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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

CONCEPTS FOR THE DESIGN OF STREAMFLOW DATA PROGRAMS

by

R. W. Carter and M. A. Benson

Open-file Report

Washington, D. C.

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ABSTRACT

This report describes concepts and procedures that have been developed for planning surface-water data programs. The principal elements in such planning are (1) establishing the objective and goals of the program, (2) examining and analyzing all available data to determine which of the goals have already been met, (3) considering alternate means of meeting the remaining goals, and (4) identifying elements that should be included in the future program. The suggested procedure is rather involved because of the variability of streamflow, the large volume of existing data to be examined, and the complexities introduced by regulation and diversion of streamflow.

The framework for program design is related to four classifications of data which are: data for current use, data for planning and design, data for definition of long-term trends, and data on stream environment. These classifications are based on use of data and the techniques employed to obtain the data.

Goals are established for each of the four classifications and acceptable accuracy levels are specified for data used in planning and design. Accuracy equivalent to 25 years of record is specified for principal streams (over 500 square miles), and an accuracy equivalent to 10 years of record is specified for minor streams.

The objective of the streamflow data program is to provide information on flow characteristics at any point on any stream. For gaging stations on minor streams with natural flow, the relation between flow characteristics and variables that describe the topography and climate is defined. The higher accuracy requirements for principal streams will usually require 25 years of record at key points on these streams.

A systems approach to definition of flow characteristics is required for regulated streams. Homogeneous data for these streams can be derived by using a model of the stream system that reflects the effect of storage, diversions and management practices, and using observed record as input.

An analysis of all available data will indicate the goals that have been met, and those that remain to be achieved. This will provide the basis for design of the streamflow data program.

CONCEPTS FOR THE DESIGN OF STREAMFLOW DATA PROGRAMS

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INTRODUCTION

The purpose of this report is to set forth concepts and procedures that have been developed for planning surface-water data programs. The principal elements in such planning are (1) establishing the objective and goals of the program, (2) examining and analyzing all available data to determine which of the goals have already been met, (3) considering alternate means of meeting the remaining goals, and (4) identifying elements that should be included in the future program. The suggested procedure is rather involved because of the variability of streamflow, the large volume of existing data to be examined, and the complexities introduced by regulation and diversion of streamflow.

This report deals only with the surface-water aspects of hydrologic data. Consideration is given, however, to the interrelation of surface water to other aspects, such as the need for streamflow information to interpret observations of water quality.

Historically, surface-water data programs have developed in the Geological Survey in response to local economic and hydrologic stimuli. Owing to their joint concern, other Federal agencies, the States, and many counties and municipalities have for 70 years contributed substantial funds to the Geological Survey to obtain data directed to specific problems and also to intensify the general inventory of water resources. Although the program has largely evolved in response to specific and local area needs rather than by broadscale national planning, a wealth of information on streamflow has been accumulated.

The accelerated need for water-resources information, coupled with advances in water science, argues for an improved approach to planning surface-water data programs. Specific goals of the program need to be set. Data accumulated during the past 70 years need to be evaluated in relation to these goals. Then the program needs to be modified as necessary to efficiently produce the types of information required to attain the goals not yet reached.

One of the chief advances in water science has been the development of methods of synthesizing data which greatly facilitates the definition of the effect of the environment on flow characteristics and the statistical definition of flow distribution in time. These advances, coupled with the availability of digital computers, provide a more efficient means of utilizing observations of streamflow in hydrologic analysis which, in turn, governs to some degree the need for collection of data. Streamflow data programs should no longer be considered in terms of a network of observation points, but rather in terms of an information system in which data are provided both by observation and synthesis.

Ideally the planning of data programs would be based on a complete knowledge of the needs for different kinds of data and the sensitivity of design decisions to the input of information on streamflow. This knowledge could be accumulated by examining models of river basin planning to test the response of optimum design to various levels of streamflow information. The value of data to project design could be determined by measuring the benefits foregone due to missing the optimum design through inadequate data, or to the penalty cost of strategies utilized to meet uncertainties. Eventually, studies of this type will provide an improved scientific basis for design of data programs. In the meantime, planning can be based only in part on rigorous analysis, supplemented by accumulated experience and judgment.

FRAMEWORK FOR PROGRAM DESIGN

Concepts of program design are presented with reference to the general framework shown in figure 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 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 at a drainage area of 500 square miles. The need for each type of data and the methods of obtaining it are described in the following sections.

