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A proposed streamflow-data program for Arizona

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CONTENTS

ILLUSTRATIONS

TABLES

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ABSTRACT

An evaluation of the streamflow data in Arizona was made to provide guidelines for planning future programs. The basic goals in the evaluation procedure were (1) to define the long-term objectives of the streamflow-data program, (2) to examine and analyze the available data to determine which goals have already been met, and (3) to consider alternate programs and techniques to meet the remaining goals. A regression analysis, using selected streamflow characteristics as dependent variables and physical and climatic characteristics as independent variables, was only partially successful in attaining the goals of the study. The regression method may be more successful in the future if an adequate sample of long-term streamflow records in presently ungaged areas is obtained. In the interim period, alternate methods of transferring information to an ungaged site will be

considered. Most of the methods require some information at the ungaged site and gaging-station records to define a specific relation. A streamflow-data program based on the guidelines developed in this study is proposed.

INTRODUCTION

The streamflow program of the U.S. Geological Survey in Arizona has evolved through the years as Federal and State interests in the surface-water resources have increased and as funds for operating the stream-gaging-station network have become available. The first measurements of river stage and discharge were made in the 1870's in the Gila River basin by the Federal government and several private companies. The Geological Survey began stream gaging in the State in 1889, and cooperation with the State of Arizona began in 1912. The network expanded slowly, and, by 1919, 24 stations were being maintained, 20 of which were equipped with water-stage recorders. Beginning in 1924 a large increase in State appropriations allowed installation of several additional stations; by 1928, 43 stations were being maintained. In 1928 the principal stations on the main stem of the Colorado River were considered paramount to the Federal interest, and, since that time, these stations have been operated using Federal funds. Cooperative funds were not available from the State in 1934-35, but the Salt River Valley Water Users' Association—an agency that needs records for the Salt and Verde Rivers and Tonto Creek for use in their projects—cooperated in the maintenance of stations on the streams and somewhat filled the financial void. Toward the end of the depression, the number of stations was increased, and, by 1939, 54 of the 58 stations were equipped with recorders.

In recent years, especially since 1950, many gaging stations have been installed and operated in cooperation with the Arizona State Land Department and the Salt River Valley Water Users' Association as part of a long-range plan to manipulate vegetation in an attempt to increase runoff. Other gaging stations have been added to the network as a part of the flood-control programs in Maricopa and Pima Counties. A crest-stage partial-record network was begun in 1962. The purpose of the program is to define characteristics of peak flows from small drainage areas. At the present time (1970), 170 gages have been installed in the network; 56 of the gages are equipped with flood-hydrograph recorders.

The increasing cost of operation, the restraints on funds and manpower, and the need for a greater variety of hydrologic data have necessitated an evaluation of the streamflow-data program in order to make efficient use of the available funds and manpower. Therefore, the purpose of this study was to evaluate the present streamflow-data program and to use the evaluation in the design of an efficient program that will produce the types of information needed to best serve Federal and State interests. The basic goals of this study were (1) to define the long-term objectives of the streamflow-data program in quantitative form, (2) to examine and analyze the available data to determine which goals have already been met, (3) to consider alternative means for meeting the remaining goals, and (4) to prepare a proposed program of data collection and analysis to meet the remaining goals.

PHYSICAL AND HYDROLOGIC DESCRIPTION OF ARIZONA

Arizona is characterized by low-altitude deserts and forested high plains and mountains. The annual precipitation ranges from less than 5 inches to more than 30 inches, and the mean annual temperature ranges from less than 45°F to more than 70°F. About half of Arizona receives less than 10 inches of precipitation during an average year.

Arizona has two distinct rainy seasons—July to September and December to March. The precipitation from July to September is characterized by high-intensity local convective storms. The precipitation from December to March is less intense, and storms normally are widespread. At altitudes above 7,000 feet, most of the winter precipitation is in the form of snow.

The occurrence of surface water in Arizona is controlled mainly by the geology and physiography of the three water provinces—the Basin and Range lowlands province, the Central highlands province, and the Plateau uplands province (fig. 1). The Basin and Range lowlands

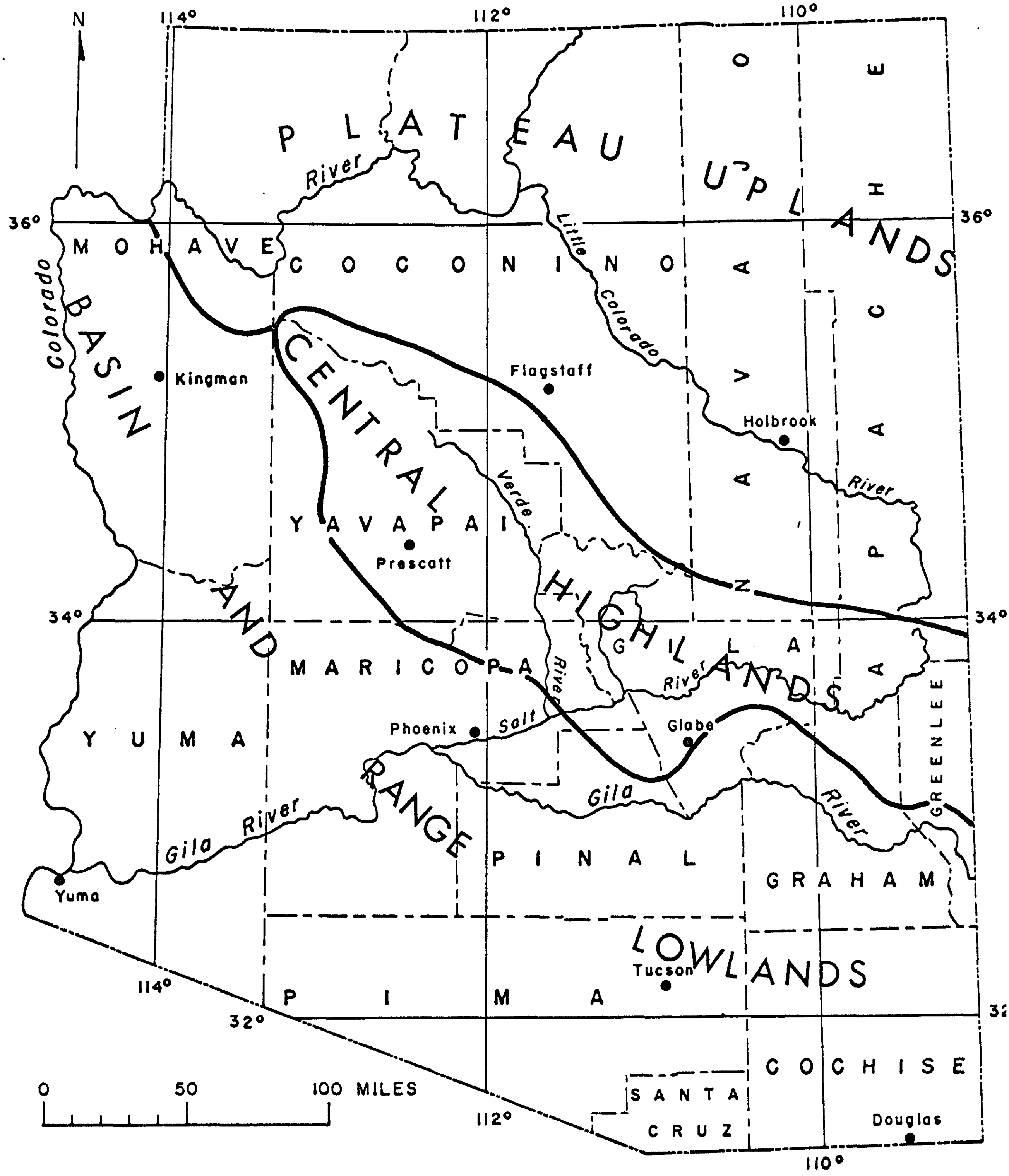

Figure 1.--Arizona's water provinces.

is characterized by isolated mountain blocks separated by broad alluvial-floored basins. Rugged topography characterizes the Central highlands, and the vegetative cover is sparse to dense. The topography of the Plateau uplands is less rugged than that of the Central highlands; warped and tilted sedimentary formations are typical of the area.

Most of the runoff in Arizona originates in the Central highlands due to winter storms and snowmelt from these storms. Average annual runoff from the higher altitudes may be 10 inches or more, but the average annual runoff for the province is less than 2 inches. Most of the runoff in the other two provinces is due to high-intensity convective storms in the summer months. Average annual runoff in most of the Basin and Range lowlands and the Plateau uplands is less than 1 inch and is highly variable from year to year.

DESCRIPTION OF THE STREAMFLOW PROGRAM AND ITS GOALS

Streamflow data are needed for planning, design, and operation of projects, for management of the water resources, and for flood control. The needed information may be obtained through a combination of data collection and analysis; however, the data to be collected and the applicable methods of analysis depend on the hydrology of the area, the specific goals of the program, and the cost that can be justified for this purpose. The overall objective of a surface-water data program is to provide the data of specified accuracy at any site on any stream. The framework for design of such a program is shown in table 1. The following paragraphs describe the Arizona surface-water program and the specific goals in terms of the four types of data required.

