EVALUATION OF AGRICULTURAL BEST-MANAGEMENT PRACTICES IN THE CONESTOGA RIVER HEADWATERS, PENNSYLVANIA: Methods of Data Collection and Analysis, and Description of Study Areas

Water-Quality Study of the
Conestoga River Headwaters,
Pennsylvania

By Douglas C. Chichester

U.S. GEOLOGICAL SURVEY

Open-File Report 88-96

Prepared in cooperation with the

U.S. DEPARTMENT OF AGRICULTURE and the
PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES

Harrisburg, Pennsylvania

1988

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108-1107

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center
Box 25425
Denver, Colorado 80225

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

TABLES

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

Methods of Data Collection and Analysis, and Description of Study Areas

By Douglas C. Chichester

ABSTRACT

The U.S. Geological Survey, in cooperation with the U.S. Department of Agriculture and the Pennsylvania Department of Environmental Resources, is conducting a study in the headwaters of the Conestoga River, Pennsylvania. The study, part of the nationally implemented Rural Clean Water Program, was designed to determine the effects of agricultural best-management practices on surface- and ground-water quality. Preliminary investigations in Pennsylvania have shown that carbonate terrane, typically highly porous and permeable, is particularly susceptible to nonpoint-source contamination from agricultural activity. As a result, the study, which began in 1982, is concentrated in four study areas within intensively farmed, carbonate terrane, and is located in southeastern Pennsylvania, in Lancaster, Berks, and Lebanon Counties. These areas are divided into three monitoring components: (1) a Regional study area, 188 square miles; (2) a Small Watershed study area, 5.82 square miles and (3) two field-site study areas, Field-Site 1, 22.1 acres and Field-Site 2, 47.5 acres. The best-management practices to be evaluated are nutrient management, animal-waste storage, and terracing systems.

Water quality has been monitored for 2 years before and will be monitored for a minimum of 2 years after the implementation of the best-management practice(s). The key water-quality constituents being analyzed are nutrients (nitrogen and phosphorus) and suspended sediment at all of the study areas, as well as selected pesticides at the Small Watershed and Field-Site 1 study areas. The report presents the type of water-quality data collected and the methods of data collection and analysis. The monitoring strategy and descriptions for all data-collection stations at the four study areas are provided.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the U.S. Department of Agriculture and the Pennsylvania Department of Environmental Resources is conducting a study in the headwaters of the Conestoga River to determine the effects of agricultural Best-Management Practices (BMPs) on surface- and ground-water quality. The Conestoga Headwaters Rural Clean Water Program (RCWP) is part of the nationally implemented RCWP approved by Congress in 1979 and directed by the U.S. Department of Agriculture. The primary objective of the national RCWP is to accelerate the installation of agricultural BMPs. A BMP is a single conservation practice or a system of practices. Additional objectives of the Conestoga Headwaters RCWP are: (1) to significantly reduce agricultural contaminants entering the public and private water of the study area; (2) to improve the potable quality of water used by people within and downstream from the study area; and (3) to improve the degraded aquatic environment in the Conestoga Headwaters.

To evaluate the effects of BMPs on water quality, the Conestoga Headwaters RCWP is divided into four study areas that represent three monitoring components: (1) a Regional study area, 188 mi^2 (square mile), the Regional representing the entire Conestoga Headwaters and encompassing all the other study areas; (2) a Small Watershed study area, 5.82 mi^2; and (3) two field-site study areas, Field-Site 1, 22.1 acres and Field-Site 2, 47.5 acres, (fig. 1). These components represent three different monitoring scales and intensities of data collection. The water-quality concerns of the project include nutrients (nitrogen and phosphorus), suspended sediment, and pesticides (herbicides and insecticides).

Background

Previous studies have indicated water-quality problems in areas within and surrounding the Conestoga Headwaters. Hall (1934) indicated that generally, ground-water nitrate concentrations in southeastern Pennsylvania were high in comparison to ground-water nitrate concentrations in other parts of the United States. The origin of these concentrations was not apparent. Meisler and Becher (1966; 1971) noted elevated ground-water nitrate concentrations in the carbonate rock areas of Lancaster County, Pennsylvania. Poth (1977) noted that elevated nitrate concentrations were a problem specific to the carbonate rocks in Lancaster County. He went on to state that, in carbonate rocks, water movement is rapid, and contamination of water by human activities can be widespread.

In 1972, Congress amended the Federal Water Pollution Control Act, which established water-quality goals. Section 208 of the Act provided for the preparation of water-quality management plans by State and local governments. In 1977, the Act was amended again and renamed the Clean Water Act. In 1979, Pennsylvania developed a comprehensive Agricultural 208 Plan which identified priority areas in need of further study on nonpoint-source contamination of surface and ground water (Schueller, 1983). The Conestoga River was designated the top-priority watershed in Pennsylvania as a result of this water-quality study.

In 1979, Congress approved the nationally implemented RCWP that is directed by the U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. The Conestoga Headwaters RCWP was approved by the national RCWP committee in July 1981 to accelerate the installation of BMPs on farms in the watershed to reduce agricultural contamination of surface and ground water. The Conestoga Headwaters RCWP is one of 20 such RCWPs nationwide and is one of five projects in which Comprehensive Monitoring and Evaluation (CM&E) is taking place. The other CM&E projects are located in South Dakota, Vermont, Idaho, and Illinois. South Dakota and Pennsylvania are the only projects in which ground-water quality and quantity are being evaluated in addition to surface water.

Because excessive nutrients and erosion are the major problems in the project area, the BMPs to be implemented and evaluated as part of the Conestoga

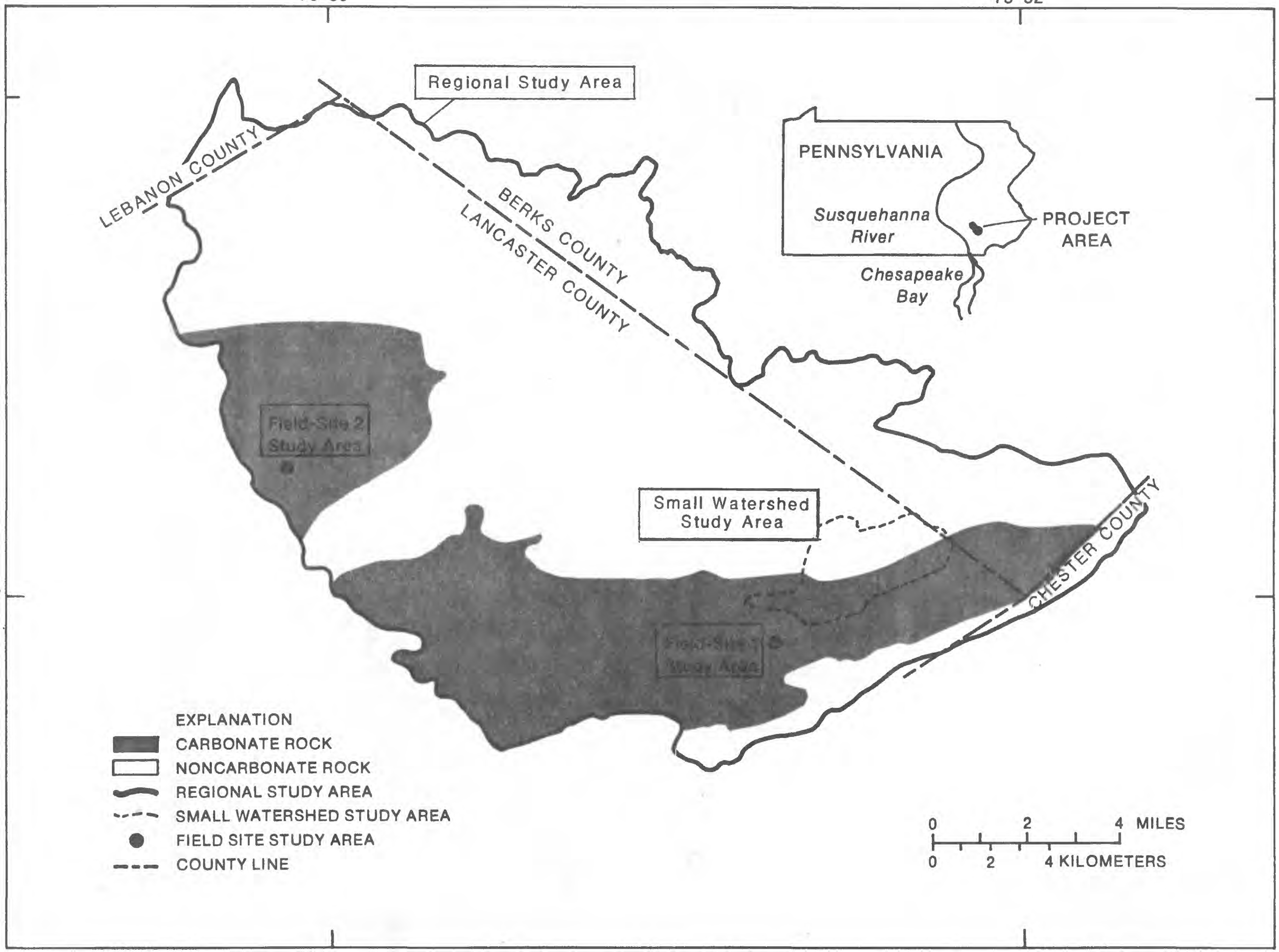

Figure 1.-- Study area locations and general geology.

