EVALUATION OF AGRICULTURAL BEST-MANAGEMENT PRACTICES IN THE CONESTOGA RIVER HEADWATERS, PENNSYLVANIA: Description and Water Quality of the Little Conestoga Creek Headwaters Prior to the Implementation of Nutrient Management

WATER-QUALITY STUDY OF THE CONESTOGA RIVER HEADWATERS, PENNSYLVANIA

By

David K. Fishel, U.S. Geological Survey
Mary Jo Brown, Pennsylvania Department of Environmental Resources
Kevin M. Kostelnik, U.S. Geological Survey
Mary A. Howse, U.S. Geological Survey

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MANUEL LUJAN, JR., *Secretary*

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, *Director*

For additional information write to:

District Chief
U.S. Geological Survey, WRD
840 Market Street
Lemoyne, Pennsylvania 17043-1586

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4.047	square kilometer (km^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound (lb)	0.4536	kilogram (kg)
pound per acre (lb/acre)	1.121	kilogram per hectare (kg/ha)
ton, short	0.9072	megagram (Mg)
ton per square mile per year [(ton/mi^2)/yr]	0.3503	metric ton per square kilometer per year [(t/km^2)/annum]
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 (°F - 32)	degree Celsius (°C)

EVALUATION OF AGRICULTURAL BEST-MANAGEMENT PRACTICES IN THE CONESTOGA RIVER HEADWATERS, PENNSYLVANIA:

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ABSTRACT

The headwaters of the Conestoga River are being studied to determine the effects of agricultural Best-Management Practices on surface-water and ground-water quality. As part of this study, a 5.82-square-mile area of the Little Conestoga Creek headwaters (Small Watershed) was monitored during 1984-86, prior to implementation of Best-Management Practices. This report describes the land use and hydrology of this study area and characterizes its surface-water and ground-water quality during the pre-Best-Management Practice phase.

During base-flow conditions, median concentrations of dissolved nitrite plus nitrate nitrogen as nitrogen increased from 2.7 to 8.1 milligrams per liter as the stream flowed through the intensively-farmed carbonate valley. Median total phosphorus increased from 0.05 to 0.20 milligram per liter. Concentrations of dissolved nitrate nitrogen as nitrogen measured in ground water in carbonate rocks in the valley were as great as 25 milligrams per liter and consistently exceeded 10 milligrams per liter.

Statistical analysis showed that it will require substantial reductions in concentrations and discharges of nitrogen and phosphorus in base flow to obtain statistically measurable improvements in water quality. If concentrations and discharges of total nitrogen in base flow at the five sites are reduced by 15 to 33 percent, and by 63 to 70 percent, respectively, then the Wilcoxon Mann-Whitney rank-sum test will be able to detect an improvement in water quality 95 percent of the time. Likewise, if concentrations of total phosphorus are reduced by 36 to 54 percent, or discharges of total phosphorus are reduced by 52 to 69 percent at the five sites, then an improvement in water quality will be able to be detected 95 percent of the time.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the Pennsylvania Department of Environmental Resources (PaDER), is studying the Conestoga River Headwaters basin as part of the Rural Clean Water Program (RCWP) directed by the U.S. Department of Agriculture (USDA). The Conestoga River Headwaters RCWP project is 1 of 20 such projects in the nation designed to accelerate the installation of Best-Management Practices (BMPs) for the reduction of agricultural contamination of surface water and ground water. In addition, the Conestoga River Headwaters RCWP project is one of five RCWP projects designated Comprehensive Monitoring and Evaluation Projects. These five RCWP projects are conducting in-depth evaluations on the effectiveness of BMPs for improving rural water quality.

The study area discussed in this report is one of three components--the Regional Network, Small Watershed, and the field site (Field-Site 1 and Field- Site 2) studies--of the Conestoga Headwaters project. The work on this component, the Small Watershed (fig. 1), began in April 1984. Because excessive nutrients are the major problem in the 5.8-mi^2 (square mile) Small Watershed, the BMPs that will be implemented include nutrient management and animal waste storage. Information presented in this report will help agricultural managers develop nutrient-management plans for farms in the basin.

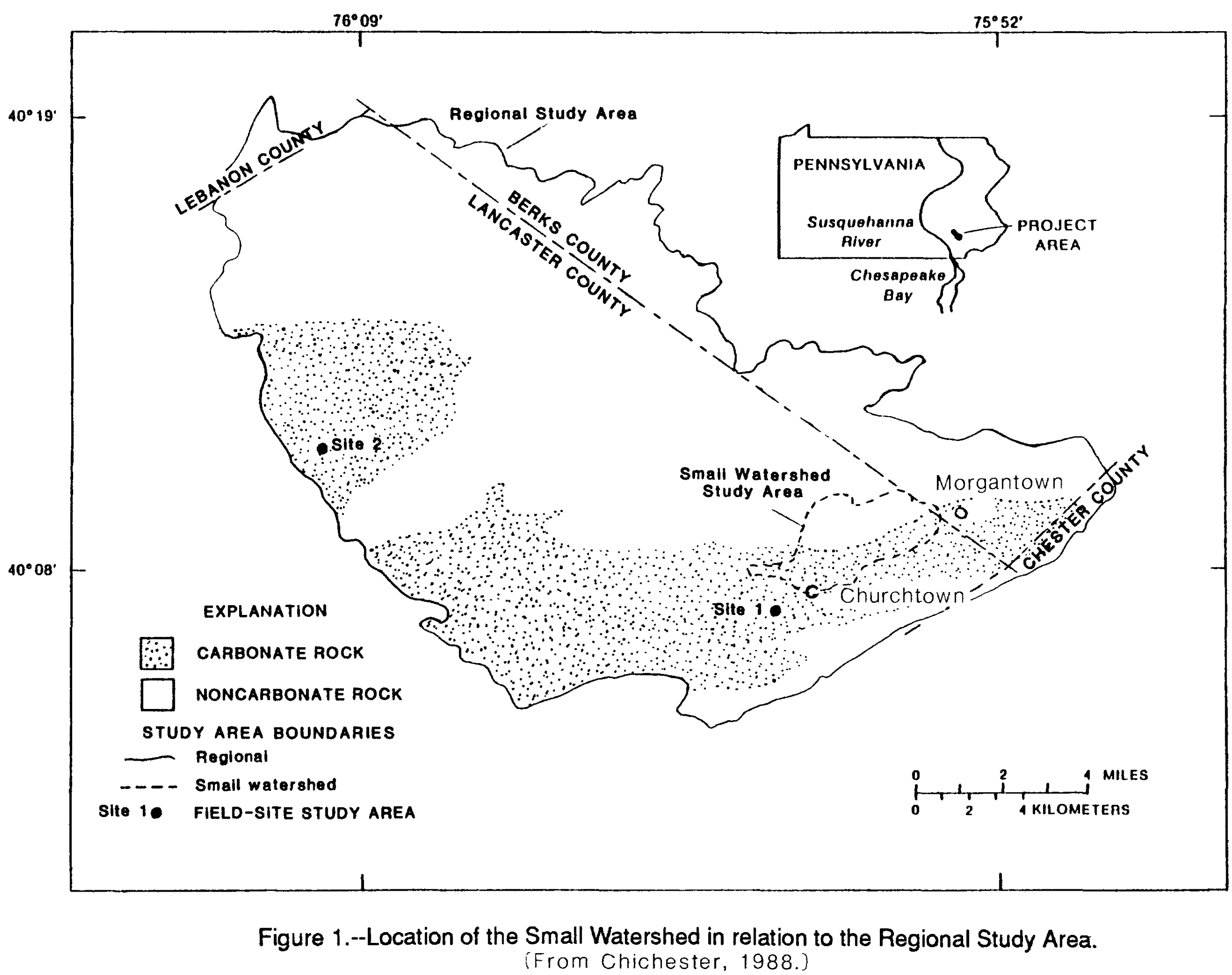

Figure 1.--Location of the Small Watershed in relation to the Regional Study Area.
(From Chichester, 1988.)

Purpose and Scope

This report describes and characterizes the water quality of the Small Watershed before implementation of nutrient management (pre-BMP). This basin represents one of the components of the Conestoga River Headwaters RCWP project. The data in this report were collected during the 2-year pre-BMP phase (April 1, 1984, through March 31, 1986).

This report describes precipitation, land use, soils, streamflow, and surface-water and ground-water quality data collected during the pre-BMP phase. It includes information on the water quality of base flow and stormflow as well as the effects of geology and periodic discharges from agricultural point sources on water quality in the Small Watershed. The report provides estimates of the probability that the sampling scheme will detect changes in water quality in base flow. These probabilities are a function of the magnitude of the underlying change.

Background and Related Studies

Background and detailed information on the overall project approach and methodology are discussed in "Evaluation of Agricultural Best-Management Practices in the Conestoga River Headwaters, Pennsylvania: Methods of Data Collection and Analysis, and Description of Study Areas," by Chichester (1988). Background specific to the component addressed in this report and studies related to this component are discussed below.

The U.S. Environmental Protection Agency's (USEPA) Chesapeake Bay Study reported that the Susquehanna River contributes 40 percent of the nitrogen and 21 percent of the phosphorus that are discharged to the Bay. Eighty-five percent of this nitrogen and 60 percent of this phosphorus were estimated to have come from cropland runoff (U.S. Environmental Protection Agency, 1983). The Chesapeake Bay Study recommended the implementation of agricultural BMPs to reduce nonpoint-source nutrient discharges. In 1979, the Conestoga River basin was designated the top-priority watershed in Pennsylvania in terms of nonpoint-source contamination of surface and ground water (Schueller, 1983). In 1981, the Conestoga River Headwaters RCWP Project was funded to install BMPs in part of the Conestoga River basin. The USGS and PaDER established the Regional Network component in the 188-mi^2 Conestoga River Headwaters RCWP project area in 1982 to determine the effects of BMPs on surface-water and ground-water quality. Data collected from the Regional Network from 1982-83 indicated that the major water-quality problem in the upper Conestoga River basin is the elevated nitrate-nitrogen concentrations in the surface water and ground water. Concentrations of nitrate-nitrogen as great as 40 mg/L (milligrams per liter) as N were found to be closely associated with intensively farmed areas having carbonate soils (Fishel and Lietman, 1986).

Intensive data collection began in the 5.82-mi^2 Small Watershed in April 1984 after maximum concentrations of dissolved-nitrate nitrogen and total phosphorus of 12 and 9.8 mg/L, respectively, were measured there. At this time, the State RCWP Coordinating Committee decided to reduce the scope of the study area from the Regional Network to the Small Watershed where better farmer cooperation was expected. At the same time, a 1.42-mi^2-Nutrient-Management Subbasin and a 1.43-mi^2-Nonnutrient-Management Subbasin (fig. 2) within the Small Watershed were established.

The Nutrient-Management Subbasin was selected in an area where cooperation with the farmers was expected, and where nutrient management, one of several possible BMPs, was expected to be implemented. In addition to the traditional BMPs recommended by the Soil Conservation Service (SCS) to reduce soil loss, plans to implement nutrient management are being developed for farms that might have excessive nutrients. The nutrient-management plans can consist of nutrient management in combination with other BMPs, such as animal-waste storage and terracing. Nutrient management is defined as a practice where proper rates and timing of applications of manure and commercial fertilizer are balanced with crop needs to reduce the amount of unused nutrients that become available for transport to streams and ground water. The rates and timing of applications are determined by: (1) considering the amount of residual nitrogen and phosphorus available in the soil for crops; (2) calculating the amount of nutrients

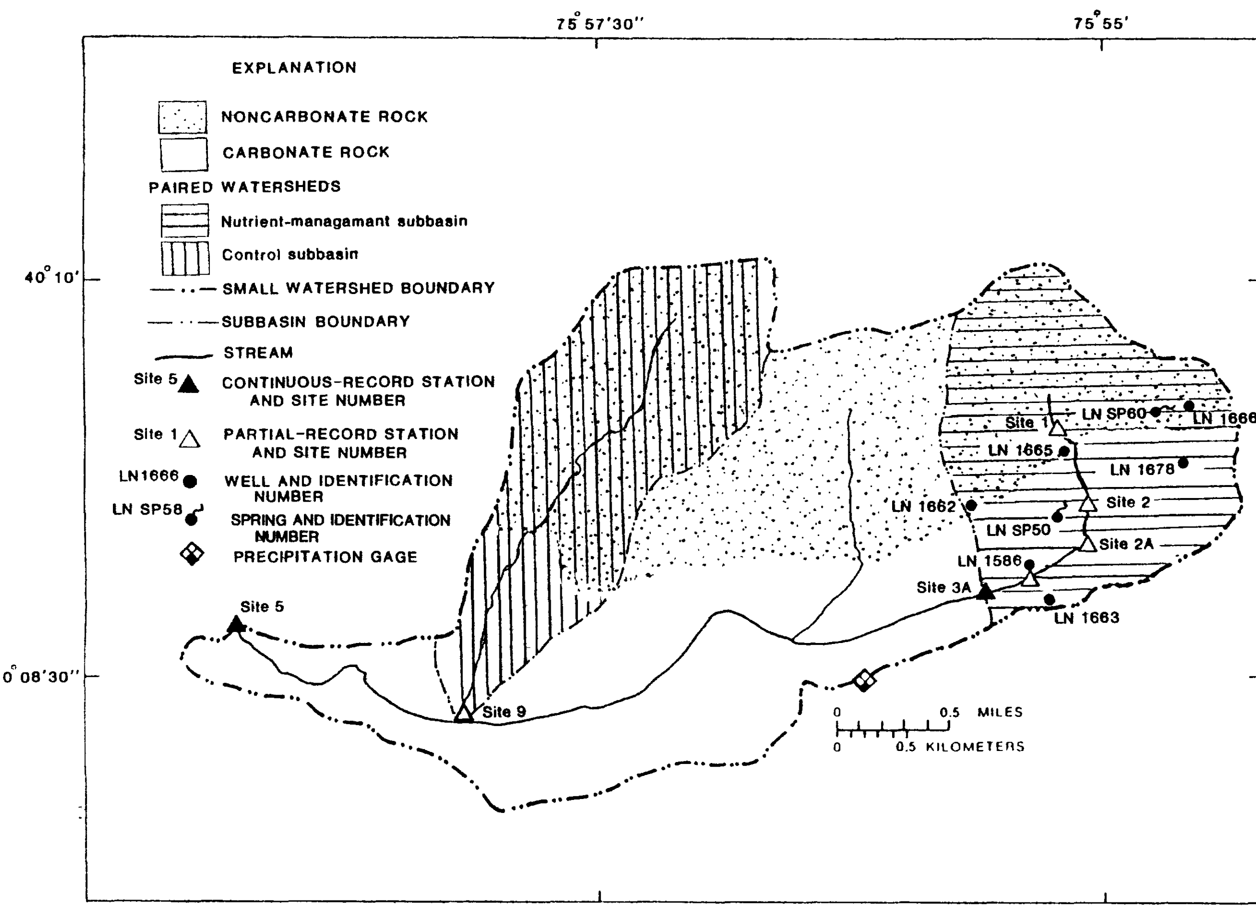

Figure 2.--Small Watershed data-collection locations and general geology.
(From Chichester, 1988.)

available from manure applications by testing manure for nutrient content; (3) knowing when and how much commercial fertilizer needs to be added; and (4) understanding when the nutrients can best be utilized by the crops.

Other related monitoring studies were begun in the 1980's as a result of the growing awareness of water-quality problems in the Chesapeake Bay. A lower Susquehanna River nutrient-control project currently is being done by the USGS to determine the effects of BMPs on water quality in noncarbonate areas in Pennsylvania. A study similar to the Conestoga River Headwaters Project is being done by the USGS in the Patuxent River Basin in Maryland. A joint study by the USGS and the Susquehanna River Basin Commission (SRBC) is being done to assess sources of nutrients in the lower Susquehanna River basin. Studies are planned by the PaDER, Bureau of Forestry, with the Lancaster and Lebanon County Conservation Districts to determine the effects of manure disposal on ground water and undisturbed soils.

Approach

Land use, soil chemistry, and hydrologic data were collected to characterize the water quality of the intensively-farmed Small Watershed. Data were grouped into growing seasons (April through September) and nongrowing seasons (October through March). Precipitation data collected at the southern boundary of the Small Watershed were used to characterize the study period, and to examine any relation between it and storm magnitude, soil chemistry, and water quality in base flow. Land-use data were obtained from farmers in the Nutrient-Management Subbasin to characterize pre-BMP conditions. Soil-chemistry data were collected to characterize the soils in the Nutrient-Management Subbasin and to identify areas where nutrient-management plans might be of most benefit. Base-flow and stormflow water-quality samples were collected to characterize the surface-water quality. Base flow was defined as the streamflow derived from ground water and delayed subsurface flow, and representative samples of base flow were collected no sooner than 3 days after any measurable precipitation. Annual loads of nutrients and suspended sediment in base flow, and loads for selected storms were calculated for the Nutrient-Management Subbasin and the Small Watershed. Base-flow data were used for paired-watershed analyses of nutrient concentrations and loads in the Nutrient-Management Subbasin and the Nonnutrient-Management Subbasin. Parametric and nonparametric statistical analyses, such as linear regression and the Wilcoxon Mann-Whitney rank-sum test, were used to examine trends in water-quality concentrations and nutrient and suspended sediment loads in base flow.

Water samples were collected from domestic wells and springs. These data were used to characterize in general the quality of local ground water.

Land-use and water-quality data were synthesized from measured data. Nonparametric statistics and Monte-Carlo simulation were used to estimate the reductions in agricultural contaminants required to detect statistically-significant reductions in concentrations and loads of nitrogen and phosphorus in base flow. A discussion of the hypothetical effects of nutrient management on water quality also is provided.

Acknowledgments

The following individuals and respective agencies are acknowledged for their assistance in making this project a success:

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2. Vincent C. White, Lynn B. Schaffer, and John H. Maljevac from the Pennsylvania Department of Environmental Resources, Bureau of Laboratories, for handling the analysis of water samples.
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5. George Royer, from the Soil Conservation Service in Lancaster County, for assisting with initial contacts with farmers in the Small Watershed, providing nutrient values for livestock and poultry manure, and compiling initial animal population and density data.
6. Richard A. Pennay, from the U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, for coordinating the transfer of information among the cooperating agencies.
7. Donald Robinson and Robert J. Anderson from the Eastern Lancaster County School District for collecting soil samples, measuring corn yields, and making many recommendations to farmers and project personnel.
8. Richard Maas from the North Carolina State University, Biological and Agricultural Engineering Department, for giving technical advice on data analysis.
9. John Hauenstein and Charles S. Takita from the Susquehanna River Basin Commission for assisting with the collection of water-quality samples.

DATA COLLECTION AND METHODOLOGY

Methods of data collection and analysis of precipitation, land use, soils, surface water, and ground water are discussed by Chichester (1988). Data specific to this report are discussed below.

Precipitation

Precipitation data were collected near the southern boundary of the study area (fig. 2). The precipitation gage, which records accumulated precipitation at 5-minute intervals, was established in mid-October 1982. Data were compared with long-term records from the National Oceanic and Atmospheric Administration (NOAA) gage at Morgantown, Pa. Information from the two precipitation gages at the Conestoga River Headwaters RCWP field sites and the NOAA precipitation gage at Morgantown, Pa., was used to estimate missing records. Two of the gages were within 4 mi (miles) of the study area, and the gage at Field-Site 2 was within 12 mi of the study area (fig. 1).

Land Use and Nutrients

Land-use data were tabulated from daily records kept by farmers in the Nutrient-Management Subbasin. Figure 3 shows farm locations. Data tabulated included crop acreage, yields, animal population and density, manure export, and daily applications of manure and commercial fertilizer for each field in the Nutrient-Management Subbasin. Field acreage was determined by measurement of aerial photographs and by field inspections each year. Land-use data were stored on a computer in the USGS Harrisburg, Pennsylvania office, and statistical analyses were performed by use of the Statistical Analysis System[1] (SAS Institute, Inc., 1979; 1982a; 1982b), and P-STAT (P-STAT Inc., 1986) computer packages. The amount of nutrients from manure applied to fields in the Nutrient-Management Subbasin was calculated with knowledge of the typical concentrations of nitrogen and phosphorus supplied by the Agricultural Stabilization and Conservation Service (ASCS) for livestock and poultry manures, and the application records provided by the farmers. Time-series plots of the manure and commercial fertilizer applications were made to determine trends and relations among applications, precipitation, and water quality.

Soil Chemistry

Soil samples were collected at seven locations (fig. 3) in the Nutrient-Management Subbasin. Samples were collected twice a year; the first samples were collected prior to applications of commercial fertilizer in the spring, and the second samples were collected following the harvest of crops in the fall. Soil core samples were collected to depths of 4 ft (feet) and split into sections representing 0 to 8 in. (inches), 8 to 24 in., 24 to 36 in., and 36 to 48 in. below the land surface. Soluble phosphorus and nitrate-nitrogen concentrations were determined for each section by the Pennsylvania State University, Soils and Environmental Chemistry Laboratory.

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[1]The use of trade, product, industry, or firm names in this report is for identification or location purposes only and does not constitute endorsement by the U.S. Geological Survey.

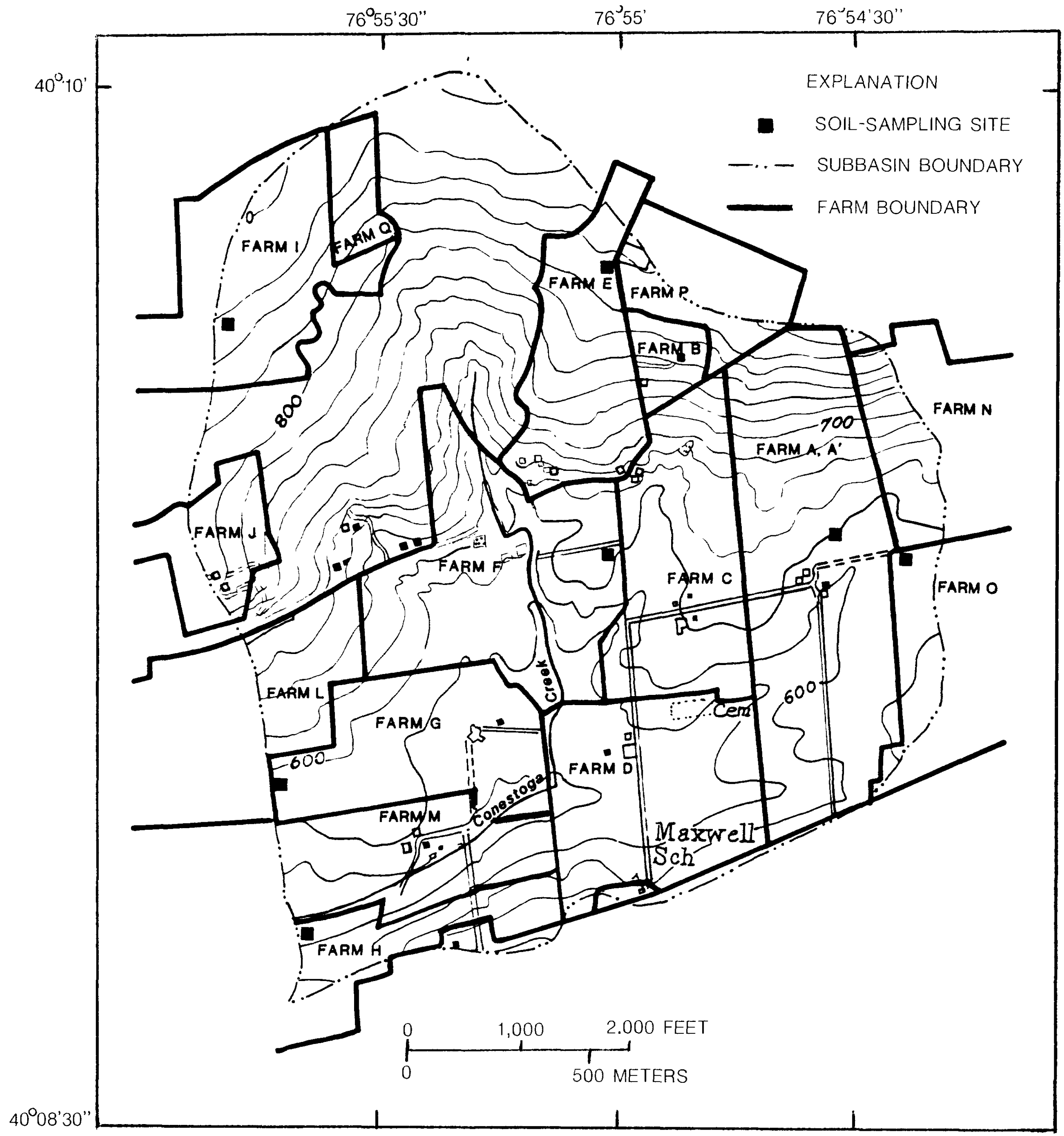


Figure 3.--Farms and soil-sampling sites in the Nutrient-Management Subbasin.

Streamflow

Streamflow data were collected at two continuous-record stations and five partial-record stations listed in table 1. Two of the partial-record stations (sites 2 and 3) were discontinued after 1 year of data collection because data from these stations were very similar to data collected at sites 2A and 3A.

Daily mean discharge records for the two continuous-record stations and from the continuous-record station at Lancaster (drainage area = 324 mi^2) along with weather records were compared to characterize the streamflow during the pre-BMP phase. Computer-generated hydrographs for the three stations were overlain to determine the streamflow similarities of the stations. Weather records were compared to determine if precipitation amounts were similar at the three stations.

Streamflow hydrographs for the two continuous-record stations were separated to determine the contributions of ground water (base flow) and surface runoff (stormflow) at each station. The hydrographs were separated by the local minimum technique described by Pettyjohn and Henning (1979) modified for computer use. This technique involved scanning the daily mean-discharge data day by day to determine the lowest value in a preset time interval. This lowest value, the local minimum, was connected by a straight line to the adjacent local minimum. The discharge values were calculated between each local minimum using the slope of the line at each discharge point.

Table 1.--Description of surface-water stations in the Small Watershed and at Lancaster
[mi^2, square miles; mi, miles]

Station number	Station name, site number, and other identifier	Location	Latitude	Longitude	Station type	Drainage area (mi^2)
015760831	Little Conestoga Creek, Site 1, near Morgantown, Pa.	Upstream side of bridge on Valley Rd., 5.5 mi upstream from mouth	400922	755514	partial record gage	0.34
015760832	Little Conestoga Creek, Site 2, near Morgantown, Pa.	Upstream side of farm lane, 5.2 mi upstream from mouth	400906	755505	partial record gage, discontinued October 1984	.60
0157608325	Little Conestoga Creek, Site 2A, near Morgantown, Pa. from	Upstream side of farm lane, 5.0 mi upstream mouth	400858	755506	partial record gage	.99
015760833	Little Conestoga Creek, Site 3, near Morgantown, Pa.	Upstream side of farm lane, 4.7 mi upstream from mouth October 1984	400850	755524	partial record gage, discontinued October 1984	1.34
0157608335	Little Conestoga Creek, Site 3A, near Morgantown, Pa. (Nutrient-Management Subbasin)	Upstream side of farm lane, 4.5 mi upstream from mouth	400847	755537	continuous record gage	1.42
015760839	Unnamed trib. to Little Conestoga Creek, Site 9, at Churchtown, Pa. (Control Subbasin)	Upstream side of farm lane, 0.04 mi upstream from mouth	400820	755814	partial record gage	1.43
1576085	Little Conestoga Creek, near Churchtown, Pa. (Site 5 and Small Watershed)	Upstream side of bridge on Smoketown Rd., 0.7 mi upstream from mouth	400841	755920	continuous record gage	5.82
01576500	Conestoga R. at Lancaster, Pa.	Upstream side of Penn Central Railroad Bridge, 0.7 mi east of Lancaster	400300	761639	continuous record gage	324

[1] The original source of reference for the Little Conestoga Creek referred to in this report comes from the U.S. Geological Survey Morgantown Quadrangle of 1939. The 1975 photorevision of the Morgantown Quadrangle designates the stream as an unnamed tributary to the Conestoga River. The Little Conestoga Creek referred to in this report should not be confused with the Little Conestoga Creek that discharges to the Conestoga River near Safe Harbor and is found on the Conestoga Quadrangle.