Data for Current Use

Data for current use—day-by-day decisions on water management, assessment of water availability, management of water quality, forecast of water hazards, and the surveillance necessary to comply with legal requirements—are commonly obtained by operating a gaging station at a site on a stream for which the information is needed. This element of the streamflow program is not subject to design but changes in response to needs. The goal for this type of data is to provide the particular information needed at specific sites for current use. Accuracy goals at a given site are governed by the use of the data. Higher than usual accuracy can be obtained by intensive observation or by more sophisticated instrumentation.

Data for Planning and Design

Data used in planning and design are commonly the statistical characteristics of streamflow, such as mean discharge, flood peaks of

(p. 10 follows)

10-, 25-, or 50-year recurrence intervals, flood volumes of 1-, 3-, or 7-day duration for different recurrence intervals, and 7-day low flows of 2- and 20-year recurrence intervals. These and other statistical characteristics can be obtained from gaging-station records. Although a long period of record is desirable for defining statistical streamflow characteristics at a site, it is not feasible to collect records at every site. Many records are needed to provide information that can be transferred from gaged sites to ungaged sites or to sites where little streamflow data are available. Information for natural flow streams may be obtained by relating flow characteristics to physical and climatic basin characteristics, by relating a short period of record to a longer one, or by interpolating between gaged points on a stream.

The definition of flow characteristics of a regulated stream often is complicated by changes in the regulation during the period of record. Frequently, it is not possible to obtain a long period of record under one condition of development. Transference of flow characteristics from one point to another on a regulated stream is difficult because the procedures used for natural streams, such as regression or interpolation, do not apply. A systems approach seems to be the most efficient way to define the flow characteristics of regulated streams. The systems approach requires an analytical model of the stream system using streamflow records, stage-capacity curves for reservoirs, operating rule curves for the release of water, losses owing to evaporation and seepage, stream-channel geometry, and records of diversions and return flows including ground-water pumpage and aquifer characteristics as inputs. The model and associated data may be used to derive homogeneous data for natural and regulated conditions.

Planning and design data are used to define streamflow characteristics at ungaged sites to an accuracy that is equivalent to 25 years of record for principal streams and 10 years of record for minor streams (table 2). In this report streamflow-gaging stations are defined as principal or minor, depending on drainage area and region (fig. 2). Percent accuracy, corresponding to the stated goals, depends on the variability of the flow characteristics being considered.

Data Needed to Define Long-Term Trends

Data needed to define long-term streamflow trends can be obtained only by operating gaging stations indefinitely on a few natural flow streams. The records from these gaging stations will either affirm that the characteristics defined from the present records are good estimates of the long-term characteristics, or the records will provide a basis for adjusting the short-term characteristics. A few gaging stations on streams that are expected to be relatively free of manmade changes in the flow regimen should be operated indefinitely.

Table 2.--Standard error in statistical streamflow characteristics for 10 years and 25 years of record at gaging stations in Arizona

Statistical streamflow characteristics	Standard error (percent)	
	10 years of record	25 years of record
Mean annual discharge	33	21
Standard deviation of annual discharge	22	14
Mean monthly discharge (average)	65	41
Standard deviation of monthly discharge (average)	22	14
Seasonal discharge (July-September)	40	25
50-year flood	60	37
7-day 50-year high flow	60	37
7-day 2-year low flow (perennial)	18	12
7-day 20-year low flow (perennial)	29	18

(p. 14 follows)

Data on Stream Environment

The environment affects the occurrence and use of streamflow; stream-environment data are especially useful in evaluating water use for recreation, waste disposal, and conjunctive surface-water and ground-water supplies. The data also are necessary in planning for the preservation of the aesthetic character of water features and in planning flood-plain development. The long-range goals for using this type of data in Arizona are given below.

1. Determination of streamflow depletion and ground-water recharge.

2. Definition of flood-plain limits for floods of different magnitudes and frequencies.

3. Definition of flood profiles along principal stream channels.

4. Surveys of traveltime of solutes in stream channels.

5. Description of channel changes in response to flow.

6. Reconnaissance studies of the streamflow and stream-channel parameters that are related to the use of the stream for recreation; the parameters are velocity, depth, bank vegetation, bed material, water temperature, water quality, and channel accessibility.

7. Research studies of the effects of manmade changes on the environment in relation to streamflow.

EVALUATION OF EXISTING DATA

All available data were analyzed in relation to the program goals. A separate evaluation was made for each of the four types of data—data for current use, data for planning and design, data needed to define long-term trends, and data on stream environment.

Data for Current Use

In Arizona most of the streamflow-gaging stations, about 70 percent, are operated to provide data for current use. The assumptions are that the need for this type of data is being satisfied and that this part of the program will be modified as requirements change. The 115 streamflow-gaging stations operated to satisfy the need for current data in Arizona and the principal uses of the data are given in table 6.

Data for Planning and Design

The statistical characteristics of streamflow are defined by streamflow measurements, regionalization by analytical methods, systems studies, or any combination of the three. The following sections on the evaluation of this type of data are according to the framework for design of a data-collection program (table 1).

Evaluation of Data for Natural Flow Systems

The purpose of this evaluation is to determine how accurately the statistical streamflow characteristics—listed as goals in table 1—can be defined by regionalization of the available data. At the present time (1970), the most effective way known to define statistical streamflow characteristics on a broad scale is to relate them to basin characteristics in equations developed by use of multiple-regression techniques applied to past data. Once the equation and its constants are defined, streamflow characteristics for a specific stream in a given basin can be computed by substituting the appropriate values for the basin characteristics in the formulas.

Most of the 104 streams used in the analyses have unregulated flow and 8 or more years of record, although several streams having less than 8 years of record were used to supplement otherwise incomplete areal coverage. Both minor and principal streams are included, and records were not adjusted to a base period. Because of varying degrees of regulation and the brevity of some records, it was not possible to define all the flow characteristics from each record. Streamflow data collected before regulation by major reservoirs were used, and streamflow characteristics were defined for the study. Streamflow-gaging stations used in the regression analysis are given in table 7.

Streamflow characteristics.--Streamflow characteristics at gaging stations include the full range of streamflow—high flow, medium flow, and low flow—and selected characteristics are given in table 7. The following streamflow characteristics have been defined and represent the data required for planning and design in Arizona:

1. Mean-flow characteristics are described by the means of the annual means, the means of records for the warm season, July through September, and the means for each calendar month.

2. Flow-variability characteristics are represented by the standard deviations of the annual and monthly means and the coefficient of variation of annual mean flows.

3. Flood-peak characteristics are represented by discharges determined by Type III log-Pearson flood-frequency analyses for recurrence intervals of 2, 5, 10, 25, and 50 years.

4. Flood-volume characteristics represent the annual highest average flow for 1-day, 3-day, and 7-day periods for recurrence intervals of 2, 10, and 50 years.

5. Low-flow characteristics are represented by the annual minimum 7-day mean flows at 2- and 20-year recurrence intervals. If values are indicated for a streamflow site, the stream is perennial or nearly perennial.

Physical and climatic basin characteristics.--Values of the physical and climatic basin characteristics for each of the 104 gaging stations used in the regression analyses are given in table 8. The physical and climatic basin characteristics defined for this study are:

1. Drainage area (A), in square miles, as used in the recent U.S. Geological Survey streamflow reports.

2. Main-channel slope (S), in feet per mile, determined from elevations at points 10 percent and 85 percent of the distance along the channel from the gaging station to the divide.

3. Main-channel length (L), in miles, from the gaging station to the basin divide.

4. Mean basin elevation (E), in feet above mean sea level, as measured by laying a grid over a 1:250,000 Army Map Service map or a 7-1/2-minute or 15-minute U.S. Geological Survey topographic map to determine the elevation at each grid intersection and to average those elevations. The grid spacing was selected to give at least 25 intersections within the basin boundary.

5. Shape factor, dimensionless, determined by dividing the square of the main-channel length by the drainage area.

6. Aspect is a measure of main-channel flow direction, in degrees, and was determined as the angle between north and the line defined by the main-channel basin divide and the gaging station.

7. Soil index, dimensionless, is an index to soil-infiltration capacity and is based on information supplied by the U. S. Soil Conservation Service from information on soil type, cover, and agricultural practices.

8. Latitude, to the nearest 0.1 degree, measured from available maps; figures given represent the approximate geographical center of the drainage basin.

9. Longitude, to the nearest 0.1 degree, measured from available maps; figures given represent the approximate geographical center of the drainage basin.

10. Mean annual precipitation, in inches, determined from an isohyetal map prepared by the University of Arizona (1965). The map was prepared on the basis of precipitation data and physiographic correlations.

11. Mean seasonal precipitation (May-September), in inches, determined from an isohyetal map prepared by the University of Arizona (1965). The map was prepared on the basis of precipitation data and physiographic correlations.

12. The maximum 6-hour point rainfall, $I_{6, 10}$, having a recurrence interval of 10 years (10-year 6-hour precipitation), expressed in inches. These values were determined using the U. S. Weather Bureau (1967a) map.