Headwaters CM&E monitoring are nutrient management, animal-waste storage, and terracing. Nutrient management involves determining proper rates and timing for applications of manure and commercial fertilizers in order to reduce the amount of unused nutrients that become available for transport to streams and ground water. Animal-waste storage is used in conjunction with nutrient management and involves accumulating manure in a concrete or earthen structure and applying it to the field at the proper time for crop usage. Terracing involves contouring and, therefore, changing the drainage pattern of the land surface and installing some form of drainage system (as part of this study a pipe-outlet drainage system was installed) so that soil can be kept on the field and so that suspended-sediment concentration in runoff can be reduced.

Purpose and Scope

The purpose of this report is to describe the Conestoga Headwaters RCWP project by discussing the methods of data collection and analysis, and by describing the study areas and approach used to determine the effects of implementing agricultural BMPs on surface- and ground-water quality. Discussion is included on the frequency and methods of data collection, the methods of chemical and statistical analyses, and description of the study areas and data-collection locations. This report discusses the first of four study phases: (1) methods of data collection and analysis; and description of study areas and approach used in determining the effects of BMP implementation on water quality; (2) collection and presentation of pre-Best-Management Practice (pre-BMP) water-quality data; (3) determining the effects of BMP implementation on water quality at each of the study areas following the collection of post-Best-Management (post-BMP) data; and (4) a summary of the effects of BMP implementation on water quality at all the study areas.

Water quality has been monitored for 2 years under pre-BMP conditions and will be monitored for at least 2 years under post-BMP conditions (table 1). Water-quality samples are collected monthly or quarterly and during some major storms at all stream, runoff, and ground-water data-collection locations. Precipitation quantity and intensity data are collected continuously at all precipitation stations and precipitation quality is measured during selected periods. Land-use data are collected from farmers on a regular basis. Manure samples are collected in the spring or fall prior to applications. Soil samples are collected two to three times per year.

Table 1.--Pre- and post-Best-Management Practice data-collection schedule for the four study areas

	Calendar Year										
Study area	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Regional	---Pre----									?-Post-?	
Small Watershed			-----Pre----		--------Post----------						
Field-Site 1	----Pre-----			---------Post----------------							
Field-Site 2			----Pre-----			---Post----					

Acknowledgments

The execution of the Conestoga Headwaters RCWP would not be possible without the cooperation of many Federal, State, and local agencies throughout the project development. These agencies include:

U.S. Agricultural Stabilization and Conservation Service
U.S. Soil Conservation Service
U.S. Geological Survey
U.S. Environmental Protection Agency
U.S. Economic Resource Service
U.S. Agricultural Research Service
Pennsylvania Department of Environmental Resources
Pennsylvania State University
North Carolina State University
Lancaster County Conservation District
Susquehanna River Basin Commission
Pennsylvania Fish Commission
Eastern Lancaster County School District

A special thanks goes out to all the farmers who provided land-use data for the project and endured all the concentrated data collection efforts on their farms.

METHODS OF DATA COLLECTION AND ANALYSIS

In this section, the frequency and methods of data collection and chemical analyses are presented. Additionally, the types and methods of statistical analyses to be used in subsequent reports are presented.

Data Collection

Precipitation

Precipitation quantity and intensity data are collected using a 13-inch funnel mounted above a 6-inch plastic receiving pipe equipped with an Analog Digital Recorder (ADR) that records rainfall every 5 minutes. The data are compared with long-term records from the National Oceanic and Atmospheric Administration (NOAA) station at Morgantown, Pennsylvania (fig. 2). The data collected at the precipitation stations and at the NOAA station are used to estimate any missing precipitation records.

Rainfall, for quality analysis, is sampled one to three times yearly using a 13-inch funnel to collect rainfall into a glass quart jar inside a cooler. Ice in the cooler is used to keep the rainwater at 4°C (39°F) until the sample can be preserved and then analyzed for nutrient content (nitrogen and phosphorus).

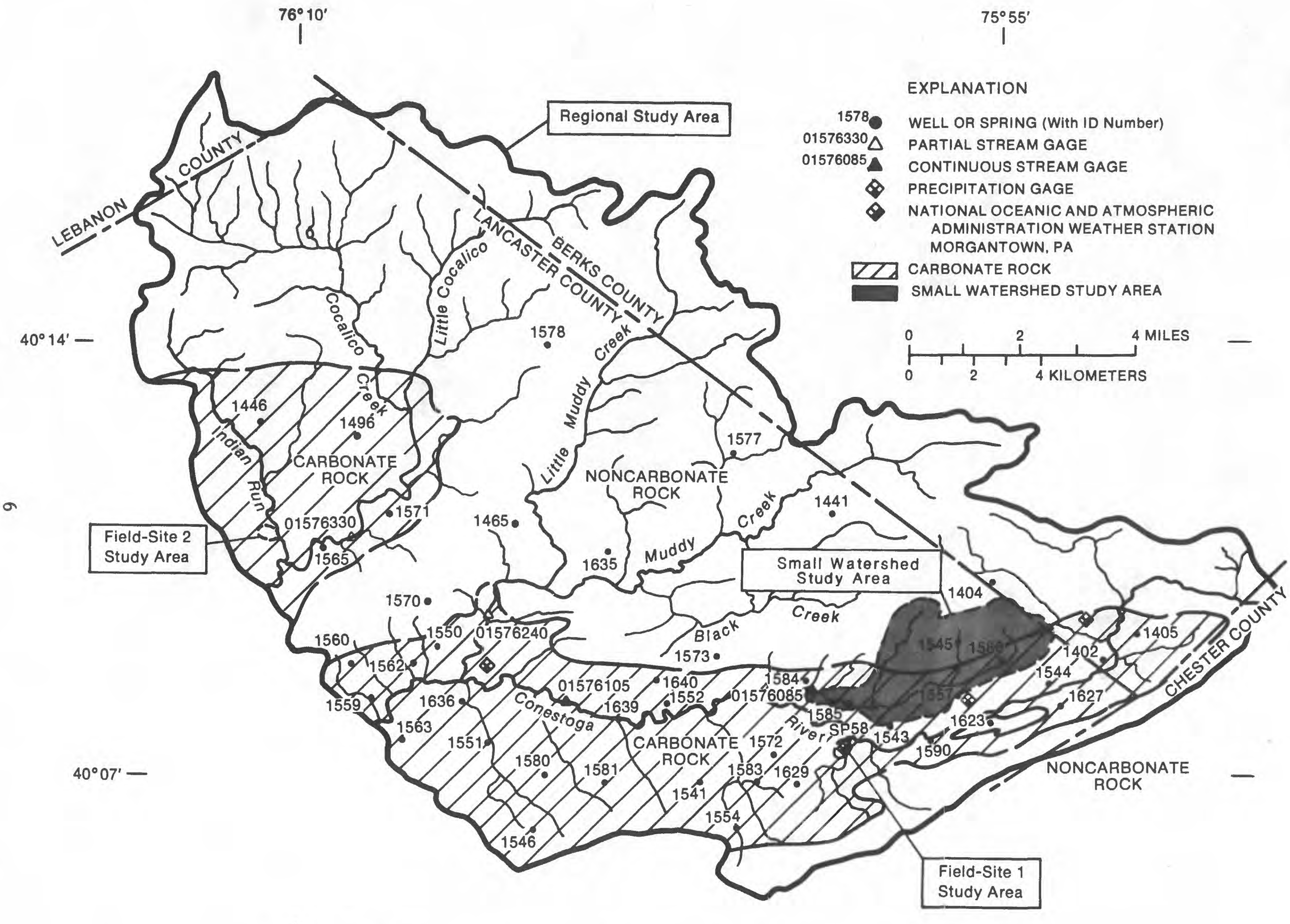

Figure 2.--Regional study area data-collection locations and general geology.

Manure

Manure samples are collected periodically when manure is being applied on the fields. These samples are collected from agitated manure pits and from livestock areas, and are representative of manure being applied to the fields. The samples are analyzed by A & L Eastern Agricultural Laboratories, Inc.[1], in Richmond, Va., for nitrogen, phosphorus, and moisture according to methods described by William (1984). The manure-nutrient analyses are used in nutrient-budget analyses of water quality and in farm nutrient-management plans developed by the Pennsylvania State University, Cooperative Extension Service.

Soil

Soil samples are collected in the spring and the fall from the top 4 feet of soil, and in the summer from the top 2 feet of soil. The 4-foot samples are collected by the Pennsylvania State University, College of Agronomy, using a tractor-mounted, deep-soil probe. The soil sampling is limited to the top 4 feet as this is the maximum depth of the root zone for corn, which is a typical crop in the study areas. The 2-foot samples are collected by hand using a soil probe. The summer sampling is limited to a 2-foot depth because crop growth prevents access to the sample location with the tractor-mounted, deep-soil probe. A soil sample is made up of three cores of soil taken to either the 4- or 2-foot depth at each location. The sample is then divided into segments. The 4-foot samples are separated into 0- to 8-, 8- to 24-, 24- to 36, and 36- to 48-inch segments. The 2-foot samples are separated into 0- to 8-, and 8- to 24-inch segments. The segments are analyzed for average soluble nitrate-nitrogen and phosphorus by the Pennsylvania State University, Soils and Environmental Chemistry Laboratory according to methods by Corey (1977) and by the USEPA (1979). The soil-nutrient analyses are used in nutrient-budget analyses of water quality and in farm nutrient-management plans developed by the Pennsylvania State University, Cooperative Extension Service.

Land Use

Land-use data are provided by the farmers every 2 to 4 weeks. Data include the amount, time, and location of applications of manure, commercial fertilizer, pesticides, and the time of plowing, planting, and harvesting.

