A United States Contribution to the International Hydrological Decade

HEC-IHD-0200

# Hydrologic Engineering Methods For Water Resources Development

# Volume 2

# Hydrologic Data Management

April 1972

IHD-2

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| **REPORT DOCUMENTATION PAGE** | | *Form Approved OMB No. 0704-0188* |

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| **1. AGENCY USE ONLY** *(Leave blank)* | **2. REPORT DATE**<br>April 1972 | **3. REPORT TYPE AND DATES COVERED**<br>IHD Volume 2 |

| | |
|---|---|
| **4. TITLE AND SUBTITLE**<br>Hydrologic Data Management | **5. FUNDING NUMBERS** |
| **6. AUTHOR(S)**<br>Leo R. Beard | |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**<br>US Army Corps of Engineers<br>Institute for Water Resources<br>Hydrologic Engineering Center<br>609 Second Street<br>Davis, CA 95616-4687 | **8. PERFORMING ORGANIZATION REPORT NUMBER**<br>IHD-2 |
| **9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**<br>N/A | **10. SPONSORING / MONITORING AGENCY REPORT NUMBER**<br>N/A |
| **11. SUPPLEMENTARY NOTES** | |
| **12a. DISTRIBUTION / AVAILABILITY STATEMENT**<br>Approved for Public Release. Distribution of this document is unlimited. | **12b. DISTRIBUTION CODE** |

**13. ABSTRACT** *(Maximum 200 words)*

This is Volume 2 of the 12 volume report prepared by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers as a contribution to the International Hydrological Decade.

Volume 2 describes methods and procedures for managing hydrologic data in a systematic manner, techniques for estimating missing portions of hydrologic records, and techniques for generating synthetic hydrologic data. A generalized computer program description, "Monthly Streamflow Simulation", is included as part of the volume. This program will analyze monthly hydrologic data at a number of interrelated stations, generate sequences of hypothetical hydrologic data, and reconstitute missing hydrologic data on the basis of concurrent data observed at other locations.

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| **14. SUBJECT TERMS**<br>International Hydrological Decade, Water Resources Development, Regional Correlation, Stochastic Hydrology | **15. NUMBER OF PAGES**<br>238 |
| | **16. PRICE CODE** |

| | | | |
|---|---|---|---|
| **17. SECURITY CLASSIFICATION OF REPORT**<br>UNCLASSIFIED | **18. SECURITY CLASSIFICATION OF THIS PAGE**<br>UNCLASSIFIED | **19. SECURITY CLASSIFICATION OF ABSTRACT**<br>UNCLASSIFIED | **20. LIMITATION OF ABSTRACT**<br>UNLIMITED |

**Hydrologic Engineering Methods for Water Resources Development**

# Volume 2
# Requirements and General Procedures

**April 1972**

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IHD-2

# FOREWORD

This volume is part of the 12-volume report entitled "Hydrologic Engineering Methods for Water Resources Development," prepared by The Hydrologic Engineering Center as part of the U. S. Army Corps of Engineers' participation in the International Hydrological Decade. Volume 2 describes methods and procedures for managing hydrologic data in a systematic manner, techniques for estimating missing portions of hydrologic records, and techniques for generating synthetic hydrologic data. Although many of the methods and procedures described herein have been used successfully in Corps of Engineers' studies, the volume should not be construed to represent the official policy or criteria for the Corps.

The author wishes to acknowledge contributions by Mr. Robert G. Willey and Mr. Harold E. Kubik to the material contained in Chapters 4 and 5.

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# Processing of Basic Data

# CHAPTER 1. PROCESSING OF BASIC DATA

## Section 1.01. Introduction

Processing of basic data includes the assembly of basic observational data and the preparation of such data for use in engineering analyses.

In many developing countries, existing basic data are retained only at the headquarters location for the area where the data are observed. Often there is no central agency that collects and prepares the data for easy use and dissemination. Use of existing data would be greatly facilitated if a system for collecting and organizing the field data was created. This would include regular (at least annual) visits to each station, at which time the methods of observation and recording could be reviewed.

The next most important requirement for processing basic data is that the observations be obtained in a systematic manner and tabulated at an acceptable regular interval. Accuracy of observation is, of course, of paramount importance. Observers must be impressed with the importance of stating exact times of manual observations, as well as exact amounts, and must be given basic instruction in observational procedures.

The processing and the analysis of basic data will be greatly facilitated when one or more long, consistent records of related phenomena are available. Accordingly, emphasis should be placed on obtaining and preserving the longest records of consistent observations that are available in any region.

The types of hydrologic data that are of most interest and that are commonly used in the development of design criteria are discussed in the following paragraphs. In hydrologic engineering, runoff data is of primary importance, followed by topography and precipitation data. These, together with temperature and evaporation data, constitute basic data that can be supplemented by other data and used for many purposes.

## Section 1.02. Meteorological Data

### General

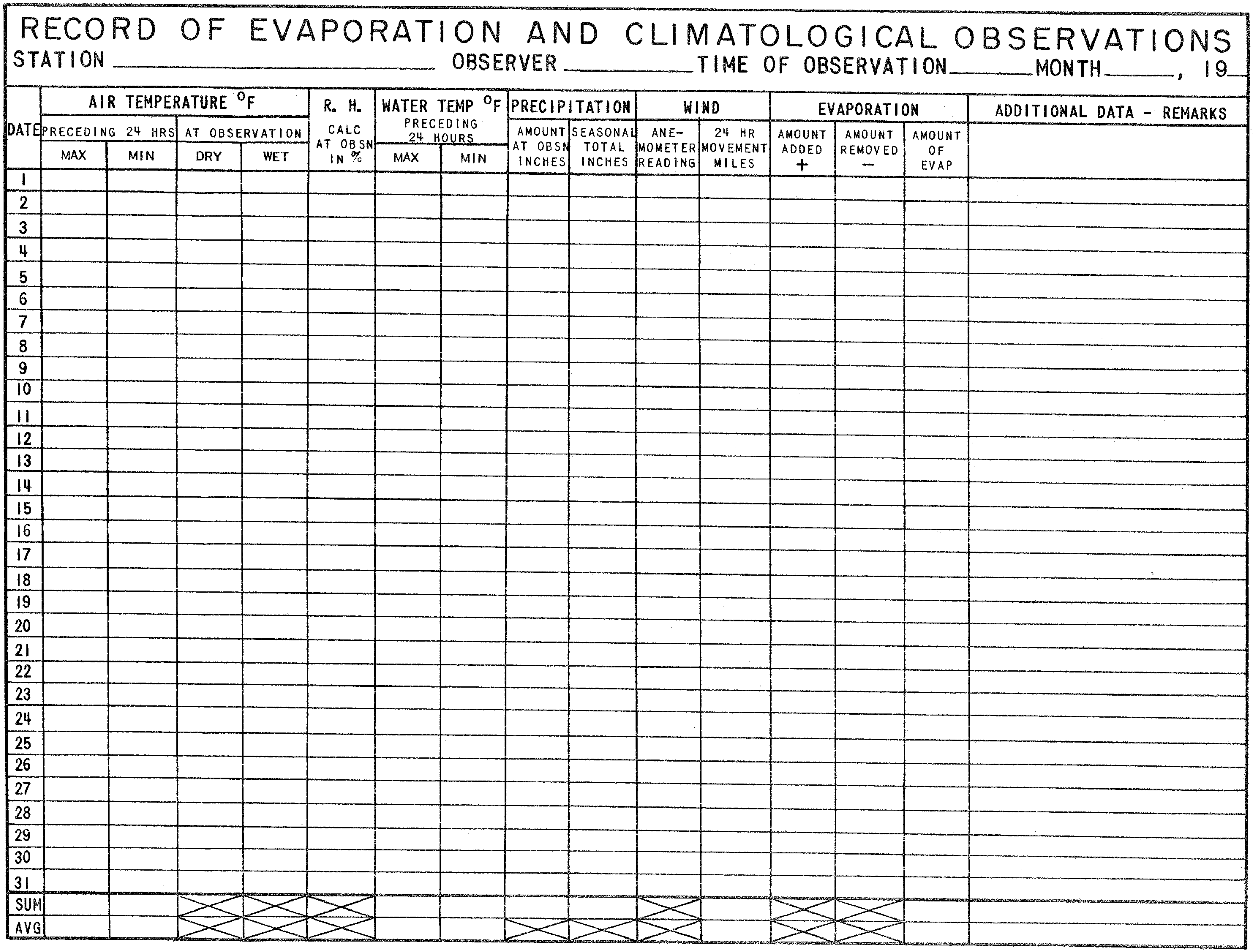
The extent of meteorological observations made at any location is determined by the use to which the data will be put and the availability of personnel and equipment. Data usually recorded at weather stations are illustrated in fig. 1.01. As indicated below, more extensive recording of various types of data is often made for special purposes.

### Storm Meteorology

The determination of runoff potential, particularly flood potential, in areas where hydrologic data are scarce can be based on a knowledge of storm meteorology. This includes sources of moisture in the paths over which the storm has traveled, as well as a knowledge of the mechanics of storm activity. Derivation of hydrologic quantities associated with various storms must take into consideration the type of storm, its path, potential moisture capacity and stability of the atmosphere, isobar, wind and isotherm patterns, and the nature and intensity of fronts separating air masses. These are usually described adequately in the synoptic charts that are prepared at regular (usually 6-hour) intervals for weather forecasting purposes, and associated upper-air soundings. Where such charts are available, it is important that they be retained as a permanent record of meteorological activity for use in supplementing information contained in the regularly prepared hemispheric charts. These latter charts summarize the daily synoptic situation throughout the hemisphere, but do not contain all of the data that are of interest or that would have direct bearing on the derivation of design criteria.

### Precipitation

The art of measuring precipitation has not yet progressed to the point that the nature and amount can be consistently and accurately



RECORD OF EVAPORATION AND CLIMATOLOGICAL OBSERVATIONS

STATION ____________ OBSERVER ____________ TIME OF OBSERVATION ________ MONTH ________, 19__

| DATE | AIR TEMPERATURE °F | | | | R. H. | WATER TEMP °F | | PRECIPITATION | | WIND | | EVAPORATION | | | ADDITIONAL DATA - REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PRECEDING 24 HRS | | AT OBSERVATION | | CALC AT OBSN IN % | PRECEDING 24 HOURS | | AMOUNT AT OBSN INCHES | SEASONAL TOTAL INCHES | ANE-MOMETER READING | 24 HR MOVEMENT MILES | AMOUNT ADDED + | AMOUNT REMOVED − | AMOUNT OF EVAP | |
| | MAX | MIN | DRY | WET | | MAX | MIN | | | | | | | | |
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| SUM | | | ☒ | ☒ | ☒ | | | | | ☒ | | ☒ | ☒ | | |
| AVG | | | ☒ | ☒ | ☒ | | | ☒ | ☒ | ☒ | | ☒ | ☒ | | |

Fig. 1.01. General form for recording weather station data

recorded at unattended locations, particularly where snow and hail frequently occur. For this reason, records obtained at unattended locations must be interpreted with care. When an observer is available regularly at a site, the times of occurrence of snowfall and hail should be noted so that accurate use of the data can be made. The exact location and elevation of the gage are important considerations in precipitation measurement and evaluation. For uniform use, this is best expressed in terms of latitude and longitude and in meters or feet of elevation above sea level. Of primary importance in processing the data is the tabulation of precipitation for regular intervals. This should be done daily for nonrecording gages with the time of observation stated. In the case of continuously recording gages, the most convenient interval of tabulation is hourly. However, the original recording charts must be preserved in order to permit study of high-intensity precipitation during short intervals for certain applications.

## Snowpack

Where snowmelt contributes materially to runoff, observations of the snowpack characteristics can be of considerable value in the development of hydrologic design criteria. Of primary importance is the observation of water equivalent (weight) of a vertical column sampled from the snowpack at specified locations and observation times. The elevation and exposure of the location must be known, inasmuch as the observations will ordinarily be used as an index for surrounding regions. The depth of snowpack is of secondary importance, but some observations of the areal extent of the snowpack are often useful. An important element in the processing of snowpack observation data is the adjustment of observations at all locations to a common date, such as the first of each month during the snowpack accumulation season. Since these observations are often made by traveling survey teams, they are not made simultaneously. Also, they cannot always be made at a specified time because it is impossible to obtain accurate or representative measurements during snowstorms.

Where continuous recordings of snowpack water equivalent by means of radioactive gages or snow pillows is available, these can be used as a basis for adjusting manual observations at nearby locations. Otherwise, some judgment or correlation technique based on precipitation measurements is required in order to adjust the observation data to a uniform date at all locations. It is important to preserve the original records whenever such adjustments are made. However, data that are disseminated for use in design should be the adjusted systematic quantities.

## Temperatures

In most hydrologic applications of temperature data, maximum and minimum temperatures for each day at the ground level are very useful. Continuous records of diurnal temperature variations at selected locations can be used to determine the daily pattern fairly accurately at nearby locations where only the maximum and minimum temperatures are known. In applying temperature data to large areas, it must be recognized that temperatures normally decrease with increasing elevation and latitude. It is therefore particularly important that the exact elevation and location of each station be known when using and applying data from that station. It is also important to preserve all of the original temperature records. Summaries of daily maximum and minimum temperatures should be maintained and, where feasible, published.

## Moisture

Moisture in the atmosphere is a major factor influencing the occurrence of precipitation. This moisture can be measured by atmospheric soundings which record temperature, pressure, relative humidity, and some other items. The total moisture in the atmosphere can be integrated and expressed as a depth of water. During storms, the vertical distribution of moisture in the atmosphere ordinarily follows a rather definite pattern, and the total moisture can therefore be related to the moisture at the surface, which is a function of the dewpoint at the surface. Accordingly, a record of daily dewpoints is of considerable value. Here, again, the elevation, latitude and longitude of the measuring station must be known.

## Winds

Probably the most difficult meteorological element to evaluate is windspeed and direction. Quite commonly, the direction of surface winds reverses diurnally, and the windspeeds fluctuate greatly from hour to hour and minute to minute. There is also a radical change of windspeed and direction with altitude. The speed and direction at lower levels is greatly influenced by obstructions such as mountains, and locally by small obstructions such as buildings and trees. Accordingly, it is important that great care is exercised in selecting a location and altitude for wind measurement. For most hydrologic applications, wind measurements at elevations of 5 to 15 meters above the ground surface are satisfactory. It is important to preserve all basic records of winds, including data on the location, ground elevation, and the height of the anemometer above the ground. Where continuous records are available, hourly tabulations of speed and direction are highly desirable. Total wind movement and the prevailing direction for each day are also useful data.

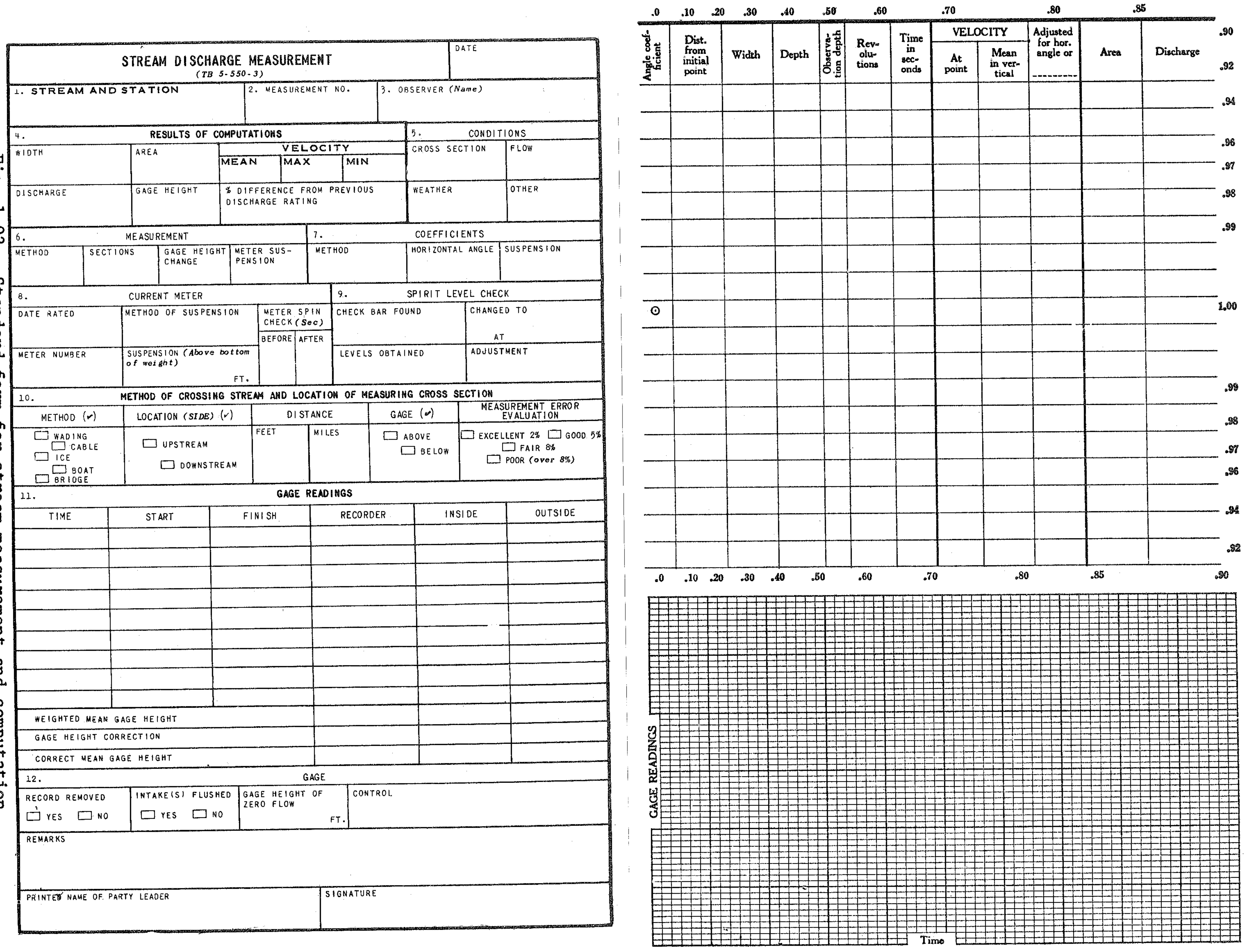
## Evaporation

Evaporation is usually measured by use of a pan about 4 feet (1 meter) in diameter filled with water to a depth of about 8 inches (20 centimeters). The evaporation can be measured each day by first removing from the pan an amount of water equal to precipitation that has occurred since the last measurement, and then adding a measured amount of water until the standard depth is attained. This volume of added water, divided by the area of the pan, is equal to the daily evaporation amount expressed in inches or millimeters. A tabulation of daily evaporation amounts should be maintained and, if possible, published. It is essential that a rain gauge be maintained at the evaporation pan site, and it is usually desirable that temperature, dewpoint (or wet-bulb temperature) and low-level wind measurements also be made at the site for future study purposes.

## Section 1.03. Basic Runoff Data

Streamflow data are usually best obtained by means of a continuous record of river stage supplemented by frequent meter measurements of flows that can be related to corresponding river stages. It is important that stage measurements be made at a good control section, even if a weir or other control must be constructed. Each meter measurement should consist of average velocity measurements within each of several (6 to 20, where practicable) subdivisions within the channel cross section. Average velocity for a subdivision is usually taken as the velocity at a depth of .6 of the distance from the surface to the streambed or as the average of velocities taken at .2 and .8 of the depth at the middle of the subdivision. Readings of river stage should be made immediately before and after the cross section is metered. The average of these two stages is the stage to be associated with the measurement. The measurement is computed by integrating the rates of flow (cubic meters per second) in all subdivisions of the cross section.

A standard form for recording measurements and computing streamflow is shown in fig. 1.02. When measurements have been made for a sufficient range of flows, the rating curve of flow vs. stage can be used to convert the continuous record of stage into a continuous record of flow. A rating table form is illustrated in fig. 1.03. The flows should be averaged for each day in order to construct a tabulation of mean daily flows. A form for this purpose is illustrated in fig. 1.04. This constitutes the most common permanent or published record of runoff. A standard form for documenting mean daily flows is shown in fig. 1.05.



**STREAM DISCHARGE MEASUREMENT**
(*TB 5-550-3*)

DATE

1. STREAM AND STATION
2. MEASUREMENT NO.
3. OBSERVER (*Name*)

4. RESULTS OF COMPUTATIONS

| | | | | |
|---|---|---|---|---|
| WIDTH | AREA | VELOCITY MEAN | VELOCITY MAX | VELOCITY MIN |
| DISCHARGE | GAGE HEIGHT | % DIFFERENCE FROM PREVIOUS DISCHARGE RATING | | |

5. CONDITIONS

| | |
|---|---|
| CROSS SECTION | FLOW |
| WEATHER | OTHER |

6. MEASUREMENT

| | | | |
|---|---|---|---|
| METHOD | SECTIONS | GAGE HEIGHT CHANGE | METER SUSPENSION |

7. COEFFICIENTS

| | | |
|---|---|---|
| METHOD | HORIZONTAL ANGLE | SUSPENSION |

8. CURRENT METER

| | | | |
|---|---|---|---|
| DATE RATED | METHOD OF SUSPENSION | METER SPIN CHECK (*Sec*) BEFORE | AFTER |
| METER NUMBER | SUSPENSION (*Above bottom of weight*) FT. | | |

9. SPIRIT LEVEL CHECK

| | |
|---|---|
| CHECK BAR FOUND | CHANGED TO<br>AT |
| LEVELS OBTAINED | ADJUSTMENT |

10. METHOD OF CROSSING STREAM AND LOCATION OF MEASURING CROSS SECTION

| METHOD (✓) | LOCATION (*SIDE*) (✓) | DISTANCE FEET | DISTANCE MILES | GAGE (✓) | MEASUREMENT ERROR EVALUATION |
|---|---|---|---|---|---|
| ☐ WADING<br>☐ CABLE<br>☐ ICE<br>☐ BOAT<br>☐ BRIDGE | ☐ UPSTREAM<br>☐ DOWNSTREAM | | | ☐ ABOVE<br>☐ BELOW | ☐ EXCELLENT 2%<br>☐ GOOD 5%<br>☐ FAIR 8%<br>☐ POOR (*over 8%*) |

11. GAGE READINGS

| TIME | START | FINISH | RECORDER | INSIDE | OUTSIDE |
|---|---|---|---|---|---|
| | | | | | |
| WEIGHTED MEAN GAGE HEIGHT | | | | | |
| GAGE HEIGHT CORRECTION | | | | | |
| CORRECT MEAN GAGE HEIGHT | | | | | |

12. GAGE

| | | | |
|---|---|---|---|
| RECORD REMOVED<br>☐ YES ☐ NO | INTAKE(S) FLUSHED<br>☐ YES ☐ NO | GAGE HEIGHT OF ZERO FLOW<br>FT. | CONTROL |

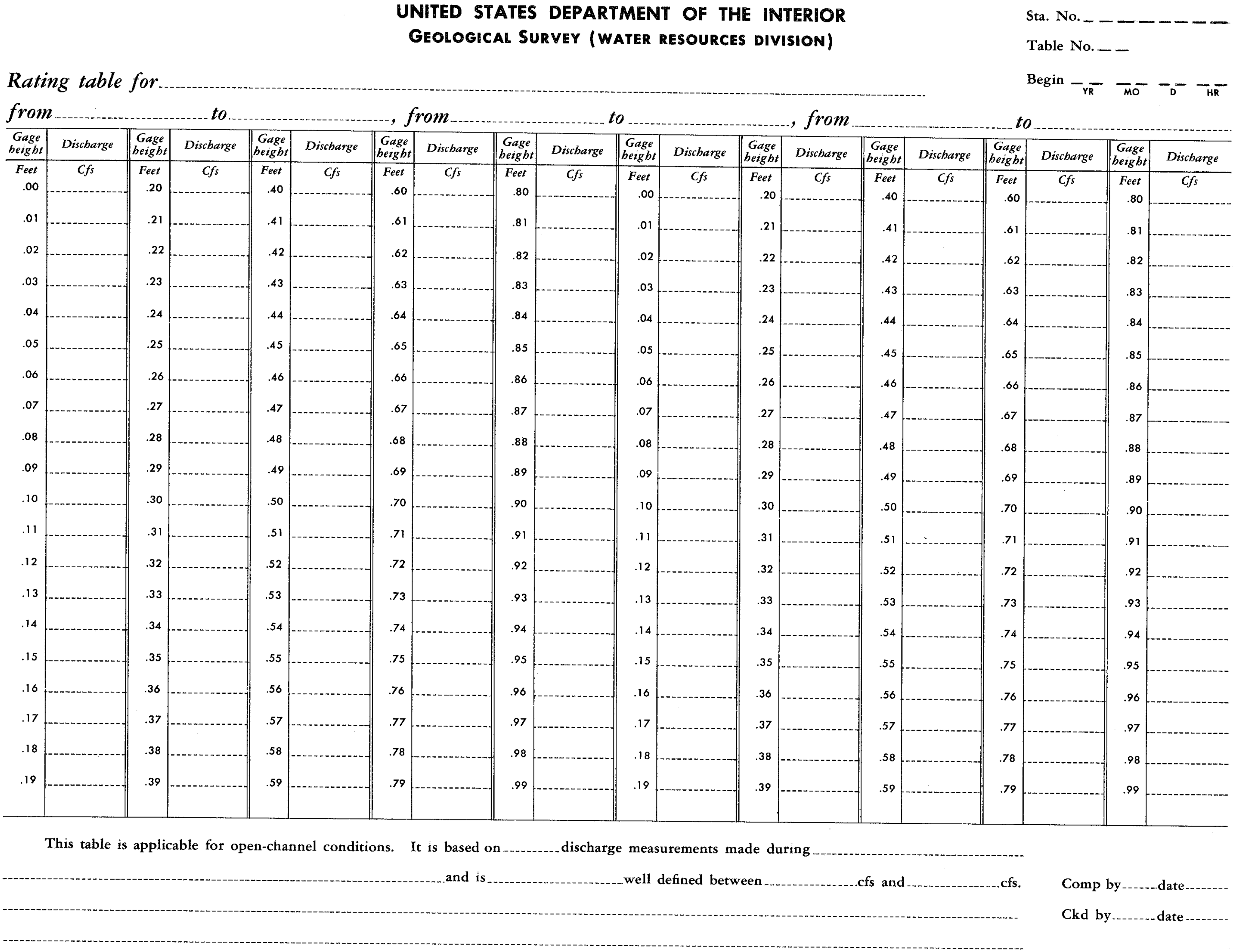
REMARKS

PRINTED NAME OF PARTY LEADER

SIGNATURE

| Angle coefficient | Dist. from initial point | Width | Depth | Observation depth | Revolutions | Time in seconds | VELOCITY At point | VELOCITY Mean in vertical | Adjusted for hor. angle or | Area | Discharge |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

Fig. 1.02. Standard form for stream measurement and computation



**UNITED STATES DEPARTMENT OF THE INTERIOR**
**GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)**

Sta. No.________
Table No.___
Begin ___ YR ___ MO ___ D ___ HR

*Rating table for*________________________________

*from*__________ *to*__________, *from*__________ *to*__________, *from*__________ *to*__________

| *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* | *Gage height* | *Discharge* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* | *Feet* | *Cfs* |
| .00 | | .20 | | .40 | | .60 | | .80 | | .00 | | .20 | | .40 | | .60 | | .80 | |
| .01 | | .21 | | .41 | | .61 | | .81 | | .01 | | .21 | | .41 | | .61 | | .81 | |
| .02 | | .22 | | .42 | | .62 | | .82 | | .02 | | .22 | | .42 | | .62 | | .82 | |
| .03 | | .23 | | .43 | | .63 | | .83 | | .03 | | .23 | | .43 | | .63 | | .83 | |
| .04 | | .24 | | .44 | | .64 | | .84 | | .04 | | .24 | | .44 | | .64 | | .84 | |
| .05 | | .25 | | .45 | | .65 | | .85 | | .05 | | .25 | | .45 | | .65 | | .85 | |
| .06 | | .26 | | .46 | | .66 | | .86 | | .06 | | .26 | | .46 | | .66 | | .86 | |
| .07 | | .27 | | .47 | | .67 | | .87 | | .07 | | .27 | | .47 | | .67 | | .87 | |
| .08 | | .28 | | .48 | | .68 | | .88 | | .08 | | .28 | | .48 | | .68 | | .88 | |
| .09 | | .29 | | .49 | | .69 | | .89 | | .09 | | .29 | | .49 | | .69 | | .89 | |
| .10 | | .30 | | .50 | | .70 | | .90 | | .10 | | .30 | | .50 | | .70 | | .90 | |
| .11 | | .31 | | .51 | | .71 | | .91 | | .11 | | .31 | | .51 | | .71 | | .91 | |
| .12 | | .32 | | .52 | | .72 | | .92 | | .12 | | .32 | | .52 | | .72 | | .92 | |
| .13 | | .33 | | .53 | | .73 | | .93 | | .13 | | .33 | | .53 | | .73 | | .93 | |
| .14 | | .34 | | .54 | | .74 | | .94 | | .14 | | .34 | | .54 | | .74 | | .94 | |
| .15 | | .35 | | .55 | | .75 | | .95 | | .15 | | .35 | | .55 | | .75 | | .95 | |
| .16 | | .36 | | .56 | | .76 | | .96 | | .16 | | .36 | | .56 | | .76 | | .96 | |
| .17 | | .37 | | .57 | | .77 | | .97 | | .17 | | .37 | | .57 | | .77 | | .97 | |
| .18 | | .38 | | .58 | | .78 | | .98 | | .18 | | .38 | | .58 | | .78 | | .98 | |
| .19 | | .39 | | .59 | | .79 | | .99 | | .19 | | .39 | | .59 | | .79 | | .99 | |

This table is applicable for open-channel conditions. It is based on________discharge measurements made during________________________________and is__________well defined between__________cfs and__________cfs.

Comp by______date________
Ckd by______date________

Fig. 1.03. Standard form for rating a stream gage

BI-HOURLY AND MEAN DAILY FLOW AT ____________ PROJECT ____________ MONTH ________ YEAR ________

DATE ____________

| Hr | Pen Reading | Pen Cor | Correct Gage Ht | Shift Cor | Flow in cfs |
|---|---|---|---|---|---|
| 1 | | | | | |
| 3 | | | | | |
| 5 | | | | | |
| 7 | | | | | |
| 9 | | | | | |
| 11 | | | | | |
| 13 | | | | | |
| 15 | | | | | |
| 17 | | | | | |
| 19 | | | | | |
| 21 | | | | | |
| 23 | | | | | |

TOTAL ________
MEAN ________

DATE ____________

| Hr | Pen Reading | Pen Cor | Correct Gage Ht | Shift Cor | Flow in cfs |
|---|---|---|---|---|---|
| 1 | | | | | |
| 3 | | | | | |
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| 9 | | | | | |
| 11 | | | | | |
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| 21 | | | | | |
| 23 | | | | | |

TOTAL ________
MEAN ________

DATE ____________

| Hr | Pen Reading | Pen Cor | Correct Gage Ht | Shift Cor | Flow in cfs |
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| 1 | | | | | |
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| 21 | | | | | |
| 23 | | | | | |

TOTAL ________
MEAN ________

DATE ____________

| Hr | Pen Reading | Pen Cor | Correct Gage Ht | Shift Cor | Flow in cfs |
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| 21 | | | | | |
| 23 | | | | | |

TOTAL ________
MEAN ________

DATE ____________

| Hr | Pen Reading | Pen Cor | Correct Gage Ht | Shift Cor | Flow in cfs |
|---|---|---|---|---|---|
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TOTAL ________
MEAN ________

DATE ____________

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| 1 | | | | | |
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TOTAL ________
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DATE ____________

| Hr | Pen Reading | Pen Cor | Correct Gage Ht | Shift Cor | Flow in cfs |
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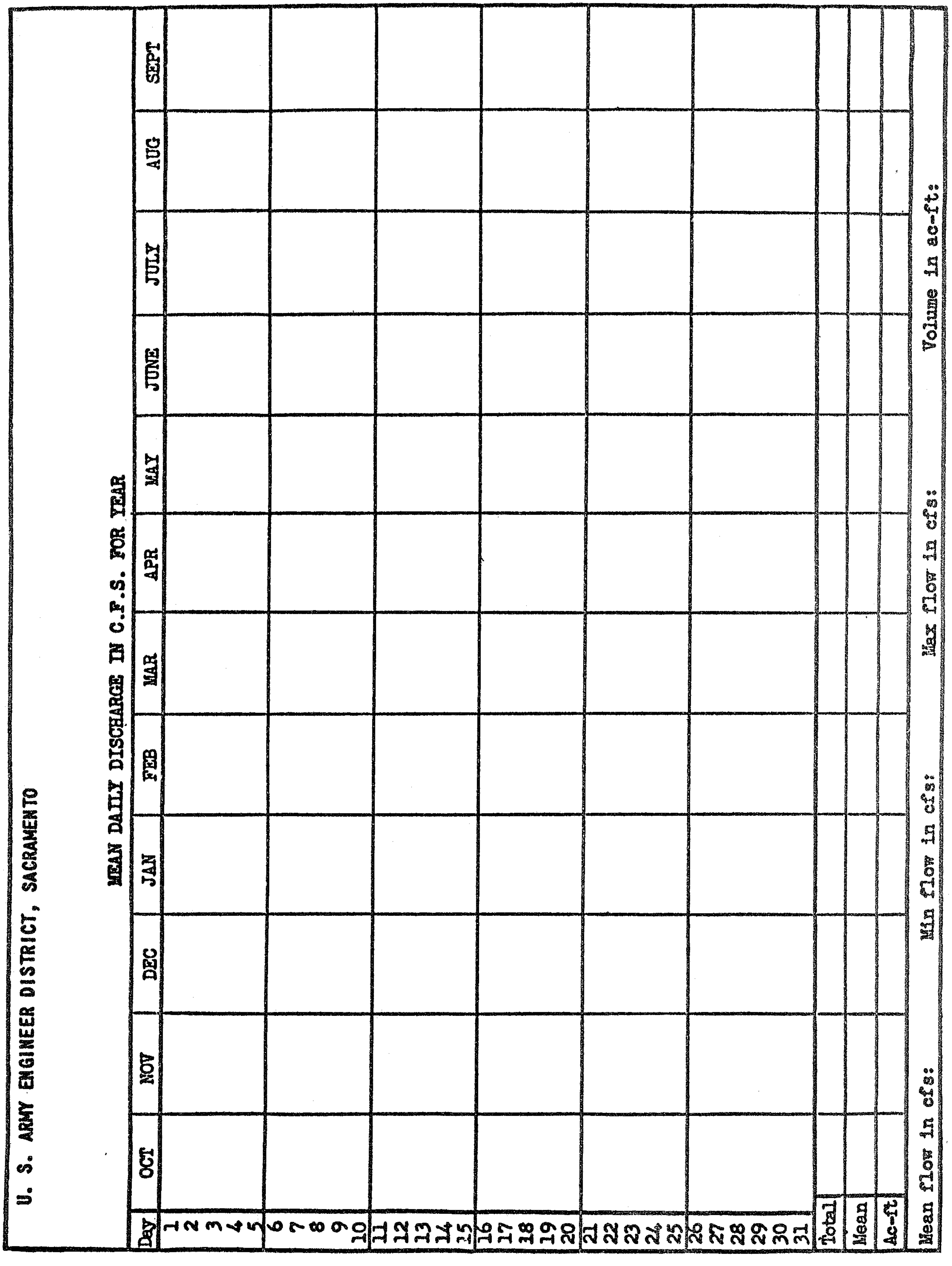
TOTAL ________
MEAN ________

REMARKS

Rating Curve No. ________

Fig. 1.04. Standard form for computing mean daily streamflows



**U. S. ARMY ENGINEER DISTRICT, SACRAMENTO**

**MEAN DAILY DISCHARGE IN C.F.S. FOR YEAR**

| Day | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| 30 | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | |
| Total | | | | | | | | | | | | |
| Mean | | | | | | | | | | | | |
| Ac-ft | | | | | | | | | | | | |

Mean flow in cfs:

Min flow in cfs:

Max flow in cfs:

Volume in ac-ft:

Fig. 1.05. Standard form for tabulating mean daily streamflows

For flood studies, it is particularly important to obtain accurate records of short-period variations during high river stages and to obtain meter measurements at or near the maximum stage during as many floods as possible. Where the river profile is very flat, as in major rivers, it is advisable to obtain meter measurements frequently on the rising stage and on the falling stage. The reason for this is that the hydraulic slope can change greatly, resulting in different rating curves for rising and falling stages.

It is of considerable value in flood control studies to obtain a complete hydrograph of flows for each flood event. Consequently, permanent records should include frequent tabulations of flows, preferably at hourly intervals or shorter. A standard form for documenting these flows is shown in fig. 1.06. Such tabulations should be maintained for easy access or should be published.

## Section 1.04. Natural Topography

### Mapping

For most hydrologic studies, it is essential that good topographic maps be used. It is important that the maps contain contours of ground-surface elevation, so that drainage basins can be delineated and important features such as slopes, exposure and stream patterns can be measured. United States Operational Navigation Charts, with a scale of 1 to 1,000,000 and contour interval of 1,000 feet, are available for most parts of the world. However, mapping to a much larger scale (1 to 25,000) and smaller contour intervals (5 to 20 feet) are usually necessary for satisfactory hydrologic studies.

### Stream Patterns and Profiles

Where detailed studies of overflow areas are required, computation of water-surface profiles is necessary. Basic data needed for this computation includes frequent, detailed cross sections of the river and overbank areas. These are usually obtained by special field surveys and

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Gage height in feet, and discharge, in cubic feet per second, at indicated time.

| HOUR | GAGE HEIGHT | DISCHARGE | HOUR | GAGE HEIGHT | DISCHARGE | HOUR | GAGE HEIGHT | DISCHARGE | HOUR | GAGE HEIGHT | DISCHARGE |
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Fig. 1.06. Standard form for tabulating hourly streamflows

are, therefore, costly. When these surveys are made, it is important to document the results permanently so that it will not be necessary to repeat them for a later study. Some work has been done to obtain relatively accurate cross section data by aerial photography, but published information on this work is not readily available. Observations of actual water-surface elevations during maximum flood stages are invaluable for calibrating backwater computations.

## Lakes and Swamps

The rate of runoff from any watershed is greatly influenced by the existence of lakes, swamps and other flat storage areas. It is therefore important to indicate these areas on available maps. Data on the outlet characteristics of lakes is important because in the absence of outflow measurements the outflow can often be computed through the development of a relationship between amount of water stored in the lake and the outlet characteristics.

## Soils and Geology

Certain maps of soils and geology can be very useful in surface-water studies if they show characteristics that relate to perviousness of the basin. These can then be used for estimating loss rates during storms. Of particular interest are areas of extensive sandy soils that do not contribute to runoff and areas of limestone and volcanic formations that are highly pervious and can store large amounts of water beneath the surface in a short time.

## Vegetal Cover

Often the type of vegetation more accurately reflects variation in hydrologic phenomena than does the type of soil or the geology. In transposing information to areas of little or no hydrologic data, generalized maps of vegetal cover are very helpful.

## Section 1.05. Existing Improvements

Streamflow at any particular location can be greatly affected by hydraulic structures located upstream. It is important, therefore, that essential data be obtained on all significant hydraulic structures located in and upstream from a study area. In the case of diversion structures, detailed data are required on the size of the diversion dam, capacity of the diversion canal, and the probable size of flood required to wash out the diversion dam. In the case of storage reservoirs, detailed data on the relation of storage capacity to elevation, location and size of outlets and spillways, types, sizes and operation of control gates, and sizes of power plant and penstocks should be known.

## Chapter 2

# Data Storage and Publication

# CHAPTER 2. DATA STORAGE AND PUBLICATION

## Section 2.01. Introduction

As a system of data collection is developed within a political subdivision, the problems of storing and retrieving information become increasingly complex and burdensome. During the early phases of a data collection program, the most expensive item is data acquisition. However, later in the program, storage and retrieval become the more expensive operations.

In order to keep costs at a minimum and permit the efficient retrieval and publication of data, it becomes necessary to use modern storage facilities, such as magnetic tape or disk storage.

## Section 2.02. Original Records

The extent to which the original observation records are stored will depend on the importance of such documents, their age, and the total volume of such storage. The original documents must be stored at least until such time as the primary processing of the data is completed, totally checked and stored for systematic retrieval. Beyond this, the basic information should be stored, if possible, in order to support legal actions and provide a basis for refining the data processing as new needs develop.

Original hydrologic records are ordinarily maintained at the location where they were observed or at the field office responsible for the collection of those records. However, where such records must be maintained for long periods of time, it may be desirable to store them at central archives especially designed to preserve and protect such records.

Before storing hydrologic records, it is essential that the original documents be totally identified with information on the estimated accuracy of the records, the physical conditions under which the data were collected, the location and description of the collection site, the date and time of observations, the nature of the measurement or observation, the techniques and equipment used to obtain the data, and other information which might be useful in future evaluations or interpretation of the records.

## Section 2.03. Processed Records

As discussed in Chapter 1, records are most useful when they are processed to form systematic tabulations such as mean daily flow or maximum and minimum daily temperatures. For such records to be useful, they must be made available to the user through systematic publication. Regardless of the retrieval process, it is usually advantageous to store the tabulations on computer cards or in one of various types of magnetic storage.

With the increasing use of the electronic computer in hydrologic analyses, many organizations are independently storing their hydrologic data on punched cards and magnetic tape. Generally, funds and time are not adequate to do this in a manner that permits these data to be satisfactorily used in other studies and, as a result, there is considerable duplication of effort. For this reason, substantial savings can be realized if a central agency is assigned the responsibility of performing this task. In order for such an operation to be successful, it is essential that the data be tabulated in a sufficiently short interval and with sufficient accuracy to permit its use for other purposes to the extent that the detail and accuracy exist in the basic observational data. It is essential that all tabulated data are completely and fully checked. Also, it is important that the data on cards or tape be easily and quickly accessible to potential users. A delay of a week can discourage some use of the data. A delay of a month will probably result in little or no use of the data. It is highly desirable to update the punched data at least annually. This can be done economically if the data are also published in tabular form, since the tables can be constructed inexpensively and accurately from the cards or magnetic tapes.

While it is important to identify the data as to location, time of observation, type of information, and unit of measurement when storing it electronically, it is not necessary to repeat detailed identification for every item of data. To do so would require too much space in the storage area. The advantage of formulating systematic tabulations of every type of data, from the standpoint of magnetic storage techniques, is that large groups of individual items can be identified by the order in which they are stored. It is then simply necessary to maintain a key to this identification in order to retrieve and utilize the information effectively.

Tabulations of the processed data should first be placed on computer cards because this is the most efficient method of accomplishing the expensive process of transferring data to electronic storage (although direct keypunching to magnetic tape is possible at some installations). As long as the number of cards is not too great, data can be stored indefinitely in this manner, provided that the cards are maintained properly. If they are used frequently, however, it may be necessary to duplicate them occasionally, because of damage that occurs in the card-reading process.

As the bulk of stored information increases it will be far more economical to store the data on magnetic tape, disks, or other types of magnetic storage, depending on the frequency of retrieval. However, the danger of losing information in magnetic storage is far greater than is the case for punched cards. It is very difficult to reconstitute a value in magnetic storage if it is defaced beyond recognition. Therefore, it is important to frequently clean the tapes or other storage media. It is also important to provide duplicate storage or some other means of reconstituting values that might be defaced.

Storage of every item in at least two locations is desirable if the tabulation process is different in the two locations and is designed for more efficient retrieval. The combinations of information needed for solving various problems are usually different, and the optimum sequence of tabulating the data are different for each retrieval needed. Consequently, tabulations of basic data in two or more different sequences should be designed so that the user can select the stored sequence that best suits his need. If these independently stored sets of common data are maintained at different locations to prevent simultaneous destruction by a single disaster, the need to preserve the basic information is satisfied, and the retrieval process is made more efficient.

Once the data are tabulated systematically for electronic storage, they can be processed for publication with very little effort and expense. Accordingly, it is usually undesirable to process the data entirely for publication and later to process the same information for electronic storage. For example, daily streamflow records for all of the coastal streams in Peru were obtained from systematic tabulations and punched directly on computer cards. These cards were then used in conjunction with a simple computer program to provide printouts that could be reproduced directly for publication, without requiring any significant amount of special typing or printing.

## Section 2.04. Selection of Material for Publication

The amount of hydrologic information that needs to be published will depend on what alternative means exist for distributing the information. Presently, most of the basic information that is used frequently by large numbers of users should be published. However, if a good network of electronic retrieval and transmission facilities exists, a user provided with a good index of data availability might obtain the necessary information more efficiently by electronic means. This would greatly increase the efficiency of use, because it would provide the material in a form directly usable for electronic computations.

At the present state of development of electronic networks, it is almost universally necessary to publish essential basic information. This should consist of systematic summaries of data in the form that is most frequently used, but should be restricted to basic information to allow adaptability to the greatest variety of problem solutions. Mean daily observed streamflow is an excellent example of highly usable basic information. Such streamflows adjusted for upstream regulation or diversions might not be so useful, because the adjustment process used might not be acceptable for certain applications. It is essential to identify the published data and to supply information on the measurement process and the reliability. It is also desirable to have information on known conditions that have affected the observations, such as upstream regulations and diversions.

Published information should be indexed for ready identification and retrieval. In the case of hydrologic data, this ordinarily requires location on a map of suitable scale and construction.

## Chapter 3

# Adjustment of Runoff Data

# CHAPTER 3. ADJUSTMENT OF RUNOFF DATA

## Section 3.01. Introduction

Adjustment of recorded streamflows is often required before the data can be used in water resources development studies. This is because flow information usually is required at locations other than gaging stations and for conditions of upstream development other than those under which flows occurred historically.

## Section 3.02. Need for Adjusted Runoff Data

In correlating flows between locations, it is desirable to use "natural" flows (unaffected by artificial storage and diversion) in order that correlation procedures will apply logically and efficiently. In generating flows as discussed in Chapter 5, it is even more desirable that natural flows be used, because general frequency functions characteristic of natural flows are employed in this process. It is not always feasible to convert flows to natural conditions, because required data might not be available or the flow modification might be so complex as to require an unreasonable amount of computation. When feasible, however, conversion is made by adding historical storage changes (plus net evaporation) and upstream diversions (less return flows) to historical flows at the gaging stations for each interval in turn. Under some conditions, it is necessary to account for differences in channel and overbank percolation losses, distributary flow diversions, travel times and other factors. Methods of determining evaporation and other losses are described in Volume 8. When it is not feasible to convert flows completely to natural conditions, they should be adjusted, if only approximately, to a uniform condition, such as present conditions. In such cases, every reasonable effort should be made to remove special influences (such as the influence of one major reservoir) that would cause unnatural variations of flow.

When it is necessary to adjust flows to a condition of higher regulation or depletion, the reverse process is used. Water that would be stored or depleted each period should be subtracted from observed flows.

## Section 3.03. Estimates of Stream Depletions

Estimation of historical depletions should be based on measurements of actual river diversions and return flows, but these are not always available. Estimation of channel and evaporation losses is important in many regions and should be based generally on observed depletions between gages where other losses or gains are not significant. Some estimates of stream depletions due to diversions for water use can be made by using tables 3-01 to 3-05.

## Table 3.01. Estimated municipal and industrial demand (based on experience in the United States)

| Population (thousands) | Low gpcpd* | Average gpcpd* | High gpcpd* |
|---|---|---|---|
| 1 | 60 | 80 | 100 |
| 5 | 70 | 120 | 150 |
| 10 | 80 | 140 | 180 |
| 50 | 90 | 150 | 210 |
| 100 or more | 100 | 160 | 230 |

* Multiply by .003785 to obtain cubic meters per capita per day.

Notes:

(1) Average demand based on use as follows: 40% domestic, 35% industrial, 10% public, and 15% waste and miscellaneous.

(2) Industrial requirements vary widely among industries and, therefore, if it appears that industrial requirements will be relatively large, specific information concerning the industry and its needs should be obtained.

(3) It has been estimated that between 75% and 90% of the total demand is returned to streamflow via sanitary sewers and industrial waste outlets.

Table 3.02. Seasonal variation in municipal and industrial water supply demand

| Month | Small Variation | Average Variation | Large Variation |
|---|---|---|---|
| | | (Percent of Annual Total) | |
| January | 7 | 6 | 4 |
| February | 7 | 6 | 4 |
| March | 7 | 6 | 4 |
| April | 7 | 7 | 6 |
| May | 8 | 8 | 7 |
| June | 9 | 10 | 9 |
| July | 10 | 11 | 14 |
| August | 10 | 12 | 16 |
| September | 10 | 11 | 14 |
| October | 9 | 9 | 12 |
| November | 9 | 8 | 6 |
| December | 7 | 6 | 4 |
| TOTAL | 100 | 100 | 100 |

Note: Seasonal variation in demand is highly dependent upon climatic variations. Large climatic variations cause large demand variations particularly in arid or semiarid regions. Shift 6 months for Southern Hemisphere.

Table 3.03. Estimated annual water requirements for various crops at various irrigation efficiency ranges

| | Low efficiency 30% - 35% meters | Avg efficiency 35% - 45% meters | High efficiency 45% - 50% meters |
|---|---|---|---|
| Pasture, alfalfa and other forage crops | 2.0 | 1.5 | 0.8 |
| Potatoes, sugar beets, cotton | 1.5 | 1.0 | 0.5 |
| Cereals (excluding rice) | 1.0 | 0.8 | 0.3 |
| Rice | 3.0 | 2.5 | 2.0 |
| Deciduous fruits | 1.5 | 1.0 | 0.8 |
| Small fruits, grapes | 1.0 | 0.8 | 0.5 |
| Citrus fruits | 1.5 | 1.0 | 0.8 |
| Vegetables | 1.5 | 1.0 | 0.3 |

Notes:

(1) Total water requirement. Precipitation immediately prior to and during growing season should be deducted to obtain irrigation requirements.

(2) Conveyance losses and wastes are not included.

Table 3.04. Typical monthly variations in irrigation requirements

| Month | Small Variation | Average Variation | Large Variation |
|---|---|---|---|
| | | (Percent of annual total) | |
| January | 5 | 0 | 0 |
| February | 6 | 0 | 0 |
| March | 10 | 2 | 0 |
| April | 10 | 13 | 0 |
| May | 10 | 20 | 1 |
| June | 11 | 19 | 11 |
| July | 11 | 19 | 23 |
| August | 10 | 13 | 30 |
| September | 19 | 10 | 27 |
| October | 7 | 3 | 8 |
| November | 6 | 1 | 0 |
| December | 5 | 0 | 0 |
| TOTAL | 100 | 100 | 100 |

Note: Variation in time of growing season could require shifting forward or backward the tabulated monthly schedules. Shift 6 months for Southern Hemisphere.

Table 3.05. Losses and wastes expressed as percentage of total diverted flow

| | Low | Average | High |
|---|---|---|---|
| Conveyance loss | 15 | 30 | 50 |
| Conveyance waste | 5 | 15 | 30 |

Chapter 4

# Regional Analysis

# CHAPTER 4. REGIONAL ANALYSIS

## Section 4.01. Introduction

It is very important in the development of hydrologic criteria for regions of sparse data to formulate generalized hydrologic relationships through which all pertinent available data can be used for estimating hydrologic quantities at any particular location. Even in regions where data are more plentiful, regional studies are helpful and, in fact, necessary in order to make the most effective use of available information. Such studies are useful for transferring information both to ungaged and gaged locations to improve the quality of estimates based on gaged data for that location. Once a basic generalized study is completed, relatively dependable estimates of hydrologic quantities can be made rapidly and inexpensively, thus greatly expanding the capability of assessing the nature and magnitude of hydrologic problems and of devising remedial measures.

In formulating generalized criteria for a region, care must be exercised in selecting the hydrologic variables to be studied. These should be effective and efficient indices that are directly pertinent to the types of hydrologic problems expected to occur. There are several very general indices that are commonly used and are useful in almost any region. These consist of maps of normal or average seasonal precipitation, maps of average annual runoff, envelope curves of maximum observed flows in relation to the size of drainage basin, and others.

## Section 4.02. Coordination of Station Data

A regional study is best accomplished by first establishing the most dependable form of an index expressing the variation of a pertinent hydrologic variable for each gaged location, and then correlating that index with pertinent characteristics of the various locations. In many cases, the reliability of an index for any gaged location can be increased by correlating data at that location with any related data that extend over a longer period at other locations. This would apply, for example, to monthly streamflows or maximum or minimum annual events. The incremental amount of information obtainable in this manner is a direct function of the additional length of time that data are available at the other locations and of the degree of correlation with the other locations. While it is most common to correlate only identical phenomena, such as runoff at one location vs. runoff at another location, it can also be helpful to relate different phenomena that would reasonably correlate, such as runoff with precipitation.

