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A PROPOSED STREAMFLOW DATA PROGRAM FOR SOUTH CAROLINA

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ABSTRACT

An evaluation of the available streamflow data in South Carolina was made to provide guidelines for planning future surface-water data programs. The basic elements in the evaluation procedure were (1) establishment of objectives and goals of the program, (2) examination and analysis of all available data to determine which goals have already been met, (3) consideration of alternate methods of meeting the remaining goals, and (4) identification of elements that should be included in the future program.

Four categories of data form the framework of program design. They are: current-purpose data, planning and design data, data to define long-term trends, and stream environment data. An accuracy goal for planning and design data of an equivalent of 25 years of record was specified for principal streams and an equivalent of 10 years of record was specified for minor streams. It was found that many of the goals could be met by generalizing data for gaged basins by regression analysis. Appropriate changes could be made in the present data program based on this fact.

A streamflow data program based on the guidelines developed in this study is proposed for the future.

INTRODUCTION

Streamflow records have been obtained in South Carolina by the U. S. Geological Survey since 1883 when a gaging station providing a daily discharge record was established on the Savannah River at Augusta, Georgia. River stages had been collected and published by the U. S. Weather Bureau as early as 1875 at the same site. By 1900, discharge records were being collected at seven sites in the State, and the program remained near this level until 1925. From 1925 to 1929, 16 additional gaging stations were operated in South Carolina. Collection of these streamflow records was the responsibility of the U. S. Geological Survey's office in Asheville, North Carolina.

On November 1, 1930, the South Carolina District was created. Cooperative programs were begun with the South Carolina State Highway Department, several Federal Power Commission licensees, and the U. S. Army's Corps of Engineers. Three new gaging stations were built in 1934 through a cooperative agreement with the U. S. Soil Erosion Service, now the Soil Conservation Service of the Department of Agriculture. Six additional gaging stations were established in 1938 at the request of the Corps of Engineers. By 1939, the South Carolina District was operating 54 stations, 33 of which had automatic recorders. By 1969, the network had grown to 66 stations.

With the formation of the South Carolina Research, Planning and Development Board (now the South Carolina State Development Board) in 1946, a low-flow partial-record program was established. The network was operated primarily to provide low-flow data at sites that were not being gaged regularly, but which were considered as potential industrial locations.

The data collection program was further expanded in 1966 when a project to investigate flood frequencies on small streams was undertaken for the South Carolina State Highway Department. The network consists of 56 partial-record stations, all of which are equipped with dual digital stage and rainfall recorders.

Expanded requirements for streamflow information have revealed a necessity for improving techniques in planning surface water data programs. Carter and Benson (1969) proposed an approach for evaluating surface water data programs and the concepts and procedures important to such an analysis. The basic framework consists of four major steps:

(1) enumerate the objectives and goals of the program, including accuracy goals, (2) evaluate all available data to determine which goals have been reached, (3) define alternate methods of satisfying the remaining goals, and (4) propose a comprehensive program of data collection and analysis that will result in the satisfaction of the remaining goals. The purpose of this study is to set goals for the program and to evaluate all available data with respect to the established goals. Based upon the results obtained, future programs must then be designed to efficiently collect data that are necessary to attain goals not yet reached.

HYDROLOGY OF THE STATE

The State of South Carolina comprises an area bounded on the northwest by the Southern Appalachian Highlands and on the southeast by the Atlantic Ocean. Topographically the State is an irregular southeast slope. This slope is divided into three physiographic provinces which trend perpendicular to it. About 500 square miles along the northwest margin of South Carolina lies within the Blue Ridge province. The Piedmont province is in the central part of the State and covers an area of about 10,500 square miles. The southeastern two-thirds of the State form part of the Coastal Plain province. Low-flow characteristics of the streams in the State are related to the materials which underlie these provinces.

Most of the State is drained by the Peedee, the Santee, and the Savannah River systems, all of which originate in North Carolina. The Edisto, Combahee, and Coosawhatchie Rivers are smaller streams that rise within the State and flow southeastward to the Atlantic Ocean. Streams in the northwestern part of the State are characterized by well-defined valleys and swift flow. Flood peaks are generally sharp and sustained high flow is of short duration. Streams in the Coastal Plain typically have wide valleys, sluggish flow, and often are bordered by extensive swamps. Flood peaks in this area characteristically have broader peaks and longer periods of sustained high flow. Coastal streams terminate in long estuaries.

Flow of the major streams in South Carolina is regulated by changes in reservoir storage as required for the generation of hydroelectric power and for other purposes.

The average annual rainfall varies from 45 to 50 inches over the central and lower parts of the State, and exceeds 60 inches in the mountainous northwest. Rainfall is fairly evenly distributed throughout the year. High air temperatures in the spring, summer, and fall cause high evapotranspiration rates. Temperature and rainfall patterns influence the quantity and distribution of streamflow during the year. Minimum flows generally occur in September and October.

The seasonal pattern of streamflow is much more pronounced than that of precipitation due to increased losses by evapotranspiration during the summer months. In general, streamflow in South Carolina is highest in the winter and lowest in the fall with higher mean flows occurring in the northwest portion of the State. Areal variation in low flow is very pronounced in the State due to differences in topography and geology.

CONCEPTS AND PROCEDURES USED IN THIS STUDY

One of the principal concepts of this study is that streamflow data may be needed at any site on any stream in South Carolina, and that the data collection system must be designed to produce the needed information. Because it is not economically feasible to collect information on every stream in the State, a sampling procedure must be used. Required information can then be provided by a combination of data collection and hydrologic analysis.

Another important concept is that the goals of the program, including accuracy goals, should be identified in quantitative form. This permits evaluation of existing data to determine which goals have been attained. Changes in the current program can then be studied to accomodate specific needs. Table 1 outlines the framework for the design of a data collection program.

In this analysis four basic types of data are discussed: (1) current-purpose streamflow data, (2) data for planning and design, (3) data to record long-term changes in time, and (4) environmental data.

Program goals were established for each type of data. Accuracy goals were established for planning and design data. All available data were then examined and analyzed with reference to the established goals and needs of future programs.

Current-Purpose Data

Current-purpose streamflow stations are needed to provide information for day-to-day decisions on water management, powerplant regulation, flood forecasting, water quality management, and surveillance necessary to comply with legal or compact requirements. A gaging station is therefore operated for the specific purpose of supplying the data necessary for the particular water management system.

Table 1.--Framework for design of data collection program

Type of Data	Current-Purpose	Planning and Design				Long-term trends	Stream environment
		Natural Flow		Regulated Flow			
		Minor streams	Principal streams	Minor streams	Principal streams		
Goals	To provide current data on streamflow needed for day-by-day decisions on water management as required.	To provide information on statistical characteristics of flow at any site on any stream in South Carolina to the specified accuracy.				To provide a long-term data base of homogeneous records on natural-flow streams.	To describe the hydrologic environment of stream channels and drainage basins.
Drainage area limits	Full range.	Less than 500 sq mi.	Greater than 500 sq mi.	Less than 500 sq mi.	Greater than 500 sq mi.	Full range.	Full range.
Accuracy goal	As required.	Equivalent to 10 years of record.	Equivalent to 25 years of record.	Equivalent to 10 years of record.	Equivalent to 25 years of record.	Highest obtainable.	As required.
Approach	Operate gaging stations as required to provide specific information needed.	Gage at selected points. Transfer data to ungaged points by regression or interpolation.	Operate gaging stations to obtain 25 years of record (or the equivalent by correlation) at a network of points on principal streams, interpolate between points.	Develop generalized relations that account for the effect of storage, diversion or regulation on natural flow characteristics.	Utilize analytical model of stream system with observed data as input to compute homogeneous records for both natural flow conditions and present conditions of development.	Operate a number of carefully selected gaging stations indefinitely.	Observe and publish information on stream environment.
Evaluate available data	Identify stations where data is used currently and code the specific use of data.	Develop relationship for each flow characteristic and compare standard error with accuracy goal. Evaluate sample.	Lay out network of points on principal streams and compare data available at these points with goal.	Appraise type of regulation, data available, and areas where relationships are needed.	Identify stream systems that should be studied using model approach and determine data requirements.	Designate one or two stations in each WRC subregion to operate indefinitely for this purpose.	Evaluate information available in relation to goals.
Design future program		Identify goals that have not been attained. Consider alternate means of attaining goals. Identify elements of future program.					

Although there is little latitude in the selection of location, or for controlling the observation period, some current-purpose stations can also provide data that may be used for regionalizating certain hydrologic characteristics.