Table 1.—*Framework for design of data collection program*

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

*May be varied with terrain and hydrologic conditions.

Data for Current Use

Streamflow data are needed at many sites on a day-to-day basis for the management of water, for the assessment of current water availablity, for the control of water quality, for the forecast of flow extremes, and for the surveillance necessary for legal requirements. This classification represents the need for information on the actual flow at any moment, or during any specified day, week, month, or year.

Streamflow data obtained for current use have a high payoff value, as a current knowledge of the rate of flow and storage at different points in the system provides a basis for water management decisions that govern the economic efficiency of the operation.

Current-purpose data are obtained by operating gaging stations to obtain the data specifically required by particular water-management systems. Current-purpose data stations are placed in a separate category because (1) justification can be related to specific needs, (2) the data may have limited transfer value in a hydrologic sense, and (3) the location of the stations and the periods of operation are specified by the user of the data, who usually provides the financing.

Data for Planning and Design

Designers and planners of water control and water-related facilities increasingly utilize the statistical characteristics of streamflow rather than flow of specific periods in the past. The probability that the historical sequence of flow history observed at a given site will occur again is remote, and estimates of future flows needed in design and planning must consider all probable flows and sequences of flow. The need is to consider what may be expected to happen in the future, not in terms of specific events, but in terms of probability of occurrence over a span of years. For example, many highway bridges are designed on the basis of the flood that will be exceeded once in 50 years on the average; storage reservoirs can be designed on the basis of the probability of deficiency of storage for a given draft rate; the water available for irrigation, dilution of waste, or other purposes may be stated in terms of the mean flow, or probability of flow magnitudes for periods of a year, season, month, week, or day. In addition, there is a marked trend toward simulation of streamflow data based on the statistical characteristics, such as the mean, standard deviation, and skew.

A record of streamflow of at least 25 years is the best basis for defining the statistical characteristics. Although it is not feasible to collect such records at every site where information may be needed, a representative sampling of these sites is required to provide information that can be transferred to ungaged sites, or to sites where a small amount of streamflow data is available.

Natural-flow streams

For natural streams the transfer of streamflow information is accomplished by regression methods; either 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 the same stream channel. These methods are not usually applicable to streams where the flow is affected by regulation and diversion. Because different techniques are required to provide information on natural streams and regulated streams the two are considered separately in program design.

For the purpose of setting accuracy goals, streams are further classified as minor streams (less than 500 square miles), and as principal streams (greater than 500 square miles). The intent is to use size of drainage area as an index of worth of data. More costly water developments can be expected on larger streams, which justify a higher accuracy goal for principal streams than for minor streams. The given point of division between the two classes, 500 square miles, may be modified according to the hydrology of the region. For example, in arid regions the division point may be set at 1,000 square miles, because major developments are not likely on streams smaller than this.

Minor streams

Definition of flow characteristics of minor streams must be by some process of regionalization, because of the large number of such streams in the country. For natural streams this can be accomplished by gaging at sample locations and relating the observed flow characteristics to basin parameters to provide definition for ungaged streams.

Principal streams

Techniques of regionalization cannot, in general, be used for principal streams because of higher accuracy requirements. Therefore the proposed approach is to operate a network of gaging stations at selected locations on principal streams and by interpolation or systems studies estimate the flow characteristics at locations between stations. Experience gained heretofore in hydrologic analysis justifies a procedure for defining the network of principal stream stations as follows: (1) Select stations with drainage area of about 500 square miles on the most 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. The drainage area should be more than doubled if another principal stream enters between two principal-stream stations.

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. This increases the scope of both the data collection and 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 before additional changes occur.

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, i.e., regression, correlation, interpolation, etc., cannot be applied.

For regulated streams a systems approach appears 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 usually consist of water-budget equations and flow-storage equations. However, in many cases the use of the digital computer is required for complex relations, 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, the geometry of the stream channel, and records of diversions and return flow. Information on streamflow at some point or points is also needed as input to the model and to verify the output. In some cases aquifer characteristics and ground-water pumpage should be taken into account.

The model and the associated data can be used to derive homogeneous data for either the natural or the regulated condition. All historical streamflow records for both natural and regulated flows could be utilized as input to the model. Furthermore, data could also be derived for ungaged sites in the stream system.

