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A PROPOSED STREAMFLOW DATA PROGRAM FOR UTAH

By

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ABSTRACT

An evaluation of the streamflow data available in Utah was made to provide guidelines for planning future programs. The basic steps in the evaluation procedure were (1) definition of the long-term goals of the streamflow-data program in quantitative form, (2) examination and analysis of all available data to determine which goals have already been met, and (3) consideration of alternate programs and techniques to meet the remaining objectives. The principal goals are (1) to provide current streamflow data where needed for water management and (2) to define streamflow characteristics at any point on any stream within a specified accuracy. It was found that the first goal generally is being satisfied but that flow characteristics at ungaged sites cannot be estimated within the specified accuracy by regression analysis with the existing data and model now available. This latter finding indicates the need for some changes in the present data program so that the accuracy goals can be approached by alternate methods. The regression method may be more successful at a future time if a more suitable model can be developed, and if an adequate sample of streamflow records can be obtained in all areas. In the meantime, methods of transferring flow characteristics which require some information at the ungaged site may be used. A modified streamflow-data program based on this study is proposed.

INTRODUCTION

The streamflow program of the U.S. Geological Survey in Utah has evolved as the Federal and State interests in surface-water resources have increased and as funds for operating the stream-gaging network have become available.

The collection of streamflow records in Utah began in 1894 with the establishment of a gage on Green River at Green River. In 1896 gaging of Logan River was begun. Many other gaging stations were established prior to 1918 with the largest increase occurring in the period 1911-14.

The first State cooperation, consisting of payment of gage readers' salaries, was advanced by the Utah State Engineer in 1904. Since 1909, when 42 stations were being operated in Utah, the State and the Survey each have contributed to the cooperative stream-gaging program.

Due to the rapid and extensive development of irrigation in the State, the need for records of surface-water supplies was recognized early, and the cooperative stream-gaging program continued to grow. By 1920, 66 streamflow stations were in operation, in addition to many stations on diversion canals. There was little change through 1940 except for discontinuing most of the canal stations and installation of several reservoir stations.

By 1950 the number of streamflow stations had increased to 151, the greatest increase being in the Colorado River Basin. During the decade 1940-50 two programs greatly influenced the course of the streamflow program in Utah. One was the creation of a Project Office at Logan to collect data and assume a leading role in the formulation, and later in the administration, of the Bear River Compact. That office, now a unit of the Utah District office, handles the stream-gaging program in all the Bear River basin, which lies in parts of Utah, Wyoming, and Idaho. The other program began during that decade was the planning stage of the Upper Colorado River Storage Project, which required the collection of much additional streamflow data. Most of this work was financed by the U.S. Bureau of Reclamation.

By 1965 the Utah District was operating 225 complete-record stations, including 38 streamflow stations in the Bear River basin, in addition to a number of stations on lakes, reservoirs, canals, and transmountain diversions.

A cooperative program with the Utah State Road Commission and the U.S. Bureau of Public Roads resulted in the installation of 120 crest-stage gages, mostly on small drainage areas, in 1959. The purpose of this program was to define the magnitude and frequency of flood peaks from small drainage areas. The program, which has provided information used in three flood-frequency reports, is being expanded to record flood hydrographs and the related precipitation at a number of partial-record stations over the State.

The first attempt by the U.S. Geological Survey on a nationwide scale to catalog and identify gaging stations according to use came in the 1950's. This effort resulted in the present numbering system of gaging-station sites, and classifications of areal primary and secondary, mainstream primary and secondary, and various categories of water management. The expectation was that correlations could be developed between areal primary and secondary stations, thus allowing periodic relocation of secondary stations and extending the short records by means of correlation equations developed with a nearby primary station. The Utah District participated actively in this effort, and one useful product has been the report by Reid, Carroon, and Pyper (1969).

The Utah Water and Power Board began work on the development of a State Water Plan in 1963 (Utah Water and Power Board and Utah State University, 1963). Preliminary results suggested the advisability of adding 105 streamflow stations to the existing network to adequately inventory the surface-water resources of the State. Funds were made available for 44 of these, which have been installed and are in operation.

The increasing cost of operation, the restraint on funds and manpower, and the need for a greater variety of hydrologic information made it imperative that a systematic evaluation of the streamflow-data program be made to determine how to apply the funds and manpower available in order to best serve State and Federal interests. The purpose of this study is to evaluate the streamflow-data program and use this evaluation to design a program that will most efficiently produce the types of information needed.

The concepts and procedures used in this study were presented in detail by Carter and Benson (1970), and are summarized only briefly in this report. The basic steps are (1) definition of the long-term objectives of the streamflow-data program in quantitative form, (2) examination and analysis of all available data to determine which objectives have already been met, (3) consideration of alternate means of meeting the remaining objectives, and (4) preparation of a proposed program of data collection and analysis to meet the remaining objectives.

HYDROLOGY OF UTAH

Utah is comprised overwhelmingly of mountainous and desert areas. There are two principal mountain ranges--the north-south Wasatch Range with its southern extension through the center of the State and the east-west Uinta Mountains in northeastern Utah. The State lies essentially in two major drainage basins--about 46,300 square miles in the Colorado River Basin on the east and southwest and about 38,600 square miles in the Great Basin on the west. A small part of the northwest corner of the State is in the Snake River basin. Altitudes vary from over 13,000 feet to less than 3,000 feet. Vegetation varies from practically none in several desert areas to sagebrush, rabbitbrush, and sparse grass in the lowlands and to juniper, pinyon pine, and larger conifers in the highlands. Mean annual precipitation ranges from less than 5 inches in some desert areas to 60 or more inches at points in the Wasatch Range.

Streamflow derives principally from melting snow accumulated during the winter months in the high mountains, augmented by ground-water inflow during most of the year. Flows of high intensity but short duration occur frequently in the desert streams during the thunderstorm season in late summer and early fall. At other times these streams are usually dry. The flows of most small streams emerging from the mountains are either diverted for irrigation or sink into the alluvial cones and become recharge to ground-water reservoirs. Floods generated from mountain streams are rare, and when they occur are generally caused by rain falling on snow or by rapid snowmelt during periods of unusually warm temperatures in late winter or spring.

The three large streams of the Upper Colorado River Basin in Utah (Colorado, Green, and San Juan Rivers) enter and leave the State in deep canyons, and very little use of their streamflow aside from storage or power development is made or would be possible. These three streams annually contribute about 12,000,000 acre-feet of water to the Lower Colorado River Basin, only about 935,000 acre-feet of which is derived from tributary streams in Utah. The streamflow from the Upper Colorado River Basin is largely controlled by reservoirs of the Upper Colorado River Storage Project.

There are many irrigation developments in the Ashley Creek and Duchesne River basins, and in the upper portions of the Price, San Rafael, Dirty Devil, and Virgin River basins of the Colorado River drainage. The Central Utah Project, under construction by the U.S. Bureau of Reclamation, will greatly increase the amount of water diverted from the headwaters of the Duchesne River into the Great Basin.

The principal streams in the Great Basin in Utah are the Bear, Jordan, Sevier, and Weber Rivers. The Little Bear and Malad Rivers are the largest tributaries of the Bear River. The Provo River and Spanish Fork discharge to Utah Lake, which is the source of the Jordan River. The East Fork Sevier and San Pitch Rivers are the main tributaries to the Sevier River. Beaver River and Chalk and Coal Creeks in southwestern Utah are the principal streams not connected with a main river system.

All the main river systems of the Great Basin are highly regulated by storage reservoirs, and nearly all the streamflow is used and reused for irrigation, power development, or municipal and industrial purposes.

Bear Lake and Utah Lake are large natural bodies of fresh water in the Great Basin which are also used for storage. Their usable storage capacities are 1,421,000 and 883,900 acre-feet, respectively. The water stored in Bear Lake passes through several hydroelectric powerplants.

Great Salt Lake is the most widely known hydrologic feature in Utah, being the largest body of water in the Western Hemisphere not having an outlet to an ocean. The brine is about seven times saltier than ocean water, and it is impossible for a person to sink in it. It is the remnant of ancient Lake Bonneville, which at one time covered about 20,000 square miles of western Utah and eastern Nevada, and reached a maximum depth of 1,000 feet. The present lake occupies about 1,200 square miles and has a maximum depth of about 35 feet. It is practically worthless as a source of water supply, but contains billions of tons of useful and valuable minerals and metals, in addition to being an important tourist attraction. It receives all the unused flow of the Bear, Weber, and Jordan River systems. This unused flow is quite highly mineralized and polluted by the time it reaches the lake.

CONCEPTS AND PROCEDURES USED IN THIS STUDY

The principal concept of this study is that streamflow information may be needed at any point on any stream in Utah, and that the program must be designed to accommodate this need. This information can be provided by a combination of data collection and hydrologic studies that generalize the information obtained at gaging sites.

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 and how the program should be modified.

The procedures used in this study are presented with reference to the general framework shown by table 1. Streamflow data are classified into four types: (1) Data for current use, (2) data for planning and design, (3) data to define long-term trends, and (4) data on the stream environment. For the second type of data, streams are classified as natural or regulated, and each of these classifications is further subdivided into principal or minor, with the separation of the two occurring at a drainage area of 500 square miles; however, there are no principal streams as herein defined in Utah that are not affected by regulation and (or) diversion. The minor streams are further subdivided into perennial and ephemeral streams. For this purpose a stream is considered to be perennial if it goes dry occasionally or not at all, and to be ephemeral if it is dry for several months each year.

In the first step of the study, program goals were established for each type of data. All available data were then examined and

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

Type of data	Current use	Planning and design: Natural flow-minor streams: Perennial	Planning and design: Natural flow-minor streams: Ephemeral	Planning and design: Regulated flow: Minor streams	Planning and design: Regulated flow: Principal streams	Long-term trends	Stream environment
Program data	To provide current data on streamflow needed for daily or monthly decisions on water-management, as required	To provide information on statistical characteristics of flow at any site on any stream in Utah 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.		Less than 500 sq. mi.	Greater than 500 sq. mi.	Less than 500 sq. mi.	Full range
Accuracy goals	As required	Equivalent to 10 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. Less than a complete record may be adequate for some purposes	Gage at selected points. Transfer data to ungaged points by regression or interpolation		Develop generalized relations that account for the effect of storage, diversions, or regulation on natural flow characteristics	Utilize analytical model of stream system with observed data as input to compute homogenous records for both natural-flow conditions and present conditions of development	Operate a few carefully selected gaging stations indefinitely	Observe, record, and publish information on stream environment
Evaluate existing program and available data	Identify stations where data are used currently and indicate the specific uses of data	Develop relationship for each flow characteristic and compare standard error with accuracy goal. Evaluate sample	Appraise existing flood-frequency analyses, results of channel geometry studies, rainfall-runoff relationships, etc.	Appraise types of regulation, data now available, and areas where relationships are needed	Identify stream systems that should be studied using model approach and determine data requirements	Determine if the present number of stations designated for this purpose is adequate	Evaluate information now available in relation to goals
Design future program	Identify goals that have been attained. Consider alternate means of attaining goals. Identify elements of future program						

analyzed. This led to a comparison of the information now available with the goals that had been set and to consideration of the elements that should be included in the future program.

Criteria for each of the four types of data and the methods employed in deriving information are discussed in the following paragraphs.

Data for current use

Current information on streamflow is needed at many sites for uses such as day-to-day or week-to-week decisions on water management, assessment of current water availability, the management of water quality, the forecast of water hazards, and the surveillance necessary to comply with legal requirements. Sites at which the needed data are collected are termed "current purpose" streamflow stations.

Data for current use are obtained by operating gaging stations to obtain the data specifically required for water-management systems. Current-purpose stations are identified separately in this study because (1) justification can be related to specific needs; (2) the data may have little or no transfer value in a hydrologic sense; and (3) the locations of the stations, the accuracy requirements, and the period of operation are specified by the user of the data, who usually provides the financing.

This part of the program is usually not subject to design, but changes in response to the needs for data in water management.

Data for planning and design

Streamflow records, either observed or synthesized, form the principal basis for the planning and design of water-related facilities. Past hydrologic experience, however, is never precisely duplicated in the future; the exact sequence of wet and dry years probably will not occur again. For this reason, designers and planners commonly utilize statistical characteristics of streamflow rather than the records of flow at specific times. It is assumed that the probability of occurrence of a flow of a given magnitude in a future period can be approximated from the frequency of such occurrence in the past. Typical statistical characteristics often used are the mean flow, the standard deviation of annual mean flows, and the flood of 50-year recurrence interval.

A long record of streamflow at a specific site is desirable for defining statistical characteristics of streamflow at that site. Although it is not feasible to collect a long continuous streamflow record at every site where it may be needed, a number of such records are necessary to provide information that can be transferred to sites where little or no streamflow information is available.

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.

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. These alterations increase the scope of both the data collection and the analysis that is required to provide information on the flow characteristics.

To be useful in statistical prediction, streamflow data must be homogeneous in time. Frequently, however, it is not possible to obtain a long record under one condition of development.

Definition of the flow characteristics at any point on any stream is also much more difficult under conditions of regulation. The procedures used for natural streams--regression, interpolation, etc.--usually cannot be applied.

For regulated streams, a systems approach seems to be the most efficient way of providing meaningful information on the statistical characteristics of flow. This approach requires some sort of analytical model of the stream system. Such models are simple in concept and generally consist of water-budget equations and flow-storage equations. However, in many instances the use of the digital computer is required for complex equations or to handle large volumes of data. A computer program tailored to the individual system can be prepared.