Current-purpose stations are listed separately in this report because they are not subject to the design plan, but rather to changes in requests for data in water management.

Planning and Design Data

The principal streamflow data for use in planning and design are provided by records at gaging stations. Since a particular sequence of hydrologic events is not likely to be precisely repeated, planners and designers are more interested in statistical characteristics of streamflow rather than data for specific events. Experience has shown that records of streamflow of the past are good indicators of events to be expected in the future, despite the fact that sequential duplications are remote. It is assumed that the probability of occurrence of a given magnitude can be estimated from the frequency of such occurrence in the past. Examples of these statistical streamflow characteristics are the mean annual flow, the lowest 7-day average flow with a recurrence interval of 2 years, the flood with a 50-year recurrence interval, and the standard deviation of annual mean flows.

Due to their nature, streamflow data contain time sampling errors that are generally reduced only by additional years of record. Although it is impractical to collect a long continuous streamflow record at all locations where information is needed, operation of a number of stations for extended periods will provide information that can be transferred to stations that have only small amounts of data as well as to ungaged sites.

Natural-Flow Streams

The transfer of information on natural-flow streams is done by relating flow characteristics to basin characteristics, such as drainage area, topography, and climate; by relating a short record to a longer one; or by interpolating between gaged points on a stream channel.

To evaluate the statistical characteristics of streamflow, the streams in South Carolina were identified as having either natural or regulated-flow conditions. For the purpose of this study, streams were also defined under each of the above categories as being minor streams (drainage area, less than 500 sq mi), or principal streams (drainage area, greater than 500 sq mi). The principal-stream network was further defined by first identifying sites with drainage areas of about 500 square miles on the upstream segment of all streams, and then identifying the next and following sites on each stream from the upstream station to the mouth at points where the drainage area has doubled, or more than doubled, due to large tributaries entering.

Regulated-flow streams

The natural flow regime of many streams is altered by the construction of storage reservoirs and the diversion of water for consumptive use. Flow characteristics on regulated streams are seldom transferable to other streams or even to other points on the same stream, so data collection and analysis are complicated by this restriction.

To provide useful statistical characteristics on regulated streams, records of streamflow at a site must be homogeneous in time. Such data are frequently difficult to obtain because additional development occurs before a sufficiently long period of record is collected.

Since methods of regression, interpolation, and other methods cannot be used for regulated streams, a systems approach appears to be the most efficient way to obtain meaningful information. The systems approach requires that an analytical or mathematical model be developed for the stream system. These models are basically water-budget equations and flow-storage equations, and although the concept is quite simple, complex relations often require computer solutions.

To provide a comprehensive accounting of flow in a modeled system, the input should include: (1) stage-capacity curves for the reservoirs, (2) operating-rule curves for water release, (3) stage-discharge curves for outlets, (4) evaporation and seepage losses, (5) any diversions in the system, (6) channel geometry, and (7) flow data at one or more points on the system. These models can provide flow information for both natural and regulated conditions at gaging stations, and at ungaged sites in the system.

Accuracy of streamflow characteristics

In using past hydrologic experience to appraise the probability of future occurrences, some error must be tolerated. Natural streamflow, like other events related to climate, is generally random in occurrence and varies greatly in time and space. Statistical techniques used in the analysis of random events, therefore, are considered applicable. Measures of the variability with time of annual mean flow and other streamflow characteristics are determined from the historical streamflow data, and the probable errors involved in defining streamflow characteristics can be appraised. The principal measure of the accuracy with which a particular streamflow characteristic can be determined is the statistical measure of error, "standard error of estimate," and is expressed in this report as a percentage of the average value of the characteristic. The standard error is the estimated limit above and below the average within which about 67 percent of future values of the characteristics are expected to fall. Conversely, there is only one chance in three that future values will differ from the average by more than one standard error.

In general, the longer the record, the more reliable are the estimates of probable future occurrences. However, even with a long record, say 50-100 years or more, it is not possible to determine with great precision the probability of certain flow characteristics such as floods of a given magnitude, for example. The standard error of various streamflow parameters decreases with the years of available record, but at a decreasing rate. (See figure 1.) The incremental economic value of the additional years of record beyond a reasonable limit in the planning and design of projects is under continuing study, but no usable guidelines are available now.

At sites on natural-flow streams where streamflow records are not available, the desired streamflow characteristics may be defined by means of the relation between the streamflow parameter and the characteristics of the drainage basin. This definition is accomplished by multiple regression analysis, a statistical method of handling sample data that can relate a streamflow characteristic to the topographic and climatic characteristics that affect streamflow. This analysis produces a regression equation that can be used to compute the flow characteristics at any point on natural streams in South Carolina. The standard error of a regression equation provides a measure of the accuracy of an estimate made from it at an ungaged site. That error may be compared with the error associated with the same characteristic defined from a given number of years of record in order to determine whether the accuracy objective has been met.

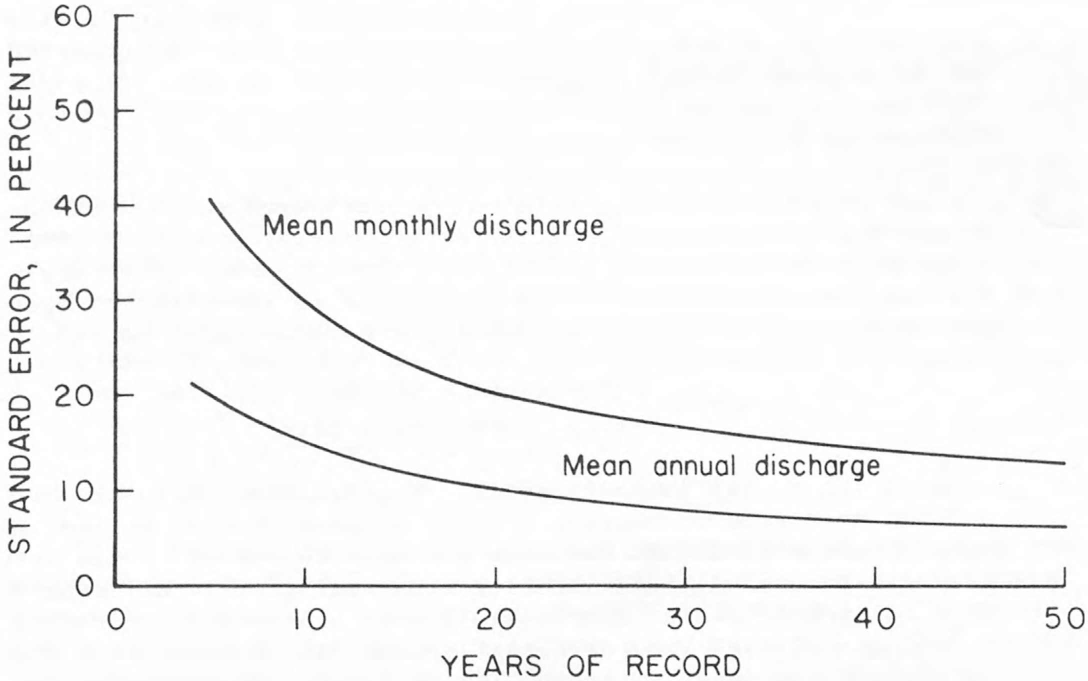

Figure 1.—Curve showing relation of standard error to length of record

Data to Define Long-term Trends

Long-term records are needed as a base for detecting changes in the natural flow regime and for analyzing the statistical nature of the hydrologic time series.

Future flow conditions can be estimated from records of streamflow observed at one or more sites, provided that the observed flows can be assumed to be a representative sample of the flow population in time. A long period of homogeneous record is required to check the assumption of representative sampling.

Flow characteristics defined by short-term records can be adjusted to more nearly conform to the characteristics of the flow population based on long-term homogeneous records. The requirements for defining long-term natural trends can be satisfied by operating a small network of gaging stations for an indefinite period.

Stream Environment Data

Environmental characteristics of a drainage basin are intimately related to stream discharge. Unlike streamflow information, however, most stream environment data are not time dependent. Once determined, they can be usefully utilized for many years. Data defining the physical properties of a drainage system are used in hydraulic and hydrologic studies for the design, plans, and operation of systems to control the quantity or quality of water. Typical examples of such data include:

1. Geometry and hydraulic roughness of stream channels.
2. Flood profiles along stream channels.
3. Areas subject to inundation by floods of various recurrence intervals.
4. Travel time of water in channel reaches.
5. Relationship between climate and streamflow.
6. Basin characteristics such as area, land cover, topography and geology.
7. Relation between aquifer characteristics and streamflow.

