Effects of Agricultural Best-Management Practices on the Brush Run Creek Headwaters, Adams County, Pennsylvania, Prior To and During Nutrient Management

By MICHAEL J. LANGLAND and DAVID K. FISHEL

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BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

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

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.004047	square kilometer
square mile (mi^2)	2.590	square kilometer
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	Volume	
gallon (gal)	3.785	liter
cubic foot per second per day [(ft^3/s)/d]	2.447	cubic kilometer per second per day
	Mass	
pound per day (lb/d)	80.45	kilogram per day
ton per day (ton/d) short	0.9072	megagram per day
ton per square mile per year	0.3503	metric ton per square kilometer per year

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

°F = 9/5 (°C) + 32.

Other abbreviated water-quality units used in report:

milligrams per liter (mg/L)

micrograms per liter (µg/L)

micrometers (µm)

milliliters (mL)

microsiemens per centimeter at 25 degrees Celsius (µS/cm)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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By Michael J. Langland *and* David K. Fishel

Abstract

The U.S. Geological Survey, in cooperation with the Susquehanna River Basin Commission and the Pennsylvania Department of Environmental Resources, investigated the effects of agricultural best-management practices on surface-water quality as part of the U.S. Environmental Protection Agency's Chesapeake Bay Program. This report characterizes a 0.63-square-mile agricultural watershed underlain by shale, mudstone, and red arkosic sandstone in the Lower Susquehanna River Basin. The water quality of the Brush Run Creek site was studied from October 1985 through September 1991, prior to and during the implementation of nutrient management designed to reduce sediment and nutrient discharges into Conewago Creek, a tributary to the Chesapeake Bay.

The original study area was 0.38 square mile and included an area immediately upstream from a manure lagoon. The study area was increased to 0.63 square mile in the fall of 1987 after an extensive tile-drain network was discovered upstream and downstream from the established streamflow gage, and the farm owner made plans to spray irrigate manure to the downstream fields.

Land use for about 64 percent of the 0.63 square mile watershed is cropland, 14 percent is pasture, 7 percent is forest, and the remaining 15 percent is yards, buildings, water, or gardens. About 73 percent of the cropland was used to produce corn during the study. The average annual animal population consisted of 57,000 chickens, 1,530 hogs, and 15 sheep during the study. About 59,340 pounds of nitrogen and 13,710 pounds of phosphorus were applied as manure and commercial fertilizer to fields within the subbasin during the 3-year period prior to implementation of nutrient management. During nutrient management, about 14 percent less nitrogen and 57 percent less phosphorus were applied as commercial and manure fertilizer.

Precipitation totaled 209 inches, or 13 percent less than the long-term normal, during the 6-year study. Concentrations of total ammonia in precipitation were as high as 2.7 mg/L (milligrams per liter); in dry deposition the concentrations were as high as 5.4 mg/L, probably because of the ammonia that had volatilized from the manure-storage lagoon. Nitrate nitrogen in the upper 4 feet of the soil ranged from 17 to 452 pounds per acre and soluble phosphorus content ranged from 0.29 to 65 pounds per acre.

The maximum concentration of total nitrogen was 2,400 mg/L on September 10, 1986, in discharge from the tile drain near the streamflow gage. Median concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow at the water-quality gage were 14 mg/L and 4.4 mg/L, respectively; prior to nutrient management and during nutrient management, median concentrations were 14 mg/L and 6.2 mg/L, respectively. Significant reductions in total phosphorus and suspended-sediment concentrations occurred at the water-quality gage. The maximum concentrations of total phosphorus (160 mg/L) and suspended sediment (3,530 mg/L) were measured at a tile line above the water-quality gage. Concentrations of total nitrogen, dissolved ammonia, and total phosphorus in base flow increased during dry periods when discharges from the tile drain were not diluted. During nutrient management, only base-flow loads of suspended sediment increased.

Total streamflow was about 121.8 inches. About 81 percent was storm runoff. Loads of total nitrogen, total phosphorus in stormflow, and suspended sediment increased 14, 44, and 41 percent during nutrient management, respectively. A load of about 787,780 pounds of sediment,

22,418 pounds of nitrogen, and 5,479 pounds of phosphorus was measured during 214 sampled stormflow days that represented 84 percent of the stormflow. About 812,924 pounds of sediment, 38,421 pounds of nitrogen, and 6,377 pounds of phosphorus were discharged during the 6-year study.

INTRODUCTION

This study began in 1985 as part of the U.S. Environmental Protection Agency (USEPA) Chesapeake Bay Program and was done in cooperation with the Susquehanna River Basin Commission (SRBC) and the Pennsylvania Department of Environmental Resources (PaDER)[1], Bureau of Soil and Water Conservation. Data were collected to characterize the Brush Run Creek study site (one, in fig. 1), and to evaluate the effects of nutrient management, an agricultural Best Management Practice (BMP) on surface-water quality at the site. The Brush Run Creek site, similar to a companion study site at Bald Eagle Creek (two, in fig. 1), is located in a noncarbonate-rock area in the Lower Susquehanna River Basin. Separate reports, one by Fishel and others (1991), provides a characterization of the Bald Eagle Creek site, and a second report by Langland and Fishel (1995) evaluates the effects of nutrient management at the Bald Eagle Creek site.

The USEPA Chesapeake Bay Program identified the Susquehanna River as a major nutrient source that discharges to the bay. The Susquehanna River contributes 40 percent of the nitrogen and 21 percent of the phosphorus discharged to the Chesapeake Bay (U.S. Environmental Protection Agency, 1983). Eighty-five percent of the nitrogen and 60 percent of the phosphorus contribution from the Susquehanna River have been reported to come from cropland runoff (U.S. Environmental Protection Agency, 1983).

The Chesapeake Bay Program recommended the implementation of BMP's to reduce nonpoint-source nutrient discharges. These management practices are recommended to farmers who request technical expertise from the U.S. Department of Agriculture (USDA), National Resources Conservation Service (NRCS).

In 1979, Pennsylvania's Agricultural 208 Plan identified priority areas in need of study on nonpoint-source contamination of surface and ground water (Schueller, 1983). The Conestoga River Basin was designated the top-priority watershed in Pennsylvania as a result of the study. In 1982, the Rural Clean Water Program (RCWP) initiated a 10-year study of the Conestoga River headwaters to determine the effects of BMP's on surface-water and ground-water quality. One of three components of the Conestoga River Headwaters Project is to evaluate the effects of BMP's in a small, intensively farmed watershed underlain by carbonate rock. A corresponding program also was needed in noncarbonate-rock areas in the Lower Susquehanna River Basin; thus, the Brush Run Creek headwaters study was initiated by the U.S. Geological Survey (USGS) under the Chesapeake Bay Program in 1985. The results could then be compared to results from carbonate-rock areas, such as the Nutrient-Management Subbasins in the Little Conestoga Creek headwaters being studied for the RCWP.

Agricultural-management plans are to be designed for farms at each site and may consist of a combination of BMP's implemented to reduce soil and nutrient loss in surface runoff to the streams. Other BMP's may be recommended by the nutrient-management specialist to balance nutrient applications with crop requirements to obtain maximum crop yields without permitting the excessive nutrients to leach to the ground water and be released in base flow to the streams. BMP's in the plans may include terraces, diversions, sediment-detention ponds, animal-waste storage facilities, barn gutters, or other innovative techniques.

Purpose and Scope

This report documents the water quality of surface runoff and base flow of a 0.63-mi^2 watershed (fig. 2) in the most upstream part of the Brush Run Creek watershed near McSherrystown, Adams County, from October 1985 through September 1991. The report also describes the effects of nutrient management on surface-water quality by comparing land use and hydrologic data collected prior to nutrient management (October 1, 1985–September 31, 1988) with data collected during nutrient management (October 1, 1988– September 31, 1991). The report describes the area of investigation, methods used, hydrology of the area, including soil chemistry, and hypothetical and actual effects of nutrient management on surface-water quality. Ground-water quality, quantity, and availability are presented with a limited discussion. Data in this report will aid agricultural managers in developing management plans for farms and water-quality managers who are evaluating whether voluntary implementation of management techniques are successful in improving the water quality of the Lower Susquehanna River Basin.

[1]In 1995, the Pennsylvania Department of Environmental Resources became the Pennsylvania Department of Environmental Protection.

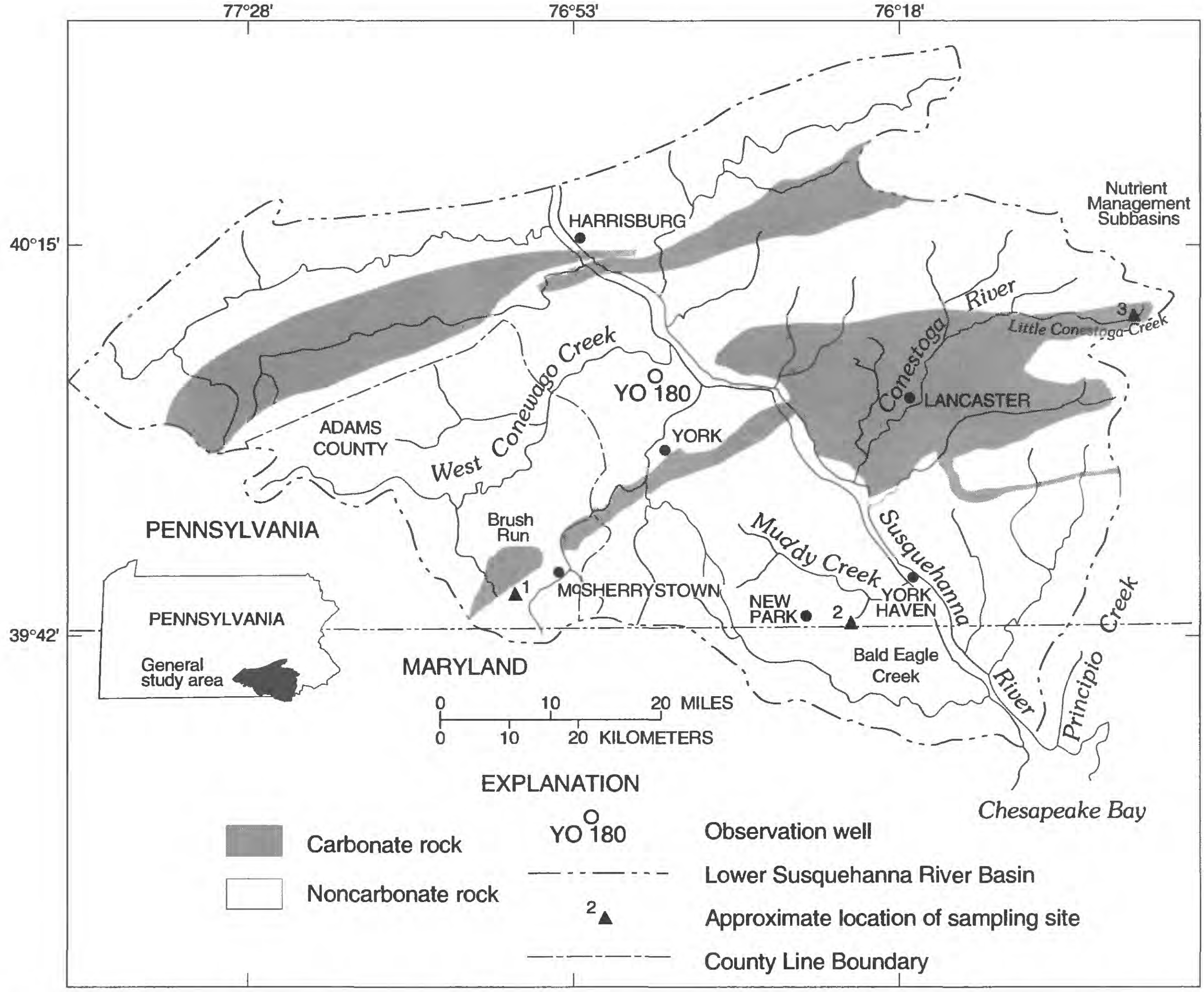


Figure 1. Locations of Brush Run Creek (site 1), Bald Eagle Creek (site 2), and Little Conestoga Creek (Nutrient-Management Subbasin, site 3) in the Lower Susquehanna River Basin.

The original scope of the study was limited to 0.38 mi^2 (fig. 2) upstream from the continuous streamflow-gaging station. However, after collecting data for 1 year, an extensive network of tile drains was discovered at the site. Some of these drains are located and discharged downstream from the streamflow-gaging station. Also, manure from a lagoon was to be distributed on fields downstream from the gage as part of the implementation of nutrient management. Therefore, the project scope was increased to include the collection of land use and water-quality data for the entire 0.63-mi^2 area.

Approach

Extensive land use, hydrologic, and soil data were collected to characterize the water quality of surface runoff and base flow at the Brush Run Creek site. Both historical and current data were used to do the characterization. Land-use data, collected from the farmer, included crop acreage and yields, animal density, manure production, and nutrient applications. Hydrologic data were collected and used to determine the quantity and quality of precipitation, dryfall, base flow, and stormflow. Soil-chemistry samples were used to identify areas where nutrient management may be most beneficial. Streamwater-quality samples during base flow and stormflow were collected to document the water chemistry prior to nutrient management and changes that occurred during nutrient management. Water samples were collected from tile drains to determine the influence of their discharges on the stream quality. Nutrient and suspended-sediment loads were calculated to characterize the water quality of

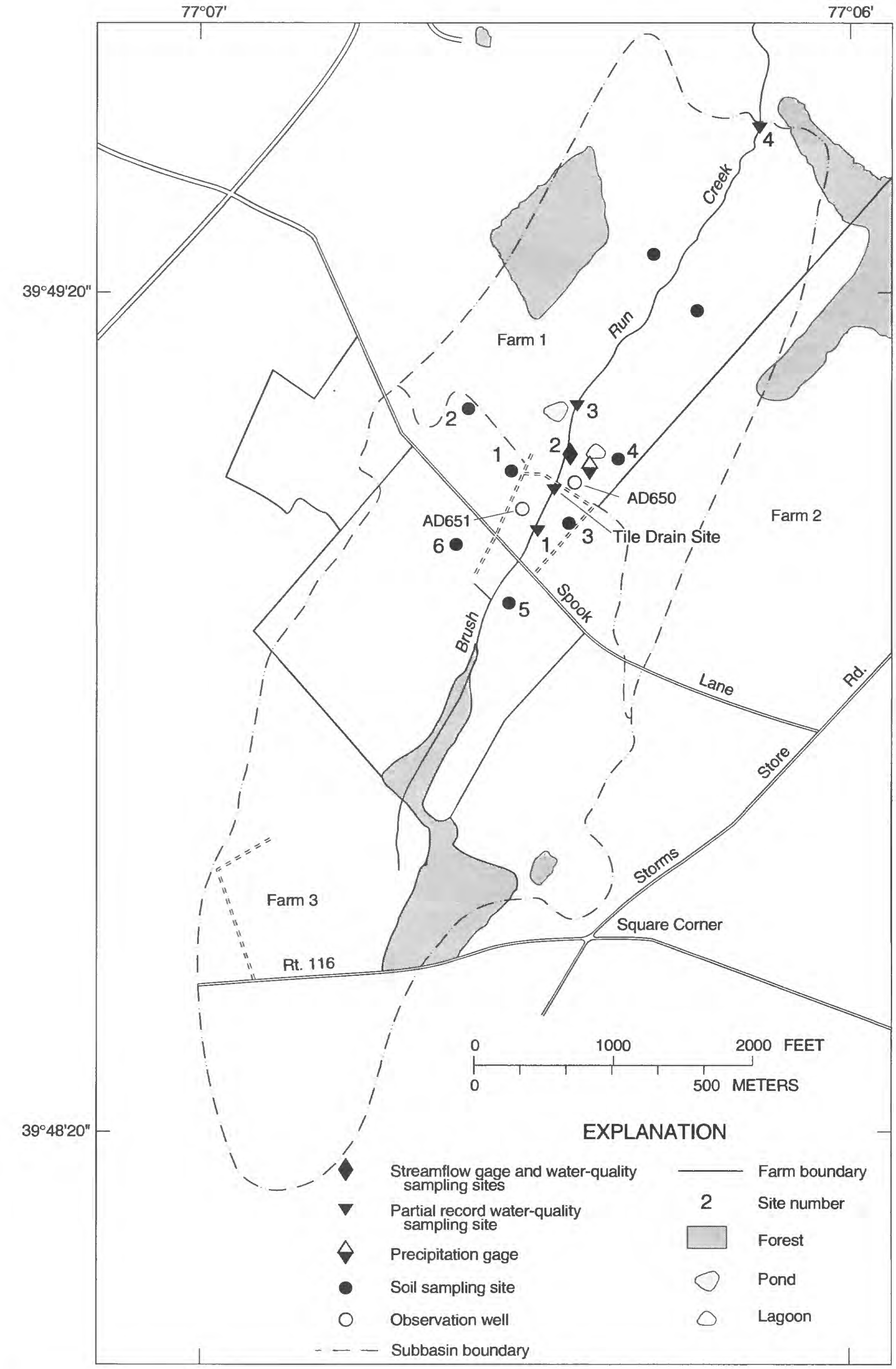


Figure 2. Locations of farms, streamflow and precipitation gages, sampling sites, and soil sampling sites at Brush Run Creek.

base flow and stormflow from selected storms prior to and during nutrient management.

Data were plotted and parametric and nonparametric statistics were calculated to identify seasonal variations and trends. Data were grouped into growing (April through September) and nongrowing (October through March) seasons. A modified form of the nonparametric Seasonal Wilcoxon (Mann-Whitney) rank-sum test for seasonal data (Crawford and others, 1983) and Monte Carlo simulation (R.M. Hirsch, U.S. Geological Survey, written commun., 1989) were used to estimate reductions in nitrogen and phosphorus concentrations and discharges in base flow. The required reductions for detecting statistically significant changes under the proposed nutrient-management practices also were determined. Hypothetical effects of nutrient-management practices on surface-water quality were presented on the basis of simulated (Monte Carlo) results. Measured data collected prior to and during nutrient management were compared by use of the rank-sum test to determine if the quality of base flow changed.

Related Studies

Studies related to this investigation include the comprehensive RCWP monitoring projects, which were designed to determine the effects of nutrient-management practices on water quality being studied in Idaho, Illinois, South Dakota, and Vermont (P.L. Lietman, U.S. Geological Survey, oral commun., 1984). The Pennsylvania and South Dakota projects are the only RCWP projects investigating nutrient transport in ground water.

Other related studies include an investigation by the USGS in the Patuxent River Basin, Md. (Steve Preston, U.S. Geological Survey, oral commun., 1987), in which nonpoint-source nutrient contamination and sediment loads in a 980-mi^2 watershed are being monitored. A joint study by the USGS and the SRBC is being conducted to assess the sources of nutrient loads transported from selected watersheds of the Susquehanna River Basin and their movement to the Chesapeake Bay. Studies by the PaDER, Bureau of Forestry, with the Lancaster and Lebanon County Conservation Districts (David Greg, Pennsylvania Department of Environmental Resources, Bureau of Forestry, written commun., 1986) also are being conducted to determine the effect of manure disposal on ground water and undisturbed soils.

Acknowledgments

The authors thank the following individuals and respective agencies for cooperating in this project:

1. Stanley Herr, the farmer at the Brush Run Creek site who assisted and volunteered to provide land-use data and access to the farm;
2. Tom Youngst, Nutrient-Management Specialist for the PaDER, Bureau of Soil and Water Conservation, assisted by determining crop yields and developing the management plan; and
3. Dr. Dale Baker and Leon Marshall, formerly of the Pennsylvania State University, Department of Agronomy, who collected and analyzed soil samples.

DESCRIPTION OF STUDY AREA

Brush Run Creek is located in south-central Pennsylvania and is part of the Susquehanna River Basin (fig. 1). The stream flows northeastward approximately 5.7 mi before draining into Swift Run. Swift Run flows northeastward before draining into West Conewago Creek, which continues northeastward before draining into the Susquehanna River at York Haven, Pa.

The 0.63-mi^2 watershed is located in southeastern Adams County and is approximately 5.0 mi west of McSherrystown. The streamflow-gaging station is 0.7 mi downstream from the headwaters and gages a 0.38-mi^2 drainage area. A V-notch weir is located at the gage where water-quality samples were collected manually; water samples are collected automatically during stormflow in the pool created by the weir.

Climate

Climate at the Brush Run Creek site is relatively mild but humid and is characterized as humid continental. Winters are relatively short, whereas summers are comparatively long and warm as evidenced by a growing season that begins in April and ends in October. The average growing season ranges from 175 days at Hanover to about 169 days near York (U.S. Department of Agriculture, 1963). Normal precipitation is 40 in/yr, is evenly distributed, and typically provides for sufficient rain during the growing season; however, occasional dry periods, tornadoes, and hail that can cause major crop damage may occur, as evidenced during the study.

Soils

The soils at the site are predominantly Abbottstown and Croton silt loams (fig. 3). Readington and Reaville silt loams are also present in smaller amounts in the valleys. The soils are poorly drained, thus bedding is required to dispose of surface runoff and tile is required to drain the seasonally high water table. Before 1985, an extensive tile system was installed at the site to increase soil productivity (fig. 4). During the study period, two new tile lines were installed and a collapsed line was replaced. The parent material for the soils is weathered shale and sandstone. Soils in the Abbottstown, Croton, Readington, and Reaville Series are located on slopes ranging from 0 to 8 percent (U.S. Department of Agriculture, 1963).

Ground Water

Ground-water information in the study area was based primarily on historical data. However, current ground-water-level data and base-flow data support the earlier findings.

Availability

The availability of ground water in Adams County depends on the capacity, storage characteristics, and transmissibility of the underlying rock structure (Lloyd and Growitz, 1977). Wells drilled into the New Oxford Formation usually provide sufficient water for domestic and farming purposes. However, a few wells provided yields greater than 100 gal/min. The large percentage of clay is the principal reason the water-bearing properties of the New Oxford Formation are average to fair. The topographic position of wells can significantly affect reported yields. Generally, yields from wells drilled in valleys are higher than yields from wells drilled on hillslopes or ridgetops. Wood and Johnston (1964) reported that the average depth of 166 wells drilled in the New Oxford Formation was 150 ft, and 70 percent of the 241 wells from which data were available had yields less than 10 gal/min, with yields ranging from less than 1 to 200 gal/min. The maximum well yields in the New Oxford Formation corresponded with well depths between 250 and 300 ft.

Wells AD650 and AD651 (fig. 2) are used for agricultural purposes. Well AD651 has a depth of 165 ft and a yield of 15 gal/min; the well characteristics for AD650 are unknown.

Occurrence and Recharge

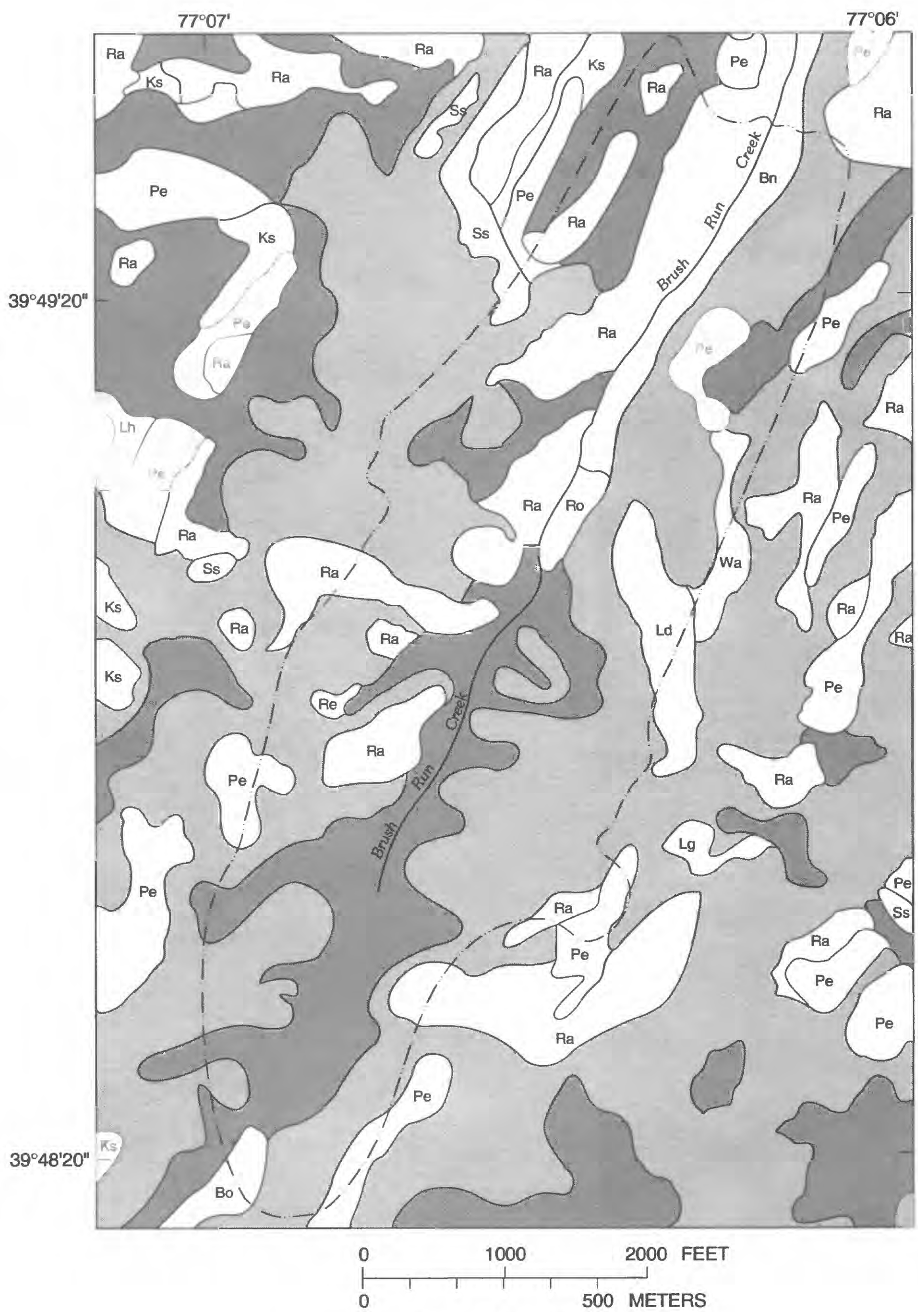
In basins where surface water is largely composed of base flow, factors affecting ground water and recharge are important. Ground-water recharge is dependent on the size and shape of the ground-water basin, the annual precipitation, surface runoff, soil infiltration, and evapotranspiration. The size and shape of the ground-water boundary at the site are assumed to be approximated by the surface-water subbasin boundary (fig. 2). Precipitation is the single input to recharge the ground-water system. The four outputs or discharges from the ground-water system at Brush Run Creek include (1) ground-water seepage (base flow), (2) seepage to the pond (fig. 2), (3) water pumped to the lagoon, and (4) evapotranspiration.

Typically, most ground-water recharge occurs between March and April (after the spring thaw but before the growing season) and between October and December (after crops are harvested but before the ground freezes). Ground-water levels usually decline during the growing season from April through September as evapotranspiration permits only a small amount of infiltration to reach the saturated zone. Therefore, seasonal variations in precipitation can be more critical to the occurrence and recharge of ground water than the annual total precipitation.

Geologic Setting and Structure

The geologic setting of the Triassic Lowlands in which the study area lies is described by Hall (1934), Wood and Johnston (1964), and Taylor and Werkheiser (1984). In summary, each describes the geology of the Triassic Lowlands Section as being moderately complex. The general area is composed primarily of metamorphosed sedimentary rocks intruded by some diabase dikes. The Brush Run Creek site is in the New Oxford Formation that probably dates to the Triassic Period. The New Oxford Formation underlies a gently rolling plain with broad, shallow valleys, and low flat ridges, averaging 400 to 650 ft above sea level (Wood and Johnston, 1964). The geologic description of the New Oxford Formation includes shale, mudstone, and red arkosic sandstone composed of quartz, mica, and feldspar.

The gradual tilting of the Triassic Lowlands from the weight of the accumulated deposits and subsequent downfaulting along the western boundary caused the New Oxford Formation to have a uniform dip averaging 25°. This formation occupies a belt 3 to 5 mi wide from the Maryland-Pennsylvania border to the Susquehanna River near Mount Wolf. In the southeast corner,



EXPLANATION

SOIL FORMATIONS

(light shading)	Abbottstown silt loam
(dark shading)	Croton silt loam
Bn	Bowmansville silt loam
Bo	Bowmansville silt loam, local alluvium
Ks	Klinesville shaly silt loam
Ld	Lansdale loam
Lg	Legore channery silt loam
Lh	Lehigh silt loam
Pe	Penn silt loam
Ra	Readington silt loam
Re	Reaville silt loam
Ro	Rowland silt loam
Ss	Steinsburg sandy loam
Wa	Watchung silt loam
— - — -	Drainage basin

Figure 3. Distribution of soil types at Brush Run Creek.

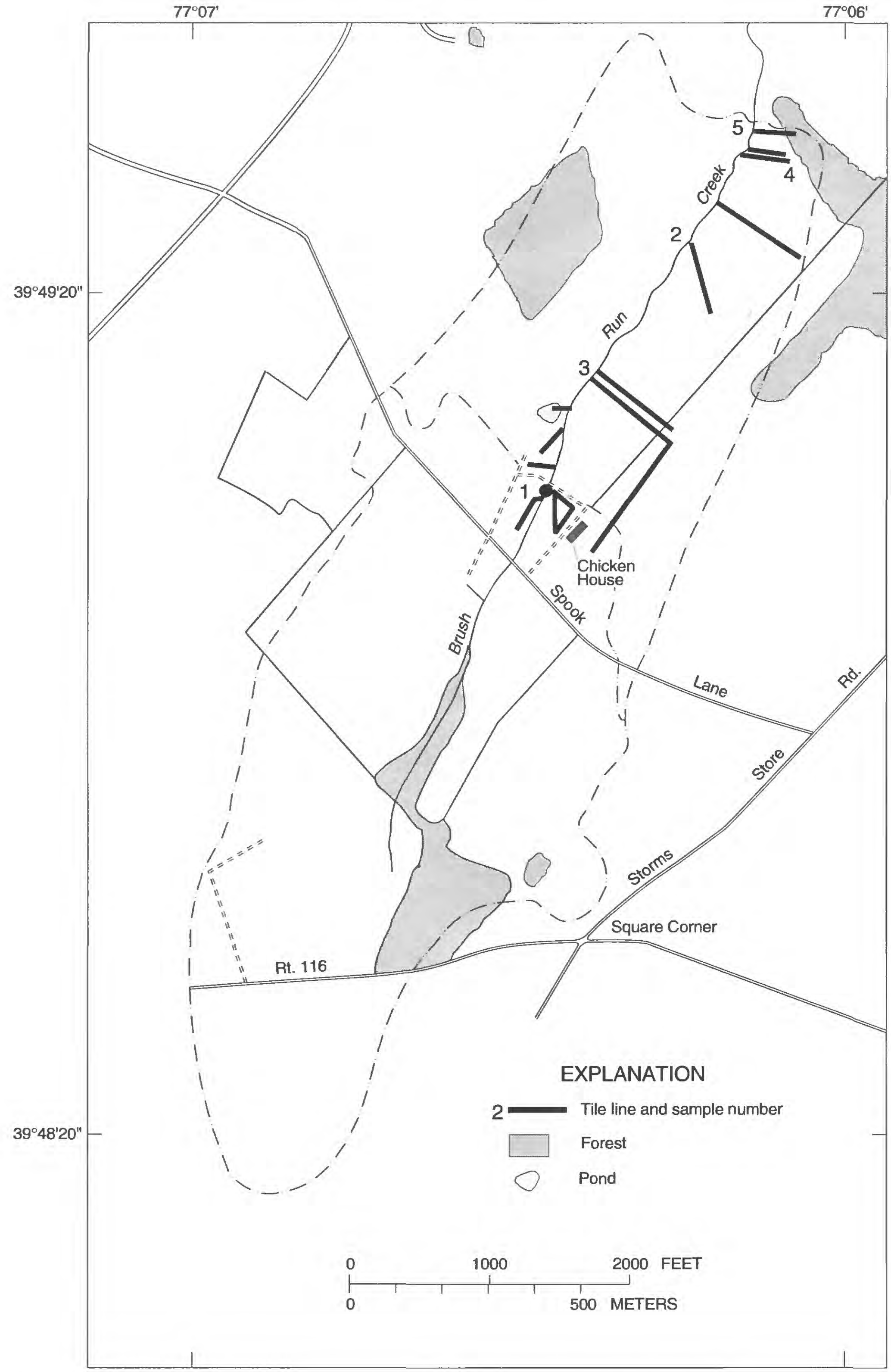


Figure 4. Location and sample number of known tile lines at Brush Run Creek.

transverse faults have caused offsets through the New Oxford Formation into the underlying rocks. Joints prominently parallel the strike of bedding planes. Although joints are common in exposed outcrops, the extent of jointing is difficult to determine because of the limited number of outcrops.

The geologic structure has an important influence on well yields, and probably has a direct influence on base-flow quantity. Faults may cause zones of fractured rock where large amounts of water may be stored. If faults become filled with clay, calcite, or quartz, little or no water may be stored, thus base flow may decline rapidly. In areas where fold hinges occur, secondary permeability may develop because of increased fractures, well-developed cleavage, and the presence of horizontal or nearly horizontal bedding. These bedding planes can increase well yields, and may contribute to extended periods of high base flow.

Basin Morphology and Topography

The Brush Run Creek watershed lies in the Gettysburg Plain of the Piedmont physiographic province of the Triassic Lowlands. The topography of the province is characterized as gently sloping to moderately rolling. However, the topography is nearly level just east of the Brush Run Creek site.

Differences between basin morphology and topography of Brush Run Creek and Bald Eagle Creek are illustrated in figure 5. The differences in basins are useful in understanding results from other basins. Generally, the Brush Run Creek Basin is long, flat, elongated, with no stream bifurcation. Brush Run Creek traverses the site from southwest to northeast. Altitudes range from 640 ft above sea level at the upper end of the watershed to 600 ft above sea level at the streamflow-gaging station. The average gradient from the headwaters to the gaging station is approximately 40 ft/mi. Over the next 5 mi to Swift Run, the gradient decreases to about 26 ft/mi.

Generally, the Bald Eagle Creek Basin is rotund in shape with little stream bifurcation, has steep hillslopes, and traverses west to east. Elevations at Bald Eagle Creek range from 800 ft above sea level near the upper end of the basin to 591 ft above sea level at the stream-gaging site. Bald Eagle Creek descends rapidly from its headwaters to the gaging site, an average gradient of 152 ft/mi. Immediately downstream from the gage, elevations decrease and the gradient flattens to about 55 ft/mi from the gage to Muddy Creek. The steep channel slope causes Bald Eagle Creek to be prone to flash-flood conditions.

LAND USE, CROP YIELD, AND NUTRIENT APPLICATIONS

Two agricultural farms where crops are grown (farm 1 and farm 2 in fig. 2) and a third farm (farm 3) where horses are raised and crops are not grown are located within the basin. Only one of the farmers (farm 1), however, participated in this study and supplied land-use data. The predominant land use within the drainage basin was agricultural. Cropland comprised about 64 percent of the 0.63-mi^2 basin prior to and during nutrient management; pasture comprised about 13.8 percent and 14.4 percent prior to and during nutrient management, respectively; and forest comprised about 7.4 percent for the entire study (table 1). About 88 percent of the cropland was planted in corn prior to nutrient management. During nutrient management, an average of 58 percent of the cropland was planted in corn. However, 80 percent of this reduction was at farm 2. Land use prior to nutrient management (1986–88 growing seasons) and during nutrient management (1989–91 growing seasons) is shown in figures 6a and 6b, respectively, and illustrates the changes in crop type from two farms within the basin. Crops were generally rotated from 3-year corn to 3-year alfalfa or soybean sequence. Alfalfa was not grown within the basin prior to nutrient management but comprised an average of 19 percent of the cropland during nutrient management. Rye, barley, and wheat commonly were planted as cover crops on fields to prevent erosion during the nongrowing season.

