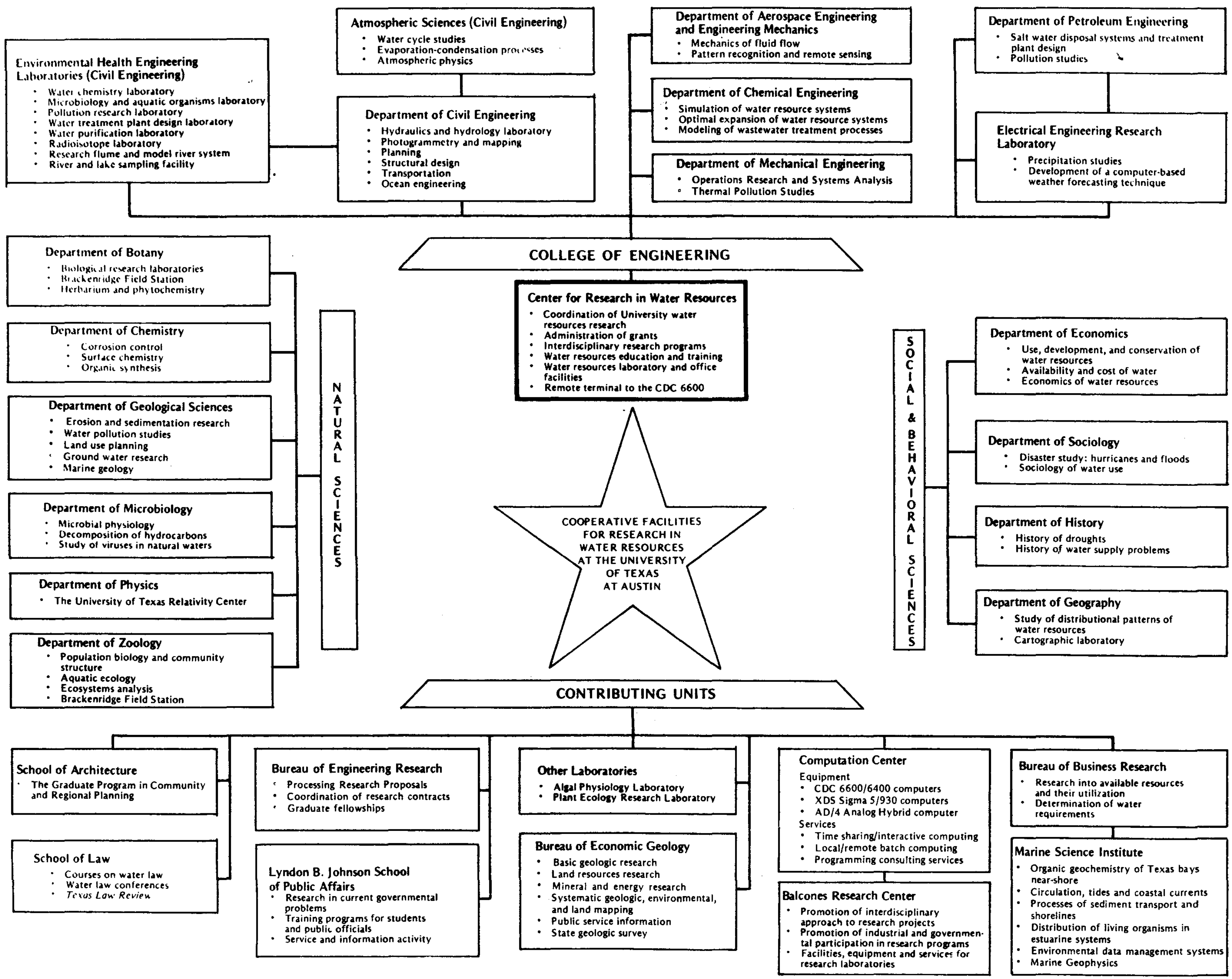
TECHNICAL REPORT

CRWR-119

Flood Flow Frequency Techniques

CENTER FOR RESEARCH IN WATER RESOURCES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FLOOD FLOW FREQUENCY TECHNIQUES

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for

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TABLE OF CONTENTS

Tables

Figures

Appendices

FLOOD FLOW FREQUENCY TECHNIQUES

I. PURPOSE OF THE STUDY

This study was made at the Center for Research in Water Resources of The University of Texas at Austin at the request of and under the general guidance of the Work Group on Flood Flow Frequencies, Hydrology Committee of the Water Resources Council through the auspices of the Office of Water Resources Research. The primary purpose is to provide the basis for selection of a technique or combination or sequence of procedures that would yield greater reliability and consistency than has heretofore been available in flood flow frequency determinations from data on natural streamflows available at the location for which each frequency estimate is to be made.