GOALS OF THE SOUTH CAROLINA STREAMFLOW DATA PROGRAM

The objective of the South Carolina streamflow data program is to provide information on flow characteristics at any point on any stream in the State. More specific goals have been assigned to each of the four basic types of data.

Current-purpose Data

The program goal for current-use data is to furnish needed information, at a specific location, for a particular user. Stations operated for this purpose are not subject to a program design plan because their operation is governed by specifications set down by the data user. A higher degree of accuracy can generally be justified for current-purpose data, since water management systems deal with known volumes of water that are subject to control. It is often necessary to intensify observations or use more sophisticated instrumentation to meet specified accuracy standards.

Planning and Design Data

The program goal for planning and design data is to define the flow characteristics listed in table 2 within the specified limits for both natural and regulated streams. As defined in this study, the accuracy goal for each streamflow characteristic is the equivalent accuracy that could be obtained from records actually collected at a gaging station for a specific number of years. The accuracy goal for minor streams is the equivalent of 10 years of record, and the goal for principal streams, due to their greater economic value, is the equivalent of 25 years of record.

Accuracy goals in terms of equivalent years of record have been converted to standard error, using standard statistical methods and assuming no serial correlation between annual occurrences. This conversion, as described by Hardison (1969), is simply an estimation of the time sampling errors that occur in streamflow records.

Table 2.--Accuracy goals

Streamflow characteristic	Standard error (percent)	
	10 years	25 years
Mean annual discharge	15	10
Mean monthly discharge (average)	29	19
Standard deviation of annual discharge	22	14
Standard deviation of monthly discharge (average)	22	14
50-year flood	35	20
7-day 2-year low flow	18	12
7-day 20-year low flow	28	17
7-day 2-year flood volume	14	9
7-day 50-year flood volume	25	15

Data to Define Long-term Trends

The goal for this type of data is to operate indefinitely a small network of gaging stations, on natural-flow streams. One or two stations should be located in each of the subregions as identified by the Federal Water Resources Council, on streams that will probably not be modified by man. Accuracy of such records should be the highest attainable.

Stream Environment Data

The goal is to define as needs arise, those types of data listed on page 10.

EVALUATION OF EXISTING DATA IN SOUTH CAROLINA

Design of streamflow data programs is based on the deficiency of existing data to satisfy established goals. Each of the four types of data already discussed will be evaluated individually because goals vary for each type.

Current-Purpose Data

The South Carolina District operates 29 gaging stations to provide information for current use. It is assumed that the requirements for this type of data are being met. Based on user needs, this part of the program can be modified. Stations and purpose(s) of operation of each are listed in table A-1.

Planning and Design Data

Generalization of data at gaging stations is necessary to define the flow characteristics at any point on any stream in South Carolina. Methods of generalization vary depending on the type of stream and the size of its drainage area. Therefore, the framework shown in table 1 will be followed with each case discussed individually.

Evaluation of natural-flow systems

Regionalization of available data can be used to estimate the statistical characteristics of streamflow at ungaged sites. The purpose of this evaluation is to determine whether this method can define the flow characteristics within the accuracies specified as goals of the program.

Multiple-regression techniques provide the most efficient way now known for defining statistical characteristics on a broad scale. The method provides equations that relate streamflow characteristics to basin characteristics. After the formula for a particular flow characteristic has been derived, that characteristic can be computed for any natural-flow stream in the defined region by substituting the appropriate values of the basin parameters into the equation.

Data from 37 gaging stations with natural or mostly unregulated flow have been used in this analysis. All stations have at least 10 years of record and include both minor and principal streams. Regulation affected low flows at several stations and they were therefore excluded from relations derived for minimum flows. No records for highly regulated streams, minor or principal, were used because regression methods are not applicable for these stations.

The following four sections describe individually the steps followed in evaluating the natural-flow system.

<u>Streamflow Characteristics</u>.--The following list of streamflow characteristics were analyzed for this study. The flow variables examined encompass the full range of the flow regime.

1. Low-flow characteristics are the annual lowest mean discharges for a 7-day period, for the climatic year (April 1 to March 31) at recurrence intervals of 2- and 20-years. These are identified by $M_{7,2}$ and $M_{7,20}$.

2. Mean-flow characteristics that were used are the means of the annual means, Q_a, and means for each calendar month, q_i, where i represents the month with January = 1, February = 2, etc.

3. Flood-peak characteristics are defined as the maximum discharge expected in a given year at recurrence intervals of 2, 5, 10, 25, and 50 years. These are symbolized P_t, where t is equal to the recurrence interval. The frequency curves were prepared as described by the Water Resources Council (1967).

4. Flood-volume characteristics represent the highest 7-day flow volume expected to be exceeded on the average at intervals of 2- and 50-years. Values were taken from flood-volume frequency curves of 7-day flood volumes and are herein referred to as $V_{7,2}$ and $V_{7,50}$.

5. Flow-variability characteristics are defined by the standard deviations of annual and monthly means. These variables are symbolized by SD, with subscripts equal to a or i (i=1,12), depending on whether the values were for standard deviations of annual or monthly means.

6. Flow-duration characteristics represent duration-curve percentile values and are symbolically noted by D_p, where p is the percent of time specified discharges were equalled or exceeded during the period of record. Values of p used in this study are 50, 90, and 95 percent.

A listing of selected flow characteristics used in this study are in table A-2.

Basin Characteristics.--Eight characteristics were determined for the drainage basin above each of the gaging stations used in the regression analysis. They are:

1. Drainage area, A, in square miles, as published in the latest Geological Survey streamflow data reports.

2. Main-channel slope, S, in feet per mile, between points 10 and 85 percent of the total main-channel length from the gaging station to the basin divide. This method was described by Benson (1962).

3. Main-channel length, L, in miles, measured from the gaging station to the basin divide. Measurements were made with dividers on best available maps.

4. Surface-storage, St, expressed in percent of drainage area occupied by lakes, ponds, and swamps. Areas were determined with transparent grid overlays.

5. Precipitation intensity, I, in inches, defined as the maximum 24-hour rainfall expected once every two years. Data were obtained from U. S. Weather Bureau Technical Paper 29.

6. Mean-annual precipitation, P, in inches, determined from an isohytal map prepared by the U. S. Weather Bureau.

7. Forest area, F, given in percent of drainage area covered by forest, shown as green on topographic maps. Areas were measured using a grid sampling method.

8. Soil index, Si, in inches, as computed from data provided by the Soil Conservation Service of the Department of Agriculture. This index represents values of potential maximum infiltration, in inches, during an annual flood, under average soil moisture conditions. Average values for each basin were determined using a grid method.

A complete list of the basin characteristics used are in table A-3.

Regression Analysis.--Regionalization of streamflow characteristics is most effectively accomplished by multiple-regression techniques. Each flow variable is related to several basin parameters and the resulting equation has the form

$$Y = aA^{b}S^{c}L^{d}P^{e} \text{------},$$

where Y is a particular statistical streamflow characteristic; A,S,L, and P are basin characteristics (topographic or climatic); and a,b,c, d, and e are coefficients defined by regression. Benson (1962) and Thomas and Benson (1969) have described this method. In the South Carolina analysis drainage area, main-channel slope, main-channel length, surface storage, precipitation intensity, mean annual precipitation, forest cover, and soil index were initially used in the regression for each flow variable.

In addition to providing a set of equations that define streamflow characteristics at any point on any natural-flow stream in the State, this procedure also provides the standard errors of estimate and the statistical significance of each basin parameter.

The regression equation for each flow variable was calculated on a computer using a step backward analysis. This method initially related all of the basin characteristics (independent variables) to a single streamflow characteristic (dependent variable). The standard error of the resulting equation and the significance of each basin characteristic was also computed. The computer then deleted the least significant basin parameter and repeated the above calculations. The procedure of recalculation, omitting the least effective variable was repeated until only the most significant variable remained.

After all relations for a given flow characteristic had been evaluated the entire procedure was repeated using another streamflow variable with the same set of basin parameters. The relation with the largest number of variables, significant at the 5 percent level, is described in table A-4.