The cooperating farmer maintained a population of about 57,000 chickens, 1,460 hogs, and 15 sheep prior to nutrient management. During nutrient management, 57,000 chickens, 1,600 hogs, and 15 sheep were housed within the basin. The animal density, which is based on crop acreage within the entire basin that is available for manure disposal, increased from about 0.94 animal units per acre (AU/acre) prior to nutrient management to about 1.12 AU/acre during nutrient management (table 2). The animal density in the Brush Run Creek Basin is less than the 2.50 AU/acre average for 10 farms in the Nutrient-Management Subbasins (identified as 3, in fig. 1) in the carbonate valley of the Little Conestoga Creek Headwaters (Fishel and others, 1992). It is also less than the 1.5 AU/acre recommended in the Conestoga Headwaters Plan of Work (U.S. Department of Agriculture, 1982) for nonpoint-source discharges.

Corn yields ranged between 8 to 100 bushels per acre at five fields sampled at the Brush Run Creek site (table 3). The yields were substantially less than the 146 bushels per acre average reported for 11 farms in the Nutrient-Management and Forested Subbasins in

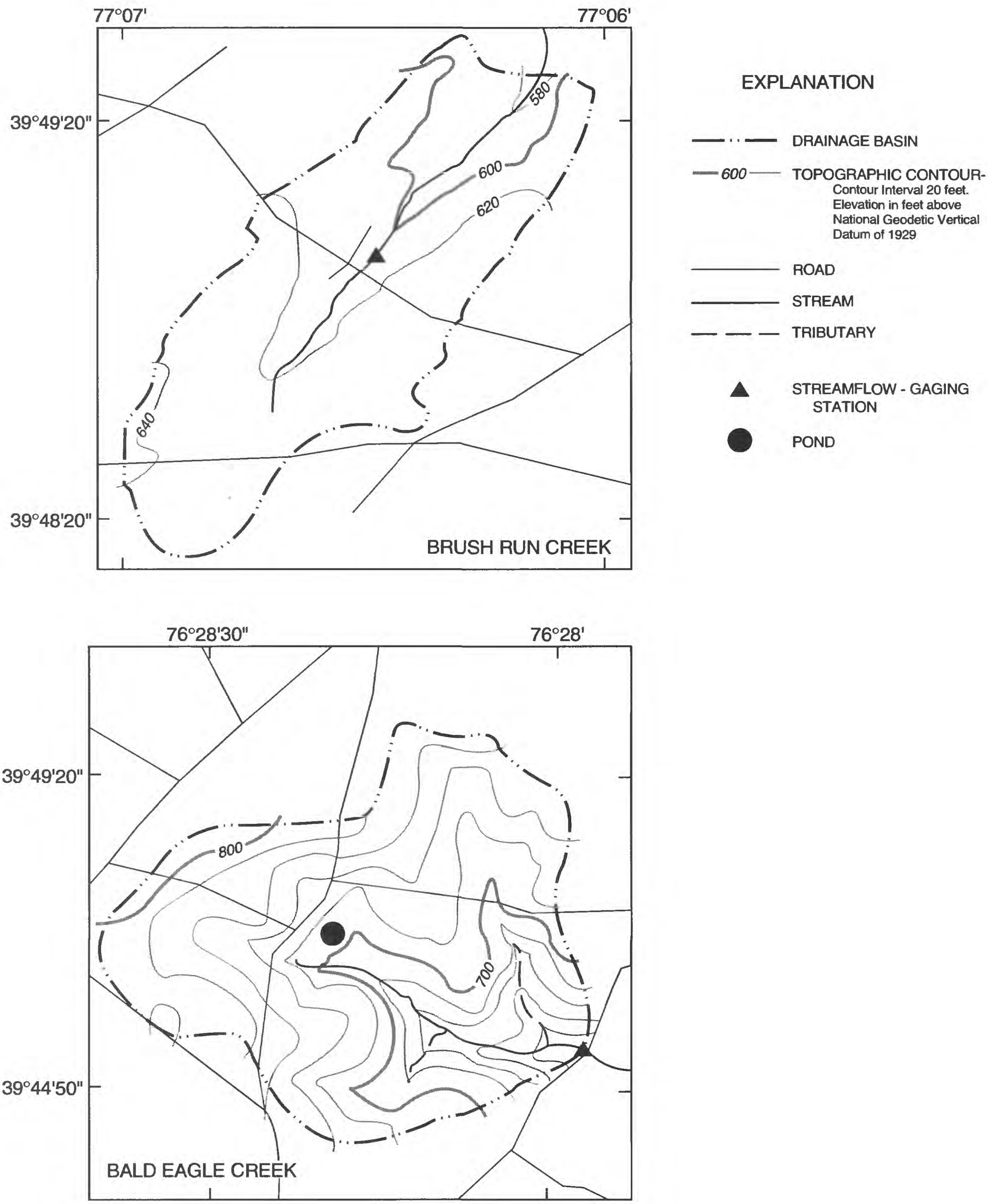


Figure 5. Basin topography and basin configuration at Bald Eagle Creek and Brush Run Creek sites.

Table 1. Land use and crop acreage in the Brush Run Creek Basin during the 1986–91 growing seasons

[--, crop not planted]

Land use	Prior to nutrient management						During nutrient management					
	1986		1987		1988		1989		1990		1991	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Cropland												
Alfalfa	--	--	--	--	--	--	53.8	13.1	92.6	22.6	92.6	22.6
Corn	260.6	63.6	256.5	62.6	179.4	43.8	189.6	46.3	141.4	34.5	129.6	31.6
Milo	2.9	.7	--	--	--	--	--	--	--	--	--	--
Soybeans	--	--	--	--	81.2	19.8	15.8	3.8	11.9	2.9	15.7	3.8
Wheat	--	--	7.0	1.7	2.9	.7	2.8	.6	14.7	3.6	23.6	5.8
Garden	1.0	.2	1.0	.2	1.0	.2	1.5	.4	1.5	.4	.6	.2
Subtotal	264.5	64.5	264.5	64.5	264.5	64.5	263.5	64.2	262.1	64.0	262.1	64.0
Pasture	57.0	13.9	57.0	13.9	57.0	13.9	58.0	14.2	59.4	14.5	59.4	14.5
Forest	30.7	7.5	30.7	7.5	30.7	7.5	30.7	7.5	30.7	7.5	30.7	7.5
Other	57.4	14.0	57.4	14.0	57.4	14.0	57.4	14.0	57.4	14.0	57.4	14.0
Total	409.6	100.0	409.6	100.0	409.6	100.0	409.6	100.0	409.6	100.0	409.6	100.0

Lancaster and Berks Counties (Fishel and others, 1990), and less than the 125 bushels per acre average reported in the Bald Eagle Creek Basin (Langland and Fishel, 1995).

Climatic factors were probably the primary cause of reduced yields at Brush Run Creek Basin. A tornado, which touched down near the basin, caused severe wind damage to the crops in July 1987. On several occasions, thunderstorms with hail damaged the crops. The lowest yields (except wheat) during the 6-year study (table 3) were during the 1991 growing season when the area experienced a drought.

Eighty-one percent of the nitrogen and 79 percent of the phosphorus were applied to the cropland above the water-quality gage between May and July (table 4), and 86 percent of the nitrogen and 93 percent of the phosphorus were applied to the cropland below the water-quality gage between May and July. However, during nutrient management, only 40 percent of the nitrogen and 56 percent of the phosphorus were applied to fields below the water-quality gage between May and July. This change in the timing of applications was primarily the result of storage problems in the manure-storage facility, forcing the farmer to spray irrigate his lower fields to decrease the level of hog waste. Some nitrogen and phosphorus were applied to fields above and below the water-quality gage as manure during the nongrowing season after the corn was harvested. During the first year, 1986, manure was applied nearly each month, but during each succeeding year, manure was applied less frequently. These changes in management were made voluntarily by the farmer before recommendations were made by the nutrient-management specialist. Similar changes in management practices were recorded in the Nutrient-Management and Forested Subbasins for the RCWP and the Bald Eagle Creek site, where not only the timing of applications changed, but also the total application amount changed.

Prior to nutrient management, 83 percent of the nitrogen (25,800 lb) and 78 percent of the phosphorus (5,830 lb) applied to fields above the water-quality gage were commercial fertilizer; the remainder was from manure. During nutrient management, 56 percent of the nitrogen (13,200 lb) and 63 percent of the phosphorus (1,840 lb) applied were from commercial fertilizer (table 5). Only 22 percent and 8 percent of the nitrogen and phosphorus, respectively, applied to the lower fields were from manure prior to nutrient management. However, during nutrient management when the farmer began spraying his lagoon waste to the lower fields, 52 percent of the nitrogen and 22 percent of the phosphorus were from manure. Prior to nutrient management, approximately 59,340 lb of nitrogen and 13,710 lb of phosphorus were applied to the cropland as manure and commercial fertilizer (table 5). During nutrient management, nitrogen applications were reduced 14 percent and phosphorus applications were reduced 57 percent. The greatest reductions in nitrogen (25 percent) and phosphorus (61 percent) applications were above the water-quality gage as cropping patterns changed (fig. 6) (table 5). Applications of

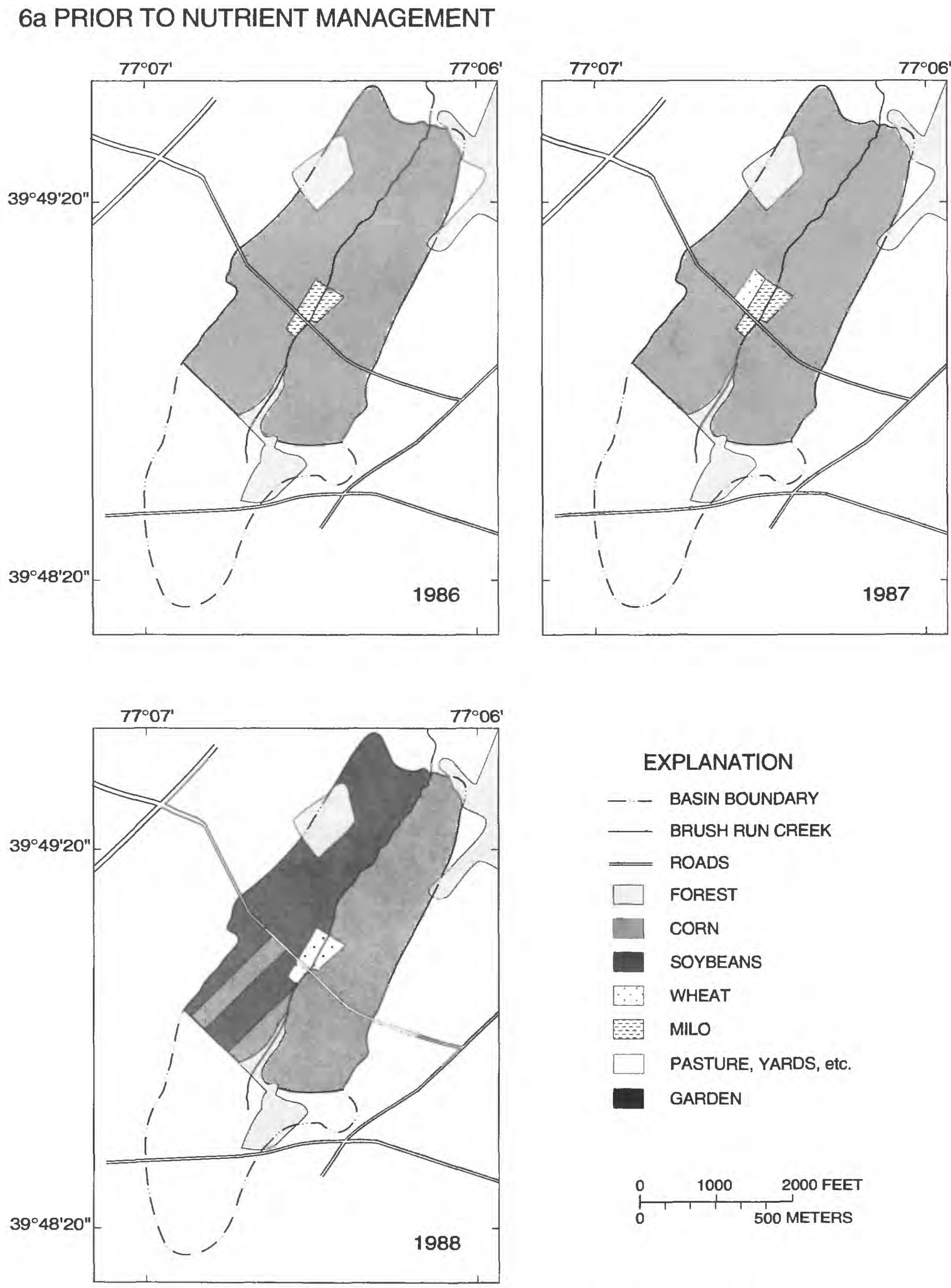


Figure 6. Land use in the Brush Run Creek Basin (a) prior to and (b) during nutrient management.

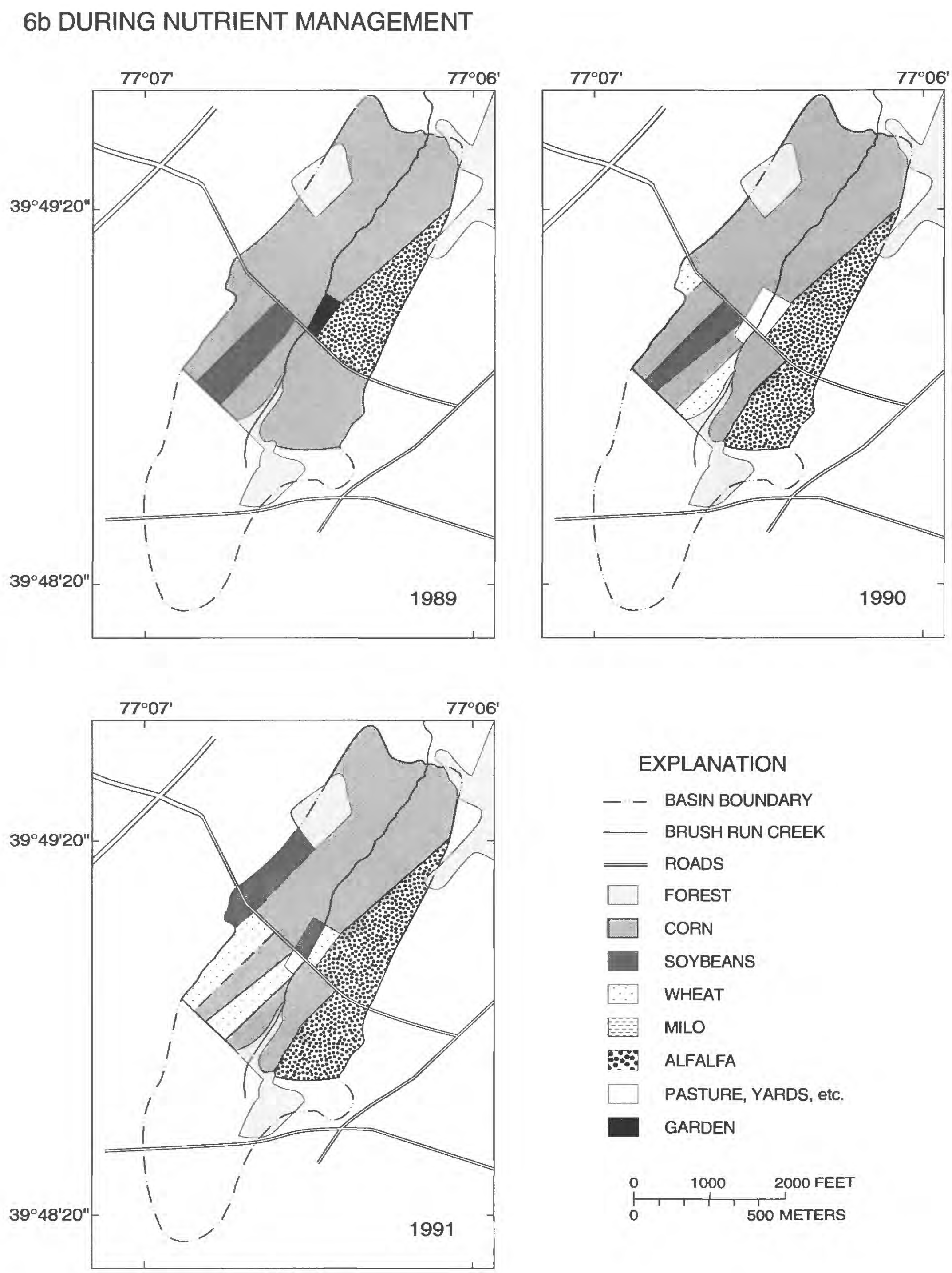


Figure 6. Land use in the Brush Run Creek Basin (a) prior to and (b) during nutrient management --Continued.

Table 2. Animal density at the Brush Run Creek site

[Animal units, in thousands of pounds of body weight; animal density, in animal units per acre of cropland]

Animal	Prior to nutrient management				During nutrient management			
	Animal number	Animal units	Cropland (acres)	Animal density	Animal number	Units	Cropland (acres)	Animal density
Poultry	57,000	92.4	264.5	0.35	57,000	92.4	262.6	0.35
Swine	1,460	152.5	264.5	.58	1,600	200.0	262.6	.76
Sheep	15	1.5	264.5	.01	15	1.5	262.6	.01
Total		246.4	264.5	.94		293.9	262.6	1.12

Table 3. Crop yields at farms in the Brush Run Creek Basin prior to and during nutrient management

[Yields are in bushels per acre; NP, crop not planted; --, no data provided]

Crop	Yields prior to nutrient management			Yields during nutrient management		
	1986	1987	1986	1989	1990	1991
Alfalfa	NP	NP	NP	--	--	--
Corn	80–95	60	50–80	60–85	85–100	8–14
Milo	30	NP	NP	NP	NP	NP
Soybeans	NP	NP	45	50	50	14
Wheat	40	20	60	35	35–50	27

Table 4. Timing of nutrient applications to fields upstream from and downstream from the water-quality gage in the Brush Run Creek Basin prior to and during nutrient management

Month	Applications prior to nutrient management		Applications during nutrient management	
	Nitrogen (pounds)	Phosphorus (pounds)	Nitrogen (pounds)	Phosphorus (pounds)
Fields upstream from water-quality gage				
May-July	25,810	5,920	18,880	2,280
August-April	5,520	1,570	4,480	640
Total	31,330	7,490	23,360	2,920
Fields downstream from water-quality gage				
May-July	24,120	5,800	11,110	1,270
August-April	3,880	440	16,660	1,640
Total	28,000	6,240	27,770	2,910

Table 5. Commercial and manure fertilizer applications to fields upstream from and downstream from the water-quality gage at Brush Run Creek prior to and during nutrient management

[All applications are in pounds]

Fertilizer used	Prior to nutrient management			Fertilizer used	During nutrient management		
	Commercial	Manure	Total		Commercial	Manure	Total
Upstream from water-quality gage							
1986				1989			
Nitrogen	9,370	1,720	11,090	Nitrogen	4,410	1,890	6,300
Phosphorus	1,550	540	2,090	Phosphorus	1,080	590	1,670
Subtotal	10,920	2,260	13,180	Subtotal	5,490	2,480	7,970
1987				1990			
Nitrogen	7,540	1,310	8,850	Nitrogen	4,870	560	5,430
Phosphorus	2,620	390	3,010	Phosphorus	760	180	940
Subtotal	10,160	1,700	11,860	Subtotal	5,630	740	6,370
1988				1991			
Nitrogen	8,950	2,450	11,400	Nitrogen	3,920	7,700	11,620
Phosphorus	1,660	720	2,380	Phosphorus	0	310	310
Subtotal	10,610	3,170	13,780	Subtotal	3,920	8,010	11,930
Total nitrogen	25,860	5,480	31,340	Total nitrogen	13,200	10,150	23,350
Total phosphorus	5,830	1,650	7,480	Total phosphorus	1,840	1,080	2,920
Grand total	31,690	7,130	38,820	Grand total	15,040	11,230	26,270
Downstream from water-quality gage							
1986				1989			
Nitrogen	6,900	2,780	9,680	Nitrogen	5,060	4,290	9,350
Phosphorus	2,710	320	3,030	Phosphorus	1,380	190	1,570
Subtotal	9,610	3,100	12,710	Subtotal	6,440	4,480	10,920
1987				1990			
Nitrogen	10,630	770	11,400	Nitrogen	5,020	6,440	11,460
Phosphorus	2,020	60	2,080	Phosphorus	220	280	500
Subtotal	12,650	830	13,480	Subtotal	5,240	6,720	11,960
1988				1991			
Nitrogen	4,280	2,640	6,920	Nitrogen	3,140	3,820	6,960
Phosphorus	1,010	110	1,120	Phosphorus	670	170	840
Subtotal	5,290	3,140	11,980	Subtotal	3,810	3,990	7,800
Total nitrogen	21,810	6,190	28,000	Total nitrogen	13,220	14,550	27,770
Total phosphorus	5,740	490	6,230	Total phosphorus	2,270	640	2,910
Grand total	27,550	6,680	34,230	Grand total	15,490	15,190	30,680

manure and commercial fertilizers from farm 1 (fig. 2) totaled about 110,460 lb of nitrogen and 19,540 lb of phosphorus during the 6-year study.

NETWORK DESIGN, INSTRUMENTATION, SAMPLING, AND ANALYTICAL TECHNIQUES

The following section describes the network design, detailed description of instrumentation and sampling techniques, and all analytical techniques used in this report.

Precipitation and Atmospheric Deposition

Precipitation quantity was measured at one location (fig. 2) by use of a tipping-bucket rain gage in conjunction with an analog digital recorder. The precipitation gage was located approximately 15 ft from the streamflow-gaging station near the center of the basin. Precipitation quantity was recorded at 5-minute intervals for 2 years and 15-minute intervals for the remainder of the study to determine the duration and intensity of storms, and the daily, monthly, and annual totals. Precipitation quantity was estimated for periods of missing record by use of data from the National Oceanic and Atmospheric Administration (NOAA) stations at Hanover and Gettysburg and from reliable records kept by the landowner of farm 1 (fig. 2).

Precipitation quantity measured at the Brush Run Creek site was compared to normal precipitation measured at the NOAA stations at Hanover and the Eisenhower farm in the Gettysburg Battlefield National Park. The station at Hanover is approximately 4.5 mi east of the site; the station at Gettysburg is approximately 7 mi west of the site.

Precipitation (wetfall) samples initially were collected at one location near the precipitation gage. However, results from precipitation samples collected during the first 2 years of the project suggested the need for an areal characterization of the distribution and quality of precipitation (wetfall) and dryfall being atmospherically deposited at the site. In this report, wetfall is defined as the wet deposition plus dry deposition collected in a 24-hour period, and dryfall is defined as dry deposition collected in a 24-hour period. Therefore, the wetfall quality was characterized by collecting data at 12 locations, and the dryfall quality was characterized by collecting data at 15 locations (fig. 7).

Wetfall was sampled during three 24-hour sampling events and dryfall during two 24-hour sampling events. Wetfall and dryfall samples were collected to characterize the quality of atmospheric deposition near the beginning and the end of the growing seasons. The pH and specific conductance of the wetfall were determined immediately after sample collection. Samples were kept at 4°C, preserved with mercuric chloride, and sent to the USGS Laboratory in Arvada, Colo., for analyses of concentrations of total nitrite plus nitrate, ammonia, ammonia plus organic nitrogen, and total phosphorus. Nutrients were analyzed according to methods described by Skougstad and others (1979).

Initially, precipitation samples were collected with 13-in. glass funnels. Later, precipitation samples were collected with 8-in. plastic funnels that were positioned at 12 locations to determine areal distribution (fig. 7). The funnels collected rainfall into 1-L precombusted glass bottles that were placed in 144-in^2 plastic pans at ground level in a metal can packed with ice.

Dryfall samples were collected at 15 locations (fig. 7) with 144-in^2 plastic pans that were positioned in the field at ground level for a 24-hour period. The pans were filled with 1,000 mL of distilled water that acted as a trap. Concentrations of selected nutrients of the dryfall were expressed as a water-weighted concentration using the volume of water remaining in the pan at the time of collection. The equation used to water weight the concentrations is as follows:

$$C_2 = \frac{V_2 \times C_1}{V_1} \quad , \qquad (1)$$

where
- C_1 is the measured concentration, in milligrams per liter;
- V_1 is the initial volume of water, in milliliters;
- C_2 is the water-weighted concentration, in milligrams per liter; and
- V_2 is the remaining volume of water, in milliliters.

The pH, specific conductance, and volume of water used in the dryfall samplers were measured before and after the samples were collected.

Soil Nutrients

Soil samples were collected from six fields prior to nutrient management and eight fields during nutrient management to determine the nutrient content of the soil where manure and commercial fertilizer were applied (fig. 2). The two additional sites were sampled after the farmer began spray irrigating fields below the

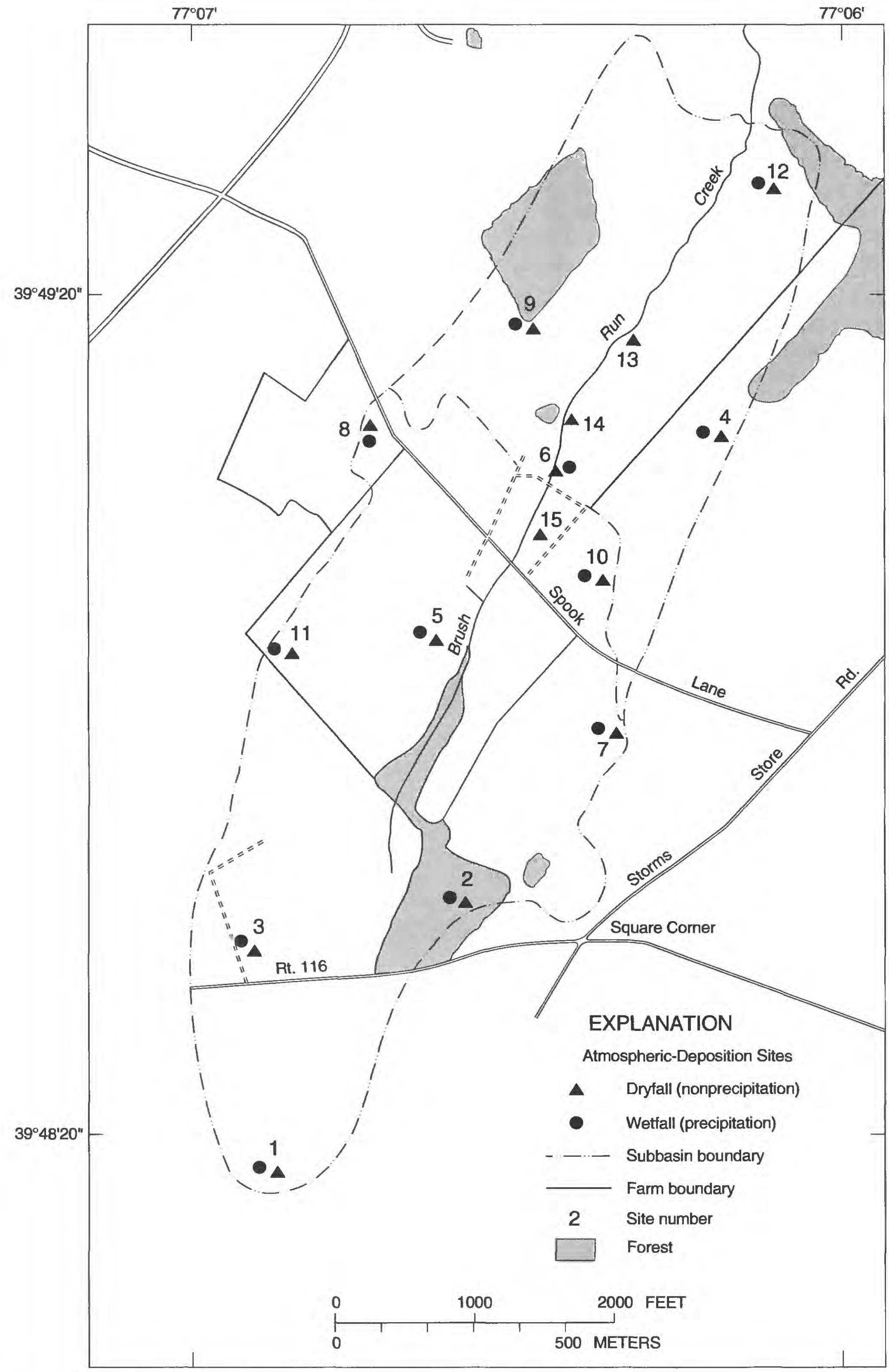


Figure 7. Brush Run Creek study area showing locations of the lagoon, water-quality gage, and atmospheric-deposition sites.

water-quality gage from the lagoon. Results of soil-nutrient analyses provided information for the nutrient-management specialist to develop nutrient-management plans for the entire farm.

Soil-nutrient samples were collected from the top 4 ft of soil in the spring before planting and in the fall after harvesting. The 4-ft samples were collected with the aid of the Pennsylvania State University, College of Agronomy, by use of a tractor-mounted, deep-soil probe. Each 4-ft sample core was divided into segments that represented depth intervals of 0 to 8 in., 8 to 24 in., and 24 to 48 in. below the surface. Three cores were collected at each location, and the segments from each core were composited in the field. Each segment was analyzed for average soluble nitrate-nitrogen and phosphorus by the Pennsylvania State University, Soils and Environmental Chemistry Laboratory, by use of methods described by Corey (1977) and by the USEPA (1979).

Streamflow

Streamflow was measured indirectly from continuous gage-height data collected at the streamflow-gaging station 01573810, located on the right bank of the stream about 10 ft downstream from a private culvert (fig. 2 and table 6). The streamflow-gaging station began operating October 1, 1985, and was equipped with a digital water-stage recorder and a continuous strip-chart recorder. Water-stage data were recorded at 15-minute intervals by the digital recorder. The gage had a 36-in.-diameter pipewell with two intakes of 2-in. pipe and a flushing system. A wooden V-notch weir was installed to provide a control during low flows at the streamflow-gaging site. The control during high flows was about 80 ft downstream from the gage where thick brush grew and trees had fallen across the 15-ft-wide stream channel and onto the plains.

Miscellaneous streamflow measurements were made at two partial-record stations [USGS stations 01573808 (site 1) and 394906077062601 (tile drain)] upstream from the continuous gage, and two partial-record stations [USGS stations 01573811 (site 3) and 01573815 (site 4)] downstream from the continuous gage (fig. 2). The station descriptions and locations are listed in table 6.

Stage-discharge relations were defined by making streamflow measurements upstream from or at the weir using methods described by Buchanan and Somers (1968). Streamflow measurements were made with a current meter. Occasionally, low-flow measurements were made at the weir and at tile drains by making volumetric measurements with a graduated cylinder. Stream stages were converted to streamflow according to methods described by Carter and Davidian (1968).

The measured streamflow for Brush Run Creek was compared with long-term streamflow record beyond the 6-year study period for the nearby continuous-record streamflow-gaging station at West Conewago Creek near Manchester, Pa. (USGS station 01574000), because long-term streamflow record was not available for the gage at Brush Run Creek. The gage near Manchester is in the same drainage basin about 29 mi northeast of the study area and has been in operation for 59 years.

Streamflow data were used to calculate nutrient and suspended-sediment discharges in base flow and stormflow. Streamflow hydrographs were separated to determine the contribution of base flow and surface runoff to the annual discharge. Hydrograph separations were performed by use of three techniques—the fixed interval, the sliding interval, and the local minima techniques described by Pettyjohn and Henning (1979).

Table 6. Station descriptions and locations of streamflow stations

[Drainage areas are in square miles; --, not applicable; latitude and longitude are in degrees, minutes, and seconds]

U.S. Geological Survey station number	Description	Drainage area	Latitude	Longitude
01573808 (partial record)	Brush Run Creek site 1 near McSherrystown	0.35	39°49'06"	77°06'26"
394906077062601 (partial record)	Tile Drain to Brush Run Creek near McSherrystown	--	39°49'06"	77°06'26"
01573810 (continuous gage)	Brush Run Creek site 2 near McSherrystown	.38	39°49'06"	77°06'26"
01573811 (partial record)	Brush Run Creek site 3 near McSherrystown	.44	39°49'11"	77°06'25"
01573815 (partial record)	Brush Run Creek site 4 near McSherrystown	.63	39°49'35"	77°06'08"

Water Quality

Collection of water-quality data began in November 1985. Water-quality samples were collected manually at the V-notch weir at the gage during base flow. A float/stage-triggered automatic pumping sampler was used to collect storm samples at 30-minute intervals. The perforated intake for the pumping sampler was located near the centroid of flow in the pool created by the weir. Water samples were collected monthly during base flow and at selected stages during storms to characterize stormflow. Storms were selected so that seasonal relations between water quality and streamflow could be determined.

Water-quality samples were also collected manually (depth integration) each month at the four partial-record stations (fig. 2). Samples collected at these stations were used to characterize the water quality upstream and downstream from tile drains that discharge to the stream.

Water-quality samples were collected during base flow by use of methods described by Guy and Norman (1970). Manual samples were collected and compared with discrete automatic samples to assure that representative samples were collected by the automatic samplers. Water samples to be analyzed for dissolved constituents were filtered through a 0.45-µm membrane filter mounted in an assembly and filtered with a peristaltic pump. Base-flow samples were filtered in the field and stormflow samples were filtered in the USGS Sediment Laboratory at Lemoyne, Pa., before being sent for analysis at the USGS National Water-Quality Laboratory, Arvada, Colo. All base-flow and stormflow samples were preserved with mercuric chloride and kept chilled at 4°C.

Water-quality samples were analyzed for concentrations of suspended sediment, total and dissolved nitrite plus nitrate, ammonia plus organic nitrogen, ammonia, phosphorus, and dissolved orthophosphorus. Suspended-sediment samples were analyzed at the USGS Sediment Laboratory in Lemoyne, Pa., by use of methods described by Guy (1969). Water-quality samples for nutrient analysis were sent to the USGS National Water-Quality Laboratory in Colorado within 24 hours after collection and analyzed by use of the same methods as described for the precipitation samples.

Nutrient and suspended-sediment loads in stormflow were computed by use of streamflow and concentration-integration methods described by Porterfield (1972). Water-quality concentration data were plotted by use of computer graphic techniques, and storm concentration hydrographs were drawn manually. Concentration data that were missing for storms were estimated using data from all 6 years and using hydrograph comparisons of storm-runoff hydrographs having similar magnitudes at similar times of the year.

Nutrient and suspended-sediment loads in stormflow and base flow were computed by use of a 7-parameter log-linear model developed by Cohn and others (1989) to describe nutrient and sediment loads from the four river-input monitoring stations to the Chesapeake Bay. This model was validated by Cohn and others (U.S. Geological Survey, written commun., 1990) with repeated split-sample studies and is of the form

$$ln[C] = \beta_0 + \beta_1 ln[Q/\bar{Q}] + \beta_2 \{ln[Q/\bar{Q}]\}^2 + \beta_3[T-\bar{T}] + \beta_4[T-\bar{T}]^2 + \beta_5 \sin[2\pi T] + \beta_6 \cos[2\pi T] + \varepsilon \qquad (2)$$

where

- ln denotes natural logarithm function;
- Q is discharge, in cubic feet per second;
- T is time, in years;
- $\bar{Q}$ and $\bar{T}$ are centering variables for discharge and time;
- β_0 through β_6 are the parameters of the model that were estimated from the data; and
- ε denotes the model errors, which are assumed to be independent, and normally distributed with zero mean and variance σ_ε^2.