Surface Water

Stream stage and field runoff are continuously recorded with a graphic recorder and an ADR. V-notch weirs were installed in the stream channels just downstream from the two continuous-record stations in the Small Watershed study area. The weirs create pools during low-flows so that an accurate gage-height record can be obtained and also are used to stabilize the stream channel.

1/ The use of trade, product, industry, or firm names in this report is for identification or location purposes only, and does not constitute endorsement of products by the U.S. Geological Survey, nor impute responsibility for any present or potential effects on the natural resources.

Water-quality samples are collected at the notch of the weir where the best mixing occurs. Stream-discharge measurements are made according to methods described by Buchanan and Somers (1968; 1969). At the field sites, runoff has been routed to one location through a Parshall flume, where runoff stage can be recorded. A standard flume rating that has been field checked and modified for low flow is used to convert gage height to flow. Stream and runoff stages are converted to streamflow using methods described by Carter and Davidian (1968).

During base flow, water-quality samples are collected using methods described by Guy and Norman (1970) and Culbertson and Feltz (1972). Pesticide samples are collected by methods described by the Federal Working Group on Pesticide Management (1974).

Storm-water samples are collected with float/stage triggered PS-69 automatic samplers, modified with refrigeration units to chill the samples to 4°C (39°F). Perforated intakes for the automatic samplers are positioned in the center of flow of the stream or Parshall flume to assure collection of representative samples. To insure that the automatic samplers are collecting representative samples, hand samples are also collected and compared with the samples collected by the automatic samplers. For each sample collected by the automatic samplers a mark is made on the graphic-stage record to identify the time and stage of collection. Discrete storm samples are analyzed. Concentrations are plotted, and graphs of constituent concentrations are drawn. The total storm discharge of each chemical constituent is computed using streamflow and concentration-integration methods described by Porterfield (1972).

Ground Water

Ground-water levels are measured manually with a steel tape and automatically with continuous-graphic recorders. Ground-water quality samples are collected at the maximum water-bearing zone in the well according to methods described by Lietman and others (1989) or by pumping and then bailing according to methods described by Classen (1982). Samples are also collected from spring outflows. Domestic-well water is sampled by running water until constant temperature and specific conductance is measured. A water sample is then collected directly from the tap (water-treatment systems are bypassed).

Analyses

Chemical

Precipitation, surface-, and ground-water samples are analyzed for some or all of the following: temperature; specific conductance; suspended sediment; total and dissolved nutrients (ammonia, ammonia + organic-nitrogen, nitrite-nitrogen, nitrate + nitrite-nitrogen, and phosphorus); major ions (calcium magnesium, sodium, potassium, sulfate, and chloride); and pesticides (alachlor, atrazine, cyanazine, metolachlor, propazine, simazine, and toxaphene). Temperature and specific conductance are measured in the field. Suspended-sediment and particle-size samples are analyzed at the U.S. Geological Survey Sediment Laboratory in Harrisburg, Pa., by methods described by Guy (1969). Water-quality samples are analyzed by the Pennsylvania Department of Environmental Resources, Bureau of Laboratories. Total concentrations of chemical constituents are determined on unfiltered samples, and concentrations of dissolved constituents are determined for samples filtered through a 0.45-micron filter. All water-quality samples are preserved by chilling to 4°C (39°F) from time of collection to analysis. Nutrient samples are also preserved with mercuric chloride. Nutrients and major ions are analyzed according to methods described by Skougstad and others (1979), and pesticides are analyzed according to modified USEPA proposed method 608 (1985).

Statistical

Extensive data analyses are necessary to evaluate water-quality changes which may occur as a result of BMP implementation. The analyses that will be used to evaluate some or all of the data collected include: simple statistic, trend, regression, nonparametric, paired data, and analysis of variance. These statistical analyses will be done using the Statistical Analysis System (SAS) Institute, Inc. (1979; 1982a; 1982b) and P-STAT, Inc. (1986) statistical packages. The nonparametric analyses will be done using modified SAS source code and procedures described by Crawford and others (1983).

DESCRIPTION OF STUDY AREAS

Descriptions of each of the four study areas are given. A discussion of the purpose, physical setting, and location and amount of data collection for each study area are also provided.

Water-quality data collected as part of this project have been published in the U.S. Geological Survey Water-Resources Data Reports PA-82-2, PA-83-2, PA-84-2, and PA-85-2 (Buchanan 1983; Buchanan and others, 1984; Loper and others, 1985; Loper and others, 1987). The data collected as part of this study can be found in the Water-Resources Data Reports using the U.S. Geological Survey local identification numbers listed in tables 3, 4, 6, 7, 9, and 11, as well as identification numbers 01576083 (Field-Site 1 continuous-record station) and 01576335 (Field-Site 2 continuous-record station).

Regional Study Area

The Regional study area, which includes the entire 188-mi^2 area of the Conestoga Headwaters, was used to determine the effects of implementing all types of BMPs on surface- and ground-water quality (fig. 1). The pre-BMP part of this study was done from April 1982 through September 1983. The results from this study were used to provide background water-quality information for the entire Conestoga Headwaters, as well as to provide information on critical areas in which further studies are necessary. The monitoring strategy for the Regional study area is shown in table 2.

Water quality at this study area is not expected to change significantly within the life of this project because of the large size of the study area, and because few BMPs are being implemented. As a result, the post-BMP sampling has been postponed until a tentative restarting date in the mid-1990's.

Table 2.--Monitoring plan for the Regional study area

SCHEDULE

April 1982 - September 1983 Pre-BMP

--------POSTPONED---------- Post-BMP

APPROACH

Compare concentrations and discharges of sediment, nutrients, and pesticides before and after implementation of all forms of BMPs.

DATA COLLECTION

2 Continuous-record stations - Suspended sediment, nutrients, and pesticides for major storms; and suspended sediment, nutrients, and pesticides monthly during base flow

2 Partial-record stations - Suspended sediment, nutrients, and pesticides monthly during base flow

42 Wells and 1 spring - Nutrients 4 times per year and pesticides 3 times per year

3 Precipitation Stations - Intensity at 5-minute intervals and total accumulation

Physiography and Geology

The Regional study area lies in two sections of the Piedmont physiographic province (U.S. Department of Agriculture, 1985). The north-central part of the study area is in the Triassic Lowland section and is characterized by conglomerate, sandstone, shale, and diabase of Triassic age. The south and southwest part of the study area is in the Conestoga Valley section and is characterized by carbonate and shale rocks of Cambrian and Ordovician age.

Soils

Soils in the Regional study area are primarily of the Duffield, Hagerstown, Ungers, Bucks, Lansdale, and Bedinton series (U.S. Department of Agriculture, 1985). Scattered throughout the study area are soils of the Clymer, Chester, Manor, and Glenelg series. The soils from these series are nearly level to steeply sloping, well drained soils. Soils from the Duffield and Hagerstown series are formed in the residuum of carbonate rock. The soils from the remaining series are formed in the residuum of siltstone, conglomerate, shale, sandstone, and metamorphic rocks.

Land Use

The Regional study area is primarily in a rural, agricultural setting with small towns and villages. The primary land-use activity in the area is agriculture, with small areas of forest, residential, and small industries scattered throughout the area.

Data-Collection Network

The data-collection locations at the Regional study area are shown in figure 2. Three precipitation stations were installed in the study area. Also, two continuous-record stations were constructed. Ground-water samples were collected from existing domestic wells and one spring.

Precipitation and soil

Precipitation quantity and intensity were collected at three stations located within the study area (fig. 2). Following the postponement of the post-BMP monitoring at the Regional study area, one station was moved to the Field-Site 2 study area. The remaining two stations continued operating and provided data for the Small Watershed and the Field-Site 1 study areas.

Soil data were not collected as part of the Regional study area.

Surface water

The surface-water network of the Regional study area consists of four stations draining about 75 percent of the 188-mi^2 area of the Conestoga Headwaters (fig. 2) (table 3). Two of these stations are continuous-record stations - Conestoga River near Terre Hill, Pa., and Little Conestoga Creek near Churchtown, Pa; and two are partial-record stations - Muddy Creek near Martindale, Pa., and Cocalico Creek near Ephrata, Pa. About half of the drainage areas of the continuous-record stations are underlain by carbonate rock. Muddy and Cocalico Creeks drain areas underlain predominantly by noncarbonate rock (99.7 and 89 percent, respectively).

Base-line data for the Conestoga River station consist of daily discharge from November 1981 through September 1983, daily suspended-sediment concentrations from April 1982 through April 1983, suspended-sediment concentrations during storms from May through September 1983, and monthly base-flow data from April 1982 through April 1983.

Base-line data for the Little Conestoga Creek station are more extensive because this station has remained in operation throughout the project, first as part of the Regional study area, and subsequently as part of the Small Watershed study area. Daily discharges have been measured since June 1982 and will continue through September 1989. Daily suspended-sediment concentration data were collected August 1982 through November 1983. Monthly base-flow and storm samples have been collected since August 1982 and will continue to be collected through September 1989. Storm samples are analyzed for suspended sediments and nutrients.

Muddy and Cocalico Creeks were sampled monthly from April 1982 through March 1983 during base-flow conditions. Discharge measurements were made at the time of sample collection.

Base-flow samples at all four stations, for samples collected through September 1983, were analyzed for specific conductance, temperature, pH, major ions, nutrients, and pesticides.