Table 3 illustrates the output of the regression analyses for mean annual flow. Using the guidelines described above for determining the equation for estimating mean annual flow for ungaged sites in South Carolina, the relation that includes all statistically significant variables is

$$Q_a = 0.0087\ A^{0.98}\ ST^{-0.08} P^{1.40}\ Si^{0.34}$$

where Q_a is the mean annual discharge, in cubic feet per second; A is the drainage area, in square miles; St is surface storage, in percent of total drainage area occupied by lakes, ponds, and swamps plus 1 percent; P is the mean annual precipitation reduced by 20 inches, in inches; and Si is the soil index, in inches. The elimination of surface storage (St) from this equation causes an increase in the standard error of 1.6 percent. The equation shown above is probably the most accurate, however, in this instance, the equation using only drainage area, mean annual precipitation and soil index probably would be the most useful, since using this equation would eliminate the computation of surface storage.

Table A-4 shows, for each of the 38 flow characteristics studied, the regression constant, the regression coefficient (exponent) for all statistically significant basin parameters, and the standard error of estimate. Each basin parameter determined for this study was significant in several regression analyses.

To determine whether the accuracy goals have been reached for the flow characteristic, the standard error in table A-4 should be compared with the corresponding values in table 3. A detailed discussion of this comparison will be deferred to a later section of the report. Briefly, however, it is apparent, with the exception of low flows, that the regression results generally meet the accuracy goals for minor streams (the equivalent of 10 years of record), and the results for some flow characteristics meet the accuracy goals for principal streams (the equivalent of 25 years of record).

Table 3.--Summary of regression analyses of mean annual flow

Dependent variable	Regression constant	Regression coefficients for independent variables								Standard error of estimate	
		Area	Slope	Length	Storage	Precipitation intensity	Precipitation	Forest cover	Soil Index	Percent	Percent change[a]
Mean annual flow	0.0152	[b]0.973	0.070	0.082	-0.069	-0.042	[b]0.949	0.647	0.327	11.9	--
	.0124	[b].956	.071	.112	-.068	--	[b].892	.671	[b].330	11.8	--
	.0120	[b]1.005	.055	--	[b]-.077	--	[b]1.020	.523	[b].319	11.8	--
	.0112	[b]1.003	.067	--	-.057	--	[b]1.261	--	[b].283	11.8	0
	.0087	[b].983	--	--	[b]-.085	--	[b]1.398	--	[b].339	12.1	+.3
	.0068	[b].969	--	--	--	--	[b]1.510	--	[b].246	13.7	+1.6
	.0110	[b].980	--	--	--	--	[b]1.461	--	--	15.0	+1.3
	2.85	[b].870	--	--	--	--	--	--	--	32.9	+17.9

a Percent change when least significant variables are dropped, as indicated by dashed line in column.

b Statistically significant at the 5-percent level.

Principal streams.--Accuracy goals for principal streams are higher than those for minor streams. Regionalization techniques generally cannot be used to achieve the equivalent of 25 years of record. Therefore, the goals for principal streams must be met by operating gaging stations at sites determined on the basis of drainage area and interpolating between them. The study for this category consists of identifying the principal-streams network and evaluating the length of record available at these sites.

The principal-streams network in South Carolina, see list below, consists of 14 sites on unregulated streams or streams that are only slightly regulated. Twelve of these stations have at least 25 years of record, with one additional site available for which an equivalent of 25 years of record may be obtained by correlating available data with a long-term station.

2-1105. Waccamaw River near Longs
2-1315. Lynches River near Bishopville
2-1320. Lynches River at Effingham
2-1325. Little Pee Dee River near Dillon
2-1350. Little Pee Dee River at Galivants Ferry
2-1360. Black River at Kingstree
2-1535. Broad River near Gaffney
2-1565. Broad River near Carlisle
2-1615. Broad River at Richtex
2-1730. South Fork Edisto River near Denmark
2-1735. North Fork Edisto River at Orangeburg
2-1740. Edisto River near Branchville
2-1750. Edisto River near Givhans
2-1960. Stevens Creek near Modoc

The principal streams are gaged at points of approximately doubled increments of drainage area. One new station on the Black River is needed to provide adequate data to satisfy the established goals. Three gaging stations in North Carolina complement the principal-streams network.

Evaluation of regulated-flow system

Techniques of regionalization cannot be used for regulated streams. The goals for regulated streams are therefore more difficult to attain. Flow characteristics for streams in this category, both minor and principal, are not necessarily stationary in time, hence meaningful correlation seldom exists between flow at two sites if at least one of the flows is regulated. Regression techniques generally cannot be reliably used for even two points on the same regulated stream. A systems approach may be used, however, to define flow characteristics of a regulated stream under different regulation patterns, or under the condition of natural flow. Each of the regulated-stream systems in South Carolina will require a significant effort when systems studies are undertaken. The evaluation for this study, therefore, is limited to (1) identifying the regulated-stream systems that should be studied, and (2) describing the general approach that would be used.

The stream systems in South Carolina materially affected by regulation are: Pee Dee River, Catawba River below Lake Wylie, Wateree River, Saluda River, Santee River, and Savannah River. The Catawba River becomes the Wateree River below Wateree Reservoir; the Saluda and Broad Rivers form the Congaree River; and the Wateree and Congaree Rivers in turn form the Santee River. The Pee Dee, Catawba, and Savannah Rivers are all major interstate streams and have complex regulation patterns. Systems studies for these streams should not be limited to only those portions in South Carolina. Stations on principal streams in the regulated-flow system are:

2-1310.	Pee Dee River at Peedee
2-1460.	Catawba River near Rock Hill
2-1470.	Catawba River near Catawba
2-1480.	Wateree River near Camden
2-1483.15	Wateree River below Eastover
2-1635.	Saluda River near Ware Shoals
2-1670.	Saluda River at Chappells
2-1690.	Saluda River near Columbia
2-1695.	Congaree River at Columbia
2-1705.	Lakes Marion-Moultrie diversion canal near Pineville
2-1715.	Santee River near Pineville
2-1716.50	Santee River below St. Stevens
2-1875.	Savannah River near Iva
2-1890.	Savannah River near Calhoun Falls
2-1970.	Savannah River at Augusta, Ga.
2-1975.	Savannah River at Burtons Ferry Bridge near Millhaven, Ga.
2-1985.	Savannah River near Clyo, Ga.

Streamflow records before reservoir construction are available at some sites, however, flow characteristics under natural conditions generally have not been adequately defined. Records of daily contents are available for all major reservoirs in these systems.

For future systems studies of the regulated-flow streams the approach can best be described by using the portion of the Saluda River between Lake Greenwood and Lake Murray as an example. This reach has been regulated since the construction of Lake Greenwood in 1940. Streamflow records are available at a site seven miles downstream from Lake Greenwood for the period 1926 to the present. Flow characteristics under the initial regulated-flow conditions have been adequately defined by the records collected between 1940 and 1966. In that year a significantly different regulation pattern was begun. Records for the period 1966 to present reflect different flow characteristics. A homogeneous record of regulated flow under the present regulation conditions can be synthesized for the site below Lake Greenwood. The approach involves (1) developing a flow-storage model of Lake Greenwood, (2) using the records under the initial regulated-flow conditions below Lake Greenwood, along with records of change in contents of the reservoir and the rule curves for operating the reservoir as inputs into a model to extend the period of record for regulated flow under the present regulated-flow conditions.

Data to Define Long-term Trends

At present, three gaging stations on unregulated streams, Lynches River at Effingham, Scape Ore Swamp near Bishopville, and Upper Three Runs near New Ellenton are designated as long-term trend stations to be operated indefinitely. The stations on Scape Ore Swamp and Upper Three Runs are hydrologic benchmark stations. Additional stations should be designated.

Stream Environment Data

Many environmental factors were determined for this study. For each of the 37 drainage basins used, basin characteristics, such as drainage area, channel slope, channel length, forest cover, area of lakes, ponds, and swamps, and climatic factors such as mean annual precipitation and rainfall intensity were determined.

Channel length and channel slope have also been computed for all of the stations in the small streams flood frequency project. Cross-sections and profiles have been determined for several streams in connection with indirect peak flow measurements. Areas inundated by flood waters have been delineated on 35 topographic quadrangle maps. Roughness coefficients have been determined at several sites in connection with hydraulic site reports.

Adequate stream environment data have been determined to satisfy current needs. Future needs for this type of data should be continuously assessed to insure satisfaction of the goals.

DISCUSSION OF THE EVALUATION

Only one of the four data categories used in this study is clearly subject to design, data for planning and design. The requirements for the other three types of data depend on response to specific needs or are defined by hydrologic judgment. It is necessary, therefore, to design a program that will emphasize important areas of streamflow information that are presently receiving little attention.