Loads were calculated with the following equation:

$$L_T = \sum_{t=1}^{T} \{C_{i,t} \times Q_t \times K\}, \qquad (3)$$

where

- L_T is calculated load over time interval T for constituent i;
- $C_{i,t}$ is predicted concentration of constituent i for day t, in milligrams per liter (calculated by the model);
- Q_t is measured mean daily discharge for day t, in cubic feet per second; and
- K is conversion factor $2.699 \times 10^{-3} \frac{s \times L \times ton}{ft^3 \times mg \times d}$, where s is seconds, L is liters, ton is tons, ft^3 is cubic feet, mg is milligrams, and d is days.

(The model usually reports estimated loads in kilograms per day; for this study, the K listed above converts kilograms per day to tons per day.)

METHODS OF DATA ANALYSIS

The following sections describe the data-analysis tests and techniques used to discuss the hydrology of the Brush Run Creek.

Descriptive Statistics

Numerous basic descriptive statistics including maximum, minimum, and medians for streamflow, chemical concentrations, discharges, and yields were calculated from statistical programs of the Statistical Analysis (SAS) Institute, Inc. (1979; 1982a; 1982b) and P-STAT, Inc. (1986). Descriptive statistics were calculated for the entire study, for the periods prior to and during nutrient management, for each year of the study, and for the growing and nongrowing seasons. Frequency distributions were plotted to determine whether water-quality data were normally distributed and to decide if data should be analyzed using parametric or nonparametric statistical procedures.

Correlation Analysis

Correlation analysis was performed to examine relations among concentrations and discharges of suspended sediment and nutrients, and streamflow and time. Relations were considered good if the correlation coefficient (r) was equal to or greater than 0.80, a value commonly used for chemical and biological studies.

Seasonal Wilcoxon (Mann-Whitney) Rank-Sum Test

Prior to implementation of nutrient management, estimates were made of the necessary reduction needed to detect significant changes in concentrations and discharges of total nitrogen, dissolved nitrite plus nitrate nitrogen, and total and dissolved phosphorus in base flow. These estimates were established as targets for the nutrient-management phase, assuming that variances in the data during nutrient management would be similar to variances prior to nutrient management. Data collected during the nutrient-management phase were tested to determine if data were significantly different from the data collected prior to nutrient management. Data were grouped into growing and nongrowing seasons after visual examination of time-series plots indicated visual differences between these periods. A null hypothesis of no difference between data collected prior to and during nutrient management was tested by means of modified Seasonal Wilcoxon (Mann-Whitney) rank-sum test for seasonal data at the 0.05 alpha level (R.M. Hirsch, U.S. Geological Survey, written commun., 1989; Crawford and others, 1983).

Because of the limited amount of measured data, Monte Carlo simulations were used to synthesize data collected prior to and during the nutrient-management phases in order to establish target goals and to perform the rank-sum test. The data were synthesized by randomly generating 1,000 data sets of each chemical constituent tested, based on the statistical 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 period prior to and during nutrient management. The mean and standard deviations of the synthesized data were then reduced by a selected percentage to determine if the amount of reduction is significant. A second approach for generating the data for the management phase from normally distributed data collected prior to nutrient management was to reduce the mean by a selected percentage without changing the standard deviation. The percentage by which the means of the synthesized data for the management phase were reduced was increased until the power of the test reached 1.0, which represented the greatest probability of rejecting the null hypothesis. Because the mean of the synthesized data for the management phase could only be lower than the mean of the data prior to nutrient management, the null hypothesis could only be rejected from one direction; thus, a one-tailed test was performed.

After the management phase was completed, the seasonal rank-sum test was used to determine if, in fact, the data collected prior to and during nutrient management were different. Because the mean of the data collected during the management phase could have either increased or decreased from the mean of the data collected prior to nutrient management, a two-tailed test was performed to determine if the target goals were achieved.

Seasonal Kendall Test

The Seasonal Kendall test for trend (Hirsch and others, 1982) was used to analyze the Brush Run Creek base-flow water-quality data. This nonparametric test for detecting monotonic trend was used because it is robust against seasonal behavior and departures from seasonality. In this test, Kendall's tau, ranging from -1.0 to +1.0, is a measure of monotonic association with 0.0 representing no association. Each tau has an associated probability value (p), which is a measure of the confidence interval associated with that tau. This study defines a statistically significant or detectable change as being within the 95-percent confidence interval ($p < 0.05$). The estimate of slope trend is defined as the median slope for the period of record on the basis of medians for all seasons.

EFFECTS OF NUTRIENT MANAGEMENT ON THE HYDROLOGY AT BRUSH RUN CREEK

Changes in the quantity and quality of precipitation, surface water, ground water, and soils are included in the following sections under hydrologic effects of nutrient management.

Precipitation and Atmospheric Deposition

Quantity

Approximately 209 in. of precipitation were recorded at the site during the 6 years of data collection (table 7). Measured precipitation at Brush Run Creek was about 13 percent less than the 30-year long-term normal at the nearby NOAA station at Hanover. Annual precipitation was below normal for each of the 6 years of the study, ranging from 6 percent below normal during water year 1987 to 26 percent below normal during water year 1991. Precipitation was about 10 percent below normal prior to nutrient management and was about 15 percent below normal during nutrient management. Precipitation during the nongrowing season ranged from 16 percent below normal in 1991 to 27 percent below normal in 1986. During the growing season, precipitation ranged from 8 percent above normal in 1987 to 44 percent below normal in 1991. On an annual and seasonal basis, only the 1987 growing season recorded above-normal precipitation. The greater variations in precipitation during the growing season probably created greater variations in hydrologic processes such as runoff, recharge, evapotranspiration, and nutrient transport. About 58 percent of the measured precipitation at Brush Run Creek was discharged in streamflow.

Monthly precipitation at Brush Run Creek was highly variable and ranged from 0.21 in. in December 1989 to 7.28 in. in September 1987. Precipitation was more than 1.5 in. less than normal each month except September during water year 1991. Prior to the wet September in 1987, the growing season was 11 percent drier than normal. During the study, precipitation was above normal only 24 of the 72 months of data collection.

In addition to the precipitation data collected during the study, antecedent conditions may have affected the surface-water quality at the beginning of the study. Historical data from the Hanover precipitation station indicate that the study began following a year that was less than 1 percent wetter than normal; the 4 years prior to the study were 1 percent drier than normal.

The monthly comparison of the positive and negative deviations from the normal precipitation (fig. 8) suggests months during which corresponding fluxes in nutrient concentrations and discharges may begin in base flow. If the quantity of nitrate nitrogen available for transport from the soil to the stream remained constant, then precipitation would have a greater influence on the transport of the nitrate during these months. For example, the illustration shows that above-normal precipitation was measured in November during the first 4 years of the study and precipitation was more than 3 in. above normal during September 1987, May 1988, and July 1989. Fluxes in concentrations and discharges of nitrate may be expected during or shortly after these months. In contrast, precipitation was significantly below normal during the month of April in each water year. Thus, fluxes in the opposite direction of those months when precipitation was above normal might be expected.

Quality

Precipitation (wetfall) was sampled March 3, 1986, April 2, 1987, April 5, 1987, May 20, 1987, and September 8, 1987, to document the chemical quality before expanded collection of atmospheric deposition began (table 8). Concentrations of total ammonia measured on May 20, 1987, were 2.8 mg/L at Brush Run Creek compared to 0.25 mg/L at Bald Eagle Creek. These results suggested that substantial amounts of ammonia deposit at the Brush Run Creek site, and that the areal distribution of wetfall and dryfall needed to be determined. Thus, additional sampling sites were established.

Wetfall events were sampled on March 25–26, 1988, May 1–2, 1989, and May 4–6, 1990, and dryfall was sampled on September 7–8, 1988, and April 20–21, 1989, at the sites shown in figure 7. The specific conductance and pH of the wetfall and dryfall, and the concentrations of nutrients deposited during the sampled deposition days are listed in tables 9 and 10.

The areal distribution of wetfall and dryfall shown in figures 9 and 10 indicates concentrations of ammonia that were deposited within 24-hour periods. The concentration contours suggest the manure lagoon acts as an ammonia source that volatilizes from the

Table 7. Measured precipitation at Brush Run Creek and normal precipitation at Hanover and deviations from normal for the growing and nongrowing seasons in water years 1986–91

[BR, Brush Run Creek; HN, Hanover; precipitation is in inches; deviation from normal is in percent; --, missing data]

Water year	Measured at Brush Run Creek			Measured at Hanover			Normal at Hanover			Deviations from normal at Brush Run Creek and Hanover					
	Non-growing season	Growing season	Total	Non-growing season	Growing season	Total	Non-growing season	Growing season	Total	Nongrowing season		Growing season		Total	
										BR	HN	BR	HN	BR	HN
1986	13.79	19.30	33.09	15.72	14.19	29.91	18.85	21.15	40.00	-27	-17	-9	-33	-17	-25
1987	14.69	22.91	37.60	18.65	19.85	38.50	18.85	21.15	40.00	-22	-1	+8	-6	-6	-4
1988	15.39	20.42	35.81	15.89	17.69	33.58	18.85	21.15	40.00	-18	-16	-4	-16	-10	-16
Sub-total	43.87	62.63	106.50	50.26	51.73	101.99	56.55	63.45	120.00	-22	-11	-1	-18	-10	-15
1989	14.38	21.78	36.16	15.00	24.40	39.40	18.86	21.15	40.00	-24	-20	-3	13	-10	-1
1990	17.32	19.47	36.79	15.84	19.68	35.52	18.86	21.15	40.00	-8	-16	-8	-7	-8	-11
1991	17.79	11.79	29.38	--	--	--	18.86	21.15	40.00	-6	--	-44	--	-26	--
Sub-total	49.29	53.04	102.33	--	--	--	56.55	63.45	120.00	-13	--	-16	--	-15	--
Total	93.16	115.67	208.83	--	--	--	113.10	126.90	240.00	-18	--	-9	--	-13	--

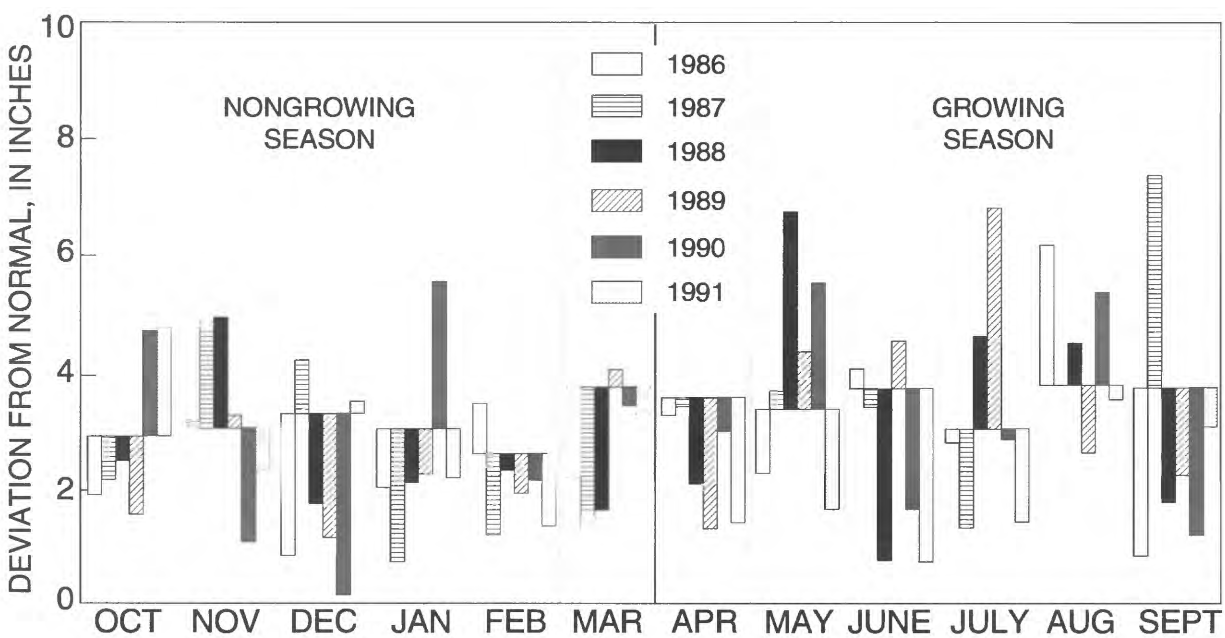


Figure 8. Monthly deviations of measured precipitation at Brush Run Creek from normal precipitation at Hanover during the growing and nongrowing seasons for water years 1986–91.

Table 8. Water quality of precipitation at Brush Run Creek (sites 1, 1a, 1b, 1c) and Bald Eagle Creek (site 2) collected before expanded atmospheric-deposition sampling began

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligram per liter; --, not measured; <, less than]

Constituents	March 3, 1986	April 2, 1987	April 5, 1987	May 20, 1987		September 8, 1987			
	1	1	1	1	2	1a	1b	1c	2
Precipitation (inches)	0.03	0.06	0.17	0.74	1.52	2.55	2.55	2.55	2.81
Specific conductance (µS/cm)	25	48	37	29	30	14	17	6	8
pH (units)	--	4.4	5.2	5.8	4.3	--	--	7.4	7.4
Nitrogen, total (mg/L)	[1]1.6	3.0	4.1	3.4	.80	.50	.80	.64	.30
Nitrite + nitrate, total (mg/L)	[1].33	1.4	1.3	.40	.30	.10	.10	.10	.10
Ammonia, total (mg/L)	[1]1.1	1.3	2.7	2.8	.25	.36	.39	.54	.02
Ammonia + organic nitrogen, total (mg/L)	[1].20	.30	.10	.20	.25	.04	.31	<.01	.18
Phosphorus, total (mg/L)	[1].05	.09	.39	.06	.01	.04	.04	.05	.30

[1]These results reflect dissolved concentrations; all others are total concentrations.

lagoon's liquid slurry to the atmosphere above the lagoon, is transported by the wind, and then some of the ammonia redeposits within the subbasin. Thus, in addition to nutrients being transported to the stream in surface runoff and ground water released as base flow, nutrients in the form of ammonia are transported from the lagoon to the stream and surrounding fields by the atmosphere. The quantity of the nutrients deposited depends on air temperature, windspeed and direction, relative humidity, and precipitation. Langland (1992) has estimated that total annual ammonia deposition in the Brush Run Creek Basin could account for 10 percent of the annual nitrogen requirements for corn.

Figure 9 shows the contoured concentrations of ammonia in the three wetfall samplings. It is evident from the contours that concentrations of ammonia in precipitation were higher and were deposited over a larger area of the subbasin upstream from the continuous gaging station than downstream from the station. All wetfall events sampled showed greater concentrations of ammonia near the lagoon with ammonia concentrations decreasing as distance from the lagoon increased. The maximum measured concentration of ammonia in wetfall was 4.1 mg/L on May 4–6, 1990.

Figure 10 shows the contoured ammonia concentrations from the two dryfall samplings. Dryfall originating from the lagoon redeposited in a similar pattern as the deposition from wetfall; most of the ammonia was either redeposited within the subbasin or was transported and dispersed in the atmosphere above the watershed. Concentrations ranged from a maximum of 5.1 mg/L near the lagoon to less than 0.20 mg/L at the most distant sampling points. Dryfall samples collected on April 20–21, 1989 (fig. 10), show concentrations of ammonia are elevated near a horse farm (farm 3, fig. 2). Although the effect of ammonia volatilizing and redepositing from this farm is small relative to the basin, it does suggest that multiple plumes of ammonia in the atmosphere may be present in the study basin. It can be concluded from these maps that the atmosphere transported nutrients from a source downstream of the gage to the land and stream surface upstream from the gage. Therefore, surface water sampled at the gage represents more than an integration of the nutrient sources applied upstream from the gage by the farmer because water samples collected at the gage are affected by the ammonia that volatilizes from the lagoon. The effect of ammonia on surface-water quality is discussed further in the base-flow water-quality section.

Generally, because of the presence of elevated ammonia concentrations, wetfall and dryfall samples collected closer to the lagoon had higher pH values than those samples collected further away from the lagoon (figs. 9 and 10), suggesting the volatilization of ammonia is neutralizing otherwise acidic precipitation. Most of the nitrogen in wetfall and dryfall was ammonia (figs. 9 and 10), and the percentage of total ammonia to total nitrogen decreases as distance from the lagoon increases. The Bald Eagle Creek samples contain a smaller percentage of ammonia to total nitrogen than do the Brush Run Creek samples, probably because of the lower animal density and lack of an open manure-storage facility at Bald Eagle Creek. Therefore, the lagoon at the Brush Run Creek site acts as a point source for ammonia, and ammonia concentrations in wetfall and dryfall are higher near the lagoon

Table 9. Quality of wetfall for three samplings at Brush Run Creek and Bald Eagle Creek (BEC)

[BEC, Bald Eagle Creek; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data available; <, less than]

Constituents	Site number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	BEC
						March 25–26, 1988										
Specific conductance (µS/cm)	16	17	13	74	11	22	15	15	30	22	14	9	14	--	--	--
pH	4.6	4.7	5.4	6.7	5.3	5.9	5.7	6.5	5.8	6.0	4.9	4.6	4.6	--	--	--
Nitrogen, total (mg/L)	1.0	1.3	.70	--	--	1.7	--	--	--	--	.80	.50	.60	--	--	--
Nitrite + nitrate, total (mg/L)	.40	.60	.30	--	--	.30	--	--	--	--	.40	.20	.20	--	--	--
Ammonia, total (mg/L)	.37	.51	.25	--	--	1.0	--	--	--	--	.34	.28	.12	--	--	--
Organic, total (mg/L)	.23	.19	.15	--	--	.40	--	--	--	--	.06	.02	.28	--	--	--
Phosphorus, total (mg/L)	.06	.02	.04	--	--	.07	--	--	--	--	.02	.02	.02	--	--	--
						May 1–2, 1989										
Specific conductance (µS/cm)	18	17	18	22	23	19	21	28	18	17	18	20	15	15	12	29
pH	4.5	4.5	4.8	4.5	4.5	6.3	5.0	4.6	5.2	5.5	4.8	4.5	5.1	5.6	5.9	4.6
Nitrogen, total (mg/L)	.60	.60	.70	.70	.70	--	--	.60	.90	1.1	.74	.70	1.2	1.6	1.5	.80
Nitrite + nitrate, total (mg/L)	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.40
Ammonia, total (mg/L)	.26	.28	.23	.25	.24	1.6	.26	.25	.34	.39	.25	.18	.67	1.1	.97	.30
Organic, total (mg/L)	.04	.02	.17	.15	.16	<.01	<.01	.05	.26	.41	.19	.22	.23	.20	.25	.10
Phosphorus, total (mg/L)	.01	.01	.02	.02	.01	.02	.01	.01	.08	.05	.02	.03	.01	.03	.01	.01
						May 4–6, 1990										
Specific conductance (µS/cm)	47	38	31	44	35	45	38	42	36	32	31	36	--	--	--	--
pH	4.1	5.9	5.2	5.8	5.2	5.7	5.6	4.1	6.2	4.4	6.0	4.5	--	--	--	--
Nitrogen, total (mg/L)	1.4	2.0	1.8	3.3	1.8	5.4	2.0	1.7	3.1	2.3	3.4	2.6	2.2	--	--	--
Nitrite + nitrate, total (mg/L)	.80	.80	.90	1.0	.80	.80	.80	.80	.90	.80	.80	.80	1.0	--	--	--
Ammonia, total (mg/L)	.64	.76	.80	1.6	.77	4.1	.98	.93	2.0	1.5	2.5	1.2	1.1	--	--	--
Organic, total (mg/L)	<.01	.44	.10	.70	.23	.50	.22	<.01	.20	<.01	.10	.60	.10	--	--	--
Phosphorus, total (mg/L)	.02	.06	.03	.06	.07	.04	.04	.02	.05	.02	.04	.02	.24	--	--	--

Table 10. Quality of dryfall for three samplings at Brush Run Creek and Bald Eagle Creek (BEC)

[BEC, Bald Eagle Creek; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mL, milliliters; mg/L, milligrams per liter; --, no data available; <, less than]

Constituents	Site number																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Control	BEC
								September 7–8, 1988									
Specific conductance (µS/cm)	8	12	8	6	6	51	10	6	7	17	6	12	7	12	10	6	8
pH	7.9	7.9	8.0	8.1	8.1	7.4	8.0	8.4	8.2	7.9	8.3	8.2	8.3	8.2	8.2	8.3	8.1
Final volume (mL)	893	859	908	913	886	950	852	924	970	881	943	870	922	923	953	1,000	937
Nitrogen, total (mg/L)	.45	.94	.36	.46	.27	5.8	.51	.28	.48	.97	.38	.52	.64	.92	.95	.30	.75
Nitrite + nitrate, total (mg/L)	.09	.09	.09	.09	.09	.10	.09	.09	.10	.09	.09	.09	.09	.09	.09	.10	.10
Ammonia, total (mg/L)	.12	.15	.11	.14	.19	5.3	.21	.09	.16	.54	.11	.17	.34	.73	.49	.08	.08
Phosphorus, total (mg/L)	.07	.15	.04	.03	.06	.08	.11	.15	.07	.27	.08	.17	.05	.06	.07	.02	.14

	Site number																	
	1	2 (2a)	3	4	5	6	7	8	9	10	11 (11a)	12 (9a)	13 (10a)	14	15 (15a)	New (16a)	Control	BEC
								April 20–21, 1989										
Specific conductance (µS/cm)	11	6	28	4	8	9	12	16	5	10	9	7	8	31	5	11	4	11
pH	7.2	7.2	6.6	6.9	6.6	7.3	6.9	6.6	6.7	7.2	6.9	7.1	6.4	7.5	7.3	7.1	7.0	5.6
Final volume (mL)	745	824	745	871	830	792	818	737	745	738	740	710	740	852	770	770	1,000	845
Nitrogen, total (mg/L)	.70	.70	1.0	.40	.60	.80	.50	1.5	.50	.80	1.0	.40	.40	3.6	.40	.60	--	.60
Nitrite + nitrate, total (mg/L)	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	<.10	.10	.10	--	.10
Ammonia, total (mg/L)	.16	.21	.42	.15	.28	.49	.17	.31	.15	.58	.61	.29	.21	2.6	.12	.23	.09	.10
Phosphorus, total (mg/L)	.03	.05	.05	.02	.02	.03	.03	.08	.03	.02	.02	.01	.06	<.01	.01	.02	.03	.05

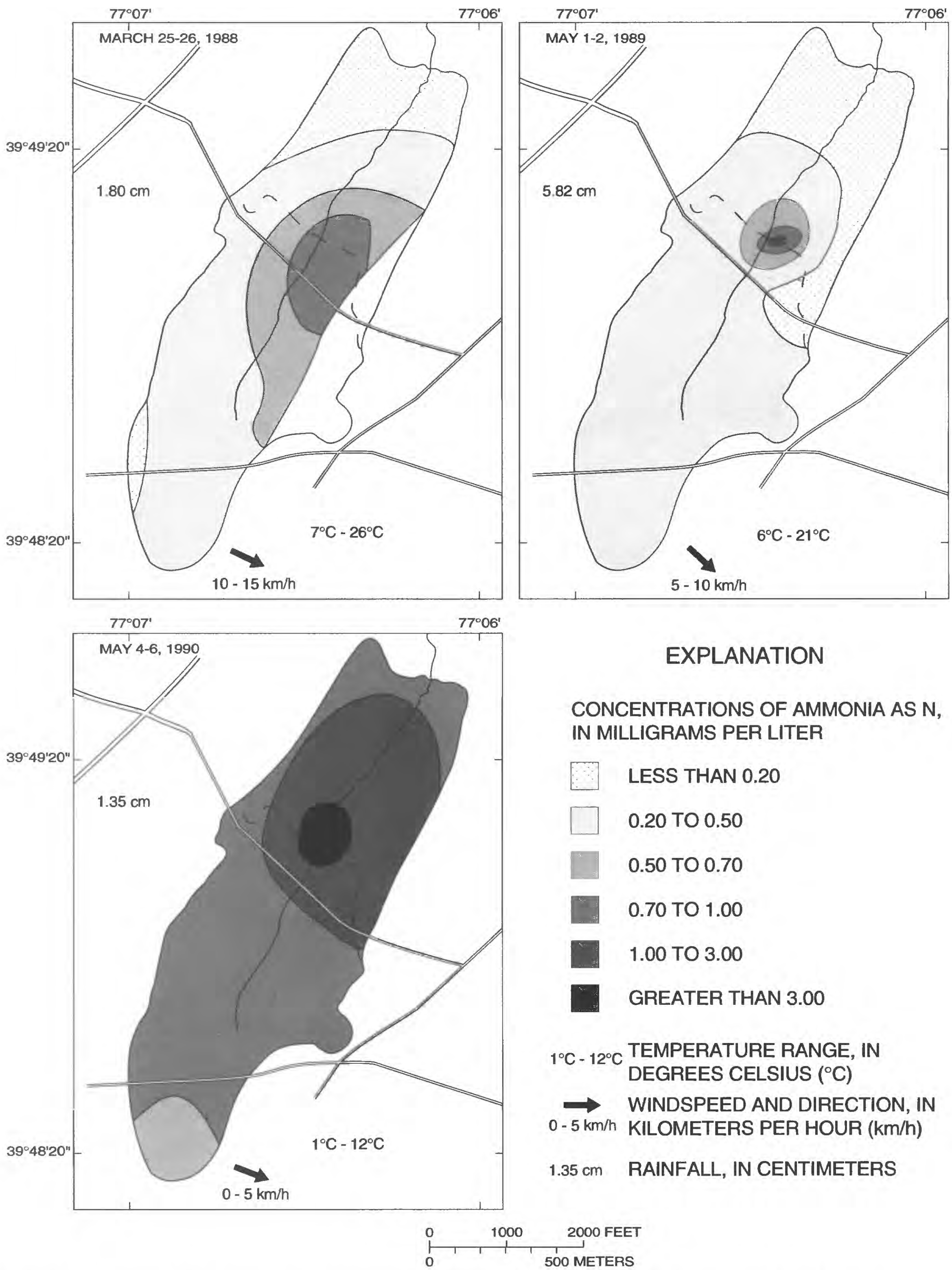


Figure 9. Atmospheric deposition of ammonia from wetfall from three samplings at Brush Run Creek.

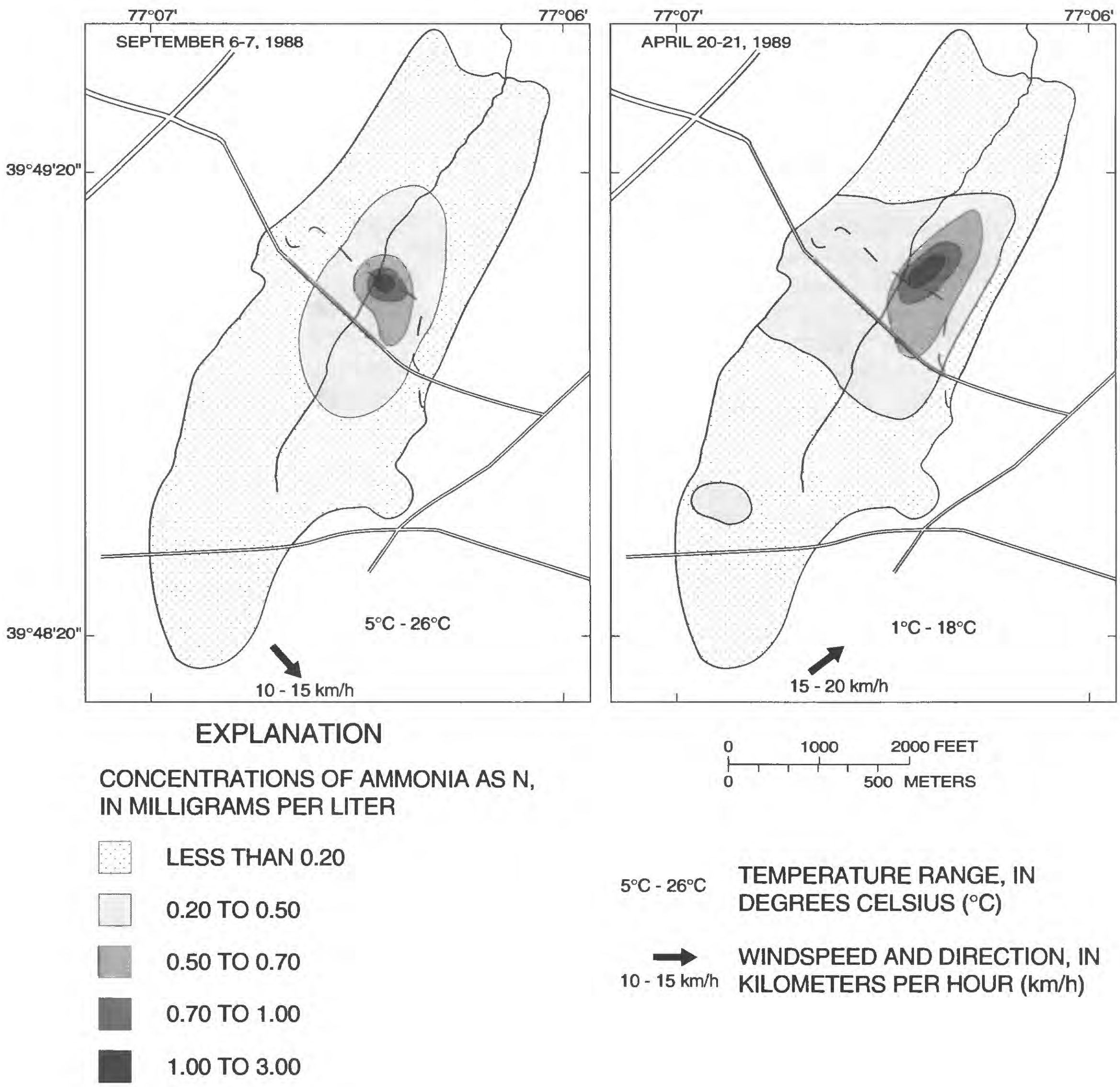


Figure 10. Atmospheric deposition of ammonia from dryfall from two samplings at Brush Run Creek.

than background concentrations at this site. Atmospheric deposition of ammonia may be an important factor to consider in any nutrient-management plan at Brush Run Creek and other agricultural basins where numerous animals are housed or large open manure-storage facilities are located.

Soils and Soil Nutrients

Soil depths were sufficient to obtain samples to depths of 48 in. at each of the eight fields, and up to depths of 72 in. at one field. This suggests that soils at Brush Run Creek are more similar to the deep soils in the carbonate area of the RCWP Nutrient-Management and Forested Subbasins than the shallow soils in the schist areas at the Bald Eagle Creek where on occasion the soil probe was unable to penetrate to depths below 24 in. Therefore, the soils at Brush Run Creek have the potential for a higher nutrient content than those at Bald Eagle Creek simply because the soils are deeper at the Brush Run Creek site than they are at the Bald Eagle Creek site.

Because concentrations of nutrients in the soil were highly variable, no trends were apparent in concentrations of nitrate in the soil with respect to season, or as a result of reductions in nutrient applications. Investigators have recognized the difficulty in collecting and interpreting representative soil samples because of varying soil and climatic conditions. Harmsen and Van Schreven (1955) stated reliable interpretations of soil data could be made when dealing with a single soil type, climatic zone, or farming system. However, variations occur from the same field for a number of reasons—different application rates for fertilizers, different flow paths, variations in soil type, and different rates of nutrient uptake by plants.

Available nitrogen (nitrate) and phosphorus concentrations of soils were measured after the growing season but before manure was applied in 1985, and before and after the growing season during 1986–91 (figs. 11 and 12). The nitrate concentrations only reflect the amount of nitrate immediately available to the plants. They do not account for nitrogen from ammonia or nitrogen that may become available from mineralization and nitrification of residual organic nitrogen in the soil, which Stevenson (1982) indicates may comprise more than 90 percent of the nitrogen in surface layers of most soils. The high concentrations throughout the soil profile indicate that the highly soluble nitrate moves readily through the profile to the bedrock where it may either continue downward through the soil matrix to the ground water or move laterally along the rock surface, eventually being released in base flow to the stream. This process is similar to that observed in noncarbonate schist and quartzite soil in Bald Eagle Creek and carbonate areas at the Nutrient-Management and Forested Subbasins of the RCWP project.

Concentrations of nitrate were commonly higher in the fall after the growing season than in the spring prior to the growing season, suggesting that the nitrate remaining in the soil probably does leach downward below 4.0 ft during the nongrowing season. Additional soil data were collected to better characterize the soils at field 1 after initial results indicated that concentrations of nitrate in the top 4 ft were greater than 450 lb/acre and the maximum concentrations were in the zone 36 to 48 in. below the surface. Soil samples were collected to a depth of 72 in. in the spring of 1987, and results indicated that concentrations of nitrate were 633 lb/acre in the top 6 ft of the soil profile at field 1. These results suggest that there is a potential for a large amount of nitrate to be located below the root zone at soil depths greater than 4 ft. Although this nitrate may not be available for crop uptake, it is available for leaching to the ground water and transport to the stream in interflow.[2]

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 legumes, can fix nitrogen from the atmosphere, but it is the nitrate ion that is utilized by most plants. The highly mobile nitrate ion is made available to solution from manure and fertilizers by 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.

The nutrient content of soils in areas where agricultural practices are intense may be best managed with proper applications of manure and commercial fertilizers, taking into consideration climate, weather, geology, and soil chemistry. Soil-monitoring studies in Nebraska, Iowa, and Wisconsin (Halberg 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 not exceed 20 mg/L nitrate nitrogen. Baker (The Pennsylvania State University, College of

[2]Interflow is that water in the soil below the land surface and above the water table that can move laterally. It is not considered to be ground water because it is above the water table.