Development of such a model requires information on stage-capacity curves of reservoirs, stage-discharge curves at the outlets, operating-rule curves for the release of water, losses due to evaporation and seepage, geometry of the stream channel, and records of diversions and return flow. Frequently aquifer characteristics and ground-water pumpage need to be considered. Streamflow records for both natural and regulated flows also are needed as input to the model and to verify the output.

The model and the associated data can be used to derive homogeneous data for both the natural and the regulated conditions. Furthermore, data could also be derived for ungaged sites in the stream system.

Carter and Benson (1970) recommended that gaging-station records on principal streams be obtained for 25 years from a network defined as follows: (1) select stations with drainage areas of about 500 square miles on the upstream segment of all streams; (2) after the upstream stations are located select the next or following stations on each stream from the upstream station to the mouth at points where the drainage area has approximately doubled.

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," which 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 two-thirds 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 characteristics decrease with the years of available record, but at a decreasing rate, as shown in figure 1. It will be noted that little accuracy is to be gained by operating a streamflow station at a typical site in Utah for longer than 20-30 years. The incremental economic value of the additional years of record beyond

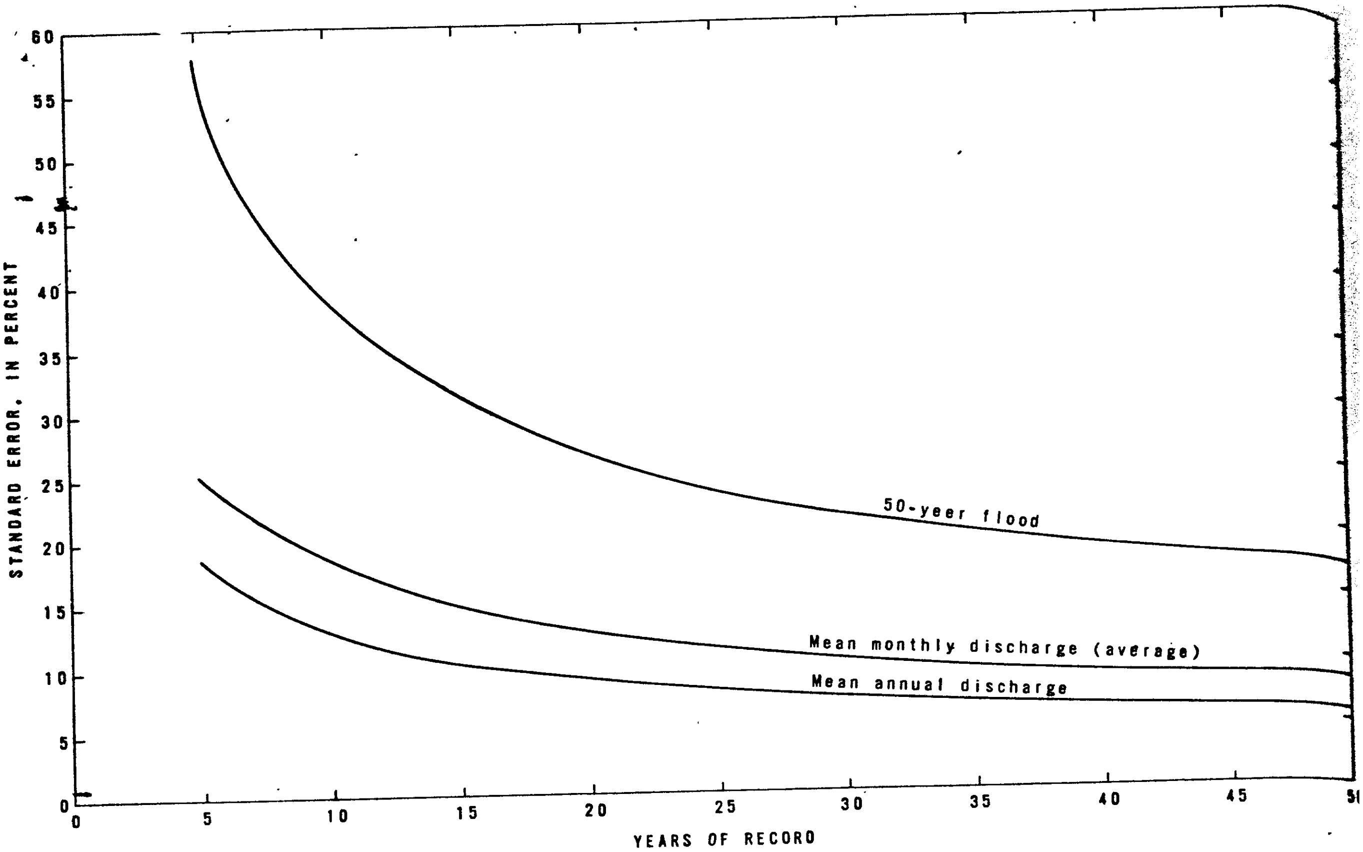

Figure 1.—Curve showing relation of standard error to length of record for Utah streams.

20 or 30 years 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 characteristic 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 geologic, topographic, and climatic characteristics that affect streamflow. This analysis produces a regression equation that can be used to compute the flow characteristics at ungaged sites. 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 (from fig. 1, for example) in order to determine whether or not an accuracy objective has been met.

Data to define long-term trends

Characteristics of streamflow defined from gaging-station records are used to estimate future-flow characteristics, on the assumption that the observed record is a representative sample of the long-term flows of the stream. To affirm this assumption, or to better define the ways in which the characteristics of flows change with time, selected gaging stations on natural streams should be operated indefinitely. The accuracy of gaging at these sites should be the highest that the state of the art permits.

Data on stream environment

Environmental data describe the physical environment in which the water exists, especially those features that relate to the use of water for recreation, waste disposal, conjunctive surface water-ground water supply, and the preservation of the esthetic character of water features. The types of data required for this purpose are suggested by the following:

1. The geologic and hydraulic properties of the stream-aquifer systems.
2. Time of travel of solutes in stream channels.
3. Definition of flood profiles along stream channels.
4. Identification of flood plains of streams for floods of different frequencies.
5. Definition of stream and stream-channel properties, such as velocities, depths, bank vegetation, bed

material, water temperature, water quality, and accessibility.
6. Data needed to define the effects of manmade changes in the environment on the quantity and quality of streamflow.
7. Character of the drainage basin, including area, vegetal cover, land and channel slopes, geology, and topography.
8. Climatic factors influencing the water supply.

GOALS OF THE UTAH STREAMFLOW DATA PROGRAM

The objective of the Utah streamflow data program is to provide information on flow at any point on any stream. Within this general objective, specific goals are set for each of the four types of data that represent the particular information that is needed. These goals, summarized in table 1, are described in more detail in this section.

Data for current use

The program 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, as specified by the data user, can be met by more or less intensive observation, or by more sophisticated instrumentation as needed.

Data for planning and design

The goal for this type of data is to define flow characteristics at ungaged sites to an accuracy that is equivalent to that obtained from 10 years of record for minor streams and from 25 years of record for principal streams. The characteristics to be defined are listed in table 2 along with the accuracy goals in standard error in percent corresponding to the two specified lengths of record. These errors in percent were calculated from a theoretical relation of standard error to index of variability of Utah streams.

The goal for ephemeral streams is limited to defining the mean annual discharge, the standard deviation of annual discharge, and the 50-year flood.

Table 2.--Accuracy goals

Streamflow characteristic	Standard error (percent) 10 years	25 years
Mean annual discharge	13	8
Standard deviation of annual discharge	22	14
Mean monthly discharge (average)	18	12
Standard deviation of monthly discharges (average)	22	14
50-year flood	39	24
7-day 2-year low flow	10	6
7-day 20-year low flow	16	10
7-day 50-year high flow	37	22

Data to define long-term trends

The goal for this type of data is to operate indefinitely a small network of gaging stations on streams that are expected to be relatively free from manmade changes. One or two stations should be located in each major drainage area in the State, and stations should be located on streams that differ in physical characteristics.

Data on stream environment

Environmental data describe the flow and the stream channel in terms that will be valuable in planning the use of the stream for any purpose such as recreation, waste disposal, conjunctive surface water-ground water supply, and in guarding against water hazards. The long-range goals are to provide the types of data in Utah which are given under this category on page 11.

EVALUATION OF EXISTING DATA IN UTAH

In this evaluation all available data were considered and analyzed in relation to program objectives. A separate evaluation was made for each of the four types of data as discussed below.

Data for current use

Almost two-thirds of the gaging stations in Utah are operated to provide data for current use and a third of these are located on regulated principal streams. It is assumed that the need for this type of data is being met, and that this part of the program can be modified as requirements change. The 103 gaging stations operated in Utah to satisfy the need for current data are listed in table A-1 along with the principal uses of the data for each station.

Data for planning and design

The statistical characteristics of streamflow can be defined by sample gaging, analytical methods of regionalization, systems studies, or any combination of the three. The following discussion of the evaluation of this type of data follows the framework shown in table 1.

EVALUATION

Evaluation of the natural-flow systems

The purpose of the evaluation is to determine how accurately the streamflow characteristics that are listed as goals in table 2 can be defined by regionalization of the data now available. Since it could be accomplished with little additional effort, several more streamflow characteristics were also analyzed. The mass of statistical data accumulated should be of great value in future programs and investigations.

The most effective way now known for defining streamflow characteristics at ungaged sites on a broad scale is to relate the streamflow characteristics to basin characteristics by multiple-regression techniques applied to past data.

Once the regression equation is defined, streamflow characteristics for a specific site can be computed by substituting the appropriate values of the basin characteristics in that equation.

The 98 streamflow records used in these analyses are those having for the most part 10 or more years of essentially unregulated flow. Records were not adjusted to a base period. Only minor streams were included; all gaged principal streams are regulated.

Streamflow characteristics.--The following streamflow characteristics defined at gaging stations include the full range of flow and represent those required for planning and design:

a. Low-flow characteristics are the annual minimum 7-day mean flows at 2-year, 10-year, and 20-year recurrence intervals ($M_{7,2}$, $M_{7,10}$, and $M_{7,20}$).
b. Flood-peak characteristics are represented by discharges from annual flood-frequency curves at recurrence intervals of 2, 5, 10, 25, and 50 years. In this report, these peak-flow rates are denoted as Q_2, Q_5, etc.
c. Flood-volume characteristics represent the annual highest average flow for 7-day periods at recurrence intervals of 2, 10, and 50 years. These characteristics are noted symbolically in this report as $V_{7,2}$, $V_{7,10}$, and $V_{7,50}$.
d. Mean-flow characteristics are described by the mean of the annual means, Q_a, and by the means of record for each calendar month, q_n, where the subscript refers to the numerical order of the month beginning with January as 1.

e. Flow-variability characteristics are represented by the standard deviations of the annual amd monthly means. The symbols used are, respectively, $\underline{SD_a}$ and $\underline{SD_n}$, where the subscript $\underline{n}$ refers to the numerical order of months with January as 1.

Drainage-basin characteristics.--Drainage-basin characteristics defined for this study are:

a. Drainage area ($\underline{A}$), in square miles, as shown in the latest Geological Survey streamflow reports. Drainage areas for a few discontinued stations were computed from recent maps.

b. Main-channel slope ($\underline{S}$), 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. This index was described and used by Benson (1962, 1964).

c. Main-channel length ($\underline{L}$), in miles, from the gaging station to the basin divide, as measured with a template graduated in 0.1 mile units, or by means of a mechanical length-measuring device.

d. Area of lakes and ponds ($\underline{St}$), expressed as percentage of the drainage area plus 1 percent, determined from the latest topographic maps by the grid method.

e. Mean-basin elevation ($\underline{E}$), in thousands of feet above mean sea level, measured on the latest topographic maps by the grid method.

f. Forest cover ($\underline{F}$), expressed as percentage of the drainage basin area plus 1 percent covered by forests as shown on the topographic map determined by the grid method.

g. Mean annual precipitation ($\underline{P}$), in inches, determined by the grid method on an isohyetal map prepared by the U.S. Weather Bureau (1963).

h. The annual maximum 24-hour rainfall having a recurrence interval of 2 years ($\underline{I}_{24-2}$, 24-hour 2-year rainfall), expressed in inches. These values were determined from an isohyetal map prepared by the Environmental Science Services Administration (no date) for the U.S. Soil Conservation Service, using the grid method.

i. Average minimum January temperature in °F ($\underline{t_1}$), determined from an isothermal map prepared by the U.S. weather Bureau (1931-62). In order to prevent any negative or zero figures from entering the computer program, these values were all increased by 5°F.

j. The average water content of snow, in inches, on the ground on April 30 (Sn), as determined from an isohyetal map sketched on the basis of topography and snow-course data obtained from U.S. Soil Conservation Service reports (1969).
k. A geologic index (G) was determined from geologic maps of Utah. It is a measure of the effect of geology on the total water yield of a basin and is dependent on both geologic structure and relative porosity and permeability of the rocks in the basin.
l. A soils index (Si), representing the water-retention capacity of the soils in a drainage basin in inches, was furnished by the Utah State Office of the U.S. Soil Conservation Service (written commun., 1970).

Values of the above basin characteristics which proved to be of significance in any of the regression analyses are listed in table A-2 for each of the 98 gaging stations used.