II. OBJECTIVES

The primary objectives of this research project are:

a. To review literature and examine current practice in order to select candidate methods and procedures for testing.

b. To select a broad spectrum of long-record data of natural streamflows in the United States for use in testing candidate procedures.

c. To develop alternative criteria for managing outliers and zero flows.

d. To develop data management and analysis computer programs for performing necessary computations and summaries of results for split-record analysis of annual-maximum flows.

e. To develop relationships between annual-maximum and partial-duration events based on data for a large number of records of natural streamflows throughout the United States.

f. To develop background material for drafting a report by the Work Group on Flood Flow Frequency recommending a set of procedures for flood flow frequency determinations.

III. DATA

The original selection of data for this study was for 227 streamflow stations having records of flows that are essentially unregulated for periods of 40 years or longer, except for a few stations having record lengths between 30 and 40 years and located in regions where longer records of natural flows were not available. A critical review of these data by the Work Group and CRWR staff resulted in the addition of 73 stations to give the best feasible coverage of drainage-area sizes and geographic location and to include a substantial number of stations having zero flows for entire years.

Complete daily streamflow data were obtained on magnetic tape from the US Geological Survey for the 227 stations on the original list. Annual maximum streamflows for all 300 stations have been obtained principally from the USGS, with some small-area station data obtained from the Agricultural Research Service, and these have been assembled by USGS geographic zone numbers 1 through 16, except that a number of supplementary stations having zero annual maximum flows for one or more years were assembled in group 17, identified as zero-flow stations in table 1.

Stations used in the study are listed in table 1, and the numbers of stations in various geographic regions and area-size categories are shown in table 2.

In addition to the above data used for test purposes, special stations listed at the end of table 1 consist of those specified by cooperating agencies of the Water Resources Council Work Group as stations where particular problems have been encountered. Plottings of computed curves and observed data for these stations by each of the 8 methods used in this study were furnished to the Work Group.

IV. SPLIT-RECORD TESTING

A primary concern in this study is the selection of a mathematical function and a fitting technique that best estimate flood flow frequencies from annual peak flow data. It is considered that the goodness of fit of a function to the data used in the fitting process is not necessarily a valid criterion for selecting a method that best estimates future frequencies, because certain functions, and particularly those with a large number of parameters, are more flexible than others and, although they may adhere to sample data better, erratic chance events in the samples might seriously mislead the user estimating future frequencies. Consequently, this primary phase of the research project was designed to simulate conditions of actual application by reserving a portion of a record from the fitting computation and using it as "future" events that would occur in practice. Goodness of fit can nevertheless be used particularly to eliminate methods whose fit is very poor.

Each record of annual maximum flows was divided into two halves, using odd sequence numbers for one half and even for the other in order to eliminate the effect of any general trend that might possibly exist. (This splitting procedure should adequately simulate practical situations as long as successive annual events are independent of each other, and this is tested as described below.) Then frequency estimates made from each half of a record can be tested against what actually happens in the other half.

The development of verification criteria is rather complicated, because what actually happens in the reserved half of a record also is subject to sampling irregularities, so the reserved data cannot be used as a simple, accurate target. Verification criteria must therefore be probabilistic. The test procedure, however, simulates very closely the condition faced by the planner, designer or operator of water resource projects, who neither knows that past events are representative or what future events will be.

It should be stressed at this point that the ultimate objective of any statistical estimation process is not to estimate the most likely theoretical distribution that generated the observed data, but to best forecast future events for which a decision is formulated. Use of theoretical distribution functions and their attendant reliability criteria is ordinarily an intermediate step to forecasting future events. Accordingly, the split-record technique of testing used in this study should be more rigorous and direct than alternative theoretical goodness-of-fit tests.

V. EXPECTED-PROBABILITY ESTIMATION

The expected probability is defined as the average of the true probabilities of all magnitude estimates that might be made (for any specified flood frequency) from successive samples of a specified size. For any specified flow magnitude, it is considered to be the most appropriate estimate of probability or frequency of future flows for water resources planning and management use, as explained in Appendix A. It is also a probability estimate that is theoretically easy to verify, because the observed frequencies in reserved data at a large number of stations should approach the computed probability or frequency estimates as the number of stations increases. Accordingly, it was considered that expected-probability estimates should be used in the split-record tests.