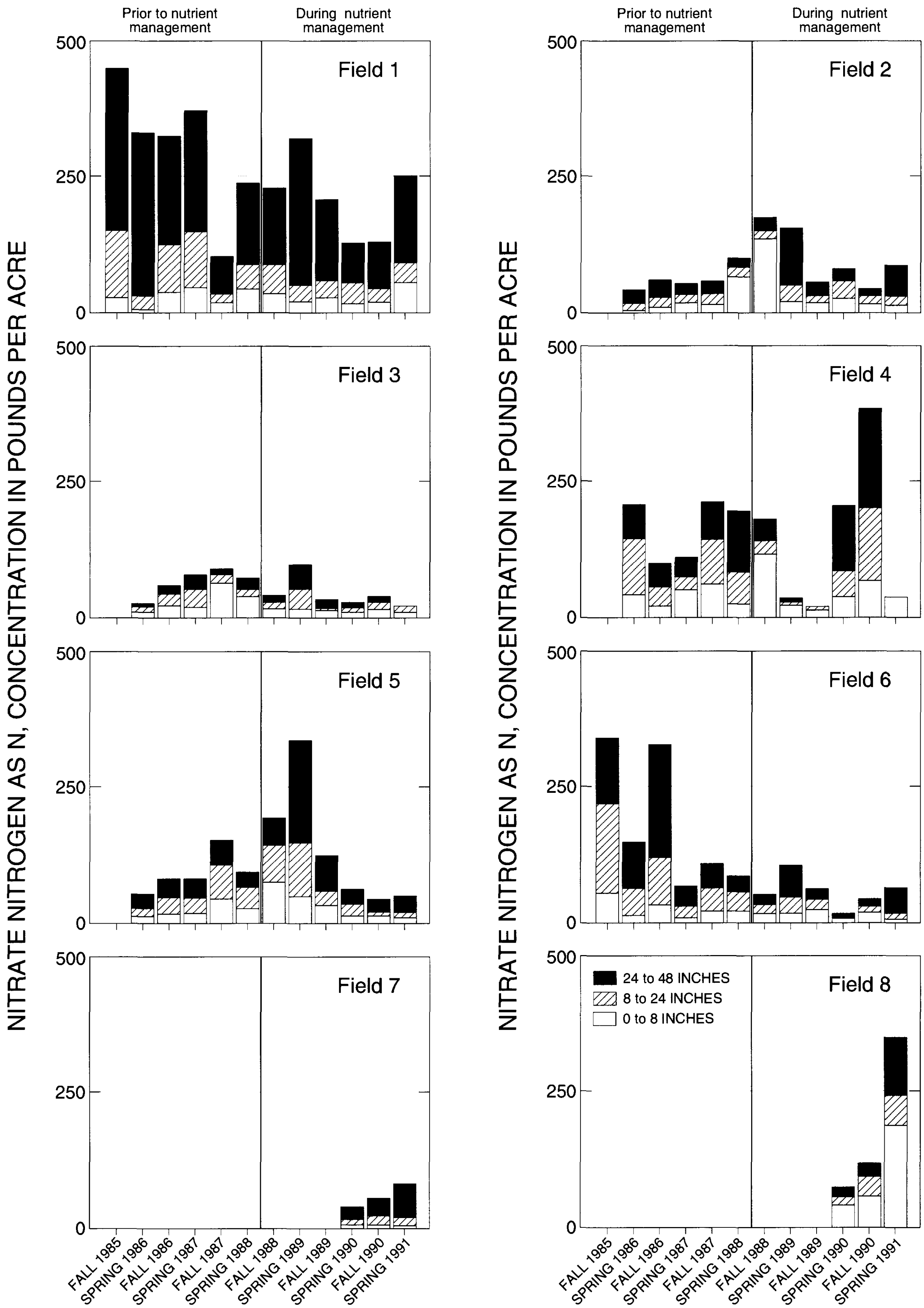


Figure 11. Soluble nitrate-nitrogen concentrations for selected soil increments on eight fields in the Brush Run Creek Basin.

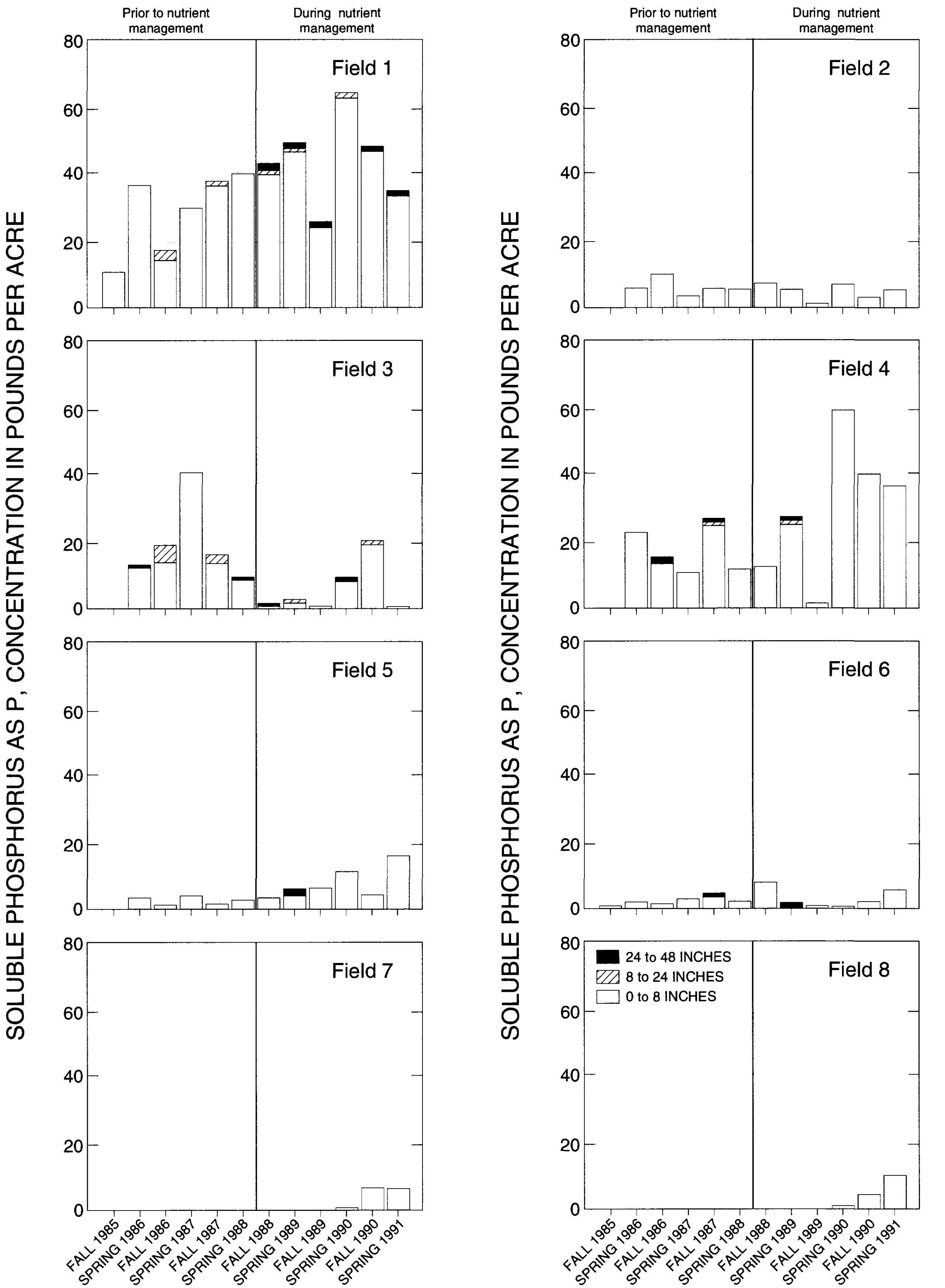


Figure 12. Soluble phosphorus concentrations for selected soil increments on eight fields in the Brush Run Creek Basin.

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. At the Brush Run Creek site, nitrate concentrations were commonly as high at depths of 36 to 48 in. below the surface as concentrations in the top 8 in. of soil. All 32 samples collected from 6 fields sampled at Brush Run Creek prior to nutrient management had over 50 lb/acre of nitrate in the top 4 ft of soil after the growing seasons, and fields 1, 4, and 6 usually had over 100 lb/acre of nitrate in the top 4 ft of soil. During nutrient management, 22 of the 36 soil samples from the eight fields had over 50 lb/acre of nitrate in the top 4 ft of soil after the growing season. Only fields 1 and 4 were usually over 100 lb/acre of nitrate in the top 4 ft of soil. Fields 4, 7, and 8 show increases in soil in nitrate concentrations during nutrient management. This increase is probably because of the farmer spraying lagoon waste to fields 4, 7, and 8 located downstream from the water-quality gage (fig. 2). Fields 2, 3, and 5 showed decreases in concentrations of nitrate, probably because of a 25-percent reduction in nitrogen applications to fields located upstream from the water-quality gage (table 5).

In contrast to the nitrate concentrations, phosphorus concentrations were nearly always highest near the surface of the soil reflecting the affinity that phosphorus has for fine soil particles (Finkle and Simonson, 1979). Most of the phosphorus in the soil at the Brush Run Creek site may be available for the crops since the optimum range of pH for phosphorus availability is 6.5 to 7.0. At a high or low pH, phosphorus may form insoluble compounds with iron or aluminum and become unavailable to plants.

Concentrations of soluble phosphorus were commonly greater in the spring before the growing season than in other seasons, suggesting that crops utilized some of the available phosphorus. Studies have shown that 69 to 80 percent of the total phosphorus in soil may be leached from dead or dormant vegetation (Edward Koerkle, U.S. Geological Survey, written commun., 1992).

Generally, the greatest reduction of phosphorus concentrations in the soil occurred in fields 1 and 4, probably because of the 61-percent reduction in phosphorus applications to fields upstream from the water-quality gage (fig. 2 and table 5). Phosphorus concentrations increased at fields 3 and 5 with little change at fields 2 and 6. Fields 7 and 8, sampled after the farmer began spraying lagoon waste to the lower fields, showed phosphorus concentrations increased with each sampling, similar to the nitrate soil sampling results.

Concentrations of nitrate and soluble phosphorus in the soil were generally lower in the Brush Run Creek Subbasin than in the Nutrient-Management Subbasin but higher than the Bald Eagle Creek Subbasin. The total amount of nitrate-nitrogen and soluble phosphorus in the Brush Run Creek Subbasin in the top 48 in. of soil ranged from 21 to 452 lb/acre and 0.98 to 42 lb/acre, respectively, prior to nutrient management. Concentrations of nitrate-nitrogen and soluble phosphorus in soil samples collected during the nutrient-management period ranged from 17 to 386 lb/acre and 0.29 to 65 lb/acre, respectively, in the top 48 in. of soil (table 11).

Table 11. Amount of nitrogen and phosphorus in soils at the Brush Run Creek, Bald Eagle Creek, and Nutrient-Management Subbasin study areas

[lb/acre, pounds per acre; --, no data]

Soil data	Brush Run Creek	Bald Eagle Creek	Nutrient Management Subbasin
Number of samples	73	34	40
Nitrate-nitrogen in soil range (lb/acre)			
Prior to nutrient management	21–452	36–135	46–380
During nutrient management	17–386	21–291	--
Percent greater than 50 lb/acre	77	74	95
Percent greater than 100 lb/acre	46	29	50
Soluble phosphorus in soil range (lb/acre)			
Prior to nutrient management	0.98–42	0.39–2.5	1.4–37
During nutrient management	0.29–65	0.73–1.7	--

Differences among three study sites can be explained because of different soil depths, different manure application rates, and the difference in the composition of the manure used in the basins. At the Bald Eagle Creek site, only dairy manure, containing less nitrogen and phosphorus than poultry or swine manure, was applied; and because the animal density was less than the animal density at the Nutrient-Management and Brush Run Creek sites, less nutrients were applied than at the Nutrient-Management site. Conversely, poultry, hog, and dairy manure nutrients were applied at the Nutrient-Management site where the animal density is much greater. For example, the phosphorus content (P_2O_5) of the dairy manure at

Bald Eagle Creek was 4.9 lb/ton as compared to 11 lb/ton for swine manure at Brush Run Creek and 54 lb/ton for turkey manure applied at Farm A in the Nutrient-Management Subbasin (Fishel and others, 1992).

Streamflow

Streamflow data collected at Brush Run Creek were correlated with streamflow data from West Conewago Creek near Manchester prior to nutrient management (water years 1986–88) and during nutrient management (water years 1989–91). The correlation between the log transformed mean-daily streamflows from the two stations prior to nutrient management was fair (r = 0.66, with a standard error of 0.65). Thus, streamflow measured at Brush Run Creek was probably similar to that at the West Conewago Creek, which had flows that were 7, 12, and 11 percent below normal for water years 1986–88, respectively. During nutrient management, the correlation between the log transformed mean-daily streamflows was poor (r = 0.59, standard error of 0.69). This poor correlation was because of the increase in zero flow days (144 to 175) at Brush Run Creek during nutrient management and the slight regulation of West Conewago Creek by the city of York. Therefore, streamflow measured at Brush Run Creek could have been similar to West Conewago Creek where flows were 8 percent above, 2 percent below, and 6 percent above normal for water years 1989–91, respectively.

Quantity

Daily streamflows at Brush Run Creek ranged from 0.00 ft^3/s recorded on many days during each of the 6 years to 43 ft^3/s on November 29, 1987 (fig. 13). Prior to nutrient management, zero streamflow was recorded for 8 days in water year 1986, 55 days in water year 1987, and 80 days for water year 1988. During nutrient management, zero streamflow was recorded because of frozen or dry stream conditions during 36 days in water year 1989, 46 days in water year 1990, and 93 days in water year 1991. Extended periods of zero streamflow were recorded for each growing season. During the nongrowing season, periods of zero streamflow occurred in January and October 1986, October and November 1987, January 1988, October and December 1989, and October and December 1990.

Figure 13 shows the relation between daily precipitation and daily base flow. Streamflow discharge peaked shortly (1 or 2 days) after a precipitation event, suggesting a rapid response between precipitation and streamflow. Because the streamflow is recorded on a log scale, a value of 0.001 ft^3/s is approximately equal to 0, or no flow.

Prior to nutrient management, the yearly mean streamflows were 0.50, 0.65, and 0.55 ft^3/s for water years 1986, 1987, and 1988, respectively. During nutrient management, the yearly mean streamflows were 0.83, 0.38, and 0.51 ft^3/s for water years 1989, 1990, and 1991, respectively. The total streamflow discharge from the site was 121.8 in.: 60.72 in. prior to nutrient management, and 61.07 in. during nutrient management.

About 57 percent of the 106.5 in. of measured precipitation prior to nutrient management and about 60 percent of the 102.7 in. of measured precipitation during management were discharged as streamflow. The remaining 43 and 40 percent were removed as evapotranspiration, flowed below the site as ground water, or remained in ground-water storage. At Bald Eagle Creek, 31 percent of the 164 in. of measured precipitation was discharged as streamflow for water years 1986–89 (Langland and Fishel, 1995).

Base Flow

Hydrograph separation techniques (Pettyjohn and Henning, 1979) were used to determine the contribution of base flow and stormflow to total streamflow. Nineteen percent of the total streamflow during the study was base flow. Prior to nutrient management, 16 percent of the total streamflow was base flow. During nutrient management, 21 percent of the total streamflow was base flow (table 12). About 20 percent of the streamflow was base flow during the nongrowing season, and 17 percent of the streamflow was base flow during the growing season. Base flow ranged between 0 to 88 percent of the monthly streamflow and depended on the amount of precipitation and storm intensities. Only 6.7 percent of the streamflow was base flow during water year 1986, a year when precipitation was 17.3 percent below normal. In contrast, 27 percent of the streamflow was base flow during water year 1989, a year when precipitation was 10 percent below normal. The contribution of base flow to total streamflow depended primarily on antecedent soil-moisture conditions and the duration, intensity, and amount of precipitation.

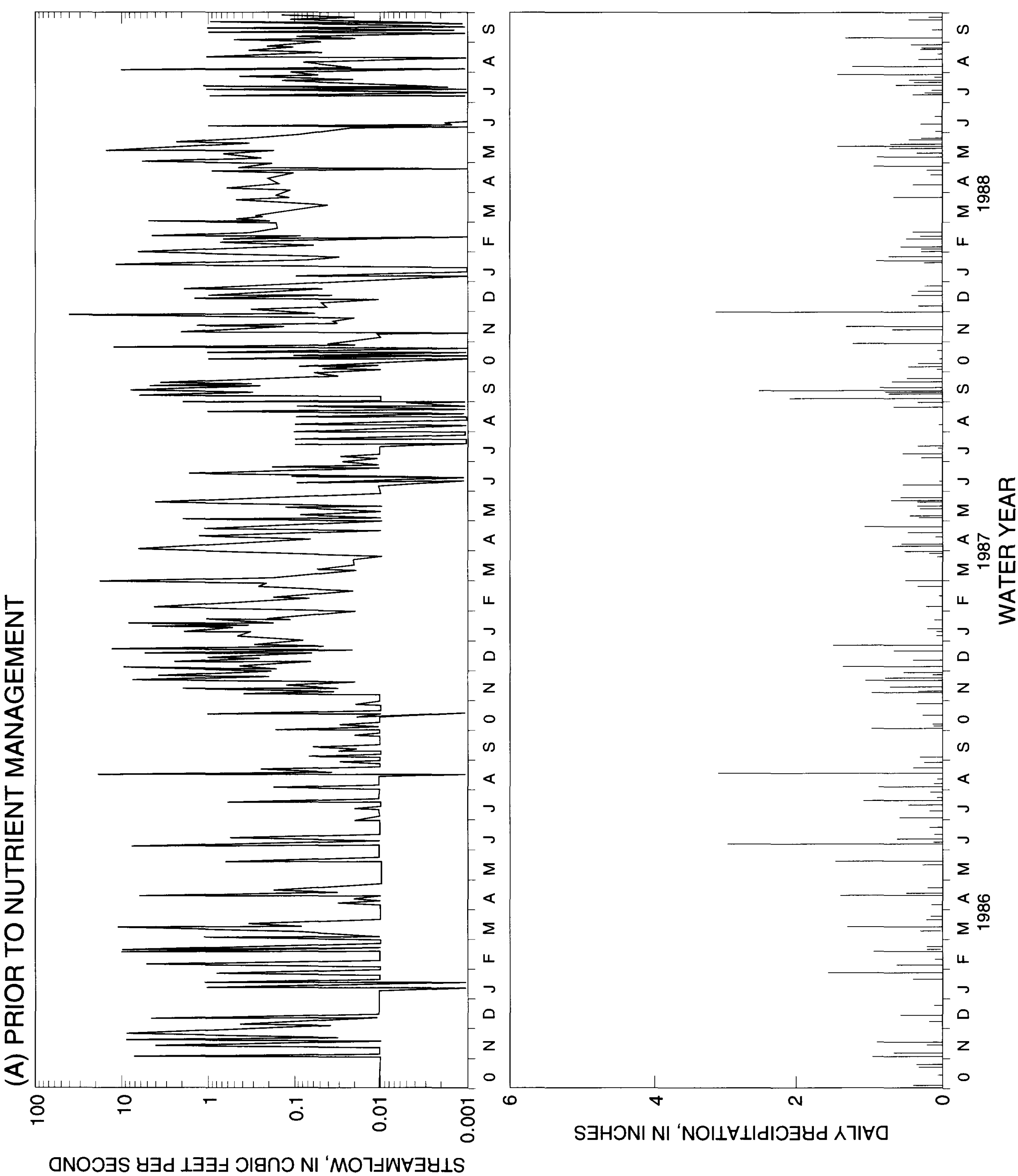


Figure 13. Hydrograph separation using local minimum method and daily precipitation at Brush Run Creek (A) prior to and (B) during nutrient management.

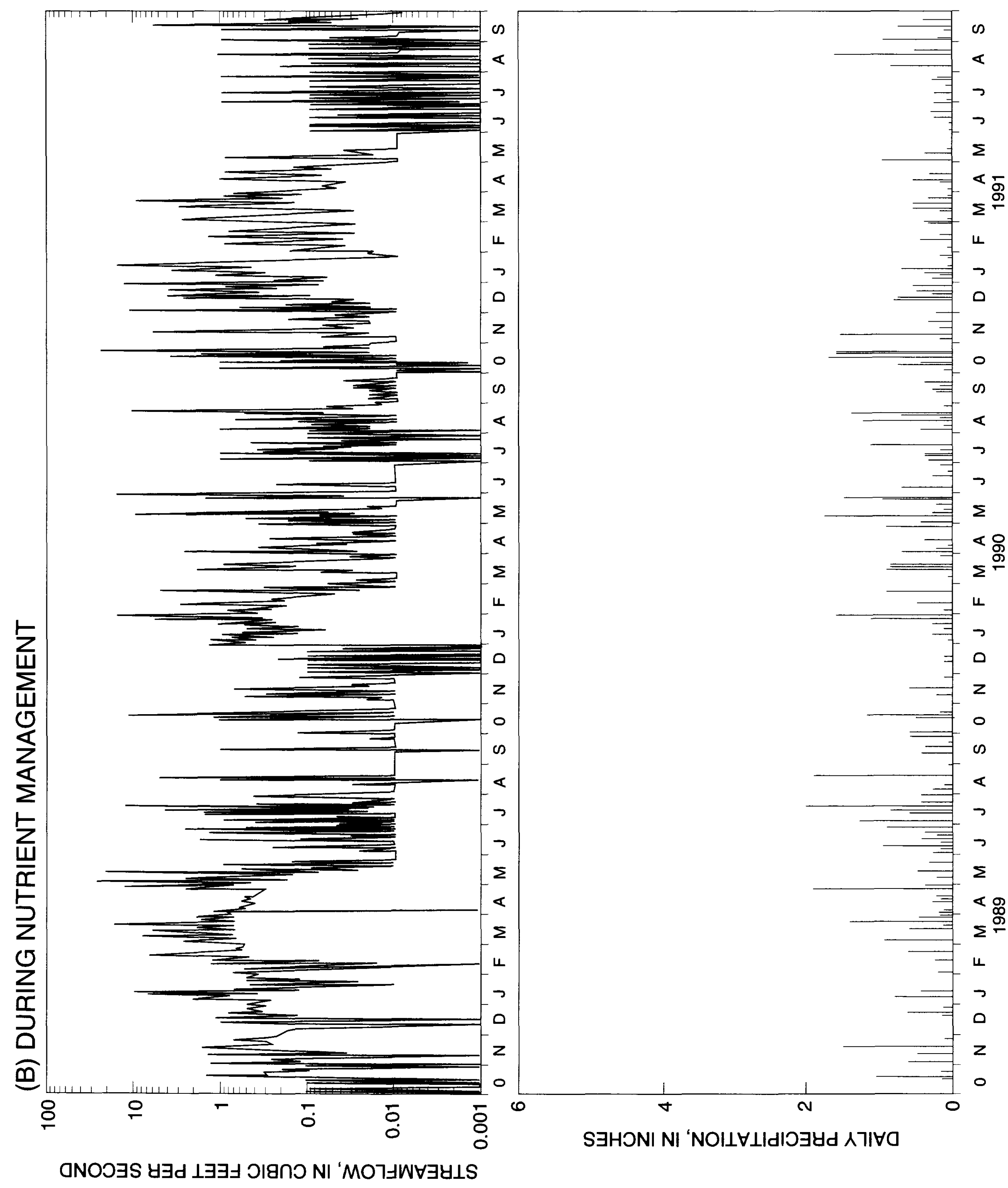


Figure 13. Hydrograph separation using local minimum method and daily precipitation at Brush Run Creek (A) prior to and (B) during nutrient management--Continued.

Table 12. Contribution of base flow at Brush Run Creek to total streamflow during water years 1986 through 1991

Timeframe	Base flow (inches)	Stormflow (inches)	Total streamflow (inches)	Percentage of base flow in total streamflow
		Subtotals		
Water year 1986	1.20	16.72	17.92	6.7
Water year 1987	4.92	18.17	23.09	21
Water year 1988	3.64	16.07	19.71	18
Water year 1989	8.06	21.33	29.39	27
Water year 1990	2.18	11.44	13.62	16
Water year 1991	2.68	15.38	18.06	15
		Growing season		
Prior to management	3.80	14.71	18.51	21
During management	3.10	19.65	22.75	14
Subtotal	6.90	34.36	41.26	17
		Nongrowing season		
Prior to management	5.96	36.25	42.21	14
During management	9.82	28.50	38.32	26
Subtotal	15.78	64.75	80.53	20
		Totals		
Prior to management	9.76	50.96	60.72	16
During management	12.92	48.15	61.07	21
Entire study	22.68	99.11	121.79	19

Stormflow

Stormflow contributed 81 percent of the total streamflow for water years 1986–91. Streamflow hydrographs (fig. 13) show that most of the stormflow (surface runoff) discharged in November 1985, February and December 1986, November 1987, and December 1990, during the nongrowing season. The figures also reflect the rapid response of stormflow shortly after precipitation began and the short durations of stormflow. Prior to nutrient management, 84 percent of the streamflow was stormflow. Thirty percent of the stormflow discharged during the growing season prior to nutrient management with about 9 percent of the stormflow discharged during the growing season in May 1988 when 6.72 in. of precipitation fell. During nutrient management, 79 percent of the streamflow was stormflow; 37 percent of the stormflow was discharged during the growing season. The annual maximum instantaneous peak stormflows at the Brush Run Creek site for water years 1986–91 were 170 ft^3/s on August 16, 1986; 90 ft^3/s on December 24, 1986; 128 ft^3/s on November 29, 1987; 175 ft^3/s on July 20, 1989; 55 ft^3/s on January 29, 1990; and 76 ft^3/s on October 23, 1991.

Quality

The following sections include base flow and stormflow data summaries for nutrient and suspended-sediment concentrations and discharges at four surface-water sites and three tile lines in the Brush Run Creek Basin. Surface-water sites and tile lines are discussed in downstream order because of the impact of the tile lines.

Base Flow

Concentrations and Loads

Descriptive statistics in Appendix 1 of streamflow and the concentrations and loads of seven nitrogen and three phosphorus constituents and suspended sediment were calculated to provide a seasonal characterization of the base-flow quality at Brush Run Creek. Statistics were calculated to investigate differences in data collected from upstream to downstream sites prior to and during nutrient management, by season, and water year. Concentrations and loads listed in Appendix 1 are from analyses of depth-integrated, manually collected discrete samples from site 1 (upstream from water-quality gage), site 2 (water-quality gage), and site 4 (downstream from water-quality gage) (fig. 2).

The Seasonal Kendall test (table 13) was used to test for long-term trends in nutrient and suspended-sediment concentrations and loads in base flow at sites 1, 2, and 4. Significant decreasing trends (negative tau and $p < 0.05$) were detected in base-flow data for total phosphorus concentrations and suspended-sediment concentrations and loads at site 1, total phosphorus and suspended-sediment concentrations at site 2, and suspended-sediment loads at site 4. Significant changes in instantaneous streamflow did not occur at the time of base-flow sample collection. Significant trends were not detected in either concentrations or discharges of total nitrogen, nitrite plus nitrate, ammonia, or organic nitrogen at sites 1, 2, and 4. Longer sampling times may be needed in order to see these trends become significant. Detailed discussion of sampled constituents at each site follows.

Concentrations of total nitrogen and dissolved nitrite plus nitrate, whose primary sources are ground water and discharges from tile lines in the Brush Run Creek Basin, generally increased from upstream to downstream sampling sites, suggesting an increasing contribution of enriched sources of nitrogen to base flow (fig. 14).

Site 1 (upstream from site 2, fig. 2) was the most upstream site to be sampled during base flow and was the only site to remain unaffected by the tile lines. At site 1, median concentrations of total nitrogen and dissolved nitrite plus nitrate were below 10 mg/L during the 6-year study (fig. 14). Median concentrations of total nitrogen and dissolved nitrite plus nitrate were reduced from 3.3 and 1.2 mg/L, respectively, prior to nutrient management to 2.5 and 0.90 mg/L, respectively, during nutrient management. Median daily loads of total nitrogen (fig. 14) and dissolved nitrite plus nitrate were reduced from 0.93 and 0.29 lb to 0.46 and 0.18 lb prior to and during nutrient management, respectively, probably as a result of a 25-percent reduction in nitrogen applications to cropland near site 1. Maximum concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow at site 1 were 21 and 11 mg/L, respectively, on July 10, 1990, when Brush Run Creek was not flowing and the sample was obtained from pooled water.

Tile 1 is located between sites 1 and 2 (water-quality gage) and drains an area from the chicken house to the stream (figs. 2 and 4). Median concentrations of total nitrogen and dissolved nitrite plus nitrate were 40 mg/L and 26 mg/L prior to nutrient management, and 41 mg/L and 20 mg/L during nutrient management. Maximum concentrations of total nitrogen from tile 1 were 2,400 mg/L and 1,100 mg/L prior to and during nutrient management, respectively. Concentrations of total ammonia and total organic nitrogen were 80 and 79 percent of the total nitrogen concentration prior to and during nutrient management, suggesting rapid transport from the nutrient source to tile 1. Median concentrations of total organic nitrogen were highest from tile 1 and lowest from tiles 2 and 3. Median concentrations of total ammonia were highest at sites 2 and 3 (fig. 15), sites closest to the lagoon. The surface-water quality probably was affected by the volatilization of ammonia at sites 1 and 2 as discussed earlier in the report.

The reasons for high nutrient concentrations measured at tile 1 include (1) manganese precipitation on gaskets in automatic water-dispensing devices in the chicken house that allowed an excess amount of nutrient-carrying water to infiltrate into the area drained by tile 1, (2) an elevated pipe carrying liquid hog waste from a barn to the manure-storage facility (lagoon) leaked in the area drained by tile 1, and (3) the lagoon overflowed in extremely wet periods into the area drained by tile 1. It should be noted that the reasons for the high nutrient-rich flows from tile 1 were corrected by the farmer before the project ended.

Although median concentrations of total nitrogen were highest from the tile lines, median loads of total nitrogen were lowest from all sampled tile line sites (fig. 16), because of the small amount of water discharged, which rarely exceeded 0.005 ft^3/s. Although not statistically significant, the decreases in total nitrogen loads were primarily because of the significant decrease in precipitation (table 7) during the growing season when most of the nutrients were applied (table 5) at Brush Run Creek.

At site 2 (water-quality gage), median concentrations of total nitrogen and dissolved nitrite plus nitrate were 14 and 4.4 mg/L prior to, and 14 and 6.2 mg/L during nutrient management, respectively. Every nitrogen constituent had an increase in median concentrations from site 1 to site 2, primarily because of the nutrient discharges from tile 1 (fig. 14).

Seasonal effects were not only less detectable at Brush Run Creek because of the influences from nutrient-rich flows from the tile lines, but also were opposite

Table 13. Seasonal Kendall test results for nitrogen (as N) and phosphorus (as P) constituents in base flow for water years 1986–91 at (A) site 1 (upstream from the water-quality gage), (B) site 2 (at the water-quality gage), and (C) site 4 (downstream from the water-quality gage), Brush Run Creek Basin

[p, probability value; (mg/L)/yr, milligrams per liter per year; lb/yr, pounds per year; ft^3/s, cubic feet per second; $(ft^3/s)/yr$, cubic feet per second per year; concentrations are in milligrams per liter; loads are in pounds per day; base-flow-water discharge is in cubic feet per second; ↓, significant decreasing trend; 0, no trend; --, no data available]

Constituent	Kendall's tau		Significance	Estimate of slope	Median
	tau	p			
A. SITE 1 (UPSTREAM FROM THE WATER-QUALITY GAGE)					
Base flow (ft^3/s)	-0.206	0.193	0	-0.01 $(ft^3/s)/yr$	0.03
Total nitrogen					
Concentration	-.27	.076	0	-.25 (mg/L)/yr	2.9
Load	-.239	.118	0	-.18 lb/yr	.76
Nitrite plus nitrate					
Concentration					
Total	--	--	--	--	--
Dissolved	-.20	.218	0	-.06 (mg/L)/yr	.90
Load					
Total	--	--	--	--	--
Dissolved	-.292	.065	0	-.037 lb/yr	.19
Ammonia nitrogen					
Concentration					
Total	-.28	.062	0	.027 (mg/L)/yr	.13
Dissolved	-.25	.118	0	-.017 (mg/L)/yr	.11
Load					
Total	-.211	.172	0	-.018 lb/yr	.059
Dissolved	-.20	.218	0	-.012 lb/yr	.035
Organic nitrogen					
Concentration					
Total	-.25	.108	0	-.075 (mg/L)/yr	1.2
Dissolved	-.17	.299	0	-.030 (mg/L)/yr	1.1
Load					
Total	-.087	.620	0	-.019 lb/yr	.40
Dissolved	-.138	.412	0	-.022 lb/yr	.32
Phosphorus					
Concentration					
Total	-.43	.006	↓	-.062 (mg/L)/yr	.165
Dissolved	-.117	.505	0	-.015 (mg/L)/yr	.165
Ortho	-.158	.362	0	-.017 (mg/L)/yr	.110
Load					
Total	.267	.102	0	-.015 lb/yr	.044
Dissolved	-.167	.326	0	.005 lb/yr	.043
Ortho	-.210	.213	0	.004 lb/yr	.029
Suspended sediment					
Concentration	-.586	.001	↓	-3.0 (mg/L)/yr	6.0
Load	-.448	.006	↓	-1.8 lb/yr	2.3

Table 13. Seasonal Kendall test results for nitrogen (as N) and phosphorus (as P) constituents in base flow for water years 1986–91 at (A) site 1 (upstream from the water-quality gage), (B) site 2 (at the water-quality gage), and (C) site 4 (downstream from the water-quality gage), Brush Run Creek Basin--Continued

Constituent	Kendall's tau		Significance	Estimate of slope	Median
	tau	p			
		B. SITE 2 (AT WATER-QUALITY GAGE)			
Base flow (ft^3/s)	0.087	0.454	0	0.0 (ft^3/s)/yr	0.03
Total nitrogen					
Concentration	-.087	.481	0	-.294 (mg/L)/yr	14
Load	-.087	.482	0	-.341 lb/yr	5.5
Nitrite plus nitrate					
Concentration					
Total	--	--	--	--	--
Dissolved	-.015	.947	0	-.093 (mg/L)/yr	5.5
Load					
Total	--	--	--	--	--
Dissolved	.054	.691	0	.096 lb/yr	1.1
Ammonia nitrogen					
Concentration					
Total	-.101	.406	0	-.167 (mg/L)/yr	2.0
Dissolved	-.115	.354	0	-.184 (mg/L)/yr	1.8
Load					
Total	-.145	.225	0	-.058 lb/yr	.69
Dissolved	-.177	.145	0	-.061 lb/yr	.63
Organic nitrogen					
Concentration					
Total	-.179	.134	0	-.110 (mg/L)/yr	1.8
Dissolved	-.077	.547	0	-.025 (mg/L)/yr	1.6
Load					
Total	.022	.896	0	.007 lb/yr	.84
Dissolved	.029	.846	0	.037 lb/yr	.73
Phosphorus					
Concentration					
Total	-.283	.015	↓	-.070 (mg/L)/yr	.46
Dissolved	-.138	.249	0	-.038 (mg/L)/yr	.40
Ortho	-.222	.063	0	-.035 (mg/L)/yr	.32
Load					
Total	-.072	.567	0	-.010 lb/yr	.16
Dissolved	-.015	.949	0	-.002 lb/yr	.22
Ortho	.046	.741	0	.002 lb/yr	.12
Suspended sediment					
Concentration	-.492	.001	↓	-2.6 (mg/L)/yr	12
Load	-.113	.374	0	-.27 lb/yr	4.6

Table 13. Seasonal Kendall test results for nitrogen (as N) and phosphorus (as P) constituents in base flow for water years 1986–91 at (A) site 1 (upstream from the water-quality gage), (B) site 2 (at the water-quality gage), and (C) site 4 (downstream from the water-quality gage), Brush Run Creek Basin --Continued

Constituent	Kendall's tau		Significance	Estimate of slope	Median
	tau	p			
C. SITE 4 (DOWNSTREAM FROM THE WATER-QUALITY GAGE)					
Base flow (ft^3/s)	-0.271	0.124	0	0.015 (ft^3/s)/yr	0.03
Total nitrogen					
Concentration	.333	.061	0	4.15 (mg/L)/yr	21.6
Load	-.174	.371	0	-1.99 lb/yr	6.7
Nitrite plus nitrate					
Concentration					
Total	--	--	--	--	--
Dissolved	.196	.295	0	1.75 (mg/L)/yr	14
Load					
Total	--	--	--	--	--
Dissolved	-.227	.240	0	-1.28 lb/yr	3.5
Ammonia nitrogen					
Concentration					
Total	.174	.371	0	.175 (mg/L)/yr	.64
Dissolved	.022	1.0	0	.008 (mg/L)/yr	.52
Load					
Total	-.200	.218	0	-.011 lb/yr	.04
Dissolved	-.180	.361	0	-.028 lb/yr	.03
Organic nitrogen					
Concentration					
Total	.114	.598	0	.054 (mg/L)/yr	1.5
Dissolved	.159	.429	0	.097 (mg/L)/yr	1.3
Load					
Total	-.136	.514	0	-.079 lb/yr	.756
Dissolved	-.136	.513	0	-.087 lb/yr	.653
Phosphorus					
Concentration					
Total	-.140	.614	0	-.073 (mg/L)/yr	.365
Dissolved	.021	1.0	0	.010 (mg/L)/yr	.390
Ortho	-.109	.607	0	-.010 (mg/L)/yr	.290
Load					
Total	-.304	.097	0	-.102 lb/yr	.146
Dissolved	-.261	.160	0	-.110 lb/yr	.134
Ortho	-.205	.292	0	-.053 lb/yr	.101
Suspended sediment					
Concentration	-.273	.144	0	-1.33 (mg/L)/yr	7.2
Load	-.409	.026	↓	-1.80 lb/yr	1.8

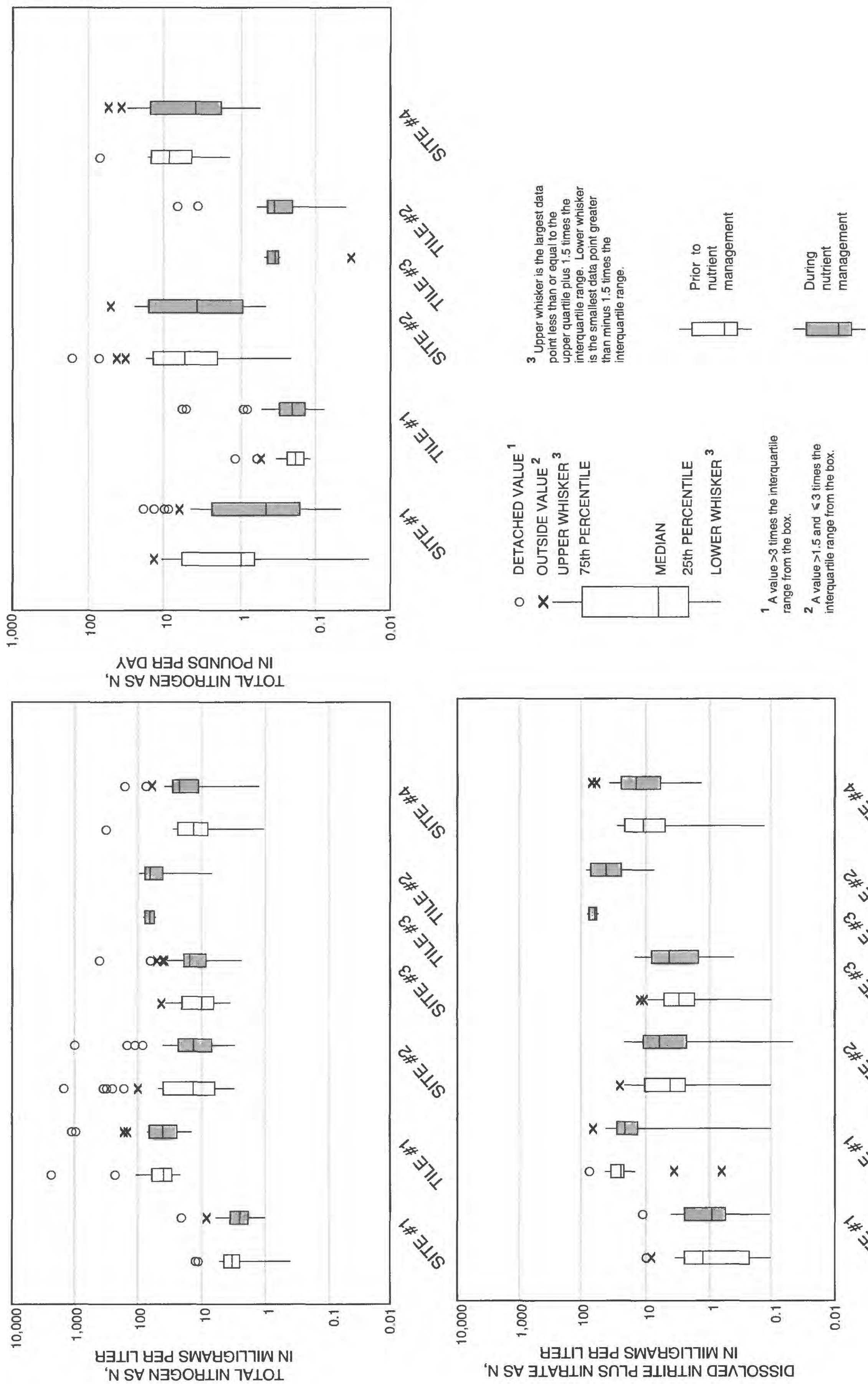


Figure 14. Distribution of concentrations and loads of total nitrogen, and dissolved nitrite plus nitrate in base flow prior to and during nutrient management at Brush Run Creek.