Regression analysis.--The next step was to relate each of the streamflow characteristics to basin and climatic characteristics in equations developed by multiple regression techniques. The equation has the form $Y = aA^b S^c P^d$ - - -, where Y is a statistical streamflow characteristic; A, S, and P are topographic, geologic, or climatic characteristics; a is the regression constant; and b, c, and d are coefficients obtained by regression. This method was described by Thomas and Benson (1969). In this study, all of the drainage basin characteristics were used initially in the regression for each flow characteristic. Following computation of an initial regression equation the coefficients were tested for statistical significance and the least significant basin characteristic was dropped. Then the calculations were repeated, omitting the least significant basin parameter from each preceding calculation until only the one most significant parameter remained. After relations for a given streamflow characteristic had all been computed, the entire computation process was repeated using another streamflow characteristic with the same basin characteristics.

Regression equations were first computed using records for 98 gaging stations covering the entire State. Because of the diversity of hydrologic conditions, not adequately explained by the basin parameters used, the standard errors of these regressions were high; that for mean flow was 58 percent. Such results fall far short of meeting the goals outlined.

In anticipation of this event, and to conserve time, the State was divided into two regions, one representing the mountainous areas where streamflow is derived principally from snowmelt (region A in fig. 2), the other representing arid or desert areas where streamflow is principally the result of summer thunderstorms (region B in fig. 2). It should be remembered that records for major rivers were not used in the analysis.

The regression equations for region A, which utilized records for 88 gaging stations, produced consistently more accurate results than those for the whole State, but which were still far below the established goals. The standard error for mean flow was 42 percent as opposed to 58 percent for the State.

There were records for only 12 gaging stations available for region B, which comprises well over two-thirds of the State, and a successful computer run was not accomplished. However, the residuals (ratio of actual to computed flow characteristic) for these stations, as obtained from the regression analysis for all stations, showed a wide dispersion, and it is safe to assume that the results would have been even less usable.

The residuals at each station in region A were then plotted on a map for selected flow characteristics. Analysis of the distribution of residuals resulted in the selection of a still smaller area (region C in fig. 2), in which records for 44 gaging stations were available. This region is actually the central portion of region A and represents only a small portion of the State. A regression analysis for this region was run on the computer and much better results were obtained. Table 3 illustrates the output of the regression analyses for mean flow for this region. The equation which includes the most variables, all of which are statistically significant, is

$$\underline{Q_a} = 0.00217\ \underline{A}^{0.939}\ \underline{P}^{1.66}\ \underline{Sn}^{0.308}\ \underline{G}^{2.13}\ \underline{Si}^{0.188}$$

where the symbols are as previously described. The standard error of estimate for this equation is 0.0923 log units which corresponds to an average of 22 percent.

Table A-3 shows, for each of 37 streamflow characteristics, the regression constant, the regression coefficient (exponent) for each statistically significant variable, and the standard error.

Comparison of the standard errors in table 3 with the goals of table 2 indicates that none of the goals have been met even for this small region. The considerable disparity between results and goals indicates that the goals will be difficult to meet in the near future by the regression method. However, the results given in table A-3 are useful for some purposes, and they can be improved by (1) use of a more suitable regression model, (2) use of more representative basin parameters, and (3) use of a number of additional gaging-station records which are now available.

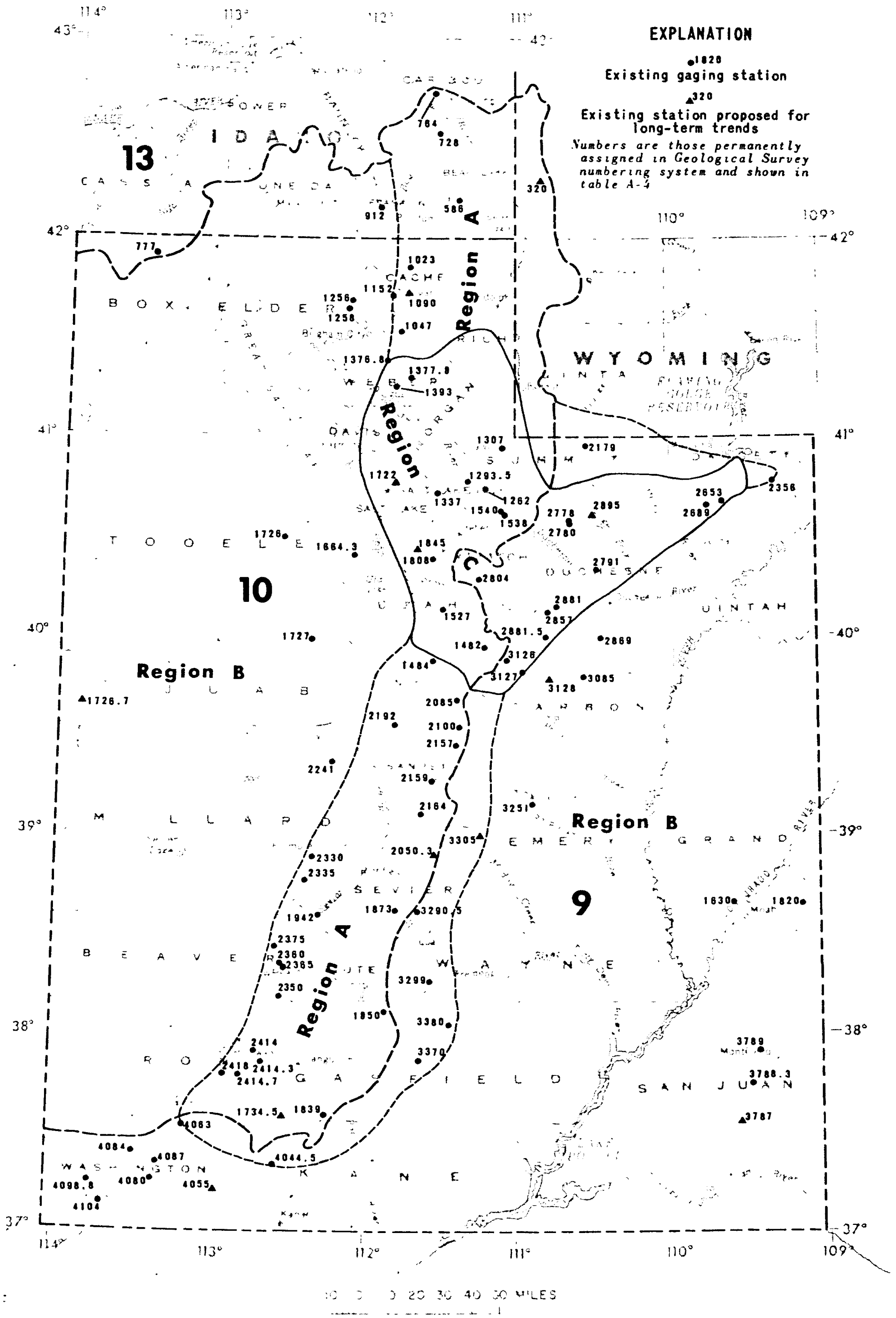

Figure 2.—Map of Utah showing gaging stations in the proposed program, except current-purpose stations not designated long-term trends, and regions for which regression analyses were performed.

Table 3.--Summary of regression analyses of mean annual flow (dependent variable Q_a)

Regression coefficients for independent variables												Regression constant	Standard error of estimate	
Area (A)	Slope (S)	Length (L)	Lakes (St)	Elevation (E)	Forest (F)	Precip. (P)	Precip. Intensity ($I_{24,2}$)	Min. Jan. temp. (t_1)	Snow (Sn)	Geology (G)	Soils (Si)		Percent	Percent change1/
0.976	-0.106	-0.224	-0.064	0.167	0.160	2.087	-0.701	-0.167	0.345	1.992	0.111	0.00109	20.8	-
.963	- .055	- .099	- .026	-	.042	0.254	- .073	- .053	.076	0.139	.043	.00145	20.5	-0.3
.970	- .127	- .204	- .053	-	.166	1.819	-	- .379	.330	1.810	.106	.00471	20.4	- .1
.950	- .139	- .182	-	-	.187	1.784	-	- .349	.312	1.712	.108	.00476	20.3	- .1
.881	- .146	-	-	-	.172	1.700	-	- .246	.354	1.766	.131	.00394	20.5	+ .2
.880	- .117	-	-	-	-	1.726	-	- .187	.409	1.842	.132	.00493	20.8	+ .3
.898	- .108	-	-	-	-	1.689	-	-	.356	2.078	.189	.00355	21.1	+ .3
.939	-	-	-	-	-	1.657	-	-	.308	2.126	.188	.00217	21.5	+ .4
.943	-	-	-	-	-	2.034	-	-	-	2.041	.213	.00124	22.5	+1.0
.980	-	-	-	-	-	2.244	-	-	-	2.015	-	.00081	25.0	+2.5
.984	-	-	-	-	-	2.788	-	-	-	-	-	.00006	31.0	+6.0
.932	-	-	-	-	-	-	-	-	-	-	-	.93761	58.0	+27.0

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

EVALUATION

There are several reasons why it has not been possible to regionalize streamflow characteristics satisfactorily in Utah. The primary reason appears to be that the regression model does not contain all the parameters required to define the spatial variation of streamflow characteristics for a region so diverse as this. A second reason is that some basin parameters are rather poorly defined because of insufficient mapping and the lack of adequate data on climatic variables.

Evaluation of the regulated-flow systems

The goals for regulated streams are even more difficult to attain 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 streamflow under different patterns of regulation, or under the condition of natural flow. Systems studies for all of the regulated-stream systems in Utah will require a major effort. Therefore, the present evaluation is limited to (1) identifying the regulated streams, and (2) evaluating the adequacy of available data.

The larger of the stream systems in Utah materially affected by regulation and (or) diversions are: Colorado, Dolores, Dirty Devil, Green, Jordan, Malad, Ogden, Price, San Rafael, San Juan and White Rivers, Bear River below Utah-Wyoming State line, Beaver River below Beaver, Duchesne River below Duchesne tunnel, Escalante River below Escalante, Provo River below Duchesne tunnel outlet, Santa Clara River below Pine Valley, Spanish Fork below Diamond Fork, Virgin River below Forks, and Weber River below Weber-Provo Diversion Canal. Systems studies for the Bear, Colorado, Green, and San Juan Rivers should not be limited to the parts in Utah. The Malad River should be included in the Bear River system, the Ogden River in the Weber River system, Provo River and Spanish Fork in the Jordan River system, and Santa Clara River in the Virgin River system.

Examination of streamflow records on the above streams with respect to length of record and location at points where the drainage area is approximately 500, 1,000, 2,000, 4,000, etc., square miles, indicates that most regulated principal streams in Utah have enough record now. A few streams, Fremont River, Muddy Creek, Dirty Devil River, Escalante River, Paria River, and Kanab Creek, are not gaged at the recommended intervals.

Records of elevation and daily or monthly contents are available for all major reservoirs in the State. Many records of diversions are also available.

Data to define long-term trends

The gaging station on Red Butte Creek at Fort Douglas, near Salt Lake City, a hydrologic bench mark, is the only station being operated in Utah at the present time for this purpose. More stations should be so designated.

Data on stream environment

Eleven basin characteristics in addition to drainage area are listed in table A-2 for 98 drainage basins and are available for nine more. Several of these characteristics have been determined for the crest-stage partial-record stations shown in figure 3. Flood plains have been outlined on two topographic quadrangle maps covering a portion of the Virgin River basin. Detailed channel and flood-plain surveys were made at four gaging stations at the times of their installation. Surveys of short reaches of channel have been made at hundreds of sites over the years in connection with indirect determinations of peak flows at crest-stage gages, regular gaging stations, and miscellaneous sites. All this information is available in the files of the District office.

Much more information needs to be collected in Utah on stream environment. The goals are largely unattained.

ALTERNATE METHODS OF TRANSFERRING STREAMFLOW DATA

Although the regression method may eventually produce estimates of acceptable accuracy at ungaged sites in Utah, in the meantime alternate methods of transferring streamflow information to an ungaged site should be considered. Most of those methods require some information at the ungaged site, and gaging station records to define specific relationships. These methods are briefly described in the following paragraphs.