While it is not necessary to estimate each item of missing data in order to improve the quality of an index of those data, it is usually desirable to do so. However, there are some difficulties that should be recognized, and the estimated quantities should be used with appropriate care. In estimating missing values for a short record, it is important that pertinent characteristics of the short-record data be preserved and, in most cases, that pertinent interrelationships between the sets of data at the various locations also be preserved. For example, if streamflow stations on two tributaries are to be used for design of projects that will serve a common need, then it is important to consider whether extreme events occur simultaneously or at different times on the two tributaries. If some data are estimated in such a manner that the resulting intercorrelation between data on the two tributaries is changed, this can greatly affect the design of such projects.

In estimating individual data values for a short-record location by correlation with longer-record locations, the only feasible means of preserving the variance at the short-record location and the intercorrelation among locations requires that a random component be introduced into each estimate. This represents that portion of the quantity that is not related to events at other locations. Since this portion of the estimate is random, it must be recognized that quantities estimated by different individuals in the same manner would ordinarily not agree item by item.

Ordinarily, the best estimate of missing data is obtained by relating data to several other locations, rather than only one. This is feasible through multiple correlation analysis, and will ordinarily improve the reliability of estimates considerably over those obtainable through simple correlation analysis. Furthermore, the interrelationships among several locations, which may be of primary concern in system development, are best preserved through multiple correlation analysis. A computer program for estimating missing values of average monthly streamflow (or other hydrologic phenomena) has been developed in The Hydrologic Engineering Center of the Corps of Engineers and is described in Appendix 1. The techniques used in this program, which include multiple correlation analysis and use of random components, can be adapted in estimating hydrologic phenomena for time intervals other than 1 month.

It is not necessary, and sometimes not desirable, to estimate missing data in order to transfer information from one location to another. Certain statistics or indices that are computed from short records can be adjusted to account for additional data at other locations by use of a relationship between the short-period and long-period statistics at the long-record location. An example of such estimation of frequency statistics is given in Volume 3.

## Section 4.03. Indices of Hydrologic Phenomena

For various reasons, regional studies of hydrologic phenomena should be limited to the minimum number of indices that are needed for application in planning and design studies. The principal reasons are that generalized studies require substantial effort and time, and that application of generalized criteria can be seriously handicapped if the indices used duplicate each other in any substantial degree. Accordingly, indices to be used in regionalized studies should be those representing the most influential hydrologic elements and should be as independent of each other as possible. Some commonly used indices are described in the following paragraphs.

A study of storm precipitation must include analysis of variations in precipitation with respect to duration and area. It is possible to represent storm depth-area-duration data by a set of figures for specific sizes of area and specific durations. However, adequate representation would require numerous items in each set, and these items would be highly interrelated. Consequently, they do not constitute good indices for regional studies. On the other hand, observation of many relationships between depth and duration in actual storms indicates that the following equation, involving two independent constants, can be used to closely represent the relationship between depth and duration in any particular storm.

$$\bar{P} = aT^{-b} \tag{4-1}$$

where:

$\bar{P}$ = average rate of precipitation
$T$ = duration
$a$ = constant coefficient
$b$ = constant exponent

Similarly, relationships exist between depth and size of area, but these are not so uniform in observed storms. In general, however, the following relationship can be used as a basis for regional studies, and can be supplemented by refinements in the descriptive function of precipitation vs. duration and area as necessary.

$$\bar{P} = aT^{-b}A^{-c} \tag{4-2}$$

where:

$A$ = area covered by precipitation
$c$ = constant exponent

The most commonly used indices of frequency or probability of hydrologic events are functions of moments of statistical distributions, which are discussed in Volume 3. Probably the best standard approach to regional analysis of the frequency of flood events involves using the mean logarithm and the standard deviation of logarithms of annual maximum events, each in multiple correlation with physical characteristics pertinent to the location.

The skew coefficient, which is related to the third moment of the observations at a particular location, is ordinarily highly erratic and undependable. Consequently, it is usually advisable to adopt an average skew coefficient for an entire region, rather than to correlate this index with physical characteristics. Indices of higher moments are increasingly erratic, and are usually ignored in regional analysis. It might be found in some cases that a parameter representing an event larger than that represented by the mean logarithm would represent a more stable phenomenon and would correlate better than the mean logarithm with physical characteristics. Such a less-common event might be desirable as an index if it more nearly approximates the magnitudes of interest in the study. Occasionally, the magnitude that is exceeded on the average of once in 10 years is used, because it represents a magnitude of more direct interest than the mean magnitude and yet can be estimated with an acceptable degree of reliability. Some generalized studies of hydrologic frequencies include separate correlation of a number of magnitudes corresponding to various exceedence probabilities. This is probably unnecessary, and introduces the problem of coordinating the various magnitudes that are estimated for ungaged locations.

There is considerable merit in some systematic approach or uniformity in the selection of indices, because this would permit ready comparisons of relationships developed for different regions. Some common recommended indices are as follows:

a. Precipitation.

(1) Normal or average annual precipitation.

(2) Normal or average seasonal precipitation (where two or more rainy seasons with different characteristics exist).

(3) Average depth of maximum storm precipitation for 24 hours over 200 square miles (or 500 square kilometers).

(4) Average depth of maximum thunderstorm precipitation for 3 hours over 50 square miles (or 100 square kilometers).

b. Runoff.

(1) Mean annual runoff.

(2) Maximum rate of flow for each storm or each year or for a specified probability.

(3) Maximum rate of flow per unit of area expressed as a coefficient, c, in the formula, $Q = cA^{1/2}$.

(4) Maximum or minimum volume of runoff expressed as average rate of flow for a specified duration.

c. Rainfall-runoff relations.

(1) Infiltration index.

(2) Clark's (TC + R) and (R/(TC + R)) (see Volume 4).

d. Temperatures.

(1) Sea level temperatures computed from observed surface temperatures, assuming that a normal lapse rate extends from the surface elevation to sea level.

(2) Average daily maximum temperature for a specified period.

(3) Average daily minimum temperature for a specified period.

(4) Average temperature for a specified period.

e. Snowpack.

(1) Water equivalent of snowpack at a particular location.

## Section 4.04. Correlation Analysis

### Nature and Application

Correlation is the process of determining the manner in which the changes in one or more independent variables affect another (dependent) variable. The dependent variable is the value sought and it is known to be physically related to various independent variables. For example, the runoff volume during the spring months at a given point on a river (dependent variable) might be correlated with the depth of snow cover above that point (independent variable). Recorded values of such variables over a period of years might be plotted, and the apparent relation sketched in by eye. However, correlation methods will generally permit a more dependable determination of the relation and have the additional advantage of providing means for evaluating the dependability of the relation or of estimates based on the relation. Correlations can be linear or curvilinear, but linear regression suffices for most applications. For this reason, curvilinear regression is not discussed in this volume.

## Calculation of Regression Equations

In a simple correlation (only one independent variable), the linear regression equation is written:

$$Y = a + bX \tag{4-3}$$

where:

$Y$ = the dependent variable
$X$ = the independent variable
$a$ = the regression constant
$b$ = the regression coefficient

The coefficient b is evaluated from the tabulated data by use of equations 4-13 and 4-14 and the following equation:

$$b = \Sigma(yx)/\Sigma(x)^2 \tag{4-4}$$

where:

$y$ = the deviation of each single value $Y$ from $\bar{Y}$, the mean of its series
$\bar{Y}$ = $\Sigma Y/N$
$N$ = the number of observations of $Y$

The value, x, is defined similarly as the deviations of X from its mean. The regression constant, a, is obtained from the tabulated data by use of the following equation:

$$a = \bar{Y} - b\bar{X} \qquad (4\text{-}5)$$

In a multiple correlation (more than one independent variable) the linear regression equation is written:

$$Y = a + b_1X_1 + b_2X_2 \; . \; . \; . \; . + b_nX_n \qquad (4\text{-}6)$$

where n is the total number of independent variables, and a, b, Y and X are defined as in equation 4-3.

In the case of two independent variables, the b coefficients are evaluated from the tabulated data by solution of the following simultaneous equations:

$$\Sigma(x_1)^2b_1 + \Sigma(x_1x_2)b_2 = \Sigma(yx_1) \qquad (4\text{-}7)$$

$$\Sigma(x_1x_2)b_1 + \Sigma(x_2)^2b_2 = \Sigma(yx_2) \qquad (4\text{-}8)$$

where x, y, and b are defined as in equation 4-4.

In the case of three independent variables, the b coefficients can be evaluated from the tabulated data by solution of the following simultaneous equations:

$$\Sigma(x_1)^2b_1 + \Sigma(x_1x_2)b_2 + \Sigma(x_1x_3)b_3 = \Sigma(yx_1) \qquad (4\text{-}9)$$

$$\Sigma(x_1x_2)b_1 + \Sigma(x_2)^2b_2 + \Sigma(x_2x_3)b_3 = \Sigma(yx_2) \qquad (4\text{-}10)$$

$$\Sigma(x_1x_3)b_1 + \Sigma(x_2x_3)b_2 + \Sigma(x_3)^2b_3 = \Sigma(yx_3) \qquad (4\text{-}11)$$

For cases of more than three independent variables, the appropriate set of simultaneous equations can be easily constructed after studying the patterns of the above two sets of equations. Computer programs are available for solution of simple or multiple linear regression problems on practically any type of electronic computer.

For multiple regression equations, the regression constant, a, should be determined as follows:

$$a = \bar{Y} - b_1\bar{X}_1 - b_2\bar{X}_2 \; . \; . \; . \; . - b_n\bar{X}_n \qquad (4\text{-}12)$$

where $\bar{Y}$, b, and n are defined as in equations 4-5 and 4-6, and $\bar{X}_1$, $\bar{X}_2$ and are the means of the respective independent variables.

In equation 4-4 and equations 4-7 to 4-11, the quantities $\Sigma(y)^2$, $\Sigma(x)^2$, and $\Sigma(yx_1)$ are obtainable rapidly by use of the following equations:

$$\left.\begin{aligned} \Sigma(y)^2 &= \Sigma(Y)^2 - (\Sigma Y)^2/N \\ \Sigma(x)^2 &= \Sigma(X)^2 - (\Sigma X)^2/N \end{aligned}\right\} \tag{4-13}$$

$$\Sigma(yx_1) = \Sigma(YX_1) - \Sigma Y \ \Sigma X_1/N \tag{4-14}$$

where x, X, y, Y, and N are defined as in equations 4-3 and 4-6.

## The Correlation Coefficient and Standard Error

The coefficient of determination is defined as the proportion of the variance of the dependent variable that is explained by the regression equation. The correlation coefficient is defined as the square root of the coefficient of determination. A correlation coefficient of 1.00 would correspond to a coefficient of determination of 1.00, and is the highest coefficient theoretically possible. This indicates that whenever the values of the independent variables are known exactly, the corresponding value of the dependent variable can be calculated exactly. On the other hand, a correlation coefficient of 0.5 would correspond to a coefficient of determination of 0.25, which would indicate that 25 percent of the variance is explained and 75 percent is unexplained.

The correlation coefficient ($\bar{R}$) is determined by first computing the unadjusted determination coefficient ($R^2$) as follows:

$$R^2 = \frac{b_1\Sigma(yx_1) + b_2\Sigma(yx_2) \ . \ . \ . \ . + b_n\Sigma(yx_n)}{\Sigma(y)^2} \tag{4-15}$$

where n is the number of independent variables, and b, y, and x are defined as in previous equations.

$R^2$ is the determination coefficient of the given sample and must, therefore, be adjusted to the universe by applying the following equation to determine the adjusted determination coefficient, $\bar{R}^2$:

$$\bar{R}^2 = 1 - (1 - R^2)(N - 1)/df \qquad (4\text{-}16)$$

where:

N = total number of observations used in the correlation analysis

df = the number of degrees of freedom

The number of degrees of freedom is obtained by subtracting the total number of dependent and independent variables from the number of observations used in the correlation analysis. Therefore, df would equal N - (n + 1).

As was previously noted, the correlation coefficient is then simply the square root of $\bar{R}^2$.

In the case of simple correlation, equation 4-15 resolves to:

$$R^2 = \frac{(\Sigma yx)^2}{\Sigma y^2 \Sigma x^2} \qquad (4\text{-}17)$$

The standard error ($S_e$) of a set of estimates is the root-mean-square error of those estimates. On the average, about one out of three estimates will have errors greater than the standard error and about one out of 20 will have errors greater than twice the standard error. The error variance ($S_e^2$) is the square of the standard error. The standard error or error variance of estimates based on a regression equation is calculated from the data used to derive the equation by use of either of the following equations:

$$S_e^2 = \frac{\Sigma(y)^2 - b_1\Sigma(yx_1) - b_2\Sigma(yx_2) \;.\;.\;.\;.\; - b_n\Sigma(yx_n)}{df} \qquad (4\text{-}18)$$

$$S_e^2 = (1 - \bar{R}^2)\Sigma(y)^2/(N - 1) \qquad (4\text{-}19)$$

where x, y, b, df, n, $\bar{R}^2$ and N are defined as in the previous equations.

In addition to considering the amount of variance that is indicated by the correlation coefficient and standard error to be solved by the regression equation, it is important to consider the reliability of these indications. There is some chance that any correlation is accidental, but the higher the correlation and the larger the sample upon which it is based, the less is the chance that it would occur by accident. Also, the reliability of a regression equation decreases as the number of independent variables increases. For example, an unadjusted correlation coefficient (R) of 0.8 based on a simple linear correlation with 12 degrees of freedom corresponds to a true value as low as 0.53 in one case out of 20. On the other hand, R based on a multiple linear correlation with 12 degrees of freedom, 1 dependent variable, and 7 independent variables corresponds to a true value as low as 0 in one case out of 20. With only 4 degrees of freedom, a value of R of 0.97 would one time in 20 correspond to a true value as low as 0.8 in the case of simple correlation and as low as zero in a 7-variable multiple correlation. Accordingly, extreme care must be exercised in the use of multiple correlation in cases based on small samples. Reference 5 (pp. 506-509) gives a set of charts illustrating the above examples.

## Simple Linear Correlation Example

An example of a simple linear correlation analysis is illustrated in figs. 4.01 and 4.02. The study from which this example was taken involved the determination of the areal distribution of short-duration precipitation in a mountainous region. Since short-duration measurements were available at a relatively small number of locations, it was decided to investigate the relationship of short-duration precipitation to long-duration precipitation measurements that were available at many locations.

Since the long-duration precipitation is made up of the sum of short-duration precipitation amounts, there is no question as to the existence of a physical relationship, and it is obvious that the first requirement of a correlation analysis (logical physical relationship) is

## Fig. 4.01. Computation of simple linear correlation

|  | Max. 12 hr |  | Mean Annual |  |  | Max. 12 hr |  | Mean Annual |  |
|---|---|---|---|---|---|---|---|---|---|
| Sta. (1) | (Y') In. (2) | (Y) Log. (3) | (X') In. (4) | (X) Log. (5) | Sta. (6) | (Y') In. (7) | (Y) Log. (8) | (X') In. (9) | (X) Log. (10) |
| 7-0-12 | 3.1 | .49 | 10.0 | 1.00 | 7-0-309 | 4.6 | .66 | 19.2 | 1.28 |
| 7-0-15 | 7.5 | .88 | 30.8 | 1.49 | 7-P-20 | 5.2 | .72 | 13.3 | 1.12 |
| 7-0-22 | 12.6 | 1.10 | 42.2 | 1.63 | 7-P-25 | 3.1 | .49 | 12.2 | 1.09 |
| 7-0-23 | 10.4 | 1.02 | 36.2 | 1.56 | 7-P-61 | 4.9 | .69 | 12.2 | 1.09 |
| 7-0-36 | 4.9 | .69 | 15.4 | 1.19 | 8-O-8 | 5.2 | .72 | 25.2 | 1.40 |
| 7-0-39 | 7.1 | .85 | 20.0 | 1.30 | 8-0-18 | 4.6 | .66 | 18.5 | 1.27 |
| 7-0-43 | 5.3 | .72 | 14.2 | 1.15 | 8-0-29 | 11.8 | 1.07 | 32.3 | 1.51 |
| 7-0-77 | 9.7 | .99 | 24.5 | 1.39 | 8-0-34 | 12.4 | 1.09 | 33.8 | 1.53 |
| 7-0-84 | 6.2 | .79 | 19.3 | 1.29 | 8-0-35 | 10.1 | 1.00 | 29.8 | 1.47 |
| 7-0-89 | 10.0 | 1.00 | 18.8 | 1.27 | 8-0-45 | 6.0 | .78 | 19.7 | 1.29 |
| 7-0-93 | 6.0 | .78 | 16.2 | 1.21 | 8-0-60 | 8.2 | .91 | 22.5 | 1.35 |
| 7-0-95 | 5.8 | .76 | 18.2 | 1.26 | 8-0-67 | 9.8 | .99 | 28.7 | 1.46 |
| 7-0-99 | 4.5 | .65 | 15.8 | 1.20 | 8-0-75 | 11.7 | 1.07 | 36.9 | 1.57 |
| 7-0-102 | 5.3 | .72 | 17.3 | 1.24 | 8-0-219 | 10.0 | 1.00 | 27.8 | 1.44 |
| 7-0-110 | 9.3 | .97 | 21.3 | 1.33 | 7-0-434 | 6.7 | .83 | 23.1 | 1.36 |
| 7-0-114 | 8.5 | .93 | 26.8 | 1.43 |  |  |  |  |  |
| 7-0-120 | 11.6 | 1.06 | 29.0 | 1.46 |  |  |  |  |  |
| 7-0-122 | 10.5 | 1.02 | 28.8 | 1.46 |  |  |  |  |  |
| 7-0-124 | 11.6 | 1.06 | 31.1 | 1.49 |  |  |  |  |  |
| 7-0-125 | 9.9 | 1.00 | 27.9 | 1.45 |  |  |  |  |  |
| 7-0-127 | 12.9 | 1.11 | 32.2 | 1.51 |  |  |  |  |  |
| 7-0-130 | 13.4 | 1.13 | 44.6 | 1.65 |  |  |  |  |  |
| 7-0-133 | 8.4 | .92 | 23.8 | 1.38 |  |  |  |  |  |
| 7-0-136 | 7.9 | .90 | 27.2 | 1.43 |  |  |  |  |  |
| 7-0-149 | 8.0 | .90 | 19.2 | 1.28 |  |  |  |  |  |
| 7-0-182 | 5.2 | .72 | 16.1 | 1.21 |  |  |  |  |  |
| 7-0-190 | 6.9 | .84 | 20.9 | 1.32 |  |  |  |  |  |

$N = 42$ $\quad$ $N = 42$

$\Sigma Y = 36.68$ $\quad$ $\Sigma X = 56.81$

$\bar{Y} = .873$ $\quad$ $\bar{X} = 1.353$

$\Sigma Y^2 = 33.2134$ $\quad$ $\Sigma X^2 = 77.8041$

$(\Sigma Y)^2/_N = 32.0339$ $\quad$ $(\Sigma X)^2/_N = 76.8423$

$\Sigma y^2 = 1.1795$ $\quad$ $\Sigma x^2 = .9618$

$\Sigma(YX) = 50.5601$

$\Sigma Y \Sigma X/N = 49.6141$

$\Sigma(yx) = .9460$

$b = .9460/.9618 = 0.98$ (eq. 4-4)

$a = .873 - .98\,(1.353) = -.453$ (eq. 4-5)

$$R^2 = \frac{(.9460)^2}{(1.1795)(.9618)} = 0.789 \quad \text{(eq. 4-17)}$$

$\bar{R}^2 = 1 - (0.211)\ 41/40 = 0.78$ (eq. 4-16) $\quad \bar{R} = 0.88$

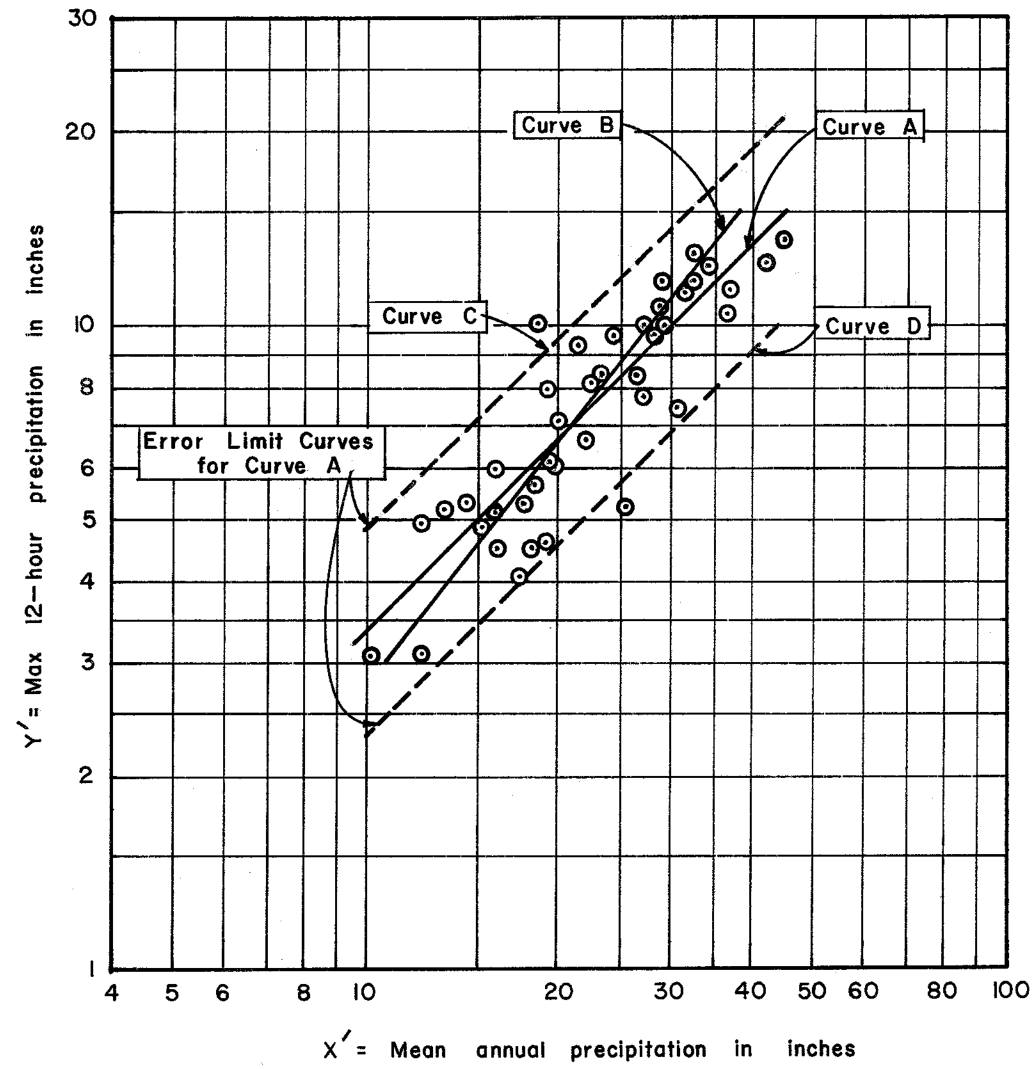
$Y = .98X - 0.45$ (regression eq., eq. 4-6)

$\log Y' = .98 \log X' - 0.45 = \log(.36\,X'^{.98})$

$Y' = .36\,X'^{.98}$ (transformed regression eq.)

$S_e^2 = 0.22\,(1.18)/41 = .0063$ (eq. 4-19)

$S_e = .079$ $\qquad$ antilog$(2\,S_e) = 1.44$



NOTE: See fig. 4.01 for computations for Curve A.

Fig. 4.02. Illustration of simple linear correlation.

satisfied. Values of maximum recorded 12-hour precipitation and of mean annual precipitation were tabulated as shown in fig. 4.01 and plotted as shown in fig. 4.02. It was determined that the relation on logarithmic paper would logically approximate a straight line. Accordingly, the logarithms of the values were tabulated, and a linear correlation study performed, as illustrated in fig. 4.01, using equations given previously. As the item to be calculated is the short-duration precipitation, the logarithm of that item is selected as the dependent variable (Y).

The regression equation is plotted as Curve A in fig. 4.02. This curve represents the best estimate of the maximum 12-hour precipitation based on the linear correlation study.

In addition to the curve of best fit, approximate reliability-limit curves are established at a distance of 2 standard errors from Curve A. As logarithms are used in the regression analysis, the effect of adding (or subtracting) twice the standard error to the estimate is equivalent to multiplying (or dividing) the precipitation values by the antilogarithm of twice the standard error. In this case, the standard error is 0.079, and the antilogarithm of twice this quantity is 1.44. Hence, values of 12-hour precipitation represented by the limit curves are those of Curve A multiplied and divided respectively by 1.44. In about 95 percent of all cases, the true value of the dependent variable will lie between these limit curves.

## Factors Responsible for Nondetermination

Factors responsible for correlations being less than 1.0 (perfect correlation) consist of pertinent factors not considered in the analysis and of errors in the measurement of those factors considered. If the effect of measurement errors is appreciable, it is possible in some cases to evaluate the standard error of measurement of each variable and to adjust the correlation results for such effects.

If an appreciable portion of the variance of $X_1$ (dependent variable) is attributable to measurement errors, then the regression equation would be more reliable than is indicated by the standard error of estimate computed from equations 4-18 or 4-19. This is because the departure of some of the points from the regression line in fig. 4.02 is artifically increased by measurement errors and therefore exaggerates the unreliability of the regression function. In such a case, the curve is generally closer to the true values than to the erroneous observed values. Where there are large measurement errors in the dependent variable, the error of regression estimates should be obtained by subtracting the measurement error variance from the error variance obtained from equation 4-18 or 4-19. If well over half of the variance of the points from the best-fit line is attributable to measurement error in the dependent variable, then the regression line would actually yield a better estimate of a value than the original measurement.

If appreciable errors exist in the values of the independent variable, the regression coefficient and constant will be affected, and fallacious estimates will result. Hence, it is important that values of the independent variable be determined as accurately as possible.

In the previous example, there may well be factors responsible for high short-time intensities that do not contribute appreciably to annual precipitation. Consequently, some locations with extremely high mean annual precipitation may have maximum short-time intensities that are not correspondingly high, and vice versa. Therefore, the station having the highest mean annual precipitation would not automatically have the highest short-time intensity. For the same example, if mean annual precipitation were made the dependent variable, the station having the highest short-time intensity would not automatically have the highest value of mean annual precipitation. Thus, by interchanging the variables, a change in the regression line is effected. Curve B in fig. 4.02 is the regression curve obtained by interchanging the variables Y and X. As there is a considerable difference in the two regression curves (since errors are being minimized in different directions), it is important to use the variable whose value is to be calculated from the regression equation as the dependent variable. If it is obvious that all of the pertinent variables are included in the analysis, then the variance of the points about the regression line and differences in the slopes of the regression lines are due entirely to measurement errors. An average slope of the regression line can be obtained by use of the following equation:

$$b = \left[\frac{\Sigma y^2}{\Sigma x_1^2}\right]^{1/2} = \left[\frac{\Sigma Y^2 - (\Sigma Y)^2 / N}{\Sigma X_1^2 - (\Sigma X_1)^2 / N}\right]^{1/2} \qquad (4\text{-}20)$$

where all the terms are defined as in previous equations.

## Multiple Linear Correlation Example

An example of a multiple linear correlation is illustrated in fig. 4.03. In this case, the volume of spring runoff is correlated with the water equivalent of the snow cover measured on April 1, the winter low-water flow (index of ground water) and the precipitation falling on the area during April. Here again, it was determined that logarithms of the values would be used in the regression equation. The number of degrees of freedom (8) is the number of observations (12) minus the number of independent and dependent variables (4). Although use of 4 degrees of freedom of the 12 available is not ordinarily desirable, the correlation attained (0.96) is particularly high, and the equation is consequently fairly reliable. Note that the column arrangement with dependent variable last results in an arrangement of the cross-product sums identical to their arrangement in the simultaneous equations.

In determining whether logarithms should be used for the dependent variable as above, questions such as the following should be considered: "Would an increase in snow cover contribute a greater increment to runoff under conditions of high ground water (wet ground conditions) than under

Fig. 4.03. Computation of multiple linear correlation

| Water Year (1) | $X_1$ Log. Snow Cover (2) | $X_2$ Log. Ground Water (3) | $X_3$ Log. April Precip. (4) | $Y$ Log. Runoff (5) |
|---|---|---|---|---|
| 1936 | .399 | .325 | .710 | .939 |
| 1937 | .343 | .385 | .634 | .945 |
| 1938 | .369 | .408 | .886 | 1.052 |
| 1939 | .246 | .428 | .581 | .744 |
| 1940 | .181 | .316 | 1.027 | .666 |
| 1941 | .297 | .460 | 1.315 | 1.081 |
| 1942 | .299 | .511 | 1.097 | 1.060 |
| 1943 | .354 | .379 | .707 | .892 |
| 1944 | .295 | .395 | 1.240 | 1.021 |
| 1945 | .321 | .376 | 1.091 | .920 |
| 1946 | .168 | .413 | 1.038 | .755 |
| 1947 | .280 | .410 | .979 | .960 |
| | $\Sigma X_1 = 3.552$ | $\Sigma X_2 = 4.806$ | $\Sigma X_3 = 11.305$ | $\Sigma Y = 11.035$ |
| | $X_1 = .296$ | $X_2 = .400$ | $X_3 = .942$ | $\overline{Y} = .920$ |
| | $\Sigma(X_1)^2 = 1.1059$ | $\Sigma(X_1 X_2) = 1.4197$ | $\Sigma(X_1 X_3) = 3.2898$ | $\Sigma(X_1 Y) = 3.3365$ |
| | $(\Sigma X_1)^2/_N = 1.0514$ | $(\Sigma X_1 \Sigma X_2)/_N = 1.4226$ | $(\Sigma X_1 \Sigma X_3)/_N = 3.3463$ | $(\Sigma X_1 \Sigma Y)/_N = 3.2664$ |
| | $\Sigma(x_1^2) = .0545$ | $\Sigma(x_1 x_2) = -.0029$ | $\Sigma(x_1 x_3) = -.0565$ | $\Sigma(x_1 y) = .0701$ |
| | | $\Sigma(X_2)^2 = 1.9558$ | $\Sigma(X_2 X_3) = 4.5730$ | $\Sigma(X_2 Y) = 4.4587$ |
| | | $(\Sigma X_2)^2/_N = 1.9248$ | $(\Sigma X_2 X_3)/_N = 4.5277$ | $(\Sigma X_2 \Sigma Y)/_N = 4.4195$ |
| | $\Sigma(x_1 x_2) = -.0029$ | $\Sigma(x_2^2) = .0310$ | $\Sigma(x_2 x_3) = .0453$ | $\Sigma(x_2 y) = .0392$ |
| | | | $\Sigma(X_3)^2 = 11.2796$ | $\Sigma(X_3 Y) = 10.5224$ |
| | | | $(\Sigma X_3)^2/_N = 10.6502$ | $(\Sigma X_3 \Sigma Y)/_N = 10.3959$ |
| | $\Sigma(x_3 x_1) = -.0565$ | $\Sigma(x_3 x_2) = .0453$ | $\Sigma(x_3^2) = .6294$ | $\Sigma(x_3 y) = .1265$ |
| | | | | $\Sigma(Y)^2 = 10.3468$ |
| | | | | $(\Sigma Y)^2/_N = 10.1476$ |
| | | | | $\Sigma(y^2) = .1992$ |

$$\left.\begin{aligned} .0545\,b_1 - .0029\,b_2 - .0565\,b_3 &= .0701 \quad (\text{eq. } 4\text{-}9) \\ -.0029\,b_1 + .0310\,b_2 + .0453\,b_3 &= .0392 \quad (\text{eq. } 4\text{-}10) \\ -.0565\,b_1 + .0453\,b_2 + .6294\,b_3 &= .1265 \quad (\text{eq. } 4\text{-}11) \end{aligned}\right\} \begin{aligned} b_1 &= 1.623 \\ b_2 &= 1.012 \\ b_3 &= 0.274 \end{aligned}$$

$$a = .920 - 1.623\,(.296) - 1.012\,(.400) - .274\,(.942) = -.223 \quad (\text{eq. } 4\text{-}12)$$

$$Y = 1.623\,X_1 + 1.012\,X_2 + 0.274\,X_3 - 0.223 \quad (\text{Regression equation})$$

$$R^2 = \frac{1.623\,(.0701) + 1.012\,(.0392) + 0.274\,(.1265)}{.1992} = .944 \qquad (\text{eq. } 4\text{-}15)$$

$$\overline{R}^2 = 1 - (.056)11/8 = 0.923 \qquad \overline{R} = 0.96 \qquad (\text{eq. } 4\text{-}16)$$

$$S_e^2 = .077\,(.1992)/11 = 0.00139 \qquad (\text{eq. } 4\text{-}19)$$

$$S_e = .037 \qquad \text{antilog } 2\,S_e = 1.18$$

conditions of low ground water?" If the answer is yes, then a logarithmic dependent variable (by which the effects are multiplied together) would be superior to an arithmetic dependent variable (by which the effects are added together). Logarithms should be used for the independent variables when they would increase the linearity of the relationship. Whenever logarithms are used, the logarithms should be taken of values that have a natural lower limit of zero and a natural upper limit that is large compared to the values used in the study.

Multiple correlation performs a function that is ordinarily difficult to perform graphically. Reliability of the results, however, is highly dependent on the availability of a large sampling of all important factors that influence the dependent variable. In this case, the standard error of an estimate shown in fig. 4.03 is approximately 0.037, which, when added to a logarithm of a value, is equivalent to multiplying that value by 1.09. Thus, the standard error is about 9 percent, and the 1-in-20 error is roughly 18 percent. As previously discussed, however, the calculated correlation coefficient may be accidentally high.

## Partial Correlation

The value gained by using any single variable (such as April precipitation) in a regression equation can be measured by making a second correlation study using all of the variables of the regression equation except that one. The loss in correlation is expressed in terms of the partial correlation coefficient, which is a measure of the decrement in error attributable to adding one variable to the correlation. The square of the partial correlation coefficient is obtained as follows:

$$r^2_{3.12} = \frac{(1 - \bar{R}^2_{.12}) - (1 - \bar{R}^2_{.123})}{1 - \bar{R}^2_{.12}} \qquad (4\text{-}21)$$

where:

$r$ = the partial correlation coefficient

$\bar{R}$ = the adjusted correlation coefficient defined in equation 4-16

and where the subscript ahead of the decimal indicates the variable whose partial correlation coefficient is being computed, and the subscripts after the decimal indicate the independent variables. This procedure is fairly laborious except where electronic computers are used. However, an approximation of the partial correlation can be made by use of beta coefficients, which are very easy to obtain by use of the following equation after the regression equation has been calculated:

$$\beta_n = b_n \frac{S_n}{S_Y} = b_n \left[ \frac{\Sigma x_n^2}{\Sigma y^2} \right]^{1/2} \qquad (4\text{-}22)$$

where:

$\beta_n$ = the beta coefficient for the nth independent variable

$b_n$ = the regression coefficient of the nth independent variable as defined in equation 4-4

$S$ = the standard deviation of the variable, calculated as $\frac{\Sigma(x_n)^2}{N - 1}$ or $\frac{\Sigma y^2}{N - 1}$

$y$ = the deviation of the individual observation of a variable from their mean as defined for equation 4-4

The beta coefficients of the variables are proportional to the influence of each variable on the result. While the partial correlation coefficient measures the increase in correlation that is obtained by addition of one more dependent variable to the correlation study, the beta coefficient is a measure of the proportional influence of a given independent variable on the dependent variable. These two coefficients are related closely only when there is no interdependence among the various "independent" variables. However, some "independent" variables naturally correlate with each other, and when one is removed from the equation, the other will take over some of its weight in the equation. For this reason, it must be kept in mind that beta coefficients indicate partial correlation only approximately.

## Verification of Correlation Results

Acquisition of basic data after a correlation study has been completed will provide an opportunity for making a check of the correlation results. This is done simply by comparing the values of the dependent variable observed with corresponding values calculated from the regression equation. The differences are the errors of estimate, and their root-mean-square is an estimate of the standard error of the regression-equation estimates. This standard error can be compared to that already established in equation 4-18 or 4-19. If the difference is not significant, there is no reason to suspect the regression equation of being invalid, but if the difference is large, the regression equation and standard error should be recalculated using the additional data acquired.

## Graphical Correlation

Where the relationships among variables used in a correlation study are expected to be curvilinear and where a simple transformation cannot be employed to make these relationships linear, graphical regression methods will prove useful. A satisfactory graphical analysis, however, requires a relatively large number of observations. The general theory employed is similar to that discussed above for linear correlation. Methods used will not be discussed herein, but can be found in references 5 and 9.

## Practical Guide Lines

The most important thing to remember in making correlation studies is that accidental correlations occur frequently, particularly when the number of observations is small. For this reason, variables should be correlated only when there is reason to believe that there is a physical relationship. It is helpful to make a preliminary examination of relationships between two or more variables by graphical plotting. This is particularly helpful for determining whether a relationship is linear and in selecting a transformation for converting curvilinear relationships to linear relationships. It should also be remembered that the chance of accidentally high correlation increases with the number of correlations tried. If a variable being studied is tested against a dozen other variables at random, there is a good chance that one of these will produce a good correlation, even though there may be no physical relation between the two. In general, the results of correlation analyses should be examined to assure that the derived relationship is reasonable. For example, if streamflow is correlated with precipitation and drainage area size, and the regression equation relates streamflow to some power of the drainage area greater than one, a maximum exponent value of one should be used, because the flow per square mile cannot increase with drainage area when other factors remain constant.

## Section 4.05. Regional Correlation

After the indices that best represent pertinent hydrologic phenomena are selected, it is necessary to relate each index to physical phenomena that reasonably have a causative relationship and that can be feasibly obtained for estimating hydrologic quantities at ungaged locations. To the extent that the physical characteristics selected can be expressed numerically, it is possible to incorporate them in a multiple regression analysis, as discussed in Section 4.04.

Ordinarily, the process of stepwise multiple linear regression is used so that variables which do not add to the correlation can be eliminated from the analysis. The determination of whether to eliminate a variable from the analysis should ordinarily be made on the basis of partial correlation, which indicates the portion of the remaining unknown variance that is explained by the particular variable, after all information obtained from the other variables is used. If the partial correlation coefficient is small, such as 0.2 or 0.3, it is probably wise to eliminate the variable, because addition of one variable increases the work required for estimating unknown quantities and may decrease the reliability of the relationship among the variables.

Although it is desirable to relate all pertinent variables through multiple regression analysis, it is not ordinarily feasible to do so because many pertinent variables cannot be expressed satisfactorily numerically. This includes such items as soil types and vegetation. After the regression analysis based on variables that can be expressed numerically is completed, it is usually possible to greatly increase the reliability of estimates using mapping techniques. This consists of solving for the regression constant for each location where data are available by substituting known data for all variables in equation 4-3 and solving for "a", using derived regression coefficients, "b". The "a" coefficients thus derived can then be plotted on a map, and lines of equal map coefficients drawn, guided by maps of pertinent physical characteristics such as topography, soils, vegetation, and geology. Where hydrologic quantities relate to runoff and consequently to a drainage basin rather than to a point location, the values plotted on the map represent quantities for the entire drainage basin, and the map must be constructed and used accordingly.

The variation of coefficients shown on the map can be due partly to errors in estimating the hydrologic index from the observed data. If the standard error of such an estimate can be computed, as illustrated in Section 4.04, then it can be used as a guide in permitting the lines of equal magnitude to depart from the plotted values in the interest of obtaining a smoother geographic pattern and increased reliability. Since the standard error of estimate is exceeded by actual errors about one time in three, and twice its magnitude is exceeded about one time in twenty, differences as large as one standard error can be tolerated freely in drawing the lines, whereas differences larger than twice the standard error should occur only rarely.

## Section 4.06. General Procedure

The general procedure for making a regional analysis is as follows:

a. Compute each required hydrologic index for locations where data are available.

b. Select and measure basin parameters for these locations. Parameters should be selected as those that have a reasonable relation to the hydrologic index and that are obtainable for ungaged locations.

c. Perform a multiple linear regression study as described in Section 4.04.

d. Select the best regression equation obtainable and round the regression coefficients, b, as desired.

e. Using these coefficients and the data available at each gaged location, solve for the regression constant, a, required to relate the dependent and independent variables exactly. This value or its antilogarithm can be used as a map coefficient.

f. Plot the map coefficient for each location on a map and draw lines of equal values.

## Section 4.07. Example

The use of multiple linear regression in a regional correlation analysis is illustrated for several drainage basins in the area shown in fig. 4.04. A function is derived to express the mean logarithm of annual peak flow in terms of easily measured basin characteristics. The following independent variables were chosen:

$X_1$ = Log of the drainage area in square miles

$X_2$ = Log of the mean annual rainfall in inches

$X_3$ = Elevation above snowline in hundred feet

In this example, the dependent variable is expressed as:

$Y$ = Mean log of annual peak flow in cubic feet per second (cfs)

The data to be used for development of the regression equation follows:

| Station | $X_1$ | $X_2$ | $X_3$ | $Y$ |
|---|---|---|---|---|
| 15 | 2.27 | 1.62 | 55 | 3.40 |
| 17 | 2.76 | 1.58 | 17 | 4.41 |
| 62 | 2.87 | 1.81 | 55 | 4.20 |
| 74 | 2.15 | 1.51 | 36 | 3.50 |
| 131 | 2.36 | 1.75 | 42 | 3.79 |
| 132 | 2.98 | 1.65 | 22 | 4.60 |
| 144 | 2.30 | 1.61 | 35 | 3.76 |
| 145 | 2.05 | 1.73 | 18 | 3.96 |
| 146 | 1.91 | 1.61 | 16 | 3.64 |
| 147 | 1.94 | 1.74 | 16 | 3.85 |
| 148 | 3.49 | 1.76 | 36 | 5.16 |
| 149 | 2.73 | 1.85 | 21 | 4.62 |
| 150 | 2.30 | 1.86 | 42 | 4.00 |
| 151 | 3.45 | 1.76 | 52 | 4.70 |

From the basic data, the following results are obtained:

$\Sigma X_1 = 35.56$ $\quad \Sigma X_2 = 23.84$ $\quad \Sigma X_3 = 463$ $\quad \Sigma Y = 57.59$

$\Sigma(X_1)^2 = 93.810$ $\quad \Sigma(X_2)^2 = 40.744$ $\quad \Sigma(X_3)^2 = 18.149$ $\quad \Sigma(Y)^2 = 240.373$

$\Sigma(YX_1) = 149.344$ $\quad \Sigma(YX_2) = 98.390$ $\quad \Sigma(YX_3) = 1897.250$

$\Sigma(X_1X_2) = 60.769$ $\quad \Sigma(X_1X_3) = 120.670$ $\quad \Sigma(X_2X_3) = 792.610$

Using the above results and equations 4-13 and 4-14, the following results are obtained:

$$\Sigma(x_1)^2 = 93.810 - (35.56)^2/14 = 3.487$$

$$\Sigma(yx_1) = 149.344 - (57.59)(35.56)/14 = 3.066$$

Similarly $\Sigma(x_2)^2$, $\Sigma(x_3)^2$, $\Sigma(x_1x_2)$ $\Sigma(x_1x_3)$, $\Sigma(x_2x_3)$, $\Sigma(yx_1)$, $\Sigma(yx_2)$, and $\Sigma(yx_3)$ are calculated and substituted into equations 4-9, 4-10, and 4-11 to give the following results:

$$3.487\,b_1 + .216\,b_2 + 33.650\,b_3 = 3.066$$

$$.216\,b_1 + .148\,b_2 + 4.187\,b_3 = .322$$

$$33.650\,b_1 + 4.187\,b_2 + 2836.929\,b_3 = 7.334$$

Solving the above equations simultaneously, the following regression coefficients are obtained:

$$b_1 = .955 \qquad b_2 = 1.230 \qquad b_3 = -.016$$

The regression constant is calculated from equation 4-12 as follows:

$$a = \bar{Y} - b_1\bar{X}_1 - b_2\bar{X}_2 - b_3\bar{X}_3 = \frac{\Sigma Y}{N} - b_1 \frac{\Sigma X_1}{N} - b_2 \frac{\Sigma X_2}{N} - b_3 \frac{\Sigma X_3}{N}$$

$$a = \left(\frac{57.59}{14}\right) - .955 \left(\frac{35.56}{14}\right) - 1.230 \left(\frac{23.84}{14}\right) + .016 \left(\frac{463}{14}\right) = .114$$

The regression equation becomes:

$$Y = .114 + .955\, X_1 + 1.230\, X_2 - .016\, X_3$$

Using the regression equation and the observed $X_1$, $X_2$, and $X_3$ values for each station, values of Y are calculated and shown in table 4.01. The map coefficients, shown in table 4.01, are computed by subtracting the calculated value of Y from the observed value of Y and adding the regression constant, "a", to the difference. This is equivalent to substituting all values of X that are known in the regression equation and solving for a new regression constant which may be called the map coefficient, "c".

Table 4.01. Observed and calculated values of Y and resulting map coefficient

| Station | Observed | Calculated | Map Coefficient |
|---|---|---|---|
| 15 | 3.40 | 3.41 | .10 |
| 17 | 4.41 | 4.43 | .09 |
| 62 | 4.20 | 4.22 | .09 |
| 74 | 3.50 | 3.46 | .15 |
| 131 | 3.79 | 3.86 | .04 |
| 132 | 4.60 | 4.64 | .07 |
| 144 | 3.76 | 3.74 | .13 |
| 145 | 3.96 | 3.92 | .15 |
| 146 | 3.64 | 3.67 | .08 |
| 147 | 3.85 | 3.85 | .11 |
| 148 | 5.16 | 5.04 | .23 |
| 149 | 4.62 | 4.67 | .06 |
| 150 | 4.00 | 3.94 | .17 |
| 151 | 4.70 | 4.76 | .05 |

In fig. 4.04, the map coefficient and the standard error of the mean for each station have been plotted at the centroid of the contributing basin, and lines of equal coefficients have been constructed. The standard error of the mean for each station can be computed, as illustrated in Section 4.04. It can then be used as a guide in permitting the lines of equal magnitude to depart from the plotted values in the interest of obtaining a smoother geographic pattern and increased reliability. The lines should be constructed in such a way that their average value over each gaged area approximately equals the coefficient for that area, considering the standard error of the mean as discussed in Section 4.05. If the mean logarithm of annual peak flow is desired at point A for the shaded ungaged basin, the necessary map coefficient can be obtained from fig. 4.04 by averaging map values for that area. The use of the map coefficient instead of the originally calculated regression constant in the regression equation will be more reliable. The use of the map allows inclusion of data that could not be quantified such as geomorphic features and natural vegetative cover. The drainage basin above point A has the following characteristics:

map coefficient (c) = .20
drainage area ($X_1$) = 600 sq. mi.
mean annual rainfall ($X_2$) = 60 inches
elevation above snowline ($X_3$) = 2,500 feet

The mean peak flow can now be calculated as follows:

$$Y = c + b_1X_1 + b_2X_2 + b_3X_3$$

$$= .20 + .955 (\log 600) + 1.230 (\log 60) - .016 (25) = 4.64$$

since Y = mean log of peak flow (to the base 10),

peak flow = antilog Y = antilog 4.64 = 43,700 cfs

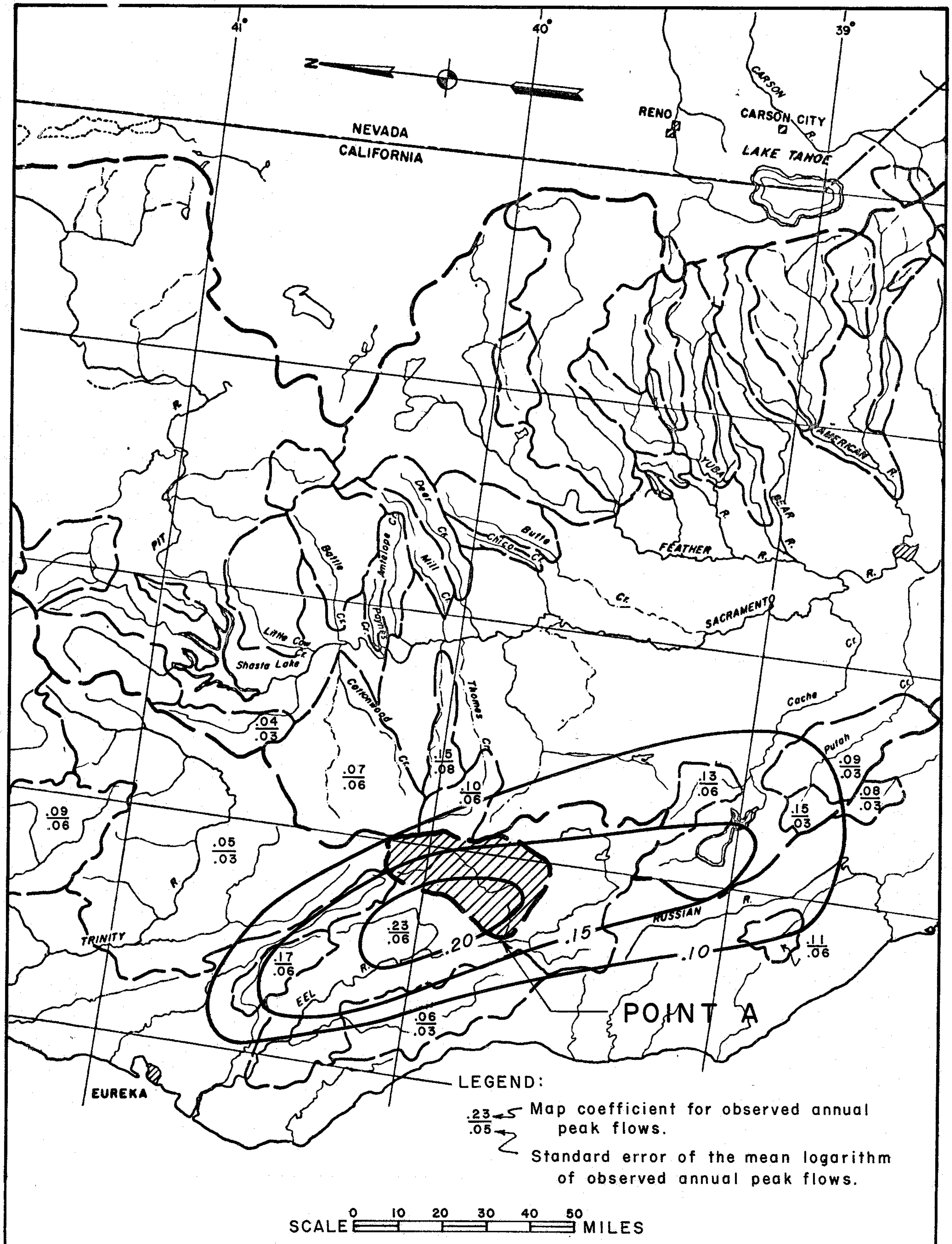


Fig. 4.04. Map coefficients for mean logarithm of annual peak flow

## Chapter 5

# Hydrologic Simulation

# CHAPTER 5. HYDROLOGIC SIMULATION

## Section 5.01. Introduction

The term "simulation" is applied to the mathematical or physical modeling of a phenomenon or process. In this section, it is used to denote only the mathematical modeling of a stochastic process. A stochastic process is one in which there is a chance component in each successive event and ordinarily some degree of correlation between successive events. Modeling of a stochastic process involves the use of the "Monte Carlo" method of adding a random (chance) component to a correlated component in order to construct each new event. The correlated component can be related, not only to preceding events of the same series, but also to concurrent and preceding events of series of related phenomena.

Work in stochastic hydrology has related primarily to annual and monthly streamflows, but the results often apply to other hydrologic quantities such as precipitation and temperatures. Some work on daily streamflow simulation has been done.