Table 3.--Regional study area surface-water data-collection stations
[mi^2, square miles]

U.S. Geological Survey identification number	Station name	Station type	Drainage area (mi^2)	Latitude/longitude	
01576085	Little Conestoga Creek near Churchtown, Pa. (Small Watershed study area)	Continuous record	5.82	40°08'41"	75°59'20"
01576105	Conestoga River near Terre Hill, Pa.	Continuous record	49	40 08 44	76 04 41
01576240	Muddy Creek near Martindale, Pa.	Partial record	49	40 10 12	76 06 21
01576330	Cocalico Creek near Ephrata, Pa.	Partial record	43	40 11 39	76 09 09

Ground water

The ground-water network of the Regional study area consists of 42 wells and one spring located in the 188-mi^2 area of the Conestoga Headwaters (fig. 2). All of these locations are currently being used for, or have been used as, a domestic water-supply source.

Thirty-three of the locations are distributed over one-third of the study area and are underlain by carbonate rock (table 4). The other locations are distributed over the remainder of the study area, and are underlain predominantly by sandstone and shale. Thirty-two of the locations are located in agricultural areas; 28 of these locations are underlain by carbonate rock. Ground-water data collection is concentrated in the agricultural and carbonate areas because these areas were determined to be most susceptible to nonpoint-source contamination of ground water.

The ground-water network was monitored four times during the pre-BMP phase; during the fall of 1982, and during the spring, summer, and fall of 1983. During each visit, depth to water level was measured and samples were collected and analyzed for specific conductance, temperature, pH, nutrients, major ions, and pesticides (pesticides were not sampled during the fall of 1982). A summary of ground-water nutrient and herbicide data is provided by Fishel and Lietman (1986).

Bacteriological samples were collected during the fall of 1982 and spring of 1983 at all of the surface- and ground-water sampling locations. The sampling was discontinued, however, because some uncharacteristic and unidentifiable colonies were observed on culture plates for bacteria.

Table 4.--Regional study area ground-water data-collection locations

U.S. Geological Survey local identification number	Latitude/longitude	Agricultural (A)/ nonagricultral (NA)	Carbonate (C)/ noncarbonate (NC)
BE 1402	40°08'51" 75°53'08"	A	C
BE 1404	40 10 12 75 55 29	NA	NC
BE 1405	40 09 13 75 52 23	A	C
LN 1441	40 11 35 75 58 51	NA	NC
LN 1446	40 13 38 76 11 07	A	C
LN 1465	40 11 42 76 05 47	A	NC
LN 1496	40 13 18 76 08 59	A	C
LN 1541	40 07 15 76 01 55	NA	C
LN 1543	40 07 58 75 57 49	NA	C
LN 1544	40 08 34 75 54 16	A	C
LN 1545	40 09 20 75 56 13	NA	NC
LN 1546	40 06 37 76 05 32	A	C
LN 1550	40 09 38 76 07 28	A	C
LN 1551	40 08 08 76 06 24	A	C
LN 1552	40 08 33 76 02 36	A	C
LN 1554	40 06 28 76 01 13	A	C
LN 1557	40 08 28 75 56 16	NA	C
LN 1559	40 08 55 76 08 57	A	C
LN 1560	40 09 32 76 09 25	A	C
LN 1562	40 09 27 76 08 01	A	C
LN 1563	40 08 13 76 08 19	A	C
LN 1565	40 11 27 76 09 49	NA	C
LN 1570	40 10 32 76 07 39	NA	NC
LN 1571	40 11 57 76 08 27	A	C
LN 1572	40 07 34 76 00 15	NA	C
LN 1573	40 09 18 76 01 30	A	NC
LN 1577	40 12 40 76 00 53	A	NC
LN 1578	40 14 36 76 04 51	NA	NC
LN 1580	40 07 30 76 05 16	A	C
LN 1581	40 07 27 76 03 56	A	C
LN 1583	40 07 12 76 00 45	A	C
LN 1584	40 08 47 75 59 35	A	C
LN 1585	40 08 23 75 58 48	A	C
LN 1586	40 08 53 75 55 21	A	C
LN 1590	40 07 44 75 56 56	A	C
LN 1623	40 07 57 75 55 38	NA	NC
LN 1627	40 08 09 75 54 06	A	C
LN 1629	40 07 02 75 59 50	A	C
LN 1635	40 11 09 76 03 42	A	NC
LN 1636	40 08 48 76 06 53	A	C
LN 1639	40 08 34 76 03 30	A	C
LN 1640	40 08 58 76 02 48	A	C
LN SP58	40 07 44 75 58 39	A	C

Small Watershed Study Area

The Small Watershed study area will be used to determine the effects of implementing the nutrient management BMP on surface- and ground-water quality. The study area consists of 5.82 mi^2 in the headwaters of the Little Conestoga Creek (fig. 3), near Morgantown, Pa. The monitoring strategy for the Small Watershed study area is shown in table 5. Two years of pre-BMP data were collected from April 1984 through March 1986. Post-BMP data collection, with nutrient management in effect, is scheduled to be completed by September 1989.

The Small Watershed was divided into two subbasins to help characterize water quality and to better determine the effects of nutrient management on water quality. In the eastern part of the Small Watershed, a 1.42-mi^2 subbasin was designated the Nutrient-Management Subbasin. In this area, a high degree of cooperation and implementation of nutrient management is expected (13 of 17 farmers are participating). The Nutrient-Management Subbasin is the area in which concentrated surface-water data collection will occur. In the northwestern part of the Small Watershed, a 1.43-mi^2 subbasin was designated the Control Subbasin. In the Control Subbasin, few if any changes in farming practices are expected, and, as a result, few water-quality changes are expected. Together, these subbasins are called the Paired-Watersheds. Paired-data analyses will be used to eliminate the influence that climatic factors might have on trends in the data collected at the two subbasins.

Table 5.--Monitoring plan for the Small Watershed study area

SCHEDULE

April 1984 - March 1986	Pre-BMP
April 1986 - September 1989	Post-BMP

APPROACH

Compare concentrations and discharges of suspended sediment and nutrients before and after implementation of the nutrient management BMP.

DATA COLLECTION

2 Continuous-record stations - Suspended sediment and nutrients for major storms, pesticides for selected storms; and suspended sediment and nutrients every 3 weeks during base flow, and pesticides every 3 weeks in the growing season during base flow

5 Partial-record stations - Suspended sediment and nutrients every 3 weeks during base flow, and pesticides (at 1 station) every 3 weeks in the growing season during base flow (2 stations were discontinued October 1984)

6 Wells and 2 springs - Nutrients 3 times per year

4 Soil-sample locations - Nutrients Spring and fall

1 Precipitation station - Intensity at 5-minute intervals and total accumulation;

Quarterly land-use reports from 13 farmers

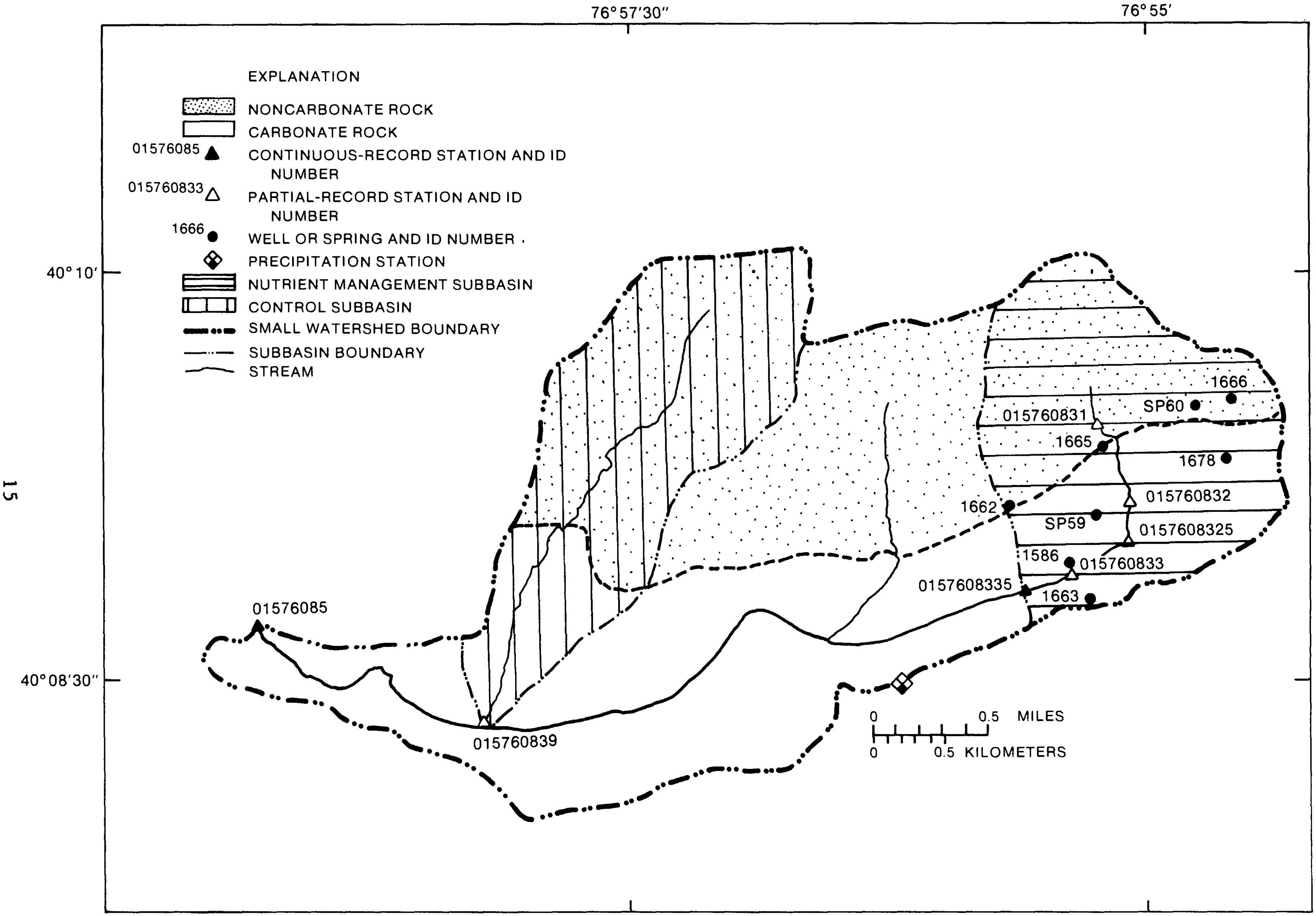

Figure 3.--Small Watershed study area data-collection locations and general geology.