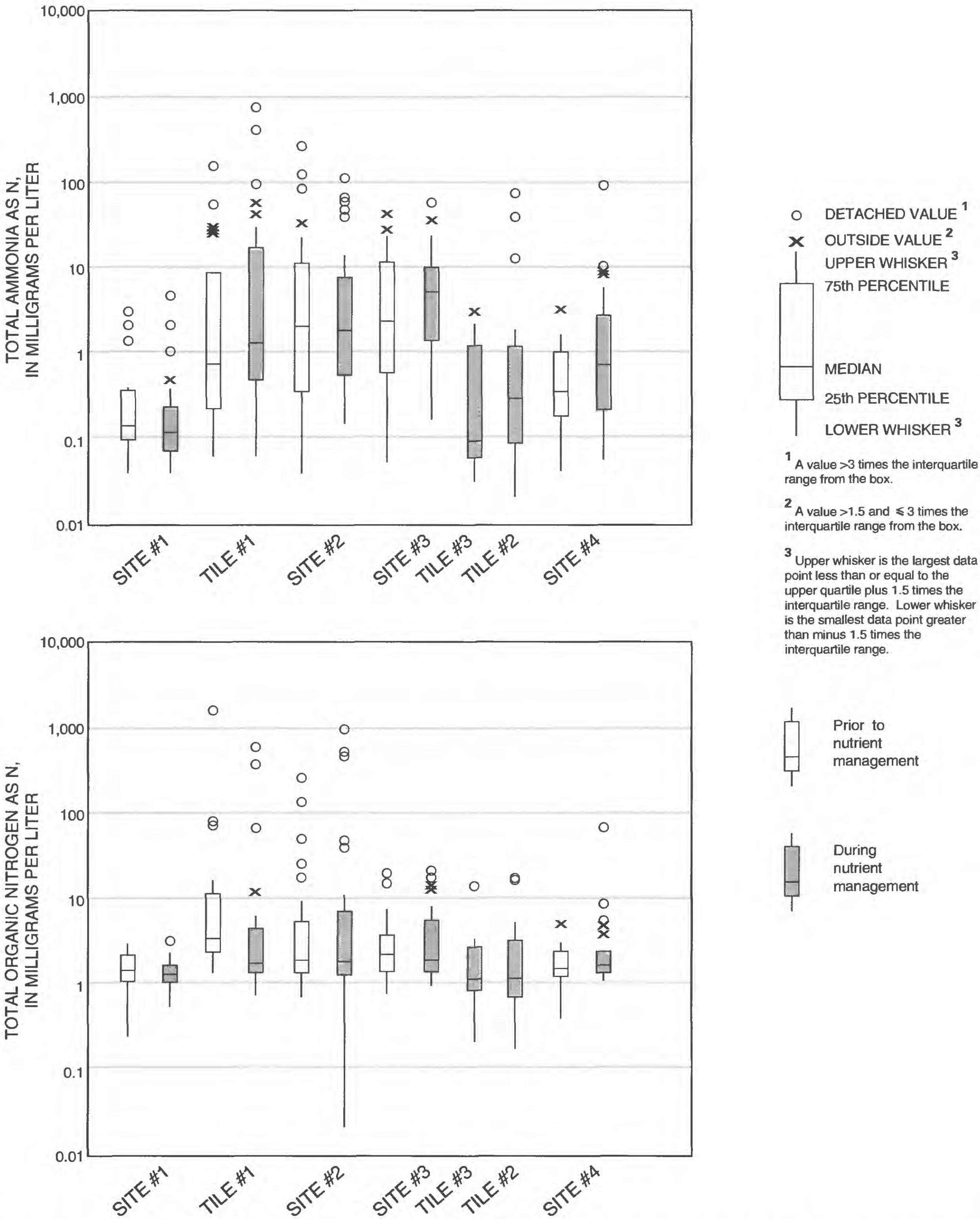


Figure 15. Distribution of concentrations of total ammonia and total organic nitrogen in base flow prior to and during nutrient management at Brush Run Creek.

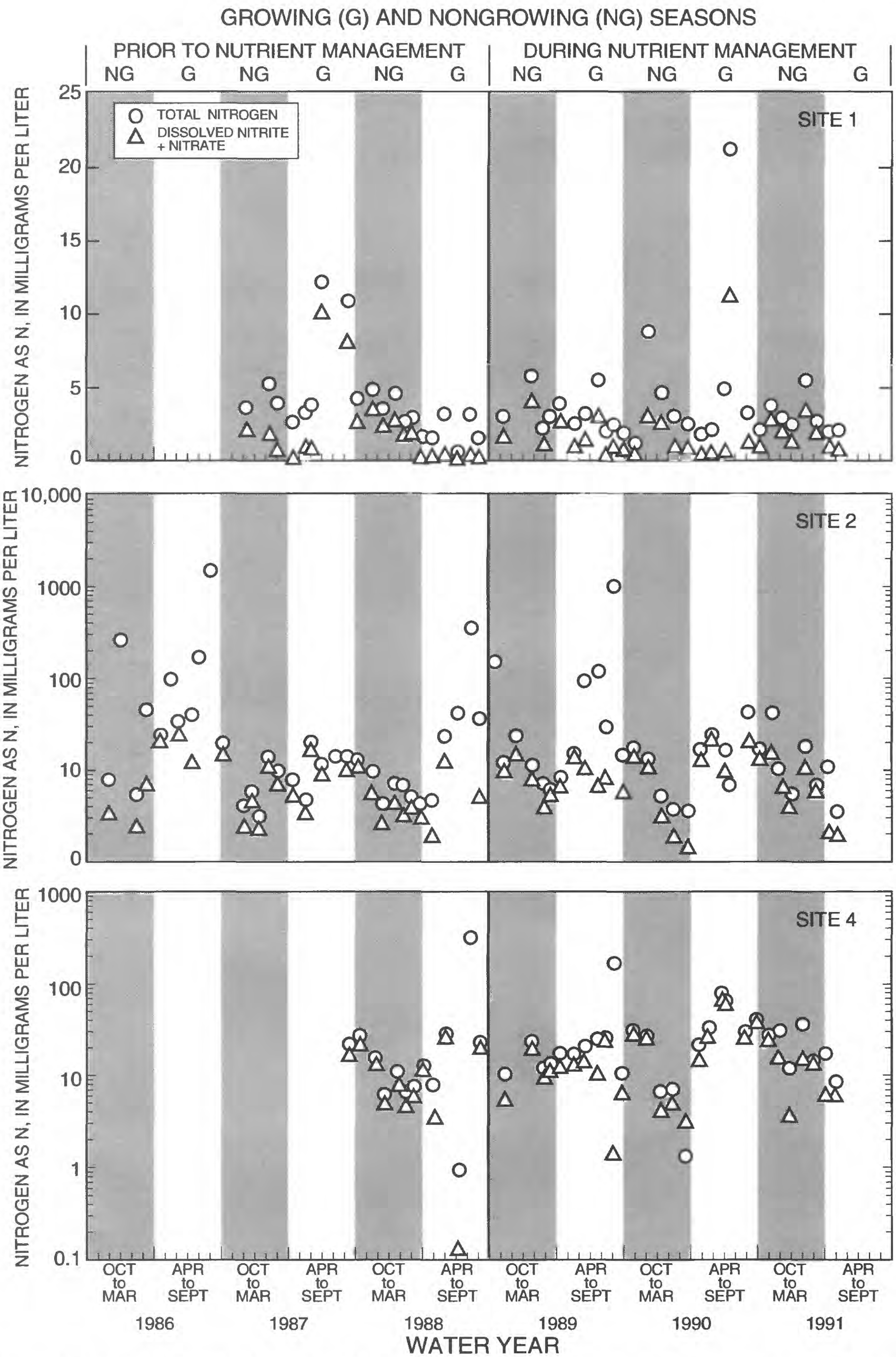


Figure 16. Total nitrogen and dissolved nitrite plus nitrate concentrations in base flow upstream from the water-quality gage (site 1), at the water-quality gage (site 2), and downstream from the water-quality gage (site 4).

those in other similar agricultural studies at Bald Eagle Creek and the Little Conestoga Creek studies. At Brush Run Creek, concentrations of total nitrogen and dissolved nitrite plus nitrate were usually at a maximum at sites 1, 2, and 4 during the summer and at a minimum during the winter (fig. 16). Usually in agricultural basins, maximum concentrations are measured in the winter when plants are dormant and minimums are measured in the growing season when nitrogen uptake is at a maximum. This seasonal reversal at Brush Run Creek probably occurred for two reasons: (1) 81 percent of the nitrogen that was applied upstream from site 2 was applied between the months of May and July (table 4), and (2) concentrations and loads from the tile lines generally were highest during the growing season.

Site 3 (pond site), located downstream from site 2, was established to determine if leakage from the lagoon was entering the stream through ground-water flow. On the basis of base-flow results from sites 2 and 3, it was determined leakage from the lagoon did not occur.

A series of tile lines existed between sites 3 and 4 (most downstream site) (fig. 4). Sampling at tile 2 began during nutrient management when the basin was expanded to include the lower fields receiving lagoon waste, after realizing the effect of tile 1 on water quality at site 2 (water-quality gage). Median concentrations of total nitrogen and dissolved nitrite plus nitrate were 70 and 42 mg/L, respectively. In November 1990, sampling began at tile 3 (fig. 4) when the farmer replaced a collapsed tile line between site 3 and tile 2. Median concentrations of total nitrogen and dissolved nitrite plus nitrate at site 3 were 68 and 63 mg/L, respectively. Sample analysis from the lagoon and lagoon spray, the primary source of nutrients in the tile drains, showed ammonia and organic nitrogen comprised greater than 95 percent of the total nitrogen. Only 20 percent of the total nitrogen concentration was dissolved nitrite plus nitrate at tile 1. At tiles 2 and 3, 79 and 94 percent of the total nitrogen concentration were dissolved nitrite plus nitrate, suggesting a slower transport time of nutrients through the soil into tiles 2 and 3, thus allowing ammonia and organic forms of nitrogen to convert to dissolved nitrite plus nitrate. Because of little variability in the water discharges from the tile lines, median loads of total nitrogen from the tile lines generally were the same: 0.18 and 0.21 lb/day prior to and during nutrient management, respectively, at tile 1, and 0.37 and 0.36 lb/day during nutrient management at tiles 2 and 3, respectively (fig. 16). Two additional tile lines 4 and 5 (fig. 4) were sampled six times during nutrient management; however, the limited data were not included in the study.

At site 4 (most downstream site), median concentrations of total nitrogen and dissolved nitrite plus nitrate increased from 14 and 11 mg/L to 22 and 14 mg/L (table 13) (fig. 14), respectively, similar to the increases observed at site 2. Median loads of total nitrogen at site 4 decreased from 8.3 to 4.2 lb/day during nutrient management, similar to the decreases measured at surface-water sites 1 and 2, probably because of the significant decreases in precipitation during the growing season in the nutrient-management period.

Median concentrations of total and dissolved phosphorus and orthophosphorus were always lowest at site 1, and higher at site 4 (compared to site 1) (table 13) (fig. 17), regardless of season, water year, or management period. The highest concentrations of total phosphorus measured prior to and during nutrient management were 40 and 160 mg/L, both from tile 1. The maximum dissolved phosphorus load, 8.6 lb/day, was at tile 1. The maximum concentrations of total phosphorus measured at tiles 2 and 3 were 6.7 and 0.97 mg/L, respectively. Concentrations of total phosphorus ranged from 0.01 to 30 mg/L at the surface-water sites.

Phosphorus concentrations and loads were elevated at tile 1 for two reasons. First, chicken manure, which occasionally leaked from the chicken house to the discharge area for tile 1, contained 10 lb/ton of phosphorus; whereas hog waste, which was applied to fields draining tiles 2 and 3, contained 4.8 lb/ton (Pennsylvania Department of Environmental Resources, 1986), and second, phosphorus concentrations in the soils were highest in the fields near tile 1 (fig. 14). Although median total phosphorus concentrations and discharges decreased at all sampling locations (except site 3) at Brush Run Creek, significant decreases occurred only in total phosphorus concentrations at site 1 (0.24 to 0.16 mg/L), and site 2 (0.53 to 0.34 mg/L) (table 13), probably as a result of a 61-percent reduction in phosphorus applications during nutrient management to fields upstream from site 2 (table 5). A longer sampling time may be needed for significant reductions to occur below site 2, where phosphorus applications were reduced 53 percent.

Median concentrations of suspended sediment were consistently greater in the growing season than the nongrowing season at sites 1, 2, and 4 (table 13) when the soils are most susceptible to erosion from plowing and planting. The highest sediment concentration during the study was 3,530 mg/L, measured at tile 1 (specific conductance of 9,750 µS/cm) and was the result of water leaking from the chicken house. Significant decreases occurred during nutrient management in suspended-sediment concentrations and loads at site 1, suspended-sediment concentrations at site 2, and suspended-sediment loads at site 4 (fig. 18).

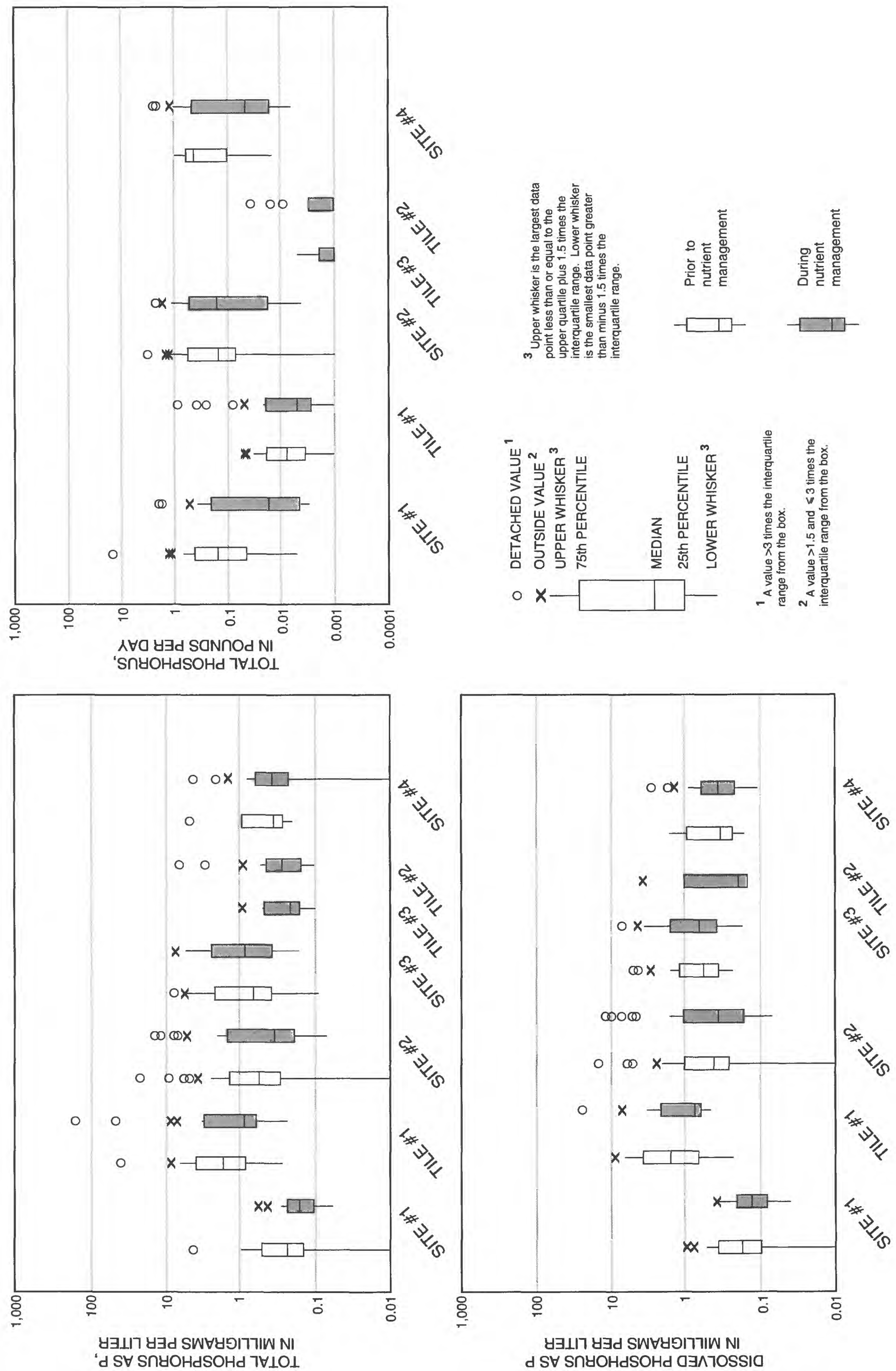


Figure 17. Distribution of total phosphorus concentrations and loads, and dissolved phosphorus concentrations in base flow prior to and during nutrient management at Brush Run Creek.

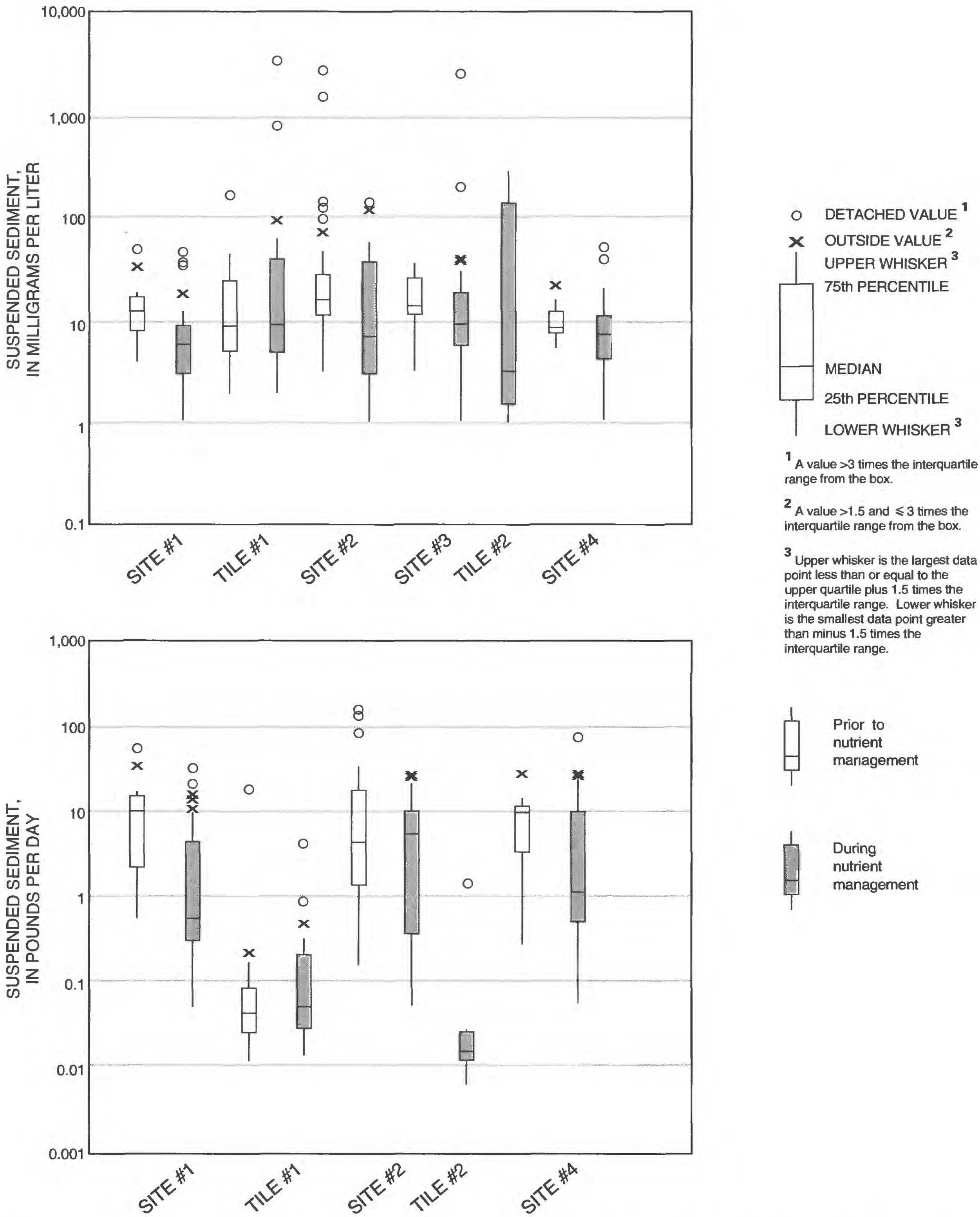


Figure 18. Distribution of suspended-sediment concentrations and loads in base flow prior to and during nutrient management at Brush Run Creek.

Significant decreases in suspended sediment probably resulted from (1) the farmer changing cropland into pasture near the sampling location for site 1 (fig. 6), (2) a significant decrease in precipitation in the growing seasons during nutrient management, and (3) a 34-percent reduction in land planted in corn (table 1) during nutrient management. Although at site 2 (water-quality gage), median suspended-sediment concentrations were 16 and 7 mg/L prior to and during nutrient management, respectively, concentrations of suspended sediment at Brush Run Creek were lower than concentrations measured in other intensively farmed basins in Pennsylvania. For example, Koerkle and others (U.S. Geological Survey, written commun., 1992) reported that, at the 1.42-mi^2 Nutrient-Management Subbasin in the Little Conestoga Creek headwaters (site 3, fig. 1), concentrations of suspended sediment in base flow ranged from 3 to 136 mg/L from April 1984 through September 1989; the median concentration was 17 mg/L.

To summarize, generally all median concentrations and loads of nutrients in base flow increased from site 1 to site 2, probably because of influences of tile 1. All median concentrations and loads in base flow were greater at site 4 that at site 1, probably because of increases in ground-water nitrate concentrations along the reach of Brush Run Creek (figs. 16–18).

Because the tile lines had the greatest effect on the concentrations and discharges of nutrients and suspended sediment at Brush Run Creek, attempts were made to analyze data collected at site 2 (water-quality gage) when tile 1 was not flowing and effects were at a minimum. On nine occasions during nutrient management, base-flow samples were collected at site 2 when tile 1 was not flowing. Trend analysis could not be made on the limited data collected. However, median concentrations and discharges of total nitrogen, total phosphorus, and suspended sediment were compared between site 2 and tile 1 (table 14). All median concentrations of total nitrogen, total phosphorus, and suspended sediment were greater at site 2 when tile 1 was not flowing; median discharges of total nitrogen, total phosphorus, and suspended sediment were greater at site 2 when tile 1 was flowing.

The unexpected increases in median concentrations of total nitrogen, total phosphorus, and suspended sediment at site 2 when tile 1 was not flowing occurred under dry conditions, when base-flow samples were obtained from nutrient-rich pools of water trapped behind site 2. As the water evaporated in these trapped pools, the nutrients were concentrated. These pools of trapped waters would form "slugs" of nutrient-rich material, available to be flushed away during the next rise in streamflow. The effects of these "slugs" on stormflow will be discussed later.

Table 14. Differences in median concentrations and discharges of total nitrogen, total phosphorus, and suspended sediment at site 2 when tile 1 was flowing and not flowing. Samples obtained from pooled water at tile 1 when not flowing

[Concentration is in milligrams per liter; discharge is in pounds per day]

Flow type	Total nitrogen	Total phosphorus	Suspended sediment
Median concentration			
Tile 1 flowing	14	0.34	7
Tile 1 not flowing	16	.97	34
Median discharge			
Tile 1 flowing	4.0	.24	5.3
Tile 1 not flowing	.07	.02	.52

Similar comparisons between tiles 2 and 3 and site 4 could not be made because the tiles were flowing on all base-flow sampling days.

Monthly and annual base-flow loads were calculated at site 2 (water-quality streamflow gage), where continuous streamflow was measured and is needed for input into the 7-parameter log-linear model described earlier (equations 1 and 2). Appendix 2 lists the parameter values used to calculate base-flow concentrations and loads by use of the 7-parameter log-linear model. The reported T values are a measure of the significance of the parameter in the model. A T value with an absolute value greater than 2 was considered to be significant. Note that in the nutrient-management period when precipitation decreased, generally the coefficients that account for seasonality (β_5 and β_6) also decreased or became insignificant. Because of equal sampling periods prior to and during nutrient management, the time parameter (β_3), was constant for calculating the concentrations and loads for each distinct constituent.

The model explained between 12 to 50 percent of the variability observed in the logarithms of the constituent concentrations in base flow prior to nutrient management, and between 22 to 56 percent during nutrient management. The model also explained between 33 to 65 percent of the variability observed in the logarithms of the constituent loads in base flow prior to nutrient management, and between 54 to 66 percent during nutrient management. The use of the model added uniformity in method among other projects for the Chesapeake Bay Program that are also using the model to calculate loads.

The monthly and annual summary (table 15) of nutrient and sediment loads in base flow lists the loads prior to and during nutrient management by season and water year.

During nutrient management, estimated monthly and annual loads in base flow decreased for total nitrogen, dissolved nitrite plus nitrate, total ammonia plus organic nitrogen, total and dissolved phosphorus and orthophosphorus; only suspended-sediment loads increased (table 15). Of the 16,003 lb of total nitrogen estimated to be discharged in base flow, 36 percent was dissolved nitrite plus nitrate. The percentage of dissolved nitrite plus nitrate to total nitrogen varied greatly by season and water year during the study. The percentage was 26 and 45 percent for the growing and nongrowing seasons, respectively, and varied from 13 to 48 percent during water years 1986 and 1989 (table 15). Dissolved nitrite plus nitrate loads increased from about 2,684 lb prior to nutrient management, to 3,091 lb during nutrient management, probably because of the significant decreases in precipitation, especially during the growing seasons, allowing nutrients in the soils and in pools of water behind the weir at site 2 to transform from ammonia to dissolved nitrite plus nitrate nitrogen.

At Bald Eagle Creek, the percentage of dissolved nitrite plus nitrate to total nitrogen was about 84 percent and varied little by season or year (Langland and Fishel, 1995). These differences in percentages of dissolved nitrite plus nitrate to total nitrogen between Brush Run Creek and Bald Eagle Creek are because of greater discharges of total ammonia plus organic nitrogen. Total ammonia plus organic nitrogen comprised between 54 to 61 percent of the total nitrogen at Brush Run Creek, the source of which was the tile lines, or overflow from the lagoon into the stream. Total ammonia plus organic nitrogen comprised less than 15 percent of the total nitrogen at Bald Eagle Creek.

Differences between the growing and nongrowing seasons were difficult to determine, primarily because of variability in nutrient concentrations discharged from tile 1. However, during the 1991 growing season when precipitation was 44 percent below normal (table 7), all constituent loads were less during the nongrowing season.

About 518 lb of total phosphorus and 368 lb of dissolved phosphorus were discharged in base flow prior to nutrient management, and about 379 and 273 lb of total and dissolved phosphorus, respectively, were discharged during nutrient management (table 15). Total and dissolved phosphorus loads decreased 27 and 26 percent, respectively, during nutrient management, probably because of a 61-percent reduction in phosphorus applications to fields upstream from site 2. About 71 percent of the 898 lb of the total phosphorus discharged in base flow during the 6-year study was dissolved phosphorus and 54 percent was orthophosphorus. Percentages of total and dissolved phosphorus loads showed less variability by management phase, season, and year than nitrogen loads. The percentages of dissolved to total phosphorus were 71 and 72 percent prior to and during nutrient management, 70 and 72 percent for the growing and nongrowing seasons, and ranged from 48 to 79 percent in water years 1990 and 1986, respectively.

A total of about 17,095 lb of suspended sediment was discharged in base flow prior to nutrient management, and about 8,050 lb was discharged in base flow during nutrient management (table 15). This decrease in sediment transport coincided with the rotation of 34 percent of the cropland from corn to alfalfa, soybeans, and pasture (table 1) and the significant decrease in precipitation during the growing seasons during nutrient management. Thus, less soil was exposed from plowing and planting and ultimately available for erosion and transport to the stream.

More precise predictions of total nitrogen, nitrite plus nitrate, ammonia plus organic nitrogen, phosphorus, and suspended-sediment loads by use of any model on small watersheds like Brush Run Creek probably should include additional variables such as precipitation, runoff, soil moisture, and manure and fertilizer applications.