13. The maximum 24-hour point rainfall, $I_{24, 10}$, having a recurrence interval of 10 years, expressed in inches. These values were determined using the U. S. Weather Bureau (1967b) map.

14. The maximum 6-hour point rainfall, $I_{6, 50}$, having a recurrence interval of 50 years, expressed in inches. These values were determined using the U. S. Weather Bureau (1967c) map.

15. The maximum 24-hour point rainfall, $I_{24, 50}$, having a recurrence interval of 50 years, expressed in inches. These values were determined using the U. S. Weather Bureau (1967d) map.

16. Mean annual snowfall, in inches, derived from a map drawn on the basis of a multiple regression of mean annual snowfall at long-term Weather Bureau stations and altitude, latitude, and longitude.

Regression analysis.--Each of the streamflow characteristics was related to the physical and climatic basin characteristics by multiple regression using the equation:

$$Y = a A^b B^c C^d,$$

where Y, the dependent variable, is a streamflow characteristic, such as mean annual flow; A, B, and C, the independent variables, are physical and climatic basin characteristics, such as drainage area or precipitation; and a, b, c, and d are coefficients obtained by regression.

Some of the streamflow characteristics given in table 7 are extremely correlative and, therefore, were not used in the regression analysis. All physical and climatic basin characteristics, except length, latitude, longitude, $I_{6,10}$, $I_{6,50}$, and $I_{24,50}$, were used in one or more of the initial regression analyses.

After the computation of an initial regression equation by a digital computer, the coefficients were tested for statistical significance, and the characteristics, which were found insignificant at a confidence level of 95 percent, were dropped. Then, the regression equation using only the significant parameters was determined, and the standard error was computed.

Residuals—the differences between the values of streamflow characteristics determined by regression analyses and the values of the characteristics determined from the gaging-station records—were plotted on a map of Arizona in order to determine any regional variations. The part of the State having sufficient streamflow data for regression analysis was divided into two regions, and additional streamflow regressions were computed for both regions (fig. 3). A sample of the regression results is given in table 3, and the results are compared with the accuracy goals in table 4 for streams having 10 and 25 years of record.

(p. 24 follows)

Table 4.--Comparison of standard errors in station data and in regression results

Statistical streamflow characteristics	Standard error (percent)			
	Station data		Regression results	
	10 years of record	25 years of record	Region 1	Region 2
Mean annual discharge	33	21	55	33
Standard deviation of annual discharge	22	14	48	33
Mean monthly discharge (average)	65	41	145	131
Standard deviation of monthly discharge (average)	22	14	152	129
Seasonal discharge (July-September)	40	25	61	60
50-year flood	60	37	97	54
7-day 50-year high flow	60	37	74	47
7-day 2-year low flow (perennial)	18	12	136	114
7-day 20-year low flow (perennial)	29	18	256	261

The standard errors in the regression equations for region 2 are about equivalent, or smaller, than those for 10 years of record at a site for mean annual discharge, 50-year flood, and 7-day 50-year high flow (table 4); values for these streamflow characteristics can be estimated by using the appropriate equations for region 2. Goals for other streamflow characteristics in region 2 are not met by the regression equations. The accuracy goals in region 1 and the rest of the State were not satisfied.

Regionalization of streamflow characteristics in most of the State has not been possible for the following reasons:

1. A relatively small number of streamflow records is available outside the Central highlands province, and most of the records are of short duration.

2. Physical and climatic basin characteristics are poorly defined. Many of these characteristics have been derived by multiple regression because of the scarcity of data. Measures of the effects of soils and geology on streamflow are almost nonexistent.

In most of the State the regression method, in time, may yield results equivalent to 10 years of record at a streamflow-gaging station, but the method probably will not be improved sufficiently to provide an accuracy equivalent to 25 years of record. In the meantime, alternate methods of transferring flow characteristics to ungaged sites may be used.

Evaluation of Data for Regulated-Flow Systems

The goals of the streamflow program are more difficult to attain for the regulated streams than for the unregulated streams in Arizona because the technique of regionalization does not apply, the characteristics are not necessarily stationary in time, and a meaningful correlation seldom exists between flows at two sites if at least one of the flows is regulated. A systems approach may be used to define the characteristics of regulated flow under different types of regulation or under the condition of natural flow. Systems studies for all regulated streams in Arizona will require a major effort. The present evaluation is limited to the identification of regulated streams and to the brief description of the approach that could be used.

In Arizona and along the boundaries of Nevada, California, and Mexico the Colorado River is completely regulated. The Gila River below Coolidge Dam is almost completely regulated by storage in Coolidge Reservoir and by storage in its main tributaries—the Salt and the Agua Fria Rivers. Bill Williams River below Alamo Dam has been partly regulated since completion of the dam in 1968.

The regulation of the major streams is almost complete. All the major dams—except Painted Rock Dam on the Gila River and Alamo Dam on the Bill Williams River—were constructed to store irrigation water, and in most years all water released is used for this purpose.

The Gila River and its main tributaries are dry below the last diversions, except during periods of tributary inflow below the dams and diversions or at infrequent times when water must be released from storage. No water has spilled over Coolidge Dam since its completion in 1928. Since the completion of the reservoir system on the Salt River above the Verde River in 1930, spillage has occurred three times. The reservoir system on the Verde River has spilled over twice since its completion in 1945. Spillage from Lake Pleasant on the Agua Fria River has occurred three times since the construction of Waddell Dam in 1928.

The statistical characteristics of regulated streamflow can be computed from synthesized records. A longer homogeneous record at a gage site or any other point on a regulated stream can be computed by developing a flow-storage model of the reservoir and the channel and by using the natural flow records and the rule curve for operation of the reservoir as inputs to the model.

Data Needed to Define Long-Term Trends

At the present time (1970), only one station—Wet Bottom Creek near Childs—is designated as a hydrologic bench-mark station that is to be operated indefinitely. Because of the varying climatic and hydrologic conditions in Arizona, additional stations should be established and are proposed in a subsequent section of this report.

Data on Stream Environment

Streamflow depletion in the Tucson basin has been evaluated by Burkham (1970), and some of the results have been incorporated by Anderson (1970) in an electrical-analog model depecting recharge to the ground-water basin. Water samples are collected at 20 gaging stations and at many miscellaneous sites for chemical analysis. In addition, intensive sampling of water in the canals and diversions near the Colorado River is conducted to meet legal requirements. Streamflow sediment data are collected at 11 gaging stations and at several miscellaneous sites. Water temperatures are monitored continuously at these sites and are measured periodically at all gaging stations and some miscellaneous sites. Flood-prone areas along the Gila and Santa Cruz Rivers and along some other streams have been identified, and the work is continuing. Channel surveys have been made at many sites in connection with indirect determinations of peak flows for unusual floods.

ALTERNATE METHODS OF TRANSFERRING STREAMFLOW DATA

The collection of additional streamflow data ultimately will lead to better definition of streamflow characteristics by regression analysis. In the interim period, alternate methods of transferring information to an ungaged site will be considered. Most of the methods require some information at the ungaged site and gaging-station records to define a specific relation.

Moore (1968) has shown that mean annual flow may be estimated using the width and depth of the lower section of the stream channel. Different relations were developed for perennial and ephemeral streams. At the present time (1970), these relations provide a means of estimating the mean annual flow at a site, and better definition of the relations through research may lead to more exact definition.

Riggs (1969) showed that the mean annual flow at a site can be estimated by measuring the discharge at the site about the middle of each calendar month for a water year if concurrent correlation can be established with a nearby gaging station. This method may have particular application in areas where runoff is from snowmelt.

The use of partical-record stations to define low-flow characteristics at sites is described by Riggs (1965). A partial-record station is one at which enough base-flow measurements are available to define an adequate relation with concurrent flows at a nearby gaging station. The frequency characteristics of the low flows at partial-record stations can be determined from the relation of concurrent flows and the historical record at the gaged site. In Arizona most streams are ephemeral; a generalized map showing reaches having perennial flow may be used to locate sites at which low-flow characteristics may be determined by correlation with concurrent flows at gaged sites (fig. 4).

Patterson and Somers (1966) provide a means of estimating flood peaks of different recurrence intervals in parts of Arizona. Using their procedure, flood-peak characteristics can be determined from the size of drainage area at an ungaged site. The standard errors inherent in using this method are not known.

THE PROPOSED PROGRAM

The results of this study indicate that the existing program does not provide sufficient data to satisfy the needs of the proposed program. The information obtained during the study has been used in planning a streamflow-data program that eventually will meet the goals for the different types of data. A balance must be maintained between data collection and data analysis for an optimum program to gain a better understanding of the hydrologic system and to enable the future evaluation of the program to meet ever-changing needs and technology.

(p. 32 follows)

Data for Current Use

The operation of the 115 stations that satisfy the current-use data needs should be continued (table 6). Needs should be assessed periodically, and this part of the data-collection network should be modified by the addition or discontinuation of stations as needs change; furthermore, the need for a continuous discharge record at each site should be examined. In some instances a stage record or definition of peak flows may suffice.

