal inventory data were then used to estimate the wet season animal population for each study basin: Schneider - 93.0 AU; Burns - 7.6 AU; and Pierre - 5.0 AU. TCEHD selected homes in critical areas (stream corridors and marine shorelines) for sanitary surveys of OSSS using dye-tracing techniques.

Water quality data were analyzed with two approaches to determine if trends in FC exist in Schneider, Burns and Pierre basins: (1) comparison of pre- and post-BMP period FC concentrations using notched boxplots which graphically depict the 95% confidence interval about the median; and (2) comparison of pre- and post-BMP period FC relationships using paired watershed data.

The paired watershed monitoring approach was applied in Kennedy (13,050 ac.) and Schneider (4590 ac.) basins. The single site over time approach was used in Pierre (65 ac.) and Burns (82 ac.) basins (Figure 1). Kennedy (control) and Schneider (treatment) basins were chosen as paired basins based on their watershed characteristics and plans for managing nonpoint pollution. For Kennedy and Schneider, pre- and post-BMP period inter-basin pollutant relationships were established for flow, FC, and FC loading. McLane (7430 ac.) and Perry (3860 ac.) basins are scheduled to receive agricultural pollution controls into 1999 after which water quality will be analyzed.

Schneider basin has about 25 small farms that potentially impact water quality (17 were targeted for pollution controls) whereas Kennedy basin has no farms. About 85% of each basin is currently forested with the remaining land use classified as agriculture, residential, or other. While Kennedy may not fit the classic definition of a “control” because agricultural land use is dissimilar to that of Schneider, bacteria concentrations in Kennedy represent the natural background condition (i.e. wildlife sources of FC only) and can be viewed as what is achievable by eliminating human-caused effects through nonpoint pollution controls.

Pollution Control Implementation

Most of the farm planning and BMP installation work in Schneider and Burns basins occurred from 1993 to 1995 and coincided with grant funding designated for agricultural remediation in the Totten watershed. In Pierre basin, most of the farm planning and BMP installation effort occurred between 1990 and 1993. The more recent efforts by TCD represent a significant achievement in the installation of pollution controls in these basins since the watershed management plan was completed in 1989. Despite these gains, funding to continue farm planning and implementation work in these basins has not been made available.

For Schneider basin, 5 of 17 priority farms developed farm plans that included 45 individual BMPs. The completeness of farm plan implementation for these 5 farms, expressed as the percentage of the number of implemented BMPs divided by the number of planned BMPs, is: 14%, 100%, 100%, 100%, and 100%. For Burns basin, 3 of 3 priority farms developed plans containing 26 BMPs and completeness of implementation was: 100%, 100%, and 100%. For Pierre basin, 2 of 2 priority farms developed farm plans containing 17 BMPs and completeness was 57% and 90%. The most commonly applied BMPs included fencing, prescribed grazing, filter strips, livestock exclusion, nutrient management, and water troughs (Mead and Konovsky, personal communication, 1997).

Of the 9 farm plans developed in these basins, 5 of the sites appear to have developed farm plans solely through voluntary action. The remaining 4 sites were encouraged to develop farm plans by use of a formal referral process which has regulatory overtones. This process involves the farm operator, TCEHD, TCD, and Ecology, in the progression of farm planning and BMP implementation until water quality threats are mitigated to a satisfactory level (Starry, 1990 and Hofstad, 1993).

TCEHD conducted sanitary surveys at 15 of a targeted 36 on-site sewage systems using dye trace technology. No repairs were found necessary for systems within the Burns and Pierre basins. In the Schneider basin, 3 systems were suspected as malfunctioning and confirmation testing is scheduled (Thoemke, personal communication, 1997).

All homeowners in the Burns and Pierre basins participated in the 1994-95 sanitary survey. About 36% of homeowners in Schneider basin participated in the 1997 sanitary surveys (Hofstad, personal communication, 1997). The option for TCEHD staff to obtain an administrative search warrant for inspecting OSSS was available during the 1994-95 sanitary surveys. This option was unavailable after 1996 due to changes in the county's Sanitary Code. This followed a Washington State Supreme Court ruling that administrative search warrants could not be obtained for such inspection programs (Hofstad, et. al., 1996).

Water Quality Results

Two approaches were used to evaluate water quality: comparison of pre-and post-BMP median FC concentrations using notched boxplots; and comparison of pre- and post-BMP paired-basin FC relationships using linear regression. These analyses suggest that fecal coliform concentrations: decreased 31% in Schneider Creek, did not change in Burns Creek, and increased 600% in Pierre Creek. Table 1 summarizes pre- and post-BMP periods that were defined by examining available farm and BMP implementation data. For the paired-watershed analysis, Kennedy data were paired according to pre- and post-BMP period data for Schneider.

Table 1. Pre-and post-BMP periods in study basins.

Basin	Pre-BMP period	Post-BMP period
Kennedy	none	none
Schneider	1988-1993, 5 seasons	1995-1997, 2 seasons
Burns	1989-1993, 4 seasons	1995-1997, 2 seasons
Pierre	1986-1989, 3 seasons	1993-1997, 4 seasons

Table 2 summarizes the results of the pre- and post-BMP comparison of the median FC concentration. Notched boxplots suggest that pre- and post-BMP median FC concentrations did not change in Schneider or Burns and increased in Pierre.

For the paired-watershed analysis with Kennedy and Schneider, pre- and post-BMP period regression outputs were examined after Zar (1984) and EPA (1993). The slopes of these regressions were not different while the y-intercepts were different ($P<0.001$). The difference in intercepts, rather than slopes, indicates a parallel shift in the regression equation (Figure 2). This shift in the regression represents a 31% decrease from the pre-BMP period (mean log FC=1.43) to the post-BMP period (mean log FC=0.99).

Table 2. Median FC concentrations from pre- and post-BMP periods.

Basin	Pre-BMP median FC and (n)	Post-BMP median FC and (n)	significant difference
Kennedy	5 (39)	5 (45)	no
Schneider	25 (39)	12 (45)	no*
Burns	84 (35)	56 (45)	no
Pierre	25 (11)	150 (89)	yes

* See discussion of paired-watershed results where a difference in the mean log FC concentration was detected.

Water Quality and Pollution Controls

Linking water quality to pollution controls is difficult due to our incomplete understanding of the operation and maintenance of pollution controls, changes in farm management, effects of climate, and sources and fate of FC in the study basins.

In Schneider basin, the decrease in FC appears to be due to the implementation of farm plans as well as changes in farm ownership and farm management. One farm, just upstream of the sample site, changed ownership after the original farm plan was developed. Fewer horses have been observed at this farm during the last two seasons than were observed in previous years. Twenty-one of a targeted 33 OSSSs were not surveyed in Schneider basin. The performance and potential impact on water quality from these systems is currently unknown. The potential effect on water quality from the farm with 14% of the planned BMPs implemented is also not known.

In Pierre basin, the increase in FC might be attributable to a combination of factors such as partial implementation of the farm plans, the lack of maintenance of previously installed BMPs, and/or climate effects. One farm in the basin implemented 57% of the recommended BMPs between 1990 and 1993; the remaining BMPs have yet to be implemented. The other farm in Pierre basin implemented 90% of planned BMPs. More time may be needed for the effects of BMPs to be measurable in Burns basin. The ability to link changes in water quality to pollution controls could be improved by gaining current, complete, and accurate information about management of farms and the operational status of BMPs and OSSSs.

The influence of climate on water quality during the study period is poorly understood. Climate data show that the first two seasons of the NMP monitoring effort coincided with several years of below-average rainfall while the latter three years (much of the post-BMP period) coincided with rainfall returning to or exceeding the historical average. Rainfall totals, in inches, for the 6-month period from November through April are: 1992-93: 29.3, 1993-94: 25.7, 1994-95: 40.5, 1995-96:

48.6, and 1996-97: 52.8. Linear regression analyses for each site suggest that FC concentrations correlate poorly with streamflow and with an antecedent precipitation index which reflects soil saturation and runoff potential.

The sources and fate of bacteria in the study basins are factors also poorly understood. Farm animals and OSSS are presumed to be the primary sources of FC in the study area. While farm animal numbers and their management have been inventoried in the past, resources are unavailable to monitor the numbers of animals and their management. Animal waste that is deposited or transported to streams may result in temporary storage, and later release, of FC bacteria. Sherer et. al. (1992) suggests that for basins with livestock impacts, stream sediments can be a reservoir and subsequent source of water column FC, particularly during periods of disturbance such as during increased runoff. Examination of relationships between FC, turbidity, and total suspended solids in these streams may help explain the role of fine sediments in water column FC concentrations.

Lessons Learned

Current, complete, and accurate information on the operational status of previously installed pollution controls is needed to link these controls to improvements in water quality. Much of this information does not exist since state and local efforts focus on developing conservation plans and helping landowners with initial installation of BMPs. Programs that actively help landowners in properly operating and maintaining pollution controls beyond initial installation and procedures for tracking such activities would contribute to long-term effectiveness and abilities to measure success.

Accounting for and quantifying the effects of climate with the pre- and post-BMP single-site monitoring design will be challenging. More thorough examinations of rainfall and hydrograph data, as well as FC relationships to turbidity and total suspended solids, may help in understanding the effects of climate.

A better understanding of the sources of FC is needed in order to link control of those sources to changes in water quality. The amount of animal waste kept out of streams is many times a better measure of environmental benefit than the enumeration of some BMPs (EPA, 1997). For a stronger evaluation of pollution controls, information should be collected on the numbers, types, locations, and management of animals as well as potential in-stream sources of FC.

Expectations for measuring water quality improvement from nonpoint pollution control projects may need to be reduced because desired levels of voluntary participation may not be reached. About 45% of the priority farms in the study basins participated in developing farm plans while 55% chose not to participate. However, of those farms with farm plans, the level of implementation was generally excellent (90-100% implementation for 8 of 10 farm plans). Lower levels of farm plan implementation could be masking benefits gained from complete implementation of other farm plans (e.g. Pierre basin).

Regulatory and voluntary factors appear to motivate landowners to participate in OSSS and farm pollution control efforts. Participation in OSSS survey programs decreased when a regulatory tool was removed. Of 10 farms where plans were developed, 5 farm plans were voluntarily developed while 5 plans were developed through the use, or probable use, of a formal referral process. Farm planning on the remaining 12 priority farms in Schneider basin seems unlikely to occur due to expiration of grant funds and time.

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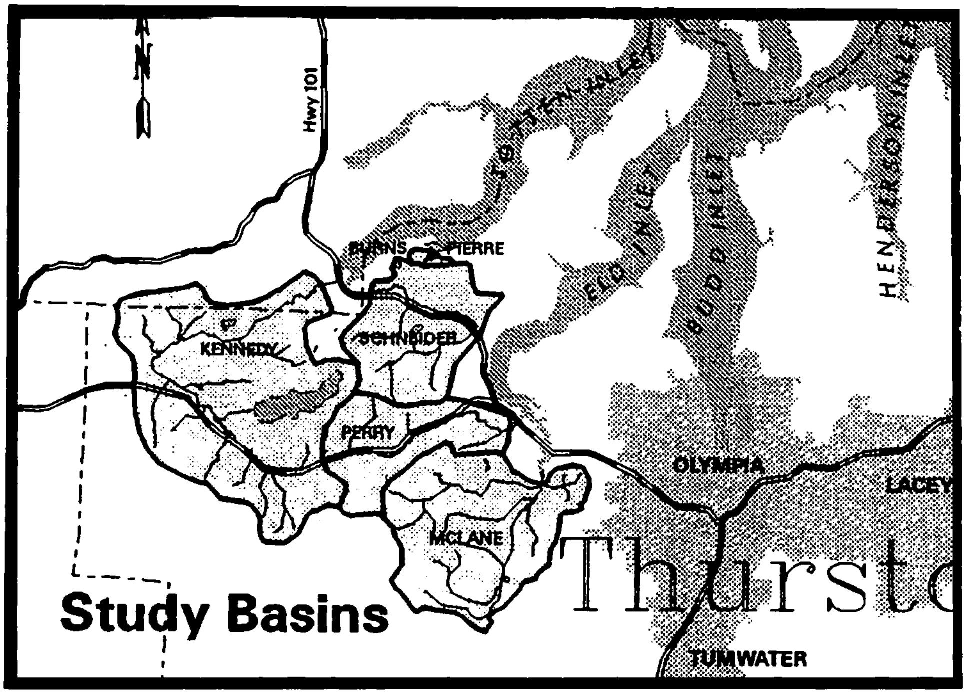


Figure 1. Study area in southern Puget Sound.

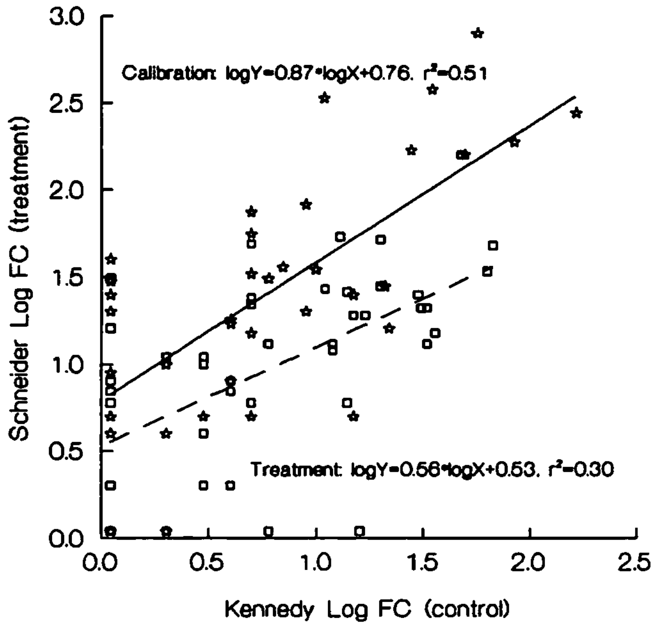


Figure 2. Treatment and calibration period regressions.