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

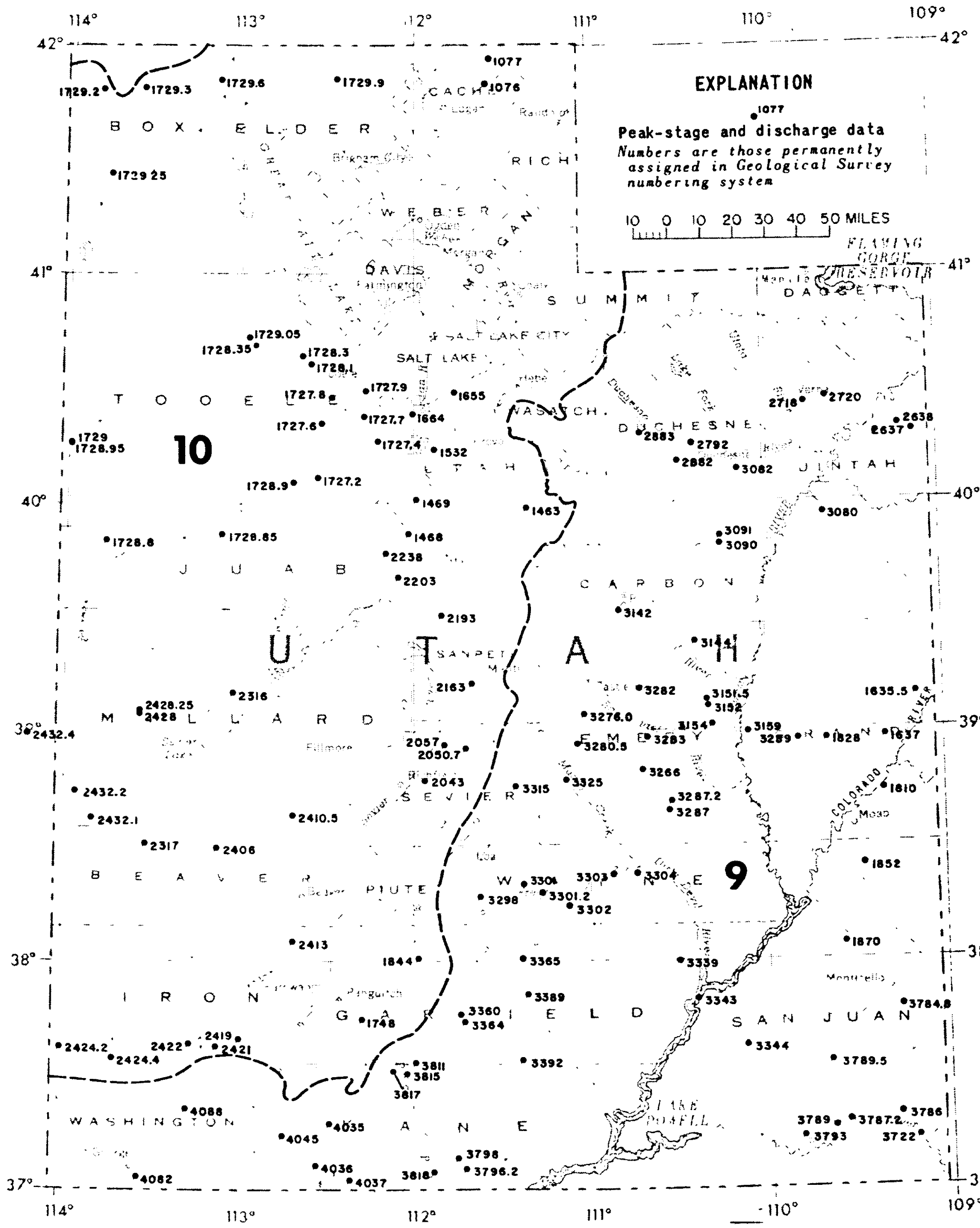

Figure 3.—Map of Utah showing locations of crest-stage partial-record stations.

Riggs (1969) showed that estimates of the mean annual flow at a site can be determined by measuring the discharge at the site near 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 seasonal and is due to snowmelt.

Moore (1968) developed relations between mean annual flow and altitude for certain parts of Nevada. Derived data based on channel geometry or monthly discharge measurements may be used in defining such relationships in parts of Utah.

Riggs (1965) describes the use of partial-record stations to define low-flow characteristics at numerous sites. A partial-record station is a site at which enough base-flow measurements are obtained to define an adequate relation with concurrent flows at a nearby gaging station. The frequency characteristics of the low flow at a partial-record station can be determined from the relation of concurrent flows and the record at the gaged site.

THE PROPOSED PROGRAM

The information developed in this study has indicated that with the exception of current-use data, the established goals have not been met. This information has been used in planning a streamflow information program which should eventually meet the needs for hydrologic data in Utah. The optimum program should maintain a balance between data collection and data analysis, because continuous interaction between the two is needed to gain a better understanding of the hydrologic system and thus to adapt to changing needs and improved technology.

Data collection

Data for current use

Operation of the 103 stations identified as meeting the needs for current-purpose data (table A-1), should be continued.

Needs should be assessed periodically, and this part of the data-collection network modified by adding or discontinuing stations as needs change. Furthermore, the need for a continuous record at each site should be examined; for some purposes a stage record, a seasonal record, or definition of peak flows may suffice.

PROPOSED PROGRAM

Data for planning and design

The flow characteristics of a great many Utah streams are well defined at gaging stations. However, it has not been possible to transfer those flow characteristics to ungaged sites with acceptable accuracy. These facts suggest the desirability of transferring some of the program effort from gaging-station operation to the development and application of methods for defining flow characteristics at other sites. The proposed data-collection program is described separately for natural-flow minor streams, regulated-flow minor streams, and principal streams.

Natural-flow minor streams.--None of the goals were met by regression analysis. This method may be more successful at a future time. Improved results can come only from use of better basin parameters in an improved regression model. Continued operation of the entire present network of gaging stations on natural-flow minor streams cannot be justified, although a certain number should be operated for use in methods other than regression, and those with only a few years of record should be continued until the flow characteristics at those sites have been defined to the desired accuracy.

In addition to continuing some of the gaging stations, the data-collection program calls for measurements of flow or of the channel at many sites for use in the techniques described below.

The mean flow of a perennial stream at a site may be estimated from (1) monthly discharge measurements for a water year and (2) the discharge record at a nearby gaging station. Mean flow of either a perennial or an ephemeral stream may be estimated from measurements of the channel cross section.

Characteristics of annual minimum flows of perennial streams may be transferred from a gaging-station site to a site at which a few base-flow measurements are available.

Although it is not feasible to define flow characteristics even by these simple methods at any site or any stream, a judicious selection of sites will permit interpolation to many more.

One of the major deficiencies in hydrologic knowledge is of the flood-peak frequency characteristics of small streams, particularly of ephemeral streams. Annual flood peaks are being defined at the 117 crest-stage partial-record sites shown in figure 3. About 10 years of record are available now. This network should be modified to include additional sites on smaller drainage areas, but in general a few more annual floods should be obtained at these sites. Annual floods should also be collected at most discontinued regular gaging stations.

Definition of the 50-year flood at a site may require much more than 10 years of record. One way of speeding up the definition is by (1) measuring both storm precipitation and the corresponding storm runoff at a site for a few years, (2) calibrating the site by developing a hydrologic model which relates flood peak to precipitation, (3) using a long recording precipitation record with the model to synthesize a long flood-peak record, and (4) analyzing the flood-frequency characteristics from the synthesized values. This method should be utilized at a few sites in Utah where long recording precipitation records were collected.

No method is presently available for transferring flood-peak characteristics to sites at which a little information is available. However, the possibility of developing a usable relation between the 10-year flood and channel size is being explored. Collection of data for investigating this and other methods, including study of the regression method is recommended.

A network of gaging stations, well distributed geographically, is needed to provide flow characteristics which (1) can be transferred to sites at which discharge measurements are made, (2) may be used to define relations between channel cross-section measurements and mean flow or flood flow, and (3) are needed to provide regional definition by regression analysis. The present network is larger than necessary for these purposes. In addition, more than 20 years of record is available at many sites; the collection of additional record at these sites would result in little improvement in the definition of flow characteristics at these sites.

Table 4 lists those stations for planning and design which now have 20 or more years of record and indicates those which should be discontinued now. Current and proposed areal investigations make it desirable to continue the operation of certain of the stations for a few more years, and a minimum base of well-distributed stations is necessary. Annual peak flows should be collected at most of the discontinued stations.

No new regular gaging stations on natural-flow minor streams are proposed at this time except for the relocation of station 9-3075 to a nearby stream. After a year or two of applying the alternate methods for defining flow characteristics at a site, it should be apparent whether or not additional continuous-record gaging stations are needed.

Regulated-flow minor streams.--Thirty-two gaging stations are being operated on minor streams at points where the flow is

Table 4.--Stations for planning and design which have 20 or more years of record

	Gaging station	No. years record
9-1840	Mill Creek near Moab, Utah1/	21
9-1855	Hatch Wash near La Sal, Utah	21
9-1865	Indian Creek above Cottonwood Creek, near Monticello, Utah	21
9-2265	Middle Fork Beaver Creek near Lonetree, Wyo.1/	22
9-2620	Big Brush Creek near Vernal, Utah	31
9-2665	Ashley Creek near Vernal, Utah	57
9-2680	Dry Fork above sinks, near Dry Fork, Utah	31
9-2685	North Fork of Dry Fork near Dry Fork, Utah	24
9-2755	West Fork Duchesne River near Hanna, Utah1/	26
9-2760	Wolf Creek above Rhoades Canyon, near Hanna, Utah1/	25
9-2790	Rock Creek near Mountain Home, Utah	33
9-2850	Strawberry River near Soldier Springs, Utah	21
9-2875	Water Hollow near Fruitland, Utah1/	24
9-2925	Yellowstone River near Altonah, Utah	26
9-2980	Farm Creek near Whiterocks, Utah	21
9-3105	Fish Creek above reservoir, near Scofield, Utah1/	32
9-3155	Saleratus Wash at Green River, Utah1/	22
9-3180	Huntington Creek near Huntington, Utah1/	56
9-3245	Cottonwood Creek near Orangeville, Utah1/	53
9-3265	Ferron Creek (upper station) near Ferron, Utah1/	35
9-3340	North Wash near Hanksville, Utah1/	20
9-3345	White Canyon near Hanksville, Utah1/	20
10-0170	Yellow Creek near Evanston, Wyo.1/	22
10-0230	Big Creek near Randolph, Utah1/	24
10-0845	Cottonwood Creek near Cleveland, Idaho	31
10-0930	Cub River near Preston, Idaho	27
10-1350	Hardscrabble Creek near Porterville, Utah1/	29
10-1420	Farmington Creek above diversions, near Farmington, Utah1/	21
10-1485	Spanish Fork at Thistle, Utah	55
10-1525	Hobble Creek near Springville, Utah	37
10-1745	Sevier River at Hatch, Utah	48
10-2325	Chalk Creek near Fillmore, Utah	26
10-2420	Coal Creek near Cedar City, Utah1/	34
13-0790	Clear Creek near Naf, Idaho1/	26

1/ Station which should be discontinued now.

affected by regulation and (or) diversion. These are all current-purpose stations and they should be continued as long as there is a need for the records.

Regulated-flow principal streams.--All the principal streams in Utah are regulated. This study of principal streams was limited to identifying them and evaluating the adequacy of gaging according to the criteria that there should be 25 years of record at sites where the drainage areas are about 500, 1,000, 2,000, 4,000, etc., square miles.

Using these criteria, a few additional gaging stations are needed. However, the definition of a principal stream in terms of drainage area is not very realistic in parts of Utah; for instance, Paria River has produced a mean flow of only 30 cfs (cubic feet per second) from 1,400 square miles. Consequently, the establishment of additional stations on streams of this type in order to conform to the recommended program does not seem justified and is not recommended.

On the other hand, gaging stations which have been operated for 25 years or more on principal streams and which are not needed for other purposes should be discontinued. All such stations are presently classified as current purpose, but a number of them may be reclassified and considered as eligible for discontinuance in the near future.

The program should include collection of records for diversions, reservoir contents, operation schedules, and other pertinent hydrologic data which will be needed in developing models of the stream systems. Much of this information is already available.

Data to define long-term trends in streamflow

The hydrologic bench mark station on Red Butte Creek at Fort Douglas, near Salt Lake City should be continued in operation indefinitely. Eleven additional stations in the present network are proposed as long-term stations to be operated indefinitely. The additional stations were selected to provide a long-term sample reflecting areal coverage of the State, a range of drainage area size, and a variety of climatic and physiographic characteristics. The 11 stations identified in this category are listed below with their drainage areas and periods of record.

	Station	Water Resources Council Sub-region	Drainage area (sq. mi.)	Period of record
9-2895	Lake Fork River above Moon Lake, near Mountain Home, Utah	Lower Green R.	78	1942-55, 1963-70
9-3128	Willow Creek near Castle Gate, Utah	Lower Green R.	62	1962-70
9-3305	Muddy Creek near Emery, Utah	Middle Colorado	105	1910-13, 1949-70
9-3787	Cottonwood Wash near Blanding, Utah	Middle Colorado	205	1964-70
9-4055	North Fork Virgin River near Spring-dale, Utah	Lower Colorado	350	1925-70
10-0320	Smiths Fork near Border, Wyo.	Bear River	165	1942-70
10-1090	Logan River above State dam, near Logan, Utah	Bear River	218	1913-70
10-1645	American Fork above upper powerplant, near American Fork, Utah	Great Salt Lake	51.1	1927-70
10-1728.7	Trout Creek near Callao, Utah	Great Salt Lake	8.8	1958-70
10-1734.5	Mammoth Creek above West Hatch Ditch, near Hatch, Utah	Sevier River	105	1964-70
10-2050.3	Salina Creek near Emery, Utah	Sevier River	53	1963-70

Data on stream environment

Data on stream environment should be collected as demands for this type of data arise and as time and funds become available. Some environmental data are being collected at the present time in connection with hydrologic investigations and channel surveys for indirect measurements.

Gaging stations for proposed program

Recommendations for gaging station operation for each of the data types are combined in table A-4 where each station is classified as to purpose. Locations are shown in figures 2 and 4.

Data analysis

The streamflow-data network operated through the years supplies a base for analyses and reports. Some aspects of data analyses are of a continuing nature for the purpose of guiding the data-collection system and reorienting it if needed.

The proposed program of data analyses for Utah streams may be classed in two phases--those based on data collected to date, and those for which additional data will be required.

Data analyses and appropriate reports which should be scheduled for early completion are:

1. An updated regional flood-frequency analysis.
2. A study of trends in streamflow as indicated by the longer records.
3. A tabulation of streamflow statistics at gaging stations.
4. Low-flow characteristics at gaging stations and changes along the channels where defined.
5. An investigation of possible methods of transferring flow characteristics along regulated minor streams.

The following investigations and analyses will require some additional data:

1. Development of a systems analysis for a regulated stream system.
2. Delineation of areas subject to inundation by floodwaters for areas not covered by programs of other Federal agencies.
3. Definition of flood profiles on important rivers.
4. Time of travel of solutes and dispersion characteristics in selected stream reaches.