Data to Define Long-Term Trends

A long continuing series of consistent observations on streamflow is needed for (1) analysis of the statistical structure of the hydrologic time series; and (2) as a reference or comparative base for noting changes in the flow regime of streams that become increasingly regulated over a period of time.

Statistical statements on flow characteristics are based on the assumption that the data series is stationary in a statistical sense, and that the observed record is a representative sample of the population of flows. Long-term homogeneous streamflow data would provide a basis for checking these assumptions, and a basis for adjusting flow characteristics from short records to more nearly represent the characteristics of the flow population.

For these purposes the gages should be located on streams draining basins that have undergone no significant man-made changes, and which are expected to remain in a comparable condition in the future. The gages should be well distributed areally, and be located on basins of different physical characteristics.

Data on the Stream Environment

Stream discharge and its use is intimately related to the environmental characteristics of the drainage basin. Environmental data include a wide variety of water-related information other than stream discharge. These data are necessary for hydrologic studies and for planning, designing, and operating systems for controlling water or pollution. For example, data on the geometry of a stream channel to appraise the use of a stream for recreation or to determine its capacity to assimilate waste; profiles of flood elevations to determine areas subject to inundation by floods; and information on aquifer characteristics is essential to describe the variability of low flow, or in planning the conjunctive use of surface water and ground water.

GOALS OF THE STREAMFLOW DATA PROGRAM

The objective of the streamflow data program is to provide information on flow characteristics at any point on any stream. Purposes for which streamflow data are used include the design of water-supply reservoirs, the control of pollution, the design of highway bridges and culverts, the management of flood plains, the development of recreation facilities, the forecast and management of floods, the production of power, the design and maintenance of navigation facilities, and the allocation of water for irrigation and other uses. Data for one or more of these purposes will eventually be needed on virtually every stream in the country, and the data system must be designed to produce the information in advance of the need.

The design of the streamflow data program should be based on specific goals that represent the type and accuracy of information that are needed. Acceptable accuracy levels should also be specified, because accuracy levels not only govern the cost and the techniques used in providing information, but also provide a measure of attainment of specific goals. Regional differences in the flow characteristics to be included in these goals may be expected because of variable hydrologic conditions and the need for information. The general framework and the accuracy levels specified in this report, however, are considered applicable to the entire country. The setting of goals for each of the four types of data are described below.

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. This part of the program is tailored to fit the requirements for data on a current basis as specified by the user of the data. These specifications may include the data to be obtained, the time of reporting, and accuracy requirements. This part of the program is not subject to advance design because its character changes frequently in response to changing need.

In general, a higher degree of stream-gaging accuracy is justified for current-purpose data used in the operation of water systems than for data to be used in the planning and design of water development projects. In contrast with the wide confidence intervals associated with the probability of future occurrences used in planning and design, the operation of water systems deals with known volumes of water that are subject to control for economic benefit. Accuracy goals at a given site depend on the requirements of the particular management system, and can be met by intensified observations, or by more sophisticated instrumentation as needed.

Data for Planning and Design

The program goal for this type of data is to define within a given accuracy the statistical flow characteristics for all streams in the country. This is indeed the major goal of the surface-water data program. It includes not only all streams with natural flow, but also those streams which are affected by regulation and diversion. For the latter streams the goal includes definition of the flow characteristics for both natural conditions and present conditions of development.

The statistical characteristics to be defined depend on the hydrology of the region. Typical characteristics are the mean and standard deviation of annual and monthly flow, the 50-year flood, and the 20-year 7-day low flow.

The accuracy goals proposed are given in terms of equivalent years of record. For minor streams the accuracy goal is the equivalent of 10 years of record, and for principal streams the equivalent of 25 years of record. The accuracy goals proposed are based on judgment as to the worth of data in planning and design, and on experience with the approaches that are used to derive information on streamflow by observation or analysis.

Accuracy goals in terms of equivalent years of record can be converted to standard error in percent of mean, using the methods described by Hardison (1969). In summary, the standard error of a characteristic for a given number of years of record depends on the variability of the annual events as defined by their coefficient of variation or by the standard deviation of their logarithms. Using this methodology, the accuracy goals in terms of standard error that correspond to 10 and 25 years of record may be computed for a given state or region.

An example of how the goal for statistical characteristics of streamflow might be set in a state in the humid East is given below:

Example

Define the following streamflow characteristics for all streams in the state to an accuracy equivalent to 10 years of record for minor streams and 25 years of record for principal streams. The accuracy figures shown below represent a conversion from equivalent years of record to standard error in percent of mean.