The National Water-Quality Assessment Program — At 5 Years Old

A Synopsis of the NAWQA Program and its Accomplishments

U.S. Department of the Interior — U.S. Geological Survey

The primary goal of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) is to systematically document water-quality conditions across the country. This allows comparisons to be made among river basins and aquifers and facilitates analysis of national issues and trends.

NAWQA assesses water-quality conditions in 59 river basin/aquifer system nationwide. Selection of study units reflects significant population centers, major sources of drinking water, and diverse environmental settings. Investigative methods used by the Program are designed not only to capture changes in water quality over time but to explain how human and natural factors affect water quality in different parts of the Nation.

Working With Other Monitoring Programs

The first 2 years of any NAWQA assessment involve compiling and analyzing existing data collected by Federal, State and university scientists and by community groups. Using both this "retrospective" information and NAWQA protocols, study-unit scientists develop a plan to guide 3 years of rigorous sampling of physical, chemical and biological characteristics of a river basin/aquifer system.

Study-Unit Investigations

In 1991, NAWQA made the transition from a pilot program to a full-scale monitoring program with the start of the first 20 study-unit investigations. An additional 16 study units started operation in 1994, and another 17 are slated to begin in 1997. Six study units have been selected for assessment but have not yet been assigned a starting date.

To make the Program cost-effective, intensive assessment activities in each study unit are conducted in rotation, with about one-third of the 59 study units active at any given time.

In full operation now for 5 years, NAWQA is designed to be an on-going program. Every 10 years, intensive sampling activities cycle through each study unit, updating data and characterizing trends.

National Synthesis Studies

In addition to study-unit investigations, NAWQA's National Synthesis Teams carry on analyses that put local and regional conditions into a larger, national perspective. Presently, there are three Synthesis Teams that focus, respectively, on pesticides, nutrients, and volatile organic compounds (VOCs). A fourth Synthesis Team with a focus on trace metals is planned.

What makes NAWQA unique?

Findings developed by NAWQA help answer questions about the condition and sustainability of the Nation's water resources: What is the condition of my drinking water source? Are streams providing good habitat for fish? Is residential expansion affecting ground water? How do agricultural effects on water quality compare with urban effects? Has the money spent cleaning up our waters made any difference?

State and local water-quality monitoring programs, which complement NAWQA assessments, are generally not designed to support the range of local, regional and national-scale analyses accommodated by NAWQA.

Elements of a NAWQA Assessment

Assessments of rivers and streams focus on:

- *pesticides*
- *nutrients*
- *polychlorinated biphenyls (PCBs)*
- *industrial chemicals*
- *metals*
- *stream habitat*
- *fish communities*

Assessments of ground water focus on:

- *pesticides*
- *nitrate*
- *dissolved solids*
- *radon*
- *industrial chemicals*

Use of NAWQA Data and Assessments

Long-term, consistent, nationwide data like these have been previously unavailable from any Federal or State monitoring program. The lack of such data has made it impossible to evaluate many questions of concern to policymakers, resource managers, and the public.

Results from the NAWQA Program form a basis upon which States and the Nation can identify existing and emerging water-quality issues, evaluate the effectiveness of management strategies, and formulate more cost-effective programs.

For example, Washington State implemented a flexible and cost-saving monitoring program for drinking water wells after collaborating with NAWQA on an assessment of pesticides in ground water. The White House Office of Science and Technology Policy (OSTP) and the U.S. Environmental Protection Agency (EPA) are using NAWQA data on the occurrence of VOCs and pesticides to consider policy and regulatory options.

STUDY-UNIT HIGHLIGHTS

Washington State health officials have implemented monitoring plans for drinking water wells based on the relative risk of pesticide contamination. The risk survey was designed and conducted in partnership with NAWQA. Savings to the State will exceed $6 million each year.

In response to public concerns, bed sediment and fish tissue in Idaho's Upper Snake River were examined for mercury contamination. While mercury was detected, concentrations do not exceed guidelines established by the U.S. Fish and Wildlife Service and Environment Canada for protection of aquatic organisms or fish-eating birds and wildlife.*

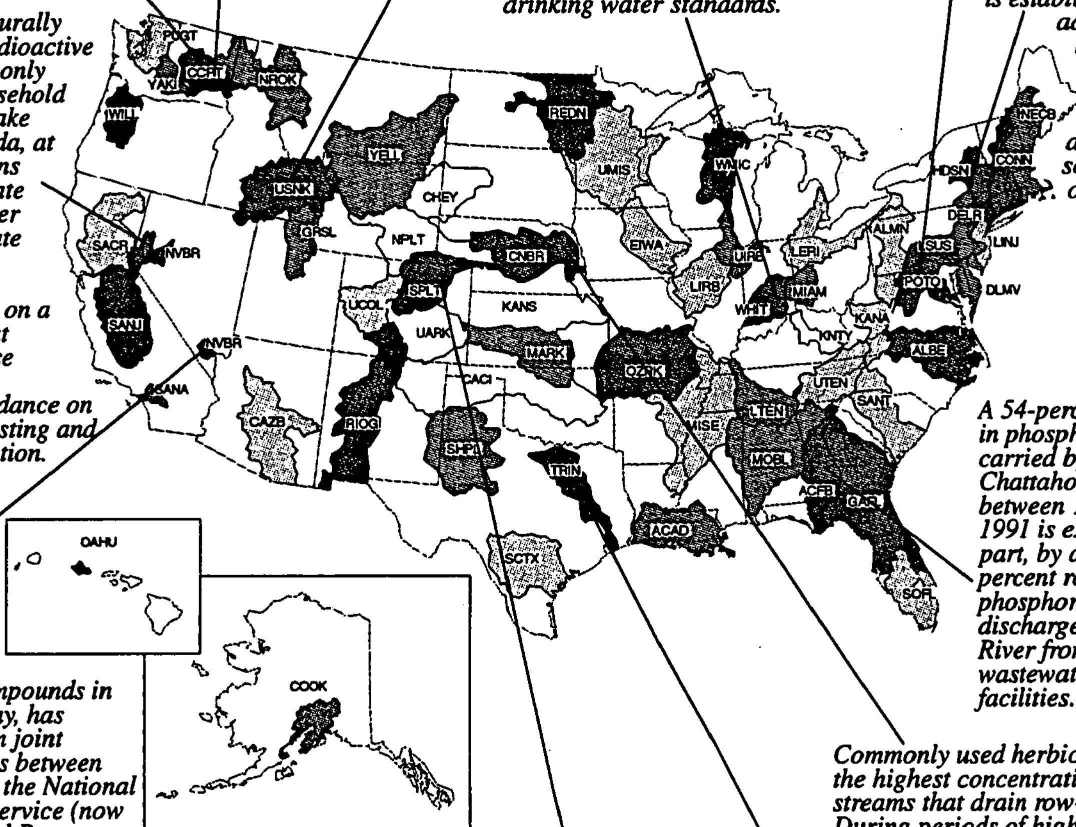
The number of pesticides detected in streams draining the suburbs of Washington, D.C. is greater than the number found in streams draining farmland. In urban streams, some insecticides typically exceed Environment Canada's guidelines for protecting aquatic health. State pesticide management plans in the Potomac Basin would be most effective if both urban and farming areas were included.*

Although banned 25 years ago, DDT persists in the Yakima and Quincy-Pasco River Basins of Washington State at concentrations that exceed wildlife protection guidelines established by the National Academy of Sciences (NAS) and Environment Canada. The Royal Lake refuge and Lind Coulee recreational fishing areas are of special concern.*

Ground water supplies drinking water to one-half the population of Indiana's White River Basin. Under cropland, 17 percent of wells exceed EPA drinking water standards for nitrate. In 50 percent of urban wells, VOCs are detectable, though not in excess of EPA drinking water standards.

As a result of NAWQA findings of PCBs in fish of the Mohawk River, New York State is establishing health advisories for affected parts of the River and will further assess the scope of PCB occurrence.

Radon, a naturally occurring radioactive gas, is commonly found in household wells near Lake Tahoe, Nevada, at concentrations above the State drinking water standard. State officials and NAWQA collaborated on a pamphlet that reported these results and provided guidance on home well-testing and corrective action.



A 54-percent decline in phosphorus loads carried by the Chattahoochee River between 1989 and 1991 is explained, in part, by an 83-percent reduction in phosphorus discharged to the River from Atlanta's wastewater treatment facilities.

Evidence of endocrine disruption, linked to the presence of numerous chemical compounds in Las Vegas Bay, has emerged from joint investigations between NAWQA and the National Biological Service (now the Biological Resources Division of USGS).

Commonly used herbicides occur in the highest concentrations in streams that drain row-crop areas. During periods of high runoff, nearly all samples exceed EPA drinking water standards for at least one herbicide.

The VOC methyl tert-butyl ether (MTBE) is detectable in low concentrations in 80 percent of urban ground-water samples from the Denver area. While the monitoring wells sampled are not used for drinking water, the presence of MTBE, which is used to reduce air pollution from car exhaust, was unexpected in ground water.

Sediment cores collected from White Rock Lake in Dallas reveal upward trends in lead, DDT, chlordane and PCBs from 1912 to 1994. Increasing concentrations of these compounds have followed increases in human population. Declining concentrations of these compounds occurred after their use was banned, but levels have not yet fallen to those recorded for 1912.

* In the absence of U.S. EPA standards for aquatic/wildlife protection, guidelines from the National Academy of Sciences and Environment Canada are frequently used by scientists to provide a context for evaluation.

EXPLANATION

Begun in 1991

ACFB Apalachicola-Chattahoochee-Flint River Basin
ALBE Albemarle-Pamlico Drainage
CCPT Central Columbia Plateau
CNBR Central Nebraska Basin
CONN Connecticut, Housatonic, Thames River Basins
GAFL Georgia-Florida Coastal Plain
HDSN Hudson River Basin
LSUS Lower Susquehanna River Basin
NVBR Nevada Basin and Range
OZRK Ozark Plateaus
POTO Potomac River Basin
REDN Red River of the North Basin
RIOG Rio Grande Valley
SANJ San Joaquin-Tulare Basins
SPLT South Platte River Basin
TRIN Trinity River Basin
USNK Upper Snake River Basin
WILL Willamette Basin
WHIT White River Basin
WMIC Western Lake Michigan Drainages

Begun in 1994

ALMN Allegheny and Monongahela Basins
CAZB Central Arizona Basins
EIWA Eastern Iowa Basins
KANA Kanawha-New River Basin
LERI Lake Erie-Lake Saint Clair Drainage
LINJ Long Island-New Jersey Coastal Drainages
LIRB Lower Illinois River Basin
MISE Mississippi Embayment
PUGT Puget Sound Basin
SACR Sacramento Basin
SANT Santee Basin and Coastal Drainages
SCTX South Central Texas
SOFL Southern Florida
UCOL Upper Colorado River Basin
UMIS Upper Mississippi River Basin
UTEN Upper Tennessee River Basin

Beginning in 1997

ACAD Acadian-Pontchartrain
COOK Cook Inlet Basin
DELR Delaware River Basin
DLMV Delmarva Peninsula
GRSL Great Salt Lake Basins
LTEN Lower Tennessee River Basin
MARK Middle Arkansas River Basin
MIAM Great and Little Miami River Basins
MOBL Mobile River and Tributaries
NECB New England Coastal Basins
NROK Northern Rockies Intermontane Basins
OAHU Oahu
SANA Santa Ana Basin
SHPL Southern High Plains
UIRB Upper Illinois River Basin
YAKI Yakima River Basin
YELL Yellowstone Basin

Unscheduled

KNTY Kentucky River Basin
CACI Canadian-Cimarron River Basins
KANS Kansas River Basin
UARK Upper Arkansas River Basin
NPLT North Platte River Basin
CHEY Cheyenne and Belle Fourche Basins

Fig. 1 Location of Study Units

NATIONAL SYNTHESIS HIGHLIGHTS

Ground-water contamination by nitrate depends on five factors and is likely to be highest where: the water table is less than 100 feet deep, soils are very permeable, nitrogen inputs (fertilizer and manure) are used heavily, population density is high, and the ratio of woodland to cropland is low. Of all wells in all land-use settings, household wells located in agricultural areas are most likely to exceed EPA drinking water standards for nitrate; public supply wells, regardless of land-use setting, are least likely to exceed those standards (fig. 2).

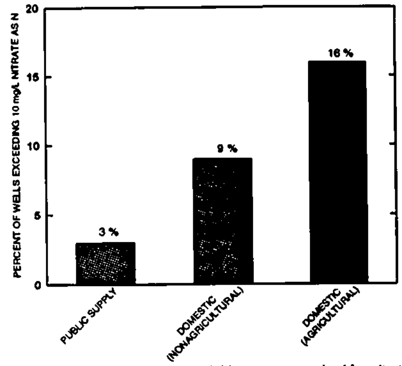


Fig. 2 Exceedances of the Federal drinking water standard for nitrate (10 n are greater in domestic (household) wells than in public-supply wells.

The relative importance of point and nonpoint sources of nutrients to water resources varies by watershed. However, nationwide, 92 percent of the nitrogen and 76 percent of the phosphorus found in streams come from nonpoint sources like manure, fertilizer and the atmosphere. Over 90 percent of all nonpoint sources of nutrients are agricultural. Atmospheric deposition, an important water-quality issue in the upper Midwest and Northeast (fig. 3), provides a pathway for point-source emissions from electric utilities, vehicles, and industrial and residential fuel combustion to become nonpoint sources of nitrogen to streams, rivers, wetlands and lakes.