5. Development and testing of relations between channel measurements and mean flows and flood-peak characteristics.
6. Development of improved models and parameters for streamflow regionalization by regression.
7. Determination of gains and losses of flow in selected reaches.

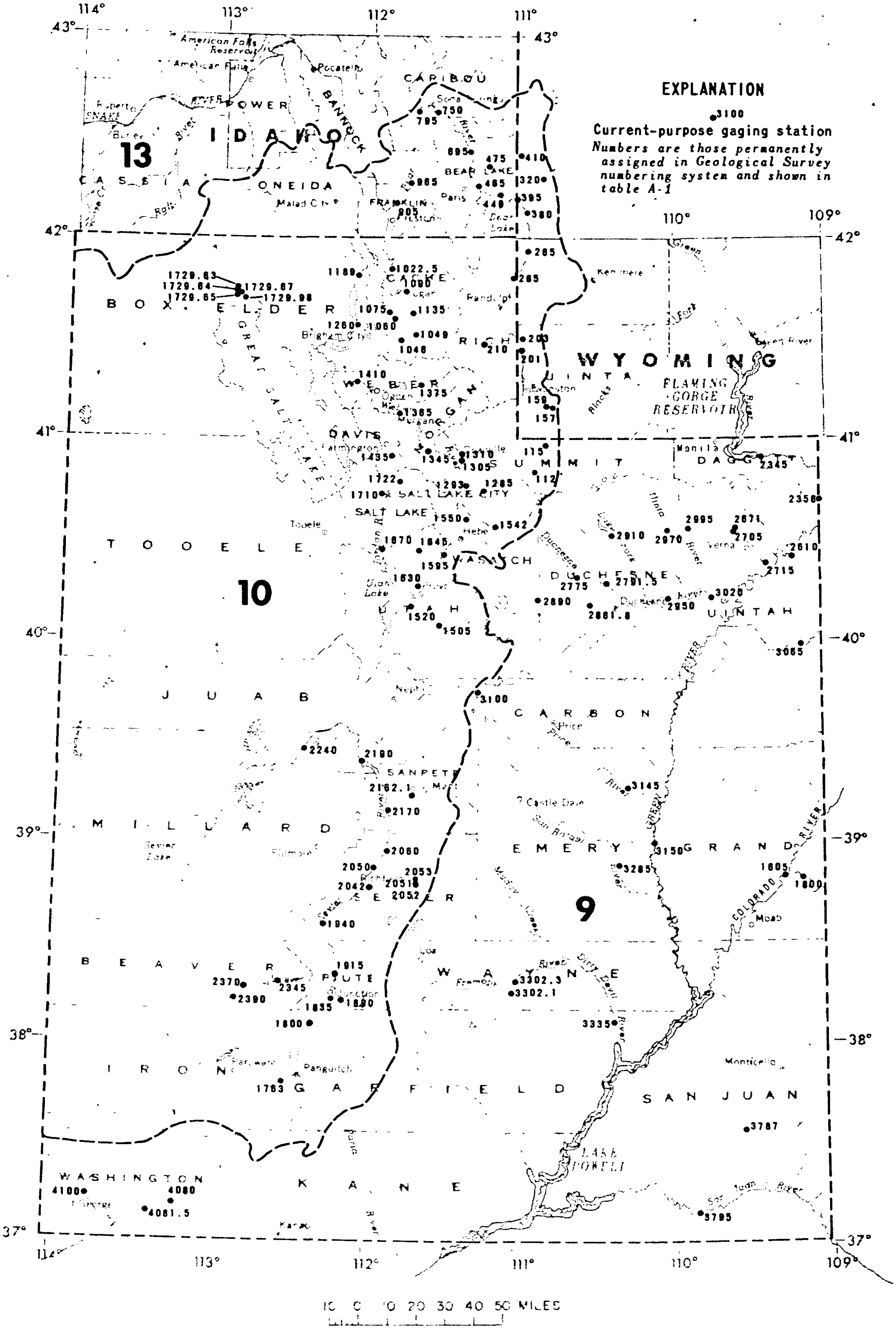

Figure 4.—Map of Utah showing locations of current-purpose gaging stations.

REFERENCES

Benson, M.A., 1962, Factors influencing the occurrence of floods in a humid region of diverse terrain: U.S. Geol. Survey Water-Supply Paper 1580-B, 64 p.

_______1964, Factors affecting the occurrence of floods in the Southwest: U.S. Geol. Survey Water-Supply Paper 1580-D, 70 p.

Carter, R. W., and Benson, M. A., 1970, Concepts for the design of streamflow-data programs: U.S. Geol. Survey open-file rept.

Environmental Science Services Administration, no date, Isopluvials of 2-year 24-hour precipitation, Utah and Wyoming: Maps of Utah and Wyoming, scale 1:100,000,000.

Moore, D. O., 1968, Estimating mean runoff in ungaged semiarid areas: Nevada Dept. Conserv. and Nat. Resources Water Resources Bull. 36.

Reid, J. K., Carroon, L. E., and Pyper, G. E., 1969, Extensions of streamflow records in Utah: Utah Dept. Nat. Resources Tech. Pub. 20, 110 p.

Riggs, H. C., 1965, Estimating probability distributions of drought flows: Water and Sewage Works, v. 112, no. 5, p. 153-157.

_______1969, Mean streamflow from discharge measurements: Internat. Assoc. Sci. Hydrology Bull. XIV, no. 4, p. 95-110.

Thomas, D. M., and Benson, M. A., 1969, Generalization of streamflow characteristics from drainage-basin characteristics: U.S. Geol. Survey open-file rept., 45 p.

U.S. Soil Conservation Service, 1969, Water-supply outlook for Utah as of April 1, 1969.

U.S. Weather Bureau, 1931-62, Climates of the States: U.S. Weather Bur. Climatography of the United States, no. 60.

_______1961, Rainfall frequency atlas of the United States: U.S. Weather Bur. Tech. Paper 40, 115 p.

_______1963, Normal annual precipitation (1931-60) for the State of Utah: Map of Utah, scale 1:500,000.

Utah Water and Power Board and Utah State University, 1963, Developing a state water plan--Utah's water resources--problems and needs--a challenge: Utah Water and Power Board-Utah State Univ.

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APPENDIX

Table A-1. - Current-purpose gaging stations

Station		Purpose						
		Assessment	Operation	Forecasting	Disposal	Water quality	Compact or legal	Research or special studies
9-1800	Dolores River near Cisco, Utah					X	X	
9-1805	Colorado River near Cisco, Utah	X				X	X	
9-2345	Green River near Greendale, Utah		X			X	X	
9-2358	Pot Creek near Vernal, Utah		X				X	
9-2610	Green River near Jensen, Utah					X	X	
9-2671	Ashley Creek above Dry Fork, near Vernal, Utah							X
9-2705	Dry Fork at mouth, near Dry Fork, Utah		X					X
9-2715	Ashley Creek near Jensen, Utah							X
9-2775	Duchesne River near Tabiona, Utah		X					
9-2791.5	Duchesne River above Knight diversion, near Duchesne, Utah		X					
9-2880	Currant Creek near Fruitland, Utah		X					
9-2881.8	Strawberry River near Duchesne, Utah		X					
9-2910	Lake Fork River below Moon Lake, near Mountain Home, Utah		X					
9-2950	Duchesne River at Myton, Utah		X					
9-2970	Uinta River near Neola, Utah		X					
9-2995	Whiterocks River near Whiterocks, Utah	X						
9-3020	Duchesne River near Randlett, Utah		X			X		
9-3065	White River near Watson, Utah					X	X	
9-3100	Gooseberry Creek near Scofield, Utah		X					
9-3145	Price River at Woodside, Utah					X		
9-3150	Green River at Green River, Utah	X				X	X	X
9-3285	San Rafael River near Green River, Utah					X	X	
9-3302.1	Pleasant Creek near Caineville, Utah					X		X
9-3302.3	Fremont River near Caineville, Utah					X		X
9-3335	Dirty Devil River above Poison Springs Wash, near Hanksville, Utah					X	X	
9-3787	Cottonwood Wash near Blanding, Utah					X		
9-3795	San Juan River near Bluff, Utah	X				X	X	
9-4060	Virgin River at Virgin, Utah					X		
9-4081.5	Virgin River near Hurricane, Utah					X		X
9-4100	Santa Clara River above Winsor Dam, near Santa Clara, Utah		X					
10-0112	West Fork Bear River at Whitney Dam, near Oakley, Utah		X				X	
10-0115	Bear River near Utah-Wyoming State line			X		X	X	
10-0157	Sulphur Creek above reservoir, near Evanston, Wyo.		X				X	
10-0159	Sulphur Creek below reservoir, near Evanston, Wyo.		X				X	
10-0201	Bear River above reservoir, near Woodruff, Utah		X				X	
10-0203	Bear River below reservoir, near Woodruff, Utah		X			X	X	
10-0210	Woodruff Creek near Woodruff, Utah		X				X	
10-0265	Bear River near Randolph, Utah		X			X	X	

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

Station		Purpose: Assessment	Operation	Forecasting	Disposal	Water quality	Compact or legal	Research or special studies
10-0285	Bear River below Pixley Dam, near Cokeville, Wyo.		X				X	
10-0320	Smiths Fork near Border, Wyo.		X	X			X	
10-0380	Bear River below Smiths Fork, near Cokeville, Wyo.		X					
10-0395	Bear River at Border, Wyo.		X			X	X	
10-0410	Thomas Fork near Wyoming-Idaho State line		X			X	X	
10-0440	Bear River at Harer, Idaho		X	X			X	
10-0465	Bear River below Stewart Dam, near Montpelier, Idaho		X				X	
10-0475	Montpelier Creek at irrigators weir, near Montpelier, Idaho		X				X	
10-0685	Bear River at Pescadero, Idaho						X	X
10-0750	Bear River at Soda Springs, Idaho		X				X	
10-0795	Bear River at Alexander, Idaho		X				X	
10-0865	Bear River below Utah Power and Light Co.'s tailrace, at Oneida, Idaho		X				X	
10-0905	Bear River near Preston, Idaho						X	
10-1022.5	Bear River near Smithfield, Utah	X					X	
10-1046	South Fork Little Bear River near Avon, Utah		X					
10-1049	East Fork Little Bear River above reservoir, near Avon, Utah		X					
10-1060	Little Bear River near Paradise, Utah		X					
10-1075	Little Bear River near Hyrum, Utah		X					
10-1090	Logan River above State dam, near Logan, Utah		X				X	
10-1135	Blacksmith Fork above Utah Power & Light Co.'s dam, near Hyrum, Utah		X	X				
10-1180	Bear River near Collinston, Utah		X				X	
10-1260	Bear River near Corinne, Utah		X				X	
10-1285	Weber River near Oakley, Utah	X	X	X				
10-1293	Weber River near Peoa, Utah		X					
10-1305	Weber River near Coalville, Utah		X					
10-1310	Chalk Creek at Coalville, Utah		X					
10-1345	East Canyon Creek near Morgan, Utah		X					
10-1365	Weber River at Gateway, Utah		X			X		
10-1375	South Fork Ogden River near Huntsville, Utah		X					
10-1410	Weber River near Plain City, Utah		X					
10-1435	Centerville Creek above diversions, near Centerville, Utah		X					
10-1505	Spanish Fork at Castilla, Utah		X					
10-1520	Spanish Fork near Lake Shore, Utah		X					
10-1542	Provo River near Woodland, Utah			X				
10-1550	Provo River near Hailstone, Utah		X					
10-1595	Provo River below Deer Creek Dam, Utah		X					
10-1630	Provo River at Provo, Utah		X					

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

Station		Purpose: Assessment	Operation	Forecasting	Disposal	Water quality	Compact or legal	Research or special studies
10-1645	American Fork above upper powerplant, near American Fork, Utah		X				X	
10-1670	Jordan River at narrows, near Lehi, Utah		X					
10-1710	Jordan River at Salt Lake City, Utah		X					
10-1722	Red Butte Creek at Fort Douglas, near Salt Lake City, Utah					X		X
10-1729.63	West Locomotive Spring at Locomotive Springs, near Snowville, Utah							X
10-1729.64	Barker Spring at Locomotive Springs, near Snowville, Utah							X
10-1729.65	Bar M Spring at Locomotive Springs, near Snowville, Utah							X
10-1729.67	Off Spring at Locomotive Springs, near Snowville, Utah							X
10-1729.68	Sparks Spring at Locomotive Springs, near Snowville, Utah							X
10-1763	Panquitch Creek near Panquitch, Utah		X					
10-1800	Sevier River near Circleville, Utah		X					
10-1835	Sevier River near Kingston, Utah		X					
10-1890	East Fork Sevier River near Kingston, Utah		X					
10-1915	Sevier River below Piute Dam, near Marysvale, Utah		X			X		
10-1940	Sevier River above Clear Creek, near Sevier, Utah		X					
10-2042	Mill Creek near Glenwood, Utah					X		X
10-2050	Sevier River near Sigurd, Utah		X					
10-2051	Sheep Creek near Salina, Utah1/							X
10-2052	West Fork Sheep Creek near Salina, Utah1/							X
10-2053	Sheep Creek at mouth, near Salina, Utah1/							X
10-2060	Salina Creek at Salina, Utah		X					
10-2162.1	San Pitch River near Sterling, Utah		X					
10-2170	Sevier River below San Pitch River, near Gunnison, Utah		X					
10-2190	Sevier River near Juab, Utah		X					
10-2240	Sevier River near Lynndyl, Utah		X			X		
10-2345	Baaver River near Beaver, Utah	X	X					
10-2370	Beaver River at Adamsville, Utah		X					
10-2390	Beaver River at Rocky Fork Dam, near Minersville, Utah		X					

