LOW-FLOW CHARACTERISTICS OF STREAMS IN VIRGINIA

U.S. GEOLOGICAL SURVEY

Open-File Report 89-586

Prepared in cooperation with the

VIRGINIA WATER CONTROL BOARD

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By Donald C. Hayes

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Richmond, Virginia

1990

DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
	Length	
inches (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3)	0.02832	cubic meter per second (m^3)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3)/km^3$]

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

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ABSTRACT

Streamflow data were collected and low-flow characteristics computed for 715 gaged sites in Virginia. Annual minimum average 7-consecutive-day flows range from 0 to 2,190 cubic feet per second, having a 2-year recurrence interval and from 0 to 1,420 cubic feet per second for a 10-year recurrence interval. Drainage areas range from 0.17 to 7,320 square miles. Existing and discontinued gaged sites are separated into three types: Long-term continuous-record sites, short-term continuous-record sites, and partial-record sites. Low-flow characteristics for long-term continuous-record sites are determined from frequency curves of annual minimum average 7-consecutive-day flows. Low-flow characteristics for short-term continuous-record sites are estimated by relating daily mean base-flow discharge values at a short-term site to concurrent daily mean discharge values at nearby, long-term continuous-record sites with similar basin characteristics. Low-flow characteristics for partial-record sites are estimated by relating base-flow measurements to daily mean discharge values at long-term continuous-record sites.

Information from the continuous-record sites and partial-record sites in Virginia are used to develop two techniques for estimating low-flow characteristics at ungaged sites. A flow-routing method is developed to estimate low-flow values at ungaged sites on gaged streams. Regional regression equations are developed for estimating low-flow values at ungaged sites on ungaged streams.

The flow-routing method consists of transferring low-flow characteristics from a gaged site, either upstream or downstream to a desired ungaged site. A simple drainage-area proration is used to transfer values when there are no major tributaries between the gaged and ungaged site. Standard errors of the estimate for 108 test sites are 19 percent of the mean for estimates of low-flow characteristics having a 2-year recurrence interval and 52 percent of the mean for estimates of low-flow characteristics having a 10-year recurrence interval. A more complex transfer method must be used when major tributaries enter the stream between the gaged and ungaged site. Twenty four stream-networks are analyzed with predictions made at 84 sites. Standard errors of estimate are 15 percent of the mean for estimates of low-flow characteristics having a 2-year recurrence interval and 22 percent of the mean for estimates of low-flow characteristics having a 10-year recurrence interval.

Regional regression equations were developed for estimating low-flow values at ungaged sites on ungaged streams. The State was divided into eight regions on the basis of physiography and geographic grouping of residuals computed in regression analyses. Basin characteristics that were significant in the regression analysis were drainage area, rock type, and strip-mined area. Standard errors of prediction range from 60 to 139 percent for estimates of low-flow characteristics having a 2-year recurrence interval, and 90 to 172 percent for estimates of low-flow characteristics having a 10-year recurrence interval.

INTRODUCTION

Understanding hydrologic characteristics of streams during low-flow periods is essential to the development and management of our water resources. Planning of water-supply, water-control, and water-quality programs begins with the analysis of flow availability and variability. Low-flow characteristics that result from such an analysis commonly are the basis for water-quality standards and minimum-flow rates for regulated streams. This report is the result of a cooperative program between the Geological Survey and the Virginia Water Control Board. Data were collected by the Geological Survey and the Virginia Water Control Board.

Purpose and Scope

This report presents low-flow characteristics for gaged sites on streams in Virginia and techniques to estimate low-flow characteristics at both gaged and ungaged sites. Low-flow characteristics are presented for 254 continuous-record sites and 461 partial-record sites. Information from the gaged sites is used to develop two techniques for estimating low-flow characteristics at ungaged sites.

Approach

Records from the U.S. Geological Survey and Virginia Water Control Board were reviewed for current and discontinued continuous-record sites and base-flow discharge measurements made at partial-record sites. A continuous-record site is a location on a stream where gage height is recorded continually, and for which daily mean discharge is computed. A partial-record site is a location on a stream where limited hydrologic data are collected, such as discharge measurements.

Continuous-record sites were analyzed to determine the degree of streamflow regulation and periods of unregulated flow. Partial-record sites were analyzed to determine the degree of streamflow regulation and the number of base-flow discharge measurements available. Analysis of the location and extent of unregulated flow at continuous-record sites and partial-record sites was performed. Areal coverage was completed by selection of additional partial-record sites.

Low-flow characteristics for long-term continuous-record sites (10 or more years of unregulated discharge record collected) are determined from frequency curves of annual minimum average 7-consecutive-day flows. Frequency curves are fitted to the logarithms of the data by use of the Pearson Type III distribution. Graphs of the plotted points are checked visually for accuracy of fit. Low-flow characteristics for the 2-year and 10-year recurrence intervals are selected from the frequency curves. Low-flow characteristics for short-term continuous-record sites (fewer than 10 years of unregulated discharge record collected) are estimated by relating daily mean base-flow discharge values at the short-term site to concurrent daily mean discharge values at nearby, long-term continuous-record sites with similar basin characteristics. Low-flow characteristics for partial-record sites are estimated by relating base-flow discharge measurements to daily mean discharge values at long-term continuous-record sites. Low-flow characteristics from the long-term station are transferred through the relation line to determine the low-flow characteristic at at the short-term or partial-record site.

Two techniques are developed for estimating low-flow characteristics at ungaged sites. A flow-routing method is developed to estimate low-flow values at ungaged sites on gaged streams. Regional regression equations are developed for estimating low-flow values at ungaged sites on ungaged streams.

The flow-routing method consists of transferring low-flow characteristics from a gaged site, either upstream or downstream to a desired ungaged site. A simple drainage-area proration is used to transfer values when there are no major tributaries between the gaged and ungaged site. A more complex transfer method, weighing the drainage area of each tributary, is used when major tributaries enter the stream between the gaged and ungaged site. Twenty four stream-networks are analyzed with predictions made at 84 sites.

Regional regression equations are developed for estimating low-flow values at ungaged sites on ungaged streams. This method divides the State into eight regions on the basis of physiography and geographic grouping of residuals computed in regression analyses. Separate equations were developed for each region by testing basin characteristics. Basin characteristics that remain significant in the regression analysis are drainage area, rock type, and strip-mined area.

Previous Studies

Several previous investigators have collected low-flow data on streams in Virginia, or analyzed low-flow characteristics of streams in Virginia. The most comprehensive study is by Nuckels (1970), which analyzes long-term continuous-record stations throughout Virginia. Most of the other investigations are only concerned with small portions of the State. Reports that contain data specific to Virginia and from which data are taken directly are Mohler and Hagan (1981), Smith (1981), Lynch (1987), and Lynch and others (1987). Other reports that present analysis of low-flow characteristics for parts of Virginia are Cushing and others (1973), Trainer and Watkins (1975), and Wetzel and Bettandorff (1986). Information in these reports was instrumental in locating discontinued sites and analyzing basin characteristics that affect low flows.

PHYSICAL SETTING

Location

Virginia is centrally located on the Atlantic Coast, bordered to the north by Maryland and West Virginia, to the south by North Carolina and Tennessee, and to the west by Kentucky and West Virginia (fig. 1). The total area of Virginia is approximately 41,000 square miles, which includes almost 1,000 square miles of lakes, tidal rivers, and bays. There are over 3,000 miles of non-tidal rivers and 5,000 miles of shoreline along the Atlantic Coast and Chesapeake Bay (Sevebeck and others, undated).

Physiography

Virginia lies within five physiographic provinces (fig. 1). The provinces are, from east to west, the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateaus. Each province is characterized by distinctive geologic features and landforms that cause substantial differences in the basin characteristics. Geology ranges from unconsolidated sands and clays in the Coastal Plain province, to igneous and metamorphic rocks in the Piedmont and Blue Ridge provinces, and to sedimentary rocks (carbonate rocks, sandstone, and shale) in the Valley and Ridge and Appalachian Plateaus provinces. Topography in the State is diverse, ranging from virtually flat in the Coastal Plain, to greater relief and rugged terrain along the Blue Ridge and Appalachian crests. The central Piedmont is characterized by rolling hills and valleys, and is separated from the ridges and valleys of the Valley and Ridge province by the Blue Ridge Mountains. Land-surface elevations range from sea level along the coast of the Coastal Plain province to more than 5,000 feet above sea level in the mountains of the Blue Ridge province (U.S. Geological Survey, 1985).

Coastal Plain Physiographic Province

The Coastal Plain physiographic province generally consists of unconsolidated, gently sloping layers of sand and gravel separated by layers of clay and marl. The eastern boundary of the Coastal Plain province is the Atlantic Ocean. The western boundary is the Fall Line, where the resistant rock of the Piedmont forms a contact with the weaker sediments of the Coastal Plain (Fenneman, 1938). Sediments are thin at the Fall Line and thicken to as much as 6,000 feet at the eastern edge of the Coastal Plain (U.S. Geological Survey, 1985). Rivers and streams are affected by tides over a substantial area. Base flows are moderate (average 7-consecutive-day low-flow discharge having a 2-year recurrence interval approximates 0.1 cubic feet per second per square mile). However, upper soils drain fairly well and tend to increase base-flow recession.

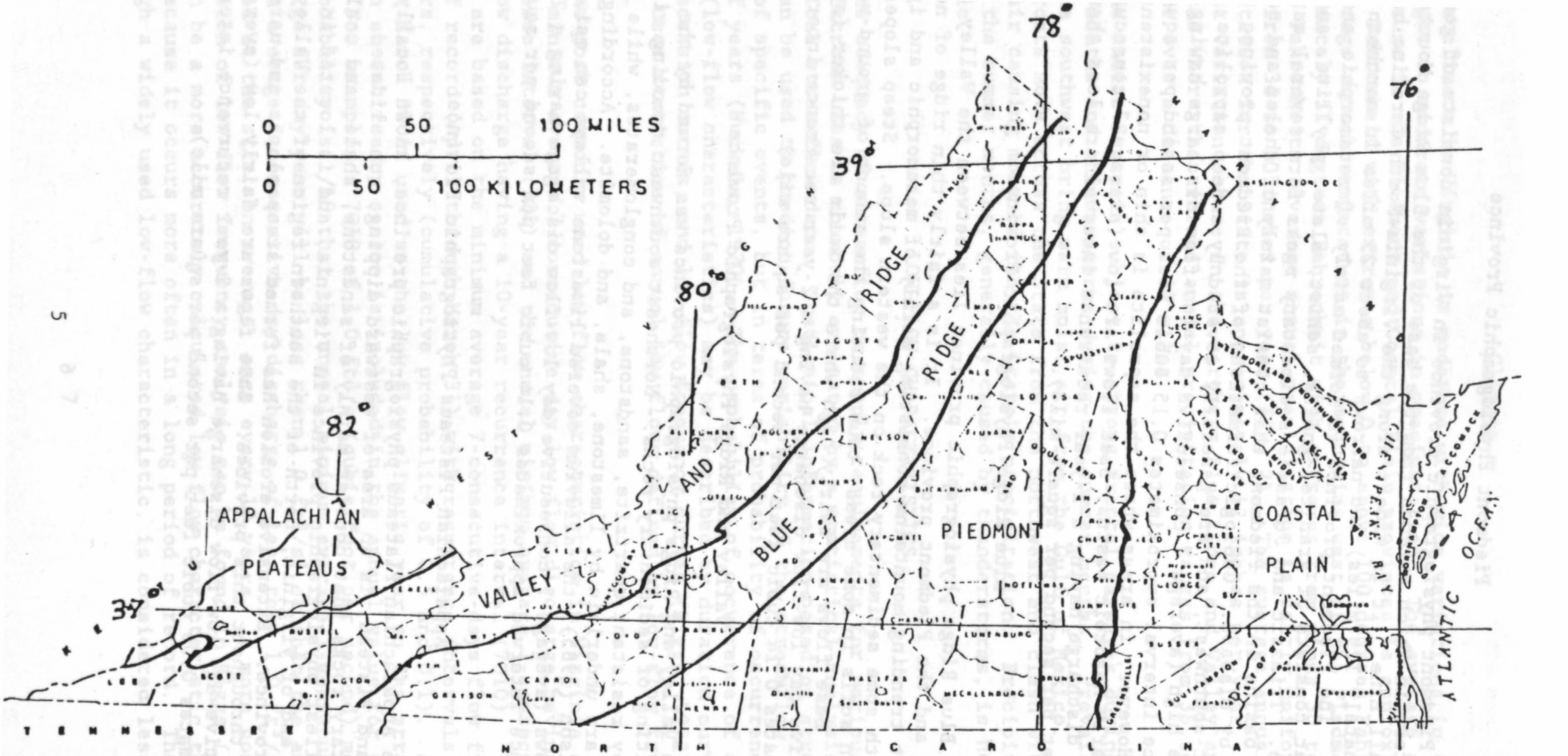

Figure 1.--Physiographic provinces of Virginia (modified from Fenneman, 1938, pl. II).

Piedmont Physiographic Province

The Piedmont physiographic province in Virginia consists of gently rolling terrain which extends from the base of the Blue Ridge Mountains east to the Fall Line. It is widest along the Virginia-North Carolina border (approximately 125 miles) and narrows to about 25 miles in northern Virginia. The Piedmont province is formed mainly of metamorphic and igneous rocks that consists of granite, gneiss, schist, slate, phyllite, and quartzite. Triassic and Jurassic sedimentary rocks form several early Mesozoic basins in the Piedmont that consist mainly of shales and sandstones intruded by diabase. Geologic formations of the Piedmont province trend northeast-southwest, and are generally covered by a deep saprolite. Base flows are high (average 7-consecutive-day low-flow discharge having a 2-year recurrence interval approximates 0.15 cubic feet per second per square mile). However, in areas where the saprolite is thin or nonexistent, such as the early Mesozoic basins, base flows are low (average 7-consecutive-day low-flow discharge having a 2-year recurrence interval are less than 0.01 cubic feet per second per square mile).

Blue Ridge Physiographic Province

The Blue Ridge physiographic province lies between the Valley and Ridge province and the Piedmont province. It is a fairly thin ridge of northeast-southwest trending mountains consisting mainly of metamorphic and igneous rocks with some sedimentary rock on the western slope. Steep slopes allow only thin soils in some areas, thus reducing the amount of ground-water storage. Base flows are fairly high where the soils are thicker (average 7-consecutive-day low-flow discharge having a 2-year recurrence interval approximates 0.14 cubic feet per second per square mile).

Valley and Ridge Physiographic Province

The Valley and Ridge physiographic province was formed by the folding and faulting of sedimentary rocks. Northeast-southwest trending ridges are formed by resistant quartzite, sandstone, and conglomerates, while narrow valleys are underlain by limestone, shale, and dolomite. According to Smith and Ellison (1985), the alluvium-covered limestone valleys can maintain high base flows (average 7-consecutive-day low-flow discharge having a 2-year recurrence interval approximates 0.14 cubic feet per second per square mile).

Appalachian Plateaus Physiographic Province

The Appalachian Plateaus physiographic province, known locally as the Cumberland Plateau, is an area of westward dipping, consolidated, sedimentary rocks that consist mainly of sandstone, shale, and coal. It is the smallest physiographic province in Virginia, and is located in the western end of Virginia, north of the southern region of the Valley and Ridge province. Extensive erosion has formed steep slopes and narrow valleys throughout this province. Base flows are fairly low (average 7-consecutive-day low-flow discharge having a 2-year recurrence interval approximates 0.06 cubic feet per second per square mile).

Climate

The climate in Virginia is moderate with wide variations in temperature and slight to moderate variations in precipitation. The average annual temperature in the Piedmont and Coastal Plain provinces is approximately 57 degrees Fahrenheit with extremes below 0 to above 100 degrees Fahrenheit. The average annual temperature in the mountains west of the Piedmont is approximately 51 degrees Fahrenheit with extremes from minus 30 to above 100 degrees Fahrenheit. Average annual precipitation is fairly uniform and ranges from 36 to 50 inches per year (fig. 2). The average annual precipitation for the State is approximately 42 inches per year. The greatest variation occurs in the northern Blue Ridge and Valley and Ridge provinces where the average annual precipitation ranges from 36 to 48 inches per year over a distance of 50 miles.

The entire State is subject to strong frontal passages during the winter months and thunderstorms during the summer months. Prevailing winds from the southwest bring warm moist air from the Gulf of Mexico. Strong cold fronts move across the State from the northwest and clash with the warm moist air causing most of the the State's precipitation. Precipitation during the summer months, generally caused by thunderstorms, is heavy, but sporadic.

LOW-FLOW CHARACTERISTICS

The adequacy of streamflow to supply requirements for various instream and offstream uses is commonly evaluated by a statistical analysis of historical streamflow data. Statistical information based on streamflow data can be used to predict future variability of the streamflow, not in terms of specific events, but in terms of probability of occurrence over a span of years (Nuckels, 1970). The probability of occurrence of annual low flows (low-flow characteristics) may be described by duration curves, base-flow recession curves, and low-flow frequency curves (Riggs, 1972). This report uses statistics of annual low flows defined by low-flow frequency curves.

The most commonly used low-flow characteristics in Virginia are the annual minimum average 7-consecutive-day low-flow discharge having a 2-year recurrence interval (7Q2) and the annual minimum average 7-consecutive-day low-flow discharge having a 10-year recurrence interval (7Q10). These values are based on the minimum average 7-consecutive-days flow from each year of record (April through March 31) with recurrence intervals of 2 and 10 years, respectively (cumulative probability of 0.5 and 0.1). April 1 through March 31 is used as the low-flow climatic year so the streamflow through an entire dry season is included in the annual value for only one year. For example, a 7Q10 of 1.0 ft^3/s (cubic foot per second) means that the probability is 1/10 that the annual minimum average 7-consecutive-day discharge for any year will be less than 1.0 ft^3/s; or that the annual minimum average 7-consecutive-day discharge of less than 1.0 ft^3/s should be expected at the site, on average, once every 10 years. A more complete discussion of low-flow frequency analysis can be found in Riggs (1972). The 7Q2 can be a more accurately calculated low-flow characteristic than the 7Q10 because it occurs more often in a long period of record. The 7Q10, although a widely used low-flow characteristic, is considered less accurate

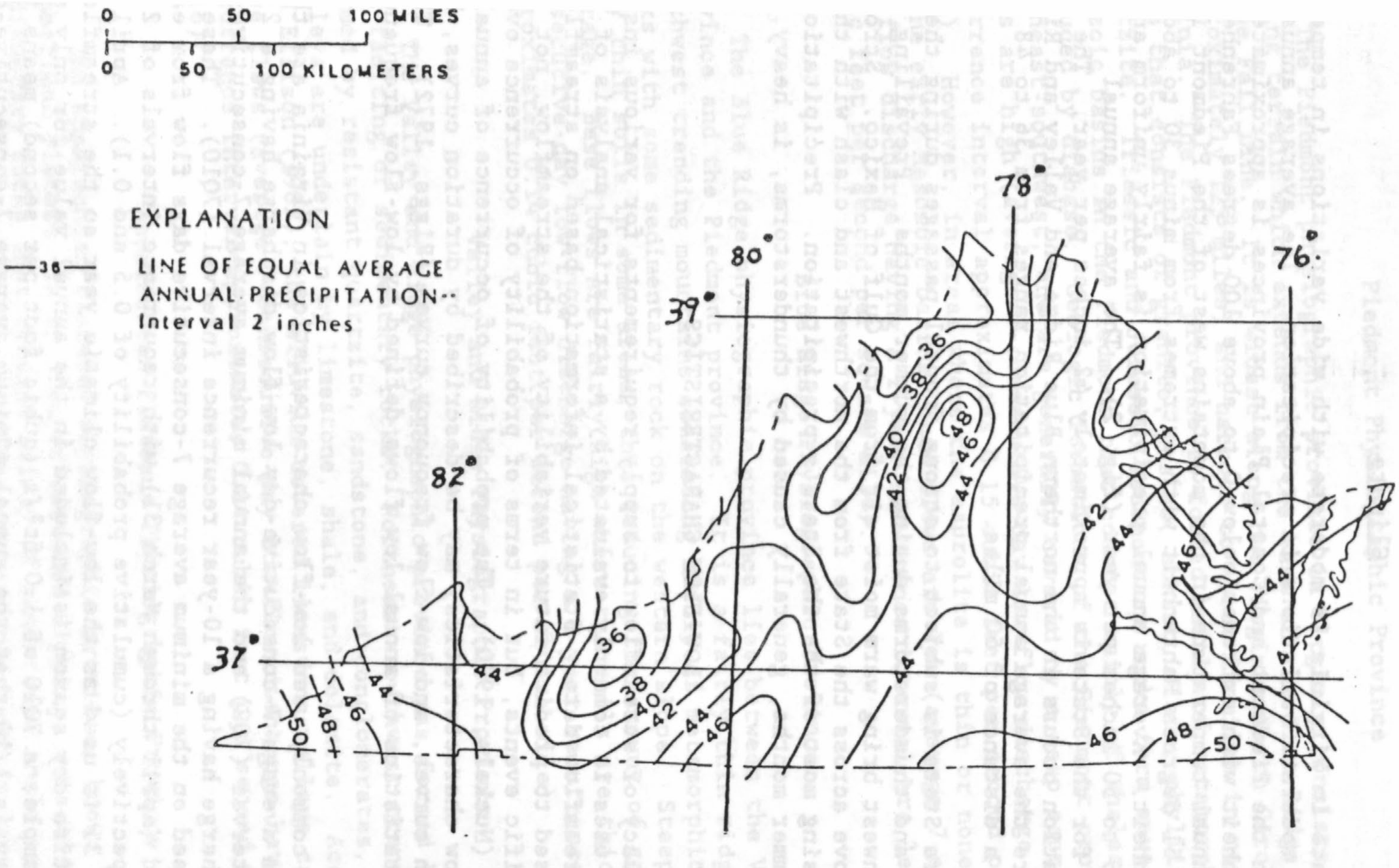

Figure 2.--Average annual precipitation in Virginia (modified from Powell and Abe, 1985, fig. 2).

because it is subject to greater time-sampling error. Data must be collected for long periods of time before sufficient data are collected to provide reliable estimates in the 10-year recurrence time frame.

Factors Affecting Low Flows

A basin can be considered a large reservoir with recharge, storage, and discharge of water (Trainer and Watkins, 1975). Recharge to this reservoir is primarily a function of precipitation, whereas storage and discharge are controlled primarily by the physical characteristics of the basin. During base-flow and low-flow conditions, ground-water discharge constitutes the majority of the streamflow. When sufficient streamflow data are collected, basin and climatological characteristics can be analyzed, with limited accuracy, to determine their influence on ground-water discharge to a stream. Some of the primary basin and climatological characteristics that influence low-flow characteristics are drainage area, rock type, soil type and depth, slope, land use, and precipitation.

Low-flow characteristics will usually relate to drainage-basin size better than any other basin or climatological characteristic when a basin is homogeneous with respect to topography, geology, and climate. Low-flow discharge values generally increase with increasing drainage basin size; however, topography, geology, and climate have such a strong influence on low flows, that minor differences in the basin characteristics may cause substantial differences in the low-flow discharges.

Rock type, soil type, and soil depth are major influences on streamflow during low-flow conditions. Rock type and the thickness and characteristics of the overburden determine the ability of the basin to accept, store, and transmit water. These properties affect the amount and the rate at which precipitation enters the shallow ground-water system and how it is released to sustain streamflow. Wide variations in the rock type and overburden contribute to the variation of low flows for streams in Virginia (Mohler and Hagan, 1981). A generalized rock-type map of Virginia is shown in figure 3.

Land slope is related to several factors that also influence low flows. Generally, the steeper the stream slope (slope of the basin along the stream), the less regolith or overburden available to store precipitation. Runoff of precipitation is more rapid. These factors allow less time for infiltration. As a stream flows out of the mountains into valleys, the stream slope decreases. When the stream slope decreases rapidly, a stream at base flow can disappear into the coarse-grained alluvium. The stream may disappear and appear as the streambed rises above and falls below the ground-water table. Side slope (slope of the basin perpendicular to the stream) also affects low flows. Shallow side slopes may allow more evapotranspiration because the ground-water table is closer to land surface, while steeper side slopes may reduce evapotranspiration and allow more seepage into a stream or creek.

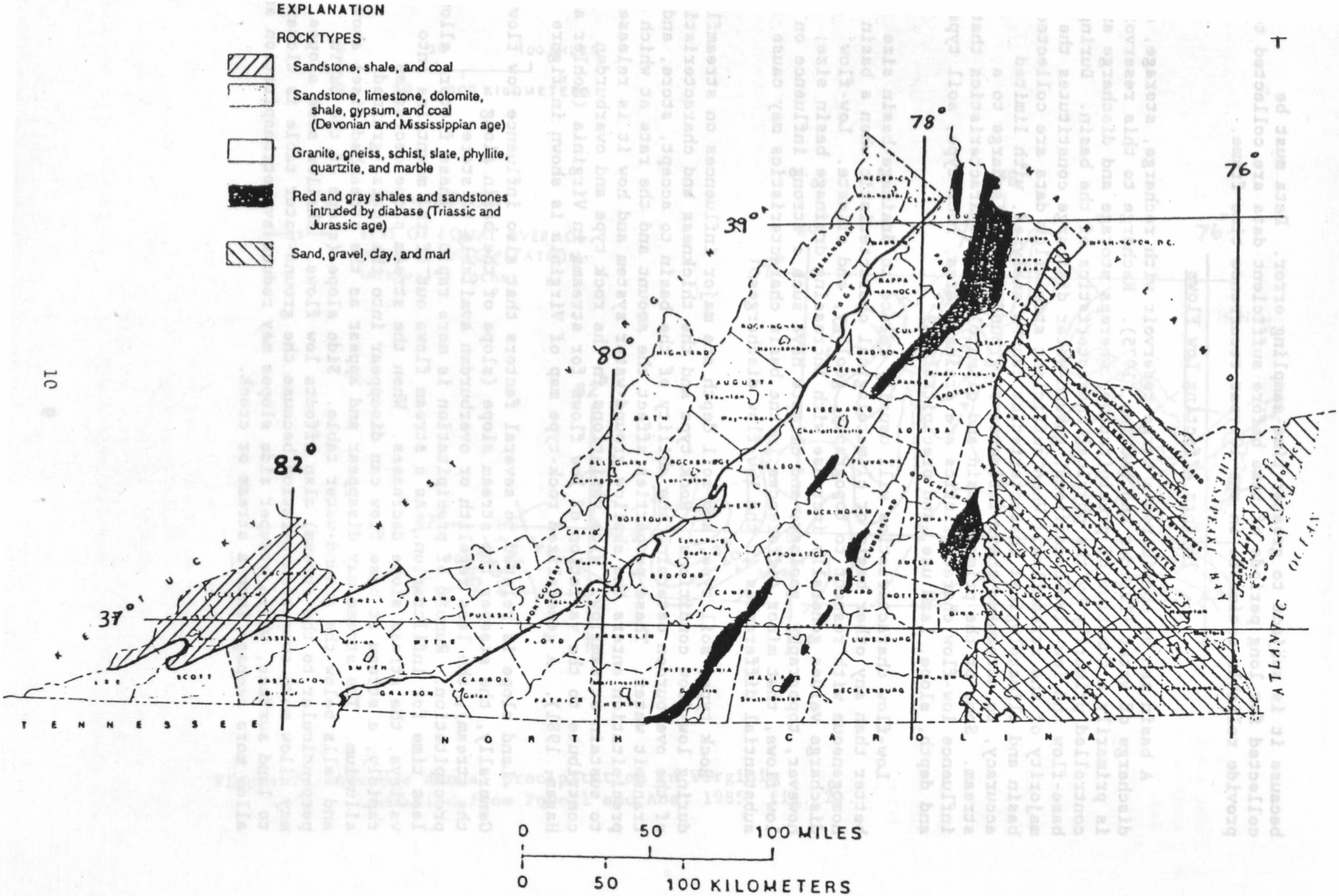

Figure 3.--Generalized rock types in Virginia (modified from Virginia Division of Mineral Resources, 1964).