Item	Accuracy: Minor streams	Accuracy: Principal streams
1. Mean annual discharge	10%	5%
2. Mean discharge for each month	25%	15%
3. Standard deviation of mean annual discharge	22%	14%
4. Standard deviation of discharge for each month	22%	14%
5. 50-year flood	30%	20%
6. Median annual 7-day low flow	15%	10%
7. 20-year 7-day low flow	25%	15%
8. 50-year 7-day high flow	25%	15%

The accuracy requirements illustrated here are for the humid East, where the flow variability is less than that for most of the United States. In other parts of the country, where the variability is higher, the standard errors would be larger than those shown. Values such as those shown here or those that would be calculated in other regions might appear high to those concerned with planning and design related to streamflow. Yet these accuracies are based on the nature of the phenomena being observed. These are the magnitudes of errors that occur in time sampling. Reduction of time-sampling errors by collection of longer records is accomplished at progressively higher cost because the error varies inversely as the square root of the number of years of record. The improvement becomes progressively less as the length of record is increased. Note that for the 50-year flood the 30 percent error from 10 years of record is reduced only 10 percent by an additional 15 years of record.

The value of accuracy of data used in planning and design must be considered in relation to the cost of attaining a given accuracy. For minor streams the regionalization procedure can eventually provide information equivalent to 10 years of record for any site at a relatively low cost. Limited studies have shown that such accuracy is on a par with, or better than, the accuracy associated with other elements that go into planning or into hydraulic design, such as the economic projections, political judgments, and the state of the art of other technical considerations. Experience has shown, moreover, that significantly greater accuracy cannot be achieved by this method. A higher accuracy goal could be achieved for minor streams only by gaging for long periods at every site where information may conceivably be needed in the future. Because of the extremely large number of such sites, the cost of this alternate would be several orders of magnitudes greater than for the regionalization scheme. In view of this, significantly greater accuracy goals for minor streams cannot be justified for this type of streamflow data.

Data to Define Long-Term Trends

The goal for this type of data is to operate indefinitely a representative sample of gaging stations on natural streams in each region of the country to provide a continuing series of consistent observations. A total of about 400 such stations would provide an acceptable long-term data base. To achieve adequate geographical coverage it is recommended that two such stations be operated primarily for this purpose in each of the 207 subregions of the United States as identified by the Water Resources Council.

Data on the Stream Environment

The goals for this type of data should be set in response to the need for information. Typical data would include:

1. Stream-channel geometry, including widths, depths, slopes, hydraulic roughness and description of bed and bank material.

2. Profiles of flood elevations and areas subject to inundation by floods.

3. Velocities and travel time of water and wastes in channels.

4. Drainage-basin characteristics, including geometry, land use such as urban areas, irrigated acres, water storage, or forested areas; and climatic characteristics.

5. Aquifer characteristics, including location, extent, hydraulic connection to stream channel, and hydraulic characteristics.

EVALUATION OF AVAILABLE DATA

Preliminary to the design of a streamflow-data program, all available data are considered and analyzed in relation to the program goals. The deficiencies between present information and the goals form the basis for the future program. A separate evaluation is made for each of the four types of data previously described.

Data for Current Use

The demand for data for current use in a given region is a function of the degree of development and use of the water resource. Countrywide about half of the total streamflow-data program is presently related to this purpose. In general, it will be found that the requirements for this type of data are being met because the data are fundamental inputs to other specific and funded missions.

Identification of current-purpose stations is a prerequisite to the appraisal of the total data program. As the flow records for many of these stations have little or no transfer value in the hydrologic sense, their operation must be justified by the current need for data. The procedure is to code each current-purpose station according to the specific use of the data and the transfer value of the record. This provides documentation of this segment of the program and information that will be useful in selecting stations needed to amass the other types of data. Current uses of data to be considered in identifying stations are:

1. Assessment of current water conditions.

2. Operation of single and multipurpose storage reservoirs.

3. Forecasting of flood peaks, low flows, or seasonal flows.

4. Disposal of waste and control of pollution.

5. Water quality data programs for which discharge records are needed.

6. Compact and legal requirements.

7. Research or special studies.

Data for Planning and Design

An analysis of available data is necessary to determine which of the goals for this type of data have been met. Because the goal is to define flow characteristics at any point on any stream, techniques for generalizing the information obtained at gaging stations must be employed in the analysis. The discussion of procedures given below follows the general framework described on page 4. Additional information on the use of the procedures is given in the report for each state.