Data from 40 continuous-record gaging stations provided the basis for the evaluation by regression analysis of available streamflow data. Records from both minor and principal natural-flow streams were included. Conclusions and implications drawn from the data evaluation are based on the standard errors shown in tables 2 and A-4. They are:

1. Application of regression equations will provide, on ungaged, natural streams, estimates within the accuracy objectives for mean annual discharge, standard deviation of annual discharge, mean monthly discharge, 50-year flood, and the 2- and 50-year 7-day high flow on minor streams; and the standard deviation of annual discharge at ungaged sites on principal streams. Additional data to define these characteristics are no longer required.

2. Regression techniques cannot be used to estimate low-flow characteristics that meet the accuracy goals at ungaged sites on natural-flow streams, either minor or principal. Accurate estimates of low-flow characteristics will require low-flow measurements at ungaged sites to be correlated with concurrent flows at a suitable continuous-record index station where similar hydrologic conditions exist.

3. Regression equations are not defined for any of the flow characteristics for streams with drainage areas less than about 100 square miles. Operation of a network of continuous-record or partial-record stations will be required to define streamflow characteristics for small drainage areas.

4. The objective established for the principal-streams network is to define flow characteristics at any point on any principal stream in the State with an accuracy goal of an equivalent of 25 years of record. This is to be accomplished by gaging at selected points and interpolating between them. The accuracy objective has been satisfied at 4 of the 5 stations on natural-flow principal streams that are identified only in this category. To satisfy the goal of sampling progressively doubled increments of drainage area on principal streams, one additional gaging station is needed.

THE PROPOSED PROGRAM

The proposed streamflow-data program for South Carolina is based on the results of information developed in several sections of this study. The program, as planned, will eventually result in satisfying as many of the remaining goals as possible within the limits of available funds. A balance must be maintained between data collection and data analysis. A continuous interaction between the two is needed to gain a better understanding of the hydrologic system, to guide future evaluation of the program with respect to satisfying ever-changing needs, and to permit adaptability to advancing technology.

Data Collection

Current-purpose data

The 29 gaging stations now being operated and identified as presently meeting the needs for current-purpose information (table A-1) should be continued. Needs for stations of this type must be continuously assessed. The data-collection network will be modified by adding or discontinuing stations as dictated by changes in needs for current-use data. Further, the needs for this type of data will be examined periodically at each station to determine whether a continuous record of daily discharge is necessary. If a measure of a specific flow characteristic, such as peak flow or instantaneous flow, is sufficient, a change can be made in the program.

Planning and design data

Although some of the objectives have been attained, continued operation of certain stations to obtain either continuous-record or partial-record data is indicated. Several stations recommended for other data needs in the proposed program will provide additional information necessary to satisfy those goals that have not been reached in planning and design.

Regression methods are unsatisfactory for use in estimating low-flow characteristics at ungaged sites. A comprehensive program of low-flow data collection is currently being pursued in the Inner Coastal Plain. Additional data are needed, however, at all of the 70 partial-record sites in this network. A low-flow partial record program providing for approximately 100 additional sites should be undertaken so that the remainder of the State can be sampled. Data from these 170 partial-record sites along with information available from the regular streamgaging network will provide a data base from which reasonable estimates of low-flow characteristics can be made at most ungaged sites. At any ungaged site estimates can be made by correlating several low-flow measurements at the particular site with concurrent discharge data at a continuous-record index station where similar hydrologic conditions exist. There is no need for additional index stations in South Carolina.

The flood with a recurrence interval of 100 years is often estimated for project design. Although the program objectives include only a 50-year flood, it would be desirable to continue collecting flood-peak data at selected sites indefinitely. Some needed data can be obtained at little cost by collecting peak stages at discontinued gaging stations.

Natural-flow, minor streams.--Application of equations developed through regression methods will provide results within the accuracy goals for minor streams for all flow characteristics except low flow and standard deviation of monthly discharges. The following stations, identified solely with planning and design data, are no longer needed and are not recommended for inclusion in the proposed program.

2-1560. Pacolet River near Clifton
2-1590. South Tyger River near Woodruff
2-1600. Fairforest Creek near Union
2-1605. Enoree River near Enoree
2-1630. Saluda River near Pelzer
2-1640. Reedy River near Greenville
2-1925. Little River near Mount Carmel

Although records for four stations with drainage areas less than 100 square miles were used in the regression analyses, regression equations are generally not defined for any streamflow characteristics for areas less than about 100 square miles. Eighteen continuous-record gaging stations with drainage areas less than 100 square miles, twelve of which have areas less than 50 square miles, and not included in this study because of insufficient record, will provide data for this deficiency in definition.

Annual flood peaks on streams with drainage areas ranging from less than 1 to about 50 square miles are being obtained at 56 sites through a project begun in 1966. Operation of partial-record stations at all 56 of these sites should be continued. Plate 1 shows the location of each station in this network.

Natural-flow, principal streams.--There are fourteen stations identified in this category of data. The accuracy objective of 25 years of record, or equivalent, has been attained at four of the five sites identified solely in this category. These four stations are not recommended to be included in the future program. The remaining nine stations, eight of which have 25 or more years of record are identified under this category of data and one or more others. All nine stations must, therefore, be continued in operation to meet those specific needs for data. The stations in the natural-flow principal-streams network not recommended for inclusion in the proposed program are:

2-1315. Lynches River near Bishopville
2-1325. Little Pee Dee River near Dillon
2-1535. Broad River near Gaffney
2-1730. South Fork Edisto River near Denmark

A new station should be established on the Black River at a site downstream from the discontinued station Black River near Gable (2-1355.), to include a drainage area of approximately 500 square miles.

Regulated-flow, minor streams.--There are several streams in South Carolina identified with this category. There does not appear to be substantial justification for defining the flow characteristics of these streams at sites other than gaging stations; therefore no additional data collection is proposed for this type of stream. The program must be adjusted when needs change.

Regulated-flow, principal streams.--The stream systems in South Carolina materially affected by regulation are: Pee Dee River, Catawba River below Lake Wylie, Wateree River, Saluda River, Santee River, and Savannah River. Of the seventeen stations on these streams, fourteen are classified as current-purpose stations and as such must be continued in operation. Records at the station Savannah River at Burtons Ferry Bridge near Millhaven, Georgia, (2-1975.) virtually duplicate records collected at other sites on this stream; and although less than 25 years of record under present regulation conditions have been collected, it is recommended that this station be discontinued. Gaging stations on the Savannah River near Iva and near Calhoun Falls, should be continued in operation to collect additional data at the two sites until construction of the Trotter Shoals Reservoir planned for the near future. The proposed data-collection program should also provide for a comprehensive collection of records of inflow, outflow, reservoir contents, diversions into and out of the stream system, operation schedules, and other pertinent hydrologic data at the major reservoirs in the regulated-stream systems enumerated above. Except for the Savannah River all regulated, principal streams are gaged at points of approximately doubled increments of drainage area. Gaging stations on the Savannah River cannot be located at the recommended intervals due to two large reservoirs on this stream.

Data to define long-term trends

One station operated for this purpose for many years and two recently established hydrologic benchmark stations should be continued in operation indefinitely. Four additional stations have been designated as long-term trend stations as a part of this study and should also be continued in operation indefinitely. To provide a comprehensive outline of long-term trends in streamflow, gaging stations were selected for this network to provide areal coverage of the State, a range of drainage-area size, and a variety of climatic and physiographic characteristics. The seven stations designated to be operated indefinitely in this netowrk, along with the drainage area and period of record for each station are listed below:

Station number	Station name	Drainage area (sq mi)	Period of record
2-1320.	Lynches River at Effingham	1,030	1929-
2-1353.	Scape Ore Swamp near Bishopville	70	1968-
2-1475.	Rocky Creek at Great Falls	194	1951-
2-1735.	North Fork Edisto River at Orangeburg	683	1938-
2-1765.	Coosawhatchie River near Hampton	203	1951-
2-1960.	Stevens Creek near Modoc	545	1930-31, 1940
2-1973.	Upper Three Runs near New Ellenton	87.0	1966-

Stream environment data

Stream environment data will be collected as needs arise and as time and funds are available.

Summary

The data collection phase of the proposed program for continuous-record gaging stations is summarized in table A-5. The table includes the one additional station to be established for the proposed program and all gaging stations presently being operated. Each station is identified as to type of data and recommendations are made to continue or discontinue operation for the proposed program. The stations recommended to be discontinued have met the objectives for which they were operated. As mentioned in a previous section of this report, data collected at some current purpose gaging stations may also be used for determining statistical characteristics for planning and design data. Plate 2 shows the location of gaging stations included in the proposed program. Each station is coded with a symbol to identify the purpose of the station operation. Low-flow partial-record data are being collected at 70 sites in the Inner Coastal Plain, and flood-flow partial-record data are being collected at 56 sites throughout the State. All sites are included in the proposed program. An additional 100 low-flow partial-record sites should be established to sample low-flow for the remainder of the State.

