State of Delaware
DELAWARE GEOLOGICAL SURVEY
Robert R. Jordan, State Geologist

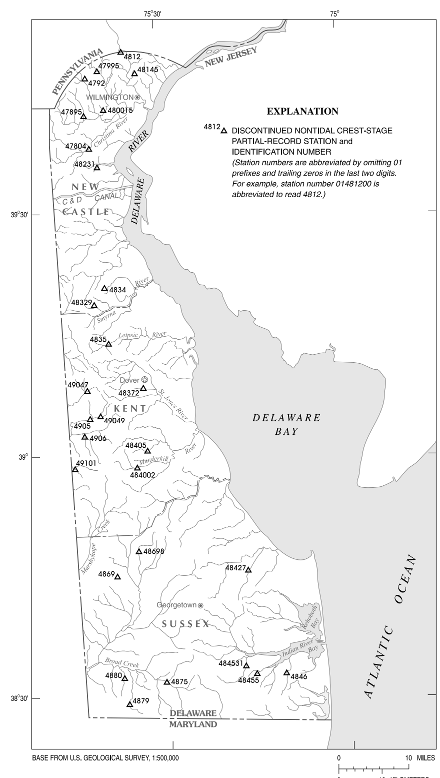
REPORT OF INVESTIGATIONS NO. 57

EVALUATION OF THE STREAM-GAGING NETWORK IN DELAWARE

by

Edward J. Doheny

U.S. Geological Survey



Prepared by the United States Geological Survey
under the Joint-Funded Program with
the Delaware Geological Survey

University of Delaware
Newark, Delaware
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ABSTRACT

The stream-gaging network in Delaware is a major component of many types of hydrologic investigations. To ensure that the network is adequate for meeting multiple data needs by a variety of users, it must represent the range of hydrologic conditions and land-use types found in Delaware, and include enough stations to account for hydrologic variability. This report describes the current stream-gaging network in Delaware and provides an evaluation of its representativeness for the State.

Temporal trends in numbers of stations operated during water years 1975-97 are presented for continuous-record stream-gaging stations in Delaware. The results of this analysis indicate (1) significant variability in the number of stations operated over time, especially during water years 1980-84, and 1989-97, (2) most continuous-record stream-gaging stations activated during 1975-97 are not being maintained for sufficient periods of time to account for local temporal hydrologic variations, and (3) stations on streams and rivers in small drainage basins (10 square miles or less), are not being maintained, especially during 1981-97.

Temporal trends were also investigated for low-flow partial-record stations, nontidal crest-stage partial-record stations, tidal crest-stage partial-record stations, and surface-water-quality stations operated in Delaware during water years 1975-97. The results indicate variable and non-systematic activity over time for these types of stations, except for the tidal crest-stage partial- record stations.

An analysis of the representativeness of the active continuous-record stream-gaging network in Delaware reveals that several principal drainage basins in the Coastal Plain Physiographic Province are currently ungaged, and there is significantly less spatial coverage by gaging stations in the Coastal Plain than in the Piedmont Physiographic Province. Analysis of land-use types in drainage basins with active continuous-record stream-gaging stations shows a lack of stations in small, in predominantly forested drainage basins in the Coastal Plain, predominantly urban areas in the Coastal Plain, and in locations in the Piedmont where farmland is predominant. Analysis of 1990 Census population data in drainage basins with active continuous-record stream-gaging stations indicates that approximately 23 percent of Delaware's inhabitants are residing in drainage basins that are gaged.

A general strategy is presented for improving the current network coverage on the basis of analyses of trends and representativeness. Recommendations from the strategy include (1) maintaining operation of all active continuous-record stream-gaging stations; (2) stronger efforts to maintain operation of new stations for a minimum of 5 years, and preferably for 10 years or more; (3) assigning priority to the Coastal Plain for the activation of new stations to improve coverage; and (4) consideration of ungaged principal drainage basins, land-use characteristics of drainage basins, and locations of projected population growth in future decisions regarding activation of stream-gaging stations. Southern New Castle County and the Leipsic River Basin are presented as examples of locations where gaps in network coverage exist.

An inventory of active and inactive stream-gaging stations in Delaware is presented in Appendix 3. This inventory includes listings of continuous-record stream-gaging stations, low- flow partial-record stations, tidal crest-stage partial-record stations, nontidal crest-stage partial-record stations, and surface-water-quality stations. Maps are included in Appendix 4 to illustrate the spatial distribution of active and discontinued stream-gaging stations in Delaware.

INTRODUCTION

The stream-gaging network in Delaware is a major component of many types of hydrologic investigations. Uses of surface-water discharge data in Delaware include (1) flood forecasting and prediction, (2) analyses of hydrologic systems, (3) evaluation of **drought**[1]-no drought conditions, (4) water-supply analyses, (5) water-quality and pollution-abatement analyses, (6) water-resources planning and management, (7) design of bridges, culverts, dams, and sediment-control structures, and (8) wildlife management. To ensure that the network is adequate for meeting multiple data needs by a variety of users, it must represent the range of hydrologic conditions and land-use types found in Delaware and include enough stations to account for hydrologic variability. The network must also be stable for an extended period of time to account for temporal hydrologic variations (Preston, 1997). Evaluation of the surface-water gaging-station network with respect to expected needs of surface-water discharge information in Delaware is necessary to ensure adequate coverage for short- and long-term data requirements in the state, and to better allocate limited funds and resources.

Background

The collection of surface-water discharge data in Delaware began in **water year**[2] 1931, when the State of Delaware entered into a cooperative agreement with the U.S. Geological Survey (USGS) for the establishment of four continuous-record stream-gaging stations. By 1936, all four of these stations had been discontinued. In 1943, two of the four stations were re-established along with five new continuous-record stations. All but one of these stations were still in operation in 1997. By 1952, the network had

[1]Words in **bold** are defined in the Glossary.
[2]All references to years of operation for gaging stations are water years unless indicated otherwise.

doubled in size to 14 stations. Between 1952 and 1978, the network ranged from 13 to 17 stations. During 1979-80, the network reached a peak of 19 continuous-record stream-gaging stations. Since 1980, the network has varied from a minimum of 12 stations operated in 1983, 1984, and 1989, to a maximum of 18 stations operated during 1994. The USGS currently is operating 15 continuous-record stream-gaging stations in cooperation with the Delaware Geological Survey, 11 of which have between 39 and 54 years of systematic records.

In addition to the continuous-record stream-gaging stations, surface-water data also have been collected at various locations throughout Delaware during different periods of time to specifically determine low-flow discharges, peak discharges, tidal stages, or surface-water quality. With the exception of tidal stages that are measured in some locations, these data are not collected continuously and are often associated with project-specific data needs.

Purpose and Scope

This report describes the current stream-gaging network in Delaware, and provides an evaluation of its representativeness for the state. A condensed re-evaluation of data-use classes defined by Carpenter and others (1987) is included. Recent changes in technology for data collection and reduction, and data presentation and availability, are discussed.

Historical data and annual water-data reports by the U.S. Geological Survey (1962-96) were used to determine temporal trends in the number of continuous-record stream-gaging stations operated during 1975-97. The results of this analysis are presented by total number of stations operated, years of systematic record, physiographic provinces, counties, and basin size.

Temporal trends were also investigated for other types of gaging stations operated in Delaware during 1975-97. These analyses were limited to yearly activity because of the non-systematic activity indicated by the periods of record for most of these stations. These additional analyses are presented for **low-flow partial-record stations, nontidal crest-stage partial-record stations, tidal crest-stage partial-record stations, and surface-water-quality stations.**

Maps are included to show the locations of active and discontinued continuous-record stream-gaging stations, and the principal drainage basins that are currently gaged and ungaged. The areal coverage of Delaware's counties and physiographic provinces by continuous-record stream-gaging stations was determined by use of published drainage areas for active stations in Delaware (U.S. Geological Survey, 1962-96). Digital drainage-basin delineations and spatial-data coverages were used to determine the distribution of land-use types and approximate population in active, gaged drainage basins.

The report presents a general strategy for improving the current network coverage on the basis of analyses of trends and representativeness. The strategy includes some ideas for meeting future data needs.

Appendix 3 contains an inventory of active and inactive stream-gaging stations in Delaware. This inventory includes listings of 34 continuous-record stream-gaging stations, 68 low-flow partial-record stations, 15 tidal crest-stage partial-record stations, 28 nontidal crest-stage partial-record stations, and 122 surface-water-quality stations. Maps also are presented (Appendix 4) to show the spatial distribution of active and discontinued stream-gaging stations in Delaware.

Previous Studies

Several earlier investigations have evaluated the stream-gaging network in Maryland and Delaware [Forrest and Walker (1970), Carpenter and others (1987), and Preston (1997)]. In all of these studies, however, the gaging stations in Delaware were evaluated as part of the regional network in concert with the gaging stations in Maryland. The study by Forrest and Walker (1970) outlined accuracy criteria for the network in Maryland and Delaware and examined the accumulated data in relation to these criteria. Carpenter and others (1987) documented data uses and funding sources, and conducted an analysis to select gaging stations for possible elimination. This analysis concluded that none of the active gaging stations in Delaware should be considered for elimination. Preston (1997) described temporal trends and presented a qualitative evaluation of the representativeness of the regional network in Maryland, Delaware, and the District of Columbia. This study showed major gaps in coverage in the eastern part of the Coastal Plain Physiographic Province, which includes most of Delaware's land area.

Other types of network evaluations have focused on the statistical adequacy of the network for performing specific hydrologic investigations (Preston, 1997). A study by Dillow (1996) evaluated the potential effects of including data from randomly selected new gaging stations for estimation of peak discharges in Delaware. The results clearly showed improvement in peak discharge estimates with the addition of new gaging stations. The analysis also was consistent with the conclusion of Carpenter and others (1987) that none of the active gaging stations in Delaware should be considered for elimination.

Acknowledgments

The author thanks John H. Talley of the Delaware Geological Survey for planning assistance and technical input. Special thanks are extended to Vanessa C. Smith of the USGS for extensive work on digital drainage-basin delineations and technical assistance.

John W. Brakebill, Andrew LaMotte, and Sarah K. Kelley of the USGS are acknowledged for additional technical assistance. Timothy W. Auer, USGS is acknowledged for extensive work on graphic illustrations. The author also thanks Anthony J. Tallman of the USGS for providing data and technical information on stream-gaging stations in Delaware, and the Delaware Economic Development Office for providing 1997 population projection data. The manuscript was critically reviewed by Robert W. James, Gary T. Fisher, and Stephen D. Preston of the USGS, and John H. Talley, Richard N. Benson, and William S. Schenck of the Delaware Geological Survey.

DESCRIPTION OF STUDY AREA

Delaware lies between 38˚ 27´ and 39˚ 51´ north latitude and 75˚ 04´ and 75˚ 48´ west longitude (Figure 1). The land area of Delaware is about 1,978 square miles (mi^2), in addition to 79 mi^2 of inland waters (Simmons, 1986). This does not include the water-surface area of the part of the Delaware River and Delaware Bay within the boundaries of Delaware (Van Zandt, 1966). Three sea-level canals are part of the inland waters of Delaware. The Chesapeake and

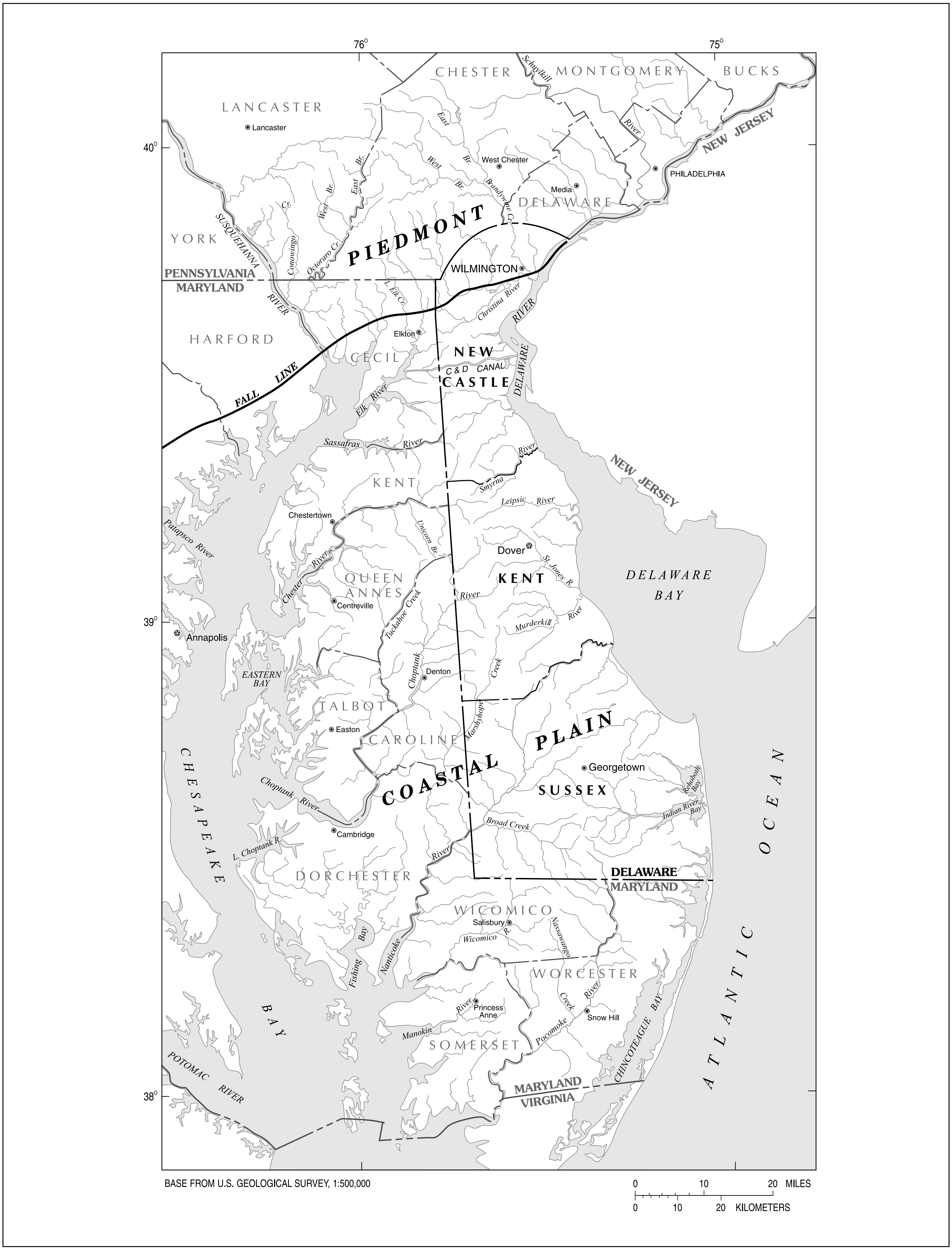

Figure 1: Map showing location of study area and physiographic provinces in Delaware (modified from Dillow, 1996)

Delaware Canal (C & D Canal) connects the Elk River to the Delaware River and is used mainly for commercial navigation. The Lewes and Rehoboth Canal connects Delaware Bay with Rehoboth Bay and the Assawoman Canal connects Indian River Bay to Little Assawoman Bay, both of which are part of the Intracoastal Waterway. About 60 freshwater ponds, formerly mill sites, are also part of Delaware's inland waters (Simmons, 1986).

Physiographic Setting

Fenneman (1938) described two distinct physiographic provinces in Delaware—the Piedmont and the Coastal Plain. The provinces are divided by a boundary referred to as the Fall Line. A description of each physiographic province is given below.

The Piedmont Province comprises the area north of the Fall Line and is underlain by crystalline bedrock. The Piedmont Province in Delaware covers approximately 112 mi^2, which is about 6 percent of the total land area of the State. The Piedmont consists of gently rolling hills and ridges with elevations generally less than 400 ft above sea level. The province is drained by streams with fairly steep gradients (Dillow, 1996). All rivers originating in the Piedmont of Delaware drain into the Delaware River. The Christina and Brandywine drainage systems carry most of the water from the Delaware Piedmont; however, several small streams to the north of Wilmington flow directly into the Delaware River (Marine and Rasmussen, 1955).

The Atlantic Coastal Plain Province comprises the area south of the Fall Line and is underlain by alternating layers of unconsolidated sand and gravel, silt, and clay (Simmons, 1986). The Coastal Plain Province in Delaware covers nearly 1,866 mi^2, which is approximately 94 percent of the total land area of the State. The Coastal Plain is characterized by low relief, rising from sea level to just less than 100 ft above sea level, and is drained mostly by small, low-gradient streams. Streams and rivers in the Coastal Plain drain into the Delaware River, Delaware Bay, the Atlantic Ocean, or the Chesapeake Bay. Most are affected by tides for a considerable distance upstream from their outlets (Dillow, 1996). A ridge line extending from southern Delaware northward divides the Delaware River drainage basin and the Atlantic Ocean from the Chesapeake Bay drainage basin (Simmons, 1986).

Land Use

Land-use data for Delaware were compiled using information from Tiner (1985) and the Delaware Economic Development Office (DEDO, 1996). Land use in Delaware can be categorized into four major types. Farmland represents more than 47 percent of Delaware's land area (DEDO, 1996). Forest and other rural areas represent about 24 percent, and tidal and freshwater wetlands represent slightly less than 18 percent of Delaware's land area (Tiner, 1985). Urban areas occupy almost 11 percent, most of which is in New Castle County. Table 1 shows approximate percentages of the major land-use types in Delaware, by county and for the State, in 1992.

Table 1. Major land-use types of Delaware, in percent by county, 1992

Land-use type	New Castle County	Kent County	Sussex County	State total
Farmland	32.0	52.0	51.0	47.2
Forest and other rural	17.8	17.5	31.6	24.3
Wetland	13.5	23.2	16.4	17.8
Urban	36.7	7.3	1.0	10.7
Total	100.0	100.0	100.0	100.0

Hydrologic Characteristics

Most stream-channel slopes in Delaware are very low and some areas of the State are poorly drained. Soils in the poorly drained areas are composed of silty clays and organic silts. The well-drained areas and prime farmland soils are underlain by loamy sands. During droughts, farmers rely heavily on irrigation to grow corn, soybeans, and other crops (Simmons, 1986). As of 1995, approximately 14.74 million gallons per day (Mgal/d), or 30.5 percent of all water irrigated in Delaware is from surface-water sources (J.C. Wheeler, U.S. Geological Survey, written commun., 1998). Approximately 49.26 Mgal/d or 70 percent of average daily demand from surface-water sources are used for public-water supply in New Castle County, accounting for 55 percent of the daily public water demand in Delaware.

Precipitation is fairly uniformly distributed areally and temporally. Average annual precipitation is about 43 inches and ranges from about 45 inches in the southeast corner of the State to about 40 inches across north-central Delaware. Average monthly precipitation ranges from about 3 to 4 inches for most months. Most areas of Delaware receive the largest average monthly precipitation in July and August because of summer thunderstorms (Simmons, 1986).

Annual evapotranspiration in Delaware ranges from about 26 inches in the south to about 24 inches in the north (Mather, 1969). Mather's data indicate that more than 90 percent of the evapotranspiration occurs from April through October in a given year (Simmons, 1986).

Average annual runoff for streams in the Coastal Plain of Delaware ranges from about 17 inches to 20 inches, of which 70 to 85 percent can be attributed to ground-water discharge. Annual runoff for streams in the Piedmont averages 18 to 20 inches, but most of the flows originate in Pennsylvania. Average monthly stream discharge, unlike precipitation, is not uniformly distributed throughout the year. Because of seasonal rates of evapotranspiration and seasonal changes in ground-water discharge to streams and wells, average monthly stream discharges generally decline from highs in March to lows in September or October. This pattern then reverses as evapotranspiration losses decrease after the growing season, resulting in increased ground-water discharge to streamflow (Simmons, 1986).

Coastal flooding in Delaware is usually caused by extreme high tides and high northeast winds (Simmons, 1986). One of the most damaging coastal storms in Delaware occurred in March 1962 (University of Delaware, Department of Geography, 1977). Hurricanes and tropical storms usually cause coastal and inland flooding from heavy rainfall associated with these storms (Simmons, 1986).

Runoff from heavy rains and severe thunderstorms has often caused flooding of freshwater streams throughout Delaware. This type of flooding has been most destructive to highway bridges, culverts, roadways, and millpond spillways (Simmons, 1986). The most recent damaging floods of this type in Delaware occurred in August 1967 (Carpenter and Simmons, 1969) and in July 1989 (Talley, 1989; Paulachok and others, 1995).

Population

According to data from the Delaware Population Consortium (1997), Delaware's total population in 1990 was just over 669,000. Between 1990 and 1996, the population grew by 8.3 percent to nearly 725,000 in 1996. Current projections indicate that Delaware's total population will increase by 18.5 percent to just over 859,000 between 1996 and the year 2020. Table 2 presents the State's projected population at selected intervals between 1990 and 2020, with breakdowns by county.

Table 2 shows that New Castle County is the most populated county in Delaware, with 66.3 percent of the total population in 1990 and 65.0 percent of the total population in 1996.