Land use can affect low-flow characteristics more than any other factor. Man can modify natural ground-water and surface-water hydrology to the extent that low-flow characteristics are drastically altered. This change can happen almost immediately or very gradually. Evapotranspiration, infiltration, and runoff rates are all affected by changes in land use. Examples of development that takes place in a basin are, forests that are cut for agricultural use and urban developments, wetlands that may be drained or filled, and lakes or ponds that are constructed. Much of the precipitation that previously may have infiltrated into the ground-water system in undeveloped areas now becomes surface runoff. As a result, the ground-water contribution to streamflow during low-flow conditions may be reduced. Many localities that are underlain by highly permeable limestone or sand and gravel deposits use retention ponds to dispose of runoff from developed areas (Seaburn and Aronson, 1974). Retention ponds not only help recharge the ground-water system, but they also keep the increased runoff from overloading the small streams during heavy rainfall periods (Parker and others, 1955).

Diversion of water from a stream for irrigation or water supply during droughts will seriously affect flow volumes. Much of the water diverted for irrigation will not return to the stream because of evapotranspiration. Controlled releases from reservoirs and discharges from sewage-treatment plants can artificially augment streamflow during dry seasons. Strip mining and deep mining also can alter the characteristics of a basin by removal of the vegetation and overburden, and by modifying the structure of the remaining rock (Larson and Powell, 1986).

Precipitation is the supply and driving force of water in the hydrologic cycle. Streamflow is the result of surface runoff of precipitation or the result of infiltration, storage, and transfer of precipitation through the ground-water system. Precipitation is fairly uniform across the State. Average annual precipitation ranges from 36 to 50 inches per year. Amounts of average annual precipitation vary gradually over most of the State except in the Blue Ridge and Valley and Ridge provinces. The largest variation in average annual precipitation, 36 inches per year to 48 inches per year over a 50 mile distance, occurs in the northern sections of these two provinces. The large variation in average annual precipitation is probably due to prevailing wind direction and orographic effects (see fig. 1). The greater amounts of precipitation generally fall during the winter months. For this reason, base flows remain fairly high during these months. However, the highest rainfall intensities usually result from thunderstorms in the summer months when base flows are declining. Because of the areal and temporal distribution of precipitation caused by thunderstorms, little effect is seen in base-flow conditions. Insufficient streamflow data have been collected on a statewide basis to determine how the seasonal distribution of precipitation affects low-flow characteristics.

Methods for Determining Low-Flow Characteristics

Methods are presented in this section for determining low-flow characteristics at gaged and ungaged sites in Virginia. Gaged sites are separated into three site types and ungaged sites are separated into two site types. The site type can be determined by the streamflow data available at the site. Gaged sites consist of--

1. Long-term continuous-record sites.
2. Short-term continuous-record sites.
3. Partial-record sites.

Ungaged sites consist of--

1. Sites on gaged streams.
2. Sites on ungaged streams.

Methods used for determining low-flow values at long-term continuous-record sites, short-term continuous-record sites, and partial-record sites are later in this section and explained in detail in Riggs (1972). Low-flow values, 7Q2 and 7 Q10, were computed for 254 continuous-record sites (Appendix 1) and for 46 partial-record sites (Appendix 2) in Virginia using these methods. Information from gaged sites is used to develop two techniques for estimating low-flow characteristics at ungaged sites. A flow-routing method is developed to estimate low-flow values at ungaged sites on gaged streams. Regional regression equations are developed for estimating low-flow values at ungaged sites on ungaged streams.

Some methods used to estimate low-flow characteristics are statistically based and assume a linear relation. However, the actual relations are not always linear throughout their extent. This nonlinearity commonly is characteristic of the relations at lower streamflows. These lower streamflows are of interest in this study. When a statistically based relation line was computed, an additional relation line was visually fitted through the data points for each analysis. The visually based relation line was not forced to be linear, and was compared to the statistically based relation line. If the two relation lines were substantially different in the area of interest, the visually based relation line was selected to estimate the low-flow characteristics.

Gaged Sites

Surface-water data collection started as early as 1898 in Virginia. Daily mean discharges have been computed and published for approximately 300 sites in the State. Base-flow discharge measurements have been made at many sites as part of local studies where continuous record of daily mean discharges were not collected.

Continuous-record sites, generally located on medium to large drainage basins, were selected for the study on the basis of analysis of historical records. Sites located in highly urban basins were avoided because of rapid changes of basin characteristics within the basins. Continuous-record sites located on streams with major streamflow regulation were eliminated if no records were collected when the streamflow was unregulated. Sites where data were collected during both unregulated and regulated streamflow periods, were retained; but only the data collected during periods of unregulated streamflow were used for determining low-flow characteristics. Because of the large number of regulated streams and large number of users on many streams, it is impractical to eliminate all sites with regulated streamflow. Therefore, sites on streams with minor streamflow regulation were retained. Streamflow regulation for continuous-record sites was determined by a review of the station descriptions. If a dam was capable of controlling the discharges at low flow by impoundment or releases, or if industry diverted or returned water that amounted to more than 10 percent of the 7Q10, the site was eliminated from the data base. Sites with 10 or more years of unregulated discharge record are considered long-term continuous-record sites. Sites with fewer than 10 years of unregulated discharge record are considered short-term continuous-record sites.

Partial-record sites were also selected through analysis of historical records. Partial-record sites were selected to fill in areal gaps in the continuous-record data-collection network and incorporate smaller drainage basins. The partial-record sites had to meet the same restrictions on basin urbanization and streamflow regulation as the continuous-record sites. Determining streamflow regulation on partial-record sites was more difficult than determining streamflow regulation on continuous-record sites because of the large number of sites, limited previous basin analysis, and the large number and small size of the water-use facilities that affect the flow. Streamflow regulation for partial-record sites was determined by reviewing the drainage basin on topographic maps. If a dam appeared capable of controlling the discharges at low flow by impoundment or releases, or if water-use facilities appeared capable of diverting or returned water that amounted to more than 10 percent of the 7Q10, the site was eliminated from the data base.

Long-term continuous-record sites

At long-term continuous-record sites, low-flow characteristics are determined by developing low-flow frequency curves from the annual low-flow data. Low-flow frequency curves are developed by first determining the annual average minimum discharge for the desired number of consecutive days. Average minimum 7-consecutive-day flows are used in this study. These values are ordered by rank or size (smallest to largest) and a plotting position (nonexceedence probability) is calculated. The following formula is used to the determine the plotting position:

$$P = 1/T = m/(n + 1), \tag{1}$$

where P is the probability of a nonexceedence in any one year,

T is the recurrence interval in years,

n is the number of items in the sample (years), and

m is the order number of the annual events when arrayed according to size (Dalrymple, 1960).

Thus, recurrence interval in years is the reciprocal of the nonexceedence probability. The rank-ordered discharges are plotted with the nonexceedence probability, or recurrence interval, on log-probability paper to define the low-flow frequency curve. A typical low-flow frequency curve for average minimum 7-consecutive-day discharges is shown in figure 4.

The graphical curve is considered the basic frequency curve for low flows (Riggs, 1971); but, for consistency, annual low-flow data should be fit to a theoretical frequency distribution. Several theoretical distributions--log-Gumbel, log-normal, Pearson Type III--have been successfully used to develop low-flow frequency curves. Because different basin characteristics can produce different shaped frequency curves, no single theoretical frequency distribution can adequately describe all low-flow frequency curves (Riggs, 1972). A plot of the theoretical distribution is visually compared to the plotting position described above. When the theoretical distribution does not fit the data in the position plot, a smooth curve is drawn through the plotting positions. Low-flow characteristics are then estimated by transferring the recurrence interval or nonexceedence probability through the curve. Because the Pearson Type III distribution has been found to match the graphical curve fairly well (Matalas, 1963), and is widely used to describe low-flow frequency curves, it is used in this study to fit frequency curves for the logarithms of annual low-flow data at long-term continuous-record sites.

Short-term continuous-record sites

Mathematical and graphical regression methods are used to relate logarithms of daily mean discharge at a short-term continuous-record site to logarithms of concurrent daily mean discharge at a nearby long-term continuous-record site (index site) at which low-flow characteristics have been determined. Between 10 and 25 concurrent daily mean discharges are selected during separate base-flow recessions to define the relation between two sites and compute a regression equation. The mathematical method uses a linear least-squares regression method to compute the regression equation. The concurrent discharges are also plotted and a visually fitted line drawn to define the relation between the two sites. As stated earlier, the visually fitted relation line is compared to the statistically based relation line, and if substantially different in the area of interest, the visually fitted relation line is used to estimate low-flow statistics. Figure 5 shows how the desired low-flow value is graphically selected by transferring the low-flow characteristics from the index site (Wolf Creek near Narrows, Virginia; 7Q2 = 35 ft^3/s, 7Q10 = 23 ft^3/s) through the relation line to the short-term continuous-record site (Wolf Creek near Staffordsville, Virginia; 7Q2 = 36 ft^3/s, 7Q10 = 24 ft^3/s). It is not necessary for the relation line to be linear as defined by the linear least-squares regression; however, a sufficient number of data points should be selected to define any changes in slope adequately.

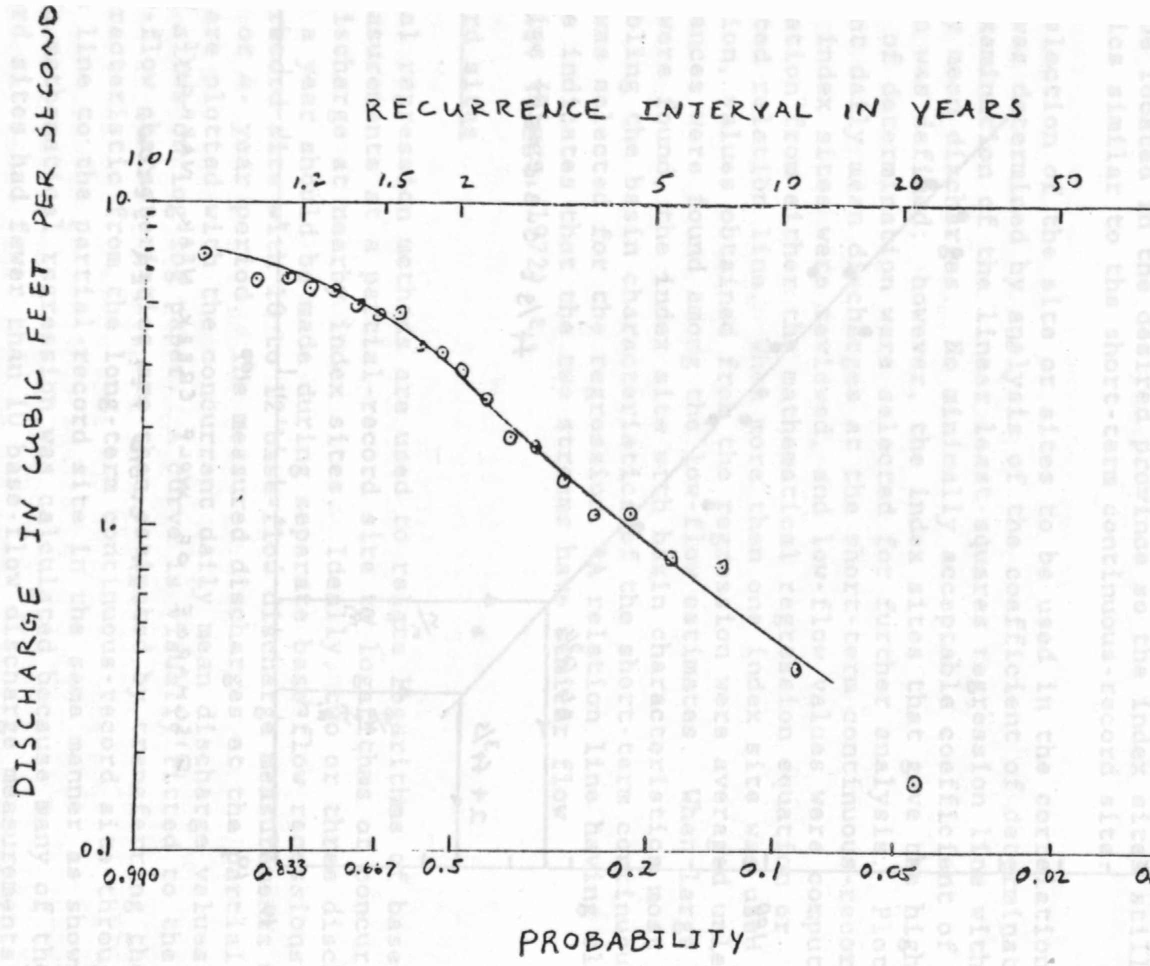

Figure 4.--Low-flow frequency curve of average minimum 7-consecutive-day discharge for Accotink Creek near Annandale, Virginia.

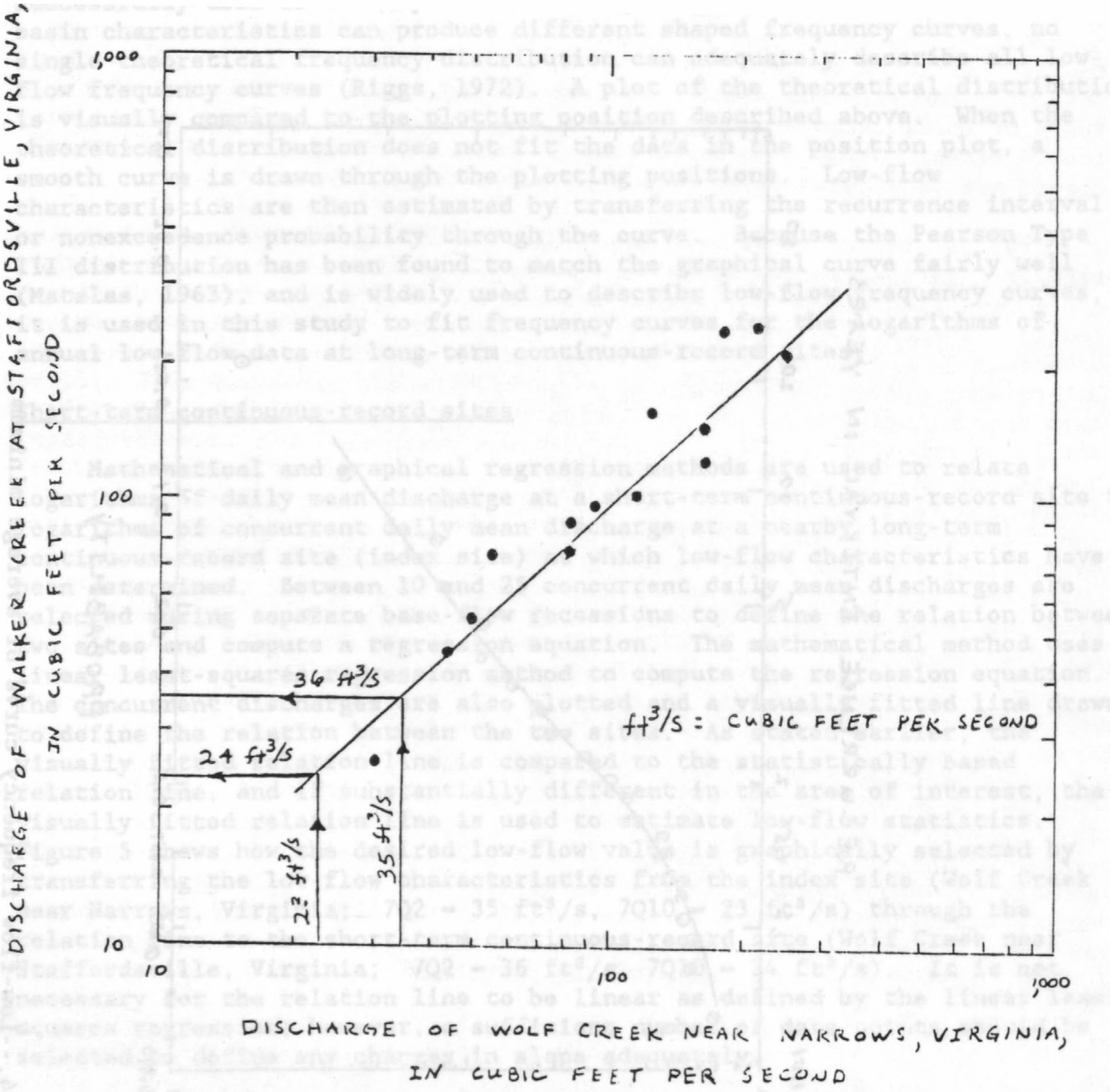

Figure 5.--Relation of daily mean discharge of Walker Creek to concurrent daily mean discharge of Wolf Creek.

For this study, discharge at a short-term continuous-record site was related to discharge at several index sites to increase confidence in the low-flow value selected. Discharge at the short-term continuous-record sites was initially related to discharge at index sites in the same basin. The index sites could be either upstream or downstream of the short-term continuous-record site and in the same physiographic province or an adjacent province. When no index site in the same basin correlated well with the short-term continuous-record site, index sites in adjacent basins within the province were used. If these sites did not correlate well, sites in any basin within the province, with similar basin characteristics were used. When necessary, index sites in a different province were used to define a relation; but 50 percent of the drainage area of the index site was required to be located in the desired province so the index sites still had characteristics similar to the short-term continuous-record site.

Final selection of the site or sites to be used in the correlation as index sites was determined by analysis of the coefficient of determination and visual examination of the linear least-squares regression line with the plotted daily mean discharges. No minimally acceptable coefficient of determination was defined; however, the index sites that gave the higher coefficients of determination were selected for further analysis. Plots of the concurrent daily mean discharges at the short-term continuous-record site and the index sites were reviewed, and low-flow values were computed for each relation from either the mathematical regression equation or visually fitted relation line. When more than one index site was used for the correlation, values obtained from the regression were averaged unless large differences were found among the low-flow estimates. When large differences were found, the index site with basin characteristics most nearly resembling the basin characteristics of the short-term continuous-record site was selected for the regression. A relation line having close to unit slope indicates that the two streams have similar flow characteristics (Riggs, 1972).

Partial-record sites

Graphical regression methods are used to relate logarithms of base-flow discharge measurements at a partial-record site to logarithms of concurrent daily mean discharge at nearby index sites. Ideally, two or three discharge measurements a year should be made during separate base-flow recessions at the partial-record site with 10 to 12 base-flow discharge measurements made during a 3- or 4- year period. The measured discharges at the partial-record site are plotted with the concurrent daily mean discharge values at nearby index sites on log-log paper. A curve is visually fitted to the data points. Low-flow characteristics are then estimated by transferring the low-flow characteristic from the long-term continuous-record site through the relation line to the partial-record site in the same manner as shown in figure 5. No mathematical regression was calculated because many of the partial-record sites had fewer than 10 base-flow discharge measurements.

For this study, an average of 8 discharge measurements (as few as 3 and as many as 31) were made at partial-record sites. All base-flow discharge measurements at a partial-record site were used, providing nearby index sites were being operated. Some partial-record sites that had a few discharge measurements made during droughts in the 1950's and early 1960's had additional discharge measurements made during this study to increase the number of base-flow discharge measurements at the partial-record site and also to increase the number of possible index sites used for regressions. Measurement notes for the partial-record site, climatological data from nearby rain gages, and discharge hydrographs at the index sites were reviewed to determine if both the partial-record site and index site were at base-flow conditions. Approximately 30 percent of the discharge measurements were not used because either the partial-record site or the index site was affected by surface runoff.

Selection of index sites was the same for the partial-record sites as for the short-term continuous-record sites, except visual examination of the visually fitted relation line was the only method used to determine which sites showed good. Values from those index sites showing good fit were compared, and if the values were consistent, a weighted average was used. The weight given to each value was determined by the distance between the partial-record site and index site, comparison of basin characteristics, and spread of data points about the relation lines. When the values from those index sites showing good fit were compared and not found consistent, the value from a single index station was used. The index site with basin characteristics most closely resembling the basin characteristics of the partial-record site was selected for the regression. The procedure was performed graphically on log-log paper. The relation line was visually fitted to the data because of the limited number of discharge measurements normally available and non-linearity of many of the relations.

Ungaged Sites

It is commonly necessary to estimate low-flow characteristics at sites where no continuous record of daily mean discharges or base-flow discharge measurements are available. Methods are presented here for estimating values at ungaged sites on gaged streams and ungaged sites on ungaged streams.

Sites on gaged streams

A flow-routing method uses low-flow characteristics derived from streamflow records at gaged sites to estimate low-flow characteristics at ungaged sites. The flow-routing method uses drainage-area proration to estimate low-flow characteristics at an ungaged site on the basis of low-flow values from gaged sites on the same stream. The low-flow values is transferred from a gaged site, either upstream or downstream, to the ungaged site. If it is necessary to proceed beyond a confluence, low-flow values are estimated at the confluence and added or subtracted (depending on direction of routing) and the sum is routed to the next confluence. This procedure is continued until the location of the ungaged site is reached. The flow-routing method can be used on basins that cross physiographic boundaries or drain regions underlain by different rock types; however, judgement must be used when basin characteristics such as channel slope or rock type change considerably between the gaged site and the ungaged site. Changes in basin characteristics can alter the base-flow characteristics of a stream.

The flow-routing equation for estimating low-flow characteristics (equation 2) consists of a simple drainage-area ratio to the 1.2 power and is limited to drainage-area ratios from 0.25 to 4.0--

$$7QT_j = 7QT_i \left[\frac{A_j}{A_i} \right]^{1.2} \quad \text{for } 0.25 \leq \left[\frac{A_j}{A_i} \right] \leq 4.0, \qquad (2)$$

where 7QT is the average minimum 7-consecutive-day discharge with a T-year recurrence interval (ft^3/s),

A is the drainage area (square miles),
i is the location at a gaged site where low-flow values have been previously determined, and
j is the location at an ungaged site or confluence where the low-flow value is to be determined.

Any computed low-flow value that is calculated as negative is assumed zero flow.

The exponent and drainage-area ratio range in equation 2 were computed by analyzing low-flow characteristics at paired, long-term and short-term continuous-record sites. Locations of all continuous-record sites with low-flow characteristics previously determined were plotted on a stream-network map of the State. Paired sites were selected on streams where no major tributaries entered the stream at any point between the selected sites. Paired sites with a tributary that entered the stream between the sites and caused the drainage area to increase at the confluence by more than 25 percent, were not analyzed. Analysis was conducted on 77 paired continuous-record sites. Only continuous-record sites were used in the analysis because of greater confidence in the low-flow values. Confidence is less for the values at partial-record sites because the values are determined by correlation of point data and many partial-record sites have small drainage areas with large natural variations in streamflow.

The following method was used to determine the exponent in the flow-routing equation. Logarithms of the ratios of the low-flow characteristics at the upstream site to low-flow characteristics at the downstream site (7Q2 and 7Q10) were related to logarithms of the ratios of the drainage area at the upstream site to drainage area of the downstream site. A relation line was determined using a least-squares regression method. A graph of the plotted points and relation line was checked visually for linearity. The linearity of the relation line was also checked mathematically by assuming the data fit an equation of the form--

$$7QT_j = 7QT_i \left[\frac{A_j}{A_i} \right]^{b \left[\frac{A_j}{A_i} \right]^{c}} \qquad (3)$$

where 7QT is the average minimum 7-consecutive-day discharge with a T-year recurrence interval (ft^3/s),

A is the drainage area (square miles),

i is the location at a site where low-flow values have been previously determined,

j is the location at an ungaged site or confluence where the low-flow value is to be determined,

b is the exponent computed by least-squares regression, and

c is the exponent selected by trial and error.

For every value of c selected from -1.0 to +1.0, a value of b and standard error of estimate was computed. The minimum standard error of estimate occurred for a value of c from 0.0 to +0.05, resulting in a computed value for b of 1.2. Because the value of c was very close to zero, equation 3 reduced to the form of equation 2. When only the 7Q2 data were used to determine the exponent, the computed value of b was 1.12. When only the 7Q10 data were used to determine the exponent, the computed value of the exponent was 1.28. Using separate equations for transferring the 7Q2 and 7Q10 values gave only slight improvements in the standard errors of estimate; therefore, the single equation for transferring both characteristics was selected.

The following examples from the Tye River basin show use of the method and an indication of the accuracy of the method. Figure 6 shows the general location of the gaging stations, and table 1 gives the data needed from the continuous-record stations as well as additional drainage areas needed in the calculations. The simplest predictions are made when the ungaged site is on the same stream as the gaged site with no major tributaries entering the stream at any point between the selected sites.