Data for Planning and Design

Only limited success has been attained using regional regression techniques in analyzing data for planning and design. Most of the existing gaging stations and the installation of additional gaging stations in areas where few records are available are necessary in order to have adequate data for planning and design.

Principal Streams Having Natural Flow

A network of well-spaced gaging stations will provide the data on flow characteristics that are needed for regional definition by regression analysis, that can be transferred to sites for which discharge measurements are available, and that may be used to define relations between channel geometry and mean flow or floodflow. All the existing gaging stations on principal streams having natural flow should be continued, except those listed below; the following stations have sufficient periods of record to satisfy the goals of the program.

Station number	Station name	Length of record as of 1970 (in years)
09-3865.00	Little Colorado River above Zuni River, near Hunt	30
09-3880.00	Little Colorado River near Hunt	34
09-3945.00	Little Colorado River at Woodruff	41
09-3980.00	Chevelon Creek near Winslow	42
09-4820.00	Santa Cruz River at Continental	25
09-4825.00	Santa Cruz River at Tucson	65
09-4858.50	Rillito Creek near Tucson	62
09-4865.00	Santa Cruz River at Cortaro	25
09-5125.00	Agua Fria River near Mayer	30

Additional gaging stations should be established on the following principal streams:

Chinle Wash near Many Farms

Carrizo Wash near mouth

Zuni River near mouth

Cottonwood Wash below Pueblo Wash, near Winslow

Corn Creek near mouth near Leupp

Havasu Creek near Supai

Trout Creek near mouth

Burro Creek at State Highway 93

Kirkland Creek above Sycamore Creek, near Yava

Bouse Wash near mouth

Santa Cruz River near Tubac

Santa Cruz River at Greens Wash

Big Chino Wash near Seligman

Hassayampa River near Arlington

Tenmile Wash at U.S. Highway 80

San Simon Wash at United States-Mexico border

The discontinued station, Puerco River near Adamana (09-3965.00), should be reestablished. Each station in the existing and proposed network should be operated for at least 25 years.

The collection of peak-flow data should be continued at all gaging stations. Each year, some effort should be devoted to the measurement of discharge and channel geometry, and the relations used in estimating flow characteristics from discharge measurements and channel geometry measurements should be tested and improved, if possible.

Minor Streams Having Natural Flow

An equivalent of 10 years of record is needed to meet the goals for minor streams. Because only limited success was achieved by using the regression method, 20 years of record at the gaged sites is recommended. All the existing continuous-record gaging stations should be continued, except those listed below; the following stations have sufficient periods of record to satisfy the goals of the program.

Station number	Station name	Length of record as of 1970 (in years)
09-4815.00	Sonoita Creek near Patagonia	38
09-4840.00	Sabino Creek near Tucson	45
09-5045.00	Oak Creek near Cornville	27

Additional continuous-record gaging stations should be established on the following minor streams, most of which are presently equipped with flood-hydrograph recorders or crest-stage gages:

Station number	Station name	Drainage area (sq mi)	Period of record
09-3790.30	Black Mountain Wash near Chinle	81	1963 to present
09-4011.00	Dinnebito Wash near Oraibi	261	1969 to present
09-4003.00	Teshbito Wash near Holbrook	57	1963 to present

Station number	Station name	Drainage area (sq mi)	Period of record
09-3951.00	Carr Lake Draw tributary near Holbrook	1.19	1964 to present
09-3795.60	El Capitan Wash near Kayenta	5.88	1963 to present
09-4005.30	Meteor Wash near Winslow	3.0	1963 to present
09-4012.20	Cedar Wash near Cameron	556	1967 to present
09-4038.00	Bitter Seeps Wash tributary near Fredonia	2.85	1963 to present
----------	Grand Wash near mouth	----	----
09-4041.00	Cataract Creek near Grand Canyon	1,200	1968 to present
09-4043.40	Truxton Wash at Valentine	370	1965 to present
09-4238.20	Sacramento Wash near Yucca	787	1966 to present
09-4244.80	Kirkland Creek tributary near Kirkland	7.62	1963 to present
09-4285.50	Bouse Wash tributary near Bouse	14.6	1963 to present
09-4288.00	Tyson Wash tributary near Quartzsite	13.7	1963 to present
09-5142.00	Waterman Wash near Buckeye	403	1964 to present
09-5174.00	Winters Wash near Tonopah	47.8	1962 to present
09-5202.00	Black Gap Wash near Ajo	12.1	1963 to present
09-5203.00	Alamo Wash tributary near Ajo	.90	1963 to present
----------	North Bank tributary of Gila between Gila Bend and Yuma	----	----
09-5352.00	Sells Wash tributary at Sells	26.8	1962 to present

The rest of the stations in the partial-record crest-stage network, which was started in 1962, should be continued until satisfactory regional regression analysis of the flood characteristics can be developed.

Streams Having Perennial Flow

A network of partial-record low-flow stations should be established on perennial streams. Sufficient base-flow measurements should be obtained at each station to establish concurrent correlation with base flow at a continuous-record gaging station. The network could be concentrated in one part of the State for several years and then shifted to another area.

Principal and Minor Streams Having Regulated Flow

All principal regulated streams in Arizona are adequately gaged to begin systems studies. The principal regulated streams are the Gila River, the Salt River below Roosevelt Dam, the Verde River below Horseshoe Dam, the Bill Williams River below Alamo Dam, and the Colorado River throughout its course in Arizona.

Many headwater tributaries of principal and minor streams are regulated to an unknown degree by stock ponds and, in recent years, by small recreational lakes. The effect of this regulation on streamflow characteristics probably is insignificant for principal streams but may be significant for minor streams. An analysis of the effects of the regulations is beyond the scope of this report.

Data Analysis

As additional gaging stations are established and longer periods of record become available, regional regression analyses should be attempted in 5 years. Studies of alternate methods of transferring flow characteristics to ungaged sites should be made. Emphasis should be placed on improving relations for estimating flow characteristics from channel geometry and the generalized relations among flow characteristics at different times of the year. Finally, continuous appraisal of the data-collection system should be made with respect to the type of information needed.

Data Needed to Define Long-Term Trends

Since 1967, one station has been operated to define long-term trends, and the station should be operated indefinitely. Six existing stations and one new station are proposed for long-term operation—three gaging stations will record perennial flow, and five will record ephemeral flow (table 5). The stations were selected to provide areal coverage in the State, a range in size and type of drainage area, a range in type of stream, and a variety of physical and climatic basin characteristics.

Table 5. --Proposed long-term stations

Station number	Station name	Drainage area (sq mi)	Period of record
09-3792.00	Chinle Wash near Mexican Water	3,660	1964 to present
09-4014.00	Moenkopi Wash near Tuba City	2,550	1941-53 1965 to present
09-4242.00	Cottonwood Wash No. 1 near Kingman	143	1964 to present
09-4244.50	Big Sandy River near Wikieup	2,800	1966 to present
09-4850.00	Rincon Creek near Tucson	44.8	1952 to present
09-4891.00	Black River near Maverick	315	1962 to present
09-5083.00	Wet Bottom Creek near Childs	37	1967 to present
09-5197.50	Bender Wash near Gila Bend	68.8	----

Data on Stream Environment

Stream-environment data should be collected as needed and as time and funds become available. Special emphasis should be placed on the following:

1. Infiltration and ground-water recharge in losing streams.
2. Traveltime and flow attenuation with emphasis on losing streams.
3. Geomorphology of losing streams.
4. Deliniation of flood-prone areas.
5. Urban hydrology.
6. Chemical quality, sediment, and temperature of streamflow with special emphasis on perennial streams.
7. Analysis and publication of existing data for stream velocities, depths, widths, streambank vegetation, and water temperatures.

Gaging Stations for Proposed Program

The gaging stations now in operation and those required for the proposed network are given in table 9 in the appendix. The locations of the gaging stations are shown in figure 5.

page 42 follows

APPENDIX ——— BASIC DATA

 (p. 55 follows)