Although New Castle County is projected to remain the most heavily populated county, the data indicate much larger percentages of projected population growth in both Kent County and Sussex County through the year 2020. Population in New Castle County is projected to grow by 21.4 percent between 1990 and 2020, and by 14.0 percent between 1996 and 2020. The population of Kent County is projected to grow by 39.0 percent between 1990 and 2020, and by 26.3 percent between 1996 and 2020. The population of Sussex County is projected to grow by 45.4 percent between 1990 and 2020, and by 27.1 percent between 1996 and 2020. By 2020, New Castle County is projected to have about 62.5 percent of Delaware's total population, whereas annual growth in Kent County and Sussex County will continue to exceed that of New Castle County.

The distribution of population growth areas varies throughout Delaware. Figure 2 shows intervals of projected population change for Delaware between 1990 and 2020 that were developed for Census County Divisions by the Delaware Population Consortium (1997).

Figure 2 indicates that the largest projected population-growth areas are near the city of Wilmington, central and southern New Castle County, and in Kent County to the east and west of Dover. Although no areas of Sussex County are in the largest projected growth interval, projected increases in the the second and third largest intervals are distributed throughout many areas of the county.

EVALUATION OF THE STREAM-GAGING NETWORK

The stream-gaging network in Delaware was evaluated to determine its adequacy. Current and expected needs for surface-water discharge data in Delaware were determined by use of data-use classes defined by Carpenter and others (1987). The implications of recent changes in technology for data collection and data presentation are discussed.

An inventory of all types of stream-gaging stations operated in Delaware was compiled and is included in Appendix 3 (Paulsen, 1953; Paulsen and others, 1954; Love and others, 1954-61; Love and others, 1964-65; Love and others, 1967-68; Hendricks and others, 1964; Hendricks and others, 1969; U.S. Geological Survey, 1962-96). These data were used to investigate temporal trends in network activity for continuous-record stream-gaging stations in Delaware with breakdowns by total number of stations operated, years of systematic record, physiographic provinces, counties, and basin size. The period of analysis selected was 1975-97 because an initial overview of the data indicated some significant changes in the composition of the network beginning in the late 1970s following a period of relative stability.

The data were also used to investigate temporal trends for low-flow partial-record stations, tidal crest-stage partial-record stations, nontidal crest-stage partial-record stations, and surface-water-quality stations. These analyses were limited to yearly activity because of the non-systematic activity shown in the periods of record for most of these stations.

The representativeness of the active continuous-record stream-gaging network in Delaware was analyzed. Maps were prepared to show the locations of active and discontinued continuous-record stream-gaging stations. Principal drainage basins that are currently gaged and ungaged in Delaware were identified. The extent of spatial gage coverage of Delaware's counties and physiographic provinces was determined by use of published drainage areas for stream-gaging stations in Delaware (U.S. Geological Survey, 1962-96). Digital drainage-basin delineations and spatial data coverages were used to determine the distribution of land-use types and approximate population in actively gaged drainage basins in Delaware.

Current and Expected Needs of Data Users

The usefulness of a stream-gaging station can be measured by analyzing the uses of the data collected from the station. Carpenter and others (1987) identified major data-use classes for each continuous-record stream-gaging station in the Maryland-Delaware-District of Columbia regional network by use of a survey of approximately 370 recipients of the annual water-data reports. Conducting another mail-response user survey was beyond the scope of this analysis; however, investigation has indicated that the data-use classes defined by Carpenter and others (1987) for Delaware are still relevant to the current network.

Table 2. Population projections for Delaware by county and state total, 1990-2020 [modified from the Delaware Population Consortium, 1997]

	1990	1996	2000	2005	2010	2015	2020
New Castle County	443,580	471,702	489,808	508,501	522,468	531,881	538,426
Kent County	111,640	122,906	130,022	137,689	144,514	150,364	155,223
Sussex County	113,849	130,201	139,970	149,148	155,989	161,613	165,539
State total	669,069	724,809	759,800	795,338	822,971	843,858	859,188

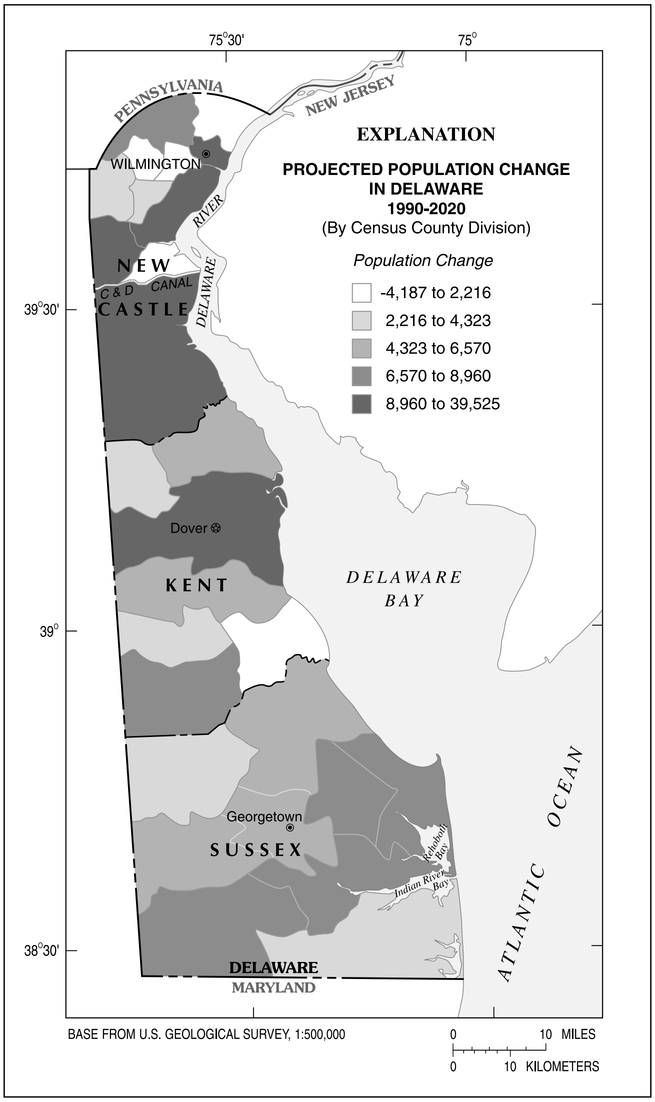

Figure 2. Intervals of projected population change in Delaware, 1990 to 2020 [Modified from the Delaware Population Consortium, 1997]

Data-use classes defined by Carpenter and others (1987) for continuous-record stream-gaging stations in Delaware include: analysis of regional hydrology; definition of current conditions and sources of water through hydrologic systems; project operation, including operational decisions for reservoir releases; hydropower operations, or diversions; hydrologic forecasts; water-quality monitoring; and "other." The data-use category for "other" includes use of data for periodic fish-kill investigations and nutrient-loading calculations. Additional data-use classes that apply to the current network include planning and design of hydrologic structures, and regulatory compliance. Table 3 presents data-use classes associated with active continuous-record stream-gaging stations in Delaware.

Table 3 shows that the data collected at all active continuous-record stream-gaging stations in Delaware have multiple uses. Analysis of regional hydrology, definition of hydrologic systems, and water-quality monitoring are the most common uses of the data. The table also indicates that the data for nearly all stations is utilized for periodic water-related emergencies, such as fishkill investigations.

These data needs will continue as population grows throughout Delaware. Population increase will cause changes in land-use and runoff characteristics of watersheds. These changes will increase the need for up-to-date streamflow and water-quality data to assess the resulting changes in flow characteristics, channel stability, and water quality of streams and rivers in affected watersheds. Greater demand for potable water also can be expected in population-growth areas, resulting in increased data needs for water supply and project-operation purposes. As changes in land use occur with population growth, regulatory data needs can also be expected to increase as efforts continue to improve the understanding of hydrologic systems, and to wisely manage and protect Delaware's natural resources, open space, and wetland areas.

Changes in Technology for Gaging Streams and Rivers

Technology for gaging streams and rivers has advanced significantly in recent years. As a result, data collection and reduction techniques, as well as data presentation and availability, have been greatly affected by these changes.

Data Collection and Reduction

Data collection and reduction describes the process of collecting and retrieving time-series stream-stage data from continuous-record stream-gaging stations. Technological advances in recent years have led to the development of electronic data loggers and data cards to replace mechanical tape recorders and punch tapes for recording stage data. With mechanical tape recorders, the punch tapes must be removed and replaced during site visits. The punch tapes are then used to create electronic files using special equipment in the office. In contrast, data from a data logger can be downloaded directly to an electronic file using a laptop computer in the field, thereby reducing manpower requirements and enhancing efficiency and data reliability. During water year 1997, all mechanical tape recorders were replaced with electronic data loggers at currently active continuous-record stream-gaging stations in Delaware. The immediate result of this change should be greater efficiency for collection and reduction of data. Other established procedures for construction, maintenance, and operation of stream-gaging stations, as well as analysis of the resulting data, however, cannot be altered or eliminated without compromising quality.

Data Presentation and Availability

Data presentation and availability describes the methods and times at which streamflow data may be furnished to the users (Carpenter and others, 1987). Previously, data could be furnished in only three ways: (1) by direct-access telemetry equipment for immediate use, (2) by periodic release of provisional data, or (3) in publication format through annual water-data reports published by the USGS for Maryland, Delaware, and the District of Columbia (Carpenter and others, 1987). Another method for furnishing data is now available. Users can access station information and historical data for active and discontinued stream-gaging stations in Delaware on the World Wide Web through the USGS Maryland, Delaware, District of Columbia Public Home Page (http://md.usgs.gov). Historical data currently available via the USGS Public

Table 3. Data-use classes associated with active, continuous-record stream-gaging stations in Delaware [modified from Carpenter and others, 1987]

Station number	Station name	Data-use classes
01477800	Shellpot Creek at Wilmington, Del.	1 2 4 5 6 7
01478000	Christina River at Coochs Bridge, Del.	1 2 3 4 5 6 7
01478650	White Clay Creek at Newark, Del.	1 3 4 5 7 8
01479000	White Clay Creek near Newark, Del.	1 2 3 4 5 6 7 8
01480000	Red Clay Creek at Wooddale, Del.	1 2 3 4 5 6 7 8
01480015	Red Clay Creek near Stanton, Del.	1 2 3 4 8
01481500	Brandywine Creek at Wilmington, Del.	1 2 3 4 5 6
01483200	Blackbird Creek at Blackbird, Del.	1 2 5 6
01483700	St. Jones River at Dover, Del.	1 2 3 5 6
01484000	Murderkill River near Felton, Del.	1 2 5 6
01484100	Beaverdam Branch at Houston, Del.	1 2 6
01484500	Stockley Branch at Stockley, Del.	1 2 5 6
01484525	Millsboro Pond Outlet at Millsboro, Del.	1 2 5 8
01487000	Nanticoke River near Bridgeville, Del.	1 2 3 4 5 6
01488500	Marshyhope Creek near Adamsville, Del.	1 2 5 6

1. Analysis of regional hydrology.
2. Definition of current conditions and sources of water through hydrologic systems.
3. Project operation and water-supply evaluation.
4. Hydrologic forecasts.
5. Water-quality monitoring.
6. Periodic fishkill investigations and nutrient-loading calculations.
7. Planning and design of hydraulic structures.
8. Regulatory compliance.

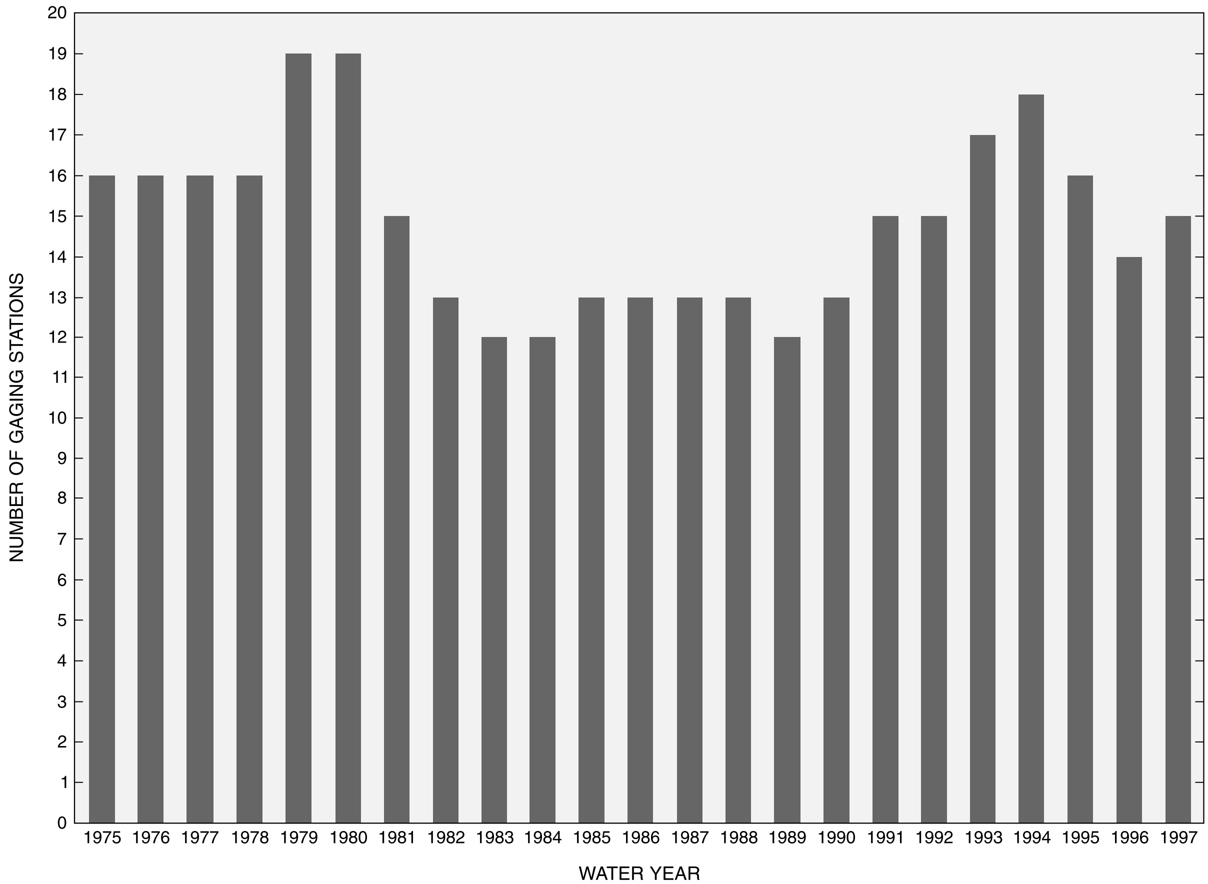

Figure 3: Graph showing number of continuous-record stream-gaging stations operated in Delaware, water years 1975-97

Home Page includes annual peak stages and discharges, as well as mean daily discharges.

Current technology has also made real-time data systems available for data users through combined use of telemetry equipment and the World Wide Web. Currently, five of Delaware's 15 active continuous-record stream-gaging stations have direct-access telemetry equipment installed, but none have real-time data available on the World Wide Web. Access to real-time data for certain stream-gaging stations is extremely valuable to certain users. With limited available funds and varied data needs among users, supporters of the network must establish priorities between installation of real-time data systems, maintaining data collection at existing stations, reactivating discontinued stations, or constructing new stations.

Trends in Activity of Continuous-Record Stream-Gaging Stations

Investigation of temporal trends in station activity can give some indication of network stability over time. To assess temporal trends in the activity of continuous-record stream-gaging stations in Delaware during 1975-97, analyses were conducted using selected operational and spatial characteristics associated with the stations.

Operational Characteristics

Analyses conducted using operational characteristics included the total number of stations operated each year throughout Delaware. The years of systematic record associated with each station were also used to assess the stability of the network over time.

Total Number of Stations Operated. On average, 15 continuous-record stream-gaging stations were operated during 1975-97 (Figure 3). In 1997, 15 continuous-record stream-gaging stations were being operated. Figure 3 also shows that the network was relatively stable during 1975-78. During 1979-80, a maximum of 19 stations were in operation. A minimum of 12 stations were operated during 1983, 1984, and 1989. Significant variability was shown in the number of stations operated over time, especially during 1980-84, and 1989-97.

Years of Systematic Record. Most hydrologic evaluations require a minimum of 5 years of discharge time-series data. To establish flood-exceedance probabilities and account for temporal hydrologic variations, generally a minimum of 10 years of discharge time-series data is needed. The accuracy of hydrologic investigations can also be significantly enhanced by records that exceed 20 years in length (Preston, 1997). To further assess stability of the continuous-record stream-gaging network in Delaware, temporal trends in the years of systematic record were analyzed for stations operated during 1975-97. The results are presented in Table 4.

Table 4 indicates that 11 of the 15 active continuous-record stream-gaging stations in Delaware have periods of systematic record exceeding 30 years. Of these 11 stations, eight have periods of systematic record exceeding 50 years, and 7 have 50 or more continuous years of systematic record. Three stations currently have systematic record in the range of 31 to 50 years. Another station in the network, Murderkill River near Felton (Station 01484000), currently has 30 years of systematic record; however, this station was reactivated in 1997 after being inactive for 12 years.

Twelve new stations were established in Delaware during 1975-97. Nine of these 12 stations have been discontinued as of 1997. All nine stations were discontinued with less than 10 years of systematic record and seven of them with less than 5 years of systematic record. Most of these stations had been operated to obtain streamflow data for specific short-term projects (J.H. Talley, written commun., 1998). One of the remaining three stations that is currently active, Millsboro Pond Outlet at Millsboro (Station 01484525), has a break in the continuous systematic record because it was discontinued at the end of 1988, and then reactivated during 1991.

These trends suggest changes in priorities for data needs associated with specific projects. The result of discontinuation of stations with very short periods of record is that the current network is not producing systematic records in the 10- to 20-year range that represent the most current temporal hydrologic variations (Figure 4). Systematic records must represent natural cycles of wet and dry periods for proper analysis of temporal hydrologic variations. Most systematic records at these discontinued stations are not long enough to account for these variations, or to correlate current hydrologic conditions with those of the long-term stations. Therefore, hydrologic investigations conducted in Delaware must make use of (1) the eleven long-term continuous-record stream-gaging stations that may not necessarily reflect the ranges of hydrologic conditions and spatial variations throughout Delaware or (2) discontinued stream-gaging stations with longer periods of record that do not reflect current temporal hydrologic variations.