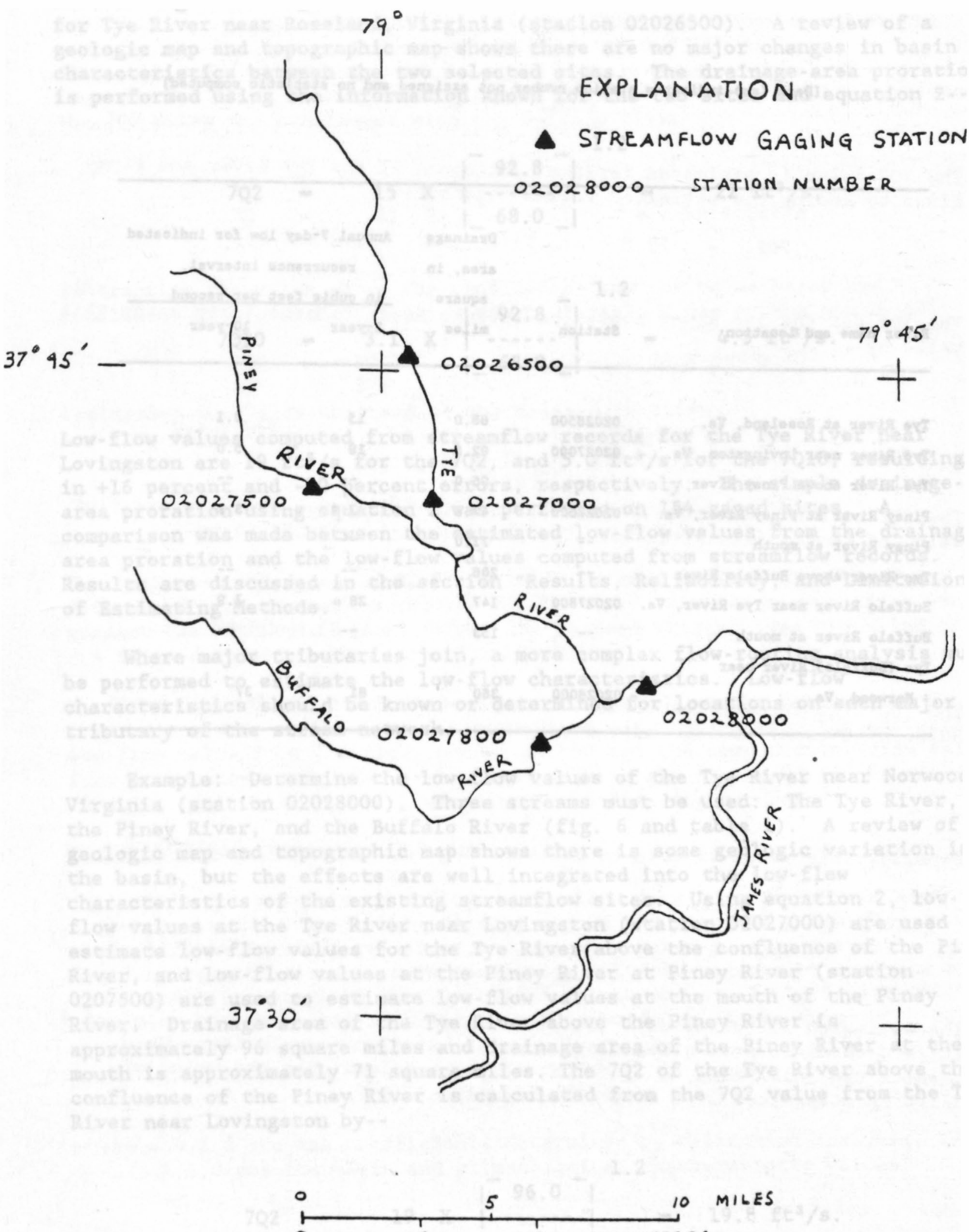

Figure 6.--Tye River basin showing location of gaging stations.

Table 1.--Drainage areas and low-flow values for selected continuous-record gaging stations in the Tye River basin, Virginia

[Dash (--) indicates station number not assigned and no statistic computed]

River name and location	Station	Drainage area, in square miles	Annual 7-day low for indicated recurrence interval, in cubic feet per second 2-year	10-year
Tye River at Roseland, Va.	02026500	68.0	15	3.1
Tye River near Lovingston, Va.	02027000	92.8	19	5.0
Tye River above Piney River	--	96.0	--	--
Piney River at Piney River, Va.	02027500	47.6	7.9	3.2
Piney River at mouth	--	71.0	--	--
Tye River above Buffalo River	--	206	--	--
Buffalo River near Tye River, Va.	02027800	147	28	7.9
Buffalo River at mouth	--	153	--	--
Tye (Buffalo) River near Norwood, Va.	02028000	360	81	37

Example: Determine the low-flow values, 7Q2 and 7Q10, of the Tye River near Lovingston, Virginia (station 02027000) on the basis of low-flow values for Tye River near Roseland, Virginia (station 02026500). A review of a geologic map and topographic map shows there are no major changes in basin characteristics between the two selected sites. The drainage-area proration is performed using the information known for the two sites and equation 2--

$$7Q2 = 15 \times \left[\frac{92.8}{68.0}\right]^{1.2} = 22 \ ft^3/s,$$

$$7Q10 = 3.1 \times \left[\frac{92.8}{68.0}\right]^{1.2} = 4.5 \ ft^3/s.$$

Low-flow values computed from streamflow records for the Tye River near Lovingston are 19 ft^3/s for the 7Q2, and 5.0 ft^3/s for the 7Q10, resulting in +16 percent and -10 percent errors, respectively. The simple drainage-area proration using equation 2 was performed on 154 gaged sites. A comparison was made between the estimated low-flow values from the drainage-area proration and the low-flow values computed from streamflow records. Results are discussed in the section "Results, Reliability, and Limitations of Estimating Methods."

Where major tributaries join, a more complex flow-routing analysis must be performed to estimate the low-flow characteristics. Low-flow characteristics should be known or determined for locations on each major tributary of the stream network.

Example: Determine the low-flow values of the Tye River near Norwood, Virginia (station 02028000). Three streams must be used: The Tye River, the Piney River, and the Buffalo River (fig. 6 and table 1). A review of a geologic map and topographic map shows there is some geologic variation in the basin, but the effects are well integrated into the low-flow characteristics of the existing streamflow sites. Using equation 2, low-flow values at the Tye River near Lovingston (station 02027000) are used to estimate low-flow values for the Tye River above the confluence of the Piney River, and low-flow values at the Piney River at Piney River (station 0207500) are used to estimate low-flow values at the mouth of the Piney River. Drainage area of the Tye River above the Piney River is approximately 96 square miles and drainage area of the Piney River at the mouth is approximately 71 square miles. The 7Q2 of the Tye River above the confluence of the Piney River is calculated from the 7Q2 value from the Tye River near Lovingston by--

$$7Q2 = 19 \times \left[\frac{96.0}{92.8}\right]^{1.2} = 19.8 \ ft^3/s.$$

The 7Q2 at the mouth of the Piney River is calculated from the 7Q2 value from the Piney River at Piney River by--

$$7Q2 = 7.9 \times \left[\frac{71.0}{47.6}\right]^{1.2} = 12.8 \text{ ft}^3/\text{s}.$$

The 7Q2 value is estimated for the confluence of the Tye River and Piney River by adding the estimated values together--

$$7Q2 = 19.8 + 12.8 = 32.6 \text{ ft}^3/\text{s}.$$

The 7Q2 for the Tye River above the Buffalo River is calculated using this value by--

$$7Q2 = 32.6 \times \left[\frac{206}{71 + 96}\right]^{1.2} = 41.9 \text{ ft}^3/\text{s}.$$

The 7Q2 at the mouth of the Buffalo River is calculated from the low-flow value of the Buffalo River near Tye River (station 02027800) by--

$$7Q2 = 28 \times \left[\frac{153}{147}\right]^{1.2} = 29.4 \text{ ft}^3/\text{s}.$$

The low-flow value is estimated at the confluence of the Tye River and Buffalo River by adding the two values--

$$7Q2 = 41.9 + 29.4 = 71.3 \text{ ft}^3/\text{s}.$$

Finally, this value is used to estimate the 7Q2 at station 02028000 by--

$$7Q2 = 71.3 \times \left[\frac{360}{359}\right]^{1.2} = 71.5 \text{ or } 72 \text{ ft}^3/\text{s}.$$

The estimated 7Q2 value of 72 ft^3/s is 11 percent less than the value of 81 ft^3/s determined from streamflow records. Similar computations would predict the 7Q10 value of 21 ft^3/s, 43 percent less than the value of 37 ft^3/s determined from streamflow records.

The method can also be used in the upstream direction. Example: Estimate the 7Q2 for the Buffalo River near Tye River (station 02027800) using data from the other sites. Computed values would be the same for the Tye River at the confluence of the Buffalo River (7Q2 = 41.9 ft^3/s) in this example as in the previous example. The value from the Tye River near Norwood (station 0202800) would be used to estimate the 7Q2 below the confluence with the Buffalo River--

$$7Q2 = 81 \times \left[\frac{359}{360} \right]^{1.2} = 80.7 \ ft^3/s.$$

Subtracting the value above the confluence from the value below the confluence gives the contribution of the Buffalo River at the mouth--

$$7Q2 = 80.7 - 41.9 = 38.8 \ ft^3/s.$$

Estimating the value upstream at the desired location--

$$7Q2 = 38.8 \times \left[\frac{147}{153} \right]^{1.2} = 37.0 \ ft^3/s.$$

The estimated 7Q2 value of 37 ft^3/s is 32 percent greater than the value determined from streamflow records of 28 ft^3/s. Similar computations would predict the 7Q10 value of 23 ft^3/s, 191 percent greater than the value of 7.9 ft^3/s determined from streamflow records.

The flow-routing analysis was performed on 24 stream networks with predictions made at 84 sites. A comparison was made between the estimated low-flow value from the flow-routing method and the computed low-flow value from streamflow records at each site. Results are discussed in the section "Results, Reliability, and Limitations of Estimating Methods."

Sites on ungaged streams

It is not possible to collect streamflow data on every stream and tributary in the State; therefore, a method for estimating low-flow characteristics at ungaged sites on ungaged streams is also needed. Regional equations can be developed using multiple-regression analyses of basin and climatological characteristic values and available low-flow values. The regression model used in this study is of the form--

$$7QT = a \ (A)^b \ (B)^c \ (C)^d \ ..., \qquad (4)$$

where a,b,c,d are the coefficients determined by regression analyses, and A,B,C are the basin and climatological characteristic values.

By taking the logarithms of both sides of equation 4, the model takes a linear form--

$$\log (7QT) = \log (a) + b \log (A) + c \log (B) + d \log (C) + \ldots \quad (5)$$

and a least-squares solution can be used to determine the coefficients.

Regression equations were developed by dividing the State into geographic regions. The regions were developed from five physiographic provinces in Virginia and on the basis of topography and geology. Continuous-record and partial-record stations were assigned to the particular region in which more than 75 percent of the stream's drainage basin for that site was located, and for which the slope of the streambed at the measuring point was consistent with the general slope of the assigned region. Multiple-regression analyses were performed in each region on the low-flow values and basin and climatological characteristic values for the stations to develop regression equations. After initial regression equations were calculated for the five regions, the residuals were examined. Three additional regions were formed, on the basis of geographic grouping of the residuals. Eight resulting regions are shown in figure 7 and plates 1 and 2, and are listed below:

1. Coastal Plain, northern region.
2. Coastal Plain, southern region.
3. Piedmont, northern region.
4. Piedmont, southern region.
5. Piedmont/Blue Ridge transition region.
6. Blue Ridge region.
7. Valley and Ridge region.
8. Appalachian Plateaus region.

Basin and climatological characteristics used as variables in the regression analysis were drainage area, area underlain by specific rock type, soil type and depth, stream length, strip-mined area, streambed slope, elevation, percent forest cover, surface storage, flow direction, and mean-annual precipitation. The following is a description of the basin and climatological characteristics analyzed and the methods used to determine the values of the characteristics.

Drainage area (A) was computed in square miles for all continuous-record and partial-record sites from 1:24,000-scale topographic maps using mechanical planimeters and electronic planimeters. Drainage area is considered the predominant factor explaining variation in low-flow characteristics and is used in some form in each equation. One set of equations was developed with drainage area as the only indicator.

Drainage area underlain by a specific rock type was identified using a grid sampling method from the 1:500,000-scale State geologic map (Virginia Division of Mineral Resources, 1963). Generalized rock types were computed as percent of the total drainage area for the Triassic and Jurassic sedimentary rock (TJ) in the Piedmont northern region, Piedmont southern region, and Piedmont/Blue Ridge transition region; and Devonian and Mississippian sedimentary rock (DM) in the Valley and Ridge region. In the

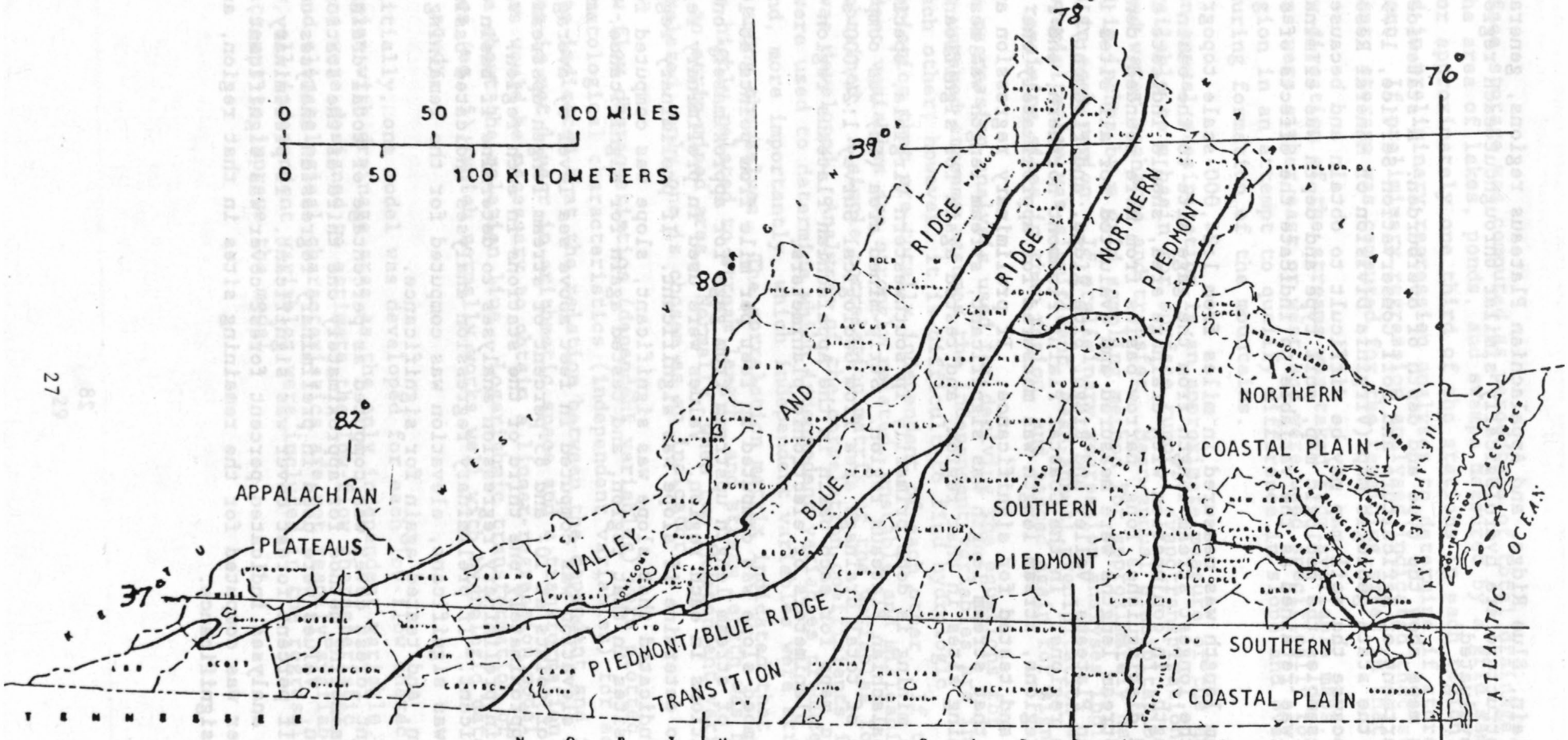

Figure 7.--Regions in Virginia for application of low-flow estimating equations.

Coastal Plain, Blue Ridge, and Appalachian Plateaus regions, general rock type and structure are hydrologically similar throughout each region and were not evaluated.

Soils maps show the type and depth of overburden. A statewide soil map (U.S. Department of Agriculture and Soil Conservation Service, 1979) closely resembles the state geologic map (Virginia Division of Mineral Resources, 1963). Because the soil map may be difficult to obtain and because the map closely resembles the geologic map, soil type and depth was eliminated and rock type was retained as the variable to indicate the effects of soil type and depth.

Stream length was measured in miles from 1:24,000-scale topographic maps for the longest stream length from the gage site to the basin divide. Stream length, in conjunction with drainage area, should indicate a basin shape, and distinguishes long, narrow basins from more rounded, dendritic basins. Stream lengths were measured and evaluated for all sites in the Appalachian Plateaus, Valley and Ridge, Blue Ridge, and Piedmont/Blue Ridge transition regions. In the Coastal Plain, Piedmont northern, and Piedmont southern regions, stream length was measured for approximately one third of the sites and tested for significance. If preliminary regression analyses indicated that stream length was significant, stream length was measured for the remaining sites in that region, and tested again for significance.

Strip mining is done primarily in southwestern Virginia, specifically in the Appalachian Plateaus region. Strip-mined area (SM) was computed as a percentage of total drainage area from Geological Survey 1:24,000-scale topographic maps for each basin in the Appalachian Plateaus region using mechanical planimeters or electronic planimeters.

Streambed slope was computed in feet per mile from points at 10- and 85-percent of stream length upstream from gage for approximately one third of the stations in each region. Values were used in preliminary regression analyses to determine if slope was significant. If preliminary regression analyses indicated that slope was significant, slope was computed for the remaining sites in that region, and tested again for significance.

Basin elevation was computed in feet above sea level by averaging the elevation of points at 10- and 85-percent of stream length upstream from gage for approximately one third of the stations in each region. Values were used in preliminary regression analyses to determine if basin elevation was significant. If preliminary regression analyses indicated basin elevation was significant, elevation was computed for the remaining sites in that region, and tested again for significance.

Percent forest cover was computed as percentage of total drainage area by a grid sampling method for approximately one third of the stations in each region. Values were used in preliminary regression analyses to determine if percent forest cover was significant. If preliminary regression analyses indicated percent forest cover was significant, percent forest cover was computed for the remaining sites in that region, and tested again for significance.

Surface storage was computed as percentage of total drainage area by adding the area of lakes, ponds, and swamps measured by a grid sampling method for approximately one third of the stations in each region. Values were used in preliminary regression analyses to determine if storage was significant. If preliminary regression analyses indicated that storage was significant, storage was computed for the remaining sites in that region.

Flow direction of the streams was taken from available maps. Directions were either east or west and were used specifically for the Blue Ridge region in an attempt to qualify difference in slope and overburden caused during formation of the mountains.

Mean-annual precipitation is an approximate measure of the amount of water available to a basin for surface runoff, evapotranspiration, storage, and ground-water recharge and transfer. Mean-annual precipitation was computed in inches by a grid sampling method for approximately half the stations in each region. If preliminary regression analyses indicated mean-annual precipitation was significant, mean-annual precipitation was computed for the remaining sites in that region, and tested again for significance.

The regression analysis used for deriving the equations for ungaged sites on ungaged streams assumes the independent variables are independent of of each other; however, it is difficult to find hydrologic characteristics that are totally independent of each other. If the independent variables are strongly related, unstable and misleading results may be obtained. A simple correlation matrix of the variables for each region was developed. Analyses of the correlation coefficients in the matrix were used to determine which independent variables produce the best model and, more importantly, which independent variables were strongly related among themselves. The correlation matrix indicated that drainage area was highly related to stream length, and stream length was highly related to strip-mined area. Normally, when two independent variables are highly related, only one is chosen as an indicator.

Low-flow characteristics (dependent variables) were plotted with basin and climatological characteristics (independent variables) for each region. The plots indicated that the relation between the dependent and independent variables is not linear in arithmetic space and a transformation of the variables would be necessary to obtain a linear-regression model with equal variance about the relation line. Logarithmic transformation of the variables (eq. 5), which normally works well with hydrologic data, was used in this study.

Initially, one model was developed for each low-flow characteristic in each region with drainage area as the only independent variable. These equations were designed to estimate the low-flow characteristic when other basin and climatological characteristics are not readily available. Finally, all independent variables were included in the regression analyses to an attempt to improve the model.

Multiple regressions were run to determine effects of the independent variables on the dependent variables. A backward elimination technique (SPSS Inc., 1986) was used to determine the final model form and coefficient values. The independent variables that were significant at a 95-percent confidence level were retained in the model.

Preliminary regressions were run using many different regression methods and data transformations in attempts to determine which independent variables were significant. The independent variables that remained significant were drainage area, percent area underlain by a specific rock type, and percent strip-mined area.

Zero values in the data sets caused problems with log transformations of both dependent and independent variables. Two solutions to the problem were--eliminate the zero flows (dependent variables) from the analysis and add a constant to the independent variables that could possibly be zero; or retain the zero flows in the analysis and add constants to both the dependent and independent variables. Zero flows were retained in the analysis because of the large number of zero flows in the data and the necessity of predicting zero flows at a site.

Separate constants were determined for each dependent variable in the eight regions. Zero flow values were eliminated from the data base and regressions were run with drainage area as the only independent variable. The slope of the linear-regression line was determine from this regression. The zero flow values were then included in the data set, and constants (0.001, 0.01, 0.1, 0.5, 1.0, 5.0, and 10.0) were added to the dependent variables. The constant that generated the slope of the regression line closest to the slope of the previous regression line (zero flows eliminated) was chosen for the final equation. In this manner, the zero flows caused minimal change in the slope of the regression line and allows the user to predict zero flows.

Separate constants were determined in a similar manner for each independent variable that could possibly be zero. Zero values in the data base were eliminated from the dependent variables as well as the independent variables and regressions were run for in each of the eight regions. Drainage area and percent area underlain by specific rock type, and drainage area and percent strip-mined area were the independent variable used. The slope of the linear-regression line was determine from this regression for each independent variable. The zero values were then included in the data set for the independent variables, and constants (0.001, 0.01, 0.1, 0.5, 1.0, 5.0, and 10.0) were added to the independent variables. The constant that generated the slope of the regression line closest to the slope of the previous regression line (with zero values for the dependent and independent variables eliminated) was chosen to be included in the final equation. The final equations (table 2) were determined by including the constants for the dependent and independent variables as determined above, log transforming all the variables, and using the entire data sets in the regression analysis.

Table 2.--Predictive equations applicable to designated regions in Virginia

[This table gives equations and standard error of prediction for annual minimum average 7-consecutive-day flows having a 2-year recurrence interval (7Q2) and a 10-year recurrence interval (7Q10). Values are determined in cubic feet per second. Basin characteristics used in the equations are: A, drainage area in square miles; TJ, area underlain by Triassic and Jurassic sedimentary rock as a percentage of total drainage area; DM, area underlain by Devonian and Mississippian sedimentary rock as a percentage of total drainage areal; and SM, area strip mined as a percentage of total drainage area; Dash indicates statistic was not computed]

Region	Equation	Standard error of prediction, in percent	Number of partial-record sites used	Number of continuous-record sites used	Drainage area in square miles Maximum	Minimum
Coastal Plain northern region			62	11	108	0.28
	$7Q2 = 0.084\,(A)^{1.010} - 0.01$	88				
	$7Q10 = 0.041\,(A)^{0.728} - 0.01$	118				
Coastal Plain southern region			28	4	456	.61
	7Q2--could not be determined	--				
	7Q10--approximately 0.0	--				
Piedmont northern region			59	23	155	0.08
	$7Q2 = 0.258\,(A)^{0.918}\,(TJ + 5.0)^{-0.846} - 0.01$	124				
	7Q10--TJ not significant	--				
	or,					
	$7Q2 = 0.027\,(A)^{0.833} - 0.01$	139				
	$7Q10 = 0.002\,(A)^{0.844} - 0.001$	172				
Piedmont southern region			59	27	269	0.33
	$7Q2 = 0.042\,(A)^{1.101} - 0.01$	98				
	$7Q10 = 0.015\,(A)^{1.025} - 0.01$	125				
Piedmont/Blue Ridge transition region			24	11	278	.46
	$7Q2 = 0.226\,(A)^{1.098} - 0.0$	60				
	$7Q10 = 0.120\,(A)^{1.045} - 0.01$	90				
Blue Ridge region			61	22	188	0.78
	$7Q2 = 0.062\,(A)^{1.117} - 0.01$	85				
	$7Q10 = 0.016\,(A)^{1.124} - 0.01$	111				
Valley and Ridge region			58	49	277	0.61
	$7Q2 = 0.467\,(A)^{1.034}\,(DM + 10.0)^{-0.491} - 0.1$	87				
	$7Q10 = 0.416\,(A)^{0.983}\,(DM + 10.0)^{-0.532} - 0.1$	96				
	or,					
	$7Q2 = 0.112\,(A)^{0.958} - 0.1$	91				
	$7Q10 = 0.088\,(A)^{0.900} - 0.1$	102				
Appalachian Plateaus region			107	10	87.4	0.17
	$7Q2 = 0.015\,(A)^{1.165}\,(SM + 1.0)^{0.354} - 0.01$	103				
	$7Q10 = 0.003\,(A)^{0.958}\,(SM + 5.0)^{0.680} - 0.01$	115				
	or,					
	$7Q2 = 0.027\,(A)^{1.202} - 0.01$	105				
	$7Q10 = 0.017\,(A)^{0.962} - 0.01$	123				

The equation for the standard error of estimate was modified to represent the error along the entire regression line. This error, now called the standard error of prediction in percentage, is defined as--

$$\left[\frac{\mathrm{SUM} \left[\frac{A - P}{(A + P)/2} \right]^{2}}{N} \right]^{0.5} \qquad (6)$$

where A is the actual value,
P is the predicted value, and
N is the number of data points.

A modified estimate of the mean, (A + P)/2, is necessary because of the large number of actual and predicted zero values. When A and P are both zero, the error term for that point is set to zero.

Because of the size of the data sets, a split sample was used to determine the errors. The sites were rank ordered according to drainage basin size and type of data collected (partial-record site or continuous-record site). The data sets were split by selection of alternate sites. Equations were developed for each split data set by using the constants previously determined from analysis of the entire data set. Errors for each split data set were computed by predicting values in the alternate data set and using equation 6. The standard error of prediction is computed as the average of the errors from the split sample for that variable and region. Reliability of the regional equations is determined from the standard errors of prediction which are also given in table 2 and discussed in the section "Results, Reliability, and Limitations of Estimating Methods."

In order to use the equations, first locate the desired basin on figure 7 or plates 1 or 2. Determine which of the eight regions contains the basin. From equations in table 2, determine which basin characteristics are needed and compute them using the best available maps. When two equations are given for a low-flow value, the more complex equation should be used. However, if the basin characteristics needed for the equation cannot be determined, the equation using drainage area (A) only may be used. When the basin is in two or more regions, compute the contributing amount from each region and combine. The predicted value, 7Q2 of 7Q10, should be set to zero if the value computed from the equation is negative.