Water Quality

The water-quality characteristics measured and the sampling frequencies for surface-water and ground-water sites are listed in table 2. All nutrient samples were preserved with mercuric chloride. Samples from selected storms were analyzed to characterize the stormflow during the growing and nongrowing seasons. An average of eight sediment and eight nutrient samples were collected during each selected storm. All samples were analyzed by approved procedures (Skougstad and others, 1979; U.S. Environmental Protection Agency, 1979, 1985). Suspended-sediment samples were analyzed by the USGS sediment laboratory in Harrisburg, Pa. Nutrient and pesticide samples were analyzed by the PaDER, Bureau of Laboratories, in Harrisburg, Pa. Water-quality data collected during this study are published in USGS Water-Resources Reports PA-84-2, PA-85-2, and PA-86-2 (U.S. Geological Survey, 1986, 1987, 1988). The data are catalogued by the USGS identification numbers shown in this report.

Preliminary laboratory results were retrieved and evaluated routinely to identify questionable samples and results at an early stage. Requests were submitted for the reanalysis of these samples. Depending on the constituents involved, the samples were either reanalyzed or the resulting calculations were checked and recalculated.

A quality-assurance plan was developed for the entire ConestogaHeadwaters project. This plan has been maintained throughout the project with the PaDER Bureau of Laboratories which performed the analysis of all nutrient and pesticide samples.

Several types of samples were used to evaluate the quality of data. Blank samples of distilled water were routinely submitted for analysis. These samples evaluated the laboratory's baseline capabilities at near detection-limit levels. Standard USEPA and USGS reference water-quality samples also were submitted for analysis on a routine basis. These samples were used to determine laboratory accuracy. Duplicate water-quality samples were split in the field and also submitted to the Bureau of Laboratories for analysis. This third sample type measured the laboratory repeatability of the individual parameters.

The Wilcoxon two-sample (Mann-Whitney rank sum) test and the Wilcoxon signed-rank (or one-sample) test--standard statistical procedures defined by Noether (1976)--were used to evaluate the quality of the Conestoga nutrient data. Quality-assurance data were collected throughout the pre-BMP phase.

Nutrient concentrations of blank samples should be near detection limits to constitute acceptable laboratory results. The statistical comparison of this data first required the calculation of the difference between the reported values and the detection limits for each property or character in each sample. These differences should be approximately equal to zero. A signed-rank test was performed on the differences to test this hypothesis. The results indicated that the means of the calculated concentrations were statistically different from the detection limits for total and dissolved ammonia and total and dissolved ammonia plus organic nitrogen. This could indicate either a positive bias for reported values of these constituents at concentration levels near detection limits, or less than pure distilled water blanks.

Standard reference samples were analyzed for total and dissolved ammonia, ammonia plus organic nitrogen, nitrate-nitrogen, and phosphorus. Evaluation of the signed-rank test results showed a statistically measurable difference between the measured and the expected values for dissolved nitrate, total ammonia, total ammonia plus organic nitrogen, and total and dissolved phosphorus at the 95-percent confidence level. Except for total ammonia plus organic nitrogen, the median difference between the known and reported values was 0.10 mg/L or less. The reported results for all other parameters did not differ significantly from their expected values at a 95-percent confidence level.

The duplicate data were compared by use of the Wilcoxon two-sample test, which compared the data as two independent groups. The results of this test showed no statistically measurable difference between groups for any constituent, indicating that there is good repeatability in laboratory analysis.

Table 2.--Water-quality characteristics measured and sampling frequencies at surface-water and ground-water sites

[Surface-water sites include sites where base flow was sampled monthly and 14 to 22 storms were sampled annually. Ground-water sites were sampled quarterly.]

Constituents and properties measured at surface-water sites		Constituents and properties measured at ground-water sites	
Specific conductance		Dissolved:	Nitrite nitrogen
Water temperature			Nitrite + nitrate nitrogen
Suspended sediment			Ammonia nitrogen
Total and dissolved:	Nitrite nitrogen		Ammonia + organic nitrogen
	Nitrite + nitrate nitrogen		Phosphorus
	Ammonia nitrogen		
	Ammonia + organic nitrogen		
	Phosphorus		
Total pesticides:	Alachlor		
	Atrazine		
	Cyanazine		
	Metolachlor		
	Propazine		
	Simazine		
	Toxaphene		

The quality of the nutrient data for the Conestoga River Headwaters project collected during the Small Watershed pre-BMP period has been evaluated with several statistical procedures and sample types. The results of this evaluation, summarized in table 3, indicate that there was an acceptable degree of repeatability by the laboratory for all analyzed water-quality characteristics. The analyses were found to be accurate for most characteristics. Total ammonia plus organic nitrogen and total phosphorus exhibited some error because of the limitation of analysis techniques. Although more error was associated with these characteristics for concentrations near detection limits, actual samples rarely had concentrations near detection limits.

Daily chemical loads in base flow were computed using the daily base-flow data generated from hydrograph separations, the measured or estimated daily concentration data, and equation (1).

$$L = Q \times C \times 5.4, \qquad (1)$$

where L = chemical load, in pounds per day;
Q = streamflow, in cubic feet per second;
C = constituent concentration, in milligrams per liter; and
5.4 = a conversion factor for converting the product to pounds per day.

Estimates of nutrient concentrations were made by straight-line interpolation between days when base-flow samples were collected. Monthly and annual base-flow nutrient loads were calculated as the sum of the daily nutrient loads.

Nutrient loads were calculated for selected storms. The subdivided-day method described by Porterfield (1972) was used to calculate nutrient storm loads.

Water-quality data from base-flow samples were analyzed using summary statistics, time-series trend analyses, and paired-watershed analyses. Univariate statistics were tested for normality. Data that were not normally distributed were log-transformed and then tested for normality. Time-series plots were used to examine trends and relations among precipitation, nutrient applications, and water-quality concentrations of nutrients and discharges. Data were grouped into two seasons: April through September was considered the growing season and October through March was the nongrowing season. Correlations between the quality of water at the Nutrient-Management and the Nonnutrient-Management Subbasins were determined by paired-watershed analyses (Spooner and others, 1985).

Table 3.--Summary statistics for quality assurance analysis

[Detection limits, ranges, and median differences in milligrams per liter; n, number of observations; <, less than; --, no data]

Constituent	Detection limit	Samples: n	Samples: Concentration range	Blanks: n	Blanks: Range of reported values	Blanks: Median difference from detection limit	Standards: n	Standards: Range of known values	Standards: Differences between known and reported values: Range	Standards: Differences between known and reported values: Median	Duplicates: n	Duplicates: Concentration range	Duplicates: Difference between pairs: Range	Duplicates: Difference between pairs: Median
Total nitrate + nitrite	0.04	562	0.86/15	7	<0.04/all	0.00	--	--	--	--	42	1.3/57	-3.0/3.1	0.00
Dissolved nitrate + nitrite	.04	346	.78/11	9	<.04/all	.00	--	--	--	--	73	1.2/115	-9.6/3.1	.00
Total nitrite	.01	522	<.01/2.3	5	<.01/.01	.00	--	--	--	--	42	<.01/2.7	-.40/.06	.00
Dissolved nitrite	.01	296	<.01/1.3	8	<.01/.01	.00	--	--	--	--	52	<.01/.44	-.07/.44	.00
Total nitrate	--	--	--	--	--	--	20	0.19/8.0	-0.20/0.60	0.04	--	--	--	--
Dissolved nitrate	--	--	--	--	--	--	10	.82/8.6	.00/.60	.06	--	--	--	--
Total ammonia + organic nitrogen	.20	559	<.20/28	7	<.20/.80	.12	20	.45/16	-3.9/3.1	1.1	41	<.20/22	-2.0/.90	.00
Dissolved ammonia+ organic nitrogen	.20	344	<.20/15	9	<.20/.80	.06	13	1.3/17	-3.9/2.6	1.3	73	<.20/9.2	-.50/.54	.00
Total ammonia	.02	522	<.02/6.6	7	.04/.11	.04	16	.15/7.6	-.20/.30	-.02	42	<.02/10	-.07/.57	.00
Dissolved ammonia	.02	347	<.02/6.0	8	<.02/.11	.03	10	.99/7.4	-.20/.30	.00	52	<.02/.45	-.04/.05	.00
Total phosphorus	.02	559	<.02/20	7	<.02/.06	.00	24	.02/3.5	-.30/.80	.02	53	<.02/25	-.10/.19	.00
Dissolved phosphorus	.02	346	<.02/3.5	8	<.02/.05	.00	13	.72/3.7	-.24/.60	.20	42	<.02/4.3	-5.6/.11	.00

[1] Difference between pairs was determined by subtracting concentration value for blind duplicate from concentration value for sample.

Estimating Reductions in Agricultural Contaminants Required for Observing a Statistically-Significant Reduction

Monte Carlo experiments were conducted to determine the likelihood of detecting changes in water quality between the pre-BMP and post-BMP periods, using the proposed methods suggested by Martin and Hirsch (U.S. Geological Survey, written commun., 1989), as a function of the magnitude of true reductions in the concentrations. It was assumed that changes in the water quality would be indicated by a statistically-significant result from a Wilcoxon-Mann-Whitney test applied to the pre-BMP and post-BMP water-quality data (R.M. Hirsch, U.S. Geological Survey, written commun., 1989; Crawford and others, 1983). The null hypothesis assumed the medians of the two populations were the same. An alpha level of 0.05 was assumed throughout the analysis.

Monte Carlo simulation suggested by Martin and Hirsch (U.S. Geological Survey, written commun., 1989) was used to synthesize pre- and post-BMP data because of the limited amount of measured data, and to develop power curves from the rank-sum test. The pre-BMP data were synthesized by randomly generating 1,000 data sets based on the characteristics of the measured data, the number of seasons, the total number of observations in each season, and the mean and standard deviations for each season during the pre-BMP phase. Post-BMP data were synthesized by reducing the mean and the standard deviation of the pre-BMP data by a selected percentage. A second approach for generating post-BMP data from pre-BMP data for normally distributed data was to reduce the mean by the selected percentage without changing the standard deviation. The mean of the distribution of the generated post-BMP data was reduced until the power of the test exceeded 0.999. As the mean of the synthesized post-BMP data would logically only be lower than the mean of the pre-BMP data, the null hypothesis could only be rejected from one direction; thus, a one-tailed test was performed.

DESCRIPTION OF THE SMALL WATERSHED STUDY AREA

Surface-Water Basin and Sampling Sites

The 5.82-mi^2 Small Watershed is located in parts of Lancaster and Berks Counties, south-central Pennsylvania (fig. 1). The Small Watershed lies in two sections of the Piedmont physiographic province. The northern half, characterized by the broad highlands and ridges, is in the Triassic Lowland section and is underlain by conglomerate, sandstone, shale, and diabase of the Hammer Creek Formation and the sandstone, mudstone, and shale of the Stockton Formation. The southern half of the watershed, characterized by rolling lowlands, is in the Cambrian and Ordovician Conestoga Valley section and is underlain by carbonate rock from the Buffalo Springs and Stonehenge Formations. The study area has had a complex geologic history with repeated episodes of folding and faulting, as evidenced by the presence of Triassic Formations unconformably overlying Cambrian Formations.

Part of the Small Watershed was divided into two subbasins similar in size, geology, and land use to help characterize water quality and determine the effects of nutrient management on water quality. In the eastern part of the Small Watershed, a 1.42-mi^2 subbasin was designated as the Nutrient-Management Subbasin and contains all or parts of 16 farms (fig. 3). Fourteen of the farmers have volunteered to cooperate with the agencies working on the Conestoga River Headwaters RCWP Project.

A 1.43-mi^2 subbasin in the northwestern part of the Small Watershed was designated as the Nonnutrient-Management Subbasin. Water-quality, streamflow, and limited land-use data for the Nonnutrient-Management Subbasin are being collected, but nutrient management is not planned for farms in this subbasin. Therefore, applications of nutrients in the Nonnutrient-Management Subbasin during the post-BMP phase should not differ substantially from the nutrient applications during the pre-BMP phase. Together, the Nutrient-Management and Nonnutrient-Management Subbasins are called the Paired Watersheds (fig. 2).

Aquifer and Ground-Water Sampling Sites

The aquifer in the Small Watershed is unconfined, and is composed of regolith overlying bedrock of the Hammer Creek, Stockton, Buffalo Springs, and Stonehenge Formations. Ground-water flow can be relatively rapid compared to the flow rate in isotropic aquifers, and is anisotropic because of the many fractures and solution-enlarged cavities in the carbonate rocks. The hydraulic connection between the weathered mantle and the secondary openings in the underlying bedrock is good because there are no well-defined confining units.

Ground-water data were collected within the Nutrient-Management Subbasin from three wells and one spring located in the carbonate-rock floored valley and three wells and one spring located in the sandstone and shale area. Locations of the wells and springs are shown in figure 1 and descriptions are given in table 4.

Precipitation

Normal yearly precipitation for the study area is about 42 in. based on long-term records from the NOAA station in Morgantown, Pa. Monthly averages range from 2.6 in. for February to 4.2 in. for August.

About 76 in. of precipitation, 10 percent less than normal, fell during the 2-year pre-BMP phase. Precipitation was 14 percent below normal during the first year and 5 percent below normal during the second year. Precipitation was more than 1.0 in. below normal for 12 of the 24 months of the pre-BMP phase, and more than 1.0 in. above normal for 6 of the months (fig. 4). Precipitation was 5 percent above normal during the 1984 growing season (April-September), and was 11 percent above normal during the 1985 growing season.

Table 4.--Description of ground-water sampling sites

Site	Latitude	Longitude	Geologic formation	Well or spring
LN SP59	400900	755515	Buffalo Springs Formation [1]	spring
LN SP60	400926	755445	Stockton Formation [2]	spring
LN 1586	400853	755521	Buffalo Springs Formation	well
LN 1662	400910	755544	Stockton Formation	well
LN 1663	400843	755527	Buffalo Springs Formation	well
LN 1665	400922	755511	Stockton Formation	well
LN 1666	400926	755436	Stockton Formation	well
LN 1678	400918	755439	Buffalo Springs Formation	well

[1] Buffalo Springs Formation (Cambrian) is light gray to pinkish gray, finely to coarsely crystalline limestone, and interbedded dolomite; numerous siliceous and clayey laminae, stromatolitic limestone beds near top; some thin sandy beds (Berg and others, 1980).

[2] Stockton Formation (Triassic) is lightgray to buff, coarse grained, arkosic sandstone, includes reddish-brown to grayish-purple sandstone, mudstone, and shale (Berg and others, 1980).

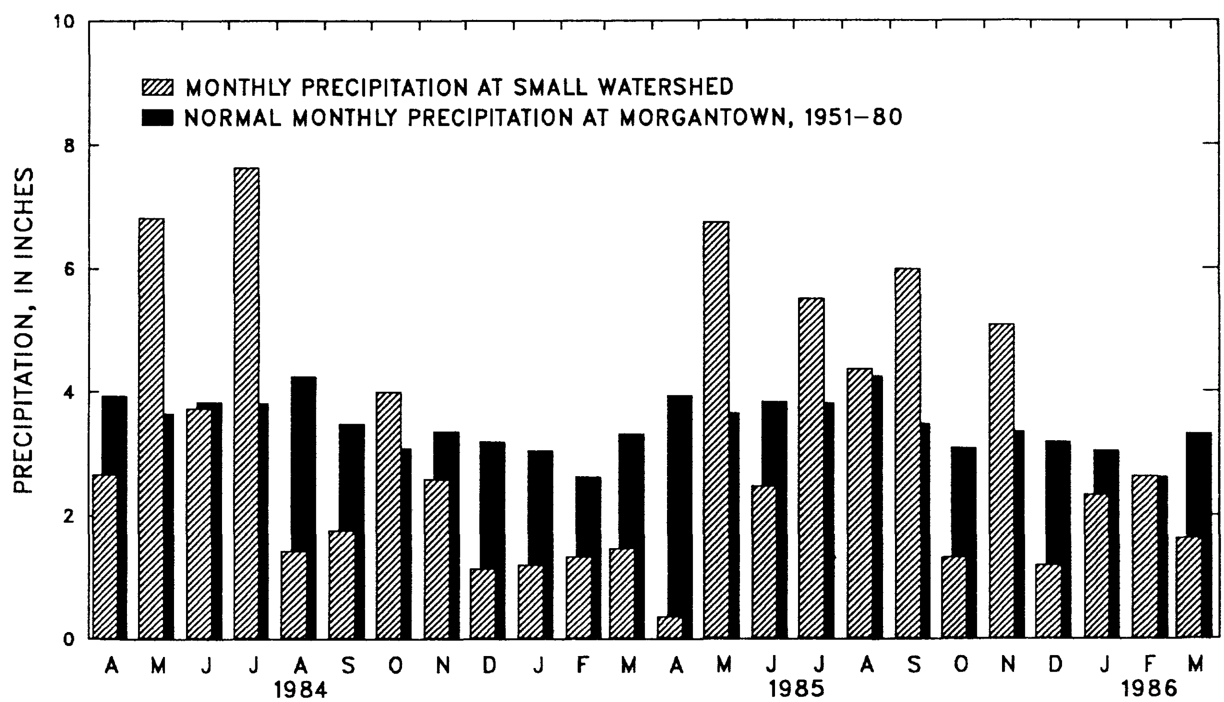


Figure 4.--Monthly precipitation at the Small Watershed and normal monthly precipitation at Morgantown.

Precipitation was in the form of rain during most of the year, but commonly in the form of snow in January and February. Three storms produced more than 2 in. of rain, and 15 storms produced more than 1 in. of rain during the 2-year study. These 18 storms accounted for about 40 percent of the precipitation that fell in the study area. The largest amount of precipitation from any single event occurred on September 26 and 27, 1985, when Hurricane Gloria produced 5.4 in. of precipitation in 18.5 hours. Without the hurricane, the second year of the study would have been 25 percent drier than normal.

Occasionally, there were large differences in the amount of precipitation between the sites in the study area, particularly during thunderstorms. These differences can produce differences in surface runoff and base flow at the two continuous-record sites. For example, the precipitation station for the study area recorded 1.1 in. of rain during a storm on August 14, 1985, while 2.4 mi away only 0.11 in. of rain was recorded.

Land Use and Agricultural Activity

The Small Watershed is in one of the most productive agricultural regions in the nation (Pennsylvania Department of Agriculture, 1985). Most Lancaster County farms are farmer-operated; the average size is 84 acres, 75 percent of which is under cultivation. The 16 farms that are either totally or partly in the Nutrient-Management Subbasin are typical of those in Lancaster County. Only two of these farms comprise more than 100 acres, and about 85 percent of the farm land is cultivated. Of the 16 farms in the Nutrient-Management Subbasin, 14 provide detailed land-use data. One of the farms that does not provide information represents 9 percent of the basin and is typical of this subbasin. The other is a small farm where no commercial fertilizer is used, and which comprises less than 1 percent of the basin.

Seventy-eight percent of the land in the Nutrient-Management Subbasin is used for agricultural purposes. Table 5 lists the land uses and the acreage devoted to each agricultural land use. Most of the land devoted to pasture borders the stream in the Nutrient-Management Subbasin, and the cattle have free access to the stream when they are grazing. The nonagricultural uses include residential, commercial, and wooded areas. Because only a small percentage of the land is devoted to residential use and the number of people in the Nutrient-Management Subbasin is small, human waste was not considered to be a major contributor of nutrients.

Table 5.–Land use and crop acreage in the Nutrient-Management Subbasin, April 1, 1984, through March 31, 1986

Land use	Percentage of total acreage	Percentage of agricultural acreage
Agricultural	78	
corn		52
hay		22
pasture		8
noncropland		18
Nonagricultural	22	
Total	100	

Three farms in the 1.42-mi^2 Nutrient-Management Subbasin--farms E, J, and a farm located on the northern border of the subbasin that is not identified in figure 3 because of its small contribution to the subbasin--were sold in 1986. No major changes in farm operation during the pre-BMP phase were documented after these farms were sold.

Land-use information from field reconnaissance of an area upstream from Site 1 (fig. 2) revealed that many used pesticide containers were scattered throughout the wooded area. The containers were removed from the area after the first year of the study.

Crop Acreage and Corn Yields

About 750 of the 909 acres in the Nutrient-Management Subbasin are planted in crops. About 52 percent of the total acreage is planted in corn, 22 percent is planted in hay (alfalfa or alfalfa and grass mixes), and 8 percent is pasture (table 5). Crop rotation commonly is practiced in the study area. Dairy farmers in the study area generally rotate crops using a schedule of 2 years for corn and 3 years for alfalfa. Agricultural-activities data provided by the farmers indicate about 40 percent of the total crop acreage in the Nutrient-Management Subbasin is rotated to a different crop each year. About 89 acres were rotated from alfalfa to corn in 1985.

The median corn yield for 11 farms in the Nutrient-Management Subbasin was 149 bushels/acre (bushels per acre). Yields ranged from 89 to 187 bushels/acre (table 6).

Table 6.--Average corn yields at farms in the Nutrient-Management Subbasin, April 1, 1984, through March 31, 1986

[Corn yield, in bushels per acre]

Farm	Average corn yield
A	151
A'	157
B	187
D	147
E	89
G	142
H	154
I	149
J	137
L	139
M	149

Animal Population and Density, and Manure Production

Dairy comprised about 43 percent of the animal population in the Nutrient-Management Subbasin on the basis of animal units; dairy comprised 23 percent; and hogs comprised 18 percent during the pre-BMP phase. Animal populations vary from year to year depending on the marketability of the animal. Table 7 shows the changes in animal populations in terms of animal units during 1984-85. The most significant change was the increase in beef cattle by about 35 animal units. The number of dairy cattle also increased slightly. Swine numbers decreased by about 25 animal units.

The Conestoga River Headwaters Plan of Work (U.S. Department of Agriculture, 1982) classified farms with more than 1.5 AU/acre (animal units per acre) as being critical areas in terms of nonpoint-source agricultural pollution. Animal densities for five of the farms in the Nutrient-Management Subbasin are greater than 1.5 AU/acre (table 8). When animal density is calculated using the amount of corn acreage available for manure disposal, then the densities range from 1.1 to 3.14 AU/acre.

In addition to animal population, table 7 also lists the corresponding amount of manure and nutrients produced by each animal type. About 14,000 tons of manure were produced in 1984 and in 1985, at 14 cooperating farms in the Nutrient-Management Subbasin. Manure is generally stored for only 3 to 5 weeks, because most of the farms have limited facilities for manure storage. Therefore, manure is spread throughout the year, even during the nongrowing season.

Table 7.--Animal types and manure production in the Nutrient-Management Subbasin during 1984-85

Animal type	Animal [1] units		Manure [2] (tons)		Nitrogen (pounds as N)		Phosphorus (pounds as P)	
	1984	1985	1984	1985	1984	1985	1984	1985
Dairy cows	478	471	7,410	7,300	74,100	73,000	13,040	12,850
Beef cattle	105	141	1,155	1,550	12,705	17,060	4,065	5,460
Swine	215	189	1,890	1,660	26,490	23,270	8,325	7,315
Poultry	254	259	2,790	2,850	83,700	85,470	24,550	25,070
Horses	25	25	415	415	4,980	4,980	915	915
Sheep	26	23	170	150	3,785	3,345	605	535
Totals	1,103	1,108	13,830	13,925	205,760	207,125	51,500	52,145

[1] One animal unit is equivalent to 1,000 pounds of animal weight.

Table 8.--Animal densities of farms in the Nutrient-Management Subbasin based on total crop acreage where manure may be applied

[AU, animal units]

Farm	Crop acreage (acres)	Animal density (AU/acre)	Farm	Crop acreage (acres)	Animal density (AU/acre)
A-A'[1]	106	1.20	H	32	3.14
B	75	1.17	I	44	1.64
D	55	2.41	J	126	1.14
E	27	.91	L	70	1.59
G	82	1.17	M	34	1.78

[1] One farmer operates both farms.

Nutrient Applications and Manure Export

Nutrients are applied to fields in the Nutrient-Management Subbasin as either manure or commercial fertilizer. Figure 5 shows the timing of nutrient applications during the pre-BMP phase. Most of the commercial fertilizer was applied in May and June near the beginning of the growing season. Exceptions were two applications of phosphorus to alfalfa fields made in July and August 1984. These applications of a 7-21-7 commercial fertilizer (7 percent N, 21 percent P_2O_5, 7 percent K_2O_5) were applied to fields that were deficient in phosphorus near Site 2A, and were rotated to corn in 1985. The sum of these two applications was about 1,040 lb of phosphorus--about 14 percent of the annual commercial fertilizer application of phosphorus.

Figure 5 also shows that most of the nitrogen and phosphorus was applied as manure. Often, manure was spread in the winter when the ground was frozen and tractors or horse-drawn manure spreaders were able to traverse the fields. If the fields were wet, heavy equipment could not be used, and the manure was piled near the barns or deposited on the closest fields.

Typical manure values and the estimated amount of manure produced by various animal types are listed in table 9. The nutrient content of manure depends on the animal type, moisture content, and the type and amount of bedding material in the manure. For example, manure from poultry, which comprised an average of 50 percent of the animal units in the Nutrient-Management Subbasin, contains three times more nitrogen and five times more phosphorus than does dairy manure. Some farmers in the Nutrient-Management Subbasin mixed the manure from more than one animal type before it was applied to cropland. Because manure samples were not collected and analyzed before each application, the nutrient content of the manure applied was calculated from the nutrient values shown in table 9.

Table 9.--Manure production and nutrient content of manure by animal type

[tons/yr, tons per year; lb/ton, pounds per ton]

Animal type	Estimated manure produced by one animal unit (tons/yr)[2]	(percent solids)[3]	Nutrient content[3] (lb/ton) Nitrogen	Phosphorus
Dairy cows	15.5	15	10	1.8
Beef cattle	11.0	15	11	3.5
Swine	8.8	14	14	4.4
Poultry	11.0	25	30	8.8
Sheep	6.6	25	22	3.5
Horses	8.2	21	12	2.2

[1] One animal unit is equivalent to 1,000 pounds of animal weight.

[2] U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, written commun., 1985.

[3] Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, Manure Management For Environmental Protection.

About 203,150 lb of nitrogen and 51,000 lb of phosphorus were reported by the farmers to have been applied as manure in the Nutrient-Management Subbasin during the pre-BMP phase (table 10). An additional 83,800 lb of nitrogen and 18,100 lb of phosphorus were estimated to have been deposited by animals grazing in pastures near the stream. Therefore, about 85 percent of the total 337,610 lb of nitrogen and 84 percent of the total 82,240 lb of phosphorus applied in the Nutrient-Management Subbasin came from manure. The largest nitrogen application for a single day, 10,740 lb, was made at farm D (fig. 3) on September 5, 1985. This single application of 600 tons of hog and chicken manure was applied to a pasture. The largest phosphorus application, 3,830 lb, was on October 11, 1985. More than 95 percent of the phosphorus applied on October 11 was from hog and chicken manure spread on several fields at farm D, after corn was harvested and before wheat was planted.