Targets for Detecting Changes in Water Quality

Nutrient-management practices at Brush Run Creek were not designed to affect streamflow or stream velocities, and because the amount and timing of precipitation cannot be controlled, water quality could only be improved by reducing concentrations in the water. Without knowledge of long-term levels in nutrient applications and land use, the effects between changes in nutrient applications and detected changes in water quality by use of statistical methods is difficult. Fishel and others (1991) used the seasonal rank-sum test to establish target goals to show the magnitude of reductions in concentrations and discharges of nutrients and suspended sediment in base flow needed to result in statistically significant changes in water quality. These estimates were made by use of the measured variation from the pre-management data. Then, using water-quality data collected during the nutrient-management period, comparisons were made of the estimated and actual measured changes (reductions or increases) in nutrient concentrations and discharges. Because nutrient applications, cropping patterns, and precipitation were constantly changing, and knowing

Table 15. Nitrogen, phosphorus, and suspended-sediment loads in base flow at Brush Run Creek prior to (October 1985-September 1988) and during (October 1988-September 1991) nutrient management

[Loads are in pounds]

Month	Year	Base flow (inches)	Loads						
			Total nitrogen	Dissolved nitrite plus nitrate	Total ammonia plus organic	Total phosphorus	Dissolved phosphorus	Dissolved ortho-phosphorus	Suspended sediment
					Nongrowing season				
October	1985	0.03	120	7	100	3.8	3.4	2.4	190
	1986	.03	120	16	90	4.0	2.5	2.0	140
	1987	.02	120	27	81	4.4	2.4	1.8	120
	1988	.16	230	75	150	27	16	15	350
	1989	.09	100	28	62	3.1	1.8	1.2	48
	1990	.06	110	23	70	4.4	2.4	1.6	61
November	1985	.51	340	29	140	11	8.1	9.6	550
	1986	.70	550	120	260	27	19	18	1,200
	1987	.25	270	110	170	18	13	11	620
	1988	.52	400	180	210	32	26	21	700
	1989	.05	74	32	41	2.1	1.0	.77	43
	1990	.07	87	31	55	3.2	1.7	1.3	59
December	1985	.16	140	24	91	6.3	6.1	5.8	450
	1986	.33	260	100	150	15	13	11	920
	1987	.21	180	95	85	8.4	6.4	4.9	400
	1988	.50	300	130	160	20	17	15	580
	1989	.01	58	31	22	.87	.40	.38	23
	1990	.69	260	120	130	11	4.2	3.6	230
January	1986	.02	45	15	25	.66	.55	.52	67
	1987	1.2	570	340	220	20	16	14	1,100
	1988	.14	94	43	49	3.6	2.7	2.2	200
	1989	1.2	440	270	170	19	18	15	640
	1990	.91	320	150	160	14	4.8	4.3	460
	1991	.81	280	160	120	9.5	3.9	3.6	220
February	1986	.07	56	21	34	1.6	1.5	1.3	170
	1987	.66	310	190	120	11	7.4	7.3	700
	1988	.85	370	200	160	15	10	9.4	740
	1989	1.1	370	210	160	15	14	13	540
	1990	.49	170	84	86	7.2	2.6	2.6	240
	1991	.20	54	22	30	1.6	1.2	1.3	49
March	1986	.17	110	35	70	4.3	4.2	3.2	400
	1987	.18	110	70	40	4.7	3.8	2.8	330
	1988	.42	210	110	100	11	8.3	5.7	540
	1989	2.3	900	560	340	34	28	26	950
	1990	.16	89	41	43	3.1	1.3	1.3	93
	1991	.50	180	80	100	7.9	6.3	6.6	190
Subtotal			8,397	3,779	4,094	384.73	278.95	246.47	14,313
					Growing season				
April	1986	.07	78	19	57	2.9	2.8	1.5	210
	1987	1.2	480	190	150	15	7.6	7.0	590
	1988	.45	290	140	140	20	15	8.8	740
	1989	1.4	790	400	380	42	36	30	1,000
	1990	.16	64	27	36	2.2	1.1	1.1	56
	1991	.24	120	42	73	5.8	5.6	5.5	110

Table 15. Nitrogen, phosphorus, and suspended-sediment loads in base flow at Brush Run Creek prior to (October 1985-September 1988) and during (October 1988-September 1991) nutrient management--Continued

Month	Year	Base flow (inches)	Loads						
			Total nitrogen	Dissolved nitrite plus nitrate	Total ammonia plus organic	Total phosphorus	Dissolved phosphorus	Dissolved ortho-phosphorus	Suspended sediment
					Growing season--Continued				
May	1986	0.04	93	14	72	3.4	2.7	1.6	170
	1987	.11	140	38	100	9.6	7.0	3.9	330
	1988	1.0	890	370	510	69	45	28	1,600
	1989	.72	360	150	210	24	20	15	490
	1990	.10	99	30	68	5.1	2.8	2.3	86
	1991	.04	61	14	39	2.6	2.3	2.1	21
June	1986	.03	110	10	95	40	2.8	1.7	140
	1987	.02	100	18	80	3.9	2.1	1.3	98
	1988	.04	130	34	93	7.1	4.4	2.1	150
	1989	.05	100	27	70	4.4	4.1	3.1	61
	1990	.03	91	19	62	3.0	2.0	1.5	36
	[1]1991	.00	(80)	(10)	(56)	(4.3)	(3.8)	(3.1)	(22)
July	1986	.03	150	10	140	6.7	4.6	2.7	200
	1987	.02	150	18	120	6.8	3.7	2.2	140
	1988	.05	200	32	160	16	11	4.4	260
	1989	.06	140	25	100	7.0	6.5	3.9	86
	1990	.06	150	21	120	9.7	5.7	3.4	100
	1991	.01	100	8	90	6.4	4.2	3.7	29
August	1986	.06	190	12	170	12	8.9	4.9	340
	[1]1987	.00	(160)	(18)	(130)	(7.4)	(3.9)	(2.4)	(140)
	1988	.15	360	51	300	42	30	12	660
	1989	.03	140	22	110	6.2	5.2	2.9	71
	1990	.09	190	23	160	16	7.8	4.2	150
	1991	.01	120	7	89	7.2	4.4	4.2	31
September	1986	.03	160	12	140	7.3	5.0	3.3	220
	1987	.45	810	110	650	99	73	48	2,000
	1988	.06	200	36	160	16	10	4.7	270
	1989	.02	130	23	88	5.0	3.5	2.0	62
	1990	.03	120	16	89	4.9	2.9	1.7	50
	1991	.06	140	10	110	13	8.1	7.3	73
Subtotal			7,606	1,996	5,151	512.6	361.7	234.4	10,831
					Prior to nutrient management				
	1986	1.20	1,592	208	1,134	63.96	50.65	38.52	3,107
	1987	4.92	3,760	1,228	2,110	223.4	159.0	119.9	7,688
	1988	3.64	3,314	1,248	2,008	230.5	158.2	95.0	6,300
Subtotal		9.76	8,666	2,684	5,252	517.96	367.85	253.42	17,095
					During nutrient management				
	1989	8.06	4,300	2,072	2,148	235.6	194.3	161.9	5,530
	1990	2.18	1,525	502	949	71.27	34.2	24.75	1,446
	1991	2.68	1,512	517	896	72.60	44.3	40.8	1,073
Subtotal		12.92	7,337	3,091	3,993	379.47	272.8	227.45	8,049
Grand total		22.68	16,003	5,775	9,245	897.33	640.65	480.87	25,144

[1]Because of program rounding, base flow during the August 1987 and June 1991 growing season was 0.00 ft^3/s. Loads (in parentheses) occurred from sampled pools of high concentrations resulting from tile discharges that were flushed with the next rise in stormflow.

that the data varied differently prior to and during nutrient management, new estimates were made of reductions needed to detect significant changes in base-flow water quality for the entire study period.

The estimated and actual changes required to have the highest probability of detecting a significant change ($p < 0.05$) in base-flow water quality for Brush Run Creek are listed in table 16. Because nutrient management was expected to cause reductions in nutrient concentrations and loads in base flow, a one-tailed test was used to estimate reductions. However, measured changes from table 16 show that some nutrient mean concentrations and loads increased during nutrient management. The measured changes in mean concentrations and mean loads for all nutrient constituents and suspended sediment did not exceed the estimated values required to detect a significant change, and therefore were considered not significant.

Table 17 lists the means, standard deviations, and number of observations of the raw concentration and discharge data collected prior to nutrient management, the entire study period, and the growing and nongrowing seasons, which were used to obtain the estimates for detecting a significant change in water quality. The nonparametric test Univariate (SAS) determined that the data for the entire study period did not approach normality; therefore, log transformations were required of all nutrient data except dissolved nitrite plus nitrate.

The probability of detecting a significant change in base-flow quality when selected reductions in concentrations and loads are achieved was determined by use of a modified form of the nonparametric Wilcoxon (Mann-Whitney) rank-sum test (figs. 19 and 20). The power of the seasonal rank-sum test, ($1-\beta$), represents the probability of rejecting the null hypothesis when, in fact, it is false and the alternative hypothesis is true. The null hypothesis is that there is no difference in the means of the water-quality data collected prior to nutrient management and during nutrient management, when the nutrient-management data are reduced by the indicated percentages. Therefore, the power of the test gives the probability of detecting a change in base-flow quality during the nutrient-management phase if the constituents were reduced by the indicated percentage. At Bald Eagle Creek, greater reductions were required in nutrient loads than nutrient concentrations because of increased variability of load data (Langland and Fishel, 1995), while at Brush Run Creek, variability in nutrient data collected at site 2 from the tile lines made log transformations of the data necessary (table 17).

Power curves for Brush Run Creek require greater reductions in nutrient concentrations and loads than are required at other small watersheds in the Lower Susquehanna River Basin for two reasons. First, the effects of agricultural activities are greater at Brush Run Creek relative to the less intensive basins such as the Forested Subbasin (within Nutrient-Management Subbasin) (fig. 1) and Bald Eagle Creek Subbasin where animal densities are less. Second, at the Brush Run Creek Subbasin, which lies within

Table 16. Estimates of reductions required in mean concentrations and mean loads to achieve statistically significant changes in base-flow water quality in the Brush Run Creek Basin

[Concentrations are in milligrams per liter; loads are in pounds; estimated reductions are in percent]

Constituent	Prior to nutrient management—estimated reductions required			During nutrient management—actual measured changes			Entire study period—new estimated reductions		
	Value	Percent	Change	Value	Percent	Change	Value	Percent	Change
Nitrite plus nitrate, dissolved as N									
Concentration	6.5	-99	-6.4	7.2	+9.7	+0.70	6.9	-42	-2.9
Load	.69	-79	-.54	1.0	+31	+.31	.95	-51	-.48
Nitrogen, total as N									
Concentration	19	-87	-16	16	-16	-3.0	16	-58	-9.3
Load	4.5	-75	-3.4	4.1	-8.9	-.40	4.2	-45	-1.9
Phosphorus, total as P									
Concentration	.69	-65	-.45	.49	-29	-.20	.58	-59	-.33
Load	.17	-75	-.13	.12	-29	-.05	.15	-52	-.08
Phosphorus, dissolved as P									
Concentration	.55	-62	-.34	.57	+.02	+3.5	.56	-54	-.30
Load	.14	-73	-.10	.14	+0	+0	.14	-48	-.07

Table 17. Water-quality characteristics of base-flow data used to generate power curves at Brush Run Creek

[Concentrations are in milligrams per liter; loads are in pounds; standard deviations are in percent except where noted; n, number of samples]

Constituents	Management period				Nongrowing season				Growing season			
		Standard deviation				Standard deviation				Standard deviation		
	Mean	Plus	Minus	n	Mean	Plus	Minus	n	Mean	Plus	Minus	n
Prior to nutrient management												
Nitrite plus nitrate, dissolved as N												
Concentration	6.5	[1]6.3	[1]6.3	32	4.6	[1]9	[1]8	16	7.8	[1]7.4	[1]7.4	16
Load	.69	1,410	93	32	1.2	560	85	16	.34	2,650	96	16
Nitrogen, total as N												
Concentration	19	340	77	32	11	250	72	16	30	370	79	18
Load	4.5	340	78	34	3.7	260	72	16	5.4	440	81	17
Phosphorus, total as P												
Concentration	.69	310	76	34	.38	200	66	16	1.1	350	78	18
Load	.17	490	83	33	.15	650	87	16	.20	380	79	17
Phosphorus, dissolved as P												
Concentration	.55	290	74	33	.31	180	64	16	.93	310	76	18
Load	.14	460	82	33	.12	620	86	16	.16	350	78	17
Entire study period												
Nitrite plus nitrate, dissolved as N												
Concentration	6.9	[1]5.8	[1]5.8	64	6.0	[1]4.3	[1]4.3	32	7.8	[1]7.0	[1]7.0	32
Load	.95	870	90	64	1.9	610	86	32	.48	900	90	32
Nitrogen, total as N												
Concentration	16	250	72	66	11	170	64	32	26	280	74	34
Load	4.2	320	76	66	4.8	270	73	32	3.5	370	79	34
Phosphorus, total as P												
Concentration	.58	310	75	66	.35	200	66	32	.93	350	78	34
Load	.15	490	83	66	.15	580	85	32	.14	410	80	34
Phosphorus, dissolved as P												
Concentration	.56	300	75	66	.34	200	67	32	.91	340	77	34
Load	.14	480	83	66	.15	590	86	32	.13	390	80	34

[1]Results for these constituents come from normal data; all other data are log transformed.

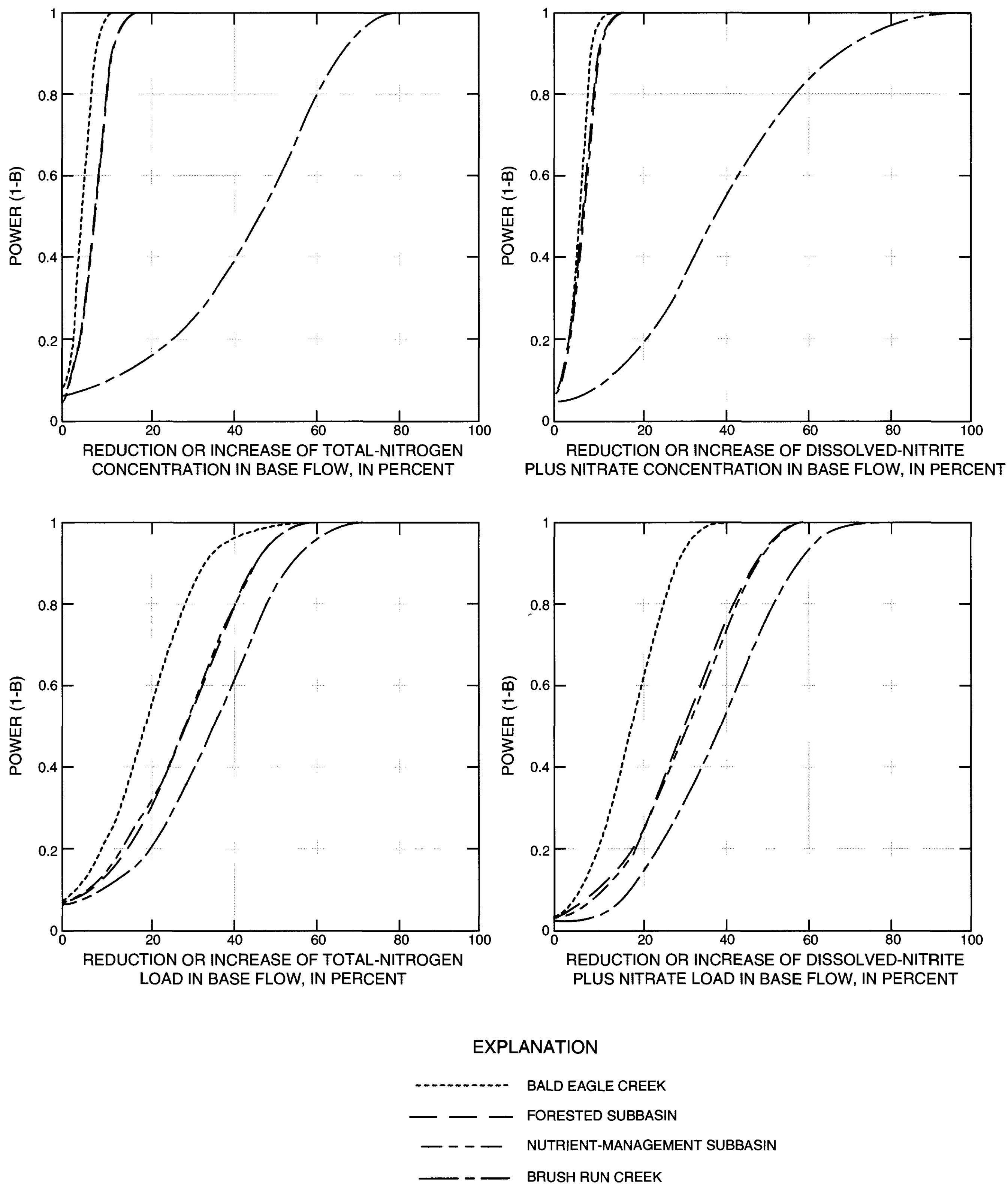


Figure 19. Probability of achieving statistically significant changes in base-flow water quality at selected reductions or increases in total nitrogen and dissolved nitrite plus nitrate concentrations and loads in base flow.

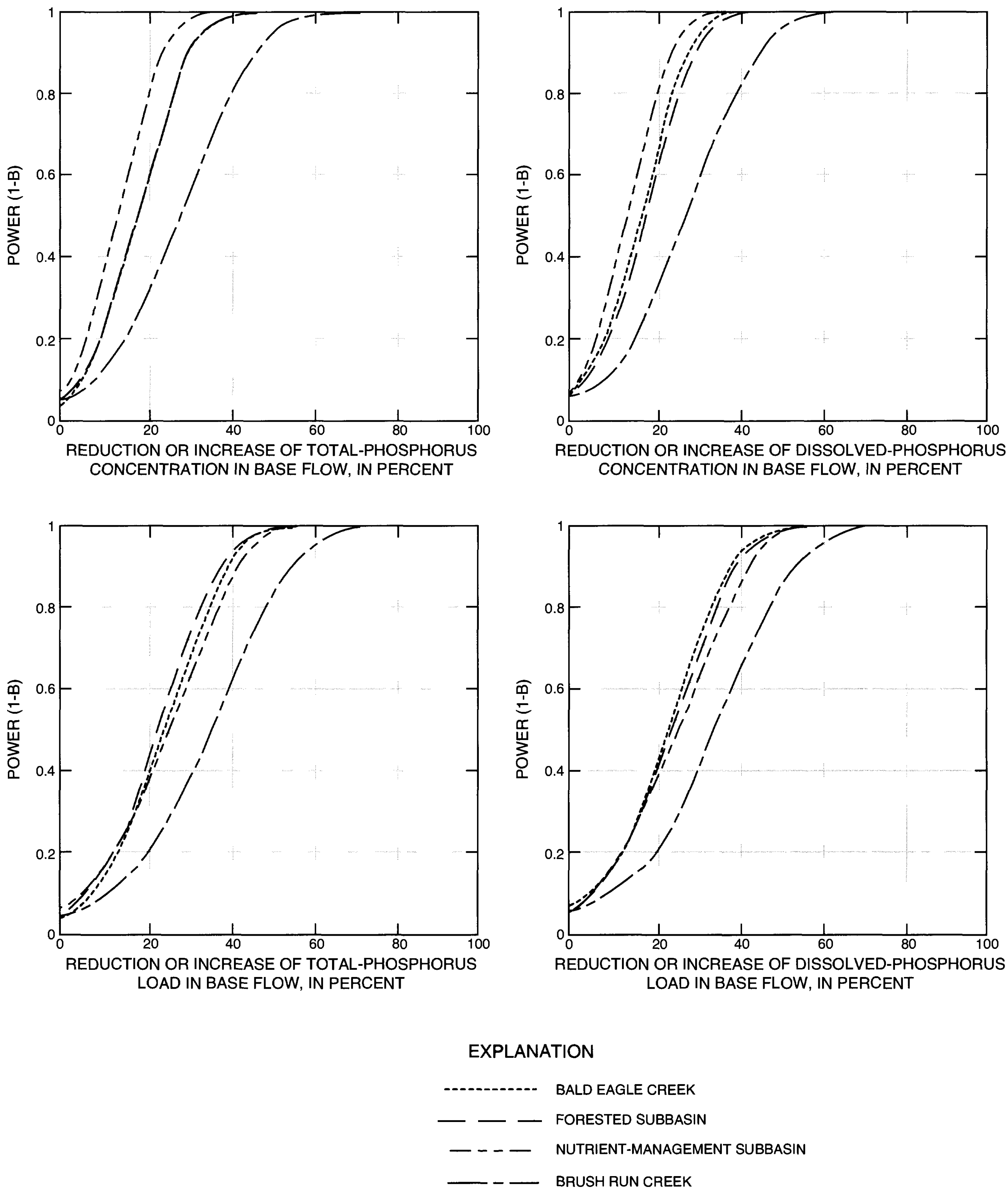


Figure 20. Probability of achieving statistically significant changes in base-flow water quality at selected reductions or increases in total phosphorus and dissolved phosphorus concentrations and loads in base flow.

noncarbonate terrain, and the Nutrient-Management Subbasin, which lies within a carbonate valley, the geology and topography permit longer subsurface transport of ground water through deeper and more nutrient-rich soils before being released as base flow. In contrast, at the Bald Eagle Creek site where steep slopes are composed of schist, like at the RCWP Forested Subbasin where Triassic sandstone ridges are predominant, the geology and topography permit rapid transport of ground water through shallow subsurface soils with little leaching before it is released as base flow. The Forested Subbasin requires the least reduction in nutrient concentrations and loads because of a lack of human activities, and the range and scatter of the water-quality data are typical of other undisturbed subbasins in the Lower Susquehanna River Basin (Lietman and others, 1983).

Although the percentage of required reductions in nutrient discharges in base flow appear large (table 16), they are relatively small in comparison with the amount of nutrients applied to the soil. For example, at Brush Run Creek, a reduction of 45 percent in total nitrogen discharges in base flow is required for an improvement in water quality to be statistically significant (power greater than 0.95, fig. 19). This represents a reduction of 7,200 lb of the 16,003 lb (table 15) discharged in base flow during the 6 years as compared to the 54,690 lb of nitrogen that were applied to the soil from the spreading of manure and applications of commercial fertilizer during the same period.

In addition to statistical testing, the effects of nutrient management on water quality should be evaluated separately for each constituent on the basis of known chemical or physical importance to water quality. Several studies have associated specific concentrations of inorganic nitrogen and total phosphorus with particular environmental conditions. For example, 0.3 mg/L of inorganic nitrogen (nitrite, nitrate, and ammonia), and 0.01 mg/L of phosphorus are critical values which, when exceeded, can stimulate excessive growth of algae in streams (McKee and Wolf, 1963; Harms and others, 1974). MacKenthum (1969) indicates that total phosphorus should not exceed 0.1 mg/L and the USEPA (1986) recommends total phosphorus should not exceed 0.05 mg/L if nuisance growths in free-flowing streams are to be prevented. All of the 615 samples collected at the Brush Run Creek site exceeded the critical value for inorganic nitrogen; only 3 of the 615 samples did not exceed the total phosphorus concentration suggested by MacKenthum (1969). The effects of reducing nitrogen and phosphorus loads on aquatic environments in stream reaches cannot be evaluated at this time because water-quality criteria have not been established for nutrient loadings from nonpoint sources.

Stormflow

Concentrations

Trends in stormflow quality prior to and during nutrient management were difficult to document because of the variability of runoff quantity, influence of tile lines, and because only selected storms were sampled. Table 18 summarizes stormflow data collected by water year.

Table 18. Number of storms, number of sampled storms, number of samples collected (nutrient and sediment), and percentage of total stormflow sampled at the Brush Run Creek site for water years 1986–91

Water year	Total storms	Storms sampled	Number of nutrient samples	Number of sediment samples	Percentage of total stormflow sampled
1986	66	39	66	233	84
1987	75	45	109	260	77
1988	65	34	94	114	87
1989	72	41	109	162	84
1990	53	28	85	79	84
1991	51	27	86	66	58
Total	382	214	549	914	84

Of the 214 storms that were sampled, 87 were during the growing season and 127 were during the nongrowing season. Fewer storms were sampled during the 1990 and 1991 growing seasons because of the significant decrease in precipitation. The 214 storms that were sampled represent the quality and quantity of about 84 percent of the total stormflow discharged from Brush Run Creek during the 6-year study.

Numerous agricultural studies in the Lower Susquehanna River Basin have characterized the relation between nitrogen, phosphorus, and sediment discharge, and water discharge in stormflow. Generally, concentrations of nitrogen, phosphorus, and sediment increased as water discharge increased and peaked just prior to or during peak streamflow (Fishel and others, 1991; Ward, 1985; Lietman and others, 1983; Fishel and others, 1992). The majority of the sampled storms at Brush Run Creek also had increasing nutrient and sediment concentrations closely related to increasing stormflows, suggesting that nitrogen, phosphorus, and sediment were transported from overland runoff and less influenced from a single source (tile line). However, two situations at Brush Run Creek created unique responses in many of the remaining sampled storms.

First, flow did not occur at site 2 (water-quality streamflow gage) about 14 percent of the time during the 6-year study because of either a lack of precipitation or frozen stream conditions. Second, the tile lines were almost continuously delivering nutrients to the stream regardless of flow. When flow did not exist in Brush Run Creek, nutrients would build up in pools formed behind the weir and other low depressions in the streambed. When the next precipitation event occurred, these pools or "slugs" of nutrients would be transported in the stream, usually reaching site 2 after the streamflow peak.

The storm on August 9, 1991 (fig. 21), represents typical nutrient and water discharge fluxes in stormflow when nutrient-rich pools were flushed after extended dry periods at Brush Run Creek. The stormflow peaked at 0400 hours and nitrogen concentrations peaked approximately one hour later. Four hours later, all nutrients had been flushed from the pools in the initial streamflow peak because all nutrients and suspended-sediment concentrations peaked prior to a subsequent stormflow peak. The percentage of ammonia plus organic nitrogen to total nitrogen (fig. 21) varied little during the storm, suggesting a constant source of ammonia plus organic nitrogen upstream from site 2, probably from tile 1. Unlike nitrogen concentrations, phosphorus and sediment concentrations peaked at or near the streamflow peak for two reasons. First, the affinity of phosphorus for sediment particles means a similar relation between concentration and flow; and second, because less phosphorus and sediment are discharged from the tiles, the effects of the nutrient pools from the tiles during stormflow are less.

Table 19 lists the minimum and maximum concentrations of 11 constituents measured in stormflow at site 2. The maximum concentration of total nitrogen in stormflow was 550 mg/L on September 4, 1991. About 73 percent of the nitrogen in that sample was total ammonia. The maximum concentration of total nitrite plus nitrate was 59 mg/L, measured on July 19, 1988; the maximum concentration of total phosphorus was 133 mg/L, measured on July 12, 1987; and the maximum concentration of suspended sediment was 17,400 mg/L, measured on May 10, 1990. The elevated concentrations measured on all dates listed above resulted when pools, rich in nutrients discharged from the tile lines, formed when Brush Run Creek was dry and were flushed out by the rise in streamflow.

Loads

Daily nitrogen, phosphorus, and suspended-sediment loads during storms that were sampled from October 1, 1985, to September 30, 1991, are presented in Appendix 3. The majority of the sampled storms produced medium to high streamflows and represent about 84 percent of the total stormflow discharged during the 6-year study (table 18). The maximum measured daily discharges of total nitrogen, total phosphorus, and suspended sediment were 878, 450, and 53,500 lb, respectively, and probably resulted from the "flushing" of nutrient-rich pools by rising streamflow.

In order to calculate total storm loads, regression equations were developed to estimate loadings for the 112 storm days that were not sampled. Storm days were determined on the basis of an examination of precipitation and streamflow records. The statistics listed in table 20 were derived from regressions between the log of the daily stormflow and the log of the daily load measured in the 214 sampled storms described earlier. Coefficients of determination (R^2) were lower at Brush Run Creek than at Bald Eagle Creek as a result of increased variability in nutrient data because of discharges from the tile lines.

Table 21 summarizes the measured stormflow loads (from Appendix 3) and the estimated stormflow loads by month for water years 1986–91. Discharges of total nitrogen and total phosphorus increased 14 and 44 percent to 12,071 and 3,515 lb, respectively, while nitrogen and phosphorus applications were being reduced 25 and 61 percent (table 5) during nutrient management. Longer sampling periods may be necessary to detect significant improvements in water quality. Discharges of both total nitrogen (56 percent) and phosphorus (60 percent) were greater in the nongrowing season when plants are dormant and nutrients are concentrated in the soil and available to be transported to the stream in runoff. During water year 1989, 24 and 18 percent of the total nitrogen and phosphorus stormflow load for the entire study were transported.

Suspended-sediment discharge increased 41 percent to 496,900 lb during nutrient management (table 21). Sixty-four percent of the suspended sediment was discharged during the growing season. During the growing season, 33 percent of the measured and estimated suspended sediment was discharged in the months of May, when soils are most susceptible to erosion from plowing and planting. Frozen and semi-frozen soils and lack of vegetative cover produced more runoff for a given storm during the winter months than other times of the year. Also, suspended-sediment discharges were usually greater in the winter than other times because higher streamflows were more frequent, scouring stream bottoms and flushing pools of nutrients. During water year 1989, 32 percent of the total suspended sediment load in stormflow was transported.

Monthly stormflow loads were not measured or estimated on seven occasions because of a lack of

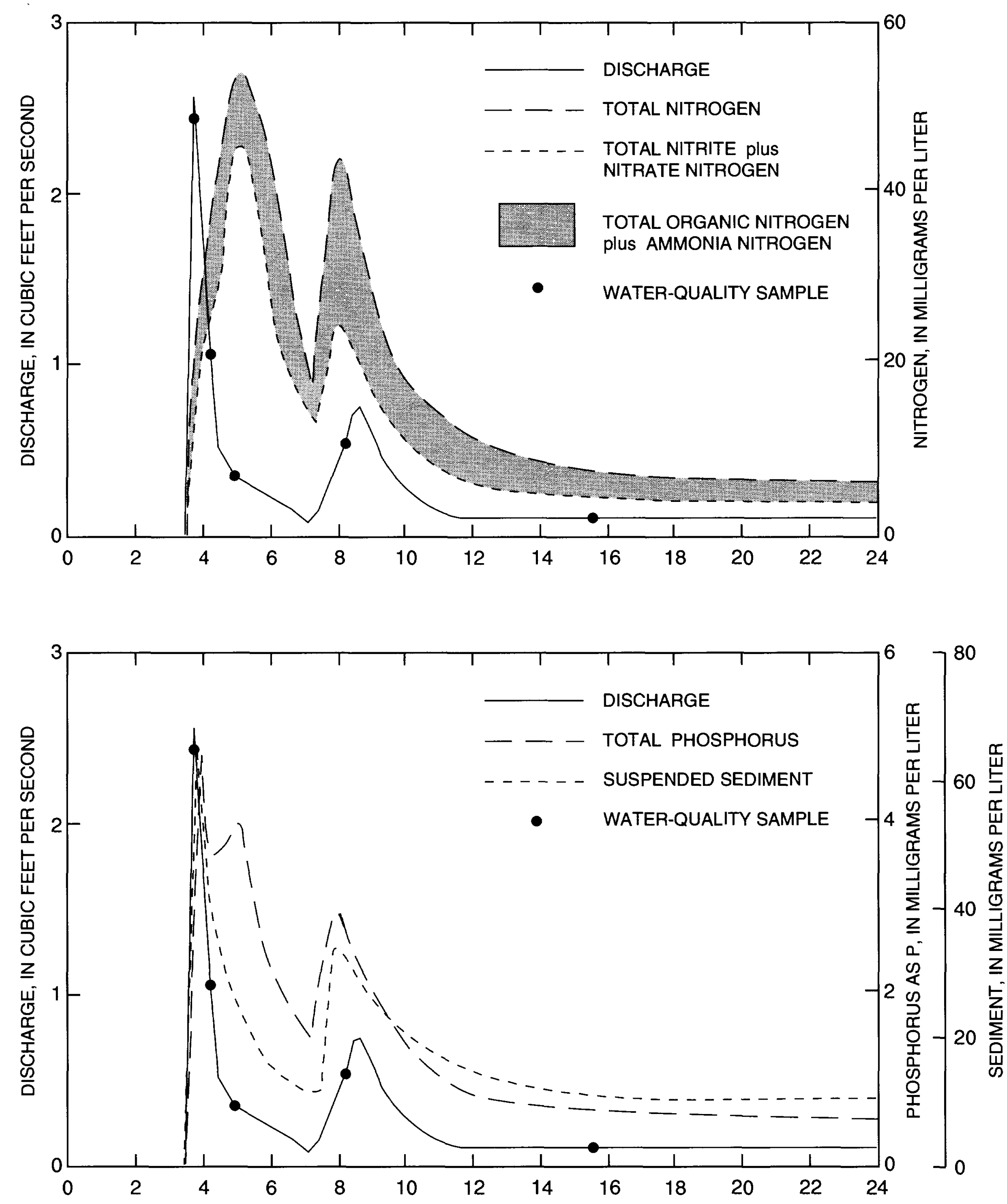


Figure 21. Streamflow hydrograph and concentrations of total nitrogen, nitrite plus nitrate, ammonia plus organic nitrogen, total phosphorus, and suspended sediment on August 9, 1991.

Table 19. Ranges of instantaneous streamflow and constituent concentrations in stormflow at Brush Run Creek site 2 for water years 1986–91

[mg/L, milligrams per liter; n, number of instantaneous samples and discharge; Min, minimum; Max, maximum; --, no data]

Constituent	Statistic	Water year 1986	Water year 1987	Water year 1986	Water year 1989	Water year 1990	Water year 1991
Streamflow	n	281	284	171	224	114	95
(cubic feet per second)	Min-Max	0.01–162	0.01–71	0.01–128	0.01–159	0.02–54	0.01–64
Nitrogen,	n	66	109	94	109	85	86
total as N (mg/L)	Min-Max	2.8–260	2.7–51	2.2–360	1.7–58	1.7–340	2.2–550
Nitrite + nitrate,	n	66	114	98	109	85	86
total as N (mg/L)	Min-Max	0.10–57	0.10–24	0.10–59	0.30–23	0.10–11	0.14–44
Nitrite + nitrate,	n	60	9	16	5	4	--
dissolved as N (mg/L)	Min-Max	0.10–22	1.7–12	0.10–4.6	0.37–1.2	0.97–2.6	--
Ammonia,	n	66	114	98	109	85	86
total as N (mg/L)	Min-Max	0.08–230	0.12–28	0.01–290	0.03–23	0.08–220	0.05–400
Ammonia,	n	60	2	16	5	4	--
dissolved as N (mg/L)	Min-Max	0.04–260	0.15–2.0	0.33–8.0	0.19–2.2	0.21–1.9	--
Ammonia + organic	n	73	111	97	109	85	86
nitrogen, total as N (mg/L)	Min-Max	1.9–260	0.46–46	1.0–360	1.2–49	1.0–330	1.0–550
Ammonia + organic nitrogen,	n	66	9	16	5	4	--
dissolved as N (mg/L)	Min-Max	0.20–260	0.70–4.1	1.4–18	1.3–4.1	1.1–3.3	--
Phosphorus,	n	73	111	98	109	85	86
total as P (mg/L)	Min-Max	0.29–13	0.04–133	0.23–11	0.36–11	0.16–66	0.38–55
Phosphorus,	n	67	9	16	5	5	--
dissolved as P (mg/L)	Min-Max	0.15–7.8	0.22–3.4	0.16–5.0	0.62–1.1	0.46–0.93	--
Orthophosphorus,	n	60	9	16	5	4	--
dissolved as P (mg/L)	Min-Max	0.03–2.5	0.22–2.8	0.12–4.3	0.55–1.0	0.45–0.84	--
Sediment,	n	233	260	114	162	79	66
suspended (mg/L)	Min-Max	1–7,130	1–4,480	9–3,290	11–2,090	6–17,400	2–904

Table 20. Regression statistics for daily nitrogen, phosphorus, and sediment loads as a function of stormflow at the Brush Run Creek site for water years 1986–91

[Constituent loads are in pounds per day; flow is in cubic feet per second]

Dependent variable (log of load) (y)	y = ax + b Slope (a)	Independent variable (log of stormflow) (x)	Intercept (b)	Coefficient of determination (R^2)	Standard error of estimate Log units	Percent Plus	Percent Minus
Total nitrogen	0.658511	Stormflow	1.65509	0.68	0.352	125	55
Total phosphorus	0.827093	Stormflow	.846598	.70	.426	167	26
Suspended sediment	0.923612	Stormflow	2.70103	.55	.599	297	25

Table 21. Measured and estimated nitrogen, phosphorus, and suspended-sediment loads in stormflow at Brush Run Creek for water years 1986–91

[Loads are in pounds]

Water year	Nitrogen			Phosphorus			Suspended sediment		
	Measured	Estimated	Total	Measured	Estimated	Total	Measured	Estimated	Total
1986	1,479	787	2,293	350	121	471	82,740	8,980	91,720
1987	2,836	1,100	3,936	599	174	773	100,770	12,060	112,830
1988	2,895	1,250	4,145	515	205	720	70,880	15,450	86,330
Subtotal	7,210	3,137	10,347	1,464	500	1,964	254,490	36,890	290,880
1989	3,647	1,670	5,317	667	309	976	229,990	21,020	251,010
1990	2,103	837	2,940	915	125	1,040	103,660	9,120	112,780
1991	2,844	970	3,814	1,346	153	1,499	122,060	11,050	133,110
Subtotal	8,594	3,477	12,071	2,928	587	3,515	455,710	41,190	496,900
Grand total	15,804	6,614	28,414	4,392	1,087	5,479	710,100	77,680	787,780

streamflow due to a lack of precipitation (fig. 8). Six of the months with zero stormflow loads were during the growing seasons when precipitation varied from 8 percent above normal to 44 percent below normal (table 7).

Total Loads

During the 6-year study, 38,421 lb of total nitrogen, 6,377 lb of total phosphorus, and 812,924 lb of suspended sediment were discharged in streamflow from Brush Run Creek (table 22). During nutrient management, streamflow discharges of total nitrogen, total phosphorus, and suspended sediment were 19,408, 3,894, and 504,949 lb, respectively, an increase of 2, 36, and 39 percent, respectively. Discharges of total nitrogen, total phosphorus, and suspended sediment in stormflow represented 58, 86, and 97 percent of the total streamflow load for water years 1986–91.