1/ Records furnished by U.S. Forest Service

Table A-2.--Basin characteristics at gaging stations

Station number	Station name	Drainage area (A) (sq mi)	Main channel slope (S) (ft/mi)	Stream length (L) (mi)	Lakes and ponds (St) (percent of A+1%)	Mean basin elevation (E) (ft/MSL)	Forested area (F) (percent of A+1%)	Mean annual precipitation (P) (in.)	Precipitation intensity (I) (24-hr/2-hr, in.)	Min. Jan. temperature (t_j) (°F)	Snowfall index (Sn) (total in. water on Apr. 30)	Geology index (G) (coeff)	Soils index (Si) (Retention, in.)
		Basin characteristics											
9-1820	Castle Creek above diversions, near Moab, Utah	7.58	831	5.2	2	9,480	22	24.7	1.5	9	11.4	0.60	11
9-1830	Courthouse Wash near Moab, Utah	162	29	30.4	1	4,810	7	8.0	.9	15	1.0	.55	1.5
9-1840	Mill Creek near Moab, Utah	74.9	270	20.8	1	7,170	57	15.4	1.18	10	4.4	.60	2.0
9-1855	Hatch Wash near La Sal, Utah	378	39.1	44.7	1	6,550	39	13.1	1.20	12	1.0	.65	2.0
9-1865.01	Indian Creek above Cottonwood Creek, near Monticello, Utah	31.2	250	13.5	1	7,130	57	24.1	1.65	8	7.3	.60	5.0
9-2185	Blacks Fork near Millburne, Wyo.	156	76.0	24.7	1.8	10,270	62	30.4	1.52	6	13.6	.78	-
9-2200	East Fork of Smith Fork near Robertson, Wyo.	53.0	109	20.0	3.2	10,250	71	28.4	1.46	6	12.4	.78	-
9-2205.	West Fork of Smith Fork near Robertson, Wyo.	37.2	156	11.2	1.8	9,790	90	25.2	1.39	6	10.0	.78	-
9-2260	Henrys Fork near Lonetree, Wyo.	56	160	17.8	3.0	10,270	62	29.1	1.45	6	9.3	.76	-
9-2265	Middle Fork Beaver Creek near Lonetree, Wyo.	28	224	9.9	3.1	10,480	69	30.5	1.53	5	7.4	.80	6.0
9-2270	East Fork Beaver Creek near Lonetree, Wyo.	8.2	241	3.2	5.4	10,680	64	22.2	1.37	5	3.0	.82	-
9-2285	Burnt Fork near Burntfork, Wyo.	52.8	209	11.1	2.2	10,300	70	29.3	1.57	6	7.5	.80	-
9-2356	Pot Creek above diversions, near Vernal, Utah	25	53.9	8.8	1	8,030	58	19.6	1.20	6	3.1	.80	9.0
9-2640	Ashley Creek below Trout Creek, near Vernal, Utah	27	132	9.9	2	9,930	86	28.0	1.57	4	10.1	.75	5.4
9-2645	South Fork Ashley Creek near Vernal, Utah	20	257	11.0	6	10,480	61	30.3	1.58	4	12.2	.75	5.4
9-2680.01	Dry Fork above sinks, near Dry Fork, Utah	48	207	40.2	6	10,240	64	29.7	1.60	3	15.2	.70	5.0
9-2685	North Fork of Dry Fork near Dry Fork, Utah	12	972	14.2	2	9,100	81	29.6	1.57	3	13.4	.70	5.0
9-2690	East Fork of Dry Fork near Dry Fork, Utah	12	662	20.6	1	9,320	91	28.6	1.53	3	11.5	.70	5.0
9-2730	Duchesne River at Provo River Trail, near Hanna, Utah	39	304	10.4	4	10,200	80	35.9	1.74	2	23.4	.70	12
9-2735	Hades Creek near Hanna, Utah	7.5	458	5.5	1	9,730	75	30.3	1.62	3	15.0	.80	12
9-2750	West Fork Duchesne River below Dry Hollow, near Hanna, Utah	47	132	12.5	1	9,100	51	28.5	1.59	4	10.0	.72	12
9-2755	West Fork Duchesne River near Hanna, Utah	61	106	18.4	1	8,840	50	26.6	1.53	4	9.8	.72	7.0
9-2760	Wolf Creek above Rhoades Canyon, near Hanna, Utah	9	258	6.9	1	9,040	68	26.6	1.58	3	10.0	.72	12
9-2780	South Fork Rock Creek near Hanna, Utah	14	220	9.1	3	10,000	61	30.8	1.61	3	8.4	.80	12
9-2785	Rock Creek near Hanna, Utah	120	172	17.9	6	10,200	70	32.9	1.71	3	17.2	.82	12
9-2790	Rock Creek near Mountain Home, Utah	149	137	24.9	5	10,000	65	31.6	1.66	4	15.8	.75	11
9-2875	Water Hollow near Fruitland, Utah	15	258	10.0	1	8,380	80	22.1	1.38		7.5	.70	5.0
9-2895	Lake Fork River above Moon Lake, near Mountain Home, Utah	78	232	14.2	5	10,800	52	35.4	1.75	2	19.0	.80	12
9-2925	Yellowstone Creek near Altonah, Utah	131	222	25.0	3	10,440	61	32.6	1.62	3	16.3	.75	12
9-2960	Uinta River above Clover Creek, near Neola, Utah	132	207	20.2	4	10,960	53	37.1	1.69	3	18.4	.75	13
9-2980	Farm Creek near Whiterocks, Utah	14.9	406	9.0	1	9,720	86	23.1	1.35	4	11.6	.60	11
9-2985	Whiterocks River above Paradise Creek, near Whiterocks, Utah	90	219	17.3	6	10,700	52	34.1	1.67	3	18.5	.70	11
9-2995	Whiterocks River near Whiterocks, Utah	113	205	23.9	3	10,370	81	32.1	1.60	4	16.8	.70	11
9-3075	Willow Creek above diversions, near Ouray, Utah	310	56.4	38.5	1	7,650	82	16.8	1.18	6	3.5	.70	2.0
9-3085	Minnie Maud Creek near Myton, Utah	30	139	9.6	1	8,460	91	18.7	1.33	6	9.8	.70	3.0
9-3105	Fish Creek above reservoir, near Scofield, Utah	65	186	10.6	4	8,710	58	29.4	1.72	5	14.5	.78	11
9-3125	White River near Soldier Summit, Utah	53	73	13.7	1	8,360	87	26.3	1.52	5	8.5	.78	5.0
9-3155	Saleratus Wash at Green River, Utah	180	26	6.4	1	5,050	40	7.5	.97	8	1.0	.45	1.0
9-3305	Muddy Creek near Emery, Utah	105	388	18.4	3	8,850	58	24.5	1.64	8	10.2	.70	4.0
9-3340	North Wash near Hite, Utah	136	131	33.0	1	5,400	14	10.0	1.15	16	1.4	.65	2.0
9-3345	White Canyon near Hite, Utah	276	49	50.5	1	6,090	51	13.0	1.41	14	2.6	.65	1.0
9-3370	Pine Creek near Escalante, Utah	78	306	18.0	7	8,890	79	22.7	1.93	8	5.0	.60	6.0
9-3380	East Fork Boulder Creek near Boulder, Utah	21.4	340	9.5	8	10,500	51	28.8	2.13	7	6.8	.55	12
9-4055	North Fork Virgin River near Springdale, Utah	350	181	27.6	1	7,350	86	25.2	1.96	20	5.7	.60	2.0
9-4095	Moody Wash near Veyo, Utah	33	142	12.6	2	6,070	70	13.7	1.58	18	1.0	.55	3.0
10-0115	Bear River near Utah-Wyoming State line	176	98	19.6	6	9,770	62	31.7	1.61	3	13.5	.80	12
10-0120	Mill Creek at Utah-Wyoming State line	59	170	13.7	4	9,320	73	24.0	1.48	4	9.5	.80	12
10-0157	Sulphur Creek above reservoir, near Evanston, Wyo.	64	183	13.5	3	8,050	34	17.5	1.26	4	3.2	.70	4.7
10-0170	Yellow Creek near Evanston, Wyo.	80	67	18.4	3	7,600	15	19.0	1.20	5	5.4	.60	3.7
10-0210	Woodruff Creek near Woodruff, Utah	65	156	12.8	1	7,900	36	25.8	1.40	4	9.4	.60	4.5

Table A-2.--Basin characteristics at gaging stations--Continued

Station number	Station name	Drainage area (A) (sq mi)	Main channel slope (S) (ft/mi)	Stream length (L) (mi)	Lakes and ponds (St) (percent of A+1%)	Mean basin elevation (E) (ft/MSL)	Forested area (F) (percent of A+1%)	Mean annual precipitation (P) (in.)	Precipitation intensity (I) (24-hr/2-hr, in.)	Min. Jan. temperature (t1) (°F)	Snowfall index (Sn) (total in. water on Apr. 30)	Geology index (G) (coeff)	Soils index (Si) (Retention, in.)
		Basin characteristics											
10-0230	Big Creek near Randolph, Utah	52.2	139	12.0	3	7,370	16	19.9	1.24	4	8.7	0.65	3.5
10-0320	Smiths Fork near Border, Wyo.	165	79	25.2	2	8,270	64	32.1	1.46	-4	17.0	.75	5.2
10-0400	Thomas Fork near Geneva, Idaho	45.3	69	9.9	3	7,170	28	19.0	1.19	-2	10.0	.70	5.7
10-9405	Salt Creek near Geneva, Idaho	37.6	148	11.4	1	7,390	46	32.9	1.22	-2	10.5	.70	6.7
10-0410	Thomas Fork near Wyoming-Idaho State line	113	127	11.8	2	7,290	40	29.0	1.20	0	10.0	.65	5.9
10-0475	Montpelier Creek at irrigators weir, near Montpelier, Idaho	50.9	82	12.8	1	7,370	44	26.7	1.2	1	10.0	.65	5.4
10-0586	Bloomington Creek at Bloomington, Idaho	24.4	261	8.3	1	7,860	18	31.0	1.2	2	19.0	.70	5.5
10-0690	Georgetown Creek near Georgetown, Idaho	22.2	206	8.9	1	7,830	53	30.3	1.3	2	12.5	.70	6.3
10-0845	Cottonwood Creek near Cleveland, Idaho	61.7	70	17.8	1	6,650	56	22.8	1.3	3	7.5	.75	4.8
10-0930	Cub River near Preston, Idaho	19.4	205	6.4	1	6,890	31	24.1	1.4	4	15.0	.85	5.4
10-1050	East Fork Little Bear River near Avon, Utah	49.7	148	16.6	1	7,370	42	27.4	1.60	6	8.5	.75	11
10-1090.01	Logan River above State dam, near Logan, Utah	218	117	34.7	2	7,460	80	33.8	1.71	6	17.2	.70	11
10-1135	Blacksmith Fork above Utah Power & Light Co. dam, near Hyrum, Utah	260	171	18.0	2	7,150	59	25.1	1.51	5	11.5	.70	11
10-1190	Little Malad River above Elkhorn Reservoir, near Malad City, Idaho	120	60	16.8	1	6,080	22	23.9	1.4	3	4.5	.75	4.4
10-1285	Weber River near Oakley, Utah	163	111	22.4	2	9,090	80	32.1	1.65	4	17.5	.78	12
10-1293	Weber River near Peoa, Utah	285	84	31.2	3	8,390	72	27.3	1.55	5	15.2	.78	10
10-1325	Lost Creek near Croydon, Utah	120	116	15.0	1	7,320	41	19.2	1.26	5	14.0	.60	9.0
10-1350	Hardscrabble Creek near Porterville, Utah	28.1	253	8.4	1	7,220	88	33.0	1.77	12	20.0	.65	10
10-1375	South Fork Ogden River near Huntsville, Utah	148	211	14.2	1	7,960	66	27.0	1.54	5	17.4	.70	8.0
10-1393	Wheeler Creek near Huntsville, Utah	11.1	543	5.8	2	6,620	93	27.2	1.89	10	20.0	.70	10
10-1415	Holmes Creek near Kaysville, Utah	2.49	110	3.2	1	7,580	97	33.8	2.00	14	17.6	.75	3.0
10-1420	Farmington Creek above diversions, near Farmington, Utah	10.0	411	6.9	1	7,470	95	37.6	1.98	13	19.0	.73	3.0
10-1425	Ricks Creek above diversions, near Centerville, Utah	2.35	1,086	3.5	1	7,360	99	31.2	2.10	14	13.1	.75	3.0
10-1430	Parrish Creek above diversions, near Centerville, Utah	2.08	1,017	4.0	1	7,090	96	31.0	2.10	15	13.4	.75	3.0
10-1435	Centerville Creek above diversions, near Centerville, Utah	3.15	680	4.2	1	6,940	94	30.1	2.10	15	13.0	.75	3.0
10-1440	Stone Creek above diversions, near Bountiful, Utah	4.48	740	4.0	1	7,050	100	31.0	2.10	15	12.8	.74	3.0
10-1450	Mill Creek at Mueller Park, near Bountiful, Utah	8.79	694	5.7	1	7,370	91	32.7	2.15	14	16.4	.65	3.0
10-1455	Salt Creek near Nephi, Utah	91.7	202	13.5	1	7,450	91	19.2	1.54	12	8.1	.65	2.0
10-1460	Salt Creek at Nephi, Utah	95.6	176	15.2	1	7,490	90	19.2	1.54	12	8.0	.65	2.0
10-1470	Summit Creek near Santaquin, Utah	14.6	405	6.6	1	8,400	100	26.4	1.73	12	9.2	.65	5.0
10-1475	Payson Creek above diversions, near Payson, Utah	18.8	652	5.0	5	7,610	94	26.3	1.70	12	12.0	.70	10
10-1485	Spanish Fork at Thistle, Utah	490	64	22.2	2	7,130	79	21.4	1.51	12	10.6	.65	2.0
10-1525	Hobble Creek near Springville, Utah	105	211	15.8	1	7,110	92	26.9	1.54	7	8.6	.60	4.0
10-1535	Provo River near Kamas, Utah	29.6	313	10.6	9	9,710	84	33.7	1.72	2	20.2	.80	10
10-1600	Deer Creek near Wildwood, Utah	27.4	244	11.5	1	7,450	88	31.7	1.81	8	16.7	.65	12
10-1645	American Fork above upper powerplant, near American Fork, Utah	51.1	247	12.3	2	8,460	70	43.0	2.00	7	11.7	.70	11
10-1722	Red Butte Creek at Fort Douglas, near Salt Lake City, Utah	7.25	393	4.7	1	6,800	95	29.2	1.87	16	16.1	.50	15
10-1727	Vernon Creek near Vernon, Utah	25	96.5	10.7	1	7,100	9	14.8	1.47	12	6.8	.70	3.7
10-1728.7	Trout Creek near Callao, Utah	8.8	583	6.0	1	9,100	83	20.7	1.57	9	8.5	.65	4.0
10-1729.4	Dove Creek near Park Valley, Utah	33.2	180	7.3	1	6,620	3	15.5	1.34	10	3.5	.70	3.0
10-1745	Sevier River at Hatch, Utah	340	176	23.7	7	8,480	75	22.5	1.76	8	7.7	.60	2.0
10-1850	Antimony Creek near Antimony, Utah	97	69	15.6	1	9,560	64	21.6	1.87	7	6.0	.55	1.5
10-1942	Clear Creek above diversions, near Sevier, Utah	164	209	18.0	4	7,880	87	20.9	1.58	12	9.8	.55	8.0
10-2051	Sheep Creek near Salina, Utah	.3	585	1.4	2	9,670	58	23.0	1.96	8	17.0	.50	12
10-2052	West Fork Sheep Creek near Salina, Utah	.43	958	1.2	1	8,690	83	23.0	1.94	8	16.0	.50	12
10-2053	Sheep Creek at mouth, near Salina, Utah	1.47	880	3.2	1	8,780	62	22.5	1.90	8	14.3	.50	11
10-2325	Chalk Creek near Fillmore, Utah	58.7	376	10.7	1	8,020	84	24.0	1.72	12	10.7	.65	8.2
10-2345	Beaver River near Beaver, Utah	82	287	16.8	3	9,280	86	27.7	1.85	7	8.4	.55	8.0
10-2420	Coal Creek near Cedar City, Utah	80.9	276	13.9	1	8,640	70	27.8	1.88	12	7.9	.60	2.1
13-0790	Clear Creek near Naf, Idaho	20.2	617	8.0	1	7,860	47	25.1	1.42	8	7.5	.75	5.0