A method of computing expected probabilities has been developed for samples drawn from a Gaussian normal distribution and is described in reference 5. Similar techniques are not available for the other theoretical distribution functions used in this study. Furthermore, since the true form of the population distribution function is not known, use of the normal-distribution function on samples from a possibly non-normal population renders inaccurate the theoretical transform for the normal distribution. Consequently, an empirical transform is derived for each distribution by using the calibration constant which, when multiplied by the theoretical Gaussian transform adjustment, will remove the observed average bias in estimating expected probabilities for the 300 stations used in this study. This empirical transform is then used in making the accuracy tests that are the main basis for judging the relative adequacy of the various methods tested.

VI. ACCURACY AND CONSISTENCY TESTS

Development of definitive verification criteria for a study such as this is one of the most difficult tasks in research. In this case, computed frequencies are to be compared with the frequencies of events that happen to occur in the reserved data (accuracy test) or with frequencies computed independently from the reserved data (consistency test). Sampling errors in the reserved data are as large or larger for the same sample size as are sampling errors of computed values. Similarly, sampling errors are comparable for estimates based on opposite record halves used for consistency tests. Consequently, a great number of tests are necessary in order to reduce the uncertainty due to sampling errors in the reserved data. Secondly, a method that is biased toward estimating frequencies too low may have a small standard error of estimating frequencies in comparison with a method that is biased toward high frequencies, if the bias is not removed. The latter may have smaller percentage errors. Accordingly, consideration of the average frequency estimate for each of the 8 methods must be a component of the verification analyses.

Three types of accuracy tests and 2 types of consistency tests were used in this study.

Accuracy criteria are:

a. Standard deviation of observed frequencies (by count) in reserved data for magnitude estimates corresponding to exceedence probabilities of .001, .01, .1 and .5 computed from the part of the record used. This is the standard error of a frequency estimate at individual stations that would occur if a correction is made for the average observed bias in each group of stations for each selected frequency and method.

b. Root-mean-square difference between expected-probability plotting position (M/(N+1)) of the largest, upper decile and median event in a half-record and the computed expected-probability exceedence frequency of that respective event in the other half. This is the standard error of a frequency estimate at individual stations without any bias adjustment for each method and for the frequency of each selected event.

c. Root-mean-square difference between 1.0 and the ratio of the computed probability of flow in the opposite half of a record to the plotting position of the largest, upper decile and median event (in turn) in a half-record. This criterion is similar to that of the preceding paragraph except that methods that are biased toward predicting small frequencies are not favored.

Consistency criteria are:

a. Root-mean-square difference between computed probabilities from the two record halves for full-record extreme, largest, upper decile and median events, in turn. This is an indicator of the relative uniformity of estimates that would be made with various random samples for the same location.

b. Root-mean-square value of (1.0 minus the ratio of the smaller to the larger computed probabilities from the two record halves) for full-record extreme, largest, upper decile and median events, in turn. This is essentially the same as the preceding criterion, except that methods that are biased toward predicting small frequencies are not favored.

The extreme events used in the consistency tests are the largest multiplied by the square root of the ratio of the largest to the median event for the full record.

VII. DERIVATION OF PARTIAL-DURATION RELATIONSHIPS

A secondary concern in this study is the relationship between annual maximum flow frequencies and partial-duration flow frequencies. Since partial-duration flows consist of all events above any specified magnitude, it is necessary to define separate events, and the definition should ordinarily depend on the application of the frequency study as well as the hydrologic characteristics of the stream. For the purpose of this research effort, separate events were arbitrarily defined as events separated by at least as many days as 5 plus the natural logarithm of the square miles of drainage area, with the requirement that intermediate flows must drop below 75 percent of the lower of the two separate maximum daily flows. This is considered representative of separation criteria appropriate for many applications. Daily flows are used for this part of the study, since insufficient data on instantaneous peak flows usable for this purpose are readily available for events smaller than the annual maximum, but there is no reason to believe that the frequency relationship would be different for peak flows than for daily flows.