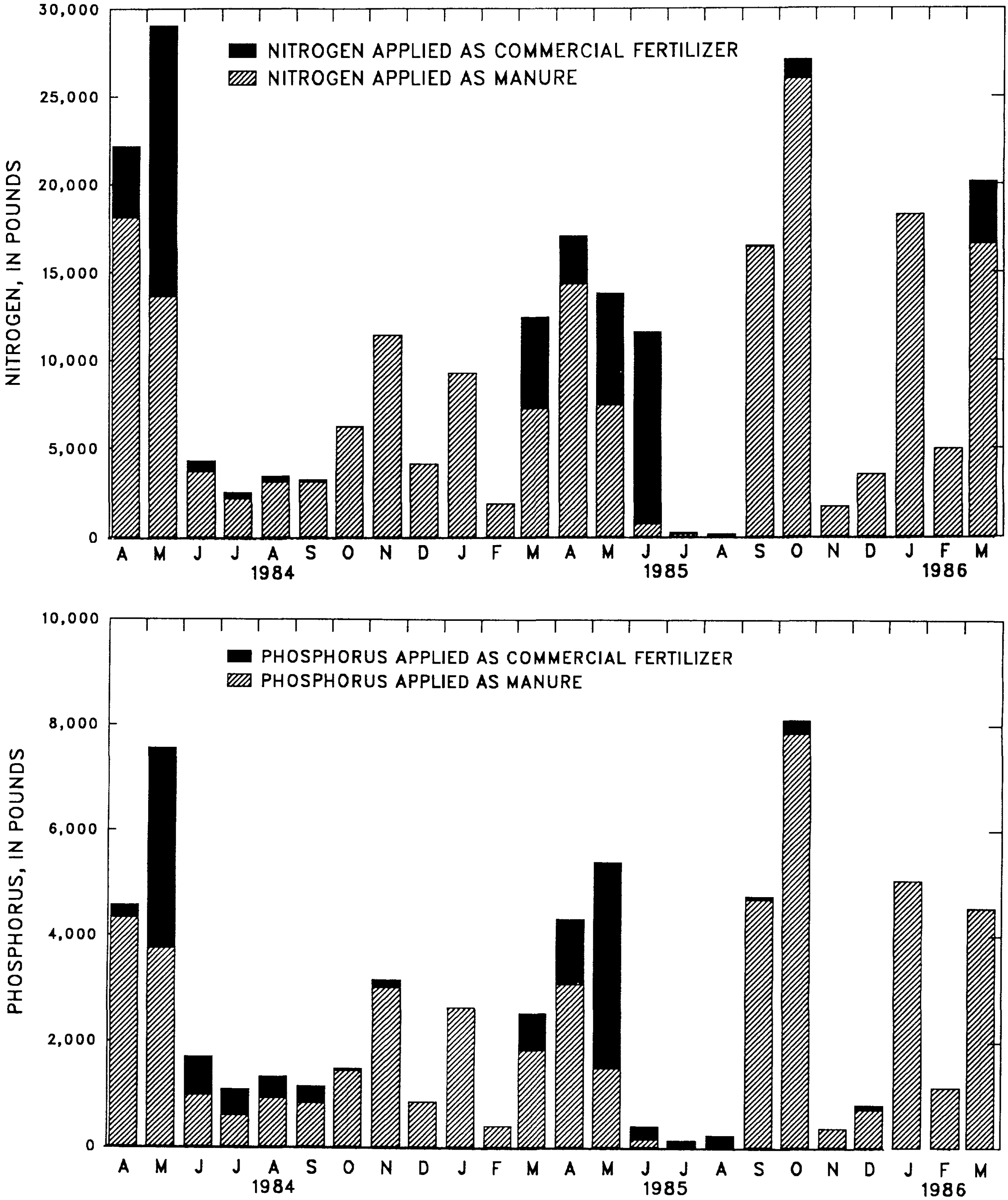


Figure 5.--Nutrient applications as reported by farmers in the Nutrient-Management Subbasin during the pre-Best-Management Practice phase, April 1, 1984, through March 31, 1986.

Table 10.--Amounts of manure and commercial fertilizer spread on fields in the Nutrient-Management Subbasin, April 1, 1984 through March 31, 1986

[lb, pounds]

Farm	Year	Manure applied (tons)	Nitrogen Manure (lb)	Nitrogen Fertilizer (lb)	Nitrogen Total (lb)	Phosphorus Manure (lb)	Phosphorus Fertilizer (lb)	Phosphorus Total (lb)
A-A'	1	1,634	22,550	2,470	25,020	5,520	800	6,320
	2	1,629	26,300	4,580	30,880	6,390	820	7,210
	Total	3,263	48,850	7,050	55,900	11,910	1,620	13,530
B	1	945	9,450	3,670	13,120	1,680	1,820	3,500
	2	863	8,630	6,460	15,090	1,450	750	2,200
	Total	1,808	18,080	10,130	28,210	3,130	2,570	5,700
D	1	1,124	20,160	6,810	26,970	6,090	1,090	7,180
	2	2,100	37,520	810	38,330	12,140	350	12,490
	Total	3,224	57,680	7,620	65,300	18,230	1,440	18,670
E	1	294	6,470	0	6,470	1,030	0	1,030
	2	275	5,860	2,010	7,870	930	530	1,460
	Total	569	12,330	2,010	14,340	1,960	530	2,490
G	1	651	6,440	3,790	10,230	1,590	110	1,700
	2	505	3,260	2,790	6,050	570	990	1,560
	Total	1,156	9,700	6,580	16,280	2,160	1,100	3,260
H	1	298	3,620	280	3,900	1,140	0	1,140
	2	643	8,560	840	9,400	2,680	170	2,850
	Total	941	12,180	1,120	13,300	3,820	170	3,990
I	1	606	6,160	2,880	9,040	2,000	430	2,430
	2	807	8,640	2,670	11,310	2,530	140	2,670
	Total	1,413	14,800	5,550	20,350	4,530	570	5,100
J	1	140	3,160	260	3,420	940	130	1,070
	2	25	500	340	840	150	160	310
	Total	165	3,660	600	4,260	1,090	290	1,380
L	1	286	3,810	1,480	5,290	1,200	440	1,640
	2	195	2,610	1,460	4,070	790	30	820
	Total	481	6,420	2,940	9,360	1,990	470	2,460
M	1	752	7,880	850	8,730	1,770	430	2,200
	2	482	5,460	190	5,650	870	220	1,090
	Total	1,234	13,340	1,040	14,380	2,640	650	3,290
N	1	148	1,350	2,520	3,870	400	840	1,240
	2	71	330	460	790	60	820	880
	Total	219	1,680	2,980	4,660	460	1,660	2,120
O	1	81	810	280	1,090	140	480	620
	2	59	1,000	1,310	2,310	180	430	610
	Total	140	1,810	1,590	3,400	320	910	1,230
P	1	231	1,410	530	1,940	440	110	550
	2	521	1,210	340	1,550	320	170	490
	Total	752	2,620	870	3,490	760	280	1,040
Q	1	0	0	210	210	0	370	370
	2	0	0	370	370	0	510	510
	Total	0	0	580	580	0	880	880
Totals for all farms	1	7,190	93,270	26,030	119,300	21,940	7,050	28,990
	2	8,175	109,880	24,630	134,510	29,060	6,090	35,150
		15,365	203,150	50,660	253,810	51,000	13,140	64,140

Table 10 indicates that 1,000 tons more manure were applied during the second year of the study than during the first year in the Nutrient-Management Subbasin. Although nitrogen and phosphorus applications from commercial fertilizer were reduced by 15 and 18 percent, respectively, about 11 percent more nitrogen and 18 percent more phosphorus were applied during the second year. These increases were partially because of the application of manure reported earlier on September 5, 1985.

The methods of applying manure and the timing of applications affect the amount of nutrients that ultimately becomes available for the crops, surface runoff, or leaching to the ground water. If manure is simply applied to the surface, then a significant amount of the nitrogen can volatilize to the atmosphere in the form of ammonia. As much as 30 percent of the nitrogen can be lost by volatilization to the atmosphere within 7 days if the manure is not incorporated into the soil shortly after it is applied (Pennsylvania Department of Environmental Resources, 1986). Volatilization also will increase as air temperatures increase. Van Breemen and others (1982), however, suggest that substantial amounts of the nitrogen lost by volatilization can return to the soil surface in precipitation.

Approximately 18,000 tons of manure were produced annually on the farms in the Nutrient-Management Subbasin during the 2 years of pre-BMP monitoring (table 7). About 7,190 tons of this manure in the first year and 8,175 tons in the second year were reported to have been spread on fields within the Nutrient-Management Subbasin (table 10). Another 3,900 tons of manure were estimated to have been deposited on pasture land annually by grazing animals. The remaining third of the manure, mostly from farms D and H (figure 3), was spread on fields outside the Nutrient-Management Subbasin.

Soils and Nutrient Content

The soils of the Small Watershed are noncarbonate, alluvial, or carbonate and are all fine to medium textured and well drained. The major noncarbonate soils are of the Brecknock, Bucks, and Unger series, whereas the minor noncarbonate soils are of the Manor, Chester, and Glenelg series. The alluvial soils of the Rowland and Readington series also were formed from noncarbonate residuum, but are greater than 20 in. deep and are located in the flood plains. The major carbonate soil series are Duffield and Hagerstown, and there are small areas of Clarksburg and Nolin series. Most of the carbonate soil series are cited as prime farm land in the Lancaster County Soil Survey (U.S. Department of Agriculture, 1985).

Soil maps from the Soil Survey were digitized to compare soils in the Small Watershed, the Nutrient-Management Subbasin, and the Nonnutrient-Management Subbasin. The soils in the Small Watershed and those of the Nutrient-Management Subbasin are nearly the same; 47 and 50 percent are noncarbonate, 41 and 36 percent are carbonate, and 12 and 14 percent are alluvial, respectively. In the Nonnutrient-Management Subbasin, 71 percent of the soils are noncarbonate, 18 percent carbonate, and 11 percent alluvial.

The soil pH of 40 fields on 10 farms in the Nutrient-Management Subbasin was measured between April 5-15, 1984. Soil pH ranged from 6.2 at a field at farm D (fig. 3) to 7.3 at a field at farm E. The average pH for the 10 farms, calculated as the mean of the hydrogen-ion concentrations, ranged from 6.5 to 7.2.

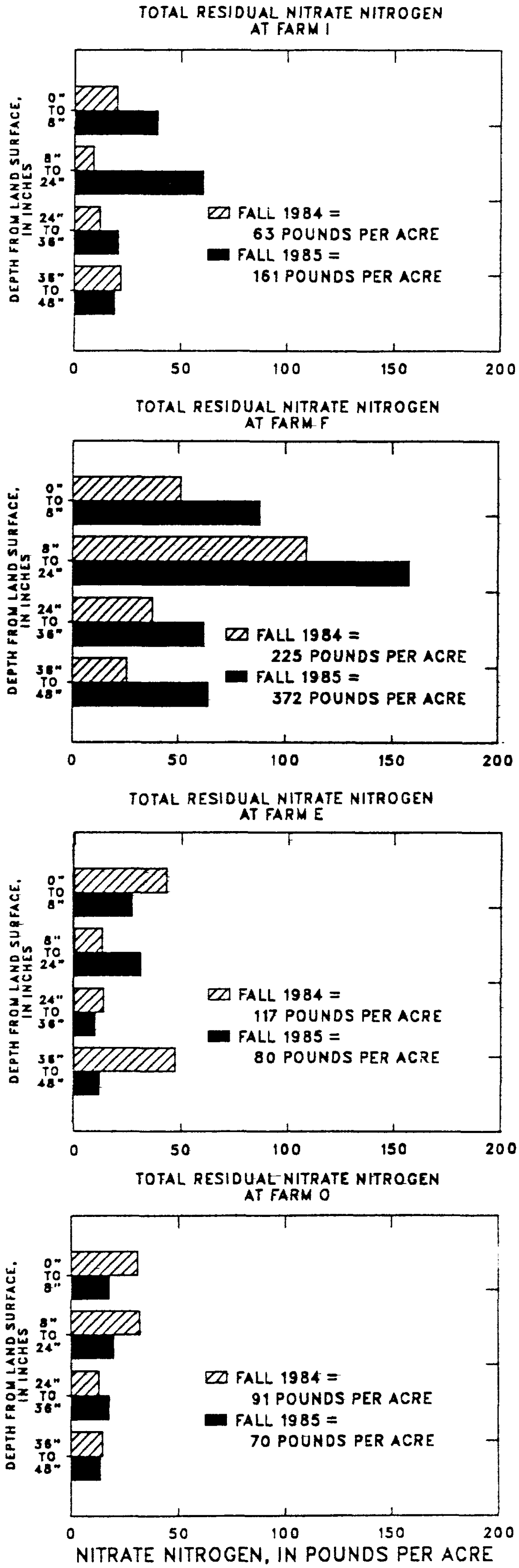
Available nitrogen (nitrate) and phosphorus concentrations of soils from seven fields were measured after the growing seasons in 1984 and 1985 (figs. 6 and 7). These concentrations reflect only the amount of nitrate nitrogen. They do not account for nitrogen from ammonia or nitrogen that may become available from nitrification of residual organic nitrogen in the soil. The total amount of nitrate-nitrogen in the top 4 ft of soil ranged from 45 to 372 lb/acre (pounds per acre). At some fields, nitrate concentrations at the 36-48 in. depth were about the same or greater than the concentrations in the top 8 in. reflecting the highly soluble nature of nitrate. The nitrate concentrations in the soil at some fields may even be greater below 4 ft. Soil-nitrate concentrations increased from 63 to 161 lb/acre and 225 to 372 lb/acre at farms I and F, respectively, from 1984 to 1985; at the other 5 sites, concentrations decreased. The cause for the increases was not determined; however, one possible cause may be that seepage from manure piles not spread evenly on the fields may percolate through the 4-ft root zone of the soil column. Nitrogen in soil is organically bound as humus, and inorganically present as nitrate (NO_3^+) and ammonium (NH_4^+) ions. About 99 percent of the total soil nitrogen is in the organic form and is not appreciably absorbed by most plants. Some plants, such as alfalfa, which is a legume, can use nitrogen from the atmosphere, but nitrate is the ion that is used by most plants. The highly mobile nitrate ion is made available to solution from manure and fertilizers and the conversion of the organic and ammonia nitrogen to the nitrate ion. When the nitrate ion is present in porous soils in greater quantities than required for optimum plant growth, the nitrate ion can leach downward from the porous surface soil layer into the deeper subsurface soils.

Soil monitoring studies in Nebraska, Iowa, and Wisconsin (Hallberg and others, 1984; Rehm, Zoubek, and Hoorman, 1983) suggest that less than 100 lb/acre of nitrate nitrogen should remain in the top 4 ft of soil so that leachate to the ground water will never exceed 20 mg/L nitrate nitrogen. Baker (Pennsylvania State University, College of Agriculture, Department of Agronomy, written commun., 1985) states that a more desirable environmental level for nitrate-nitrogen may be 50 lb/acre in the upper 4 ft of soil. Nitrate-nitrogen concentrations in soils at all of the farms (fig. 6) in the fall of 1984 and six of the farms in the fall of 1985 exceeded the value recommended by Baker.

Crop management can affect the nutrient content of soil. Corn and alfalfa, the major crops grown in the study area, have different nitrogen requirements. Corn utilizes large amounts of nitrogen that are added to soil through manure and commercial fertilizer applications, whereas alfalfa adds nitrogen to the soil. The Penn State Agronomy Guide (1987-88, p.23) indicates that the first year after an average stand of alfalfa is plowed under, about 80 lb/acre of nitrogen becomes available in the soil for crop production. This is especially true when soil temperatures exceed 50 °F (degrees Fahrenheit) and the active nitrifying bacteria accelerate the release of soluble nitrogen. Therefore, on the basis of the reported crop rotation for 1985 and the assumption that the alfalfa stands in the Nutrient-Management Subbasin were average stands, it was calculated that about 7,120 lb of nitrogen were made available for crops or for leaching to ground water from the 89 acres of alfalfa when it was plowed into the soil. Thus, about 5 percent of the nitrogen input to cropland in the Nutrient-Management Subbasin was from alfalfa (126,905 lb from table 9 plus 7,120 lb from alfalfa). This is comparable to the 8 to 10 percent contribution of nitrogen by legumes, such as alfalfa, to cropland in the Big Spring Basin in Iowa reported by Hallberg (1987, p.52).

Farmers in the Small Watershed generally follow the SCS recommendation that plowing, and therefore, rotation of alfalfa to corn, be done in the spring. This practice helps to reduce soil loss in the fall and winter when it may be difficult to establish cover crops, and it also improves utilization of the nitrogen for corn production, thereby reducing the leaching of nitrogen to the ground water.

The total amount of phosphorus in the top 4 ft of soil ranged from 1.4 to 23 lb/acre. In contrast to the nitrate concentrations, phosphorus concentrations were consistently greater in the top 8 in. of the soil reflecting the affinity that phosphorus has for fine soil particles. Phosphorus concentrations increased at farm G from 2.4 to 5.4 lb/acre from 1984 to 1985; at the other six sites, the concentrations remained the same or decreased. Most of the phosphorus in the soil in the Nutrient-Management Subbasin may be available for the crops inasmuch as the optimum range of pH for phosphorus availability is 6.5 to 7.0. At a high or low pH, phosphorus can form insoluble compounds with iron or aluminum and become unavailable to plants.



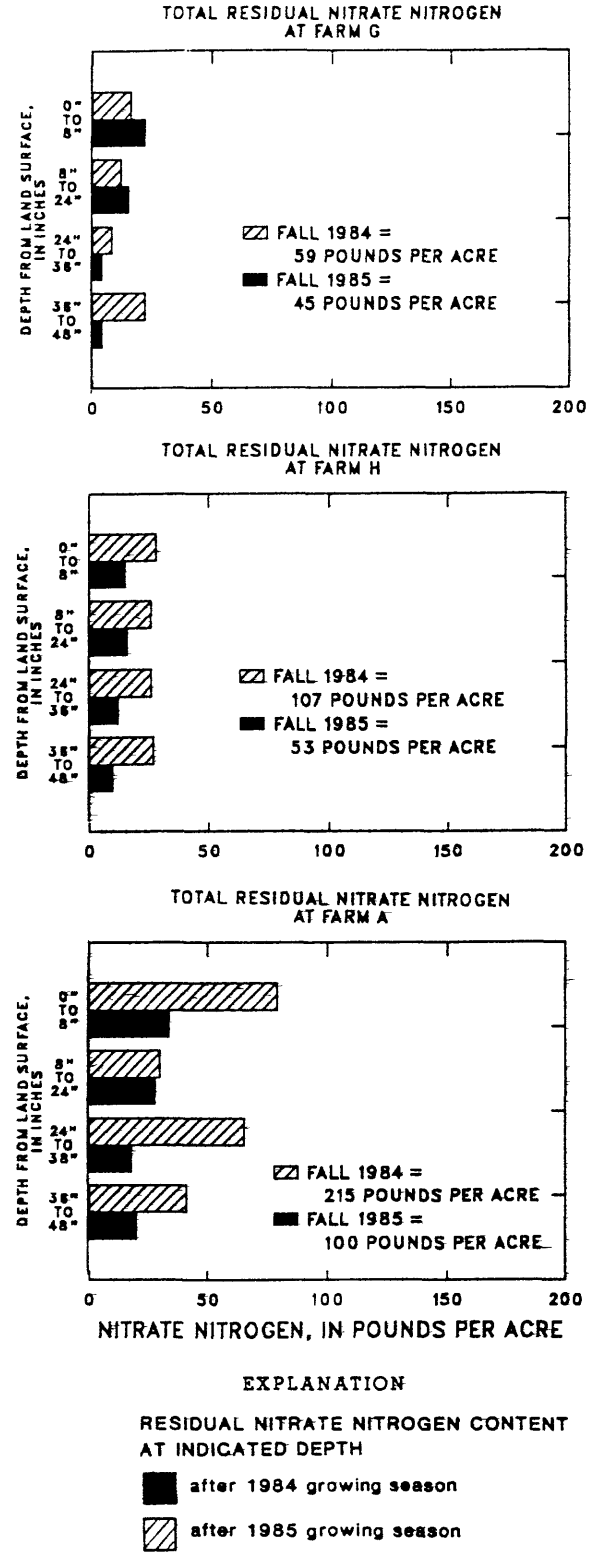
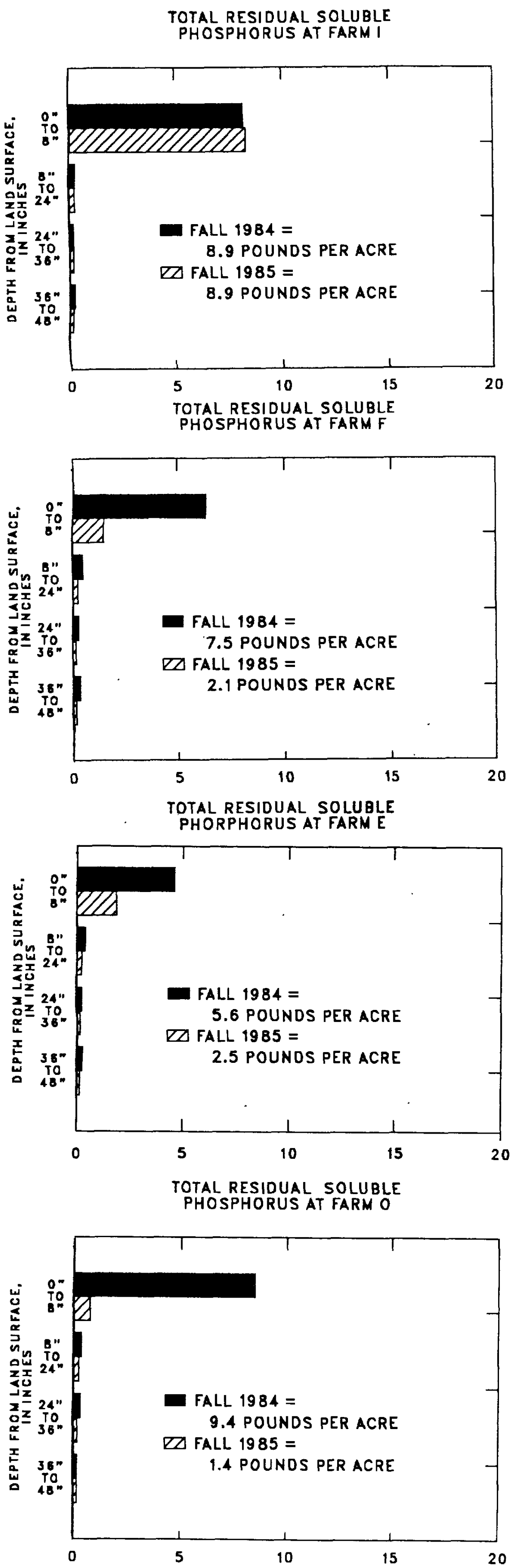


Figure 6.--Residual nitrate-nitrogen in the top four feet of soil after the 1984 and 1985 growing seasons (November 3, 1984, and October 9, 1985) at seven farms in the Nutrient-Management Subbasin.



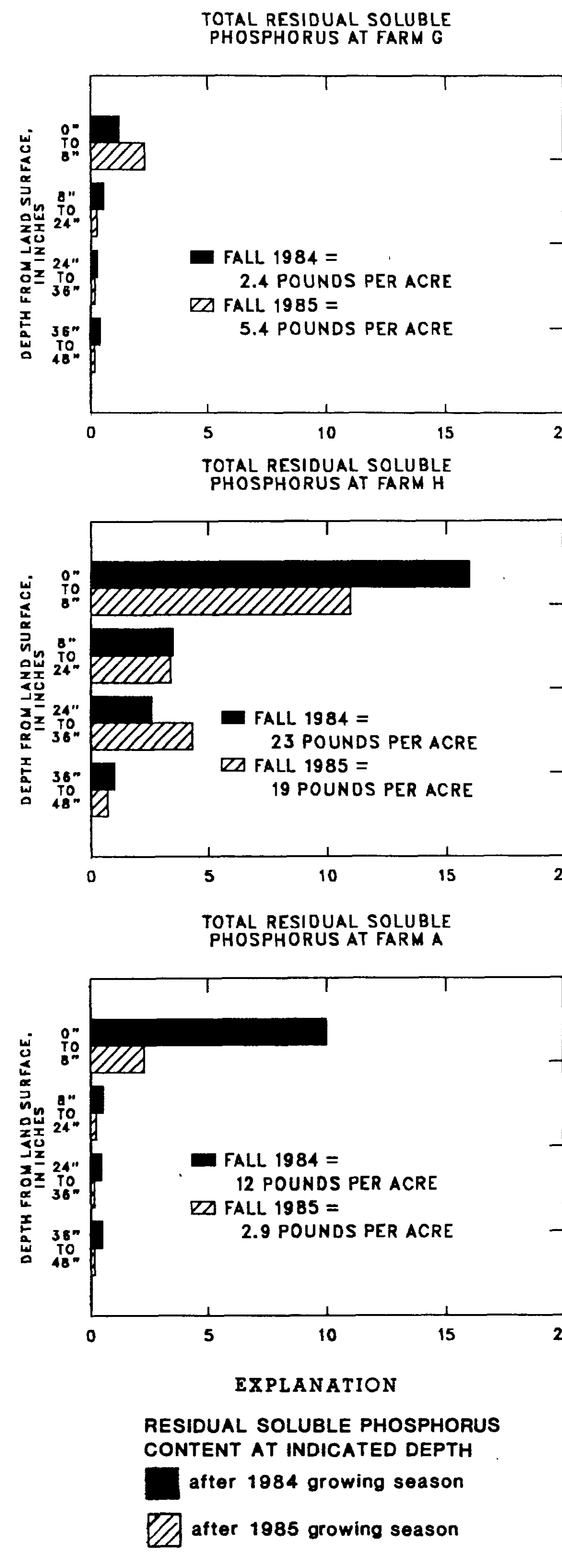


Figure 7.--Residual soluble phosphorus in the top four feet of soil after the 1984 and 1985 growing seasons (November 3, 1984, and October 9, 1985) at seven farms in the Nutrient-Management Subbasin.

Streamflow

Streamflow data collected in the Small Watershed were compared to the 55 years of record for the gage at the Conestoga River at Lancaster (USGS station no. 01576500), which is 16.75 mi southwest (28.2 river miles downstream) of the study area. Streamflows at the Small Watershed for the first year (April 1984 through March 1985) of the study were not well related to those at Lancaster because 8 in. less precipitation was recorded at the Small Watershed than at Lancaster. Streamflows during the second year (April 1985 through March 1986) of the study were about 15 percent lower than normal at the Small Watershed since the amounts of precipitation at the Small Watershed and Lancaster were similar, and the streamflows at Lancaster were 15 percent below the long-term mean. Streamflow was about 36 percent greater during the first year than during the second year at the Small Watershed, and streamflow was 4 percent greater during the first year than during the second year at the Nutrient-Management Subbasin.