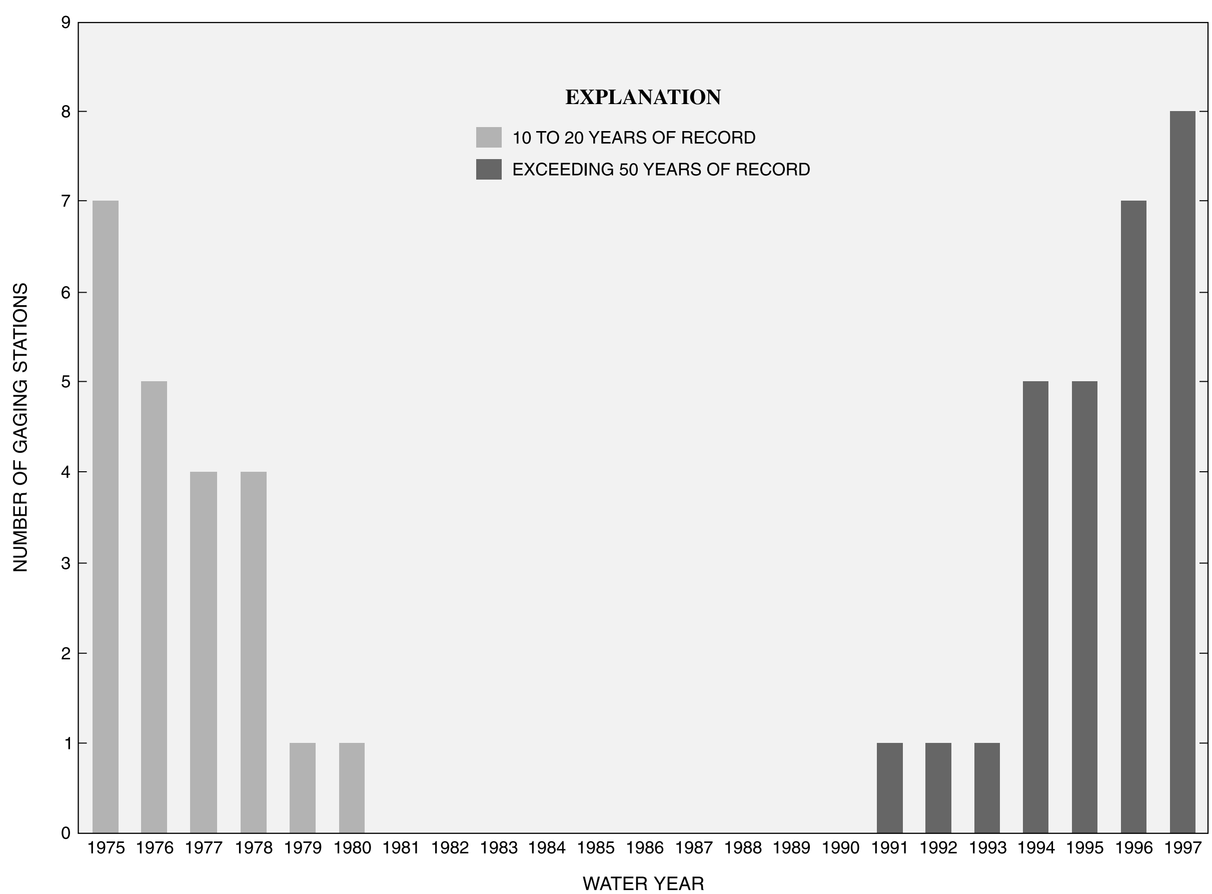

Figure 4: Graph showing number of continuous-record stream-gaging stations in Delaware with periods of record of 10 to 20 years, and exceeding 50 years, water years 1975-97

Table 4. Number of continuous-record stream-gaging stations by years of systematic record in Delaware, water years 1975-97 [< = less than, > = greater than]

Water year	< 5 years	5-9 years	10-20 years	21-30 years	31-40 years	41-50 years	> 50 years
1975	1	0	7	4	4	0	0
1976	0	1	5	3	7	0	0
1977	0	1	4	3	8	0	0
1978	0	1	4	2	9	0	0
1979	4	1	1	5	8	0	0
1980	4	1	1	5	8	0	0
1981	3	0	0	4	7	1	0
1982	1	0	0	4	7	1	0
1983	0	0	0	4	7	1	0
1984	0	0	0	4	3	5	0
1985	1	0	0	4	3	5	0
1986	2	0	0	3	1	7	0
1987	2	0	0	2	1	8	0
1988	2	0	0	1	2	8	0
1989	1	0	0	0	3	8	0
1990	2	0	0	0	3	8	0
1991	4	0	0	0	3	7	1
1992	4	0	0	0	3	7	1
1993	4	2	0	0	3	7	1
1994	4	3	0	0	3	3	5
1995	1	4	0	0	3	3	5
1996	1	2	0	0	3	1	7
1997	1	2	0	1	2	1	8

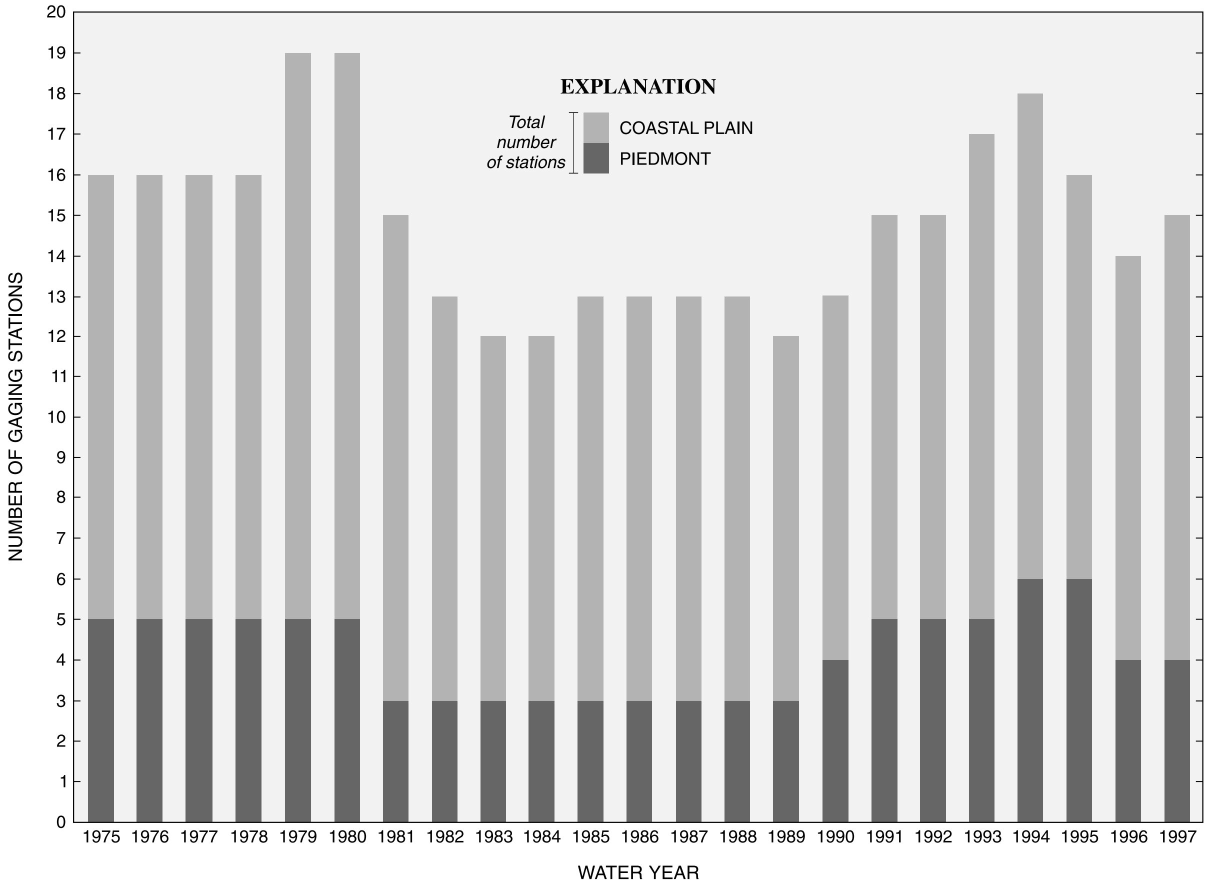

Figure 5: Graph showing number of continuous-record stream-gaging stations by physiographic province in Delaware, water years 1975-97

Spatial Characteristics

Temporal trends in station activity were also investigated using selected spatial characteristics associated with each station. Analyses conducted using spatial characteristics included activity of stations by physiographic province, county, and basin size.

Physiographic Provinces. A network of stream-gaging stations should include stations in all physiographic provinces in the region because hydrologic response varies with physiography. During 1975-97, Delaware averaged slightly more than four continuous-record stream-gaging stations annually in the Piedmont Physiographic Province. During the same period, Delaware averaged slightly more than 10 continuous-record stream-gaging stations annually in the Coastal Plain Physiographic Province. Table 5 presents a listing of all active and inactive continuous-record stream-gaging stations in Delaware and associated physiographic provinces. Figure 5 shows the total number of continuous-record stream-gaging stations operated in Delaware by physiographic province during 1975-97.

Figure 5 shows that a maximum of six stations were operated in the Piedmont Physiographic Province during 1994-95 and a minimum of three stations were operated during 1981-89. The largest periods of variability in the number of stations operated during 1975-97 were (1) 1980-81, when the total was reduced from five stations to three stations, (2) 1989-94, when the total doubled from three stations to six stations, and (3) 1995-96, when the total was reduced from six stations to four stations.

A maximum of 14 stations were operated in the Coastal Plain Physiographic Province during 1979-80, and a minimum of nine were operated during 1983-84 and 1989-90. Significant variability is shown in the number of stations operated in the Coastal Plain Physiographic Province during most of the period of analysis. The largest period of variability was during 1980-83, when the network was gradually reduced from 14 stations to nine stations.

These trends indicate some variability in operation of stations in both the Piedmont and the Coastal Plain Physiographic Provinces. The reduction in the number of stations operated in both provinces between 1980-83 corresponds to the reduction in the number of stations with short periods of systematic record that were defined in the Years of Systematic Record section.

Counties. Hydrologic investigations are often conducted on a countywide basis. The network of stream-gaging stations should include stations located in each county to provide data for these investigations. An analysis was con-

Table 5. Location of continuous-record stream-gaging stations in Delaware by physiographic province

Station number	Station name	Period of record (water years)	Physiographic province
01477800	Shellpot Creek at Wilmington, Del.	1946-present	Piedmont
01478000	Christina River at Coochs Bridge, Del.	1943-present	Coastal Plain
01478040	Christina River near Bear, Del.	1979-1982	Coastal Plain
01478500	White Clay Creek above Newark, Del.	1952-59, 62-80	Piedmont
01478650	White Clay Creek at Newark, Del.	1994-present	Piedmont
01479000	White Clay Creek near Newark, Del.	1932-36, 43-57, 1960-present	Coastal Plain
01479197	Mill Creek at Mill Creek Road at Hockessin, Del.	1990-1995	Piedmont
01479500	Mill Creek at Stanton, Del.	1931-1934	Piedmont
01480000	Red Clay Creek at Wooddale, Del.	1943-present	Piedmont
01480015	Red Clay Creek near Stanton, Del.	1989-present	Coastal Plain
01480095	Little Mill Creek near Newport, Del.	1991-1995	Piedmont
01480100	Little Mill Creek at Elsmere, Del.	1964-1980	Piedmont
01481500	Brandywine Creek at Wilmington, Del.	1947-present	Piedmont
01482200	Army Creek at State Road, Del.	1979-1981	Coastal Plain
01482298	Red Lion Creek near Red Lion, Del.	1979-1981	Coastal Plain
01483153	Noxontown Lake Outlet near Middletown, Del.	1993-1994	Coastal Plain
01483170	Drawyer Creek Tributary near Odessa, Del.	1979-1980	Coastal Plain
01483200	Blackbird Creek near Blackbird, Del.	1957-present	Coastal Plain
01483500	Leipsic River near Cheswold, Del.	1931-34, 43-57	Coastal Plain
01483670	Mudstone Branch at Chestnut Grove, Del.	1993-1994	Coastal Plain
01483700	St. Jones River at Dover, Del.	1958-present	Coastal Plain
01484000	Murderkill River near Felton, Del.	1931-34, 60-85,1997-present	Coastal Plain
01484100	Beaverdam Branch at Houston, Del.	1958-present	Coastal Plain
01484270	Beaverdam Creek near Milton, Del.	1971-1980	Coastal Plain
01484300	Sowbridge Branch near Milton, Del.	1957-1978	Coastal Plain
01484500	Stockley Branch at Stockley, Del.	1943-present	Coastal Plain
01484525	Millsboro Pond Outlet at Millsboro, Del.	1986-88, 1991-present	Coastal Plain
01484548	Vines Creek at Omar, Del.	1985-1988	Coastal Plain
01487000	Nanticoke River near Bridgeville, Del.	1943-present	Coastal Plain
01487500	Trap Pond Outlet near Laurel, Del.	1951-1971	Coastal Plain
01488000	Holly Ditch near Laurel, Del.	1950-1956	Coastal Plain
01488500	Marshyhope Creek near Adamsville, Del.	1943-69, 1972-present	Coastal Plain
01488600	Marshyhope Creek at Adamsville, Del.	1969-1971	Coastal Plain
01490500	Culbreth Marsh Ditch near Chapeltown, Del.	1951-1956	Coastal Plain

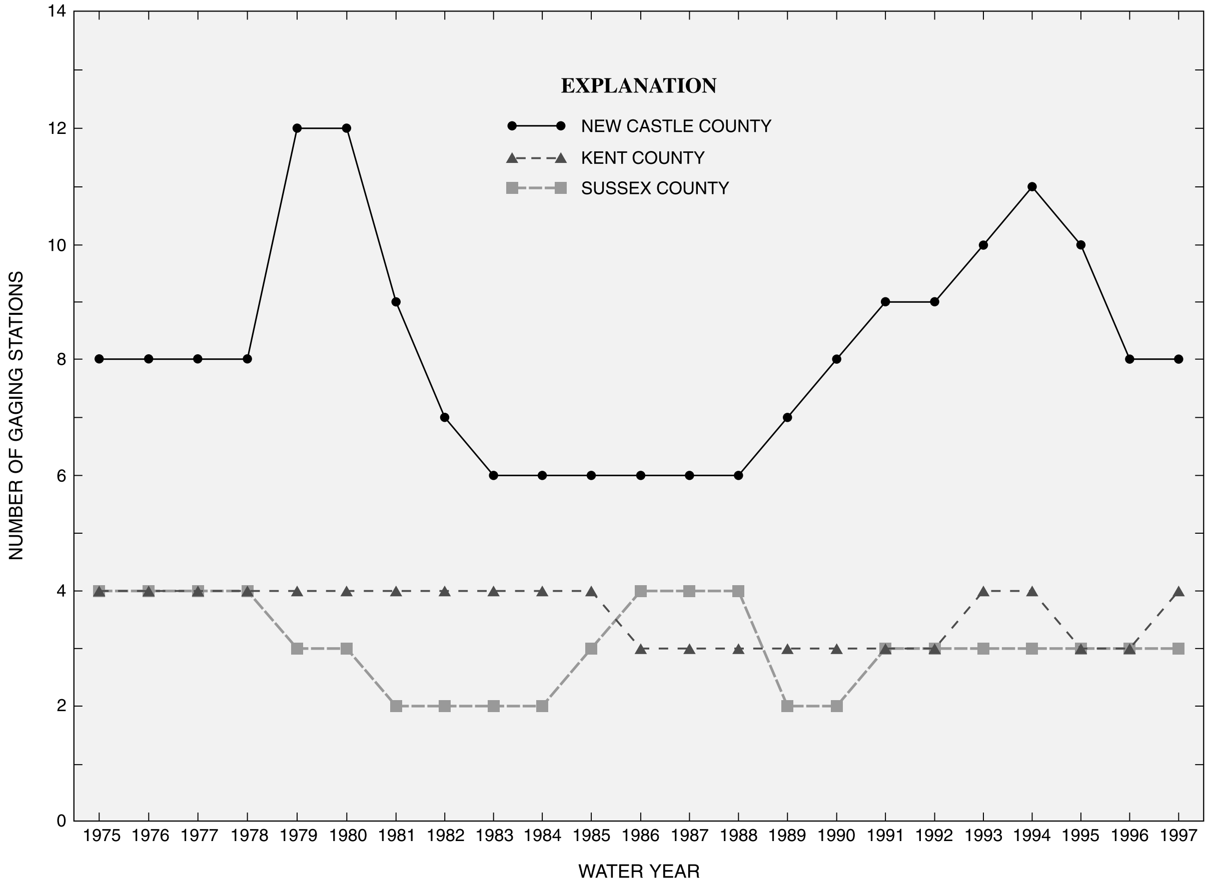

Figure 6: Graph showing number of continuous-record stream-gaging stations by county in Delaware, water years 1975-97

ducted to determine the number of continuous-record stream-gaging stations operated in each county in Delaware during 1975-97.

During 1975-97, an average of eight continuous-record stream-gaging stations were operated in New Castle County. During the same period, the averages for Kent County and Sussex County were four stations and three stations, respectively. Figure 6 shows the total number of continuous-record stream-gaging stations operated in each county during 1975-97.

Figure 6 shows that a maximum of 12 stations and a minimum of six stations were operated in New Castle County during 1975-97. Significant variability is shown in the number of stations operated during most of the study period. The most significant periods of variability were during (1) 1978-83, when the network increased from eight to 12 stations, and then decreased from 12 stations to six stations, and (2) 1988-96, when the network gradually increased from six stations to 11 stations, and then decreased from 11 stations to eight stations.

Figure 6 indicates that a maximum of four stations were operated in Kent County during 1975-85, 1993-94, and during 1997, whereas a minimum of three stations were operated during all other intervening years in the study period. Although the numbers show limited variability, the total number of stations operated in Kent County has changed three times during 1992-97.

A maximum of four stations were operated in Sussex County during 1975-78, and 1986-88. A minimum of two stations were operated during 1981-84, and 1989-90. Despite several periods of variability in the number of stations operated during 1978-91, three stations have been maintained each year in Sussex County since 1991.

The trends shown in Figure 6 indicate some variability in the operation of stations, primarily in New Castle County. Both Kent County and Sussex County also have shown some variability at different times, despite the relatively small numbers of stations operated in these counties. Overall, this variability can be attributed to shifting funding priorities and discontinuation of stations that were operated as part of projects (J.H. Talley, written commun., 1998).

Basin Size. A network of stream-gaging stations should include a range of drainage basin sizes to represent hydrology on a statewide basis. Table 6 shows the number of continuous-record stream-gaging stations by drainage-area intervals in Delaware during 1975-97.

Table 6 shows that all drainage-area intervals are currently represented by one or more continuous-record stream-gaging stations. However, Table 6 also indicates instability in maintaining operation of stations on streams and rivers in drainage basins of 10 mi^2 or less, especially during 1981-97. Although most of these stations were operated to obtain data

Table 6. Number of continuous-record stream-gaging stations by drainage-area intervals in Delaware, water years 1975-97
[> = greater than, mi^2 = square miles]

Water year	0-5 mi^2	5-10 mi^2	10-25 mi^2	25-50 mi^2	50-75 mi^2	75-100 mi^2	> 100 mi^2
1975	2	5	2	3	1	2	1
1976	2	5	2	3	1	2	1
1977	2	5	2	3	1	2	1
1978	2	5	2	3	1	2	1
1979	5	4	2	4	1	2	1
1980	5	4	2	4	1	2	1
1981	4	2	2	4	0	2	1
1982	2	2	2	4	0	2	1
1983	2	2	2	3	0	2	1
1984	2	2	2	3	0	2	1
1985	2	2	3	3	0	2	1
1986	2	2	2	3	1	2	1
1987	2	2	2	3	1	2	1
1988	2	2	2	3	1	2	1
1989	2	2	1	3	1	2	1
1990	3	2	1	3	1	2	1
1991	3	3	1	3	2	2	1
1992	3	3	1	3	2	2	1
1993	3	5	1	3	2	2	1
1994	3	5	1	3	3	2	1
1995	3	3	1	3	3	2	1
1996	2	2	1	3	3	2	1
1997	2	2	2	3	3	2	1

for a specific project, the data indicate that many of them were not operated long enough to be useful for statistical analysis and investigation of long-term hydrologic trends. When the data in Table 6 were compared to the periods of record for discontinued and reactivated continuous-record stream-gaging stations in the inventory, it was determined that 10 of 13 continuous-record stream-gaging stations discontinued during 1975-97 were in locations with drainage areas of 10 mi^2 or less. During 1975-78, seven stations were operated on streams in drainage basins of 10 mi^2 or less. In 1979, three stations were established in the 0- to 5- mi^2 interval, and one station in the 5- to 10- mi^2 interval was discontinued. This brought the total number of stations operated on streams in drainage basins of 10 mi^2 or less to nine. During 1980-82, the number of stations operated on streams in drainage basins of 10 mi^2 or less decreased from nine to four. Four stations were maintained during 1983-89. By 1993, the total had gradually doubled from four stations to eight stations. By 1996, the total had once again decreased to four stations. In 1997, four stations were being operated on streams in drainage basins of 10 mi^2 or less (Figure 7).

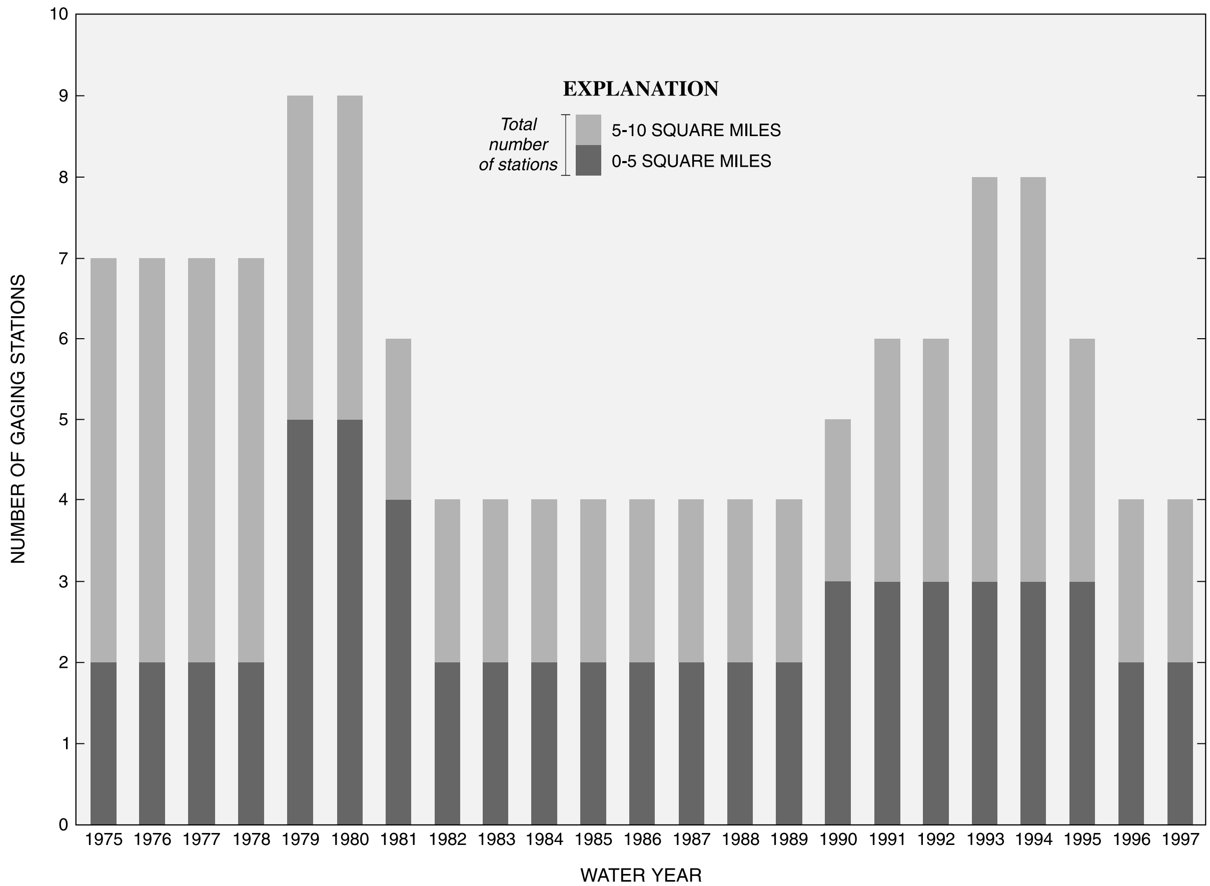

Figure 7: Graph showing number of continuous-record stream-gaging stations in Delaware with drainage areas of 0 to 5 square miles and 5 to 10 square miles, water years 1975-97

Trends in Activity of Other Types of Gaging Stations

In addition to continuous-record stream-gaging stations, other types of gaging stations were operated throughout Delaware during various periods to determine low-flow discharges, peak discharges, tidal stages, or surface-water quality. To determine temporal trends in the activity of these gaging stations in Delaware during 1975-97, analyses were conducted of (1) low-flow partial-record stations, (2) tidal crest-stage partial-record stations, (3) nontidal crest-stage partial-record stations, and (4) surface-water-quality stations.