The relationship between the partial-duration and annual-maximum series was expressed as a ratio of partial-duration to annual-maximum-event frequencies for selected annual-event frequencies. In order to develop partial-duration relationships independent of any assumptions as to frequency functions, magnitudes corresponding to annual-maximum event exceedence probabilities of .1, .2, .3, .4, .5, .6 and .7 are established for complete records at each station by linear interpolation between expected-probability plotting positions (M/(n+1)) for the annual maximum events. (For these frequencies, events are fairly closely spaced, and such linear interpolation should be fairly accurate.) Corresponding frequencies of partial-duration flows are established simply by counting the total number of independent maximum daily flows at each station above each magnitude and dividing by the total number of years at that station. The ratios of partial-duration to annual-event frequencies are averaged for all stations in each USGS zone and compared with ratios derived for certain theoretical conditions by Langbein and described in reference 42.

VIII. FREQUENCY COMPUTATION METHODS

Basic methods and fitting techniques tested in this study were selected by the author and the WRC Work Group on Flood Flow Frequencies after careful review of the literature and experience in the various agencies represented and are described in the following paragraphs. Numbering of the paragraphs corresponds to the identification number of the methods in the computer programs.

1. Log Pearson III (LP3). The technique used for this is that described in reference 87. The mean, standard deviation and skew coefficients for each data set are computed in accordance with the following equation:

$$\bar{X} = \frac{\Sigma X}{N} \tag{1}$$

$$S^2 = \frac{\Sigma X^2 - (\Sigma X)^2/N}{N-1} \tag{2}$$

$$g = \frac{N^2 \Sigma X^3 - 3N\Sigma X \Sigma X^2 + 2(\Sigma X)^3}{N(N-1)\ (N-2) S^3} \tag{3}$$

where:

X = logarithm of peak flow (incremented by 1% of the average annual peak flow only in cases of data sets having zero flows)

N = number of items in the data set

$\bar{X}$ = mean logarithm

S = standard deviation of logarithms

g = skew coefficient of logarithms

Flow logarithms are related to these statistics by use of the following equation:

$$X = \bar{X} + kS \quad (4)$$

Exceedence probabilities for specified values of k and values of k for specified exceedence probabilities are calculated by use of Gaussian normal distribution routines available in computer libraries and the approximate transform to Pearson deviates given in reference 6.

2. Log Normal (LN). This method uses a 2-parameter function identical to the Log Pearson III function except that the skew coefficient is not computed (a value of zero applies) and values of k are related to exceedence probabilities by use of the Gaussian normal distribution transform available in computer libraries.

3. Gumbel (G). This is the Fisher-Tippett extreme-value function, which related magnitude linearly with the log of the log of the reciprocal of the exceedence probability (natural logarithms). Maximum-likelihood estimates of the mode and slope (location and scale parameters) are made by iteration, using procedures described by Harter and Moore in reference 29. The initial estimates of the location and scale statistics are obtained as follows:

$$M = \bar{X} - .045005\ S \quad (5)$$

$$B = .7797\ S \quad (6)$$

Magnitudes are related to these statistics as follows:

$$X = M + B\ (-\ln(-\ln P)) \quad (7)$$

where:

M = mode (location statistic)

B = slope (scale statistic)

X = magnitude

P = exceedence probability

S = standard deviation of flows

Some of the computer routines used in this method were furnished by the Central Technical Unit of the Soil Conservation Service.

4. Log Gumbel (LG). This technique is identical to the Gumbel technique, except that logarithms (base 10) of the flows are used. In data sets having zero values, 1% of the average annual maximum flow is added to each value before taking the logarithm. Of course, as in the case of the Log Pearson III method, this increment is later subtracted from computed values.

5. Two-parameter Gamma (G2). This is identical to the 3-parameter Gamma method described below, except that the location parameter is set to zero. The shape parameter α is determined directly by solution of Morlund's expansion of the maximum-likelihood equation, which gives the following as an approximate estimate of α:

$$\alpha = \frac{1 + \sqrt{1 + \frac{4}{3}(\ln \bar{Q} - \frac{1}{N}\Sigma \ln Q)}}{4(\ln \bar{Q} - \frac{1}{N}\Sigma \ln Q)} - \Delta\alpha \qquad (8)$$

where:

$\bar{Q}$ = average annual peak flow (incremented by 1% in cases of data sets having zero flows)

N = number of items in the data set

Q = peak flow (incremented by 1% of average annual peak flow in cases of data sets having zero flows)

$\Delta\alpha$ = correction factor

β is estimated as follows:

$$\beta = \frac{1}{\alpha} \cdot \frac{1}{N} \Sigma Q \qquad (9)$$

6. Three-parameter Gamma (G3). Computation of maximum-likelihood statistics for the 3-parameter Gamma distribution is accomplished using procedures described in reference 53. If the minimum flow is zero, or if the calculated lower bound is less than zero, the statistics are identical to those for the 2-parameter Gamma distribution. Otherwise, the lower bound,

γ, is initialized at a value slightly smaller than the lowest value of record, and the maximum likelihood value of the lower bound is derived by iteration using criteria in reference 53. Then the parameters α and β are solved for directly using the equations above replacing Q with $Q-\gamma$. Probabilities corresponding to specified magnitudes are computed directly by use of a library gamma routine. Magnitudes corresponding to specified probabilities are computed by iteration using the inverse solution.