Natural-flow streams

Minor streams

The first question to be answered is how accurately can the statistical characteristics that are listed as goals be defined by regionalization of the data now available.

The most effective way presently known for defining statistical streamflow characteristics on a broad scale is to relate them to basin characteristics in equations developed by use of multiple-regression techniques applied to past data. Such an equation usually has the form

$$Y = a\, A^b\, S^c\, P^d \text{ ------}$$

where Y is a statistical streamflow characteristic, such as one of the eight items on page 16, and A, S, and P are topographic or climatic characteristics. The values of a, b, c, d, etc., are defined by multiple regression. This method was described by Benson (1962) and Thomas and Benson (1969).

All available records that represent natural streamflow are used in the multiple-regression study, with the statistical streamflow characteristics being those defined for the gaged sites by standard techniques. An equation of best fit is then developed that relates each flow characteristic to basin characteristics, such as drainage area, slope, length, area of lakes and ponds, soils, precipitation, and temperature.

This procedure provides not only a set of equations that define streamflow characteristics at any point on any natural flow stream, but also the corresponding standard errors of estimate that represent the accuracy with which estimates of these characteristics can be made. By comparing the errors of estimate with the accuracy goals for streamflow information, the degree of definition of each characteristic can be judged.

Thomas and Benson (1969) reported the results of multiple-regression studies in four areas of the country that represent a wide range in hydrologic conditions. Figure 1 illustrates the accuracy, in terms of the standard error in percent, of the regression equations defined for the Potomac Basin. The flows vary in magnitude from the left to the right side of the figure. It can be seen that the defined relations are most accurate for flows nearest the mean and become less accurate for extreme flows, being least accurate for extreme low flows. Similar trends with the range of flow were found in the other regions where studies were made. In general, it was found that the method produces more accurate relations for the humid eastern and southern regions than for the arid central and western regions.

Principal streams

In general, the accuracy goals for principal streams cannot be met by the results of multiple-regression studies; more intense gaging is usually required.