Physiography and Geology

The Small Watershed lies in two sections of the Piedmont physiographic province in Lancaster and Berks counties. The northern half of the watershed is in the Triassic Lowland section and is underlain by conglomerate, sandstone, shale, and diabase of Triassic age. The southern half is in the Conestoga Valley section and is underlain by carbonate rocks of the Buffalo Springs and Stonehenge Formations of Cambrian and Ordovician age, respectively.

Soils

Soils in the Small Watershed are primarily of the Duffield and Unger series with small portions of the Bucks, Hagerstown, Linden, Manor, and Chester series scattered throughout the area (U.S. Department of Agriculture, 1985). The soils from the Duffield series are formed in the residuum of carbonate rock, while the Unger soils are formed in the residuum of siltstone and sandstone. Narrow bands of the Readington and Rowland soil series are located along the streambanks of the Nutrient-Management Subbasin. These soils are well drained, silt loam soils.

Land Use

The Nutrient-Management Subbasin contains all or parts of 17 farms. Farmers from 13 of these farms work closely with the various agencies involved in the RCWP project and provide detailed information on their farming practices. Data collected include crop acreage, yields, animal density, manure export, and applications of manure, commercial fertilizer, and pesticides.

Data-Collection Network

The data-collection locations at the Small Watershed are shown in figure 3. The instrumentation installed for monitoring at the Small Watershed includes two continuous-record stations and a precipitation station. The stream station at Little Conestoga Creek near Churchtown was installed during the summer of 1982. The stream station at Little Conestoga Creek near Morgantown was installed during the spring of 1984. The precipitation station for the Small Watershed was also installed during the fall of 1982.

Precipitation and soil

Precipitation quantity and intensity are collected at a station located immediately south of the Small Watershed study area near Churchtown, Pa. (fig. 3).

Soil samples were initially collected at each of the 13 cooperating farms within the Nutrient-Management Subbasin, but sampling has been reduced to four locations. The soil samples are collected in the spring and the fall of the year from the top 4 feet of soil. The soil samples are collected in the same general locations so that comparison of soil nutrients over time can be made.

Surface water

Streamflow data is collected at two continuous-record stations and at five partial-record stations (fig. 3) (table 6). Two of the partial-record stations, 015760832 and 015760833, were discontinued because the data collected were very similar to the stations just downstream, 0157608325 and 0157608335, respectively. At the continuous-record stations, stream stage is measured and recorded using a graphic-stage recorder and an ADR. During storm events, when the stream level exceeds a set stage, samples are collected with an automatic-pumping sampler (PS-69), modified with a refrigeration unit to keep samples chilled until they can be preserved.

Table 6.--Small Watershed study area surface-water data-collection stations
[mi^2, square miles]

U.S. Geological Survey identification number	Station name	Station type	Drainage area (mi^2)	Latitude	Longitude
015760831	Little Conestoga Creek, Site 1, near Morgantown, Pa.	Partial record	0.34	40°09'22"	75°55'14"
015760832	Little Conestoga Creek, Site 2, near Morgantown, Pa. (Discontinued October 1984)	Partial record	.60	40 09 06	75 55 05
0157608325	Little Conestoga Creek, Site 2A, near Morgantown, Pa.	Partial record	.99	40 08 58	75 55 06
015760833	Little Conestoga Creek, Site 3, near Morgantown, Pa. (Discontinued October 1984)	Partial record	1.34	40 08 50	75 55 24
0157608335	Little Conestoga Creek, Site 3A, near Morgantown, Pa. (Nutrient-Mangement Subbasin)	Continuous record	1.42	40 08 47	75 55 37
015760839	Unnamed tributary to Little Conestoga Creek, Site 9, at Churchtown, Pa. (Control Subbasin)	Partial record	1.43	40 08 20	75 58 14
01576085	Little Conestoga Creek, near Churchtown, Pa. (Small Watershed study area)	Continuous record	5.82	40 08 41	75 59 20

Ground water

Ground water is sampled three times per year at six wells and two springs in the Nutrient-Management Subbasin to characterize ground-water quality (fig. 3). Three wells and one spring are located in carbonate rocks and the remaining three wells and one spring are located in noncarbonate rocks (table 7.) These domestic wells and springs represent local conditions, and may not show the effects of specific BMPs, but they are expected to be helpful in showing general trends in ground-water quality for the Nutrient-Management Subbasin.

Table 7.--Small Watershed study area ground-water data-collection locations

U.S. Geological Survey local identification number	Latitude/longitude	Geologic formation
LN SP59	40°09'03" 75°55'15"	Buffalo Springs[1]
LN SP60	40 09 26 75 54 45	Stockton[2]
LN 1586	40 08 53 75 55 21	Buffalo Springs
LN 1662	40 09 10 75 55 44	Stockton
LN 1663	40 08 43 75 55 27	Buffalo Springs
LN 1665	40 09 22 75 55 11	Stockton
LN 1666	40 09 26 75 54 36	Stockton
LN 1678	40 09 18 75 54 39	Buffalo Springs

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

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

Field-Site 1 Study Area

The Field-Site 1 study area will be used to determine the effects of nutrient management, animal-waste storage, and terracing on surface- and ground-water quality. The study area consists of a 22.1-acre basin located near Churchtown, Pennsylvania in northeastern Lancaster County (fig. 4). The monitoring strategy for the Field-Site 1 is shown in table 8. Two years of pre-BMP data was collected from October 1982 through September 1984. Post-BMP data collection, with nutrient management, animal-waste storage, and terracing in effect, began in October 1984 and is scheduled to end in September 1989.

Table 8.--Monitoring plan for the Field-Site 1 study area

SCHEDULE

October 1982 - September 1984	Pre-BMP
October 1984 - September 1989	Post-BMP

APPROACH

Compare concentrations and discharges of sediment, nutrients, and pesticides before and after implementation of the nutrient management, animal waste storage, and terracing BMPs.

DATA COLLECTION

1 Continuous-record station - Suspended sediment and nutrients for major storms; pesticides for selected storms

5 Wells and 1 spring - Nutrients monthly and during 3 recharge events; pesticides at 2 wells monthly April through November and during 3 recharge events