Mean daily streamflow at the Small Watershed ranged from 0.76 ft^3/s (cubic feet per second) on September 20 and 21, 1985, to 165 ft^3/s on July 7, 1984. The annual average streamflows at the Small Watershed were 7.57 and 5.55 ft^3/s for the first and second year of the study, respectively. Mean daily streamflow at the Nutrient-Management Subbasin ranged from 0.06 ft^3/s on January 21 and 22, 1985, to 41 ft^3/s on September 27, 1985. Annual average streamflows at the Nutrient-Management Subbasin were 1.28 and 1.23 ft^3/s for the 2 years of the pre-BMP phase, respectively.

Hydrograph separations of the continuous streamflow data from the Small Watershed and the Nutrient-Management Subbasin indicate that the streamflow characteristics of the two sites are similar (fig. 8). Surface runoff increased in streamflow within a few hours after precipitation began at both sites.

Table 11 lists the monthly contribution of base flow of the Small Watershed and the Nutrient-Management Subbasin. Total streamflow and base flow are expressed in the table as inches of runoff. Runoff is the depth to which the drainage area would be covered if all the streamflow for a given time period were distributed uniformly on it. Base flow comprised from 9 to 96 percent of the monthly streamflow, the percentage depending on the amount of precipitation and storm intensities. The monthly percentages of base flow were usually similar at the sites. Similarities in streamflow characteristics at the sites were probably because both sites lie within the carbonate-rock floored valley, have similar water-bearing formations, and are only 3.3 mi apart. The large differences in the monthly percentage of base flow between the sites in May 1985 were likely the result of local storms.

Total runoff from the Small Watershed during the pre-BMP phase was 30.59 in., of which 17.43 in. (56 percent) was base flow. Total runoff from the Nutrient-Management Subbasin was about 25.25 in., of which 15.26 in. (60 percent) was base flow. About 20 percent of the flow at Site 5 was from Site 3A.

About 74 and 79 percent of the streamflow at the Small Watershed and the Nutrient-Management Subbasin, respectively, occurred in the growing season (April through September) during the first year of the study. About 30 and 28 percent of the streamflow at the Small Watershed and the Nutrient-Management Subbasin, respectively, occurred in the growing season during the second year of the study.

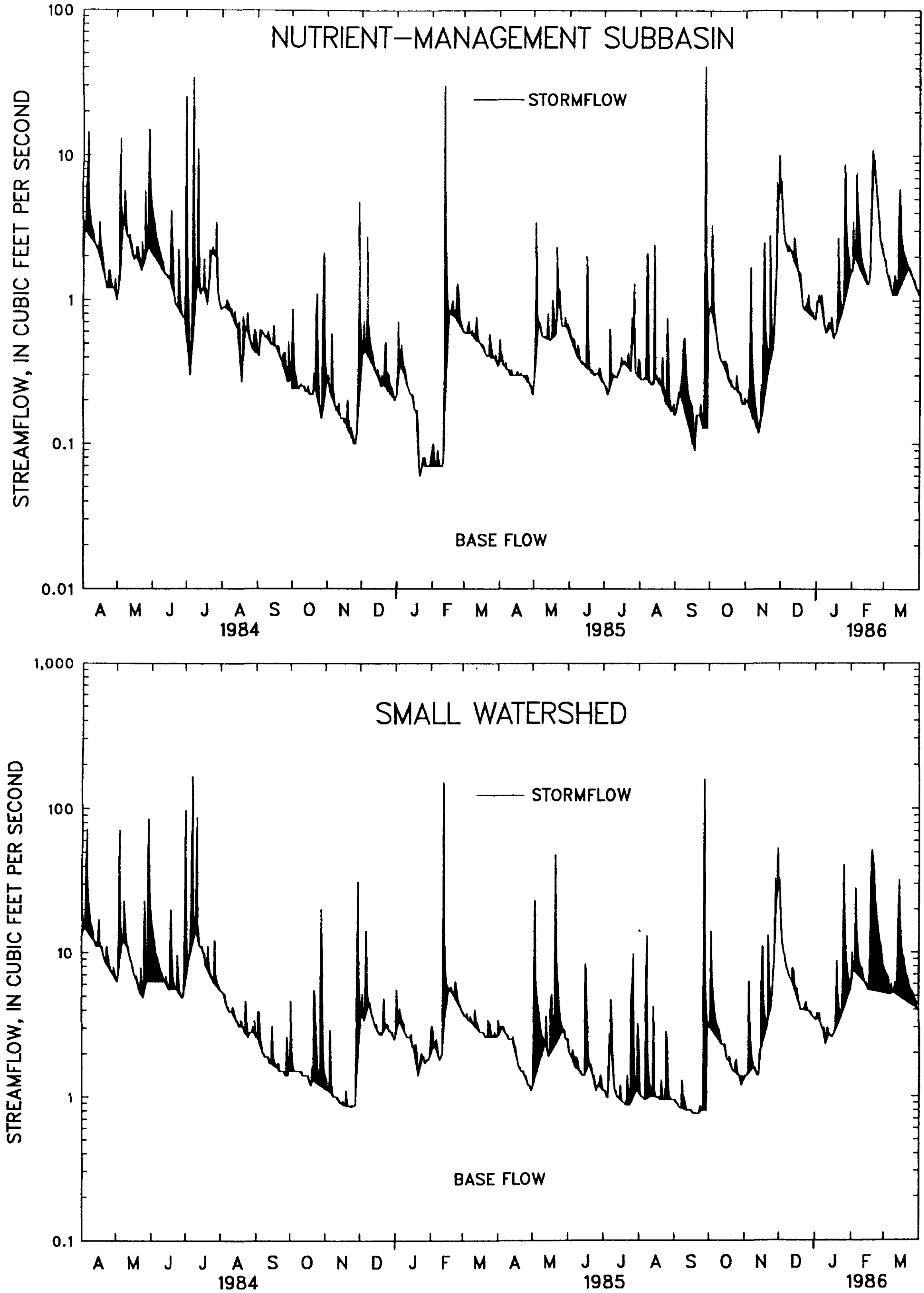


Figure 8.--Surface runoff and base flow components of total streamflow at the Nutrient-Management Subbasin and the Small Watershed, April 1, 1984, through March 31, 1986.

Table 11.--Total streamflow and base-flow contributions at the Small Watershed and the Nutrient-Management Subbasin during the pre-Best-Management Practice phase, April 1, 1984 through March 31,1986

[Streamflow and base flow of runoff, in inches]

Month	Year	Small Watershed			Nutrient-Management Subbasin		
		Total streamflow	Base flow	Percentage of base flow in total streamflow	Total streamflow	Base flow	Percentage of base flow in total streamflow
April	1984	2.92	2.08	71	2.27	1.51	66
	1985	.41	.39	96	.28	.27	95
May	1984	3.15	1.53	48	3.01	1.72	57
	1985	1.12	.42	37	.65	.47	72
June	1984	1.62	1.12	69	1.49	1.04	70
	1985	.37	.29	79	.36	.30	82
July	1984	4.16	1.76	42	2.93	.92	31
	1985	.39	.23	59	.32	.27	84
August	1984	.75	.71	95	.57	.50	88
	1985	.37	.19	52	.38	.20	52
September	1984	.39	.34	87	.37	.34	91
	1985	1.26	.16	12	1.33	.11	9
October	1984	.54	.27	49	.34	.18	53
	1985	.55	.40	73 27	.40	.31	78
November	1984	.47	.20	43	.28	.13	46
	1985	1.39	.86	62	1.03	.55	53
December	1984	.77	.64	82	.36	.24	68
	1985	1.55	1.47	95	1.61	1.48	92
January	1985	.51	.46	90	.17	.15	85
	1986	1.13	.66	58	1.15	.69	60
February	1985	1.75	.63	36	1.25	.29	24
	1986	2.81	1.08	38	2.76	2.06	75
March	1985	.62	.59	94	.44	.42	95
	1986	1.59	.95	59	1.50	1.11	74
Totals							
	Year 1	17.65	10.33	59	13.48	7.44	55
	Year 2	12.94	7.10	55	11.77	7.82	66
pre-BMP phase		30.59	17.43	57	25.25	15.26	60

WATER-QUALITY CHARACTERIZATION

Surface Water

Base Flow

The median dissolved nitrite plus nitrate-nitrogen concentration in base flow at Site 1 in the nonagricultural, noncarbonate area of the Nutrient-Management Subbasin was 2.7 mg/L during the 2-year study (table 12). Median dissolved nitrate-nitrogen concentrations increased to 8.1 mg/L as the water flowed through the intensively farmed carbonate-rock floored valley at Site 3A, the most downstream site in the Nutrient-Management Subbasin. The median dissolved nitrite plus nitrate-nitrogen concentration at Site 5, the most downstream site in the Small Watershed, was 7.0 mg/L. Median total-phosphorus concentrations increased from 0.05 mg/L at Site 1 to 0.20 mg/L at Site 2A in the agricultural, carbonate area and then decreased to 0.18 mg/L at Site 3A, reflecting the deposition of sediment that was observed between Sites 2A and Site 3A when sampling base flow. At Site 2A, the streamflow changes from southward to westward (fig. 1), and the stream velocity begins to decrease causing sediment deposition near the bridge immediately downstream from Site 2A. The median total-phosphorus concentrations were about the same at all of the agricultural, carbonate sites--from 0.18 to 0.23 mg/L. Variations in nutrient concentrations and loads were greater in the agricultural, carbonate area (Sites 2A, 3A, 9, and 5) than in the most upstream site (Site 1) in the nonagricultural, noncarbonate area (table 12 and figs. 9-10).

Time-series plots (figs. 11 to 17) of precipitation, nutrient applications, and concentrations and loads of total nitrogen, dissolved nitrite plus nitrate nitrogen, and total and dissolved phosphorus at Sites 1, 3A, and 5 show the relations between these variables and base flow during growing and nongrowing seasons. Concentrations of dissolved nitrite plus nitrate nitrogen were greater following wet periods after crops were harvested and manure was applied. For example, in September 1985 when Hurricane Gloria produced 5.4 in. of precipitation shortly after crops were removed and about 1,150 tons of manure were applied to a 7.5-acre pasture on farm D--a substantial increase in the concentrations of dissolved nitrite plus nitrate nitrogen was noted at Sites 3A and 5 (figs. 13 and 16).

Concentrations of dissolved nitrite plus nitrate nitrogen in base flow decreased more during the second growing season than during the first growing season at Sites 3A and 5 (figs. 13 and 16). Decreases in concentrations were greater when precipitation, infiltration, and recharge to the ground water decreased (January 1985 through April 1985) and nutrient utilization and evapotranspiration by crops increased (May 1985 through September 1985). Nitrite plus nitrate-nitrogen concentrations were comparatively low during nonrecharge periods when the ground water that discharged as base flow was in little contact with the soil but in prolonged contact with the carbonate rock. Dissolved-nitrite plus nitrate nitrogen concentrations decreased from 7.6 to 3.9 mg/L, and specific conductance increased from 275 to 390 μS/cm (microsiemens per centimeter at 25 degrees Celsius) at Site 3A from April through August 1985. The minimum dissolved-nitrite plus nitrate nitrogen concentration in base flow of 3.9 mg/L on August 20, 1985, at Site 3A suggests that water quality is better when base flow discharges from the lower ground-water zone than it is when base flow discharges from the upper ground-water zone. During periods when the ground-water table was low (in late summer and early fall) the ground water had little contact time with the nutrient-rich soils, so the nitrate concentration in the ground water was probably lower than when the ground-water table was high. When base flow is low, it is sustained primarily by discharges of ground water that had percolated vertically through the soil column to the lower ground-water zone within the carbonate rock and then discharged through the streambed. This ground water had a short period of contact with the soil. This is reflected by the decreases in nitrite plus nitrate-nitrogen concentrations and increases in specific conductance, especially at Site 3A. In contrast, when base flow is high, it is sustained by lateral discharges of ground water, some of which is interflow, that have migrated horizontally for longer time periods through the nutrient-rich soils.

discharged at the rate of 16 (tons/mi^2)/yr in base flow from Site 3A. Like the nutrients, most of the sediment load in base flow was transported during high base flow. Over 1.8 times more sediment was discharged from Site 3A during the first year than during the second year. Most of the suspended-sediment load in base flow during the first year was transported by high base flows in May and June. The high base flows were the result of storms which carried sediment to the streams shortly after fields were plowed.

Pesticide samples were collected during the growing seasons of the pre-BMP phase. Atrazine and simazine, herbicides commonly used for weed control in corn fields, were detected in base flow at Site 1 in the nonagricultural, noncarbonate area during the first year of the study (table 12). Field reconnaissance revealed that used pesticide containers were throughout the wooded area upstream from the site. Pesticides were not detected at Site 1 after the landowner was notified by PaDER to dispose of the used containers in an approved manner (table 14). However, these results are not conclusive because the detection limit for atrazine increased from 0.10 µg/L (micrograms per liter) to 0.20 µg/L after the disposal area was identified.

Nitrite plus nitrate nitrogen concentrations and loads probably varied greatly throughout the year in the Nutrient-Management Subbasin because of the intensity of agriculture and the interaction with the timing of precipitation. For example, commercial applications of nitrogen were decreased by 5 percent in the second year, thereby making less nitrate available for transport to the stream. Secondly, because 52 percent of the total acreage was planted in corn, large amounts of nitrate were required for crop production; most of this nitrate was removed when the crop was harvested. Lastly, evapotranspiration increased substantially in the subbasin as the corn grew. As evapotranspiration increased, proportionally less water percolated to carry nitrate to the ground water, which could discharge later as base flow.

Unlike dissolved-nitrite plus nitrate nitrogen concentrations, total-phosphorus concentrations in base flow at Site 3A increased during the pre-BMP phase and were greatest near the end of the growing season (fig. 14). This pattern may have been caused by the large amounts of soluble phosphorus applied late in the growing season as commercial fertilizer to alfalfa fields that were deficient in phosphorus. Excess phosphorus from this application was probably transported to the stream in stormflow, absorbed by fine sediments, and deposited on the stream bottom. Phosphorus redissolves when anaerobic conditions develop. Masses of tubifex worms were found in the streambed material at Site 2A; these worms thrive in poorly oxygenated water, suggesting that the water was anaerobic at Site 2A during June, July, and August of each year. Another cause for increases in phosphorus during warmer months was that cattle deposit manure rich in phosphorus directly into the stream at Sites 2A and 3A. Phosphorus also is released to the stream from the decomposition of algal blooms and other aquatic vegetation. Finally, base flow decreased at the end of the growing season; therefore, dilution of the phosphorus decreased at this time.

At the Paired-Watersheds, the median dissolved-nitrite plus nitrate nitrogen concentration in base flow was greater at Site 3A (Nutrient-Management Subbasin) than at Site 9 (Nonnutrient-Management Subbasin), and median concentrations of total phosphorus and total-ammonia plus organic nitrogen were generally greater at Site 9 than at Site 3A (table 12). Less dilution of dissolved nitrite plus nitrate nitrogen and greater deposition of suspended phosphorus and suspended ammonia plus organic nitrogen occurred at Site 3A than at Site 9 because of comparatively lower streamflows and slower stream velocities at Site 3A. Correlations between nutrient concentrations and nutrient loads at Sites 3A and 9 were poor ($r < 0.80$) except for the loads of dissolved nitrite plus nitrate nitrogen ($r = 0.92$) (figs. 18 and 19). These poor correlations suggest that the availability of nutrients for transport at the Paired- Watersheds or the factors controlling the transport of the nutrients, such as land-use practices and precipitation, may be different at the two sites.

Further examination of the data in figure 18 indicates that dissolved-nitrite plus nitrate nitrogen concentrations in base flow at both subbasins are affected by precipitation. This was exemplified when base-flow concentrations increased from 7.5 to 10 mg/L at Site 3A and from 2.2 to 5.7 mg/L at Site 9 following Hurricane Gloria in September 1985.

Monthly nutrient and suspended-sediment loads in base flow at Sites 3A and 5 during the pre-BMP phase are listed in table 13. The nitrogen, phosphorus, and suspended-sediment loads were greater during high base flow than during low base flow. Annual nitrogen and phosphorus loads for Sites 3A and 5 were about the same both years; however, there were large differences between months. During the 2 years, nearly 162,000 lb (81 tons) of nitrogen were discharged at the rate of 7.0 (tons/mi^2)/yr (tons per square mile per year) in base flow at Site 5 during the pre-BMP phase, and nearly 32,000 lb (16 tons) of the nitrogen were discharged at the rate of 5.5 (tons/mi^2)/yr at Site 3A. Most of the nitrogen load was composed of dissolved nitrite plus nitrate nitrogen and was discharged during months of high base flow. About 2,900 lb (1.45 tons) of phosphorus were discharged at the rate of 0.12 (ton/mi^2)/yr in base flow at Site 5 and about 536 lb (0.268 ton) were discharged at the rate of 0.10 (ton/mi^2)/yr at Site 3A.

Nearly 576,000 lb (288 tons) of suspended sediment were discharged at the rate of 24 (tons/mi^2)/yr in base flow at Site 5 during the pre-BMP phase. About 90,500 lb (45.25 tons) of the suspended sediment were

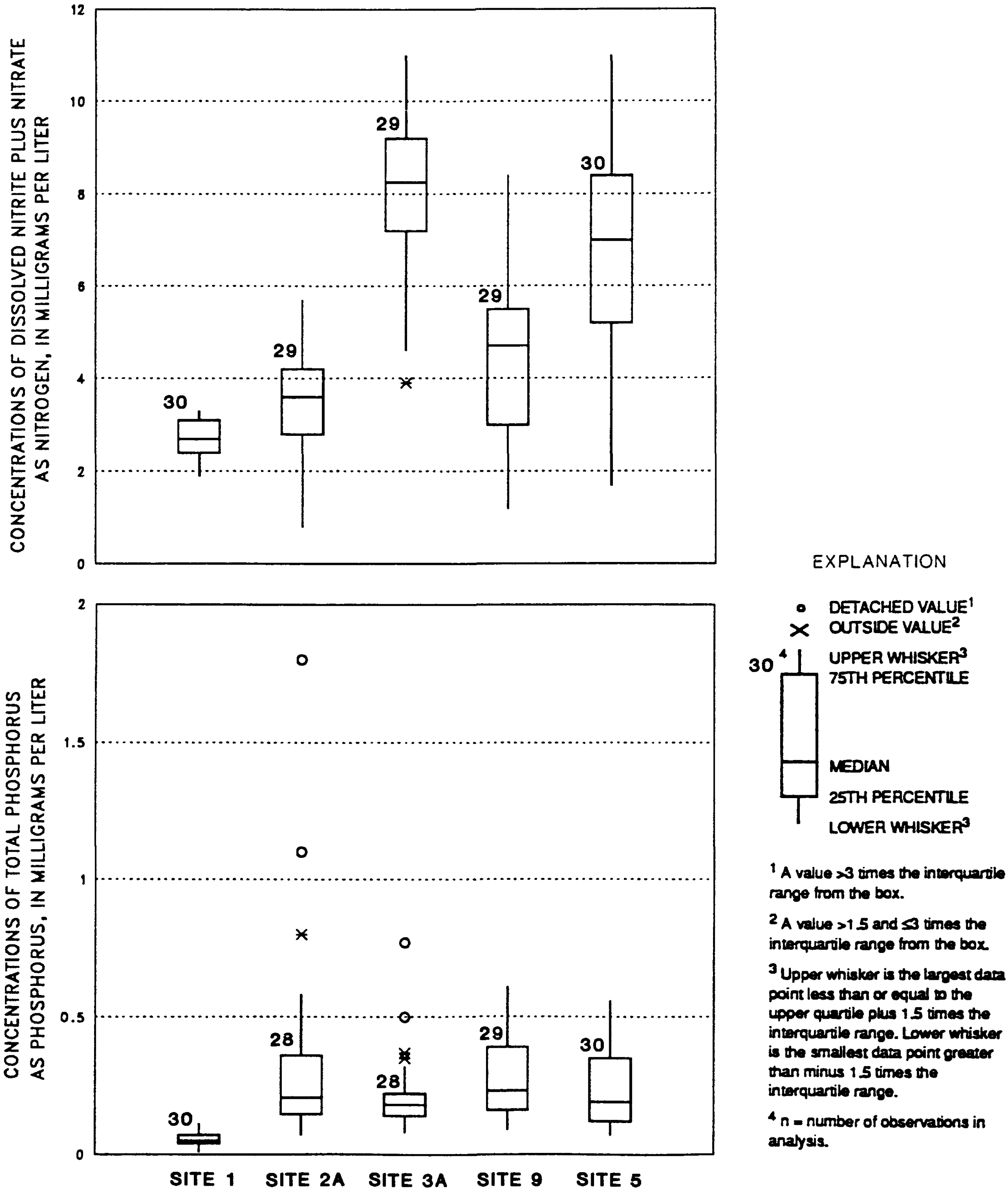


Figure 9.--Concentrations of dissolved nitrite plus nitrate as nitrogen and total phosphorus as phosphorus at surface-water sites during pre-Best-Management Practice phase, April 1, 1984, through March 31, 1986.

Table 12.--Water-quality characteristics of base flow in the Small Watershed, April 1, 1984 through March 31, 1986 (pre-Best-Management Practice period data)

[Conc., concentration in milligrams per liter; load, load in pounds per day; n, number of values; N, nitrogen; P, phosphorus; Min, minimum; Max, maximum; ft^3/s, cubic feet per second; <, less than; --, sample not analyzed for indicated constituent]

Characteristic or constituent	Statistic	Nonagricultural, noncarbonate	Agricultural, carbonate area			
		Site 1	Site 2A	Site 3A	Site 9	Site 5
Streamflow (ft^3/s)	Median	0.21	0.29	0.63	0.95	3.2
	n	30	28	29	29	30
	Min	.06	.06	.12	.26	.81
	Max	1.3	1.7	2.7	5.0	15
Nitrite + nitrate, total as N	Median conc.	2.9	3.6	8.4	4.7	7.0
	n	30	29	29	29	30
	Min conc.	1.9	.86	3.9	1.3	1.7
	Max conc.	3.3	5.7	11	8.4	11
	Min load	.81	.81	4.6	3.1	8.3
	Max load	20	52	124	204	891
Nitrite + nitrate, dissolved as N	Median conc.	2.7	3.6	8.1	4.7	7.0
	n	30	29	29	29	30
	Min conc.	1.9	.80	3.9	1.2	1.7
	Max conc.	3.3	5.7	11	8.4	11
	Min load	.81	.78	4.6	3.1	8.3
	Max load	20	52	124	204	891
Ammonia, total as N	Median conc.	.02	.12	.10	.08	.10
	n	30	29	28	29	30
	Min conc.	<.01	.04	.02	.02	.02
	Max conc.	.10	2.9	.72	.78	2.1
	Min load	<.01	.05	.03	.12	.33
	Max load	.59	1.4	3.1	9.7	81
Ammonia, dissolved as N	Median conc.	.02	.12	.10	.08	.10
	n	30	29	28	29	30
	Min conc.	<.01	.04	.02	.02	.02
	Max conc.	.07	2.2	.72	.78	2.1
	Min load	<.01	.05	.03	.09	.23
	Max load	.42	1.2	3.1	9.7	81
Ammonia + organic nitrogen, total as N	Median conc.	.47	1.3	.89	1.2	.99
	n	30	28	28	29	30
	Min conc.	<.20	.50	.10	.60	.38
	Max conc.	1.6	15	2.5	10	4.4
	Min load	.64	.65	.14	1.7	3.2
	Max load	3.4	22	9.6	36	169
Ammonia + organic nitrogen, dissolved as N	Median conc.	.40	.90	.82	.94	.93
	n	30	29	28	29	30
	Min conc.	<.20	.20	<.20	.50	.38
	Max conc.	.60	13	2.2	8.8	3.7
	Min load	<.06	.55	.14	1.6	3.1
	Max load	3.4	17	8.7	36	142
Nitrogen, total as N	Median conc.	3.4	5.1	9.6	6.2	8.0
	n	30	29	28	29	30
	Min conc.	2.1	2.4	4.7	2.5	4.7
	Max conc.	4.7	18	12	12	12
	Min load	.91	1.9	6.5	6.8	22
	Max load	22	57	124	221	972

Table 12.--Water-quality characteristics of base flow in the Small Watershed, April 1, 1984 through March 31, 1986 (pre-Best-Management Practice period data) --Continued

[Conc., concentration in milligrams per liter; load, load in pounds per day; n, number of values; N, nitrogen; P, phosphorus; Min, minimum; Max, maximum; ft³/s, cubic feet per second; <, less than; --, sample not analyzed for indicated constituent]

Characteristic or constituent	Statistic	Nonagricultural, noncarbonate	Agricultural, carbonate area			
		Site 1	Site 2A	Site 3A	Site 9	Site 5
Phosphorus, total as P	Median conc.	0.05	0.20	0.18	0 .23	0.19
	n	30	28	28	29	30
	Min conc.	.01	.07	.08	.09	.07
	Max conc.	.11	1.8	.50	.61	.56
	Min load	.02	.11	.12	.44	.65
	Max load	.18	4.3	2.0	5.2	16
Phosphorus, dissolved as P	Median conc.	.04	.14	.14	.19	.16
	n	30	29	28	29	30
	Min conc.	.01	<.01	.05	.07	.05
	Max conc.	.08	.61	.30	.48	.42
	Min load	.01	<.01	.10	.34	.65
	Max load	.18	2.0	1.5	3.6	10
Sediment, suspended	Median conc.	12	38	17	26	31
	n	29	28	29	28	29
	Min conc.	2.0	1.0	3.0	7.0	4.0
	Max conc.	47	371	97	321	265
	Min load	1.1	.76	4.5	36	106
	Max load	113	2,000	1,410	5,370	4,100
Alachlor, total	Median conc.	<.1	--	<.1	--	<.1
	n	12	--	12	--	12
	Min conc.	<.1	--	<.1	--	<.1
	Max conc.	<.1	--	.1	--	.1
Atrazine, total	Median conc.	<.2	--	.3	--	.4
	n	12	--	12	--	12
	Min conc.	<.2	--	<.2	--	<.2
	Max conc.	.1	--	.5	--	.8
Cyanazine, total	Median conc.	<.2	--	<.2	--	<.2
	n	12	--	12	--	12
	Min conc.	<.2	--	<.2	--	<.2
	Max conc.	<.2	--	.5	--	.8
Metolachlor, total	Median conc.	<.1	--	<.1	--	<.1
	n	12.	--	12	--	12
	Min conc.	<.1	--	<.1	--	<.1
	Max conc.	.1	--	<.4	--	.9
Propazine, total	Median conc.	<.2	--	<.2	--	<.2
	n	12	--	12	--	12
	Min conc.	<.2	--	<.2	--	<.2
	Max conc.	<.2	--	<.2	--	<.2
Simazine, total	Median conc.	<.2	--	.3	--	.3
	n	12	--	12	--	12
	Min conc.	<.2	--	<.2	--	<.2
	Max conc.	.6	--	<.8	--	2.8
Toxaphene, total	Median conc.	<1	--	<1	--	<1
	n	12	--	12	--	12
	Min conc.	<1	--	<1	--	<1
	Max conc.	<1	--	<1	--	<1

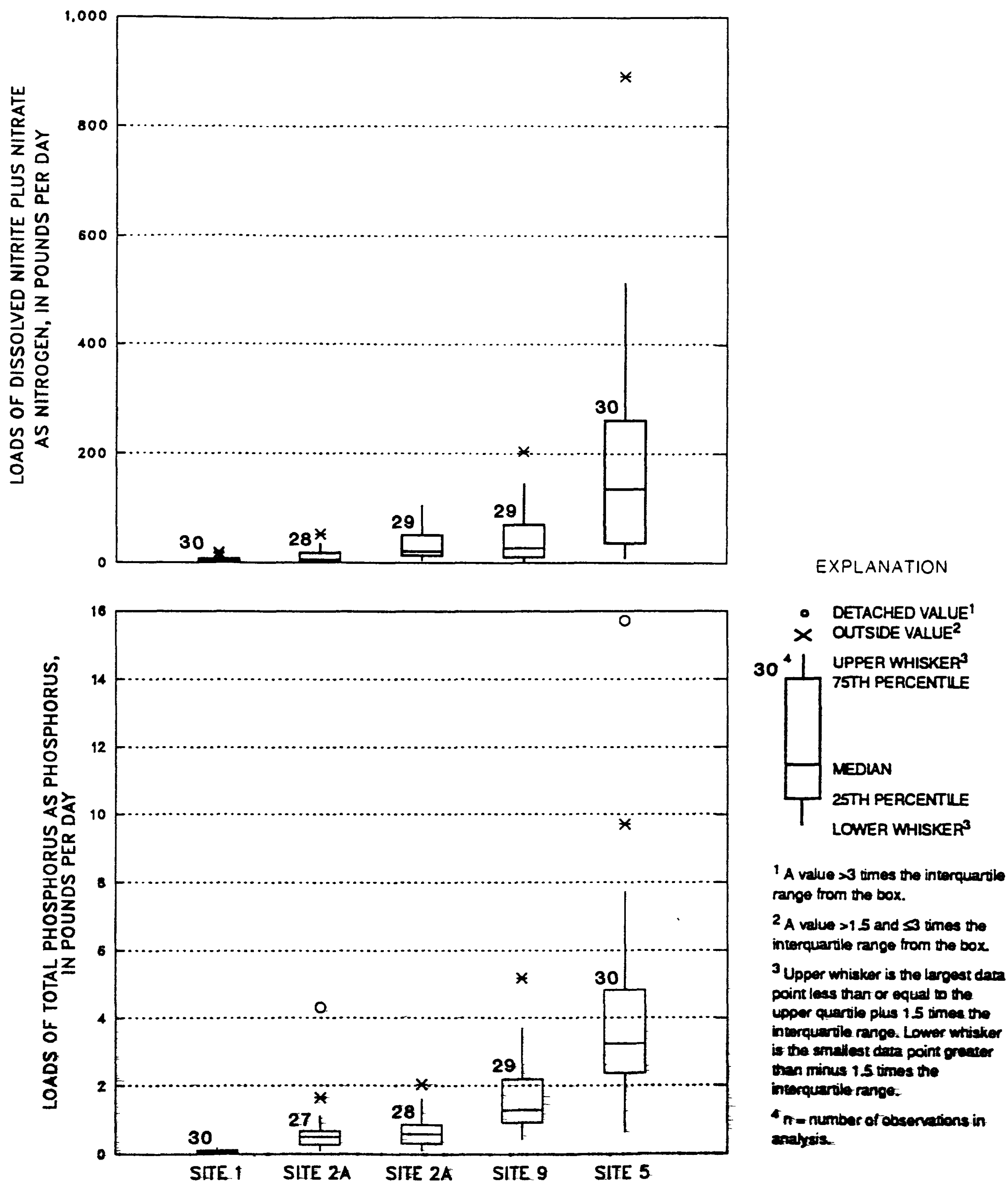


Figure 10.--Loads of dissolved nitrite plus nitrate as nitrogen and total phosphorus as phosphorus at surface-water sites during pre-Best-Management Practice phase, April 1, 1984, through March 31, 1986.