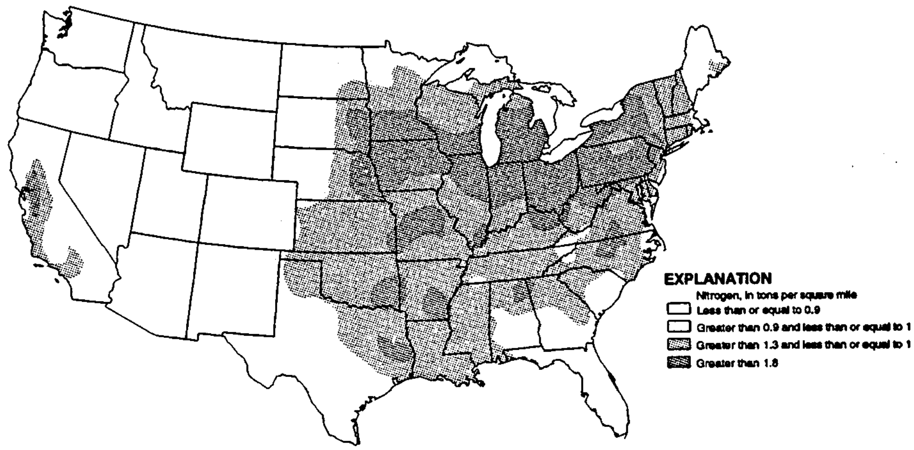


Fig. 3 Nationwide patterns of atmospheric deposition of nitrogen

Low but detectable concentrations of many pesticides occur in streams and ground water, as well as in air, fog, snow and rain nationwide. Most compounds found are used locally, although some pesticides are transported through the atmosphere for hundreds or thousands of miles. Persistent compounds like DDT and toxaphene are still cycling through the atmosphere in the United States more than a decade after their use was banned. Although most pesticide concentrations in the atmosphere are very low, adverse effects on wildlife, caused by continuous deposition and accumulation in the food chain, have been documented.

Among 37 VOCs detected in ground-water samples from eight cities, chloroform was detected most often, followed by the automotive fuel oxygenate MTBE. Although no detections of MTBE exceeded EPA health advisory levels (HALs), its presence in ground water was unexpected and prompted OSTP to assess the use of oxygenated fuels for air-pollution control. NAWQA scientists chaired an interagency working group for OSTP to document the occurrence of fuel oxygenates in the environment.

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U.S. Geological Survey
413 National Center
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phone: (703) 648-5716
fax: (703) 648-6693

email: nawqa_whq@usgs.gov

Information from NAWQA Includes:

- Historical water-quality data from 37 river/aquifer basins
- New water-quality assessments from 20 of those basins, with an emphasis on identifying human and natural factors that affect current conditions
- New investigations in 16 basins, with findings due in 1998-99
- Evaluation of historical, nationwide occurrence of pesticides, nutrients, and volatile organic compounds in streams and ground water

Detecting Fecal Contamination and Enteric Microbes in Watersheds

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Fecal contamination from human and animal sources continues to pose risks to human and animal health from the disease-causing microorganisms commonly found in such wastes. Fecal contamination from agricultural animals must be managed effectively because it can contain a variety of human pathogens. Such pathogens include the enteric protozoans *Cryptosporidium parvum* and *Giardia lamblia* and enteric bacteria such as *Salmonella* species, *Campylobacter* species and pathogenic strains of *Escherichia coli*. Our current studies indicate that typical animal waste management practices, such as lagooning, is sometimes inefficient in reducing some of these pathogens. Therefore, land application of lagooned animal wastes can result in surface water contamination if runoff is not adequately controlled or ground water contamination if soils are coarse, fractured or otherwise capable allowing rapid microbial transport. We have found that surface waters passing though animal agriculture operations often experience dramatic increases in fecal contamination from animal wastes, as indicated by excessive levels of indicator bacteria and viruses. Information on the extent of increase in parasitic pathogens such as *Cryptosporidium parvum* oocysts from agricultural animal wastes in inadequate, but there is evidence of increased levels from animal agriculture operations. Studies on the survival and persistence of the more resistant microbial pathogens in agriculture animal waste treatment practices are now in progress. We have found that some pathogens are highly persistent at lower temperatures but are rapidly inactivated at higher temperatures typical of thermophilic waste treatment processes. Because of the unreliability and high cost of detecting enteric pathogens in water, improved microbial indicators of these pathogens are needed. We have found that male-specific coliphages and the spores of the bacteria *Clostridium perfringens* have considerable value in tracing and identifying sources of fecal contamination in water. However, further studies are needed to determine the reliability of these indicators in predicting the risks from some of the more persistent protozoan pathogens, such as oocysts of *Cryptosporidium parvum* and cysts of *Giardia lamblia*.

The Role of Consultants in Addressing Water Quality Issues

Richard S. Fawcett

Farming has become much more complicated than in the past. More information is needed to make decisions on the use of inputs like pesticides and nutrients, and use of various tillage and crop production practices. Integrated Pest Management systems employ crop scouting to determine pest populations and utilize economic thresholds to determine when pest management strategies will be initiated. Modern nutrient management often employs intensified soil or plant sampling regimes. Yield maps generated using GPS must be analyzed to determine reasons for yield variability. Layers of data for each field, including yield, soil tests, soil productivity ratings, and input records can then be integrated to guide variable rate input applications and variations in crop varieties and populations to match site specific conditions. More farmers are looking to consultants to provide advice and analysis.

Many management changes adopted to improve efficiency and economics will have a positive impact on water quality. Pesticides can be matched to pest and soil conditions, avoiding inappropriate or unnecessary treatments. Ground and surface water vulnerability can be considered in selecting products and rates. Comprehensive nutrient management plans will take credit for non-fertilizer sources of nutrients and match fertilizer rates to crop production potential of soils. Variable rate application can avoid over fertilizing lower productivity soils, while providing sufficient nutrients for better soils to produce top economic yields.

Consultants can help select specific Best Management Practices (BMPs) to protect ground and surface water. For example, no-till is an effective surface water BMP on most soils, but herbicide runoff may not be reduced when this practice is used on claypan soils. The consultant can help select effective alternative BMP's.

Contamination of farm wells by pesticides, nutrients, and bacteria has often been traced to point sources near wells, such as pesticide and fertilizer mixing and disposal sites, septic systems, feedlots, and manure storage. Consultants can play a role in testing well water, identifying potential causes of contamination, and changing management practices to protect the well. Well construction and maintenance deficiencies can also be identified and corrected.

Farmers are increasingly considering water quality impacts when making management decisions. Consultants can help farmers obtain and interpret the data needed to make those decisions.

Richard S. Fawcett is President of Fawcett Consulting, Huxley IA 50124

Twenty Years of Change: The Lake Erie Agricultural Systems for Environmental Quality (LEASEQ) Project

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Concern over the "impending death" of Lake Erie in the early 1970's led not only to extensive point-source improvements but to some of the earliest and largest-scale efforts to implement agricultural best-management practices in the United States. Between 1975 and 1995, a number of implementation, education, and demonstration projects were carried out. While all were in response to the general goal of reducing pollutant export into Lake Erie, they were run by different managers responsible to different agencies. In a sense, this has been an experiment to see if environmental progress can flow from a mosaic of loosely-integrated programs in which participation is largely voluntary.

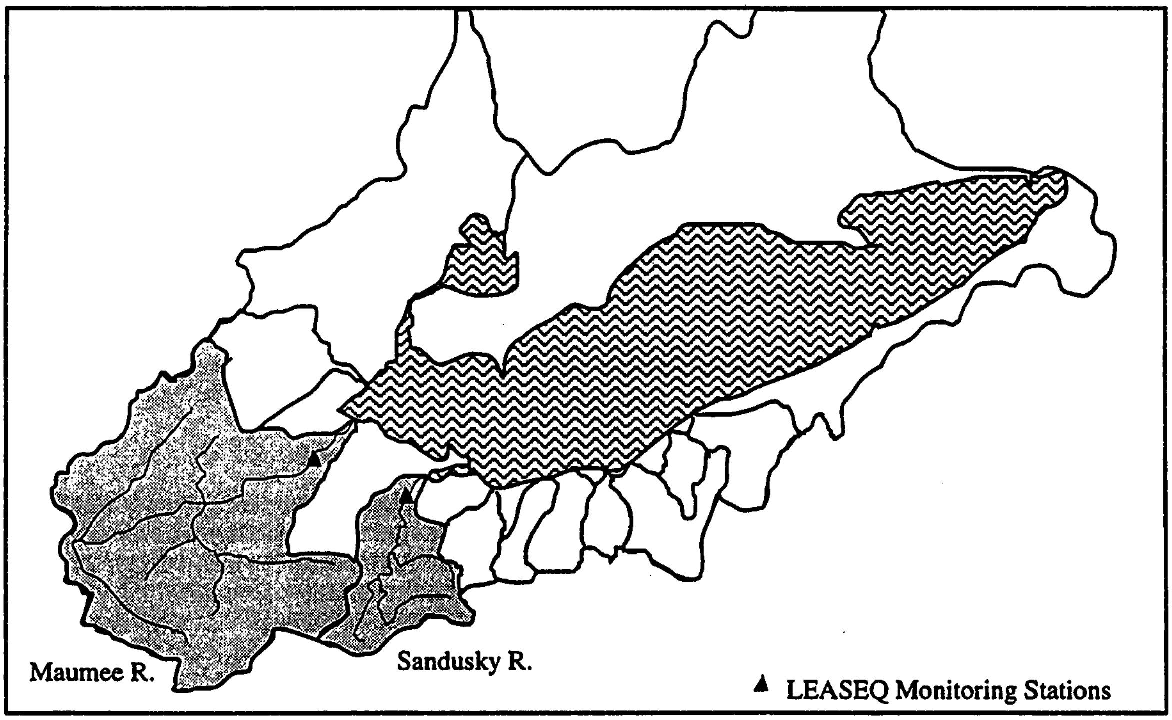

Figure 1. The Lake Erie drainage basin, showing the location of the study watersheds

The Lake Erie basin has also been the site of an ongoing monitoring program of unusual detail, carried out by the Water Quality Laboratory at Heidelberg College (HCWQL), which has produced daily and more frequent observations of sediment and nutrient concentrations in the

Maumee River at Bowling Green and the Sandusky River at Fremont beginning in 1975. These datasets now contain in excess of 8500 records each, and represent a valuable resource for evaluating the water quality benefits of changing agricultural management practices.

LEASEQ is a USDA-funded retrospective evaluation of changes in land management, soil fertility, farm economics, and water quality in the Maumee and Sandusky River basins of the Lake Erie watershed in the 21-year period between 1975 and 1995. Due to space constraints, this paper will report findings for the Maumee River basin only; results for the Sandusky are similar in most respects.

Environmental Management

Changes in Point Sources

Early efforts to reduce eutrophication in Lake Erie focused on upgrading sewage treatment plants in the Lake Erie watershed; these improvements were well underway by the beginning of the study period. As a result, and because of the relatively small populations served by sewage treatment plants located upstream of the monitoring stations, point sources are relatively minor components of annual nutrient loads, as shown for phosphorus in Figure 2. Point source data for nitrogen are not available, but our estimates indicate that point sources contribute an even smaller portion of the total nitrogen loads than they do for phosphorus, even with the nitrification of ammonia.

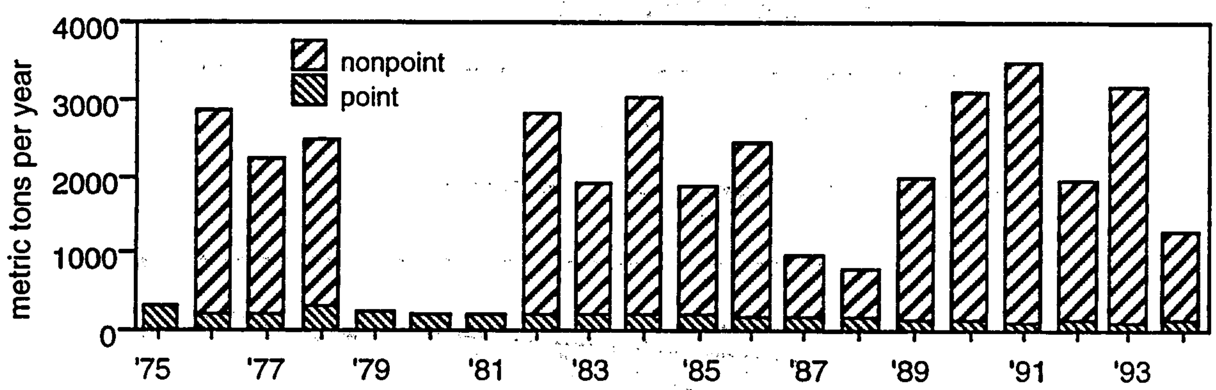

Figure 2. Total annual loads of phosphorus in the Maumee River, divided into point and non-point components

Changes in Agricultural Land Use

Agriculture is the dominant land use in the Maumee basin: in 1995, 88% of the land area was farmland, and 76% of the basin was in crop production. During the study period, the number of farms has decreased but the average farm size has increased. The total acreage of farm land has remained about the same (Figure 3). The major crops in the basin are corn, soybeans, and wheat. In 1995, 35% of the Maumee watershed was in soybeans, 23% in corn, 13% in wheat, 6% in other crops, and 12% in non-crop agricultural land use. During the study period, the number of acres in corn and in wheat has decreased by about 20%, while the number of acres in soybeans has increased by about 12%, as shown in Figure 4.

During the study period, implementation of no-till and reduced-till farming has increased substantially (Figure 5), from less than 5% to more than 50%, although data are not available for the early part of the period. The greatest increases have occurred in the last five years, and are due to no-till soybeans. Successful no-till corn farming is more challenging, and implementation percentages have plateaued or decreased slightly in recent years.