Table A-3.--Summary of regression results for regions shown in figure 2

[Model is $Y = aA^{b} S^{c} L^{d} St^{e} F^{f} E^{g} P^{h} I^{i} t_1^{j} Sn^{k} G^{l} Si^{m}$]

Flow characteristic Y	Exponent of basin characteristic b, c, d, etc. — Regression constant a	Drainage area A	Main channel slope S	Stream length L (miles)	Lakes and ponds St (percent plus 1%)	Mean basin elevation E	Forested area F (percent plus 1%)	Mean annual precipitation P	Precipitation intensity I (24 hr, 2-yr)	Min. Jan. temperature t_1 (plus 5°F)	Snowfall index Sn (Apr. 30 total)	Geology index G	Soils index Si (in.)	Standard error of estimate (percent)
Q_a	0.00217	0.939	-	-	-	-	-	1.657	-	-	0.308	2.126	0.188	21.3
SD_a	.0118	.923	-	-	-	-	-	1.159	-	-	-	1.589	-	27
Q_1	.000145	1.521	-	-1.072	-0.480	-	0.581	1.722	-	-	-	2.504	.441	55
Q_2	.000555	1.465	-	- .932	- .382	-	-	1.428	-	0.816	-	2.820	.507	48
Q_3	.000971	1.513	-	- .962	- .382	-	-	1.088	-	1.110	-	2.375	.429	47.5
Q_4	.428	1.380	-	- .889	-	-2.925	-	2.220	-	-	-	-	-	40.5
Q_5	.001104	.916	-	-	-	-	-	-2.957	-	-	-	-	-	40.5
Q_6	.000008	.919	-	-	-	-2.372	-	2.520	-	-	-	2.500	-	37.5
Q_7	.000002	.951	-	-	-	1.979	.596	1.956	-	-	-	2.905	.423	30.5
Q_8	.000001	1.004	-	-	-	1.870	.822	1.588	-	-	-	2.416	.446	43
Q_9	.000015	1.048	-	-	-	-	.757	1.553	-	-	-	2.911	.580	50
Q_{10}	.000008	1.115	-	-	- .302	-	.922	1.849	-	-	-	2.933	.526	52.5
Q_{11}	.000017	1.107	-	-	- .399	-	.844	1.728	-	-	-	2.628	.475	50
Q_{12}	.000167	1.402	-	- .818	- .430	-	.597	1.619	-	-	-	2.546	.461	46
Mean of standard errors of regression equations of mean monthly discharges														45.1
SD_1	.00793	.917	-	-	- .265	-	-	-	-	-	.928	-	-	40
SD_2	3.3682	.790	-0.299	-	-	-1.915	-	-	-	-	.940	-	-	42
SD_3	4.5730	1.018	-	-	-	-3.699	-	1.115	-	-	-	-	-	51
SD_4	.1334	1.140	-	- .662	-	-3.518	-	3.312	-2.783	-	-	-	-	40.5
SD_5	.001406	1.111	.189	- .566	-	-	-	2.466	-2.204	-	-	-	-0.281	37
SD_6	.00000008	.945	-	-	-	4.375	-	2.419	-	-	-	-	- .523	74
SD_7	.0000009	.948	-	-	-	3.216	-	2.105	-	-	-	2.709	-	49
SD_8	.001879	.888	-	-	- .273	-	.572	1.690	-	-1.121	-	2.031	-	38
SD_9	.009311	.943	-	-	-	-	-	-	-	-	-	-	-	47
SD_{10}	.000148	.959	-	-	-	-	.892	1.652	-	-1.211	-	-	-	47
SD_{11}	.000493	.934	-	-	-	-	.635	1.157	-	- .607	-	-	-	39.5
SD_{12}	11.016	.843	-	-	-	-2.487	-	-	-	- .915	1.125	-	-	43.5
Mean of standard errors of regression equations of standard deviations of mean monthly discharges														45.7
P_2	.000033	.883	-	-	-	2.762	-	1.964	-	-	-	-	-	44
P_5	.0235	.855	-	-	-	2.210	-	-	-	-	.701	1.755	-	41
P_{10}	.0942	.847	-	-	-	1.944	-	-	-	-	.687	1.631	-	42.5
P_{25}	.0492	.823	-	-	-	2.070	-	-	-	-	.723	-	-	50
P_{50}	4.8000	.795	-	-	.393	-	-	-	-	-	.656	-	-	57.5
$M_{7,2}$	.00000009	1.322	-	-	- .926	-	3.282	-	-	-	-	5.863	.886	142
$M_{7,10}$	.00000007	1.344	-	-	- .891	-	3.183	-	-	-	-	5.940	.970	156
$M_{7,20}$	.00000007	1.351	-	-	- .884	-	3.154	-	-	-	-	6.003	1.004	162
$V_{7,2}$	.0000334	.865	-	-	-	2.407	-	2.117	-	-	-	-	-	66.5
$V_{7,10}$	.28556	.414	-	1.074	-	-	-	-	-	-	1.085	-	-	62.5
$V_{7,50}$	.04966	.874	-	-	-	-	-	3.112	-	-	-	-	-	64.0

Table A-4.--Streamflow stations now in operation and those needed for proposed program

Station		Recommendations		Types of data			
					Planning and design		
		Include in network	Not recommended for inclusion	Current purpose	Minor streams	Regulated principal streams	Long-term trends
9-1800	Dolores River neer Cisco, Utah	X		X		X	
9-1805	Colorado River near Cisco, Utah	X		X		X	
9-1820	Castle Creek above diversions, near Moab, Utah	X			X		
9-1830	Courthouse Wash near Moab, Utah	X			X		
9-1840	Mill Creek near Moab, Utah		X		X		
9-1855	Hatch Wash near La Sel, Utah		[1]X		X		
9-1865	Indian Creek above Cottonwood Creek, near Monticello, Utah		[1]X		X		
9-2179	Blacks Fork near Robertson, Wyo.	X			X		
9-2265	Middle Fork Beaver Creek near Lonetree, Wyo.		[1]X		X		
9-2345	Green River near Greendale, Utah	X		X		X	
9-2356	Pot Creek above diversions, near Vernal, Utah	X			X		
9-2358	Pot Creek near Vernal, Utah	X		X			
9-2610	Green River near Jensen, Utah	X		X		X	
9-2620	Big Brush Creek near Vernal, Utah		[1]X		X		
9-2653	Ashley Creek above Red Pine Creek, neer Vernal, Utah	X			X		
9-2665	Ashley Creek near Vernal, Utah		[1]X		X		
9-2671	Ashley Creek above Dry Fork, near Vernal, Utah	X		X			
9-2680	Dry Fork above sinks, near Dry Fork, Utah		[1]X		X		
9-2685	North Fork of Dry Fork near Dry Fork, Utah		[1]X		X		
9-2689	Brownie Canyon above sinks, near Dry Fork, Utah	X			X		
9-2705	Dry Fork at mouth, near Dry Fork, Utah	X		X			
9-2715	Ashley Creek near Jensen, Utah	X		X			
9-2755	West Fork Duchesne River near Hanna, Utah		X		X		
9-2760	Wolf Creek above Rhoades Canyon, near Hanna, Utah		X		X		
9-2775	Duchesne River near Tabiona, Utah	X		X			
9-2778	Rock Creek above South Fork, near Hanna, Utah	X			X		
9-2780	South Fork Rock Creek near Hanna, Utah	X			X		
9-2790	Rock Creek near Mountain Home, Utah		[1]X		X		
9-2791	Rock Creek near Talmage, Utah	X			X		
9-2791.5	Duchesne River above Knight diversion, near Duchesne, Utah	X		X		X	
9-2804	Hobble Creek at Daniels Summit, near Wallsburg, Utah	X			X		
9-2850	Stawberry River near Soldier Springs, Utah		[1]X		X		
9-2857	Strawberry River above Red Creek, near Fruitland, Utah	X			X		
9-2875	Water Hollow near Fruitland, Utah		X		X		
9-2880	Currant Creek near Fruitland, Utah	X		X			
9-2881	Red Creek below Currant Creek, near Fruitland, Utah	X			X		
9-2881.5	Cottonwood Creek near Fruitland, Utah	X			X		
9-2881.8	Strawberry River near Duchesne, Utah	X		X		X	
9-2889	Sowers Creek near Duchesne, Utah	X			X		

Table A-4.--Streamflow stations now in operation and those needed for proposed program--Continued

Station		Recom-		Types of data			
					Planning and design		
		Include in network	Not recom-mended for inclusion	Current purpose	Minor streams	Regulated principal streams	Long-term trends
9-2895	Lake Fork River above Moon Lake, near Mountain Home, Utah	X			X		X
9-2910	Lake Fork River below Moon Lake, near Mountain Home, Utah	X		X			
9-2925	Yellowstone River near Altonah, Utah		1/X		X		
9-2950	Duchesne River at Myton, Utah	X		X		X	
9-2970	Uinta River near Neola, Utah	X		X			
9-2980	Farm Creek near Whiterocks, Utah		1/X		X		
9-2995	Whiterocks River near Whiterocks, Utah	X		X	X		
9-3020	Duchesne River near Randlett, Utah	X		X		X	
9-3065	White River near Watson, Utah	X		X		X	
9-3075	Willow Creek above diversions, near Ouray, Utah		X		X		
9-3085	Minnie Maud Creek near Myton, Utah	X			X		
9-3100	Gooseberry Creek near Scofield, Utah	X		X			
9-3105	Fish Creek above reservoir, near Scofield, Utah		X		X		
9-3126	White River below Tabbyune Creek, near Soldier Summit, Utah	X			X		
9-3127	Beaver Creek near Soldier Summit, Utah	X			X		
9-3128	Willow Creek near Castle Gate, Utah	X			X		X
9-3145	Price River at Woodside, Utah	X		X		X	
9-3150	Green River at Green River, Utah	X		X		X	
9-3155	Saleratus Wash at Green River, Utah		X		X		
9-3180	Huntington Creek near Huntington, Utah		X		X		
9-3245	Cottonwood Creek near Orangeville, Utah		X		X		
9-3251	San Rafael River above Ferron Creek, near Castle Dale, Utah	X				X	
9-3265	Ferron Creek (upper station) near Ferron, Utah		X		X		
9-3285	San Rafael River near Green River, Utah	X		X		X	
9-3290.5	Seven Mile Creek near Fish Lake, Utah	X			X		
9-3299	Pine Creek near Bicknell, Utah	X			X		
9-3302.1	Pleasant Creek near Caineville, Utah	X		X			
9-3302.3	Fremont River near Caineville, Utah	X		X		X	
9-3305	Muddy Creek near Emery, Utah	X			X		X
9-3335	Dirty Devil River above Poison Springs Wash, near Hanksville, Utah	X		X		X	
9-3340	North Wash near Hanksville, Utah		X		X		
9-3345	White Canyon near Hanksville, Utah		X		X		
9-3370	Pine Creek near Escalante, Utah	X			X		
9-3380	East Fork Boulder Creek near Boulder, Utah	X			X		
9-3769	Spring Creek above diversions, near Monticello, Utah	X			X		
9-3786.3	Recapture Creek near Blanding, Utah	X			X		
9-3787	Cottonwood Wash near Blanding, Utah	X		X	X		X
9-3795	San Juan River near Bluff, Utah	X		X		X	
9-4044.5	East Fork Virgin River near Glendale, Utah	X			X		
9-4055	North Fork Virgin River near Springdale, Utah	X			X		X