7. Regional Log Pearson III (LPR). This method is identical to the Log Pearson III method, except that the skew coefficient is taken from figure 1 instead of using the computed skew coefficient. Regionalized skew coefficients were furnished by the U.S. Geological Survey.

8. Best Linear Invariant Gumbel (BLI). This method is the same as for the Gumbel method, except that best linear invariant estimates (BLIE) are used for the function statistics instead of the maximum likelihood estimates (MLE). An automatic censoring routine is used for this method only; so there are not alternative outlier techniques tested for this method. Statistics are computed as follows:

$$M = \Sigma(X \cdot U(N,J,I)) \tag{10}$$

$$B = \Sigma(X_1 \cdot V(N,J,I)) \tag{11}$$

where:

U	=	coefficient UMANN described in reference 50
V	=	coefficient BMANN described in reference 50
J	=	number of outliers deleted plus 1
I	=	order number of flows arranged in ascending-magnitude order
N	=	sample size as censored.

Since weighting coefficients U and V were made available in this study only for sample sizes ranging from 10 to 25, 5-year samples are not treated by this method, and records (or half-records) of more than 25 years are divided into chronological groups and weighted average coefficients used in lieu of coefficients that might otherwise be obtained if more complete sets of weighting coefficients were available. Up to 2 outliers are censored at the upper end of the flow array. Each one is removed if sequential tests show that a value that extreme would occur by chance less than 1 time in 10 on the basis of the BLIE statistics. Details of this censoring technique are contained in reference 67. Weighting coefficients and most of the routines used in this method were furnished by the Central Technical Unit of the Soil Conservation Service.

IX. COMPUTER PROGRAMS

Three primary computer programs were used in this study, and these are described in detail in the appendices to this report. In addition, a number of data handling computer programs were used, but these are of such transient value that they are not described in this report. A program designed specifically for application of techniques recommended in this report is contained in appendix F.

Initial data processing.

The master computer program, FREQNCY, accepts annual maximum streamflow data for each station in turn. It first deletes and identifies all flows at the start of the list for each station until it reaches 2 flows in consecutive water-years. Flows thus eliminated are assumed to be pre-record (historical) flows to be treated separately from the direct statistical analysis. These are listed in table 3. For each of the 8 methods studied, the frequency curve for the entire record is computed. Pre-record flows in table 3 were not used in this study, but are provided as potentially useful information.

Split-record computations.

Their records are split into equal parts by odd and even chronological sequence (independent of calendar-year numbers) and, in the cases of odd-numbered record lengths, the last flow is not assigned to either half. Also, 5-year and 10-year samples are drawn from each record starting with the first flow and selecting evenly-spaced values with the longest possible interval.

These selection methods are designed specifically to minimize the possible effects of trends in the data and to assure objectivity. For each candidate method, best-fit curves are computed for these 4 samples of each record. For each method and each subsample, the magnitudes of flows corresponding to the 0.5, 0.1, 0.01, and 0.001 exceedence probabilities were obtained from the fitted curve. The number of flows exceeding each magnitude in the remaining record were counted and the relative frequencies computed, stored on tape and printed out. These data are for use in program VERIFY to establish expected-probability adjustment criteria for each method and for one of the accuracy comparison tests.

Split-record test data are developed by first selecting the maximum, upper decile and median flow for each full record and, for each candidate procedure, computing exceedence probabilities for each of these magnitudes for each record half. These exceedence probabilities are printed and stored on tape for later use in comparing the consistency with which the various methods estimate flood flow frequencies. Data for comparing the accuracy with which the various methods estimate flood flow frequencies is established by computing the expected-probability plotting position for the largest, upper decile and median event for each half record and the corresponding exceedence frequency for the other half of the record, and printing these and storing them on tape for later use.

Zero-flow and outlier computations.