3 Soil-sample locations - Nutrients spring, summer,and fall

Manure - Nutrients spring

1 Precipitation station - Intensity at 5-minute intervals and total accumulation; nutrients 2 times per year

Biweekly land-use report from farmer

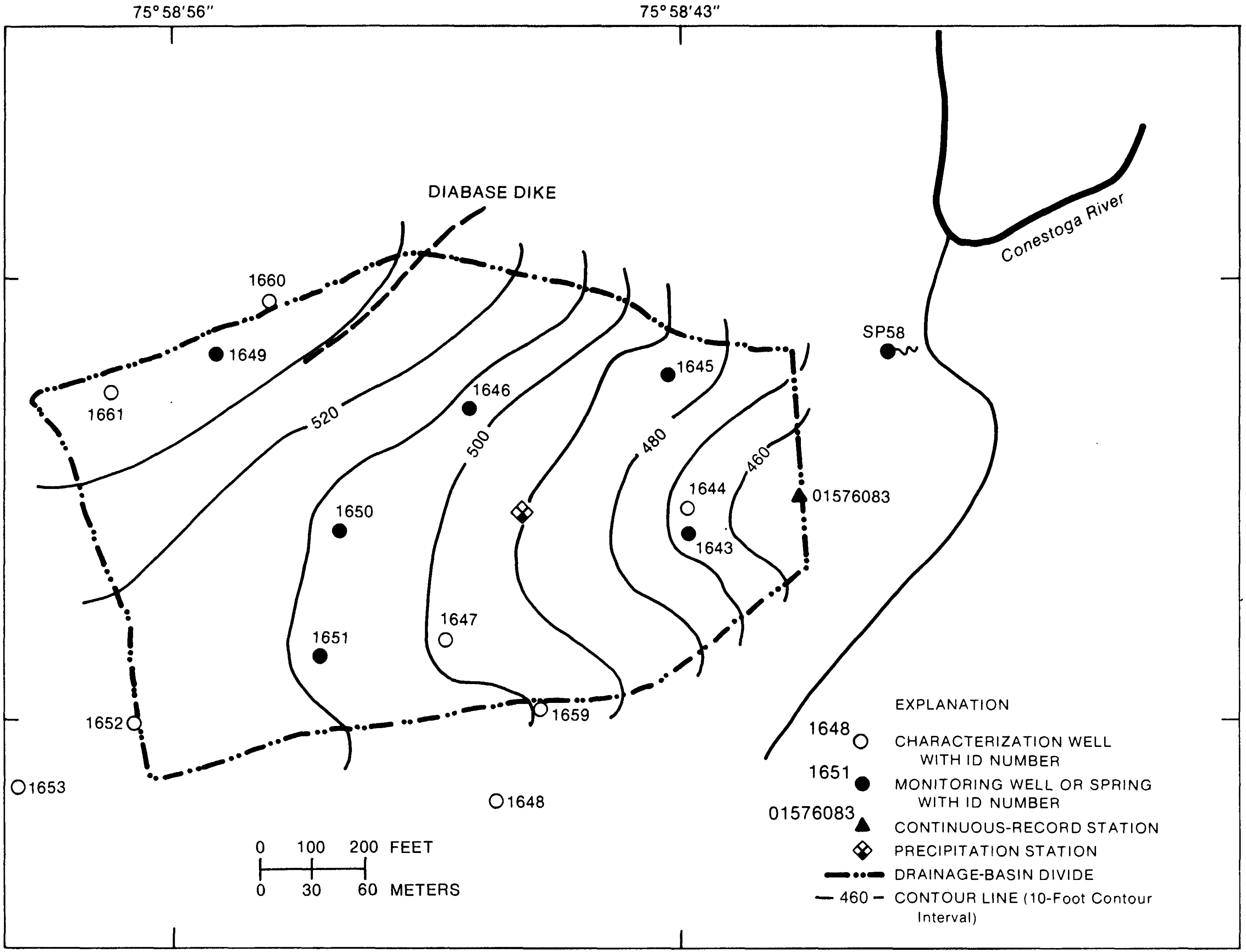

Figure 4.-- Field-Site 1 study area data-collection locations.

Physiography and Geology

Field-Site 1 is located within the Piedmont physiographic province in the Conestoga Valley section. This section is characterized by carbonate and shale rocks that have been repeatedly deformed by folding and faulting. Field-Site 1 is underlain by dolomitic rocks of the Zooks Corner Formation, Cambrian age. This formation consists primarily of thin- to thick-bedded, medium gray, very finely crystaline dolomite (Meisler and Becher, 1971). Bedding strike ranges from N60°E to N70°E, and dip ranges from about 40°NW to 70°NW.

A diabase dike of Triassic age protrudes into the northern edge of the study area (Berg, 1980). A ground-magnetic geophysical survey was conducted to verify the existence of the dike, and to determine the position and the areal extent of the dike. From the geophysical survey it was found that the dike extends approximately 300 feet at a NE trend into the north-central part of the study area (fig. 4).

Soils

Soils at the Field-Site 1 study area are classified as Duffield silt loam and Hagerstown silty clay loam (U.S. Department of Agriculture, 1985). These well-drained soils are formed in the residuum of carbonate rock, and are formed on slopes that range from 2 to 22 percent, with a median slope of 6 percent.

Land Use

During the pre-BMP phase, conventional farming practices (using moldboard plowing) were carried out at the study area with a cropping pattern consisting of primarily corn (15 acres) and alfalfa (5.5 acres). The alfalfa was situated as a strip in the middle of the field. As a part of the BMP, a management plan was developed by the Pennsylvania State University, Cooperative Extension Service. The plan suggested that the alfalfa strip be moved to the lowest part of the field, below the bottom terrace, to provide erosion control.

Six pipe-outlet terraces and an animal-waste storage structure were installed as part of the management plan for the study area in the fall of 1984 to be used in conjuction with nutrient management. The pipe-outlet terraces were constructed to withstand a 5-inch, 24-hour storm. As a result of terracing, the area of the drainage basin was changed from 22.1 acres during the pre-BMP period to 23.1 acres during the post-BMP period (fig. 5). The outlet pipe was situated so that the discharge water would run through the Parshall flume at the runoff station. The animal-waste storage structure consists of a 225,000 gallon concrete storage tank. This is approximately a 6-month storage capacity for this farm. The storage structure will enable the timing of nutrient applications to be made according to crop needs rather than manure disposal needs.

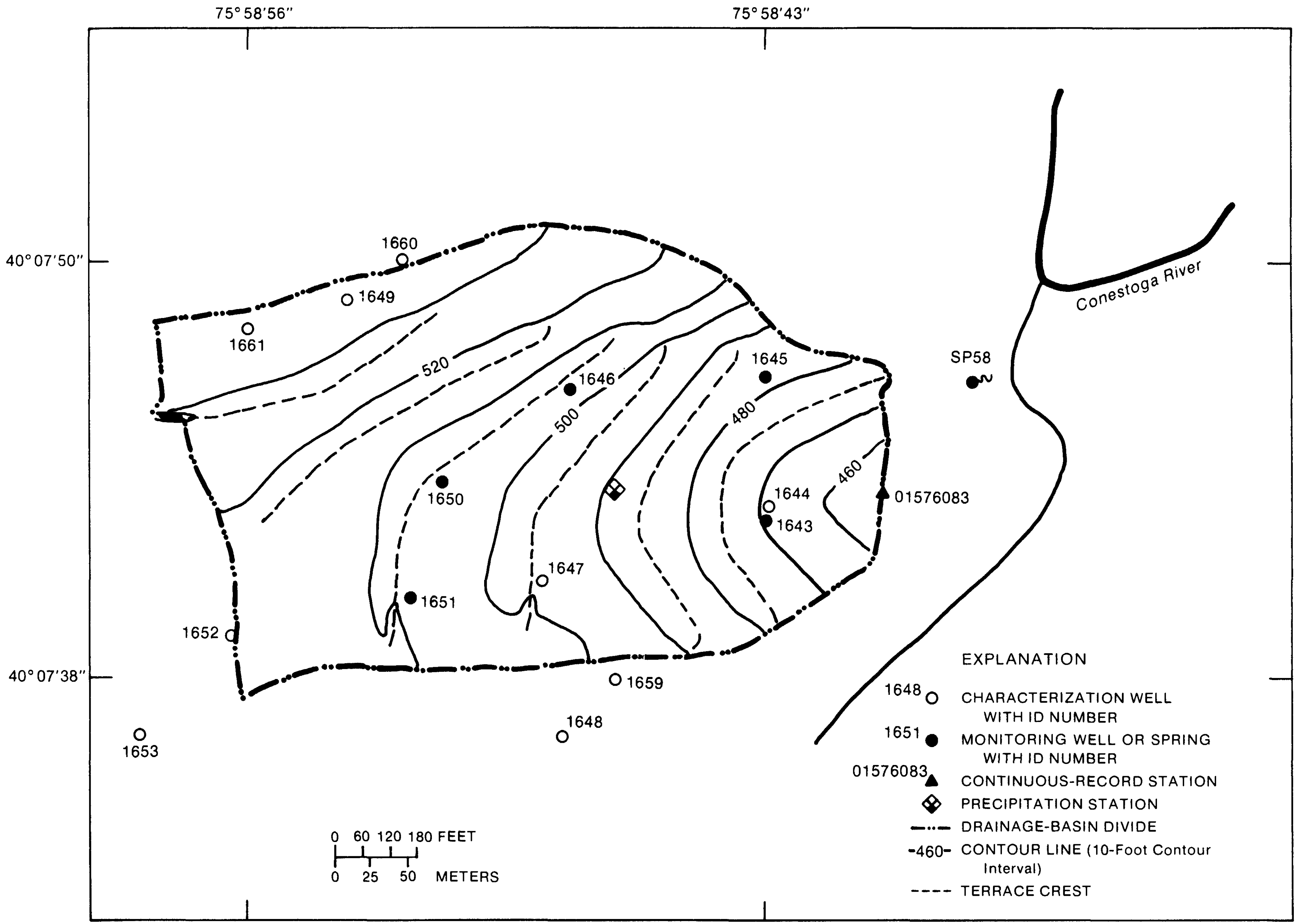

Figure 5.-- Field-Site 1 study area post-BMP topography with terraces.

Data-Collection Network

The data-collection locations at Field-Site 1 are shown in figure 4. A continuous-record station was constructed in the fall of 1982 to monitor the runoff from the study area. A precipitation station has been operational at the study area since December 1982. Fourteen wells were drilled on or near the study area in the fall of 1982 to help in the physical and chemical characterization of the ground-water system. A nearby spring (LN SP58), used for domestic supply, is also used in the water-quality sampling.

Precipitation and soil

Precipitation quantity and intensity are collected at a precipitation station located in the middle of the study area (fig. 4). Precipitation-quality samples were collected one to three times per year adjacent to the study area.

Soil samples are collected in the spring and fall from the top 4 feet of soil, and in the summer from the top 2 feet of soil. These soil samples are collected in the same general locations (one in alfalfa and two in corn) so that comparison of soil nutrients over time can be made.

Surface water

All surface runoff from the field, both before and after terracing, is routed through a Parshall flume at the base of the field (U.S. Geological Survey identification number 01576083). The water level in the flume is continuously measured with a graphic-stage recorder. An ADR also monitors runoff, and indicates the stage at which samples are collected. During storm events, samples are collected with an automatic-pumping sampler (PS-69), modified with a refrigeration unit to keep samples chilled until they can be preserved.

Ground water

The 14 wells were drilled by air-rotary methods, cased to solid bedrock with 6-inch steel casing, then continued as open holes into the unconfined, carbonate rock aquifer (table 9). The wells were then grouted with cement and sealed at the surface with bentonite. Depths to water level range from 30 to 75 feet. In the wells, weathered rock exists to depths of 100 feet, and numerous cavities and voids are present at all depths within the weathered and fresh bedrock.