Low-Flow Partial-Record Stations

The activity of low-flow partial-record stations in Delaware during 1975-97 was investigated to determine temporal trends. The results indicate that activity of low-flow partial-record stations has been relatively variable and non-systematic during 1975-97 (Figure 8). During 10 of the 23 years analyzed, no low-flow partial-record stations were in operation. These years were not consecutive, and occurred at different times during the 23-year period. The number of stations operated during the other years varied from as many as 13 stations operated during 1978, 1979, and 1993, to one station operated in 1991. This indicates that the data were collected more for project-specific purposes, rather than systematically as part of a network. These projects include studies to determine the contribution of ground-water discharge to streamflow.

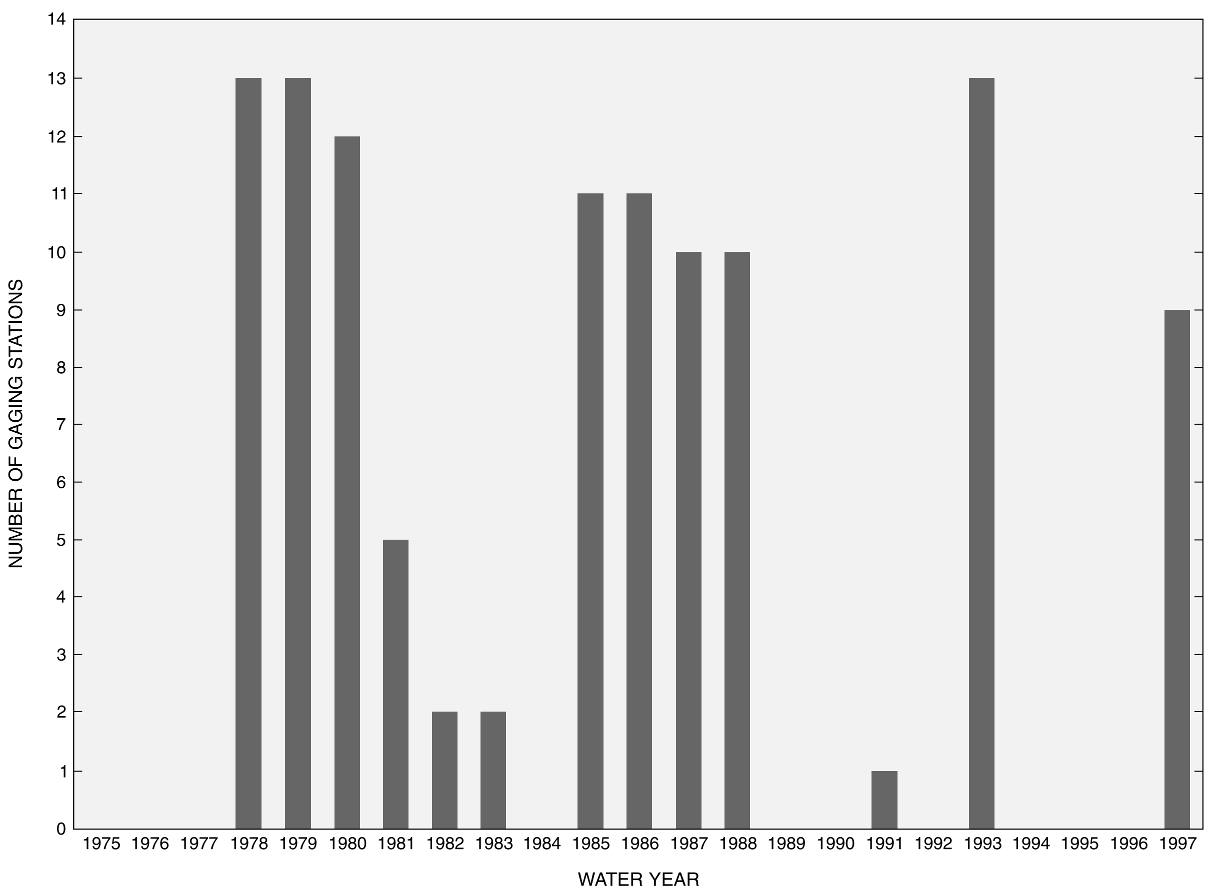

Figure 8: Graph showing number of low-flow partial-record stations operated in Delaware, water years 1975-97

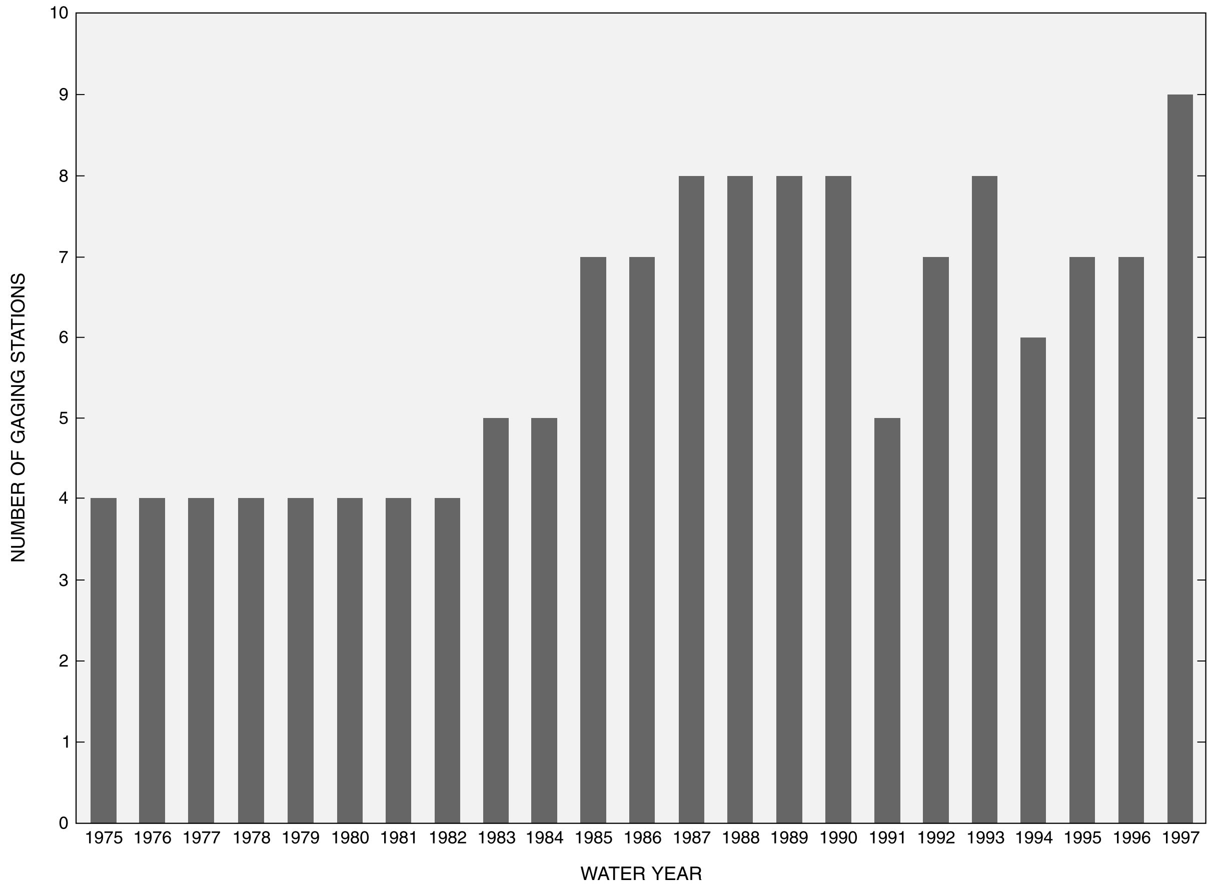

Figure 9: Graph showing number of tidal crest-stage partial-record stations operated in Delaware, water years 1975-97

Tidal Crest-Stage Partial-Record Stations

The activity of tidal crest-stage partial-record stations in Delaware during 1975-97 was analyzed to determine temporal trends. Figure 9 shows the number of tidal crest-stage partial-record stations operated each year during 1975-97.

Figure 9 indicates more systematic activity for tidal crest-stage partial-record stations than for other types of partial-record stations. During 1975-97, the number of stations operated increased from four to nine, despite discontinuation of three stations in 1991 and two others in 1994. The increased activity can be explained by greater interest in the evaluation of coastal geology and hydrology, the effects of coastal storms, the function of tidal wetlands, and dynamic surface-water modeling associated with nutrient loading.

Nontidal Crest-Stage Partial-Record Stations

The activity of nontidal crest-stage partial-record stations in Delaware during 1975-97 was analyzed to determine temporal trends (Figure 10). The results indicate systematic data collection through 1975, when 21 nontidal crest-stage partial-record stations were operated in Delaware. All 21 of these stations were discontinued after 1975. Further investigation determined that most of these stations were operated from 1966-75 to obtain 10 years of peak flows for use in a flood-frequency analysis for Delaware (Simmons and Carpenter, 1978). Activity during 1976-97 was minimal. After 1975, the only activity of nontidal crest-stage partial-record gaging stations in Delaware was a range of one to three stations operated from 1983-91.

Surface-Water-Quality Stations

Surface-water-quality stations in operation in Delaware during 1975-97 were analyzed to determine temporal trends. The investigation included an analysis of the total number of stations operated, with data sorted by continuous-record stations and partial-record stations. The category for continuous-record stations includes (1) stations where continuous surface-water-quality samples were obtained over the period of record and (2) continuous-record stream-gaging stations where periodic surface-water-quality samples were obtained. The total number of surface-water-quality stations operated in Delaware during 1975-97 is shown in Figure 11.

Figure 11 shows a decreasing number of surface-water-quality stations operated over time with a significant decrease in the continuous-record category. Further analysis revealed that during the mid-to-late 1970s, periodic water-quality measurements were synonymous with most active continuous-record stream-gaging stations in Delaware. By 1982, water-quality sampling at these stations had ceased. A range of one to two continuous-record water-quality stations have been operated since then; however, 1991 and 1997 were the only years after 1981 where periodic water-quality sampling was conducted at any currently active continuous-record stream-gaging stations.

Water-quality sampling at partial-record stations was relatively consistent during 1976-80. The number of partial-record stations operated began to decline in 1981 and has since shown significant variability, particularly during 1985-97. Much of this variability can be attributed to project-specific and non-systematic water-quality sampling. The overall decline in sampling may be attributed in part to costs and shifts in funding priorities among cooperating agencies, and also to other agencies conducting their own sampling.

Representativeness of the Current Continuous-Record Stream-Gaging Network

To ensure that the stream-gaging network in Delaware is adequate to meet multiple data needs by a variety of users, it must represent the range of hydrologic conditions and geographic variation found in Delaware, and include an adequate number of stations to account for hydrologic vari-

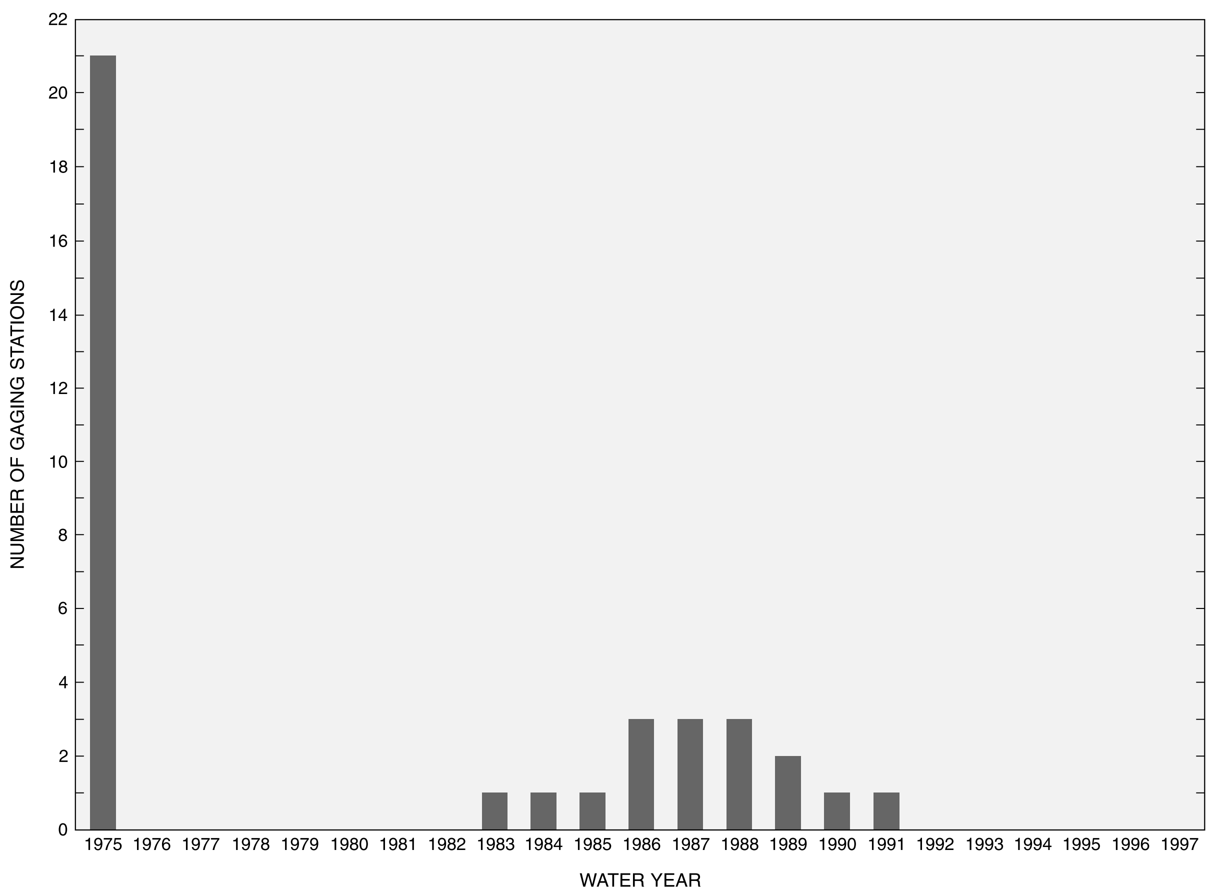

Figure 10: Graph showing number of nontidal crest-stage partial-record stations operated in Delaware, water years 1975-97

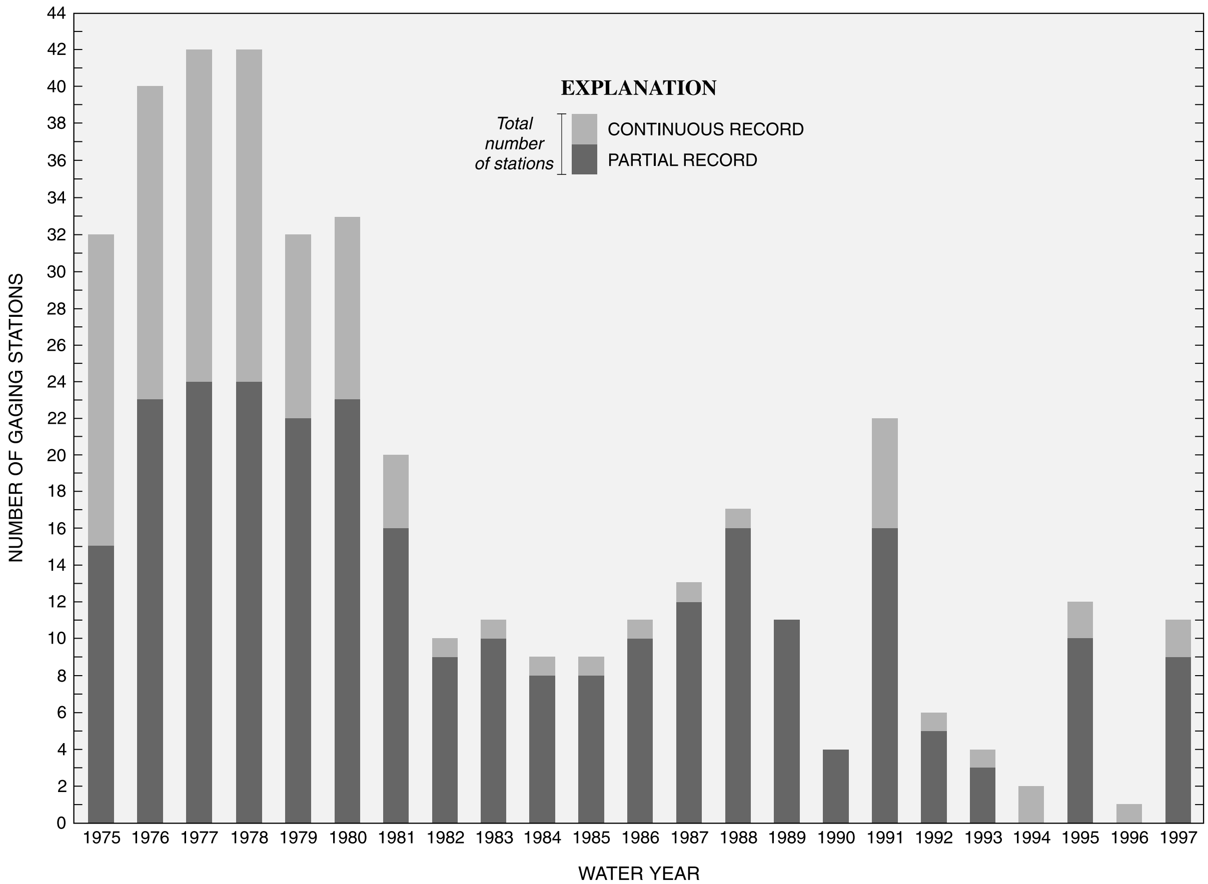

Figure 11: Graph showing number of surface-water-quality stations operated in Delaware, water years 1975-97

ability. To determine the representativeness of the current continuous-record stream-gaging network in Delaware, a variety of factors were investigated.

Locations of Active and Discontinued Stations

The locations of the 15 active continuous-record stream-gaging stations were plotted on a map of Delaware to show their distribution (Figure 12). Seven active stations are located in the northernmost region of Delaware, where the principal source of public drinking-water supplies are from surface-water sources. Coverage per square mile is relatively low throughout the rest of Delaware, where drinking-water supplies are obtained from wells.

The locations of all discontinued continuous-record stream-gaging stations were added to the map to indicate their distribution in relation to the active stations (Figure 13). Figure 13 shows eight discontinued stations in the northernmost region of Delaware. Eleven other discontinued stations are distributed throughout central and southern Delaware. Most of the discontinued stations were in locations where significant geographical gaps in the current network could be filled. They also represent locations where collection of current data would provide comparative value to the data previously collected at these locations. Additional maps showing the distribution of other types of active and discontinued stream-gaging stations in Delaware are included in Appendix 4.

Gaged and Ungaged Drainage Basins

To adequately represent the overall hydrology of Delaware, the network must include stream-gaging stations that are located in most, if not all, of the principal drainage basins within the State (Figure 14). Annual water-data reports by the U.S. Geological Survey (1962-96) were used to determine the principal drainage basins in Delaware where continuous-record stream-gaging stations are currently in operation. Discontinued continuous-record stream-gaging stations were also grouped according to drainage basin. The results are presented in Table 7.