## Section 5.02. Application

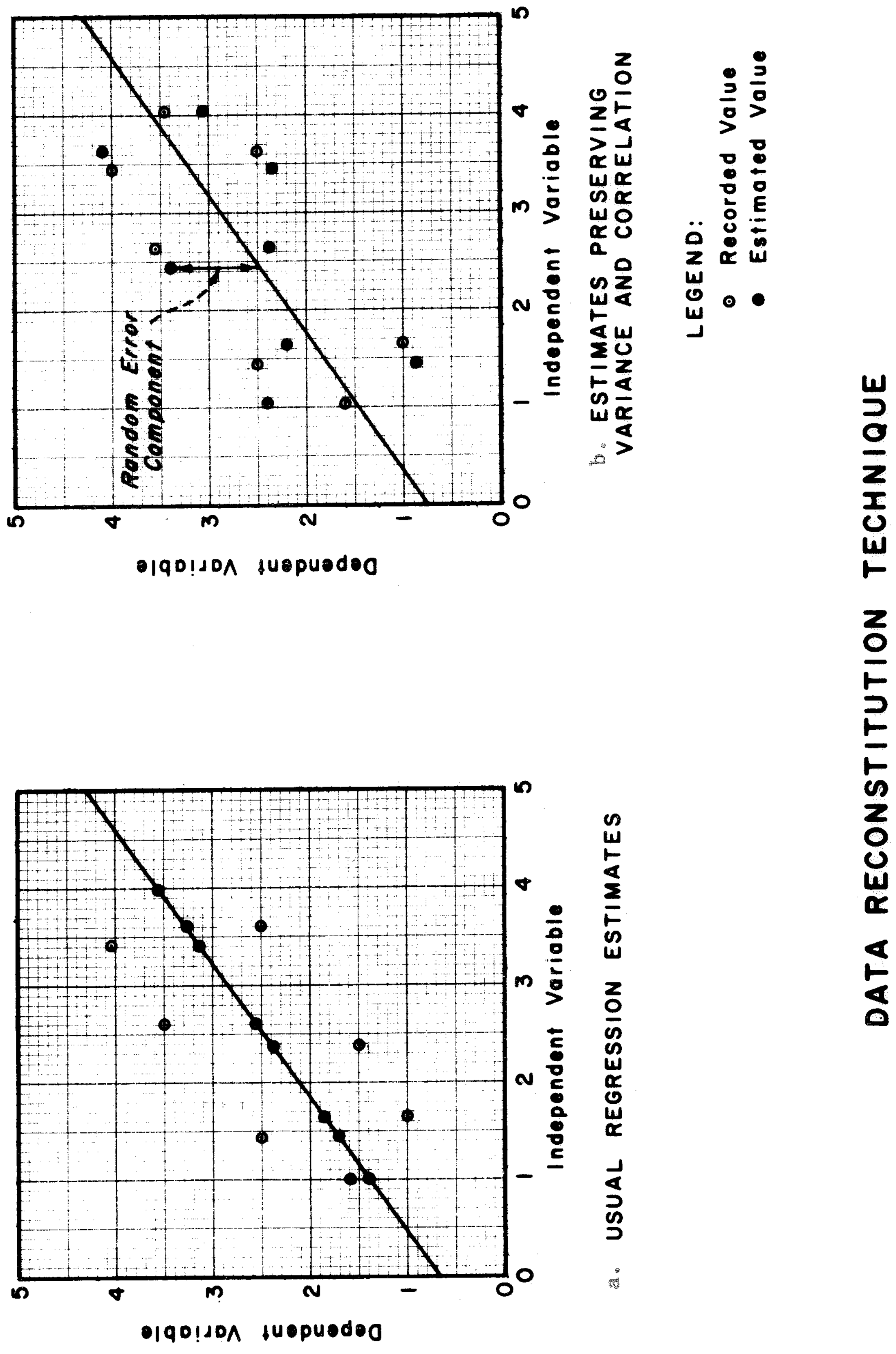
Hydrologic records are usually shorter than 100 years in length, and most of them are shorter than 25 years. Even in the case of the longest records, the most extreme drought or flood event can be far different from the next most extreme event. There is often serious question as to whether the extreme event is representative of the period of record. The severity of a long drought can be changed drastically by adding or subtracting 1 year of its duration. In order that some estimate of the likelihood of more severe sequences can be made, the stochastic process can be simulated, and long sequences of events can be generated. If the generation is done correctly, the hypothetical sequences would be as likely to occur in the future as would a repetition of the past recorded events.

The design of water resource projects is commonly based on assumed recurrence of past hydrologic events. By generating a number of hydrologic sequences, each of a specified desired length, it is possible to create a much broader base for hydrologic design. While it is not possible to create information that is not already in the record, it is possible to use the information more systematically and more effectively. In selecting the number and length of hydrologic sequences to be generated, it is usually considered that 10 to 20 sequences would be adequate and that their length should correspond to the period of project amortization.

It must be recognized that the more hydrologic events that are generated, the more chance there is that an extreme event or combination of events will be exceeded. Consequently, it is not logical that a design be based on the most extreme generated event, but rather on some consideration of the total consequences that would prevail for a given design if all generated events should occur. The more events that are generated, the less proportional weight each event is given. If a design is tested on 10 sequences of hydrologic events, for example, the benefits and costs associated with each sequence would be divided by 10 and added in order to obtain the "expected" net benefits.

## Section 5.03. Basic Procedure

Successful simulation of stochastic processes in hydrology has been based generally on the concept of multiple linear regression, where the regression equation determines the correlated component, and the standard error of estimate determines the random component. Fig. 5.01 illustrates the general nature of the process. In this case, a low degree of correlation is illustrated, in order to emphasize important aspects of the process. It can be seen that, if every estimate of the dependent variable is determined by the regression line, the estimated points would be perfectly correlated with the independent variable and would have a much smaller range of magnitude than the actual observed values of the dependent variable. In order to avoid such unreasonable results, it is necessary to add a random component to each estimate, and this random component should conform to the scatter of the observed data about the regression line.



a. USUAL REGRESSION ESTIMATES

b. ESTIMATES PRESERVING VARIANCE AND CORRELATION

Fig. 5.01. Data reconstitution technique

## Section 5.04. Monthly Streamflow Model

In accordance with the above basic procedure, a simulation model for generating values of a variable which can be defined only partially by a deterministic relation is:

$$Y = \overbrace{a + b_1X_1 + b_2X_2}^{\text{deterministic component}} + \overbrace{Z\, S\sqrt{1 - R^2}}^{\text{random component}} \tag{5-1}$$

where:

$Y$ = dependent variable

$a$ = regression constant

$b_1, b_2$ = regression coefficients

$X_1, X_2$ = independent variables

$Z$ = random number from normal standard population with zero mean and unit variance

$S$ = standard deviation of dependent variable

$R$ = multiple correlation coefficient

This type of simulation model can be used to generate related monthly streamflow values at one or more stations. Multiple linear regression theory is based on the assumed distribution of all variables in accordance with the Gaussian normal distribution. Therefore, mathematical integrity requires that each variable be transformed to a normal distribution, if it is not already normal. It has been found that the logarithms of streamflows are approximately normally distributed in most cases. For computational efficiency it is convenient to work with deviations from the mean which have been normalized by dividing by the standard deviation. This deviate is sometimes called the Pearson Type III deviate and can be computed as follows:

$$t_i = \frac{X_{i,j} - M_i}{S_i} \tag{5-2}$$

where:

$t$ = Pearson Type III deviate
$i$ = month number
$j$ = year number
$X$ = logarithm of flow
$M$ = mean of flow logarithms
$S$ = standard deviation of flow logarithms .

If these deviates exhibit a skewness, they can be further transformed, if necessary, to a distribution very close to normal by use of the following approximate Pearson Type III transform equation:

$$K_i = 6/g_i \; [((g_i t_i/2) + 1)^{1/3} - 1] - g_i/6 \qquad (5\text{-}3)$$

where:

$K$ = normal standard deviate
$i$ = month number
$g$ = skew coefficient
$t$ = Pearson Type III deviate as defined in equation 5-2

An equation for generating monthly streamflow is:

$$K'_{i,k} = \beta_1 K'_{i,1} + \beta_2 K'_{i,2} + \cdots + \beta_{k-1} K'_{i,k-1} + \beta_k K'_{i-1,k} + \beta_{k+1} K'_{i-1,k+1} + \cdots + \beta_n K'_{i-1,n} + Z_{i,k} \sqrt{1-R^2_{i,k}} \qquad (5\text{-}4)$$

where:

$K'$ = monthly flow logarithm, expressed as a normal standard deviate
$\beta$ = beta coefficient as defined in equation 4-22
$i$ = month number for value being generated
$k$ = station number for value being generated
$n$ = number of interrelated stations
$R$ = multiple correlation coefficient
$Z$ = random number from normal standard population

For the case of a single station, this resolves to:

$$K'_i = R_i K'_{i-1} + Z_i \sqrt{1-R_i^2} \qquad (5\text{-}5)$$

Note that equation 5-4 is very similar to equation 5-1. The differences result from using normal standard deviates. When this in done, the regression constant, a, equals zero, the regression coefficients, b, become beta coefficients, β, and the standard deviation, S, does not appear in the random component since it equals 1. Note also that one of the independent variables is the flow for the preceding month in order to preserve the inherent serial correlation. The flow value in the original units is computed by reversing the transformation process; i.e., from normal standard deviate to Pearson Type III deviate, to logatithm of flow and finally flow value.

A step-by-step procedure for generating monthly streamflows for a number of interrelated locations having simultaneous records is as follows:

a. Compute the logarithm of each streamflow quantity. If a value of zero streamflow is possible, it is necessary to add a small increment, such as 0.1 percent of the mean annual flow, to each monthly quantity before taking the logarithm.

b. Compute the mean, standard deviation and skew coefficient of the values for each location and each month, using equaitons given in Volume 3.

c. For each month and location, subtract the mean from each event and divide by the standard deviation (equation 5-2).

d. Transform these "standardized" quantities to a normal distribution by use of equation 5-3.

e. Arrange the locations in any sequence, and compute a regression equation for each location in turn for each month. In each case, the independent variables will consist of concurrent monthly values at preceding stations and preceding monthly values at the current and subsequent stations.

f. Generate standardized variates for each location in turn for each month, starting with the earliest month of generated data. This is accomplished by computing a regression value and adding a random component.

The random component, according to equation 5-1, is a random selection from a normal distribution with zero mean and unit standard deviation, multiplied by the alienation coefficient which is $(1 - R^2)^{1/2}$.

g. Transform each generated value by reversing the transform of equation 5-3 with the appropriate skew coefficient, multiplying by the standard deviation and adding the mean in order to obtain the logarithm of streamflow.

h. Find the antilogarithm of the value determined in step g and subtract the small increment added in step a. If a negative value results, set it to zero.

It is obviously not feasible to accomplish the above computations without the use of an electronic computer. A computer program, HEC-4 Monthly Streamflow Simulation, number 723-X6-L2340, that can be used for this purpose is described in Appendix 1.

## Section 5.05. Data Fill-In

Ordinarily, periods of recorded data at different locations do not cover the same time span, and therefore, it is necessary to estimate missing values in order to obtain a complete set of data for analysis as described above. In estimating the missing values, it is important to preserve all statistical characteristics of the data, including frequency and correlation characteristics. To preserve these characteristics, it is necessary to estimate each individual value on the basis of multiple correlation with the preceding value at that location and with the concurrent or preceding values in all other locations. A random component is also required, as indicated in equation 5-1. There are many mathematical problems involved in this process, and the details involved are discussed in the computer program description contained in Appendix 1.

## Section 5.06. Application in Areas of Limited Data

The streamflow generation models discussed so far have assumed that sufficient records were available to derive the appropriate statistics.

For instance, the monthly streamflow model requires four frequency and correlation coefficients for each of the 12 months, or 48 values for one station simulation. A model has been developed (reference 6) that combines the coefficients into a few generalized coefficients for the purpose of generating monthly streamflow at ungaged locations. (Procedures for determining generalized statistics for use in generating daily flows have not yet been developed.) The generalized model considers the following:

- a. Season of maximum runoff.
- b. Lag to season of minimum runoff.
- c. Average runoff.
- d. Variation between maximum and minimum runoff.
- e. Standard deviation of flows.
- f. Interstation and serial correlations of flows.

The application of the generalized model to the generation process is described in Appendix 1.

## Section 5.07. Daily Streamflow Model

Generation of daily streamflows can be accomplished in a manner very similar to the generation of monthly streamflow quantities. A computer program, 723-G2-L2190, described in Appendix 2, has been prepared for this purpose. It is capable only of generating flows at a single location. Flows for any particular day are correlated with flows for the preceding day and for the second antecedent day. Since it is desired in many operation studies to use a monthly interval most of the time, and to perform daily operation computations for only a few critical periods, the program has been designed to generate daily flows after the monthly total runoff has been generated by another program.

## Section 5.08. Reliability

While the simulation of stochastic processes can add considerable dependability in hydrologic design, the techniques have not yet developed to the stage that they are completely dependable. All mathematical models involve some simplification of the physical phenomena represented. In most applications, simplifying assumptions do not cause serious discrepancies. It is important at this state of the art, however, to examine carefully the results of hydrologic simulation to assure that they are reasonable in each case.

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Appendix 1

# Monthly Streamflow Simulation

# HEC-4

# MONTHLY STREAMFLOW SIMULATION

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L2340

## CONTENTS

## EXHIBITS

# HEC-4

# MONTHLY STREAMFLOW SIMULATION

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L2340

## 1. ORIGIN OF PROGRAM

This program was prepared in The Hydrologic Engineering Center, Corps of Engineers. Up-to-date information and copies of source statement cards for various types of computers can be obtained from the Center upon request by Government and cooperating agencies. Programs are furnished by the Government and are accepted and used by the recipient upon the express understanding that the United States Government makes no warranties, express or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in the programs or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made thereof.

The programs belong to the Government. Therefore, the recipient further agrees not to assert any proprietary rights therein or to represent the programs to anyone as other than a Government program.

## 2. PURPOSE OF PROGRAM

This program will analyze monthly streamflows at a number of interrelated stations to determine their statistical characteristics and will generate a sequence of hypothetical streamflows of any desired length having those characteristics. It will reconstitute missing streamflows on the basis of concurrent flows observed at other locations and will obtain maximum and minimum quantities for each month and for specified durations in the recorded, reconstituted and generated flows. It will also use the generalized simulation model for generating monthly streamflows at ungaged locations based on regional studies. There are many options of using the program for various related purposes, and it can be used for other variables such as rainfall, evaporation, and water requirements, alone or in combination.

## 3. DESCRIPTION OF EQUIPMENT

This program requires a FORTRAN IV compiler, a random number generator (function RNGEN included, see exhibit 2), and a fairly large memory (64K on the CDC 6600). Provision is made for use of three scratch tapes, 7 (for punched output), 8 and 9.

## 4. METHODS OF COMPUTATION

a. In the statistical analysis portion of this program, the flows for each calendar month at each station are first incremented by 1 percent of their calendar-month average in order to prevent infinite negative logarithms. This increment is later subtracted. The mean, standard deviation and skew coefficients for each station and calendar month are then computed. This involves the following equations:

$$X_{i,m} = \log (Q_{i,m} + q_i) \tag{1}$$

$$\bar{X}_i = \sum_{m=1}^{N} X_{i,m}/N \tag{2}$$

$$S_i = \sqrt{\sum_{m=1}^{N} (X_{i,m} - \bar{X}_i)^2 / (N-1)} \tag{3}$$

$$g_i = N \sum_{m=1}^{N} (X_{i,m} - \bar{X}_i)^3 \;/\; ((N-1)(N-2)S_i^3) \tag{4}$$

in which:

$X$ = Logarithm of incremented monthly flow
$Q$ = Monthly recorded streamflow
$q$ = Small increment of flow used to prevent infinite logarithms for months of zero flow
$\bar{X}$ = Mean logarithm of incremented monthly flows
$N$ = Total years of record
$S$ = Unbiased estimate of population standard deviation
$g$ = Unbiased estimate of population skew coefficient
$i$ = Month number
$m$ = Year number

b. For each station and month with incomplete record, a search is made for longer records among the stations used, to find that which will contribute most toward increasing the reliability of the statistics computed from the incomplete record. The mean and standard deviation are then adjusted. Equation 5 is used to compute the equivalent record required to obtain statistics equally reliable to these adjusted statistics and is the basis for selecting the best record to be used in the adjustment. Equations 6 and 7 are the adjustment equations.

$$N_1' = \frac{N_1}{1 - \dfrac{N_2' - N_1}{N_2'} R^2} \tag{5}$$

$$\bar{X}_1' - \bar{X}_1 = (\bar{X}_2' - \bar{X}_2)\, RS_1/S_2 \tag{6}$$

$$S_1' - S_1 = (S_2' - S_2)\, R^2 S_1/S_2 \tag{7}$$

The primes indicate the long-period values and those without primes are based on the same short period for both stations 1 and 2, and:

$N$ = Length of record
$R$ = Linear correlation coefficient

c. Each individual flow is then converted to a normalized standard variate, using the following approximation of the Pearson Type III distribution:

$$t_{i,m} = (X_{i,m} - \bar{X}_i) / S_i \tag{8}$$

$$K_{i,m} = 6/g_i \left[ ((g_i t_{i,m}/2) + 1)^{1/3} - 1 \right] + g_i/6 \tag{9}$$

$t$ = Pearson Type III standard deviate
$K$ = Normal standard deviate

d. After transforming the flows for all months and stations to normal, the gross (simple) correlation coefficients R between all pairs of stations for each current and preceding calendar month are computed by use of the following formula:

$$R_{i,i-1} = \left\{ 1 - \left[ 1 - \left( \sum_{m=1}^{N} x_{i,m} x_{i-1,m} \right)^2 / \left( \sum_{m=1}^{N} x^2_{i,m} \sum_{m=1}^{N} x^2_{i-1,m} \right) \right] (N-1)/(N-2) \right\}^{\frac{1}{2}} \tag{10}$$

in which:

$x = X - \bar{X}$

e. If there are insufficient simultaneous observations of any pair of variables to compute a required correlation coefficient, that value must be estimated. Each missing value is estimated by examining its relationship to related pairs of values in the current and preceding month by use of the following formula using i, j, and k subscripts to indicate variables used in the gross correlation.

$$R_{ij} = R_{ki} R_{kj} \pm \sqrt{(1 - R_{ki}^2)(1 - R_{kj}^2)} \qquad (11)$$

Since, in order to be consistent with the two related correlation coefficients, the correlation coefficient must lie between the limits given by equation 11, the lowest upper limit and highest lower limit are established for all related pairs, and the average of these two limits is taken as the estimated correlation coefficient.

f. Monthly streamflows missing from the records of the various stations are estimated for all stations for each month in turn. Accordingly, whenever a missing flow is being reconstituted, there always exists a valid value for all stations already examined that month and for all remaining stations in either the current or preceding month. For these remaining stations, the current value is selected where available; otherwise the preceding value is used. In order to reconstitute the missing value, a regression equation in terms of normal standard variates is computed by selecting required coefficients from the complete correlation matrix for that month and solving by the Crout method (See exhibit 1). The missing value is computed from this regression equation, introducing a random component equal to the nondetermination of the equation, as discussed in the streamflow generation procedure.

g. It has been found that valid use of the regression technique requires that all correlation coefficients agree with the data that will be substituted into the equations and that the correlation coefficients be mutually consistent. Inconsistency in the correlation coefficients causes the dependent variable to be over-defined and is evidenced by a determination coefficient greater than 1.0. If this occurs (because of incomplete data), the independent variable contributing least to the correlation is dropped, and a new regression equation is computed. This process is repeated as necessary until consistency is reached (which must occur by the time that only one independent variable remains). In order to make the correlation matrix consistent with the data matrix, all affected correlation coefficients are recomputed after each estimate of missing data.

h. Normal standard deviates are then converted to flows by use of the following equations:

$$t_{i,m} = \left\{ \left[ (g_i/6)(K'_{i,m} - g_i/6) + 1 \right]^3 -1 \right\} 2/g_i \tag{12}$$

$$X_{i,m} = \bar{X} + t_{i,m} S_i \tag{13}$$

$$Q_{i,m} = \text{Antilog } X_{i,m} - q_i \tag{14}$$

imposing the constraint:

$$Q_{i,m} \geq 0 \tag{15}$$

i. When the set of flows is complete, all correlation matrices should be consistent except for truncation errors in the computer, since the data arrays are complete. Any consistency of matrices obtained in this manner or of matrices read into the computer will result in determination coefficients greater than 1.0. If this occurs, consistency of each correlation matrix is assured by first testing all combinations of triads of correlation coefficients in the current and preceding month for all calendar months using equation 11 and raising the lowest of the three coefficients to obtain a consistent triad. The test of consistency of each complete matrix is made by recomputing the multiple correlation coefficient. If this value is greater than 1.0, further adjustment is required. Such further adjustment is obtained by introducing a coefficient, successively smaller by 0.2, on the radical in equation 11 and repeating all triad consistency tests until all matrices are consistent. If consistency is not reached, coefficients in each inconsistent matrix are moved toward the average value of all coefficients in that matrix until consistency is reached.

j. Generation of hypothetical streamflows is accomplished by computing a regression equation, by the Crout method (described in exhibit 1) for each station and month and then computing streamflows for each station in turn for one month at a time using the following equation. This process is started with average values (zero deviation) for all stations in the first month and discarding the first 2 years of generated flows.

$$K'_{i,j} = \beta_1 K'_{i,1} + \beta_2 K'_{i,2} + \cdots + \beta_{j-1} K'_{i,j-1} + \beta_j K'_{i-1,j} + \beta_{j+1} K'_{i-1,j+1} + \cdots + \beta_n K'_{i-1,n} + \sqrt{1-R^2_{i,j}} \quad Z_{i,j} \tag{16}$$

in which:

$K'$ = Monthly flow logarithm, expressed as a normal standard deviate

$\beta$ = Beta coefficient computed from correlation matrix

$i$ = Month number

$j$ = Station number

$n$ = Number of interrelated stations

$R$ = Multiple correlation coefficient

$Z$ = Random number from normal standard population

k. Maximum, minimum and average flows are obtained for the entire period of flows as recorded and for specified periods of reconstituted and generated flows by routine search technique.

l. Provision is also included in this program for use of the generalized model requiring only 4 generalized coefficients for each station (in place of 48) and one generalized correlation coefficient (in place of 12) for each pair of stations, in addition to identification of wet and dry seasons for each station. These are defined as follows:

(1) The average value of mean logarithms of flows for the wet season (3 months). This value plus 0.2 is applied to the middle month and the average minus 0.1 is applied to the other 2 months.

(2) The average value of mean logarithms of flows for the dry season (3 months). This is applied to all 3 dry months. Mean logarithms for months between dry and wet seasons are interpolated linearly.

(3) The average standard deviation for all 12 months. This is applied to each of the 12 months.

(4) The average serial correlation coefficient for all 12 months. This value minus .15 (but not less than zero) is applied to each wet-season month, and the value plus .15 (but not more than .98) is applied to each dry-season month. The average value is applied to all intermediate months.

(5) The average interstation correlation coefficient for all 12 months is applied to each month for that pair of stations.

m. Because of limitations in computer memory size and because of increasing change of computational instability with larger matrices, the number of stations usable simultaneously in this program has been limited to 10. However, the program can reconstitute and generate streamflows for any number of stations in groups of 10 or less. It will ordinarily be desirable to include one or more stations from earlier groups in each successive group in order to preserve important correlations. In addition to providing flow data for all stations, it is necessary to designate NPASS and to follow each group of flow data with a standard-format card with NSTX (number of stations in next pass that were also used in preceding passes) and station identification numbers for those stations. These numbers must be listed in the same sequence as their data were arranged in earlier passes. Data for the new stations for the new pass should then be read. None of these flows can occur in a year later than the latest year for which flow data occurred in the first pass.

n. As soon as flows are reconstituted for any pass, they are read onto the flow tape. After statistics are computed from transformed reconstituted flows, they are read onto the statistics tape (after identification of stations in the pass for future reference). Final regression equation data for each pass are read onto the same tape at the same time (for use in generation later). For each new pass, the flow and statistics tapes are searched separately for data for those stations already used that also occur in the new pass. In order to read and write intermittently and alternatively on the same tapes, it is necessary to keep track of tape records so as to assure that any read statement does not read beyond the record mark and so that new write statements occur at the end of all previous write statements that are to be saved.

o. Once that statistics are put on tape, they are retained throughout the reconstitution and generation processes. Flows, however, are saved only for the set of data in which they were reconstituted or generated, until the last pass for that set is completed. In the generation process, it is necessary to save the last flow generated for each station in one set for use as the antecedent flow in starting generation in the next set. These are saved in the QSTAP array with subscript ISTAP.

## 5. INPUT

Input is summarized in exhibits 7 and 8. Data are entered consecutively on each card using a simple variety of formats to simplify punching and handling cards. Computed and generated flows cannot be 1,000,000 units or larger, and consequently must be expressed in units that cannot exceed this magnitude. Units should be indicated on one of the 3 header cards. Column 1 of each card is reserved for card identification. These are ignored by the computer except for the A in column 1 of the first header card, which is used to identify the first data card. An example of input is given in exhibit 3. Certain inadequacies of data will abort the job and waste input cards until the next card with A in column 1 is reached. A card with A in column 1 followed by 4 blank cards causes the computer to stop.

## 6. OUTPUT

Printed output includes key input information for job identification and all results of computations. Generated flows are put on magnetic tape, and computed statistics are punched on cards in the format usable later by the program. An example of printed output is given in exhibit 4.

## 7. OPERATING INSTRUCTIONS

Standard FORTRAN IV instructions and random number generator are required. No sense switches are used.

## 8. DEFINITIONS OF TERMS

Terms used in the program are defined in exhibit 5 .

## 9. PROPOSED FUTURE DEVELOPMENT

There are cases where the model used herein does not reproduce historical droughts with reasonable frequency. Consequently, the model is under continuous study and development. It is requested that any user who finds an inadequacy or desirable addition or modification notify The Hydrologic Engineering Center.

# EXHIBIT 1

## DETAILED EXPLANATION
## OF
## COMPUTER PROGRAM

### GENERAL

Much of the program is explained by comment cards and definitions of variables. Supplementary explanation follows, referring to sections identified with the indicated letter in column 2 of a comment card.

### SECTION A

Correlation coefficients, R, and beta coefficients, B, are in double precision for matrix inversion computation, in order to minimize computational instability. Correlation coefficient, RA, as originally computed and stored, may be defined in single precision. For computers with word length smaller than 32 bits, many other variables in this program should be in double precision.

When dimensions are changed, the corresponding variable (starting with K) should be changed accordingly, as these are used to prevent exceedence of dimensions. If an excessive subscript is used, the job will be dumped until a card with A in column 1 is encountered, at which time a new job is automatically started. If 5 blank cards (with an A in column 1 of the first) are encountered, the run will be terminated. Job specification cards are read in this section.

### SECTION B

NSTAX is number of columns in correlation matrix. These consist of NSTA columns for the current-month values and a similar number for antecedent-month values. NSTAA is initial column number for antecedent-month coefficients. These are computed from NSTA, which is read in if statistics are to be provided, rather than computed from raw data. If raw data are to be used, NSTA is defined in the program later and NSTAA and NSTA must be also. Data for each new pass are processed after transferring back to statement 42. In the multipass operation, NSTX is the number of stations used from previous passes and NSTXX is the subscript of the first new station for the current pass. Station identification for the NSTX stations must be in the order in which data for those stations were originally used, because search of data and statistics on tape is made in this order. Flows for these stations are read from tape IQTAP, and corresponding statistics from tape ISTAT. Variables LQTAP and LSTAT are used to keep track of tape position for subsequent writing.

*Provided through the cooperation of the Texas Water Development Board.

Months are identified consecutively by the variable M starting with the month preceeding the first year of data. Some quantities to be accumulated are initialized. Station combination data are stored for the purpose of obtaining maximums and minimums (section D) of weighted flow values later. Tandem stations are identified for cases where a check on consistency of generated quantities is deemed appropriate. Station identification numbers are set to a large number so they will not be undefined. The flow array is filled with -1 values to indicate missing values. For each station and calendar month, the total flow and number of recorded values are computed for computing a flow increment and other statistics later. The minimum flow for each station month is also computed in order to avoid negative logarithms later.

## SECTION C

Station data can be read in random order. Stations are identified by subscript in the order in which data for each station are first read. The year subscript is computed. Negative subscripts will occur if data are for years earlier than the starting year indicated on B card, and data for these are rejected, with diagnostic printout. The stations are counted and the flows for each month at each station are counted for the purpose of computing frequency statistics later. If the number of stations or years exceeds its dimension limit, the job is aborted. The number of stations is permanently stored in the NSTNP array for later identification in multipass operations. The remainder of this section is self explanatory, except to state that permanent identification station numbers are given for stations in combination, for tandem stations, and for consistency-test stations, and subscripts are identified for rapid computation later.

## SECTION D

In this section, maximum and minimum recorded flows for each calendar month , the water year and for durations of 1, 6, and 54 months, and average flows are computed for each station and combination. Durations do not span a break in any record. Quantities are rounded off and printed in fixed-point format.

## SECTION E

The logarithm transform of flows is accomplished here. Missing values are indicated by an impossibly large number (the -1 used for missing flows is a reasonable logarithm and therefore cannot be used for missing logarithms). Before the log transform, the average flow for each calendar month at each station is computed and one (constrained to a minimum of 0.1 flow unit) is added to each flow. If the minimum observed flow for that station month is negative, that absolute value

EXHIBIT 1

is also added before the transform. After the logarithm transform, frequency statistics for each calendar month and station are computed. An increment needed to convert the logarithms to an approximately normal distribution is also computed as an alternative future transform. Logarithms to the base 10 are used so that statistics are comparable to other commonly used statistics. A variable IRCON is set to 1 if any missing values are encountered, so that the flow reconstitution routine will be called later. A variable INDC is set to 1 if the first approximation of increments causes any one of the skew coefficients to be smaller than 0.1 or larger than 0.1. In an optional routine that follows, the increment for each station and calendar month is adjusted individually and iteratively (up to 14 trials) until skew is within 0.1 of zero.

Stations with less than three years of data for any calendar month are deleted, since skew and correlation computations require at least three items of data.

## SECTION F

Correlation matrices are computed here for the purpose of adjusting frequency statistics for short-record stations. All correlation coefficients are first set to -4.0 in order to identify those not computed later for lack of sufficient observed data. Then accumulations of the various quantities required are computed for all items above the main diagonal in the correlation matrix for each month, using all data common to the two stations involved. If more than two items of data are available, the correlation coefficients are computed. Coefficients for the main diagonal are set to 1.0, and those below the main diagonal are set equal to their symmetrical element. Coefficients between the current and preceding month's values are similarly computed. These items constitute an extension of the matrix to the right, which doubles its size, and the new portion is not necessarily symmetrical. Similar complete arrays of average values and root-mean-square values for only those logarithms common to each pair of stations are found for later use in adjusting statistics.

A search is then made to determine the station that would be most useful in adjusting statistics for station months with incomplete record, and the means and standard deviations are adjusted in accordance with the following equations:

$$S_1' = S_1 + (S_2' - S_2)\ R^2 S_1/S_2$$

$$\bar{X}_1' = \bar{X}_1 + (\bar{X}_2' - \bar{X}_2)\ RS_1/S_2$$

where primes indicate long-period values, subscripts are 1 for the short-record station and 2 for the long-record station and,

$\overline{X}$ = mean logarithm

S = standard deviation of the logarithms

R = correlation coefficient.

An optional check of consistency of standard deviations between adjacent stations for the same month is next made. This is to assure that frequency curves do not cross within three standard deviations from the mean. If there is a conflict, the standard deviation of that station designated in the input data as the dependent variable is modified accordingly. All frequency statistics are then printed out.

## SECTION G

All flows are next standardized by subtracting the mean and dividing by the standard deviation for the month and station. An approximate Pearson Type III transform is then applied as follows:

$$K = 6\left[(.5\,gt + 1)^{1/3} - 1\right]/g + g/6$$

where:

K = normal standard deviate
t = Pearson Type III standard deviate
g = skew coefficient

New correlation matrices are then computed, based on the normalized variates and using the same standard procedures previously employed for correlating logarithms. The sign of the correlation coefficient is preserved, since the coefficient will be used to establish regression equations. Correlation coefficients are set to zero if the variance of either variable approximates zero, since the computation of the coefficient is highly unstable and since its use would be of little value.

## SECTION H

For jobs where correlation data are given, the portion of the correlation matrix above the main diagonal for all months and the entire correlation matrix relating current and preceding month's values are read, with a different card for each pair of stations. Values for all 12 months are contained on one card, and the two stations involved are identified on the same card. An automatic check is made to assure that cards are in the required order of columns and rows in the correlation matrix. When generalized statistics are used, only one correlation coefficient for the entire year is read, but card order is the same. Symmetrical elements below the main diagonal are then filled in and values af 1.0 are placed in the main diagonal.

Frequency statistics are then read, 4 cards per station, with 12 monthly values and station identifications on each card. A check is made of the station order, to assure proper subscripting. When generalized statistics are used, only one card per station is read, and this contains the maximum and minimum mean logarithms and the average standard deviation for the year. The months of maximum and minimum mean logarithms are also read and converted to corresponding subscripts. These subscripts will differ from the calendar month number if the year used in the study does not begin with January.

## SECTION I

This section searches for each calendar month the entire correlation matrix to be the right of the main diagonal for misiing correlation coefficients due to the nonexistence of at least three years of simultaneous data for the month. As soon as a coefficient between two variables is identified as missing, a search of the correlation matrix is made to find established correlation coefficients between each of these variables (i and j) and any other variable (k). The range within which correlation between the two variables must lie in order to be mathematically consistent with the correlation with the third variable is established by use of the following equation:

$$R_{ij} = R_{ki} R_{kj} \pm \sqrt{(1-R_{ki}^2)(1-R_{kj})^2}$$

As each successive third variable with established correlation coefficients is found, the upper limit of $R_{ij}$ is constrained to the lowest of all upper limits computed, and the lower limit is constrained to the highest of all such lower limits computed. When the entire matrix has been searched the correlation coefficient is estimated as the average of these two constrained limits. If this element is above the main diagonal, the value is also entered for the element symmetrically across the main diagonal. The search for further missing correlation coefficients is then continued.

## SECTION J

Where a correlation matrix is not to be used for reconstituting data but might be inconsistent, a triad consistency test can be made in this section. This is done by examining all groups of three related correlation coefficients, and testing the lowest one to determine whether it is above minimum constraint established by the equation in the preceding station. If not, it is raised to that minimum. When this is done, it is possible that the adjusted coefficient had already been used in another triad test, and consequently that previous test would need to be repeated. In order to do this properly, the entire matrix is searched up to 12 NSTA times, where NSTA is the number of stations, until a complete search reveals no inconsistent triad (INDC = 0).

A coefficient FAC of the radical in the equation is used in order to obtain complete matrix consistency in difficult cases, whenever possible by this means. A test for overall consistency is made in section K, and if this fails, FAC is successively reduced by 0.2 until overall consistency is reached.

SECTION K

The test for overall consistency of the correlation matrix for each month is made by constructing for each station the correlation matrix that would be used in flow generation for that station and computing the multiple determination coefficient. If the determination coefficient of the matrix for any station and any month exceeds 1.0, all correlation matrices must be reexamined, since some coefficients are common to two or more matrices. This is done by reducing FAC in the triad test (section J) by 0.2 and repeating all triad tests. If FAC is reduced to zero and consistency is not obtained, an index of NCB is set to 1 and an averaging routine is used for each inconsistent matrix. A quantity SUM is computed as the average of all correlation coefficients in that matrix, and each element is modified by multiplying SUM by the excess of determination coefficient and adding this product to the product of the complement of this multiplier and the value of the element in the inconsistent matrix. The averaged or smoothed values are replaced in the complete matrix for the month, and this requires some careful manipulation of subscripts. A new computation of determination coefficient is made and the smoothing process is repeated up to nine times until consistency prevails. If this does not occur, the job is terminated. When consistency is established all complete matrices are printed out and essential elements are punched if desired.

SECTION L

In reconstituting missing data, a search is made for each month of record starting with the first for stations that have no record during that month (Q=T). When one is found, a search of all other stations is made to determine whether recorded or previously reconstituted flows exist for the current month or, if not, for the preceding month. If one is found, it will constitute an independent variable for estimating the missing value, and its value and pertinent correlation coefficients are stored in new arrays for computation purposes. The correlation coefficients with the dependent variable is temporarily stored in the NVAR (NSTA+1) column to assure that coefficients relating independent variables which have sufficient array space (they cannot exceed NSTA in number). A variable ITEMP counts the number of independent variables (stations for which recorded or reconstituted data are available). It is incremented after its set of correlation coefficients are stored in the R array, and is finally used to relocate the correlation coefficients involving the dependent variable. If no independent variables with data are found, as can happen in the first month of record, a correlation is made with the preceding value for the same station and that preceding value is arbitrarily set at the average for the month. The regression equation and determination coefficient are then computed using subroutine CROUT. The variable having the lowest absolute value of correlation with the dependent variable is identified, and beta coefficients are searched in order to eliminate all unreasonable coefficients. In the usual case where the simple correlation coefficient between any variable and the dependent variable is positive, unreasonable coefficients are assumed to be those larger than 1.5 or smaller than -.5. In the case where the variable correlates negatively with the dependent variable, the reasonable range is -1.5 to 0.5. If an unacceptable coefficient is found, INDC is set to 1. If this happens or if the determination coefficient does not lie between 0 and 1.0, the variable with the smallest correlation coefficient is eliminated, the correlation array reconstructed accordingly, and the regression equation recomputed. This process is repeated until all required conditions exist. The missing value is then computed by use of the regression equation and adding a random component normally distributed with zero mean and with variance equal to the error variance of the regression equation.

As soon as the missing value is estimated a search is made for all established values in the current and preceding month with which it is to be correlated, and sums of logarithms, squares, and cross products are incremented in preparation for recomputing all affected correlation coefficients. After checking for sufficient (three years) record and nonzero variance, the correlation coefficient is recomputed. If the standard deviation of either variable is very small, the correlation coefficient is set to zero. If the coefficient is above the main diagonal of the correlation matrix, its value is also assigned to symmetrical element. Since estimation of a missing value affects correlation coefficients between variables in the current and following month, which coefficients are stored in a different matrix, this process of adjusting the correlation coefficient is applied to those values next.

## SECTION M

After all flows are reconstituted, the flow tape is read until the proper position for writing the newly computed flow data on that tape is reached, and headings are printed for writing flows on the printer later. Then the standard deviates are converted to flows by reversing the Pearson type III transform, multiplying by the standard deviation, adding to the mean and taking the antilogarithm. The increment is then subtracted and if the resulting value is negative for a variable with zero lower limit, it is set to zero. In the case of reconstituted flows, the Pearson Type III transform is constrained so that the excess of the standard deviate over and above 2.0 is multiplied by a maximum of 0.3 (if the standard diviation exceeds 0.3). This simply prevents obtaining unreasonably extreme values due to sampling errors. It is a moderation of the extrapolation rather than an abrupt truncation.

The test for tandem station consistency is next made. and inconsistent flows are identified for printout and changed to the limit of consistency. The downstream flow is made consistent with the sum of upstream flows. Flows are punched on cards, if desired, printed out, and written on the flow tape for use in future passes. NQTAP is incremented and represents the total number of records on the tape.

SECTION N

After converting deviates to flows, the frequency statistics are recomputed in order to agree accurately with observed and reconstituted data. If a consistency test is called for, the variable ITRNS is set to 2 and computation is transferred to near the end of section F, where the test is made and the transfer index causes a return to this portion of the program. Adjusted statistics are printed, and the consistent correlation matrix is printed (and, if desired. also punched) by transfer to section K, using ITRNS as a return indicator again. The statistics are then punched, if desired. Flows for the specified station combinations are then computed.

SECTION O

Maximum and minimum recorded flows are computed by transfer to section S, using ITRNS=1 as a return indicator. The variable ITMP keeps a record of the remaining years whose maximum and minimum flows have not been searched yet.

Next, generalized statistics are computed, if desired, (if IGNRL equals two). As indicated, straight averages of all 12 monthly correlation coefficients in every category are taken. Means are averaged for the three wettest consecutive months and the three driest consecutive months and the seasonal timing noted. Standard deviations for all 12 months are averaged. Generalized statistics are then printed out.

Next, generalized statistics read in section H are used to compute required arrays of statistics. Skew and increments are set to zero. The mean for the middle month of the wet season is .2 higher than the wet season average and means for the other two months are .1 lower. Means for the dry seasons are uniform, and means for the transition seasons are interpolated linearly. Correlation coefficients for the dry season are .15 higher (constrained below .98) than the annual average, and those for the wet season are .15 low (constrained above zero). All of these operations are in accord with the generalized model developed in HEC.

## SECTION P

After obtaining monthly statistics and correlation matrices, regression equations for each station and calendar month are computed. Flows are generated in the station order in which data or statistics are read and are generated for each month at all stations before proceeding to the next month. Flows at each station are correlated with flows of the antecedent month at that station and at all stations for which the current month's flows have not yet been generated. For other stations, flows for the current month are used.

Regression equations are computed in subroutine CROUT. If any correlation matrix formed is inconsistent (which should not occur at this stage, except for truncation of computated intermediate variables), a transfer to section J is effected, and consistency operations performed on all correlation matrices. After such a transfer, all regression equations must be recomputed, since any correlation coefficient might have changed. After this, only the beta and alienation coefficients need be retained, in addition to the frequency statistics. In the multipass operation, these are all written on tape ISTST at this point.

## SECTION Q

A routine for projecting historical sequences into the future is employed here. Values of QPREV (previous month's deviate) for each station is determined as the transform of the flow for the month preceding the first month specified (by input data) to be generated. The variable MA is computed for the subscript of Q that conforms to the first month of projected flows. If the projected flow routine is not to be used, the computer is next set up to generate two years of flows, at the end of which synthetic sequences will have a virtually random start.

In the multipass operation, stations are identified and all necessary statistics are contained in the order needed on tape ISTAT. In any pass after the first, flows generated in earlier passes for the same period (the same sequence of data) must be read from tape IQTAP, and this tape must be rewound before each pass in order to permit a complete search. In any sequence after the first, the preceding flow for the first month to be generated is the last flow in the preceding sequence for that station, and these are saved in the QSTAP array for multipass operation. If the multipass feature is not used, all necessary statistics and flows for generating are in memory.

## SECTION R

In starting to generate flows, a variable JXTMP is used to identify the year number of the first year of each sequence in the multipass operation. Variables AVG and SDV are used to compute the mean and standard deviation of the deviates for each flow sequence. These are later used to adjust all deviates so that the means and standard deviations in every generated sequence will be the same as those of the historical sequence.

Variables JA and NJ are set up to correspond to the first and last year of generation in each successive sequence, depending on the type of operation. MA has already been set up as the subscript of Q corresponding to the first month of flows to be generated (for use in projecting historical flows recorded to the current time). QPREV for each station has been identified as the previous month's flow for that station. Flows are then generated for each station, using stored regression equations and a random component. Each generated flow is immediately entered into the QPREV array, because its preceding flow will never again be used in that pass.

In the multipass routine, flows (as deviates) are written on tape at the end of each pass, and the last flow for each station is stored in the QSTAP array for use in the next sequence.

If more than 19 years (an arbitrarily selected length) of flow are being generated in any sequence, deviates are adjusted so that their mean is zero and variance 1.0. Their unadjusted mean and standard deviation are printed. Then they are transformed to flows, and, if called for, consistency tests between stations are made. For variables with zero natural limit, a check for negative values is then made. Flows are then printed and, if desired, punched. Flow combinations are then computed.

## SECTION S

Before computing maximum and minimum values of generated flows, a positive value of JX is looked for to assure that flows generated are not to be discarded (the first two years generated for a random start). Also, at least NYMXG years must have been generated before maximum and minimum values are computed (this applies only when the number of years remaining for generation in the last sequence does not equal NYMXG). Maximum sums are initiated at an extremely large negative number and minimum sums as an extremely large positive number (T). Then a routine search of flow sums for the specified durations at each station is made for the sequence, and results are printed out. Since this routine is used for reconstituted flows as well as for generated flows, a transfer indicator is used to determine whether the next step is back to the reconstitution routine or the generation routine. If the latter, a check is made for the multipass routine. If all passes are not completed, a transfer to section Q is made. If all passes are completed for this sequence or if the multipass routine is not being used, a check is made of remaining years to be generated. If greater than zero, a transfer to section Q is made after adjusting years yet to be generated. Otherwise the job is ended and a new job, if any, is started.

## RANDOM NUMBER FUNCTION RNGEN

This random number function is for a binary machine and the constants must be computed according to the number of bits in an integer word. The numbers generated are uniformly distributed in the interval 0 to 1.

The function is called from the main program by a statement similar to the following:

A = RNGEN (IX)

Where A is some floating point variable name and IX is some integer variable name. The argument name IX need not be the same in the main program and the function. The argument must be initialized to zero in the main program. The location of the initializing statement is important and depends on the results desired. If it is desired to have different sets of random numbers for each of several different sets of computations (jobs) that are run sequentially on the same program, then the argument must be initialized at the very beginning of the program and never reinitialized. If it is permissible to use the same sequence of random numbers for each job, the argument must be initialized at the beginning of each job. The advantage of this latter option occurs when one of the jobs must be re-run for some minor reason as the same random numbers will be used and the results will be comparable.

Three constants must be computed by the following equations:

Constant one (C1) = $2^{(B+1)/2} + 3$

Constant two (C2) = $2^{B} - 1$

Constant three (C3) = $1./2.^{B}$

Where: B = number of bits in an <u>integer</u> word

The constants for some of the common computers are listed in the following table:

| COMPUTER | SIZE OF INTEGER WORD | C1 | CONSTANTS C2 | C3 |
|---|---|---|---|---|
| GE 200 Series | 19 | 1027 | 524287 | 0.190734863E-05 |
| GE 400 Series | 23 | 4099 | 8388607 | 0.119209290E-06 |
| IBM 360 Series | 31 | 65539 | 2147483647 | 0.465661287E-09 |
| IBM 7040 and 7090 Series | 35 | 262147 | 34359738367 | 0.2910383046E-10 |
| UNIVAC 1108 | " | " | " | " |
| CDC 6000 Series | 48 | 16777219 | 281474976710655 | 0.3552713678E-14 |

EXHIBIT 1

April 1960

## EXHIBIT 2

## Crout's Method

One of the best methods for solving systems of linear equations on desk calculating machines was developed by P. D. Crout in 1941. This method is based on the elimination method, with the calculations arranged in systematic order so as to facilitate their accomplishment on a desk calculator. In this method the coefficients and constant terms of the equations are written in the form of a "matrix," which is a rectangular array of quantities arranged in rows and columns.

The method is best explained by an example. Suppose that in a multiple correlation analysis it is required to solve the following system of linear equations to obtain the unknown values of $b_2$, $b_3$, $b_4$ and $b_5$.

$$\Sigma x_2^2 \; b_2 + \Sigma x_2x_3 \; b_3 + \Sigma x_2x_4 \; b_4 + \Sigma x_2x_5 \; b_5 = \Sigma x_1x_2$$

$$\Sigma x_2x_3 \; b_2 + \Sigma x_3^2 \; b_3 + \Sigma x_3x_4 \; b_4 + \Sigma x_3x_5 \; b_5 = \Sigma x_1x_3$$

$$\Sigma x_2x_4 \; b_2 + \Sigma x_3x_4 \; b_3 + \Sigma x_4^2 \; b_4 + \Sigma x_4x_5 \; b_5 = \Sigma x_1x_4$$

$$\Sigma x_2x_5 \; b_2 + \Sigma x_3x_5 \; b_3 + \Sigma x_4x_5 \; b_4 + \Sigma x_5^2 \; b_5 = \Sigma x_1x_5$$

For simplicity let us replace the coefficients of the b's by the letters p, q, r and s, and the constant terms by the letter t, using subscripts 1, 2, 3 and 4 to denote the respective equations:

$$p_1 \; b_2 + q_1 \; b_3 + r_1 \; b_4 + s_1 \; b_5 = t_1$$

$$p_2 \; b_2 + q_2 \; b_3 + r_2 \; b_4 + s_2 \; b_5 = t_2$$

$$p_3 \; b_2 + q_3 \; b_3 + r_3 \; b_4 + s_3 \; b_5 = t_3$$

$$p_4 \; b_2 + q_4 \; b_3 + r_4 \; b_4 + s_4 \; b_5 = t_4$$

A continuous check on the computations as they progress may be obtained by adding to the matrix of the above system a column of u's, such that $u = p + q + r + s + t$. The matrix and check column are written as follows:

$$\begin{vmatrix} p_1 & q_1 & r_1 & s_1 & t_1 & u_1 \\ p_2 & q_2 & r_2 & s_2 & t_2 & u_2 \\ p_3 & q_3 & r_3 & s_3 & t_3 & u_3 \\ p_4 & q_4 & r_4 & s_4 & t_4 & u_4 \end{vmatrix}$$

The elements $p_1$, $q_2$, $r_3$ and $s_4$ form the "principal diagonal" of the matrix. Examination of the original equations shows that the coefficients are symmetrical about the principal diagonal, i.e., $q_1 = p_2$, $r_1 = p_3$, $r_2 = q_3$, $s_1 = p_4$, $s_2 = q_4$, and $s_3 = r_4$. This is characteristic of the system of equations to be solved in any multiple correlation analysis. Because of this symmetry, the computations are considerably simplified. While the Crout method may be used to solve any system of linear equations, the computational steps given here are applicable only to those with symmetrical coefficients.

The solution consists of two parts, viz., the computation of a "derived matrix" and the "back solution." Let the derived matrix be denoted as follows:

$$\begin{vmatrix} P_1 & Q_1 & R_1 & S_1 & T_1 & U_1 \\ P_2 & Q_2 & R_2 & S_2 & T_2 & U_2 \\ P_3 & Q_3 & R_3 & S_3 & T_3 & U_3 \\ P_4 & Q_4 & R_4 & S_4 & T_4 & U_4 \end{vmatrix}$$

EXHIBIT 2

The elements of the derived matrix are computed as follows:

$$P_1 = p_1 \qquad P_2 = p_2 \qquad P_3 = p_3 \qquad P_4 = p_4$$

$$Q_1 = \frac{q_1}{p_1} \qquad R_1 = \frac{r_1}{p_1} \qquad S_1 = \frac{s_1}{p_1} \qquad T_1 = \frac{t_1}{p_1} \qquad U_1 = \frac{u_1}{p_1}$$

$$Q_2 = q_2 - P_2Q_1 \qquad Q_3 = q_3 - P_3Q_1 \qquad R_2 = \frac{Q_3}{Q_2}$$

$$Q_4 = q_4 - P_4Q_1 \qquad S_2 = \frac{Q_4}{Q_2} \qquad T_2 = \frac{t_2 - T_1P_2}{Q_2} \qquad U_2 = \frac{u_2 - U_1P_2}{Q_2}$$

$$R_3 = r_3 - Q_3R_2 - P_3R_1 \qquad R_4 = r_4 - Q_4R_2 - P_4R_1 \qquad S_3 = \frac{R_4}{R_3}$$

$$T_3 = \frac{t_3 - T_2Q_3 - T_1P_3}{R_3} \qquad U_3 = \frac{u_3 - U_2Q_3 - U_1P_3}{R_3}$$

$$S_4 = s_4 - R_4S_3 - Q_4S_2 - P_4S_1$$

$$T_4 = \frac{t_4 - T_3R_4 - T_2Q_4 - T_1P_4}{S_4} \qquad U_4 = \frac{u_4 - U_3R_4 - U_2Q_4 - U_1P_4}{S_4}$$

The general pattern of the above computations, which may be applied to a system containing any number of equations, is as follows:

(1) The first column of the derived matrix is copied from the first column of the given matrix.

(2) The remaining elements in the first row of the derived matrix are computed by dividing the corresponding elements in the first row of the given matrix by the first element in that row.

(3) After completing the nth row, the remaining elements in the (n+1)th column are computed. Such an element (X) equals the corresponding element of the given matrix minus the product of the element immediately to the left of (X) by the element immediately above the principal diagonal in the same column as (X), minus the product of the second element to the left of (X) by the second element above the principal diagonal in the same column as (X), etc. After each element below the principal diagonal is recorded, and while that element is still in the calculator, it is divided by the element of the principal diagonal which is in the same column. The quotient is the element whose location is symmetrical to (X) with respect to the principal diagonal.

(4) When the elements in the (n+1)th column and their symmetrical counterparts have been recorded, the (n+1)th row will be complete except for the last two elements, which are next computed. Such an element (X) equals the corresponding element of the given matrix minus the product of the element immediately above (X) by the element immediately to the left of the principal diagonal in the same row as (X), minus the product of the second element above (X) by the second element to the left of the principal diagonal in the same row as (X), etc., all divided by the element of the principal diagonal in the same row as (X).

The check column (U) of the derived matrix serves as a continuous check on the computations in that each element in the column equals one plus the sum of the elements in the same row to the right of the principal diagonal. That is,

$$U_1 = 1 + Q_1 + R_1 + S_1 + T_1$$

$$U_2 = 1 + R_2 + S_2 + T_2$$

$$U_3 = 1 + S_3 + T_3$$

$$U_4 = 1 + T_4$$

This check should be made after completing each row.