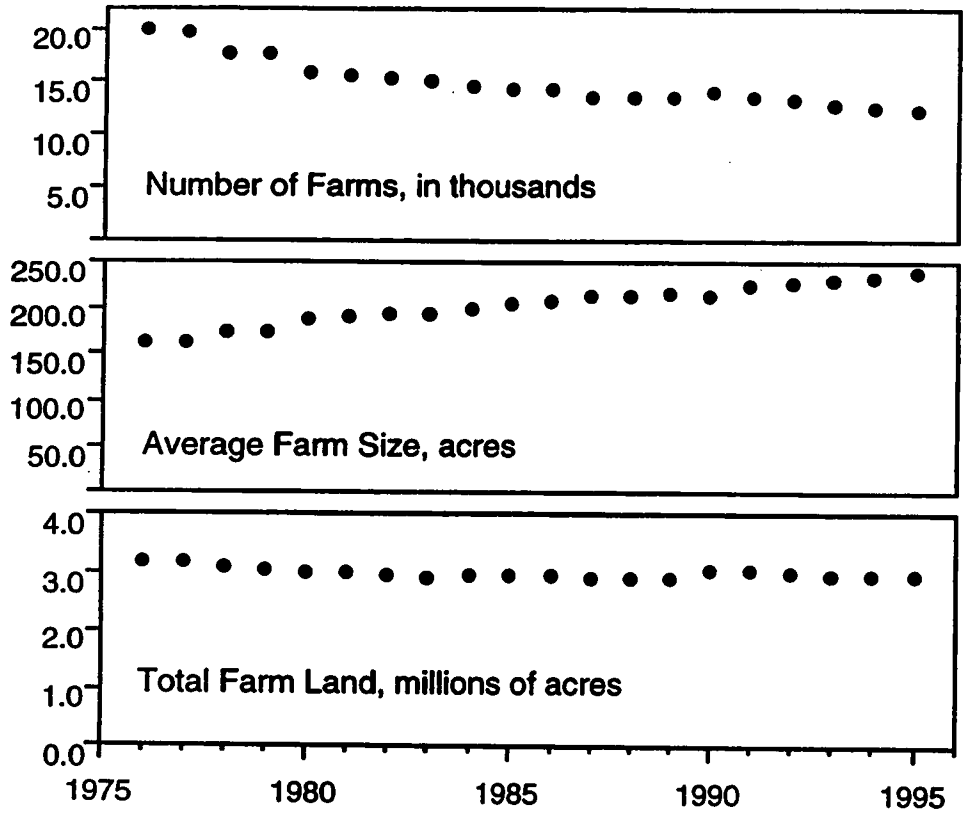

Figure 3. Farm land use in the Maumee Basin, 1975-1995

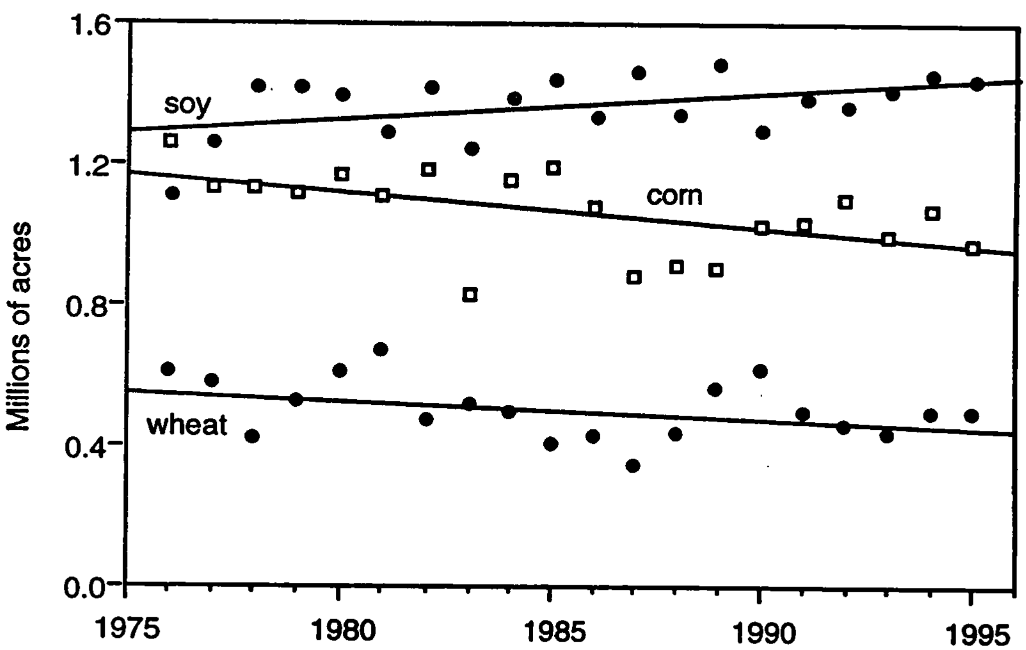

Figure 4. Trends in cropping patterns in the Maumee Basin, 1975-1995

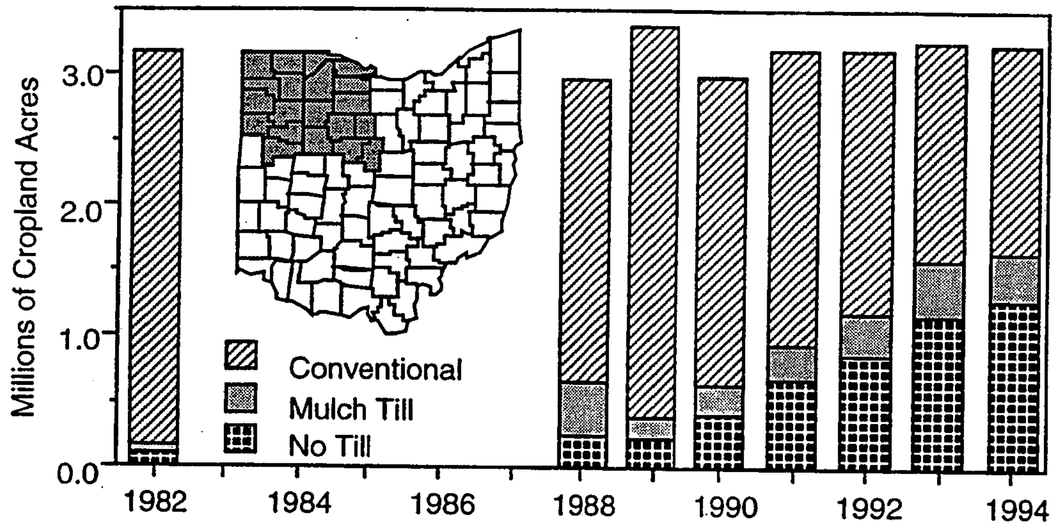

Figure 5. Conservation tillage adoption in northwest Ohio, 1975-1995

Sales of fertilizer phosphorus peaked about 1980 and have since declined by nearly 50%. Sales of fertilizer nitrogen peaked in the Maumee basin about 1980 and have since decreased by about 25% (Figure 6). Phosphorus from manure constitutes 15% to 20% of that from commercial fertilizer, and nitrogen from manure constitutes 30% to 40% of that from commercial fertilizer. Both have declined about 20% over the 20 year study pattern, primarily since the early 1980's.

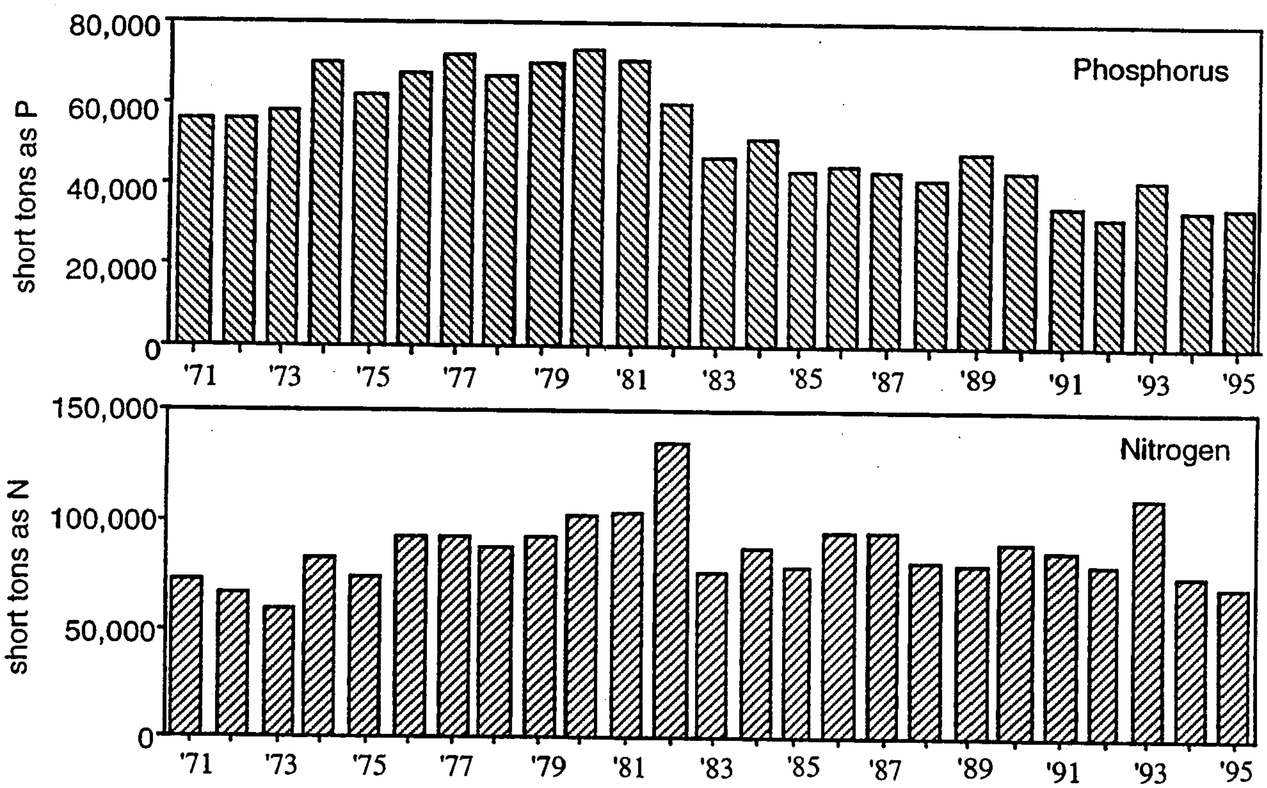

Figure 6. Commercial fertilizer sales in the Maumee Basin, 1971-1995

Changes in the Soil Resource

Unit area loads of sediment, phosphorus and nitrogen (nitrate plus Kjeldahl) monitored at the Maumee River sampling station at Bowling Green, Ohio, average 614, 1.2, and 19.9 lb/acre/yr, respectively. Over the 21-year study period, these losses amount to more than 26,000,000 tons of sediment and 50,000 tons of phosphorus, and nearly 850,000 tons of nitrogen for the watershed as a whole. Since point sources are a minor component of loads, and 88% of the basin is in agricultural land uses, most of these loads represent losses of resources from agricultural lands.

Comparisons of soil cores from the 1950's and 1960's, archived at Ohio State University, with cores from the same locations taken in the past year, indicate that soil fertility has generally increased during the study period, in spite of losses to erosion. Phosphorus levels are generally above those required for crop maintenance, and are believed to still be increasing gradually. However, nutrient use has become much more efficient. Watershed-wide mass balance calculations indicate that, in the peak three years of the study period, 1979-1981, about half of the phosphorus coming into the watershed from all sources was not exported, but contributed to nutrient buildup. In the final three years of the study, the phosphorus surplus was down to five percent, a very significant improvement in the efficiency of nutrient use.

Change in Crop Yields

Crop yields for the three major crops, measured on a per-acre basis, have increased during the study period (Figure 7). Corn yields are up about 25%, wheat 30%, and soybeans 17%.

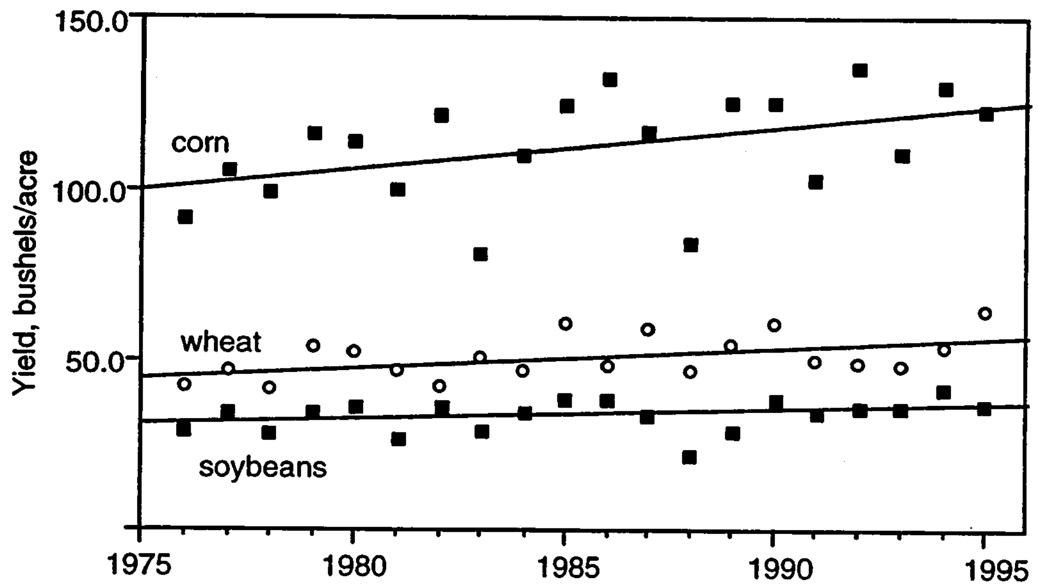

Figure 7. Crop yields in the Maumee Basin, 1975-1995

Changes in Water Quality

Water quality changes were evaluated by conducting trend studies of concentrations and loads. Trend analyses were performed on load and concentration data aggregated at the daily, monthly, and annual levels as well as on storm event loads and concentrations. Most analyses were done using log-transformed concentrations or loads, using an ANCOVA model which included the month (categorical variate) and the log of flow (continuous) as well as time (continuous).