Table A-4.--Streamflow stations now in operation and those needed for proposed program--Continued

Station		Recommendations: Include in network	Recommendations: Not recommended for inclusion	Types of data: Current purpose	Types of data: Planning and design: Minor streams	Types of data: Planning and design: Regulated principal streams	Types of data: Long-term trends
9-4060	Virgin River at Virgin, Utah	X		X		X	
9-4063	Kanarra Creek at Kanarraville, Utah	X			X		
9-4067	South Ash Creek below Mill Creek, near Pintura, Utah	X			X		
9-4080	Leeds Creek near Leeds, Utah	X			X		
9-4081.5	Virgin River near Hurricane, Utah	X		X		X	
9-4084	Santa Clara River near Pine Valley, Utah	X			X		
9-4098.8	Santa Clara River near Gunlock, Utah	X			X		
9-4100	Santa Clara River above Winsor Dam, near Santa Clara, Utah	X		X			
9-4104	Santa Clara River near Santa Clara, Utah	X			X		
10-0112	West Fork Bear River at Whitney Dam, near Oakley, Utah	X		X			
10-0115	Bear River near Utah-Wyoming State line	X		X	X		
10-0157	Sulphur Creek above reservoir near Evanston, Wyo.	X		X	X		
10-0159	Sulphur Creek below reservoir, near Evanston, Wyo.	X		X			
10-0170	Yellow Creek near Evanston, Wyo.		X		X		
10-0201	Bear River above reservoir, near Woodruff, Utah	X		X		X	
10-0203	Bear River below reservoir, near Woodruff, Utah	X		X			
10-0210	Woodruff Creek near Woodruff, Utah	X		X	X		
10-0230	Big Creek near Randolph, Utah		X		X		
10-0265	Bear River near Randolph, Utah	X		X		X	
10-0285	Bear River below Pixley Dam, near Cokeville, Wyo.	X		X			
10-0320	Smiths Fork near Border, Wyo.	X		X	X		X
10-0380	Bear River below Smiths Fork, near Cokeville, Wyo.	X		X		X	
10-0395	Bear River at Border, Wyo.	X		X		X	
10-0410	Thomas Fork near Wyoming-Idaho State line	X		X	X		
10-0440	Bear River at Harer, Idaho	X		X		X	
10-0465	Bear River below Stewart Dam, near Montpelier, Idaho	X		X		X	
10-0475	Montpelier Creek at irrigators weir, near Montpelier, Idaho	X		X			
10-0586	Bloomington Creek at Bloomington, Idaho	X			X		
10-0685	Bear River at Pescadero, Idaho	X		X		X	
10-0728	Eightmile Creek near Soda Springs, Idaho	X			X		
10-0750	Bear River at Soda Springs, Idaho	X		X		X	
10-0764	Soda Creek at Fivemile Meadows, near Soda Springs, Idaho	X			X		
10-0795	Bear River at Alexander, Idaho	X		X		X	
10-0845	Cottonwood Creek near Cleveland, Idaho		[1]X		X		
10-0865	Bear River below Utah Power & Light Co.'s tailrace, at Oneida, Idaho	X		X		X	
10-0905	Bear River near Preston, Idaho	X		X		X	
10-0912	Deep Creek near Clifton, Idaho	X			X		
10-0930	Cub River near Preston, Idaho		[1]X		X		

Table A-4.--Streamflow stations now in operation and those needed for proposed program--Continued

Station		Recommendations: Include in network	Recommendations: Not recommended for inclusion	Types of data: Current purpose	Types of data: Planning and design: Minor streams	Types of data: Planning and design: Regulated principal streams	Types of data: Long-term trends
10-1022.5	Bear River near Smithfield, Utah	X		X		X	
10-1023	Summit Creek above diversions, near Smithfield, Utah	X			X		
10-1046	South Fork Little Bear River near Avon, Utah	X		X			
10-1047	Little Bear River below Davenport Creek, near Avon, Utah	X		X	X		
10-1049	East Fork Little Bear River above reservoir, near Avon, Utah	X		X	X		
10-1060	Little Bear River near Paradise, Utah	X		X			
10-1075	Little Bear River near Hyrum, Utah	X		X			
10-1090	Logan River above State dam, near Logan, Utah	X		X	X		X
10-1135	Blacksmith Fork above Utah Power & Light Co.'s dam, near Hyrum, Utah	X		X	X		
10-1152	Logan River below Blacksmith Fork, near Logan, Utah	X				X	
10-1180	Bear River near Collinston, Utah	X		X		X	
10-1256	Malad River near Plymouth, Utah	X				X	
10-1258	Malad River below Bear River Duck Club Canal, near Bear River City, Utah	X				X	
10-1260	Bear River near Corinne, Utah	X		X		X	
10-1282	South Fork Weber River near Oakley, Utah	X			X		
10-1285	Weber River near Oakley, Utah	X		X	X		
10-1293	Weber River near Peoa, Utah	X		X			
10-1293.5	Crandall Creek near Peoa, Utah	X			X		
10-1305	Weber River near Coalville, Utah	X		X		X	
10-1307	East Fork Chalk Creek near Coalville, Utah	X			X		
10-1310	Chalk Creek at Coalville, Utah	X		X			
10-1337	Threemile Creek near Park City, Utah	X			X		
10-1345	East Canyon Creek near Morgan, Utah	X		X			
10-1350	Hardscrabble Creek near Porterville, Utah		X		X		
10-1365	Weber River at Gateway, Utah	X		X		X	
10-1375	South Fork Ogden River near Huntsville, Utah	X		X			
10-1376.8	North Fork Ogden River near Eden, Utah	X			X		
10-1377.8	Middle Fork Ogden River above diversions, near Huntsville, Utah	X			X		
10-1393	Wheeler Creek near Huntsville, Utah	X			X		
10-1410	Weber River near Plain City, Utah	X		X		X	
10-1420	Farmington Creek above diversions, near Farmington, Utah		X		X		
10-1435	Centerville Creek above diversions, near Centerville, Utah	X		X	X		
10-1460	Salt Creek at Nephi, Utah	X		X	X		
10-1482	Tie Fork near Soldier Summit, Utah	X			X		
10-1484	Nebo Creek near Thistle, Utah	X			X		
10-1485	Spanish Fork at Thistle, Utah		1/ X		X		

Table A-4.--Streamflow stations now in operation and those needed for proposed program--Continued

Station		Recommendations: Include in network	Recommendations: Not recommended for inclusion	Types of data: Current purpose	Types of data: Planning and design: Minor streams	Types of data: Planning and design: Regulated principal streams	Types of data: Long-term trends
10-1505	Spanish Fork at Castilla, Utah	X		X		X	
10-1520	Spanish Fork near Lake Shore, Utah	X		X		X	
10-1525	Hobble Creek near Springville, Utah		[1]X		X		
10-1527	Maple Creek near Mapleton, Utah	X			X		
10-1538	North Fork Provo River near Kamas, Utah	X			X		
10-1540	Shingle Creek near Kamas, Utah	X			X		
10-1542	Provo River nnar Woodland, Utah	X		X	X		
10-1550	Provo River near Hailstone, Utah	X		X			
10-1595	Provo River below Deer Creek Dam, Utah	X		X		X	
10-1608	North Fork Provo River at Wildwood, Utah	X			X		
10-1630	Provo River at Provo, Utah	X		X		X	
10-1645	American Fork above upper powerplant, near American Fork, Utah	X		X	X		X
10-1664.3	West Canyon near Cedar Fort, Utah	X			X		
10-1670	Jordan River at narrows, near Lehi, Utah	X		X		X	
10-1710	Jordan River at Salt Lake City, Utah	X		X		X	
10-1722	Red Butte Creek at Fort Douglas, near Salt Lake City, Utah	X		X	X		X
10-1727	Vernon Creek near Vernon, Utah	X			X		
10-1728	South Willow Creek near Grantsville, Utah	X			X		
10-1728.7	Trout Creek near Callao, Utah	X			X		X
10-1729.63	West Locomotive Spring at Locomotive Springs, near Snowville, Utah	X		X			
10-1729.64	Barker Spring at Locomotive Springs, near Snowville, Utah	X		X			
10-1729.65	Bar M Spring at Locomotive Springs, near Snowville, Utah	X		X			
10-1729.67	Off Spring at Locomotive Springs, near Snowville, Utah	X		X			
10-1729.68	Sparks Spring at Locomotive Springs, near Snowville, Utah	X		X			
10-1734.5	Mammoth Creek above West Hatch Ditch, near Hatch, Utah	X			X		X
10-1745	Sevier River at Hatch, Utah		[1]X		X		
10-1763	Panquitch Creek near Panquitch, Utah	X		X			
10-1800	Sevier River near Circleville, Utah	X		X		X	
10-1835	Sevier River near Kingston, Utah	X		X		X	
10-1839	East Fork Sevier River near Rubys Inn, Utah	X			X		
10-1850	Antimony Creek near Antimony, Utah	X			X		
10-1873	Otter Creek near Koosharem, Utah	X			X		
10-1890	East Fork Sevier River near Kingston, Utah	X		X		X	
10-1915	Sevier River below Piute Dam, near Marysvale, Utah	X		X		X	
10-1940	Sevier River above Clear Creek, near Sevier, Utah	X		X		X	
10-1942	Clear Creek above diversions, near Sevier, Utah	X			X		
10-2042	Mill Creek near Glenwood, Utah	X		X			
10-2050	Sevier River near Sigurd, Utah	X		X		X	

Table A-4.--Streamflow stations now in operation and those needed for proposed program--Continued

Station		Recommendations: Include in network	Recommendations: Not recommended for inclusion	Types of data: Current purpose	Types of data: Planning and design: Minor streams	Types of data: Planning and design: Regulated principal streams	Types of data: Long-term trends
10-2050.3	Salina Creek near Emery, Utah	X			X		X
10-2051	Sheep Creek near Salina, Utah 2/	X		X	X		
10-2052	West Fork Sheep Creek near Salina, Utah 2/	X		X	X		
10-2053	Sheep Creek at mouth, near Salina, Utah 2/	X		X	X		
10-2060	Salina Creek at Salina, Utah	X		X			
10-2085	Oak Creek near Fairview, Utah	X			X		
10-2100	Pleasant Creek near Mount Pleasant, Utah	X			X		
10-2157	Oak Creek near Spring City, Utah	X			X		
10-2159	Manti Creek below Dugway Creek, near Manti, Utah	X			X		
10-2162.1	San Pitch River near Sterling, Utah	X		X		X	
10-2164	Twelvemile Creek near Mayfield, Utah	X			X		
10-2170	Sevier River below San Pitch River, near Gunnison, Utah	X		X		X	
10-2190	Sevier River near Juab, Utah	X		X		X	
10-2192	Chicken Creek near Levan, Utah	X			X		
10-2240	Sevier River near Lynndyl, Utah	X		X		X	
10-2241	Oak Creek above Little Creek, near Oak City, Utah	X			X		
10-2325	Chalk Creek near Fillmore, Utah		1/ X		X		
10-2330	Meadow Creek near Meadow, Utah	X			X		
10-2335	Corn Creek near Kanosh, Utah	X			X		
10-2345	Beaver River near Beaver, Utah	X		X	X		
10-2350	South Creek near Beaver, Utah	X			X		
10-2360	North Fork North Creek near Beaver, Utah	X			X		
10-2365	South Fork North Creek near Beaver, Utah	X			X		
10-2370	Beaver River at Adamsville, Utah	X		X			
10-2375	Indian Creek near Beaver, Utah	X			X		
10-2390	Beaver River at Rocky Ford Dam, near Minersville, Utah	X		X		X	
10-2414	Little Creek near Paragonah, Utah	X			X		
10-2414.3	Red Creek near Paragonah, Utah	X			X		
10-2414.7	Center Creek above Parowan Creek, near Parowan, Utah	X			X		
10-2416	Summit Creek near Summit, Utah	X			X		
10-2420	Coal Creek near Cedar City, Utah		X		X		
13-0777	George Creek near Yost, Utah	X			X		
13-0790	Clear Creek near Naf, Idaho		X		X		

1/ Current or proposed areal investigation makes it desirable to continue for a few more years.
2/ Records furnished by U.S. Forest Service.