A preliminary report on ground-water recharge and nitrate concentrations at this study area is provided in Gerhart (1986).

Table 9.--Field-Site 1 study area ground-water data-collection locations and descriptions

U.S. Geological Survey local identification number	Latitude/longitude	Total well depth	Depth to bedrock	Sample depth	Data collected[1/]
		(depth in feet from land surface)			
LN SP58	40°07'44" 75°58'39"	-	0	-	N
LN 1643	40 07 41 75 58 43	100	20	82	NWL
LN 1644	40 07 42 75 58 43	75	22	-	WL
LN 1645	40 07 46 75 58 43	80	7	62	NWLP
LN 1646	40 07 44 75 58 47	125	5	107	NWLP
LN 1647	40 07 40 75 58 49	75	17	-	WL
LN 1648	40 07 38 75 58 46	100	2	-	WL
LN 1649	40 07 44 75 58 54	85	35	72	NWL
LN 1650	40 07 41 75 58 51	125	63	112	NWL
LN 1651	40 07 39 75 58 51	105	68	92	NWL
LN 1652	40 07 38 75 58 53	125	12	-	WL
LN 1653	40 07 37 75 58 56	132	27	-	WL
LN 1659	40 07 39 75 58 45	142	18	-	WL
LN 1660	40 07 45 75 58 53	150	12	-	WL
LN 1661	40 07 44 75 58 56	75	20	-	WL

Note: All ground-water data-collection locations are in the Zooks Corner Formation. See text for geologic description of this Formation.

1/ NWLP - Nutrient, water-level, and pesticide data

NWL - Nutrient and water-level data

WL - Water-level data only

N - Nutrient data only

Field-Site 2 Study Area

The Field-Site 2 study area will be used to determine the effects of nutrient management on surface- and ground-water quality. The study area consists of a 47.5-acre field located near Ephrata, PA (fig. 6). The monitoring strategy for the Field-Site 2 study area is shown in table 10. Two years of pre-BMP data were collected from October 1984 through September 1986. Post-BMP data collection, with nutrient management BMP in effect, is scheduled to end in September 1988.

Table 10.--Monitoring plan for the Field-Site 2 study area

SCHEDULE

October 1984 - September 1986	Pre-BMP
October 1986 - September 1988	Post-BMP

APPROACH

Compare concentrations and discharges of nutrients before and after implementation of the nutrient management BMP.

DATA COLLECTION

1 Continuous-record station - Nutrients for major storms

8 Wells and 1 spring - Nutrients monthly and during 4 recharge events

9 Soil-sample locations - Nutrients spring, summer,and fall

Manure - Nutrients spring

1 Precipitation station - Intensity at 5-minute intervals and total accumulation; nutrients 2 times per year

Biweekly land-use report from farmer

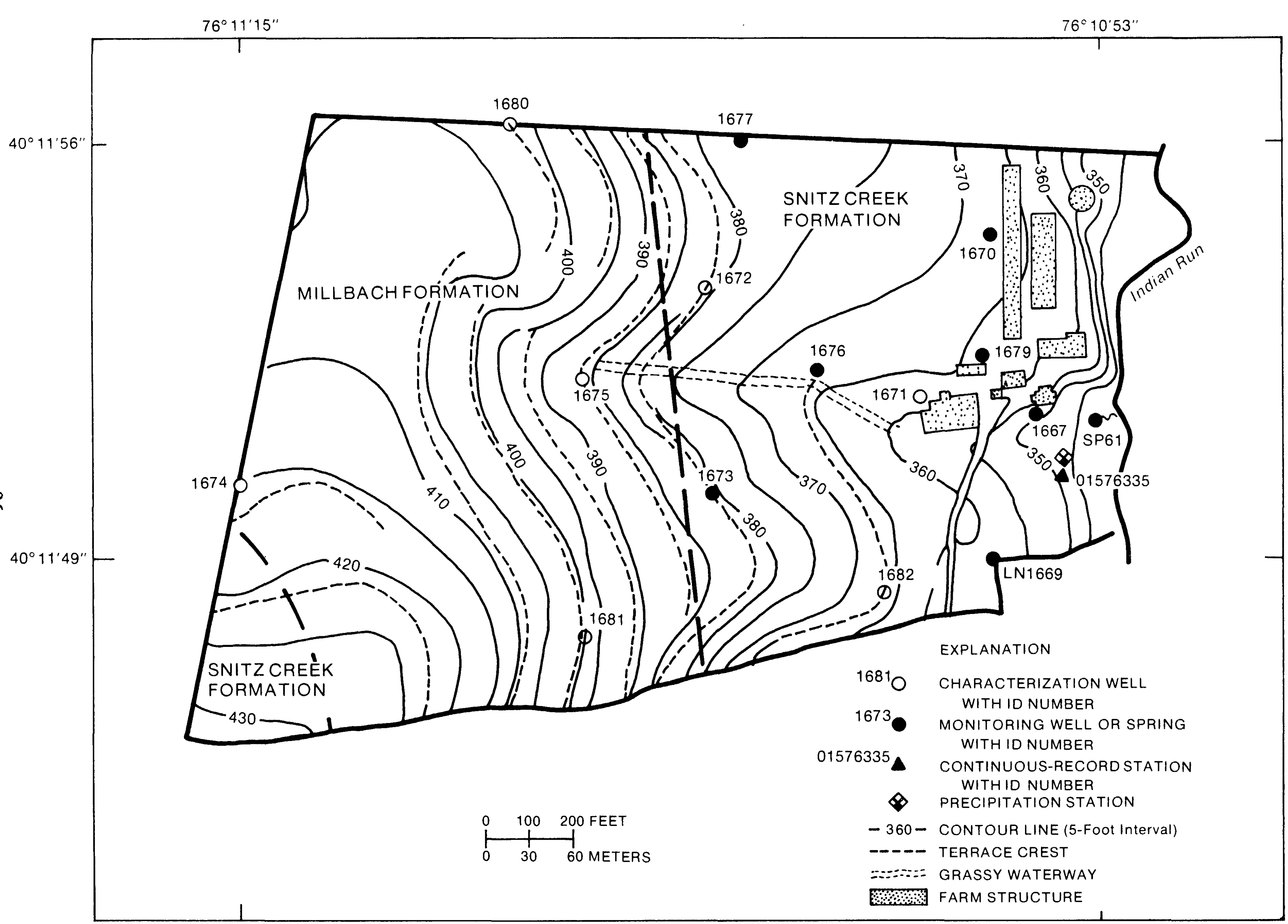

Figure 6.--Field-Site 2 study area data-collection locations.

Physiography and Geology

Field-Site 2 is located within the Piedmont physiographic province in the Conestoga Valley section. This section is characterized by carbonate and shale rocks that have been repeatedly deformed by folding and faulting.

Approximately two-thirds of the site is underlain by limestone of the Millbach Formation, of Cambrian age; the other one-third of the site is underlain by dolomite of the underlying Snitz Creek Formation, of Cambrian age. The Millbach Formation consists primarily of light-pinkish-gray to medium-dark-gray, finely to very finely crystaline limestone with light-gray to medium-gray laminae of dolomite (Meisler and Becher, 1971). The Snitz Creek Formation consists primarily of light- to dark-gray, finely to very finely crystalline dolomite.

Soils

The soil at the Field-Site 2 study area is Hagerstown silt loam (U.S. Department of Agricultural, 1985). This soil is formed in the residuum of carbonate rock on slopes that range from 2 to 9 percent, with a median slope of about 5 percent.

Land Use

Field-Site 2 is typically planted in corn with 3 to 5 acres of tobacco planted in the lower part of the study area. Approximately half of the field is cultivated using no-till methods (corn is planted in unplowed ground), and half is cultivated using minimum-till (soil is chisel plowed in the spring prior to planting). Twenty-five acres of the field are drained by pipe-outlet terraces. These terraces were originally installed in 1965 for erosion control purposes, and were reshaped and modified in 1981. Annual animal populations are typically 100 beef cattle, 1,500 hogs (three sets of 500 per year), and 110,000 chickens (five sets of 22,000 per year), or 2.9 animal units per acre (an animal unit is 1,000 pounds of animal weight).

Data-Collection Network

The data-collection locations at Field-Site 2 are shown in figure 6. A continuous-record station was installed in the fall of 1984 to monitor surface-runoff quality and quantity from the pipe-outlet terraces. A precipitation station has been operational at the site since mid-October 1984. Thirteen wells were drilled on the study area between the fall of 1984 and the spring of 1986 to help in the physical and chemical characterization of the ground-water system. A spring (LN SP61) and hand-dug well (LN 1667), used for domestic water supply, are also used in the water-quality sampling network.

Precipitation and soil

Precipitation quality and intensity are collected at the station located beside the runoff station at the base of the study area. Precipitation water-quality samples are collected one to three times per year adjacent to the station.

Soil samples are collected during the spring, summer, and fall at three to nine locations throughout the study area. The soil samples are collected from the top 4 feet of soil in the spring and fall, and from the top 2 feet of soil and in the summer. These soil samples are collected in the same general location so that comparison of soil nutrient over time can be made.

Surface water

Surface runoff from the study area represents only the water that is drained from the pipe-outlet terraces (25 acres). Runoff from the terraces is routed through a Parshall flume at the base of the field (U.S. Geological Survey identification number 01576335). The water level in the flume is continuously measured with a graphic-stage recorder. An ADR also monitors runoff, and indicates the stage at which samples are collected. During storm events, samples are collected with an automatic-pumping sampler (PS-69), modified with a refrigeration unit to keep samples chilled until they can be preserved.