All of these consistency and accuracy tests are made for 2 different zero-flow techniques for those record-halves where zero annual maximum flows exist and, in the case of each record and zero-flow technique, for 4 outlier techniques for those record-halves where outliers exist (except that in the case of the Best Linear Invariant technique for the Gumbel method, only the standard outlier censoring is used). Outliers are defined for the purpose of this study as extreme values whose ratio to the next most extreme value in the same (positive or negative) direction is more extreme than the ratio of that next-most-extreme value to the eighth-most-extreme value.

Zero-flow techniques consist of:

a. adding 1 percent of the mean magnitude to all values for computation purposes and subtracting that amount from subsequent estimates, and

b. removing all zeros and multiplying estimated exceedence frequencies by the ratio of the number of non-zero values to the total number of values.

Outlier techniques consist of:

a. keeping the value as is

b. reducing the value to the product of the second-largest event and the ratio of the second-largest to eighth-largest event

c. reducing the value to the product of the second largest event and the square root of that ratio, and

d. discarding the value.

In the cases of outliers at the low end, the words largest in (b) and (c) should be changed to smallest.

These zero-flow and outlier techniques were selected simply to represent ideas that have appeared in literature or to cover the range of possible logical treatment.

Autocorrelation computations.

In addition to the above, the lag-one autocorrelation coefficients of flows and of logarithms of flows for each complete record and for each half record are computed and printed. Autocorrelation coefficients of flows for complete records at all stations are arranged in the order of magnitude and printed for assessing the degree to which successive annual peak flows are independent.

Verification computations.

Computer program VERIFY accepts the output from the master computer program, which is on one magnetic tape simulation in disk file for each USGS zone. Two types of analyses are made by VERIFY. In the first, total observed exceedence frequencies in the 2 halves of all records are compared with the total computed frequencies and the normal-distribution adjustment for expected probability. This is done separately for each method, and the ratio of observed to computed exceedence-frequency adjustment for expected probability is printed for each of the 3 magnitudes and each of the 3 record sample lengths. In the second type of analysis, accuracy and consistency comparisons are made as discussed above.

For the first zero-flow and the first outlier technique, the standard deviation of observed frequencies and the average observed frequency in the reserved data corresponding to the largest, upper decile and median values of a half-record are printed as an indication of relative reliability and bias of the various methods.

Partial-duration computations.

Computer program PARE evaluates the relationship between partial-duration and annual-event observed frequencies of daily flows in a number of station records. For each station, daily flows are read in for one year at a time, the annual maximum event selected, and all maximum events separated by at least 5 (plus the natural logarithm of the square miles of the drainage area) days during which interval at least one flow occurred lower than 75 percent of the lower of the 2 maximum flows are selected and printed. Using the expected-probability plotting position formula, $M/(N+1)$, for annual-event magnitudes, such magnitudes corresponding to exceedence probabilities of .1, .2, .3, .4, .5, .6, and .7 are interpolated linearly between observed events for each station, and the average number of partial-duration events per year above each of these 7 magnitudes is computed. Ratios of partial-duration to annual-event frequencies are computed and printed.

X. GRAPHICAL PRINT-OUT RESULTS

Because of the possible light it might shed on the verification results, basic print-out plotting was obtained for complete records for all stations and all methods, omitting any expected-probability adjustment. Of special note is the relative frequency with which 1000-year magnitudes greatly (unreasonably) exceeded maximum observed events on log-Gumbel plots. Table 4 shows for each method and each USGS Zone the number of stations where an observed flow exceeded the computed 1000-year flow. With 14,200 station-years of record, it might be expected that about 14 observed events would exceed true 1,000-year magnitudes. The Best Linear Invariant method is indicated to be particularly weak in this respect, probably because of the low significance level (10 percent) used for censoring outliers. A higher level of significance, such as 1 percent, might give more satisfactory results.

XI. EXPECTED-PROBABILITY ADJUSTMENT RESULTS

The ratios by which the Gaussian expected-probability theoretical adjustment must be multiplied in order to compute average probabilities equal to those observed for each zone are shown in tables 5 to 7. The Theoretical Gaussian adjustment was used as a reference because it is available in mathematics and is convenient for this particular portion of the study. It will be noted that these vary considerably from zone to zone and for different exceedence intervals, but it is considered that much of this variation is due to vagaries of sampling. Average ratios for the 100-year flood level shown on the last line in table 6 were adopted for each distribution for the purpose of comparing accuracy of the various methods. These are as follows:

1.	Log Pearson III	2.1
2.	Log Normal	0.9
3.	Gumbel, MLE	3.4
4.	Log Gumbel	-1.2
5.	2-parameter gamma	3.4
6.	3-parameter gamma	2.3
7.	Log Pearson, regional skew	1.1
8.	Gumbel, BLIE	5.7

The high multiplier for the Best Linear Invariant Estimate of the Gumbel parameters is due to censoring high upper values and consequently predicting much rarer frequencies than would otherwise be predicted. Observed frequencies are far greater than predicted, on the average for this method, and use of this high multiplier should compensate for this in the average case, but might create opposite bias in cases where censoring does not occur.