Table 7 shows that seven principal drainage basins are currently represented by continuous-record stream-gaging stations located in Delaware. Although the Pocomoke River Basin and Choptank River Basin do not have active stations located in Delaware, their drainage areas in Delaware are

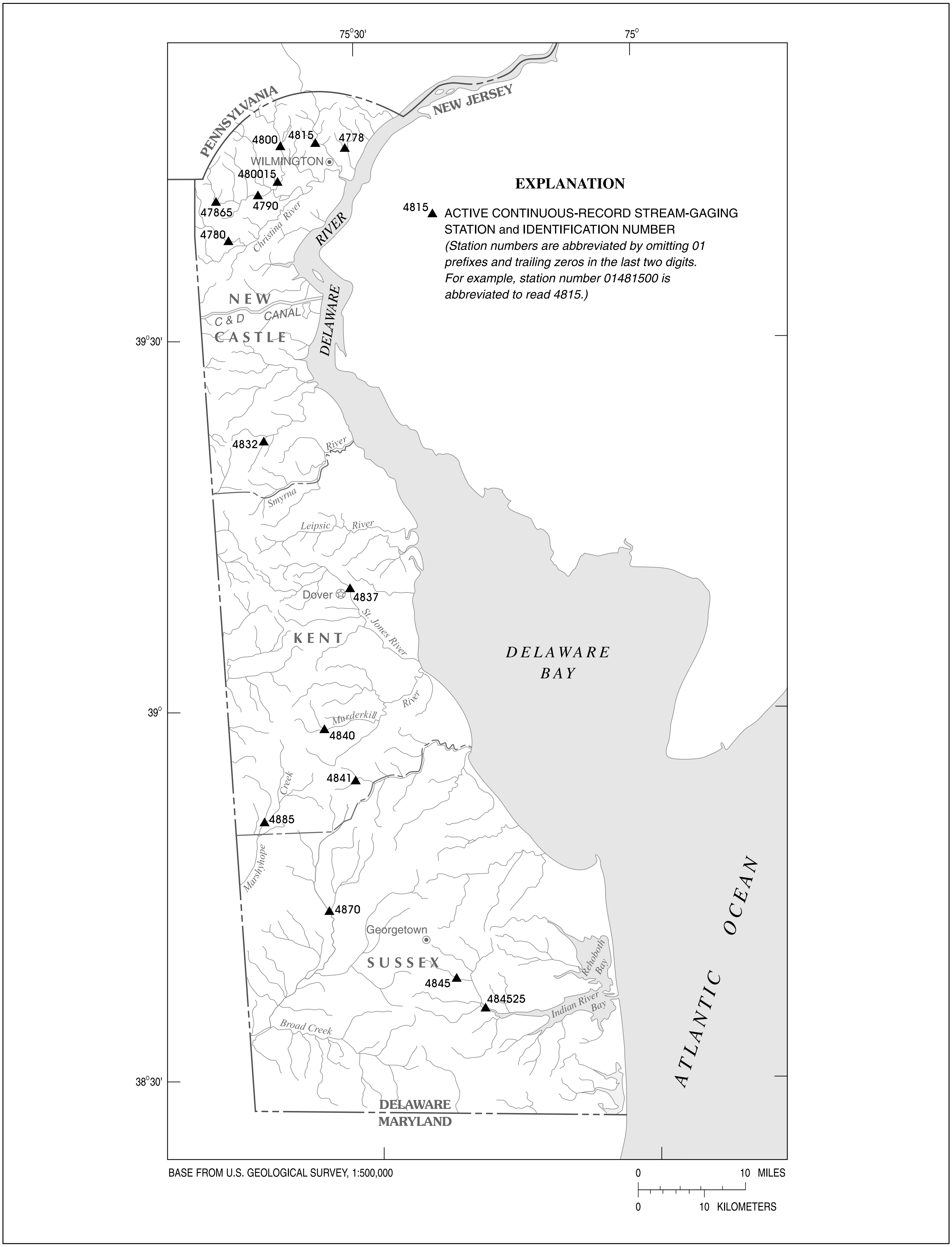

Figure 12: Map showing locations of active continuous-record stream-gaging stations in Delaware

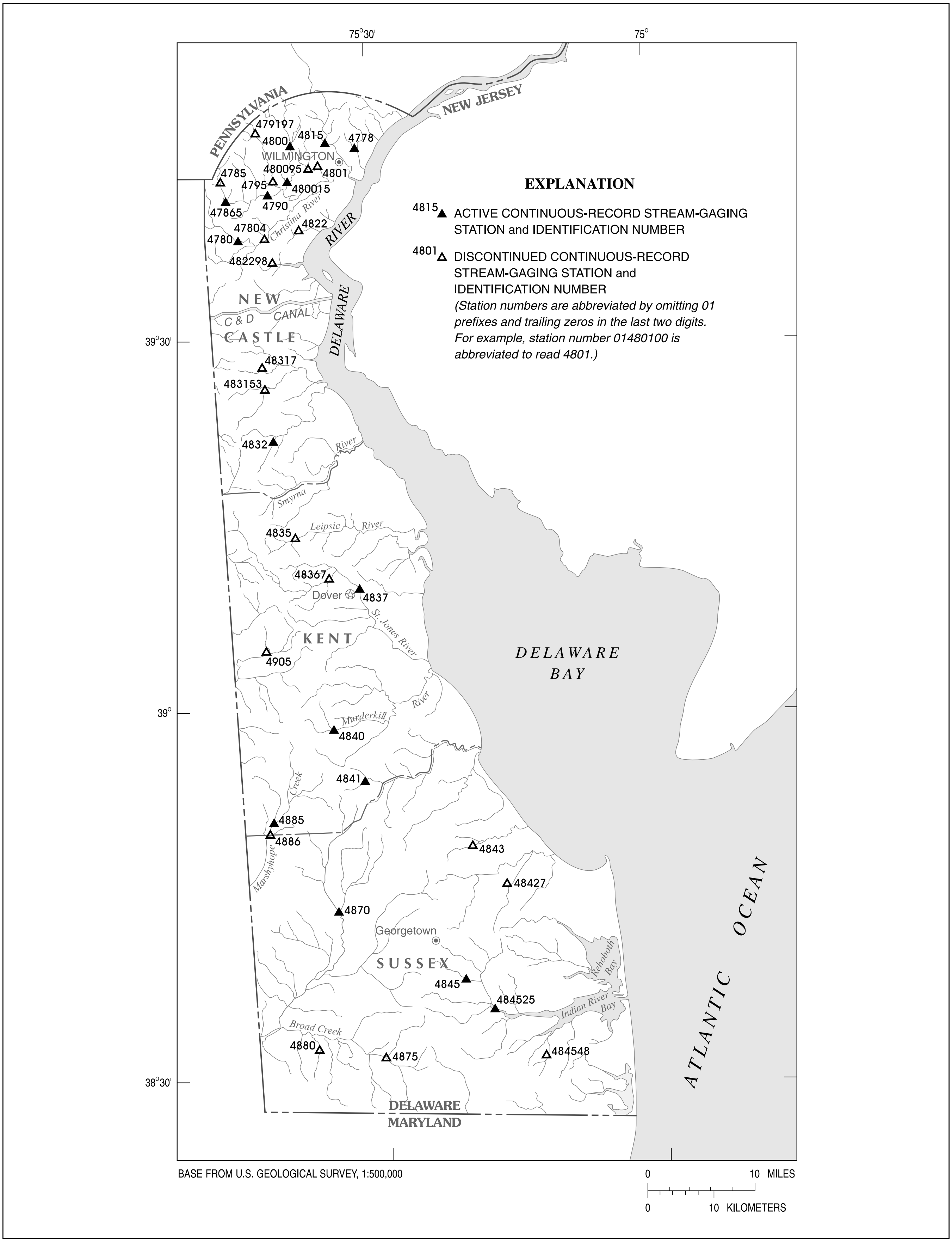

Figure 13: Map showing locations of active and discontinued continuous-record stream-gaging stations in Delaware

included at stations currently in operation within the State of Maryland. Table 7 also shows seven other drainage basins that are currently unrepresented, including the Smyrna River, Leipsic River, Broadkill River, Dirickson Creek, Chester River, Sassafras River, and Elk River basins. The Leipsic and Broadkill River basins had continuous-record stream-gaging stations in the past. A station on Long Creek near Chesapeake City, Md. (Station 01495800) included a part of the Elk River Basin in Delaware during its period of operation (1978-81). The Smyrna River, Dirickson Creek, and Chester River Basin have never been continuously gaged in Delaware, and have been represented only by selected low-flow partial-record stations, nontidal crest-stage partial-record stations, or surface-water-quality partial-record stations. The Sassafras River Basin has never been gaged in Delaware.

Further investigation showed that all discontinued continuous-record stream-gaging stations in Delaware with at least 10 years of record had been inactive since 1980 or before. Although these stations had periods of record suitable for use in hydrologic investigations, the data were not indicative of current temporal hydrologic variations because of the gap in time since the stations were last operated. Unless new data are collected at these stations for comparison with the previous period of record, the usefulness of data from these discontinued stations will become more and more limited over time.

Counties

Spatial coverage of drainage areas within county boundaries must be adequate for countywide hydrology studies. Data obtained from the Delaware State Data Center (1996) were used with data files from the USGS Maryland-Delaware-D.C. District to determine the current spatial coverage of drainage areas from continuous-record stream-gaging stations in New Castle County, Kent County, and Sussex County, Delaware.

The total area in New Castle County is 438 mi^2. About 69.5 mi^2 of this total (about 15.9 percent) includes wetlands and inland water. At present, eight continuous-record stream-gaging stations cover approximately 87.7 mi^2 of cumulative drainage area, representing 20 percent of the total area in New Castle County. Of the total land area in New Castle County, 190 mi^2 is below the C & D Canal. The

Table 7. Number of active and discontinued continuous-record stream-gaging stations in principal drainage basins in Delaware

Drainage basin	Active stations	Active stations with at least 10 years of record	Discontinued stations	Discontinued stations with at least 10 years of record
Delaware River[1]	2	2	4	0
Christina River[2]	6	4	6	2
Smyrna River	0	0	0	0
Leipsic River	0	0	1	1
St. Jones River	1	1	1	0
Murderkill River	1	1	0	0
Mispillion River	1	1	0	0
Broadkill River	0	0	2	2
Indian River	2	2	1	0
Dirickson Creek	0	0	0	0
Pocomoke River[3]	0	0	0	0
Nanticoke River[4]	2	2	3	1
Choptank River[5]	0	0	1	0
Chester River[6]	0	0	0	0
Sassafras River[7]	0	0	0	0
Elk River[8]	0	0	0	0

1. Christina River basin is excluded.
2. 34.7 percent of drainage basin is located in Delaware.
3. 7.8 percent of drainage basin is located in Delaware.
4. 60.1 percent of drainage basin is located in Delaware.
5. 12.9 percent of drainage basin is located in Delaware.
6. 9.3 percent of drainage basin is located in Delaware.
7. 7.2 percent of drainage basin is located in Delaware.
8. 10.2 percent of drainage basin is located in Delaware.

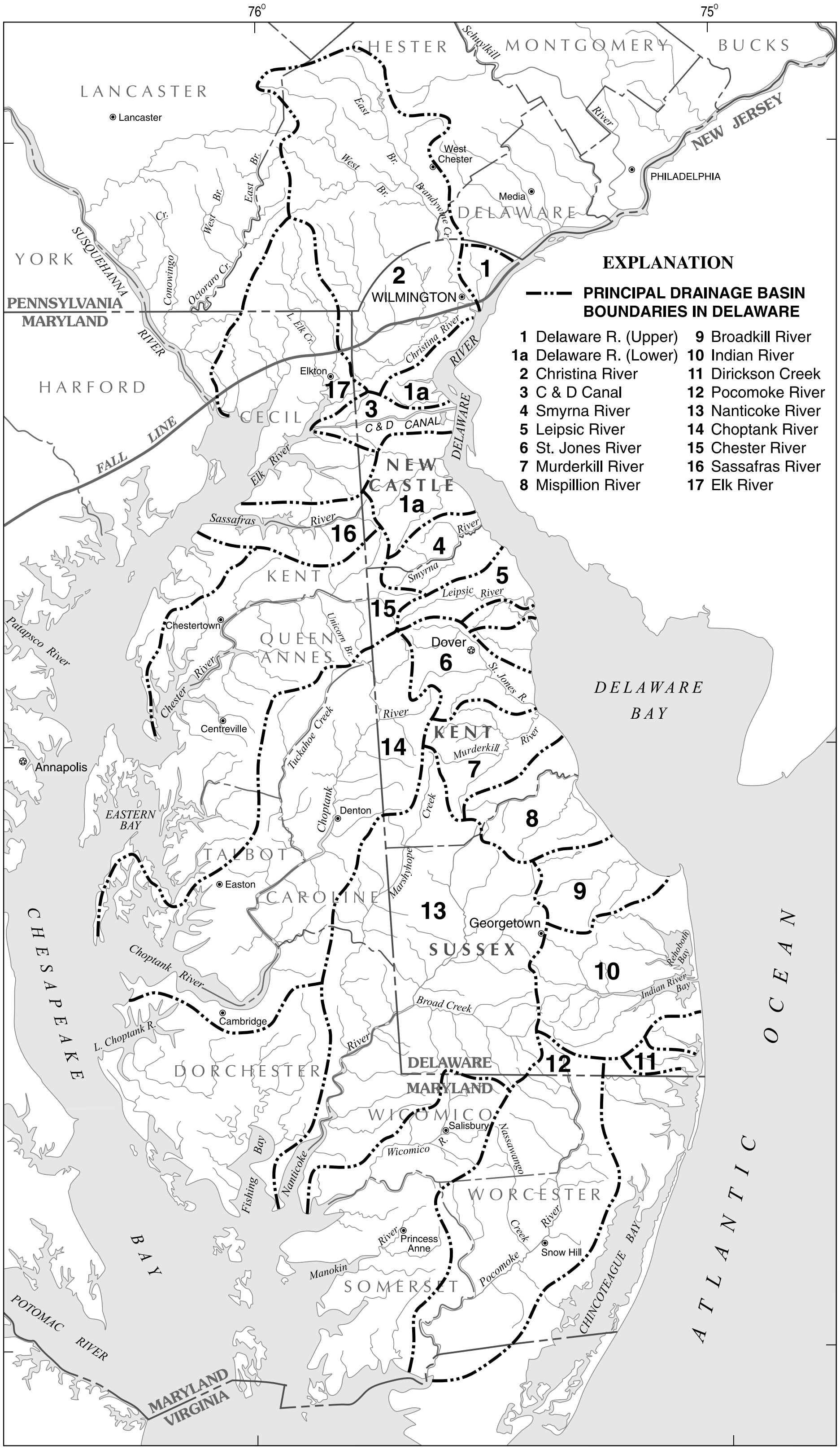

Figure 14: Map showing locations and approximate boundaries of principal drainage basins in Delaware

only active continuous-record stream-gaging station in New Castle County below the C & D Canal is Blackbird Creek at Blackbird (Station 01483200) with a drainage area of 3.85 mi^2. Therefore, only 2 percent of the land area in New Castle County below the C & D Canal is currently gaged. The remaining stations provide coverage for approximately 33.8 percent of the total area in New Castle County above the C & D Canal.

The total area in Kent County is 594 mi^2 . About 140.5 mi^2 of this total (about 23.7 percent) includes wetlands and inland water. Currently, four continuous-record stream-gaging stations cover approximately 92.2 mi^2 of cumulative drainage area, or 15.5 percent of the total area in Kent County. The continuous-record stream-gaging station on the Choptank River near Greensboro, Maryland (Station 01491000) also includes 92.8 mi^2 of drainage area in Kent County, Delaware Therefore, a total of approximately 185 mi^2 of cumulative drainage area is gaged in Kent County, representing 31.1 percent of the total land area.

The total area in Sussex County is 950 mi^2. About 165.5 mi^2 of this total (about 17.4 percent) includes wetlands and inland water. Currently, three continuous-record stream-gaging stations cover approximately 141.4 mi^2 of cumulative drainage area, or 14.9 percent of the total area in Sussex County. The continuous-record stream-gaging station on the Pocomoke River near Willards, Maryland (Station 01485000) also includes 38.2 mi^2 of drainage area in Sussex County. Therefore, a total of approximately 179.6 mi^2 of cumulative drainage area is gaged in Sussex County, representing 18.9 percent of the total land area.

The above analysis suggests that spatial coverage can potentially be improved in all counties in Delaware. However, additional coverage may be limited because of (1) tidal and nontidal wetlands, (2) inland water, (3) ditching of drainage basins in agricultural areas, and (4) tides that affect many streams and rivers in the Coastal Plain of Delaware.

Physiographic Provinces

To adequately represent Delaware for purposes of hydrologic investigation, the network must include a requisite number of continuous-record stream-gaging stations that provide spatial coverage in both physiographic provinces. Data from the files of the USGS Maryland-Delaware-D.C. District were used to determine the current spatial coverage of drainage areas from continuous- record stream-gaging stations within both the Piedmont and Coastal Plain Physiographic Provinces in Delaware.

The Piedmont Physiographic Province in Delaware covers approximately 112 mi^2. Four continuous-record stream-gaging stations currently cover approximately 62 mi^2 of cumulative drainage area in the Piedmont in Delaware, or 55 percent of the total land area.

The Coastal Plain Physiographic Province in Delaware covers almost 1,866 mi^2. Eleven continuous-record stream-gaging stations are currently covering approximately 260 mi^2 of cumulative drainage area in the Coastal Plain in Delaware, or 13.9 percent of the total land area. An additional 131 mi^2 of drainage area in the Coastal Plain of Delaware is covered by stations on the Choptank River and Pocomoke River in Maryland. Including the area covered by the stations in Maryland, the current network covers 391 mi^2 of cumulative drainage area in the Coastal Plain in Delaware, or 21.0 percent of the total land area.

The above analysis suggests that current coverage is significantly greater in the Piedmont than in the Coastal Plain. Reasons for greater coverage in the Piedmont include greater susceptibility to flooding and flood damage, and significant use of surface water for public-water supply (J.H. Talley, written commun., 1998). Improving coverage in the Piedmont may also be less difficult because of fewer natural and manmade constraints. The Piedmont comprises only about 6 percent of the total land area in Delaware, however, and currently has coverage of 55 percent. The Coastal Plain

Table 8. Approximate percentages of major land-use types in drainage basins above active, continuous-record stream-gaging stations in Delaware [mi^2 =square miles, % = percent]

Station number	Drainage area (mi^2)	Urban (%)	Farmland (%)	Forest (%)	Wetland (%)	Other (%)
01477800	7.46	62.0	1.7	32.3	0.1	3.9
01478000	20.5	25.3	37.1	35.6	1.0	1.0
01478650	69.0	6.3	52.2	39.3	1.1	1.1
01479000	89.1	14.0	46.7	37.3	1.0	1.0
01480000	47.0	9.9	43.2	44.6	0.9	1.4
01480015	52.4	13.6	39.3	44.2	1.0	1.9
01481500	314.0	7.6	44.0	44.8	0.5	3.1
01483200	3.85	0.9	47.4	40.2	10.6	0.9
01483700	31.9	10.4	49.6	22.6	15.6	1.8
01484000	13.6	1.8	65.9	20.5	11.7	0.1
01484100	2.83	0.0	60.1	34.0	5.8	0.1
01484500	5.24	6.3	55.0	23.3	14.3	1.1
01484525	66.0	4.3	45.2	35.5	13.6	1.4
01487000	75.4	2.4	55.9	28.0	13.7	0.1
01488500	43.9	0.5	59.7	28.0	11.7	0.1

comprises nearly 94 percent of the total land area in Delaware, yet currently has coverage of only about 21 percent. These results suggest that consideration should be given to enhancing the network to improve coverage in the Coastal Plain.

Land Use

An analysis was conducted to determine the approximate distribution of land-use types in drainage basins above active continuous-record stream-gaging stations in Delaware. Digital drainage basin delineations were used with 1994 land-use spatial data for Delaware and surrounding states to determine approximate percentages of urban, farmland, forest, and wetland areas within each drainage basin (Vogelmann and others, 1998). Other land-use types that occur in minimal percentages in these drainage basins include: other grasses; transitional barren; quarries, stripmines, gravel pits; and open water. These land-use types were grouped into a category entitled "other." The results are presented in Table 8. Data from other sources regarding land use and other basin characteristics for selected stream-gaging stations in Delaware can be found in Dillow (1996) and in Carpenter and Hayes (1996).

Table 8 indicates that all major land-use types are represented in widely varying percentages in drainage basins above active continuous-record stream-gaging stations in Delaware. The data show that farmland is the predominant land-use type at 11 of the 15 stations. Forest land use predominates slightly over farmland at three stations. Urban land use is predominant at one station. Further investigation revealed that all 11 stations where farmland is predominant are located in the Coastal Plain. All four stations where forest or urban land use is predominant are located in the Piedmont. The data also showed no stations in drainage basins of 10 mi^2 or less that are predominantly forested. The results of this analysis suggest that consideration be given to establishing one or more gaging stations in (1) small, predominantly forested drainage basins in the Coastal Plain of Delaware, (2) predominantly urban areas in the Coastal Plain of Delaware, and (3) locations in the Piedmont where farmland is predominant.