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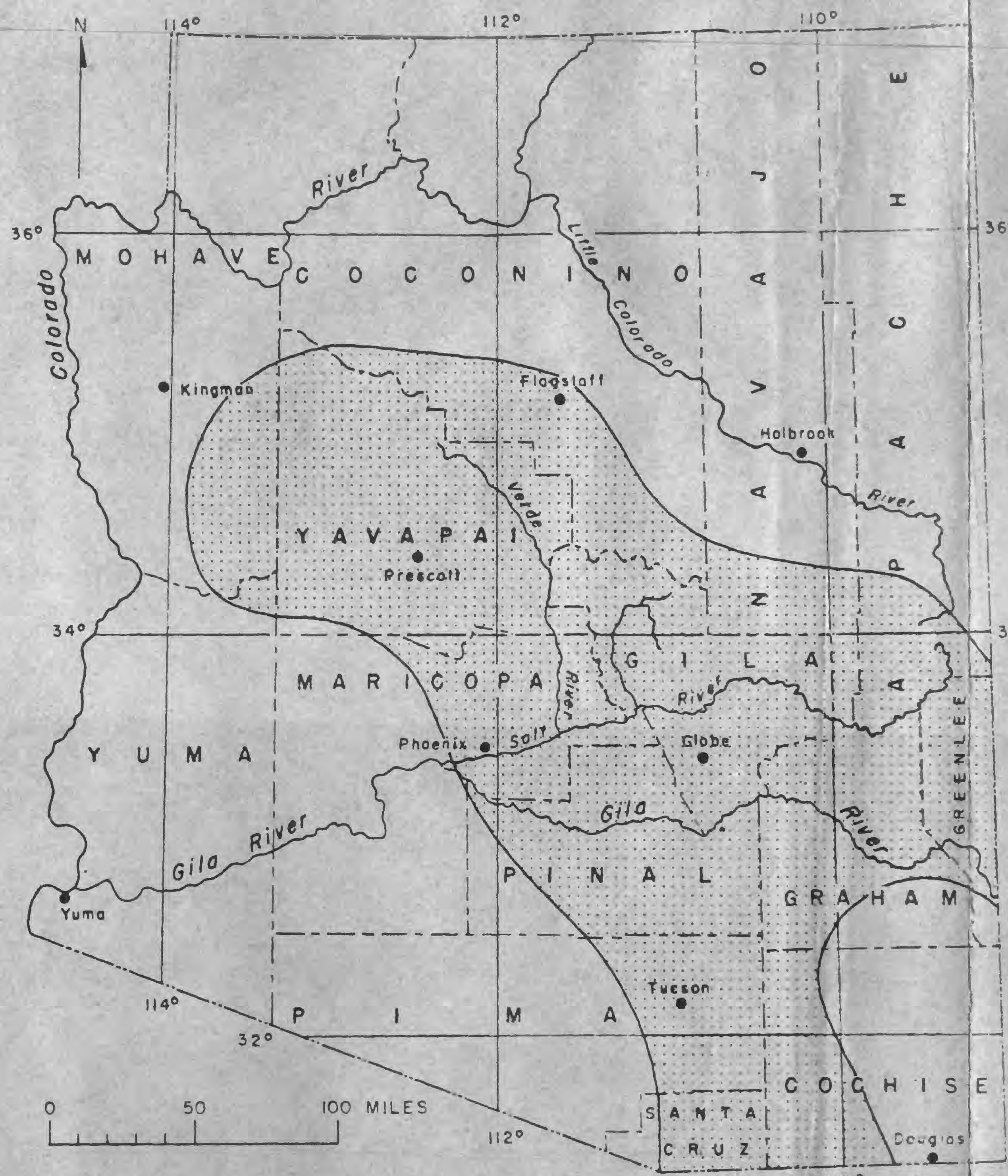
__________________ 1967d, Arizona, 50-year 24-hour precipitation: U.S. Dept. Commerce map.

70-231

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

Type of data	Current use	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 as required on streamflow needed for day-by-day decisions on water management	To provide information on statistical characteristics of flow at any site on any stream 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	1/	1/	1/	1/	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	Relate flow characteristics to drainage basin characteristics using data for gaged basins	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 are 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	Select two stations in each Water Resources Council 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.					

1/ Depends on region (see fig. 2).



EXPLANATION

Area in which a principal streamflow-gaging station is defined as one where runoff from about 500 square miles is measured; each succeeding downstream station should receive runoff from a drainage area about double the size of that at the preceding station

Area in which a principal streamflow-gaging station is defined as one where runoff from about 2,000 square miles is measured; each succeeding downstream station should receive runoff from a drainage area about double the size of that at the preceding station

NOTE: The Colorado River is considered a principal stream throughout its length in Arizona

Figure 2.--Areas in Arizona where principal streamflow-gaging stations are defined in relation to drainage basin.

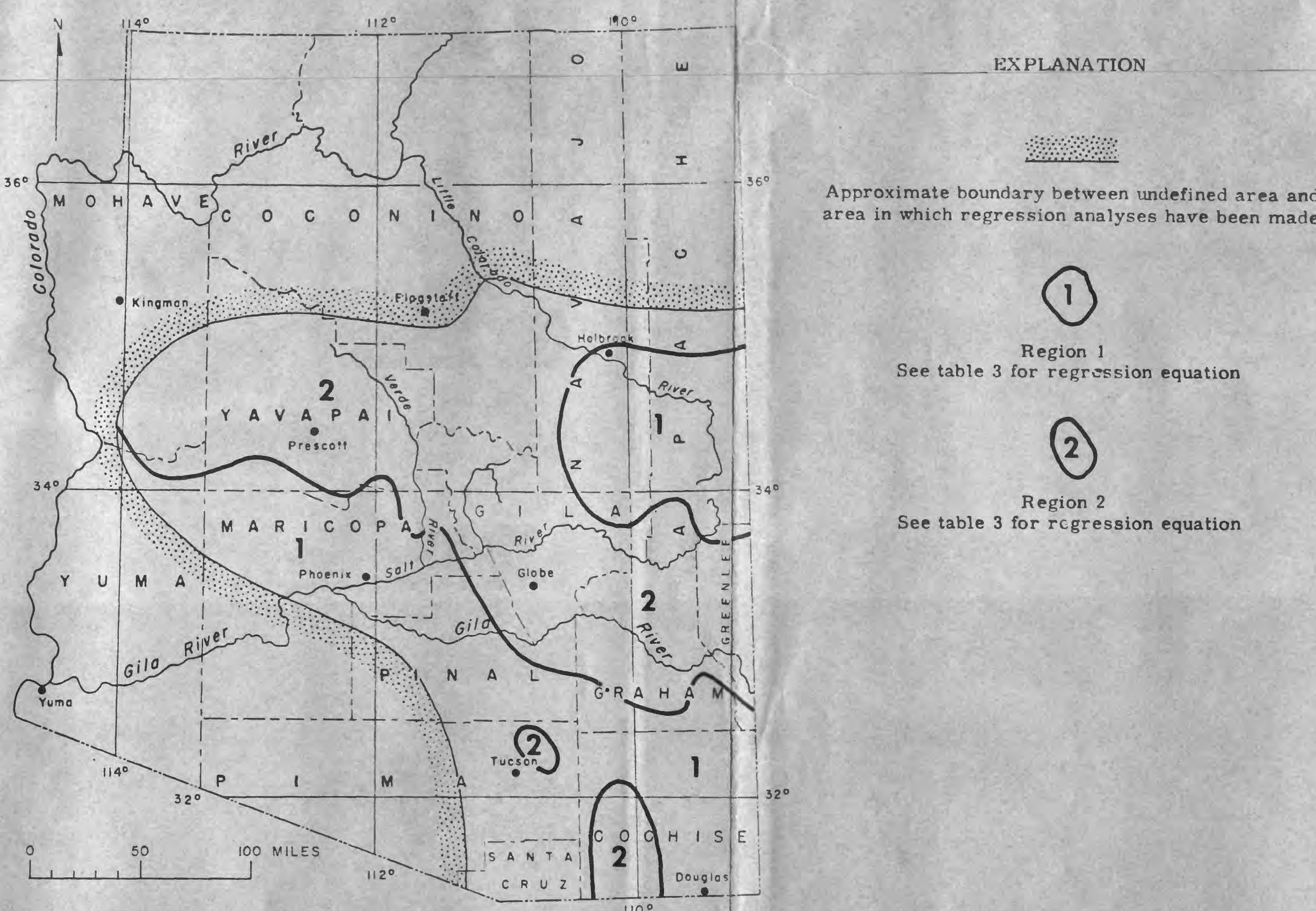


Figure 3.--Regions in Arizona where regression analyses have been made.

Table 3.--Selected regression equations and standard errors for regions analyzed in Arizona

A: Total drainage area.
P: Mean annual precipitation.
S: Shape factor.
SN: Mean annual snowfall.
I: 10-year 24-hour precipitation.
SL: Main channel slope.
SO: Soil index.
PS: Mean seasonal precipitation.
E: Mean basin elevation.