The elements of the derived matrix to the right of the principal diagonal form a system of equations which may now be used to compute the unknown values of $b_2$, $b_3$, $b_4$ and $b_5$ by successive substitution. This is known as the "back solution." The computations are as follows:

$$b_5 = T_4$$

$$b_4 = T_3 - S_3 b_5$$

$$b_3 = T_2 - S_2 b_5 - R_2 b_4$$

$$b_2 = T_1 - S_1 b_5 - R_1 b_4 - Q_1 b_3$$

It is very important that the computations be carried to a sufficient number of digits, both in computing the coefficients and constant terms of the original equations, and in computing the elements of the derived matrix. It is possible for relatively small errors in the coefficients and constant terms of the original equations to result in relatively large errors in the computed solutions of the unknowns. The greatest source of error in computing the elements of the derived matrix arises from the loss of leading significant digits by subtraction. This must be guarded against and can be done by carrying the computations to more figures than the data. As a general rule, it is recommended that the coefficients and constant terms of the original equations be carried to a sufficient number of decimals to produce at least five significant digits in the smallest quantity, and that the elements of the derived matrix be carried to one more decimal than this, but to not less than six significant digits.

```
A                  TEST DATA - 723-X6-L2340
A            MONTHLY STREAMFLOW SIMULATION - NOV 1970
A                STANDARD ANALYSIS AND GENERATION
B   1904       10        1        5        10        5        1
C      1
D      3     107       110       111
E      3       1.        1.        1.
H1071905 4.64   2.24   3.74   9.72 30.2   36.5   13.8   14.8    4.36   1.48    .553   .085
H1071906  .372  1.35   2.25  33.2  16.7   84.2   33.1   18.3   10.7    3.24   1.09    .400
H1071907  .867  1.98  31.4   72.6  32.5  121.    32.4   12.2    6.49   2.80   1.19   1.15
H1101904  2.72  4.08   3.38   3.65 13.2   46.7   62.5  141.    70.2   14.1    6.76   7.14
H1101905 33.5   6.49   5.50   6.89 14.0   34.4   47.5   88.5   82.7   18.4    4.52   2.61
H1101906  2.59  3.31   5.04  48.9  23.1  152.   110.   200.   288.   216.    42.6   12.3
H1101907  6.40  6.07  14.1   25.6  33.4   64.0  118.   122.   124.    64.6   16.1    5.60
H1101908  7.07  6.37  12.3   12.8  18.8   37.1   48.0   55.5   36.2   11.4    5.44   5.01
H1111904 12.4  13.9   13.1   12.5  37.4  134.   212.   590.   431.   123.    65.2   42.7
H1111905 119.  37.7   22.6   28.1  50.8  116.   165.   366.   386.   116.    28.3   12.6
H1111906 11.2  12.1   16.3  146.   68.3  330.   287.   682.  1010.  1000.   270.    67.2
H1111907 31.4  23.4   43.0   87.9 101.   248.   403.   563.   625.   454.   121.    32.5
I
A                  TEST DATA - 723-X6-L2340
A            MONTHLY STREAMFLOW SIMULATION - NOV 1970
A            MULTI-PASS RECONSTITUTION AND GENERATION
B   1904       10        1        5        10        5        2
C
H1071905 4.64   2.24   3.74   9.72 30.2   36.5   13.8   14.8    4.36   1.48    .553   .085
H1071906  .372  1.35   2.25  33.2  16.7   84.2   33.1   18.3   10.7    3.24   1.09    .400
H1071907  .867  1.98  31.4   72.6  32.5  121.    32.4   12.2    6.49   2.80   1.19   1.15
H1101904  2.72  4.08   3.38   3.65 13.2   46.7   62.5  141.    70.2   14.1    6.76   7.14
H1101905 33.5   6.49   5.50   6.89 14.0   34.4   47.5   88.5   82.7   18.4    4.52   2.61
H1101906  2.59  3.31   5.04  48.9  23.1  152.   110.   200.   288.   216.    42.6   12.3
H1101907  6.40  6.07  14.1   25.6  33.4   64.0  118.   122.   124.    64.6   16.1    5.60
H1101908  7.07  6.37  12.3   12.8  18.8   37.1   48.0   55.5   36.2   11.4    5.44   5.01
I
J      1      110
H1111904 12.4  13.9   13.1   12.5  37.4  134.   212.   590.   431.   123.    65.2   42.7
H1111905 119.  37.7   22.6   28.1  50.8  116.   165.   366.   386.   116.    28.3   12.6
H1111906 11.2  12.1   16.3  146.   68.3  330.   287.   682.  1010.  1000.   270.    67.2
H1111907 31.4  23.4   43.0   87.9 101.   248.   403.   563.   625.   454.   121.    32.5
I
```

```
A                       TEST DATA - 723-X6-L2340
A               MONTHLY STREAMFLOW SIMULATION - NOV 1970
A                           FLOW PROJECTIONS
B   1904      10       1       5                       1
C                                      2    1909      10    1913
H1101904  2.72  4.08  3.38  3.65 13.2  46.7  62.5 141.   70.2  14.1   6.76  7.14
H1101905 33.5   6.49  5.50  6.89 14.0  34.4  47.5  88.5  82.7  18.4   4.52  2.61
H1101906  2.59  3.31  5.04 48.9  23.1 152.  110.  200.  288.  216.   42.6 12.3
H1101907  6.40  6.07 14.1  25.6  33.4  64.0 118.  122.  124.   64.6 16.1   5.60
H1101908  7.07  6.37 12.3  12.8  18.8  37.1  48.0  55.5  36.2  11.4   5.44  5.01
H1111904  12.4  13.9  13.1  12.5  37.4 134.  212.  590.  431.  123.   65.2  42.7
H1111905 119.   37.7  22.6  28.1  50.8 116.  165.  366.  386.  116.   28.3  12.6
H1111906  11.2  12.1  16.3 146.   68.3 330.  287.  682. 1010. 1000.  270.   67.2
H1111907  31.4  23.4  43.0  87.9 101.  248.  403.  563.  625.  454.  121.     -1
I
A                       TEST DATA - 723-X6-L2340
A               MONTHLY STREAMFLOW SIMULATION - NOV 1970
A                COMPUTE AND USE GENERALIZED STATISTICS
B   1904      10       1       5      10      10       1
C                              2
H1101904  2.72  4.08  3.38  3.65 13.2  46.7  62.5 141.   70.2  14.1   6.76  7.14
H1101905 33.5   6.49  5.50  6.89 14.0  34.4  47.5  88.5  82.7  18.4   4.52  2.61
H1101906  2.59  3.31  5.04 48.9  23.1 152.  110.  200.  288.  216.   42.6 12.3
H1101907  6.40  6.07 14.1  25.6  33.4  64.0 118.  122.  124.   64.6 16.1   5.60
H1101908  7.07  6.37 12.3  12.8  18.8  37.1  48.0  55.5  36.2  11.4   5.44  5.01
H1111904  12.4  13.9  13.1  12.5  37.4 134.  212.  590.  431.  123.   65.2  42.7
H1111905 119.   37.7  22.6  28.1  50.8 116.  165.  366.  386.  116.   28.3  12.6
H1111906  11.2  12.1  16.3 146.   68.3 330.  287.  682. 1010. 1000.  270.   67.2
H1111907  31.4  23.4  43.0  87.9 101.  248.  403.  563.  625.  454.  121.   32.5
I
A                       TEST DATA - 723-X6-L2340
A               MONTHLY STREAMFLOW SIMULATION - NOV 1970
A                         STATISTICS FURNISHED
B             10                      10      10
C                                                                                3
 107 107  .864  .949  .521  .402  .000  .000  .916  .000  .000  .947  .880  .897
 107 110  .390  .951  .532  .407  .000  .999  .867  .000  .998  .936  .850  .754
 107 111  .390  .956  .510  .392 0.     .967  .946 0.     .926  .955  .863  .769
 110 107  .998  .979  .988  .793  .000  .770  .992  .000  .988  .965  .822  .596
 110 107  .866  .928  .518  .317  .999  .000  .923  .833  .000  .983  .963  .729
```

```
110 110  .391  .930  .529  .321  .793  .757  .860  .826  .986  .971  .959  .833
110 111  .391  .936  .507  .309  .789  .733  .938  .763  .915  .975  .974  .850
111 107  .992  .979  .968  .784  .000  .866  .917  .000  .992  .980  .858  .591
111 110  .994  .957  .963  .995  .967  .917  .924  .924  .980  .985  .980  .998
111 107  .861  .970  .538  .315  .968  .000  .999  .906  .000  .968  .974  .728
111 110  .389  .971  .550  .319  .767  .826  .795  .899  .990  .956  .940  .832
111 111  .388  .977  .526  .307  .763  .799  .867  .831  .918  .974  .955  .849
    107  .123  .277  .917 1.378 1.449 1.851 1.393 1.156  .778  .327 -.079 -.529
    107  .509  .100  .651  .339  .151  .196  .154  .076  .176  .152  .138  .412
    107  .015 -.027  .157 -.211 -.750 -.829 -.658 -.164 -.098 -.643 -.793 -.253
    107    .0    .0    .1    .5    .3   1.0    .3    .2    .1    .0    .0    .0
    110  .817  .712  .849 1.132 1.291 1.760 1.859 2.052 1.983 1.538 1.021  .768
    110  .443  .131  .263  .437  .164  .259  .189  .208  .327  .528  .399  .241
    110  .220 -.036 -.048  .150  .418  .586  .262 -.006  .236  .550  .464  .307
    110    .1    .1    .1    .2    .2    .8    .9   1.5   1.4    .8    .2    .1
    111 1.529 1.332 1.401 1.637 1.798 2.281 2.407 2.707 2.712 2.345 1.878 1.574
    111  .451  .207  .242  .416  .160  .184  .143  .118  .195  .469  .391  .283
    111  .289  .505  .359  .118  .073  .144 -.099 -.253  .125  .274 -.074 -.115
    111    .5    .3    .3    .8    .8   2.5   3.2   6.6   7.4   5.1   1.5    .5
A                         TEST DATA - 723-X6-L2340
A                 MONTHLY STREAMFLOW SIMULATION - NOV 1970
A                        GENERALIZED STATISTICS FURNISHED
B          10                                   10       10
C                                    1                                       3
 107 107  .531
 110 107  .741
 110 110  .763
 111 107  .744
 111 110  .965
 111 111  .763
     107 1.494 -.189   .290    4.   10.
     110 1.965  .766   .299    6.   11.
     111 2.611 1.427   .269    6.   12.

A
```

```
                  TEST DATA - 723-X6-L2340
          MONTHLY STREAMFLOW SIMULATION - NOV 1970
             STANDARD ANALYSIS AND GENERATION

 IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS  NSTA NCOMB NTNDM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ
 1964    10     1     5    10     5     1    -0    -0    -0     1    -0    -0    -0    -0    -0    -0    -0

COMB 1  STA         3     107      110      111
      RATIO             1.000    1.000    1.000

MAXIMUM VOLUMES OF RECORDED FLOWS
 STA      10       11       12        1        2        3        4        5        6        7        8        9     1-MO      6-MO     54-MO    AV MO
 107       5        2       31       73       33      121       33       18       11        3        1        1      121       302-99999998       18
 110      34        6       14       49       33      152      118      200      288      216       43       12      288      1009      2656       45
 111     119       38       43      146      101      330      403      682     1010     1000      270       67     1010      3579-99999998      204
 996     157       46       89      228      167      566      553      900     1309     1219      314       80     1309      4738-99999998      299

MINIMUM VOLUMES
 STA      10       11       12        1        2        3        4        5        6        7        8        9     1-MO      6-MO     54-MO    AV MO
 107       0        1        2       10       17       37       14       12        4        1        1        0        0         6  99999999
 110       3        3        3        4       13       34       48       56       36       11        5        3        3        36      2519
 111      11       12       13       13       37      116      165      366      386      116       28       13       11       196  99999999
 996      14       17       24       45       95      187      226      469      473      136       33       15       14       239  99999999

FREQUENCY STATISTICS

  STA     ITEM      10       11       12        1        2        3        4        5        6        7        8        9

  107     MEAN     .112     .283     .820    1.465    1.410    1.862    1.395    1.177     .834     .395     .000    -.312
       STD DEV     .513     .108     .597     .433     .157     .263     .214     .087     .192     .173     .162     .415
          SKEW    1.041   -1.308    1.491    -.627   -1.653   -1.073   -1.728     .144     .348   -1.489   -1.641    -.122
        INCRMT     .10      .10      .12      .39      .26      .81      .26      .15      .10      .10      .10      .10
         YEARS        3        3        3        3        3        3        3        3        3        3        3        3

  110     MEAN     .815     .715     .849    1.130    1.290    1.758    1.858    2.051    1.982    1.536    1.020     .770
       STD DEV     .444     .130     .262     .439     .164     .259     .190     .208     .328     .530     .400     .240
          SKEW    1.211    -.835     .220     .071     .626    1.454     .371    -.453     .485    1.041    1.085    -.121
        INCRMT     .10      .10      .10      .20      .20      .67      .77     1.21     1.20      .65      .15      .10
         YEARS        5        5        5        5        5        5        5        5        5        5        5        5

  111     MEAN    1.439    1.298    1.335    1.673    1.784    2.281    2.407    2.734    2.760    2.462    1.953    1.524
       STD DEV     .469     .223     .223     .473     .182     .213     .166     .115     .187     .449     .408     .302
          SKEW    1.117     .620    1.004    -.243     .258     .208     .278   -1.429     .892     .472    -.019    -.939
        INCRMT     .43      .22      .24      .69      .64     2.07     2.67     5.50     6.13     4.23     1.21      .39
         YEARS        4        4        4        4        4        4        4        4        4        4        4        4
```

EXHIBIT 4

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FREQUENCY STATISTICS AFTER ADJUSTMENTS

STA    ITEM      10      11      12       1       2       3       4       5       6       7       8       9

107    MEAN     .012    .283    .769   1.403   1.410   1.826   1.321   1.177    .710    .316   -.033   -.312
    STD DEV     .409    .389    .537    .363    .157    .227    .187    .087    .228    .166    .133    .415
       SKEW    1.041  -1.308   1.491   -.627  -1.653  -1.073  -1.728    .144    .348  -1.489  -1.641   -.122
     INCRMT     .10     .10     .12     .39     .26     .81     .26     .15     .10     .10     .10     .10

110    MEAN     .315    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
    STD DEV     .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
       SKEW    1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
     INCRMT     .10     .10     .10     .20     .20     .67     .77    1.21    1.20     .65     .15     .10

111    MEAN    1.448   1.334   1.385   1.669   1.782   2.250   2.372   2.681   2.693   2.368   1.890   1.507


    STD DEV     .407    .209    .224    .409    .158    .198    .163    .153    .220    .441    .380    .265
       SKEW    1.117    .620   1.004   -.243    .258    .208    .278  -1.429    .892    .472   -.019   -.939
     INCRMT     .43     .22     .24     .69     .64    2.07    2.67    5.50    6.13    4.23    1.21     .39



RAW CORRELATION COEFFICIENTS FOR MONTH 10

 STA    107     110     111
                       WITH CURRENT MONTH
 107  1.000    .998    .987
 110   .998   1.000    .997
 111   .987    .997   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
 107 -4.000    .534    .526
 110   .905    .588    .578
 111 -4.000    .663    .656

RAW CORRELATION COEFFICIENTS FOR MONTH 11

 STA    107     110     111
                       WITH CURRENT MONTH
 107  1.000    .970   1.000
 110   .970   1.000    .974
 111  1.000    .974   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
 107   .964    .984    .994
 110   .870    .881    .944
 111   .964    .982    .994
```

NOTE: *Remaining months not shown.*

RECORDED AND RECONSTITUTED FLOWS

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 107 | 1904 | 0E | 2E | 1E | 15E | 24E | 48E | 20E | 11E | 4E | 2E | 1E | 0E | 128 |
| 107 | 1905 | 5 | 2 | 4 | 10 | 30 | 36 | 14 | 15 | 4 | 1 | 1 | 0 | 122 |
| 107 | 1906 | 0 | 1 | 2 | 33 | 17 | 84 | 33 | 18 | 11 | 3 | 1 | 0 | 203 |
| 107 | 1907 | 1 | 2 | 31 | 73 | 32 | 121 | 32 | 12 | 6 | 3 | 1 | 1 | 315 |
| 107 | 1908 | 1E | 2E | 16E | 46E | 32E | 56E | 15E | 13E | 2E | 1E | 1E | 0E | 185 |

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 1904 | 3 | 4 | 3 | 4 | 13 | 47 | 62 | 141 | 70 | 14 | 7 | 7 | 375 |
| 110 | 1905 | 33 | 6 | 5 | 7 | 14 | 34 | 47 | 88 | 83 | 18 | 5 | 3 | 343 |
| 110 | 1906 | 3 | 3 | 5 | 49 | 23 | 152 | 110 | 200 | 288 | 216 | 43 | 12 | 1104 |
| 110 | 1907 | 6 | 6 | 14 | 26 | 33 | 64 | 118 | 122 | 124 | 65 | 16 | 6 | 600 |
| 110 | 1908 | 7 | 6 | 12 | 13 | 19 | 37 | 48 | 55 | 36 | 11 | 5 | 5 | 254 |

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 1904 | 12 | 14 | 13 | 12 | 37 | 134 | 212 | 590 | 431 | 123 | 65 | 43 | 1686 |
| 111 | 1905 | 119 | 38 | 23 | 28 | 51 | 116 | 165 | 366 | 386 | 116 | 28 | 13 | 1449 |
| 111 | 1906 | 11 | 12 | 16 | 146 | 68 | 330 | 287 | 682 | 1010 | 1000 | 270 | 67 | 3899 |
| 111 | 1907 | 31 | 23 | 43 | 88 | 101 | 248 | 403 | 563 | 625 | 454 | 121 | 32 | 2732 |
| 111 | 1908 | 30E | 24E | 40E | 51E | 64E | 107E | 149E | 294E | 269E | 70E | 48E | 29E | 1175 |

ADJUSTED FREQUENCY STATISTICS

| STA | ITEM | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 107 | MEAN | .019 | .278 | .761 | 1.451 | 1.424 | 1.807 | 1.336 | 1.141 | .712 | .313 | .009 | -.314 |
|  | STD DEV | .412 | .086 | .575 | .350 | .122 | .202 | .176 | .082 | .233 | .172 | .116 | .294 |
|  | SKEW | 1.185 | -.585 | .399 | -.251 | -1.298 | .445 | .192 | 1.018 | .135 | .335 | -1.606 | -.061 |
|  | INCRMT | .10 | .10 | .12 | .39 | .26 | .81 | .26 | .15 | .10 | .10 | .10 | .10 |
| 110 | MEAN | .815 | .715 | .849 | 1.130 | 1.290 | 1.758 | 1.858 | 2.051 | 1.982 | 1.536 | 1.020 | .770 |
|  | STD DEV | .444 | .130 | .262 | .439 | .164 | .259 | .190 | .208 | .328 | .530 | .400 | .240 |
|  | SKEW | 1.211 | -.835 | .220 | .071 | .626 | 1.454 | .371 | -.453 | .485 | 1.041 | 1.085 | -.121 |
|  | INCRMT | .10 | .10 | .10 | .20 | .20 | .67 | .77 | 1.21 | 1.20 | .65 | .15 | .10 |
| 111 | MEAN | 1.447 | 1.314 | 1.388 | 1.682 | 1.789 | 2.232 | 2.361 | 2.683 | 2.696 | 2.344 | 1.902 | 1.512 |
|  | STD DEV | .407 | .197 | .227 | .410 | .158 | .215 | .176 | .152 | .216 | .470 | .372 | .263 |
|  | SKEW | .964 | .188 | .070 | -.335 | .094 | .677 | .580 | -.629 | .541 | .722 | .545 | -.671 |
|  | INCRMT | .43 | .22 | .24 | .69 | .64 | 2.07 | 2.67 | 5.50 | 6.15 | 4.23 | 1.21 | .39 |

```
CONSISTENT CORRELATION MATRIX FOR MONTH 10

  STA     107     110     111
                        WITH CURRENT MONTH
  107   1.000    .997    .989
  110    .997   1.000    .997
  111    .989    .997   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  107    .463    .526    .516
  110    .458    .588    .576
  111    .481    .660    .651

CONSISTENT CORRELATION MATRIX FOR MONTH 11

  STA     107     110     111
                        WITH CURRENT MONTH
  107   1.000    .960    .999
  110    .960   1.000    .954
  111    .999    .954   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  107    .964    .975    .985
  110    .867    .881    .904
  111    .969    .980    .990
```

NOTE: *Remaining months not shown.*

```
MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF RECORDED AND RECONSTITUTED FLOWS
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO  54-MO  AV MO
 107      5      2     31     73     32    121     33     18     11      3      1      1    121    302    954     16
 110     33      6     14     49     33    152    118    200    288    216     43     12    288   1009   2656     45
 111    119     38     43    146    101    330    403    682   1010   1000    270     67   1010   3579  10826    182
 996    157     46     88    228    167    566    553    900   1309   1219    314     80   1309   4738  14411    243
MINIMUM VOLUMES
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO  54-MO  AV MO
 107      0      1      1     10     17     36     14     11      2      1      1      0      0      6    869
 110      3      3      3      4     13     34     47     55     36     11      5      3      3     36   2564
 111     11     12     13     12     37    107    149    294    269     70     28     13     11    196  10220
 996     14     17     18     31     74    187    212    362    308     83     33     15     14    239  13726
INCONSISTENT CORREL MATRIX FOR I=  1  K=  2  DTRMC= 1.001

INCONSISTENT CORREL MATRIX ADJUSTED   0   1   3       1.000
```

```
GENERATED FLOWS FOR PERIOD  1

 STA   YEAR     10     11     12      1      2      3      4      5      6      7      8      9     TOTAL
 107     1       1      2      4     12     37     28      8     11      6      7      8      9      107
 107     2       0      2      3      9     12     43     17     13      2      1      1      0      111
 107     3       0      2      9     49     24     64     31     15      9      2      1      0      207
 107     4       1      2     11     36     28     61     22     15      9      3      1      0      189
 107     5       1      2      1      6     27     50     16     11      3      3      1      0      119
                                                                                 1
 STA   YEAR     10     11     12      1      2      3      4      5      6      7      8      9     TOTAL
 110     1       7      5      6      3     11     25     28     55     36     10      4      5      195
 110     2       3      4      5     22     15     40     56    184    200     41      9      6      585
 110     3       3      5      9     30     22     96    103    154    226    125     29     15      817
 110     4       8      6      9     13     19     50     69    162    228    112     16      6      698
 110     5       6      5      3      4     14     49     58     84     50      9      4      2      288

 STA   YEAR     10     11     12      1      2      3      4      5      6      7      8      9     TOTAL
 111     1      26     22     22     11     40     60    124    254    237     62     32     30      920
 111     2      13     14     18     80     46    132    190    698    836    337     71     34     2469
 111     3      13     16     28    100     75    287    290    575    741    552    245     81     3003
 111     4      39     28     34     51     63    163    214    615    781    572    109     34     2703
 111     5      25     19     13     13     44    109    213    420    308     77     22      6     1269


MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF SYNTHETIC FLOWS
 STA    10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO   54-MO   AV MO
 107     1      2     11     49     37     64     31     15      9      3      1      0     64    192     724      12
 110     8      6      9     30     22     96    103    184    228    125     29     15    228    731    2555      43
 111    39     28     34    100     75    287    290    698    836    572    245     81    836   2691   10255     173
 996    47     36     54    178    121    447    424    895   1046    687    275     96   1046   3545   13522     228
MINIMUM VOLUMES
 STA    10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO   54-MO   AV MO
 107     0      2      1      6     12     28      8     11      2      1      1      0      0      6     648
 110     3      4      3      3     11     25     28     55     36      9      4      2      2     31    2427
 111    13     14     13     11     40     60    124    254    237     62     22      6      6    149    9506
 996    16     20     17     23     74    113    160    320    275     73     26      8      8    207   12648
```

```
GENERATED FLOWS FOR PERIOD  2

 STA   YEAR      10      11      12       1       2       3       4       5       6       7       8       9       TOTAL
 107     6        0       1       1      15      16      77      34      18       7       3       1       1        174
 107     7        9       2     145     160      35      79      20      15       5       2       1       0        473
 107     8        0       1       8      48      26      65      20      11       4       1       1       0        185
 107     9        1       2       3      20      25      51      24      13       3       2       1       0        145
 107    10        1       2      20      61      23     115      33      13       8       3       1       0        280

 STA   YEAR      10      11      12       1       2       3       4       5       6       7       8       9       TOTAL
 110     6        2       3       3      20      22     106     113     124     151      72      27      12        655
 110     7       64       8      33      28      25      42      66     106      90      32      10       6        510
 110     8        2       4       9      21      21      47      71     114      63      12       6       4        374
 110     9        4       5       5       9      18      84      79      94      55      38       7       6        404
 110    10        5       7      13      19      27      87     122     169     197     146      26      11        829

 STA   YEAR      10      11      12       1       2       3       4       5       6       7       8       9       TOTAL
 111     6        9      11       9      64      63     292     325     542     641     438     218      68       2680
 111     7      207      48      92     102      85     146     189     476     470     198      87      34       2134
 111     8        9      11      25      72      68     149     243     508     396     104      50      26       1661
 111     9       17      17      20      34      57     211     249     385     337     174      53      33       1587
 111    10       23      23      39      71      69     284     373     672     784     675     199      62       3274


MAXIMUM VOLUMES FOR PERIOD  2 OF   5 YEARS OF SYNTHETIC FLOWS
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO    54-MO   AV MO
 107       9       2     145     160      35     115      34      18       8       3       1       1     160     454     1254      21
 110      64       8      33      28      27     106     122     169     197     146      27      12     197     748     2707      46
 111     207      48      92     102      85     292     373     672     784     675     218      68     784    2987    11121     189
 996     280      59     270     289     145     485     528     855     990     824     246      81     990    3908    15054     256

MINIMUM VOLUMES
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO    54-MO   AV MO
 107       0       1       1      15      16      51      20      11       3       1       1       0       0       8     1150
 110       2       3       3       9      18      42      66      94      55      12       6       4       2      33     2216
 111       9      11       9      34      57     146     189     385     337     104      50      26       9     163     8936
 996      11      15      12      63     100     261     275     492     395     118      56      30      11     223    12386
```

```
                 TEST DATA - 723-X6-L2340
         MONTHLY STREAMFLOW SIMULATION - NOV 1970
         MULTI-PASS RECONSTITUTION AND GENERATION

 IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS  NSTA NCOMB NTNDM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ
 1904    10     1     5    10     5     2    -0    -0    -0    -0    -0    -0    -0    -0    -0    -0    -0

MAXIMUM VOLUMES OF RECORDED FLOWS
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO     54-MO   AV MO
 107      5      2     31     73     33    121     33     18     11      3      1      1    121    302-99999998      18
 110     34      6     14     49     33    152    118    200    288    216     43     12    288   1009      2656      45

MINIMUM VOLUMES
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO     54-MO   AV MO
 107      0      1      2     10     17     37     14     12      4      1      1      0      0      6  99999999
 110      3      3      3      4     13     34     48     56     36     11      5      3      3     36      2519

FREQUENCY STATISTICS

  STA     ITEM     10      11      12       1       2       3       4       5       6       7       8       9

  107     MEAN    .112    .283    .820   1.465   1.410   1.862   1.395   1.177    .834    .395    .000   -.312
       STD DEV    .513    .108    .597    .433    .157    .263    .214    .087    .192    .173    .162    .415
          SKEW   1.041  -1.308   1.491   -.627  -1.653  -1.073  -1.728    .144    .348  -1.489  -1.641   -.122
        INCRMT     .10     .10     .12     .39     .26     .81     .26     .15     .10     .10     .10     .10
         YEARS       3       3       3       3       3       3       3       3       3       3       3       3

  110     MEAN    .815    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
       STD DEV    .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
          SKEW   1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
        INCRMT     .10     .10     .10     .20     .20     .67     .77    1.21    1.20     .65     .15     .10
         YEARS       5       5       5       5       5       5       5       5       5       5       5       5

FREQUENCY STATISTICS AFTER ADJUSTMENTS

  STA     ITEM     10      11      12       1       2       3       4       5       6       7       8       9

  107     MEAN    .012    .283    .769   1.403   1.410   1.862   1.321   1.177    .710    .316   -.033   -.312
       STD DEV    .409    .089    .637    .363    .157    .263    .187    .087    .228    .166    .133    .415
          SKEW   1.041  -1.308   1.491   -.627  -1.653  -1.073  -1.728    .144    .348  -1.489  -1.641   -.122
        INCRMT     .10     .10     .12     .39     .26     .81     .26     .15     .10     .10     .10     .10

  110     MEAN    .815    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
       STD DEV    .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
          SKEW   1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
        INCRMT     .10     .10     .10     .20     .20     .67     .77    1.21    1.20     .65     .15     .10
```

**EXHIBIT 4**

```
RAW CORRELATION COEFFICIENTS FOR MONTH 10

  STA     107     110
                       WITH CURRENT MONTH
  107  1.000    .998
  110    .998  1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  107 -4.000    .534
  110    .905    .588


RAW CORRELATION COEFFICIENTS FOR MONTH 11

  STA     107     110
                       WITH CURRENT MONTH
  107  1.000    .970
  110    .970  1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  107    .964    .980
  110    .870    .881
```

NOTE: *Remaining months not shown.*

```
RECORDED AND RECONSTITUTED FLOWS
PASS  1

 STA  YEAR      10      11      12       1       2       3       4       5       6       7       8       9     TOTAL
 107  1904      0E      2E      1E     12E     27E     68E     20E     11E      4E      2E      1E      0E       148
 107  1905      5       2       4      10      30      36      14      15       4       1       1       0        122
 107  1906      0       1       2      33      17      84      33      18      11       3       1       0        203
 107  1907      1       2      31      73      32     121      32      12       6       3       1       1        315
 107  1908      1E      2E     20E     44E     24E     84E     16E     17E      3E      1E      1E      0E       213

 STA  YEAR      10      11      12       1       2       3       4       5       6       7       8       9     TOTAL
 110  1904      3       4       3       4      13      47      62     141      70      14       7       7        375
 110  1905     33       6       5       7      14      34      47      88      83      18       5       3        343
 110  1906      3       3       5      49      23     152     110     200     288     216      43      12       1104
 110  1907      6       6      14      26      33      64     118     122     124      65      16       6        600
 110  1908      7       6      12      13      19      37      48      55      36      11       5       5        254


ADJUSTED FREQUENCY STATISTICS

  STA     ITEM      10       11       12       1        2        3        4        5        6        7        8        9

  107     MEAN     .019     .285     .788    1.427    1.408    1.870    1.342    1.167     .707     .318    -.037    -.453
       STD DEV     .412     .085     .586     .365     .113     .189     .172     .091     .230     .166     .144     .424
          SKEW    1.185    -.822     .383    -.144   -1.182    -.994     .140    -.143     .453     .436    -.327    -.071
        INCRMT     .10      .10      .12      .39      .26      .31      .26      .15      .10      .10      .10      .10

  110     MEAN     .315     .715     .849    1.130    1.290    1.758    1.858    2.051    1.982    1.536    1.020     .770
       STD DEV     .444     .130     .262     .439     .164     .259     .190     .208     .328     .530     .400     .240
          SKEW    1.211    -.835     .220     .071     .626    1.454     .371    -.453     .485    1.041    1.085    -.121
        INCRMT     .10      .10      .10      .20      .20      .67      .77     1.21     1.20      .65      .15      .10
```

```
CONSISTENT CORRELATION MATRIX FOR MONTH 10

  STA     107     110
                       WITH CURRENT MONTH
  107  1.000    .997
  110   .997   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  107   .481    .526
  110   .475    .588


CONSISTENT CORRELATION MATRIX FOR MONTH 11

  STA     107     110
                       WITH CURRENT MONTH
  107  1.000    .972
  110   .972   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  107   .941    .950
  110   .867    .881
```

NOTE: *Remaining months not shown.*

```
MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF RECORDED AND RECONSTITUTED FLOWS
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO   54-MO   AV MO
 107       5       2      31      73      32     121      33      18      11       3       1       1     121     302    1000      17
 110      33       6      14      49      33     152     118     200     288     216      43      12     288    1009    2656      45
MINIMUM VOLUMES
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO   54-MO   AV MO
 107       0       1       1      10      17      36      14      11       3       1       1       0       0       6     894
 110       3       3       3       4      13      34      47      55      36      11       5       3       3      36    2564
INCONSISTENT CORREL MATRIX FOR I=  1  K=  2  DTRMC= 1.000
```

```
PASS  2
STA(S) FROM PREVIOUS PASSES   110

MAXIMUM VOLUMES OF RECORDED FLOWS
 STA     10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO     54-MO   AV MO
 111    119      38      43     146     101     330     403     682    1010    1000     270      67    1010    3579-99999998     204

MINIMUM VOLUMES
 STA     10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO     54-MO   AV MO
 111     11      12      13      13      37     116     165     366     386     116      28      13      11     196 99999999

FREQUENCY STATISTICS

  STA    ITEM     10       11       12        1        2        3        4        5        6        7        8        9

  111     MEAN  1.439    1.298    1.335    1.673    1.784    2.281    2.407    2.734    2.760    2.462    1.953    1.524
       STD DEV   .469     .223     .223     .473     .182     .213     .166     .115     .187     .449     .408     .302
          SKEW  1.117     .620    1.004    -.243     .258     .208     .278   -1.429     .892     .472    -.019    -.939
        INCRMT   .43      .22      .24      .69      .64     2.07     2.67     5.50     6.13     4.23     1.21      .39
         YEARS     4        4        4        4        4        4        4        4        4        4        4        4

FREQUENCY STATISTICS AFTER ADJUSTMENTS

  STA    ITEM     10       11       12        1        2        3        4        5        6        7        8        9

  110     MEAN   .815     .715     .849    1.130    1.290    1.758    1.858    2.051    1.982    1.536    1.020     .770
       STD DEV   .444     .130     .262     .439     .164     .259     .190     .208     .328     .530     .400     .240
          SKEW  1.211    -.835     .220     .071     .626    1.454     .371    -.453     .485    1.041    1.085    -.121
        INCRMT   .10      .10      .10      .20      .20      .67      .77     1.21     1.20      .65      .15      .10

  111     MEAN  1.448    1.334    1.385    1.669    1.782    2.250    2.372    2.681    2.693    2.368    1.890    1.507
       STD DEV   .407     .209     .224     .409     .158     .198     .163     .153     .220     .441     .380     .265
          SKEW  1.117     .620    1.004    -.243     .258     .208     .278   -1.429     .892     .472    -.019    -.939
        INCRMT   .43      .22      .24      .69      .64     2.07     2.67     5.50     6.13     4.23     1.21      .39
```

```
RAW CORRELATION COEFFICIENTS FOR MONTH 10

  STA     110     111
                        WITH CURRENT MONTH
  110  1.000    .997
  111   .997   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110   .588    .578
  111   .663    .656

RAW CORRELATION COEFFICIENTS FOR MONTH 11

  STA     110     111
                        WITH CURRENT MONTH
  110  1.000    .974
  111   .974   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110   .881    .944
  111   .982    .994
```

NOTE: *Remaining months not shown.*

```
RECORDED AND RECONSTITUTED FLOWS
PASS  2

 STA  YEAR     10     11     12      1      2      3      4      5      6      7      8      9    TOTAL
 111  1904     12     14     13     12     37    134    212    590    431    123     65     43    1686
 111  1905    119     38     23     28     51    116    165    366    386    116     28     13    1449
 111  1906     11     12     16    146     68    330    287    682   1010   1000    270     67    3899
 111  1907     31     23     43     88    101    248    403    563    625    454    121     32    2732
 111  1908    34E    23E    35E    47E    52E   137E   180E   256E   313E    95E    33E    29E    1234


ADJUSTED FREQUENCY STATISTICS

  STA    ITEM     10      11      12       1       2       3       4       5       6       7       8       9

  111    MEAN   1.458   1.312   1.378   1.674   1.771   2.254   2.378   2.671   2.709   2.369   1.870   1.512
      STD DEV    .409    .196    .216    .409    .163    .195    .158    .173    .198    .441    .399    .263
         SKEW    .820    .239    .089   -.243    .615    .737    .811   -.878    .898    .896    .578   -.674
       INCRMT    .43     .22     .24     .69     .64    2.07    2.67    5.50    6.13    4.23    1.21     .39
```

```
CONSISTENT CORRELATION MATRIX FOR MONTH 10

  STA      110      111
                         WITH CURRENT MONTH
  110   1.000     .996
  111    .996    1.000
                         WITH PRECEDING MONTH AT ABOVE STATION
  110    .588     .578
  111    .653     .642


CONSISTENT CORRELATION MATRIX FOR MONTH 11

  STA      110      111
                         WITH CURRENT MONTH
  110   1.000     .949
  111    .949    1.000
                         WITH PRECEDING MONTH AT ABOVE STATION
  110    .881     .920
  111    .981     .994
```

NOTE: *Remaining months not shown.*

```
MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF RECORDED AND RECONSTITUTED FLOWS
 STA     10      11      12      1      2      3      4      5      6      7      8      9    1-MO    6-MO    54-MO   AV MO
 111    119      38      43    146    101    330    403    682   1010   1000    270     67   1010    3579    10890     183
MINIMUM VOLUMES
 STA     10      11      12      1      2      3      4      5      6      7      8      9    1-MO    6-MO    54-MO   AV MO
 111     11      12      13     12     37    116    165    256    313     95     28     13     11     196    10264

GENERATED FLOWS FOR PERIOD  1
PASS  1

 STA  YEAR       10       11       12        1        2        3        4        5        6        7        8        9      TOTAL
 107    1         2        2       11       67       25       67       25       19        6        3        1        1        229
 107    2         2        2       18       54       29      133       36       15        6        3        1        2        304
 107    3         0        1        0        7       24      119       42       17       11        3        1        0        225
 107    4         1        2       93      101       25      103       16       14        4        2        1        0        362
 107    5         1        2        3       28       25      100       28       15        5        2        1        0        210

 STA  YEAR       10       11       12        1        2        3        4        5        6        7        8        9      TOTAL
 110    1        14        6       10       30       20       55       75      135      106       82       47        6        586
 110    2        12        6       12       32       32      110      123      183      201       89       12        2        814
 110    3         2        3        2       12       19      143      140      237      267      111       33       13        982
 110    4        10        7       23       29       24       31       51       64       65       20        7        4        335
 110    5         8        5        5       41       24       79       91      150       91       23        9        5        531
```

```
MAXIMUM  VOLUMES  FOR  PERIOD  1 OF   5 YEARS OF SYNTHETIC FLOWS
 STA       10      11      12      1      2      3      4      5      6      7      8      9    1-MO    6-MO    54-MO    AV MO
 107        2       2      93    101     29    133     42     19     11      3      1      2     133     352     1318       22
 110       14       7      23     41     32    143    140    237    267    111     47     13     267     931     3180       54
MINIMUM  VOLUMES
 STA       10      11      12      1      2      3      4      5      6      7      8      9    1-MO    6-MO    54-MO    AV MO
 107        0       1       0      7     24     67     16     14      6      7      8      9    1-MO    6-MO    54-MO    AV MO
 110        2       3       2     12     19     31     51     64     65     20      7      2       2      34     2955



GENERATED FLOWS FOR PERIOD  1
PASS  2

 STA  YEAR      10      11      12      1      2      3      4      5      6      7      8      9      TOTAL
 111    1       56      28      33    103     62    188    275    538    565    435    433     37      2753
 111    2       52      29      37    107     84    302    343    690    757    529     81     10      3021
 111    3        9      12       9     40     52    262    453    837   1182    586    238     73      3753
 111    4       50      30      60    104     70    115    181    331    373    135     55     20      1524
 111    5       34      23      20    127     57    239    257    577    397    156     83     31      2001



MAXIMUM  VOLUMES  FOR  PERIOD  1 OF   5 YEARS OF SYNTHETIC FLOWS
 STA       10      11      12      1      2      3      4      5      6      7      8      9    1-MO    6-MO    54-MO    AV MO
 111       56      30      60    127     84    302    453    837   1182    586    433     73    1182    3558    12738      218
MINIMUM  VOLUMES
 STA       10      11      12      1      2      3      4      5      6      7      8      9    1-MO    6-MO    54-MO    AV MO
 111        9      12       9     40     52    115    181    331    373    135     55     10       9     131    11751
```

```
GENERATED FLOWS FOR PERIOD  2
PASS  1

 STA  YEAR       10      11      12       1       2       3       4       5       6       7       8       9      TOTAL
 107    6         1       2       7      29      14      83      18      12       3       2       1       0       172
 107    7         1       2       5      23      24      89      36      18      18       6       2       1       225
 107    8         2       2       2       5      22      22      14      16       4       2       1       0        92
 107    9         0       1       2      24      22      64      18      15       2       1       1       0       150
 107   10         0       1       3      31      19      57      15      15       3       1       1       0       146

 STA  YEAR       10      11      12       1       2       3       4       5       6       7       8       9      TOTAL
 110    6         6       6       7      21      16      37      61      84      54      14       8       8       322
 110    7         6       6       6      18      18      96     115     164     534     783     335      21      2102
 110    8        19       6       4       2       9      40      45      95      74      28       9       6       337
 110    9         2       4       4      15      16      42      55      65      34       9       3       3       252
 110   10         3       4       6      30      17      34      48      91      54      11       4       4       306


MAXIMUM VOLUMES FOR PERIOD  2 OF   5 YEARS OF SYNTHETIC FLOWS
 STA     10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO     54-MO    AV MO
 107      2       2       7      31      24      89      36      18      18       6       2       1      89     208       778       13
 110     19       6       7      30      18      96     115     164     534     783     335      21     783    2027      3281       55

MINIMUM VOLUMES
 STA     10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO     54-MO    AV MO
 107      0       1       2       5      14      22      14      12       2       1       1       0       0       6       650
 110      2       4       4       2       9      34      45      65      34       9       3       3       2      27      3149

GENERATED FLOWS FOR PERIOD  2
PASS  2

 STA  YEAR       10      11      12       1       2       3       4       5       6       7       8       9      TOTAL
 111    6        26      22      26      67      56     135     208     390     392     108      60      48      1538
 111    7        28      22      24      67      65     252     339     635    1339    2916    2337     100      8124
 111    8        96      34      18       6      31     115     157     394     400     182      72      33      1538
 111    9         8      11      14      52      42     136     176     316     281      72      22      14      1144
 111   10        11      13      18      99      62     131     164     395     379     117      26      22      1437

MAXIMUM VOLUMES FOR PERIOD  2 OF   5 YEARS OF SYNTHETIC FLOWS
 STA     10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO     54-MO    AV MO
 111     96      34      26      99      65     252     339     635    1339    2916    2337     100    2916    7819     13594      230

MINIMUM VOLUMES
 STA     10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO     54-MO    AV MO
 111      8      11      14       6      31     115     157     316     281      72      22      14       6     152     12818
```

**EXHIBIT 4**

```
                 TEST DATA - 723-X6-L2340
          MONTHLY STREAMFLOW SIMULATION - NOV 1970
                     FLOW PROJECTIONS

 IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS  NSTA NCOMB NTNDM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ
 1904    10     1     5    -0    -0     1    -0    -0    -0    -0    -0    -0    -0     2  1909    10  1913

MAXIMUM VOLUMES OF RECORDED FLOWS
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO      6-MO     54-MO    AV MO
 110      34       6      14      49      33     152     118     200     288     216      43      12     288      1009      2656       45
 111     119      38      43     146     101     330     403     682    1010    1000     270      67    1010      3579-99999998      207

MINIMUM VOLUMES
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO      6-MO     54-MO    AV MO
 110       3       3       3       4      13      34      48      56      36      11       5       3       3        36      2519
 111      11      12      13      13      37     116     165     306     386     116      28      13      11       196  99999999

FREQUENCY STATISTICS

 STA      ITEM      10      11      12       1       2       3       4       5       6       7       8       9

 110      MEAN    .815    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
       STD DEV    .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
          SKEW   1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
        INCRMT     .10     .10     .10     .20     .20     .67     .77    1.21    1.20     .65     .15     .10
         YEARS       5       5       5       5       5       5       5       5       5       5       5       5

 111      MEAN   1.439   1.298   1.335   1.673   1.784   2.281   2.407   2.734   2.760   2.462   1.953   1.526
       STD DEV    .469    .223    .223    .473    .182    .213    .166    .115    .187    .449    .408    .370
          SKEW   1.117    .620   1.004   -.243    .258    .208    .278  -1.429    .892    .472   -.019  -1.204
        INCRMT     .43     .22     .24     .69     .64    2.07    2.67    5.50    6.13    4.23    1.21     .41
         YEARS       4       4       4       4       4       4       4       4       4       4       4       3

FREQUENCY STATISTICS AFTER ADJUSTMENTS

 STA      ITEM      10      11      12       1       2       3       4       5       6       7       8       9

 110      MEAN    .815    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
       STD DEV    .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
          SKEW   1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
        INCRMT     .10     .10     .10     .20     .20     .67     .77    1.21    1.20     .65     .15     .10

 111      MEAN   1.448   1.334   1.385   1.669   1.782   2.250   2.372   2.681   2.693   2.368   1.890   1.499
       STD DEV    .407    .299    .224    .409    .158    .198    .163    .153    .220    .441    .380    .266
          SKEW   1.117    .620   1.004   -.243    .258    .208    .278  -1.429    .892    .472   -.019  -1.204
        INCRMT     .43     .22     .24     .69     .64    2.07    2.67    5.50    6.13    4.23    1.21     .41
```

**EXHIBIT 4**

```
RAW CORRELATION COEFFICIENTS FOR MONTH 10

  STA     110     111
                        WITH CURRENT MONTH
  110   1.000    .997
  111    .997   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110    .588    .538
  111    .663    .613


RAW CORRELATION COEFFICIENTS FOR MONTH 11

  STA     110     111
                        WITH CURRENT MONTH
  110   1.000    .974
  111    .974   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110    .881    .944
  111    .982    .994
```

*NOTE: Remaining months not shown.*

```
RECORDED AND RECONSTITUTED FLOWS

 STA  YEAR      10      11      12       1       2       3       4       5       6       7       8       9     TOTAL
 110  1904       3       4       3       4      13      47      62     141      70      14       7       7       375
 110  1905      33       6       5       7      14      34      47      88      83      18       5       3       343
 110  1906       3       3       5      49      23     152     110     200     288     216      43      12      1104
 110  1907       6       6      14      26      33      64     118     122     124      65      16       6       600
 110  1908       7       6      12      13      19      37      48      55      36      11       5       5       254

 STA  YEAR      10      11      12       1       2       3       4       5       6       7       8       9     TOTAL
 111  1904      12      14      13      12      37     134     212     590     431     123      65      43      1686
 111  1905     119      38      23      28      51     116     165     366     386     116      28      13      1449
 111  1906      11      12      16     146      68     330     287     682    1010    1000     270      67      3899
 111  1907      31      23      43      88     101     248     403     563     625     454     121     33E      2733
 111  1908     34E     26E     39E     47E     59E    116E    136E    279E    315E     98E     43E     30E      1222
ADJUSTED FREQUENCY STATISTICS

  STA      ITEM     10      11      12       1       2       3       4       5       6       7       8       9

  110      MEAN    .815    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
        STD DEV    .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
           SKEW   1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
         INCRMT    .10     .10     .10     .20     .20     .67     .77    1.21    1.20     .65     .15     .10

  111      MEAN   1.459   1.321   1.386   1.674   1.783   2.240   2.354   2.678   2.709   2.371   1.892   1.518
        STD DEV    .409    .200    .224    .409    .158    .207    .186    .160    .198    .439    .379    .262
           SKEW    .806    .043    .068   -.239    .297    .741    .399   -.725    .906    .908    .581   -.785
         INCRMT    .43     .22     .24     .69     .64    2.07    2.67    5.50    6.13    4.23    1.21     .41
```

```
CONSISTENT CORRELATION MATRIX FOR MONTH 10

  STA     110     111
                       WITH CURRENT MONTH
  110   1.000    .995
  111    .995   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  110    .588    .531
  111    .652    .396


CONSISTENT CORRELATION MATRIX FUR MONTH 11

  STA     110     111
                       WITH CURRENT MONTH
  110   1.000    .967
  111    .967   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  110    .881    .922
  111    .972    .990
```

*NOTE: Remaining months not shown.*

```
MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF RECORDED AND RECONSTITUTED FLOWS
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO   54-MO   AV MO
 110      33       6      14      49      33     152     118     200     288     216      43      12     288    1009    2656      45
 111     119      38      43     146     101     330     403     682    1010    1000     270      67    1010    3579   10872     183
MINIMUM VOLUMES
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO   54-MO   AV MO
 110       3       3       3       4      13      34      47      55      36      11       5       3       3      36    2564
 111      11      12      13      12      37     116     136     279     315      98      28      13      11     196   10214
```

GENERATED FLOWS FOR PERIOD 1

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 1909 | 3 | 5 | 12 | 99 | 37 | 43 | 74 | 124 | 162 | 47 | 26 | 10 | 642 |
| 110 | 1910 | 11 | 7 | 19 | 27 | 19 | 131 | 106 | 172 | 241 | 304 | 65 | 12 | 1114 |
| 110 | 1911 | 6 | 6 | 4 | 11 | 36 | 136 | 103 | 267 | 744 | 766 | 123 | 13 | 2215 |
| 110 | 1912 | 11 | 7 | 14 | 79 | 37 | 42 | 66 | 110 | 159 | 35 | 8 | 4 | 572 |
| 110 | 1913 | 2 | 3 | 8 | 28 | 16 | 58 | 62 | 120 | 59 | 25 | 13 | 10 | 404 |

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 1909 | 16 | 17 | 33 | 265 | 96 | 185 | 216 | 480 | 650 | 418 | 197 | 55 | 2628 |
| 111 | 1910 | 52 | 29 | 54 | 99 | 55 | 291 | 293 | 666 | 1037 | 1561 | 384 | 69 | 4590 |
| 111 | 1911 | 29 | 23 | 15 | 38 | 81 | 344 | 241 | 833 | 2588 | 3593 | 626 | 73 | 8484 |
| 111 | 1912 | 54 | 30 | 45 | 218 | 129 | 182 | 189 | 475 | 642 | 217 | 59 | 27 | 2267 |
| 111 | 1913 | 6 | 9 | 23 | 92 | 49 | 185 | 167 | 474 | 399 | 209 | 129 | 60 | 1802 |

GENERATED FLOWS FOR PERIOD 2

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 1909 | 6 | 5 | 9 | 27 | 28 | 59 | 90 | 150 | 118 | 31 | 8 | 4 | 535 |
| 110 | 1910 | 6 | 5 | 7 | 34 | 34 | 84 | 116 | 217 | 201 | 65 | 21 | 10 | 800 |
| 110 | 1911 | 29 | 8 | 12 | 9 | 16 | 28 | 38 | 45 | 37 | 9 | 4 | 3 | 238 |
| 110 | 1912 | 2 | 3 | 4 | 29 | 19 | 53 | 73 | 127 | 161 | 72 | 26 | 11 | 580 |
| 110 | 1913 | 19 | 7 | 13 | 4 | 13 | 34 | 57 | 90 | 52 | 11 | 4 | 4 | 308 |

| STA | YEAR | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 1909 | 26 | 21 | 29 | 96 | 97 | 214 | 248 | 596 | 649 | 225 | 69 | 24 | 2294 |
| 111 | 1910 | 28 | 20 | 23 | 113 | 129 | 329 | 280 | 727 | 631 | 433 | 165 | 60 | 2938 |
| 111 | 1911 | 122 | 42 | 44 | 35 | 52 | 88 | 138 | 257 | 309 | 77 | 30 | 19 | 1213 |
| 111 | 1912 | 10 | 12 | 14 | 99 | 62 | 169 | 238 | 495 | 669 | 519 | 205 | 62 | 2554 |
| 111 | 1913 | 87 | 37 | 46 | 15 | 44 | 114 | 196 | 396 | 346 | 87 | 33 | 21 | 1422 |

```
                          TEST DATA - 723-X6-L2340
                    MONTHLY STREAMFLOW SIMULATION - NOV 1970
                     COMPUTE AND USE GENERALIZED STATISTICS

 IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS  NSTA NCOMB NTNDM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ
 1904    10     1     5    10    10     1    -0    -0    -0    -0    -0    -0     2    -0    -0    -0    -0