Data Analysis

Information obtained through the streamflow-data program in past years provides a data base for analyses and reports that should be started as soon as the proposed program is implemented. Since some phases of data analyses are of a continuing nature, the data collection program must be adjusted periodically to supply information necessary to eliminate deficiencies so that continuing future analyses will be possible.

Data analyses and subsequent reports, based primarily on available data, should be scheduled for completion within the next several years on the following subjects:

1. Low-flow frequency and flow duration--an update of the report entitled, "South Carolina Streamflow Characteristics--Low-Flow Frequency and Flow Duration" prepared in 1967 based on discharge records at gaging stations through the 1965 water year (1964 climatic year). The report should include gaging station records through the 1970 water year (1969 climatic year).

2. Low-flow characteristics of streams in the South Carolina Inner Coastal Plain based on low-flow partial-record data being collected in that area.

3. River-mile and drainage-area determinations in South Carolina.

4. Magnitude and frequency of peak flows--a report based on peak discharge data being collected at regular stream-gaging stations and peak discharge data being collected at flood-flow partial-record stations on streams with drainage areas less than 50 square miles.

Based primarily on data collected for specific needs, using available data as much as possible, the following studies should be included as part of the proposed streamflow data program:

1. Low-flow characteristics of streams in the South Carolina Lower Coastal Plain.

2. Low-flow characteristics of streams in the South Carolina Piedmont.

3. Definition of flow characteristics of regulated streams by systems studies.

The above list represents only a few of the data analyses and studies, both hydraulic and hydrologic, that would be desirable in South Carolina. Advancements in the technology of water-related sciences and changing needs for streamflow information must be continuously evaluated with respect to the streamflow data program for South Carolina.

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Table A-1.--Current-purpose gaging stations

Station number	Station name	Purpose						
		Assess-ment	Power-plant opera-tion	Forecast-ing	Waste Dispos-al	Water quality	Compact or legal	Research
02-1105.	Waccamaw River near Longs	X	---	---	---	---	---	---
02-1309.	Black Creek near McBee	---	---	---	---	---	X	---
02-1309.10	Black Creek near Hartsville	---	---	---	---	---	X	---
02-1310.	Pee Dee River at Peedee	X	---	---	---	X	---	---
02-1320.	Lynches River at Effingham	X	---	---	---	---	---	---
02-1350.	Little Pee Dee River near Galivants Ferry	X	---	---	---	---	---	---
02-1360.	Black River at Kingstree	X	---	---	---	---	---	---
02-1460.	Catawba River near Rock Hill	---	---	---	---	---	X	---
02-1470.	Catawba River near Catawba	---	X	---	---	X	---	---
02-1480.	Wateree River near Camden	---	X	---	---	---	X	---
02-1483.15	Wateree River below Eastover	---	X	---	---	X	---	---
02-1545.	North Pacolet River at Fingerville	---	X	---	---	---	---	---
02-1555.	Pacolet River near Fingerville	---	X	---	---	---	---	---
02-1565.	Broad River near Carlisle	---	---	---	---	---	X	---
02-1615.	Broad River at Richtex	---	---	---	---	---	X	---
02-1635.	Saluda River near Ware Shoals	---	---	---	---	---	X	---
02-1650.	Reedy River near Ware Shoals	---	---	---	---	---	X	---
02-1670.	Saluda River at Chappells	---	---	---	---	---	X	---
02-1690.	Saluda River near Columbia	---	---	---	---	---	X	---
02-1695.	Congaree River at Columbia	---	X	---	---	---	---	---
02-1705.	Lake Marion-Moultrie diversion canal near Pineville	X	X	---	---	---	---	---
02-1715.	Santee River near Pineville	X	X	---	---	---	---	---
02-1716.50	Santee River below St. Stephens	---	X	---	---	---	---	---
02-1750.	Edisto River near Givhans	X	---	---	---	X	---	---
02-1755.	Salkehatchie River near Miley	X	---	---	---	---	---	---
02-1765.	Coosawhatchie River near Hampton	X	---	---	---	---	---	---
02-1967.	Dead River near Beech Island	---	---	---	X	---	---	---
02-1970.	Savannah River at Augusta, Ga.	---	---	X	---	---	---	---
02-1985.	Savannah River near Clyo, Ga.	X	---	---	---	---	---	---

Table A-2.--Selected streamflow characteristics at gaging stations. See p.14 for description of flow symbols.

Station number	Station name	Q_a	SD_a	P_{50}	P_{25}	P_{10}	P_5	P_2	$V_{7,50}$	$V_{7,2}$	$M_{7,20}$	$M_{7,2}$	D_{50}	D_{90}	D_{95}
02-1105.	Waccamaw River near Longs	1,150	536	14,400	12,900	10,700	8,760	5,670	12,000	5,750	3.67	31.0	600	40.0	21.6
02-1315.	Lynches River near Bishopville	769	238	22,400	19,000	14,600	11,400	7,140	8,620	3,350	129	209	510	232	198
02-1320.	Lynches River at Effingham	980	348	21,100	17,100	12,500	9,380	5,490	13,100	3,770	125	218	645	250	209
02-1325.	Little Pee Dee River near Dillon	571	231	8,220	6,680	4,920	3,760	2,340	5,940	1,860	35.8	122	410	159	120
02-1350.	Little Pee Dee River at Galivants Ferry	3,110	1,320	27,100	24,000	19,900	16,600	11,500	25,100	10,700	272	645	2,050	720	565
02-1355.	Black River near Gable	383	178	10,700	8,840	6,470	4,720	2,430	4,690	1,610	0	15.2	263	35.0	10.8
02-1360.	Black River at Kingstree	874	515	30,000	23,100	15,500	10,800	5,410	16,800	4,570	4.03	22.6	400	33.5	16.0
02-1475.	Rocky Creek at Great Falls	188	65.1	29,800	21,600	14,100	10,200	6,600	5,370	1,580	0	9.10	60	15.4	9.60
02-1535.	Broad River near Gaffney	2,470	642	94,700	76,400	56,600	44,200	30,100	21,100	10,400	451	909	1,880	950	790
02-1545.	North Pacolet River at Fingerville	207	55.8	11,500	9,460	7,020	5,350	3,240	2,090	897	36.4	75.5	153	81.0	66.0
02-1555.	Pacolet River near Fingerville	340	90.0	17,700	15,100	11,700	9,090	5,540	3,340	1,580	51.3	117	251	126	100
02-1560.	Pacolet River near Clifton	493	135	25,000	21,500	17,100	13,800	9,360	4,570	2,330	69.7	168	360	176	140
02-1565.	Broad River near Carlisle	3,900	1,020	99,100	85,900	69,800	58,200	42,700	32,300	18,700	571	1,290	2,870	1,280	915
02-1570.	North Tyger River near Fairmont	64	16.2	3,660	3,350	2,870	2,430	1,660	576	334	8.17	18.7	45.5	22.9	18.8
02-1575.	Middle Tyger River near Lyman	103	28.7	4,460	4,140	3,650	3,220	2,460	1,120	572	13.9	34.1	71.0	36.0	28.0
02-1580.	North Tyger River near Moore	233	64.6	11,600	9,790	7,540	5,900	3,680	2,690	1,200	31.4	75.8	163	76.0	61.0
02-1585.	South Tyger River near Reidville	160	45.0	7,130	6,110	4,820	3,850	2,510	1,610	725	11.5	38.8	112	21.0	14.7
02-1590.	South Tyger River near Woodruff	236	69.4	10,400	8,600	6,450	4,940	2,980	2,720	1,100	20.6	66.5	168	67.0	52.0
02-1600.	Fairforest Creek near Union	210	63.8	7,690	7,300	6,580	5,810	4,220	2,410	1,420	11.3	41.4	114	49.5	33.0
02-1605.	Enoree River near Enoree	418	118	22,300	18,600	14,100	10,900	6,720	5,650	2,250	40.5	116	275	130	105
02-1615.	Broad River at Richtex	6,050	1,620	204,000	166,000	123,000	94,500	60,200	71,800	31,100	791	1,710	4,100	1,890	1,470
02-1625.	Saluda River near Greenville	627	169	12,000	10,400	8,390	6,930	4,910	4,320	2,260	105	218	505	239	188
02-1630.	Saluda River near Pelzer	786	207	14,300	13,000	11,200	9,670	7,000	6,080	3,180	139	264	600	290	240
02-1635.	Saluda River near Ware Shoals	991	262	22,600	20,200	16,900	14,300	10,100	7,750	4,340	160	298	720	320	260
02-1640.	Reedy River near Greenville	84	19.1	4,290	3,790	3,140	2,660	1,980	912	437	13.5	24.2	55.0	27.8	23.0
02-1650.	Reedy River near Ware Shoals	320	89.7	12,300	10,600	8,490	6,840	4,500	3,300	1,630	29.5	78.4	230	64.0	25.0
02-1725.	South Fork Edisto River near Montmorenci	244	73.7	4,520	3,890	3,070	2,460	1,590	1,540	697	55.5	98.8	200	111	94.0
02-1730.	South Fork Edisto River near Denmark	799	267	9,170	7,320	5,300	4,030	2,560	5,610	2,060	188	303	635	353	301
02-1735.	North Fork Edisto River at Orangeburg	791	261	8,310	6,910	5,240	4,090	2,630	4,760	1,970	208	344	665	362	310
02-1740.	Edisto River near Branchville	2,010	820	17,300	14,700	11,400	8,920	5,610	14,100	4,990	380	759	1,590	780	610
02-1750.	Edisto River near Givhans	2,640	1,170	25,800	22,900	18,900	15,500	10,200	22,800	9,130	367	691	1,750	740	600
02-1755.	Salkehatchie River near Miley	331	127	3,020	2,610	2,100	1,720	1,210	2,140	1,020	25.7	65.2	250	94.0	60.0
02-1765.	Coosawhatchie River near Hampton	181	89.2	4,510	3,990	3,290	2,720	1,840	1,850	1,070	0	1.31	80.0	4.20	0.90
02-1845.	Whitewater River at Jocassee	177	34.8	8,670	7,220	5,550	4,430	3,040	1,030	714	28.0	47.2	141	58.0	47.4
02-1850.	Keowee River near Jocassee	486	106	24,900	21,200	16,800	13,600	9,390	3,740	2,040	70.7	144	375	160	125
02-1925.	Little River near Mount Carmel	215	79.2	16,100	13,400	10,100	7,730	4,720	2,780	1,580	3.79	34.2	110	40.5	29.3
02-1960.	Stevens Creek near Modoc	402	212	36,700	33,200	27,500	22,100	13,000	11,000	3,380	0.58	7.30	88.0	13.7	7.40