Statistical streamflow characteristics	Region (see fig. 3)	Standard error (percent)
Mean annual discharge		
$Q_a = 1.30 \times 10^{-6} A^{0.77} P^{3.94}$	1	55
$Q_a = 5.09 \times 10^{-5} A^{0.82} P^{2.76} S^{0.41}$	2	33
Standard deviation of mean annual discharge		
$SD_a = 1.09 \times 10^{-4} A^{0.75} I^{5.00} SN^{0.44}$	1	48
$SD_a = 1.92 \times 10^{-5} A^{0.94} SL^{2.29} P^{2.53} S^{0.48} SO^{-0.56}$	2	33
Seasonal mean discharge (July-September)		
$Q_s = 1.82 \times 10^{-3} A^{0.71} PS^{2.25}$	1	61
$Q_s = 5.89 \times 10^{-3} A^{0.71} PS^{2.08}$	2	60
50-year flood		
$Q_{50} = 181 A^{0.45} SO^{-1.15} I^{1.98}$	1	97
$Q_{50} = 2,560 A^{0.64} E^{-5.27} P^{1.58} SN^{0.74}$	2	54
7-day 50-year high flow		
$V_{7,50} = 1.11 \times 10^{-6} A^{0.65} I^{4.09}$	1	74
$V_{7,50} = 9.34 \times 10^{-2} A^{0.83} P^{0.97} SO^{-0.80} I^{2.62}$	2	47
7-day 2-year low flow		
$MIN_{7,2} = 9.65 \times 10^{-4} E^{3.51}$	1	136
$MIN_{7,2} = 1.98 \times 10^{1} SL^{-1.52} SO^{-6.75} SN^{3.28}$	2	114

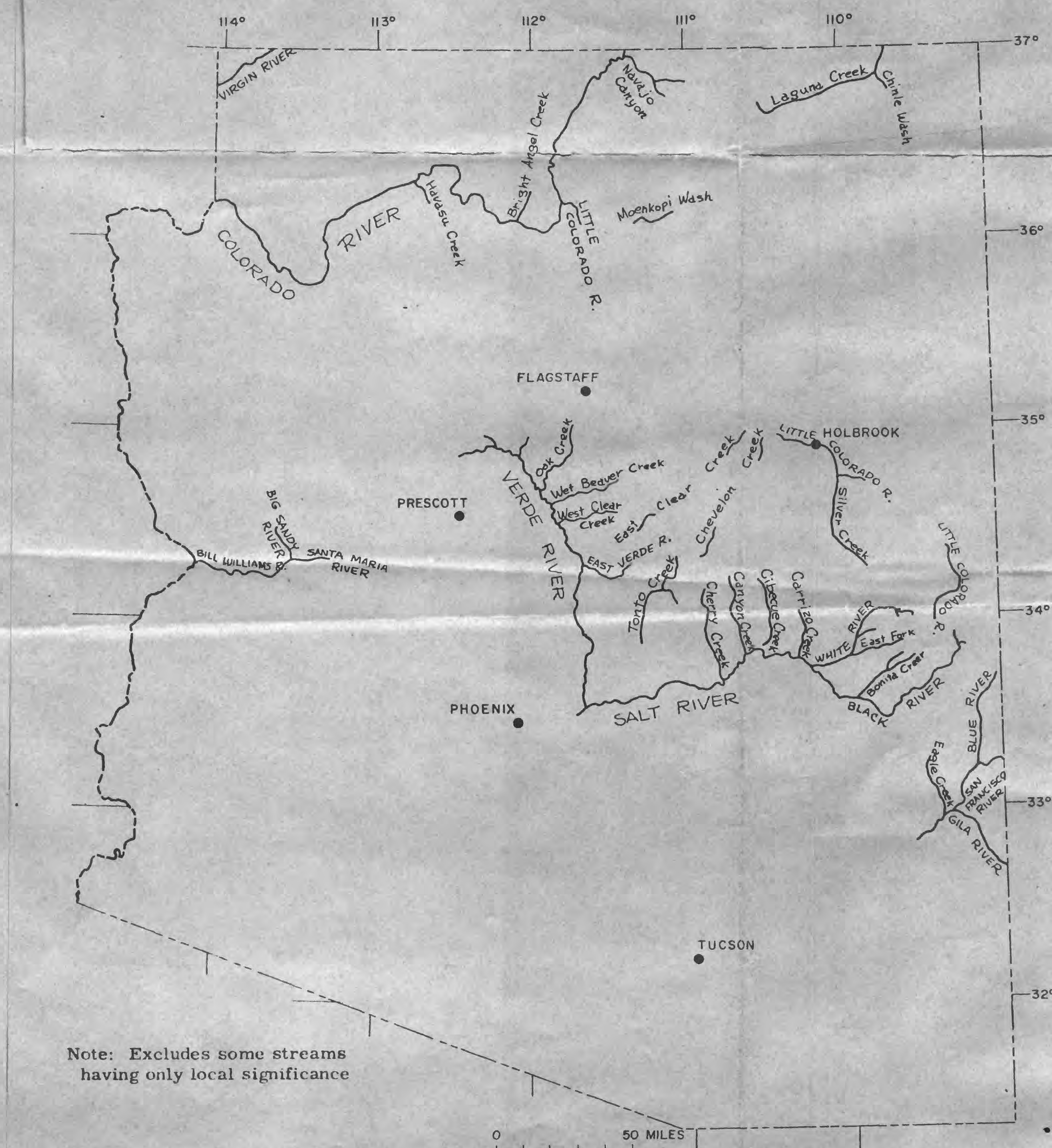


Figure 4. --Arizona streams having significant perennial flow.

70-2

Table 6.--Current-use gaging stations

[Reservoir, canal, and diversion stations not included]

Station number	Station name	Purpose: Accounting	Operation	Water quality	Compact or legal	Research or special studies
9-3792	Chinle Wash near Mexican Water	--	--	--	--	X
9-3799.1	Colorado River below Glen Canyon Dam	--	X	--	--	--
9-3800	Colorado River at Lees Ferry	--	X	X	X	--
9-3820	Paria River at Lees Ferry	X	--	X	X	--
9-3830	Colorado River at Compact point, near Lees Ferry	--	--	--	X	--
9-3832	Lee Valley Creek above Lee Valley Reservoir, near Greer	--	--	--	X	X
9-3832.2	Lee Valley Creek tributary near Greer	--	--	--	X	X
9-3832.5	Lee Valley Creek below Lee Valley Reservoir, near Greer	--	--	--	X	X
9-3834	Little Colorado River at Greer	--	X	--	--	--
9-3835	Nutrioso Creek above Nelson Reservoir, near Springerville	--	--	--	X	X
9-3835.5	Nutrioso Creek below Nelson Reservoir, near Springerville	--	--	--	X	X
9-3840	Little Colorado River above Lyman Reservoir, near St. Johns	--	X	--	--	--
9-3855	Little Colorado River below Lyman Reservoir, near St. Johns	--	X	--	--	--
9-3905	Show Low Creek near Lakeside	--	X	--	--	--
9-3920	Show Low Creek below Jacques Dam, near Show Low	--	X	--	--	--
9-3959	Black Creek near Lupton	--	--	--	--	X
9-3970	Little Colorado River at Holbrook	--	--	--	--	X
9-3994	Jacks Canyon Creek near Winslow	--	--	--	--	X
9-4014	Moenkopi Wash near Tuba City	--	--	--	X	--
9-4020	Little Colorado River near Cameron	X	--	X	X	--
9-4025	Colorado River near Grand Canyon	X	--	X	X	--
9-4030	Bright Angel Creek near Grand Canyon	--	--	X	X	--
9-4037.8	Kanab Creek near Fredonia	--	--	X	--	--
9-4150	Virgin River at Littlefield	X	--	X	X	--
9-4215	Colorado River below Hoover Dam, Ariz.-Nev	X	X	--	X	--
9-4230	Colorado River below Davis Dam, Ariz.-Nev	X	X	--	X	--
9-4240	Colorado River near Topock	--	X	--	--	--
9-4249	Santa Maria River near Bagdad	--	--	--	--	X
9-4260	Bill Williams River below Alamo Dam	--	X	--	--	--
9-4275.2	Colorado River below Parker Dam, Ariz.-Calif	--	X	--	--	--
9-4290.1	Colorado River at Palo Verde Dam, Ariz.-Calif	--	X	--	--	--
9-4293	Colorado River below Cibola Valley	--	X	--	--	--
9-4295	Colorado River at Imperial Dam, Ariz.-Calif	X	X	--	X	--
9-4420	Gila River near Clifton	--	--	--	X	--
9-4445	San Francisco River at Clifton	--	--	--	X	--