Results of this portion of the study indicate that only methods 2 and 7 are free of substantial bias, since zero bias should correspond approximately to a coefficient of 1.0 (assuming that distribution characteristics do not greatly influence the adjustment factor). The following table for method 7 was prepared from data in tables 5-7 and indicates that the theoretical expected-probability adjustment for the Gaussian distribution applies approximately to the Pearson Type III distribution with regional skew coefficients (Method 7). Coefficients shown range around the theoretical value of 1.0 and with only one exception, do not greatly depart from it in terms of standard-error multiples. It is particularly significant that the most reliable data (the 100-year values) indicate an adjustment factor near 1.0.

Expected-Probability Adjustment Ratios for All Zones

Sample size	10-yr Avg.	10-yr Std. err.	100-yr Avg.	100-yr Std. err.	1000-yr Avg.	1000-yr Std. err.
5	.81	.17	.94	.12	1.01	.13
10	.60	.22	1.12	.20	1.45	.27
23	.17	.27	1.14	.23	1.68	.28

In these computations, a single 5-year and a single 10-year sample were selected from each half-record, selecting equally-spaced values covering the period of the half-record.

XII. EVALUATION OF DISTRIBUTIONS

Table 8 shows average observed frequencies (by count) in the reserved portions of half records for computed probabilities of 0.001, 0.01, 0.1, and 0.5 and standard deviations of the observed frequencies from their averages for each computed frequency. Tables 9 and 10 show accuracy comparisons for 3 observed flood magnitudes in one half of each record in terms of plotting positions of those events and computed frequencies for the other half of the record.

It is difficult to draw conclusions from table 8, except that all methods except 2 and 7 have observed frequencies far different from computed frequencies and that standard deviations for those methods are commensurate with those for other methods in relation to average observed probabilities. Figure 2 shows a plotting of this for the .01 probability estimates.

Results shown in tables 9 and 10 also are not very definitive, but again the low-bias methods 2 and 7 show results as favorable as any other method, as illustrated in figure 3.

Tables 11 and 12 show consistency-test results for 4 observed flood magnitudes in the entire record in terms of relative computed frequencies in the 2 record halves.

Consistency-test results are not substantially different or more definitive than accuracy-test results. However, figure 4 indicates that method 7 yields considerably more consistent results than does method 2.

XIII. EVALUATION OF OUTLIER AND ZERO-FLOW TECHNIQUES

Tables 13 and 14 show accuracy comparisons for the maximum observed flood in each half-record only for 4 different outlier techniques. These are restricted to stations without zero flows. Tables 15 and 16 show consistency comparisons for the maximum observed flood for 4 different outlier techniques, omitting stations with zero flows. Unfortunately, no discrimination was made in the verification tests between treatment of outliers at the upper and lower ends of the frequency arrays. Outliers at the lower end can greatly increase computed frequencies at the upper end. Average computed frequencies for all half records having outliers at the upper or lower end are generally high for the first 3 outlier techniques and low for the fourth. It is considered that this is caused primarily by outliers at the lower end. Values observed are as follows:

Average plotting position of maximum flow	.042
Average computed probability, technique a	.059
Average computed probability, technique b	.050
Average computed probability, technique c	.045
Average computed probability, technique d	.038

Until more discriminatory outlier studies are made, technique a appears to be the most logical and justifiable to use.

Tables 17 and 18 show accuracy comparisons for the 2 different zero-flow techniques, using outliers as recorded (outlier technique a). Results in tables 17 and 18 indicate that, for the favorable methods 2 and 7, zero-flow technique b is slightly better than zero-flow technique a which show slightly smaller errors for technique b. Tables 19 and 20 show consistency-test results for the 2 different zero-flow techniques, using outlier technique a. Results are not highly definitive.