The results of representative trend analyses are shown in Figure 8 for discharge, suspended sediment (SS), total phosphorus (TP), soluble reactive phosphorus (SRP), nitrate + nitrite (NO3), and total Kjeldahl nitrogen (TKN). Within each group of bars, the leftmost is the trend based on annual loads, the next is annual flow-weighted mean concentrations (FWMCs), the third is storm event mean concentrations (SEMCs), the fourth is monthly FWMCs, and the fifth is daily FWMCs. Annual trends were not analyzed for TKN. The percent change over 21 years relative to the initial values is shown by the length of the bar, and the statistical significance of the trend analysis is shown by dots within the bar: none, not significant; •, p<.05; ••, p<.01; •••, p<.0001.

These analyses show that average discharge has increased in the Maumee River. Very major decreases have occurred in SRP concentrations, and substantial decreases have occurred in SS, TP, and TKN concentrations. Substantial increases in NO3 concentrations have also occurred.

While most analyses suggested comparable amounts of change for a given parameter, the level of statistical significance was generally highest for daily data, and lowest for annual and storm event data. We were somewhat surprised that daily data performed the best, because of its tremendous variability. However, the use of log transformations and the use of flow and seasonality (months) as covariates substantially reduce this variability, and the large number of observations lend statistical strength. Apparently, the benefit of reduced variability afforded by averaging data over monthly or larger time scales is outweighed by the loss of degrees of freedom which results from the averaging process.

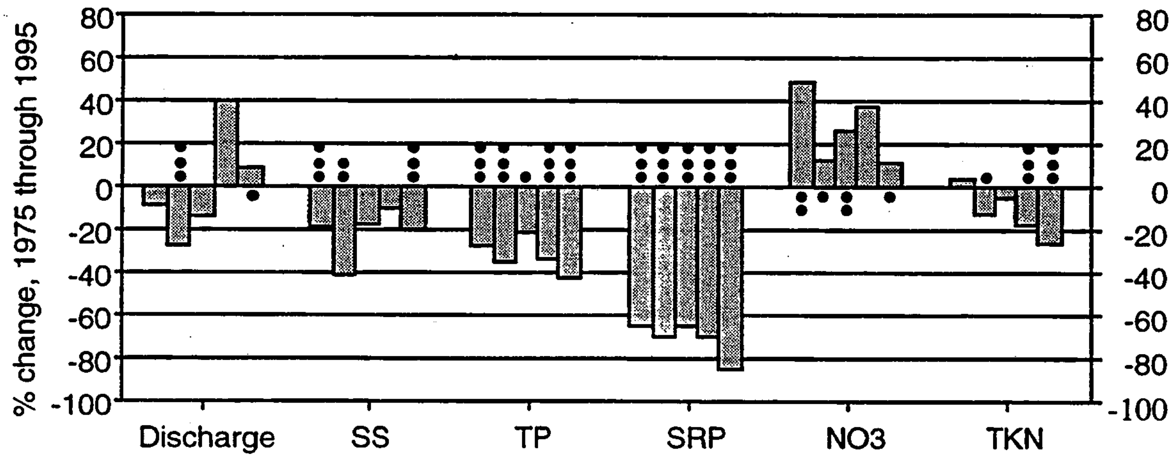

Figure 8. Trends in nutrient and sediment concentrations in the Maumee Basin, 1975-1995. Within each group of bars, the leftmost is the trend based on annual flow-weighted mean concentrations (FWMCs), the next is storm event mean concentrations (SEMCs), the third is monthly FWMCs based on storm data only, the fourth is monthly FWMCs based on all data, and the fifth is daily FWMCs. The percent change over 21 years relative to the initial values is shown by the length of the bar, and the statistical significance of the trend analysis is shown by dots within the bar: none, not significant; •, p<.10; ••, p<.01; •••, p<.0001.

The relatively poor performance of storm event measures was unexpected, since many BMPs are designed specifically to stop erosion during storm runoff. Analysis of the trends in data partitioned into three ranges by flow showed that, for parameters for which the overall trend is downward, the greatest change occurs during the low flow periods, and the smallest during high flow periods. NO3 shows upward trends in the high and medium flow ranges, but downward trend in the low flow range. Flows in the highest range themselves show a downward trend, those in the middle range show no trend, and those in the lowest range show an upward trend.

Similarly, flows during the first storm runoff event in a group of closely spaced events have a downward trend, while flows in the later events in a cluster have an upward trend.

One reasonable interpretation of these results is that infiltration has increased, and overland flow has decreased. Conservation tillage is at least partly responsible for this change. Trends in concentrations at different flow regimes suggest that changes in nutrient use patterns and management practices which target erosion have both contributed to improvements in water quality. The largest *percent* changes are typically associated with low flows, when erosion is not an active process. However, since concentrations and especially loads are usually higher under high flow conditions, the largest *absolute* changes are associated with storm runoff.

Lessons Learned

- Management programs sometimes succeed in ways other than planned. No-till was initially intended as a corn practice, but most of its implementation in the Lake Erie basin has been with soybeans.

- Substantial water quality improvements can be accomplished at a large watershed scale by a mosaic of agricultural management programs, even if optimal targeting is not practiced and a single oversight agency is lacking. However, 10-20 years may be required before sufficient change occurs to be statistically significant.

- Water quality improvements need not come at the expense of lowered crop yields.

- Water quality improvements can be readily documented given appropriate statistical approaches and detailed monitoring data over a long enough period of time.

- At least for this study area, storm event concentrations and loads are less efficient metrics for revealing trends than traditional daily observations. Stratification of the data by flow showed that decreases, in percentage terms, were generally greater at lower flows, but were greater in absolute terms at higher flows.

Acknowledgments

We thank our LEASEQ colleagues Frank Calhoun and Don Eckert for providing data on changes in soil fertility and agricultural practices, respectively. Data on conservation tillage implementation were provided by Gary Overmyer of the Natural Resources Conservation Service. Point source phosphorus load data were provided by the International Joint Commission, Windsor Office, and the Ohio EPA.

Elm Creek HUA: Results and Impact

Chuck Burr
Clay County Cooperative Extension, Clay Center, Nebraska

Setting

Elm Creek is a spring fed stream located in south central Nebraska that supports a put-and-take trout fishery. High peak flows and subsequent sedimentation caused by high intensity-short duration thunderstorms are factors which negatively impact instream water quality and habitat.

Objectives and Implementation

Project objectives include reducing peak flows, in-stream sedimentation, and maximum summer water temperatures, as well as improving aquatic habitat. Implementation involves public education and cost-share assistance to encourage adoption of best management practices. Evaluation includes tracking adoption of BMPs. To determine if improvements in water quality and aquatic habitat are being achieved, weekly grab samples, seasonal fish and macro-invertebrate collections, and substrate and habitat evaluations are being conducted.

Environmental Benefits Measured

The Natural Resources Conservation Service is tracking acres and total soil savings that have been protected with structural BMPs. Artificial habitat improvements involved the installation of seven lunkers to stabilize streambanks while providing habitat and protection from peak flows. The AGNPS computer model was run at the beginning of the project and a follow-up analysis will be used at the conclusion of the project.

Lessons Learned

Improvements in water quality or reductions in peak flow are difficult at best to measure directly since large runoff events may be masking any improvements that would exist under normal flow conditions. Also, in a State like Nebraska where the majority of land is privately owned, having project support from landowners is critical for success.

HUA Crop Management Service Continues As Farmer-Run Crop Management Association

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Missisquoi Bay is one of the most eutrophic in Lake Champlain with phosphorus concentrations as high as those in Lake Erie in the 1970's. A significant portion of the P load in this dairy production area has been attributed to runoff from agricultural nonpoint sources such as manure, fertilizer and cropland erosion.

As part of the Lower Missisquoi HUA, we established a Crop Management Service to develop whole-farm nutrient management plans, which included nutrient, pest, and other crop management services. The goal was to improve management practices, especially for manure and fertilizer, to reduce the potential for environmental impact and to increase the farmers' economic return. Between 10 and 14 farmers enrolled a total of up to 1700 acres of cropland each year of the program (Table 1).

Table 1. Yearly summary of number of farms and acreage enrolled in the Missisquoi Crop Management Service. 1991-1994.

		Crop				
Year	# Farms	Corn	Alfalfa	Clover	Grass	Total
		----------	----------	acres	----------	----------
1991	10	511	339	44	493	1386
1992	12	566	434	125	459	1584
1993	14	462	287	169	812	1731
1994	10	478	284	252	710	1725

The services provided varied with the crop, as follows:

Nutrient Management Package (all crops)
- Fall soil sampling and analysis
- Manure sampling and analysis
- Nutrient management planning
- Fertilizer recommendations
- Pre-sidedress Nitrate Test for corn (sampling and analysis)
- Computerized crop record keeping

Corn Pest Management Package
- Spring weed assessment
- Population count
- Scouting through season of insect pests
- Fall weed assessment
- Pest management planning and recommendations

Alfalfa Management Package
- Winter injury assessment
- Spring crown count
- Scouting through season of insect pests
- Fall Crown Count
- Pest management planning and recommendations

Grass, Clover and Pasture Management
- Species assessment

The Vermont computerized crop recordkeeping system was used by the farmers to monitor crop inputs, manure applications, yields, weeds and pest problems, costs and returns. Participants received an Input Booklet at the beginning of each cropping season for recording information and returned it at the end of the season for entry into a computer database. Computer-generated summary reports were made for each farm and included comprehensive data by field and by crop. These summaries were then used by the farmer and the ICM consultant to make management decisions for the next cropping season.

Nutrient Management Planning

A key element of the Crop Management Services was the development of nutrient recommendations for individual fields on each farm. The ideal is to have soils that have adequate nutrient levels to support good crop production but not excessive levels that have a greater potential for adverse impact on water quality. To these ends, each field on each of the cooperating farms was soil sampled annually, usually in the fall, for routine soil testing of pH, available and reserve P, K, Mg and Al. Corn fields were sampled for nitrate in the summer, as well. Soil test results were combined with crop and soil information and manure analysis and management information to make nutrient recommendations using the Vermont Manure Nutrient Manager, a Lotus123 spreadsheet template.

Soil test results varied greatly on individual fields. For example, in 1993 over half (56%) of the fields were medium to optimum in available phosphorous, about a fourth (24%) were low to very low, and the remaining 20% were high to excessive. Almost all farms have some fields higher than optimum (high or excessive), which means they need no additional P for crop production and pose a potential problem for surface water quality. But most farms also have some fields with lower than optimum P soil test levels, indicating a need for additional manure or fertilizer P to maintain crop yields. Results of the Pre-sidedress Nitrate Soil Test (PSNT) for corn showed a large range in nitrate test levels among individual fields, as well as differences in overall average values for different years. Several cooperators saved N fertilizer expense and reduced the potential for nitrate pollution of surface and groundwater through use of the PSNT. These results point out the critical importance of soil testing to indicate those fields that need little or no additional fertilizer to maintain top yields and those that require additional amounts to maintain top productivity.

Manure sampling was done, as part of the nutrient management package, to assess the nutrient contribution from manure and to avoid excessive applications. Manure was sampled at least annually on all farms on the program, either by the farmer or by the project technician. Considerable variation occurred among farms, as much as a two-fold difference in nutrient content of manure from different farms, which points out the importance of basing recommendations on nutrient analysis rather than on standard estimates. This is particularly important in watersheds such as the Missisquoi where two-thirds of the phosphorus applied to cropland comes from manure.

Recommended vs. Applied Nutrients: Environmental and Economic Impacts

To evaluate how well farmers were following our manure and fertilizer recommendations we used information from the crop record keeping system to compare rates actually applied to those recommended. In 1993 application rates of phosphorus were within 20 lbs P_2O_5/acre of the recommended rate on about 75 percent of all crop acreage (Fig. 1). Nitrogen fertilizer was applied to corn at rates recommended by the PSNT (+/- 20 lb/acre) on 80 percent of the acreage, the average rate being within 5 lb/acre of the recommended rate. This appears to indicate fairly good acceptance of a nitrogen test that, on average, recommends less than conventional recommendation methods.

Following recommendations gave positive economic and environmental results for participating farmers. Overall, there was a significant reduction in the use of commercial fertilizer after the farms enrolled in the crop management service, based on a study of seven farms in the project (Knight et al., 1997. See these proceedings). Phosphorus use decreased by an average of 40 percent and potassium by 29 percent over a 3-year period. Also, farmers changed their timing of nitrogen application in ways that increase the availability to the crop and decrease losses to the environment. The farms in the study reduced total expenses by an average of $27/ acre, while crop yields remained constant.

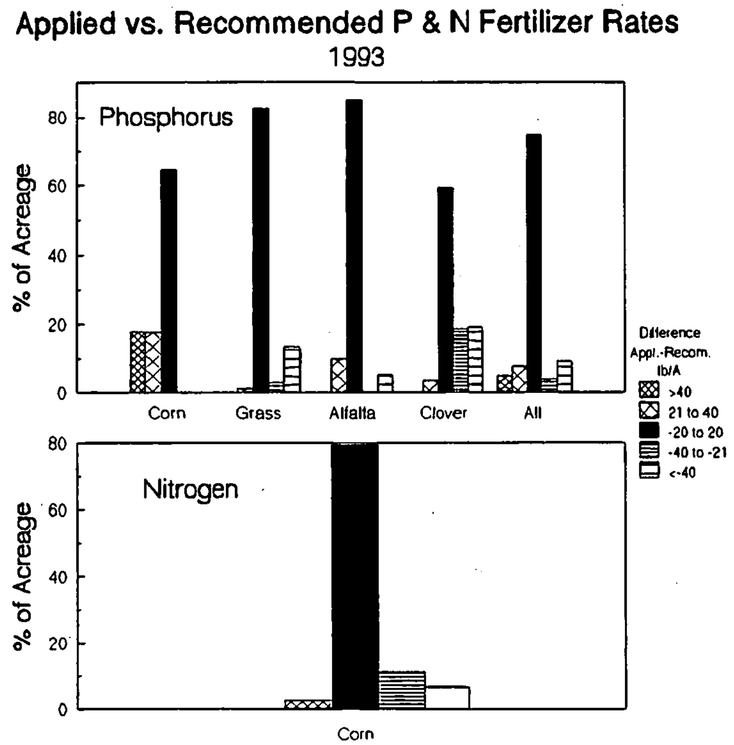

Fig. 1. Difference between applied and recommended P and N application rates. 1993.