Example: Determine the low-flow characteristics, 7Q2 and 7Q10, or the Tye River near Lovingston, Virginia (station 02027000). From plate 1, the entire basin is located in the Blue Ridge region. Drainage area is the only basin characteristic needed and is known to be 92.8 square miles. Using the equations in table 2 for the Blue Ridge region, the low-flow values 7Q2 and

7Q10 are computed as 9.8 and 2.6 ft^3/s, respectively. These differ from the low-flow values computed by actual streamflow data (19 and 5.0 ft^3/s, respectively) by 48 percent for the 7Q2 and 48 percent for the 7Q10.

Results, Reliability, and Limitations of Estimating Methods

Low-flow characteristics at a site are based on natural and man-made factors that affect low flows. Data collected to estimate these low-flow characteristics are subject to time-sampling errors primarily due to changes in climate and land use. Also, attempts to use low-flow values determined from unregulated conditions in basins that have become highly regulated or have rapidly changing land use should be avoided because the current low flows are based on the nature of the regulation and land use. Measures of reliability for low-flow values and problems that cause inaccurate estimates are discussed below for each site type.

Long-Term Continuous-Record Sites

Reliability of calculated low-flow values at long-term continuous-record sites depends on the length of data recorded, the time period the data were recorded, stability of basin characteristics, and type of statistical analysis applied to the data. The longer the period of record, the more representative the record should be of the hydrology of the site. Estimates of low-flow characteristics for a site based on 20 years of record would normally be better than estimates based on 10 years of record. More wet and dry periods may be sampled by the longer record and representative low-flow values can be determined. The shorter the period of record or more extreme the climatological conditions, the greater the time-sampling error of the estimated low-flow value. Streamflow records collected during extremely wet or dry climatic cycles may bias the low-flow characteristics. Characteristics based on data recorded forty or fifty years earlier may have changed with changes in land use; and unless historical and current data are supplied, no knowledge of this land-use change will exist. The easiest methods to determine if the low-flow values are biased because of time-sampling error or changes in land use is through analyses of climatological data and streamflow records at stations spanning long time periods. Changes in land use may be very gradual and not as easily recognizable. Plots of the annual low-flow values with time should be analyzed to determine if any trends exist before the data are used to determine the low-flow statistics.

Although Leatherwood Creek near Old Liberty, Virginia (station 02073500) is not a long-term continuous-record site, it provides an example of several of the problems mentioned above. Continuous data were collected for 8 climatic years between 1925 and 1934. Frequency curves were graphically fit to the annual low-flow data even though there are only 8 years of record. The estimated 7Q2 and 7Q10 values are 6.5 ft^3/s and 1.0 ft^3/s, respectively. Mean-daily discharges from this station were related with concurrent mean-daily discharges at stations 02070000 and 02074500, (both with more than 50 years of record). From these relations, estimates of the 7Q2 and 7Q10 values are 7.5 ft^3/s and 2.7 ft^3/s, respectively. Finally, 10 base-flow discharge measurements were made from 1981 to 1985. These were related to mean-daily discharges at stations 02070000, 02074500, and 02069700 with resulting estimates of 7Q2 and 7Q10 of 15 ft^3/s and 7.5 ft^3/s, respectively. Because of a severe drought during the early 1930's, estimates from the graphical frequency distribution should be less than the estimates from correlation of daily mean flows. Also, low-flow estimates from correlation of the 1930's continuous-record data should be close to low-flow estimates from correlation of the 1980's base-flow discharge measurement data. However, the estimates from the 1930's continuous-record data are substantially less than the estimates from the 1980's base-flow discharge measurement data. Because two of the correlation stations are used for both sets of relations, possible explanations for the differences are a change in land use or diversion of streamflow. A change in land use is probably the more correct reason of the two because all the data correlate extremely well with the long-term continuous-record sites.

Where current data were not available, attempts were made to update the low-flow characteristics at unregulated sites to present day values; however, this was not always possible. For example, 8 years of continuous record daily mean discharges collected during the drought of the 1930's are available for the Rivanna River below Moores Creek near Charlottesville, Virginia. There are no nearby long-term continuous-record stations with concurrent streamflow data available for correlation. The estimated low-flow values are known to be low but cannot be adjusted.

Low-flow characteristics derived from unregulated periods at a site that has become regulated have only regional importance, and characteristics based on regulated periods are useful only while the regulation scheme remains constant. Extreme caution must be used when discussing characteristics at regulated sites. Generally, low-flow characteristics for stream reaches that are affected by regulation cannot be used for planning purposes or correlation to unregulated sites. In this report, low-flow values computed from unregulated periods at currently regulated sites are used only for determining regression equations and accuracy of values at ungaged sites.

So far, discussion of errors has involved the collection of flow data. Reliability and limitations of low-flow characteristics due to the use of the Pearson Type III distribution are not analyzed in this report but are discussed in Hardison (1969), Hardison (1971), Kite (1977), and Rao (1980).

Short-Term Continuous-Record Sites and Partial-Record Sites

Reliability of calculated low-flow values at short-term continuous-record sites and partial-record sites depends on the reliability of the flow data collected at the short-term or partial-record site, the flow data and frequency analysis at the index sites, and the relation line between the related sites. In addition to problems already mentioned at long-term continuous-record sites, other time sampling errors may arise from low-flow data at short-term continuous-record sites and partial-record sites.

Selection of daily mean base-flow discharges at short-term continuous-record sites sampled the full range of base-flow discharges over the entire period of discharge record, so that a representative low-flow value could be computed. Only one daily mean, base-flow discharge for a single streamflow recession was selected. The discharge was selected so that the related station was also at base-flow conditions. A relation line was developed using a linear least-squares regression method on the logarithms of the concurrent daily mean discharges. The linear-regression line was plotted with the data and visually adjusted at lower discharges when necessary. The coefficient of determination, which indicates how well the regression line explains the observed values, was computed for each pair of related sites and given in appendix 3. There was no method for determining the reliability or error associated with extension of the relation line below the observed values to estimate the T-year event; however, the short-term continuous-record sites were related to several index sites where available. Analysis of the variation of the computed values from separate correlations indicates the reliability of the relation between the sites (Appendix 3) and reduces the possibility of chance correlations. Accuracy of low-flow characteristics estimated from correlation of daily mean, base-flow discharges is discussed in Hardison and Moss (1972).

The timing and distribution of base-flow discharge measurements at partial-record sites can influence the accuracy of the predicted low-flow values. By distributing the discharge measurements over several years and selecting the discharge so an adequate range of flows are sampled, a representative low-flow value can be computed. Analysis of measurement notes, climatological data, and hydrographs of the index sites were used to determine if the partial-record site and index site were at base-flow conditions. Less weight was given to those points that may have been influenced by runoff. Logarithms of the discharge measurement values at the partial-record site was plotted with logarithms of the concurrent daily mean discharge values at the index site. A relation line was visually fitted through the points. Because of the limited number of discharge measurements and nonlinearity of the relation lines, a statistically based relation line and associated coefficient of determination were not computed. Like the short-term continuous-record sites, there was no method for determining the reliability or error associated with extension of the relation line below the measured values to estimate the T-year event; however, the partial-record sites were related to several index sites where available. Analysis of the variation of the computed values from separate correlations indicates the reliability of the relation between the sites (Appendix 4) and reduces the possibility of chance correlations. Accuracy of low-flow characteristics estimated from correlation of base-flow measurements is discussed in Hardison and Moss (1972).

Ungaged Sites on Gaged Streams

The flow-routing method predicts low-flow values fairly well along gaged streams while the basin characteristics remain homogenous between the gaged site and ungaged site. Test were performed on the continuous-record data to determine the maximum distance data from a gaged site can be reliably transferred to an ungaged site.

The drainage-area ratio range was determined for the flow-routing equation by analyzing predictions at the 77 paired continuous-record sites described in the section "Methods for Determining Low-Flow Characteristics." The paired sites were ranked-ordered according to drainage-area ratio from maximum to minimum. The standard error of estimate as a percentage of the mean was calculated for both the 7Q2 and 7Q10 data sets. The paired sites with the largest drainage-area ratio was eliminated from the group and the standard error of estimate recalculated. Fifty paired sites were eliminated, in order, which reduced the maximum drainage-area ratio from 90.2 to 1.56. The standard error of estimate was calculated for the paired sites remaining in the group after each additional set of paired sites was eliminated. The logarithm of the standard error of estimate was plotted with the corresponding logarithm of the maximum drainage-area ratio for each group (fig. 8), and a relation line visually fitted. The slope of the relation line is well defined and linear for maximum drainage-area ratios of 1.6 to 4.0. A significant increase in standard error of estimate for the 7Q2 and a slight increase in standard error of estimate for the 7Q10 occurs when the maximum drainage-area ratio exceeded 4.0. A new slope of the relation line is established above the drainage-area ratio of 4.5 and remains constant until the maximum drainage-area ratio exceeds 16. Above this point, the slope of the relation line remains constant for the 7Q10 plot and increases for the 7Q2 plot.

The maximum drainage-area ratio for transferring low-flow characteristics is limited to 4.0 because of the large increase in standard error of estimate for drainage-area ratios of 4.0 to 5.0. This increase is probably not due to outliers because five of the six paired sites with drainage-area ratios of 4.0 to 5.0 had large percent errors (greater than 100 percent). The exponent in equation 2 was calculated again using only those sites with drainage-area ratios of 0.25 to 4.0 (54 paired sites). The exponent of 1.2 remained valid.

Reliability of estimates at ungaged sites on gaged streams is difficult to determine, however, analysis of standard errors of estimate can also be used to partially understand how well the method predicts low-flow characteristics. The standard error of estimate indicates how well predicted values fit measured values.

Low-flow characteristics were estimated at 108 sites (from the 54 paired sites) using the flow-routing method and equation 2. These values are compared to the values computed from continuous-record data. The standard error of estimate for predicting 7Q2 values at the 108 test sites is 19 ft^3/s or 19 percent of the mean. The standard error of estimate when predicting 7Q10 values for the same stations is 31 ft^3/s or 52 percent of the mean. For comparison to the regional regression equations, the standard error of prediction was computed using equation 6. The standard errors of prediction are 32 percent and 57 percent for the 7Q2 values and 7Q10 values, respectively.

When a site is estimated downstream from a gaged site, the results are well balanced. For 7Q2 values, 25 sites are underestimated, 28 sites are overestimated and 1 site is estimated exactly. For the 7Q10 values, 20 sites are underestimated, 30 sites are overestimated, and 4 sites are estimated exactly.

When the estimated site is upstream from a gaged site, the results are also balanced. For 7Q2 values, 27 sites are underestimated, 25 sites are overestimated, and 2 sites are estimated exactly. For 7Q10 values, 28 sites are underestimated 19 sites are overestimated, and 7 sites are estimated exactly. Errors tend to be greater when the predictions are made at sites with small drainage areas. One explanation is that there is greater variance in basin characteristics.

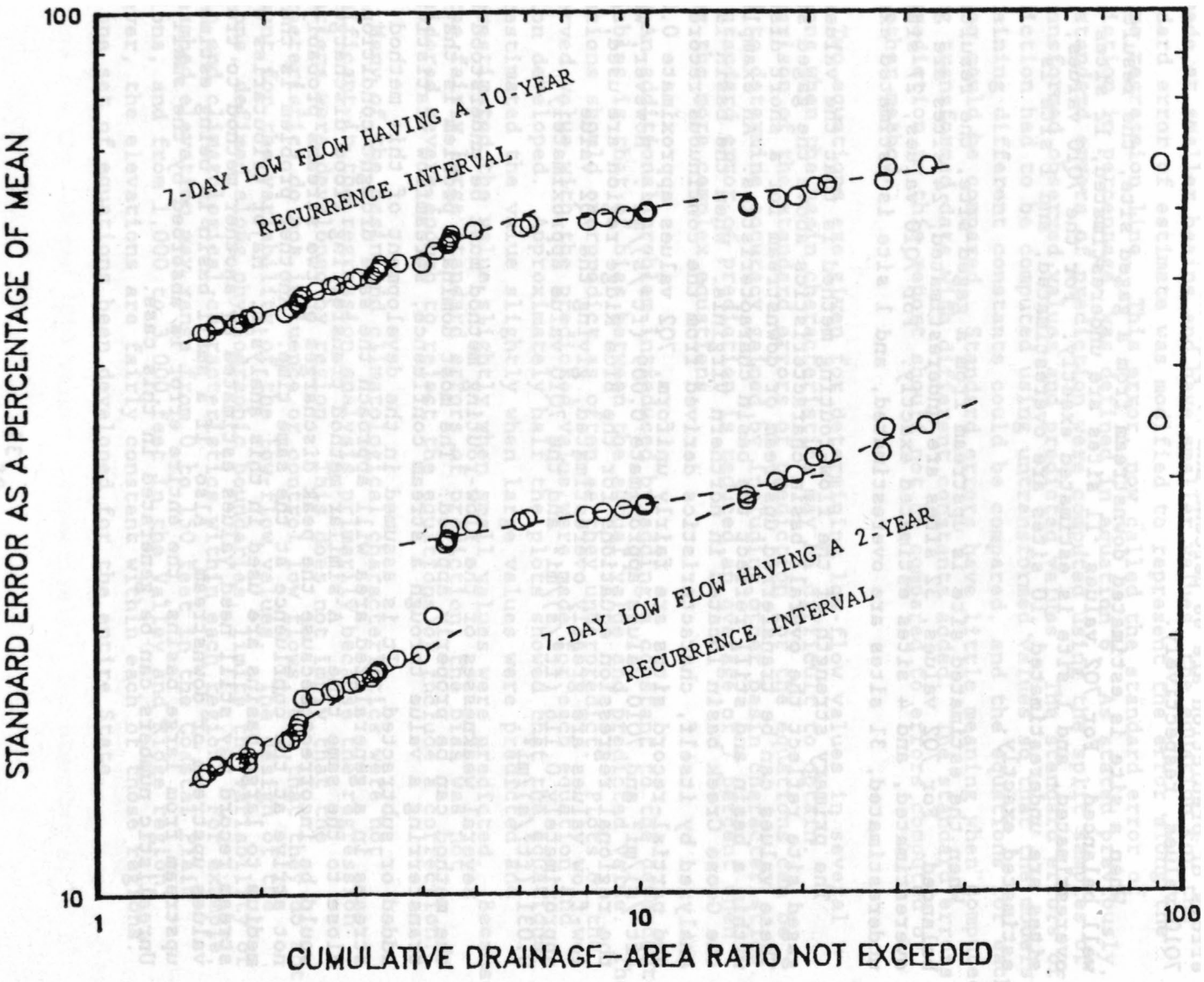

Figure 8.--Relation of cumulative drainage-area ratios and standard error of estimate.

The reliability of the more complex flow-routing method was determined by selection of 24 stream networks similar to those for the Tye River Basin (fig. 6). The stream networks were identified throughout the State where continuous-record stations are located. Predictions were made at the upstream as well as downstream stations. Low-flow values were estimated at each station using equation 2. The values are estimated at 84 sites using this method and compared to the values computed from continuous-record data. The standard error of estimate for predicting 7Q2 values at the 84 test sites is 15 ft^3/s or 15 percent of the mean. The standard error of estimate when predicting 7Q10 values for the same stations is 13 ft^3/s or 22 percent of the mean. For comparison to the regional regression equations, the standard error of prediction was computed using equation 6. The standard errors of prediction are 68 percent and 77 percent for the 7Q2 values and 7Q10 values, respectively.

When a site is estimated downstream from a gaged site, the results are well balanced. For 7Q2 values, 11 sites are underestimated, 12 sites are overestimated, and 1 site is estimated exactly. For the 7Q10 values, 13 sites are underestimated, 10 sites are overestimated, and 1 site is estimated exactly.

When the estimated site is upstream from a gaged site, the results are balanced. For 7Q2 values, 32 sites are underestimated, 24 sites are overestimated, and 4 sites estimated exactly. For 7Q10 values, 27 sites are underestimated, 31 sites are overestimated, and 1 site is estimated exactly.

The primary strength of the flow-routing method is that the values at a gaged site reflect the overall basin characteristics above the gaged site. These values can be transferred upstream or downstream for a short distance within a basin and still reflect the basin characteristics. An example is the Goose Creek basin located in northern Virginia. When the basin is analyzed by itself, characteristics derived from the continuous-record sites and partial-record sites are fairly uniform, 7Q2 values approximate 0.042 $(ft^3/s)/mi^2$ and 7Q10 values approximate 0.009 $(ft^3/s)/mi^2$. However, when the regional regression equations for the Blue Ridge region are used, the low-flow values are greatly overestimated, giving the 7Q2 value approximately 0.116 $(ft^3/s)/mi^2$ and the 7Q10 value approximately 0.031 $(ft^3/s)/mi^2$.

Several weaknesses of the flow-routing method must be understood before the method can be properly applied. The most dominant problem is that while transferring a value through a stream confluence, streamflow statistics are added or subtracted. It is assumed in the development of this method, streams in a generalized area will approach the same drought conditions at close to the same time. A similar method transferring flood discharges would be incorrect because the peak discharges on two streams probably will not arrive at the confluence at the same time. Another problem is that only medium to large basins are used in this analysis. Major tributaries without stream record may still need values estimated by another method to transfer values upstream or downstream. Also, if a small basin is being estimated upstream from large basins, the entire error is absorbed by the small basin. Unrealistic numbers can be generated in this case.

Ungaged Sites on Ungaged Streams

Reliability of low-flow characteristics based on regression equations can be estimated by analysis of how well the equations fit the actual data. The standard error of prediction is a good indicator. Standard errors of prediction in percentage are given in table 2 for each equation.

The standard error of estimate, which is normally used to show reliability, was not used for this portion of the study because it can give misleading results. The standard errors of estimate, given in cubic feet per second or as a percentage of the mean-sample value, represent the errors near the mean value only. Because the majority of predictions will normally be made at smaller basins and have smaller values, the equation for the standard error of estimate was modified to represent the error along the entire regression line. This error, now called the standard error of prediction in percentage, was defined in equation 6. As stated previously, the standard errors of prediction were computed using the split samples of untransformed observed values and predicted values. The standard errors of prediction had to be computed using untransformed values so that the models containing different constants could be compared, and the equations for each region could be compared. Standard errors have little meaning when computed using transformed data with different constants added. The standard errors of prediction in this report should not be compared to errors computed by any other method.

Two equations are given for determining low-flow values in several regions when the basin characteristics may be difficult to obtain. Comparison of the standard errors of prediction for the equations can be used to determine accuracy gained by including other basin characteristics. The standard error of prediction is reduced an average of 7 percent when using the more complex equations.

An additional problem introduced by adding a constant to the dependent variables is that of bias between the actual value and predicted value. The equations should overpredict as often as they underpredict. Plots of the observed value with the predicted value were made for each equation and region developed. Approximately half the plots showed that the equations overestimated the value slightly when large values were predicted and underestimated the value slightly when small values were predicted. Because of the fairly large standard errors of prediction, the bias was not considered severe enough to reject the equations or include a correction.

Many of the basin and climatological characteristics were not significant in the regression analysis primarily because the regression equations were developed by region. This does not imply that the characteristics do not influence or control low flows, but that they do not account for the variability of the low-flow values. The design of the regions, defined along physiographic boundaries, limits the variability of basin and climatological characteristics within each region. For example, streambed elevation may range from 0 to 150 feet in the Coastal Plain regions, and from 1,000 to 3,000 feet in the Valley and Ridge region; however, the elevations are fairly constant within each of those regions. Had one set of equations been developed for the entire State, characteristics such as streambed slope and streambed elevation may have been highly significant and remained in the equation. Results for each region follow.

Coastal Plain region

Plots of unit low-flow values on a map of the gaging stations in the Coastal Plain indicate a difference in the values above and below the James River. South of the James River (southern region), the area is agriculturally intensive with a loose sandy soil and low relief. Three quarters of the 7Q10 values were less than 0.001 $(ft^3/s)/mi^2$, resulting in an assigned value of 0.0 ft^3/s. No relation could be determined between the 7Q2 values and drainage area or any other basin characteristic; therefore, no equation was developed. In the southern region, 28 partial-record sites and 5 continuous-record sites were used in the regression analysis. Drainage areas ranged from 0.61 to 456 square miles.

North of the James River (northern region), there is less agricultural land, soils contain more clay, and there is greater relief. Equations were developed for both the 7Q2 and 7Q10 values; however, drainage area (A) was the only basin characteristic that was significant. Standard errors of prediction are 88 and 118 percent for the 7Q2 and 7Q10 regression equations, respectively. In the northern region, 62 partial-record sites and 11 continuous-record sites were used in the regression analysis. Drainage areas range from 0.28 to 108 square miles.

Piedmont region

Drainage area (A) and percent area underlain by Triassic and Jurassic sedimentary rock (TJ) are the two basin characteristics that remained significant during regression analysis of the data in the Piedmont province. The majority of the Piedmont province consists of igneous and metamorphic rock. About 20 percent of the province consists of Triassic and Jurassic sedimentary rock. The Triassic and Jurassic sedimentary rocks produce much lower base flows than the igneous rock. Analysis of residuals plotted on station location maps showed three regional groupings of data, the Piedmont northern region, Piedmont southern region, and Piedmont/Blue Ridge transition region.

The Piedmont northern region, (Rappahannock River basin and north) has the largest standard errors of prediction for any of the regression equations. The standard errors of prediction for the equations with drainage area as the only variable are 139 and 172 percent for 7Q2 and 7Q10 regression equations, respectively. Many of the stations used in the regression analysis had small drainage basins (mean drainage area of sites sampled is 18 square miles) and are somewhat urbanized. There are large variations in low-flow values in relation to drainage area. Percent area underlain by Triassic and Jurassic sedimentary rock was significant in the regression of the 7Q2 values but not for the 7Q10 values; therefore, only one additional equation is developed for this region including rock type as a variable. By including percent area underlain by Triassic and Jurassic sedimentary rock in the regression equation, the standard error of prediction reduced to 124 percent for the 7Q2 regression equation. In the northern region, 59 partial-record sites and 23 continuous-record sites were used in the regression analysis. Drainage area range from 0.08 to 155 square miles.

In the Piedmont southern region, sites have larger drainage basins (mean drainage area of sites sampled is 49 square miles) and are less urbanized. Reduced variation of the low-flow values is shown by standard errors of prediction of 98 and 125 percent for the 7Q2 and 7Q10 regression equations, respectively. Percent area underlain by Triassic sedimentary rock was eliminated from the analysis. At only 6 of the 86 sites is more than 20 percent of the basin area underlain by Triassic sedimentary rock. At 69 sites, no area is underlain by Triassic sedimentary rock. In the southern region, 59 partial-record sites and 27 continuous-record sites were used in the regression analysis. Drainage areas range from 0.33 to 269 square miles.

Piedmont/Blue Ridge transition region

The southwestern area of the Piedmont and the southeastern area of the Blue Ridge were grouped together. This is considered a transition zone because it is not as mountainous as the Blue Ridge, yet land surface is higher and gradients are steeper than most of the Piedmont. Drainage area (A) was the only basin characteristic that remained significant in the regression analysis. Resulting standard errors of prediction were 60 and 90 percent for the 7Q2 and 7Q10 regression equations, respectively. Percent area underlain by Triassic sedimentary rock was not included in the regression analysis because only 2 of the 35 sites were underlain by any Triassic sedimentary rock. In the Piedmont/Blue Ridge transition region, 24 partial-record sites and 11 continuous-record sites were used in the regression analysis. Drainage areas range from 0.46 to 278 square miles.

Blue Ridge region

Drainage area (A) was the only basin characteristic that remained significant in the regression analysis. As stated earlier, sites in the southeastern Blue Ridge province grouped together and were included in the Piedmont/Blue Ridge transition region. Eliminating the stations in the southeastern portion of the province reduced the standard error of prediction for the 7Q2 regression equation from approximately 100 to 85 percent. The standard error of prediction for the 7Q10 regression equation was not reduced substantially and remained at 111 percent. In the Blue Ridge region, 61 partial-record sites and 22 continuous-record sites were used in the regression analysis. Drainage areas range from 0.78 to 188 square miles.

Valley and Ridge region

Drainage area (A) and percent area underlain by Devonian and Mississippian sedimentary rock (DM) were the only basin characteristics that remained significant in the regression analysis. For the equations containing drainage area and percent area underlain by Devonian and Mississippian sedimentary rock, standard errors of prediction are 87 and 96 percent for the 7Q2 and 7Q10 values, respectively. The standard error of prediction are slightly higher--91 and 102 percent for the 7Q2 and 7Q10 regression equations, respectively--when drainage area is the only independent variable. The small differences in standard errors indicates that the Devonian and Mississippian sedimentary rock is hydrologically similar to the rest of the basin material, or that the region is well mixed geologically. In the Valley and Ridge region, 58 partial-record sites and 49 continuous-record sites were used in the regression analysis. Drainage areas range from 0.61 to 277 square miles.

Appalachian Plateaus region

In the Appalachian Plateaus region, drainage area (A), stream length, and strip-mined area (SM) remained significant in the regression analysis. Analysis of the correlation matrix showed that stream length was highly related to drainage area and strip-mined area. Therefore, stream length was eliminated from the regression equation. The high correlation between stream length and drainage area and strip-mined area may be due to the method of site selection. The basins are small (mean drainage area is 13.3 square miles), and are greatly disturbed by both strip-mining and deep-mining. For the equations containing drainage area and percent area strip mined, standard errors of prediction are 103 and 115 percent for the 7Q2 and 7Q10 values, respectively. The standard error of prediction are slightly higher--105 and 123 percent for the 7Q2 and 7Q10 regression equations, respectively--when drainage area is the only independent variable. In the Appalachian Plateaus region, 107 partial-record sites and 10 continuous-record sites were used in the regression analysis. Drainage areas range from 0.17 to 87.4 square miles.

The Appalachian Plateaus region is one of the smallest regions in the analysis and contains the largest number of sites. However, the standard errors for the regression equations may not be representative of the errors in relation to the other regions because of possible serial correlation. Fifteen long-term continuous-record sites were used to estimate low-flow values at 107 partial-record sites. Normally, the partial-record sites correlated well with only one continuous-record site. Also, the size of the basins for the partial-record sites (mean drainage area is 10 square miles) is much smaller than the size of the basins for the continuous-record sites (mean drainage area is 245 square miles). Additional analysis would probably not improve the regression equations significantly, but may adjust the standard errors to be more representative of the errors in relation to the other regions.

SUMMARY

Streamflow data were collected and low-flow characteristics computed for 715 gaged sites in Virginia. Annual minimum average 7-consecutive-day flow range from 0 to 2,190 cubic feet per second for a 2-year recurrence interval and from 0 to 1,420 cubic feet per second for a 10-year recurrence interval. Drainage areas for the sites range from 0.17 to 7,320 square miles.