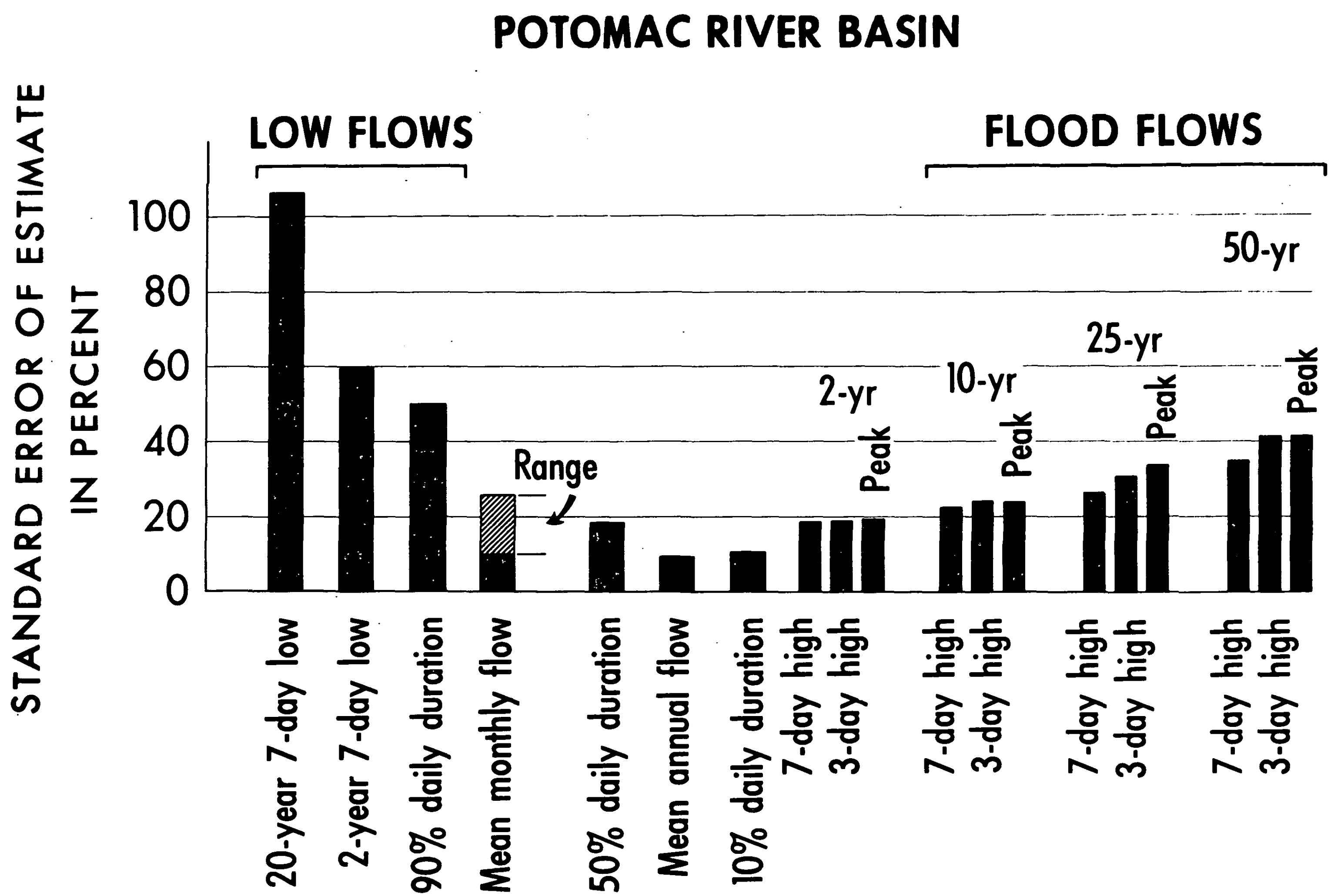

Figure 1.--Standard error in Potomac River basin relations.

The suggested method of attaining the accuracy goal is to set up a system of principal-stream gaging points as described on page 8. This system of points is established regardless of whether or not the stream now represents natural or regulated flow because these points represent sites at which it is considered desirable to define natural flow even though the streamflow may be currently regulated.

The accuracy goal could be met at each of the principal-stream gaging sites by an actual 25-year record of natural flow. In some cases, the goal could also be met by a record of less than 25 years at each site, extended by correlation with a nearby natural flow station with a longer record to provide the equivalent of a 25-year record of monthly and annual discharge.

Streamflow information on principal streams between principal-stream gaging sites would be based on interpolation supplemented by information for tributaries, or would be obtained from relations based on several of the principal-stream gaging sites. It is assumed that with 25-year accuracy at the selected principal-stream points streamflow information can be developed for all sites throughout the principal-stream system with little or no decrease from the 25-year accuracy standard.

Evaluation of existing data for natural-flow principal streams in relation to the goals is accomplished as follows: (1) Determine the system of principal-stream gaging points, (2) identify such of those points where 25 years of natural-flow record are already available or where records could be extended by regression to obtain the equivalent of 25 years of record, and (3) identify points where a station must be continued or a new station installed to obtain the equivalent of 25 years of record of natural flow.

Regulated-flow streams

As discussed earlier in this report, a systems approach is considered necessary, if meaningful information is to be provided on regulated streams. The goal is to define statistical flow characteristics for both the natural and regulated condition. Model studies will usually be required.

It is difficult to assess existing data in relation to the goals for regulated streams. It is evident, however, that existing streamflow programs are not providing the information required. In many cases it is not possible to develop even a simple water-budget equation for stream systems from the data available. The available records are not homogeneous in time, and are thus of limited use in statistical prediction. Little or no information is available for ungaged sites.

For the purpose of program design it will be useful to (1) identify the regulated stream systems that should be studied, (2) consider the approach to be used, and (3) assess the data requirements. In some cases a single stream may be involved with a simple pattern of regulation, and in other cases it may be an entire basin with a complex system of regulatory work, diversions, and management practices. In either case some type of analytical model is necessary by which the entire system is described. Consideration of the model approach will probably also indicate deficiencies in the present data-collection scheme.

Data to Define Long-Term Trends

The goal for this type of data is to operate two natural-flow stations indefinitely in each Water Resources Council Subregion. The Federal network of recently established bench-mark stations will provide this type of data. This network, however, includes only 57 stations because of the difficulty that was experienced in finding basins that are expected to remain in a natural condition in future years. Therefore, to augment the long-term data base, other stations that now represent essentially natural flow should be selected and operated until such time as the flow is markedly affected by developments in the basin. These stations should be selected from the existing network, giving consideration to (1) present length of record, (2) chance of the basin remaining in natural condition, (3) conditions for accurate gaging, and (4) use of the station records for other purposes.