MAXIMUM VOLUMES OF RECORDED FLOWS
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO    6-MO      54-MO    AV MO
 110     34      6     14     49     33    152    118    200    288    216     43     12    288    1009       2656       45
 111    119     38     43    146    101    330    403    682   1010   1000    270     67   1010    3579-99999998      204

MINIMUM VOLUMES
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO    6-MO      54-MO    AV MO
 110      3      3      3      4     13     34     48     56     36     11      5      3      3      36       2519
 111     11     12     13     13     37    116    165    366    386    116     28     13     11     196   99999999

FREQUENCY STATISTICS

  STA     ITEM       10        11        12         1         2         3         4         5         6         7         8         9

  110     MEAN      .815      .715      .849     1.130     1.290     1.758     1.858     2.051     1.982     1.536     1.020      .770
       STD DEV      .444      .130      .262      .439      .164      .259      .190      .208      .328      .530      .400      .240
          SKEW     1.211     -.835      .220      .071      .626     1.454      .371     -.453      .485     1.041     1.085     -.121
        INCRMT      .10       .10       .10       .20       .21       .67       .77      1.21      1.20       .65       .15       .10
         YEARS         5         5         5         5         5         5         5         5         5         5         5         5

  111     MEAN     1.439     1.298     1.335     1.673     1.784     2.261     2.407     2.734     2.760     2.462     1.953     1.524
       STD DEV      .469      .223      .223      .473      .182      .213      .166      .115      .187      .449      .408      .302
          SKEW     1.117      .620     1.004     -.243      .258      .208      .278    -1.429      .892      .472     -.019     -.939
        INCRMT      .44       .22       .24       .69       .64      2.07      2.67      5.50      6.13      4.23      1.21       .39
         YEARS         4         4         4         4         4         4         4         4         4         4         4         4

FREQUENCY STATISTICS AFTER ADJUSTMENTS

  STA     ITEM       10        11        12         1         2         3         4         5         6         7         8         9

  110     MEAN      .815      .715      .849     1.130     1.290     1.758     1.858     2.051     1.982     1.536     1.020      .770
       STD DEV      .444      .130      .262      .439      .164      .259      .190      .208      .328      .530      .400      .240
          SKEW     1.211     -.835      .220      .071      .626     1.454      .371     -.453      .485     1.041     1.085     -.121
        INCRMT      .10       .10       .10       .20       .21       .67       .77      1.21      1.20       .65       .15       .10

  111     MEAN     1.448     1.334     1.385     1.669     1.782     2.250     2.372     2.681     2.693     2.368     1.890     1.507
       STD DEV      .407      .209      .224      .409      .158      .198      .163      .153      .220      .441      .380      .265
          SKEW     1.117      .620     1.004     -.243      .258      .208      .278    -1.429      .892      .472     -.019     -.939
        INCRMT      .44       .22       .24       .69       .64      2.07      2.67      5.50      6.13      4.23      1.21       .39
```

```
RAW CORRELATION COEFFICIENTS FOR MONTH 10

  STA     110     111
                       WITH CURRENT MONTH
  110   1.000    .997
  111    .997   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  110    .588    .578
  111    .663    .656


RAW CORRELATION COEFFICIENTS FOR MONTH 11

  STA     110     111
                       WITH CURRENT MONTH
  110   1.000    .974
  111    .974   1.000
                       WITH PRECEDING MONTH AT ABOVE STATION
  110    .881    .944
  111    .982    .994
```

NOTE: Remaining months not shown

```
RECORDED AND RECONSTITUTED FLOWS

 STA  YEAR     10      11      12      1       2       3       4       5       6       7       8       9      TOTAL
 110  1904      3       4       3      4      13      47      62     141      70      14       7       7       375
 110  1905     33       6       5      7      14      34      47      88      83      18       5       3       343
 110  1906      3       3       5     49      23     152     110     200     286     216      43      12      1104
 110  1907      6       6      14     26      33      64     118     122     124      65      16       6       600
 110  1908      7       6      12     13      19      37      48      55      36      11       5       5       254

 STA  YEAR     10      11      12      1       2       3       4       5       6       7       8       9      TOTAL
 111  1904     12      14      13     12      37     134     212     590     431     123      65      43      1686
 111  1905    119      38      23     28      51     116     165     366     386     116      28      13      1449
 111  1906     11      12      16    146      68     330     287     682    1010    1000     270      67      3899
 111  1907     31      23      43     88     101     246     403     563     625     454     121      32      2732
 111  1908     30E     25E     39E    48E     59E    131E    153E    216E    253E    117E     48E     29E     1148


ADJUSTED FREQUENCY STATISTICS

 STA    ITEM       10      11      12       1       2       3       4       5       6       7       8       9

 110     MEAN     .815    .715    .849   1.130   1.290   1.758   1.858   2.051   1.982   1.536   1.020    .770
      STD DEV     .444    .130    .262    .439    .164    .259    .190    .208    .328    .530    .400    .240
         SKEW    1.211   -.835    .220    .071    .626   1.454    .371   -.453    .485   1.041   1.085   -.121
       INCRMT      .10     .10     .10     .20     .21     .67     .77    1.21    1.20     .65     .15     .10

 111     MEAN    1.447   1.319   1.386   1.675   1.783   2.250   2.363   2.657   2.691   2.386   1.900   1.513
      STD DEV     .407    .199    .225    .409    .158    .198    .173    .200    .224    .424    .372    .263
         SKEW     .972    .077    .068   -.261    .281    .758    .626  -1.148    .389    .957    .550   -.696
       INCRMT      .44     .22     .24     .69     .64    2.07    2.67    5.50    6.13    4.23    1.21     .39
```

```
CONSISTENT CORRELATION MATRIX FOR MONTH 10

  STA     110     111
                        WITH CURRENT MONTH
  110   1.000    .997
  111    .997   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110    .588    .578
  111    .660    .651


CONSISTENT CORRELATION MATRIX FOR MONTH 11

  STA     110     111
                        WITH CURRENT MONTH
  110   1.000    .964
  111    .964   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110    .881    .903
  111    .974    .984
```

NOTE: Remaining months not shown

```
MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF RECORDED AND RECONSTITUTED FLOWS
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO   54-MO   AV MO
 110      33       6      14      49      33     152     118     200     288     216      43      12     288    1009    2656      45
 111     119      38      43     146     101     330     403     682    1010    1000     270      67    1010    3579   10797     182

MINIMUM VOLUMES
 STA      10      11      12       1       2       3       4       5       6       7       8       9    1-MO    6-MO   54-MO   AV MO
 110       3       3       3       4      13      34      47      55      36      11       5       3       3      36    2564
 111      11      12      13      12      37     116     153     216     253     116      28      13      11     196   10240

GENERALIZED STATISTICS

ST1 ST2  RAV
110 110  .774
111 110  .981
111 111  .789

    STA  AVMX  AVMN  SDAV MAXMO MINMO
    110 1.964  .767  .300     6    11
    111 2.578 1.384  .271     7    12
```

```
CONSISTENT CORRELATION MATRIX FOR MONTH 10

  STA     110     111
                        WITH CURRENT MONTH
  110  1.000    .981
  111   .981   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110   .924    .853
  111   .853    .939

CONSISTENT CORRELATION MATRIX FOR MONTH 11

  STA     110     111
                        WITH CURRENT MONTH
  110  1.000    .981
  111   .981   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
  110   .924    .853
  111   .853    .939
```

NOTE: Remaining months not shown

```
MAXIMUM VOLUMES FOR PERIOD  1 OF   5 YEARS OF RECORDED AND RECONSTITUTED FLOWS
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO   54-MO   AV MO
 110     33      6     14     49     33    152    118    200    288    216     43     12    288   1009    2656      45
 111    119     38     43    146    101    330    403    682   1010   1000    270     67   1010   3579   10797     182
MINIMUM VOLUMES
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO   54-MO   AV MO
 110      3      3      3      4     13     34     47     55     36     11      5      3      3     36    2564
 111     11     12     13     12     37    116    153    216    253    116     28     13     11    196   10240
```

```
GENERATED FLOWS FOR PERIOD  1

 STA   YEAR       10      11      12       1       2       3       4       5       6       7       8       9        TOTAL
 110     1         6       5      14      29      43      36      74     129      66      31      21      11         465
 110     2        11       9      23      45      45      56      85     137      62      27      16       9         525
 110     3         9       7      14      34      48      45     187     392      90      19       7       3         855
 110     4         5       7       8      12      25      62      61      68      38      25      21      14         346
 110     5        17      21      14       7       7      19      50     166     107      48      20       8         484
 110     6         6       6      13      26      35      50      65     143     104      48      17       6         519
 110     7        10      11      24      56      85      82     101     118      28      11       8       5         539
 110     8         4       5       8      23      57     121     211     195      34       9       6       4         677
 110     9         4       3       5      10      27      65     106     181      66      23       4       1         495
 110    10         2       2       2       3       5      27      38     185     134      60      12       3         473

 STA   YEAR       10      11      12       1       2       3       4       5       6       7       8       9        TOTAL
 111     1        24      22      29      65     106     106     182     272     543     255     169      92        1865
 111     2        43      39      49     103     124     154     222     299     529     208     136      87        1993
 111     3        38      31      34      76     121     130     378     774     876     228      78      26        2790
 111     4        17      23      22      32      59     137     169     163     313     187     161      83        1366
 111     5        54      71      45      25      21      44     109     297     806     448     192      77        2189
 111     6        28      26      29      60      90     130     174     294     791     441     173      53        2289
 111     7        33      39      50     120     208     232     280     279     277     124      67      45        1754
 111     8        18      19      20      49     123     269     500     475     364      95      53      44        2029
 111     9        17      15      14      24      59     142     256     385     586     303      57      16        1874
 111    10         7       7       5       7      13      51      92     312     975     573     138      31        2211


MAXIMUM VOLUMES FOR PERIOD  1 OF  10 YEARS OF SYNTHETIC FLOWS
 STA      10      11      12       1       2       3       4       5       6       7       8       9     1-MO     6-MO     54-MO    AV MO
 110      17      21      24      56      85     121     211     392     134      60      21      14      392      797      2691       45
 111      54      71      50     120     208     269     500     774     975     573     192      92      975     2507     10214      170

MINIMUM VOLUMES
 STA      10      11      12       1       2       3       4       5       6       7       8       9     1-MO     6-MO     54-MO    AV MO
 110       2       2       2       3       5      19      38      68      28       9       4       1        1       14      1935
 111       7       7       5       7      13      44      92     163     277      95      53      16        5       56      7809
```

```
                    TEST DATA - 723-X6-L2340
          MONTHLY STREAMFLOW SIMULATION - NOV 1970
                      STATISTICS FURNISHED

 IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS  NSTA NCOMB NTNDM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ
   -0    10    -0    -0    10    10    -0    -0    -0     3    -0    -0    -0    -0    -0    -0    -0    -0


GENERATED FLOWS FOR PERIOD  1

 STA  YEAR      10      11      12       1       2       3       4       5       6       7       8       9      TOTAL
 107     1       4       3     237      18      28      77      30      15      10       3       1       1       427
 107     2       8       3     236      13      44      22       9      19       4       2       1       0       361
 107     3       1       2      19       6      18      61      17      18       8       3       1       0       154
 107     4       1       2      21      23      24      74      30      14       7       2       1       0       199
 107     5       1       2      15      35      25      89      34      14      10       3       1       1       230
 107     6       3       2      10       8      34      67      18      13       5       2       1       0       163
 107     7       1       2      25      31      28     111      38      18       7       2       1       0       264
 107     8       4       2      43     157      25     106      27      15       6       2       1       0       388
 107     9       1       1       2       8      25      47      14      12       4       2       1       0       117
 107    10       0       1       4      14      25      75      24      12       4       2       1       0       162

 STA  YEAR      10      11      12       1       2       3       4       5       6       7       8       9      TOTAL
 110     1      16       8      26      16      20      64      98     224     214     185      31       9       911
 110     2      26       8      28       4       9      22      31      63      45      11       5       6       258
 110     3       3       4       8      14      17      24      48     145     125      48      15       6       457
 110     4       5       6      10      16      19      76      89     131     137      71      18      10       588
 110     5       4       4       9      18      22      73      96     191     267     121      20       7       832
 110     6      15       5       8       4      17      47      54      90      80      12       5       4       341
 110     7       4       4      12      28      29      79     129     126     126      36      13       8       594
 110     8      17       8      13      66      28      52      74     107      88      32      10       3       498
 110     9       3       4       4       4      14      24      41      73      46      10       6       3       232
 110    10       2       3       5       7      20      52      67      83      64      24       6       8       341
```

```
 STA  YEAR      10     11     12      1      2      3      4      5      6      7      8      9      TOTAL
 111     1      76     40    104     47     59    250    284    633    991   1354    169     63      4070
 111     2     114     50    100     13     29     69    163    295    297     88     46     42      1306
 111     3      13     14     28     33     56    123    209    613    606    305    102     46      2148
 111     4      27     21     30     43     70    227    294    507    572    327    168     71      2357
 111     5      22     19     36     54     76    222    344    690    843    596    135     47      3084
 111     6      65     24     30     13     57    113    208    443    383    130     24     24      1514
 111     7      22     17     28     82    103    271    373    643    594    252    109     61      2555
 111     8      82     31     42    181     76    217    215    535    492    201     87     19      2178
 111     9      18     15     15     15     46     99    177    386    323     88     39     19      1240
 111    10       9     13     19     24     71    168    281    363    411    144     46     52      1601



MAXIMUM VOLUMES FOR PERIOD  1 OF  10 YEARS OF SYNTHETIC FLOWS
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO   54-MO   AV MO
 107      8      3    237    157     44    111     38     19     10      3      1      1    237    405    1346      21
 110     26      8     28     66     29     79    129    224    267    185     31     10    267    816    2951      42
 111    114     50    104    181    103    271    373    690    991   1354    169     71   1354   3681   12588     184

MINIMUM VOLUMES
 STA     10     11     12      1      2      3      4      5      6      7      8      9   1-MO   6-MO   54-MO   AV MO
 107      0      1      2      6     18     22      9     12      4      2      1      0      0      8     751
 110      2      3      4      4      9     22     31     63     45     10      5      3      2     26    1712
 111      9     13     15     13     29     69    163    295    297     88     24     19      9    123    7668
```

```
                     TEST DATA - 723-X6-L2340
                MONTHLY STREAMFLOW SIMULATION - NOV 1970
                  GENERALIZED STATISTICS FURNISHED

  IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS  NSTA NCOMB NTNOM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ
    -0    10    -0    -0    10    10    -0    -0    -0     3    -0    -0    -0     1    -0    -0    -0    -0

 INCONSISTENT CORREL MATRIX ADJUSTED   0   1   2       1.194

 INCONSISTENT CORREL MATRIX ADJUSTED   0   1   2       1.094

 INCONSISTENT CORREL MATRIX ADJUSTED   0   1   2       1.011


 RAW CORRELATION COEFFICIENTS FOR MONTH 10

   STA     107     110     111
                        WITH CURRENT MONTH
   107   1.000    .741    .744
   110    .741   1.000    .965
   111    .744    .965   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
   107    .681    .567    .570
   110    .567    .913    .838
   111    .570    .838    .913


 RAW CORRELATION COEFFICIENTS FOR MONTH 11

   STA     107     110     111
                        WITH CURRENT MONTH
   107   1.000    .741    .744
   110    .741   1.000    .965
   111    .744    .965   1.000
                        WITH PRECEDING MONTH AT ABOVE STATION
   107    .531    .567    .570
   110    .567    .915    .838
   111    .570    .838    .913
```

NOTE: Remaining months not shown

```
 GENERATED FLOWS FOR PERIOD  1

   STA   YEAR      10      11      12       1       2       3       4       5       6       7       8       9       TOTAL
   107      1       2       9      29      13      31      25      24      10       3       1       1       1        149
   107      2       1       3      14       7      53      72      32      24       7       3       1       1        218
   107      3       1       2       8       5       9      15       9      13       6       4       0       1         73
   107      4       1       4       7      11      20      30      36      13       9       2       1       0        134
   107      5       0       2      11      20      25      56      80      22       9       2       1       1        231
   107      6       1       1       3       3      22      44      18       5       2       1       0       0        100
   107      7       1       1       6      12      27      43      60      37       9       2       1       1        200
   107      8       2       2       5      48      30      34       9       8       3       2       1       1        145
   107      9       0       1       2       4      14      20      14       5       2       3       1       0         66
   107     10       0       2       6       9      20      14      14       5       2       2       1       1         76
```

EXHIBIT 4

4

```
STA  YEAR    10    11    12     1     2     3     4     5     6     7     8     9   TOTAL
110    1     14    21    34    34    40    49    94   286    63    25     7     3    670
110    2      3     4    13    13    23    39   147   411   299   129    29    12   1122
110    3     10    10     9    13    20    17    28   200    83    50    16     6    462
110    4      6     8    13    23    37    50    84   166   191   110    47    13    748
110    5     10     7    20    31    39    53   105   273   190    55    15     6    804
110    6      7     6     9     8    22    42   208   238    95    25     5     3    668
110    7      3     2     8    31    72    72   126   268   137    28    16     7    770
110    8      6    10    12    32    40    41    33   105    59    34    20     5    397
110    9      5     4     6     9    15    17    46    97    46    35    20     6    306
110   10      6     5    12    17    27    23    42    51    60    37    12     8    300

STA  YEAR    10    11    12     1     2     3     4     5     6     7     8     9   TOTAL
111    1     57    90    98   105   131   217   356   950   318   183    51    33   2589
111    2     14    22    32    45    89   132   633  1308  1034   708   235    96   4348
111    3     38    40    29    29    62    81   141   861   326   223   109    58   1997
111    4     31    35    34    54   132   221   383   649   619   478   305    97   3038
111    5     45    39    55    95   148   222   546  1259   749   283   105    48   3594
111    6     26    23    25    25    70   104   586   940   326   184    32    30   2371
111    7     16    12    15    64   217   311   576  1462   701   196   111    73   3754
111    8     33    38    33    93   119   158   132   490   272   165   129    42   1704
111    9     24    19    17    27    53    68   191   400   180   172   114    44   1309
111   10     26    29    32    57   106    99   210   190   263   170    91    52   1325




MAXIMUM VOLUMES FOR PERIOD  1 OF  10 YEARS OF SYNTHETIC FLOWS
 STA     10    11    12     1     2     3     4     5     6     7     8     9   1-MO   6-MO  54-MO   AV MO
 107      2     9    29    48    53    72    80    37     9     4     1     1     80    216    798      12
 110     14    21    34    34    72    72   208   411   299   129    47    13    411   1053   3759      52
 111     57    90    98   105   217   311   633  1462  1034   708   305    97   1462   4049  15176     217

MINIMUM VOLUMES
 STA     10    11    12     1     2     3     4     5     6     7     8     9   1-MO   6-MO  54-MO   AV MO
 107      0     1     2     3     9    14     9     5     2     1     0     0      0      6    513
 110      3     2     6     8    15    17    28    51    46    25     5     3      2     43   2200
 111     14    12    15    25    53    68   132   190   180   165    32    30     12    168   9433
```

EXHIBIT 4

EXHIBIT 5

## DEFINITIONS - 723-X6-L2340

AC1 - Alienation coefficient for station 1
AC2 - Alienation coefficient for station 2
AC3 - Alienation coefficient for station 3
ADJ - Plus sign indicates value smaller than upstream sum by tandem test
ADJ1 - Equal sign indicates value adjusted by tandem test
ALCFT(I,K) - Alienation coefficient array
ALOG - Computer library function of natural logarithm
ANLCG - Number of logarithms
ANYRS - Number of years of record
AV(I,K) - Mean logarithm
AVG(I,K) - Average of the generated deviates
AVGQ(I) - Average monthly flow for a station
AVMN(I) - Average logarithm of flow for minimum 3 consecutive months
AVMX(I) - Average logarithm of flow for maximum 3 consecutive months
B(L) - Beta coefficient
BETA(I,K,L) - Beta coefficient for generation equation
BLANK - Blank space
CROUT - Program subroutine to solve simultaneous equations
CSTAC(KX,K) - Coefficient by which flows are multiplied before adding in a combination
DABS - Computer library function of absolute value of double precision number
DQ(I,K) - Increment of flow
DTRMC - Determination coefficient
E - Letter E indicates estimated value
FAC - Temporary factor
I - Index for calendar month
IA - Indicator in column 1 of first card for each job
IANAL - Indicator, positive value calls for analysis
IENDF - End of file indicator
IGNRL - Indicator, + 2 calls for computing generalized statistics and + 1 or + 2 calls for using generalized statistics for generating flows
IMN(I) - Month sequence number of last month of 3 driest consecutive months
IMNTH - Calendar month number for first month of water year
IMX(I) - Month sequence number of last month of 3 wettest consecutive months
INDC - Transfer indicator
IP - Month number for preceding month
IPASS - Sequence number of pass (subset of stations)
IPCHQ - Indicator, positive value calls for writing discharges on tape
IPCHS - Indicator, positive value calls for punching statistics
IQ(I) - Fixed-point conversion of flow values

IQTAP - Tape number for storing flows
IRCON - Indicator, positive value calls for flow reconstitution
ISKZ - Positive value calls for varying flow increment (DQ) to make skew zero.
IST(K,L) - Sequence number of upstream station for tandem test
ISTA(K) - Station number
ISTAC(KX,K) - Station number in a combination
ISTAN - Temporary station number
ISTAP - Station sequence number for all passes
ISTAT - Tape number for storing statistics
ISTN(L) - Station number of downstream tandem station
ISTT(K,L) - Station number of upstream tandem station
ISTX(L) - Station number of independent station for consistences test
ISTY(L) - Station number of dependent station for consistences test
ITEMP - Temporary variable
ITMP - Temporary variable
ITMPP - Temporary variable
ITP - Temporary variable
ITRNS - Transfer indicator
IX - Temporary variation of I
IXX - Argument for random number function
IYR - Number of current year
IYRA - First year of data
IYRPJ - Year of start of flow projection
J - Index for year
JA - Sequence number of projection year
JTMP(L) - Matrix column number
JTP - Matrix column number
JX - Temporary variation of J
JXTMP - Temporary variation of J
K - Index for station
KM - Dimension limit for number of consecutive months
KPASS - Dimension limit for number of passes
KSTA - Dimension limit for total number of stations
KSTAC(KX,K) - Index number of station in a combination
KSTAP - Dimension limit for total number of stations
KX - Temporary variation of K or combination sequence
KYR - Dimension limit for number of consecutive years
L - Index for related station
LA - Temporary variation of L
LQTAP - Number of records up to present position on tape IQTAP
LSTAT - Number of records up to present position on tape ISTAT
LTMP(L) - Matrix row number
LTP - Matrix row number
LTRA - Letter A
LX - Temporary variation of L
LYRPJ - Last year of each projection
M - Serial number of month
MA - Sequence number of month of projected flow

EXHIBIT 5

MO(I) - Calendar month number
MPASS - Temporary counter for number of passes
MTHPJ - Calendar month of start of each projection
MXRCS - Number of years in each period for which maximum and minimum recorded and reconstituted flows are desired
N - Serial number of period of flows
NC - Counter to prevent continuous looping
NCA - Counter to prevent continuous looping
NCAB(I,K,L) - Number of values and cross products used to compute correlation coefficients
NCB - Transfer indicator
NCOMB - Number of combinations of stations max. and min. quantities are to be computed
NCSTY - Number of consistency tests
NINDP - Number of independent variables in regression study
NJ - Number of years in computation sequence
NLOG(I,K) - Number of logarithms used to compute frequency statistics
NMNMX - Number of months following dry season and preceding wet season
NMXMN - Number of months following wet season and preceding dry season
NPASS - Total number of passes in job
NPROJ - Number of projections of future flows from present conditions
NQ - Counter for number of flows
NQTAP - Total number of records saved on tape IQTAP
NSMX(L) - Number of upstream stations in tandem test
NSTA - Number of stations in analysis
NSTAA - NSTA + 1
NSTAC(KX) - Number of stations in a combination
NSTAT - Total number of records saved on tape ISTAT
NSTAX - NSTA + NSTA
NSTNP(I) - Number of stations in a particular pass
NSTX - Number of stations in current pass that occurred in preceding passes
NSTXX - NSTX + 1
NSUM(K) - Number of stations upstream from a station for tandem test
NTNDM - Number of tandem tests
NVAR - Total number of variable in regression study
NYMXG - Number of years of generated flows in each period for which maximum and minimum flows are desired
NYRG - Total number of years of generated flows
NYRS - Number of years of recorded flows
Q(M,K) - Monthly flow
QM(I) - Monthly flow
QMIN(I,K) - Minimum flow
QPREV(I) - Flow for previous month
QR(M,K) - Identification symbol
QSTAP(I) - Temporary storage of QPREV
R(K,L) - Correlation coefficient in a given matrix
RA(I,K,L) - Correlation coefficient
RAV(K,L) - Average correlation coefficient for 12 calendar months

RMAX - Maximum consistent correlation coefficient
RMIN - Minimum consistent correlation coefficient
RNGEN(IXX) - Program random number function
R1 - Correlation coefficient being tested
R2 - Correlation coefficient being tested
R3 - Correlation coefficient being tested
SD(I,K) - Standard devaition of logarithms for calendar month
SDAV(K) - Average standard deviation for 12 consecutive months
SDV(I,K) - Standard deviation of the generated deviates
SKEW(I,K) - Skew coefficient of logarithms for calendar month
SMQ(J,K) - Maximum or minimum flow for month or duration
SQA(I,K,L) - Sum of squares of first variable
SQB(I,K,L) - Sum of squares of second variable
SUM - Average correlation coefficient of matrix
SUMA(I,K,L) - Sum of first variable
SUMB(I,K,L) - Sum of second variable
T - Large positive constant
TEMP - Temporary variable
TMP - Temporary variable
TMPA - Temporary variable
TMPB - Temporary variable
TMPP - Temporary variable
TP - Temporary variable
X(I) - Value of independent variable in regression equation
XINCR(I) - Iteration value for flow increment
XPAB(I,K,L) - Sum of cross products of first and second variables

EXHIBIT 5

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C     723-X6-L2340 MONTHLY STREAMFLOW SIMULATION HEC, C OF E, USA  NOV 1970
CA * * * * * * LIBRARY FUNCTIONS ALOG, DABS      * * * * * * * * * * * * 1002
C     PROGRAM SUBROUTINE CROUT,RNGEN -- SEE COMMENTS IN RNGEN               1003
C INDEXES I=CALENDAR MONTH J=YEAR K=STA L=RELATED STA M=SUCCESSIVE MONTH 1004
C                                                                           1005
      DIMENSION                                                             1006
     ,B(10),R(10,11),                                                       1007000
     .ALCFT(12,10),AV(12,10),AVG(12,10),AVGR(10),AVMN(10),AVMX(10),
     ,BETA(12,10,10),DD(12,10),IMN(10),IMX(10),IQ(15),
     .ISTA(10),JTMP(9),LTMP(10),MO(12),NCAB(12,10,20),
     .NLOG(12,10),Q(1201,10),QM(12),QMIN(12,10),QPREV(10),QR(1201,10),
     ,QSTAP(100),RA(12,10,20),RAV(10,10),SD(12,10),SDAV(10),SDV(12,10),
     ,SKEW(12,10),SMQ(30,10),SQA(12,10,20),SQR(12,12,20),SUMA(12,10,20),
     ,SUMB(12,10,20),X(10),XINCR(12),XPAS(12,10,20),
     .CSTAC(2,10,5),ISTAC(2,10),ISTN(10),ISTT(10,10),ISTX(10),
     .ISTY(10),KSTAC(2,10,5),NSMX(10),NSTAC(2,5),NSTNP(5),
     .NSUM(10,5),MCOMB(5),MTNDM(5),IST(10,10,5)
      DOUBLE PRECISION R,B                                                  1016
      COMMON DTRMC,NINDP,B                                                  1017
      DATA LTRA/1HA/,BLANK/1H /,E/1HE/,ADJ/1H+/,ADJ1/1H=/                   1018
   10 FORMAT(1H1)                                                           1019
   20 FORMAT (1X,I5,19I6)                                                   1020000
   30 FORMAT(1X,I7,9I8)                                                     1021
   40 FORMAT(1X,A3,9A4,10A4)                                                1022
   50 FORMAT(1X,I3,I4,12F6.0)                                               1023
   60 FORMAT(1X,F7.0,9F8.0)                                                 1024
   70 FORMAT (1X,I3,I4,12F6.3)                                              1025
   80 FORMAT (1X,I7,12F6.3)                                                 1026
   90 FORMAT (1X,I7,12F6.1)                                                 1027
  100 FORMAT(1X,I4,I6,12I8,I10)                                             1028
  110 FORMAT (A1,A3,9A4,10A4)                                               1029
  120 FORMAT (1X,I7,3F6.3,2I6)                                              1030000
  130 FORMAT (/23H GENERALIZED STATISTICS//13H ST1 ST2  RAV)                1031
  140 FORMAT(/38H      STA  AVMX  AVMN  SDAV MAXMO MINMO)                   1032
      ISTAT=8                                                               1034
      IQTAP=9                                                               1035
      KPASS=5                                                               1037
      KSTAP=100                                                             1038
      KSTA=10                                                               1039
      KYR=100                                                               1040
      KM=KYR*12+1                                                           1042
      NSTA=0                                                                1043
C              WASTE CARDS UNTIL AN A IN COLUMN 1, FIRST TITLE CARD         1043
C                                                           ** CARD A **    1044
  150 READ(5,110) IA,(SMQ(M,1),M=1,20)                                      1045
      IF (IA.NE.LTRA) GO TO 150                                             1046
      WRITE(6,10)                                                           1049
      READ(5,40)((SMQ(M,K),M=1,20),K=2,3)                                   1050
      WRITE(6,40)((SMQ(M,K),M=1,20),K=1,3)                                  1051
C                                                  ** CARD B CARD C **      1052000
      READ(5,30)IYRA,IMNTH,IANAL,MXRCS,NYRG,NYMXG,NPASS,IPCHQ,IPCHS,NSTA 1053
     1,NCOMB,NTNDM,NCSTY,IGNRL,NPROJ,IYRPJ,MTHPJ,LYRPJ                      1055
C              TERMINATE WITH 5 BLANK CARDS, AN A IN COL 1 OF FIRST         1056
      ITMP=IANAL+NYRG                                                       1057
      IF(ITMP.GT.0)GO TB 180                                                1058
      STOP                                                                  1059
  160 WRITE (6,170) NYRS,NSTA,NCOMB,IPASS                                   1060
  170 FORMAT (/19H DIMENSION EXCEEDED ,5X,4HNYRS,I4,5X,4HNSTA,I3,5X,        1061000
     15HNCOMB,I3,5X,5HIPASS,I3)                                             1062000
      GO TO 150                                                             1063
  180 WRITE(6,190)                                                          1064
  190 FORMAT(/108H  IYRA IMNTH IANAL MXRCS  NYRG NYMXG NPASS IPCHQ IPCHS 1065
     1  NSTA NCOMB NTNDM NCSTY IGNRL NPROJ IYRPJ MTHPJ LYRPJ )              1066
      WRITE(6,20) IYRA,IMNTH,IANAL,MXRCS,NYRG,NYMXG,NPASS,IPCHQ,IPCHS,      1067
     1NSTA,NCOMB,NTNDM,NCSTY,IGNRL,NPROJ,IYRPJ,MTHPJ,LYRPJ                  1068
      IF (LYRPJ-IYRA.GE.KYR) GO TO 160                                      1069
CB * * * * *   SET CONSTANTS   * * * * * * * * * * * * * * * * * * * * * * 1070
      IXX=0                                                                 1071
      NSTAA=NSTA+1                                                          1072
      NSTAX=NSTA+NSTA                                                       1073
      T=99999999.                                                           1074
      IYRA=IYRA-1                                                           1075
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EXHIBIT 6

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      IMNTH=IMNTH-1                                                     1076
      NSTX=0                                                            1077
      NSTXX=1                                                           1078
      IPASS=1                                                           1079
      REWIND ISTAT                                                      1080
      NSTAT=0                                                           1081
      LSTAT=0                                                           1082
      REWIND IOTAP                                                      1083
      NOTAP=0                                                           1084
      LOTAP=0                                                           1085
      DO 195 J=1,KPASS
      MCOMB(J)=0
      MTNOM(J)=0
  195 CONTINUE
      GO TO 270                                                         1086
C               SAVE STATIONS FROM PREVIOUS PASSES IF NECESSARY         1087
  200 IPASS=IPASS+1                                                     1088
      WRITE(6,10)                                                       1089
      IF (IPASS.GT.KPASS) GO TO 160                                     1090
C                                                       ** CARD J **    1091
      READ(5,30)NCOMB,NTNOM,NCSTY,NSTX,(ISTA(K),K=1,NSTX)
      WRITE(6,210) IPASS,(ISTA(K),K=1,NSTX)                             1093
  210 FORMAT(5H0PASS ,I3/28H STA(S) FROM PREVIOUS PASSES ,10I6)         1094
      NSTXX=NSTX+1                                                      1095
      REWIND IOTAP                                                      1096
      LOTAP=0                                                           1097
      REWIND ISTAT                                                      1098
      MPASS=1                                                           1099
      READ (ISTAT)                                                      1100
      LSTAT=1                                                           1101
      ITP=NYRS*12+1                                                     1102
      ITEMP=NSTNP(MPASS)                                                1103
      ITMPP=0                                                           1104
      DO 250 K=1,NSTX                                                   1105
  220 READ(IOTAP)ITMP,(Q(M,K),M=1,ITP)                                  1106
      LOTAP=LOTAP+1                                                     1107
      IF (ISTA(K).NE.ITMP) GO TO 220                                    1108
  230 ITMPP=ITMPP+1                                                     1109
      IF(ITMPP.GT.ITEMP) GO TO 240                                      1110
      READ (ISTAT)ITMP,(AV(I,K),SD(I,K),SKEW(I,K),DQ(I,K),(BETA(I,K,L),L 1111
     1=1,ITEMP),ALCFT(I,K),I=1,12)                                      1112
      LSTAT=LSTAT+1                                                     1113
      IF (ITMP.EQ.ISTA(K)) GO TO 250                                    1114
      GO TO 230                                                         1115
  240 READ(ISTAT)                                                       1116
      LSTAT=LSTAT+1                                                     1117
      MPASS=MPASS+1                                                     1118
      ITEMP=NSTNP(MPASS)                                                1119
      ITMPP=0                                                           1120
      GO TO 230                                                         1121
  250 CONTINUE                                                          1122
      DO 260 K=1,NSTX                                                   1123
      NSUM(K,IPASS)=0
      DO 260 I=1,12                                                     1125
  260 NLOG(I,K)=NYRS                                                    1126
  270 IF(IANAL.GT.0) NSTA=NSTX                                          1127
      DO 280 I=1,12                                                     1128
      MO(I)=IMNTH+I                                                     1129
      IF(MO(I).LT.13)GO TO 280                                          1130
      MO(I)=MO(I)-12                                                    1131
  280 CONTINUE                                                          1132
      IF(NCOMB.LE.0) GO TO 320                                          1133
      MCOMB(IPASS)=NCOMB
C             IDENTIFY STATION COMBINATIONS                             1134
      DO 300 K=1,NCOMB                                                  1135
C                                                       ** CARD D **    1136
      READ(5,30)ITP,(ISTAC(K,L),L=1,ITP)                                1137
      WRITE (6,290) K,ITP,(ISTAC(K,L),L=1,ITP)                          1138
  290 FORMAT (/5H COMB,I2,5H  STA,15I8)                                 1139000
      NSTAC(K,IPASS)=ITP
C                                                       ** CARD E **    1141
      READ(5,60) TEMP,(CSTAC(K,L,IPASS),L=1,ITP)
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EXHIBIT 6

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  300 WRITE(6,310) (CSTAC(K,L,IPASS),L=1,ITP)
  310 FORMAT (7X,5HRATIO,8X,14F8.3)                                         1144000
  320 IF(NTNDM.LE.0) GO TO 350                                              1145
      MTNDM(IPASS)=NTNDM
      DO 340 LX=1,NTNDM                                                     1146
C                                                           ** CARD F **    1147
      READ(5,30) ISTN(LX),ITMP,(ISTT(LX,L),L=1,ITMP)                        1148
      WRITE(6,330) LX,ISTN(LX),(ISTT(LX,L),L=1,ITMP)                        1149
  330 FORMAT (/13H TANDEM GROUP,I3,6X,14HDOWNSTREAM STA,I5,6X,             1150000
     115HUPSTREAM STA(S),10I5)                                              1151000
  340 NSMX(LX)=ITMP                                                         1152
  350 IF(IPASS.EQ.1)NYRS=0                                                  1153
      DO 360 K=NSTXX,KSTA                                                   1154
      NSUM(K,IPASS)=0
      ISTA(K)=1000-K                                                        1156
C                 INITIATE -1, NO RECORD FOR ALL FLOWS                      1157
      DO 360 M=1,KM                                                         1158
  360 Q(M,K)=-1.                                                            1159
      DO 370 I=1,12                                                         1160
      NLOG(I,K)=0                                                           1161
      DQ(I,K)=0.                                                            1162
      QMIN(I,K)=T                                                           1163
  370 CONTINUE                                                              1164
  380 CONTINUE                                                              1165
      IF(NCSTY.LE.0) GO TO 420                                              1166
      WRITE(6,390)                                                          1167
  390 FORMAT(/30X,8HSTATIONS/17H CONSISTENCY TEST,5X,23HINDEPENDENT   DE 1168
     1PENDENT)                                                              1169
      DO 400 L=1,NCSTY                                                      1170
C                                                           ** CARD G **    1171
      READ (5,30)  ISTX(L),ISTY(L)                                          1172
  400 WRITE(6,410)      L,ISTX(L),ISTY(L)                                   1173
  410 FORMAT(13X,I3,8X,I5,8X,I5)                                            1174
  420 IF(IANAL.LE.0)GO TO 1570                                              1175
CC * * * * * * READ AND PROCESS 1 STATION-YEAR OF DATA * * * * * * * * * * 1176
C                                                           ** CARD H **    1177
  430 READ(5,50) ISTAN,IYR,(QM(I),I=1,12)                                   1178
C                                                           ** CARD I **    1179
C                 BLANK CARD INDICATES END OF FLOW DATA                     1180
      IF(ISTAN.LT.1)GO TO 500                                               1181
      IF(NSTA.LT.1)GO TO 450                                                1182
C                 ASSIGN SUBSCRIPT TO STATION                               1183
      DO 440 K=NSTXX,NSTA                                                   1184
      IF(ISTAN.EQ.ISTA(K))GO TO 460                                         1185
  440 CONTINUE                                                              1186
  450 NSTA=NSTA+1                                                           1187
      IF(NSTA.GT.KSTA) GO TO 160                                            1187-2*
      K=NSTA                                                                1188
      ISTA(K)=ISTAN                                                         1189
C                 ASSIGN SUBSCRIPT TO YEAR                                  1190
  460 J=IYR-IYRA                                                            1191
      IF(NYRS.LT.J.AND.IPASS.EQ.1)NYRS=J                                    1192
      IF(J.GT.0.AND.J.LE.NYRS) GO TO 480                                    1193
      WRITE (6,470)IYR                                                      1194
  470 FORMAT (/18H UNACCEPTABLE YEAR,I5)                                    1195000
      GO TO 150                                                             1196
C                 STORE FLOWS IN STATION AND MONTH ARRAY                    1197
  480 M=J*12-11                                                             1198
      DO 490 I=1,12                                                         1199
      M=M+1                                                                 1200
      IF(QM(I).LE.(-1.)) GO TO 490                                          1201
      IF(QM(I).LT.QMIN(I,K)) QMIN(I,K)=QM(I)                                1202
      NLOG(I,K)=NLOG(I,K)+1                                                 1203
      DQ(I,K)=DQ(I,K)+QM(I)                                                 1204
      Q(M,K)=QM(I)                                                          1205
  490 CONTINUE                                                              1206
      GO TO 430                                                             1207
  500 NSTAA=NSTA+1                                                          1208
      IF (NYRS.GT.KYR.OR.NSTA+NCOMB.GT.KSTA) GO TO 160                      1209
      IF(NSTA.LE.0) GO TO 160                                               1210
      NSTNP(IPASS)=NSTA                                                     1211
      NSTAX=NSTA+NSTA                                                       1212
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      IF(NCOMB.LE.0)GO TO 540
C                IDENTIFY STA SUBSCRIPTS FOR STAS IN COMBINATIONS
      DO 530 KX=1,NCOMB
      ITP=NSTAC(KX,IPASS)
      LX=0
      DO 520 L=1,ITP
      ITEMP=ISTAC(KX,L)
      DO 510 K=1,NSTA
      IF(ISTA(K).NE.ITEMP)GO TO 510
      LX=LX+1
      KSTAC(KX,LX,IPASS)=K
      GO TO 520
  510 CONTINUE
  520 CONTINUE
C                REDUCE STATIONS TO THOSE IDENTIFIABLE
      NSTAC(KX,IPASS)=LX
  530 CONTINUE
C                IDENTIFY STATIONS IN TANDEM
  540 IF(NTNOM.LE.0) GO TO 600
      DO 590 LX=1,NTNOM
      DO 550 K=1,NSTA
      IF(ISTA(K).EQ.ISTN(LX)) GO TO 560
  550 CONTINUE
  560 ISTN(LX)=K
      NSUM(K,IPASS)=NSMX(LX)
      ITMP=NSMX(LX)
      DO 580 L=1,ITMP
      DO 570 KX=1,NSTA
      IF(ISTA(KX).EQ.ISTT(LX,L)) GO TO 580
  570 CONTINUE
  580 IST(K,L,IPASS)=KX
  590 CONTINUE
C                IDENTIFY PAIRS OF STATIONS FOR CONSISTENCY TESTS
  600 IF(NCSTY.LE.0) GO TO 650
      DO 640 L=1,NCSTY
      DO 630 K=1,NSTA
      IF(ISTA(K).EQ.ISTX(L)) GO TO 610
      IF(ISTA(K).EQ.ISTY(L)) GO TO 620
      GO TO 630
  610 ISTX(L)=K
      GO TO 630
  620 ISTY(L)=K
  630 CONTINUE
  640 CONTINUE
  650 ITMP=NSTA+NCOMB
CD * * * * * * MAX AND MIN RECORDED VOLUMES  * * * * * * * * * * * * * *
C                INITIATE SUMS
      DO 790 K=NSTXX,ITMP
      AVGQ(K)=0.
      NQ=0
      DO 660 I=1,15
  660 SMQ(I,K)=-T
      DO 670 I=16,30
  670 SMQ(I,K)=T
      TMP=0.
      TMPA=0.
      M=1
      N=0
      DO 780 J=1,NYRS
      DO 770 I=1,12
      M=M+1
      N=N+1
      IF(K.LE.NSTA)GO TO 700
C                COMPUTE COMBINED FLOWS
      KX=K-NSTA
      ITP=NSTAC(KX,IPASS)
      Q(M,K)=0.
      DO 690 L=1,ITP
      ITEMP=KSTAC(KX,L,IPASS)
C                COMBINED FLOW MISSING
      IF(Q(M,ITEMP).EQ.-1..OR.Q(M,K).EQ.-1.) GO TO 680
      Q(M,K)=Q(M,K)+Q(M,ITEMP)*CSTAC(KX,L,IPASS)
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      GO TO 690
  680 Q(M,K)=-1.
  690 CONTINUE
  700 IF(Q(M,K).NE.-1.) GO TO 710
C               START NEW ACCUMULATIONS WHEN FLOW MISSING
      N=0
      TMP=0.
      TMPA=0.
      GO TO 770
  710 TEMP=Q(M,K)
C               1-MONTH FLOWS
      IF(SMQ(I,K).LT.TEMP)SMQ(I,K)=TEMP
      IF(SMQ(I+15,K).GT.TEMP)SMQ(I+15,K)=TEMP
      IF(SMQ(13,K).LT.TEMP)SMQ(13,K)=TEMP
      IF(SMQ(28,K).GT.TEMP)SMQ(28,K)=TEMP
C               6-MONTH FLOWS
      TMP=TMP+TEMP
      TMPA=TMPA+TEMP
      IF(N-6)760,730,720
  720 TMP=TMP-Q(M-6,K)
  730 IF(TMP.LT.SMQ(29,K))SMQ(29,K)=TMP
      IF(TMP.GT.SMQ(14,K))SMQ(14,K)=TMP
C               54-MONTH FLOWS
      IF(N-54)760,750,740
  740 TMPA=TMPA-Q(M-54,K)
  750 IF(TMPA.LT.SMQ(30,K))SMQ(30,K)=TMPA
      IF(TMPA.GT.SMQ(15,K))SMQ(15,K)=TMPA
C               AVERAGE FLOW
  760 AVGQ(K)=AVGQ(K)+TEMP
      NQ=NQ+1
  770 CONTINUE
  780 CONTINUE
      TEMP=NQ
      AVGQ(K)=AVGQ(K)/TEMP
  790 CONTINUE
      WRITE(6,800)
  800 FORMAT(/34H MAXIMUM VOLUMES OF RECORDED FLOWS)
      WRITE(6,810)(MO(I),I=1,12)
  810 FORMAT (5H  STA,12I7,33H    1-MO    6-MO    54-MO   AV MO)
      ITMP=NSTA+NCOMB
      DO 830 K=NSTXX,ITMP
      ITEMP=AVGQ(K)+.5
      DO 820 I=1,15
  820 IQ(I)=SMQ(I,K)+.5
  830 WRITE(6,840)ISTA(K),(IQ(I),I=1,15),ITEMP
  840 FORMAT(1X,I4,12I7,2I8,I9,I8)
      WRITE(6,850)
  850 FORMAT(/16H MINIMUM VOLUMES)
      WRITE(6,810)(MO(I),I=1,12)
      DO 870 K=NSTXX,ITMP
      DO 860 I=1,15
  860 IQ(I)=SMQ(I+15,K)+.5
  870 WRITE(6,840)ISTA(K),(IQ(I),I=1,15)
CE * * * * * * COMPUTE FREQUENCY STATISTICS  * * * * * * * * * * * * * *
      WRITE (6,880)
  880 FORMAT (/21H FREQUENCY STATISTICS)
      WRITE(6,890)(MO(I),I=1,12)
  890 FORMAT (/14H    STA     ITEM,I7,11I8)
C               MISSING FLOW PRECEDING FIRST RECORD MONTH
      DO 900 K=NSTXX,NSTA
  900 Q(1,K)=T
      IPCON=0
      ITEMP = NSTA
      DO 1180 K=1,ITEMP
      IF (ITEMP.GT.NSTA) GO TO 1180
      IF(K.LE.NSTX) GO TO 942
  910 DO 920 I=1,12
      TEMP=NLOG(I,K)
      DQ(I,K)=DQ(I,K)*.01/TEMP
      IF(DQ(I,K).LT..1) DQ(I,K)=.1
      IF(QMIN(I,K).LT.0.) DQ(I,K)=DQ(I,K)-QMIN(I,K)
  920 CONTINUE
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      N=0
  930 DO 940 I=1,12
      AV(I,K)=0.
      SD(I,K)=0.
      SKEW(I,K)=0.
      TMP=N
      XINCR(I)=(DD(I,K)+QMIN(I,K))/(16.-TMP)
  940 CONTINUE
  942 M=1
      DO 970 J=1,NYRS
      DO 960 I=1,12
      M=M+1
      IF(Q(M,K).EQ.-1.) GO TO 950
C               REPLACE FLOW ARRAY WITH LOG ARRAY
      TEMP=ALOG(Q(M,K)+DD(I,K))/2.3025851
      Q(M,K)=TEMP
      IF(K.LE.NSTX) GO TO 960
C               SUM, SQUARES, AND CUBES
      AV(I,K)=AV(I,K)+TEMP
      SD(I,K)=SD(I,K)+TEMP*TEMP
      SKEW(I,K)=SKEW(I,K)+TEMP*TEMP*TEMP
      GO TO 960
C               MISSING FLOWS EQUATED TO T
  950 Q(M,K)=T
      IRCON=1
  960 CONTINUE
  970 CONTINUE
      IF(K.LE.NSTX) GO TO 1180
      INDC=0
      DO 1000 I=1,12
      TEMP=NLOG(I,K)
      IF(TEMP.LT.3.)GO TO 1120
      TMP=AV(I,K)
      AV(I,K)=TMP/TEMP
      IF(SD(I,K).LE.0.)GO TO 980
      TMPA=SD(I,K)
      SD(I,K)=(SD(I,K)-AV(I,K)*TMP)/(TEMP-1.)
      IF(SD(I,K).LE.0.) GO TO 980
      SD(I,K)=SD(I,K)**.5
      IF(SD(I,K).LT..0005) GO TO 990
      SKEW(I,K)=(TEMP*TEMP*SKEW(I,K)-3.*TEMP*TMP*TMPA+2.*TMP*TMP*TMP)
     1/(TEMP*(TEMP-1.)*(TEMP-2.)*SD(I,K)**3)
      IF(SKEW(I,K).LT.(-.1).OR.SKEW(I,K).GT..1) INDC=1
      IF(SKEW(I,K).GT.3.) SKEW(I,K)=3.
      IF(SKEW(I,K).LT.-3.) SKEW(I,K)=-3.
      GO TO 1000
  980 SD(I,K)=0.
  990 SKEW(I,K)=0.
 1000 CONTINUE
      N=N+1
      IF(N.GT.1)GO TO 1060
      WRITE(6,1010)ISTA(K),(AV(I,K),I=1,12)
 1010 FORMAT (/1X,I5,8H    MEAN,12F8.3)
      WRITE(6,1020)(SD(I,K),I=1,12)
 1020 FORMAT (7X,7HSTD DEV,12F8.3)
      WRITE(6,1030)(SKEW(I,K),I=1,12)
 1030 FORMAT (10X,4HSKEW,12F8.3)
      WRITE(6,1040)(DD(I,K),I=1,12)
 1040 FORMAT (8X,6HINCRMT,F7.2,11F8.2)
      WRITE(6,1050)(NLOG(I,K),I=1,12)
 1050 FORMAT (9X,5HYEARS,12I8)
 1060 IF(N.GE.14) GO TO 1180
      IF(INDC.LE.0) GO TO 1180
C               THE FOLLOWING ROUTINE WILL ADJUST THE INCREMENT TO
C                 TRY TO OBTAIN ZERO SKEW
C                   CHANGE THE FOLLOWING STAT TO  ISKZ=1  TO ACTIVATE
      ISKZ=0
      IF(ISKZ.LE.0) GO TO 1180
      ITP=-11
      DO 1110 I=1,12
      M=ITP+I
      DO 1080 J=1,NYRS
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      M=M+12
      IF(Q(M,K).EQ.T) GO TO 1070
      TMP=Q(M,K)
      Q(M,K)=10.**TMP -DQ(I,K)
      GO TO 1080
 1070 Q(M,K)=-1.
 1080 CONTINUE
      TEMP=SKEW(I,K)
      IF(TEMP.GT.(-.1).AND.TEMP.LT..1) GO TO 1110
      IF(TEMP) 1090,1110,1100
 1090 DQ(I,K)=DQ(I,K)*2.
      GO TO 1110
 1100 DQ(I,K)=DQ(I,K)-XINCR(I)
 1110 CONTINUE
      GO TO 930
C  * * * * * * DELETE STATIONS WITH LESS THAN 3 YEARS OF DATA* * * * * *
 1120 WRITE(6,1130)ISTA(K)
 1130 FORMAT (/4H STA,I6,28H  DELETED, INSUFFICIENT DATA)
      NSTA=NSTA-1
      NSTAA=NSTA+1
      NSTAX=NSTA+NSTA
      IF(K.GT.NSTA)GO TO 1180
C                REDUCE SUBSCRIPTS OF SUBSEQUENT STATIONS
      DO 1170 KX=K,NSTA
      ISTA(KX)=ISTA(KX+1)
      M=1
      DO 1150 J=1,NYRS
      DO 1140 I=1,12
      M=M+1
 1140 Q(M,KX)=Q(M,KX+1)
 1150 CONTINUE
      DO 1160 I=1,12
      QMIN(I,KX)=QMIN(I,KX+1)
      NLOG(I,KX)=NLOG(I,KX+1)
 1160 DQ(I,KX)=DQ(I,KX+1)
 1170 CONTINUE
      GO TO 910
 1180 CONTINUE
      ITRNS=0
      IF(TRCON.LE.0) GO TO 1370
CF* * * * * *  ADJUSTMENT OF FREQUENCY STATISTICS TO LONG TERM    * * * *
      DO 1190 I=1,12
      DO 1190 K=1,NSTA
      DO 1190 L=1,NSTAX
      NCAB(I,K,L)=0
      SUMA(I,K,L)=0.
      SUMB(I,K,L)=0.
      SQA(I,K,L)=0.
      SQB(I,K,L)=0.
      XPAB(I,K,L)=0.
      RA(I,K,L)=-4.
 1190 CONTINUE
      DO 1220  K=1,NSTA
      KX=K+1
      M=1
      DO 1220 J=1,NYRS
      DO 1210 I=1,12
      M=M+1
      TEMP=Q(M,K)
      IF(TEMP.EQ.T) GO TO 1210
      DO 1200 L=KX,NSTAX
      LX=L-NSTA
      IF(LX.LT.1) TMP=Q(M,L)
      IF(LX.GT.0) TMP=Q(M-1,LX)
      IF(TMP.EQ.T) GO TO 1200
      NCAB(I,K,L)=NCAB(I,K,L)+1
      SUMA(I,K,L)=SUMA(I,K,L)+TEMP
      SUMB(I,K,L)=SUMB(I,K,L)+TMP
      SQA(I,K,L)=SQA(I,K,L)+TEMP*TEMP
      SQB(I,K,L)=SQB(I,K,L)+TMP*TMP
      XPAB(I,K,L)=XPAB(I,K,L)+TEMP*TMP
      IF(L.GT.NSTA) GO TO 1200
```