Methods for determining low-flow characteristics at gaged sites depend on the type of unregulated surface-water data collected and length of the record. Existing and discontinued gaged sites were separated into three types: long-term continuous-record sites, short-term continuous-record sites, and partial-record sites. Low-flow characteristics for long-term continuous-record sites were determined from frequency curves of annual minimum average 7-consecutive-day flows. Frequency curves were fitted to the logarithm of the data by use of the Pearson Type III distribution, and plots of the data were checked visually for accuracy of fit. Low-flow characteristics for short-term continuous-record sites were estimated by relating logarithms of daily mean base-flow discharge values at the sites to logarithms of concurrent daily mean discharge values at nearby long-term continuous-record sites that have similar basin characteristics. Low-flow characteristics for partial-record sites were estimated by relating base-flow discharge measurements to daily mean discharge values at long-term continuous-record sites. The low-flow characteristics were transferred from the long-term station through the relation line to the short-term or partial-record site.

Information from the continuous-record and partial-record sites in Virginia were used to develop two techniques for estimating low-flow characteristics at ungaged sites. A flow-routing method was developed to estimate low-flow values at ungaged sites on gaged streams. Regional regression equations were developed for estimating low-flow values at ungaged sites on ungaged streams.

The flow-routing method consists of transferring low-flow characteristics from a gaged site, either upstream or downstream, to the ungaged site of interest. A simple drainage area proration is used to transfer values when there are no major tributaries between the gaged and ungaged site. The flow-routing equation consists of a drainage-area ratio to the 1.2 power and is limited to drainage-area ratios from 0.25 to 4.0. Predicted values were compared to observed values for 108 test sites. Standard errors of estimate were 19 percent of the mean for estimates of low-flow characteristics having a 2-year recurrence interval and 52 percent of the mean for estimates of low-flow characteristics having a 10-year recurrence interval. When major tributaries enter between the gaged and ungaged site, a more complex flow-routing method was used to estimate low-flow characteristics. The system entails the transfer of values to the stream confluence, the addition or subtraction of the values, depending on direction of routing; and the transfer of the combined value to the next confluence until the ungaged site is reached. Twenty four stream-networks were analyzed by comparing predicted values with observed values at 84 test sites. Standard errors of estimate were 15 percent of the mean for estimates of low-flow characteristics having a 2-year recurrence interval and 22 percent of the mean for estimates of low-flow characteristics having a 10-year recurrence interval. The primary strength of the flow-routing method is that the values at a gaged site reflect the overall basin characteristics above that site. Normally, these values can be transferred upstream or downstream for a short distance within a basin and still reflect the basin characteristics. The principal weakness is that as a value is transferred through a stream confluence, streamflow statistics are added or subtracted. It was assumed in the development of the method that the streamflow in each tributary within a basin will reflect similar statistical conditions.

Regional regression equations were developed for estimating low-flow values at ungaged sites on ungaged streams. The State was divided into eight regions on the basis of physiography and the geographic grouping of residuals computed in regression analysis. Basin characteristics that were significant in the regression analysis are drainage area, rock type, and strip-mined area. Standard errors of prediction range from 60 to 139 percent for estimates of low-flow characteristics having a 2-year recurrence interval, and 90 to 172 percent for estimates of low-flow characteristics having a 10-year recurrence interval.

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GLOSSARY

Base flow: The contribution of flow in a stream from ground-water or spring effluent.

Climatic year: A continuous 12-month period in which a complete climatic cycle exist. It is usually designated by the year in which the majority of the 12 months occur. The climatic year used in this report for presentation of low-flow characteristics, is from April 1 through March 31. The year begins and ends during the period of increased flows so that the flows during a single dry season are included in annual values for that year.

Continuous-record gaging station: A site on a stream where continuous records of gage height are collected, and daily mean discharge is computed. Data from a continuous-record station are expected to be representative of the hydrology in the basin upstream.

Cubic feet per second (ft^3/s): A unit expressing rate of flow. It is the volume of water passing a point on a stream per unit of time. 1 ft^3/s = 448.8 gallons per minute.

Drainage area: The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide. All streamflow that passes the specified location will have its origin within the drainage basin.

Gage height: The water-surface elevation referenced to some arbitrary gage datum. It is often used interchangeably with the term stage.

Partial-record gaging station: A site on a stream where periodic measurements are collected, usually for a period of years. The data collected at partial-record sites are often correlated to data at nearby continuous-record gaging stations to estimate hydrologic information at the partial-record sites.

Recurrence interval: The average interval of time within which the magnitude of an extreme event will be exceeded once. For low flow, the recurrence interval is the average interval of time between occurrences of a low flow less than a given magnitude. The major recurrence intervals used in this report are 2-year and 10-year. A 10-year low-flow discharge is a value that, on the average, the flow will be less than, once every 10 years. Thus, there is 1 chance in 10 that flows will drop below that discharge in any year. The 10-year low-flow discharge could be met in consecutive years; however, on the average, the discharge will be met only once in 10 years. The 7-day, 10-year low-flow discharge (7Q10) is the annual minimum average 7-consecutive-day discharge having a 10-year recurrence interval, and the 7-day, 2 year low-flow discharge (7Q2) is the annual minimum average 7-consecutive-day discharge having a 2-year recurrence interval.

Water year: The 12-month period, October 1 through September 30, designated by the calendar year in which the period ends. For example, the 1984 water year is the period October 1, 1983 through September 30, 1984. Average discharge and flow-duration data are computed using the water-year timeframe. The water year ends and begins during the period of low flow so that the majority of runoff is included in annual values for a single year.

APPENDIXES

Appendix 1.--Magnitude and frequency of average minimum 7-consecutive-day discharge at continuous-record gaging stations on streams in Virginia

[Low-flow values followed by "g" indicate that the value was determined graphically]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	Annual 7-day low flow for recurrence interval, in cubic feet per second: 10-year
01484800	Guy Creek near Nassawadox, Va.	373008	0755222	1.72	0.13	0.04
01613900	Hogue Creek near Hayfield, Va.	391252	0781718	15.0	.75	.37
01615000	Opequon Creek near Berryville, Va.	391040	0780420	57.4	4.5	1.4
01615500	Abrams Creek at Winchester, Va.	390950	0781015	5.60	1.2	.85
01616000	Abrams Creek near Winchester, Va.	391040	0780510	16.5	9.6	6.5
01620500	North River near Stokesville, Va.	382015	0791425	17.2	.68	.21
01621000	Dry River at Rawley Springs, Va.	383010	0790314	72.6	.83	.12
01622000	North River near Burketown, Va.	382025	0785450	379	58	39
01623000	Bell Creek at St Pauls Chapel near Staunton, Va.	381000	0790735	.61	.0	.0
01623500	Bell Creek near Staunton, Va.	381100	0790705	3.80	.0	.0
01624000	Bell Creek at Franks Mill near Staunton, Va.	381310	0790635	9.60	.0	.0
01624300	Middle River near Verona, Va.	381436	0790208	178	39	28
01624800	Christians Creek near Fisherville, Va.	380742	0785941	70.1	17	11
01625000	Middle River near Grottoes, Va.	381542	0785144	375	77	52
01626000	South River near Waynesboro, Va.	380327	0785430	127	30	24
01626500	South River at Waynesboro, Va.	380340	0785350	144	37	26
01626850	South River near Dooms, Va.	380519	0785238	149	55	45
01627500	South River at Harriston, Va.	381307	0785013	212	66	48
01628060	White Oak Run near Grottoes, Va.	381501	0784457	1.94	.0	.0
01628150	Deep Run near Grottoes, Va.	381623	0784536	1.17	.09	.05
01628500	South Fork Shenandoah River near Lynnwood, Va.	381921	0784518	1,084	227	147
01631000	South Fork Shenandoah River at Front Royal, Va.	385450	0781240	1,642	344	235
01632000	North Fork Shenandoah River at Cootes Store, Va.	383813	0785111	210	3.2	.77
01632900	Smith Creek near New Market, Va.	384136	0783835	93.2	14	8.0
01633000	North Fork Shenandoah River at Mount Jackson, Va.	384444	0783821	506	37	18
01633500	Stony Creek at Columbia Furnace, Va.	385155	0783745	79.4	5.8	3.3
01634500	Cedar Creek near Winchester, Va.	390452	0781947	103	7.7	4.3
01635500	Passage Creek near Buckton, Va.	385729	0781601	87.8	2.8	1.3
01638480	Catoctin Creek at Taylorstown, Va.	391516	0773436	89.6	6.8	2.9
01643700	Goose Creek near Middleburg, Va.	385911	0774749	123	6.0	.71
01644000	Goose Creek near Leesburg, Va.	390110	0773440	332	12	2.5
01644291	Stave Run near Reston, Va.	385656	0772216	.08	.0	.0
01644295	Smilax Branch at Reston, Va.	385710	0772204	.32	.0	.0
01646000	Difficult Run near Great Falls, Va.	385833	0771446	57.9	12	3.0
01652500	Fourmile Run at Alexandria, Va.	385036	0770446	13.8	1.7	1.1
01653000	Cameron Run at Alexandria, Va.	384820	0770608	33.7	3.1	1.7
01654000	Accotink Creek near Annandale, Va.	384846	0771343	23.5	2.9 g	.43 g
01654500	Long Beach near Annandale, Va.	384839	0771407	3.71	.50	.06
01655000	Accotink Creek near Accotink station, Va.	384515	0771209	37.0	3.8	.56
01656100	Cedar Run near Aden, Va.	383658	0773316	155	2.5	.45 g
01656500	Broad Run at Buckland, Va.	384650	0774022	50.5	3.2	.92
01656725	Bull Run near Catharpin, Va.	385321	0773414	25.8	.16	.0
01656960	Cub Run near Bull Run, Va.	384916	0772757	49.9	1.6 g	.15 g
01657500	Occoquan River near Occoquan, Va.	384220	0771935	570	30	8.4
01657655	Hooes Run near Occoquan, Va.	384048	0771725	3.97	.10	.01
01658480	Quantico Creek near Dumfries, Va.	383422	0772051	6.90	.23	.01
01658500	South Fork Quantico Creek near Independent Hill, Va.	383514	0772544	7.64	.08	.0
01658550	South Fork Quantico Creek at Camp 5 near Joplin, Va.	383438	0772436	9.61	.51	.04
01658650	South Fork Quantico Creek near Dumfries, Va.	383418	0772057	16.6	.90	.06
01659000	North Branch Chopawamsic Creek near Independent Hill, Va.	383358	0772548	5.79	.07	.0

Appendix 1.--Magnitude and frequency of average minimum 7-consecutive-day discharge at continuous-record gaging stations on streams in Virginia--Continued

[Low-flow values followed by "g" indicate that the value was determined graphically]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
01659500	Middle Fork Chopawamsic Creek near Garrisonville, Va.	383326	0772532	4.51	0.07	0.0
01660000	South Branch Chopawamsic Creek near Garrisonville, Va.	383222	0772530	2.56	.06	.0
01660400	Aquia Creek near Garrisonville, Va.	382925	0772602	34.9	.90 g	.01 g
01661800	Bush Mill Stream near Heathsville, Va.	375236	0762942	6.82	.70	.13
01661900	Carter Run near Marshall, Va.	384758	0775209	19.5	1.8	.52
01662000	Rappahannock River near Warrenton, Va.	384105	0775415	195	13	2.5
01662500	Rush River at Washington, Va.	384250	0780905	14.7	.34	.0
01662800	Battle Run near Laurel Mills, Va.	383920	0780427	27.6	2.0	.34
01663000	Thornton River near Laurel Mills, Va.	383741	0780347	142	10.5 g	1.4 g
01663500	Hazel River at Rixeyville, Va.	383530	0775755	287	28	6.1
01664000	Rappahannock River at Remington, Va.	383150	0774850	620	50	11
01664500	Rappahannock River at Kellys Ford, Va.	382838	0774653	641	80	11
01665500	Rapidan River near Ruckersville, Va.	381650	0782025	114	15	4.3
01666500	Robinson River near Locust Dale, Va.	381930	0780545	179	31	9.7
01667000	Rapidan River at Rapidan, Va.	381847	0780350	446	72	14
01668500	Cat Point Creek near Montross, Va.	380223	0764938	45.6	2.0	.08
01668800	Hoskins Creek near Tappahannock, Va.	375538	0765716	15.5	2.8 g	.54 g
01669000	Piscataway Creek near Tappahannock, Va.	375237	0765403	28.0	4.0	.83
01669500	Dragon Swamp near Church View, Va.	374105	0764337	84.9	3.1	.0
01669520	Dragon Swamp at Mascot, Va.	373801	0764148	108	5.5	.64
01670000	Beaverdam Swamp near Ark, Va.	372814	0763348	6.63	.50	.02 g
01670300	Contrary Creek near Mineral, Va.	380353	0775245	5.53	.18	.04
01671100	Little River near Doswell, Va.	375221	0773048	107	3.5	.58
01671500	Bunch Creek near Boswells Tavern, Va.	380154	0781130	4.37	.17	.0
01672500	South Anna River near Ashland, Va.	374748	0773257	394	34	9.7
01673500	Totopotomoy Creek near Atlee, Va.	374009	0772258	5.89	.20	.06
01673550	Totopotomoy Creek near Studley, Va.	373945	0771529	26.2	3.4	.93
01673800	Po River near Spotsylvania, Va.	381017	0773542	77.4	1.5	.22
01674000	Mattaponi River near Bowling Green, Va.	380342	0772310	257	8.0	.68
01677000	Ware Creek near Toano, Va.	372017	0764712	6.29	.58	.22
02011400	Jackson River near Bacova, Va.	380232	0795254	158	26	20.
02011460	Back Creek near Sunrise, Va.	381443	0794608	56.7	4.2	2.1
02011480	Back Creek on Rt 600 near Mountain Grove, Va.	380805	0795157	85.8	5.5	2.5
02011500	Back Creek near Mountain Grove, Va.	380410	0795350	134	7.7	3.6
02012000	Falling Springs Creek near Falling Springs, Va.	375205	0795645	11.5	5.4	4.5
02012500	Jackson River at Falling Spring, Va.	375236	0795839	411	81	64.
02013000	Dunlap Creek near Covington, Va.	374810	0800250	164	15	11.
02014000	Potts Creek near Covington, Va.	374344	0800233	153	24	17
02014500	Smith Creek above Old Dam near Clifton Forge, Va.	375105	0795048	12.4	1.2	.87
02015000	Smith Creek near Clifton Forge, Va.	375103	0795033	12.5	2.6	1.9
02015700	Bullpasture River at Williamsville, Va.	381143	0793414	110	30	25
02016000	Cowpasture River near Clifton Forge, Va.	374730	0794535	461	73	54
02017000	Meadow Creek at New Castle, Va.	372935	0800635	13.8	3.1	1.9
02017500	Johns Creek at New Castle, Va.	373022	0800625	104	11	7.8
02018000	Craig Creek at Parr, Va.	373957	0795442	329	43	31.
02018500	Catawba Creek near Catawba, Va.	372805	0800020	34.3	4.0	2.1
02019000	Catawba Creek near Fincastle, Va.	373300	0795005	104	11	7.5
02019500	James River at Buchanan, Va.	373150	0794045	2,075	378	271
02020500	Calfpasture River above Mill Creek at Goshen, Va.	375916	0792938	144	4.8	1.7
02021000	Calfpasture River at Goshen, Va.	375910	0792938	190	14.	8.5

Appendix 1.--Magnitude and frequency of average minimum 7-consecutive-day discharge at continuous-record gaging stations on streams in Virginia--Continued

[Low-flow values followed by "g" indicate that the value was determined graphically]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second 2-year	10-year
02021500	Maury River at Rockbridge Baths, Va.	375426	0792520	329	24	14
02022500	Kerrs Creek near Lexington, Va.	374932	0792636	35.0	6.8	4.9
02023000	Maury River near Lexington, Va.	374849	0792642	487	66	43
02024000	Maury River near Buena Vista, Va.	374545	0792330	646	89	62
02025000	Pedlar River near Pedlar Mills, Va.	373225	0791510	91.0	9.8	3.0 g
02026000	James River at Bent Creek, Va.	373210	0784930	3,683	730	449
02026500	Tye River at Roseland, Va.	374513	0785912	68.0	15.	3.1 g
02027000	Tye River near Lovingston, Va.	374255	0785855	92.8	19.	5.0
02027500	Piney River at Piney River, Va.	374208	0790140	47.6	7.9	3.2
02027800	Buffalo River near Tye River, Va.	373620	0785525	147	28	7.9
02028000	Buffalo River near Norwood, Va.	373740	0785250	360	81	37
02028500	Rockfish River near Greenfield, Va.	375210	0784925	94.6	15	4.1 g
02029000	James River at Scottsville, Va.	374750	0782930	4,584	871	508
02029500	Hardware River near Scottsville, Va.	375024	0782828	104	20	4.2
02030000	Hardware River below Briery Run near Scottsville, Va.	374845	0782720	116	24 g	7.5 g
02030500	Slate River near Arvonia, Va.	374210	0782240	226	34	9.5
02031000	Mechums River near White Hall, Va.	380609	0783535	95.4	16 g	1.6 g
02031500	North Fork Moormans River near Whitehall, Va.	380825	0784505	11.4	.33	.0
02032400	Buck Mountain Creek near Free Union, Va.	380916	0783222	37.0	3.9	.88
02032680	North Fork Rivannia River near Proffit, Va.	380516	0782444	176	29.4	8.17
02033500	Rivannia River below Moores Creek near Charlottesville, Va.	380109	0782713	507	48 g	4.8 g
02034500	Willis River at Lakeside Village, Va.	374000	0781000	262	26.8	7.19
02035000	James River at Cartersville, Va.	374015	0780510	6,257	1,120	584
02035500	Lickinghole Creek near Goochland, Va.	374131	0775722	70.0	7.4	4.7
02036500	Fine Creek at Fine Creek Mills, Va.	373552	0774912	22.1	2.0	.47
02038000	Falling Creek near Chesterfield, Va.	372637	0773121	32.8	1.8 g	.64 g
02038850	Holiday Creek near Andersonville, Va.	372455	0783810	8.53	1.6 g	.52 g
02039000	Buffalo Creek near Hampden Sydney, Va.	371525	0782912	69.7	15	6.0
02039500	Appomattox River at Farmville, Va.	371825	0782320	303	52	21
02040000	Appomattox River at Mattoax, Va.	372517	0775133	726	86 g	30 g
02041000	Deep Creek near Mannboro, Va.	371659	0775212	158	12	1.4
02042000	Swift Creek near Chester, Va.	371855	0772940	143	4.2	.75
02042500	Chickahominy River near Providence Forge, Va.	372610	0770340	248	16	4.0
02043500	Cypress Swamp at Cypress Chapel, Va.	363724	0763607	23.8	.0	.0
02044000	Nottoway River near Burkeville, Va.	370440	0781150	38.7	.92	.11
02044500	Nottoway River near Rawlings, Va.	365900	0774800	309	26	4.0
02045000	Nottoway River near Mckenney, Va.	365645	0774355	362	33	4.0
02046000	Stony Creek near Dinwiddie, Va.	370401	0773610	112	4.3 g	.25
02047000	Nottoway River near Sebrell, Va.	364613	0770959	1,421	82	24
02047100	Assamoosick Swamp near Sebrell, Va.	364622	0770557	86.4	.06	.0
02047500	Blackwater River near Dendron, Va.	370130	0765230	294	1.3	.0 g
02048000	Blackwater River at Zuni, Va.	365205	0765007	456	4.1	.07
02048500	Seacock Creek at Unity, Va.	364915	0765300	102	.17	.0
02050500	North Meherrin River near Keysville, Va.	370305	0782520	9.20	.54	.21
02051500	Meherrin River near Lawrenceville, Va.	364300	0774955	552	52	16
02051600	Great Creek near Cochran, Va.	364846	0775519	30.7	3.1 g	.35 g
02052000	Meherrin River at Emporia, Va.	364124	0773227	747	60	23
02052500	Fountains Creek near Brink, Va.	363655	0774200	65.2	.76	.0
02053800	South Fork Roanoke River near Shawsville, Va.	370824	0801600	110	21	11 g
02054500	Roanoke River at Lafayette, Va.	371411	0801234	257	42	24

Appendix 1.--Magnitude and frequency of average minimum 7-consecutive-day discharge at continuous-record gaging stations on streams in Virginia--Continued

[Low-flow values followed by "g" indicate that the value was determined graphically]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second 2-year	10-year
02055000	Roanoke River at Roanoke, Va.	371530	0795620	395	58	35
02055100	Tinker Creek near Daleville, Va.	372503	0795608	11	2.2	1.4
02056650	Back Creek near Dundee, Va.	371340	0795206	56.8	5.5	2.2
02056900	Blackwater River near Rocky Mount, Va.	370242	0794540	115	23	9.1
02057000	Blackwater River near Union Hall, Va.	370235	0794107	208	66	26 g
02057500	Roanoke (Staunton) River near Toshes, Va.	370203	0793118	1,020	246	142
02058000	Snow Creek at Sago, Va.	365350	0793905	60.0	20	10
02058500	Pigg River near Toshes, Va.	365901	0793052	394	131	66
02059500	Goose Creek near Huddleston, Va.	371023	0793114	188	40	23
02060500	Roanoke River at Altavista, Va.	370616	0791744	1,789	492	266
02061000	Big Otter River near Bedford, Va.	372150	0792510	116	17	7.3
02061500	Big Otter River near Evington, Va.	371230	0791814	320	69	28
02062000	Big Otter River near Altavista, Va.	371105	0791645	372	51	21
02062500	Roanoke (Staunton) River at Brookneal, Va.	370228	0785702	2,415	648	344
02063000	Caldwells Creek near Appomattox, Va.	371940	0785120	5.10	.84	.40
02063500	Falling River at Spring Mills, Va.	371440	0785500	52.2	9.5	3.6
02064000	Falling River near NaRuna, Va.	370736	0785736	173	32	15
02064500	Little Falling River at Hat Creek, Va.	370750	0785450	43.0	4.6	1.5
02065500	Cub Creek at Phenix, Va.	370445	0784550	98.0	22	8.2
02066000	Roanoke (Staunton) River at Randolph, Va.	365454	0784428	2,977	847	426
02066500	Roanoke Creek at Saxe, Va.	365549	0783956	135	8.7	.80 g
02067000	Roanoke (Staunton) River near Clover, Va.	365017	0784002	3,230	914	433
02069700	South Mayo River near Nettleridge, Va.	363415	0800747	84.6	44	27
02070000	North Mayo River near Spencer, Va.	363405	0795915	108	44	25
02072500	Smith River at Bassett, Va.	364612	0800004	259	125	95
02073500	Leatherwood Creek near Old Liberty, Va.	363810	0794730	68.0	15	7.5
02074500	Sandy River near Danville, Va.	363710	0793016	112	29	15
02075000	Dan River at Danville, Va.	363515	0792255	2,050	739	515
02076500	Georges Creek near Gretna, Va.	365611	0791842	9.24	3.2	1.6 g
02078000	Hyco River near Omega, Va.	363809	0784820	413	14	2.7 g
02079000	Roanoke (Staunton) River at Clarksville, Va.	363740	0783304	7,320	2,195	1,423
02079640	Allen Creek near Boydton, Va.	364046	0781937	53.4	.94	.03
03164000	New River near	363850	0805845	1,131	611	400
03165500	New River at Ivanhoe, Va.	365005	0805710	1,340	663	427
03166000	Cripple Creek near Ivanhoe, Va.	365135	0805850	148	38	27
03166800	Glade Creek at Grahams Forge, Va.	365551	0805402	7.15	.14	.10
03167000	Reed Creek at Grahams Forge, Va.	365622	0805313	247	70	52
03167500	Big Reed Island Creek near Allisonia, Va.	365320	0804340	278	146	101
03168000	New River at Allisonia, Va.	365615	0804445	2,202	1,040	725
03168500	Peak Creek at Pulaski, Va.	370250	0804635	60.9	3.8	2.5
03170000	Little River at Graysonton, Va.	370215	0803325	300	109	69
03171500	New River at Eggleston, Va.	371722	0803701	2,941	1,280 g	770 g
03172500	Walker Creek at Staffordsville, Va.	371430	0804240	277	36	24
03173000	Walker Creek at Bane, Va.	371605	0804235	305	44	33
03175500	Wolf Creek near Narrows, Va.	371820	0805100	223	35	23
03176500	New River at Glen Lyn, Va.	372222	0805139	3,768	1,700 g	800 g
03207800	Levisa Fork at Big Rock, Va.	372113	0821145	297	24	8.3 g
03208034	Grissom Creek near Council, Va.	370443	0820225	2.82	.0	.0
03208036	Barton Fork near CounciL, Va.	370437	0820221	1.23	.02	.0
03208040	Russell Fork at CounciL, Va.	370441	0820356	10.2	.12	.01
03208100	Russell Fork near Birchleaf, Va.	370950	0821520	87.4	.95	.04
03208500	Russell Fork at Haysi, Va.	371225	0821745	286	8.7 g	1.0 g
03208700	North Fork Pound River at Pound, Va.	370732	0823736	18.5	1.0	.32
03208900	Pound River near Georges Fork, Va.	370951	0823130	82.5	7.1	3.2
03208950	Cranes Nest River near Clintwood, Va.	370726	0822620	66.5	4.6	1.9

Appendix 1.--Magnitude and frequency of average minimum 7-consecutive-day discharge at continuous-record gaging stations on streams in Virginia--Continued