Ground water

The 13 wells at Field-Site 2 were drilled by air-rotary methods, cased with 6-inch steel casing to solid bedrock, and continued as open holes into the unconfined, carbonate-rock aquifer (table 11). The wells were then grouted with cement and sealed at the surface with bentonite. Depths to water level range from 6 to 33 feet.

Table 11.--Field-Site 2 study area ground-water data-collection locations and descriptions
[A dash indicates no data collected]

U.S. Geological Survey local identification number	Latitude/longitude	Total well depth	Depth to bedrock	Sample depth	Data collected[1]	Geologic formation[2]
		(depth in feet from land surface)				
LN SP61	40°11'53" 76°10'52"	-	-	-	N	Snitz Creek
LN 1667	40 11 52 76 10 55	-	-	-	N	Snitz Creek
LN 1669	40 11 49 76 10 55	100	6	84	NWL	Snitz Creek
LN 1670	40 11 56 76 10 57	75	6	62	NWL	Snitz Creek
LN 1671	40 11 52 76 10 58	28	13	-	WL	Snitz Creek
LN 1672	40 11 52 76 11 05	100	10	-	-	Snitz Creek
LN 1673	40 11 48 76 11 03	46	12	33	NWL	Snitz Creek
LN 1674	40 11 45 76 11 15	125	19	-	-	Millbach
LN 1675	40 11 50 76 11 07	55	14	-	WL	Millbach
LN 1676	40 11 52 76 11 01	40	8	34	NWL	Snitz Creek
LN 1677	40 11 56 76 11 05	50	28	34	NWL	Snitz Creek
LN 1679	40 11 52 76 10 57	60	10	32	NWL	Snitz Creek
LN 1680	40 11 56 76 11 09	60	7	-	WL	Millbach
LN 1681	40 11 47 76 11 08	60	8	-	WL	Millbach
LN 1682	40 11 48 76 10 59	350	18	34	NWL	Snitz Creek

[1]NWL - Nutrient and water-level data

WL - Water-level data only

N - Nutrient data only

[2]See text for geologic description of the Formations.

SUMMARY

A water-quality investigation has been conducted by the U.S. Geological Survey, in cooperation with the U.S. Department of Agriculture and the Pennsylvania Department of Environmental Resources in the Conestoga Headwaters area of Lancaster County, Pa. since 1982. This project is one of 20 such projects implemented nationwide as part of the Rural Clean Water Program. The purpose of the Conestoga Headwaters project is to determine the effects of agricultural BMPs on surface- and ground-water quality. To accomplish this, water--quality data are being collected and analyzed for 2 years before (pre-BMP) and at least 2 years after (post-BMP) implementation of BMPs. Data collection is concentrated in four study areas. These study areas are divided into three monitoring components: (1) a Regional study area (188-mi^2); (2) a Small Watershed study area (5.82-mi^2) and (3) two field-site study areas, Field-Site 1 (22.1 acres) and Field-Site 2 (47.5 acres). This report presents the preliminary characterization for each of the study areas in the Conestoga Headwaters RCWP, and describes the frequency and methods of data collection, the types and methods of chemical and statistical analyses to be used on the water-quality data for subsequent reports, and locations and descriptions for all data-collection locations.

The Regional study area includes the entire 188-mi^2 area of the Conestoga Headwaters. In this study area the effects of implementing all types of BMPs on surface- and ground-water quality are being monitored. Pre-BMP data were collected from April 1982 through September 1983. A preliminary report by Fishel and Lietman (1986) describes the ground-water nitrate and herbicide data for the Regional study area. The post-BMP monitoring has been postponed until a tentative restarting date in the mid-1990's.

The Small Watershed is part of the Little Conestoga Creek watershed. In this study area, the effects of implementing nutrient management on surface- and ground-water quality will be monitored. Pre-BMP data were collected from April 1984 through March 1986. Post-BMP data will be collected until September 1989.

Field-Site 1, 22.1 acres in area, was instrumented during the fall of 1982 to determine the effects of implementing nutrient management, animal-waste storage, and terracing on surface- and ground-water quality. At Field-Site 1, six pipe-outlet terraces and a animal-waste storage structure (to be used as part of nutrient management), were installed in the fall of 1984. Pre-BMP data were collected from December 1982 through September 1984. Post-BMP data will be collected until September 1989. A preliminary report by Gerhart (1986) describes the ground-water recharge and nitrate concentrations for the Field-Site 1 study area.

Field-Site 2, 47.5 acres in area (25 of which were previously established in pipe-outlet terraces), was instrumented in the fall of 1984. The purpose of this study area is to determine the effects of implementing nutrient management on surface- and ground-water quality. Pre-BMP data have been collected from October 1984 through September 1986. Post-BMP data collection will continue until September 1988.

REFERENCES

Berg, T.M., and others, 1980, Geologic map of Pennsylvania: Pennsylvania Geological Survey.

Buchanan, J.W., 1983, Water resources data for Pennsylvania, Water Year 1982, Volume 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-82-2, 244 p.

Buchanan, T.J., and Somers, W.P., 1968, Stage measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A7, 28 p.

----- 1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A8, 65 p.

Buchanan, J.W., and others, 1984, Water resources data for Pennsylvania, Water Year 1983, Volume 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-83-2, 283 p.

Carter, R.W., and Davidian, J., 1968, General procedures for gaging streams: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A6, 13 p.

Classen, H.C., 1982, Guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an Aquifer: U.S. Geological Survey Open-File Report 82-1024, 49 p.

Corey, R.B., 1977, Progress on a new soil test: Wisconsin Fertilizer, Aglime, and Pest Management Conference Proceedings, no. 16, p. 57-62.

Crawford, C.G., Slack, J.R., and Hirsch, R.M., 1983, Nonparametric tests for trends in water-quality data using the Statistical Analysis System: U.S. Geological Survey Open-File Report 83-550, 102 p.

Culbertson, J.K., and Feltz, H.R., 1972, Sampling procedures and problems in determining pesticide residues in the hydrologic environment: Pesticide Monitoring Journal, v. 6, no. 3, p. 171-178.

Federal Working Group on Pesticide Management, 1974, Guidelines on sampling and statistical methodologies for ambient pesticide monitoring: U.S. Government Printing Office - 1975-626-592/2163-1, 50 p.

Fishel, D.K., and Lietman, P.L., 1986, Occurrence of nitrate and herbicides in ground water in the Upper Conestoga River Basin, Pennsylvania: Water-quality study of the Conestoga River Headwaters, Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 85-4202, 8 p.

Gerhart, J.M., 1986, Ground-water recharge and its effects on nitrate concentation beneath a manured field site in Pennsylvania: Ground Water, v. 24, no. 4, p. 483-489.

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter C1, 58 p.

Guy, H.P., and Norman, V.W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter C2, 59 p.

Hall, G.M., 1934, Ground water in southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., Bull. W-2, p. 255.

Lietman, P.L., and others, 1989, Comparison of methods for sampling dissolved nitrogen in a fractured-carbonate rock aquifer: Ground Water Monitoring Review, v. 9, no. 1.

Loper, W.C., and others, 1985, Water resources data for Pennsylvania, Water Year 1984, Volume 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report PA-84-2, 327 p.

----- 1987, Water resources data for Pennsylvania, Water Year 1985, Volume 2, Susquehanna and Potomac River Basins: U.S. Geological Survey Water-Data Report, PA-85-2, 361 p.

Meisler, H. and Becher, A.E., 1966, Hydrology of the carbonate rocks of the Lancaster 15-minute quadrangle, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Progress Report 171, 36 p.

----- 1971, Hydrogeology of the carbonate rocks of the Lancaster 15-minute quadrangle, Southeastern Pennsylvania: Pennsylvania Geological Survey, 4th ser., Bull. W-26, 149 p.

P-STAT, Inc., 1986, P-STAT: User's manual: Duxbury Press, Boston, 852 p.

Porterfield, G., 1972, Computation of fluvial-sediment discharge: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter 3, 66 p.

Poth, C.W., 1977, Summary ground-water resources of Lancaster County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 43, 80 p.

SAS Institute, Inc., 1979, SAS users guide, 1979 edition: Gary, North Carolina, SAS Institute, Inc., 494 p.

SAS Institute, Inc., 1982a, SAS users guide - basics, 1982 edition: Gary, North Carolina, SAS Institude, Inc., 924 p.

SAS Institute, Inc., 1982b, SAS users guide - statistics, 1982 edition: Gary, North Carolina, SAS Institute, Inc., 584 p.

Schueller, J.P., 1983, An assessment of agricultural nonpoint source pollution in selected high priority watersheds in Pennsylvania: Pennsylvania Department of Environmental Resources, Bureau of Soil and Water Conservation, 48 p.

Skougstad, M.W., and others, 1979, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A1, 626 p.

U.S. Department of Agriculture, 1985, Soil Survey of Lancaster County, Pennsylvania, 152 p.

U.S. Evironmental Protection Agency, 1979, Methods for chemical analysis of water and wastes: USEPA-600/4-79-020.

----- 1985, Organochlorine Pesticides and PCBs - Method 608: Availability, Code of Federal Regulations, Special Edition of Federal Register, v. 40, pt. 136, App. A, p. 348-367.

William, S., ed., 1984, Official methods of analysis of the Association of Official Analytical Chemists: 14th ed., Association of Official Analytical Chemists, Arlington, Virginia, 1,141 p.

☆ U.S. GPO: 1989—612-882