Table 6. --Current-use gaging stations—Continued

Station number	Station name	Purpose				
		Ac-counting	Operation	Water quality	Compact or legal	Research or special studies
9-4470	Eagle Creek above pumping plant, near Morenci	--	X	--	X	--
9-4485	Gila River at head of Safford Valley, near Solomon	X	X	--	X	--
9-4570	San Simon River near Solomon	X	--	--	--	--
9-4582	Deadman Creek near Safford	X	--	--	--	--
9-4601.5	Frye Creek near Thatcher	X	--	--	--	--
9-4602	Frye Creek at Thatcher	--	--	X	--	--
9-4663	Gila River near Bylas	--	--	--	--	X
9-4665	Gila River at Calva	X	--	--	X	--
9-4665.63	Gila River at Section 13, near Calva	--	--	--	--	X
9-4671	Gila River near Calva	--	--	--	--	X
9-4674	Gila River above Coolidge Dam, near Peridot	--	--	--	--	X
9-4685	San Carlos River near Peridot	X	--	--	--	--
9-4695	Gila River below Coolidge Dam	--	X	--	--	--
9-4700	Gila River at Winkelman	--	--	--	--	X
9-4705	San Pedro River at Palominas	--	--	--	X	--
9-4710	San Pedro River at Charleston	X	--	X	--	--
9-4715.5	San Pedro River near Tombstone	--	--	--	--	X
9-4718	San Pedro River near Benson	--	--	X	--	--
9-4721	Peck Canyon tributary near Redington	--	--	--	--	X
9-4730	Aravaipa Creek near Mammoth	--	--	--	--	X
9-4735	San Pedro River at Winkelman	--	--	X	--	--
9-4740	Gila River at Kelvin	X	--	X	--	--
9-4800	Santa Cruz River near Lochiel	--	--	--	X	--
9-4805	Santa Cruz River near Nogales	--	--	--	X	--
9-4824	Airport Wash at Tucson	--	--	--	--	X
9-4845.6	Cienega Creek near Pantano	--	--	--	--	X
9-4863	Canada del Oro near Tucson	--	--	--	--	X
9-4866	Arivaca Wash near Arivaca	--	--	--	--	X
9-4868	Altar Wash near Three Points	--	--	--	--	X
9-4885	Santa Rosa Wash near Vaiva Vo, near Sells	--	--	--	--	X
9-4890	Santa Cruz River near Laveen	--	--	--	--	X
9-4890.7	North Fork of East Fork Black River near Alpine	--	--	--	--	X
9-4895	Black River below pumping plant, near Point of Pines	--	X	--	X	--
9-4966	Cibecue No. 1, tributary to Carrizo Creek, near Show Low	--	--	--	--	X
9-4967	Cibecue No. 2, tributary to Carrizo Creek, near Show Low	--	--	--	--	X
9-4975	Salt River near Chrysotile	--	X	--	--	--
9-4979	Cherry Creek near Young	--	--	--	--	X
9-4979.8	Cherry Creek near Globe	--	--	--	--	X
9-4985	Salt River near Roosevelt	X	X	--	--	--
9-4988	Tonto Creek near Gisela	--	--	--	--	X

Table 6. --Current-use gaging stations—Continued

Station number	Station name	Purpose				
		Ac-counting	Operation	Water quality	Compact or legal	Research or special studies
9-4988.7	Rye Creek near Gisela	--	--	--	--	X
9-4990	Tonto Creek above Gun Creek, near Roosevelt	--	X	--	--	--
9-5020	Salt River below Stewart Mountain Dam	--	X	X	--	--
9-5028	Williamson Valley Wash near Paulden	--	--	--	--	X
9-5052	Wet Beaver Creek near Rimrock	--	--	--	--	X
9-5052.5	Red Tank Draw near Rimrock	--	--	--	--	X
9-5053	Rattlesnake Canyon near Rimrock	--	--	--	--	X
9-5053.5	Dry Beaver Creek near Rimrock	--	--	--	--	X
9-5058	West Clear Creek near Camp Verde	--	--	--	--	X
9-5076	East Verde River near Pine	--	--	--	--	X
9-5079.8	East Verde River near Childs	--	--	--	--	X
9-5083	Wet Bottom Creek near Childs	--	--	--	--	X
9-5085	Verde River below Tangle Creek, above Horseshoe Dam	X			--	--
9-5100	Verde River below Bartlett Dam	--			--	--
9-5100.7	West Fork Sycamore Creek above McFarland Canyon, near Sunflower	--			--	X
9-5100.8	West Fork Sycamore Creek near Sunflower	--			--	X
9-5101	East Fork Sycamore Creek near Sunflower	--			--	X
9-5101.5	Sycamore Creek near Sunflower	--			--	X
9-5101.8	Rock Creek near Sunflower	--			--	X
9-5102	Sycamore Creek near Fort McDowell	--			--	X
9-5121	Indian Bend Wash near Scottsdale	--			--	X
9-5122	Salt River tributary in South Mountain Park, at Phoenix	--			--	X
9-5124	Cave Creek at Phoenix	--			--	--
9-5130	Agua Fria River at Waddell Dam	--			--	--
9-5137.8	New River near Rock Springs	--			--	X
9-5138	New River at New River	--			--	X
9-5138.35	New River at Bell Road, near Peoria	--			--	X
9-5138.6	Skunk Creek near Phoenix	--			--	X
9-5139.1	New River near Glendale	--			--	X
9-5139.7	Agua Fria River at Avondale	--			--	X
9-5180	Gila River above diversions, at Gillespie Dam	--			--	--
9-5195	Gila River below Gillespie Dam	--			--	--
9-5198	Gila River below Painted Rock Dam	--			--	--
9-5201.7	Rio Cornez near Ajo	--			--	X
9-5205	Gila River near Dome	--			X	--
9-5211	Colorado River below Yuma Main Canal wasteway, at Yuma	--			X	--
9-5220	Colorado River at northerly international boundary above Morelos Dam, near Andrade, Calif	--			X	--
9-5222	Colorado River at southerly international boundary, near San Luis	--			X	--
9-5372	Leslie Creek near McNeal	--			--	X
9-5375	Whitewater Draw near Douglas	--			X	--

Table 7.--Selected Arizona statistical streamflow characteristics used in regression analyses

Station number	Station name	Mean annual flow (cfs)	Standard deviation of the mean annual flow (cfs)	Mean seasonal flow, July-September (cfs)	50-year peak flow (cfs)	50-year 7-day high mean flow (cfs)	2-year 7-day low flow (cfs)
9-3832.99	Little Colorado River above Greer, Ariz . .	17.6	6.27	1/	545	270	5.2
9-3840	Little Colorado River above Lyman Reservoir, near St. Johns, Ariz.	20.3	15.4	19.6	12,600	1,160	.36
9-3860	Little Colorado River at St. Johns, Ariz . .	7.55	5.82	1/	3,300	380	2/
9-3865	Little Colorado River above Zuni River, near Hunt, Ariz.	5.33	6.83	15.7	1,550	1,080	2/
9-3870	Zuni River at Blackrock, N. Mex	26.8	1/	1/	1/	1/	2/
9-3880	Little Colorado River near Hunt, Ariz	15.3	19.2	50.1	6,980	1,340	2/
9-3905	Show Low Creek near Lakeside, Ariz	8.81	7.53	4.56	11,800	1,390	.25
9-3925	Show Low Creek at Show Low, Ariz	10.1	1/	1/	4,600	1/	2/
9-3935	Silver Creek near Snowflake, Ariz	15.8	14.2	25.4	13,700	1,630	.42
9-3940	Silver Creek near Woodruff, Ariz	27.3	20.5	40.0	22,000	2,810	2/
9-3945	Little Colorado River at Woodruff, Ariz . .	49.9	35.7	124	16,400	2,610	2/
9-3965	Puerco River near Adamana, Ariz	64.2	51.1	1/	49,000	3,000	2/
9-3970	Little Colorado River at Holbrook, Ariz . .	106	60.6	309	25,700	5,300	.74
9-3975	Chevelon Creek below Wildcat Canyon, near Winslow, Ariz	49.2	34.6	16.0	36,900	2,610	2/
9-3980	Chevelon Creek near Winslow, Ariz	51.5	31.2	12.8	26,700	2,140	2.8
9-3985	Clear Creek below Willow Creek, near Winslow, Ariz	73.7	54.4	15.1	27,400	2,650	2/
9-3990	Clear Creek near Winslow, Ariz	75.4	58.6	7.69	41,100	2,810	2/
9-4010	Little Colorado River at Grand Falls, Ariz .	260	191	344	64,000	7,680	2/
9-4014	Moenkopi Wash near Tuba City, Ariz	19.9	14.5	5.22	13,000	1,470	2/
9-4015	Moenkopi Wash near Cameron, Ariz	13.8	10.0	43.0	10,200	1,050	2/
9-4020	Little Colorado River near Cameron, Ariz .	206	123	318	27,700	6,030	2/
9-4030	Bright Angel Creek near Grand Canyon, Ariz	35.2	14.9	22.3	3,720	853	17.8
9-4255	Santa Maria River near Alamo, Ariz	30.0	51.9	23.5	34,600	6,960	.86
9-4260	Bill Williams River below Alamo Dam, Ariz	94.0	145	43.9	97,600	13,200	4.0
9-4265	Bill Williams River at Planet, Ariz	149	170	126	88,000	32,100	13.5
9-4305	Gila River near Gila, N. Mex	131	78.9	99.3	15,000	3,030	29.2
9-4315	Gila River near Redrock, N. Mex	180	128	138	30,000	4,930	15.9
9-4320	Gila River below Blue Creek, near Virden, N. Mex	167	111	151	23,300	4,650	5.6
9-4420	Gila River near Clifton, Ariz	194	164	186	24,700	6,530	15.1

See footnotes at end of table.