[Low-flow values followed by "g" indicate that the value was determined graphically]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second 2-year	10-year
03209000	Pound River below Flannagan Dam near Haysi, Va.	371413	0822036	221	4.1	.61
03213590	Knox Creek at Kelsa, Va.	372702	0820334	84.3	3.0	.80
03471500	South Fork Holston River at Riverside near Chilhowie, Va.	364537	0813753	76.1	25.	20.
03472500	Beaverdam Creek at Damascus, Va.	363740	0814728	56.0	9.5	4.7
03473000	South Fork Holston River near Damascus, Va.	363906	0815039	301	99	73.
03474000	Middle Fork Holston River at Seven Mile Ford, Va.	364826	0813720	132	34	27
03474500	Middle Fork Holston River at Chilhowie, Va.	364745	0814050	155	40	25
03475000	Middle Fork Holston River near Meadowview, Va.	364247	0814908	211	65	50
03477500	Beaver Creek near Wallace, Va.	363825	0820642	13.7	4.5	3.2
03478400	Beaver Creek at Bristol, Va.	363754	0820802	27.7	11.	8.5
03487800	Lick Creek near Chatham Hill, Va.	365744	0812821	25.5	.75	.39
03488000	North Fork Holston River near Saltville, Va.	365348	0814447	222	34	24
03488100	North Fork Holston River near Plasterco, Va.	365152	0815017	259	39	28
03488445	Brumley Creek near Hansonville, Va.	365121	0820243	4.29	.14	.05
03488450	Brumley Creek at Brumley Gap, Va.	364730	0820110	21.1	.4	.15
03488500	North Fork Holston River at Holston, Va.	364629	0820422	402	66	48
03489500	North Fork Holston River at Mendoia, Va.	364205	0821826	493	81	46
03489870	Big Moccasin Creek at Collinwood near Hansonville, Va.	364416	0821925	41.9	5.3	3.5
03489900	Big Moccasin Creek near Gate City, Va.	363847	0823312	79.6	10.	6.7
03490000	North Fork Holston River near Gate City, Va.	363631	0823405	672	97	56
03521500	Clinch River at Richlands, Va.	370510	0814652	137	29	19
03522000	Little River at Wardell, Va.	370216	0814752	103	25	18
03523000	Big Cedar Creek near Lebanon, Va.	365429	0820220	51.5	5.1	3.2
03524000	Clinch River at Cleveland, Va.	365641	0820918	528	81	54
03524500	Guest River at Coeburn, Va.	365545	0822723	87.3	5.4	1.8
03524900	Stony Creek at Ka, Va.	364857	0823702	30.9	1.2	.42
03525000	Stony Creek at Fort Blackmore, Va.	364630	0823450	41.4	1.8	.52
03526000	Copper Creek near Gate City, Va.	364026	0823357	106	24	18
03527000	Clinch River at Speers Ferry, Va.	363855	0824502	1,126	148	100
03527500	North Fork Clinch River at Duffield, Va.	364240	0824745	23.1	1.9	.95
03529500	Powell River at Big Stone Gap, Va.	365208	0824632	112.	14.	6.9
03530000	South Fork Powell River at Big Stone Gap, Va.	365154	0824616	40.0	4.0	2.0
03530500	North Fork Powell River at Pennington Gap, Va.	364626	0830159	71.4	4.0	1.3
03531000	Powell River near Pennington Gap, Va.	364404	0825956	290	28	14
03531500	Powell River near Jonesville, Va.	363943	0830542	319	42	24

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
01484750	Assawoman Creek at Route 695 near Temperanceville, Va.	375338	0753145	2.8	0.16	0.05
01484755	Whites Creek at Route 679 near Modest Town, Va.	374707	0753527	1.8	.77	.47
01484760	Ross branch at Route 605 near Accomack, Va.	374150	0754006	1.2	.31	.14
01484765	Nickawampus Creek at Route 600 near Melfa, Va.	373811	0754328	1.2	.27	.12
01484780	Mattawdman Creek tributary at Route 13 near Eastville, Va.	372240	0755519	.3	--	--
01484790	Nassawadox Creek at Route 606 near Nassawadox, Va.	373131	0755237	4.2	.31	.08
01484820	Taylor Branch Painter, Va.	373425	0754827	2.6	.74	.36
01484830	Pungoteague Creek at Route 178 near Onancock, Va.	374023	0754557	1.1	.12	.05
01484840	Taylor Creek at Route 180 at Pungoteague, Va.	373720	0754829	2.6	.27	.10
01484880	Lee Mont Branch at Route 658 near Lee Mont, Va.	374633	0754057	2.1	.15	.04
01484885	Katy Young Branch at Route 658 near Parksley, Va.	374751	0754002	2.7	.34	.11
01484900	Bethel Branch at Route 687 near Bloxom, Va.	375053	0753613	2.7	.17	.10
01613570	Back Creek at Gainesboro, Va.	391709	0781551	34.4	2.8	2.0
01613590	Issac Creek near Gainesboro, Va.	391805	0781650	15.8	.36	.18
01616100	Dry Marsh near Berryville, Va.	391132	0780410	11.4	4.7	2.9
01620690	North River at Route 727 near Bridgewater, Va.	382342	0790155	102	4.9	2.3
01621300	Dry River at Route 257 at Bridgewater, Va.	382427	0785833	120	6.4	3.4
01622230	Middle River below Trimbles Mill near Swoope, Va.	380810	0791306	20.6	3.6	2.7
01626900	Sawmill Run near Dooms, Va.	380546	0784838	3.62	.08	.0
01627100	Meadow Run near Crimora, Va.	380929	0784838	3.45	.15	.03
01627400	Paine Run near Harriston, Va.	381154	0784733	4.92	.2	.02
01628080	Madison Run near Grottoes, Va.	381524	0784606	5.78	.33	.12
01628700	Twomile Run near Mcgaheysville, Va.	382004	0784020	2.17	.05	.02
01628900	Hawksbill Creek tributary near Swift Run, Va.	382047	0783435	1.32	.13	.03
01629120	East Branch Naked Creek near Jollett, Va.	382807	0782950	4.58	.5	.04
01629920	Little Hawksbill Creek tributary near Ida, Va.	383323	0782555	.78	.07	.02
01630542	Pass Run near Thornton Gap, Va.	383905	0782114	2.00	.25	.05
01630585	Jeremys Run near Oak Hill, Va.	384318	0782315	9.72	.02	.0
01630620	Overall Run near Bentonville, Va.	384818	0782034	4.41	.06	.0
01630649	Phils Arm Run near Browntown, Va.	384734	0781429	.98	.07	.01
01630680	Lands Run near Browntown, Va.	384920	0781222	1.38	.13	.04
01630700	Gooney Run near Glen Echo, Va.	385006	0781356	20.6	3.2	1.8
01631500	North Fork Shenandoah River at Route 917 at Fulks Run, Va.	384018	0785547	106	--	--
01632080	Linville Creek at Broadway, Va.	383622	0784813	42.3	6.0	4.0
01632300	Long Meadow near Broadway, Va.	383443	0784540	8.15	.0	.0
01632840	Smith Creek at Route 717 near Lacey Spring, Va.	383218	0784503	21.3	3.1	1.8
01632890	Smith Creek at Route 794 near Lacey Spring, Va.	383651	0784021	72.7	15.	9.2
01633475	Riles Run at Route 703 near Conicville, Va.	385039	0784229	5.65	.61	.47
01633485	Stony Creek near Liberty Furnance, Va.	385341	0783957	57.0	6.9	4.4
01633487	Stony Creek tributary near Liberty Furnance, Va.	385344	0784003	.79	--	--

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station no.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second 2-year	10-year
01633510	Swover Creek near Conicville, Va.	385029	0784039	3.26	0.10	0.05
01633540	Stony Creek at US HWY 11 at Edinburg, Va.	384921	0783408	104	18	11
01633730	Toms Brook at Toms Brook, Va.	385642	0782632	9.35	.54	.34
01633745	Toms Brook near Toms Brook, Va.	385535	0782530	16.2	1.1	.85
01635045	Buffalo Marsh Run near Middletown, Va.	390334	0781817	5.27	1.0	.54
01635100	Cedar Creek near Strasburg, Va.	385927	0781942	157	16	11
01635250	Passage Creek at Route 776 near Detrick, Va.	384749	0782742	31.7	1.7	.91
01635300	Peters Mill Run near Detrick, Va.	385148	0782625	4.22	.42	1.2
01636270	Borden Marsh Run at Route 624 near Boyce, Va.	390009	0780551	8.71	2.1	1.2
01636300	Westbrook Run near Boyce, Va.	390422	0780530	1.40	.40	.20
01636690	Piney Run near Lovettsville, Va.	391839	0774306	13.7	.53	.11
01643585	Potomac River tributary No 1 near Lucketts, Va.	391232	0772839	2	.10	.04
01643600	Limestone Branch tributary No 1 near Leesburg, Va.	391027	0773148	6.82	1.2	.6
01643643	Goose Creek at Delaplane, Va.	385451	0775520	45.6	1.6	.20
01643800	North Fork Goose Creek at Route 722 near Lincoln, Va.	390438	0774152	24.0	1.1	.34
01643950	Goose Creek at Oatlands, Va.	390138	0773717	276	12	2.9
01643988	Little River near Oatlands, Va.	390025	0773653	47.7	2.1	.5
01643990	Howsers Branch near Oatlands, Va.	390012	0773630	5.98	.0	.0
01644255	South Fork Broad Run at Arcola, Va.	385710	0773209	5.31	.01	.0
01644277	Beaverdam Run near Ashburn, Va.	390253	0772659	11.2	.0	.0
01644280	Broad Run near Lessburg, Va.	390335	0772622	76.1	.28	.02
01644283	Potomac River tributary No 2 near Sterling, Va.	390338	0772406	3.47	.0	.0
01644300	Sugarland Run at Herndon, Va.	385800	0772217	3.36	.0	.0
01645750	South Fork Little Difficult Run near Fairfax, Va.	385352	0772112	1.59	.19	.03
01645800	Piney Brancy at Vienna, Va.	385406	0771557	.29	.0	.0
01645900	Colvin Run at Reston, Va.	385756	0771836	5.09	.78	.13
01645950	Piney Run at Reston, Va.	385849	0771909	2.06	.17	.0
01646200	Scott Run near Mclean, Va.	385732	0771221	4.69	.73	.12
01646600	Pimmit Run near Falls Church, Va.	385441	0771105	2.8	.09	.0
01646700	Pimmit Run at Arlington, Va.	385605	0770826	8.12	1.1	.07
01652400	Long Branch at Arlington, Va.	385131	0770737	.94	.11	.06
01652600	Holmes Run at Merrifield, Va.	385157	0771245	2.70	.15	.01
01652610	Holmes Run near Annandale, Va.	385047	0771028	7.10	.38	.01
01652645	Tripps Run tributary near Falls Church, Va.	385154	0771016	.50	.0	.0
01652650	Tripps Run near Falls Church, Va.	385137	0770957	4.55	.34	.01
01652710	Backlick Run at Springfield, Va.	384805	0771114	2.02	.0	.0
01652910	Backlich Run at Alexandria, Va.	384811	0770741	13.4	1.7	.32
01653210	Pike Branch at Alexandria, Va.	384735	0770502	2.65	.16	.0
01653447	Penn Daw outfall at Alexandria, Va.	384719	0770354	.82	.06	.03
01653700	Little Hunting Creek at Gum Springs, Va.	384421	0770520	1.78	.23	.08
01653800	Dogue Creek near Accotink, Va.	384308	0770744	10	.7	.3
01653900	Accotink Creek at Fairfax, Va.	385139	0771617	6.80	.45	.06
01653950	Long Branch at Vienna, Va.	385223	0771434	1.18	.04	.0
01655310	Rabbit Branch near Burke, Va.	384806	0771919	3.81	.58	.10
01655350	Pohick Creek near Springfield, Va.	384526	0771337	15.0	1.3	.04
01655370	Middle Run near Lorton, Va.	384501	0771403	3.56	.10	.0
01655380	South Run near Lorton, Va.	384411	0771510	6.54	.20	.0
01655390	Pohick Creek at Lorton, Va.	384214	0771252	31.0	3.0	.06
01656200	Broad Run near Warrenton, Va.	384825	0774847	2.94	.11	.03
01656645	Rocky Branch tributary near Gainesville, Va.	384543	0773457	2.32	.0	.0

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
01656655	Kettle Run near Nokesville, Va.	384328	0773632	11.9	0	0
01656659	Kettle Run at Brentsville, Va.	384158	0773042	25.0	0	0
01656670	Broad Run at Brentsville, Va.	384132	0772942	137	3.3	1.2
01656705	Black Branch near Haymarket, Va.	385446	0773743	3.05	.02	.0
01656715	Chestnut Lick near Catharpin, Va.	385317	0773537	11.1	.01	.0
01656743	Lick Branch at Catharpin, Va.	385058	0773424	3.06	.0	.0
01656750	Little Bull Run near Bull Run, Va.	385032	0773222	27.2	.2	.0
01656768	FLat Branch near Manassas, Va.	384622	0772957	1.10	.0	.0
01656800	Cub Run near Chantilly, Va.	385430	0772801	7.13	.0	.0
01656930	Elklick Run near Chantilly, Va.	385216	0772940	10.9	.0	.0
01657245	Russia Branch at Manassas, Va.	384542	0772637	1.47	.02	.0
01657300	Popes Head Creek near Fairfax, Va.	384857	0772016	3.88	.48	.07
01657435	Wolf Run near Clifton, Va.	384409	0772151	5.39	.13	.01
01657600	Sandy Run near Fairfax station, Va.	384453	0771923	2.35	.12	.0
01657800	Giles Run near Woodbridge, Va.	384048	0771336	4.54	.60	.12
01657890	Neabsco Creek tributary near Dale City, Va.	383713	0771635	3.33	.56	.12
01660670	Accokeek Creek near Brooke, Va.	382238	0772126	18.0	.75	.25
01660765	Upper Machodoc Creek near Dahlgren, Va.	381857	0770520	26.2	1.1	.25
01660870	Fox Hall Swamp near Potomac Mills, Va.	380924	0765743	2.28	.26	.13
01661160	Nomini Creek near Neenah, Va.	380228	0764222	9.99	5.0	1.6
01661840	Rappahannock River near Flint Hill, Va.	384532	0780142	65.9	3.0	.46
01662100	Hazel River near Nethers, Va.	383654	0781544	5.15	1.0	.2
01662110	Hazel River at Route 631 near Woodville, Va.	383627	0781415	5.54	1.7	.36
01662150	Hughes River near Nethers, Va.	383427	0781749	9.92	1.8	.3
01662160	Brokenback Run near Nethers, Va.	383416	0781801	4.30	.5	.05
01662190	Ragged Run near Etlan, Va.	383156	0781744	1.14	.09	.02
01662310	Thornton R above Beech Sp Hollow near Sperryville, Va.	383912	0781623	6.40	1.0	.3
01662350	North Fork Thornton River near Sperryville, Va.	384136	0781633	7.21	.5	.09
01662370	Piney River near Sperryville, Va.	384146	0781530	5.58	.5	.10
01662480	Rush River at Route 622 near Washington, Va.	384429	0781308	2.34	.21	.05
01662490	Rush River at State Route 624 at Washington, Va.	384337	0781013	11.1	.34	.0
01664100	Tinpot Run at Remington, Va.	383225	0774819	9.70	.0	.0
01664690	Browns Run near Elk Run, Va.	383244	0774312	2.55	.0	.0
01664750	Marsh Run near Remington, Va.	383029	0774553	37.3	.0	.0
01665100	Jonas Run near Brandy Station, Va.	382920	0775408	11.4	.0	.0
01665150	Mountain Run near Kellys Ford, Va.	382737	0774850	118	4.1	.8
01665220	Deep Run at Route 615 near Goldvein, Va.	382707	0773746	15.4	.53	.10
01665260	Rapidan River near Graves Mill, Va.	382638	0782211	9.74	2.4	.5
01665270	Staunton River near Graves Mill, Va.	382638	0782212	4.21	.9	.14
01665340	Conway River near Kinderhook, Va.	382459	0782617	9.66	1.4	.3
01665400	Conway River near Stannrdsville, Va.	381958	0782353	25.8	1.7	.3
01665740	Robinson River near Syria, Va.	383214	0782049	9.53	1.5	.15
01665800	Rose River near Syria, Va.	383055	0782159	9.15	2.1	.3
01665850	Robinson River at Route 231 near Criglersville, Va.	382654	0781644	47.8	3.0	.45
01667600	Cedar Run tributary near Culpeper, Va.	382350	0780025	.58	.01	.0
01667650	Cedar Run near Culpeper, Va.	382148	0775832	33.2	.03	.0
01667700	Sumerduck Run near Culpeper, Va.	382219	0775627	11.0	.0	.0
01667750	Potato Run near Stevensburg, Va.	382455	0775500	6.67	.0	.0
01667848	Black Walnut Run at Burr Hill, Va.	382036	0775134	12.1	.35	.05
01667850	Mine Run at Burr Hill, Va.	382036	0775133	31.8	1.0	.10
01668100	White Oak Run near Passapatanzy, Va.	381535	0772141	8.29	.0	.0
01668200	Gingoteague Run near Port Royal, Va.	381240	0770910	2.82	.04	.0

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
01668305	Farmers Hall Creek at Route 631 near Champlain, Va.	380053	0765747	3.65	0.14	0
01669100	Totuskey Creek near Emmerton, Va.	375447	0763929	28.4	4.5	2.5
01669150	Bellwood Swamp near Lancaster, Va.	374647	0762947	8.23	1.6	.61
01669400	Timber Branch Swamp tributary at Dragonville, Va.	374125	0764625	.61	.08	.01
01669810	Healys Pond tributary near Harmony Village, Va.	373453	0763024	.72	.29	.16
01669850	Queens Creek near Blakes, Va.	372922	0762255	1.56	.0	.0
01669885	North End Branch tributary near North, Va.	372817	0762515	1.04	.0	.0
01670010	Beaverdam Swamp tributary No 2 at Ark, Va.	372635	0763427	1.29	.12	.02
01670020	Beaverdam Swamp at Gloucester, Va.	372534	0763148	22.1	1.5	.12
01670120	Mountain Run at Route 643 near Gordonsville, Va.	380939	0780606	14.1	.95	.20
01670200	Pamunkey Creek at Route 651 near Lahore, Va.	380916	0775702	51.7	4.0	1.0
01671040	Long Creek at Route 655 near Buckner, Va.	375538	0774744	8.01	.35	.10
01671680	South Anna River at Route 208 near Louisa, Va.	375850	0780254	113	6.0	2.0
01671950	Deep Creek at Route 640 near Apple Grove, Va.	375157	0775453	10.1	.42	.10
01672200	Taylors Creek at Route 715 near Montpelter, Va.	374749	0774327	22.0	1.5	.50
01672400	South Anna River tributary No 6 near Ashland, Va.	374840	0773420	.33	.02	.0
01672800	Newfound River at Route 685 near Ashland, Va.	375035	0773230	36.3	1.4	.40
01673560	Totopotomy Creek near Manquin, Va.	374045	0771308	30.9	3.1	.91
01673620	Acquinton Creek near King William, Va.	374104	0770244	8.93	.1	.0
01673700	Catharpin Run at Route 608 near Brokenburg, Va.	381322	0774330	7.52	.0	.0
01673900	Poni River tributary No 1 near Guinea, Va.	380907	0772716	6.15	.1	.0
01673960	Mat River near Marye Va.	380623	0773607	14.5	.05	.0
01674172	Polecat Creek near Ladysmith, Va.	375813	0772913	10.8	.17	.0
01674200	Reedy Creek near Dawn, Va.	375255	0772135	16.8	1.2	.10
01674250	Maracossic Creek at Sparta, Va.	375923	0771430	37.6	5.5	2.2
01674300	Maracossic Creek above Beverly Run near Gether, Va.	375515	0771129	72.4	7.0	1.5
01674350	Beverly Run at Route 630 near Alps, Va.	375929	0770910	26.5	3.4	.84
01674400	Beverly Run at Route 721 near Alps, Va.	375708	0771048	46.9	6.0	1.2
01674600	Herring Creek near Aylett, Va.	375012	0771003	28.9	2.4	.9
01674805	Dickeys Swamp near Stevensville, Va.	374403	0765756	19.8	2.5	.92
01675550	GLebe Swamp near Shacklefords, Va.	373321	0764238	4.57	.27	.04
01677100	France Swamp near Toano, Va.	372515	0764706	6.70	1.6	.69
01677200	Skimino Creek BL Barlows Pond near Lightfoot, Va.	372158	0764257	8.19	2.5	1.1
01677900	Moores Creek near Poquoson, Va.	370728	0762515	1.03	.0	.0
02002000	Jackson River at US HWY 220 at Vanderpool, Va.	382205	0793735	13.0	1.4	.90
02015600	Cowpasture River near Head Waters, Va.	381930	0792614	11.3	1.6	1.0
02015800	Thompson Creek at Route 39 near Bath Alum, Va.	380238	0794105	15.7	2.2	1.8
02015930	Pads Creek near Longdale Furnace, Va.	375154	0794356	26.3	.0	.0
02016600	Craig Creek above Muddy Branch near McDonalds Mill, Va.	372116	0801723	23.0	.31	.17
02017300	Craig Creek at New Castle, Va.	373006	0800618	112	.20	.15
02017400	Johns Creek tributary near New Castle, Va.	373030	0801130	1.57	.09	.06
02019100	Spreading Spring Branch at Springwood, Va.	373257	0794442	6.76	1.0	.55
02020170	East Fork Elk Creek at Belfast Trail near Natural Bridge, Va.	373417	0792931	4.15	.32	.22

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area, in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
02020200	Calfpasture River near West Augusta, Va.	381624	0791802	12.8	0.01	0
02021700	Cedar Grove Branch near Rockbridge Baths, Va.	375300	0792308	12.3	1.8	1.4
02023300	South River near Steeles Tavern, Va.	375550	0790955	15.7	.0	.0
02024240	South Buffalo Creek at Route 611 near Lexington, Va.	374414	0793418	21.1	4.2	3.4
02024900	Pedlar River below Davis Mill Creek near Buena Vista, Va.	374448	0791609	18.2	4.2	3.0
02025650	Harris Creek at Route 675 near Monroe, Va.	372935	0790910	34.5	4.2	1.1
02025800	Burton Creek tributary at Lynchburg, Va.	372110	0791105	2.36	.30	.10
02025900	Beaver Creek at Route 660 near Bocock, Va.	372116	0790427	24.0	4.6	2.1
02026400	South Fork Tye River at Nash, Va.	375124	0790247	14.2	4.4	2.1
02027600	Buffalo River below Forks of Buffalo, Va.	374047	0791320	15.9	2.0	.69
02027670	Buffalo River near Amherst, Va.	373618	0790135	93.1	14	6.6
02027700	Buffalo River tributary near Amherst, Va.	373345	0785735	.46	.03	.0
02028450	Sycamore Creek at Route 601 near Howardsville, Va.	374043	0783955	9.94	1.6	.55
02028700	Cove Creek near Covesville, Va.	375206	0784332	4.00	.90	.30
02029200	North Fork Hardware River at Red Hill, Va.	375803	0783704	11.0	3.0	.85
02029400	South Branch North Fork Hardware River near North Garden, Va.	375721	0783935	6.59	1.6	.50
02030150	Slate River at Buckingham, Va.	373308	0783353	63.0	11	3.5
02030300	Slate River near Dillwyn, Va.	373708	0782910	154	22	5.8
02030850	Stockton Creek near Crozet, Va.	380237	0784154	20.4	2.0	.22
02032545	Ivy Creek near Boonesville, Va.	381607	0783645	6.11	.05	.0
02033750	Buck Island Creek below Houchins Creek near Simeon, Va.	375713	0782415	31.0	1.3	.18
02034150	Little Byrd Creek at Route 667 near Fife, Va.	374550	0780524	29.9	.66	.10
02034300	Little Willis River at Curdsville, Va.	372438	0782735	7.07	.95	.40
02035075	Maxey Mill Creek at Ballsville, Va.	373107	0780731	12.0	1.1	.34
02035460	Big Lickinghole Creek at Route 613 near Goochland, Va.	374352	0775721	28.7	2.3	.96
02036700	Bernards Creek near Manakin, Va.	373325	0774033	15.4	.0	.0
02038730	Fourmile Creek near Richmond Heights, Va.	372716	0771953	4.01	.7	.5
02038780	Johnson Creek near Rivermont, Va.	371958	0771937	6.22	.1	.01
02038900	Dry Creek near Farmville, Va.	372045	0782445	3.64	.05	.0
02039600	Briery Creek at US HWY 460 (Bus) near Rice, Va.	371649	0782148	41.5	3.7	1.4
02039700	Sandy River at US HWY 460 near Rice, Va.	371631	0781917	39.7	3.6	1.3
02039800	Angola Creek near Angola, Va.	372216	0781744	6.74	.86	.46
02040500	Flat Creek near Amelia, Va.	372327	0780345	73.0	2.6	.3
02040900	Little Creek near Denaro, Va.	371332	0780110	3.93	.46	.14
02041150	Winterpock Creek at Route 664 near Winterpock, Va.	372138	0774256	3.77	--	--
02041400	Whipponock Creek at Route 627 near Church Road, Va.	371145	0773923	3.27	.12	.01
02042050	Franks Branch at Route 626 near Colonial Heights, Va.	371642	0772835	16.8	.25	.01
02042140	Powell Creek at Garysville, Va.	371454	0770909	14.6	2.7	1.6
02042160	West Run at Barnetts, Va.	372130	0770956	20.3	1.6	.65
02042200	Glebe Creek tributary near Charles City, Va.	372205	0770415	.70	.0	.0
02042210	Courthouse Creek at Charles City, Va.	372037	0770414	9.79	2.5	2.2
02042450	White Oak Swamp near White Oak Swamp, Va.	372903	0771605	8.26	1.1	.75
02042600	Rumley Marsh near Providence Forge, Va.	372832	0770249	11.9	2.4	1.4
02042700	Collins Run near Providence Forge, Va.	372359	0770254	2.84	.40	.20
02042710	Collins Run tributary near Providence Forge, Va.	372415	0770250	.28	.02	.0