Transition to a Farmer-owned Crop Management Association

The Crop Management Services Program was designed to be a pilot program that would eventually become self-sustaining so that it would continue beyond the funding period of the HUA. In an attempt to accomplish that goal, ICM services were offered free of charge in the first year to encourage participation without financial risk, but in successive years farmers were required to pay an increasing share of the cost of the services (Table 2). The intent was to have a self-supporting program by the end of the 5-year funding period, whether by private consultants, by a crop management association, or by farmers providing their own crop management services. That goal became a reality in the 1995 growing season with formation of the Missisquoi Crop Management Association, a farmer owned and operated crop management association.

The Association offers the same services as were offered by the HUA crop service. However, the ability to pick and choose services has been greatly increased to allow members to pay only for services they feel they need. All costs for services are based on the "actual cost of doing business".

During the 1996 season the CMA had 12 members and over 2000 acres enrolled (800 acres of corn, primarily silage, and over 1200 acres of legume and grass hay). A complete nutrient management program was done on 152 fields, including most of the crop acreage in the program. Scouting for a variety of pests was carried out on 55 corn fields (656 acres) and 14 alfalfa fields (170 acres). Corn scouting included fall and spring weed assessments, plant population counts, corn rootworm counts, and/or a complete weed management package. Alfalfa scouting options were fall and spring crown counts and scouting for potato leafhopper and alfalfa weevil. Computerized crop record keeping was carried out on ten farms (168 fields).

Table 2. Yearly pricing structure for the Missisquoi Crop Management Services.

	Crop			
Year	Corn	Alfalfa	Clover	Grass Hay
	Cost, $ per acre			
1991	No Charge			
1992	2	2	1	1
1993	4	4	2	2
1994				
Complete	6	6	3	3
Nutrient only	4	3	3	3

Summary

- Nineteen farms have participated in the Missisquoi Crop Management Services since 1991. The Missisquoi Crop Management Association, a farmer owned and managed independent organization, grew out of the Crop Management Service and now has twelve members and over 2000 acres enrolled.

- Soil test levels varied greatly among fields (low to excessive) and manure nutrient content showed two-fold differences among farms, emphasizing the importance of soil testing and manure analysis for field-specific nutrient management plans.

- Farmers enrolled in the Crop Management Services program generally followed the nutrient recommendations made by the project technician. This resulted in nutrient applications that reduced loading of phosphorus to fields and decreased fertilizer costs to the farmers, contributing to both water quality and economic goals of the project.

On-Farm Field Trials Demonstrate and Quantify the Environmental and Economic Benefit of BMPs.

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Missisquoi Bay is one of the most eutrophic in Lake Champlain with phosphorus concentrations as high as those in Lake Erie in the 1970's. A significant portion of the P load in this dairy production area has been attributed to runoff from agricultural nonpoint sources such as manure, fertilizer and cropland erosion.

As part of the Lower Missisquoi HUA, we conducted a number of on-farm trials, in most cases replicated, to demonstrate best management practices we were encouraging farmers to adopt and to quantify the economic and potential environmental effect of the practices. Other demonstration trials were done as part of an RCWP project in the same county.

All demonstrations were done on farms participating in the crop management services or association. Most field operations were carried out by the farmers as part of their normal activities so that conditions would represent those on Vermont dairy farms. Field sites were included in tours and field days for viewing by farmers and other ag professionals; the data from the trials has been used at many educational meetings and included in written materials and mass media presentations. Selected results include the following:

- Top yields of alfalfa-grass on soils testing "optimum" or higher in phosphorus can be maintained with application of potash only, thus avoiding economic, and potentially environmental, costs associated with applying unnecessary phosphorus fertilizer (e.g. a typical 0-10-40 or 0-10-30 blend). Avoiding P-containing fertilizer blends on these soils showed reductions in P application of as much as 60 lb P_2O_5 per acre and potential cost savings to the farmer of $10 to $15 per acre.

- Application of either liquid dairy manure or NPK fertilizer doubled yields of mixed grass-broadleaf hay that had been historically under managed. Reliance solely on manure to meet crop nitrogen needs, however, provided excess phosphorus and raised the P soil test into the high category. Concentrations of P in runoff were highest from the manured plots, reflecting higher P loading and resultant soil test levels. A combination of lower manure rates and N fertilizer is probably the best recommendation to optimize use of resources and reduce adverse water quality impact.

- Because of poor nitrogen utilization, semi-solid dairy manure was not able to meet the nitrogen needs of orchardgrass hay, even when applied in multiple applications at high rates (about 30 tons/acre/year). However, the combination of N fertilizer and manure provided excellent yields and forage quality. Phosphorus removal was primarily a function of crop yield; therefore, fertilizer N was an important tool in optimizing a P balance (by increasing yield without adding P). A moderate rate of manure (approximately 10 tons/year) combined with fertilizer N provided adequate P for crop needs while reducing adverse water quality impact.

- Dairy manure applied in the fall or spring with methods that provide immediate incorporation (sweep injectors, s-tine/field cultivator) produced higher corn silage yields than manure surface-applied in the fall. Incorporation minimized ammonia N losses and protected manure nutrients from loss in runoff. Slightly higher yields were obtained with sidedressed fertilizer N, presumably because the timing avoided the high rainfall periods in the spring and early summer when N loss was highest.

- The pre-sidedress nitrate test (PSNT) reflected the differences in N availability shown in yields from different manure application methods, reinforcing its value as a tool to assess N fertilizer need. Several cooperators saved N fertilizer expense and reduced the potential for nitrate pollution of surface and groundwater through use of the PSNT.

- Ryegrass or clover covercrops interseeded at last cultivation can be successfully established in silage corn, providing erosion and runoff protection at a relatively low cost.

- Starter fertilizer rates half of those typically used (e.g. 25 vs 50 lb P_2O_5/acre) consistently produced top corn silage yields, thus saving farmers $10/acre and reducing P loading and its potential runoff effects. (From St. Albans Bay RCWP)

- Well-managed dairy manure applied at a typical rate (20 ton/acre) supplied the equivalent of 100 lb N/acre as fertilizer, eliminating the need for all but a low rate of planter-applied starter fertilizer. The pre-sidedress nitrate test (PSNT) reflected this increased N availability, supporting its use as management tool to avoid excessive N application. (From St. Albans Bay RCWP)

Arizona's Water Quality and Hydrologic Unit Area Projects to Promote BMPs

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This presentation centers on Arizona's experience with projects to minimize losses of fertilizer nitrogen below the root zone of cotton. Environmental benefits were inferred by the documentation of changes in production practices that impact groundwater quality. The primary production practice change measured was use of split applications of nitrogen fertilizer. This practice provides the single most important practice change to protect groundwater from nitrate nitrogen leaching losses, for growers who have already minimized irrigation water applications and total nitrogen applications. This is due to the fact that those who do not split their applications of nitrogen, usually apply it prior to planting and early season irrigations. For agricultural production systems using surface application of water, the initial 2 or 3 irrigations are the least efficient, resulting in the greatest likelihood of water and nitrate leaching losses below the root zone.

Demonstration plots indicated that the most serious losses of nitrogen occurred when animal manure was used in the cotton production system. For growers who changed from one time nitrogen fertilizer applications to split applications, reductions in nitrogen losses ranged from estimates of approximately 10 pounds per acre, to almost 100 pounds per acre, in one case. An increase in grower use of split nitrogen fertilizer applications occurred over the first 3 year period of the projects, as documented by surveys conducted by the Arizona Agricultural Statistics Service. The percentage of growers applying fertilizer only at the beginning of the growing season decreased from 12% to 3% from 1991 through 1993.

Additional information obtained from the surveys indicated that the statewide application rates of nitrogen per acre to cotton decreased during the first 3 years of the project, from 170 to 149 pounds per acre. However, survey data indicated that nitrogen application rates increased to 223 pounds per acre in 1994 and 194 pounds per acre in 1995. A regression analysis indicated that approximately two-thirds of the variation in N fertilizer applied in any given year could be explained by the price received for upland cotton in that year. Secondly, yields in 1993 and 1994 were greater than in 1992, likely encouraging growers to plan greater N applications in subsequent years (1994 and 1995) to meet the crop N needs due to greater expected yields. Additionally, crop growing conditions in 1995 resulted in a statewide trend to extend the growing season, requiring the addition of more nitrogen fertilizer late in the growing season, even though the actual crop yields were lower than they were in 1993 and 1994.

Practice changes related to reductions in nitrogen losses to groundwater can be documented, particularly the reduction in the percentage of growers applying nitrogen only at the beginning of the season. Cooperators in the Hydrologic Unit Areas were interested in protecting water supplies and reducing on-farm costs, and implemented selected Best Management Practices.

Accomplishments and Challenges of Data Collection and Modeling in North Carolina Demonstration Watershed Project

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This report describes some of the water quality modeling accomplishments and the lessons learned on the North Carolina Demonstration Project. In 1990 the Herrings Marsh Run Watershed in the Southeastern coastal was chosen as the site of a Demonstration Project. The overall goal of the demonstration project was to encourage the accelerated voluntary adoption of management practices and technologies that measurably improve the surface and ground water quality. The 5000 acre watershed is in Duplin County North Carolina, an area of intense and diversified cropping with increasing livestock production. There are about 120 farms and 350 fields in the watershed. This is an environmentally sensitive area where some of the streams are currently suffering water quality impairments. A wide variety of best management practices (BMPs) have been applied on the watershed as part of the project. See the papers by Humenik and Cook, both in this volume, for additional project information.

The modeling component of this project is meant to support the overall goal by evaluating individuals BMPs and specific models at the field and watershed scale. Additionally, we would like to use watershed scale models to assess the application of BMPs over broader regions.

A variety of data was collected to support the modeling and other components of the project. Farmer surveys were taken every year to identify the field-specific cropping and management practices, and the number and management of livestock. Cropping and management information on the farmer surveys have been augmented by other data sources such and the US Department of Agriculture (USDA) Farm services Agency (FSA) and Natural Resources Conservation Service (NRCS) databases. Water quantity and quality data have been collected by a variety of agencies including the Cooperative Extension Service (CES), the USDA Agricultural Research Service (ARS), and the US Geological Survey (USGS). Climate data was collected from an on-site weather station and augmented with local weather station data. Spatial data describing soils, topography, hydrology, and non-agricultural land cover was collected from a variety of sources. The agricultural field boundaries were digitized from FSA aerial photography. Most of this data has been incorporated into a geographic information system (GIS) to facilitate data queries and modeling. With respect to modeling, this data has been used to calibrate or validate GLEAMS, EPIC, and SWAT under a variety of situations, to classify remotely sensed imagery, and to evaluate BMPs at the field scale.

Modeling Accomplishments

Simulating a Swine Waste Field With GLEAMS

The GLEAMS model was used to simulate an overloaded spray field and to investigate the spray field's recovery as application rates were reduced. Initial monitoring at the spray field found nitrate-N > 80 mg/L in the shallow ground water and nitrate-N > 8 mg/L in an adjacent stream. The GLEAMS model was used to simulate the observed high initial ground water nitrate-N concentration simulating the high loading rates at this site. BMPs were implemented at this site; the spray field was expanded and the nutrient application rates reduced. Ground water nitrate-N concentration reduced approximately 40% in three years after the BMPs were implemented. The GLEAMS model simulated this recovery and reduction of the ground water nitrate-N concentration with absolute errors of less than 18 mg/L.

Simulating Changes in Leaching Due to Reduced Pesticide Application

EPIC was used to simulate the effect of nitrogen (N) and pesticide application rate on pollutant leaching for several cropping scenarios. For example, one study included a conventional corn production scenario with the same sidedress N application rate for each soil (160 lbs/acre N) and an alternative scenario where the sidedress N rate was varied to reflect crop production and plant uptake capabilities for each soil (55 to 149 lbs/acre N). Results of a 30-year, daily time step simulation (Table 1) show that leaching can be reduced by avoiding over application of N. Conventional and alternative pesticide simulation results show that reducing pesticide application rate, reduces leaching for the Norfolk soil (Table 2).

Table 1. Shows simulated nitrate leaching for corn produced with mineral fertilizers.

Soil	Conventional lbs/acre (ppm)	Alternative lbs/acre (ppm)	%Change in Loading dimensionless
Autryville	28 (4)	25 (4)	11
Blanton	81 (11)	75 (10)	7
Foreston	16 (6)	12 (4)	25
Goldsboro	62 (17)	57 (15)	8
Norfolk	36 (11)	29 (9)	19
Rains	43 (21)	42 (20)	2

Assessing the Leaching Potential of Soil/Pesticide Combinations

EPIC was used to run 30 year simulations for combinations of 17 soils, 12 pesticides, and four crops typically occurring in the Herrings Marsh Run watershed. The model was quite sensitive to changes in the pesticide parameters for adsorption and degradation, indicating the need to provide values that reflect actual field conditions or present results as a range of values. Different soils also presented a wide range of predicted leaching losses. The results are being compared to a simple index of soil and pesticide leaching potential as well as actual ground water detections in order to determine the most efficient and effective approach to predicting ground water sensitivity to pesticide contamination. Once this evaluation is completed, the resulting ground water vulnerability assessment will be incorporated into the WATERSHEDSS online decision support system.

Table 2. Simulated pesticide leaching for corn production.