Population

An analysis was conducted to determine the approximate population in the drainage basins of active continuous-record stream-gaging stations. Digital drainage-basin delineations were used with a digital map file of 1990 Census data for Delaware to determine the approximate population within the drainage basin at each station (Hitt, 1994). Population estimates for the Delaware portions of the Choptank and Pocomoke River drainage basins that are gaged in Maryland were not available. For stations located in Delaware with drainage basins that extend beyond the State border, only Delaware population was included. The results are presented in Table 9.

The population estimates in Table 9 were summed to calculate the total population residing in gaged drainage basins in Delaware, based on the 1990 Census data. The estimate was then adjusted to account for nested stations. The results indicated that a total population of 153,567 out of 669,909, or approximately 23 percent of the 1990 Census population, reside in gaged drainage basins in Delaware.

The population estimates in Table 9 were used to determine the total population residing in gaged basins by county. The results are presented in Table 10.

The data show that Sussex County has significantly less gage coverage in populated areas than either New Castle County or Kent County. The current estimates for both Kent County and Sussex County could be improved slightly by inclusion of population estimates for the Delaware portions of the Choptank River and Pocomoke River drainage basins upon availability.

A STRATEGY FOR IMPROVEMENT OF NETWORK COVERAGE

Improving the coverage of any stream-gaging network is an ongoing process that requires simultaneous consideration of numerous issues and alternatives. Issues and alternatives that must be considered when determining the benefits of activating new stream-gaging stations, reactivating discontinued stream-gaging stations, or continuing operation of active stream-gaging stations include (1) continuing or new data needs, (2) the type of stream-gaging station required to meet these needs, (3) funding, (4) location, and (5) basin characteristics. To assist in evaluating potential improvements to the stream-gaging network in Delaware, a general strategy was developed based on the results of the analyses of trends and representativeness. The strategy also includes some ideas for meeting future data needs based on these analyses.

Priority must initially be given to maintaining the 15 continuous-record stream-gaging stations that are currently in operation. Previous investigations by Carpenter and others (1987) and Dillow (1996) indicated that none of the active continuous-record stream-gaging stations in Delaware that were included in their respective analyses should be considered for discontinuation. Analysis of data uses in this investigation determined that the data for all of the active continuous-record stream-gaging stations in Delaware continue to have multiple uses. If any current stations must be discontinued, locations should be limited to streams and rivers with nested stations to minimize reductions in current coverage of drainage area.

To enhance future hydrologic investigations, any new or previously-discontinued continuous record stream-gaging station that is activated in the future should be operated for a minimum of 5 years, and preferably for 10 years or more. Five- to 10-year commitments should be considered as part of initial discussions between cooperating agencies for new or reactivated stream-gaging stations. This investigation has shown that most continuous-record stream-gaging stations activated between 1975 and 1997 are not being maintained for sufficient periods of time to account for local temporal hydrologic variations. Data users must currently rely on the 11 long-term stations throughout Delaware to predict current temporal hydrologic variations at other ungaged locations. Operation of new stations for longer periods will provide sufficient record at additional locations to more accurately define temporal hydrologic variations throughout Delaware.

Crest-stage partial-record stations can be considered as an economical option for obtaining limited streamflow data in nontidal locations that are currently ungaged. Stage-discharge relations can be established at crest-stage partial-record stations using indirect or direct measurements of discharge. Crest-stage partial-record stations could be used to improve spatial coverage of the network by strategic placement in locations where stage-discharge relations can be expected to be stable and geographical gaps in coverage currently exist. This analysis showed that 21 nontidal crest-stage partial-record stations were operated in Delaware in 1975, 18 of which had 10 years of record prior to being discontinued after 1975, and there was very limited usage of nontidal crest-stage partial-record stations in Delaware after 1975. Reactivation of any of these discontinued stations would provide additional data on peak stages and discharges in locations in Delaware where no current data are available and provide current data for comparison with the previous periods of station record.

The Coastal Plain Physiographic Province should be given priority if new stations or previously-discontinued stations are to be activated in the future. This analysis indicated (1) significant variability in numbers of stations operated in the Coastal Plain during 1975-97, (2) several princi pal drainage basins in the Coastal Plain are currently ungaged, and (3) significantly less spatial coverage by gaging stations in the Coastal Plain than in the Piedmont Physiographic Province. Activation of additional stations in the Coastal Plain should simultaneously improve spatial coverage and population coverage on a countywide basis if the current stations are maintained and new stations are distributed throughout currently ungaged locations in the Coastal Plain.

Priority for new stations in the Coastal Plain should be given to drainage basins that are predominantly forested or urban for purposes of variability in coverage. The analysis of land use in this study indicated that all 11 active continuous-record stream-gaging stations in the Coastal Plain of Delaware are located in drainage basins where farmland is predominant. Farmland is the overall predominant land-use type in the Coastal Plain of Delaware, and thus should be represented by the majority of continuous-record stream-gaging stations. Future improvements or additions to the Coastal Plain stations, however, should be directed towards achieving greater balance among predominant land-use types.

Priority for new stations in the Coastal Plain should be given to principal drainage basins other than the Choptank River Basin and the Pocomoke River Basin for purposes of improving spatial coverage in Delaware, unless specific regional or local concerns dictate otherwise. The Delaware portions of the Choptank River Basin and the Pocomoke River Basin are already included in drainage areas covered by active continuous-record stream-gaging stations in Maryland. If the current data being collected in Maryland are adequate for Delaware’s needs, network improvements should be focused on providing coverage to other ungaged drainage basins in Delaware.

Efforts to improve network coverage should also consider projected population growth in Delaware and the locations where growth is expected to be greatest. Land-use changes, increased runoff to streams, channel instability, sediment supply, water quality, and water supply are issues of concern in population-growth areas. Streamflow data collected before, during, and after watershed changes occur can provide a valuable record of physical and hydraulic adjustments by rivers and streams in response to development. Data presented as part of this analysis showed that (1) Delaware’s total population is projected to increase by 18.5 percent between 1996 and the year 2020, (2) projected annual population growth percentages in Kent County and Sussex County significantly exceed that of New Castle County through the year 2020, and (3) the two largest intervals of projected population growth are distributed in several projected growth areas throughout Delaware. Many of these projected growth areas are in the Coastal Plain Physiographic Province and should be considered as possible locations for continuous-record stream-gaging stations.

Table 9. Approximate census population residing within drainage basins above active, continuous-record stream-gaging stations in Delaware, 1990 [mi^2 = square miles]

Station number	Drainage area (mi^2)	Drainage area within Delaware (mi^2)	1990 Census population	Population density (population/mi^2)
01477800	7.46	7.46	21,674	2,905
01478000	20.5	12.65	26,630	2,105
01478650	69.0	6.6	5,226	792
01479000	89.1	26.7	52,440	1,964
01480000	47.0	18.7	4,281	229
01480015	52.4	24.1	14,592	605
01481500	314.0	13.0	2,989	230
01483200	3.85	3.85	308	80
01483700	31.9	31.9	16,694	523
01484000	13.6	13.6	2,099	154
01484100	2.83	2.83	1,625	574
01484500	5.24	5.24	868	166
01484525	66.0	66.0	7,829	119
01487000	75.4	75.4	3,713	49
01488500	43.9	43.9	2,974	68

Table 10. Approximate census population residing within gaged drainage basins in Delaware, by county and state total, 1990 [% = percent]

Location	Total 1990 Census population	1990 Census population residing in gaged drainage basins	Percentage of total 1990 Census population (%)
New Castle County	443,580	118,633	26.7
Kent County	111,640	23,392	21.0
Sussex County	113,849	11,542	10.1
State total	669,069	153,567	23.0

Data needs for streams in small watersheds could increase with demands for comprehensive watershed management. In other states, these data needs have included streamflow, sediment, stream-channel geometry and profile, water quality, biological data, and ecological data. This study showed that (1) four of 15 active continuous-record stream-gaging stations are in locations with drainage areas of 10 mi^2 or less, (2) none of these four stations are in predominantly forested watersheds, and (3) 10 of 13 continuous-record stream-gaging stations that were discontinued between 1975 and 1997 were in locations with drainage areas of 10 mi^2 or less. The network could potentially be improved by activation of one or more stations in small, predominantly forested watersheds. Data from new stations would be useful for comparison with data from the existing stations in small watersheds where farmland and urban land use are predominant. Improvement of spatial coverage in the Coastal Plain could also depend on the activation of additional stations in small watersheds because of the significant influence of tides, which become more prevalent as drainage basin size increases in Coastal Plain watersheds.

Further investigation is necessary to determine geographical gaps and additional data needs for low flows and surface-water quality. This analysis revealed extremely variable activity of low-flow partial-record stations and surface-water-quality stations over time. Project-specific sampling or other agencies conducting their own sampling were presented as possible explanations for the trends or lack of trends that were shown. A compilation or synthesis of all compatible low-flow and water-quality data from different agencies could help to determine current geographical gaps in information and additional data needs.

A regional-scale example that shows gaps in the current network and potential improvements using specific elements of the above strategy is New Castle County, which includes 190 mi^2 of land area in the Coastal Plain, south of the C & D Canal. Only one continuous-record stream-gaging station is being operated in this area presently, and the drainage basin covers only 2 percent of the total land area. Current population projections indicate that this region is one of three regions with the largest interval of projected growth in Delaware between the years 1990 and 2020. Continuous-record stream-gaging stations were operated previously on Drawyer Creek Tributary near Odessa (Station 01483170, 1979-81, drainage area of 4.68 mi^2) and Noxontown Lake Outlet near Middletown (Station 01483153, 1993-94, drainage area of 8.85 mi^2). The lack of current and historical gage coverage, combined with expected population growth emphasize a need for additional stations to be activated before hydrologic characteristics are altered by development.

A local-scale example showing gaps in the current network and potential improvements using specific elements of the above strategy is the Leipsic River Basin, an ungaged basin in the Coastal Plain in Kent County. A continuous-record stream-gaging station was previously operated on the Leipsic River near Cheswold (Station 01483500, 1943-57, drainage area of 9.35 mi^2). The station was subsequently operated as a nontidal crest-stage partial-record station during 1958-75. The drainage basin does not include the City of Dover, which is one of the regions in the largest interval of projected population growth. The hydrologic characteristics of the Leipsic River Basin could be altered, however, if population growth results in additional suburban development 5 or more miles to the north of Dover. Current patterns of development indicate this possibility. Reactivating the continuous-record stream-gaging station on the Leipsic River will (1) provide coverage to a currently ungaged basin, (2) improve coverage of the Coastal Plain region and Kent County, and (3) provide current data to assess the effects of population growth on flow characteristics of the drainage basin, and for comparison with data from the previous period of record.

SUMMARY AND CONCLUSIONS

This report describes the current stream-gaging network in Delaware and provides an evaluation of its representativeness for the State. The network, operated cooperatively between the U.S. Geological Survey and the Delaware Geological Survey, provides long-term and short-term hydrologic data to meet the needs of government agencies and private consultants for conducting hydrologic investigations both locally and statewide.

Re-evaluation of earlier established data-use classes for stream-gaging stations in Maryland and Delaware indicated that the data for all active continuous-record stream-gaging stations in Delaware continue to have multiple uses. These uses include (1) analysis of regional hydrology, (2) definition of current hydrologic conditions and sources of water through hydrologic systems, (3) project operation and water-supply evaluation, (4) hydrologic forecasts, (5) water-quality monitoring, (6) fishkill investigations and nutrient loading calculations, (7) planning and design of hydraulic structures, and (8) regulatory compliance.

Analysis of temporal trends in numbers of continuous-record stream-gaging stations operated during water years 1975-97 showed (1) significant variability in the number of stations operated over time, especially during water years 1980-84, and 1989-97, (2) most continuous-record stream-gaging stations activated between 1975 and 1997 are not being maintained for sufficient periods of time to account for local temporal hydrologic variations, and (3) instability in maintaining operation of stations on streams and rivers in small drainage basins (10 mi^2 or less), especially during 1981-97.

Investigation of temporal trends for low-flow partial-record stations, tidal crest-stage partial-record stations, non-tidal crest-stage partial-record stations, and surface-water-quality stations, operated during water years 1975-97 indicated variable and non-systematic activity over time for most stations. Tidal crest-stage partial-record stations were operated more systematically and increased in number between 1975 and 1997, possibly because of greater interest in the evaluation of coastal geology and hydrology, the function of tidal wetlands, and the effects of coastal storms.

Analysis of the representativeness of the active continuous-record stream-gaging network in Delaware indicated that several principal drainage basins in the Coastal Plain Physiographic Province are currently ungaged, and there is significantly less spatial coverage by gaging stations in the Coastal Plain than in the Piedmont. Analysis of land-use types in drainage basins with active continuous-record stream-gaging stations showed a lack of stations in (1) small, predominantly forested drainage basins in the Coastal Plain, (2) predominantly urban areas in the Coastal Plain, and (3) locations in the Piedmont where farmland is predominant. Investigation of 1990 Census population in drainage basins with active continuous-record stream-gaging stations indicated that approximately 23 percent of Delaware's inhabitants are residing in drainage basins that are gaged.

A strategy for improvement of current network coverage was developed based on the analyses of trends and representativeness. Recommendations from the strategy included (1) maintaining operation of all active continuous-record stream-gaging stations in Delaware, (2) greater efforts to maintain operation of new stations for a minimum of 5 years, and preferably for 10 years or more, (3) giving priority to the Coastal Plain for activating new stations to improve coverage, (4) conducting further investigation to determine geographical gaps and data needs for low flows and surface-water quality, and (5) greater consideration of ungaged principal drainage basins, land-use characteristics of drainage basins, and locations of projected population growth in future decisions regarding activation of stream-gaging stations.

Southern New Castle County and the Leipsic River Basin represent regional- and local-scale examples that demonstrate gaps in network coverage. Applying specific elements of the strategy to these and other locations in Delaware can assist in prioritizing locations for activating new stream-gaging stations and improving network coverage for future hydrologic investigations.

Appendix 3 and 4 include an inventory of all types of stream-gaging stations operated in Delaware from 1931-97 and maps showing locations of selected stations. The Appendices can be used to help evaluate improvements to the network, or for locating historical data to supplement current hydrologic investigations throughout Delaware.

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APPENDIX 1

Glossary

Average Annual Runoff: The average depth, in inches, to which a drainage area would be covered if all runoff for a given year were uniformly distributed over that area.

Continuous-Record Stream-Gaging Station: Location where a water-stage recorder is used to collect continuous time-series stage data that are related to systematic discharge measurements at the station. Continuous-record stream-gaging stations are often operated for purposes of long-term monitoring or as part of hydrologic investigations.

Drought: A period of 15 consecutive days or more where the total daily rainfall is 0.01 inches or less. A partial drought is a period of 29 consecutive days or more where the mean daily rainfall does not exceed 0.01 inches.

Low-Flow Partial-Record Station: Ungaged locations where discharge measurements are made during the periods of lowest flows to determine the contributions of ground-water storage to the discharge. Stages are not recorded at these stations. Data collected from these stations are used to generate statistical predictions of low flows for various time periods, generally in years. Examples of these types of statistics include the 7-day, 2-year low-flow discharge, or the 7-day, 10-year low-flow discharge.

Nontidal Crest-Stage Partial-Record Station: Nontidal locations where peak stages and discharges are determined by use of a crest-stage gage instead of a water-stage recorder. A crest-stage gage will register the peak stage occuring between inspections of the gage. A crest-stage gage can be used to obtain a high-water mark during a flood, or to determine water-surface slopes if placed in multiple locations along a reach of stream. A stage-discharge relation for a nontidal crest-stage partial-record station can be developed using discharge data obtained by indirect measurement of peak flow, or direct measurement of a range of discharges by current meter.

Surface-Water-Quality Station: Location where surface-water-quality samples are collected to determine concentrations of selected chemicals in the water. Samples can be collected (1) periodically at continuous-record stream-gaging stations to relate chemical concentrations to streamflow, (2) continuously at a selected station to determine changes in concentration over time, or (3) periodically at ungaged locations to improve the spatial coverage of a study area. These ungaged locations are known as water-quality partial-record stations.

Tidal Crest-Stage Partial-Record Station: Tidal locations where measurements of stage are made using either a crest-stage gage or a water-stage recorder. Discharge is not associated with these measurements. Tidal crest-stage partial-record stations are often operated for use in hydrologic investigations of tidal wetlands, coastal geology and hydrology, and in evaluating coastal storms.

Water Year: The 12-month period beginning October 1 and ending September 30. The water year is determined according to the calendar year in which it ends and includes 9 of the 12 months. The year beginning on October 1, 1995 and ending September 30, 1996, is called “water year 1996.” All references to years of operation for gaging stations in this report are water years.

APPENDIX 2

Conversion factors and vertical datum

Multiply	By	To obtain
foot (ft)	0.3048	meter
square foot (ft^2)	0.0929	square meter
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
square mile (mi^2)	2.590	square kilometer
million gallons per day (Mgal/d)	3785	cubic meters per day

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

Use of trade names in this report does not imply endorsement by the U.S. Geological Survey or the Delaware Geological Survey.

APPENDIX 3

Stream-gaging network inventory

A complete listing of stream-gaging stations operated in Delaware by the U.S. Geological Survey through water year 1997 is presented. This inventory also exists as a World Wide Web document and can be accessed at *http://md.usgs.gov/data/delagage.html*. The World Wide Web document will be updated periodically to reflect future changes to the network.

The inventory includes (1) active and discontinued continuous-record stream-gaging stations, (2) active and discontinued low-flow partial-record stations, (3) active and discontinued tidal crest-stage partial-record stations, (4) discontinued non-tidal crest-stage partial-record stations, and (5) active and discontinued surface-water-quality stations. Included are the stream name and the location of the station, the drainage area (if available), and the period of record in water years.

APPENDIX 3-1. Active Continuous-Record Stream-Gaging Stations in Delaware

	Station number	Drainage area (sq. mi.)	Period of record
DELAWARE RIVER BASIN			
Shellpot Creek at Wilmington, DE	01477800	7.46	1946-present
Christina River at Coochs Bridge, DE	01478000	20.5	1943-present
White Clay Creek at Newark, DE	01478650	69.0	1994-present
White Clay Creek near Newark, DE	01479000	89.1	1932-1936 1943-1957 1960-present
Red Clay Creek at Wooddale, DE	01480000	47.0	1943-present
Red Clay Creek near Stanton, DE	01480015	52.4	1989-present
Brandywine Creek at Wilmington, DE	01481500	314.0	1947-present
Blackbird Creek at Blackbird, DE	01483200	3.85	1957-present
ST. JONES RIVER BASIN			
St. Jones River at Dover, DE	01483700	31.9	1958-present
MURDERKILL RIVER BASIN			
Murderkill River near Felton, DE	01484000	13.6	1931-1934 1960-1985 1997-present
MISPILLION RIVER BASIN			
Beaverdam Branch at Houston, DE	01484100	2.83	1958-present
INDIAN RIVER BASIN			
Stockley Branch at Stockley, DE	01484500	5.24	1943-present
Millsboro Pond Outlet at Millsboro, DE	01484525	66.0	1986-1988 1991-present
NANTICOKE RIVER BASIN			
Nanticoke River near Bridgeville, DE	01487000	75.4	1943-present
Marshyhope Creek near Adamsville, DE	01488500	43.9	1943-1969 1972-present

NOTE: Station 01480025, White Clay Creek at Stanton, is used as a slope gage in conjunction with Station 01480015 above. Stages are monitored at Station 01480025 for computing backwater at Station 01480015.