EXHIBIT 6

```
      NCAB(I,L,K)=NCAB(I,K,L)
      SUMA(I,L,K)=SUMB(I,K,L)
      SUMB(I,L,K)=SUMA(I,K,L)
      SQA(I,L,K)=SQB(I,K,L)
      SQB(I,L,K)=SQA(I,K,L)
      XPAB(I,L,K)=XPAB(I,K,L)
 1200 CONTINUE
 1210 CONTINUE
 1220 CONTINUE
      INDC=0
      DO 1260 K=1,NSTA
      KX=K+1
      DO 1260 I=1,12
      RA(I,K,K)=1.
      DO 1250 L=KX,NSTAX
      IF(NCAB(I,K,L).LE.2) GO TO 1250
      TEMP=NCAB(I,K,L)
      TMP=SQA(I,K,L)
      TP=SQB(I,K,L)
      TMPA=SUMA(I,K,L)
      TMPP=(TMP-TMPA**2/TEMP)/TEMP
      IF(TMPP.LT.0.) TMPP=0.
      SQA(I,K,L)=TMPP**.5
      TMPB=SUMB(I,K,L)
      TMPP=(TP-TMPB**2/TEMP)/TEMP
      IF(TMPP.LT.0.) TMPP=0.
      SQB(I,K,L)=TMPP**.5
      TMP=(TMP-TMPA**2/TEMP)*(TP-TMPB**2/TEMP)
      IF(TMP.LE.0.) GO TO 1230
      TMPA=XPAB(I,K,L)-TMPA*TMPB/TEMP
      TMPB=1.
      IF(TMPA.LT.0.) TMPB=-TMPB
      TMPA=TMPA*TMPA/TMP
      TMPA=1.-(1.-TMPA)*(TEMP-1.)/(TEMP-2.)
      IF(TMPA.LT.0.)TMPA=0.
      RA(I,K,L)=TMPB*TMPA**.5
      ITP=I
      LA=L
      LX=L-NSTA
      IF(L.LE.NSTA) GO TO 1235
      ITP=I-1
      IF(ITP.LT.1) ITP=12
      LA=LX
 1235 IF(SD(I,K).LT..0001.OR.SD(ITP,LA).LT..0001) GO TO 1230
      GO TO 1240
 1230 RA(I,K,L)=0.
 1240 IF(L.GT.NSTA) GO TO 1250
      SQA(I,L,K)=SQB(I,K,L)
      SQB(I,L,K)=SQA(I,K,L)
      RA(I,L,K)=RA(I,K,L)
 1250 CONTINUE
 1260 CONTINUE
      DO 1280 K=1,NSTA
      DO 1280 I=1,12
      TEMP=NLOG(I,K)
      LX=0
      DO 1270 L=1,NSTA
      IF(L.EQ.K.OR.RA(I,K,L).LE.-4.) GO TO 1270
      IF(NLOG(I,L).LE.NLOG(I,K)) GO TO 1270
      TMPA=NCAB(I,K,L)
      TMPB=NLOG(I,L)
      TP=TMPA/(1.-(TMPB-TMPA)*RA(I,K,L)**2/TMPB)
      IF(TP.LE.TEMP) GO TO 1270
      LX=L
      TEMP=TP
      TMPP=TMPA
 1270 CONTINUE
      IF(LX.LE.0) GO TO 1280
      IF(SQA(I,K,LX).LE..0001.OR.SQB(I,K,LX).LE..0001) GO TO 1280
      INDC=1
      TMP=SQA(I,K,LX)/SQB(I,K,LX)
      TMPA=SUMA(I,K,LX)/TMPP
```

```
      TMPB=SUMB(I,K,LX)/TMPP
      AV(I,K)=TMPA+(AV(I,LX)-TMPB)*RA(I,K,LX)*TMP
      SD(I,K)=SQA(I,K,LX)+(SD(I,LX)-SQB(I,K,LX))*RA(I,K,LX)**2*TMP
 1280 CONTINUE
C               ADJUST STANDARD DEVIATIONS FOR CONSISTENCY
      IF(NCSTY.LE.0) GO TO 1340
C               TRANSFER FROM 1011
 1290 DO 1330 LX=1,NCSTY
      K=ISTX(LX)
      L=ISTY(LX)
      DO 1320 I=1,12
      TEMP=(AV(I,K)-AV(I,L))/3.
      IF(AV(I,K).GT.AV(I,L)) GO TO 1300
      TEMP=TEMP+SD(I,K)
      IF(SD(I,L).LT.TEMP) GO TO 1310
      TEMP=SD(I,K)*2.-TEMP
      IF(SD(I,L) - TEMP) 1320,1320,1310
 1300 TEMP=TEMP+SD(I,K)
      IF(SD(I,L).GT.TEMP) GO TO 1310
      TEMP=SD(I,K)*2. - TEMP
      IF(SD(I,L).GE.TEMP) GO TO 1320
 1310 SD(I,L)=TEMP
 1320 CONTINUE
 1330 CONTINUE
      IF(ITRNS.GT.0) GO TO 2820
 1340 IF(INDC.LE.0.AND.NCSTY.LE.0) GO TO 1370
      WRITE(6,1350)
 1350 FORMAT(/39H FREQUENCY STATISTICS AFTER ADJUSTMENTS )
      WRITE(6,890)(MO(I),I=1,12)
      DO 1360 K=1,NSTA
      WRITE(6,1010)ISTA(K),(AV(I,K),I=1,12)
      WRITE(5,1020)(SD(I,K),I=1,12)
      WRITE(6,1030)(SKEW(I,K),I=1,12)
      WRITE(6,1040)(DD(I,K),I=1,12)
 1360 CONTINUE
CG * * * * * * TRANSFORM TU STANDARDIZED VARIATES  * * * * * * * * * * * *
 1370 DO 1420 K=1,NSTA
      M=1
      DO 1410 J=1,NYRS
      DO 1400 I=1,12
      M=M+1
      QR(M,K)=BLANK
      IF(Q(M,K).EQ.T)GO TO 1400
      IF(SD(I,K).EQ.0.)GO TO 1390
      Q(M,K)=(Q(M,K)-AV(I,K))/SD(I,K)
C               PEARSON TYPE III TRANSFORM
      IF(SKEW(I,K).EQ.0.)GO TO 1400
      TEMP=.5*SKEW(I,K)*Q(M,K)+1.
      TMP=1.
      IF(TEMP.GE.0.)GO TO 1380
      TEMP=-TEMP
      TMP=-1.
 1380 Q(M,K)=6.*(TMP*TEMP**(1./3.)-1.)/SKEW(I,K)+SKEW(I,K)/6.
      GO TO 1400
 1390 Q(M,K)=0.
 1400 CONTINUE
 1410 CONTINUE
 1420 CONTINUE
C  * * * * * * COMPUTE SUMS OF SQUARES AND CROSS PRODUCTS  * * * * * * *
      DO 1450 K=1,NSTA
      DO 1440 I=1,12
      DO 1430 L=1,NSTAX
      RA(I,K,L) =(-4.)
      SUMA(I,K,L)=0.
      SUMB(I,K,L)=0.
      SQA(I,K,L)=0.
      SQB(I,K,L)=0.
      XPAB(I,K,L)=0.
 1430 NCAB(I,K,L)=0
      RA(I,K,K)=1.
 1440 CONTINUE
 1450 CONTINUE
```

```
      DO 1540 K=1,NSTA
      KX=K+1
      M=1
      DO 1480 J=1,NYRS
      DO 1470 I=1,12
      M=M+1
      TEMP=Q(M,K)
      IF(TEMP.EQ.T)GO TO 1470
      DO 1460 L=KX,NSTAX
C             SUBSCRIPTS EXCEEDING NSTA RELATE TO PRECEDING MONTH
      LX=L-NSTA
      IF(LX.LT.1) TMP=Q(M,L)
      IF(LX.GT.0) TMP=Q(M-1,LX)
      IF(TMP.EQ.T)GO TO 1460
C             COUNT AND USE ONLY RECORDED PAIRS
      NCAB(I,K,L)=NCAB(I,K,L)+1
      SUMA(I,K,L)=SUMA(I,K,L)+TEMP
      SUMB(I,K,L)=SUMB(I,K,L)+TMP
      SQA (I,K,L)=SQA (I,K,L)+TEMP*TEMP
      SQB (I,K,L)=SQB (I,K,L)+TMP*TMP
      XPAB(I,K,L)=XPAB(I,K,L)+TEMP*TMP
      IF(L.GT.NSTA) GO TO 1460
      NCAB(I,L,K)=NCAB(I,K,L)
      SUMA(I,L,K)=SUMB(I,K,L)
      SUMB(I,L,K)=SUMA(I,K,L)
      SQA (I,L,K)=SQB (I,K,L)
      SQB (I,L,K)=SQA (I,K,L)
      XPAB(I,L,K)=XPAB(I,K,L)
 1460 CONTINUE
 1470 CONTINUE
 1480 CONTINUE
C   * * * * * * COMPUTE CORRELATION COEFFICIENTS  * * * * * * * * * * * *
      DO 1530 I=1,12
      DO 1520 L=KX,NSTAX
      LX=L-NSTA
C             ELIMINATE PAIRS WITH LESS THAN 3 YRS DATA
      IF(NCAB(I,K,L).LE.2) GO TO 1510
      TEMP=NCAB(I,K,L)
      TMP=(SQA(I,K,L)-SUMA(I,K,L)*SUMA(I,K,L)/TEMP)*(SQB(I,K,L)-SUMB
     1(I,K,L)*SUMB(I,K,L)/TEMP)
C             ELIMINATE PAIRS WITH ZERO VARIANCE PRODUCT
      IF(TMP.LE.0.) GO TO 1500
      TMPB=1.
      TMPA=XPAB(I,K,L)-SUMA(I,K,L)*SUMB(I,K,L)/TEMP
C             RETAIN ALGEBRAIC SIGN
      IF(TMPA.LT.0.)TMPB=-TMPB
      TMPA=TMPA*TMPA/TMP
      RA(I,K,L)=TMPB*TMPA**.5
      ITP=I
      LA=L
      IF(L.LE.NSTA) GO TO 1490
      ITP=I-1
      IF(ITP.LT.1) ITP=12
      LA=LX
 1490 IF(SD(I,K).LT..0001.OR.SD(ITP,LA).LT..0001) RA(I,K,L)=0.
      GO TO 1510
 1500 RA(I,K,L)=0.
 1510 IF(L.GT.NSTA) GO TO 1520
      RA(I,L,K)=RA(I,K,L)
 1520 CONTINUE
 1530 CONTINUE
 1540 CONTINUE
      GO TO 2170
 1550 WRITE(6,1560)
 1560 FORMAT(/18H DATA OUT OF ORDER)
      GO TO 150
CH * * * * * * READ CORRELATION COEFFICIENTS * * * * * * * * * * * * * *
 1570 DO 1630 K=1,NSTA
      IF (K.EQ.1)GO TO 1600
      ITP=K-1
      DO 1590 L=1,ITP
C             CURRENT MONTH CORRELATION
```

EXHIBIT 6

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C                                                          ** CARD L **
      READ(5,70)ITMP,ITEMP,(RA(I,K,L),I=1,12)
      RAV(K,L)=RA(1,K,L)
      IF(IGNRL.EQ.1)ISTA(K)=ITMP
      IF(ITMP.NE.ISTA(K))GO TO 1550
      IF(ITEMP.NE.ISTA(L))GO TO 1550
      DO 1580 I=1,12
 1580 RA(I,L,K)=RA(I,K,L)
 1590 CONTINUE
C              PRECEDING MONTH CORRELATION
 1600 LX=NSTAA
      IF (IGNRL.EQ.1) LX=NSTA+K
      LA=NSTAX
      IF (IGNRL.EQ.1) LA=LX
      DO 1610 L=LX,LA
      ITP=L-NSTA
C                                                      ** CARD K OR M **
      READ(5,70)ITMP,ITEMP,(RA(I,K,L),I=1,12)
      IF(K.EQ.1)ISTA(K)=ITMP
      IF(K.EQ.1)ISTA(ITP)=ITEMP
      IF (IGNRL.EQ.1) RAV(K,K)=RA(1,K,L)
      IF(ITMP.NE.ISTA(K))GO TO 1550
      IF(ITEMP.NE.ISTA(ITP))GO TO 1550
 1610 CONTINUE
      DO 1620 I=1,12
 1620 RA(I,K,K)=1.
 1630 CONTINUE
C  * * * * * * READ FREQUENCY STATISTICS * * * * * * * * * * * * * * * * * * *
      DO 1640 K=1,NSTA
C                                                      ** CARD N OR O **
      READ(5,80) ITP,(AV(I,K),I=1,12)
      IF(ITP.NE.ISTA(K))GO TO 1550
C              GENERALIZED STATISTICS ON ONE CARD PER STATION
      AVMX(K)=AV(1,K)
      AVMN(K)=AV(2,K)
      SDAV(K)=AV(3,K)
      ITMP=AV(4,K)+.1
      IMX(K)=ITMP-MO(12)
      ITMP=AV(5,K)+.1
      IMN(K)=ITMP-MO(12)
      IF (IMX(K).LT.1) IMX(K)=IMX(K)+12
      IF (IMN(K).LT.1) IMN(K)=IMN(K)+12
      IF(IGNRL.EQ.1)GO TO 1640
C                                                          ** CARD P **
      READ(5,80)ITP,(SD(I,K),I=1,12)
      IF(ITP.NE.ISTA(K))GO TO 1550
C                                                          ** CARD Q **
      READ(5,80)ITP,(SKEW(I,K),I=1,12)
      IF(ITP.NE.ISTA(K))GO TO 1550
C                                                          ** CARD R **
      READ(5,90)ITP,(DD(I,K),I=1,12)
      IF(ITP.NE.ISTA(K))GO TO 1550
 1640 CONTINUE
C * * * * * * ESTIMATE MISSING CORRELATION COEFFICIENTS * * * * * * * * *
 1650 IF(IGNRL.EQ.1)GO TO 3020
      IF(NSTA.LE.1)GO TO 2310
      DO 1720 I=1,12
      IP=I-1
      IF(IP.LT.1)IP=12
      DO 1710 K=1,NSTA
      ITP=K+1
      DO 1700 L=ITP,NSTAX
C              L AND K CORRELATION POSSIBLY MISSING
      IF(RA(I,K,L).GE.(-1.)) GO TO 1700
      RMAX=1.
      RMIN=-1.
C              LX SEARCHES ALL RELATED CORRELATIONS EXCEPT FOLLOWING MTH
      DO 1690 LX=1,NSTAX
      IF(LX.EQ.K)GO TO 1690
      IF(L.EQ.LX)GO TO 1690
      TEMP=RA(I,K,LX)
      IF(L.LE.NSTA)GO TO 1660
```

EXHIBIT 6

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      IF(LX.LE.NSTA)GO TO 1670
C                BOTH L AND LX REPRESENT PRECEDING MONTH
      ITMP=L-NSTA
      ITEMP=LX-NSTA
      TMP=RA(IP,ITMP,ITEMP)
      GO TO 1680
C                L REPRESENTS CURRENT MONTH
 1660 TMP=RA(I,L,LX)
      GO TO 1680
C                LX AND NOT L REPRESENTS CURRENT MONTH
 1670 TMP=RA(I,LX,L)
 1680 IF (TMP+TEMP.LT.-2.0) GO TO 1690
      TMPA=((1.-TEMP*TEMP)*(1.-TMP*TMP))
      IF(TMPA.LT.0.)TMPA=0.
      TMPA=TMPA**.5
      TMPB=TMP*TEMP+TMPA
      IF(TMPB.LT.RMAX)RMAX=TMPB
      TMPB=TMPB-TMPA-TMPA
      IF(TMPB.GT.RMIN)RMIN=TMPB
 1690 CONTINUE
C                AVERAGE SMALLEST MAX AND LARGEST MIN CONSISTENT VALUE
      RA(I,K,L)=(RMAX+RMIN)*.5
      IF(L.LE.NSTA)RA(I,L,K)=RA(I,K,L)
 1700 CONTINUE
 1710 CONTINUE
 1720 CONTINUE
      GO TO 2310
CJ * * * * * * TEST FOR TRIAD CONSISTENCY  * * * * * * * * * * * * * * *
 1730 NCA=0
 1740 FAC=1.
      NCA=NCA+1
      IF(NCA.LT.NSTA*12) GO TO 1750
      WRITE(6,1840)
      GO TO 150
 1750 NCB=0
      NC=0
 1760 INDC=0
      DO 1830 I=1,12
      IP=I-1
      IF(IP.LT.1)IP=12
C                K, L, AND LX SEARCH ALL RELATED TRIOS OF CORREL COEFS
      DO 1820 K=1,NSTA
      ITMP=K+1
      DO 1810 L=ITMP,NSTAX
      IF(L.EQ.NSTAX)GO TO 1810
      LA=L-NSTA
      R1=RA(I,K,L)
      ITP=L+1
      DO 1800 LX=ITP,NSTAX
      ITEMP=LX-NSTA
      R2=RA(I,K,LX)
      IF(L.LE.NSTA)R3=RA(I,L,LX)
C                BOTH L AND LX REPRESENT PRECEDING MONTH
      IF(L.GT.NSTA)R3=RA(IP,LA,ITEMP)
C                RAISE LOWEST COEFFICIENT IF INCONSISTENT
      AC1=(1.-R1*R1)**.5
      AC2=(1.-R2*R2)**.5
      AC3=(1.-R3*R3)**.5
      IF(R1.GT.R2) GO TO 1770
      IF(R1.GT.R3) GO TO 1780
      RMIN=R2*R3-AC2*AC3*FAC
      IF(RMIN.LT.-1.) RMIN=-1.
      IF(R1.GE.RMIN) GO TO 1800
      INDC=1
      RA(I,K,L)=RMIN
      IF (L.LE.NSTA) RA(I,L,K)=RMIN
      GO TO 1800
 1770 IF(R2.GT.R3) GO TO 1780
      RMIN=R1*R3-AC1*AC3*FAC
      IF(RMIN.LT.-1.) RMIN=-1.
      IF(R2.GE.RMIN) GO TO 1800
      INDC=1
```

```
      RA(I,K,LX)=RMIN
      IF (LX.LE.NSTA) RA(I,LX,K)=RMIN
      GO TO 1800
 1780 RMIN=R1*R2-AC1*AC2*FAC
      IF(RMIN.LT.-1.) RMIN=-1.
      IF(R3.GE.RMIN) GO TO 1800
      INDC=1
      IF (L.GT.NSTA) GO TO 1790
      RA(I,L,LX)=RMIN
      IF (LX.LE.NSTA) RA(I,LX,L)=RMIN
      GO TO 1800
 1790 RA(IP,LA,ITEMP)=RMIN
      RA(IP,ITEMP,LA)=RMIN
 1800 CONTINUE
 1810 CONTINUE
 1820 CONTINUE
 1830 CONTINUE
      NC=NC+1
      IF(NC.LE.NSTA*12) GO TO 1850
      WRITE(6,1840)
 1840 FORMAT(32H CORRELATION MATRIX INCONSISTENT)
      GO TO 150
 1850 IF(INDC.EQ.1) GO TO 1760
CK * * * * * * TEST FOR OVER-ALL CONSISTENCY * * * * * * * * * * * * * * *
      ITEMP=0
      GO TO 1870
 1860 ITEMP=1
C               WHEN ITEMP=1, CURRENT MONTH USED FOR ALL INDEPENDENT STAS
C               OTHERWISE, PREC MTH USED FOR CURRENT AND SUBSEQUENT STAS
 1870 NINDP=NSTA
      NVAR=NINDP+1
      DO 2160 I=1,12
      IP=I-1
      IF(IP.LT.1)IP=12
C               CONSTRUCT COMPLETE CORREL MATRIX FOR EACH MONTH AND STA
      DO 2150 K=1,NSTA
C               L IS ROW NUMBER, J IS COLUMN NUMBER
      DO 2020 L=1,NSTA
      LX=L+NSTA
      DO 1980 J=1,NSTA
      JX=J+NSTA
      IF(L-K) 1880,1920,1960
 1880 IF(J-K) 1890,1910,1900
 1890 R(L,J) = DBLE(RA(I,L,J))
      LTMP(L)=L
      JTMP(J)=J
      GO TO 1970
 1900 IF(ITEMP) 1910,1910,1890
 1910 R(L,J) = DBLE(RA(I,L,JX))
      LTMP(L)=L
      JTMP(J)=JX
      GO TO 1970
 1920 IF(J-K) 1930,1940,1950
 1930 R(L,J) = DBLE(RA(I,J,LX))
      LTMP(L)=J
      JTMP(J)=LX
      GO TO 1970
 1940 R(L,J) = DBLE(RA(IP,L,J))
      LTMP(L)=LX
      JTMP(J)=JX
      GO TO 1970
 1950 IF(ITEMP) 1940,1940,1930
 1960 IF(ITEMP) 1920,1920,1880
 1970 R(J,L)=R(L,J)
 1980 CONTINUE
      LTMP(L)=K
C               SPECIAL SUBSCRIPT FOR DEPENDENT VARIABLE
      IF (L-K) 1990,2010,2000
 1990 R(L,NSTAA) = DBLE(RA(I,K,L))
      JTMP(NSTAA)=L
      GO TO 2020
 2000 IF (ITEMP.GT.0) GO TO 1990
```

```
 2010 R(L,NSTAA) = DBLE(RA(I,K,LX))                                  1916000
      JTMP(NSTAA)=LX                                                  1917
 2020 CONTINUE                                                        1918
C                 MATRIX CONSISTENT IF CORREL DOES NOT EXCEED 1.0     1919
      N=0                                                             1920
      NC=0                                                            1921
C     ==========                                                      1922
 2030 CALL CROUT(R)                                                   1923
C     ==========                                                      1924
      IF(DTRMC.LE.1.) GO TO 2130                                      1925
      WRITE(6,2040) N,I,K,DTRMC                                       1926
 2040 FORMAT (/36H INCONSISTENT CORREL MATRIX ADJUSTED,3I4,F12.3)     1927000
C                                                     WITHDRAW 1928-1931
      FAC=FAC-.2                                                      1932
      IF(FAC.GT.-.1)GO TO 1750                                        1933
      NC8=1                                                           1934
      N=N+1                                                           1935
      IF(N.GT.10) GO TO 150                                           1936
      SUM=0.                                                          1937
      DO 2080 L=1,NINDP                                               1938
      DO 2070 LX=1,NVAR                                               1939
      IF(L.EQ.LX) GO TO 2070                                          1940
      TMPP=R(L,LX)                                                    1941
      SUM=SUM+TMPP                                                    1942
 2070 CONTINUE                                                        1943
 2080 CONTINUE                                                        1944
      TEMP=NINDP*NINDP                                                1945
      SUM=SUM/TEMP                                                    1946
      TEMP=DTRMC-1.                                                   1947
      IF(TEMP.GT..1) TEMP=.1                                          1948
      TMP=1.-TEMP                                                     1949
      DO 2120 L=1,NINDP                                               1950
      ITP=L+1                                                         1951
      DO 2110 LX=ITP,NVAR                                             1952
      R(L,LX) = DBLE(TMPP*TMP + SUM*TEMP)                             1953000
      IF(LX.LE.NINDP) R(LX,L)=R(L,LX)                                 1954
      LTP=LTMP(L)                                                     1955
      JTP=JTMP(LX)                                                    1956
      IF(LTP.LE.NSTA) GO TO 2100                                      1957
      IF(ITP.LE.NSTA) GO TO 2090                                      1958
      LTP=LTP-NSTA                                                    1959
      JTP=JTP-NSTA                                                    1960
      RA(IP,LTP,JTP)=R(L,LX)                                          1961
      RA(IP,JTP,LTP)=R(L,LX)                                          1962
      GO TO 2110                                                      1963
 2090 ITMP=LTP                                                        1964
      LTP=JTP                                                         1965
      JTP=ITMP                                                        1966
 2100 RA(I,LTP,JTP)=R(L,LX)                                           1967
      IF(JTP.LE.NSTA) RA(I,JTP,LTP)=R(L,LX)                           1968
 2110 CONTINUE                                                        1969
 2120 CONTINUE                                                        1970
      GO TO 2030                                                      1971
 2130 IF(DTRMC.GE.0.) GO TO 2140                                      1972
      WRITE(6,70)I,K,DTRMC                                            1973
      DTRMC=0.                                                        1974
 2140 IF(NC8.GT.0) GO TO 1740                                         1975
 2150 CONTINUE                                                        1976
 2160 CONTINUE                                                        1977
      IF (ITEMP.EQ.0) GO TO 1860                                      1978
      IF(ITRNS.EQ.2) GO TO 3100                                       1979
 2170 WRITE(6,10)                                                     1980
C   * * * * * * PRINT CORRELATION MATRIX  * * * * * * * * * * * * * * * * 1981
      DO 2260 I=1,12                                                  1982
      IF(ITRNS.LE.0) WRITE(6,2180)MO(I)                               1983
 2180 FORMAT (//39H RAW CORRELATION COEFFICIENTS FOR MONTH,I3)        1984000
      IF(ITRNS.GT.0) WRITE(6,2190) MO(I)                              1985
 2190 FORMAT (//40H CONSISTENT CORRELATION MATRIX FOR MONTH,I3)       1986000
      WRITE(6,2200)(ISTA(K),K=1,NSTA)                                 1987
 2200 FORMAT (/3X,3HSTA,18I7)                                         1988000
      WRITE(6,2210)                                                   1989
 2210 FORMAT(20X,19H WITH CURRENT MONTH)                              1990
```

```
      DO 2220 K=1,NSTA
 2220 WRITE(6,2230) ISTA(K),(RA(I,K,L),L=1,NSTA)
 2230 FORMAT (1X,I5,18F7.3)
      WRITE(6,2240)
 2240 FORMAT (20X,36H WITH PRECEDING MONTH AT ABOVE STATION)
      ITP=NSTA+1
      DO 2250 K=1,NSTA
 2250 WRITE(6,2230)ISTA(K),(RA(I,K,L),L=ITP,NSTAX)
 2260 CONTINUE
      IF(IANAL.LE.0) GO TO 3100
      IF(ITRNS.LE.0) GO TO 1650
      IF(IPCHS.LE.0) GO TO 2870
C                 PUNCH ESSENTIAL ELEMENTS OF MATRIX
      DO 2300 K=1,NSTA
      IF (K.EQ.1) GO TO 2280
      ITP=K-1
      DO 2270 L=1,ITP
 2270 WRITE(7,70)ISTA(K),ISTA(L),(RA(I,K,L),I=1,12)
 2280 DO 2290 L=NSTAA,NSTAX
      ITEMP=L-NSTA
 2290 WRITE(7,70) ISTA(K),ISTA(ITEMP),(RA(I,K,L),I=1,12)
 2300 CONTINUE
      GO TO 2850
CL * * * * * * RECONSTITUTE MISSING DATA * * * * * * * * * * * * * * * *
 2310 IF(IANAL.LE.0) GO TO 3100
      IF (IRCON.LE.0) GO TO 2610
      NVAR=NSTA+1
      M=1
      DO 2600 J=1,NYRS
      DO 2590 I=1,12
      IX=I-1
      IF(IX.LT.1)IX=12
      M=M+1
      DO 2580 K=1,NSTA
      IF(Q(M,K).NE.T) GO TO 2580
C                 FORM CORRELATION MATRIX FOR EACH MISSING FLOW
      NINDP=0
      DO 2390 L=1,NSTA
      LX=L+NSTA
      IF(Q(M,L).NE.T) GO TO 2320
      IF(Q(M-1,L).EQ.T) GO TO 2390
      NINDP=NINDP+1
      ITEMP=NINDP
      X(NINDP)=Q(M-1,L)
      R(NINDP,NVAR) = DBLE(RA(I,X,LX))
      GO TO 2330
 2320 NINDP=NINDP+1
      ITEMP=NINDP
      X(NINDP)=Q(M,L)
      R(NINDP,NVAR) = DBLE(RA(I,K,L))
 2330 R(NINDP,NINDP) = 1.0D0
      IF(L.EQ.NSTA) GO TO 2390
      ITP=L+1
      DO 2380 LA=ITP,NSTA
      JX=LA+NSTA
      IF(Q(M,L).EQ.T) GO TO 2350
      IF(Q(M,LA).EQ.T) GO TO 2340
      ITEMP=ITEMP+1
      R(NINDP,ITEMP) = DBLE(RA(I,L,LA))
      GO TO 2370
 2340 IF(Q(M-1,LA).EQ.T) GO TO 2380
      ITEMP=ITEMP+1
      R(NINDP,ITEMP) = DBLE(RA(I,L,JX))
      GO TO 2370
 2350 IF(Q(M,LA).EQ.T) GO TO 2360
      ITEMP=ITEMP+1
      R(NINDP,ITEMP) = DBLE(RA(I,LA,LX))
      GO TO 2370
 2360 IF(Q(M-1,LA).EQ.T) GO TO 2380
      ITEMP=ITEMP+1
      R(NINDP,ITEMP) = DBLE(RA(IX,L,LA))
C                 ADD SYMMETRICAL ELEMENTS
```

EXHIBIT 6

```
 2370 R(ITEMP,NINDP)=R(NINDP,ITEMP)
 2380 CONTINUE
 2390 CONTINUE
      IF(NINDP.GT.0) GO TO 2400
      NINDP=1
      X(1)=0.
      R(1,1) = 1.0D0
      LX=K+NSTA
      R(1.NVAR) = DBLE(RA(I,K,LX))
 2400 ITEMP=NINDP+1
      DO 2410 L=1,NINDP
 2410 R(L,ITEMP)=R(L,NVAR)
C     ==========
 2420 CALL CROUT (R)
C     ==========
      ITEMP=NINDP+1
      TEMP=1.
      INDC=0
      DO 2440 L=1,NINDP
      TMP=DABS(R(L,ITEMP))
      IF(TMP.GT.TEMP) GO TO 2430
      TEMP=TMP
      ITP=L
 2430 IF(R(L,ITEMP).LE.0..AND.B(L).GT.(-1.5).AND.B(L).LT.0.5) GO TO 2440
      IF(R(L,ITEMP).GE.0..AND.B(L).GT.(-0.5).AND.B(L).LT.1.5) GO TO 2440
      INDC=1
 2440 CONTINUE
      IF(TNDC.GT.0) GO TO 2450
      IF(DTRMC.LE.1..AND.DTRMC.GE.0.) GO TO 2510
C               IF MATRIX INCONSISTENT, OMIT VARIABLE WITH LEAST
C                    CORRELATION
 2450 ITMP=NINDP-1
      IF(ITP.GT.ITMP) GO TO 2480
      DO 2470 L=ITP,ITMP
      DO 2460 LA=1,ITEMP
 2460 R(L,LA)=R(L+1,LA)
 2470 X(L)=X(L+1)
 2480 DO 2500 L=1,ITMP
      DO 2490 LA=ITP,NINDP
 2490 R(L.LA)=R(L,LA+1)
 2500 CONTINUE
      NINDP=ITMP
      GO TO 2420
C               ADD RANDOM COMPONENT TO PRESERVE VARIANCE
 2510 TEMP=0.
      DO 2520 L=1,6
      TEMP=TEMP+RNGEN(IXX)
 2520 TEMP=TEMP-RNGEN(IXX)
C               COMPUTE FLOW
      AL=(1.-DTRMC)**.5
      TEMP=TEMP*AL
      DO 2530 L=1,NINDP
 2530 TEMP=TEMP+B(L)*X(L)
      Q(M,K)=TEMP
      QP(M,K)=E
      TP=Q(M,K)
C               ADD NEW VALUE TO SUMS OF SQUARES AND CROSS PRODUCTS
      DO 2560 L=1,NSTAX
      IF(L.EQ.K) GO TO 2560
C               SUBSCRIPTS EXCEEDING NSTA RELATE TO PRECEDING MONTH
      LX=L-NSTA
      IF(LX.LT.1) TMP=Q(M,L)
      IF(LX.GT.0) TMP=Q(M-1,LX)
      IF (TMP.EQ.T) GO TO 2560
C               COUNT AND USE ONLY RECORDED PAIRS
      NCAB(I,K,L)=NCAB(I,K,L)+1
      SUMA(I,K,L)=SUMA(I,K,L)+TP
      SUMB(I,K,L)=SUMB(I,K,L)+TMP
      SQA (I,K,L)=SQA (I,K,L)+TP*TP
      SQB (I,K,L)=SQB (I,K,L)+TMP*TMP
      XPAB(I,K,L)=XPAB(I,K,L)+TP*TMP
      IF(L.GT.NSTA) GO TO 2540
```

```
      NCAB(I,L,K)=NCAB(I,K,L)
      SUMA(I,L,K)=SUMB(I,K,L)
      SUMB(I,L,K)=SUMA(I,K,L)
      SQA (I,L,K)=SQB (I,K,L)
      SQB (I,L,K)=SQA (I,K,L)
      XPAB(I,L,K)=XPAB(I,K,L)
C               RECOMPUTE CORRELATION COEFFICIENTS TO INCLUDE NEW DATA
 2540 IF(NCAB(I,K,L).LE.2) GO TO 2560
      TEMP=NCAB(I,K,L)
      TMP=(SQA(I,K,L)-SUMA(I,K,L)*SUMA(I,K,L)/TEMP)*(SQB(I,K,L)-SUMB
     1(I,K,L)*SUMB(I,K,L)/TEMP)
C               ELIMINATE PAIRS WITH ZERO VARIANCE PRODUCT
      IF(TMP.LE.0.) GO TO 2560
      TMPB=1.
      TMPA=XPAB(I,K,L)-SUMA(I,K,L)*SUMB(I,K,L)/TEMP
C               RETAIN ALGEBRAIC SIGN
      IF(TMPA.LT.0.)TMPB=-TMPB
      TMPA=TMPA*TMPA/TMP
      RA(I,K,L)=TMPB*TMPA**.5
      ITP=I
      LA=L
      IF(L.LE.NSTA) GO TO 2550
      ITP=I-1
      IF(ITP.LT.1) ITP=12
      LA=LX
 2550 IF(SD(I,K).LT..0001.OR.SD(ITP,LA).LT..0001) RA(I,K,L)=0.
      IF(L.GT.NSTA) GO TO 2560
      RA(I,L,K)=RA(I,K,L)
 2560 CONTINUE
      ITMP=NYRS*12+1
      IF(M.GE.ITMP) GO TO 2580
      TEMP=Q(M,K)
      DO 2570 L=1,NSTA
      TMP=Q(M+1,L)
      IF(TMP.EQ.T) GO TO 2570
      LX=K+NSTA
      ITP=I+1
      IF(ITP,GT.12) ITP=1
      NCAB(ITP,L,LX)=NCAB(ITP,L,LX)+1
      SUMA(ITP,L,LX)=SUMA(ITP,L,LX)+TMP
      SUMB(ITP,L,LX)=SUMB(ITP,L,LX)+TP
      SQA (ITP,L,LX)=SQA (ITP,L,LX)+TMP*TMP
      SQB (ITP,L,LX)=SQB (ITP,L,LX)+TP*TP
      XPAB(ITP,L,LX)=XPAB(ITP,L,LX)+TP*TMP
      IF(NCAB(ITP,L,LX).LE.2) GO TO 2570
      TEMP=NCAB(ITP,L,LX)
      TMP=(SQA(ITP,L,LX)-SUMA(ITP,L,LX)*SUMA(ITP,L,LX)/TEMP)*
     1(SQB(ITP,L,LX)-SUMB(ITP,L,LX)*SUMB(ITP,L,LX)/TEMP)
      IF(TMP.LE.0.) GO TO 2570
      TMPB=1.
      TMPA=XPAB(ITP,L,LX)-SUMA(ITP,L,LX)*SUMB(ITP,L,LX)/TEMP
      IF(TMPA.LT.0.) TMPB=-TMPB
      TMPA=TMPA*TMPA/TMP
      RA(ITP,L,LX)=TMPB*TMPA**.5
      IF(SD(I,K).LT..0001.OR.SD(ITP,L).LT..0001) RA(ITP,L,LX)=0.
 2570 CONTINUE
 2580 CONTINUE
 2590 CONTINUE
 2600 CONTINUE
 2610 IF(IANAL.LE.0) GO TO 3100
CM * * * * * * CONVERT STANDARD DEVIATES TO FLOWS    * * * * * * * * * * *
      IF(NPASS.LE.1) GO TO 2630
      ITMPP=NYRS*12+1
      DO 2620 ITMP=1,100
      IF(LQTAP.EQ.NQTAP) GO TO 2630
      READ(IQTAP)
 2620 LQTAP=LQTAP+1
 2630 WRITE(6,10)
      WRITE (6,2640)
 2640 FORMAT(33H RECORDED AND RECONSTITUTED FLOWS)
      IF(NPASS.GT.1) WRITE(6,2650) IPASS
 2650 FORMAT(5H PASS,I3)
```

```
      ANYRS=NYRS
      DO 2810 K=1,NSTA
      IF(K.GT.NSTX) WRITE(6,2660) (MO(I),I=1,12)
 2660 FORMAT (/11H  STA  YEAR,12I8,6X,5HTOTAL)
      M=1
      DO 2760 J=1,NYRS
      ITP=0
      DO 2720 I=1,12
      M=M+1
      TEMP=Q(M,K)
      TMP=SKEW(I,K)
      IF(TMP.NE.0.) TEMP=((TMP*(TEMP-TMP/6.)/6.+1.)**3 -1.)*2./TMP
      IF(QR(M,K).NE.E) GO TO 2690
      IF(TEMP.GT.2..AND.SD(I,K).GT..3) TEMP=2.+(TEMP-2.)*.3/SD(I,K)
      IF(TMP.LT.-.0001.OR.TMP.GT..0001) TMP=(-2.)/TMP
      IF(SKEW(I,K)) 2670,2690,2680
 2670 IF(TEMP.GT.TMP) TEMP=TMP
      GO TO 2690
 2680 IF(TEMP.LT.TMP) TEMP=TMP
 2690 TMP=TEMP*SD(I,K)+AV(I,K)
      Q(M,K)=10.**TMP-DQ(I,K)
      IF(Q(M,K).LT.0..AND.QMIN(I,K).GE.0.) Q(M,K)=0.
      QM(I)=QR(M,K)
      ITMP=NSUM(K,IPASS)
      IF(ITMP.LE.0) GO TO 2710
      TEMP=0.
      DO 2700 L=1,ITMP
      LX=IST(K,L,IPASS)
 2700 TEMP=TEMP+Q(M,LX)
      IF(Q(M,K).GT.TEMP) GO TO 2710
      QM(I)=ADJ
      IF(QR(M,K).NE.E) GO TO 2710
      QM(I)=ADJ1
      Q(M,K)=TEMP
 2710 IQ(I)=Q(M,K)+.5
 2720 ITP=ITP+IQ(I)
      IYR=IYRA+J
      IF(K.LE.NSTX) GO TO 2760
      IF(IPCHQ.LE.0)GO TO 2740
      WRITE(7,2730) ISTA(K),IYR,(IQ(I),I=1,12)
 2730 FORMAT(2I4,12I6)
 2740 WRITE(6,2750)ISTA(K),IYR,(IQ(I),QM(I),I=1,12) ,ITP
 2750 FORMAT(1X,I4,I6,I8,A1,11(I7,A1),I10)
 2760 CONTINUE
      IF(NPASS.LE.1) GO TO 2765
      WRITE(IQTAP)ISTA(K),(Q(M,K),M=1,ITMPP)
      NQTAP=NQTAP+1
 2765 IF(IRCON.LE.0) GO TO 2810
CN * * * * *RECOMPUTE MEAN AND STANDARD DEVIATION  * * * * * * * * * * *
      DO 2770 I=1,12
      AV(I,K)=0.
      SKEW(I,K)=0.
 2770 SD(I,K)=0.
      M=1
      DO 2790 J=1,NYRS
      DO 2780 I=1,12
      M=M+1
      TEMP=ALOG(Q(M,K)+DQ(I,K))*.4342945
      AV(I,K)=AV(I,K)+TEMP
      SKEW(I,K)=SKEW(I,K)+TEMP**3
 2780 SD(I,K)=SD(I,K)+TEMP*TEMP
 2790 CONTINUE
      DO 2800 I=1,12
      TEMP=AV(I,K)
      TMPA=SD(I,K)
      TMP=(SD(I,K)-TEMP*TEMP/ANYRS)/(ANYRS-1.)
      IF(TMP.LT.0.) TMP=0.
      AV(I,K)=TEMP/ANYRS
      SD(I,K)=TMP**.5
      TMP=SKEW(I,K)
      SKEW(I,K)=0.
      IF(SD(I,K).LE..0005) GO TO 2800
```

```
      SKEW(I,K)=(ANYRS**2*TMP-3.*ANYRS*TEMP*TMPA+2.*TEMP**3)
     1/(ANYRS*(ANYRS-1.)*(ANYRS-2.)* SD(I,K)**3)
 2800 CONTINUE
 2810 CONTINUE
      LOTAP=NQTAP
      ITRNS=1
      IF(IRCON.LE.0) GO TO 2930
      IF(NCSTY.GT.0) GO TO 1290
C                PRINT ADJUSTED FREQUENCY STATISTICS
 2820 WRITE(6,10)
      WRITE(6,2830)
 2830 FORMAT(/30H ADJUSTED FREQUENCY STATISTICS)
      WRITE (6,890) (MO(I),I=1,12)
      DO 2840 K=NSTXX,NSTA
      WRITE (6,1010) ISTA(K),(AV(I,K),I=1,12)
      WRITE (6,1020) (SD(I,K),I=1,12)
      WRITE (6,1030) (SKEW(I,K),I=1,12)
      WRITE (6,1040) (DQ(I,K),I=1,12)
 2840 CONTINUE
C                PRINT CONSISTENT CORRELATION MATRIX
      ITRNS=1
      GO TO 2170
 2850 IF (IPCHS.LE.0) GO TO 2870
C                PUNCH FREQUENCY STATISTICS
      DO 2860 K=NSTXX,NSTA
      WRITE(7,80)ISTA(K),(AV(I,K),I=1,12)
      WRITE(7,80)ISTA(K),(SD(I,K),I=1,12)
      WRITE(7,80)ISTA(K),(SKEW(I,K),I=1,12)
      WRITE(7,90)ISTA(K),(DQ(I,K),I=1,12)
 2860 CONTINUE
C                COMPUTE COMBINATION FLOWS
C
 2870 IF(NCOMB.LE.0) GO TO 2910
      ITMP=12*NYRS+1
      DO 2900 M=2,ITMP
      DO 2890 KX=1,NCOMB
      K=KX+NSTA
      ITP=NSTAC(KX,IPASS)
      Q(M,K)=0.
      DO 2880 L=1,ITP
      ITEMP=KSTAC(KX,L,IPASS)
 2880 Q(M,K)=Q(M,K)+Q(M,ITEMP)*CSTAC(KX,L,IPASS)
 2890 CONTINUE
 2900 CONTINUE
C
CO * * * * * * MAX AND MIN RECONSTITUTED FLOWS * * * * * * * * * * * * * *
 2910 N=0
      ITRNS=1
      IF(MXRCS.LE.0) GO TO 2930
      ITMP=NYRS
 2920 IF(ITMP.LE.0) GO TO 2930
      N=N+1
      NJ=MXRCS
      ITMP=ITMP-MXRCS
      IF(ITMP.GE.0) GO TO 3730
      ITMP=MXRCS+ITMP
      NJ=ITMP
      ITMP=0
      GO TO 3730
 2930 IF(IGNRL.NE.2)GO TO 3020
C  * * * * * * COMPUTE GENERALIZED STATISTICS* * * * * * * * * * * * * * *
      WRITE(6,130)
      DO 3000 K=1,NSTA
C                AVERAGE CORRELATION COEFFICIENT
      DO 2950 L=1,K
      LX=L+NSTA
      RAV(K,L)=0.
      DO 2940 I=1,12
      TMP=RA(I,K,L)
      IF(L.GE.K)TMP=RA(I,K,LX)
 2940 RAV(K,L)=RAV(K,L)+TMP
      RAV(K,L)=RAV(K,L)/12.
```

```
      WRITE(6,70)ISTA(K),ISTA(L),RAV(K,L)
 2950 CONTINUE
C               AVERAGE LOGS FOR WET AND DRY SEASONS
      AVMX(K)=AV(11,K)+AV(12,K)+AV(1,K)
      IMX(K)=1
      AVMN(K)=AVMX(K)
      IMN(K)=1
      TMP=AV(12,K)+AV(1,K)+AV(2,K)
      IF(AVMX(K).GE.TMP)GO TO 2960
      AVMX(K)=TMP
      IMX(K)=2
      GO TO 2970
 2960 AVMN(K)=TMP
      IMN(K)=2
C               AND AVERAGE STANDARD DEVIATION
 2970 SDAV(K)=SD(1,K)+SD(2,K)
      DO 2990 I=3,12
      SDAV(K)=SDAV(K)+SD(I,K)
      TMP=AV(I-2,K)+AV(I-1,K)+AV(I,K)
      IF(AVMX(K).GE.TMP)GO TO 2980
      AVMX(K)=TMP
      IMX(K)=I
 2980 IF(AVMN(K).LE.TMP)GO TO 2990
      AVMN(K)=TMP
      IMN(K)=I
 2990 CONTINUE
      AVMX(K)=AVMX(K)/3.
      AVMN(K)=AVMN(K)/3.
      SDAV(K)=SDAV(K)/12.
 3000 CONTINUE
      WRITE(6,140)
      DO 3010 K=1,NSTA
      ITP=IMX(K)
      ITMP=IMN(K)
 3010 WRITE(6,120)ISTA(K),AVMX(K),AVMN(K),SDAV(K),MO(ITP),MO(ITMP)
C * * * * * * APPLY GENERALIZED STATISTICS* * * * * * * * * * * * * * * *
 3020 IF(IGNRL.LE.0)GO TO 3100
      DO 3080 K=1,NSTA
      KX=K+NSTA
C               INTERMEDIATE MONTHS
      NMXMN=IMN(K)-IMX(K)-3
      IF(NMXMN.LT.0)NMXMN=NMXMN+12
      NMNMX=6-NMXMN
      DO 3040 I=1,12
C               STANDARD DEVIATION UNIFORM, SKEW ZERO
      SKEW(I,K)=0.
      DQ(I,K)=0.
      SD(I,K)=SDAV(K)
      DO 3030 L=1,NSTA
C               ZERO CORRELATION WITH OTHER STATIONS AND PRECEDING MONTH
      LX=L+NSTA
      RA(I,K,LX)=0.
      IF(L.GE.K)GO TO 3030
C               UNIFORM SERIAL CORREL INTERMEDIATE MONTHS AND INTER-STA
      RA(I,K,L)=RAV(K,L)
      RA(I,L,K)=RA(I,K,L)
 3030 CONTINUE
      RA(I,K,KX)=RAV(K,K)
      RA(I,K,K)=1.
 3040 CONTINUE
C               MEAN AND SERIAL CORREL, WET AND DRY SEASONS
      TMP=RAV(K,K)+.15
      TEMP=TMP-.3
      IF(TMP.GT..98)TMP=.98
      IF(TEMP.LT.0)TEMP=0.
      ITP=IMX(K)
      AV(ITP,K)=AVMX(K)-.1
      RA(ITP,K,KX)=TEMP
      ITP=IMX(K)-1
      IF(ITP.LT.1)ITP=12
      AV(ITP,K)=AVMX(K)+.2
      RA(ITP,K,KX)=TEMP
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      ITP=IMX(K)-2
      IF(ITP.LT.1)ITP=ITP+12
      AV(ITP,K)=AVMX(K)-.1
      RA(ITP,K,KX)=TEMP
      ITP=IMN(K)
      AV(ITP,K)=AVMN(K)
      RA(ITP,K,KX)=TMP
      ITP=IMN(K)-1
      IF(ITP.LT.1)ITP=12
      AV(ITP,K)=AVMN(K)
      RA(ITP,K,KX)=TMP
      ITP=IMN(K)-2
      IF(ITP.LT.1)ITP=ITP+12
      AV(ITP,K)=AVMN(K)
      RA(ITP,K,KX)=TMP
C                 MEANS FOR MONTHS FOLLOWING WET SEASON
      IF(NMXMN.LT.1)GO TO 3060
      ITP=IMX(K)
      TEMP=NMXMN+1
      TEMP=(AVMX(K)-.1-AVMN(K))/TEMP
      DO 3050 IX=1,NMXMN
      TMP=IX
      I=IMX(K)+IX
      IF(I.GT.12)I=I-12
 3050 AV(I,K)=AV(ITP,K)-TEMP*TMP
C                 MEANS FOR MONTHS FOLLOWING DRY SEASON
 3060 IF(NMNMX.LT.1)GO TO 3090
      ITP=IMN(K)
      TEMP=NMNMX+1
      TEMP=(AVMX(K)-.1-AVMN(K))/TEMP
      DO 3070 IX=1,NMNMX
      TMP=IX
      I=IMN(K)+IX
      IF(I.GT.12)I=I-12
 3070 AV(I,K)=AV(ITP,K)+TEMP*TMP
 3080 CONTINUE
 3090 IGNPL=0
      IRCON=0
      GO TO 1730
 3100 IF(NYRG.LE.0.AND.NPROJ.LE.0.AND.NPASS.LE.1) GO TO 150            *
CP * * * * * * FLOW GENERATION EQUATIONS * * * * * * * * * * * * * * * * * *
      NINDP=NSTA
      NVAR=NSTA+1
      DO 3200 I=1,12
      IP=I-1
      IF (IP.LT.1) IP=12
      DO 3190 K=1,NSTA
      DO 3140 L=1,NSTA
C                 CORRELATIONS IN CURRENT MONTH
      IF (L.GE.K) GO TO 3120
      R(L,NVAR) = DBLE(RA(I,K,L))
      DO 3110 LA=L,NSTA
      LX=LA+NSTA
      IF (LA.LT.K) R(L,LA) = DBLE(RA(I,L,LA))
      IF (LA.GE.K) R(L,LA) = DBLE(RA(I,L,LX))
 3110 R(LA,L)=R(L,LA)
      GO TO 3140
C                 CORRELATIONS WITH PRECEDING MONTH
 3120 LX=L+NSTA
      R(L,NVAR) = DBLE(RA(I,K,LX))
      DO 3130 LA=L,NSTA
      R(L,LA) = DBLE(RA(IP,L,LA))
 3130 R(LA,L)=R(L,LA)
 3140 CONTINUE
C     ==========
      CALL CROUT(R)
C     ==========
      DO 3150 L=1,NSTA
 3150 BETA(I,K,L)=B(L)
      IF(DTRMC.LE.1.) GO TO 3170
       WRITE(6,3160)I,K,DTRMC
 3160 FORMAT (34H INCONSISTENT CORREL MATRIX FOR I=,I3,4H  K=,I2,
```

```
     19H  DTRMS=,F6.3)
      ITRNS=2
      GO TO 1730
 3170 IF(DTRMC.GE.0.) GO TO 3180
      WRITE(6,70)I,K,DTRMC
      DTRMC=0.
 3180 ALCFT(I,K)=(1.-DTRMC)**.5
 3190 CONTINUE
 3200 CONTINUE
C  * * * * * * GENERATE FLOWS  * * * * * * * * * * * * * * * * * * * * * *
      IF(NPASS.LE.1) GO TO 3240
 3210 IF(LSTAT.EQ.NSTAT) GO TO 3220
      READ (ISTAT)
      LSTAT=LSTAT+1
      GO TO 3210
 3220 WRITE(ISTAT)NSTXX,NSTA,(ISTA(K),K=1,NSTA)
      NSTAT=NSTAT+1
      LSTAT=NSTAT
      DO 3230 K=1,NSTA
      WRITE(ISTAT) ISTA(K),(AV(I,K),SD(I,K),SKEW(I,K),DQ(I,K),
     1        (BETA(I,K,L),L=1,NSTA),ALCFT(I,K),I=1,12)
 3230 NSTAT=NSTAT+1
      LSTAT=NSTAT
      IF(IPASS.LT.NPASS) GO TO 200
 3240 JA=1
      IPASS=1
      N=0
      MA=0
      IF (NPROJ.LE.0) GO TO 3310
CQ * * * * * * PROJECTED FLOW SEQUENCES  * * * * * * * * * * * * * * * *
 3250 JA=IYRPJ-IYRA
      NJ=LYRPJ-IYRA
      ITMP=0
      ITP=MTHPJ-IMNTH-1
      IF(ITP.NE.0) GO TO 3260
      ITMP=12
 3260 IF (ITP.LT.1) ITP=ITP+12
      MA=(JA-1)*12+ITP+1-ITMP
      DO 3290 K=1,NSTA
      IF (SD(ITP,K).EQ.0..OR.MA.EQ.1) GO TO 3280
      TEMP=ALOG(Q(MA,K)+DQ(ITP,K))*.4342945
      QPREV(K)=(TEMP-AV(ITP,K))/SD(ITP,K)
      IF (SKEW(ITP,K).EQ.0.) GO TO 3290
      TEMP=.5*SKEW(ITP,K)*QPREV(K)+1.
      TMP=1.
      IF (TEMP.GE.0.) GO TO 3270
      TEMP=(-TEMP)
      TMP=(-TMP)
 3270 QPREV(K)=6.*(TMP*TEMP**(1./3.)-1.)/SKEW(ITP,K)+SKEW(ITP,K)/6.
      GO TO 3290
 3280 QPREV(K)=0.
 3290 CONTINUE
      JX=IYRPJ-1
C                N = SEQUENCE NO., M = MONTH NO., JX = YEAR NO.
 3300 N=N+1
      GO TO 3330
C                START WITH ZERO DEVIATION AT ALL STATIONS
 3310 DO 3320 K=1,KSTA
 3320 QPREV(K)=0.
C                GENERATE 2 YEARS FOR DISCARDING
      NJ=2
      JX=-2
 3330 IF(NPASS.LE.1) GO TO 3400
      IF(IPASS.GT.1) GO TO 3340
      REWIND ISTAT
      NQTAP=0
      ISTAP=0
 3340 REWIND IQTAP
      LQTAP=0
      READ(ISTAT)NSTXX,NSTA,(ISTA(K),K=1,NSTA)
      NSTX=NSTXX-1
      IF(NSTX.LE.0) GO TO 3380
```

```
      ITP=NJ*12+1
      DO 3370 K=1,NSTX
      IF(IPASS.LE.1) GO TO 3360
 3350 READ(IOTAP) ITEMP,(Q(M,K),M=2,ITP)
      LQTAP=LQTAP+1
      IF(ITEMP.NE.ISTA(K)) GU TO 3350
 3360 READ(ISTAT) IP,(AV(I,K),SD(I,K),SKEW(I,K),DQ(I,K),(BETA(I,K,L),L=1
     1,NSTA),ALCFT(I,K),I=1,12)
 3370 CONTINUE
 3380 DO 3390 K=NSTXX,NSTA
      ISTAP=ISTAP+1
      IF(N.GT.0) QPREV(K)=QSTAP(ISTAP)
 3390 READ(ISTAT) IP,(AV(I,K),SD(I,K),SKEW(I,K),DQ(I,K),(BETA(I,K,L),L=1
     1,NSTA),ALCFT(I,K),I=1,12)
CR * * * * * * GENERATE CORRELATED STANDARD DEVIATE  * * * * * * * * * *
 3400 IF(IPASS.EQ.1) JXTMP=JX
      NCOMB=MCOMB(IPASS)
      NTNDM=MTNDM(IPASS)
      DO 3420 K=1,NSTA
      DO 3410 I=1,12
      AVG(I,K)=0.
      SDV(I,K)=0.
 3410 CONTINUE
 3420 CONTINUE
      IF(N.LE.0) GO TO 3440
      WRITE(6,10)
      WRITE (6,3430) N
 3430 FORMAT (27H GENERATED FLOWS FOR PERIOD,I3)
      IF(NPASS.GT.1) WRITE(6,2650) IPASS
 3440 DO 3510 J=JA,NJ
      M=12*(J-1)+1
      DO 3500 I=1,12
      M=M+1
      IF(NSTX.LE.0) GO TO 3460
      DO 3450 K=1,NSTX
 3450 QPREV(K)=Q(M,K)
 3460 IF (M.LE.MA) GO TO 3500
      DO 3490 K=NSTXX,NSTA
C                RANDOM COMPONENT
      TEMP=0.
      DO 3470 L=1,6
      TEMP=TEMP+RNGEN(IXX)
 3470 TEMP=TEMP-RNGEN(IXX)
      TEMP=TEMP*ALCFT(I,K)
      DO 3480 L=1,NSTA
 3480 TEMP=TEMP+BETA(I,K,L)*QPREV(L)
      AVG(I,K)=AVG(I,K)+TEMP
      SDV(I,K)=SDV(I,K)+TEMP*TEMP
      Q(M,K)=TEMP
      QPREV(K)=TEMP
 3490 CONTINUE
 3500 CONTINUE
 3510 CONTINUE
      IF(NPASS.LE.1) GO TO 3550
 3520 IF(LQTAP.EQ.NQTAP) GO TO 3530
      READ (IQTAP)
      LQTAP=LQTAP+1
      GO TO 3520
 3530 ITP=NJ*12+1
      ISTAP=ISTAP-NSTA+NSTX
      DO 3540 K=NSTXX,NSTA
      WRITE(IQTAP)ISTA(K),(Q(M,K),M=2,ITP)
      NQTAP=NQTAP+1
      ISTAP=ISTAP+1
      IF (ISTAP.GT.KSTAP) GO TO 160
 3540 QSTAP(ISTAP)=Q(ITP,K)
 3550 ANLOG=NJ-JA+1
      DO 3670 K=NSTXX,NSTA
      IF(NJ+JXTMP.GT.0) WRITE(6,2660) (MO(I),I=1,12)
      DO 3560 I=1,12
      AVG(I,K)=AVG(I,K)/ANLOG
      SDV(I,K)=((SDV(I,K)-AVG(I,K)**2*ANLOG)/ANLOG)**.5
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```
 3560 CONTINUE
      JX=JXTMP
      DO 3660 J=JA,NJ
      JX=JX+1
      M=12*J-11
      IF (JX.LE.0) GO TO 3660
      ITP=0
      DO 3650 I=1,12
      M=M+1
      IF (M.LE.MA) GO TO 3640
C               TRANSFORM TO LOG PEARSON TYPE III VARIATE (FLOW)
      TMP=SKEW(I,K)
      IF(ANLOG.GT.19..AND.SDV(I,K).GT.0.)
     3    Q(M,K)=(Q(M,K)-AVG(I,K))/SDV(I,K)
      IF (TMP.EQ.0.) GO TO 3600
C                                                            WITHDREW      *
      TMP=((TMP*(Q(M,K)-TMP/6.)/6.+1.)**3 -1.)*2./TMP
      TEMP=(-2.)/SKEW(I,K)
      IF(SKEW(I,K)) 3580,3600,3590
 3580 IF(TMP.GT.TEMP)TMP=TEMP
      GO TO 3610
 3590 IF(TMP.LT.TEMP) TMP=TEMP
      GO TO 3610
 3600 TMP=Q(M,K)
 3610 IF(TMP.GT.2..AND.SD(I,K).GT..3) TMP=2.+(TMP-2.)*.3/SD(I,K)
      TMP=TMP*SD(I,K)+AV(I,K)
      Q(M,K)=10.**TMP-DQ(I,K)
      ITMP=NSUM(K,IPASS)
      IF(ITMP.LE.0) GO TO 3630
      TEMP=0.
      DO 3620 L=1,ITMP
      LX=IST(K,L,IPASS)
 3620 TEMP=TEMP+Q(M,LX)
      IF(Q(M,K).LT.TEMP) Q(M,K)=TEMP
 3630 IF(Q(M,K).LT.0..AND.QMIN(I,K).GE.0.) Q(M,K)=0.
 3640 IQ(I)=Q(M,K)+.5
      ITP=ITP+IQ(I)
 3650 CONTINUE
C                                                            WITHDREW      *
      IQ(13)=ITP
      WRITE (6,100) ISTA(K),JX,(IQ(I),I=1,13)
      IF(IPCHQ.LE.0)GO TO 3660
      WRITE(7,2730) ISTA(K), JX,(IQ(I),I=1,12)
 3660 CONTINUE
 3670 CONTINUE
      IF(NCOMB.LE.0) GO TO 3720
      DO 3710 J=JA,NJ
      M=12*J-11
      DO 3700 I=1,12
      M=M+1
C               COMPUTE COMBINATION FLOWS
      DO 3690 KX=1,NCOMB
      K=KX+NSTA
      ITP=NSTAC(KX,IPASS)
      Q(M,K)=0.
      DO 3680 L=1,ITP
      ITEMP=KSTAC(KX,L,IPASS)
 3680 Q(M,K)=Q(M,K)+Q(M,ITEMP)*CSTAC(KX,L,IPASS)
 3690 CONTINUE
 3700 CONTINUE
 3710 CONTINUE
 3720 IF(N.LT.NPROJ) GO TO 3250
      IF(NYMXG.LE.0)GO TO 3860
CS * * * * * * MAX AND MIN GENERATED FLOWS * * * * * * * * * * * * * * *
      IF(JX.LE.0)GO TO 3870
C               SKIP MAXMIN IF REMAINING YEARS INSUFFICIENT
      IF(JX.GT.0.AND.NJ.LT.NYMXG)GO TO 150
      ITRNS=0
 3730 ITP=NSTA+NCOMB
      DO 3800 K=NSTXX,ITP
C               MAX CALENDAR MO 1-12, MAX MO 13, 6-MO 14, 54-MO 15
      DO 3740 I=1,15
```

```
 3740 SMQ(I,K)=-T
C                MIN CALENDAR MO 16-27, MIN MO 28, 6-MO 29, 54-MO 30
      DO 3750 I=16,30
 3750 SMQ(I,K)=T
C                TMP = 6-MO, TEMP = 54-MO VOLUME, TMPA = 1-MO
      TEMP=0.
      TMP=0.
      AVGQ(K)=0.
      NQ=0
      M=1
      IF(ITRNS.GT.0) M=(N-1)*MXRCS*12+1
      DO 3790 J=1,NJ
      DO 3780 I=1,12
      IX=I+15
      M=M+1
      TMPA=Q(M,K)
      AVGQ(K)=AVGQ(K)+TMPA
      NQ=NQ+1
      IF(TMPA.GT.SMQ(I,K))SMQ(I,K)=TMPA
      IF(TMPA.LT.SMQ(IX,K))SMQ(IX,K)=TMPA
      IF(TMPA.GT.SMQ(13,K))SMQ(13,K)=TMPA
      IF(TMPA.LT.SMQ(28,K))SMQ(28,K)=TMPA
      TMP=TMP+TMPA
      TEMP=TEMP+TMPA
      IF(M.LT.8)GO TO 3760
      TMP=TMP-Q(M-6,K)
      IF(TMP.GT.SMQ(14,K))SMQ(14,K)=TMP
      IF(TMP.LT.SMQ(29,K))SMQ(29,K)=TMP
      IF(M.LT.56)GO TO 3770
      TEMP=TEMP-Q(M-54,K)
      IF(TEMP.GT.SMQ(15,K))SMQ(15,K)=TEMP
      IF(TEMP.LT.SMQ(30,K))SMQ(30,K)=TEMP
      GO TO 3780
 3760 SMQ(14,K)=TMP
 3770 SMQ(15,K)=TEMP
 3780 CONTINUE
 3790 CONTINUE
C                AVERAGE MONTHLY FLOW
      TEMP=NQ
      AVGQ(K)=AVGQ(K)/TEMP
 3800 CONTINUE
      WRITE (6,10)
      IF(ITRNS.GT.0)WRITE(6,3810)N,NJ
 3810 FORMAT (/27H MAXIMUM VOLUMES FOR PERIOD,I3,3H OF,I4,
     142H YEARS OF RECORDED AND RECONSTITUTED FLOWS)
      IF(ITRNS.LE.0)WRITE(6,3820)N,NJ
 3820 FORMAT (/27H MAXIMUM VOLUMES FOR PERIOD,I3,3H OF,I4,
     125H YEARS OF SYNTHETIC FLOWS)
      WRITE(6,810)(MO(I),I=1,12)
      ITP=NSTA+NCOMB
      DO 3840 K=NSTXX,ITP
      ITEMP=AVGQ(K)+.5
      DO 3830 I=1,15
 3830 IQ(I)=SMQ(I,K)+.5
      WRITE(6,840)ISTA(K),(IQ(I),I=1,15),ITEMP
 3840 CONTINUE
      WRITE(6,850)
      WRITE(6,810)(MO(I),I=1,12)
      DO 3860 K=NSTXX,ITP
      DO 3850 I=1,15
 3850 IQ(I)=SMQ(I+15,K)+.5
      WRITE(6,840)ISTA(K),(IQ(I),I=1,15)
 3860 CONTINUE
C                TRANSFER BACK TO RECONSTITUTED FLOWS
      IF(ITRNS.GT.0)GO TO 2920
 3870 NJ = NYMXG
      GO TO 3890
 3880 NJ = KYR
 3890 IF(NPASS.LE.1) GO TO 3900
      IPASS=IPASS+1
      IF(N.EQ.0.AND.IPASS.LE.NPASS) GO TO 3310
      IF(IPASS.LE.NPASS) GO TO 3340
```