Pesticide		Conventional		Alternative	
Brand Name	Common Name	active ingredient applic. rate lbs/acre	Leachate oz/acre (ppt)	active ingredient applic. rate lbs/acre	Leachate oz/ac (ppt)
Bicep 6L	MetolachlorAt	1.60	0.142 (3000)	1.28	0.114 (2000)
	razine	1.20	0.086 (2000)	0.97	0.071 (1000)
Furadan 4F	Carbofuran	5.84	0.557 (11000)	4.49	0.428 (9000)
Lasso 4EC	Alachlor	3.00	0 (24)	2.00	0 (20)
Aatrex 4L	Atrazine	1.50	0.099 (2000)	1.00	0.071 (1000)
Lariat 4F	Alachlor	2.50	0 (17)	1.56	0 (16)
	Atrazine	1.50	0.099 (2000)	0.938	0.057 (1000)

Simulating Changes in Water Quality due to Changes in Riparian Buffer Widths

The Soil and Water Assessment Tool (SWAT) was used to assess the impact of varying riparian buffer widths on nitrogen load. Digital elevation models were used to divide part of the watershed into subbasins. Approximate land use was derived from farmer survey data. After calibration of flow and nutrient loading different subbasin sizes were evaluated. The watershed was broken up into 3, 11 21, and 81 subbasins; 11 subbasins gave the best results. Hypothetical riparian areas of 0 to 60 meters in width were added around all streams and the simulations were run again on this new data. The simulation results indicated that increasing the riparian areas would decrease the nitrogen load. Two caveats should be noted: 1) the nitrogen loads could not be calibrated well given the data set being used at that time, and 2) the SWAT model has not been validated for riparian areas. We are working to overcome both of these limitations.

Development of Spatial Filters to Incorporate Remotely Sensed Land Cover Imagery

A Landsat Thematic Mapper image was classified using image processing techniques. The accuracy of the classified land cover data was quantified using overall and class specific accuracy measures. In addition to the typical rectangular mode (or majority) filter, a polygon mode filter (also called an object filter) was applied to the classified data. After the application of the filters the overall land cover accuracy was measured again. Whereas the rectangular filter used a kernel of fixed size the polygon filter uses a kernel determined by *a priori* knowledge of homogenous regions (e.g., fields). Each of these filters reduces the 'salt-and-pepper' or speckle associated with digitally classified satellite data.

The rectangular mode filters improved the classification accuracy of the land cover data by 4% to 6%, but decreased the class specific accuracy in the classes containing many small patches. The polygon mode filter improved the overall accuracy by 14% to 16% and the class specific accuracy by up to 28%. The polygon mode filter also reduced the heterogeneity of the classified image so that only one crop was represented for each farm field.

The application of the spatial filters is an important step in incorporating digitally classified remotely-sensed data into a GIS. The rectangular mode filters while good at reducing image heterogeneity can destroy small patches. The polygon mode filter improves classification accuracy better than the rectangular filter and does not destroy small patches, however, it requires *a priori* knowledge of the homogenous areas.

Lessons Learned

Lack of Response on Farmer Surveys

Initially, it was planned to gather all land use, livestock, and management data via farmer surveys. Before any surveys were collected, the project and its goals were advertised heavily within the watershed and the local area. The goal in advertising was to make sure each farmer heard about the project at least four times before they were contacted personally to complete a survey. Then, farmers were contacted on the phone or personally by a Cooperative Extension Service (CES) technician, who explained the project and the reason for the survey, and distributed an educational brochure.

The number of farmers willing to complete the survey was rather low. The initial survey in 1990 got responses covering 40% of the fields. Responses covered only 17% of the fields during 1991 to 1993, and 31% of the fields in 1994. The decrease after 1990 could have been due to the length and time required fill out the first survey tool. The increase in 1994 was due to the efforts of a new technician trained in animal science.

Recommendations: Keep the surveys as short as possible. Farmer surveys are an excellent tool to get very specific information for field scale studies. However, plan to use some alternate sources of information on cropping and management data for watershed studies.

The Reliability of Farmer Survey Information Varied

The reliability of information obtained from the farmers varied considerably. Because some of the farmers relied on memory to answer questions, their information was not as reliable as those who kept records. Some farmers were unsure about the crop, tillage, and nutrient or pesticide applications on a particular field.

Farmers relying on memory were sometimes not able to give basic information for the field. More often they knew what crop was grown, but could not remember information such as the planting and harvesting date, and the levels of chemicals applied. This situation was exacerbated on occasions when the surveys were given to the farmers more than a year after the end of a growing season.

Recommendations: Identify critical information for each application and try to ensure it is collected. Use alternate data sources to simplify the farmer surveys (see later discussion). Survey the farmers soon after harvest.

Additional Sources of Cropping and BMP Implementation Practices are Valuable

As it became clear that the farmer surveys were not going to meet all of the data needs of this project additional sources of information were utilized. The simplest data to collect were "windshield surveys". Technicians visually inspected the fields in the watershed twice a year determining the summer and winter crops on each field. This provided cropping data for every field in the watershed.

Data from the NRCS was obtained to indicate where BMPs were being implemented. These data were helpful in determining how some of the farmers were managing their fields. The FSA also keeps records on summer and winter crops planted on each field. This provided field specific cropping information for the five previous years. However, when farmers split cropped the fields this data did not indicate where on the field the each crop was planted.

Recommendations: Use alternate information sources to acquire data or fill in missing data and where possible to simplify the farmer surveys.

Complex Simulation Models are Extremely Data Intensive

Water quality models designed for agricultural areas are fairly complex. The data requirements, however, can be very intense since site-specific data on cropping and management, climate, sub-surface variables, and stream reaches must be supplied. Recently, for the purposes of simulation, this watershed is split into 100 to 500 subwatersheds and contains as many stream reaches, and about 10 ponds. Detailed descriptions for each of these entities are necessary. Additionally, multiple years of cropping and management data must be supplied for model calibration. A calibration run in this situation can require that over 100,000 values be specified.

Several tools are making the job of specifying simulation values easier. Notably windows-based database interfaces and GIS interfaces can greatly simplify the task. However, it is still nearly impossible to acquire excellent estimates for all of the site-specific and multi-temporal values needed.

Recommendation: Identify the most important input variables and concentrate on getting good estimates for those variables. Estimate the remaining variables as well as possible.

Spatial Generalization of Soils Data Introduces High Variances in Model Results

Physical environmental data; particularly soils, slope, and agricultural fields; describing the watershed were integrated into a GIS. A GIS-based interface to GLEAMS was used to run GLEAMS on randomly chosen fields. As a baseline, the original detailed soils and slope data were used. The results of these simulations were compared to simulations where the slope or soils data were generalized to the dominant class within each field.

Comparison of these simulation results showed that field scale model results can vary by up to 100% when soils data is generalized within an individual field. This did not account for natural variation in soil properties. Variation due to the generalization of slope was much less, although this is a topographically mild area.

Recommendation: Researchers should be very careful about simplifying soils data to be used in simulation models as it can introduce high variances in some output variables. These variances should not be ignored. Rather the variances should either be avoided or taken into account when using modeling results to simulate the effects of BMPs in the landscape.

Phosphate Concentrations in Subsurface Drainage Effluent In East-central Illinois

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Abstract

The objective of this study was to quantify the movement of dissolved, molybdate-reactive phosphate (DMRP) to subsurface perforated drainage tubes (tiles) in fine textured soils with a variety of crop management systems commonly used in the Midwestern-US. Subsurface tile flow and DMRP concentrations from seven fields with various crop management practices have been monitored for 22 months and an eighth field has been monitored for 16 months. DMRP concentrations were also determined at various locations along the mainstream of the watershed. Concentrations of Bray P-1 in the top 10 cm of the soil were also measured. Flow weighted mean DMRP concentrations in the tile drain effluent ranged from 0.05 to 0.13 mg-P/L. There was little apparent relation between Bray P-1 concentration in the surface layers of soil and the concentrations in the tile drain effluent. Concentrations of DMRP in the river averaged 0.12 mg-P/L.

Introduction

In the 19th century, much of the land in the Midwestern US was converted from prairie to row-crop agriculture due to favorable soils, climate and social institutions (Bouge, 1963). Many areas were swampy and water was removed by the construction of drainage ditches and installation of subsurface drain tubes commonly referred to as tiles (Bouge, 1951). Presently, 90% or more of the land in many Midwestern watersheds is used for row crop production. Chemical fertilizers and pesticides are used and a significant portion of fields are underlain with tiles. The movement of agrichemicals to drain tiles, ditches and streams may significantly impair down-stream water quality depending on the rate of chemical movement.

There have been many studies of the movement of nitrate nitrogen to tile drain effluent and drinking water supplies in this setting (Logan et al., 1980). Studies of phosphorus transport have been less common. Compared to nitrate, phosphorus is much less mobile in the soil and does not present a direct risk to human health. Nonetheless, phosphorus is an important water quality constituent because it influences the growth of algae and the process of eutrophication (Sharpley et al., 1994). Eutrophication can reduce the quality of water for recreation and wildlife and increase the cost of treating water for human consumption. In Illinois, more than 93% of the lakes and reservoirs were classified as either eutrophic or hyper-eutrophic (USEPA, 1992). Total phosphorus concentrations in Illinois streams average 0.41 mg -P/L and have been increasing in recent years (Ramamurthy, 1994). Total phosphorus concentrations in excess of 0.05 mg-P/L are thought to promote eutrophication.

The objective of this study was to quantify the concentration and loads of dissolved molybdate-reactive phosphate (DMRP) in drain tiles in fine textured soils with a variety of crop management practices. This is part of a larger study in the Little Vermilion River Watershed in East-Central Illinois examining nitrate, phosphate and pesticide transport from several fields where different tillage, fertilizer and pesticide management systems and conservation practices are employed.

PROCEDURES

The Setting

The Little Vermilion River Watershed is located in East Central Illinois, where average annual rainfall is approximately 1000 mm. The soils of the watershed are mostly flat, dark prairie soils with poor internal drainage. Approximately 90% of the watershed is used for row crop production, primarily corn rotated with soybeans. The upper reaches of the Little Vermilion River are man-made drainage ditches created in the late 19th century when the area was first drained. The River was impounded at the village of Georgetown in 1936 to create the 46 acre Georgetown Reservoir which serves as a drinking water supply to Georgetown and the village of Olivet. The reservoir periodically has high levels of nitrate, suspended solids, and atrazine, low concentrations of dissolved oxygen, and an unpleasant taste and odor. The 48,900 ha watershed above the reservoir is the study area.

In 1991, seven water quality sampling sites were established along the Little Vermilion River, including the Georgetown Reservoir. Water samples were collected manually at two week intervals and following major rainfall events. At one of these sites, designated R05, a stream flow gage and automatic water sampler were also installed. Starting in early 1994, water samples were analyzed for molybdate-reactive phosphate concentrations using a Technicon AutoAnalyzer II.

Field Site Monitoring and Management Systems

With the assistance of Natural Resource Conservation Service and Cooperative Extension Service personnel, eight privately owned, small tile drainage systems were identified for monitoring. The soils and crop management systems employed in these fields are representative of the range of conditions and cropping systems in the Little Vermilion River watershed. The areas drained by the monitored systems range in size from 2 to 15 hectares. At each site, a Palmer-Bowlus flow measuring flume was installed in the tile line. Water depth in each flume was recorded continuously with a stage recorder. Depth was converted to flow using the flume depth-discharge equation.

Water samples for chemical analysis were collected on the same schedule as the river stations. Automatic flow monitoring and sampling equipment was installed at 7 field sites in 1992 and 1993 and at an eight in the summer of 1994. DMRP analysis of samples began in March, 1994. Samples taken with the automatic samplers were usually retrieved within 24 hours of the sampling event. Samples were refrigerated at 3°C until chemical analysis could be performed. Dissolved molybdate-reactive phosphate concentration was determined using a Technicon AutoAnalyzer II. Mass of DMRP load exiting the tile drain was estimated by assuming that the measured concentrations represented actual concentrations for variable periods of time before and after sampling so that a concentration could be assigned to each recorded flow rate. Flow weighted mean concentrations were also calculated by dividing the cumulative DMRP load by the cumulative drainage volume.

Crop and fertilizer management decisions in the monitored fields were made by the land owners. Fertilizer application rates, methods and timing, and crop yields were communicated to the research team. Seven of the sites are currently used for corn and soybean production and one site is maintained in permanent grass as part of the Conservation Reserve Program. Soil types and phosphorus management practices for these sites are presented in Table 1.

Table 1. Soils, Cropping System, Phosphorus Application Method and Mean Phosphorus Applications, kg-P/ha-yr.

Soils	Site ID	Cropping System	Phosphorus Application Timing	Mean Annual P Application Rate (kg P/ha-yr)
Drummer silt loam	A	Reduced-till Corn-Beans	every other fall	22
& Flanagan silty	B	Reduced-till Beans-Corn	each fall - VRT[1]	25
clay loam	C	Seed Corn - Beans	Fall &winter	28
	D	oats-corn-soybeans	Spring	28
	E	Conv.-till Beans-Corn	Fall	11

Sabina & Xenia silt loams	F	No-Till Corn-Beans	Spring	19
	G	Continuous Meadow	None	None
Sabina & Birkbeck silt loams	H	Soybean-Corn-Corn Silage	Winter & Spring (manure)	20

[1] Variable Rate Technology

Bray P-1 in the top 10 cm of soil was measured after planting and harvest for each growing season. Samples were collected at four locations at each site. Statistical differences in mean Bray P-1 concentrations were identified using the test for Least Significant Difference (SAS).

Five of the sites are located in predominantly Drummer and Flanagan soils. These soils are among the most highly productive in the state. They were developed under native prairie vegetation, and typically have 5% organic matter and 70% silt. Two of the Drummer-Flanagan sites, designated as A and B in Table 1, are chisel plowed and disked or field cultivated each year. In a given year, one of these sites will be planted to soybeans and the other planted to corn. At A, 44 kg-P/ha is applied every other year. At B, P fertilizer is applied each year using variable rate technology (VRT).

At another site on Drummer Flanagan soils, C, seed corn is produced in rotation with soybeans. At this site, tillage includes chisel plowing and field cultivation. Approximately 56 kg P/ha is applied every other year in the fall after soybean harvest. Site D is similarly managed. From 1991 to 1994 it had been used to grow oats and corn in rotation. In 1995, soybeans were grown. The tile monitoring equipment at site D was installed during the 1994 growing season and tile flow was not recorded until August of that year. Hence the period of record for this site is 6 months shorter than the other sites in this study.