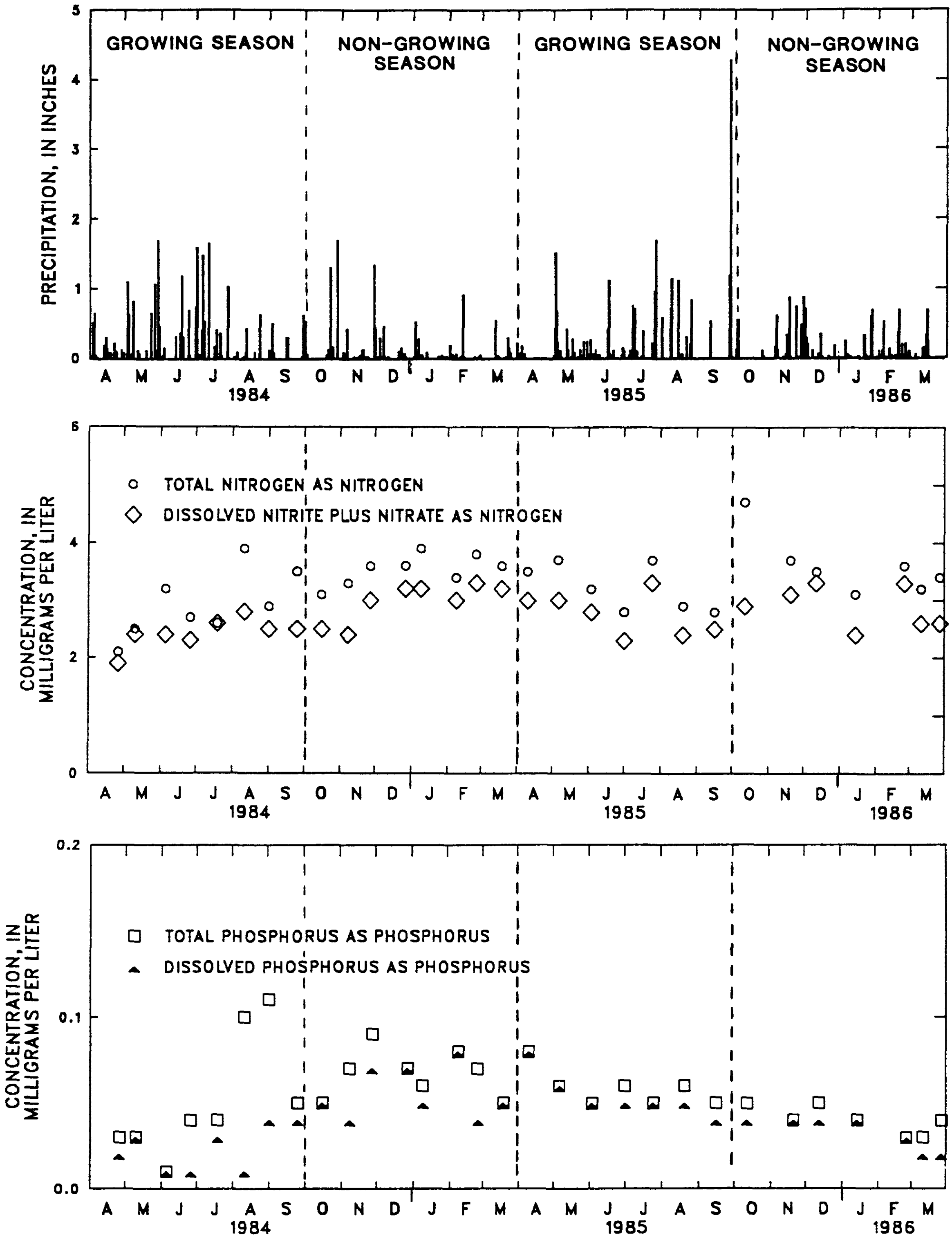


Figure 11.--Precipitation in the Small Watershed and concentrations of total nitrogen, and dissolved nitrite plus nitrate as nitrogen, and total and dissolved phosphorus as phosphorus in base flow at Site 1, April 1, 1984, through March 31, 1986.

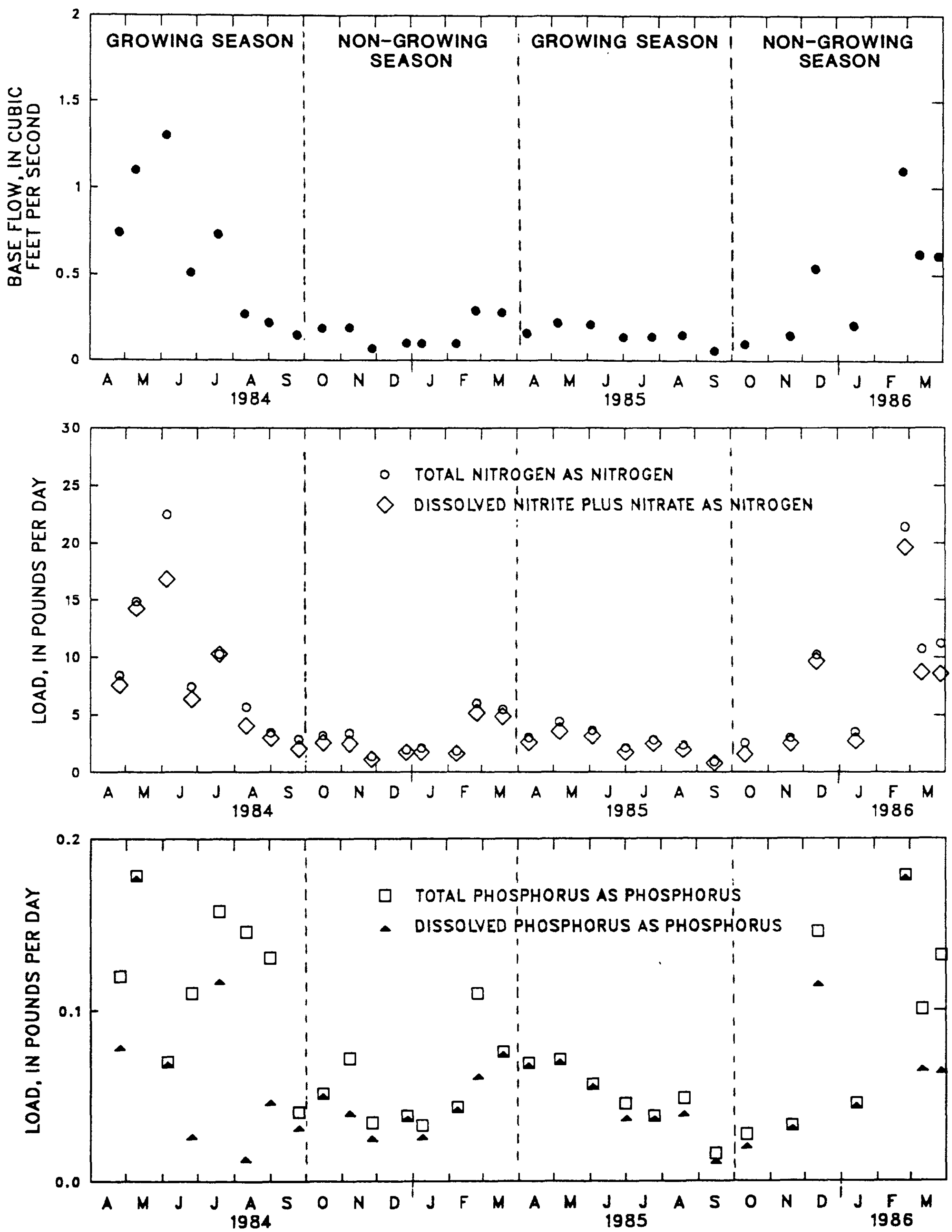


Figure 12.--Base flow and loads of total nitrogen, and dissolved nitrite plus nitrate as nitrogen, and total and dissolved phosphorus, as phosphorus at Site 1, April 1, 1984, through March 31, 1986.

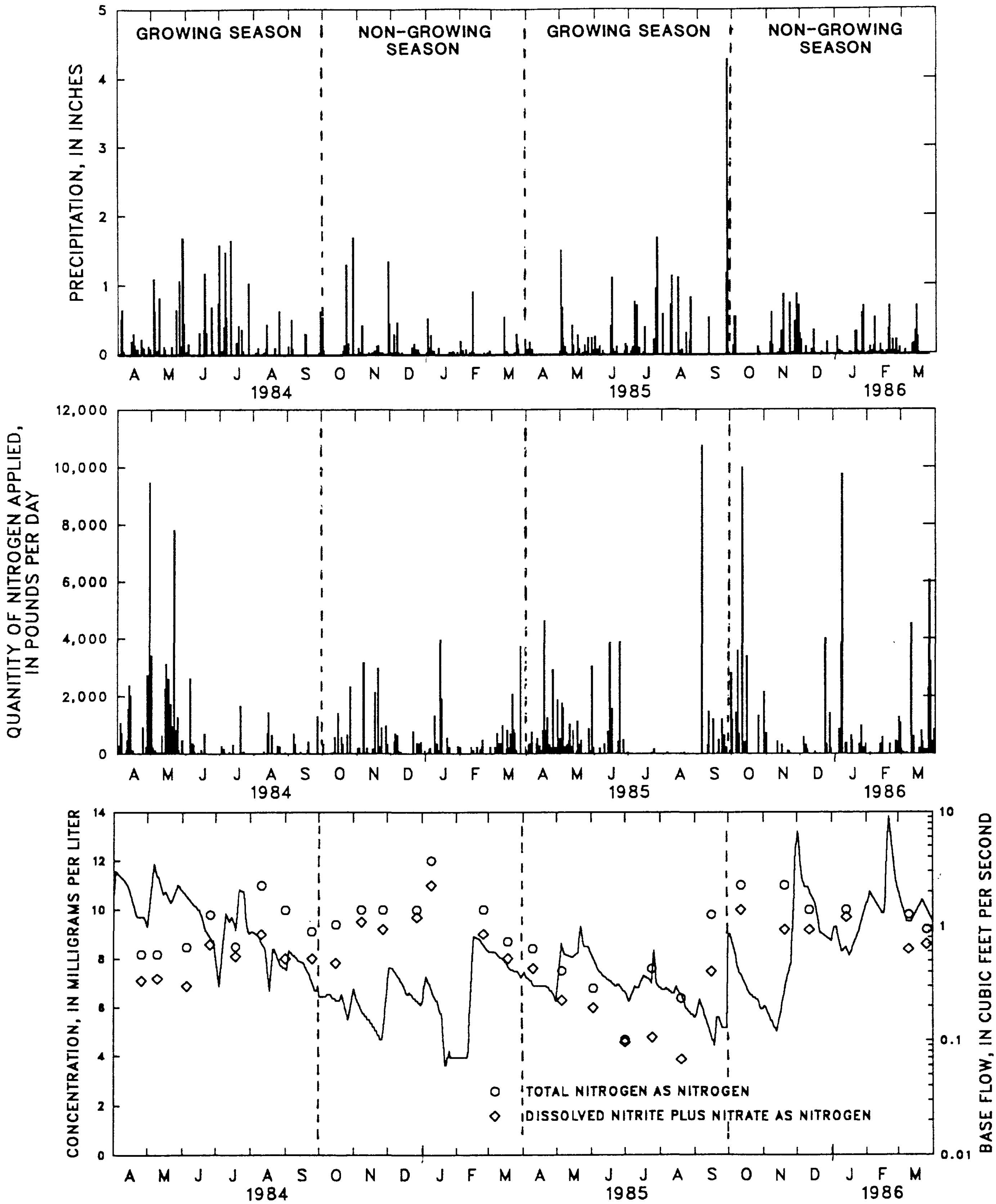


Figure 13.--Precipitation in the Small Watershed, nitrogen applications, and concentrations of total nitrogen, and dissolved nitrite plus nitrate as nitrogen in base flow at Site 3A, April 1, 1984, through March 31, 1986.

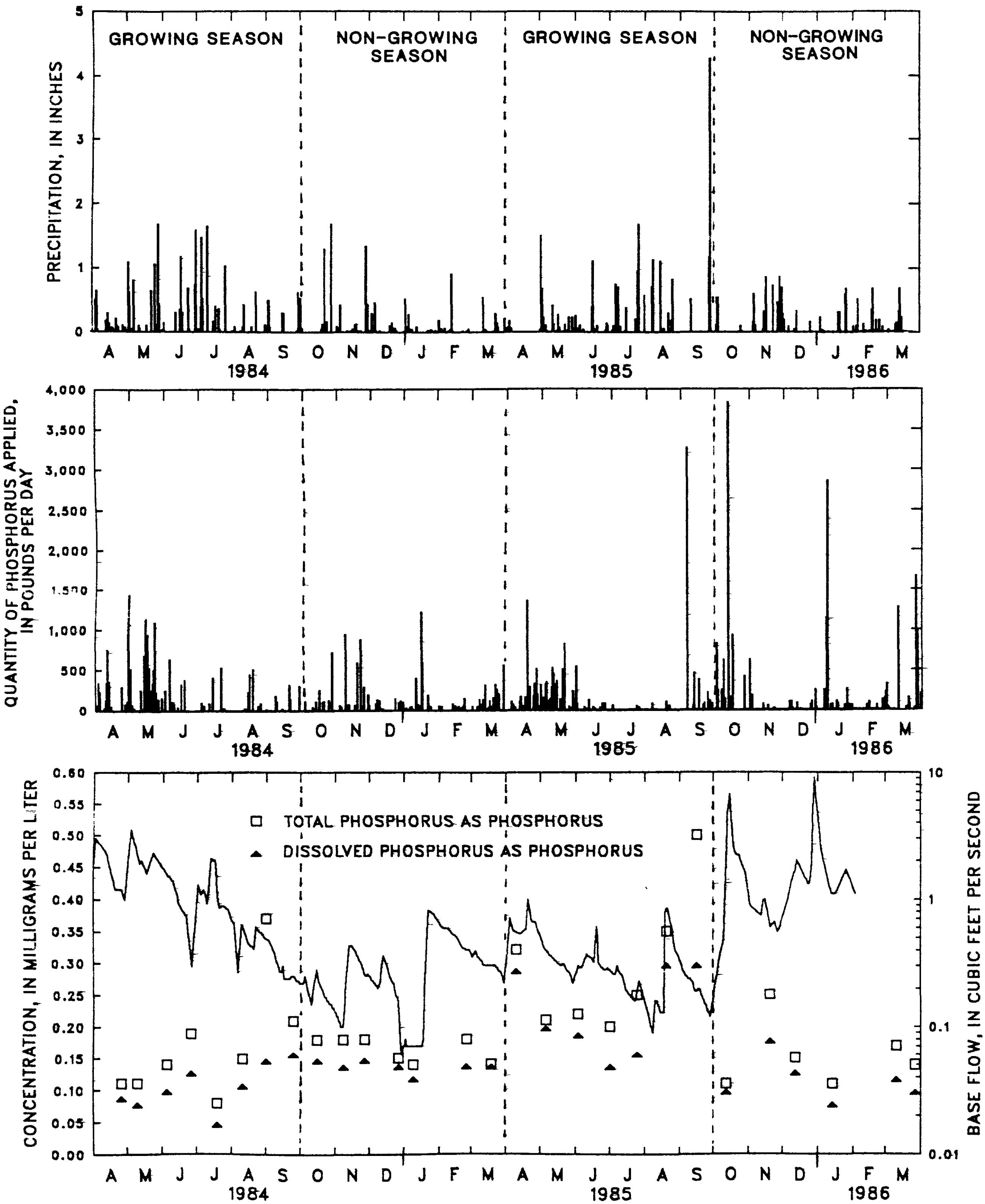


Figure 14.--Precipitation in the Small Watershed, phosphorus applications, and concentrations of total and dissolved phosphorus as phosphorus in base flow at Site 3A, April 1, 1984, through March 31, 1986.

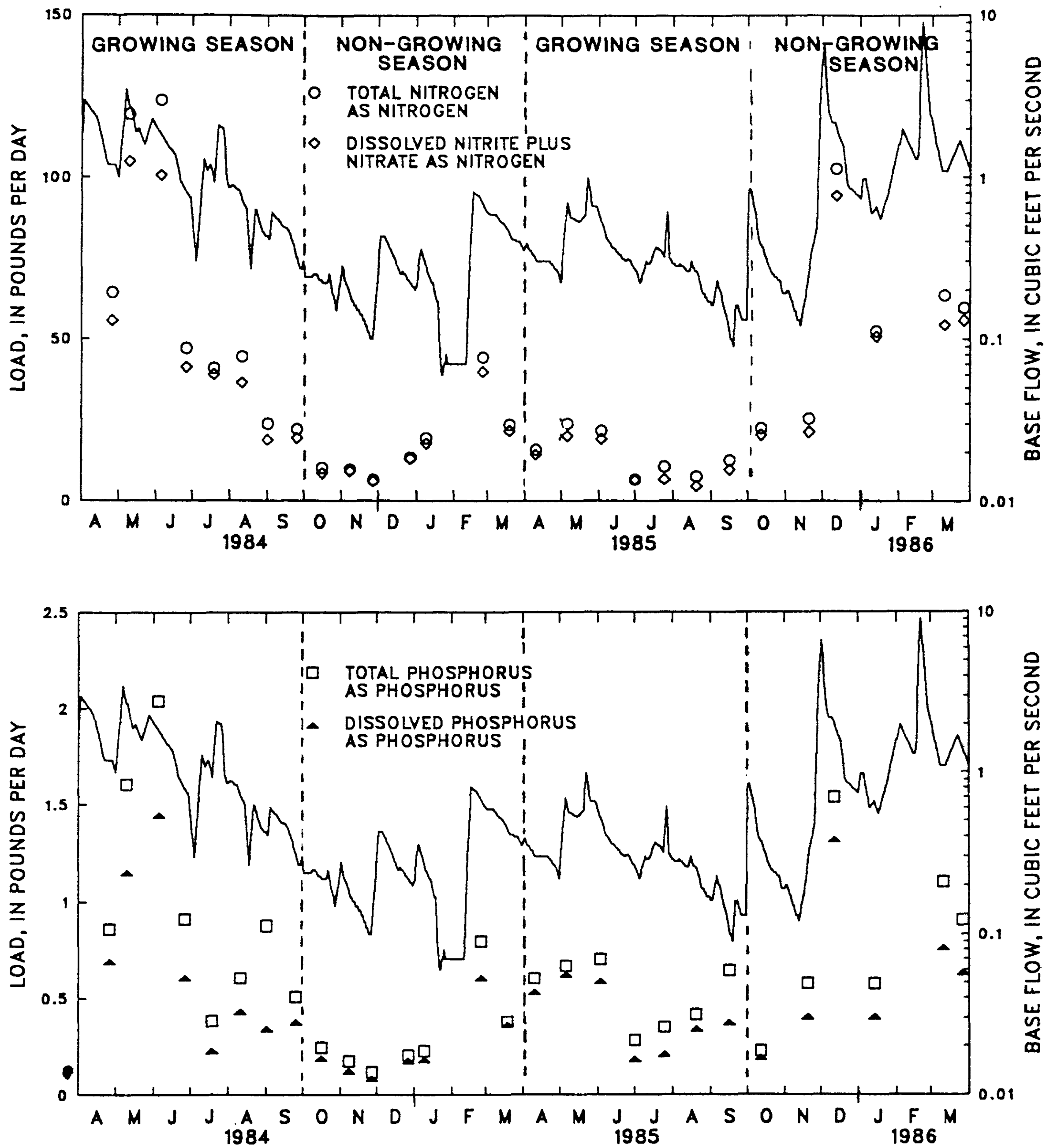


Figure 15.--Loads of total nitrogen and dissolved nitrite plus nitrate as nitrogen, and total and dissolved phosphorus as phosphorus in base flow at Site 3A, April 1, 1984, through March 31, 1986.

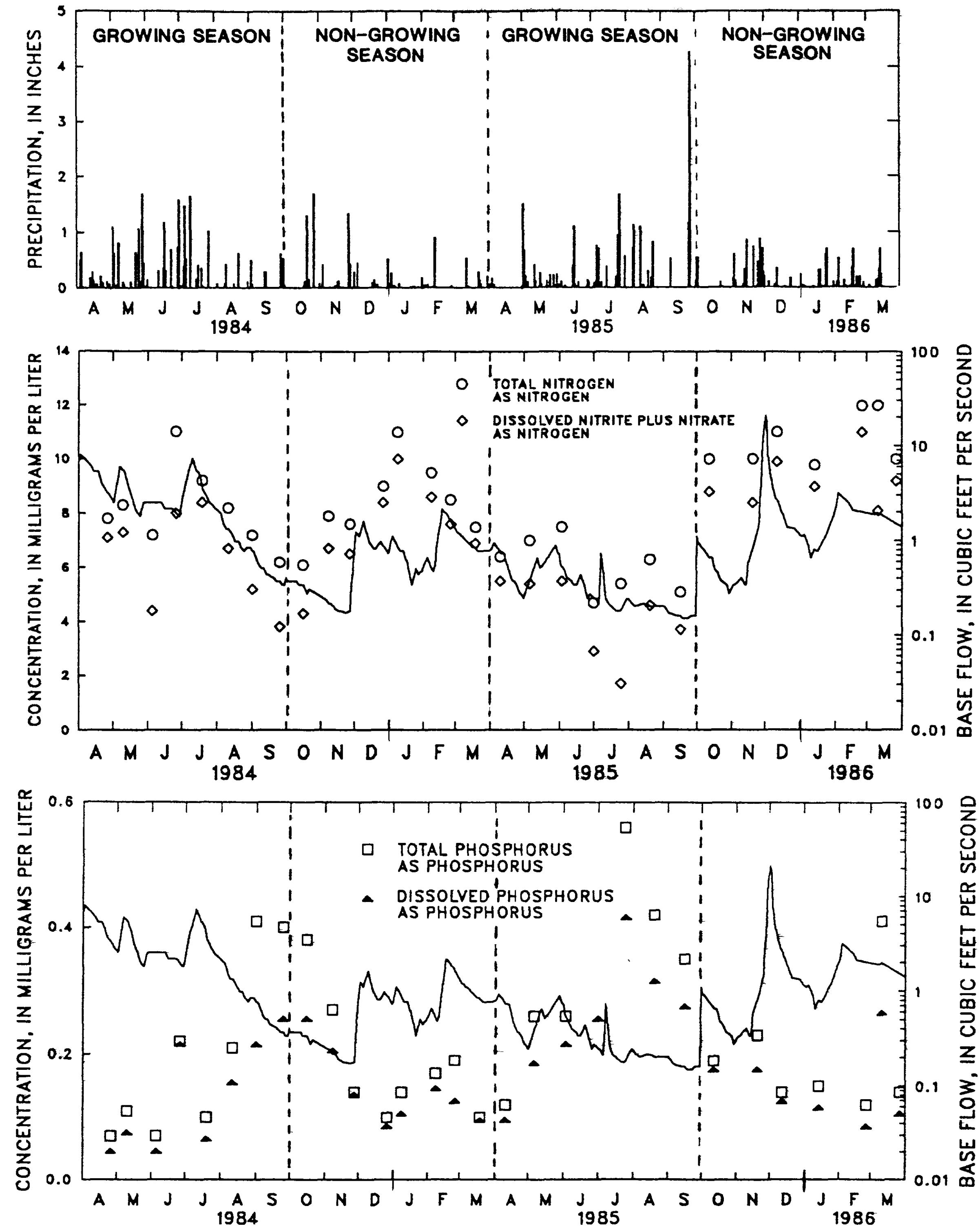


Figure 16.--Precipitation in the Small Watershed and concentrations of total nitrogen and dissolved nitrite plus nitrate as nitrogen, and total and dissolved phosphorus as phosphorus in base flow at Site 5, April 1, 1984, through March 31, 1986.