EXHIBIT 6

```
      IPASS=1
C                 GO TO NEW JOB
 3900 IF(NYRG.LE.0) GO TO 150
      IF(NJ.GT.NYRG)NJ=NYRG
      NYRG=NYRG-NJ
      GO TO 3300
      END
      SUBROUTINE CROUT(RX)
      DIMENSION B(10),R(10,11),RX(10,11)
      DOUBLE PRECISION R,B,RX
      COMMON DTRMC,NINDP,B
      NVAR=NINDP+1
      DO 20 J=1,NINDP
      B(J)=0.
      DO 10 K=1,NVAR
   10 R(J,K)=RX(J,K)
   20 CONTINUE
      IF(NINDP.GT.1)GO TO 30
      B(1)=R(1,2)/R(1,1)
      DTRMC=B(1)*B(1)
      RETURN
C   * * * * * * DERIVED MATRIX  * * * * * * * * * * * * * * * * * * * * *
   30 DO 40 K=2,NVAR
   40 R(1,K)=R(1,K)/R(1,1)
      DO 80 K=2,NINDP
      ITP=K-1
      DO 60 J=K,NINDP
      DO 50 I=1,ITP
      L=K-I
   50 R(J,K)=R(J,K)-R(J,L)*R(L,K)
      IF(J.EQ.K) GO TO 60
      R(K,J)=R(J,K)/R(K,K)
   60 CONTINUE
      DO 70 I=1,ITP
      L=K-I
   70 R(K,NVAR)=R(K,NVAR)-R(L,NVAR)*R(K,L)
      TEMP=DABS(R(K,K))
      IF(TEMP.GT..000001) GO TO 80
      DTRMC=1.5
      RETURN
   80 R(K,NVAR)=R(K,NVAR)/R(K,K)
C   * * * * * * BACK SOLUTION * * * * * * * * * * * * * * * * * * * * * *
      B(NINDP)=R(NINDP,NVAR)
      DO 100 I=2,NINDP
      J=NVAR-I
      IX=I-1
      B(J)=R(J,NVAR)
      DO 90 L=1,IX
      K=J+L
   90 B(J)=B(J)-B(K)*R(J,K)
  100 CONTINUE
      DTRMC=0.
      DO 110 J=1,NINDP
  110 DTRMC=DTRMC+B(J)*RX(J,NVAR)
      RETURN
      END
      FUNCTION RNGEN(IX)
C     RANDOM NUMBER SUBROUTINE FOR A BINARY MACHINE
C     GENERATES UNIFORM RANDOM NUMBERS IN THE INTERVAL 0 TO 1
C     GENERAL USAGE IS AS FOLLOWS
C     A=RNGEN(IX)
C     IX SHOULD BE INITIALIZED TO ZERO IN THE PROGRAM
C     IARG CAN BE ANY LARGE, ODD INTEGER
C     CONSTANTS MUST BE COMPUTED BY FOLLOWING EQUATIONS
C     * * * *  ICON1=(2**((B+1)/2))+3   * * * *
C     * * * *  ICON2=(2**B)-1           * * * *
C     * * * *  FCON3=1./(2.**B)         * * * *
C     WHERE B= NUMBER OF BITS IN THE INTEGER WORD
C
      DATA IARG/759821/
      IF(IARG.EQ.IX) GO TO 10
      IX=IARG
```

```
      IY=IX
      ICON1=16777219
   10 IY=IY*ICON1
      ICON2=281474976710655
      IF(IY.LT.0) IY=IY+ICON2+1
      RNGEN=IY
      FCON3=.3552713678E-14
      RNGEN=RNGEN*FCON3
      RETURN
      END
```

EXHIBIT 6

# EXHIBIT 7

## INPUT DATA 723-X6-L2340

| CARD | VARIABLE | COMMENTS |
|---|---|---|
| A | | Three title cards, first must have A in column 1. |
| B | | First specification card. |
| | 1. IYRA | - Earliest year of record at any station. |
| | 2. IMNTH | - Calendar month number of first month of water year. |
| | 3. IANAL | - Indicator, positive value calls for statistical analysis routines. |
| | 4. MXRCS | - Number of years in each period of recorded and reconstituted flows for which maximum and minimum values are to be obtained, dimensioned for 100. |
| | 5. NYRG | - Total number of years of hypothetical flows to be generated. |
| | 6. NYMXG | - Number of years in each period of generated flows which maximum and minimum values are to be obtained, dimensioned for 100. |
| | 7. NPASS | - Number of consecutive passes, each pass consisting of a new group of stations which can be correlated with specified stations in previous passes, dimensioned for 5. |
| | 8. IPCHQ | - Indicator, positive value calls for writing recorded and reconstituted flows and generated flows on Tape 7. |
| | 9. IPCHS | - Indicator, positive value calls for writing statistics on Tape 7. |
| | 10. NSTA | - Number of stations at which flows are to be generated, not required if flow data are supplied. NSTA + NCOMB (C-1) dimensioned for 10. |
| C | | Second specification card. |
| | 1. NCOMB | - Number of combinations of stations, the totals of which are used to obtain maximum and minimum flows, dimensioned for 2. If positive, provide D and E cards. |
| | 2. NTNDM | - Number of tandem situations, compares sum of monthly values of upstream stations with downstream station and adjusts if value is less than sum and that station's value has been estimated or generated, dimension for 10. If positive, provide F card. |
| | 3. NCSTY | Number of consistency tests. Adjusts standard deviation of a dependent station in tandem with an independent station to prevent frequency curves from crossing, dimensioned for 10. If positive, provide G card. |

| CARD | VARIABLE | COMMENTS |
|---|---|---|
| C (Cont'd) | | |
| | 4. IGNRL | - Indicator, + 1 calls for reading generalized statistics and using for generation, + 2 calls for computing generalized statistics from flow data and using for generation. |
| | 5. NPROJ | - Number of projections of future flows from present conditions, usually 0. |
| | 6. IYRPJ | - Year of start of each projection. |
| | 7. MTHPJ | - Calendar month of start of each projection. |
| | 8. LYRPJ | - Last year of each projection, number of recorded and reconstituted years plus number of projected years dimensioned for 100. |
| D | | Identification of combination, NCOMB (C-1) sets of D and E cards. |
| | 1. NSTAC | - Number of stations in this combination, dimensioned for 10. |
| | 2. ISTAC | - Station number (NSTAC values). |
| E | | Combining coefficients, NCOMB (C-1) sets of D and E cards. |
| | 1. NSTAC | - Same as D-1. |
| | 2. CSTAC | - Coefficient of flow used for adding, corresponds to respective items in D-2. |
| F | | Identification of tandem situation, NTNDM (C-2) cards. |
| | 1. ISTN | - Station number of downstream station. |
| | 2. NSMX | - Number of upstream stations, dimensioned for 10. |
| | 3. ISTT | - Station number of upstream station (NSMX values). |
| G | | Identification of consistency test, NCSTY (C-3) cards. |
| | 1. ISTX | - Independent station number. |
| | 2. ISTY | - Dependent station number. |
| H | | Flow data, cards in any order, omit if IANAL (B-3) is not positive, follow all flow data cards by 1 blank card (I card). |
| | 1. Cols 2-4, Station number | |
| | 2. Cols 5-8, Year number. | |

| CARD | VARIABLE | COMMENTS |
|---|---|---|
| H (Cont'd) | | |
| | 3. | Cols 9-14, 15-20, etc., Flow in desired units. Units should be selected so generated flows will not exceed 999,999. Use -1 for missing record. If record for entire year is missing, omit card for that year. |
| I | | Card blank after Col 1 to indicate end of flow data, omit if IANAL (B-3) is not positive. |
| J | | Identification of stations in previous passes to be used in current pass, supply only if NPASS (B-7) is greater than 1. The variables NCOMB, NTNDM, and NCSTY apply to the current pass only. |
| | 1. NCOMB | - Number of combinations of stations, the totals of which are used to obtain maximum and minimum flows, dimensioned for 2. If positive, provide D and E cards. |
| | 2. NTNDM | - Number of tandem situations, compares sum of monthly values of upstream stations with downstream station and adjusts if value is less than sum and that station's value has been estimated or generated, dimension for 10. If positive, provide F card. |
| | 3. NCSTY | Number of consistency tests. Adjusts standard deviation of a dependent station in tandem with an independent station to prevent frequency curves from crossing, dimensioned for 10. If positive, provide G card. |
| | 4. NSTX | - Number of stations from previous passes which are to be used with the additional data in current pass as a means of maintaining consistent flows between groups of stations, number of stations from previous passes plus number of new stations dimensioned for 10. |
| | 5. ISTA | - Station number of station in a previous pass which is to be used in current pass (NSTX values). Must be in same order as stations first appear. |
| | Note: | Flow data for current pass supplied as described for H card and follow data with a blank card (I card), supply NPASS-1 sets of J, H, and I cards (also D,E,F, and G, if necessary) when NPASS greater than 1. |
| K | | Preceding-month correlation coefficients for first station, omit if IANAL (B-3) is positive (NSTA cards). |
| | 1. ISTA(K) | - Cols 2-4, Number of first station. |
| | 2. ISTA(L) | - Cols 5-8, Number of station from 1 to NSTA (B-10) on successive cards. If IGNRL (C-4) = 1, only first card is used. |
| | 3. RA(I,K,LX) | - Cols 9-14, 15-20, etc., Correlation coefficients for successive months between flows at first station and preceding-month flows at stations from 1 to NSTA (B-10) on separate cards. If IGNRL (C-4) = 1, only generalized coefficient (in cols 9-14) is given. |

EXHIBIT 7

| CARD | VARIABLE | COMMENTS |
|---|---|---|
| L* | | Current-month correlation coefficients, omit if IANAL (B-3) is positive, (NSTA-1) pairs of L and M cards. |
| | 1. ISTA(K) - | Cols 2-4, Number of station, progressing from K = 2 through NSTA (B-10) stations on different sets of L and M cards. |
| | 2. ISTA(L) - | Cols 5-8, Number of station, progressing on different cards through all stations from L = 1 to K-1. |
| | 3. RA(I,K,L) - | Cols 9-14, 15-20, etc., Correlation coefficient for each successive calendar month between flows at station K and concurrent flows at station L (12 items). If IGNRL (C-4) = 1, only generalized coefficient in cols 9-14 is given. |
| M* | | Preceding-month correlation coefficients for remaining stations, omit if IANAL (B-3) is positive. Paired with L card. |
| | 1. ISTA(K) - | Cols 2-4, Same station number as on corresponding L card (L-1). |
| | 2. ISTA(L) - | Cols 5-8, Number of station, progressing in same order on different cards through all stations from L = 1 to NSTA (B-10). If IGNRL (C-4) = 1, only card with L = K is used. |
| | 3. RA(I,K,LX)- | Cols 9-14, 15-20, etc., Correlation coefficient for each successive calendar month between flows at station K and flows in preceding month at station L (12 items). If IGNRL (C-4) = 1, only generalized coefficient in Cols 9-14 is given. |
| N | | Generalized frequency statistics, omit if IANAL (B-3) is positive or IGNRL (C-4) does not equal 1. |
| | 1. ISTA(K) - | Cols 2-8, Station number for NSTA (B-10) stations on successive cards in same order as supplied by L cards (L-1). |
| | 2. AVMX(K) - | Cols 9-14, Average mean logarithm for wet season (3 months). |
| | 3. AVMN(K) - | Cols 15-20, Average mean logarithm for dry season (3 months). |
| | 4. SDAV(K) - | Cols 21-26, Average standard deviation for the 12 months. |

* Sets of L and M cards are required for each station from K = 2 to NSTA.

EXHIBIT 7

| CARD | VARIABLE | COMMENTS |
|---|---|---|
| N (Cont'd) | | |
| | 5. MOMX(K) | Calendar number of last month of wet season. |
| | 6. MOMN(K) | Calendar number of last month of dry season. |
| O | | Mean logarithms, omit if IANAL (B-3) is positive or IGNRL (C-4) equals 1. |
| | 1. ISTA(K) | Same as (M-1). |
| | 2. AV(I,K) | Cols 9-14, 15-20, etc., Mean logarithms for successive calendar months. |
| P | | Standard deviations, omit if IANAL (B-3) is positive or IGNRL (C-4) equals 1. |
| | 1. ISTA(K) | Same as (M-1). |
| | 2. SD(I,K) | Cols 9-14, 15-20, etc., Standard deviations for successive calendar months. |
| Q | | Skew coefficients, omit if IANAL (B-3) is positive or IGNRL (C-4) equals 1. |
| | 1. ISTA(K) | Same as (M-1). |
| | 2. SKEW(I,K) | Cols 9-14, 15-20, etc., Skew coefficients for successive calendar months. |
| R | | Flow increments, omit if IANAL (B-3) is positive or IGNRL (C-4) equals 1. |
| | 1. ISTA(K) | Same as (M-1). |
| | 2. DQ(I,K) | Cols 9-14, 15-20, etc., Flow increments for successive calendar months. |

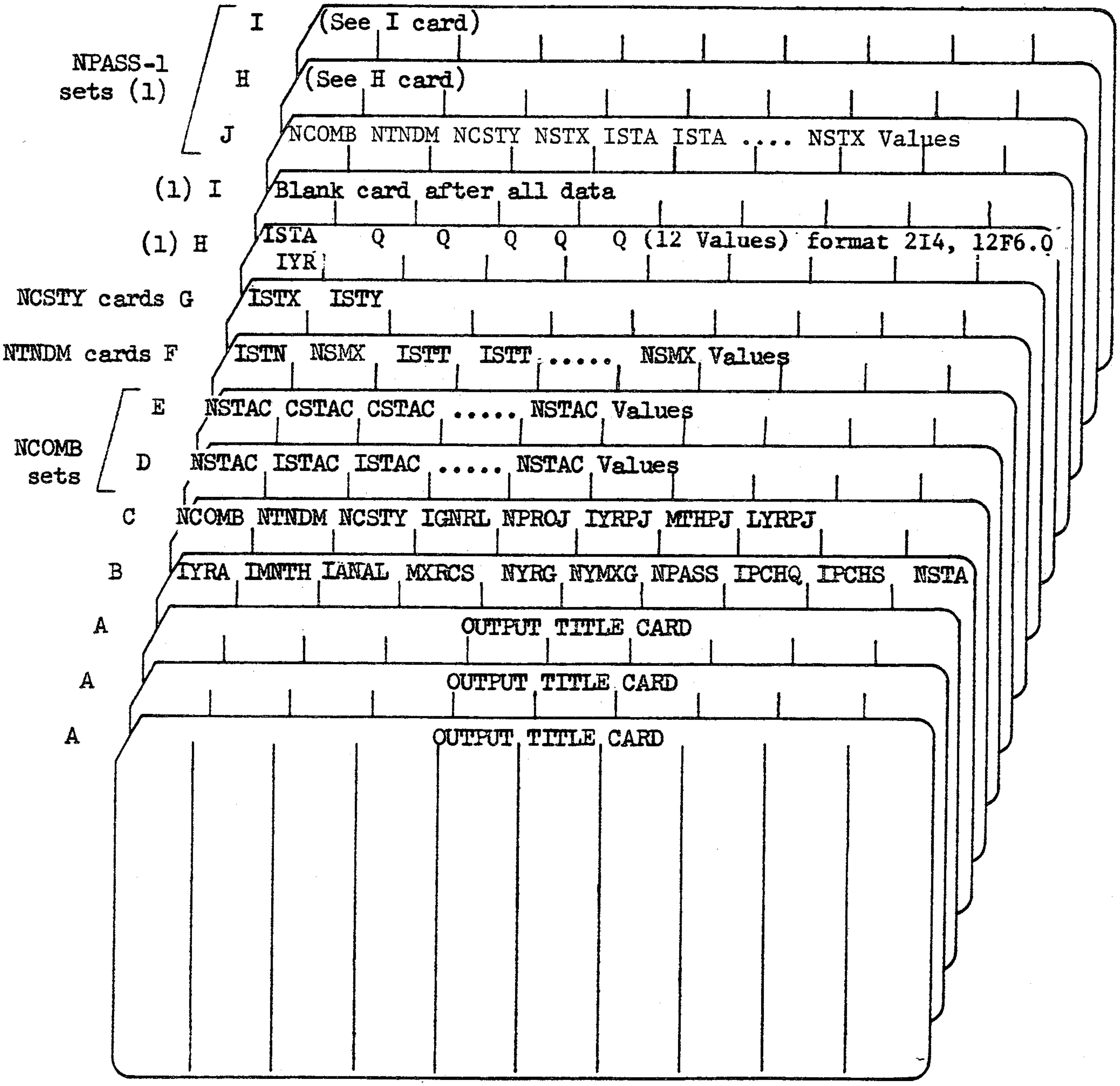
Five blank cards with A in Col 1 of first should follow last job.

Note: Cards K through R are not required if cards H and I are supplied. Cards K through R are as punched by computer when IPCHS is positive.

EXHIBIT 7

EXHIBIT 8

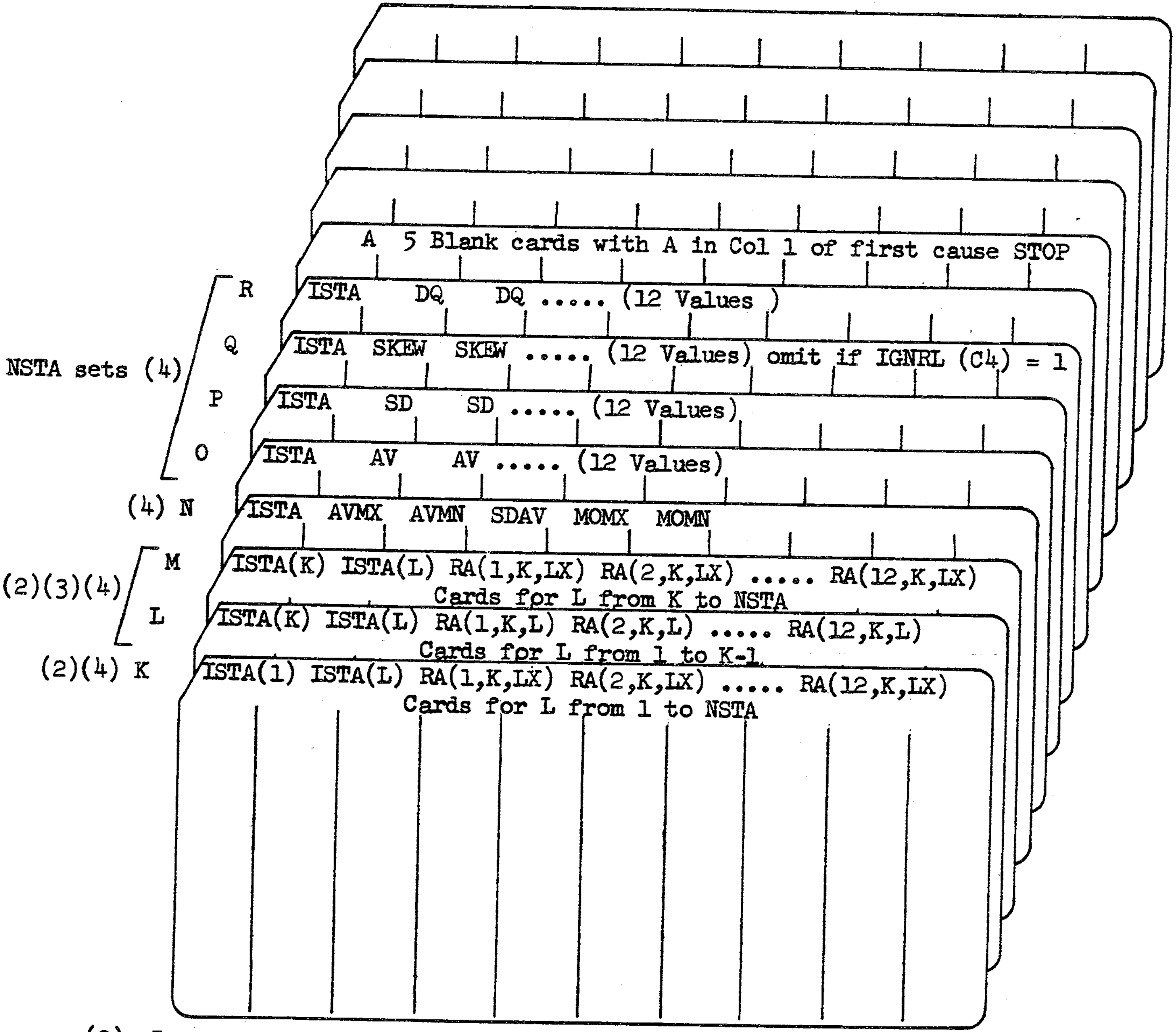
## SUMMARY OF REQUIRED CARDS
723-X6-L2340



Notes:

(1) Supply only if IANAL (B3) is positive. Repeat H card for each station-year of data before supplying I card.

## SUMMARY OF REQUIRED CARDS
Continued
723-X6-L2340



(2) L designates correlation with current month and LX with preceding month. If IGNRL(C4) = 1, only one (generalized) coefficient is given following station numbers on each card and only 1 K and M card is used for each K station, with L = K. Use same format as H card.

(3) Repeat set of L and M cards for each K station except first.

(4) Omit if IANAL (B3) is positive.

EXHIBIT 8

## Appendix 2

# Daily Streamflow Simulation

# DAILY STREAMFLOW SIMULATION

THE HYDROLOGIC ENGINEERING CENTER

COMPUTER PROGRAM 723-G2-L2190

APRIL 1968

Sacramento District, Corps of Engineers
650 Capitol Mall
Sacramento, California

# DAILY STREAMFLOW SIMULATION

## THE HYDROLOGIC ENGINEERING CENTER
## COMPUTER PROGRAM 723-G2-L2190

## CONTENTS

## EXHIBITS

# DAILY STREAMFLOW SIMULATION

## THE HYDROLOGIC ENGINEERING CENTER
## COMPUTER PROGRAM 723-G2-L2190

## 1. ORIGIN OF PROGRAM

This program was prepared in The Hydrologic Engineering Center by R. G. Willey. It was derived from programs 24-J2-L224 and 24-J2-L235, written by William Morse, and supersedes them. Up-to-date information and copies of source statement cards for various types of computers can be obtained from the Center upon request by Government and other cooperating agencies.

## 2. PURPOSE OF PROGRAM

This program analyzes historical daily streamflows at one station to determine their statistical characteristics and generates a sequence of hypothetical daily streamflows. The generated streamflows, which can be of any desired length and will have statistical characteristics similar to the historical daily streamflows, are based on given monthly flows. The sum of each month's generated daily flows is equal to the monthly flow previously generated by another program such as 23-C*-L267.

## 3. DESCRIPTION OF EQUIPMENT

Use of this program requires a computer with a FORTRAN IV compiler and about 20,000 words of storage capacity (in the CDC 6600 computer). Library functions for cosine and natural logarithms are required routines. It is desirable, but not necessary, to use two input tapes and one output tape.

## 4. METHODS OF COMPUTATION

a. The daily streamflow simulator is based on a second-order Markov chain and therefore requires computation of serial correlation among flows for 3 successive days and of the frequency statistics. All of these vary seasonally and they are therefore computed separately for each calendar month.

b. The frequency function used is the log-normal, defined by the mean and standard deviation of daily-flow logarithms.

In order to avoid large negative logarithms, a small increment is added to each daily flow before the logarithm transform is applied. The increment is later subtracted from the generated flows. The mean and standard deviation of the logarithm of incremented daily flows for each calendar month are computed as follows:

$$X_{i,m} = \log (Q_{i,m} + q) \tag{1}$$

$$\bar{X}_m = \sum_{i=1}^{N_m} X_{i,m}/N_m \tag{2}$$

$$S_{m,j} = \left[ \frac{\sum_{i=1}^{N_m} X_{i,m}^2 - (\sum_{i=1}^{N_m} X_{i,m})^2/N_m}{N_m - 1} \right]^{\frac{1}{2}} \tag{3}$$

in which:

$X_{i,m}$ = Logarithm of incremented flow for day i of month m
$Q_{i,m}$ = Recorded flow for day i of month m
$q$ = Small increment of flow used to prevent large negative logarithms
$\bar{X}_m$ = Mean daily flow logarithm for month m
$N_m$ = Total number of days in month m
$S_{m,j}$ = Unbiased estimate of population standard deviation for month m of year j
$i$ = Day number
$m$ = Calendar month number
$j$ = Year number

c. It was found that for the same calendar month the standard deviation of daily flow logarithms is greater in wet months than in dry months. This important variation is accounted for by using a regression equation of the standard deviation of a month's daily flows as a function of the total monthly flow computed as follows:

$$S_m = a + b X_{m,j} \tag{3a}$$

where:

$a$ = regression constant
$b$ = regression coefficient
$X_{m,j}$ = logarithm of incremented monthly flow

d. The serial correlation coefficients for a one-day and a two-day lag for each calendar month are calculated by the use of the following equations:

$$R_{1.2,m} = \left\{ \frac{\sum_{i=1}^{N_m} (X_{i,m} X_{i-1,m}) - \sum_{i=1}^{N_m} X_{i,m} \sum_{i=1}^{N_m} X_{i-1,m} / N_m}{\left[ \sum_{i=1}^{N_m} (X_{i,m})^2 - \left( \sum_{i=1}^{N_m} X_{i,m} \right)^2 / N_m \right] \cdot \left[ \sum_{i=1}^{N_m} (X_{i-1,m})^2 - \left( \sum_{i=1}^{N_m} X_{i-1,m} \right)^2 / N_m \right]} \right\}^{\frac{1}{2}} \qquad (4)$$

$$R_{1.3,m} = \left\{ \frac{\sum_{i=1}^{N_m} (X_{i,m} X_{i-2,m}) - \sum_{i=1}^{N_m} X_{i,m} \sum_{i=1}^{N_m} X_{i-2,m} / N_m}{\left[ \sum_{i=1}^{N_m} (X_{i,m})^2 - \left( \sum_{i=1}^{N_m} X_{i,m} \right)^2 / N_m \right] \cdot \left[ \sum_{i=1}^{N_m} (X_{i-2,m})^2 - \left( \sum_{i=1}^{N_m} X_{i-2,m} \right)^2 / N_m \right]} \right\}^{\frac{1}{2}} \qquad (5)$$

$R_{1.2,m}$ = Serial correlation coefficient for one-day lag in month m
$R_{1.3,m}$ = Serial correlation coefficient for two-day lag in month m
$X_{i,m}$ = Logarithm of incremented daily flow for day i in month m
$N_m$ = Total number of days in month m
$m$ = Month number

e. In order to stabilize the erratic variation of certain statistics from month to month, their computed values are smoothed by averaging the computed value with the average of the corresponding computed values for the preceding and following months. These consist of the serial correlation coefficients and the regression coefficient and constant that relate the standard deviation to monthly flow.

f. Calculation of the multiple linear regression equation for generating daily streamflows for each calendar month requires three simple correlation coefficients. These constitute a "triad" of coefficients: $R_{1.2}$, $R_{2.3}$ and $R_{1.3}$, where subscripts refer to successive day numbers. It will be recognized that the first two are identical, inasmuch as they represent correlation between adjacent days in the same month. Since they are offset one day, however, there will be a slight difference in calculated values due to sampling error. When they are equated in this model, it is possible that the triad will inadvertently be made inconsistent. When this occurs, the value of $R_{1.3}$ is changed slightly to assure consistency, since it is by far the less reliable and influential statistic.

g. The beta coefficients for each month for the 1-day and 2-day lag are calculated using the following equations:

$$\beta_{1.2,m} = (R_{1.2,m} - R_{1.3,m} \cdot R_{1.2,m})/(1 - R_{1.2,m} \cdot R_{1.2,m}) \tag{6}$$

$$\beta_{1.3,m} = (R_{1.3,m} - R_{1.2,m} \cdot R_{1.2,m})/(1 - R_{1.2m} \cdot R_{1.2,m}) \tag{7}$$

h. The adjusted multiple determination coefficient of the lagged daily flows for each month is calculated using the following equation:

$$\begin{aligned} \bar{R}^2_{1.23,m} = {} & (R_{1.2,m} \cdot R_{1.2,m} + R_{1.3,m} \cdot R_{1.3,m} - \\ & 2\,R_{1.2,m} \cdot R_{1.2,m} \cdot R_{1.3,m})/(1-R_{1.2,m} \cdot R_{1.2,m}) \end{aligned} \tag{8}$$

**i.** To insure a random start, daily flow logarithms for one month (month m-1) are generated (based on arbitrary initial deviates) and discarded except for the last two daily flow values (defined as $X_{i-1,m}$ and $X_{i-2,m}$). These two daily flow values from the preceding month are transformed to normal standard deviates based on the current month's mean and standard deviation as shown by the following equations:

$$D_{i-1,m} = (X_{i-1,m} - \bar{X}_m)/S_m \tag{9}$$

$$D_{i-2,m} = (X_{i-2,m} - \bar{X}_m)/S_m \tag{10}$$

where:

$D_{i-1,m}$ = Daily flow logarithm for the first antecedent day, expressed as a normal standard deviate

$D_{i-2,m}$ = Daily flow logarithm for the second antecedent day, expressed as a normal standard deviate

The above calculation occurs every month between the last two daily flow values in the preceding month and the two starting deviates in the current month. Flow values for a full month can now be generated using the following equations:

$$D_{i,m} = \beta_{1.2,m} \cdot D_{i-1,m} + \beta_{1.3,m} \cdot D_{i-2,m} + (1-\bar{R}^2)^{.5} \cdot RN_{i,m} \qquad (11)$$

$$X_{i,m} = \bar{X}_m + S_m \cdot D_{i,m} \qquad (12)$$

$$Q_{i,m} = (\text{antilog } X_{i,m}) - q_m \text{ (negative values are set to zero} \qquad (13)$$

in which:

$D_{i,m}$ = Daily flow logarithm in current month, expressed as a normal standard deviate

$\beta$ = Beta coefficient

$RN_{i,m}$ = Random number normally distributed with zero mean and unit standard deviation

$X_{i,m}$ = Daily flow logarithm

$\bar{X}_m$ = Mean daily flow logarithm

$S_m$ = Standard deviation for current month calculated from the regression equation

$Q_{i,m}$ = Daily flow

$q_m$ = Small incremental flow for current month

$m$ = Month number

$i$ = Day number

j. After flows for an entire month are computed, their sum is tested against the given monthly flow, and they are then adjusted to equal the given value. In order to minimize discontinuities at the end of each month, a second pass generation is accomplished by using the identical random numbers of the first pass generation but with the adjusted monthly mean. Since the sum of the second pass will not exactly equal the given monthly flow, the generated flows are multiplied by a constant (very close to 1.0) to obtain the exact sum.

## 5. INPUT

Input is summarized in Exhibits 5 and 6. An example of the input is given in Exhibit 1. Column 1 on all cards is reserved for identification and is not read by the program. All data (except as noted) are punched using 8 columns per variable (except the first field which is 7 columns) and right justified.

## 6. OUTPUT

Printed output includes the three input title cards and all results of the computations. Generated flows can be written on magnetic tape or punched on card output. An example of the printed output is given in Exhibit 2.

## 7. OPERATING INSTRUCTIONS

Standard FORTRAN IV coding is used. Library functions for cosine and natural logarithms are required routines. No sense switches are used.

## 8. DEFINITIONS OF TERMS

Terms used in this program are defined in Exhibit 3.

## 9. PROPOSED FUTURE DEVELOPMENT

a. Although skew coefficients are highly variable, there has been considerable consistency between corresponding values in the two halves of each record. Accordingly, an appropriate technique should be developed to account for the coefficient of skew within the model.

b. The model must eventually be expanded to generate flows for more than one station simultaneously. This is complicated considerably by the fact that the relative timing of flows in different parts of a drainage system must be recognized.