[sq. mi. = square miles]

APPENDIX 3-2. Discontinued Continuous-Record Stream-Gaging Stations in Delaware

	Station number	Drainage area (sq. mi.)	Period of record
DELAWARE RIVER BASIN			
Christina River near Bear, DE	01478040	40.6	1979-1982
White Clay Creek above Newark, DE	01478500	66.7	1952-1959 1962-1980
Mill Creek at Mill Creek Road at Hockessin, DE	01479197	3.66	1990-1995
Mill Creek at Stanton, DE	01479500	12.4	1931-1934
Little Mill Creek near Newport, DE	01480095	5.24	1991-1995
Little Mill Creek at Elsmere, DE	01480100	6.70	1964-1980
Army Creek at State Road, DE	01482200	2.42	1979-1981
Red Lion Creek near Red Lion, DE	01482298	3.08	1979-1981
Noxontown Lake Outlet near Middletown, DE	01483153	8.85	1993-1994
Drawyer Creek Tributary near Odessa, DE	01483170	4.68	1979-1980
LEIPSIC RIVER BASIN			
Leipsic River near Cheswold, DE	01483500	9.35	1931-1934 1943-1957
ST. JONES RIVER BASIN			
Mudstone Branch at Chestnut Grove, DE	01483670	8.96	1993-1994
BROADKILL RIVER BASIN			
Beaverdam Creek near Milton, DE	01484270	6.10	1971-1980
Sowbridge Branch near Milton, DE	01484300	7.08	1957-1978
INDIAN RIVER BASIN			
Vines Creek at Omar, DE	01484548	13.6	1985-1988
NANTICOKE RIVER BASIN			
Trap Pond Outlet near Laurel, DE	01487500	16.7	1951-1971
Holly Ditch near Laurel, DE	01488000	2.19	1950-1956
Marshyhope Creek at Adamsville, DE	01488600	60.4	1969-1971
CHOPTANK RIVER BASIN			
Culbreth Marsh Ditch near Chapeltown, DE	01490500	11.6	1951-1956

[sq. mi. = square miles]

APPENDIX 3-3. Active and Discontined Low-Flow Partial-Record Stations in Delaware

	Station number	Drainage area (sq. mi.)	Period of record
DELAWARE RIVER BASIN			
South Branch Naaman Creek near Claymont, DE	01477400	3.83	1955-1966 1968-1971
Christina River near Newark, DE	01477850	3.76	1982-1983
West Branch Christina River near Newark, DE	01477860	4.20	1982-1983
Belltown Run near Glasgow, DE	01478009	3.35	1978-1981
Muddy Run at Glasgow, DE	01478024	5.43	1978-1981
Muddy Run near Cooches Bridge, DE	01478028	8.21	1978-1980
White Clay Creek Tributary near Ogletown, DE	01478878	3.68	1978-1980
Mill Creek at Stanton, DE	01479500	12.40	1955-1966 1968-1971
Rocky Run at Talleyville, DE	01481350	1.76	1957-1959 1966
Wilson Run at Guyencort, DE	01481400	1.62	1957-1959
North Fork Wilson Run at Guyencort, DE	01481430	1.12	1957-1959
Wilson Run at Rockland, DE	01481440	3.05	1957-1963
Husbands Run at Rockland, DE	01481460	1.28	1957-1959
Squirrel Run at Montchanin, DE	01481480	1.67	1957-1959
Alapocas Run at Concord, DE	01481530	0.81	1957-1959
Army Creek Tributary at State Road, DE	01482210	0.32	1978-1979
Red Lion Creek near Red Lion, DE	01482298	3.08	1993
Red Lion Creek at Red Lion, DE	01482300	3.20	1955-1960 1962-1971
Doll Run at Red Lion, DE	01482310	1.07	1993
Red Lion Creek Tributary at Red Lion, DE	01482313	1.67	1993
Dragon Creek near Kirkwood, DE	01482397	1.42	1993
Dragon Creek at Kirkwood, DE	01482400	1.93	1978-1981
Dragon Creek Tributary at Kirkwood, DE	01482405	0.16	1978-1981
Joy Run near Summit Bridge, DE	01482670	1.26	1978-1980
Scott Run near Boyds Corner, DE	01482690	2.18	1978-1981
Wiggins Millpond Outlet at Townsend, DE	01483150	3.82	1957-1960 1962-1966 1968-1971 1978-1980
Drawyer Creek near Mt. Pleasant, DE	01483160	1.54	1978-1980
Drawyer Creek Tributary near Armstrong, DE	01483165	1.79	1978-1980
SMYRNA RIVER BASIN			
Providence Creek at Clayton, DE	01483300	11.80	1955-1960 1962-1963 1966 1968-1969
Mill Creek at Smyrna, DE	01483350	4.98	1955-1957 1959-1960 1962-1963 1966 1968-1969

[sq. mi. = square miles]

APPENDIX 3-3. Active and Discontined Low-Flow Partial-Record Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
ST. JONES RIVER BASIN			
Fork Branch near Dover, DE	01483640	5.73	1993
Fork Branch at Dupont, DE	01483650	7.50	1955-1957
			1959-1960
			1962-1966
			1968-1971
Fork Branch near Dover, DE	01483655	9.46	1991, 1993
Penrose Branch Tributary at Casson Corner, DE	01483663	1.04	1993
Mudstone Branch at Casson Corner, DE	01483666	7.48	1993
Mudstone Branch at Chestnut Grove, DE	01483670	8.96	1993
Cahoon Branch near Paden Corner, DE	01483673	2.34	1993
Cahoon Branch at Chestnut Grove, DE	01483676	6.70	1993
Maidstone Branch at Dupont, DE	01483680	17.3	1955-1957
			1959-1960
			1962-1966
			1968-1971
Mudstone Branch at Dupont, DE	01483682	17.4	1993
Silver Lake Tributary at Dover, DE	01483690	0.26	1993
MURDERKILL RIVER BASIN			
Browns Branch near Houston, DE	01484020	12.4	1955-1971
Hudson Branch near Canterbury, DE	01484040	8.40	1955-1960
Pratt Branch near Felton, DE	01484050	3.29	1955-1957
			1959-1960
			1962-1971
Double Run near Magnolia, DE	01484060	5.68	1955-1957
			1959-1960
			1962-1964
			1966-1971
MISPILLION RIVER BASIN			
Cedar Creek near Lincoln, DE	01484200	7.21	1955-1960
			1962-1963
			1966
			1968-1969
BROADKILL RIVER BASIN			
Pemberton Branch near Milton, DE	01484240	6.68	1955-1966
			1968-1971
Beaverdam Creek near Milton, DE	01484270	6.10	1955-1971

[sq. mi. = square miles]

Appendix 3-3. Active and Discontined Low-Flow Partial-Record Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
<u>INDIAN RIVER BASIN</u>			
Sheep Pen Ditch near Shortly, DE	01484510	5.40	1986-1988 1997
Millsboro Pond Outlet at Millsboro, DE	01484525	66.0	1985-1986
Iron Branch at Millsboro, DE	01484530	8.00	1985-1988 1997
Whartons Branch near Millsboro, DE	01484531	5.80	1968-1969 1971 1985-1988
Swan Creek near Warwick, DE	01484535	7.20	1985-1988 1997
Vines Creek at Omar, DE	01484548	13.60	1985
Pepper Creek at Dagsboro, DE	01484550	8.78	1955-1971 1985-1988 1997
Blackwater Creek near Clarksville, DE	01484600	3.50	1968-1969 1971 1985-1988 1997
White Creek at Millville, DE	01484610	1.10	1988
Love Creek at Robinsonville, DE	01484655	12.0	1985-1988 1997
Chapel Branch at Angola, DE	01484677	8.00	1985-1988 1997
Beaver Dam Ditch near Millville, DE	01484695	2.25	1997
<u>DIRICKSON CREEK BASIN</u>			
Bearhole Ditch at Bunting, DE	01484700	6.40	1968-1971 1985-1988 1997
<u>NANTICOKE RIVER BASIN</u>			
Deep Creek at Old Furnace, DE	01487100	33.00	1955-1960 1962-1963 1968
Tyndall Branch near Hardscrabble, DE	01487120	12.30	1955-1963 1966
Butler Mill Branch near Woodland, DE	01487300	6.85	1955-1963 1966 1968-1969
Elliott Pond Branch near Laurel, DE	01487700	8.55	1955-1966 1968-1971
Baron Creek at MD-DE State Corner	01489400	8.93	1950-1953 1969-1970

[sq. mi. = square miles]

Appendix 3-3. Active and Discontined Low-Flow Partial-Record Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
CHOPTANK RIVER BASIN			
Choptank River near Choptank Mills, DE	01490550	58.00	1985-1987
ELK RIVER BASIN			
Back Creek near Mt. Pleasant, DE	01495700	4.40	1968-1969 1978-1980

[sq. mi. = square miles]

APPENDIX 3-4. Active and Discontinued Tidal Crest-Stage Partial-Record Stations in Delaware

	Station number	Period of record
DELAWARE RIVER BASIN		
Christina River at Newport, DE	01480065	1995-present
Delaware River below Christina River at Wilmington, DE	01481602	1983-1991 1995-present
Appoquinimink River at Odessa, DE	01483158	1993-1994
SMYRNA RIVER BASIN		
Duck Creek at Smyrna, DE	01483335	1966-1990
MURDERKILL RIVER BASIN		
Murderkill River at Frederica, DE	01484080	1997-present
Murderkill River at Bowers, DE	01484085	1966-1990 1997-present
CEDAR CREEK BASIN		
Cedar Creek near Slaughter Beach, DE	01484235	1966-1991
INDIAN RIVER BASIN		
Vines Creek near Dagsboro, DE	01484549	1985-present
Indian River at Rosedale Beach, DE	01484540	1992-present
Indian River at Oak Orchard, DE	01484595	1966-1990
Rehobeth Bay at Dewey Beach, DE	01484670	1985-present
Massey Ditch at Massey Landing, DE	01484680	1992-1993
Indian River Bay at Indian River Inlet near Bethany Beach, DE	01484683	1992-present
NANTICOKE RIVER BASIN		
Nanticoke River at Seaford, DE	01487200	1992-1993

NOTE: Station 01483740, St. Jones River at Lebanon, is operated as an auxiliary tidal gaging station to measure high tides during peak flows. The station has been in operation since July, 1987. The data are used for correlation with Station 01483700, St. Jones River at Dover. However, the data are unpublished for the period of record.

APPENDIX 3-5. Discontinued Nontidal Crest-Stage Partial-Record Stations in Delaware

	Station number	Drainage area (sq. mi.)	Period of record
<u>DELAWARE RIVER BASIN</u>			
Christina River near Bear, DE	01478040	40.60	1983-1991
Pike Creek near Newark, DE	01478950	6.04	1969-1975
Mill Creek at Hockessin, DE	01479200	4.19	1966-1975
Red Clay Creek Tributary near Yorklyn, DE	01479950	0.38	1966-1975
Red Clay Creek near Stanton, DE	01480015	52.4	1989
Brandywine Creek Tributary near Centerville, DE	01481200	0.97	1966-1975
Willow Run at Rockland, DE	01481450	0.37	1966-1975
Doll Run at Red Lion, DE	01482310	1.07	1966-1975
<u>SMYRNA RIVER BASIN</u>			
Paw Paw Branch Tributary near Clayton, DE	01483290	1.30	1966-1975
Sawmill Branch Tributary near Blackbird, DE	01483400	0.60	1966-1975
<u>LEIPSIC RIVER BASIN</u>			
Leipsic River near Cheswold, DE	01483500	9.35	1958-1975
<u>ST. JONES RIVER BASIN</u>			
Puncheon Branch at Dover, DE	01483720	2.30	1966-1975
<u>MURDERKILL RIVER BASIN</u>			
Murderkill River Tributary near Felton, DE	01484002	0.97	1966-1975
Pratt Branch near Felton, DE	01484050	3.29	1966-1975
<u>BROADKILL RIVER BASIN</u>			
Beaverdam Creek near Milton, DE	01484270	6.10	1966-1975
<u>INDIAN RIVER BASIN</u>			
Whartons Branch near Millsboro, DE	01484531	5.80	1986-1988
Pepper Creek at Dagsboro, DE	01484550	8.78	1960-1975
Blackwater Creek near Clarksville, DE	01484600	3.50	1986-1988

[sq. mi. = square miles]

Appendix 3-5. Discontinued Nontidal Crest-Stage Partial-Record Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
NANTICOKE RIVER BASIN			
Bridgeville Branch Tributary at Bridgeville, DE	01486900	0.80	1966-1968
Toms Dam Branch near Greenwood, DE	01486980	5.28	1966-1975
Trap Pond Outlet near Laurel, DE	01487500	16.7	1972-1973 1975
Meadow Branch near Delmar, DE	01487900	3.47	1967-1975
Holly Ditch near Laurel, DE	01488000	2.19	1959-1975
CHOPTANK RIVER BASIN			
Tappahanna Ditch near Hartly, DE	01490470	5.93	1961-1973
Beachy Neidig Ditch near Willow Grove, DE	01490490	2.30	1966-1975
Culbreth Marsh Ditch near Chapeltown, DE	01490500	11.60	1957-1968
Meredith Branch near Sandtown, DE	01490600	8.40	1966-1975
Sangston Prong near Whiteleysburg, DE	01491010	1.90	1966-1975

[sq. mi. = square miles]

APPENDIX 3-6. Active and Discontinued Surface-Water-Quality Stations in Delaware

[(C) = chemical data, (B) = biological data, (T) = water temperature, (S) =sediment data, — = unknown drainage area, * = stations where no measured discharges are associated with the collected water-quality data, sq. mi. = square miles]

	Station number	Drainage area (sq. mi.)	Period of record
DELAWARE RIVER BASIN			
South Branch Naaman Creek near Claymount, DE (C)	01477400	3.83	1966
			1968
			1970-1971
Shellpot Creek at Wilmington, DE (C)	01477800	7.46	1955-1956
			1964
			1974-1978
Christina River near Newark, DE (C)	01477850	3.76	1982-1983
West Branch Christina River near Newark, DE (C)	01477860	4.20	1982-1983
Christina River at Hunting Hills, Newark, DE (C, B)	01477875	—	1975-1981
Christina River at Rolling Green, Newark, DE (C, B)	01477960	—	1975-1981
Christina River at Coochs Bridge, DE (C)	01478000	20.50	1955-1956
			1964
			1974-1978
Christina River at Christiana, DE (C)	01478050	—	1976-1978
White Clay Creek above Newark, DE (C)	01478500	66.70	1955
			1974-1981
White Clay Creek above Newark, DE (B)	01478500	66.70	1976-1981
White Clay Creek above Newark, DE (S)	01478500	66.70	1965-1980
White Clay Creek at Newark, DE (C)	01478650	69.00	1955
White Clay Creek below Newark, DE (C)	01478700	—	1975-1981
White Clay Creek below Newark, DE (B)	01478700	—	1975-1976
			1978-1981
White Clay Creek Tributary near Newark, DE (C)	01478880	—	1974-1980
White Clay Creek near Newark, DE (C)	01479000	89.10	1955-1956
			1967-1968
			1974-1981
White Clay Creek near Newark, DE (B)	01479000	89.10	1976-1981
Mill Creek at Mill Creek Road at Hockessin, DE (C)	01479197	3.66	1991
Mill Creek at Stanton, DE (C)	01479500	12.40	1956
			1966
			1968
			1970-1971
Red Clay Creek at Ashland, DE (C)	01479955	—	1975-1981
Red Clay Creek at Ashland, DE (B)	01479955	—	1975-1976
			1978-1981
Red Clay Creek at Wooddale, DE (C)	01480000	47.00	1955-1956
Red Clay Creek at Wooddale, DE (T)	01480000	47.00	1953-1981
Red Clay Creek at Stanton, DE (C)	01480019	—	1975-1981
Red Clay Creek at Stanton, DE (B)	01480019	—	1975-1976
			1978-1981

Appendix 3-6. Active and Discontinued Surface-Water-Quality Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
<u>DELAWARE RIVER BASIN</u> (continued)			
Little Mill Creek at Elsmere, DE (C)	01480100	6.70	1974-1978
Brandywine Creek at Smith Bridge, DE (C)	01481280	—	1975-1979
			1981
Brandywine Creek at Smith Bridge, DE (B)	01481280	—	1975-1976
			1978-1981
Brandywine Creek at Hagley Museum, Wilmington, DE (C)	01481490	—	1975-1981
Brandywine Creek at Hagley Museum, Wilmington, DE (B)	01481490	—	1975-1976
			1978-1981
Brandywine Creek at Wilmington, DE (C)	01481500	314.00	1955
			1962
Brandywine Creek at Wilmington, DE (T)	01481500	314.00	1957-1961
			1971-1973
			1975-1980
Brandywine Creek at Wilmington, DE (S)	01481500	314.00	1947-1980
Brandywine Creek below Alapocas Run, at Wilmington, DE (C)	01481550	—	1975-1981
Brandywine Creek below Alapocus Run, at Wilmington, DE (B)	01481550	—	1975-1976
			1978-1981
*Delaware River at Delaware Memorial Bridge, near Wilmington, DE (T)	01482100	11030.00	1957-1981
*Delaware River at Delaware Memorial Bridge, near Wilmington, DE (C)	01482100	11030.00	1955-1956
		1963-1981	
Red Lion Creek near Red Lion, DE (C)	01482298	3.08	1991
Red Lion Creek at Red Lion, DE (C)	01482300	3.20	1956
			1966-1968
			1971
Doll Run at Red Lion, DE (C)	01482310	1.23	1974
			1976-1980
*Delaware River at Reedy Island Jetty, DE (C)	01482800	11222.0	1964-1988
*Delaware River at Reedy Island Jetty, DE (T)	01482800	11222.0	1970-1988
Wiggins Millpond Outlet at Townsend, DE (C)	01483150	3.82	1965-1966
			1968
			1971
Wiggins Millpond Outlet near Townsend, DE (C)	01483151	—	1991
Drawyer Creek Tributary near Odessa, DE (C)	01483170	4.68	1974
			1976-1980
Blackbird Creek at Blackbird, DE (C)	01483200	3.85	1956
			1958
			1961
			1964
			1974-1978

Appendix 3-6. Active and Discontinued Surface-Water-Quality Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
SMYRNA RIVER BASIN			
Providence Creek at Clayton, DE (C)	01483300	11.80	1956 1991
Mill Creek near Smyrna, DE (C)	01483348	—	1974 1976-1980
LEIPSIC RIVER BASIN			
Leipsic River near Cheswold, DE (C)	01483500	9.35	1959 1962 1974 1976-1980
ST. JONES RIVER BASIN			
Fork Branch at Dupont, DE (C)	01483650	7.50	1965-1966 1968 1970-1971
Fork Branch near Dover, DE (C)	01483655	9.46	1991
Cahoon Branch at Dover, DE (C)	01483675	—	1974 1976-1980
Maidstone Branch at Dupont, DE (C)	01483680	17.3	1965-1966 1968 1970-1971
St. Jones River at Dover, DE (C)	01483700	31.9	1964-1972 1974-1980 1991
Puncheon Branch at Dover, DE (C)	01483720	2.30	1991
MURDERKILL RIVER BASIN			
Murderkill River near Felton, DE (C)	01484000	13.60	1964 1974-1978
Browns Branch near Houston, DE (C)	01484020	12.40	1965-1968 1970-1971
Pratt Branch near Felton, DE (C)	01484050	3.29	1965-1968 1970-1971 1974 1976-1980 1991-1992
Double Run near Magnolia, DE (C)	01484060	5.68	1966-1968 1970-1971

Appendix 3-6. Active and Discontinued Surface-Water-Quality Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
MISPILLION RIVER BASIN			
Beaverdam Branch at Houston, DE (C)	01484100	2.83	1973-1978 1991-1992
Presbyterian Branch at Milford, DE (C)	01484145	—	1974
BROADKILL RIVER BASIN			
Pemberton Branch near Milton, DE (C)	01484240	6.68	1965-1966 1968 1970-1971
Beaverdam Creek near Milton, DE (C)	01484270	6.10	1965-1966 1968 1970 1974-1980
Sowbridge Branch near Milton, DE (C)	01484300	7.08	1958 1974-1978
DELAWARE BAY			
*Delaware Bay near Lewes, DE (C, T)	01484450	—	1993-present
INDIAN RIVER BASIN			
Stockley Branch at Stockley, DE (C)	01484500	5.24	1974-1978 1997
Sheep Pen Ditch near Shortly, DE (C)	01484510	5.40	1997
Iron Branch at Millsboro, DE (C)	01484530	8.00	1997
Swan Creek near Warwick, DE (C)	01484535	7.20	1997
Vines Creek at Omar, DE (C)	01484548	13.6	1991
Pepper Creek at Dagsboro, DE (C)	01484550	8.78	1965-1966 1968 1970-1971 1991-1992 1997
Blackwater Creek near Clarksville, DE (C)	01484600	3.5	1997
Love Creek at Robinsonville, DE (C)	01484655	12.0	1997
Chapel Branch at Angola, DE (C)	01484677	8.0	1997
Beaver Dam Ditch near Millville, DE (C)	01484695	2.25	1997
DIRICKSON CREEK BASIN			
Bearhole Ditch at Bunting, DE (C)	01484700	6.4	1997

Appendix 3-6. Active and Discontinued Surface-Water-Quality Stations in Delaware (continued)

	Station number	Drainage area (sq. mi.)	Period of record
NANTICOKE RIVER BASIN			
Toms Dam Branch near Greenwood, DE (C)	01486980	5.28	1991
Nanticoke River near Bridgeville, DE (C)	01487000	75.4	1961-1972 1974-1980 1991 1994-1995
Elliott Pond Branch near Laurel, DE (C)	01487700	8.55	1965-1966 1968 1970-1971
Marshyhope Creek near Adamsville, DE (C)	01488500	43.9	1974-1980 1991
CHOPTANK RIVER BASIN			
Meredith Branch near Sandtown, DE (C)	01490600	8.40	1974 1976-1980 1991-1992
Sangston Prong near Whiteleysburg, DE (C)	01491010	1.90	1991-1992
CHESTER RIVER BASIN			
Cypress Branch near Vandyke, DE (C)	01492960	—	1991-1992

NOTE: Drainage areas are provided where available. Records for Pemberton Branch near Milton during 1965-66 are listed under Station 01484370 in respective water-resources data reports. Records for Beaverdam Creek near Milton during 1965 are listed under Station 01484400 in the annual water-resources data report. No stations exist in USGS data bases under these station numbers.