The fifth site with Drummer-Flanagan soils, E, is moldboard plowed and field cultivated following corn production, and field cultivated following soybeans. Phosphorus fertilizer is applied every other year in the fall after soybean harvest at an average rate of 22 kg-P/ha.

Two sites are located in predominantly Sabina and Xenia silt loam soils. These soils are somewhat less productive than the Drummer-Flannagan soils. They were developed under deciduous forest, and typically have 2% organic matter in the top 20 cm. One of these sites, F, is used for corn-soybean production using no-till. Fertilizer is applied as a side-dress during the growing season. The other site, G, is in permanent grass cover and no fertilizer is applied.

Finally, one site is located in predominantly Sabina-Birkbeck silt loam soils. These soils were also developed under forest vegetation, have approximatey 2% organic matter in the surface horizon and are somewhat less productive than the Drummer-Flanagan soils. At this site, a three year rotation of soybean-corn-corn is produced using chisel plowing and disking. The second year of corn is harvested for silage. The only phosphorus applied from 1990 through 1995 has been in the form of cattle manure. Phosphorus content was estimated to be 1.85 kg-P/Mg of raw manure (Midwest Plan Service, 1975).

RESULTS

Mean soil Bray P-1 concentrations, tile flow, DMRP loads and concentrations appear in Table 2. Soil Bray P-1 was significantly greater at sites D and H than any other site. Site H has received treatments of 20 Mg/ha cattle manure for many years. There is evidence from historical aerial photos that a portion of site D was a feedlot in the 1940s. The least soil P-1 concentration was observed at site G, which has been in meadow and has not received any addition of P fertilizer since 1990.

Tile flow ranged from 81 mm/yr for site D to 159 mm/yr for site G. For most sites, flow tended to be flashy with most of the flow occurring during a few weeks of the year. The DMRP loads ranged from 0.051 kg-P/ha-yr for site D to 0.202 Kg-P/ha-yr for site F. These values are generally less than 1% of the P fertilizer application rates and consequently do not represent a significant loss from a crop production perspective.

Table 2. Subsurface tile flow, DMRP load, flow weighted concentration and mean concentration in tile effluent from the tile monitoring stations and the county line river station for the period from March, 1994 through December, 1995.

Site	Soil Bray P-1	Annual Flow Depth	DMRP Load	DMRP Concentrations			% of obs. >0.05 mg-P/L	N
				Flow Weighted	Mean of samples	Max		
	(mg-P/kg)	(mm/yr)	(kg-P/ha-yr)	--------(mg-P/ L)-------				
A	66 d[1]	139	0.126	0.080	0.071	0.48	53	75
B	66 d	138	0.143	0.091	0.072	0.39	45	29
C	74 c	99	0.080	0.072	0.065	0.37	42	48
D[2]	103 a	81	0.051	0.058	0.062	0.31	40	116
E	59 d	127	0.082	0.057	0.055	0.33	43	94
F	64 d	138	0.202	0.130	0.134	2.78	53	171
G	21 e	159	0.122	0.068	0.061	0.18	50	93
H	87 b	84	0.075	0.078	0.161	1.64	64	103
R05		64	0.169	0.230	0.205	2.10	70	120
River[3]					0.130	2.10	69	498

[1] values followed by any identical letters are not statistically different at the 0.05 level of significance
[2] monitoring at D began in August, 1994
[3] river concentrations include station R05

Flow weighted average concentrations of DMRP in tile effluent ranged from 0.057 to 0.13 mg P/L. The mean concentrations of the individual sample values ranged from 0.161 to 0.055 mg-P/L. For most sites, the two measures of average DMRP concentration were similar. The one exception to this was site H where the flow weighted concentration was 0.078 and the mean of the sample values was 0.161 mg-P/L. This indicates that more samples were taken when flow was low and concentration was relatively high. All of these average concentrations are considered to be sufficient to promote eutrophication.

There was little apparent relation between soil Bray P-1 and mean DMRP in the tile drain effluent for these sites. The greatest and the least concentrations were observed at sites F and E, respectively, two sites where soil concentrations were intermediate. Similarly, the sites with the greatest and the least soil Bray P-1 concentrations, sites D and G, both had low levels of DMRP as compared to the other sites.

The lack of correlation between Bray P-1 in the top soil and tile DMRP in the drain effluent is perhaps because both Bray P-1 and DMRP represent only portions of total P, and perhaps due to the relative immobility of P in the soil. Given this relative immobility there is likely to be a very long lag time between land management practices and P concentrations in tile drain effluent.

Maximum concentrations from individual samples of tile effluent range from 0.19 at G to 2.78 at F. Between 40 and 64% of the samples taken from the subsurface drain tiles exceeded the 0.05 mg-P/L level.

DMRP concentrations at river station R05 were greater than at the tile stations and the loads at R05 were greater than all tile stations except for F. Seventy percent of the samples taken from R05 had DMRP concentrations greater than 0.05 mg-P/L. Concentrations at R05 were also greater than other river stations. This may have been because an automatic sampler was used at R05, which captured more samples during storm events and at higher flow rates than the manually collected samples. Due to the relative immobility of phosphorus in the soils, it tends to accumulate in soil surface layers and to move more readily in surface runoff than subsurface flow. Consequently, phosphate concentrations in surface runoff are likely to be greater than in subsurface flow. Furthermore, river concentrations of DMRP are likely to increase during runoff events. Although DMRP concentrations observed in tile drain effluent in this study were less than observed in the river and in other runoff studies (McIsaac et al., 1995), they are somewhat greater than observed in tile drainage in pastures in England (Hawkins and Scholefield, 1996).

LESSONS LEARNED

In summary, this study has shown that the concentration of phosphorus in subsurface drainage in the study area frequently exceeds the level thought to promote eutrophication. The fact that P concentrations in drainage from the unfertilized continuous meadow site was greater than those from some of the intensively fertilized and cropped sites suggests that modifying fertilizer and cropping patterns will not have an immediate impact on P concentration of the subsurface drainage water and downstream water bodies.

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The Success of Farm *A* Syst and Safe H_2*OME* Water Quality Programs in Maine

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The University of Maine Cooperative Extension has begun two programs to address possible non-point source pollution impacts on water from two sources: farmlands and residential communities. The Farm *A* Syst program aids producers to identify how they may be affecting their own drinking water and nearby water bodies. Eighty farms have participated in the program and where needed, best management practices have been recommended. Common problem areas found on farms included livestock yard maintenance, manure storage, pesticide storage, and nutrient management. Similarly, the Safe H_2*OME* Program aids homeowners to assess the impact of their activities on their well water. One hundred-twenty families have participated in a program correlating their activities with actual water analyses. Approximately 25 percent of respondents indicated that they believed their activities put them at high risk for potential water quality problems. Twenty-seven percent of home wells tested positive for the presence of bacteria in water.

Introduction

Maine is a very rural state. Most of its population live in communities with populations less than 10,000 people. Maine covers approximately 19.8 million acres. Approximately 89 percent of this area is forested, while only eight percent is farmland. Maine's 2400 full-time farms produce potatoes, wild blueberries, milk, brown eggs, chickens, and apples on a large scale. Maine also has many small scale vegetable farms and their numbers are growing.

Ninety-five percent of Maine's rural communities rely upon well water for their drinking water supply. With such a high percentage, we are very concerned about the quality of Maine's water and the health of her people and environment. Maine's superficial geology is such that Maine has few shortages of water with its sand and gravel aquifers and abundant lakes and streams. We are concerned with keeping these waters clean. In the past two years the University of Maine Cooperative Extension in conjunction with the Maine Department of Environmental Protection and other state agencies has prepared the Safe H_2OME and Farm *A* Syst programs for the residents of Maine. These programs are educational tools that help homeowners and farmers to assess how their activities could negatively impact water quality.

Procedure

Both the Safe H_2*OME* and the Farm *A* Syst programs are organized in a series of fact sheets and work sheets. The fact sheets are included in the packet to provide background information to the program participants so that they will be well versed in program terminology. The work sheets asks the participant specific information about the given topic areas. Participants then assign a rating to their activities based on how they assess their impact on water quality for that topic area.

The Safe H_2*OME* Program was made available to interested residents of Maine and to 120 residents of the Royal River watershed in southern Maine where a water quality education effort was underway. Watershed residents received a free water test kit in exchange for completing a program evaluation. Individual assessments could then be compared to actual water test results to determine the accuracy of a homeowner's impression of their impact on water quality. The results of that evaluation are given below.

The Farm *A* Syst Program focuses on assessing farm impacts on water quality. This program was made available in the winter and spring of 1996. This program was made available to 80 farms in five Maine counties with the help of Americorps Volunteers associated with the Consolidated Farm Services Agency. Volunteers met with individual farmers to complete the program evaluation.

Results and Discussion

Safe H_2OME Program

Maine's Safe H_2*OME* Program is largely an educational tool to help Maine families identify possible pollution risks in or around their homes. The five fact and work sheets help to evaluate activities around the home that may present possible health risks to the family by affecting the water supply. The Safe H_2*OME* Program fact sheets and work sheets cover the following topics:

Table 1. Safe H_2*OME* Program Topic Areas

Well construction and maintenance
Household hazardous waste
Household wastewater
Lawn and garden care
Lead in the environment

Through our evaluation, participants living in the Royal River watershed were asked to assess whether their activities involving the five previous topic areas put their water supply at low, low-moderate, moderate-high or high risk for contamination. The results for those participants who felt their water supply was put at moderate-high or high risk of contamination due to their home activities is presented in Table 2.

Table 2. **Evaluation respondents who felt their drinking water supply could be at moderate-high to high risk for contamination.**

Topic Area	Percent of Respondents
Well construction and maintenance	25.8†
Household wastewater	25.8
Lead in the home	24.1
Household hazardous waste	23.6
Lawn and garden care	23.2

† Remainder of percentages indicate a response of low to moderate-low risk.

Actual water quality results indicated that the respondents were able to make a fairly accurate assessment of their impact on their water quality by working through the Safe H_2*OME* Program work sheets. More than 25 percent of the program respondents had a contaminated water supply (Table 3). For this program, we were concerned with the following water quality parameters: total bacteria, fecal coliform, *E. coli*, nitrate, and arsenic. It is likely that the wells contaminated with bacteria (27 percent) are related to the percentage of moderate-high to high risk ratings for the following categories: well construction and maintenance, household wastewater and lawn and garden care.

Table 3. **Percentage of homeowners with contaminated water supplies.**

Contaminant	Percent of Water Samples
Total bacteria	27.4
Fecal coliform	15.4
E. coli	15.4
Nitrate (NO_3)	0.0†
mean value	0.68 mg l^{-1}
Arsenic (As)	1.1 §
mean value	0.008 mg l^{-1}

† Those samples that tested above the EPA standard of 10.0 mg l^{-1} for nitrate.
§ Those samples that tested above the EPA standard of 0.05 mg l^{-1} for arsenic.

The final revealing question on the Safe H_2*OME* Program evaluation asked program participants what activities around the home they would change as a result of reviewing the Safe H_2*OME* Program fact sheets and work sheets. Almost 39 percent of the participants felt inclined to reduce the use of hazardous material around the home (Table 4). Other areas of concern include regular water testing, septic system maintenance and to improve well construction.

In a follow-up survey, those participants with bacterial contamination were able to correct the problem through information and education from our program. Through the Safe H_2*OME* Program and our evaluation process, we have been able to assess the actual quality of water supplies in the Royal River watershed and of the educational needs of citizens so that they may work towards improving their water supplies.

Table 4. Areas of anticipated change to improve home water quality.

Activity	Percent response
Reduce use of hazardous products	38.9
Regular water testing	23.4
Maintain septic system	13.7
Improve well construction	10.9
Decrease water use	5.7
Install lead free plumbing	3.4
Increase garden soil organic matter	2.3
Increase soil testing	1.7

*Farm *A* Syst*

Maine's farming community does not encompass a large part of Maine's landscape. These farms are located on many of Maine's rivers and near population centers where farming activities could have a significant impact on water quality. With the initiation of Maine's Farm *A* Syst Program, Maine's farm families will hopefully better understand how their activities can affect local water quality. By identifying these activities, recommendations for change will not only benefit water quality but will hopefully improve farm productivity and quality of life on the farm.

Maine's Farm *A* Syst Program, a series of 11 fact sheets and work sheets, that help farms to identify activities that may impact water quality. The Farm *A* Syst Program fact sheets and work sheets cover the following topics:

Table 5. Farm *A* Syst Topic Areas

Drinking water well condition
Pesticide storage and handling
Fertilizer storage and handling
Petroleum product storage
Hazardous waste management
Household wastewater treatment
Livestock waste storage
Livestock yard management
Silage storage
Milking center wastewater storage
Overall farmstead assessment

Many producers identified activities that put their home well water at moderate-high to high risk for contamination (Table 6). Over 20 percent of the respondents felt the following activities could contaminate their water supply: livestock yard management, pesticide storage and handling, well construction and silage storage. As with the Safe H_2*OME* Program, this evaluation process provides Cooperative Extension and other agencies important information about educational needs as identified by farms themselves.

Table 6. Evaluation respondents who felt their drinking water supply could be at moderate-high to high risk for contamination.

Topic Area	Percent of Respondents
Livestock yard management	32.6
Pesticide storage and handling	24.4
Drinking water well condition	21.0
Silage storage	20.5
Petroleum product storage	18.2
Milking center wastewater treatment	15.6
Household hazardous waste	10.5
Fertilizer storage and handling	9.7
Hazardous waste management	3.8

Conclusion

The Safe H_2*OME* and Farm *A* Syst programs are easy to use sources of information for homes and farms. Both help the user understand possible threats to water supplies and to determine if their activities could be a threat. The evaluation process for these programs is extremely useful in targeting educational opportunities towards both of these groups. Both groups of participants identified what areas were of greatest concern to them. With the Safe H_2*OME* Program, we were able to validate these concerns with actual water test results.

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