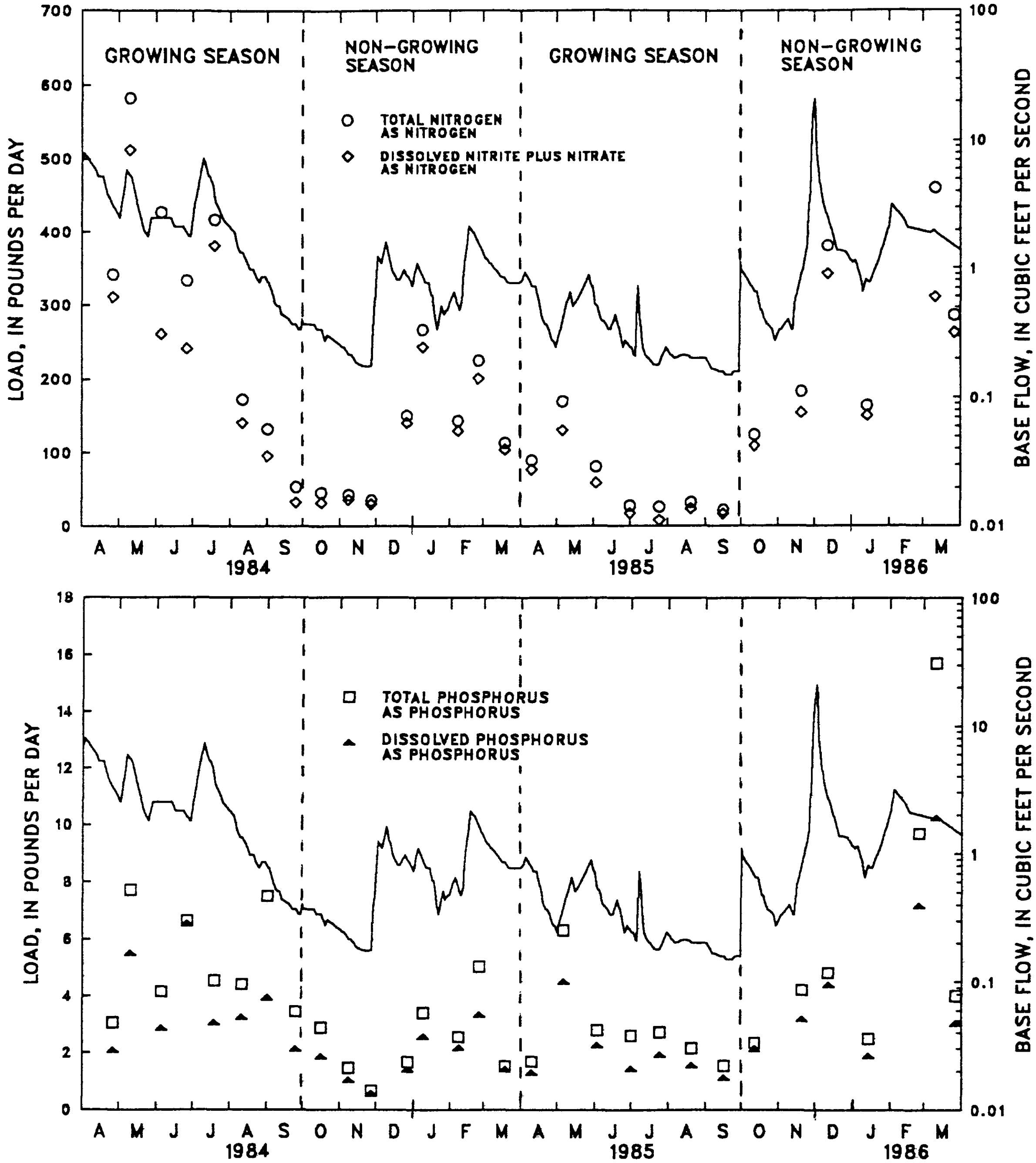


Figure 17.--Loads of total nitrogen and dissolved nitrite plus nitrate as nitrogen, and total and dissolved phosphorus as phosphorus in base flow at Site 5, April 1, 1984, through March 31, 1986.

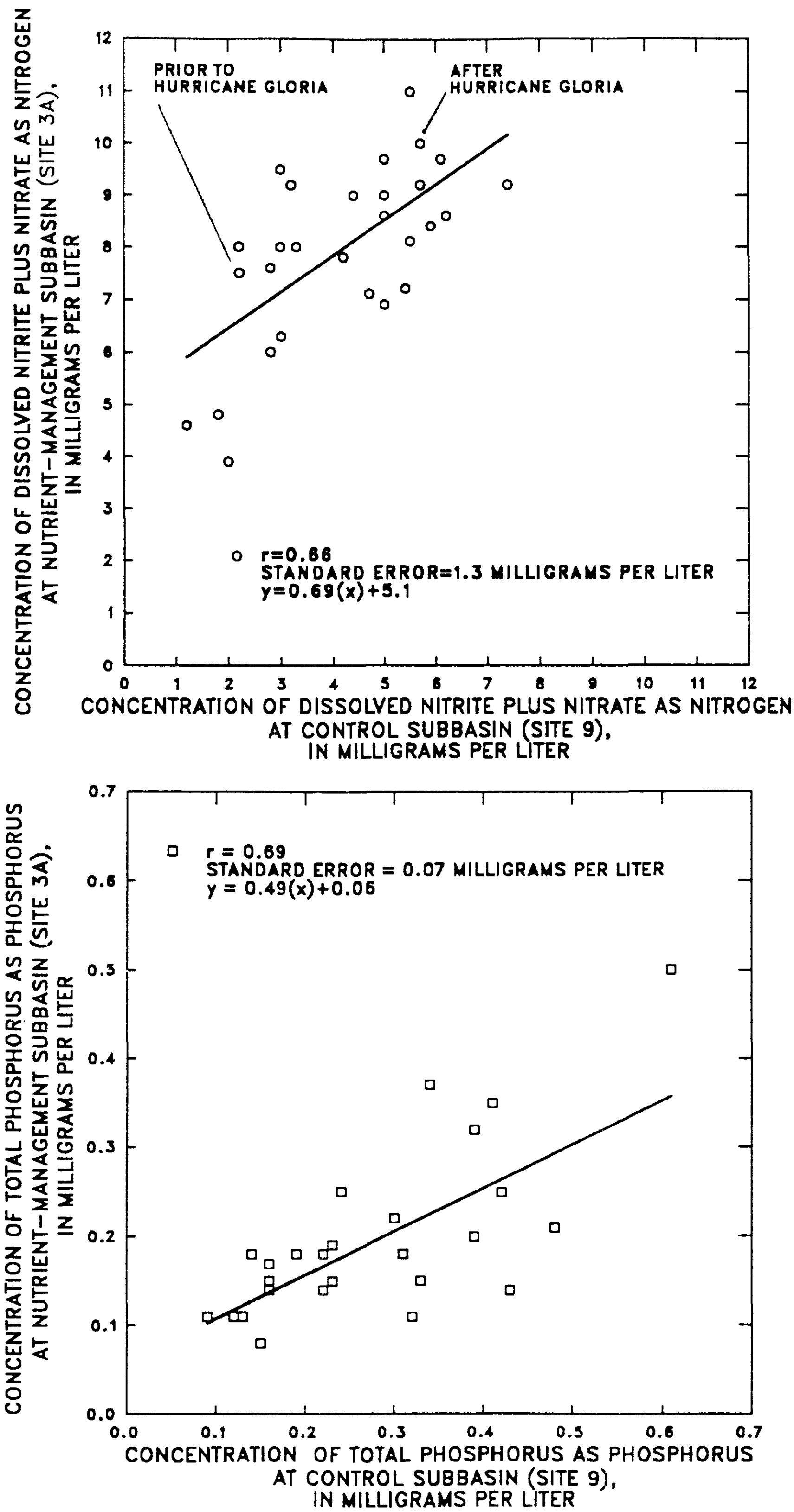
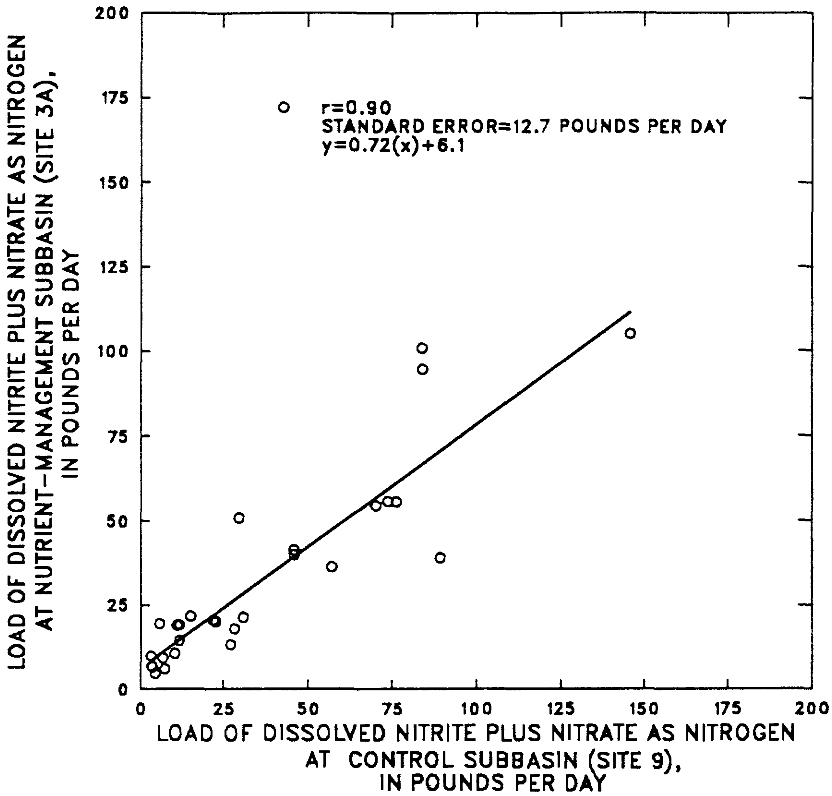


Figure 18.--Relation of concentrations of dissolved nitrite plus nitrate as nitrogen and total phosphorus as phosphorus between the Paired-Watersheds.



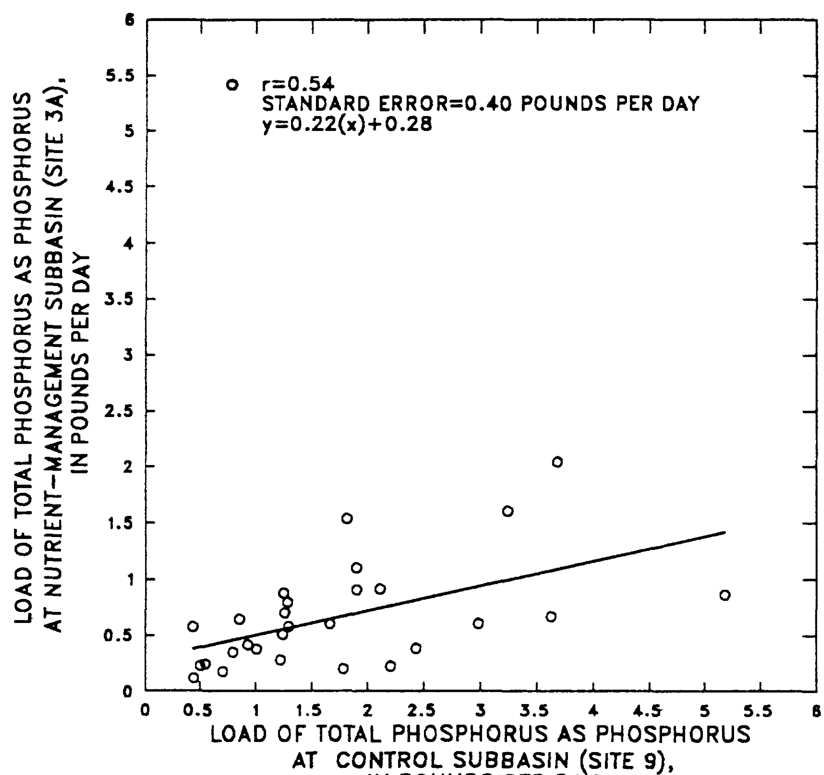


Figure 19.--Relation of loads of dissolved nitrite plus nitrate as nitrogen and total phosphorus as phosphorus between the Paired-Watersheds.

Table 13a.--Monthly and annual nutrient and suspended-sediment loads in base flow at the Nutrient-Management Subbasin (Site 3A) during the pre-Best-Management Practice phase, April 1, 1984 through March 31, 1986

[Base flow, in inches of runoff; loads, in pounds]

Month	Year	Base flow	Total nitrogen	Total nitrite plus nitrate nitrogen	Dissolved nitrite plus nitrate nitrogen	Total phosphorus	Dissolved phosphorus	Suspended sediment
April	1984	1.51	4,080	2,750	2,650	39	30	4,460
	1985	.27	450	400	400	15	14	3,070
May	1984	1.72	3,380	3,110	2,860	49	35	19,100
	1985	.47	710	570	570	21	19	1,080
June	1984	1.04	2,240	2,010	1,860	39	27	17,400
	1985	.30	370	280	280	13	10	820
July	1984	.92	1,790	1,650	1,640	22	14	3,300
	1985	.27	380	240	240	13	9	1,420
Aug.	1984	.50	1,050	890	850	20	11	7,150
	1985	.20	280	150	150	13	11	870
Sept.	1984	.34	680	560	550	20	11	3,160
	1985	.11	360	270	270	20	10	940
Oct.	1984	.18	420	380	360	8	7	650
	1985	.31	700	590	590	12	9	940
Nov.	1984	.13	270	250	250	5	4	260
	1985	.55	1,080	890	890	21	16	2,280
Dec.	1984	.24	570	540	530	9	8	780
	1985	1.48	3,030	2,720	2,720	48	40	4,240
Jan.	1985	.15	360	330	320	4	4	210
	1986	.69	1,540	1,460	1,460	19	14	2,470
Feb.	1985	.29	740	670	670	13	10	490
	1986	2.06	4,280	3,830	3,830	63	45	9,230
March	1985	.42	780	710	710	15	13	1,160
	1986	1.11	2,440	2,170	2,170	39	28	5,000
Total	year 1	7.44	16,360	13,850	13,250	243	174	58,120
	year 2	7.82	15,620	13,570	13,570	293	225	32,360
Total		15.26	31,980	27,420	26,820	536	399	90,480

Table 13b.--Monthly and annual nutrient and suspended-sediment loads in base flow at the Small Watershed (Site 5) during the pre-Best-Management Practice phase, April 1, 1984 through March 31, 1986

Base flow, in inches of runoff; loads, in pounds]

Month	Year	Base flow	Total nitrogen	Total nitrite plus nitrate nitrogen	Dissolved nitrite plus nitrate nitrogen	Total phosphorus	Dissolved phosphorus	Suspended sediment
April	1984	2.08	16,800	15,600	15,500	150	120	13,300
	1985	.39	2,140	1,800	1,800	47	38	5,320
May	1984	1.53	12,400	11,200	9,950	150	110	58,400
	1985	.42	3,310	2,340	2,340	120	92	30,600
June	1984	1.12	9,380	8,590	6,610	150	130	48,400
	1985	.29	1,610	970	970	84	60	25,300
July	1984	1.76	15,100	13,900	12,800	220	190	24,500
	1985	.23	1,250	440	440	120	87	18,100
Aug.	1984	.71	4,790	3,860	3,810	150	97	33,100
	1985	.19	1,000	600	600	75	57	7,180
Sept.	1984	.34	1,930	1,330	1,230	120	69	19,800
	1985	.16	1,020	780	760	53	43	4,110
Oct.	1984	.27	1,700	1,210	1,190	95	66	14,500
	1985	.40	3,700	3,280	3,080	83	74	5,390
Nov.	1984	.20	1,300	1,120	1,100	36	30	23,000
	1985	.86	6,620	5,650	5,600	130	110	6,480
Dec.	1984	.64	4,630	4,270	4,190	64	61	64,400
	1985	1.47	13,300	11,600	11,540	190	170	10,700
Jan.	1985	.46	4,110	4,190	3,730	55	46	3,370
	1986	.66	6,180	5,700	5,700	87	69	10,900
Feb.	1985	.63	5,340	3,730	4,810	110	82	9,840
	1986	1.08	21,200	19,400	19,400	230	180	49,300
March	1985	.59	3,850	3,480	3,480	64	54	11,500
	1986	.95	18,900	11,400	11,400	350	240	78,400
Total	year 1	10.33	81,780	73,100	68,400	1,364	1,055	324,110
	year 2	7.10	80,200	63,960	63,630	1,569	1,220	251,780
Total		17.43	161,980	137,060	132,030	2,933	2,275	575,890

Table 14.--Concentrations of total atrazine and total simazine in base flow at Site 1 prior to and following the identification of the disposal area, May 10, 1984 through November 20, 1985

[Detection limits for atrazine and simazine were 0.10 and 0.20 µg/L (micrograms per liter), respectively, except as noted. Concentrations below these limits were considered undetected; <, less than]

Date	Atrazine (µg/L)	Simazine (µg//L)
05/10/84	<0.10	0.20
06/05/84	.10	<.20
06/26/84	<.10	.20
07/19/84	<.10	<.20
08/11/84	<.10	<.20
09/01/84	<.10	<.20
09/25/84	<.10	<.20
10/16/84	<.10	.60
	Disposal area identified[1]	
05/06/85	<.20	<.20
07/25/85	<.20	<.20
08/20/85	<.20	<.20
11/20/85	<.20	<.20

[1] The detection limit used by the Pennsylvania Department of Environmental Resources laboratory for these samples was increased from 0.10 to 0.20 mg/L.

Stormflow

Stormflow, for the purpose of this report, represents the total streamflow minus the base flow from the time of the initial rise in stream stage until the stream stabilizes or returns to the prestorm level. Thus, total streamflow during storms consists of both surface runoff and base flow from ground water. Storms were defined as beginning when the stream stage increased 0.10 ft at Site 3A and 0.25 ft at Site 5, and ending when the rate of decrease was less than 0.05 ft per hour at the sites. Tables 15 and 16 summarize streamflow for selected storms. During the pre-BMP phase there were 33 storms at Site 3A and 45 storms at Site 5. Samples from 29 of the storms at Site 3A, representing 94 percent of the annual stormflow, were analyzed for nutrients and/or sediment. Samples from 34 of the storms at Site 5, representing 96 percent of the annual stormflow at that site, were analyzed for nutrients and/or sediment.

Maximum and minimum instantaneous nutrient, suspended-sediment, and pesticide concentrations in stormflow at the Nutrient- Management Subbasin (Site 3A) and the Small Watershed (Site 5) are given in table 15. Most maximum nutrient concentrations during storms at the downstream site (Site 5) were only slightly lower than those at the upstream site (Site 3A). This indicates that tributaries draining areas with minor agricultural land use did not greatly dilute the nutrient content of the stream between these sites during storms and that the concentrations of nitrogen and phosphorus discharged to the stream downstream from Site 3A (Nutrient-Management Subbasin) are about equal to those at Site 3A. Maximum concentrations of total nitrogen at Sites 3A and 5 were measured during storms in May shortly after crops were planted. The maximum total-nitrogen concentration at Site 3A was 34 mg/L on May 26, 1984, and the maximum concentration at Site 5 was 28 mg/L on May 21, 1985. Maximum concentrations of total phosphorus (20 mg/L and 17 mg/L at Sites 3A and 5, respectively) were measured during a storm on May 21, 1985. The maximum suspended-sediment concentration at Site 3A (16,700 mg/L) was measured during a storm on May 26, 1984, and the maximum concentration at Site 5 (34,300 mg/L) was measured on May 21, 1985. Pesticide concentrations in stormflow were determined during the growing season each year of the study. Results were similar for both sites. Maximum concentrations of metolachlor, atrazine, alachlor, and cyanazine were measured in May after pesticides had been applied to the crops. Concentrations decreased through the growing season. Maximum simazine concentrations were measured in July.

At the onset of storms, nitrite plus nitrate-nitrogen concentrations in the stream decreased rapidly and concentrations of total ammonia plus organic nitrogen, total phosphorus, and suspended sediment increased rapidly at Sites 3A and 5 (figs. 20 and 21). Storms with short durations and little runoff from overland flow usually had little effect on nitrite plus nitrate-nitrogen concentrations during and following the storms. However, if the storms were intense and produced 1.0 in. or more of precipitation, such as Hurricane Gloria, then more of the runoff came from surface flow than from subsurface flow. It was during these large storms that dissolved-nitrite plus nitrate concentrations were initially diluted from overland flow until the streamflows peaked. Afterwards, dissolved-nitrite plus nitrate concentrations began to increase as less of the stormflow consisted of overland flow and more consisted of subsurface flow and ground water that migrated through the nutrient-rich soils.

About 13,000 lb of nitrogen discharged during storms from Site 3A and 69,000 lb from Site 5 during the pre-BMP phase. Half of the nitrogen discharged during storms from both sites was organic nitrogen (table 16). During the first year of the study, 5,800 tons of suspended sediment were discharged from Site 5 during storms, resulting in a storm yield of about 1.6 tons/acre (tons per acre) (table 16). Storm yields for particular fields are probably significantly greater because of differences in land use. More than 19 percent of the suspended sediment discharged from Site 5 during the pre-BMP phase was transported on May 21, 1985, when 2.8 in. of rain fell in the basin.

Table 15.—Ranges of instantaneous storm concentrations from April 1, 1984 through March 31, 1986
[Concentration, in milligrams per liter except where noted; n, number of values; µg/L, micrograms per liter; <, less than]

Constituent	Statistic	Nutrient-Management Subbasin (Site 3A)	Small Watershed (Site 5)
Nitrite + nitrate, total as N	n	178	237
	Minimum	.90	.94
	Maximum	15	13
Nitrite + nitrate, dissolved as N	n	61	90
	Minimum	.78	.92
	Maximum	11	11
Ammonia, total as N	n	158	217
	Minimum	.02	.02
	Maximum	6.6	6.0
Ammonia, dissolved as N	n	61	91
	Minimum	.02	.02
	Maximum	5.9	6.0
Ammonia + organic nitrogen, total as N	n	180	232
	Minimum	.24	.26
	Maximum	28	22
Ammonia + organic nitrogen, dissolved as N	n	61	88
	Minimum	.26	.22
	Maximum	15	8.8
Nitrogen, total as N	n	176	232
	Minimum	2.8	3.2
	Maximum	34	28
Phosphorus, total as P	n	179	234
	Minimum	.10	.07
	Maximum	20	17
Phosphorus, dissolved as P	n	61	90
	Minimum	.07	.05
	Maximum	3.5	2.6
Sediment, suspended	n	175	253
	Minimum	6.0	4.0
	Maximum	16,700	34,300
Alachlor, total, in µg/L	n	16	24
	Minimum	<.1	<.5
	Maximum	56	85
Atrazine, total, in µg/L	n	16	24
	Minimum	<.1	<1
	Maximum	210	120
Cyanazine, total, in µg/L	n	16	24
	Minimum	<.2	<.8
	Maximum	200	72
Metolachlor, total, in µg/L	n	16	24
	Minimum	<.1	<.1
	Maximum	250	75
Propazine, total, in µg/L	n	16	24
	Minimum	<.2	<.2
	Maximum	[1] <4	13
Simazine, total, in µg/L	n	16	24
	Minimum	<.2	<.2
	Maximum	14	21
Toxaphene, total, in µg/L	n	16	24
	Minimum	<1	<1
	Maximum	20	[1] <10

[1] Detection limits for these samples were higher because of the volume of the sample collected.

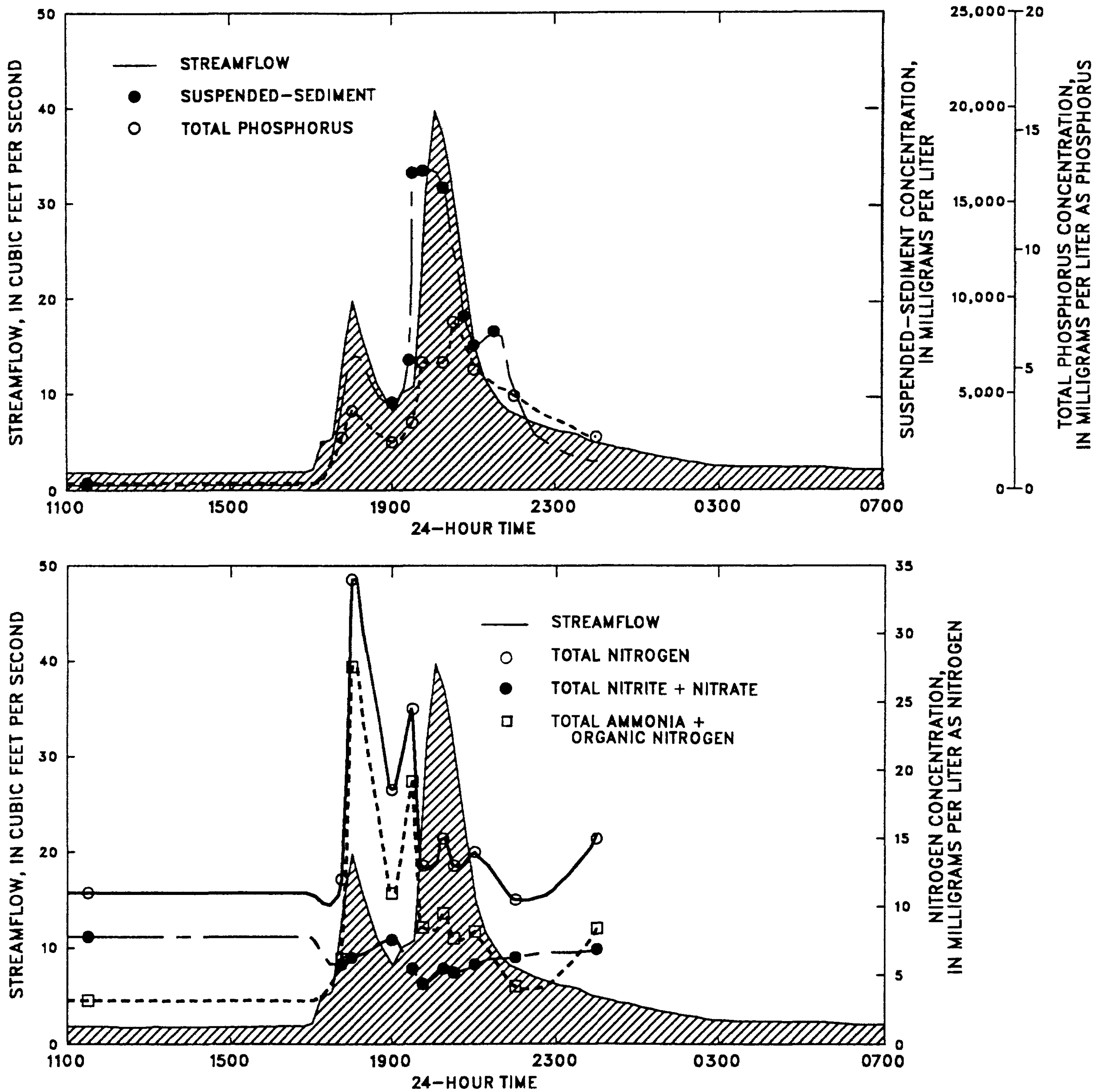


Figure 20.--Streamflow and concentrations of suspended sediment, total-nitrogen constituents, and total phosphorus at the Nutrient-Management Subbasin during the storm of May 26-27, 1984.