INPUT EXAMPLE

```
A      KENTUCKY RIVER
A     AT WINCHESTER, KY
ADAILY STREAMFLOW SIMULATION
B    840       5       5      10       1       0       0       0
C   55.5      48      49       0       0       1       0
D                                                 50.0    50.0
E   1908      10    50.0    50.0    50.0    50.0    50.0    80.0    50.0    50.0
E                   50.0    80.0    80.0    80.0    80.0   150.0    80.0   150.0
E                   80.0    80.0    80.0    50.0   220.0   150.0   150.0    80.0
E                   80.0    80.0    50.0    50.0   150.0   220.0   220.0   2920.
E   1908      11   220.0   370.0   370.0   150.0   220.0   220.0   150.0    80.0
E                   80.0   150.0   220.0   220.0   940.0  1460.0  1060.0  1060.0
E                  830.0   630.0   370.0   450.0   540.0   450.0   370.0   450.0
E                  370.0   450.0   370.0   370.0   370.0   450.0           13440.
E   1908      12   450.0   450.0   540.0   540.0   540.0   540.0   450.0   540.0
E   THERE WILL BE 4 CARDS PER MONTH, 12 MONTHS PER YEAR,
E           AND NYANL NUMBER OF YEARS
F8401908 12823  4983 98357533377209898 43511 91119285968 79395149446 15231 32923
F8401909 584171225833231474532352234342184061713152988021012l9 31258  4647  1714
F   THERE WILL BE NYSYN NUMBER OF F CARDS
    EITHER THE NEXT JOB FOLLOWS WITH ITS TITLE CARDS OR ELSE 4 BLANK
            CARDS TO END THE JOB
```

EXHIBIT 1

# OUTPUT EXAMPLE

```
                              KENTUCKY RIVER
                            AT WINCHESTER, KY
                        DAILY STREAMFLOW SIMULATION



    ANALYSIS OF STREAMFLOW DATA



    ENTIRE RECORD    48YEARS AT STATION NO.            840

       MONTH          MEAN           SD            G            R12          R13
        10           2.582          .490        1.029          .951         .876
        11           2.930          .573         .687          .943         .853
        12           3.351          .578         .072          .953         .864
         1           3.718          .530        -.202          .939         .822
         2           3.789          .481        -.313          .948         .847
         3           3.909          .391         .198          .915         .756
         4           3.735          .366         .417          .930         .792
         5           3.478          .450         .090          .944         .846
         6           3.145          .499         .508          .939         .842
         7           3.020          .537         .503          .938         .848
         8           2.856          .493         .554          .935         .853
         9           2.652          .459         .715          .936         .850

                    SIMPLE REGRESSION EQUATION
              STANDARD DEVIATION VERSUS LOG MONTHLY FLOW

       MONTH      CONSTANT   COEFFICIENT  DET. COEF.
        10          -.901        .280        .634
        11          -.736        .233        .564
        12          -.416        .156        .401
         1          -.001        .069        .021
         2          -.066        .076        .014
         3          -.285        .109        .072
         4          -.915        .226        .363
         5          -.058        .076        .046
         6          -.468        .165        .450
         7          -.545        .189        .614
         8          -.507        .179        .551
         9          -.721        .234        .628
```

EXHIBIT 2

```
GENERATION OF STREAMFLOW DATA


ENTIRE RECORD     49 YEARS AT STATION NO.          840

   MONTH         MEAN          SD           G          R12        R13
    10          2.715        .522         .343        .978       .944
    11          2.966        .555         .231        .981       .950
    12          3.400        .541        -.081        .974       .929
     1          3.803        .452        -.217        .958       .875
     2          3.882        .409        -.278        .952       .856
     3          3.930        .421        -.103        .952       .859
     4          3.727        .365        -.054        .946       .845
     5          3.562        .412         .018        .959       .881
     6          3.161        .548        -.117        .977       .938
     7          3.103        .546        -.037        .975       .940
     8          2.858        .492         .261        .972       .935
     9          2.680        .469         .494        .975       .941

        SIMPLE REGRESSION EQUATION
STANDARD DEVIATION VERSUS LOG MONTHLY FLOW

   MONTH      CONSTANT   COEFFICIENT   DET. COEF.
    10         -.332        .136          .306
    11         -.350        .136          .307
    12         -.042        .072          .068
     1         -.174        .092          .077
     2          .409       0.            -.009
     3         -.334        .117          .061
     4         -.191        .090          .028
     5         -.166        .087          .064
     6          .548       0.            -.011
     7         -.010        .062          .064
     8          .492       0.            -.017
     9         -.529        .182          .385
```

EXHIBIT 2

# EXHIBIT 3

## DEFINITIONS - 723-G2-L2190

A - Variable used for input and output of title cards
ASD(MO,J) - Standard deviation as calculated by the regression equation
B(MO,J) - Regression coefficient for ASD = C+B•QM
BO(MO) - Alienation coefficient of lagged daily flow
B1(MO) - Beta coefficient for 2-day lagged flow
B2(MO) - Beta coefficient for 1-day lagged flow
C(MO,J) - Regression constant for ASD = C+B•QM
CONST - The value to multiply times the monthly flows to convert them to day-second-feet
D(ND) - Normal standard deviate
DELIK - Monthly total of the logarithms of flow for day i times day i + 2
DELK - Monthly total of the logarithms of flow for day i + 1
DELKK - Monthly total of the logarithms of flow for day i + 1 times day i + 1
DELL - Monthly total of the logarithms of flow for day i + 2
DELLL - Monthly total of the logarithms of flow for day i + 2 times day i + 2
DELQ - Monthly total of the logarithms of flow for day i
DELQ2 - Monthly total of the logarithms of flow for day i squared
DELQ3 - Monthly total of the logarithms of flow for day i cubed
DELTA - Incremental daily flow to prevent large negative logarithms
E - Temporary variable for an intermediate calculation
G(MO,J) - Coefficient of skew
I - Miscellaneous subscript
ICOUNT - Counter for the number of leap years in record
II - Subscript for number of sets of records which increments from 1 to NPASS
IFILE - Dummy variable
IMO - Month read from tape or cards
IRCD - Dummy variable for both ISKIP and ISKP
ISKIP - Number of records to waste before starting to read daily flows from tape
ISKP - Number of records to waste before starting to read monthly flows from tape
ISMDO - Indicator to select option of smoothing statistics
ISTA - Station number at which flows are to be generated
ISTART - Indicator to select option of estimating first 2 days of daily record
ITAPE - Input tape number which contains historical daily flows
ITEST - Indicator to select option of testing martix consistency
J - Miscellaneous subscript
JCOUNT - Counter for the number of leap years in the entire record
JJ - Indicator to determine which pass of the generator is to be used next

JTAPE - Input tape number which contains monthly flows
KD(MO) - Number of days plus two in month MO
KTAPE - Output tape number which will contain the synthetic daily flows
L - Miscellaneous subscript
M(MO) - Actual calendar month numbers (10=Oct, 11=Nov, 12=Dec, etc.)
MO - Month number (1=Oct, 2=Nov, 3=Dec, etc.)
MO1 - Month number plus one
MSTAT - Indicator to select option of monthly statistics
M1 - Indicator for determining which section of the subroutine STAT is to be used next
N - Subscript for number of years which increments from 1 to NYR
ND - Temporary location for number of days in month plus 2
NN - Number of days in entire record
NPASS - Subscript for number of sets of records desired
NT - Total number of years in entire record
NTOT - Number of days in entire record
NYANL - Number of years of record for analysis
NYR - Subscript for maximum number of years in a half record
NYSYN - Number of years desired for synthesis
Q(ND) - Daily flow
Q(32) - Total monthly flow for analysis
QD - Mean monthly flow for simulation
QDLOG(MO) - Logarithm of mean monthly flow for simulation
QLOD(ND) - Logarithm of daily flow
QLOG(34) - Logarithm of total monthly flow for analysis
QM(MO,N) - Total monthly flow for simulation
RATIO - Total monthly flow for simulation divided by total of daily simulated flows
RN(ND) - Random numbers with zero mean and unit standard deviation
R12(MO,J) - Serial correlation coefficient for 1-day lag flow
R13(MO,J) - Serial correlation coefficient for 2-day lag flow
R2(MO,J) - Determination coefficient for regression equation of ASD=C+B•QM
SD(MO,J) - Standard deviation of logarithm of daily flows (actual and simulated)
T - Temporary variable
TM(MO,J) - Total of logarithms of total monthly flow (actual and simulated)
TMPIK(MO,J) - Temporary location for TQIK
TMPIL(MO,J) - Temporary location for TQIL
TMPK(MO,J) - Temporary location for TQK
TMPKK(MO,J) - Temporary location for TQKK
TMPL(MO,J) - Temporary location for TQL
TMPLL(MO,J) - Temporary location for TQLL
TMPQ(MO,J) - Temporary location for TQ
TMPQ2(MO,J) - Temporary location for TQ2
TMPQ3(MO,J) - Temporary location for TQ3
TMS(MO,J) - Total of logarithms of total monthly flow times standard deviation
TM2(MO,J) - Total of logarithms of total monthly flow squared

EXHIBIT 3

TOT(MO,J) - Total of logarithms of generated daily flows
TQ(MO,J) - Total of logarithms of flow for day i
TQIK(MO,J) - Total of logarithms of flow for day i times day i + 1
TQIL(MO,J) - Total of logarithms of flow for day i times day i + 2
TQK(MO,J) - Total of logarithms of flow for day i + 1
TQKK(MO,J) - Total of logarithms of flow for day i + 1 squared
TQL(MO,J) - Total of logarithms of flow for day i + 2
TQLL(MO,J) - Total of logarithms of flow for day i + 2 squared
TQ2(MO,J) - Total of logarithms of flow for day i squared
TQ3(MO,J) - Total of logarithms of flow for day i cubed
TS(MO,J) - Total of standard deviations
TS2(MO,J) - Total of standard deviations squared
U1 - Temporary location for random number
U2 - Temporary location for random number
V(I) - Temporary location for logarithms of flow for last 2 days in previous month
VAR - Dummy variable name
W - Temporary variable
X - Temporary variable
XBAR(MO,J) - Mean of logarithms of daily flow
XD - Number of days in month
XN - Number of years in record
XTOT - Number of days in record
X1 - Temporary variable
X2 - Temporary variable
Y - Temporary variable
Z - Temporary variable

EXHIBIT 3

# LISTING OF SOURCE PROGRAM

```
C     HYDROLOGIC ENGINEERING CENTER PROGRAM NO. 723-G2-L2190            1001
C     DAILY STREAMFLOW SIMULATOR                                        1002
C     DECEMBER 1967                                                     1003
C     FORTRAN IV                                                        1004
C     ****MAIN CALLING PROGRAM****                                      1005
      DIMENSION EOFX(20)
      COMMON A(13,3),ASD(12,2),B(13,2),B0(12),B1(12),B2(12),C(13,2),    1006
     1   CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2   DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2   JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3   NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4   RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),          1011
     5   TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),                1012
     6   TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),                 1013
     7   TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),           1014
     8   TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),          1015
     9   TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)         1016
  140 WRITE (6,100)
  100 FORMAT (1H1)                                                      1019
C     INPUT AND OUTPUT OF TITLE CARDS                                   1020
      READ (5, 110)((A(I,J),I=1,13),J=1,3)                              1021
  110 FORMAT (1X,13A6)                                                  1022
      WRITE (6,120)((A(I,J),I=1,13),J=1,3)                              1023
  120 FORMAT (20X,13A6)
C     READ INPUT-OUTPUT CONTROL CARD                                    1025
C     ISTA =STATION NUMBER
C     ITAPE=TAPE NUMBER CONTAINING HISTORIC DAILY FLOWS, USE 5 FOR CARDS
C     JTAPE=TAPE NUMBER CONTAINING SYNTHETIC MONTHLY FLOWS, 5 FOR CARDS
C     KTAPE=TAPE NUMBER TO BE USED FOR OUTPUT OF SYNTHETIC DAILY FLOWS,
C              USE 5 FOR CARD OUTPUT
C     CONST= 1.      IF SYNTHETIC MONTHLY FLOWS ARE IN CFS-DAYS
C          = 1000.   IF SYNTHETIC MONTHLY FLOWS ARE IN THOUSAND CFS-DAYS
C          =-1.      IF SYNTHETIC MONTHLY FLOWS ARE IN CFS
C          =.504167 IF SYNTHETIC MONTHLY FLOWS ARE IN ACRE-FEET
C          =504.167 IF SYNTHETIC MONTHLY FLOWS ARE IN THOUSAND ACRE-FEET
C          =26.9*DA IF SYNTHETIC MONTHLY FLOWS ARE IN INCHES
C     MSTAT= 1 IF MONTHLY STATISTICS ARE DESIRED
C     ISMOO= 1 IF SMOOTHING OF STATISTICS IS NOT DESIRED
C     ITEST= 1 IF CONSISTENCY TEST OF THE CORRELATION COEFFICIENTS IS
C              NOT DESIRED
      READ (5,130) ISTA,ITAPE,JTAPE,KTAPE,CONST,MSTAT,ISMOO,ITEST
```

EXHIBIT 4

```
130 FORMAT (1X,I7,3I8,F8.0,3I8)
    IF (ITAPE.LE.0) STOP
    CALL ANAL                                                            1035
    CALL GEN                                                             1036
    IF (ITAPE.LE.0) GO TO 141
    IF(JTAPE.EQ.5) GO TO 140
    READ (JTAPE,131) EOFX
131 FORMAT (20A4)
    IF (EOF,JTAPE) 140,132
132 WRITE (6,133)
133 FORMAT (70H AN EOF SHOULD HAVE BEEN READ FROM THE TAPE OF GENERATE
   1D MONTHLY FLOWS**)
    STOP
141 WRITE (6,150)
150 FORMAT(1H1)                                                          1039
    ENDFILE KTAPE
    REWIND KTAPE
    STOP                                                                 1042
    END                                                                  1043
```

```
      SUBROUTINE ANAL                                                   1001
      DIMENSION M(12)                                                   1002
      COMMON A(13,3),ASD(12,2),B(13,2),B0(12),B1(12),B2(12),C(13,2),    1003
     1   CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2   DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2   JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3   NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4   RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),          1008
     5   TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),                1009
     6   TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),                 1010
     7   TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),           1011
     8   TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),          1012
     9   TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)         1013
      COMMON/DAYS/KD(12)                                                1014
      DATA (KD(I),I=1,12)/33,32,33,33,30,33,32,33,32,33,33,32/          1015
      DATA (M(MO),MO=1,12)/10,11,12,1,2,3,4,5,6,7,8,9/                  1016
C     READS STATION DATA CARD                                           1021
C     DELTA=INCREMENT TO BE ADDED TO FLOWS                              1022
C     NYANL=NUMBER OF YEARS OF DAILY FLOW INPUT
C     NYSYN=NUMBER OF YEARS OF MONTHLY FLOW INPUT
C     ISKIP=NUMBER OF RECORDS TO WASTE BEFORE READING DAILY FLOW TAPE
C     ISTART=0 FOR READING IN FIRST TWO DAYS OF RECORD, 1 FOR ESTIMATING 1017
C     NPASS=NUMBER OF PERIODS OF GENERATED DATA REQUIRED
C     ISKP =NUMBER OF RECORDS TO WASTE BEFORE READING MONTHLY FLOW TAPE
C     NYR3 =NUMBER OF YEARS OF DAILY FLOW INPUT IN SECOND HALF OF RECORD
C     NYR4 =NUMBER OF YEARS OF MONTH.FLOW INPUT IN SECOND HALF OF RECORD
      READ (5,210) DELTA,NYANL,NYSYN,ISKIP,ISTART,NPASS,ISKP,NYR3,NYR4
  210 FORMAT (1X,F7.0,9I8)                                              1027
      NYR=NYANL
C     INITIALIZE ALL BLOCKS USED FOR SUMMING                            1029
      DO 220 MO=1,12                                                    1030
      DO 220 J=1,2                                                      1031
      TQ  (MO,J)=0.                                                     1032
      TQ2 (MO,J)=0.                                                     1033
      TQ3 (MO,J)=0.                                                     1034
      TM  (MO,J)=0.                                                     1035
      TM2 (MO,J)=0.                                                     1036
      TS  (MO,J)=0.                                                     1037
      TS2 (MO,J)=0.                                                     1038
      TMS (MO,J)=0.                                                     1039
      TQIK(MO,J)=0.                                                     1040
```

EXHIBIT 4

```
      TQIL(MO,J)=0.                                                     1041
      TQKK(MO,J)=0.                                                     1042
      TQLL(MO,J)=0.                                                     1043
      TQK(MO,J)=0.                                                      1044
      TQL(MO,J)=0.                                                      1045
      TMPK(MO,J)=0.                                                     1046
      TMPL(MO,J)=0.                                                     1047
      TMPQ (MO,J)=0.                                                    1048
      TMPQ2(MO,J)=0.                                                    1049
      TMPQ3(MO,J)=0.                                                    1050
      TMPIK(MO,J)=0.                                                    1051
      TMPIL(MO,J)=0.                                                    1052
      TMPKK(MO,J)=0.                                                    1053
      TMPLL(MO,J)=0.                                                    1054
  220 CONTINUE                                                          1055
      J=0                                                               1056
      JCOUNT = 0                                                        1057
      WRITE(6,450)                                                      1058
      WRITE (6,450)
  240 WRITE (6,250)                                                     1062
  250 FORMAT (28H0ANALYSIS OF STREAMFLOW DATA)                          1063
      WRITE (6,450)                                                     1064
  260 J=J+1                                                             1065
      ICOUNT = 0                                                        1066
      IF (NYR3.LE.0) GO TO 271
      WRITE (6,270) J,NYR,ISTA
  270 FORMAT(1H ,I2,11HHALF-RECORD,I6,20HYEARS AT STATION NO.,I12)
  271 DO 520 N=1,NYR
      IF (MSTAT.EQ.1) WRITE (6,280)
  280 FORMAT(1H0,3X,5HMONTH,7X,4HMEAN,9X,2HSD,11X,1HG,10X,3HR12         1072
     1,9X,3HR13)                                                        1073
      DO 510 MO=1,12                                                    1074
      M1=0                                                              1075
  340 IF (N.NE.1.OR.MO.NE.1.OR.J.NE.1)      GO TO 370                   1088
      CALL SKPFILE (ITAPE,0,ISKIP)
      IF (ISTART.NE.0) GO TO 370
  350 READ (ITAPE,360) Q(1),Q(2)
  360 FORMAT (48X,2F8.2)
      QLOG  (1)=ALOG(Q  (1)+DELTA)*.434295                              1093
      QLOG  (2)=ALOG(Q  (2)+DELTA)*.434295                              1094
  370 READ (ITAPE,380)      IYR,IMO,   (Q(I),I=3,34)
```

```
380 FORMAT (1X,I7,I8,8F8.2/3(16X,8F8.2))
    IF (N.NE.1.OR.MO.NE.1.OR.ISTART.NE.1) GO TO 410
    QLOG(1)=ALOG(Q(3)+DELTA)*.434295                                     1100
    QLOG(2)=QLOG(1)                                                      1101
410 ND=KD(MO)                                                            1104
    IF (IYR/4*4.EQ.IYR.AND.MO.EQ.5.AND.IYR.NE.1900) GO TO 420            1105
    GO TO 430                                                            1106
420 ND=31                                                                1107
    ICOUNT = ICOUNT + 1                                                  1108
    JCOUNT = JCOUNT + 1                                                  1109
430 DO 440 I=3,ND                                                        1110
    QLOG   (I) =ALOG (Q   (I)+DELTA)*.434295                             1111
440 CONTINUE                                                             1112
    XD=ND-2
    QLOG(34) =ALOG(Q(34)+XD*DELTA)*.434295                               1113
    CALL STAT                                                            1114
    IF (MSTAT.NE.1) GO TO 480
460 WRITE(6,470) M(MO),XBAR(MO,J),SD(MO,J),G(MO,J),R12(MO,J),R13(MO,J) 1117
470 FORMAT (I8,5F12.3)                                                   1119
480 CALL REGRES                                                          1120
490 IF (N.NE.NYR) GO TO 500                                              1121
    M1=1                                                                 1122
    IF (MO.EQ.5) ND=30                                                   1123
    CALL STAT                                                            1124
500 QLOG(1)=QLOG(ND-1)                                                   1125
    QLOG(2)=QLOG(ND)                                                     1126
510 CONTINUE                                                             1127
520 CONTINUE                                                             1128
    IF (NYR3.LE.0) GO TO 590
    WRITE(6,450)                                                         1129
450 FORMAT (1H0)                                                         1115
    WRITE (6,530) NYR,ISTA
530 FORMAT (I6,20HYEARS AT STATION NO.,I12)
    WRITE (6,280)                                                        1132
    WRITE (6,470) (M(MO),XBAR(MO,J),SD(MO,J),G(MO,J),                    1133
   1R12(MO,J),R13(MO,J),MO=1,12)                                         1134
540 WRITE (6,550)                                                        1135
550 FORMAT(1X/15X,26HSIMPLE REGRESSION EQUATION/6X,43H STANDARD DEVIAT 1136
   1ION VERSUS LOG MONTHLY FLOW/1H0,3X,5HMONTH,5X,8HCONSTANT,2X,11HCOE 1137
   1FFICIENT,2X,10HDET. COEF.)                                           1138
    WRITE (6,560) (M(MO),C(MO,J),B(MO,J),R2(MO,J),MO=1,12)               1139
```

EXHIBIT 4

```
560 FORMAT (I8,3F12.3)
570 NYR=NYR3
580 GO TO (260,590),J
590 J=1
    NYR1=NYANL
    NYR2=NYR3
    CALL ENTIRE
    WRITE(6,450)
    NT =NYANL+NYR3
    WRITE (6,600) NT,ISTA
600 FORMAT (14H ENTIRE RECORD,I6,20HYEARS AT STATION NO.,I12)
    WRITE (6,280)
    WRITE (6,470) (M(MO),XBAR(MO,J),SD(MO,J),G(MO,J),
   1R12(MO,J),R13(MO,J),MO=1,12)
610 WRITE (6,550)
    WRITE (6,560) (M(MO),C(MO,J),B(MO,J),R2(MO,J),MO=1,12)
620 RETURN
    END
```

```
      SUBROUTINE GEN                                                    1001
      DIMENSION M(12)                                                   1002
      COMMON A(13,3),ASD(12,2),B(13,2),B0(12),B1(12),B2(12),C(13,2),    1003
     1    CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2    DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2    JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3    NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4    RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),         1008
     5    TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),               1009
     6    TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),                1010
     7    TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),          1011
     8    TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),         1012
     9    TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)        1013
      COMMON /START/JJJ,IX
      COMMON/DAYS/KD(12)                                                1015
C     DATA HAS NUMBER OF DAYS IN EACH MONTH                             1016
      DATA (KD(I),I=1,12)/33,32,33,33,30,33,32,33,32,33,33,32/          1017
      DATA (M(MO),MO=1,12)/10,11,12,1,2,3,4,5,6,7,8,9/                  1018
      WRITE (6,700)                                                     1020
  700 FORMAT (1H1)                                                      1021
      WRITE (6,710)                                                     1022
  710 FORMAT (30HOGENERATION OF STREAMFLOW DATA)                        1023
      IX=0
C     NOW SMOOTHING ALL STATISTICS                                      1024
      IF (ISMOO.EQ.1) GO TO 740
  720 TEMPR1=R12 (12,1)                                                 1026
      TEMPR2=R13 (12,1)                                                 1027
      TEMPC =C   (12,1)                                                 1028
      TEMPB =B   (12,1)                                                 1029
      R12 (13,1)=R12 (1,1)                                              1030
      R13 (13,1)=R13 (1,1)                                              1031
      C   (13,1)=C   (1,1)                                              1032
      B   (13,1)=B   (1,1)                                              1033
      DO 730 MO=1,12                                                    1034
      T=TEMPR1                                                          1035
      W=TEMPR2                                                          1036
      X=TEMPC                                                           1037
      Y=TEMPB                                                           1038
      TEMPR1=R12 (MO,1)                                                 1039
      TEMPR2=R13 (MO,1)                                                 1040
      TEMPC =C   (MO,1)                                                 1041
```

EXHIBIT 4

```
      TEMPB =B   (MO,1)
      MO1=MO+1
      R13(MO,1)=.5*R13(MO,1)+.25*(W+R13(MO1,1))
      R12(MO,1)=.5*R12(MO,1)+.25*(T+R12(MO1,1))
      B(MO,1)=.5*B(MO,1)+.25*(Y+B(MO1,1))
      C(MO,1)=.5*C(MO,1)+.25*(X+C(MO1,1))
  730 CONTINUE
C
C     NOW TESTING THE CONSISTENCY OF THE CORRELATION COEFFICIENT MATRIX
C
  740 IF (ITEST.EQ.1) GO TO 890
  750 DO 880 MO=1,12
      AC=1.-R12(MO,1)*R12(MO,1)
      XA=R12(MO,1)*R12(MO,1)+AC
      XS=R12(MO,1)*R12(MO,1)-AC
      IF (R13(MO,1).LT.XA) GO TO 760
      WRITE (6,770) ISTA,M(MO),R13(MO,1),XA
  770 FORMAT (12H STATION NO.,I12,5HMONTH,I2,4HR13=,F7.3,3HXA=,F7.3,
     1   37HR13 FAILED CONSISTENCY TEST, TOO HIGH)
      R13(MO,1)=XA
      GO TO 880
  760 IF (R13(MO,1).GT.XS) GO TO 880
      WRITE (6,810) ISTA,M(MO),R13(MO,1),XS
  810 FORMAT (12H STATION NO.,I12,5HMONTH,I2,4HR13=,F7.3,3HXS=,F7.3,
     1   36HR13 FAILED CONSISTENCY TEST, TOO LOW)
      R13(MO,1)=XS
  880 CONTINUE
  890 DO 900 MO=1,12
C     NOW CALCULATING THE BETA COEFFICIENTS, THE MULTIPLE DET. COEF.
      E=1.-R12(MO,1)*R12(MO,1)
      B2(MO)=(R12(MO,1)-R13(MO,1)*R12(MO,1))/E
      B1(MO)=(R13(MO,1)-R12(MO,1)*R12(MO,1))/E
      B0(MO)=(R12(MO,1)*R12(MO,1)+R13(MO,1)*R13(MO,1)-2.*R12(MO,1)*R12(M
     1    O,1)*R13(MO,1))/E
      IF (B0(MO).GT.1.) B0(MO)=1.0
      B0(MO)=(1.-B0(MO))**.5
  900 CONTINUE
      JJJ=0
      DO 1190 II=1,NPASS
C     INITIALIZE ALL BLOCKS USED FOR SUMMING
      DO 910 MO=1,12
```

```
      DO 910 J=1,2
      TQ   (MO,J)=0.
      TQK(MO,J)=0.
      TQL(MO,J)=0.
      TQ2 (MO,J)=0.
      TQ3 (MO,J)=0.
      TM   (MO,J)=0.
      TM2 (MO,J)=0.
      TS   (MO,J)=0.
      TS2 (MO,J)=0.
      TMS (MO,J)=0.
      TQIK(MO,J)=0.
      TQIL(MO,J)=0.
      TQKK(MO,J)=0.
      TQLL(MO,J)=0.
      TMPQ  (MO,J)=0.
      TMPK(MO,J)=0.
      TMPL(MO,J)=0.
      TMPQ2(MO,J)=0.
      TMPQ3(MO,J)=0.
      TMPIK(MO,J)=0.
      TMPIL(MO,J)=0.
      TMPKK(MO,J)=0.
      TMPLL(MO,J)=0.
  910 CONTINUE
      J=0
      NYR=NYSYN
      WRITE (6,920)
  920 FORMAT (1H0)
      JCOUNT = 0
      V(1)=0.1
      V(2)=0.1
      DO 930 MO=1,12
      C(MO,2)=C(MO,1)
      B(MO,2)=B(MO,1)
  930 CONTINUE
  940 J=J+1
      ICOUNT = 0
      IF (NYR4.LE.0) GO TO 951
      WRITE (6,950) J,NYR,ISTA
  950 FORMAT (1H ,I2,11HHALF-RECORD,I6,20HYEARS AT STATION NO.,I12)
```

EXHIBIT 4

```
  951 DO 1120 N=1,NYR
      WRITE (10,960) ISTA,N
  960 FORMAT (2I12)
      IF (MSTAT.EQ.1) WRITE (6,970)
  970 FORMAT (1X/4X,5HMONTH,7X,4HMEAN,9X,2HSD,11X,1HG,10X,3HR12
     1,9X,3HR13)
      IF (II.NE.1) GO TO 1000
      IF (N.NE.1.OR.J.NE.1) GO TO 980
      CALL SKPFILE (JTAPE,0,ISKP)
  980 READ (JTAPE,990) (QM(MO,N),MO=1,12)
  990 FORMAT (8X,12F6.0)
 1000 DO 1110 MO=1,12
      M1=0
      ND=KD(MO)
C ****MAKE LEAP YEAR TEST****
      IF(N/4*4.EQ.N.AND.MO.EQ.5)  GO TO 1010
      GO TO 1020
 1010 ND=31
      ICOUNT = ICOUNT + 1
C     NOW CALCULATING THE STANDARD DEVIATION BASED ON THE SMOOTHED REGRE
C         CONSTANT + COEFFICIENT.
 1020 XD=ND-2
      IF (II.NE.1 ) GO TO 1021
      IF (CONST.EQ.-1.) CONST = XD
      QM(MO,N)=QM(MO,N)*CONST
 1021 ASD(MO,1)=C(MO,J)+B(MO,J)*ALOG(QM(MO,N)+XD*DELTA)*.434295
      IF(ASD(MO,1).GE.0.05)GO TO 1040
      WRITE (6,1030) M(MO),ASD(MO,1)
 1030 FORMAT (5H ASD(,I2,4H,1)=,F5.3)
      ASD(MO,1)=.05
 1040 CALL DASIM
      IX3=ND-2
      WRITE (KTAPE,1050) M(MO),IX3,(Q(I),I=3,ND)
 1050 FORMAT (2I5,7F10.1/(8F10.1))
      IF (N.NE.1.OR.MO.NE.1) GO TO 1060
      QLOG(1)=QLOG(3)
      QLOG(2)=QLOG(3)
 1060 CALL STAT
      QLOG(1)=QLOG(ND-1)
      QLOG(2)=QLOG(ND)
      IF (MSTAT.LE.0) GO TO 1090
```

```
1070 WRITE(6,1080)M(MO),XBAR(MO,J),SD(MO,J),G(MO,J),R12(MO,J),R13(MO,J)
1080 FORMAT (I8,5F12.3)
1090 CALL REGRES
1100 IF (N.NE.NYR) GO TO 1110
     M1=1
     CALL STAT
1110 CONTINUE
1120 CONTINUE
     IF (NYR4.LE.0) GO TO 1161
     NYR=NYR4
     WRITE (6,920)
     WRITE (6,1130) NYR,ISTA
1130 FORMAT (I6,20HYEARS AT STATION NO.,I12)
     WRITE (6,970)
     WRITE (6,1080) (M(MO),XBAR(MO,J),SD(MO,J),G(MO,J),
    1R12(MO,J),R13(MO,J),MO=1,12)
     WRITE (6,1140)
1140 FORMAT (1X/9X,26HSIMPLE REGRESSION EQUATION/43H STANDARD DEVIATION
    1 VERSUS LOG MONTHLY FLOW/1H0,3X,5HMONTH,5X,8HCONSTANT,2X,11HCOEFFI
    1CIENT,2X,10HDET. COEF.)
     WRITE (6,1150) (M(MO),C(MO,J),B(MO,J),R2(MO,J),MO=1,12)
1150 FORMAT (I8,3F12.3)
     JCOUNT = JCOUNT + ICOUNT
1160 IF (J.EQ.1) GO TO 940
1161 J=1
     IF (NYR4.LE.0) JCOUNT = ICOUNT
     NYR1=NYSYN
     NYR2=NYR4
1170 CALL ENTIRE
     WRITE (6,920)
     NT =NYSYN+NYR4
     WRITE (6,1180) NT,ISTA
1180 FORMAT (14H ENTIRE RECORD,I6,20HYEARS AT STATION NO.,I12)
     WRITE (6,970)
     WRITE (6,1080) (M(MO),XBAR(MO,J),SD(MO,J),G(MO,J),
    1R12(MO,J),R13(MO,J),MO=1,12)
     WRITE (6,1140)
     WRITE (6,1150) (M(MO),C(MO,J),B(MO,J),R2(MO,J),MO=1,12)
1190 CONTINUE
     RETURN
     END
```

EXHIBIT 4

```
      SUBROUTINE DASIM
      COMMON A(13,3),ASD(12,2),B(13,2),BO(12),B1(12),B2(12),C(13,2),
     1    CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2    DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2    JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3    NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4    RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),
     5    TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),
     6    TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),
     7    TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),
     8    TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),
     9    TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)
      COMMON /START/JJJ,IX
 1200 IF (QM(MO,N).NE.0.) GO TO 1220
      DO 1210 II=3,ND
      Q(II)=0.
 1210 CONTINUE
      RATIO = 1.
      GO TO 1260
 1220 XD=ND-2
      QD=QM(MO,N)/XD
      QDLOG(MO)=ALOG(QD+DELTA)*.434295
      JJ=0
      DO 1230 I=3,ND
      U1=RNGEN(IX)
      U2=RNGEN(IX)
      RN(I)=(-2.*ALOG(U1))**.5*COS(6.2831853*U2)
 1230 CONTINUE
 1240 D(1)=(V(1)-QDLOG(MO))/ASD(MO,1)
      D(2)=(V(2)-QDLOG(MO))/ASD(MO,1)
      JJ=JJ+1
      TOT = 0.
      DO 1250 I=3,ND
      D(I)=B2(MO)*D(I-1)+B1(MO)*D(I-2)+BO(MO)*RN(I)
      QLOG(I)=QDLOG(MO)+ASD(MO,1)*D(I)
      Q(I)=EXP (QLOG(I)*2.302585)-DELTA
      IF (Q(I).LE.0.) Q(I)=0.
      TOT = TOT + Q(I)
 1250 CONTINUE
      IF (TOT.EQ.0.) TOT = 1.E-08
      RATIO=QM(MO,N)/TOT
```

```
      Q(34)=0.
      IF(JJ.NE.1) GO TO 1260
      QDLOG(MO)=QDLOG(MO)+ALOG(RATIO)*.434295
      GO TO 1240
 1260 DO 1270 I=3,ND
      Q(I)=Q(I)*RATIO
      Q(34)=Q(34)+Q(I)
      QLOG(I)=ALOG(Q(I)+DELTA)*.434295
 1270 CONTINUE
      QLOG(34)=ALOG(Q(34)+XD*DELTA)*.434295
 1280 V(1)= ALOG(Q(ND-1)+DELTA)*.434295
      V(2)= ALOG(Q(ND)   +DELTA)*.434295
      IF (JJJ.NE.0) GO TO 1290
      JJJ=1
      GO TO 1200
 1290 RETURN
      END
```

EXHIBIT 4

```
      SUBROUTINE STAT
      COMMON A(13,3),ASD(12,2),B(13,2),B0(12),B1(12),B2(12),C(13,2),
     1    CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2    DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2    JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3    NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4    RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),
     5    TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),
     6    TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),
     7    TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),
     8    TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),
     9    TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)
      IF (M1.EQ.1) GO TO 1340
      DO 1300 I=3,ND
      KK=I-1
      L=I-2
      TQ  (MO,J)=TQ  (MO,J)+QLOG   (I)
      TQK(MO,J)=TQK(MO,J)+QLOG(KK)
      TQL(MO,J)=TQL(MO,J)+QLOG(L)
      TQ2 (MO,J)=TQ2 (MO,J)+QLOG   (I)*QLOG   (I)
      TQ3 (MO,J)=TQ3 (MO,J)+QLOG   (I)*QLOG   (I)*QLOG   (I)
      TQIK(MO,J)=TQIK(MO,J)+QLOG   (I)*QLOG   (KK)
      TQIL(MO,J)=TQIL(MO,J)+QLOG   (I)*QLOG   (L)
      TQKK(MO,J)=TQKK(MO,J)+QLOG  (KK)*QLOG   (KK)
      TQLL(MO,J)=TQLL(MO,J)+QLOG   (L)*QLOG   (L)
 1300 CONTINUE
      DELQ =TQ  (MO,J)-TMPQ (MO,J)
      DELK=TQK(MO,J)-TMPK(MO,J)
      DELL=TQL(MO,J)-TMPL(MO,J)
      DELQ2=TQ2 (MO,J)-TMPQ2(MO,J)
      DELQ3=TQ3 (MO,J)-TMPQ3(MO,J)
      DELIK=TQIK(MO,J)-TMPIK(MO,J)
      DELIL=TQIL(MO,J)-TMPIL(MO,J)
      DELKK=TQKK(MO,J)-TMPKK(MO,J)
      DELLL=TQLL(MO,J)-TMPLL(MO,J)
      IF (DELQ.NE.0.) GO TO 1310
      XBAR(MO,J)=0.
      SD  (MO,J)=0.
      G   (MO,J)=0.
      R12 (MO,J)=1.0
      R13 (MO,J)=1.0
```

```
      GO TO 1330                                                        1042
 1310 XD=ND-2
      XBAR(MO,J)= DELQ/XD                                               1043
      IF (DELQ2-DELQ**2/(ND-2).GT..0001  ) GO TO 1320                   1044
      SD(MO,J)=0.                                                       1045
      G (MO,J)=0.                                                       1046
      R12(MO,J)=1.                                                      1047
      R13(MO,J)=1.                                                      1048
      GO TO 1330                                                        1049
 1320 SD  (MO,J)=((DELQ2-DELQ*DELQ/XD)/(XD-1.))**.5                     1050
      G(MO,J)=(XD*XD*DELQ3-3.*XD*DELQ*DELQ2+2.*DELQ*DELQ*DELQ)/(XD*     1051
     1   (XD-1.)*(XD-2.) *SD(MO,J)*SD(MO,J)*SD(MO,J))                   1052
      R12(MO,J)=(DELIK-DELQ*DELK/XD)**2/((DELQ2-DELQ*DELQ/XD)*          1054
     1(DELKK-DELK*DELK/XD))                                             1055
      R12(MO,J)=1.-(1.-R12(MO,J))*(XD-1.)/(XD-2.)                       1056
      IF (R12(MO,J).LT.0.) R12(MO,J)=0.                                 1057
      R12(MO,J)=(R12(MO,J))**.5                                         1058
      R13(MO,J)=(DELIL-DELQ*DELL/XD)**2/((DELQ2-DELQ*DELQ/XD)*          1059
     1   (DELLL-DELL*DELL/XD))                                          1060
      R13(MO,J)=1.-(1.-R13(MO,J))*(XD-1.)/(XD-2.)                       1061
      IF (R13(MO,J).LT.0.) R13(MO,J)=0.                                 1062
      R13(MO,J)=(R13(MO,J))**.5                                         1063
 1330 TMPQ (MO,J)=TQ  (MO,J)                                            1064
      TMPK(MO,J)=TQK(MO,J)                                              1065
      TMPL(MO,J)=TQL(MO,J)                                              1066
      TMPQ2(MO,J)=TQ2 (MO,J)                                            1067
      TMPQ3(MO,J)=TQ3 (MO,J)                                            1068
      TMPIK(MO,J)=TQIK(MO,J)                                            1069
      TMPIL(MO,J)=TQIL(MO,J)                                            1070
      TMPKK(MO,J)=TQKK(MO,J)                                            1071
      TMPLL(MO,J)=TQLL(MO,J)                                            1072
      RETURN                                                            1073
 1340 NTOT = NYR*(ND-2)                                                 1074
      IF (MO.EQ.5) NTOT = NTOT +ICOUNT                                  1075
      XTOT=NTOT
      XBAR(MO,J)=TQ (MO,J)/XTOT                                         1076
      SD  (MO,J)=((TQ2(MO,J)-TQ (MO,J)*TQ (MO,J)/XTOT)/(XTOT-1.))**.5   1077
      G   (MO,J)=(XTOT*XTOT*TQ3(MO,J)-3.*XTOT*TQ (MO,J)*TQ2(MO,J)       1078
     1+2.*TQ (MO,J)*TQ (MO,J)*TQ(MO,J))/(XTOT*(XTOT-1.)*(XTOT-2.)       1079
     1*SD(MO,J)*SD(MO,J)*SD(MO,J))                                      1080
      R12(MO,J)=(TQIK(MO,J)-TQ(MO,J)*TQK(MO,J)/XTOT)**2/((TQ2(MO,J)-    1081
```

EXHIBIT 4

```
1TQ(MO,J)*TQ(MO,J)/XTOT)*(TQKK(MO,J)-TQK(MO,J)*TQK(MO,J)/XTOT))       1082
 R12(MO,J)=(1.-(1.-R12(MO,J))*(XTOT-1.)/(XTOT-2.))**.5                1084
 R13(MO,J)=(TQIL(MO,J)-TQ(MO,J)*TQL(MO,J)/XTOT)**2/((TQ2(MO,J)-       1085
1TQ(MO,J)*TQ(MO,J)/XTOT)*(TQLL(MO,J)-TQL(MO,J)*TQL(MO,J)/XTOT))       1086
 R13(MO,J)=(1.-(1.-R13(MO,J))*(XTOT-1.)/(XTOT-2.))**.5                1088
 RETURN                                                               1089
 END                                                                  1090
```

```
      SUBROUTINE REGRES                                                 1001
      COMMON A(13,3),ASD(12,2),B(13,2),B0(12),B1(12),B2(12),C(13,2),    1002
     1   CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2   DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2   JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3   NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4   RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),          1007
     5   TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),                1008
     6   TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),                 1009
     7   TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),           1010
     8   TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),          1011
     9   TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)         1012
      TM (MO,J)=TM (MO,J)+QLOG(34)                                      1013
      TM2(MO,J)=TM2(MO,J)+QLOG(34)*QLOG(34)                             1014
      TS (MO,J)=TS (MO,J)+SD(MO,J)                                      1015
      TS2(MO,J)=TS2(MO,J)+SD(MO,J)*SD(MO,J)                             1016
      TMS(MO,J)=TMS(MO,J)+QLOG(34)  *SD(MO,J)                           1017
      IF (N.NE.NYR) RETURN                                              1018
      XN=N
      Z=TMS(MO,J)-TS (MO,J)*TM (MO,J)/XN                                1019
      Y=TM2(MO,J)-TM (MO,J)*TM (MO,J)/XN                                1020
      B(MO,J)=Z/Y                                                       1021
      C(MO,J)=TS(MO,J)/XN-B(MO,J)*TM(MO,J)/XN                           1022
      R2(MO,J)=Z*Z/(Y*(TS2(MO,J)-TS (MO,J)*TS (MO,J)/XN))               1023
      R2(MO,J)=1.-(1.-R2(MO,J))*(XN-1.)/(XN-2.)                         1024
      IF ( R2(MO,J).GE.0.) GO TO 1400                                   1025
      B(MO,J)=0.                                                        1026
      IF (MO.EQ.5) ND=30                                                1027
      NTOT =NYR*(ND-2)                                                  1028
      IF (MO.EQ.5) NTOT = NTOT + ICOUNT                                 1029
      XTOT=NTOT
      C(MO,J)=((TQ2(MO,J)-TQ(MO,J)*TQ(MO,J)/XTOT)/(XTOT-1.))**.5        1030
 1400 RETURN                                                            1031
      END                                                               1032
```

EXHIBIT 4

```
      SUBROUTINE ENTIRE                                                 1001
      COMMON/DAYS/KD(12)                                                1002
      COMMON A(13,3),ASD(12,2),B(13,2),BO(12),B1(I2),B2(12),C(13,2),    1003
     1    CONST,D(33),DELIK,DELIL,DELK,DELKK,DELL,DELLL,DELQ,DELQ2,
     2    DELQ3,DELTA,G(12,2),ICOUNT,ISMOO,ISKP,ISTA,ITAPE,ITEST,J,
     2    JCOUNT,JTAPE,K,KTAPE,MO,MSTAT,M1,N,ND,NP,NYANL,NYR,NYSYN,NYR1,
     3    NYR2,NYR3,NYR4,Q(34),QD,QDLOG(12),QLOG(34),QM(12,100),RN(33),
     4    RATIO,R12(13,2),R13(13,2),R2(12,2),SD(12,2),TM(12,2),         1008
     5    TMPIK(12,2),TMPIL(12,2),TMPK(12,2),TMPKK(12,2),               1009
     6    TMPL(12,2),TMPLL(12,2),TMPQ(12,2),TMPQ2(12,2),                1010
     7    TMPQ3(12,2),TMS(12,2),TM2(12,2),TQ(12,2),TQIK(12,2),          1011
     8    TQIL(12,2),TQK(12,2),TQKK(12,2),TQL(12,2),TQLL(12,2),         1012
     9    TQ2(12,2),TQ3(12,2),TS(12,2),TS2(12,2),V(2),XBAR(12,2)        1013
      DIMENSION ETM(12,2),EXBAR(12,2),ETQ(12,2),ETQ2(12,2),ETQ3(12,2),  1014
     1    ETS(12,2),ETS2(12,2),ETMS(12,2),ETQIK(12,2),ETQIL(12,2),      1015
     2    ETQKK(12,2),ETQLL(12,2),EB(13,2),EC(13,2),ER2(12,2),ESD(12,2),1016
     3   EG(12,2),ETQL(12,2),ER12(13,2),ER13(13,2),ETM2(12,2),ETQK(12,2)1017
      EQUIVALENCE (B,EB),(C,EC),(R2,ER2)                                1018
      EQUIVALENCE (SD,ESD),(G,EG),         (R12,ER12),(R13,ER13)        1019
      EQUIVALENCE (    EXBAR,XBAR),(ETQ,TQ),(ETQ2,TQ2),(ETQ3,TQ3),      1020
     1   (ETM2,TM2),(ETS,TS),(ETS2,TS2),(ETMS,TMS),(ETQIK,TQIK),        1021
     2   (ETQIL,TQIL    ),(ETQKK,TQKK    ),(ETQLL,TQLL),(ETQK,TQK),     1022
     3  (ETQL,TQL),(ETM,TM)                                             1023
      DO 1510 MO=1,12                                                   1024
      ETM  (MO,1)=TM   (MO,1)+TM   (MO,2)                               1025
      ETQ  (MO,1)=TQ   (MO,1)+TQ   (MO,2)                               1026
      ETQK(MO,1)=TQK(MO,1)+TQK(MO,2)                                    1027
      ETQL(MO,1)=TQL(MO,1)+TQL(MO,2)                                    1028
      ETQ2 (MO,1)=TQ2 (MO,1)+TQ2 (MO,2)                                 1029
      ETQ3 (MO,1)=TQ3 (MO,1)+TQ3 (MO,2)                                 1030
      ETM2 (MO,1)=TM2 (MO,1)+TM2 (MO,2)                                 1031
      ETS  (MO,1)=TS   (MO,1)+TS   (MO,2)                               1032
      ETS2 (MO,1)=TS2 (MO,1)+TS2 (MO,2)                                 1033
      ETMS (MO,1)=TMS (MO,1)+TMS (MO,2)                                 1034
      ETQIK(MO,1)=TQIK(MO,1)+TQIK(MO,2)                                 1035
      ETQIL(MO,1)=TQIL(MO,1)+TQIL(MO,2)                                 1036
      ETQKK(MO,1)=TQKK(MO,1)+TQKK(MO,2)                                 1037
      ETQLL(MO,1)=TQLL(MO,1)+TQLL(MO,2)                                 1038
      ND=KD(MO)                                                         1039
      NT=NYR1+NYR2                                                      1040
      XT=NT
```

```
      NN=NT*(ND-2)                                                      1041
      IF (MO.EQ.5) NN=NN+ JCOUNT                                        1042
      XN=NN
      EXBAR(MO,1)=ETQ(MO,1)/XN                                          1043
      ESD(MO,1)=((ETQ2(MO,1)-ETQ(MO,1)*XBAR(MO,1)) / (XN-1.))**.5       1044
      EG(MO,1)=(XN*XN*ETQ3(MO,1)-3.*XN*ETQ(MO,1)*ETQ2(MO,1)+2.*ETQ(MO,1) 1045
     1*ETQ(MO,1)*ETQ(MO,1))/(XN*(XN-1.)*(XN-2.)*ESD(MO,1)*ESD(MO,1)*    1046
     2   ESD(MO,1))                                                     1047
      ER12(MO,J)=(ETQIK(MO,J)-ETQ(MO,J)*ETQK(MO,J)/XN)**2/((ETQ2(MO,J)- 1048
     1ETQ(MO,J)*ETQ(MO,J)/XN)*(ETQKK(MO,J)-ETQK(MO,J)*ETQK(MO,J)/XN))   1049
      ER12(MO,1)=(1.-(1.-ER12(MO,1))*(XN-1.)/(XN-2.))**.5               1051
      ER13(MO,J)=(ETQIL(MO,J)-ETQ(MO,J)*ETQL(MO,J)/XN)**2/((ETQ2(MO,J)- 1052
     1ETQ(MO,J)*ETQ(MO,J)/XN)*(ETQLL(MO,J)-ETQL(MO,J)*ETQL(MO,J)/XN))   1053
      ER13(MO,1)=(1.-(1.-ER13(MO,1))*(XN-1.)/(XN-2.))**.5               1055
 1500 Y=ETM2(MO,1)-ETM(MO,1)*ETM(MO,1)/XT                               1056
      Z=ETMS(MO,1)-ETM(MO,1)*ETS(MO,1)/XT                               1057
      EB(MO,1)=Z/Y                                                      1058
      EC(MO,1)=ETS(MO,1)/NT-EB(MO,1)*ETM(MO,1)/XT                       1059
      ER2(MO,1)=Z*Z/(Y*(ETS2(MO,1)-ETS(MO,1)*ETS(MO,1)/XT))             1060
      ER2(MO,1)=1.-(1.-ER2(MO,1))*(XT-1.)/(XT-2.)                       1061
      IF (ER2(MO,1).GE.0.) GO TO 1510                                   1062
      EB(MO,1)=0.                                                       1063
      EC(MO,1)=ESD(MO,1)                                                1064
 1510 CONTINUE                                                          1065
      RETURN                                                            1066
      END                                                               1067
```

EXHIBIT 4

```
      FUNCTION RNGEN(IX)
C     RANDOM NUMBER SUBROUTINE FOR A BINARY MACHINE
C     GENERATES UNIFORM RANDOM NUMBERS IN THE INTERVAL 0 TO 1
C     CONSTANT ONE=(2**((B+1)/2))+3
C     CONSTANT TWO=(2**B)-1
C     CONSTANT THREE=1.0/(2.**B)
C     B= NUMBER OF BITS IN THE INTEGER WORD
C     GENERAL USAGE IS AS FOLLOWS
C     A=RNGEN(IX)
C     IX SHOULD BE INITIALIZED TO ZERO IN THE PROGRAM
      DATA IARG/759821/
      IF(IARG.EQ.IX) GO TO 3
      IX=IARG
      IY=IX
    3 IY=IY*16777219
      IF(IY.LT.0) IY=IY+281474976710655+1
      RNGEN=IY
      RNGEN=RNGEN*.3552713678E-14
      RETURN
      END
```

```
      SUBROUTINE SKPFILE (ITAPE,IFILE,IRCD)
      IF (IFILE) 1640,1640,1600
 1600 DO 1630 I=1,IFILE
 1610 READ (ITAPE,1620) VAR
 1620 FORMAT(20A4)
      IF (ENDFILE ITAPE) 1630,1610
 1630 CONTINUE
 1640 IF (IRCD) 1670,1670,1650
 1650 DO 1660 I=1,IRCD
      READ (ITAPE,1620)VAR
 1660 CONTINUE
 1670 RETURN
      END
```

Revised 3 June 1968

# EXHIBIT 5

## INPUT DATA - 723-G2-L2190

A Three title cards

B Specification card - input and output control

1. ISTA - Station number at which flows are to be generated
2. ITAPE - Number of the input tape containing historic daily flows. If daily flows are on cards use 5
3. JTAPE - Number of the input tape containing monthly flows. If monthly flows are on cards use 5
4. KTAPE - Number of the tape to be used for output of synthetic daily flows. If output should be on cards use 5
5. CONST - A constant to convert monthly flows to cfs-days. Its value is determined as follows:

   If synthetic monthly flows are in cfs-days use 1.
   If synthetic monthly flows are in thousand cfs-days use 1000.
   If synthetic monthly flows are in cfs use -1.
   If synthetic monthly flows are in acre-feet use .504167
   If synthetic monthly flows are in thousand acre-feet use 504.167
   If synthetic monthly flows are in inches use 26.9 × (Drainage area in square miles)

6. MSTAT - Indicator, + 1 if monthly statistics are desired
7. ISMOO - Indicator, + 1 if smoothing is not desired
8. ITEST - Indicator, + 1 if matrix consistency test is not desired

C Specification card - station information

1. DELTA - Incremental flow which is added to all flows before converting to a logarithmic value (.01095 × MEAN ANNUAL FLOW IN CFS).
2. NYANL - Number of years of historical daily flow input
3. NYSYN - Number of years of monthly flow input
4. ISKIP - Number of records to waste before starting to read daily flows from tape (leave blank if using cards for daily data)
5. ISTART - Indicator, + 1 if estimate of first two days of record is desired
6. NPASS - Number of sets of records of NYSYN years to be generated

7. ISKP - Number of years of monthly flows to waste before starting to read monthly flows from tape (leave blank if using cards for monthly data)

D Initial daily flows - only need the D card if ISTART is zero or blank

1. IYR - Calendar year
2. IMO - Month
3. - 6. - Blank fields
7. QS(1) - First starting daily flow value (Sept. 29)
8. QS(2) - Second starting daily flow value (Sept. 30)

E Historical daily flow data (12 × NYANL sets of data) - 4 card format

1. IYR - Calendar year
2. IMO - Month
3. Q - Daily flows in cfs (format 8F8.2)
   ($Q_{32}$ is the total monthly flow in cfs-days)

F Simulated monthly flow data (NYSYN sets of data)

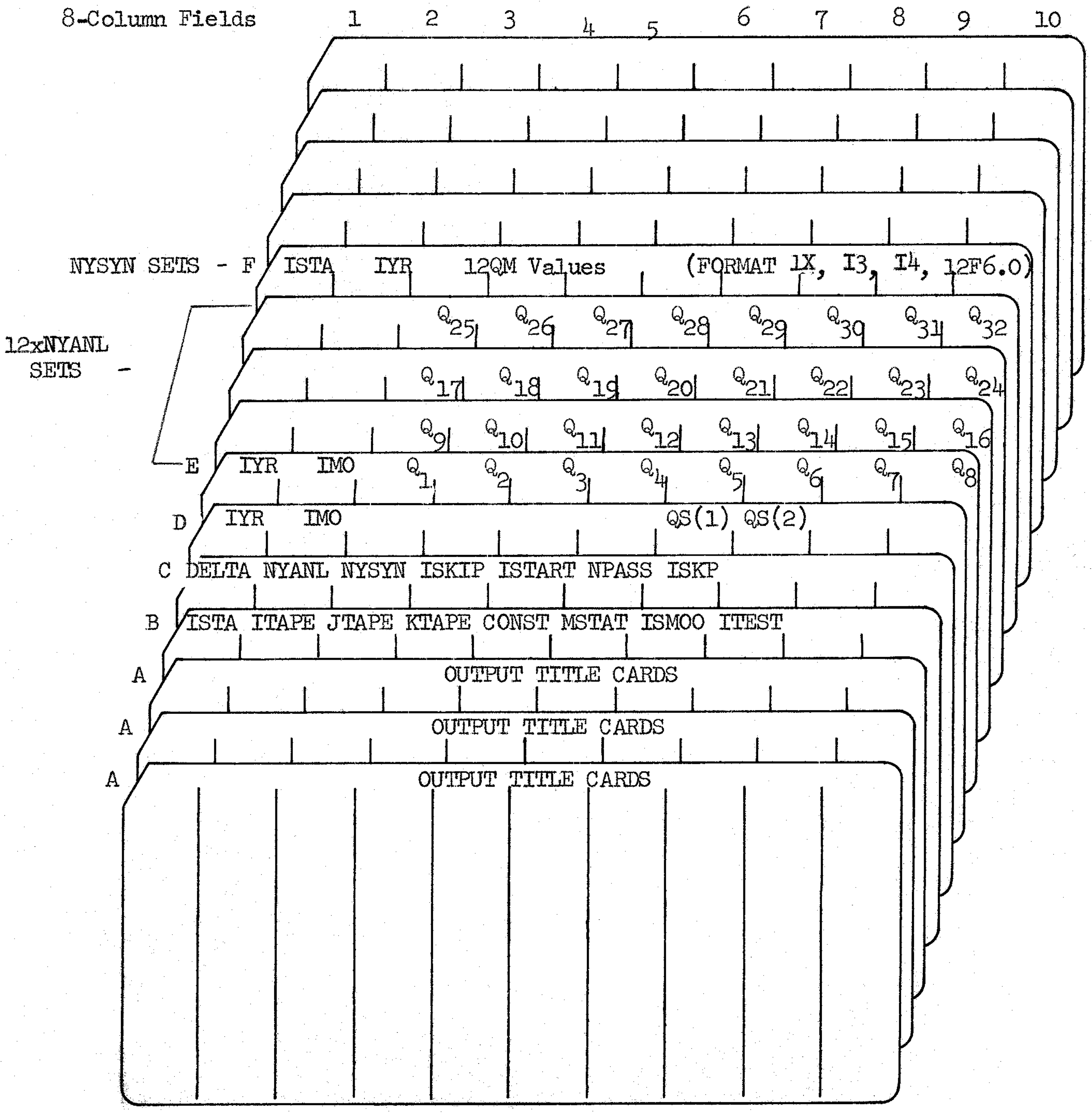
1. ISTA - Same as on card B1 (cols. 2-4)
2. IYR - Calendar year (cols. 5-8)
3. QM - Monthly flows (12 fields of 6 columns each)

EXHIBIT 5

# EXHIBIT 6

## SUMMARY OF REQUIRED CARDS

723-G2-L2190



All data (except as noted) are read using 10 fields of eight columns each except that column one of each card is reserved for identification of the card. Therefore, the first field is restricted to seven columns. The above input should be followed by either the next job or 4 blank cards to end the program.

## ELECTRONIC COMPUTER PROGRAM ABSTRACT

| | |
|---|---|
| TITLE OF PROGRAM<br>Daily Streamflow Simulation | PROGRAM NO.<br>723-G2-L2190 |

PREPARING AGENCY The Hydrologic Engineering Center, U.S. ARmy Corps of Engineers
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| AUTHOR(S) | DATE PROGRAM COMPLETED | STATUS OF PROGRAM<br>PHASE | STAGE |
| R. G. Willey | April 1968 | Init. | Op. |

**A. PURPOSE OF PROGRAM**

This program analyzes historical daily streamflows at one station to determine their statistical characteristics and generates a sequence of hypothetical daily streamflows. The generated streamflows, which can be of any desired length and will have statistical characteristics similar to the historical daily streamflows, are based on given monthly flows. The sum of each month's generated daily flows is equal to the monthly flow previously generated by another program such as 723-X6-L2340.

**B. PROGRAM SPECIFICATIONS**

The program is written in standard FORTRAN IV. The program is dimensioned for 300 years of synthetic data.

**C. METHODS**

The method is based on the second-order Markov Chain using Beta coefficients for each month of the year to acco for seasonal variations. The daily streamflow data is assumed to be log-normally distributed.

**D. EQUIPMENT DETAILS**

Required storage capacity is about 20,000 words (in the CDC 6600) and required library functions are the cosine and natural logarithm routines.

**E. INPUT-OUTPUT**

It is desirable, but not necessary, to use two input tapes and one output tape. An on-line printer is required. Card input is Tape 5 and printer output is Tape 6.

**F. ADDITIONAL REMARKS**

Occasionally this program does not provide acceptable results. Research studies are planned to develop a more acceptable model.

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PREVIOUS EDITIONS ARE OBSOLETE.

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