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area, in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second 2-year	10-year
02042752	Mill Creek at Diasound, Va.	372323	0765205	8.59	1.1	0.44
02042754	Yarmouth Creek below Cranstons Pond near Toano, Va.	372048	0764856	6.93	3.0	1.5
02042756	Gordon Creek below Jolly Pond near Lightfoot, Va.	371748	0764910	4.89	.25	.04
02042765	James River tributary near Five Forks, Va.	371518	0764846	.91	.09	.02
02042780	West Branch Long Hill Swamp near Lightfoot, Va.	371850	0764602	2.47	.94	.4
02042782	Powhattan Creek at Five Forks, Va.	371457	0764623	19.7	1.0	.1
02042784	Grays Creek near Surry, Va.	371006	0765125	8.09	--	--
02042787	Skiffles Creek near Lee Hall, Va.	371248	0763650	1.32	.07	.01
02042790	Beaverdam Creek near Yorktown, Va.	371209	0763116	5.46	.30	.1
02042794	Cypress Creek near Benns Church, Va.	365522	0763615	5.23	.50	.07
02042830	Shingle Creek at Suffolk, Va.	364316	0763402	3.56	.30	.08
02042890	Drum Point Creek at Boone, Va.	365044	0762603	.61	.0	.0
02042950	Great Neck Creek tributary at Oceana, Va.	365003	0760047	.90	.4	.3
02043000	Beggars Bridge Creek near Pleasant Ridge, Va.	364057	0760037	.76	.0	.0
02043100	Albemarle/Chesapeake Canal tributary near Greatbrigde, Va.	364107	0761317	3.80	.25	.06
02044200	Falls Creek tributary near Victoria, Va.	370204	0781026	.34	.01	.0
02044300	Little Nottoway River at Route 40 near Blackstone, Va.	370225	0780207	72.6	3.4	.48
02045800	White Oak Creek at Route 620 near Hebron, Va.	370740	0774854	5.94	.12	.01
02046230	Sappony Creek at Route 681 near Stoney Creek, Va.	365636	0772708	64.0	--	--
02046300	Hatcher Run at Route 613 near Reems, Va.	370723	0772845	35.7	.86	.08
02046370	Rowanty Creek at Route 602 near Stoney Creek, Va.	365857	0772253	119	--	--
02046480	Hunting Quarter Swamp near Sussex, Va.	365325	0772954	9.25	.0	.0
02046500	Anderson Branch at Sussex, Va.	365510	0771545	5.35	.0	.0
02046700	Raccoon Creek near Sebrell, Va.	364811	0771228	65.0	.36	.04
02046720	Tryall Creek near Smokey Ordinary, Va.	364703	0773955	5.61	.0	.0
02046750	Three Creek at Route 616 near Emporia, Va.	364325	0773113	67.2	1.2	.29
02046830	Applewhite Swamp near Drewryville, Va.	364336	0772103	5.96	.01	.0
02046900	Musgrave Branch near Drewryville, Va.	364213	0771629	1.99	.0	.0
02047050	Assamoosick Swamp near Homeville, Va.	365830	0770911	22.0	.30	.01
02047300	Nottoway Swamp near Story, Va.	364322	0765943	12.2	.01	.0
02047360	Mill Creek near Sunbeam, Va.	363412	0770219	23.7	.0	.0
02047400	Blackwater Swamp near Disputanta, Va.	370802	0771230	75.6	.0	.0
02047420	Warwick Swamp near Disputanta, Va.	370534	0770908	38.2	.3	.0
02047440	Otterdam Swamp near Waverly, Va.	370457	0770319	22.4	.0	.0
02047460	Pigeonroost Swamp near Elberon, Va.	370635	0765342	5.98	.08	.0
02047480	Cypress Swamp near Dendron, Va.	370318	0765515	54.4	--	--
02047520	Rattlesnake Swamp at Raynor, Va.	365730	0764625	40.3	--	--
02048460	Round Hill Swamp near Berlin, Va.	365102	0765621	25.6	.0	.0
02049700	Cypress Swamp near Burdette, Va.	364429	0765618	8.55	.02	.0
02050113	Quaker Swamp near Lumis, Va.	364142	0764335	4.02	.0	.0
02050115	Chapel Swamp near Somerton, Va.	363434	0764828	17.9	--	--
02050130	Beaverdam Creek near Cleopus (Factory Hill), Va.	363310	0765030	9.17	.0	.0
02050400	North Meherrin River near Briery, Va.	370420	0782745	1.19	.14	.05
02051100	South Meherrin River near Chase City, Va.	365134	0782522	27.6	.70	.16
02051175	Meherrin River at Route 636 near North View, Va.	364803	0781004	305	13	8.7

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area, in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
02051200	Flat Rock Creek near Kenbridge, Va.	365358	0780722	21.5	1.8	0.36
02051650	Rocky Run near Dolphin, Va.	364735	0774935	1.41	.01	.0
02052100	Rattlesnake Creek near Ankum, Va.	363648	0775225	6.55	.04	.0
02053030	Mill Swamp near Claresville, Va.	363632	0772910	10.4	.0	.0
02053100	Tarrara Creek at Boykins, Va.	363520	0771203	57.5	.1	.01
02054120	North Fork Roanoke River near Lusters Gate, Va.	371318	0802156	44.6	4.8	2.6
02054650	Mason Creek at Mason Cove, Va.	372218	0800402	11.9	--	--
02056700	Beaverdam Creek at Route 757 near Hardy, Va.	371328	0794523	24.8	3.2	.88
02056950	Maggodee Creek near Boones Mill, Va.	370757	0795820	11.0	1.2	.34
02057050	Gills Creek at Route 122 near Burnt Chimney, Va.	370731	0794658	21.8	6.0	.24
02057600	Pigg River at Route 40 near Rocky Mount, Va.	365834	0795532	40.5	17	8.5
02057700	Powder Mill Creek at Rocky Mount, Va.	370026	0795225	.64	.11	.05
02057750	Little Chestnut Creek near Syndorsville, Va.	365407	0795055	15.5	2.9	1.1
02058100	Turkeycock Creek at Route 969 at Sago, Va.	365253	0793752	29.5	8.9	4.2
02059420	North Fork Goose Creek near Montvale, Va.	372214	0794155	31.5	8.4	6.5
02059460	Shockoe Creek at Route 755 near Irving, Va.	371846	0794034	4.02	.30	.10
02060400	Sycamore Creek at Sycamore, Va.	370125	0792124	5.30	1.0	.70
02061200	Little Otter River at Route 122 near Bedford, Va.	372141	0793003	18.3	3.6	1.5
02062300	Seneca Creek at Route 633 near Long Island, Va.	370623	0790722	52.0	8.0	3.3
02063400	Reddy Creek near Spring Mills, Va.	371654	0785414	12.6	2.4	.90
02063600	Button Creek near Rustburg, Va.	371525	0790410	.59	.08	.03
02065100	Snake Creek near Brookneal, Va.	370042	0785752	1.68	.40	.25
02065220	Catawba Creek at Route 626 at CLarkton, Va.	365830	0785345	40.3	8.0	4.4
02065300	Right Hand Fork near Appomattox, Va.	371612	0784914	2.08	.57	.30
02065400	Big Cub Creek at Route 701 near Madisonville, Va.	371213	0784405	37.2	9.0	4.0
02066450	Roanoke Creek near Charlotte Court House, Va.	370327	0783503	42.7	4.8	1.6
02067100	Difficult Creek at US HWY 360 near Scottsburg, Va.	364746	0784710	40.3	6.2	2.4
02067810	Maple Swamp Branch near Meadows of Dan, Va.	364410	0802628	.49	.30	.21
02069550	North Fork South Mayo River at US HWY 58 at Stuart, Va.	363903	0801708	10.0	5.2	2.8
02069600	Anglin Branch near Stuart, Va.	363815	0801255	3.10	1.2	.58
02071600	Smith River near Charity, Va.	364818	0801204	79.7	32.	22
02071800	Nicholas Creek near Ferrum, Va.	365211	0800310	12.2	3.6	1.3
02072600	Reed Creek near Collinsville, Va.	364517	0795448	12.4	2.8	1.4
02074450	Sandy River near Swansonville, Va.	364423	0793654	24.1	6.0	3.2
02075020	Fall Creek at Route 719 near Danville, Va.	364042	0792413	5.39	.44	.15
02075275	Sandy Creek (River) at US HWY 58 near Ringgold, Va.	363450	0791331	18.2	3.5	1.9
02075600	Birch Creek near Birch, Va.	364212	0791303	19.8	3.2	1.3
02075900	Lawsons Creek at Turbeville, Va.	363639	0790128	8.70	.98	.42
02076300	Banister River at US HWY 29 near Chatham, Va.	364641	0792333	84.8	16	6.7
02076650	Banister River at Route 640 near Mount Airy, Va.	365439	0791100	269	63	31
02076700	Blacks Creek near Mount Airy, Va.	365640	0790956	3.44	.12	.02
02076770	Sandy Creek at Route 832 at Meadville, Va.	364932	0790139	99.0	19	9.1
02078300	Aarons Creek near Nelson, Va.	363512	0784300	41.5	--	--
02078400	Bluestone Creek at Route 699 near Laconi, Va.	364348	0783658	47.8	.60	.05
02079660	Jolly Hollow Branch at Boydton, Va.	364038	0782313	3.60	.32	.18

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area, in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
02079665	Cox Creek at Baskerville, Va.	364058	0781615	11.5	1.3	0.40
02079740	Great Creek near Marengo, Va.	363622	0780505	7.79	--	--
02113550	Ararat River at Route 749 near Ararat, Va.	363407	0803303	21.7	8.0	3.4
03162415	Helton Creek near Whitetop, Va.	363633	0813352	5.28	2.6	1.6
03162650	Wilson Creek at Volney, Va.	363720	0812336	17.7	2.2	1.3
03163500	Elk Creek at Mount Carmel Church near Galax, Va.	364153	0810326	63.5	12	5.1
03165350	Brush Creek at Route 94 near Ivanhoe, Va.	364559	0805905	15.1	1.0	.25
03165750	Blue Springs Creek near Cedar Springs, Va.	364814	0811822	12.9	2.4	1.7
03166400	Stony Fork near Favonia, Va.	370030	0811127	7.77	.52	.34
03167200	Laurel Fork at Route 638 near Laurel Fork, Va.	364434	0803149	28.3	20	14
03167695	Beaverdam Creek at Hillsville, Va.	365545	0804342	4.19	2.3	1.6
03168750	Thorne Springs Branch near Dublin, Va.	370530	0804434	4.77	.10	.04
03169150	Pine Creek at Route 682 near Floyd, Va.	365703	0801703	10.7	5.6	4.4
03169370	Brush Creek at Route 616 near Riner, Va.	370157	0802349	19.1	1.9	1.1
03171550	Sinking Creek at Route 700 near Newport, Va.	371840	0803055	65.4	10	6.0
03171900	Kimbeling Creek near Holly Brook, Va.	371038	0805854	27.3	.18	.08
03177600	Bluestone River above Bluefield, Va.	371357	0811800	16.7	7.1	6.0
03207223	Levisa Fork at Oakwood, Va.	371243	0820020	29.0	1.4	.44
03207225	Garden Creek at Mount Heron, Va.	371117	0820008	11.3	.38	.10
03207228	Right Fork at Mount Heron, Va.	371116	0820018	15.7	.58	.16
03207250	Dismal Creek at Whitewood, Va.	371408	0815127	27.8	2.5	.78
03207280	Laurel Fork at Whitewood, Va.	371401	0815145	16.6	.77	.23
03207295	Lower Big Branch near Patterson, Va.	371603	0815949	2.76	.04	.01
03207390	Big Prater Creek near Vansant, Va.	371301	0820615	10.2	.32	.10
03207398	Trace Fork Branch near Vansant, Va.	371305	0820602	9.33	.38	.10
03207407	Dry Fork at Vansant, Va.	371325	0820542	4.32	.15	.04
03207440	Slate Creek near Stacy, Va.	371844	0815841	16.1	.06	.01
03207450	Slate Creek at Grundy, Va.	371639	0820548	41.0	1.8	.52
03207505	Looney Creek near Grundy, Va.	371836	0820746	6.00	.95	.42
03207520	Poplar Creek near Harman Junction, Va.	371821	0820921	6.18	.22	.07
03207530	Bull Creek near Harman Junction, Va.	371841	0820957	12.1	1.3	.32
03207550	Lynn Camp Creek near Harman Junction, Va.	371930	0820951	4.06	.52	.24
03207600	Home Creek near Big Rock, Va.	372042	0821030	12.1	1.2	.42
03207792	Rocklick Creek at Big Rock, Va.	372121	0821122	7.73	.74	.28
0320803170	Ball Creek above Nance White Creek near Council, Va.	370512	0820205	.91	.10	.04
0320803180	Nance White Branch near Council, Va.	370513	0820207	1.13	.0	.0
0320803350	Grisson Creek above Veina near Council, Va.	370612	0820302	1.44	.01	.0
032080351	Barton Fork above Jackson Fork near Council, Va.	370438	0820141	.31	.01	.0
032080352	Jackson Fork above Barton Fork near Council, Va.	370435	0820141	.33	.0	.0
0320803570	Barton Fork tributary near Council, Va.	370434	0820210	.17	.0	.0
03208042	Big Branch below Route 672 near Council, Va.	370504	0820501	.97	.01	.0
03208043	Russell Fork at Davenport, Va.	370557	0820810	16.8	.27	.04
03208044	Hurricane Creek above Left Fork near Davenport, Va.	370758	0820425	1.76	.0	.0
03208045	Parett-Fletcher Branch near Davenport, Va.	370729	0820449	.48	.0	.0
03208046	Hurricane Creek near Davenport, Va.	370634	0820742	8.84	.09	0.0
0320804630	Left Fork Hurricane Creek above New Camp Branch near Davenport, Va.	370846	0820629	1.18	.05	.01
0320804670	Boyd Branch near Davenport, Va.	370754	0820700	.68	.0	.0
0320804780	Ivy Lick Branch near Davenport, Va.	370716	0820725	.74	.0	.0
03208048	Left Fork Hurricane Creek near Davenport, Va.	370643	0820740	6.76	.10	.01

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area, in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second: 2-year	10-year
0320806100	Little Indian Creek near Council, Va.	370255	0820503	1.01	0.02	0.0
0320806200	Puncheon Camp Branch near Council, Va.	370410	0820649	.78	.01	.0
0320806390	Indian Creek tributary No 2 near Duty, Va.	370455	0820832	.39	.06	.01
03208064	Indian Creek at Duty, Va.	370457	0820901	11.1	.55	.10
032080646	Cane Creek above tributary No 2 near Duty, Va.	370316	0821041	1.73	.0	.0
032080647	Cane Creek tributary No 2 at Mouth near Duty, Va.	370318	0821043	.46	.0	.0
0320806600	Tiller Fork above Left Fork near Duty, Va.	370400	0820923	1.73	--	--
0320806640	Left Fork above Tiller Fork near Duty, Va.	370401	0820920	1.02	.01	.0
0320806680	Cane Creek tributary No 3 at Route 601 near Duty, Va.	370418	0820943	.64	.0	.0
03208067	Cane Creek at Duty, Va.	370450	0821013	6.83	.33	.06
0320807050	Big Branch near Murphy, Va.	370646	0821003	1.10	.0	.0
0320807200	Abner Branch at Mouth near Murphy, Va.	370654	0821020	2.01	.01	.0
03208079	Fox Creek above Left Fork near Murphy, Va.	370943	0821021	3.68	.01	.0
0320807950	Left Fork near Murphy, Va.	370946	0821023	1.6	.0	.0
03208087	Pawpaw Creek above Hackney Hollow near Prater, Va.	371005	0821158	4.12	.0	.0
03208088	Pawpaw Creek tributary near Colley, Va.	371006	0821202	1.44	.0	.0
03208089	Little Pawpaw Creek near Colley, Va.	371000	0821217	1.36	.0	.0
03208090	Pawpaw Creek near Colley, Va.	370956	0821223	7.09	--	--
03208096	Laurel Branch (South) at Viers near Colley, Va.	371016	0821412	1.43	.0	.0
03208110	Fryingpan Creek near Birchleaf, Va.	370947	0821519	26.4	2.5	.51
03208150	Lick Creek at Birchleaf, Va.	371027	0821614	31.7	.44	.04
03208220	Russell Prater Creek at Prater, Va.	371256	0821202	3.11	.15	.03
03208240	War Fork at Prater, Va.	371248	0821158	5.48	.23	.07
03208365	McClure River above Open Fork at Nora, Va.	370408	0822441	22.2	1.1	.14
03208370	Open Fork at Nora, Va.	370409	0822049	21.4	1.1	.15
03208400	McClure River at Nora, Va.	370412	0822050	46.1	1.2	.16
03208410	Buffalo Creek near Nora, Va.	370447	0822059	3.06	.03	.0
03208420	Caney Creek at McClure, Va.	371433	0822247	28.9	.76	.10
03208550	Barts Lick Creek at Bartlick, Va.	371433	0821903	12.1	.58	.08
03208670	North Fork Pound River at Gilley near Flat Gap, Va.	370615	0824010	11.6	.24	.04
03208795	South Fork Pound River at Pound, Va.	370716	0823650	17.4	1.4	.58
03208810	Indian Creek at Pound, Va.	370707	0823555	11.1	.60	.25
03208905	Georges Fork near Isom, Va.	371045	0822858	7.99	1.3	.54
03208922	Cane Creek near Blowing Rock, Va.	371313	0822702	2.73	.10	.0
03208935	Cranes Nest River near Duncan Gap, Va.	370334	0822940	18.1	1.4	.45
03208937	Birchfield Creek near Duncan Gap, Va.	370315	0823315	5.29	--	--
03208938	Dotson Creek near Duncan Gap, Va.	370314	0823310	9.07	1.7	.76
03209250	Grassy Creek near Breaks, Va.	371746	0821849	15.5	1.3	.31
03213572	Knox Creek at Hurley, Va.	372511	0820110	27.8	1.2	.34
03213575	Lester Fork at Hurley, Va.	372508	0820118	12.0	.85	.32
03213578	Guess Fork near Hurley, Va.	372607	0820154	13.7	--	--
03213581	Race Fork near Kelsa, Va.	372618	0820245	7.32	.36	.12
03213584	Paw Paw Creek near Kelsa, Va.	372607	0820502	7.49	.28	.08
03213587	Left Fork near Kelsa, Va.	372602	0820502	9.16	.91	.36
03475700	Spring Creek near Abingdon, Va.	364403	0820229	2.99	1.0	.70
03489800	Cove Creek near Shelleys, Va.	363913	0822116	17.3	1.2	.65
03520700	Indian Creek at Harman, Va.	370927	0814230	11.1	.49	.25
03520800	Greasy Creek at Harman, Va.	370923	0814230	4.72	.23	.12
03521100	Middle Creek at Cedar Bluff, Va.	370528	0814603	11.2	.73	.40
03521600	Big Creek at Richlands, Va.	370549	0814803	15.0	1.1	.62
03521650	Town Hill Creek at Doran, Va.	370544	0814927	5.91	.16	.06

Appendix 2.--Magnitude and frequency of average minimum 7-consecutive-day discharge at partial-record gaging stations on streams in Virginia--Continued

[Dash indicates that attempts to relate discharge measurements at the partial-record site to daily mean discharge at a continuous-record site were unsuccessful]

Station No.	Station name	Latitude	Longitude	Drainage area, in square miles	Annual 7-day low flow for recurrence interval, in cubic feet per second 2-year	10-year
03521700	Mudlick Creek at Doran, Va.	370543	0815006	7.35	0.36	0.20
03521850	Swords Creek near Dye, Va.	370344	0815542	11.9	1.4	.86
03521900	Hess Creek near Dye, Va.	370329	0815546	9.79	.90	.56
03521950	Maiden Spring Creek near Thompson Valley, Va.	370328	0813126	17.8	7.0	6.0
03522525	Grassy Creek near Drill, Va.	370402	0815951	1.74	.12	.08
03522550	Flatrock Creek near Drill, Va.	370331	0815853	1.94	.15	.08
03522600	Lewis Creek at Honaker, Va.	370022	0815820	20.6	2.0	1.2
03523650	Thompson Creek at Artrip, Va.	365801	0820642	19.5	1.0	.55
03523700	Weaver Creek at Artrip, Va.	365733	0820748	18.1	.37	.18
03524010	Dumps Creek near South Clinchfield, Va.	365816	0821135	6.99	.14	.05
03524020	Hurricane Fork near South Clinchfield, Va.	365819	0821125	11.3	.22	.11
03524030	Chaney Creek near South Clinchfield, Va.	365708	0821245	6.05	.15	.07
03524050	Lick Creek at St Paul, Va.	365428	0821759	28.5	2.4	1.5
03524060	Russell Creek near St Paul, Va.	365417	0822048	8.02	.63	.40
03524070	Bull Run near St Paul, Va.	365329	0822237	9.98	.52	.32
03524340	Guest River at Norton, Va.	365613	0823611	29.2	1.0	.31
03524346	Bear Creek near Wise, Va.	365720	0823444	7.45	.75	.33
03524348	Yellow Creek near Wise, Va.	365728	0823450	4.95	.12	.04
03524700	Little Stony Creek near Dungannon, Va.	365048	0822707	16.2	.23	.11
03524870	Stony Creek near Ka, Va.	376049	0823708	18.2	--	--
03524880	Straight Fork near Ka, Va.	364915	0823745	6.03	.51	.28
03524890	Devil Fork near Ka, Va.	364909	0823749	6.03	.31	.16
03525100	Cove Creek near Stanleytown, Va.	364500	0823725	23.5	2.8	1.9
03525490	Stock Creek at Clinchport, Va.	364032	0824444	31.2	3.2	2.1
03527480	North Fork Clinch River near Duffield, Va.	364402	0824751	16.1	1.6	1.0
03527490	Dry Branch near Duffield, Va.	364354	0824749	4.24	.0	.0
03529300	Powell River near Norton, Va.	365509	0824217	27.5	4.2	2.3
03529310	Roaring Fork at Dunbar, Va.	365822	0824405	8.70	1.6	.87
03529315	Potcamp Fork at Dunbar, Va.	365808	0824422	7.21	.49	.22
03529400	Callahan Creek near Stonega, Va.	365634	0824750	9.59	.64	.28
03529410	Mud Lick Creek near Stonega, Va.	365627	0824759	10.7	1.1	.52
03529450	Looney Creek at Appalachia, Va.	365350	0824730	5.97	1.2	.60
03529475	Roaring Branch at Big Stone Gap, Va.	365301	0824718	1.58	.30	.16
03529800	South Fork Powell River at East Stone Gap, Va.	365205	0824448	27.2	3.0	1.6
03529900	Butcher Fork at East Stone Gap, Va.	365224	0824414	8.15	1.2	.69
03530400	North Fork Powell River at Pocket, Va.	364640	0830302	42.3	2.4	1.1
03530440	Straight Creek at St Charles, Va.	364821	0830321	6.84	.23	.08
03530460	Baileys Trace at St Charles, Va.	364816	0830326	4.23	.47	.24
03530470	Puckett Creek at Maness, Va.	364656	0830328	2.93	.15	.06
03530485	Bergen Branch near Stone Creek, Va.	364553	0830639	2.67	.42	.24
03530495	Stone Creek at Stone Creek, Va.	364636	0830323	11.0	.35	.10
03531505	Batie Creek near Jonesville, Va.	363934	0830908	17.4	2.8	1.9
03531520	Wallen Creek near Jonesville, Va.	363758	0831019	47.4	11	7.3
03531530	Hardy Creek near Smiley, Va.	363901	0831450	17.3	3.4	2.1
03531535	Dry Creek near Smiley, Va.	363908	0831448	23.6	1.5	.88

Appendix 3.--Low-flow characteristics at short-term continuous-record gaging stations and related index stations

Short-term continuous-record station number	Index-station number	Coefficient of determination	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 10-year
01615500	01634500	0.892	1.2	0.85
01621000	01632000	.940	.83	.12
01624000	01625000	.874	.0	.0
01626850	01627500	.991	55	45
01628150	01628500	.964	.09	.05
01633500	01634500	.844	5.8	3.3
01654500	01654000	.926	.50	.06
01655000	01654000	.892	3.8	.56
01657655	01654000	.936	.10	.01
	01653000	.720	.1	.02
01658480	01658500	.883	.9	.0
	01660400	.943	.27	.01
01658550	01658500	.912	.46	.03
	01660400	.933	.58	.05
01658650	01658500	.950	.80	.04
	01660400	.950	1.08	.07
01659000	01658500	.941	.07	.0
01659500	01658500	.965	.07	.0
01660000	01658500	.918	.06	.0
01660500	01658500	.921	.50	.0
01661900	01662000	.845	1.8	.52
01667000	01664500	.964	72	14
01669520	01668800	.708	5.5	.64
01670300	01672500	.807	.18	.04
	01671100	.745	.15	.03
01673550	01672500	.818	3.4	.93
01677000	01484800	.753	.58	.22
02011400	02012500	.961	26	20
02011460	02011480	.985	4.5	2.1
	02011500	.932	4.1	2.0
02012000	02012500	.933	5.4	4.5
02014500	02012500	.745	1.2	.86
	02016000	.686	1.2	.88
02019000	02018000	.570	11	7.5
	02019500	.678	12	7.5
02032400	02032680	.880	3.9	.88
02035500	02035000	.500	7.4	4.7
02042000	02041500	.795	4.2	.75
02045000	02046000	.937	33	4.0
02047100	02052500	.888	.06	.0
02048500	02048000	.822	.17	.0
02056650	02055000	.930	6.4	3.3
	02054500	.907	5.3	2.3
	02053800	.926	4.9	1.8
02056900	02055000	.951	24	15
	02054500	.919	21	11
	02053800	.950	20	8.8
02058000	02058500	.801	20	10
02062000	02062500	.877	54	23
	02064000	.840	48	19
02063000	02064000	.760	.84	.40
02063500	02064000	.952	9.5	4.2
	02065500	.972	9.5	3.2
02064500	02064000	.888	4.6	1.5
02065000	02067000	.866	63	33
03166000	03167000	.581	38	27
03166800	03167000	.841	.13	.09
	03167500	.807	.14	.11
03168500	03167000	.798	4.0	2.4
	03173000	.782	3.6	2.6
03172500	03175500	.910	36	24

Appendix 3.--Low-flow characteristics at short-term continuous-record gaging stations and related index stations--Continued

Short-term continuous-record station number	Index-station number	Coefficient of determination	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second	
			2-year	10-year
03208034	03208500	0.816	0.0	0.0
03208036	03208500	.869	.02	.0
03208040	03208500	.889	.12	.01
03208100	03208500	.918	.95	.04
03208700	03208900	.887	1.0	.32
03208900	03208950	.932	7.1	3.2
03475000	03473000	.889	64	50
	03471500	.884	66	51
03487800	03488000	.804	.75	.39
03488100	03488000	.943	39	28
03488445	03488000	.726	.14	.06
	03490000	.665	.14	.05
03488450	03488000	.798	.38	.15
	03490000	.884	.48	.15
03488500	03488000	.932	66	48
03489850	03478400	.691	2.3	1.6
	03526000	.739	2.2	1.6
	03490000	.771	1.9	1.1
03489870	03526000	.948	5.3	3.5
03489900	03526000	.818	10	6.7
03522000	03521500	.878	26	17
	03488000	.935	26	19
	03524000	.908	24	17
03523000	03524000	.766	5.1	3.2
03525000	03524500	.950	1.8	.52
03527500	03531500	.965	1.9	.95
03530000	03529500	.706	4.0	2.0
03530500	03529500	.963	4.0	1.3

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
01484750	5	0.20	01484800	0.16	0.05
01484755	6	.68	01484800	.77	.47
01484760	6	.27	01484800	.31	.14
01484765	7	.23	01484800	.27	.12
01484790	31	.23	01484800	.31	.08
01484820	5	.11	01484800	.74	.36
01484830	6	.10	01484800	.12	.05
01484840	6	.22	01484800	.27	.10
01484880	7	.11	01484800	.15	.04
01484885	8	.30	01484800	.34	.11
01484900	7	.13	01485500	.17	.10
01613570	9	3.24	01616000	2.7	2.0
			01634500	2.8	1.9
01613590	12	.16	01634500	.36	.18
01616100	13	4.71	01613900	4.2	3.2
			01615000	5.2	2.6
01620690	11	2.22	01620500	5.4	2.5
			01622000	4.4	2.1
01621300	12	4.03	01628500	6.4	3.4
01622230	8	3.55	01624300	3.8	3.0
			01624800	3.4	2.3
01626900			(S)	.08	.0
01627100			(S)	.15	.03
01627400			(S)	.2	.02
01628080	7	.42	01628500	.33	.12
01628700			(S)	.05	.02
01628900			(S)	.13	.03
01629120			(S)	.5	.04
01629920			(S)	.07	.02
01630542			(S)	.25	.05
01630585			(S)	.02	.0
01630620			(S)	.06	.0
01630649			(S)	.07	.01
01630680			(S)	.13	.04
01630700	13	2.36	01631000	3.4	1.7
			01635500	3.0	1.8
01632080	9	5.87	01632900	6.0	4.0
01632300	24	.0	None	.0	.0
01632840	8	2.88	01632900	3.1	1.8
01632890	12	14.9	01632900	15	9.2
01633475	7	.81	01634500	.61	.47
01633485	9	4.72	01635500	6.9	4.4
01633510	11	.08	01632000	.11	.04
			01634500	.10	.06
01633540	13	17.3	01632900	17	10.5
			01634500	18	13
01633730	10	.48	01634500	.54	.34
01633745	8	1.15	01634500	1.2	.94
			01635500	1.0	.75
01634340	13	4.08	01634500	4.3	3.2
01635045	13	1.33	01615000	1.0	.54
01635100	13	15.7	01634500	17	11
			01635500	16	11
01635250	9	2.20	01635500	1.7	.91
01635300	9	.25	01634500	.42	0.24
01636270	9	2.25	01613900	1.6	.95
			01615000	2.6	1.5