Table 16.—Nitrogen, phosphorus, and suspended-sediment loads during storm days at the Nutrient-Management Subbasin (Site 3A) and the Small Watershed (Site 5), April 4, 1984 through March 15, 1986

[Streamflow in cubic feet per second; sediment loads in tons, nutrient loads in pounds; --, no data]

Date	Mean stream flow	Total nitrite plus nitrate nitrogen	Dissolved nitrite plus nitrate nitrogen	Total ammonia nitrogen	Dissolved ammonia nitrogen	Total ammonia plus organic nitrogen	Dissolved ammonia plus organic nitrogen	Total nitrogen	Total phos-phorus	Dissolved phos-phorus	Suspended sediment
						Site 3A, Nutrient-Management Subbasin					
05/03/84	3.0	82	80	63	63	180	104	262	26	8.5	7.9
05/04/84	13.0	206	191	179	175	301	224	507	93	24	59
05/08/84	5.7	158	--	17	--	107	--	265	22	--	--
05/26/84	5.7	178	158	79	60	229	163	407	92	14	5.7
05/29/84	12	324	294	102	80	394	172	718	114	31	57
05/30/84	9.1	310	289	55	41	141	--	451	26	14	5.2
06/17/84	2.2	74	--	6.9	--	39	--	113	18	--	5.6
06/18/84	4.3	78	--	13	--	90	--	168	30	--	6.7
06/19/84	2.2	--	--	--	--	--	--	--	--	--	2.5
06/24/84	2.2	--	--	--	--	--	--	--	--	--	2.0
06/30/84	1.6	42	--	3.9	--	27	--	69	3.8	--	1.5
07/01/84	25	629	--	69	--	865	--	1,494	454	--	153
07/06/84	2.3	36	--	6.5	--	46	--	82	41	--	23
07/07/84	34	422	408	48	46	288	58	710	272	70	--
07/10/84	1.3	84	84	1.5	1.5	6.7	3.0	91	4.1	.8	1.2
07/11/84	11	203	189	8.2	8.2	99	56	302	77	21	44
07/27/84	3.4	100	--	10	--	66	--	166	11	--	3.1
10/28/84	1.4	18	--	9.6	--	86	--	104	26	--	8.1
10/29/84	2.1	49	--	2.4	--	44	--	93	16	--	--
11/29/84	4.7	154	--	9.9	--	110	--	264	31	--	--
02/12/85	30	247	230	271	213	1,011	559	1,258	288	164	46
02/13/85	4.0	112	112	13	13	45	45	157	18	18	1.1
05/03/85	3.4	146	144	7.4	6.7	46	37	192	17	7.5	--
05/20/85	.6	17	--	5.7	--	22	--	39	5.2	--	--
05/21/85	2.3	58	--	--	--	133	--	191	68	--	26
06/16/85	2.0	44	--	--	--	82	--	126	21	--	4.1
07/25/85	.7	17	--	5.7	--	22	--	39	5.2	--	--
07/27/85	1.3	28	26	6.3	6.3	28	27	56	11	9.5	--
08/07/85	2.0	15	--	19	--	189	--	204	28	--	--
08/08/85	2.1	26	--	14	--	76	--	102	11	--	--
08/14/85	2.4	--	--	--	--	--	--	--	--	--	--
09/26/85	.2	7.1	7.1	.04	.04	1.3	.9	8.4	.2	.2	--
09/27/85	41	660	650	114	114	860	545	1,520	553	213	--
09/28/85	2.0	107	104	7.1	7.1	33	29	140	6.6	3.8	--
11/04/85	.2	11	--	.1	--	1	--	12	.2	--	--
11/05/85	1.7	51	--	8.8	--	62	--	113	22	--	.77
11/16/85	1.5	--	--	--	--	--	--	--	--	--	--
11/17/85	2.5	--	--	--	--	--	--	--	--	--	--
11/22/85	2.8	82	--	18	--	74	--	156	30	--	--
11/23/85	.8	36	--	1.3	--	7.4	--	43	1.9	--	--
11/26/85	1.3	--	--	--	--	--	--	--	--	--	.53
11/27/85	15	--	--	--	--	--	--	--	--	--	3.3
11/28/85	6.6	--	--	--	--	--	--	--	--	--	3.7
11/29/85	4.7	--	--	--	--	--	--	--	--	--	1.3
11/30/85	10	260	--	24	--	370	--	630	192	--	17
02/18/86	7.1	124	--	--	--	263	--	387	50	--	5.8
02/19/86	11	231	225	112	104	329	172	560	95	58	11
02/20/86	9.1	290	280	45	45	183	107	473	37	37	5.4
02/21/86	9.5	--	--	--	--	--	--	--	--	--	11
03/14/86	4.5	147	147	24	17	125	56	272	37	23	13
03/15/86	5.9	204	204	20	19	124	67	328	31	17	7
Total		6,067	3,822	1,400	1,020	7,205	2,425	13,272	2,885	734	559

Table 16.--Nitrogen, phosphorus, and suspended-sediment loads during storm days at the Nutrient-Management Subbasin (Site 3A) and the Small Watershed (Site 5), April 4, 1984 through March 15, 1986--Continued

[Streamflow in cubic feet per second; sediment loads in tons, nutrient loads in pounds; --, no data]

Date	Mean stream flow	Total nitrite plus nitrate nitrogen	Dissolved nitrite plus nitrate nitrogen	Total ammonia nitrogen	Dissolved ammonia nitrogen	Total ammonia plus organic nitrogen	Dissolved ammonia plus organic nitrogen	Total nitrogen	Total phos-phorus	Dissolved phos-phorus	Suspended sediment
						Site 5, Small Watershed					
04/04/84	20	684	667	24	22	206	201	890	32	32	–
04/05/84	71	1,777	1,722	148	127	1,349	1,036	3,126	541	121	–
05/03/84	7.5	270	264	13	12	67	45	337	18	8.1	10
05/04/84	71	1,386	1,230	737	695	2,900	1,453	4,286	1,096	179	538
05/26/84	23	599	560	269	231	1,122	539	1,721	240	72	444
05/29/84	85	1,873	1,483	336	240	2,190	776	4,063	840	177	890
05/30/84	46	1,814	1,502	81	62	409	328	2,223	116	52	18
06/17/84	6.6	–	–	–	–	–	–	–	–	–	2.1
06/18/84	20	517	–	55	–	602	–	1,119	165	–	36
06/20/84	12	–	–	–	–	–	–	–	–	–	13
07/01/84	97	2,321	–	142	–	1,674	–	3,995	963	–	750
07/06/84	30	595	529	60	45	283	45	878	353	74	237
07/07/84	165	2,203	2,014	160	160	1,621	203	3,824	991	369	1,350
07/11/84	87	1,265	1,150	91	68	911	482	2,176	565	167	654
07/27/84	12	434	–	23	–	178	–	612	38	–	–
11/28/84	6.2	130	120	19	17	247	95	377	129	23	–
11/29/84	31	671	613	142	118	872	528	1,543	424	187	65
02/12/85	150	1,119	1,045	1,377	1,321	6,543	4,524	7,662	1,477	887	785
05/03/85	23	635	590	82	75	502	358	1,137	157	69	37
05/21/85	48	1,364	–	–	–	3,130	–	4,494	2,891	–	1,770
06/16/85	8.3	184	–	–	–	172	–	356	66	–	–
07/25/85	4.5	50	41	21	19	139	113	189	48	31	16
07/26/85	6.3	73	–	37	–	211	–	284	55	–	5.9
07/27/85	9.7	81	–	40	–	228	–	309	89	–	9.8
07/31/85	3.2	–	–	–	–	–	–	–	–	–	1.8
08/07/85	6.1	49	–	16	–	256	–	305	58	–	39
08/08/85	13	132	–	41	–	238	–	370	124	–	22
09/27/85	159	2,170	1,516	469	367	4,010	1,840	6,180	2,687	1,318	862
09/28/85	8.9	423	423	14	14	89	75	512	21	16	1.7
11/05/85	6.3	191	182	53	53	213	173	404	80	39	–
11/16/85	7.9	198	–	29	–	179	–	377	95	–	8.2
11/17/85	11	348	–	45	–	177	–	525	115	–	4.6
11/28/85	33	–	–	–	–	–	–	–	–	–	23
11/29/85	23	–	–	–	–	–	–	–	–	–	17
11/30/85	53	1,582	–	62	–	1,029	–	2,611	797	–	216
02/05/86	28	869	–	114	–	477	–	1,346	205	–	54
02/18/86	42	1,161	1,117	247	213	912	528	2,073	304	96	90
02/19/86	52	1,562	1,520	272	254	1,107	688	2,669	340	171	72
02/20/86	44	1,745	1,675	148	143	575	334	2,320	170	107	23
03/14/86	20	816	806	77	77	525	268	1,341	163	61	63
03/15/86	32	1,234	1,088	96	96	659	405	1,893	169	113	40
Total		32,525	21,857	5,540	4,429	36,002	15,037	68,527	16,622	4,269	9,152

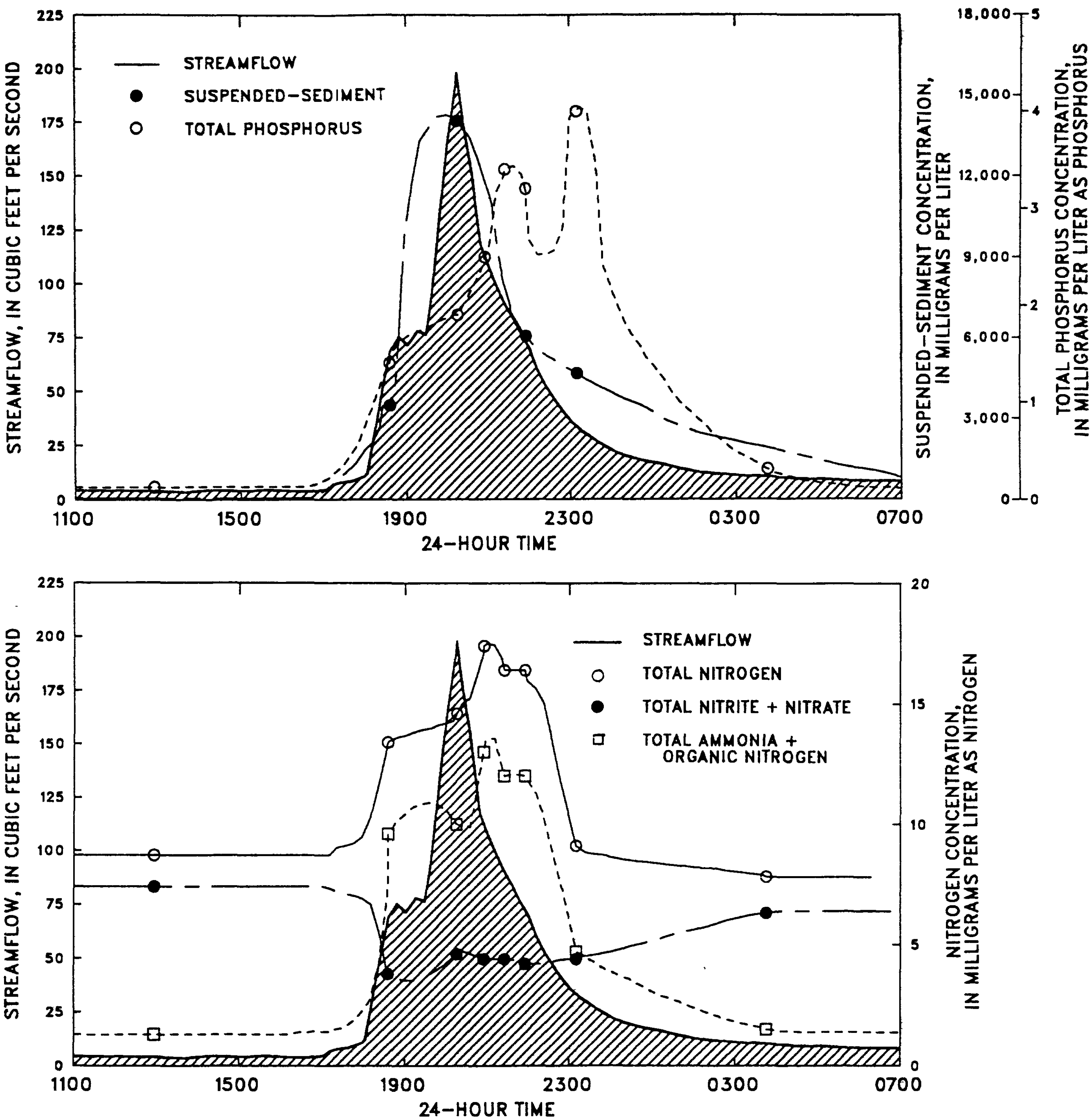


Figure 21.--Streamflow and concentrations of suspended sediment, total-nitrogen constituents, and total phosphorus at the Small Watershed during the storm of May 26-27, 1984.

Periodic Discharges

A reconnaissance of the Nutrient-Management Subbasin and results of analyses of base-flow samples collected during the pre-BMP phase showed that nutrient-rich discharges occur periodically in the Nutrient-Management Subbasin. These discharges may come from tile drains, barn-yard runoff from cleaning manure storage pits, or from milk-house waste.

In the study area, tile drains have been installed to increase the productivity of low lying areas where surface runoff accumulates, and to divert water away from agricultural structures including barns and manure storage facilities. The water quality of the discharges from the tile drains is influenced by associated land-use practices, whereas the quantity depends on the amount of water in the soil. Four tile drains that discharge directly to the streams were located in the Nutrient-Management Subbasin. One of the tile drains, located at farm D (fig. 3), was installed to intercept subsurface flow that migrates from cropland towards an earthen animal-waste storage facility and a chicken and hog barn.

Barn-yard runoff, which may have been produced by the cleaning of manure-storage pits, can have a significant effect on the water quality in the Nutrient-Management Subbasin. Discharges from barn yards were observed on several occasions when base-flow samples were being collected.

Data in table 17 reflect the water quality of base flow in the Small Watershed when periodic discharges were being released and were characterized by discoloration of the water and a pungent odor. Elevated concentrations of ammonia plus organic nitrogen and phosphorus were measured when these discharges occurred in the Small Watershed. The solids from these discharges were deposited on the stream bottom. When ground water enters the stream through the fractured limestone streambed, the solids can be resuspended and redissolved, and the nutrient concentrations may not be representative of the ground water from the carbonate formation underlying the surface.

Table 17.--Nutrient concentrations in base flow in the Small Watershed during times of periodic point-source discharges, October 24, 1984, through March 13, 1986

[Streamflow, in cubic feet per second; concentration, in milligrams per liter; --, sample not analyzed for indicated constituent]

Site	Date	Stream-flow	Total nitrite nitrogen	Dissolved nitrite nitrogen	Total nitrite plus nitrate nitrogen	Dissolved nitrite plus nitrate nitrogen	Total ammonia nitrogen	Dissolved ammonia nitrogen	Total ammonia plus organic nitrogen	Dissolved ammonia plus organic nitrogen	Total phos-phorus	Dissolved phos-phorus
3A	10/24/84	0.30	0.37	--	6.5	--	0.26	--	2.8	--	0.52	--
3A	08/26/85	.35	.68	--	5.3	--	.57	--	2.2	--	.68	--
5	08/26/85	2.3	.29	--	3.3	--	.53	--	4.4	--	.97	--
3-3A[1]	03/13/86	--	.06	.04	7.0	7.0	5.2	5.2	13	11	1.6	1.4
3A	03/13/86	1.3	.06	.04	8.1	8.1	4.4	4.4	12	10	1.9	1.8

[1] 3-3A Sample collected immediately downstream from drainage ditch discharging from farm G.

Ground Water

Ground water was sampled from six wells and two springs (fig. 2) about three times per year in the Nutrient-Management Subbasin to determine general ground-water quality. The data from these wells and springs represent very local conditions, so they cannot be used to determine the effects of nutrient management at specific farms; however, the data may be helpful in showing general trends in the subbasin. The ground water at each of the sites is used for domestic and agricultural purposes. Because the wells are used in conjunction with automatic waterers for livestock, water levels in the wells fluctuate rapidly, and static water levels could not be measured at the time that water-quality samples were collected.

Table 18 and figure 22 indicate dissolved-nitrate concentrations in ground water were greater and varied more in the intensively farmed carbonate-rock floored valley than in the sandstone and shale area where slopes are steeper. The maximum dissolved-nitrate nitrogen concentrations were measured at well LN 1663 in the valley. Although dissolved-nitrate nitrogen concentrations at LN 1663 ranged from 25 to 15 mg/L, no trend was apparent during the pre-BMP phase. The decrease in dissolved-nitrate nitrogen concentration at LN 1586 in March 1986 (fig. 22) is attributed to a long period of operation of the farmer's diesel pump that improved evacuation of the well casing when the sample was collected. Therefore, the dissolved-nitrate nitrogen concentration measured in March 1986 was probably from a more representive ground-water sample than those collected earlier at LN 1586. Nitrate-nitrogen concentrations in all samples collected from LN SP59, LN 1663, and LN 1678 exceeded the USEPA 10-mg/L nitrate nitrogen maximum contaminant level (MCL) for safe drinking water (U.S. Environmental Protection Agency, 1989). Dissolved-nitrate nitrogen concentrations changed relatively little at LN 1665, LN 1662, and LN 1666, all of which are representative of ground water in the sandstone and shale region rather than the carbonate-rock floored valley. No seasonal trends were apparent.

Ground water in the Nutrient-Management Subbasin has relatively low and constant phosphorus concentrations. Dissolved-phosphorus concentrations at all of the ground-water sites ranged from less than 0.02 to 0.07 mg/L, indicating that little phosphorus leaches through the soils to the ground water.

Table 18.--Summary statistics of ground-water quality for the Nutrient-Management Subbasin

[Specific conductance, in microsiemens per centimeter; concentration, in milligrams per liter; n, number of values; <, less than]

Characteristic or constituent	Statistic	Well or spring: Carbonate valley: LNSP59	LN1586	LN1663	LN1678	Sandstone and shale area: LNSP60	LN 1662	LN 1665	LN1666
Specific conductance	Median	603	645	705	680	162	445	400	594
	n	7	7	7	3	4	7	7	6
	Minimum	570	555	595	672	159	417	382	385
	Maximum	730	775	735	795	185	532	497	785
Nitrate, dissolved as N	Median	14	6.7	24	15	6.9	.42	1.6	.17
	n	7	7	7	3	4	7	7	6
	Minimum	13	1.1	15	14	6.8	.29	.69	.08
	Maximum	16	9.0	25	15	8.8	.99	1.8	3.6
Ammonia, dissolved as N	Median	.02	.02	.02	.02	.02	.02	.01	.02
	n	7	7	7	3	4	7	7	6
	Minimum	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
	Maximum	.11	.04	.05	.02	.02	.04	.04	.03
Ammonia + organic nitrogen, dissolved as N	Median	.42	.30	.36	.30	.30	.28	.30	.26
	n	7	7	7	3	4	7	7	6
	Minimum	.20	<.20	<.20	<.20	.26	<.20	<.20	<.20
	Maximum	1.3	.40	.60	.64	.50	.52	.52	.42
Phosphorus, dissolved as P	Median	.02	.03	.03	.03	.01	.02	.03	.02
	n	7	7	7	3	4	7	7	6
	Minimum	<.02	<.02	.03	.03	<.02	<.02	<.02	<.02
	Maximum	.06	.05	.07	.06	.02	.05	.06	.05

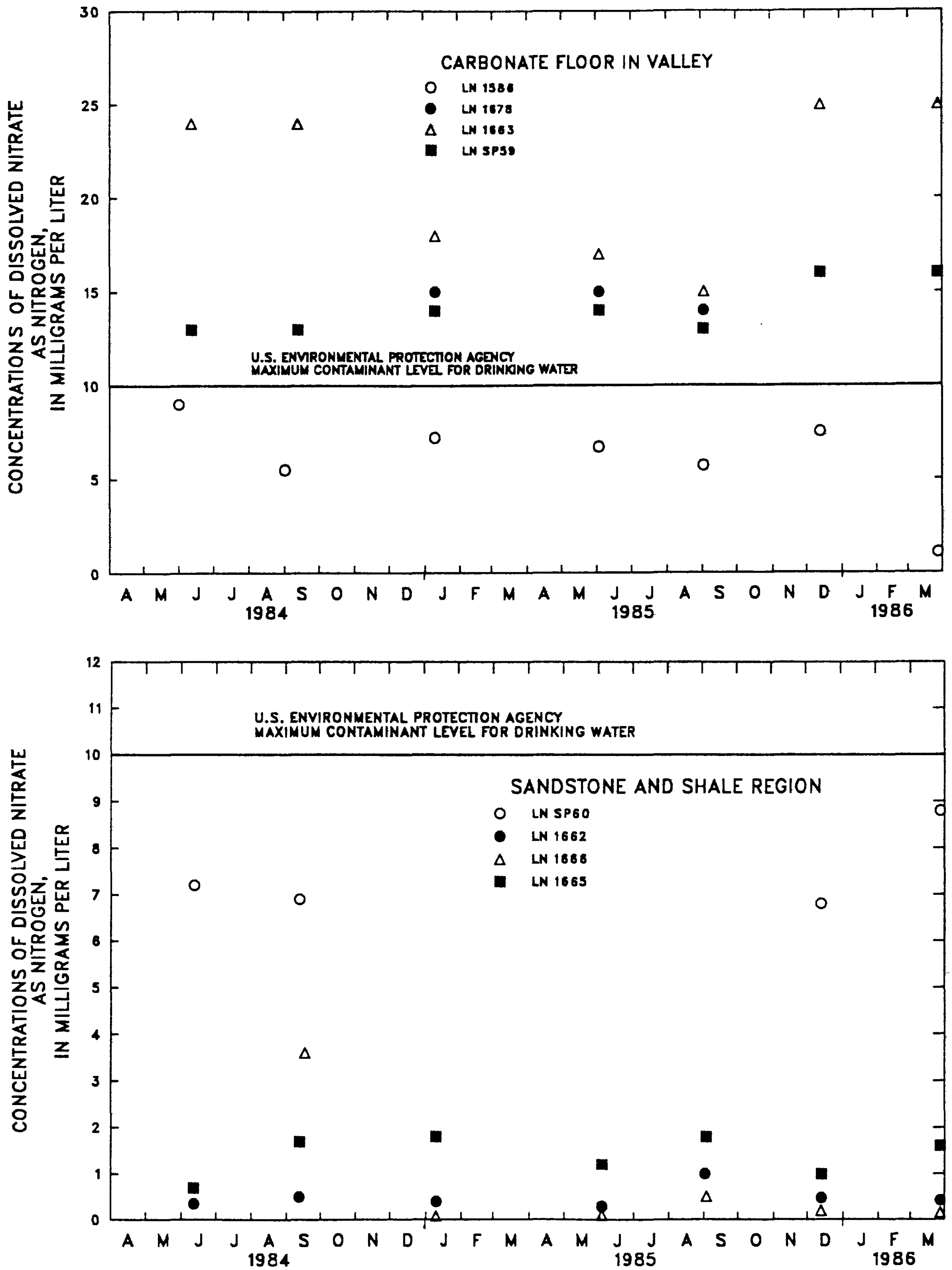


Figure 22.--Dissolved-nitrate as nitrogen concentrations in ground water in the Nutrient-Management Subbasin, April 1, 1984, through March 31, 1986.

ESTIMATES OF REDUCTIONS IN AGRICULTURAL CONTAMINANTS REQUIRED FOR OBSERVING A STATISTICALLY-SIGNIFICANT CHANGE IN WATER QUALITY

The executive summary of the Conestoga River Headwaters RCWP 1982 Plan of Work (U.S. Department of Agriculture, 1982, p. 1) stated that the first objective of the RCWP is "to significantly reduce agricultural pollutants: nitrogen, phosphorus, pesticides, sediment, and other pollutants, entering public and private waters of the Conestoga Headwaters Watershed." More specific objectives (page 13) included the goal to "reduce nitrates and phosphates in solutions from entering receiving streams and lakes by applying the fertilizer management (nutrient management) BMP on 3,600 acres." The achievement of these objectives was felt to be instrumental in meeting the other objectives, including improving the potable quality of water and the aquatic environment within and downstream from the Conestoga Headwaters Watershed.

There are several difficulties in achieving the objectives. Estimates were made of reductions in nutrient concentrations and loads in base flow that could be measured statistically, inasmuch as the Plan of Work did not specify numerical instream nutrient reductions. In order to accomplish this, the background levels and pre-BMP trends need to be determined. Second, an investigation into the relation between statistical changes and environmental changes needs to be made. Extensive hydrologic data collection is required to develop these relations.

Other investigators, like Richards (1985), have used the Student t-test (two-sample, one-tailed) in reverse to establish target goals. Richards, in a study of phosphorus loads in the Sandusky River basin, found that, given available data and conventional statistical techniques, the probability of observing a statistically-significant reduction in phosphorus loads was only 95 percent if the true reduction were 35.6 percent. Richards said he used the t-test because it was a technique familiar to most workers and was readily adaptable to the problem of estimating the needed reduction. However, he acknowledged, as suggested by Hirsch and others (1982), Helsel (1987), and the National Water Quality Evaluation Project (1988), that nonparametric techniques would be more appropriate and may be more powerful than parametric techniques for analyzing water-quality data, primarily because most of the hydrologic data are non-normal (usually positively skewed). No attempt was made by Richards to determine the relation between changes that were statistically measurable and improvements in potable water or aquatic environments.

The estimated probability of observing a statistically-significant reduction in nitrogen and phosphorus loads, as a function of the true reduction in the loads, are listed in table 19. These estimates were obtained by using the means and standard deviations of the raw data for the two seasons as input to the Monte Carlo simulation of the nonparametric Seasonal rank-sum test. The procedure used to calculate these reductions is discussed on page 12. Standard deviations for data that were log normal are listed as a positive and negative percent rather than the standard deviations of the raw data.

Figures 23 and 24 show the results of estimating the amount of reduction required for statistically measurable changes, and the power of the Seasonal rank-sum test, (1-B), which represents the probability of rejecting the null hypothesis when, in fact, it is false and the alternative hypothesis is true. The null hypothesis was that there was no difference in the mean of the pre-BMP and post-BMP data. Therefore, the power of the test gives the probability of detecting a statistically measurable change during a 2-year post-BMP phase, if the data are reduced by the indicated percentage.

Although the water quality at Site 1 will likely not be affected by nutrient management, estimated reductions were calculated for this site to show differences between agricultural and nonagricultural areas prior to the implementation of a management plan. Site 1 requires the least reduction in nutrient concentrations and loads in base flow (table 19 and figures 23-24) because of the narrow range and little scatter in the data for this site. The range and scatter in the data for Site 1 are typical of other small forested and undisturbed watersheds in the Lower Susquehanna River basin (Lietman, Ward, and Behrendt, 1983) where the effects of human activities are minimal, and the geology and topography permit rapid transport of ground water through subsurface soils with little leaching before it is released as base flow. The requirements for measurable changes increase downstream at Sites 2A, 3A, 9, and 5 where the influence by agricultural activities increase. The results suggest that, although significant reductions in concentrations and loads can occur at an upstream site, reductions may have little effect farther downstream unless nutrient management is implemented on a regional basis. For example, a reduction of 63 percent or 16 lb less than the mean total-nitrogen load in base flow is required at Site 3A to be statistically significant. However, this reduction is less than one quarter of the 69-percent or 95-lb reduction required downstream at Site 5.