Table A-3.--Basin characteristics at gaging stations

Station number	Station name	Basin Characteristics: Drainage area (sq mi)	Slope (feet per mile)	Main channel length (miles)	Surface storage (percent)	2-year 24-hour rainfall (inches)	Annual precip-itation (inches)	Forest cover (per-cent)	Soil index (inches)
02-1105.	Waccamaw River near Longs	1,110	1.1	73.2	13.5	4.0	48	77	3.16
02-1315.	Lynches River near Bishopville	675	6.3	53.5	4.0	3.5	44	53	7.10
02-1320.	Lynches River at Effingham	1,030	3.5	94.5	8.0	3.7	44	54	5.83
02-1325.	Little Pee Dee River near Dillon	524	3.7	50.8	5.7	3.7	46	51	5.40
02-1350.	Little Pee Dee River at Galivants Ferry	2,790	2.5	89.2	10.3	4.0	46	60	4.68
02-1355.	Black River near Gable	401	3.2	38.0	12.1	3.7	44	50	5.59
02-1360.	Black River at Kingstree	1,260	2.7	72.5	11.8	3.8	45	48	4.22
02-1475.	Rocky Creek at Great Falls	194	9.2	26.5	0	3.5	44	58	3.74
02-1535.	Broad River near Gaffney	1,490	8.9	80.0	0	4.0	50	63	4.04
02-1545.	North Pacolet River at Fingerville	116	30.3	29.8	0.3	4.0	52	79	4.15
02-1555.	Pacolet River near Fingerville	212	28.3	31.8	1.4	4.0	52	68	4.11
02-1560.	Pacolet River near Clifton	320	20.7	49.2	1.0	3.8	50	48	3.96
02-1565.	Broad River near Carlisle	2,790	7.5	123	0	3.8	48	60	3.93
02-1570.	North Tyger River near Fairmont	44	17.7	14.8	0	4.0	48	56	3.74
02-1575.	Middle Tyger River near Lyman	68.3	12.5	22.5	1.2	4.5	52	50	3.91
02-1580.	North Tyger River near Moore	162	12.3	27.0	1.0	4.0	52	46	3.82
02-1585.	South Tyger River near Reidville	106	9.8	28.5	0.8	4.5	56	65	3.85
02-1590.	South Tyger River near Woodruff	174	5.6	44.5	0.6	4.0	52	58	3.80
02-1600.	Fairforest Creek near Union	183	11.6	38.8	0.4	3.5	46	44	3.74
02-1605.	Enoree River near Enoree	307	8.2	58.8	0.2	3.8	47	39	3.74
02-1615.	Broad River at Richtex	4,850	5.5	159	0	3.7	47	61	3.85
02-1625.	Saluda River near Greenville	293	13.9	40.2	1.2	4.5	64	89	4.65
02-1630.	Saluda River near Pelzer	405	7.5	56.5	0.9	4.5	60	74	4.39
02-1635.	Saluda River near Ware Shoals	569	7.0	82.5	0.7	4.0	54	66	4.19
02-1640.	Reedy River near Greenville	48.6	12.9	17.0	0.4	4.3	50	37	3.74
02-1650.	Reedy River near Ware Shoals	228	10.0	53.8	0.4	4.0	52	24	3.74
02-1725.	South Fork Edisto River near Montmorenci	198	10.2	26.2	2.7	3.5	44	55	8.61
02-1730.	South Fork Edisto River near Denmark	720	5.5	53.0	5.8	3.5	44	34	7.40
02-1735.	North Fork Edisto River at Orangeburg	683	4.1	41.0	4.0	3.5	44	63	8.72
02-1740.	Edisto River near Branchville	1,720	3.7	80.5	7.0	3.6	44	49	7.11
02-1750.	Edisto River near Givhans	2,730	3.0	112	5.5	3.8	45	53	5.63
02-1755.	Salkehatchie River near Miley	341	4.6	42.5	8.5	3.7	44	35	4.46
02-1765.	Coosawhatchie River near Hampton	203	7.1	20.5	9.3	4.0	44	59	3.23
02-1845.	Whitewater River at Jocassee	47.3	245	14.2	0	5.7	72	95	4.72
02-1850.	Keowee River near Jocassee	148	118	26.8	0.2	5.5	72	96	4.72
02-1925.	Little River near Mount Carmel	217	8.9	37.2	0	3.7	44	48	3.74
02-1960.	Stevens Creek near Modoc	545	8.3	41.5	0	3.5	44	72	3.49

Table A-4.--Summary of regression results

(Model is $Y=aA^{b}S^{c}L^{d}St^{e}F^{f}P^{g}I^{h}Si^{i}$)