Data on the Stream Environment

The assessment of this type of data requires no special techniques. It is accomplished by comparing the information available with the goals that were established.

PLANNING FUTURE STREAMFLOW DATA PROGRAMS

The study as outlined in the previous section of this report will yield the goals of the streamflow data program and an evaluation of presently available data in relation to these goals. The information developed in various segments of the study can be merged and plans for the future data program developed that will eventually attain as many of the goals as possible within the limits of available funds.

From the evaluation study it will be found that some streamflow characteristics can and some cannot be predicted within the standards of accuracy that have been specified. Where streamflow characteristics have been adequately defined, it is wasteful to continue to collect further data on the same scale unless it is needed for some other purpose; instead an elimination or reduction in collection of that type of data is justified. If, on the other hand, the accuracy of definition of streamflow is deficient, the various remedial steps that can be taken should be considered in the planning. Among the alternatives are (1) continued or augmented collection of the specific type of data necessary to increase time or geographic coverage of the sampling, (2) improvement in analytical methods by research, and (3) change in the analytical methods, possibly a change from generalization to intensive measurement programs for special conditions where generalization may not furnish the desired accuracy. On regulated streams there seems to be no alternative to systems studies, if the effect of various operational patterns are to be predicted.

Under the first alternative, partial-record gaging may offer the most efficient means of collecting information for minor streams, particularly if the accuracy goals for annual and monthly flow have been met. For example, if the failure is in areal definition of flood flows, the collection of data on storm rainfall and runoff to define model parameters may be the best approach, anticipating that records could be extended in time by use of the model and long-term rainfall records. If the results of regionalization do not apply to small-sized basins or urbanized basins because these conditions were not adequately represented by the available data, then an increase in this activity will be needed in complete-record gaging or partial-record gaging for these types of basins in order to attain the goals.

Under the second alternative, the reason for deficiencies in the multiple-regression method would need to be examined. The method may be deficient (1) because the model is inadequate, and (2) because indices of all the important basin characteristics have not been included or are not adequately defined. The effect of geology or soils or urbanization, for example, is difficult to evaluate numerically. Research may indicate more suitable models and means of developing better indices of basin characteristics.

One example of action under the last-named alternative is the use of specialized miscellaneous measurements. In defining low-flow characteristics, a number of locations can be measured during periods of base flow, and, by correlation with index stations, the desired characteristics may be determined. If this approach is to be used, the availability of index stations to be used for this purpose must be considered.

In general, it will be found that the accuracy goals for principal streams cannot be met by techniques for regionalization. It may be found, however, that 25 or more years of record is already available for most of the sites in the principal-stream network with natural flow. Thus, it may be possible to discontinue a number of gaging stations in this category, and continue to gage only those sites where the goal has not been attained.

The regulated portion of principal streams will offer the greatest challenge in the future program. The present surface-water data programs are not yielding all of the information required on regulated streams, because the effort has been generally limited to operation of gages at particular points, with little consideration as to what is being measured or of the related data that are necessary to provide meaningful answers. These streams should be considered as a flow system and plans made to obtain the required input data. Where for example is water diverted or returned from the stream channel? How much is diverted or returned at each point? Where are the storage reservoirs in the basin, and what are the operational characteristics? What is the net loss due to evaporation from reservoirs or evapotranspiration from irrigated lands in the basin? What is the effect of ground-water pumpage in the basin on streamflow? Is sufficient information available to develop a water budget or flow-storage model of the stream system? A model approach is considered to be necessary, if meaningful information is to be provided on regulated streams. Full advantage should be taken of studies made and of models developed by agencies primarily concerned with design and operation of water systems.

Planning the surface-water information system cannot be done by formula. It must be done by hydrologists who are familiar with the hydrology of the region, the needs for information, the information presently available, and methods of hydrologic analysis. The results of an evaluation such as described in this paper, however, will provide a firm basis for planning the future program. Decisions on number, location, and length of operation of continuous stations and partial-record stations can be based on these results. Less productive elements can be weeded out and the effort devoted to important areas of streamflow information that are now receiving little attention. The overall plan should provide for a continuous interaction between data collection and analysis not only to gain a better understanding of the hydrologic system, but to guide the future data-collection program.

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