Table 7.--Selected Arizona statistical streamflow characteristics used in regression analyses—Continued

Station number	Station name	Mean annual flow (cfs)	Standard deviation of the mean annual flow (cfs)	Mean seasonal flow, July-September (cfs)	50-year peak flow (cfs)	50-year 7-day high mean flow (cfs)	2-year 7-day low flow (cfs)
9-4426.80	San Francisco River near Reserve, N. Mex	25.6	18.0	1/	1,880	950	2.4
9-4435	Whitewater Creek near Mogollon, N. Mex	16.2	13.6	10.1	1,000	457	2.5
9-4440	San Francisco River near Glenwood, N. Mex	67.5	51.3	59.0	8,570	2,200	10.7
9-4445	San Francisco River at Clifton, Ariz	166	120	153	65,900	6,930	21.3
9-4455	Willow Creek near Point of Pines, near Morenci, Ariz	1/	1/	1/	3,140	661	2/
9-4460	Willow Creek near Double Circle Ranch, near Morenci, Ariz	1/	1/	1/	7,770	1/	2/
9-4465	Eagle Creek near Double Circle Ranch, near Morenci, Ariz	1/	1/	1/	12,000	1,810	2/
9-4470	Eagle Creek above pumping plant, near Morenci, Ariz	1/	1/	1/	21,300	3,120	2/
9-4485	Gila River at head of Safford Valley, near Solomon, Ariz	348	252	320	67,000	11,300	35.6
9-4560	San Simon River near San Simon, Ariz	5.45	5.89	20.3	7,250	603	2/
9-4570	San Simon River near Solomon, Ariz	14.0	9.33	54.5	18,800	1,110	2/
9-4585	Gila River at Safford, Ariz	284	263	266	60,000	7,870	2/
9-4665	Gila River at Calva, Ariz	250	219	242	45,100	10,600	2/
9-4685	San Carlos River near Peridot, Ariz	46.8	51.8	1/	45,500	6,420	2/
9-4695	Gila River below Coolidge Dam, Ariz	498	469	481	130,000	40,600	1.5
9-4705	San Pedro River at Palominas, Ariz	33.0	19.6	113	23,400	2,350	2/
9-4710	San Pedro River at Charleston, Ariz	55.1	25.4	167	45,200	2,670	2.9
9-4720	San Pedro River near Redington, Ariz	48.1	42.2	181	31,900	3,480	2/
9-4725	San Pedro River near Mammoth, Ariz	61.6	25.6	1/	61,000	7,500	2/
9-4730	Aravaipa Creek near Mammoth, Ariz	26.6	12.3	37.6	25,000	948	2.6
9-4740	Gila River at Kelvin, Ariz	759	745	851	175,000	54,300	3.9
9-4785	Queen Creek at Whitlow damsite, near Superior, Ariz	4.15	3.69	7.76	41,100	519	2/
9-4800	Santa Cruz River near Lochiel, Ariz	3.59	4.08	12.4	4,010	309	2/
9-4805	Santa Cruz River near Nogales, Ariz	22.3	20.2	60.9	13,200	1,470	2/
9-4815	Sonoita Creek near Patagonia, Ariz	8.15	5.65	17.7	11,400	370	.12
9-4820	Santa Cruz River at Continental, Ariz	19.3	23.2	62.5	15,400	2,190	2/
9-4825	Santa Cruz River at Tucson, Ariz	22.5	20.7	70.9	17,100	2,260	2/

See footnotes at end of table.

Table 7.--Selected Arizona statistical streamflow characteristics used in regression analyses—Continued

Station number	Station name	Mean annual flow (cfs)	Standard deviation of the mean annual flow (cfs)	Mean seasonal flow, July-September (cfs)	50-year peak flow (cfs)	50-year 7-day high mean flow (cfs)	2-year 7-day low flow (cfs)
9-4830	Tucson Arroyo at Vine Avenue, Tucson, Ariz	0.76	0.41	2.50	5,800	89.6	2/
9-4831	Tanque Verde Creek near Tucson, Ariz	9.29	9.78	1/	4,230	1,100	2/
9-4833	Sabino Creek near Mount Lemmon, Ariz	1.63	1.27	1/	488	190	2/
9-4840	Sabino Creek near Tucson, Ariz	9.90	9.50	8.65	5,940	509	2/
9-4842	Bear Creek near Tucson, Ariz	5.20	5.15	1/	1,630	500	2/
9-4846	Pantano Wash near Vail, Ariz	8.03	4.03	1/	10,600	900	0.8
9-4850	Rincon Creek near Tucson, Ariz	5.08	5.99	7.78	16,400	329	2/
9-4860	Rillito Creek near Tucson, Ariz	14.0	17.1	30.5	19,600	1,940	2/
9-4865	Santa Cruz River at Cortaro, Ariz	30.4	27.6	91.2	20,900	2,580	2/
9-4885	Santa Rosa Wash near Vaiva Vo, near Sells, Ariz	18.0	19.3	56.3	78,600	4,830	2/
9-4890	Santa Cruz River near Laveen, Ariz	20.8	1[illegible].7	49.2	8,040	3,080	2/
9-4892	Pachete Creek at Maverick, Ariz	7.85	5.49	3.20	279	248	.6
9-4894.99	Black River above pumping plant, near Point of Pines, Ariz	184	113	105	7,850	4,670	26.9
9-4897	Big Bonita Creek near Fort Apache, Ariz	59.2	31.8	35.6	1,710	1,150	5.0
9-4905	Black River near Fort Apache, Ariz	339	206	172	33,900	6,910	24.0
9-4910	North Fork White River near McNary, Ariz	41.5	20.2	30.6	1,750	816	9.4
9-4924	East Fork White River near Fort Apache, Ariz	30.2	10.8	23.9	775	296	7.0
9-4940	White River near Fort Apache, Ariz	161	83.4	98.9	14,200	2,780	11.0
9-4943	Carrizo Creek above Corduroy Creek, near Show Low, Ariz	9.71	10.3	4.16	8,760	1,470	2/
9-4960	Corduroy Creek near mouth, near Show Low, Ariz	18.8	20.5	6.15	18,200	3,450	1.4
9-4965	Carrizo Creek near Show Low, Ariz	33.7	39.4	1/	24,000	10,700	1.1
9-4966	Cibecue No. 1, tributary to Carrizo Creek, near Show Low, Ariz	.01	.01	1/	298	4.6	2/
9-4967	Cibecue No. 2, tributary to Carrizo Creek, near Show Low, Ariz	.01	.01	1/	93	2.0	2/
9-4975	Salt River near Chrysotile, Ariz	590	366	1/	79,700	14,100	107
9-4978	Cibecue Creek near Chrysotile, Ariz	35.0	1[illegible].2	1/	14,200	2,200	6.4

See footnotes at end of table.

Table 7. --Selected Arizona statistical streamflow characteristics used in regression analyses—Continued

Station number	Station name	Mean annual flow (cfs)	Standard deviation of the mean annual flow (cfs)	Mean seasonal flow, July-September (cfs)	50-year peak flow (cfs)	50-year 7-day high mean flow (cfs)	2-year 7-day low flow (cfs)
9-4985	Salt River near Roosevelt, Ariz	841	623	502	165,000	32,000	133
9-4990	Tonto Creek above Gun Creek, near Roosevelt, Ariz	105	80.3	66.8	56,100	6,790	.60
9-4995	Tonto Creek near Roosevelt, Ariz	141	97.8	56.7	1/	12,100	.52
9-5030	Granite Creek near Prescott, Ariz	5.88	1/	1/	4,480	671	2/
9-5045	Oak Creek near Cornville, Ariz	82.3	43.2	33.9	23,200	3,570	15.1
9-5052	Wet Beaver Creek near Rimrock, Ariz . . .	31.0	19.2	1/	11,100	1,600	6.4
9-5052.50	Red Tank Draw near Rimrock, Ariz	6.14	6.38	1/	4,490	320	2/
9-5053	Rattlesnake Canyon near Rimrock, Ariz . .	6.54	6.50	1/	3,330	333	2/
9-5053.50	Dry Beaver Creek near Rimrock, Ariz . . .	35.8	31.4	1/	19,300	3,600	2/
9-5060	Verde River near Camp Verde, Ariz	465	253	205	165,000	21,700	66.8
9-5077	Webber Creek above West Fork Webber Creek, near Pine, Ariz	2.24	1.60	1/	644	160	.20
9-5085	Verde River below Tangle Creek, above Horseshoe Dam, Ariz	435	217	279	76,600	14,600	83.0
9-5100	Verde River below Bartlett Dam, Ariz . . .	800	420	418	200,000	31,600	97.7
9-5102	Sycamore Creek near Fort McDowell, Ariz.	13.2	17.8	1/	31,600	3,100	2/
9-5121	Indian Bend Wash near Scottsdale, Ariz . . .	.29	.27	1/	3,000	300	2/
9-5122	Salt River tributary in South Mountain Park, at Phoenix, Ariz	.02	.03	1/	1,200	22	2/
9-5123	Cave Creek near Cave Creek, Ariz	4.07	5.72	1/	21,200	2,300	2/
9-5125	Agua Fria River near Mayer, Ariz	15.6	15.0	24.9	16,600	1,210	.13
9-5138	New River at New River, Ariz	5.63	7.07	1/	16,800	3,500	2/
9-5155	Hassayampa River at Box damsite, near Wickenburg, Ariz	12.6	14.0	16.9	26,900	1,640	.60
9-5165	Hassayampa River near Morristown, Ariz	17.3	31.4	1/	16,700	2,700	2/
9-5175	Centennial Wash near Arlington, Ariz	3.05	3.74	1/	24,900	2,700	2/
9-5375	Whitewater Draw near Douglas, Ariz	12.0	9.40	42.8	5,200	789	.05

1/ Value not available.

2/ Value is affected by diversion or is zero.