Flow characteristic, Y See p. 14	Regression constant, a*	Exponent of basin characteristics: Drainage area, A	Main channel slope, S	Main channel length, L	Area of lakes, ponds and swamps plus 1 percent St	Forest cover, F	Mean annual precipitation minus 20, P	2-yr 24-hr rainfall I	Soil Index Si	Standard error of estimate (percent)
P_{50}	216	.87	.31	---	-.33	---	---	---	-.84	35
P_{25}	210	.86	.30	---	-.34	---	---	---	-.85	32
P_{10}	194	.84	.28	---	-.36	---	---	---	-.86	28
P_{5}	172	.83	.28	---	-.37	---	---	---	-.88	27
P_{2}	42.9	.80	.22	---	-.42	.31	---	---	-.84	24
$V_{7,50}$	11.2	.94	---	---	-.16	.32	---	---	-.40	22
$V_{7,2}$	3.07	.98	.10	---	-.15	---	---	1.12	-.57	14
D_{50}	4.25(-4)	.66	.14	.78	---	---	.76	1.70	.98	29
D_{90}	4.71(-6)	---	---	1.95	-.44	---	1.70	---	2.85	64
D_{95}	3.36(-7)	---	---	2.08	-.63	---	1.99	---	3.51	83
$M_{7,2}$	3.26(-7)	---	---	2.11	-.57	---	2.14	---	3.19	73
$M_{7,20}$	1.23(-15)	---	---	3.25	-1.19	---	4.96	---	6.30	425
Q_{a}	8.71(-3)	.98	---	---	-.08	---	1.40	---	.34	12
q_{10}	5.73(-3)	1.03	.14	---	---	---	.58	1.44	.50	28
q_{11}	4.92(-3)	1.01	---	---	-.26	-.41	1.17	1.17	.99	21
q_{12}	0.0127	1.04	.11	---	-.14	-.34	.81	1.29	.72	14
q_{1}	0.0420	.99	---	---	-.14	---	.60	.96	.33	9
q_{2}	0.142	1.01	.09	---	-.05	---	.26	1.15	---	9
q_{3}	0.148	1.01	.09	---	---	---	.19	1.33	---	10
q_{4}	0.0204	1.00	---	---	-.11	---	.55	1.68	.34	10
q_{5}	3.00(-3)	.98	---	---	-.24	---	.84	1.70	.76	21
q_{6}	1.14(-3)	.99	---	---	-.23	---	1.01	1.72	.80	29
q_{7}	3.06(-3)	1.00	---	---	-.13	---	.98	1.38	.43	23
q_{8}	1.54(-3)	---	---	1.86	---	1.01	---	---	.83	45
q_{9}	0.104	.88	---	---	---	---	.85	---	---	52
Mean of standard errors of regression equations of mean monthly discharges										23
SD_{a}	0.0387	1.02	.06	---	.07	.16	---	1.04	---	8
SD_{10}	0.0634	1.06	.13	---	---	---	---	1.57	---	23
SD_{11}	0.0640	1.03	---	---	-.13	---	.38	.75	---	17
SD_{12}	8.50(-3)	1.04	---	---	---	---	.51	1.82	---	21
SD_{1}	0.119	1.02	---	---	-.12	---	.42	.98	-.52	20
SD_{2}	0.0101	1.20	---	-.37	---	---	---	.85	-.36	13
SD_{3}	0.561	.98	---	---	---	---	---	1.17	-.57	12
SD_{4}	0.141	.91	---	.21	---	---	---	1.46	-.24	12
SD_{5}	0.0242	1.01	.14	---	.06	---	---	1.88	---	14
SD_{6}	0.0123	1.07	---	---	---	---	---	2.41	---	48
SD_{7}	0.0437	1.01	---	---	---	.61	---	---	---	46
SD_{8}	0.0411	.96	---	---	---	---	.86	---	---	34
SD_{9}	0.0328	1.07	---	---	.24	---	---	1.71	---	28
Mean of standard errors of regression equations of standard deviations of mean monthly discharges										24

* Number in ( ) is power of 10 by which value must be multiplied.

Table A-5.--Streamflow stations now in operation and those needed for proposed network

Station number	Station name	Recommendations: Include in network	Recommendations: Not recommended for inclusion	Types of Data: Current purpose	Planning and design: Minor streams	Planning and design: Principal streams	Long-term trend
02-1105.	Waccamaw River near Longs	X	---	X	---	X	---
02-1309.	Black Creek near McBee	X	---	X	X	---	---
02-1309.10	Black Creek near Hartsville	X	---	X	X	---	---
02-1310.	Pee Dee River at Peedee	X	---	X	---	X	---
02-1311.50	Catfish Canal near Sellers	X	---	---	X	---	---
02-1315.	Lynches River near Bishopville	---	X	---	---	---	---
02-1320.	Lynches River at Effingham	X	---	X	---	X	X
02-1325.	Little Pee Dee River near Dillon	---	X	---	---	---	---
02-1350.	Little Pee Dee River at Galivants Ferry	X	---	X	---	X	---
02-1353.	Scape Ore Swamp near Bishopville	X	---	---	X	---	X
	Black River below Gable[a]	X	---	---	---	X	---
02-1360.	Black River at Kingstree	X	---	X	---	X	---
02-1460.	Catawba River near Rock Hill	X	---	X	---	X	---
02-1470.	Catawba River near Catawba	X	---	X	---	X	---
02-1475.	Rocky Creek at Great Falls	X	---	---	X	---	X
02-1480.	Wateree River near Camden	X	---	X	---	X	---
02-1483.	Colonels Creek near Leesburg	X	---	---	X	---	---
02-1483.15	Wateree River below Eastover	X	---	X	---	X	---
02-1535.	Broad River near Gaffney	---	X	---	---	---	---
02-1545.	North Pacolet River at Fingerville	X	---	X	X	---	---
02-1555.	Pacolet River near Fingerville	X	---	X	X	---	---
02-1556.	Buck Creek near Fingerville	X	---	---	X	---	---
02-1560.	Pacolet River near Clifton	---	X	---	---	---	---
02-1563.	Lawson Fork Creek near Spartanburg	X	---	---	X	---	---
02-1565.	Broad River near Carlisle	X	---	X	---	X	---
02-1570.	North Tyger River near Fairmont	X	---	---	X	---	---
02-1590.	South Tyger River near Woodruff	---	X	---	---	---	---
02-1596.	Dutchman Creek near Pauline	X	---	---	X	---	---
02-1598.	Fairforest Creek near Spartanburg	X	---	---	X	---	---
02-1600.	Fairforest Creek near Union	---	X	---	---	---	---
02-1605.	Enoree River near Enoree	---	X	---	---	---	---
02-1615.	Broad River of Richtex	X	---	X	---	X	---
02-1620.10	Cedar Creek near Blythewood	X	---	---	X	---	---
02-1620.80	Crane Creek at Columbia	X	---	---	X	---	---
02-1625.	Saluda River near Greenville	X	---	---	X	---	---
02-1630.	Saluda River near Pelzer	---	X	---	---	---	---
02-1635.	Saluda River near Ware Shoals	X	---	X	---	X	---
02-1640.	Reedy River near Greenville	---	X	---	---	---	---
02-1650.	Reedy River near Ware Shoals	X	---	X	X	---	---

Table A-5.--Streamflow stations now in operation and those needed for proposed network--continued

Station number	Station name	Recommendations: Include in network	Recommendations: Not recommended for inclusion	Types of Data: Current purpose	Planning and design: Minor streams	Planning and design: Principal streams	Long term tr[ends]
02-1652.	South Rabon Creek near Gray Court	X	---	---	X	---	---
02-1670.	Saluda River at Chappells	X	---	X	---	X	---
02-1690.	Saluda River near Columbia	X	---	X	---	X	---
02-1695.	Congaree River at Columbia	X	---	X	---	X	---
02-1695.50	Congaree Creek at Cayce	X	---	---	X	---	---
02-1695.70	Gills Creek at Columbia	X	---	---	X	---	---
02-1696.15	Mill Creek near Hopkins	X	---	---	X	---	---
02-1696.30	Big Beaver Creek near St. Matthews	X	---	---	X	---	
02-1705.	Lake Marion-Moultrie diversion canal near Pineville	X	---	X	---	X	-
02-1715.	Santee River near Pineville	X	---	X	---	X	---
02-1716.50	Santee River below St. Stephens	X	---	X	---	X	-
02-1716.80	Wedboo Creek near Jamestown	X	---	---	X	---	---
02-1730.	South Fork Edisto River near Denmark	---	X	---	---	---	-
02-1735.	North Fork Edisto River at Orangeburg	X	---	---	---	X	
02-1740.	Edisto River near Branchville	X	---	---	---	X	---
02-1750.	Edisto River near Givhans	X	---	X	---	X	---
02-1755.	Salkehatchie River near Miley	X	---	X	X	---	---
02-1765.	Coosawhatchie River near Hampton	X	---	X	X	---	[illegible]
02-1850.20	Eastatoe Creek near Pickens	X	---	---	X	---	---
02-1852.	Little River near Walhalla	X	---	---	X	---	---
02-1875.	Savannah River near Iva	X	---	---	---	X	---
02-1879.	Broadway Creek near Anderson	X	---	---	X	---	---
02-1890.	Savannah River near Calhoun Falls	X	---	---	---	X	---
02-1925.	Little River near Mt. Carmel	---	X	---	---	---	---
02-1960.	Stevens Creek near Modoc	X	---	---	---	X	X
02-1967.	Dead River near Beech Island	X	---	X	---	---	---
02-1970.	Savannah River at Augusta, Ga.	X	---	X	---	X	---
02-1973.	Upper Three Runs near New Ellenton	X	---	---	X	---	
02-1975.	Savannah River at Burtons Ferry Bridge near Millhaven, Ga.	---	X	---	---	---	
02-1985.	Savannah River near Clyo, Ga.	X	---	X	---	X	---

a New station.