Although the reductions required in the base flow loads appear large (table 19 and figs. 23-24), the reductions are relatively small if compared with the nutrient applications. For example, the total-nitrogen load in base flow at Site 3A needs to be reduced by 63 percent to observe a statistically-significant reduction (table 19). This reduction represents 20,147 lb of the 31,980 lb of total-nitrogen (table 13) discharged during the 2 years as compared to the 337,610 lb of nitrogen that were applied to the soil from the spreading of manure, commercial fertilizer, and the grazing of animals during the same period. It also should be stressed that, because the implementation of nutrient management is not expected to alter streamflows or velocities, reductions in loads can only be achieved by reducing the nutrient concentrations in the stream.

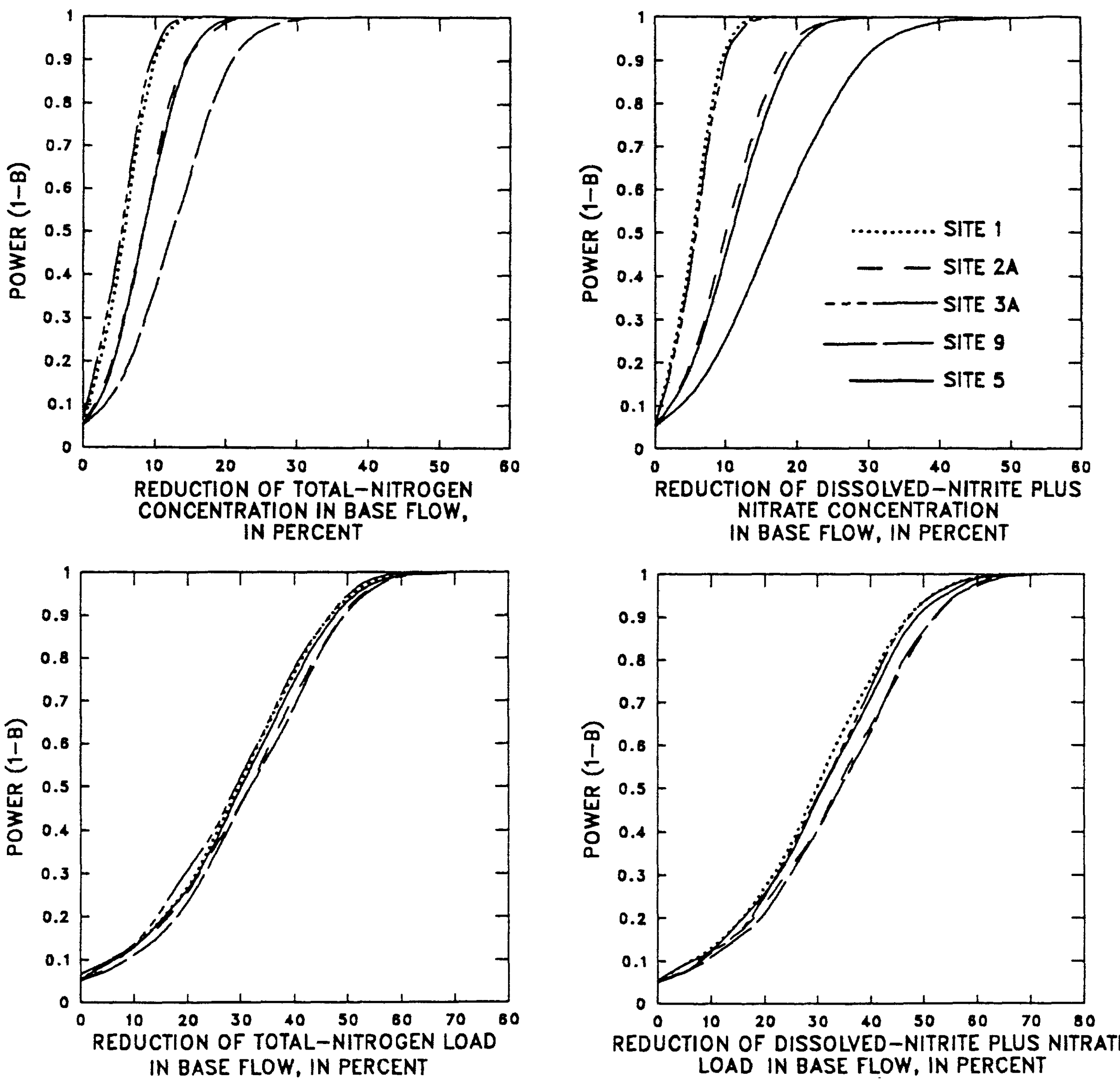


Figure 23.--Probability of achieving statistically-significant changes at selected reductions in total-nitrogen and dissolved-nitrite plus nitrate as nitrogen concentrations and loads in base flow.

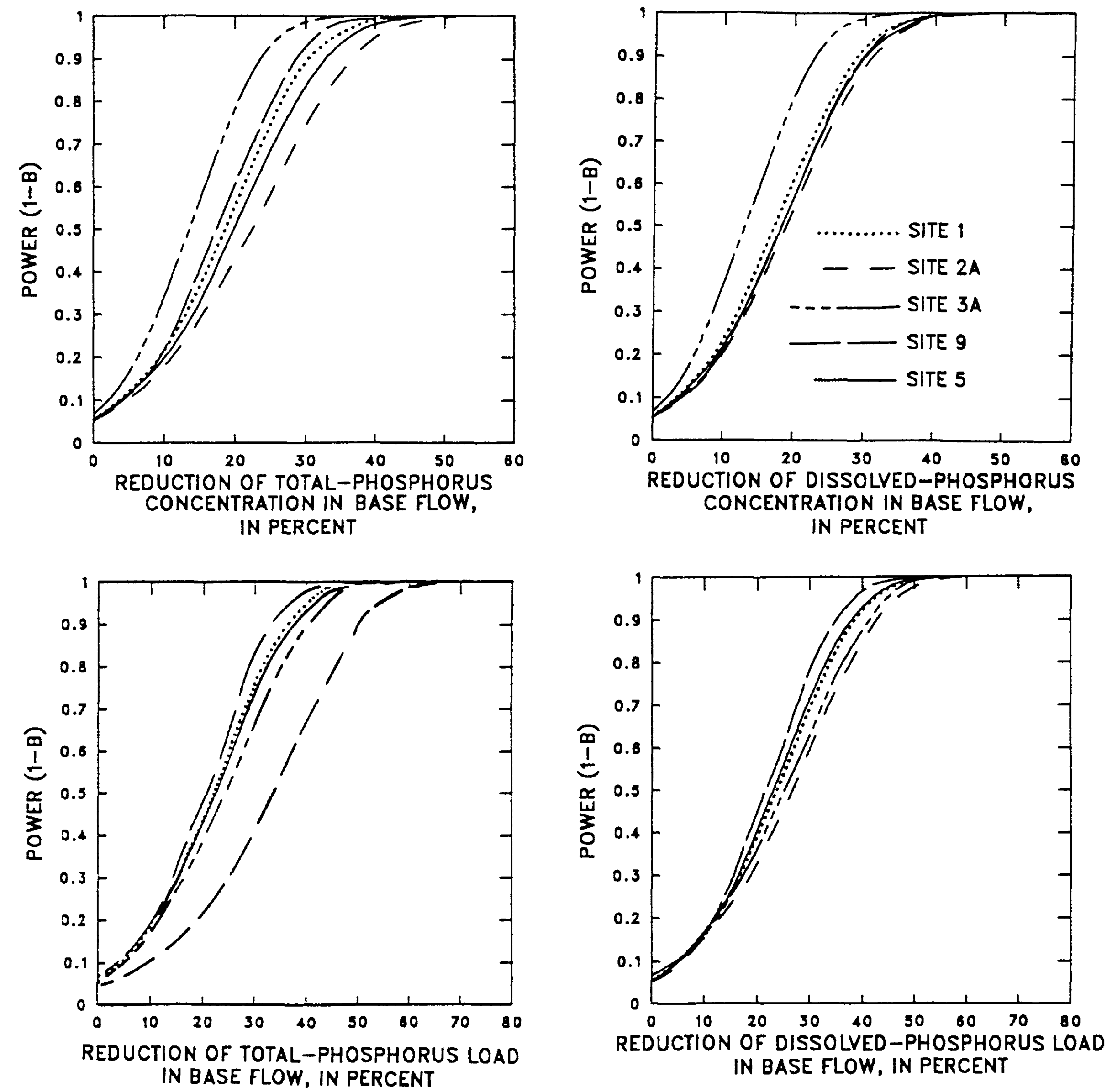


Figure 24.--Probability of achieving statistically-significant changes at selected reductions in total- and dissolved-phosphorus concentrations and loads in base flow.

Table 19.--Water-quality characteristics of base flow during the study period, nongrowing seasons, and growing seasons, and estimated reductions in agricultural contaminants required for observing statistically-significant reductions

[concentration, in milligrams per liter (mg/L); load, in pounds (lb); estimated reductions, in percent; n, number of observations]

	Study period				Nongrowing seasons				Growing seasons				Estimated reductions
		Standard deviation				Standard deviation				Standard deviation			
Constituent	Mean	plus	minus	n	Mean	plus	minus	n	Mean	plus	minus	n	percent
Site 1													
Nitrite plus nitrate, dissolved as N													
concentration	2.7	15	13	30	2.9	10	10	15	2.6	14	13	15	17
load	3.7	124	57	30	3.5	130	57	15	3.8	135	57	15	69
Nitrogen, total as N													
concentration	3.3	[a].52	[a].52	30	3.5	12	10	15	3.0	20	16	15	18
load	4.4	123	55	30	4.2	125	55	15	4.5	130	56	15	68
Phosphorus, total as P													
concentration	.05	60	40	30	.05	47	28	15	.05	77	44	15	48
load	.07	86	47	30	.06	87	46	15	.07	93	47	15	57
Phosphorus, dissolved as P													
concentration	.04	76	43	30	.04	49	33	15	.03	98	47	15	46
load	.05	88	47	30	.05	77	44	15	.05	94	53	15	58
Site 2A													
Nitrite plus nitrate, dissolved as N													
concentration	3.5	1.1	1.1	29	4.2	.71	.71	14	2.8	.86	.86	15	31
load	6.6	183	65	28	8.1	135	57	14	5.4	233	70	14	71
Nitrogen, total as N													
concentration	5.7	47	33	29	5.2	13	10	14	6.0	62	42	15	25
load	10	139	58	28	10	120	53	14	11	164	64	14	67
Phosphorus,total as P													
concentration	.25	108	52	28	.18	44	30	14	.34	139	56	14	54
load	.46	117	54	27	.36	108	53	14	.62	112	53	13	69
Phosphorus, dissolved as P													
concentration	.14	115	50	29	.13	42	31	14	.16	175	62	15	47
load	.26	148	58	28	.25	88	48	14	.28	218	68	14	60
Site 3A													
Nitrite plus nitrate, dissolved as N													
concentration	7.8	27	22	29	9.1	10	9	14	6.7	28	21	15	17
load	24	150	60	29	26	150	58	14	22	159	62	15	68
Nitrogen, total as N													
concentration	9.0	22	18	28	10	[a].85	[a].85	13	8.3	[a]1.6	[a]1.6	15	15
load	26	135	58	28	26	127	58	13	27	148.	59	15	63
Phosphorus, total as P													
concentration	.18	50	33	28	.16	25	19	13	.20	70	40	15	36
load	.52	98	50	28	.40	128	55.	13	.66	71	41	15	56
Phosphorus, dissolved as P													
concentration	.14	49	33	28	.13	185	23	13	.15	60	40	15	35
load	.40	98	50	28	.33	115	55	13	.48	75	44	15	56

Table 19.--Water-quality characteristics of base flow during the study period, nongrowing seasons, and growing seasons, and estimated reductions in agricultural contaminants required for observing statistically-significant reductions--Continued

[concentration, in milligrams per liter (mg/L); load, in pounds (lb); estimated reductions, in percent; n, number of observations]

Constituent	Study period Mean	Study period Standard deviation plus	Study period Standard deviation minus	Study period n	Nongrowing seasons Mean	Nongrowing seasons Standard deviation plus	Nongrowing seasons Standard deviation minus	Nongrowing seasons n	Growing seasons Mean	Growing seasons Standard deviation plus	Growing seasons Standard deviation minus	Growing seasons n	Estimated reductions percent
Site 9													
Nitrite plus nitrate, dissolved as N													
concentration	3.9	62	36	29	5.3	1.6	1.6	14	3.4	1.5	1.5	15	50
load	23	230	70	29	30	167	63	14	18	288	74	15	72
Nitrogen, total as N													
concentration	5.7	39	26	29	6.1	30	23	14	5.4	44	31	15	33
load	34	171	62	29	36	152	61	14	32	191	66	15	70
Phosphorus, total as P													
concentration	.24	79	42	29	.19	53	37	14	.31	58	35	15	45
load	1.4	93	47	29	1.1	87	47	14	1.9	81	47	15	52
Phosphorus, dissolved as P													
concentration	.19	63	42	29	.16	71	42	14	.22	62	37	15	46
load	1.1	82	47	29	.91	88	47	14	1.3	80	44	15	53
Site 5													
Nitrite plus nitrate, dissolved as N													
concentration	6.8	2.3	2.3	30	8.2	1.7	1.7	15	5.3	1.9	1.9	15	33
load	110	217	68	30	160	149	61	15	83	265	72	15	35
Nitrogen, total as N													
concentration	8.3	2.0	2.0	30	9.3	18	17	15	7.0	26	20	15	25
load	138	180	64	30	160	149	60	15	110	210	66	15	69
Phosphorus, total as P													
concentration	.19	79	42	30	.17	59	35	15	.22	100	50	15	51
load	3.3	97	48	30	3.1	119	55	15	3.6	69	39	15	58
Phosphorus, dissolved as P													
concentration	.15	73	40	30	.15	.06	.06	15	.19	.11	.11	15	48
load	2.6	81	46	30	2.5	101	50	15	2.7	67	40	15	57

[a] Results for these constituents come from normally distributed data.

HYPOTHETICAL EFFECTS OF REDUCTIONS IN NUTRIENT APPLICATIONS ON IMPROVEMENT IN WATER QUALITY AND EFFECT OF LAND-USE CHANGES AND RANDOM EVENTS ON WATER QUALITY

The characterization of the Little Conestoga Creek headwaters points out the complexity of attempting to improve water quality through the implementation of nutrient management because of the variability in nutrient applications, water-quality data, land-use changes, and random events. Generally, the variability in the nutrient applications was caused by the timing of applications, which was regulated on the basis of precipitation occurrence and timing, crop requirements, and manure-storage capacities. Variability in water-quality data generally increased with the increase in size of the watershed and the increase in the area under cultivation within the watershed. Other land-use changes besides nutrient management, including random events, produce effects that add to the complexity of attempting to improve the water quality.

If the seasonal variation in applications of nitrogen and phosphorus changes, as is expected when nutrient management is implemented, then the utilization of the nutrients by crops also will change. As a result, a change would be expected to occur in the amount of nutrients available for transport to the stream in surface runoff or in ground water that is released as base flow.

Improvement of Water Quality

The effects of nutrient management on water quality in the Little Conestoga Creek headwaters will depend on the total area for which plans are developed. If plans are developed at a future date for the Nonnutrient-Management Subbasin, then implementation of nutrient management will improve the chances of detecting improved water quality at Site 5. The Paired-Watershed analyses should, with high probability, detect any substantial changes in the water quality. In particular, if the phosphorus loads decline by 56 percent at the Nutrient-Management Subbasin, given the resolution of the statistical methods employed here, the probability of detecting a significant downtrend is approximately 95 percent. Inasmuch as nutrient management will not have an effect on streamflow or stream velocities, and the amount and timing of precipitation can not be controlled, water quality will be improved by nutrient management only if nutrient concentrations in the water are reduced.

In addition to various statistical analyses, the hypothetical effects of nutrient management for each constituent need to be evaluated separately on the basis of that constituent's known chemical or physical importance to water quality. For example, if all nitrate-nitrogen concentrations during the post-BMP phase are less than the Commonwealth of Pennsylvania water-quality criterion of 10 mg/L (Pennsylvania Department of Environmental Resources, 1989), then some improvement will have been made, inasmuch as nitrate-nitrogen concentrations exceeded the 10 mg/L criterion in five samples collected at Site 3A and in six samples collected at Site 5 during the pre-BMP phase. Thus, true improvement in water quality could occur even though the statistical tests indicated that the probability was very low.

As with nitrogen, specific concentrations of phosphorus have been associated with particular environmental conditions. Although the Commonwealth of Pennsylvania has no water-quality criteria for total or dissolved phosphorus in free-flowing streams, according to Mackenthum (1969) and USEPA (1986) concentrations of total phosphorus should not exceed 0.1 mg/L if nuisance growths in streams are to be prevented. The 0.01-mg/L concentration was rarely exceeded at Site 1 but was exceeded nearly 100 percent of the time at sites 2A, 3A, 9, and 5. Although table 19 indicates that reductions in mean concentrations of total phosphorus in base flow of 54, 36, 45, and 51 percent are required to produce statistically measurable changes at sites 2A, 3A, 9, and 5, respectively, reductions of these magnitudes will still result in mean concentrations that exceed 0.1 mg/L. Thus, it is possible to have statistically measurable changes without actually observing changes in water quality. Because no criteria have been established for nutrient discharges from nonpoint sources, the effects of reducing nitrogen and phosphorus loads on aquatic environments can not be evaluated at this time.

Finally, this characterization has indicated that even if a change in water quality is detected within the 1.42-mi^2 Nutrient-Management Subbasin, the improvement may have little effect just 4.3 mi downstream at the 5.82-mi^2 Small Watershed site. It is evident that the 63-percent reduction (table 19) of the 31,980 lb of total nitrogen (table 13) discharged in base flow at Site 3A needed to detect an improvement will not be sufficient to meet the 70-percent reduction (table 19) of the 161,980 lb (table 13) required at Site 5 to detect an improvement. Therefore, nutrient management can affect local water quality, but regional implementation is needed to affect regional water quality.

Effects of Land-Use Changes

The preceding discussion was based on the assumption that no major changes in land use or management practices other than nutrient management are implemented within the study area during the post-BMP phase. However, during the pre-BMP phase, three of the farms in the Nutrient-Management Subbasin were sold and changes in land use were planned. The division of one of the farms, Farm E (fig. 3), into building lots may affect water quality because soils will be exposed and the potential for transport of sediment and associated nutrients will increase. In 1986, plans were made to rehabilitate an old park near Farm E in the northeastern part of the Nutrient-Management Subbasin. Included in this park will be the construction of a small parking lot, picnic grounds, and a pond. Another farm that was sold is on the northern border of the subbasin. This farm, not identified in figure 3 because of its small contribution to the subbasin, was purchased by a private school as a site for its athletic field.

The construction of manure-storage facilities can affect soil nutrients. If open-storage facilities gain increased acceptance in the study area, the amount of nutrients from atmospheric deposition can increase. Recent studies by van Breeman and others (1982) and data collected from a small agricultural watershed in Adams County (Fishel, D.K., Truhlar, M.V., and Langland, M.J., U.S. Geological Survey, written commun., 1989) indicate that nitrogen concentrations in precipitation, especially ammonia, are significant near manure-storage facilities. The construction of any manure-storage facility will affect the timing of manure applications and thus alter nutrient concentrations in the soils.

Changes in cropping patterns also can affect soil nutrients. If the amount of alfalfa in the subbasin increases (as can be recommended as part of the total farm-conservation plan) then soil-nitrogen concentrations may increase. If not utilized by other crops, then the nitrogen will be available for leaching to the ground water.

Effects of Random Events

Random events that can affect nutrient management and water quality include large storms, changes in animal population or types, outbreaks of animal diseases, and other events. The effects of Hurricane Gloria have been described earlier in the report. Such random events can have substantial effects on water quality by affecting the processes of surface runoff, infiltration, recharge, crop uptake, evapotranspiration, and the timing of most farm operations. If changes occur in animal populations or types, additional manure may need to be exported (a costly procedure) or the manure will be applied to the soil. Changes in animal populations depend on the market demands, which can change suddenly. If animal diseases break out in the subbasin, restrictions can be placed on the removal of manure from the subbasin. (Avian influenza and swine pseudorabies were prevalent in the general area during the pre-BMP phase.) Other random events can have an impact on farmer cooperation. These include changes in the financial status of the agricultural community, health of the land owner, and the religious and cultural mores of the dominant Amish and Mennonite populations in the study area.

SUMMARY

Hydrologic and land-use data were collected in a Small Watershed study area in the Conestoga River Headwaters from April 1984 through March 1986 as part of the Rural Clean Water Program directed by the U.S. Department of Agriculture. The study was done to describe the land use and hydrology and characterize the water quality of the Small Watershed, the Nutrient-Management Subbasin, and the Nonnutrient-Management Subbasin during the 2-year pre-Best-Management Practice phase.

Overall, precipitation during the 2 years was about 10 percent below normal but was 5 percent above normal during the 1984 growing season and 11 percent above normal during the 1985 growing season. A total of 76 in. of precipitation was recorded during the 2 years.

Ninety-one percent of the land in the Nutrient-Management Subbasin is used for agriculture. Most farms are small (less than 100 acres) and are operated by the owner. Approximately 52 percent of the crop acreage in the Nutrient-Management Subbasin is planted in corn. In the Nutrient-Management Subbasin, poultry composed about half of the animal population; dairy cows and hogs composed most of the other half. The total animal population for the farms was about 1,500 animal units or an average of about 1.8 animal units per acre; a maximum of 1.5 animal units per acre is considered critical with respect to the generation of nonpoint-source discharges.

The animals produced an annual average of 18,000 tons of manure, which was estimated to contain 345,000 lb of nitrogen and 93,000 lb of phosphorus. About 7,190 tons of manure were applied by the farmers the first year, and 8,175 tons were applied during the second year to cropland in the Nutrient-Management Subbasin. An additional 3,900 tons was estimated to be deposited by grazing animals in pastures near the stream. Excess manure that was not spread to cropland was deposited on pastures or fields outside the Nutrient-Management Subbasin. Most farms have limited manure-storage facilities. Therefore, manure is applied to the fields whenever spreaders can get onto the fields.

Fourteen of the 16 farmers in the Nutrient-Management Subbasin applied 203,150 lb of nitrogen in the form of manure and 50,660 lb in the form of commercial fertilizer during the 2 years (no data were available from the other two farmers). About 51,000 lb of phosphorus in the form of manure and 13,140 lb of phosphorus in the form of commercial fertilizer were applied. About 83,800 lb of nitrogen and 18,100 lb of phosphorus are estimated to have been deposited by grazing animals. Another 7,120 lb of nitrogen are estimated to have been contributed from the rotation of alfalfa. During the first year, about 119,300 lb of nitrogen were applied by the 14 farmers. During the second year, about 134,510 lb of nitrogen were applied. Phosphorus applications increased from 28,990 lb the first year to 35,150 lb the second year.

Concentrations of nitrate-nitrogen in the soil ranged from 45 to 372 lb/acre in the upper 4 ft after the growing season. Concentrations of phosphorus ranged from 1.4 to 23 lb/acre.

Streamflow was nearly normal during the first year and was estimated to be 15 percent below normal during the second year. Streamflow characteristics at Site 3A (at the mouth of the Nutrient-Management Subbasin) and Site 5 (at the mouth of the Small Watershed study area) were similar. Streamflow at both sites increased rapidly during storms. About 57 percent of the total streamflow at Site 5 during the 2 years was base flow, and 20 percent of the flow at Site 5 was from Site 3A. Annual average streamflows were 7.57 and 5.55 ft^3/s at Site 5, and 1.28 and 1.23 ft^3/s at Site 3A for the periods April 1984 through March 1985 and April 1985 through March 1986, respectively.

Nutrient concentrations in base flow increased as the stream flowed from the steep shale and sandstone areas to the carbonate floor of the valley. The maximum median total-nitrogen concentration in base flow was 9.8 mg/L at the Nutrient-Management Subbasin (Site 3A). The median total-nitrogen concentration in base flow at the most upstream site (Site 1) was 3.4 mg/L and, at the most downstream site (Site 5), was 8.0 mg/L. Most of the nitrogen in base flow was dissolved nitrate. Median dissolved-nitrite plus nitrate nitrogen concentrations increased from 2.7 mg/L at Site 1 to 8.1 mg/L at Site 5. Median total-phosphorus concentrations in base flow increased from 0.05 mg/L at Site 1 to 0.20 mg/L at Site 2A in the middle of the Nutrient-Management Subbasin. Maximum total-phosphorus concentrations in base flow were measured at the Nonnutrient-Management Subbasin (Site 9); the median concentration there was 0.23 mg/L.

Maximum concentrations of dissolved nitrite plus nitrate nitrogen in base flow were measured during wet periods when infiltrating precipitation was in longer contact with the nutrient-rich soil. Concentrations of dissolved-nitrite plus nitrate nitrogen increased rapidly in the fall after manure was spread on harvested fields. Decreases in dissolved-nitrite plus nitrate nitrogen concentrations during the growing season coincided with increases in nutrient utilization and evapotranspiration by crops and vegetation, and decreases in precipitation, infiltration, and subsequent recharge of the ground water. The effects of precipitation, nutrient applications, and nutrient utilization by crops on dissolved-nitrite plus nitrate nitrogen concentrations and loads may have been greater at Site 3A than Site 5, because 52 percent of the total acreage at Site 3A was planted in corn, which has a high nitrogen demand. Maximum phosphorus concentrations were measured during low base flows when the length of time for interaction between sediment and ground water is the greatest.

About 290 tons of suspended sediment, 81 tons of nitrogen, and 1.45 tons of phosphorus discharged during base flow at Site 5 during pre-BMP phase. During the same period, 45 tons of suspended sediment, 16 tons of nitrogen, and 0.27 ton of phosphorus discharged during base flow from Site 3A.

About 9,150 tons of suspended sediment, 34 tons of nitrogen, and 8.3 tons of phosphorus discharged past Site 5 during storms while 560 tons of suspended sediment, 6.6 tons of nitrogen and 1.4 tons of phosphorus discharged past Site 3A.

The availability of nutrients for transport at the Paired-Watersheds or the factors controlling nutrient transport probably are different at the two subbasins.

Ground water in the intensively farmed carbonate-rock floored valley of the Nutrient-Management Subbasin had greater nitrate-nitrogen concentrations than did ground water in the steep sandstone and shale areas. Ground water in three wells in the valley consistently had nitrate-nitrogen concentrations that exceeded the U.S. Environmental Protection Agency maximum contaminant level of 10 mg/L. The maximum nitrate-nitrogen concentration measured in a well was 25 mg/L.

Discharges from an area where pesticide containers were disposed of, from tile drainage, and from farm-lot runoff periodically affect water quality in the Nutrient-Management Subbasin. The total affect of these discharges on water quality was not quantified because of their intermittent nature.

Results from a nonparametric statistical test for seasonal data indicate that substantial reductions in concentrations and loads of nitrogen and phosphorus in base flow will be needed to observe statistically-significant improvements in water quality. It was calculated that concentrations and loads of total nitrogen in base flow at the five sites need to be reduced by 15 to 33 percent, and by 63 to 70 percent, respectively, to be assured of detecting the changes in water quality, and concentrations and loads of total phosphorus need to be reduced by 36 to 54 percent, and by 52 to 69 percent, respectively.

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