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
01636300	13	0.36	01615000	0.43	0.18
			01634500	.33	.23
01636690	11	1.05	01644000	.53	.11
01643585			(C)	.10	.04
01643600			(C)	1.2	.6
01643643	9	.62	01643700	1.4	.14
			01662000	1.7	.27
01643800	9	1.14	01638480	1.1	.34
01643950	9	10.2	01644000	12	2.9
01643988			(C)	2.1	.5
01643990			(C)	.0	.0
01644255			(C)	.01	.0
01644277			(C)	.0	.0
01644280			(C)	.28	.02
01644283			(C)	.0	.0
01644300			(F)	.0	.0
01645750			(F)	.19	.0
01645800			(F)	.0	.0
01645900			(F)	.78	.13
01645950			(F)	.17	.0
01646200			(F)	.73	.12
01646600			(F)	.09	.0
01646700			(F)	1.1	.07
01652400			(F)	.11	.06
01652600			(F)	.15	.01
01652610			(F)	.38	.01
01652620			(F)	.10	.01
01652645			(F)	.0	.0
01652650			(F)	.34	.01
01652710			(F)	.0	.0
01652910			(F)	1.7	.32
01653210			(F)	.16	.0
01653447			(F)	.06	.03
01653700	7	.12	01660400	.23	.08
01653800	7	.11	01660400	.7	.3
01653900			(F)	.45	.06
01653950			(F)	.04	.0
01655310			(F)	.58	.10
01655350			(F)	1.3	.04
01655370			(F)	.10	.0
01655380			(F)	.20	.0
01655390			(F)	3.0	.06
01656200	19	.0	01656500	.09	.03
			01662000	.14	.03
01656645			(C)	.0	.0
01656655			(C)	.0	.0
01656659			(C)	.0	.0
01656670			(C)	3.3	1.2
01656705			(C)	.02	.0
01656715			(C)	.01	.0
01656743			(C)	.0	.0
01656750			(C)	.2	.0
01656768			(C)	.0	.0
01656800			(F)	.0	.0
01656930			(C)	.0	.0
01657245			(C)	.02	.0
01657300			(F)	.48	.07
01657400			(F)	1.2	.11
01657435			(F)	.13	.01

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
01657600			(F)	0.12	0.0
01657800			(F)	.60	.12
01657890	6	0.58	01660400	.56	.12
01660670	7	.31	01654000	.67	.16
			01661050	.80	.34
			01670000	.75	.30
01660765	8	.0	01660400	1.2	.08
			01661050	1.3	.30
			01661500	.84	.29
01660870	8	.30	02042500	.22	.13
			01661800	.37	.21
			01669000	.20	.61
			01661500	.25	.13
			01660400	.30	.10
01661160	7	3.21	01661500	4.0	1.6
			01654000	5.5	1.6
01661840	9	3.48	01662000	3.0	.42
			01663500	3.0	.52
01662100			(S)	1.0	.2
01662110	9	1.11	01663500	1.7	.36
01662150			(S)	1.8	.3
01662160			(S)	.5	.05
01662190			(S)	.09	.02
01662310			(S)	1.0	.3
01662350			(S)	.5	.09
01662370			(S)	.5	.10
01662480			(S)	.21	.05
01662490			(S)	.34	.0
01664100			(C)	.0	.0
01664690			(C)	.0	.0
01664750			(C)	.0	.0
01665100			(C)	.0	.0
01665150			(C)	4.1	.8
01665220	9	.14	01656000	.60	.17
			01660400	.44	.01
01665260			(S)	2.4	.5
01665270			(S)	.9	.14
01665340			(S)	1.4	.3
01665400	9	2.42	01665500	1.7	.3
01665440			(S)	.6	.06
01665740			(S)	1.5	.15
01665800			(S)	2.1	.3
01665850	9	6.96	01663500	3.1	.40
			01665500	3.0	.48
01667600	4	.0	01662800	.01	.0
			01666500	.01	.0
01667650			(C)	.03	.0
01667700			(C)	.0	.0
01667750			(C)	.0	.0
01667848	9	.12	01663500	.42	.06
			01670300	.32	.06
			01673800	.30	.03
01667850	9	.54	01663500	.66	.07
			01673800	.90	.13
01668100	7	.0	01653600	.0	.0
01668200	11	.0	01661800	.04	.0
01668305	7	.0	01668500	.14	.0
			01669000	.13	.0
01669100	5	4.31	01669000	4.5	2.5

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
01669150	7	1.35	01661800	1.5	0.57
			01669000	1.7	.65
01669400	8	.02	01668800	.07	.01
			01669000	.08	.02
01669810	7	.70	01661800	.29	.17
			01668500	.29	.16
01669850	7	.0	None	.0	.0
01669885	7	.0	01661800	.0	.0
01670010	7	.04	01670000	.12	.02
01670020	7	.0	01670000	1.5	.12
01670120	12	.10	01665500	.95	.20
01670200	9	2.15	01666500	4.8	1.4
			02032680	3.5	.60
01671040	9	.07	01671100	.31	.08
			01672500	.47	.15
			01673800	.29	.09
01671680	9	4.35	01670300	6.6	2.5
			02032680	5.8	1.7
01671950	9	.13	01670011	.45	.11
			01672500	.40	.08
			02036500	.42	.12
01672200	9	.0	01671100	2.0	.80
			02036500	1.2	.22
01672400	4	.03	01671100	.03	.0
			01672500	.02	.0
01672800	9	.64	01671100	1.8	.60
			01673550	1.3	.32
01673560	5	1.51	01673550	3.1	.91
01673600	8	2.46	01669000	4.7	1.3
			01673550	5.1	1.9
			01677000	3.4	1.1
01673620	7	.0	01670000	.12	.0
			01673500	.06	.0
01673700	9	.0	None	.0	.0
01673900	7	.0	01669000	.13	.0
			01670000	.06	.0
			01671100	.10	.0
			01673800	.05	.0
01673960	9	.0	01673800	.05	.0
01674172	9	.0	01673800	.18	.0
			01674000	.12	.0
			01674500	.24	.0
01674200	8	.0	01668800	1.15	.11
			01670000	1.3	.09
01674250	8	2.88	01669000	4.5	1.2
			01671100	5.8	2.4
			01672500	7.2	2.4
			01673800	5.5	2.5
			01674000	6.5	2.0
01674300	7	3.21	01671100	6.4	1.5
			01673800	6.5	1.5
			01674000	8.2	1.0
01674350	8	1.78	01671100	3.4	.82
			01673550	3.0	.70
			01673800	3.8	1.0

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second 2-year	10-year
01674400	8	3.49	01668500	4.2	0.4
			01671100	5.8	1.4
			01673800	6.2	1.7
			01674000	7.7	1.4
01674600	8	.0	01668800	2.2	.9
			01669000	2.4	.8
			01672500	3.4	1.2
			01673550	2.4	1.2
			01673800	1.8	.7
			01674000	2.7	1.0
01674805	8	1.69	01673550	2.5	.92
01675550	6	.17	01668800	.27	.03
			01669000	.26	.05
01677100	18	.0	01669000	1.9	.85
			01671100	1.2	.43
			01672500	1.8	.88
			01673800	1.6	.74
			01674000	1.7	.56
01677200	9	.84	01671100	2.5	1.2
			01672500	3.2	1.7
			01673800	1.9	.72
			01674000	2.6	.95
01677900	7	.0	None	.0	.0
02002000	8	1.18	02011460	1.4	.90
02015600	6	2.88	01620500	1.5	.75
			02011400	2.1	1.7
			02011500	2.0	1.4
			02016000	1.4	.97
02015800	8	2.22	02015700	2.3	1.9
			02016000	2.2	1.7
			02020500	1.6	.90
02015930	8	.0	None	.0	.0
02016600	7	.03	02017500	.31	.17
02017300	4	.46	0201750	.13	.10
			02018500	.26	.20
02017400	3	.46	02017500	.09	.06
02019100	8	.82	02055100	.87	.59
			02061500	1.1	.52
02020170	7	.42	02016000	.32	.21
			02024000	.33	.22
02020200	8	.10	02020500	.01	.0
02021700	5	2.85	02021500	1.7	1.3
			02024000	1.8	1.4
02023300	8	.0	None	.0	.0
02024240	8	4.57	02016000	4.2	3.4
			02024000	4.1	3.4
02024760	6	1.40	02022500	3.0	2.2
			02024000	2.5	1.5
			02059500	3.4	1.9
			02061500	3.1	1.47
02024900	7	3.03	02024000	4.2	3.0
02025650	8	5.87	02027000	4.2	1.1
02025800	5	.16	02027800	.26	.06
			02059500	.21	.10
			02061500	.35	.14
02025900	8	3.49	02027800	3.8	1.4
			02061500	5.0	2.9
			02064000	4.9	2.1

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
02026400	7	3.64	02028500	4.4	2.1
02027600	6	2.69	02027000	2.3	.62
			02027500	1.4	.60
			02027800	2.4	.85
02027670	11	.18	02027000	16	6.5
			02027500	13	6.8
02027700	5	.18	02027800	.03	.0
02028450	7	1.18	02027800	1.4	.50
			02038850	1.8	.60
02028700	9	.80	02027000	.85	.28
			02028500	.85	.30
			02030000	1.0	.37
02029200	9	2.03	02030000	3.0	.85
02029400	10	1.25	02030000	1.6	.50
02030150	8	8.61	02027800	9.1	3.1
			02030500	10.	3.3
			02038850	14.	4.2
02030300	8	20.1	02030500	22.	5.8
02030850	9	2.49	02031000	2.0	.22
02032545			(S)	.05	.0
02033750	10	.33	02030000	1.3	.18
02034150	9	.33	02030000	.66	.12
			02034000	.65	.07
02034300	8	.84	02038850	1.1	.52
			02039000	.80	.28
02035075	9	.81	02030500	1.3	.34
			02036500	1.2	.39
			02040000	.86	.28
02035460	9	1.40	01671100	2.1	.96
			01672500	2.5	.95
02036700	9	.0	02038000	.0	.0
02038730	8	.60	01670000	.67	.41
			01673550	.68	.48
			01677000	.72	.68
			01668500	.71	.57
			02042500	.67	.57
02038780	9	.0	01670000	.12	.04
			01673550	.10	.03
			02038000	.07	.03
02038900	5	.11	02038850	.05	.0
02039600	9	2.82	02039000	4.0	1.5
			02039500	3.4	1.4
02039700	9	1.80	02039000	3.5	1.0
			02039500	3.8	1.6
02039800	9	.82	02039000	.86	.46
02040500	9	2.24	02041000	3.5	.46
			02044000	1.8	.15
02040600	6	.02	02036500	.01	.0
02040900	9	.44	02041000	.42	.08
			02044000	.48	.17
02041400	9	.04	02041000	.12	.02
			02046000	.12	.01
02042050	9	.16	02040000	.28	.02
			02041000	.17	.0
			02046000	.33	.01
02042140	8	1.54	01670000	2.7	1.6
02042160	8	.59	01661800	1.6	.65

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
02042200	10	0.0	None	0.0	0.0
02042210	7	1.97	01661800	2.55	2.13
			01677000	2.53	2.34
			02042500	2.49	2.26
02042450	7	.0	02038000	1.1	.75
02042600	8	.0	01677000	2.4	1.4
02042700	9	.05	01677000	.40	.20
02042710	3	.07	01670000	.01	.0
			02042500	.02	.0
			02046000	.02	.0
02042752	9	.26	02042500	1.1	.44
02042754	9	1.45	01668800	2.85	1.02
			02042500	3.18	2.02
02042756	9	.07	01668500	.30	.02
			01669000	.30	.04
			01677000	.21	.06
			02042500	.19	.04
02042765	9	.02	01661800	.12	.03
			01668500	.03	.0
			01669000	.09	.02
			01670000	.09	.01
			02042500	.08	.03
02042780	10	.30	01670000	.95	.24
			02042500	.92	.53
02042782	15	.26	01661800	1.1	.14
			01669000	.96	.12
			01670000	.92	.03
02042787	16	.0	01661800	.08	.02
			01668800	.06	.01
			01669000	.07	.01
02042790	8	.52	02042500	.30	.1
02042794	8	.43	01669000	.54	.04
			02042500	.38	.11
02042830	8	.24	01668800	.30	.08
			01669000	.24	.06
			02046000	.35	.08
02042890	8	.0	None	.0	.0
02042950	8	.30	01484800	.40	.27
			01668500	.38	.33
			02046000	.46	.23
02043000	8	.0	None	.0	.0
02043100	8	.0	01668500	.19	.01
			01677000	.30	.14
			02042500	.20	.06
			02046000	.36	.06
			02048000	.22	.04
02044200	6	.0	02041000	.01	.0
			02046000	.01	.0
02044300	9	5.39	02044000	3.8	.56
			02044500	3.1	.30
02044400	5	.08	02041000	.02	.0
02045800	9	.38	02044000	.12	.01
02046300	9	.08	02046000	.86	.08
02046480	9	.0	None	.0	.0
02046500	7	.0	None	.0	.0
02046700	7	.0	02042500	.36	.04
02046720	9	.0	None	.0	.0

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second 2-year	10-year
02046750	9	.54	02044500	0.77	0.10
			02051500	1.5	.36
			02051600	1.3	.10
02046830	7	.0	01668500	.01	.0
			02046000	.01	.0
02046900	6	.20	01668800	.0	.0
			02046000	.0	.0
02047050	8	.0	01661800	.25	.01
			01669000	.45	.01
02047300	7	.0	02047500	.01	.0
02047360	8	.0	None	.0	.0
02047400	10	.0	None	.0	.0
02047420	10	.0	02046000	.3	.0
02047440	9	.0	None	.0	.0
02047460	8	.01	02046000	.08	.0
02048460	8	.0	None	.0	.0
02049700	5	.0	01677000	.02	.0
			02046000	.02	.0
02050113	7	.0	None	.0	.0
02050130	8	.0	None	.0	.0
02050400	6	.12	02051000	.14	.05
02051100	9	.86	02051000	.70	.11
			02079640	.71	.31
02051175	8	15.7	02051000	13	8.7
02051200	9	1.99	02051000	1.8	.36
02051300	9	.42	02051500	1.6	.60
			02051600	2.0	.69
02051650	7	.01	02044500	.01	.0
			02051500	.01	.0
			02051600	.02	.0
			02052500	.0	.0
02052100	9	.04	02044500	.03	.0
			02051500	.05	.0
02053030	8	.0	None	.0	.0
02053100	7	.0	01661800	.10	.01
			01669000	.15	.01
02054120	7	5.56	02053800	4.6	2.3
			02054500	5.0	2.8
02056700	7	.53	02056650	3.2	.88
02056950	8	.28	02056900	1.2	.34
02057050	8	.73	02058400	6.0	.24
02057600	9	5.61	02056900	13	6.0
			02058400	21	11.
02057700	6	.09	02058400	.10	.04
			02059500	.12	.06
02057750	10	.52	02058400	2.9	1.1
02058100	10	2.51	02058400	8.9	4.2
02059420				8.4	6.5
02059460	8	.02	02059500	.30	.10
02060400	10	.82	02061500	1.0	.70
02061200	8	3.70	02061500	3.6	1.5
02062300	9	6.45	02064000	8.0	3.3
02063400	8	1.89	02038850	2.6	.81
			02064000	2.2	1.0
			02065500	2.5	.85
02063600	6	.02	02064000	.08	.03
02065100	6	.29	02064000	.43	.30
			02065500	.46	.25
			02076500	.32	.16

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
02065220	9	6.06	02065500	8.0	4.2
			02076500	8.0	4.6
02065300	6	.29	02061500	.52	.26
			02064000	.55	.31
			02065500	.64	.32
02065400	9	5.93	02064000	8.8	4.4
			02065500	9.2	3.6
02066450	9	.0	02039000	4.8	1.6
02067100	9	5.50	02051000	5.8	2.4
			02065500	6.5	2.3
02067810	4	.32	02069700	.29	.19
			03167500	.30	.22
			03170000	.31	.22
02069550	9	2.17	02069700	5.2	2.8
02069600	7	1.48	02070000	1.2	.58
02069800	9	.62	02069700	1.4	.82
			02070000	1.4	.81
02071600	9	15.0	02069700	39	24
			02070000	37	21
02071800	9	.67	02070000	3.6	1.3
02072600	9	1.10	02070000	2.8	1.4
02074450	10	4.69	02070000	6.7	3.7
			02074500	5.4	2.6
02075020	10	.25	02070000	.44	.12
			02074500	.44	.17
02075275	10	2.37	02070000	3.6	1.9
			02074500	3.5	2.1
			02076500	3.5	1.8
02075600	10	1.86	02077200	3.2	1.3
02075900	10	.62	02076500	.98	.42
02076300	8	4.85	02074500	15	6.0
			02076500	16	7.4
02076650	10	45.8	02058400	68	37
			02064000	56	23
			02076500	64	32
02076700	7	.09	02076500	.12	.02
02076770	10	14.6	02051000	18	5.4
			02058400	21	11
			02064000	18	9.0
			02076500	20	11
02078400	9	.80	02051000	.60	.05
02079660	9	.04	02051000	.32	.18
02079665	9	.0	02051000	1.2	.36
			02051500	1.4	.60
			02051600	1.3	.25
02113550	8	.90	02069700	8.0	3.4
03162415	5	1.71	03471500	2.8	1.8
			03473000	2.4	1.5
03162650	5	3.26	03473000	2.2	1.3
03163500	6	12.8	03164000	11	5.6
			03165000	13	4.8
03165350	6	1.13	03165000	1.0	.25
			03166800	1.0	.25
03165750	5	2.57	03167000	2.4	1.7
03166400	6	.01	03471500	.52	.34
03167200	6	20.1	03165000	19	13
			03167500	21	16
03167695	6	2.73	03165000	2.4	1.6
			03167500	2.2	1.7

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second 2-year	10-year
03168750	7	0.05	03166800	0.10	0.04
03169150	7	6.37	02053800	5.6	4.4
			03170000	5.5	4.5
03169370	7	1.52	02053800	1.7	.75
			03167500	2	
			03170000	1.8	1.1
03171400	7	1.97	03173000	1.9	1.5
			03175500	2.1	1.6
03171550	7	19.1	03170000	10.	4.8
			03173000	11.	7.2
03171900	6	.20	03175500	.18	.08
03177600	6	7.42	03175500	7.2	6.1
			03521500	7.4	5.9
03207223	6	2.61	03207800	1.4	.44
03207225	11	.49	03207800	.38	.10
03207228	5	1.1	03207800	.58	.16
03207250	13	3.17	03207800	2.7	.95
			03208500	2.2	.53
03207280	5	3.0	03207800	.77	.23
03207295	13	.03	03207800	.04	.01
03207390	5	1.2	03207800	.32	.10
03207398	13	.52	03207800	.38	.10
03207407	13	.14	03207800	.15	.04
03207440	8	.09	03207800	.06	.01
03207450	6	1.9	03207800	1.8	.52
03207505	6	1.5	03207800	.95	.42
03207520	6	.37	03207800	.22	.07
03207530	6	3.0	03208500	1.3	.32
03207550	13	.55	03207800	.52	.24
03207600	6	1.4	03207800	1.2	.42
03207792	6	.67	03207800	.74	.28
0320803170	6	.13	03207800	.11	.05
			03208500	.09	.03
0320803180	6	.01	03207800	.0	.0
			03208500	.0	.0
0320803350	6	.01	03207800	.01	.0
032080351	6	.02	03207800	.01	.0
			03208500	.01	.0
032080352	6	.01	03208500	.0	.0
0320803570	6	.0	03208500	.0	.0
03208042	6	.03	03208500	.01	.0
03208043	12	.45	03207800	.30	.06
			03208500	.24	.02
03208044	6	.01	03208500	.0	.0
0320804480	6	.01	03208500	.01	.0
03208045	6	.01	03208500	.0	.0
03208046	12	.16	03208500	.09	.0
0320804630	6	.11	03208500	.05	.01
0320804670	6	.0	03208500	.0	.0
0320804780	6	.01	03208500	.0	.0
03208048	5	.63	03208500	.10	.01
0320806100	6	.04	03208500	.02	.0
0320806200	6	.02	03208500	.01	.0
0320806390	6	.10	03208500	.06	.01
03208064	5	1.9	03208500	.55	.10
032080646	6	.0	None	.0	.0
032080647	6	.0	None	.0	.0
032080664	6	.02	03208500	.01	.0

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second 2-year	10-year
0320806680	6	0.02	03208500	0.0	0.0
03208067	5	1.3	03208500	.33	.0
0320807050	6	.01	03208500	.0	.0
0320807200	6	.02	03208500	.01	.0
03208079	6	.05	03208500	.01	.0
0320807950	6	.01	03208500	.0	.0
03208087	5	.02	03208500	.0	.0
03208088	5	.0	03208500	.0	.0
03208089	6	.01	03208500	.0	.0
03208096	6	.01	03208500	.0	.0
03208110	6	7.1	03208500	2.5	.51
03208150	6	1.8	03208500	.44	.04
03208220	5	.52	03207800	.18	.06
			03208500	.11	.0
03208240	12	.14	03207800	.23	.07
03208280	12	.07	03208500	1.3	0.36
03208365	4	6.1	03208500	1.1	.14
03208370	6	2.9	03208500	1.1	.15
03208400	13	2.1	03208500	1.2	.16
03208410	13	.04	03208500	.03	.0
03208420	6	2.2	03208500	.76	.10
03208550	5	2.9	03208500	.58	.08
03208670	12	.67	03208500	.32	.04
			03208950	.15	.04
03208795	5	5.2	03208950	1.4	.58
03208810	13	.97	03208950	.60	.25
03208905	5	4.1	03208500	1.5	.48
			03208950	1.1	.60
03208922	5	.13	03208500	.10	.0
			03208950	.10	.0
03208935	5	5.5	03208500	1.4	.26
			03208950	1.5	.65
03208938	5	4.0	03208500	1.8	.64
			03208950	1.6	.89
03209250	5	.99	03208500	1.3	.31
03213572	13	.66	03213590	1.2	.34
03213575	5	2.2	03207800	.85	.32
03213581	12	.30	03213590	.36	.12
03213584	13	.16	03213590	.28	.08
03213587	5	2.1	03207800	.91	.36
03475700	6	.93	03475000	1.1	.70
			03478400	.90	.70
03489800	12	.60	03526000	1.2	.65
03520700	5	1.3	03521500	.49	.25
03520800	5	.58	03521500	.23	.12
03521100	5	1.4	03521500	.73	.40
03521600	5	1.9	03521500	1.1	.62
03521650	13	.15	03488000	.13	.06
			03521500	.20	.05
03521700	13	0.26	03488000	.31	.17
			03521500	.40	.23
03521800	5	.49	03521500	.91	.58
03521850	5	.87	03521500	1.4	.86
03521900	5	2.0	03524000	.90	.56
03521950	5	6.81	03524000	7.0	6.0
03522525	6	.03	03521500	.14	.08
			03524000	.11	.07
03522550	13	.10	03527000	.15	.08

Appendix 4.--Low-flow characteristics at partial-record gaging stations and related index stations--Continued

[Reports that contain data specific to Virginia and from which data are taken directly are indicated by: (S)--values taken from Lynch, 1987, (C)--values taken from Lynch and Others, 1987, (F)--values taken from Mohler and Hagan, 1981]

Partial record station number	Number of discharge measurements	Minimum discharge measured, in cubic feet per second	Index-station number	Annual 7-day low flow for indicated recurrence interval, in cubic feet per second: 2-year	10-year
03522600	5	4.3	03521500	2.1	1.2
			03524000	1.9	1.2
03523650	5	3.0	03524000	.90	.50
			03527000	1.1	.64
03523700	6	1.0	03521500	.38	.17
			03524000	.36	.19
03524010	13	.12	03521500	.13	.04
			03524000	.15	.07
03524020	6	.78	03521500	.24	.11
			03524000	.21	.11
03524030	15	.15	03521500	.15	.07
03524050	14	2.07	03524000	2.4	1.5
03524060	6	1.8	03524000	.63	.40
03524070	5	1.6	03524000	.52	.32
03524340	5	5.2	03524500	1.0	.31
03524346	13	1.34	03524500	.75	.33
03524348	13	.27	03524500	.12	.04
03524700	6	.75	03524000	.23	.11
03524880	5	.64	03527000	.50	.32
			03529500	.52	.24
03524890	5	.25	03524500	.24	.10
			03527000	.40	.26
			03529500	.30	.13
03525100	6	4.5	03527000	2.8	1.9
03525490	6	6.0	03527000	3.2	2.1
03527480	6	4.6	03527000	1.6	1.0
03527490	6	.01	03529500	.0	.0
			03531500	.0	.0
03529300	6	5.8	03529500	4.0	2.1
			03531500	4.3	2.5
03529310	14	1.80	03529500	1.6	.87
03529315	6	1.4	03529500	.49	.22
03529400	6	2.1	03529500	.64	.28
03529410	6	2.9	03529500	1.1	.52
03529450	14	1.50	03529500	1.2	.60
03529475	6	.41	03529500	.30	.16
03529800	6	3.6	03529500	3.0	1.6
03529900	6	1.7	03529500	.95	.50
			03531500	1.4	.88
03530400	5	5.5	03529500	1.8	.70
			03531500	3.0	1.5
03530440	13	.24	03530500	.23	.08
03530460	5	1.1	03531500	.47	.24
03530470	4	.37	03529500	.12	.05
			03531500	.17	.08
03530485	4	.75	03529500	.33	.17
			03531500	.49	.30
03530495	4	1.2	03530500	.35	.10
03531505	5	5.2	03531500	2.8	1.9
03531520	5	15.	03531500	11.	7.3
03531530	6	9.3	03531500	3.4	2.1
03531535	5	1.8	03531500	1.5	.88