APPENDIX 3-7. Miscellaneous Surface-Water-Quality Stations in Delaware, Chemical Analyses by Year (Latitude and Longitude Station Numbers)

	Station number	Period of record
HERRING CREEK BASIN		
Phillips Branch at Fairmount, DE	383924075125501	1986-1987
Phillips Branch at Fairmount, DE	383917075130701	1995
Phillips Branch near Fairmount, DE	383930075123101	1986-1987
		1989
		1995
ST. JONES RIVER BASIN		
Isaac Branch near Wyoming, DE	390715075364401	1995
Allabands Mill Stream near Wyoming, DE	390652075361801	1995
Isaac Branch at Wyoming, DE	390724075352101	1995
NANTICOKE RIVER BASIN		
Gravelly Ditch near Redden, DE	384429075235301	1993
Gravelly Ditch at Redden, DE	384502075242401	1993
Gravelly Ditch Tributary at Redden, DE	384443075234101	1993
Gravelly Branch Tributary Drainage Ditch near Ellendale, DE	384608075245201	1995
Gravelly Branch Tributary near Ellendale, DE	384528075245701	1995
Bucks Branch near Atlanta, DE	384129075380601	1995
CHESTER RIVER BASIN		
Cypress Branch near Clayton, DE	391815075433801	1995
Bucks Branch at Atlanta, DE	384203075395601	1995
Ephemeral Pond 1 near Vandyke, DE	392046075443401	1987
Ephemeral Pond 1 near Vandyke, DE	392047075443401	1988
Ephemeral Pond 2 near Vandyke, DE	392102075443801	1987
Ephemeral Pond 2 near Vandyke, DE	392059075443801	1988
Ephemeral Pond 3 near Vandyke, DE	392044075443201	1988
Ephemeral Pond 6A near Vandyke, DE	392045075443301	1988
Ephemeral Pond 7 near Vandyke, DE	392053075443401	1988
Ephemeral Pond 8 near Vandyke, DE	392048075444101	1988
Ephemeral Pond 9 near Vandyke, DE	392126075440901	1989
Interstitial Water From Peat near Vandyke, DE	392045075443302	1988
Cypress Branch Tributary near Vandyke, DE	392032075442401	1988
Cypress Branch Tributary at Vandyke, DE	392117075441801	1989

NOTE: These stations were assigned station numbers according to their latitude and longitude. All data collected at these stations are chemical data unless otherwise noted. No measured discharges are associated with these chemical analyses.

APPENDIX 3-8. Miscellaneous Surface-Water-Quality Stations in Delaware, Chemical Analyses by Year

	Station number	Period of record
DELAWARE RIVER BASIN		
Mill Creek Tributary at Hockessin, DE	01479175	1991
Mill Creek at Mill Creek, DE	01479189	1991
Mill Creek at Evanson Road at Hockessin, DE	01479191	1991
Mill Creek Tributary near Hockessin, DE	01479193	1991
Tributary to Mill Creek Tributary at Hockessin, DE	01479195	1991
SMYRNA RIVER BASIN		
Providence Creek at Smyrna, DE	01483320	1970 1972 1974-1989
LEIPSIC RIVER BASIN		
Pinks Branch at Kenton, DE	01483495	1977-1978 1980-1989
MURDERKILL RIVER BASIN		
Browns Branch near Milford, DE	01484023	1977-1990
MISPILLION RIVER BASIN		
Tantrough Branch at Milford, DE	01484125	1974
Lednum Branch at Milford, DE	01484134	1974
Copper Branch at Milford, DE	01484137	1974
Bowman Branch at Milford, DE	01484142	1974
Haven Lake Outlet at Milford, DE	01484143	1974
Silver Lake at Milford, DE	01484146	1974
North Silver Lake Outlet at Milford, DE	01484147	1974
South Silver Lake Outlet at Milford, DE	01484149	1974
Mispillion River at Milford, DE	01484153	1970 1973-1990
DIRICKSON CREEK BASIN		
Buntings Branch near Selbyville, DE	01484710	1970-1989
NANTICOKE RIVER BASIN		
Nanticoke River at Middleford, DE	01487030	1970-1990
Broad Creek at Laurel, DE	01487450	1970 1973-1990
CHESTER RIVER BASIN		
Cypress Branch at Delaney Corner, DE	01492970	1983-1989

NOTE: All data collected at these stations are chemical data unless otherwise noted. No measured discharges are associated with these chemical analyses.

APPENDIX 3-9. Miscellaneous Surface-Water-Quality Stations in Delaware,
Chemical Analyses by Year
(Station Numbers or Locations Unknown)

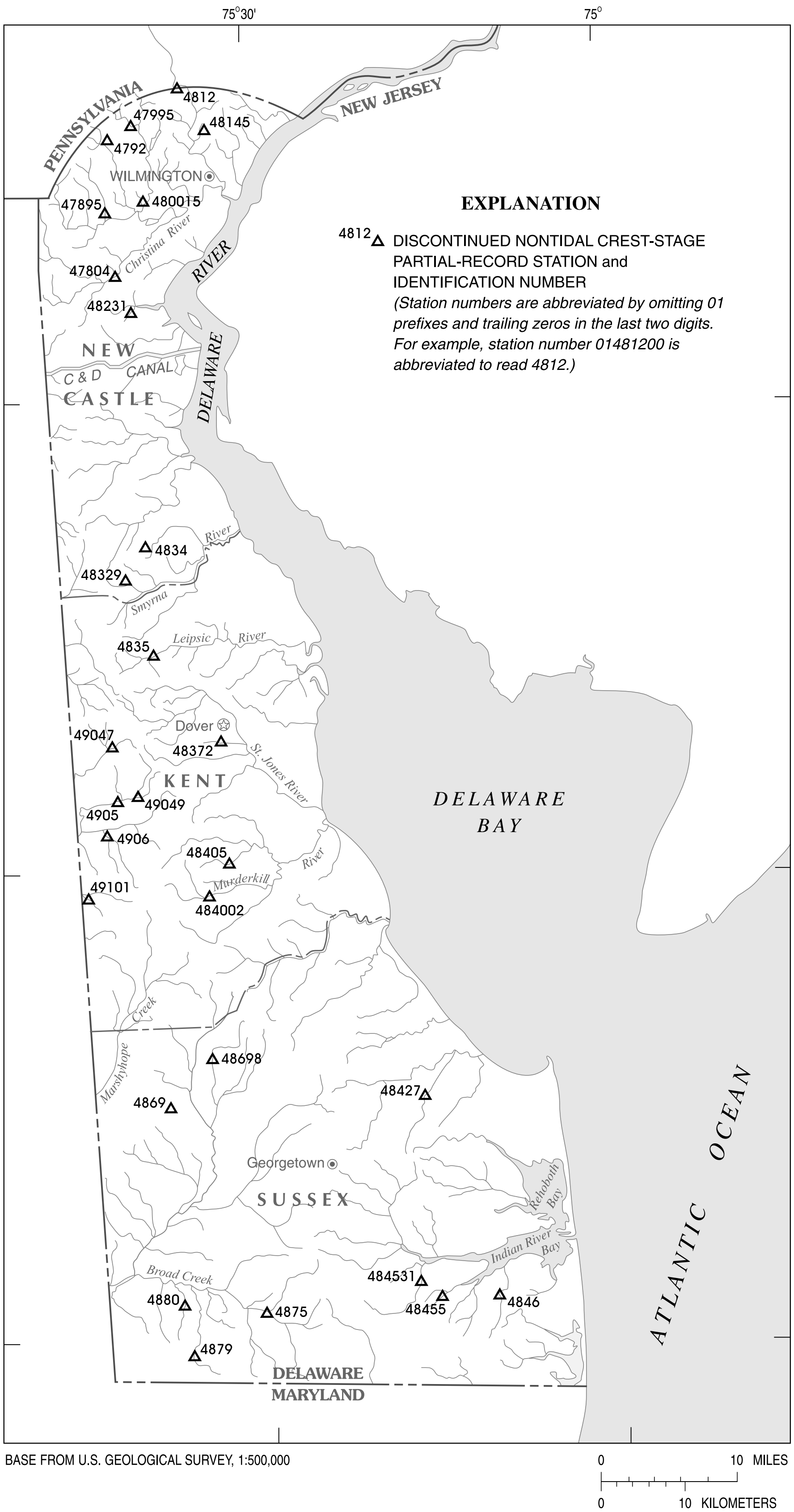
	Station number	Period of record
DELAWARE RIVER BASIN		
South Branch Naaman Creek at Arden, DE	Unknown	1956
Red Clay Creek near Marshallton, DE	Unknown	1956
Red Clay Creek at Marshallton, DE	Unknown	1955-1956
Red Clay Creek near Wooddale, DE	Unknown	1955
Brandywine Creek at New Castle, DE	Unknown	1955
Delaware River at Reedy Point, DE	01482700	1962

APPENDIX 4

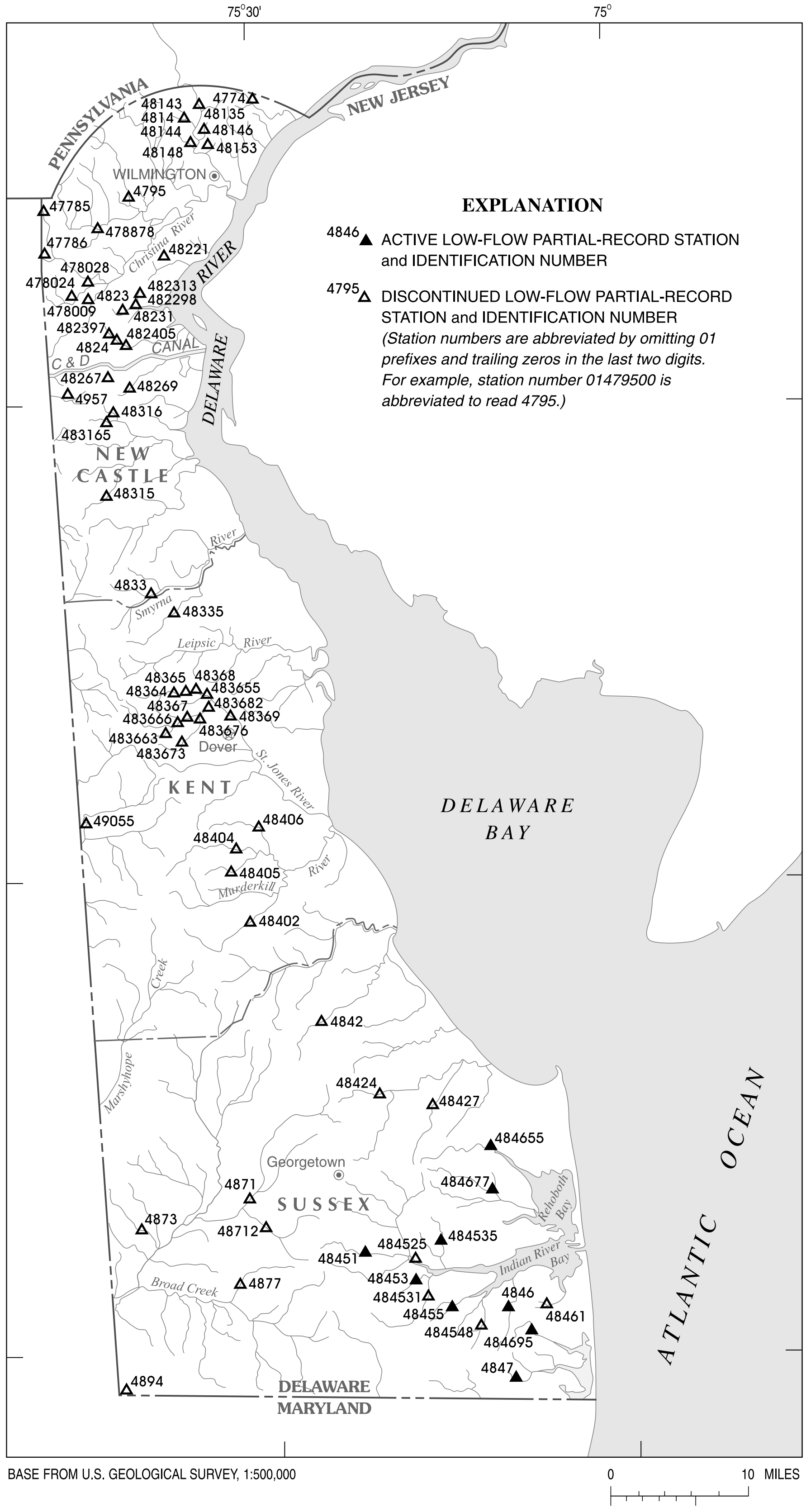
Maps showing locations of selected stream-gaging stations in Delaware.

Appendices 4-1 through 4-4 show the locations of (1) active and discontinued low-flow partial-record stations, (2) discontinued nontidal crest-stage partial-record stations, (3) active and discontinued tidal crest-stage partial-record stations, and (4) active and discontinued surface-water-quality stations, in various groupings of gage type. Stations listed as miscellaneous are not included.

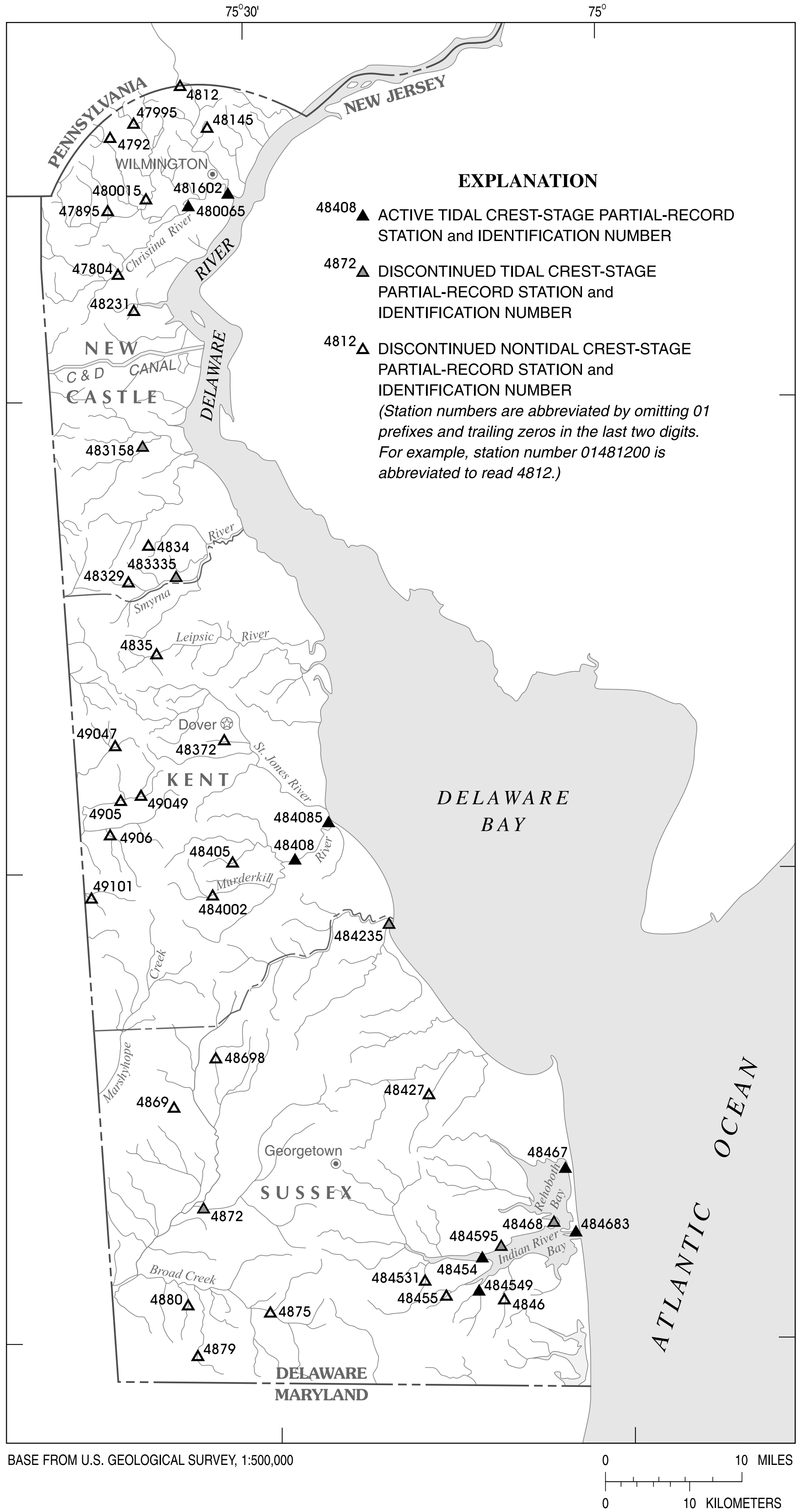
APPENDIX 4-1. Discontinued nontidal crest-stage partial-record stations in Delaware



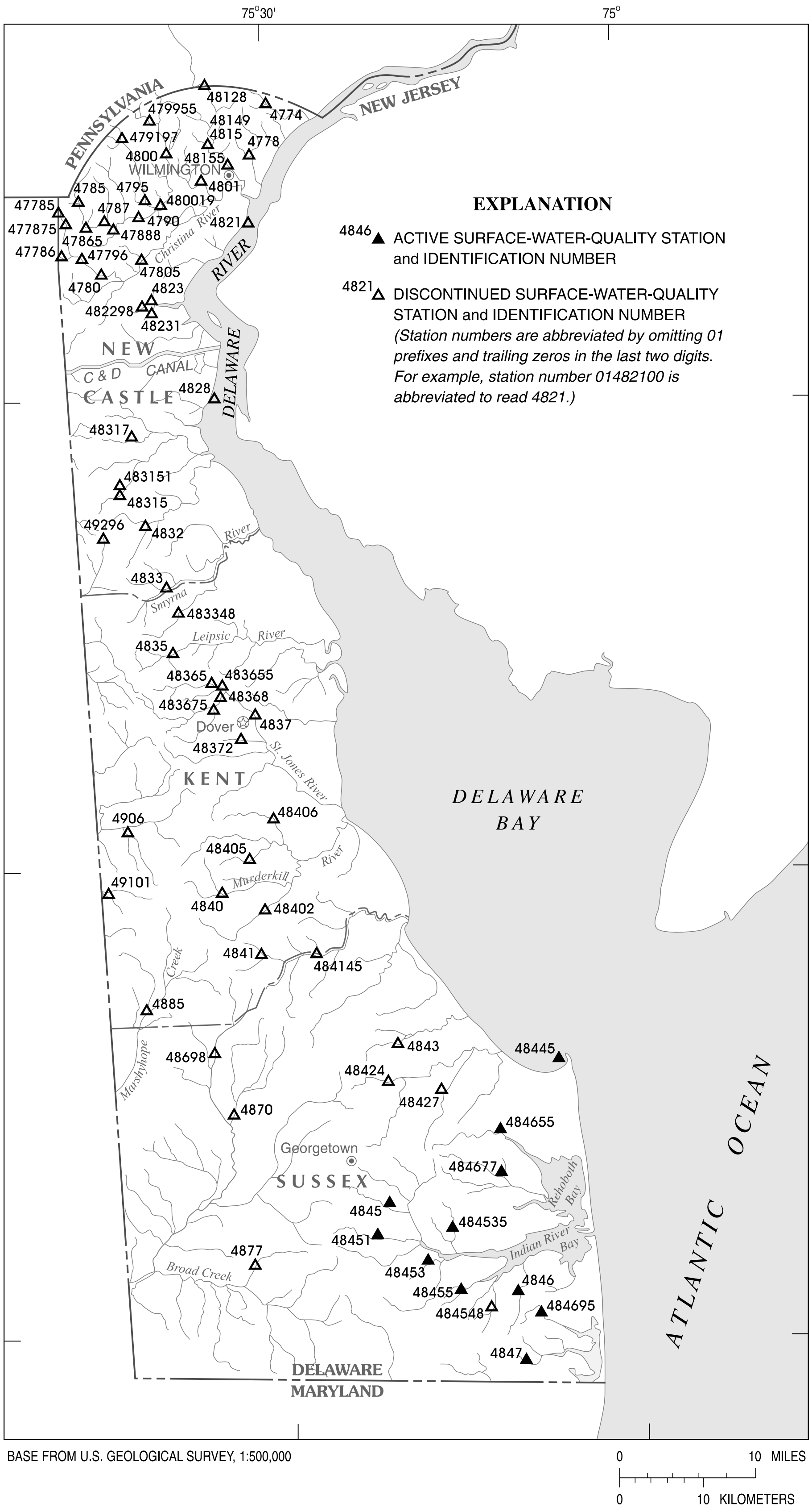
APPENDIX 4-2. Active and discontinued low-flow partial-record stations in Delaware



APPENDIX 4-3. Active and discontinued tidal crest-stage partial-record stations and discontinued nontidal partial-record stations in Delaware



APPENDIX 4-4. Active and discontinued surface-water-quality stations in Delaware



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