Annual yields of total nitrogen were 24 lb/acre, total phosphorus were 4 lb/acre, and suspended sediment were 513 lb/acre. Similar results were observed at Bald Eagle Creek, where stormflow discharges of total nitrogen, total phosphorus, and suspended sediment accounted for 43, 91, and 99 percent of total streamflow discharges for water years 1986–89. Yields for total nitrogen, total phosphorus, and suspended sediment at Bald Eagle Creek were 20, 1.3, and 762 (lb/acre)/yr, respectively (Langland and Fishel, 1995).

Ground-Water Quality

The quality of ground water is determined by the precipitation quality, the composition of the rock and soil through which it flows, nutrient applications to the soil through which ground water flows, and the amount of time that the water has contact with the rock and soil. Generally, historical data indicate ground water from water-bearing zones in the New Oxford Formation is moderately hard to very hard and high in dissolved solids (Wood and Johnston, 1964). Hardness ranged from 17 to 460 mg/L in 160 ground-water samples collected near the study area between April 1960 and December 1963; the median hardness was 159 mg/L. The pH ranged from 5.7 to 7.8 in 160 ground-water samples; the median was 7.0. Specific conductance ranged from 93 to 1,280 µS/cm in 160 samples; the median specific conductance was 344 µS/cm. Concentrations of nitrate and iron in the ground water were frequently high.

Table 22. Total base flow and stormflow loads for total nitrogen, total phosphorus, and suspended sediment at Brush Run Creek for water years 1986–91

[Loads are in pounds]

Water year	Base flow			Stormflow		
	Nitrogen	Phosphorus	Suspended sediment	Nitrogen	Phosphorus	Suspended sediment
Prior to nutrient management						
1986	1,592	64.0	3,107	2,293	471	91,720
1987	3,760	233.4	7,688	3,936	773	112,830
1988	3,314	230.5	6,300	4,145	720	86,330
Subtotal	8,666	517.9	17,095	10,347	1,964	290,880
During nutrient management						
1989	4,300	235.6	5,530	5,317	976	251,010
1990	1,525	71.3	1,446	2,940	1,040	112,780
1991	1,512	72.6	1,073	3,814	1,499	113,110
Subtotal	7,337	379.5	8,049	12,071	3,515	496,900
Total	16,003	897.4	25,144	22,418	5,479	787,780
Grand totals:						
Nitrogen	38,421					
Phosphorus	6,377					
Suspended sediment	812,924					

Concentrations of nitrate ranged from 1.8 to 124 mg/L in 160 samples; the median concentration was 27 mg/L, almost three times higher than the Maximum Contaminant Level of 10 mg/L set by the USEPA for drinking water. Iron concentrations ranged from 0.03 to 22 mg/L; the median concentration was 0.14 mg/L. The USEPA has set 0.3 mg/L as the Secondary Maximum Contaminant Level for iron in drinking water.

Wells AD650 and 651, located at the site, and water lines inside a chicken house supplied by well AD650 were inspected and sampled during the pre-BMP phase to determine the source of nutrient-rich discharges from the tile drain leading from the chicken house to the stream (fig. 2). During the visual inspection of the automatic waterers in the chicken house, a black precipitate was observed on the seals which prevented many of the nearly 20,000 water-supply units from shutting off. About 16 in. of water had accumulated in the chicken house. This water, along with the chicken manure that had been deposited on the floor of the building, produced a nutrient-rich solution that began to seep out of the chicken house and into the tile drain. Ground-water and surface-water samples were collected on February 11, April 9, and May 19, May 21, and May 26, 1987, and analyzed for selected metals and nutrients to determine the source of the precipitate, and then to determine the effects of a water conditioner installed to correct the problem (table 23).

On February 11, 1987, the concentration of total manganese was 12,000 μg/L at the end of the water line in the chicken house, whereas the concentration was 580 μg/L at the well (AD650) which supplies the chicken house. On April 9, 1987, the concentration of total manganese also was elevated to 1,200 μg/L at the chicken house from the 50 μg/L measured at the well. These results suggest that the black precipitate on the seals was manganese. Near the end of February, the farmer installed a water conditioner to remove manganese. On May 21, 1987, the concentration of manganese decreased from 220 μg/L at the well prior to entering the conditioner in the pump house to 20 μg/L after passing through the conditioner; at the end of the water line in the chicken house, the concentration of total manganese was 10 μg/L. These results indicate that the conditioner was effective in removing the manganese from the ground water. After the conditioner was installed, new seals were installed in the automatic water-supply units. The chicken house remained dry. Nutrient discharges from the chicken house to the tile drain and stream were then reduced.

SUGGESTIONS FOR FURTHER STUDY

As a result of nutrient management in the Brush Run Creek Basin, significant decreases in phosphorus and suspended-sediment concentrations and loads in base flow occurred at three sites during the 6-year study. Nutrient applications reductions totaling 8,308 lb of nitrogen and 7,815 lb of phosphorus were accomplished; however, significant changes were not observed in nitrogen concentrations or loads. Valuable information was gained about the water quality of surface-water processes within a small noncarbonate basin in south-central Adams County, Pennsylvania.

In any future studies relating water quality to nutrient management, the study must be well designed and planned before sampling begins. A longer sampling time (greater than 6 years) may be necessary to assure sampling over a full range of hydrologic conditions and allow water quality to reflect agricultural-activity changes. Extremely wet and dry periods make accurate interpretation of water-quality data difficult because nutrient-transport processes are primarily controlled by precipitation. It is also important that water-quality studies fully incorporate all interactions of surface water and ground water. Only one specific nutrient-management practice should be tested within a watershed during the study. Problems arise with multiple practices occurring simultaneously, because relating the contribution of an individual practice to changes in water quality becomes difficult, if not impossible. Selecting agricultural basins suitable for cause and effect water-quality studies is difficult; sites should be selected to reduce or eliminate possible inputs that introduce uncontrolled data variability. At Brush Run Creek, discharges of nutrients from tile lines and atmospheric deposition of ammonia originating from the manure-storage facility required extensive data analysis and interpretation to reach the objectives of the project. Finally, future studies need to consider soil-nutrient interactions, nutrient-transport mechanisms, and nitrogen transformations with changes in water quality.

Reliable land-use data are critical when trying to relate changes in nutrient management to changes in water quality. Therefore, a cooperative environment must exist between all Federal, State, and local agencies, and landowners. All concerns and implications resulting from the project should be discussed with the landowners as the need arises. Landowners are more likely to be involved in the project if they understand the goals, problems, and results of the study.

Table 23. Water quality of ground water from wells AD650 and AD651, water lines in the chicken house, tile drain 1, and surface-water site 2

[Concentrations are in milligrams per liter and micrograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C]

Station	Date	Water temperature (°C)	Specific conductance (µS/cm)	pH (units)	Nitrogen, total (mg/L)	Nitrite plus nitrate, total (mg/L)	Ammonia, total (mg/L)	Ammonia plus organic nitrogen, total (mg/L)	Iron, total (µg/L)	Iron, dissolved (µg/L)	Sulfate, dissolved (µg/L)	Manganese, total (µg/L)	Manganese, dissolved (µg/L)
AD650													
	11-04-85	--	1,200	--	40	10	14	30	--	--	--	--	--
	10-07-86	--	539	--	--	6.7	.03	--	--	10	--	--	--
	12-10-86	--	--	--	--	--	--	--	--	--	35	--	--
	02-11-87	13.0	925	7.4	--	--	--	--	70	--	45	580	--
	04-09-87	--	--	--	--	--	--	--	--	--	--	50	50
Before conditioner													
	05-21-87	--	--	--	--	--	--	--	--	--	--	220	170
After conditioner													
	05-21-87	--	--	--	--	--	--	--	--	--	--	20	10
AD651													
	12-10-86	--	--	--	--	--	--	--	--	--	33	--	--
	02-11-87	10.5	606	8.0	--	--	--	--	30	39	90	--	
CHICKEN HOUSE WATER LINE													
	02-11-87	9.0	875	7.7	--	--	--	--	990	--	41	12,000	--
	04-09-87	--	--	--	--	--	--	--	--	--	--	1,200	10
	05-21-87	--	--	--	--	--	--	--	--	--	--	10	10
TILE DRAIN 1													
	10-07-86	--	1,380	--	--	91	24	--	--	--	--	--	--
	02-11-87	4.0	960	7.6	29	26	.51	2.9	170	--	71	200	--
	05-19-87	--	2,380	--	15	11	1.2	3.8	--	--	--	--	--
	05-26-87	--	--	--	27	24	.26	3.1	--	--	--	--	--
SURFACE-WATER SITE 2													
	11-04-85	--	349	--	5.9	3.1	.32	2.8	--	--	--	--	--
	10-07-86	--	--	--	32	16	2.0	3.8	--	--	--	--	--
	02-11-87	2.0	301	6.8	8.7	7.1	.18	1.6	400	--	--	30	--
	05-19-87	--	326	--	9.6	4.4	3.0	5.2	--	--	--	--	--
	05-21-87	--	--	--	3.6	.90	.55	2.7	--	--	--	--	--
	05-26-87	--	--	--	5.1	3.4	.30	1.7	--	--	--	--	--

SUMMARY

Hydrologic and land-use data were collected at the Brush Run Creek Study site from October 1985 through September 1991 in cooperation with the SRBC and PaDER as part of the USEPA's Chesapeake Bay Program. This report describes a 0.63-mi^2 watershed underlain by shale, mudstone, and red arkosic sandstone. This study documents and evaluates the effects of agricultural nutrient-management practices on water quality of a small watershed underlain by noncarbonate rock in the Lower Susquehanna River Basin. Data collected for a 3-year period prior to the implementation of agricultural management practices were compared to data collected for 3 years after management practices had been implemented.

About 64 percent of the land is used for cropland, 14 percent is pasture, and the remaining 22 percent is forest, water, or domestic buildings and yards. About 88 percent of the cropland was used for production of corn prior to nutrient management, and only 58 percent of the cropland was planted in corn during nutrient management.

Although farms generally are small in area, animal populations can be large. Prior to nutrient management, the farmer cooperating at the site maintained a population of about 57,000 chickens, 1,460 hogs, and 15 sheep. During nutrient management, average hog population was 1,600 animals, increasing the animal density that is based on crop acreage available for disposal of manure from 0.94 to 1.12 AU/acre, less than the recommended 1.5 AU/acre considered critical for nonpoint-source discharges.

Crop yields ranged from 8 to 100 bushels per acre at fields at Brush Run Creek, substantially less than the 146 bushels per acre reported in the Nutrient-Management Subbasin in Lancaster County. Climatic factors, including severe wind damage and droughts, caused the reduced yields.

Most of the nitrogen and phosphorus was applied as commercial fertilizer between March and June. About 59,340 lb of nitrogen and 13,710 lb of phosphorus were applied as manure and commercial fertilizer prior to nutrient management. About 14 percent less nitrogen and 57 percent less phosphorus were applied during nutrient management. Reductions in nutrient applications were made voluntarily before recommendations were made by a nutrient-management specialist.

About 209 in. of precipitation was recorded at Brush Run Creek during the study. Precipitation was 10 percent lower than normal prior to and 15 percent lower than normal during nutrient management. Prior to nutrient management, the growing seasons (April through September) were 1 percent drier than normal; during nutrient management, the 1989, 1990, and 1991 growing seasons were 3, 8, and 44 percent drier than normal, respectively. About 58 percent of the measured precipitation was discharged in streamflow. It was determined that atmospheric deposition of ammonia from a manure-storage facility could account for 10 percent of the annual nitrogen requirements for corn in the basin.

Soils at the site were greater than 48 in. deep. Soils at Brush Run Creek are similar to those at the Nutrient-Management Subbasin and have the potential to hold a large amount of nutrients. Nitrate nitrogen ranged from 17 to 452 lb/acre and phosphorus ranged from 0.29 to 65 lb/acre in the top 4.0 ft of soil. Concentrations of nitrate were usually higher in the fall after the growing season and phosphorus concentrations were highest in the top 8 in. of soil.

Two wells located on the farm and water lines inside a chicken house were sampled to determine sources of nutrient-rich discharges from tile 1. A black precipitate had formed in the 20,000 automatic water-supply units in the chicken house, preventing many of the water-supply units from shutting off, thus allowing 16 in. of water to accumulate on the floor. Total manganese was 12,000 μg/L in the water line and 580 μg/L in one of the wells. The farmer then installed a water conditioner which lowered the manganese to 10 μg/L in the water line.

Mean daily streamflows ranged from 0.00 to 43 ft^3/s. Prior to nutrient management, streamflow was about 10 percent below normal, and during nutrient management, streamflow was about 6 percent above normal. Nineteen percent of the total streamflow discharge was base flow, ranging from 7 to 27 percent of the annual streamflow discharge. Monthly base flow ranged from 0 to 88 percent of monthly streamflows. The annual maximum instantaneous stormflow peak was 175 ft^3/s.

The Seasonal Kendall test detected significant decreasing trends in base flow for total phosphorus concentrations and suspended-sediment concentrations and discharges at site 1, total phosphorus and suspended-sediment concentrations at site 2, and suspended-sediment discharges at site 4. Significant trends were not detected in either concentrations or discharges of total nitrogen, dissolved nitrite plus nitrate, ammonia, or organic nitrogen at sites 1, 2, or 4.

Concentrations of nutrients in base flow generally increased from upstream to downstream along Brush Run Creek. Median concentrations of total nitrogen and dissolved nitrite plus nitrate were less than 3 mg/L at site 1 (most upstream site) and greater

than 11 mg/L at site 4 (most downstream site). Median concentrations of nutrients were highest from the tile lines. Median concentrations of dissolved nitrite plus nitrate from tiles 1, 2, and 3 were 40, 70, and 68 mg/L, respectively. Maximum concentrations of total nitrogen from tile 1 were 2,400 and 1,100 mg/L, prior to and during nutrient management. Twenty percent of the total nitrogen was dissolved nitrite plus nitrate at tile 1; however, at tile 2 and tile 3, 79 and 94 percent of the total nitrogen was dissolved nitrite plus nitrate.

Median concentrations of total and dissolved phosphorus and orthophosphorus were lowest at site 1 and highest at site 4, regardless of season, water year, or management period. The maximum concentration of total phosphorus measured was 160 mg/L from tile 1. Concentrations of total phosphorus ranged from 0.01 to 30 mg/L at the surface-water sites.

Median concentrations of suspended sediment were greater in the growing season when soils are susceptible to erosion from plowing. The maximum concentration of suspended sediment in base flow was 3,530 mg/L, measured from tile 1. Median concentrations in base flow decreased at all surface-water sites because of the decrease in precipitation in the growing seasons during nutrient management.

During nutrient management, monthly and annual loads for total nitrogen, total ammonia plus organic, total and dissolved phosphorus and orthophosphorus decreased, only dissolved nitrite plus nitrate loads increased. About 16,003 lb of total nitrogen, 898 lb of total phosphorus, and 25,144 lb of suspended sediment were discharged in base flow during the 6-year study.

Discharges of nutrients and suspended sediment in stormflow were affected from dry or frozen conditions when Brush Run Creek did not flow. Nutrients being discharged from the tile drains would build up in pools behind the weir or other low depressions and be transported with the next precipitation event, causing nutrients to peak after the stormflow peak. Eighty-four percent of the stormflow was sampled in 214 storms. The maximum instantaneous concentration of total nitrogen in stormflow was 550 mg/L; about 73 percent was total ammonia. The maximum instantaneous concentration of suspended sediment in stormflow was 17,400 mg/L. Discharges of total nitrogen, total phosphorus, and suspended sediment in stormflow increased 14, 44, and 41 percent, respectively, during management, to 12,071 lb, 3,515 lb, and 496,900 lb, respectively.

During the 6-year study, 38,421 lb of total nitrogen, 6,377 lb of total phosphorus, and 812,924 lb of suspended sediment were discharged in streamflow from Brush Run Creek. Annual yields of total nitrogen were 24 lb/acre, total phosphorus were 4 lb/acre, and suspended sediment were 513 lb/acre.

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APPENDIXES 1–3

Appendix 1. Water-quality characteristics of base flow prior to and during nutrient management by growing and nongrowing season and by water year (A) upstream from water-quality gage 01573808, (B) at water-quality gage 01573810, and (C) downstream from water-quality gage 01573815, Brush Run Creek Basin

[n, number of samples; Max, maximum; Min, minimum; Med, median; ft^3/s, cubic feet per second; concentrations are in milligrams per liter; discharges are in pounds per day]

Constituent/ characteristic	Pre-nutrient management (n=20)			Post-nutrient management (n=29)			Pre-growing season (n=11)			Post-growing season (n=15)			Pre-nongrowing season (n=9)			Post-nongrowing season (n=14)		
	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med
A. Upstream from water-quality gage 01573808																		
Instantaneous streamflow (ft^3/s)	0.69	0	0.05	0.83	0.01	0.03	0.69	0	0.05	0.34	0.01	0.01	0.57	0.01	0.05	0.83	0.01	0.11
Nitrite + nitrate, dissolved as N																		
Concentration	9.9	.10	.86	11	.10	.90	9.9	.10	.33	11	.10	.60	3.4	.72	1.9	3.9	.10	1.5
Discharge	4.3	0	.29	10	.005	.18	4.3	0	.08	4.8	.005	.04	3.8	.14	.50	10	.005	.39
Nitrite + nitrate, total as N																		
Concentration	10	.10	1.2	13	.10	.90	10	.10	.33	13	.20	.6	3.4	.72	2.1	6.2	.10	1.6
Discharge	6.5	0	.39	11	.005	.22	4.3	0	.10	4.8	.01	.04	6.5	.14	.55	11	.005	.63
Ammonia, dissolved as N																		
Concentration	3.0	.03	.13	3.1	.03	.09	3	.03	.10	3.1	.04	.08	2.0	.08	.14	1	.03	.09
Discharge	4.5	0	.04	1.6	.002	.02	4.5	0	.04	.33	.002	.02	.44	.01	.12	1.6	.005	.05
Ammonia, total as N																		
Concentration	3	.04	.14	4.6	.04	.12	3	.04	.10	4.6	.04	.09	2.1	.08	.15	1.5	.04	.13
Discharge	4.8	0	.06	3.1	.002	.02	4.8	0	.06	.92	.002	.02	1.2	.01	.21	3.1	.006	.10
Ammonia + organic, dissolved as N																		
Concentration	3.2	.30	1.3	6.6	.70	1.3	2.9	.30	1.7	6.6	.80	1.3	3.2	.57	1	1.9	.70	1.1
Discharge	11	0	.52	8.1	.04	.16	11	0	.58	1.8	.04	.15	2.4	.09	.36	8.1	.04	.21
Ammonia + organic, total as N																		
Concentration	3.3	.30	1.6	8.1	.70	1.4	2.9	.30	2.3	8.1	1.1	1.5	3.3	1.4	.90	2.2	.70	1.2
Discharge	11	0	.71	8.5	.04	.23	11	0	.58	2.6	.06	.15	4.3	.09	.84	8.5	.04	.66
Nitrogen, total N																		
Concentration	12	.40	3.3	21	.90	2.5	12	.40	3.0	21	1.5	2.2	5.1	2.5	3.8	8.5	.90	2.7
Discharge	14	0	.93	19	.05	.46	14	0	.65	6.6	.08	.19	11	.22	1.0	19	.05	1.3
Phosphorus, total as P																		
Concentration	4.3	.01	.24	.59	.06	.16	4.3	.01	.23	.59	.07	.18	1	.13	.25	.46	.06	.14
Discharge	16	0	.14	2.06	.004	.032	16	0	.11	.24	.004	.01	1.2	.01	.28	2.1	.004	.09
Phosphorus, dissolved as P																		
Concentration	.92	.01	.17	.42	.04	.13	.92	.01	.11	.36	.04	.13	.76	.10	.18	.42	.06	.13
Discharge	1.4	0	.08	1.88	.003	.017	1.4	0	.08	.22	.003	.01	.37	.01	.17	1.9	.003	.04
Orthophosphorus, dissolved as P																		
Concentration	.84	.01	.13	.38	.04	.10	.84	.01	.09	.34	.04	.11	.72	.05	.13	.38	.04	.10
Discharge	1	0	.07	1.70	.002	.015	1	0	.05	.15	.002	.01	.02	.01	.15	1.7	.003	.04
Sediment, suspended																		
Concentration	51	4	12	37	1	5	51	8	16	37	1	6	19	4	9	19	1	4
Discharge	56	.59	9.6	30.8	.05	.65	56	.59	13	16	.05	.38	17	.59	8.1	30.8	.05	2.4

Appendix 1. Water-quality characteristics of base flow prior to and during nutrient management by growing and nongrowing season and by water year (A) upstream from water-quality gage 01573808, (B) at water-quality gage 01573810, and (C) downstream from water-quality gage 01573815, Brush Run Creek Basin--Continued

Constituent/ characteristic	Pre-nutrient management									Post-nutrient management								
	1986 (n=0)			1987 (n=12)			1988 (n=12)			1989 (n=10)			1990 (n=11)			1991 (n=7)		
	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med
A. Upstream from water-quality gage 01573808																		
Instantaneous streamflow (ft^3/s)	--	--	--	0.69	0.01	0.08	0.44	0	0.05	0.66	0.01	0.03	0.83	0.01	0.01	0.22	0.01	0.03
Nitrite + nitrate, dissolved as N																		
Concentration	--	--	--	9.9	.13	.86	3.4	.10	.98	3.9	.20	1.1	11	.10	.60	3.0	.23	1.5
Discharge	--	--	--	4.3	.01	.53	3.8	0	.11	9.3	.02	.32	10	.005	.05	.87	.16	.24
Nitrite + nitrate, total as N																		
Concentration	--	--	--	10	.13	1.4	3.4	.01	1.0	4.3	.40	1.2	13	.10	.60	3.0	.23	1.5
Discharge	--	--	--	6.5	.01	1.2	3.8	0	.12	10	.03	.49	11	.005	.05	.87	.16	.24
Ammonia, dissolved as N																		
Concentration	--	--	--	2.0	.03	.13	3.0	.04	.14	.30	.07	.11	3.1	.04	.09	.17	.03	.07
Discharge	--	--	--	4.4	.01	.04	.87	0	.05	.45	.004	.02	1.6	.002	.01	.13	.005	.01
Ammonia, total as N																		
Concentration	--	--	--	2.1	.04	.26	3.0	.04	.14	1	.07	.12	4.6	.04	.13	.17	.04	.07
Discharge	--	--	--	4.8	.01	.20	.65	0	.05	3.1	.004	.03	1.7	.002	.01	.15	.006	.10
Ammonia + organic, dissolved as N																		
Concentration	--	--	--	3.2	.57	1.8	2.7	.30	1.2	1.7	.80	1.2	6.6	.80	1.4	1.6	.70	1
Discharge	--	--	--	11	.06	.52	2.4	0	.49	2.6	.05	.27	8.1	.04	.11	1.3	.09	.16
Ammonia + organic, total as N																		
Concentration	--	--	--	3.3	1.4	2.6	2.7	.30	1.2	2.2	.80	1.4	8.1	.80	1.9	1.6	.70	1.1
Discharge	--	--	--	11	.09	1.1	2.4	0	.57	3.9	.06	.36	8.5	.04	.12	1.4	.09	.16
Nitrogen, total N																		
Concentration	--	--	--	12	2.5	3.8	4.7	.40	2.8	5.6	1.6	2.7	.21	.90	2.7	5.0	1.6	2.2
Discharge	--	--	--	14	.14	3.5	5.9	0	.74	13	.09	.80	19	.05	.24	2.0	.27	.55
Phosphorus, total as P																		
Concentration	--	--	--	4.3	.09	.50	1	.01	.19	.29	.10	.21	.59	.07	.12	.23	.06	.12
Discharge	--	--	--	16	.01	.33	.66	0	.11	.52	.01	.04	2.06	.004	.01	.24	.006	.04
Phosphorus, dissolved as P																		
Concentration	--	--	--	.87	.08	.38	.92	.01	.16	.28	.08	.16	.42	.04	.10	.19	.06	.12
Discharge	--	--	--	1.4	.01	.12	.37	0	.08	.40	.007	.04	1.88	.003	.005	.22	.005	.02
Orthophosphorus, dissolved as P																		
Concentration	--	--	--	.84	.05	.27	.64	.01	.12	.26	.06	.13	.38	.04	.08	.15	.04	.08
Discharge	--	--	--	1.0	.01	.12	.24	0	.06	.36	.004	.04	1.7	.002	.004	.15	.004	.02
Sediment, suspended																		
Concentration	--	--	--	51	4	16	18	6	9	37	3	6	12	1	2	10	3	6
Discharge	--	--	--	56	.59	8.7	17	.59	9.6	31	.27	2.0	9.88	.05	.38	11.9	.32	.97

Appendix 1. Water-quality characteristics of base flow prior to and during nutrient management by growing and nongrowing season and by water year (A) upstream from water-quality gage 01573808, (B) at water-quality gage 01573810, and (C) downstream from water-quality gage 01573815, Brush Run Creek Basin--Continued

Constituent/ characteristic	Pre-nutrient management (n=34)			Post-nutrient management (n=32)			Pre-growing season (n=18)			Post-growing season (n=16)			Pre-nongrowing season (n=16)			Post-nongrowing season (n=16)		
	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med
B. At water-quality gage 01573810																		
Instantaneous streamflow (ft^3/s)	1	0.01	0.04	0.83	0.01	0.03	1.0	0.01	0.05	0.34	0.01	0.01	0.69	0.0	0.02	0.83	0.01	0.18
Nitrite + nitrate, dissolved as N																		
Concentration	25	0.01	4.4	20	.05	6.2	15	.11	3.9	20	.05	7	25	.01	5.1	14	.18	5.6
Discharge	63	.01	1.3	18	.003	1.0	12	.01	1.8	11	.003	.77	63	.01	1.2	18	.01	2.9
Nitrite + nitrate, total as N																		
Concentration	25	.01	4.6	21	.05	7.4	16	.11	4.2	21	.05	8.8	25	.01	5.1	17	.20	5.8
Discharge	67	.01	1.3	18	.003	1.1	12	.01	1.8	11	.003	.80	67	.01	.89	18	.01	3.1
Ammonia, dissolved as N																		
Concentration	410	.04	1.3	100	.11	1.7	280	.20	1.3	56	.11	2.3	410	.04	1.8	100	.15	1.3
Discharge	44	.01	.48	8.6	.009	.60	15	.03	.48	8.6	.009	.34	44	.01	.49	7.1	.05	1
Ammonia, total as N																		
Concentration	490	.04	1.7	110	.11	1.8	460	.23	1.3	63	.11	2.6	490	.04	4.6	110	.15	1.3
Discharge	54	.01	.49	10	.009	.62	25	.03	.49	10	.009	.38	54	.01	.49	7.5	.06	1
Ammonia + organic, dissolved as N																		
Concentration	250	.06	1.9	930	.80	2.9	80	.60	1.8	930	1.2	4.0	250	.70	2.9	140	.80	2.6
Discharge	54	.04	.84	50	.06	2.3	6.9	.06	.54	50	.06	1.0	54	.04	1.6	9.7	.15	3.3
Ammonia + organic, total as N																		
Concentration	1,500	.90	3.6	940	1.1	3.0	590	.90	3.1	940	1.4	5.2	1,500	1.5	11	150	1.1	2.6
Discharge	162	.01	1.8	51	.07	2.4	32	.12	3.1	51	.08	1.1	162	.01	2.1	9.7	.15	3.9
Nitrogen, total N																		
Concentration	1,500	3.1	13.5	960	3.2	14	590	3.1	7.6	960	3.2	16	1,500	4.3	24	150	3.4	10
Discharge	162	.01	3.7	52	.69	4.0	32	.44	2.6	52	.70	2.2	162	.01	4.7	25	.69	7.2
Phosphorus, total as P																		
Concentration	30	.01	.53	14	.07	.34	1.4	.01	.41	14	.11	.73	30	.15	.86	12	.07	.29
Discharge	3.2	.01	.15	2.3	.006	.24	1.5	.01	.12	2.3	.006	.16	3.2	.01	.19	2.2	.009	.53
Phosphorus, dissolved as P																		
Concentration	14	.01	.41	11	.07	.34	1.0	.01	.32	11	.08	.62	14	.13	.79	9.1	.07	.25
Discharge	1.5	.01	.14	1.9	.004	.16	1.3	.01	.10	1.8	.004	.14	1.5	.01	.15	1.9	.008	.47
Orthophosphorus, dissolved as P																		
Concentration	4.8	.01	.34	8.1	.06	.27	.96	.01	.30	8.1	.08	.33	4.8	.07	.48	6	.06	.23
Discharge	1.1	.01	.12	1.7	.004	.12	1.1	.01	.09	1.3	.004	.08	.74	.01	.12	1.7	.008	.38
Sediment, suspended																		
Concentration	2,790	3	15	146	1	7	2,790	6	14	125	1	8	1,560	3	16	146	1	6
Discharge	168	.01	3.9	27	.05	5.3	150	.76	9.4	15	.05	4.6	168	1	2.6	27	.05	7.1

Appendix 1. Water-quality characteristics of base flow prior to and during nutrient management by growing and nongrowing season and by water year (A) upstream from water-quality gage 01573808, (B) at water-quality gage 01573810, and (C) downstream from water-quality gage 01573815, Brush Run Creek Basin --Continued

Constituent/ characteristic	Pre-nutrient management									Post-nutrient management								
	1986 (n=10)			1987 (n=12)			1988 (n=12)			1989 (n=13)			1990 (n=11)			1991 (n=8)		
	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med
B. At water-quality gage 01573810																		
Instantaneous streamflow (ft³/s)	0.22	0.01	0.01	1	0.01	0.07	0.44	0.0	0.05	0.66	0.01	0.03	0.83	0.01	0.01	0.2	0.01	0.3
Nitrite + nitrate, dissolved as N																		
Concentration	25	.01	2.8	17	.15	6.1	12	1.8	3.9	14	.15	6.2	20	.70	10	14	.05	4.4
Discharge	2.8	.01	.28	63	.01	1.9	7.1	.54	1.9	18	.008	1.6	12	.08	.70	3.4	.003	1.2
Nitrite + nitrate, total as N																		
Concentration	25	.01	2.8	18	.02	6.2	12	.10	4.2	14	.20	7.5	21	.70	11	17	.05	4.5
Discharge	2.9	.01	.29	67	.008	1.9	7.1	.59	1.7	18	.01	1.6	13	.08	.76	3.5	.003	1.3
Ammonia, dissolved as N																		
Concentration	410	2	26	1.5	.04	.30	22	.19	1.2	100	.24	2.4	6.3	.15	.62	38	.11	2.8
Discharge	44	.14	1.9	1.1	.003	.17	5.9	.03	.69	8.6	.06	1.7	2.2	.008	.14	6.5	.05	.26
Ammonia, total as N																		
Concentration	490	2	28	2	.04	.32	250	.21	1.8	110	.24	2.5	7.2	.15	.72	38	.11	2.8
Discharge	53	.14	2.1	1.2	.004	.17	54	0	.71	10	.06	1.8	2.3	.009	.15	8.1	.06	.26
Ammonia + organic, dissolved as N																		
Concentration	130	.70	4.1	10	.60	1.8	250	1	2.3	930	.80	3.0	12	1.2	2.1	47	1	4.4
Discharge	14	.05	.58	11	.04	.51	54	.10	2.2	50	.13	6.8	8.1	.06	.19	9.3	.16	1.3
Ammonia + organic, total as N																		
Concentration	1,500	3.2	34	14	.90	2.8	350	1.1	3.2	940	1.1	3.2	14	1.4	2.1	47	1.1	4.9
Discharge	162	.21	2.9	11	.12	.78	76	0	2.1	51	.13	6.8	8.9	.07	.25	9.6	.18	1.4
Nitrogen, total N																		
Concentration	1,500	5.6	44	21	3.1	11	350	4.3	8.4	960	6.1	15	35	3.4	14	47	3.2	9.9
Discharge	162	.44	3.9	78	.44	2.6	76	0	4.7	52	.75	19	22	.70	.91	12	.93	2.8
Phosphorus, total as P																		
Concentration	30	.01	1.2	2	.15	.47	4.8	.19	.52	14	.15	.57	1.6	.11	.30	7	.07	.23
Discharge	3.2	.01	.11	1.5	.01	.12	1.4	0	.34	2.3	.02	.53	2.2	.006	.05	.59	.01	.16
Phosphorus, dissolved as P																		
Concentration	14	.01	.78	1.8	.13	.39	4.8	.15	.41	11	.12	.49	1.4	.08	.26	6.8	.07	.21
Discharge	1.5	.01	.09	1.3	.01	.11	1.4	0	.29	1.8	.02	.49	1.9	.004	.05	.45	.01	.14
Orthophosphorus, dissolved as P																		
Concentration	4.8	.01	.75	1.4	.07	.34	1.5	.09	.30	8.1	.10	.34	1.1	.08	.23	5.8	.06	.17
Discharge	.26	.01	.08	1.1	.005	.09	1	.01	.24	1.3	.01	.43	1.7	.004	.03	.37	.01	.11
Sediment, suspended																		
Concentration	2,790	4	38	19	3	14	96	9	14	146	1	10	48	1	6	44	1	4
Discharge	168	.22	2.6	86	.16	4	26	0	7.7	25	.05	8.6	27	.05	.38	9.5	.11	2.9

Appendix 1. Water-quality characteristics of base flow prior to and during nutrient management by growing and nongrowing season and by water year (A) upstream from water-quality gage 01573808, (B) at water-quality gage 01573810, and (C) downstream from water-quality gage 01573815, Brush Run Creek Basin --Continued

Constituent/ characteristic	Pre-nutrient management (n=13)			Post-nutrient management (n=29)			Pre-growing season (n=7)			Post-growing season (n=15)			Pre-nongrowing season (n=6)			Post-nongrowing season (n=14)		
	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med
C. Downstream from water-quality gage 01573815																		
Instantaneous streamflow (ft³/s)	0.44	0	0.10	0.83	0.01	0.03	0.18	0	0.05	0.34	0.01	0.01	0.44	0.01	0.28	0.83	0.01	0.11
Nitrite + nitrate, dissolved as N																		
Concentration	29	.14	11	69	1.4	14	29	.14	16	69	1.4	15	24	5	7.7	29	3.2	12
Discharge	12	0	6.1	49	.07	2.4	10	0	6.1	24	.07	2.1	12	1.2	7	50	.52	3.6
Nitrite + nitrate, total as N																		
Concentration	29	.10	8.8	79	3.3	14	29	.10	13	79	6.5	15	29	5	8	31	3.3	13
Discharge	12	0	5.9	49	.42	2.4	11	0	5.9	26	.43	2.3	12	1.1	6.6	50	.53	6.8
Ammonia, dissolved as N																		
Concentration	3.1	.04	.31	85	.04	.52	3.1	.07	.28	85	.06	.95	1.6	.04	.51	9.1	.04	.43
Discharge	3.0	0	.10	7.6	.003	.24	3	0	.07	7.6	.003	.09	2.4	.01	.21	5.0	.003	.44
Ammonia, total as N																		
Concentration	3.1	.04	.32	87	.05	.65	3.1	.07	.30	87	.07	.95	1.6	.04	.52	9.5	.05	.54
Discharge	3	0	.10	8.6	.003	.32	3	0	.07	8.5	.004	.10	2.4	.01	.22	5.0	.003	.74
Ammonia + organic, dissolved as N																		
Concentration	330	.32	1.9	18	.90	1.7	330	.32	2.6	120	.9	2.7	2.5	1.1	1.6	18	1.1	1.4
Discharge	71	0	.89	8.5	.05	.25	71	0	.89	8.5	.05	.19	3.6	.07	1.1	7.6	.07	1.3
Ammonia + organic, total as N																		
Concentration	350	.70	2.2	150	1.1	2.1	.07	2.6	2.7	150	1.2	2.8	2.7	1.1	1.9	19	1.1	1.8
Discharge	76	0	8.3	9.7	.06	1.03	.91	5.2	.08	9.7	.06	.24	5.2	.08	1.1	9.8	.07	1.9
Nitrogen, total N																		
Concentration	350	1.0	14	177	4.5	22	350	1	24	177	8.2	26	30	6.7	10	36	4.5	14
Discharge	76	0	8.3	58	.58	4.2	76	0	8.3	34	.56	3.6	17	1.4	8	58	.73	8.1
Phosphorus, total as P																		
Concentration	4.8	.20	.37	4.3	.12	.42	4.8	.20	.92	4.3	.17	.49	.40	.22	.32	2.2	.12	.33
Discharge	1	0	.45	3.6	.007	.11	1	0	.25	.77	.009	.05	.88	.02	.46	3.6	.008	.19
Phosphorus, dissolved as P																		
Concentration	1.5	.16	.33	2.7	.11	.34	1.5	.16	.90	2.7	.16	.45	.40	.22	.27	1.7	.11	.25
Discharge	.78	0	.32	2.7	.007	.05	.49	0	.25	.60	.009	.05	.78	.01	.38	2.8	.007	.17
Ortho-phosphorus, dissolved as P																		
Concentration	.89	.14	.24	1.4	.09	.29	.89	.14	.52	1.3	.09	.33	.29	.18	.20	1.4	.10	.20
Discharge	.62	0	.24	2.3	.005	.04	.40	0	.20	.53	.005	.03	.62	.01	.27	2.3	.006	.13
Sediment, suspended																		
Concentration	21	5	8	49	1	7	21	8	14	49	1	9	11	5	7	16	1	5
Discharge	26	.27	9.4	2.3	.004	.04	15	1.7	5.7	23	.05	1.3	26	.27	9.6	71	.16	1.1

Appendix 1. Water-quality characteristics of base flow prior to and during nutrient management by growing and nongrowing season and by water year (A) upstream from water-quality gage 01573808, (B) at water-quality gage 01573810, and (C) downstream from water-quality gage 01573815, Brush Run Creek Basin--Continued

Constituent/ characteristic	Pre-nutrient management									Post-nutrient management								
	1986 (n=0)			1987 (n=1)			1988 (n=12)			1989 (n=11)			1990 (n=11)			1991 (n=7)		
	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med
C. Downstream from water-quality gage 01573815																		
Instantaneous streamflow (ft³/s)	--	--	--	0.10	0.10	0.1	0.44	0	0.09	0.66	0.01	0.03	0.83	0.01	0.01	0.22	0.01	0.03
Nitrite + nitrate, dissolved as N																		
Concentration	--	--	--	19	19	19	29	0	.14	25	1.4	12	69	3.2	26	24	3.5	13
Discharge	--	--	--	10	10	10	12	0	5.9	49	.08	2.7	18	.52	1.6	7.0	.81	3.4
Nitrite + nitrate, total as N																		
Concentration	--	--	--	21	21	21	29	.10	7.9	27	5.8	14	79	3.3	28	26	6.5	13
Discharge	--	--	--	11	11	11	12	0	4.8	49	.43	2.7	21	.53	1.7	9.5	.92	4.2
Ammonia, dissolved as N																		
Concentration	--	--	--	.15	.15	.15	3.1	.04	.32	85	.11	1.6	1.8	.05	.25	9.1	.04	.27
Discharge	--	--	--	.08	.08	.08	3.0	0	.12	6.2	.02	1.3	2.3	.003	.03	7.6	.006	.32
Ammonia, total as N																		
Concentration	--	--	--	.15	.15	.15	3.1	.04	.34	87	.11	2.1	1.9	.05	.50	9.5	.05	1.2
Discharge	--	--	--	.08	.08	.08	3.0	0	.12	6.2	.02	1.3	2.6	.003	.03	8.5	.008	.51
Ammonia + organic, dissolved as N																		
Concentration	--	--	--	2.6	2.6	2.6	330	.32	1.8	12	1.1	3.0	3.8	.90	1.4	18	1.1	1.6
Discharge	--	--	--	1.4	1.4	1.4	71	0	.83	7.9	.14	1.9	7.6	.05	.10	8.4	.18	1.1
Ammonia + organic, total as N																		
Concentration	--	--	--	2.6	2.6	2.6	350	.70	2.1	150	1.1	4.5	6.6	1.2	1.6	19	1.1	2.3
Discharge	--	--	--	1.4	1.4	1.4	76	0	.90	8.5	.15	3.9	9.8	.06	.11	9.7	.18	1.6
Nitrogen, total N																		
Concentration	--	--	--	24	24	24	350	1.0	13	150	1.1	4.5	81	4.5	30	36	8.2	17
Discharge	--	--	--	13	13	13	76	0	7.5	58	.58	9.6	31	.73	1.8	16	1.9	4.4
Phosphorus, total as P																		
Concentration	--	--	--	.92	.92	.92	4.8	.20	.36	4.3	.25	.62	2.2	.14	.30	.77	.12	.28
Discharge	--	--	--	.50	.50	.50	1.0	0	.35	3.6	.03	.24	2.6	.007	.02	.63	.02	.08
Phosphorus, dissolved as P																		
Concentration	--	--	--	.90	.90	.90	1.5	.16	.31	2.7	.21	.56	.87	.13	.30	.49	.11	.24
Discharge	--	--	--	.49	.49	.49	.78	0	.29	2.7	.03	.23	2.3	.007	.02	.48	.013	.04
Orthophosphorus, dissolved as P																		
Concentration	--	--	--	.75	.75	.75	.89	.14	.22	1.4	.09	.46	.78	.09	.21	.45	.10	.19
Discharge	--	--	--	.41	.41	.41	.62	0	.24	2.3	.005	.21	2.0	.005	.01	.44	.008	.03
Sediment, suspended																		
Concentration	--	--	--	9	9	9	21	5	7.5	38	3	8	49	1	6	11	1	7
Discharge	--	--	--	4.9	4.9	4.9	26	.27	9.6	24	.38	2.1	71	.05	.59	11	.16	.97

Appendix 2. Coefficients, standard deviations, and T values for the 7-parameter log-linear model used to estimate concentrations and loads in base flow at Brush Run Creek, water years 1986–91

[Pre, prior to nutrient management; Post, during nutrient management; β_0, constant; β_1, log of streamflow; β_2, log of streamflow squared; β_3, decimal time; β_4, decimal time squared; β_5, sin (time); β_6, cos (time)]

Constituent	Parameter	Coefficient		Standard deviation		T value	
		Pre	Post	Pre	Post	Pre	Post
Total nitrogen							
Concentration	β_0	2.7967	2.1884	0.5272	0.3995	5.30	5.48
	β_1	-.1490	-.4332	.2456	.1739	-.61	-2.49
	β_2	-.1235	.1023	.2016	.1325	-.61	.77
	β_3	-.3763	-.5263	.3376	.2110	-1.11	-2.49
	β_4	.3289	-.0061	.3424	.2397	.96	-.03
	β_5	-.4794	-.2140	.3219	.2867	-1.49	-.75
	β_6	-.7818	-.2694	.3729	.2817	-2.10	-.96
Load	β_0	.6724	.1650	.5272	.3995	1.28	.41
	β_1	.8510	.5668	.2456	.1739	3.47	3.26
	β_2	-.1235	.1023	.2016	.1325	-.61	.77
	β_3	-.3763	-.5263	.3376	.2110	-1.11	-2.49
	β_4	.3289	-.0060	.3424	.2397	.96	-.03
	β_5	-.4794	-.2140	.3219	.2867	-1.49	-.75
	β_6	-.7818	-.2694	.3729	.2817	-2.10	-.96
Dissolved nitrite plus nitrate							
Concentration	β_0	.8585	1.6865	.7161	.6737	1.20	2.50
	β_1	-.2201	-.3288	.3251	.2849	-.68	-1.15
	β_2	.1137	.0403	.2739	.2152	.42	.19
	β_3	.4647	-.2837	.4720	.3959	.98	-.72
	β_4	-.0777	-1.0060	.4868	.4847	-.16	-2.08
	β_5	.2256	.4572	.4239	.4959	.53	.92
	β_6	.1703	.7291	.4959	.4550	.34	1.60
Load	β_0	-1.2581	-.3206	.7161	.6737	-1.76	-.48
	β_1	.7799	.6712	.3251	.2849	2.40	2.36
	β_2	.1137	.0403	.2739	.2152	.42	.19
	β_3	.4647	-.2837	.4720	.3959	.98	-.72
	β_4	-.0777	-1.0060	.4868	.4847	-.16	-2.08
	β_5	.2256	.4572	.4239	.4959	.53	.92
	β_6	.1703	.7291	.4959	.4550	.34	1.60
Total ammonia plus organic nitrogen							
Concentration	β_0	1.6729	1.4218	0.6906	0.6234	2.42	2.28
	β_1	-.1499	-.3277	.3216	.2714	-.47	-1.21
	β_2	-.1376	-.0312	.2640	.2067	-.52	-.15
	β_3	-.3791	-.6165	.4422	.3292	-.86	-1.87
	β_4	.6891	.1324	.4484	.3740	1.54	.35
	β_5	-.5319	-.4594	.4216	.4474	-1.26	-1.03
	β_6	-.9291	-.6023	.4885	.4395	-1.90	-1.37

Appendix 2. Coefficients, standard deviations, and T values for the 7-parameter log-linear model used to estimate concentrations and loads in base flow at Brush Run Creek, water years 1986–91--Continued

Constituent	Parameter	Coefficient		Standard deviation		T value	
		Pre	Post	Pre	Post	Pre	Post
		Total ammonia plus organic nitrogen--Continued					
Load	β_0	-0.4514	-0.6017	0.6906	0.6234	-0.65	-0.97
	β_1	.8501	.6723	.3216	.2714	2.64	2.48
	β_2	-.1376	-.0312	.2640	.2067	-.52	-.15
	β_3	-.3791	-.6165	.4422	.3292	-.86	-1.87
	β_4	.6891	.1324	.4484	.3740	-1.54	.35
	β_5	.5319	-.4594	.4216	.4474	-1.26	-1.03
	β_6	-.9291	-.6023	.4885	.4395	-1.90	-1.37
		Total phosphorus					
Concentration	β_0	.0197	-.4968	.4740	.5289	.04	-.94
	β_1	.1879	-.1571	.2208	.2302	.85	-.68
	β_2	-.1597	.1480	.1812	.1754	-.88	-.84
	β_3	-.2354	-.7414	.3035	.2793	-.78	-2.65
	β_4	.0932	.0506	.3078	.3174	.30	.16
	β_5	-.8904	-.4534	.2894	.3796	3.08	-1.19
	β_6	-.9887	-.8706	.3353	.3729	-2.95	-2.33
Load	β_0	-2.1045	-2.5202	.4740	.5289	-4.44	-4.76
	β_1	1.1879	.8429	.2208	.2302	5.38	3.66
	β_2	-.1597	-.1480	.1812	.1754	-.88	-.84
	β_3	-.2354	-.7414	.3035	.2793	-.78	-2.65
	β_4	.0932	.0506	.3078	.3174	.30	.16
	β_5	-.8904	-.4534	.2894	.3796	-3.08	-1.19
	β_6	-.9887	-.8706	.3353	.3729	-2.95	-2.33
		Dissolved phosphorus					
Concentration	β_0	-.2679	-.9862	.4400	.4884	-.61	-2.02
	β_1	.1869	-.0561	.2049	.2065	.91	-.27
	β_2	-.1190	-.0637	.1682	.1560	-.71	-.41
	β_3	-.2238	-.4072	.2818	.2870	-.79	-1.42
	β_4	.0931	.7319	.2857	.3513	.33	2.08
	β_5	-.9022	-.8132	.2686	.3594	-3.36	-2.26
	β_6	-.9426	-1.1481	.3112	.3298	-3.03	-3.48
Load	β_0	-2.3921	-2.9933	.4400	.4884	-5.44	-6.13
	β_1	1.1869	.9439	.2049	.2065	5.79	4.57
	β_2	-.1190	-.0637	.1682	.1560	-.71	-.41
	β_3	-.2238	-.4072	.2818	.2870	-.79	-1.42
	β_4	.0931	.7319	.2857	.3513	.33	-2.08
	β_5	-.9022	-.8132	.2686	.3594	-3.36	-2.26
	β_6	-.9426	-1.1481	.3112	.3298	-3.03	-3.48

Appendix 2. Coefficients, standard deviations, and T values for the 7-parameter log-linear model used to estimate concentrations and loads in base flow at Brush Run Creek, water years 1986–91--Continued

Constituent	Parameter	Coefficient		Standard deviation		T value	
		Pre	Post	Pre	Post	Pre	Post
		Dissolved orthophosphorus					
Concentration	β_0	-0.7254	-1.3256	0.4396	0.5093	-1.65	-2.60
	β_1	.1542	-.1159	.1996	.2143	.77	.54
	β_2	.0298	-.0552	.1681	.1627	-.18	-.34
	β_3	-.2407	-.3647	.2897	.2993	-.83	-1.22
	β_4	.0294	.7380	.2988	.3664	.10	2.01
	β_5	-.8616	-.4987	.2602	.3749	-3.31	-1.33
	β_6	-.6859	-.9310	.3044	.3440	-2.25	-2.71
Load	β_0	-2.8420	-3.3326	.4396	.5093	-6.47	-6.54
	β_1	1.1542	.8841	.1996	.2143	5.78	4.10
	β_2	-.0298	-.0552	.1681	.1627	-.18	-.34
	β_3	.2407	-.3647	.2897	.2993	-.83	-1.22
	β_4	.0294	.7380	.2988	.3664	.10	2.01
	β_5	-.8616	-.4987	.2602	.3749	-3.31	-1.33
	β_6	-.6859	-.9310	.3044	.3440	-2.25	-2.71
		Suspended sediment					
Concentration	β_0	3.1983	1.9075	.6291	.6191	5.08	3.08
	β_1	-.0595	.3101	.2930	.2565	-.20	1.21
	β_2	-.2139	-.0197	.2405	.1876	-.89	-.10
	β_3	.2958	-.2904	.4029	.3657	-.73	-.79
	β_4	.3296	.9564	.4085	.4741	.81	2.02
	β_5	-.3747	-1.0228	.3841	.4200	-.98	-2.44
	β_6	.1742	-1.1985	.4450	.4086	-.39	-2.93
Load	β_0	1.0740	-.0856	.6291	.6191	1.71	-.14
	β_1	.9405	1.3101	.2930	.2565	3.21	5.11
	β_2	-.2139	-.0197	.2405	.1876	-.89	-.10
	β_3	-.2958	-.2904	.4029	.3657	-.73	-.79
	β_4	.3296	.9564	.4085	.4741	.81	2.02
	β_5	-.3747	-1.0228	.3841	.4200	-.98	2.44
	β_6	-.1742	-1.1985	.4450	.4086	-.39	-2.93

Appendix 3. Daily nitrogen, phosphorus, and suspended-sediment loads during storms at the Brush Run Creek site

[Discharge is in cubic feet per second; loads are in pounds; --, not determined]

Date	Mean daily dis-charge	Total nitro-gen	Total nitrate plus nitrite	Dis-solved nitrate plus nitrite	Total ammo-nia	Dis-solved ammo-nia	Total organ-ic nitro-gen	Dis-solved organic nitro-gen	Total phos-phorus	Dis-solved phos-phorus	Dis-solved ortho-phos-phorus	Sus-pended sedi-ment
11/04/85	2.5	93	47	44	6.4	6.0	40	18	26	21	20	1,243
11/05/85	6.9	175	73	63	13	10	89	63	60	51	40	3,226
11/16/85	4.0	--	--	--	--	--	--	--	--	--	--	2,470
11/17/85	2.0	--	--	--	--	--	--	--	--	--	--	232
11/22/85	8.7	--	--	--	--	--	--	--	--	--	--	11,580
11/23/85	.79	--	--	--	--	--	--	--	--	--	--	151
11/26/85	2.6	--	--	--	--	--	--	--	--	--	--	2,260
11/27/85	5.4	--	--	--	--	--	--	--	--	--	--	1,425
11/28/85	9.0	--	--	--	--	--	--	--	--	--	--	2,580
11/29/85	2.8	--	--	--	--	--	--	--	--	--	--	333
11/30/85	3.9	--	--	--	--	--	--	--	--	--	--	712
12/01/85	4.5	--	--	--	--	--	--	--	--	--	--	1,025
12/02/85	3.1	--	--	--	--	--	--	--	--	--	--	358
12/13/85	4.4	--	--	--	--	--	--	--	--	--	--	4,066
12/14/85	.72	--	--	--	--	--	--	--	--	--	--	189
02/02/86	.89	--	--	--	--	--	--	--	--	--	--	1,044
02/03/86	.26	--	--	--	--	--	--	--	--	--	--	23
02/04/86	4.9	--	--	--	--	--	--	--	--	--	--	5,964
02/05/86	5.0	--	--	--	--	--	--	--	--	--	--	3,344
02/06/86	2.3	--	--	--	--	--	--	--	--	--	--	389
02/19/86	10	--	--	--	--	--	--	--	--	--	--	3,720
02/20/86	8.7	--	--	--	--	--	--	--	--	--	--	2,870
02/21/86	8.7	--	--	--	--	--	--	--	--	--	--	4,459
03/11/86	2.8	155	17	--	33	--	105	--	--	--	--	2,181
03/13/86	3.2	85	26	26	16	14	43	--	15	11	7.9	--
03/14/86	11	251	73	66	36	31	142	--	49	47	44	--
03/15/86	7.6	198	41	38	53	50	104		33	30	28	--
04/15/86	.52	34	19	15	4.9	4.0	9.7	2.4	5.1	4.2	3.7	890
04/16/86	6.1	179	117	103	13	10	49	15	19	18	13	2,729
04/17/86	6.1	179	106	89	7.5	6.7	66	23	21	20	17	1,320
04/18/86	1.7	48	30	28	1.6	1.4	16	5.4	4.5	4.2	3.9	191
05/20/86	.64	41	13	10	8.3	6.4	19	8.7	3.9	1.8	1.6	2,375
06/06/86	7.2	--	--	--	--	--	--	--	--	--	--	4,720
06/07/86	1.4	--	--	--	--	--	--	--	--	--	--	39
06/12/86	.53	--	--	--	--	--	--	--	--	--	--	55
07/20/86	.58	41	9.8	--	23	--	8.2	--	5.7	--	--	184
08/02/86	.17	--	--	--	--	--	--	--	--	--	--	397
08/16/86	.82	267	108	64	44	38	115	69	91	44	38	4,894
08/17/86	1.8	47	25	23	2.8	2.0	19	16	12	9.3	8.2	512
10/01/86	.17	--	--	--	--	--	--	--	--	--	--	107
11/05/86	0.38	--	--	--	--	--	--	--	--	--	--	221
11/18/86	2.9	--	--	--	--	--	--	--	--	--	--	1,448

Appendix 3. Daily nitrogen, phosphorus, and suspended-sediment loads during storms at the Brush Run Creek site --Continued

Date	Mean daily dis-charge	Total nitro-gen	Total nitrate plus nitrite	Dis-solved nitrate plus nitrite	Total ammo-nia	Dis-solved ammo-nia	Total organ-ic nitro-gen	Dis-solved organic nitro-gen	Total phos-phorus	Dis-solved phos-phorus	Dis-solved ortho-phos-phorus	Sus-pended sedi-ment
11/19/86	2.7	--	--	--	--	--	--	--	--	--	--	938
11/20/85	7.4	--	--	--	--	--	--	--	--	--	--	1,627
11/21/86	3.6	--	--	--	--	--	--	--	--	--	--	668
11/26/86	3.9	--	--	--	--	--	--	--	--	--	--	1,606
11/27/86	1.6	--	--	--	--	--	--	--	--	--	--	139
12/02/86	9.4	327	135	--	22	--	170	--	45	--	--	12,123
12/03/86	9.3	141	75	--	6.2	--	60	--	304	--	--	4,676
12/09/86	2.5	--	--	--	--	--	--	--	--	--	--	828
12/18/86	5.5	--	--	--	--	--	--	--	--	--	--	2,360
12/19/86	1.2	--	--	--	--	--	--	--	--	--	--	66
12/24/86	13	--	--	--	--	--	--	--	--	--	--	4,398
12/25/86	5.3	--	--	--	--	--	--	--	--	--	--	1,718
01/14/87	2.6	--	--	--	--	--	--	--	--	--	--	604
01/15/87	4.7	--	--	--	--	--	--	--	--	--	--	748
01/19/87	8.3	--	--	--	--	--	--	--	--	--	--	4,367
01/20/87	2.7	--	--	--	--	--	--	--	--	--	--	203
02/03/87	1.6	--	--	--	--	--	--	--	--	--	--	207
02/04/87	4.2	--	--	--	--	--	--	--	--	--	--	630
02/05/87	2.3	--	--	--	--	--	--	--	--	--	--	173
02/06/87	1.6	--	--	--	--	--	--	--	--	--	--	143
02/07/87	2.0	--	--	--	--	--	--	--	--	--	--	447
02/28/87	1.2	--	--	--	--	--	--	--	--	--	--	1,085
03/01/87	18.	443	145	--	63	--	236	--	70	--	--	23,900
03/02/87	2.7	313	153	--	33	--	128	--	6.6	--	--	560
04/04/87	6.6	173	75	--	11	--	88	--	43	--	--	11,650
04/05/87	4.2	67	48	--	3.3	--	16	--	8.0	--	--	940
04/06/87	6.3	136	86	--	5.8	--	44	--	25	--	--	2,140
04/24/87	1.1	--	--	--	--	--	--	--	--	--	--	440
04/25/87	.42	--	--	--	--	--	--	--	--	--	--	60
05/04/87	1.9	--	--	--	--	--	--	--	--	--	--	260
05/20/87	2.2	--	--	--	--	--	--	--	--	--	--	820
05/23/87	4.1	138	16	--	7.6	--	114	--	28	--	--	27,570
05/24/87	7.1	26	4.6	--	.80	--	20	--	1.8	--	--	780
06/04/87	1.0	--	--	--	--	--	--	--	--	--	--	230
06/30/87	.03	--	--	--	--	--	--	--	--	--	--	56
08/31/90	.88	--	--	--	--	--	--	--	--	--	--	4,440
09/01/87	.11	--	--	--	--	--	--	--	--	--	--	8
09/08/87	6.5	510	360	--	19	--	130	--	61	--	--	6,000
09/09/87	0.69	54	44	--	2	--	9	--	4	--	--	90
09/13/87	8.4	--	--	--	--	--	--	--	--	--	--	690
09/18/87	5.2	--	--	--	--	--	--	--	--	--	--	550

Appendix 3. Daily nitrogen, phosphorus, and suspended-sediment loads during storms at the Brush Run Creek site --Continued

Date	Mean daily dis-charge	Total nitro-gen	Total nitrate plus nitrite	Dis-solved nitrate plus nitrite	Total ammo-nia	Dis-solved ammo-nia	Total organ-ic nitro-gen	Dis-solved organic nitro-gen	Total phos-phorus	Dis-solved phos-phorus	Dis-solved ortho-phos-phorus	Sus-pended sedi-ment
09/21/87	3.7	--	--	--	--	--	--	--	--	--	--	1,670
10/27/87	2.3	98	54	--	13	--	32	--	10	--	--	1,770
10/28/87	1.3	49	34	--	3.6	--	11	--	14	--	--	400
11/10/87	1.4	--	--	--	--	--	--	--	--	--	--	900
11/11/87	.55	--	--	--	--	--	--	--	--	--	--	100
11/12/87	2.1	--	--	--	--	--	--	--	--	--	--	300
11/17/87	.29	--	--	--	--	--	--	--	--	--	--	110
11/18/87	1.4	--	--	--	--	--	--	--	--	--	--	200
11/29/87	43	878	424	--	80	--	374	--	--	--	--	14,260
11/30/87	3.3	49	26	--	8	--	15	--	--	--	--	1,200
12/15/87	1.5	61	30	--	13	--	17	--	5.4	--	--	640
12/16/87	.49	6.3	2.8	--	1.1	--	2.4	--	.3	--	--	200
01/18/88	.77	35	4	3.4	12	10	19	--	3.8	3.2	2.2	310
01/19/88	.22	10	2.4	1.8	2.4	2.0	5.2	--	1.4	1.0	.6	500
01/20/88	12	446	61	55	145	129	240	--	154	110	96	7,200
01/31/88	.68	--	--	--	--	--	--	--	--	--	--	130
02/01/88	6.9	--	--	--	--	--	--	--	--	--	--	8,780
02/02/88	3.9	--	--	--	--	--	--	--	--	--	--	2,980
02/03/88	1.2	--	--	--	--	--	--	--	--	--	--	1,100
05/05/88	.48	31	6.2	5.4	13	11	13	11	8.2	7.6	7.3	100
05/06/88	6.2	140	64	59	18	16	59	53	34	31	29	3,900
05/07/88	1.1	20	9.5	8.1	2.1	2.0	8.4	8.0	2.8	2.2	1.8	200
05/08/88	.45	7.7	3.6	3.4	1.4	1.3	2.8	2.7	0.76	.68	.62	50
05/17/88	9.7	345	161	--	58	--	125	--	76	--	--	3,200
05/18/88	16	403	215	--	35	--	153	--	82	--	--	9,200
05/19/88	9.4	20	8.4	--	1.5	--	11	--	5.6	--	--	1,220
05/24/88	3.0	--	--	--	--	--	--	--	--	--	--	510
07/19/88	.13	29	14	--	12	--	2.5	--	3.8	--	--	150
07/20/88	.01	.7	.2	--	.2	--	.3	--	.02	--	--	400
07/21/88	.11	46	27	--	3.9	--	15	--	5.1	--	--	11,280
07/22/88	.14	74	28	--	14	--	33	--	3.8	--	--	--
07/23/88	.06	21	12	--	1.1	--	8.7	--	1.4	--	--	--
08/24/88	.36	54	22	--	22	--	9.6	--	5.0	--	--	370
09/04/88	.53	47	16	--	24	--	7.3	--	8.6	--	--	100
09/05/88	.17	11	5.1	--	4.0	--	1.5	--	.88	--	--	20
10/21/88	.01	2.1	.75	--	.67	--	.63	--	.22	--	--	10
10/22/88	.45	42	32	--	8	--	5	--	6	--	--	50
11/05/88	0.22	--	--	--	--	--	--	--	--	--	--	520
11/13/88	.31	--	--	--	--	--	--	--	--	--	--	650
11/20/88	1.6	108	67	--	5.6	--	35	--	18	--	--	640
11/21/88	.63	34	26	--	1.5	--	6.4	--	2.8	--	--	50

Appendix 3. Daily nitrogen, phosphorus, and suspended-sediment loads during storms at the Brush Run Creek site --Continued

Date	Mean daily dis-charge	Total nitro-gen	Total nitrate plus nitrite	Dis-solved nitrate plus nitrite	Total ammo-nia	Dis-solved ammo-nia	Total organ-ic nitro-gen	Dis-solved organic nitro-gen	Total phos-phorus	Dis-solved phos-phorus	Dis-solved ortho-phos-phorus	Sus-pended sedi-ment
12/24/88	0.78	--	--	--	--	--	--	--	--	--	--	630
12/25/88	.75	--	--	--	--	--	--	--	--	--	--	150
01/08/89	1.9	103	77	--	15	--	11	--	13	--	--	450
01/09/89	2.1	94	70	--	18	--	6	--	7.5	--	--	680
01/14/89	.74	38	28	--	6.9	--	2.9	--	4.5	--	--	170
01/15/89	9.5	330	240	--	20	--	70	--	20	--	--	3,920
02/16/89	1.3	34	20	--	3.2	--	11	--	31	--	--	110
02/21/89	6.1	255	145	--	19	--	91	--	29	--	--	9,120
03/06/89	2.6	--	--	--	--	--	--	--	--	--	--	18,000
03/12/89	7.7	--	--	--	--	--	--	--	--	--	--	8,530
03/18/89	5.9	--	--	--	--	--	--	--	--	--	--	35,130
03/19/89	1.4	--	--	--	--	--	--	--	--	--	--	400
03/21/89	1.8	--	--	--	--	--	--	--	--	--	--	450
03/24/89	16	--	--	--	--	--	--	--	--	--	--	17,200
03/30/89	1.5	36	21	--	2.0	--	13	--	5.5	--	--	--
03/31/89	1.9	28	10	--	2.5	--	16	--	3.8	--	--	--
05/01/89	13	400	70	--	120	--	210	--	120	--	--	22,900
05/02/89	9.6	330	45	--	125	--	160	--	62	--	--	4,720
05/05/89	14	160	25	--	11	--	110	--	63	--	--	18,300
05/06/89	27	300	50	--	85	--	165	--	120	--	--	47,900
05/07/89	1.2	42	7	--	14	--	21	--	4.4	--	--	540
05/10/89	2.5	--	--	--	--	--	--	--	--	--	--	910
05/11/89	1.5	--	--	--	--	--	--	--	--	--	--	275
05/14/89	.33	--	--	--	--	--	--	--	--	--	--	450
05/15/89	9.9	--	--	--	--	--	--	--	--	--	--	8,740
05/16/89	21	--	--	--	--	--	--	--	--	--	--	12,200
05/24/89	.88	--	--	--	--	--	--	--	--	--	--	1,760
06/09/89	.25	--	--	--	--	--	--	--	--	--	--	300
06/10/89	.18	--	--	--	--	--	--	--	--	--	--	40
07/06/89	.88	--	--	--	--	--	--	--	--	--	--	400
07/07/89	.45	--	--	--	--	--	--	--	--	--	--	720
07/13/89	1.5	--	--	--	--	--	--	--	--	--	--	860
07/16/89	4.3	415	190	--	100	--	35	--	100	--	--	3,980
07/20/89	6.5	230	135	--	6.2	--	89	--	25	--	--	--
07/21/89	12	350	195	--	9.5	--	149	--	31	--	--	--
10/19/89	2.3	73	44	--	3.3	--	26	--	16	--	--	640
10/20/89	11	187	100	--	13	--	74	--	104	--	--	1,150
10/21/89	.49	17	8.8	--	3.6	--	4.8	--	1.9	--	--	200
11/09/89	.55	--	--	--	--	--	--	--	--	--	--	440
11/16/89	.72	--	--	--	--	--	--	--	--	--	--	320
01/26/90	5.7	125	43	--	12	--	70	--	27	--	--	--
01/29/90	16	315	90	--	44	--	135	--	78	--	--	47,980

Appendix 3. Daily nitrogen, phosphorus, and suspended-sediment loads during storms at the Brush Run Creek site --Continued

Date	Mean daily dis-charge	Total nitro-gen	Total nitrate plus nitrite	Dis-solved nitrate plus nitrite	Total ammo-nia	Dis-solved ammo-nia	Total organ-ic nitro-gen	Dis-solved organic nitro-gen	Total phos-phorus	Dis-solved phos-phorus	Dis-solved ortho-phos-phorus	Sus-pended sedi-ment
01/30/90	3.2	52	27	--	4.9	--	20	--	8.8	--	--	1,770
02/10/90	2.9	39	13	--	4.8	--	21	--	13	--	--	1,970
02/11/90	.75	13	5.3	--	.5	--	7.1	--	1.2	--	--	190
02/12/90	.56	11	5.1	--	2.3	--	3.1	--	.90	--	--	50
02/23/90	2.5	44	13	--	6.2	--	25	--	20	--	--	7,500
02/24/90	4.8	51	20	--	21	--	10	--	19	--	--	5,348
03/17/90	1.8	--	--	--	--	--	--	--	--	--	--	1,680
03/18/90	.86	--	--	--	--	--	--	--	--	--	--	200
05/10/90	9.4	185	25	--	33	--	117	--	450	--	--	14,460
05/11/90	.89	26	6.5	--	3.2	--	17	--	1.9	--	--	470
05/29/90	15	785	510	--	76	--	199	--	64	--	--	4,780
05/30/89	1.9	90	45	--	22	--	22	--	7.6	--	--	520
07/11/90	.02	.70	.40	--	.20	--	.10	--	.20	--	--	10
07/12/90	.08	50	4.5	--	12	--	33	--	9.8	--	--	160
07/13/90	.08	6.2	4.2	--	1.0	--	1.2	--	1.8	--	--	860
07/21/90	.26	17	8.4	--	1.4	--	6.8	--	3.2	--	--	615
07/22/90	.32	16	11	--	.70	--	4.7	--	1.3	--	--	80
08/13/90	.56	37	15	--	2.6	--	19	--	12	--	--	1,220
08/14/90	.19	68	3.6	--	.60	--	2.6	--	1.6	--	--	120
08/22/90	8.8	270	110	--	37	--	123	--	44	--	--	6,900
08/23/90	4.5	134	62	--	6.8	--	65	--	27	--	--	1,710
10/13/90	.21	11	6.2	--	1.2	--	3.8	--	1.7	--	--	100
10/18/90	3.8	91	46	--	11	--	32	--	29	--	--	170
10/19/90	1.6	32	18	--	1.8	--	12	--	7.8	--	--	160
10/23/90	24	810	150	--	270	--	--	--	440	--	--	53,500
12/03/90	11	152	68	--	12	--	72	--	65	--	--	8,100
12/04/90	12	223	103	--	13	--	107	--	57	--	--	7,100
12/05/90	.58	10	6.0	--	.40	--	3.7	--	.90	--	--	50
12/15/90	2.8	44	24	--	4.6	--	15	--	10	--	--	190
12/16/90	1.0	13	7.3	--	1.2	--	4.6	--	1.9	--	--	630
12/18/90	4.4	63	27	--	2.8	--	33	--	20	--	--	2,600
12/19/90	.94	12	5.8	--	.74	--	5.2	--	1.9	--	--	170
12/21/90	1.4	18	8.6	--	1.8	--	7.6	--	3.6	--	--	180
12/22/90	.81	9.3	2.8	--	.70	--	5.8	--	3.1	--	--	120
12/23/90	4.4	58	18	--	3.1	--	37	--	17	--	--	1,400
03/23/91	9.7	317	47	--	100	--	170	--	83	--	--	24,200
03/24/91	1.0	22	7.9	--	4.0	--	10	--	4.0	--	--	470
03/27/91	.93	--	--	--	--	--	--	--	--	--	--	430
03/30/91	.73	--	--	--	--	--	--	--	--	--	--	490
05/06/91	.91	33	7.0	--	5.6	--	20	--	9.9	--	--	810
05/07/91	.63	10	2.8	--	.80	--	6.7	--	2.4	--	--	80

Appendix 3. Daily nitrogen, phosphorus, and suspended-sediment loads during storms at the Brush Run Creek site --Continued

Date	Mean daily dis-charge	Total nitro-gen	Total nitrate plus nitrite	Dis-solved nitrate plus nitrite	Total ammo-nia	Dis-solved ammo-nia	Total organ-ic nitro-gen	Dis-solved organic nitro-gen	Total phos-phorus	Dis-solved phos-phorus	Dis-solved ortho-phos-phorus	Sus-pended sedi-ment
08/09/91	0.02	2.9	1.8	--	0.50	--	0.60	--	0.30	--	--	--
08/20/91	.15	22	17	--	2.3	--	3.1	--	2.1	--	--	180
08/21/91	.02	3.1	2.3	--	.20	--	.60	--	.10	--	--	10
09/04/91	.05	79	4.0	--	48	--	27	--	6.9	--	--	100
09/05/91	.03	35	4.6	--	24	--	6.0	--	1.4	--	--	100
09/18/91	1.2	73	63	--	3.8	--	6.0	--	22	--	--	2,580
09/19/91	610	675	18	--	18	--	47	--	53	--	--	18,200

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