XIV. PARTIAL-DURATION RELATIONSHIPS

Results of partial-duration studies are shown in table 21. It can be seen that there is some variation in values obtained for different zones and that the average of all zones is somewhat greater than the theoretical values developed by Langbein and described in reference 42. The theoretical values were based on the assumption that a large number of independent (random) events occur each year. If the number of events per year is small, the average values in table 21 would be expected to be smaller than the theoretical values. If the events are not independent such that large events tend to cluster in some years and small events tend to cluster in other years, then the average values in table 21 would be expected to be larger than the theoretical values. It is considered that values computed for any given region (not necessarily zones as used in this study) should be used for stations in that region after smoothing the values such that they have a constant relation to the Langbein theoretical function.

XV. AUTOCORRELATION RESULTS

Results of autocorrelation studies are shown in table 22. It is apparent that there is a tendency toward positive autocorrelation, indicating a tendency for flood years to cluster more than would occur in a completely random process. The t values shown are multiples of the standard error of the correlation coefficient, and it is obvious that extreme correlation coefficients observed are not seriously different from variations that would occur by chance. It is considered that annual peak flows approximate a random process in streams used in this study.

XVI. GENERAL CONSIDERATIONS

Trends and cycles.

There is some question as to whether long-term trends and cycles (longer than one year) exist in nature such that knowledge of their nature can be used to improve forecasts of flood flow frequencies for specific times in the future. In the absence of conclusive evidence of substantial trends or cycles, and in the absence of knowledge of causes that would tend to create trends or cycles, it is usually assumed that such phenomena do not exist in any magnitude that would affect frequency estimates.

As a part of this research project, autocorrelation coefficients of annual peak flows for all stations were computed. If trends or cycles exist in any substantial part of the data, there should be a net positive average autocorrelation for all stations. The results of the study are shown in table 22. It is apparent that the evidence of natural trends or cycles is very weak in the data used in this analysis and in terms of autocorrelation coefficients. In the absence of more substantial evidence, it appears that the assumption of negligible natural trends or cycles in flood frequency applications is warranted.

It is possible that trends or cycles can be induced by human activity. Where trends exist, data should be adjusted to a stationary condition by subtracting the trend-line value from each data item, and predicted values must then be added to the extended trend line. However, care should be exercised to avoid the use of accidental trends due to sampling errors (non-representativeness of sample data), and it is usually wise to use only those trends that can be explained by knowledge of physical causes. Where cycles exist, data can be adjusted to stationarity by subtracting base cycle magnitudes from each data item and then adding predicted values to the extended cycle magnitudes. Alternatively, only complete cycles of data and prediction periods might be used, as in the case of the annual cycle.

Treatment of incomplete data.

Where a streamflow record is incomplete because flows in some periods were too low or too high to record, data can be analyzed graphically by leaving blank spaces for such data in those cases where the range of magnitude of the missing events is known. If reliable estimates of the magnitudes of missing events are possible, the estimates should be made, and the analysis should proceed as for any other complete record.

In the case of a broken record, where a period of no data occurs as a result of conditions that are not related to flood magnitude, then the remaining record can be analyzed as a continuous record having a length equal to the total of the lengths of the individual record periods. In general, only complete years of record are used in order to avoid bias effects due to seasonal variations. If trends or cycles longer than one year exist, some adjustment of all values to create a stationary time series is required, and this adjustment would be made in relation to the original chronologic record before combining the parts. In general, however, annual maximum events recorded under natural conditions are independent of each other, as discussed in the preceding section on trends and cycles, and adjustment to a stationary time series is therefore not necessary under those conditions (stationarity already exists).

Effects of errors in flow estimates.

Errors in measuring streamflows can be random or systematic. Systematic errors such as those created by once-a-day readings during snowmelt or power-plant operations should be removed from the data insofar as possible before a frequency study is made, in order to avoid a bias in the estimates. Otherwise, once-a-day readings might represent mean daily flows, but not peak flows, and care should be exercised in their use.

Random errors such as those associated with alluvial channels and other unstable controls cannot be removed from the data, and tend to increase the over-all variance of flows as measured in comparison to true flows. Ordinarily, however, the variance of true flows from year to year is so great in comparison to measurement-error variance that this increase is negligible. Consequently, ordinary measurement errors that are random will not appreciably affect the reliability of flow frequency estimates and can be neglected in this application of the data.

In general, there is no substitute for complete familiarity with conditions under which flow measurements are made. Knowledge of systematic flow variations, channel rating conditions, bypass or overflow channels, ice effects, etc., is essential to a rigorous frequency analysis of the flow data for any specific location.

One should be very careful in censoring data on the basis of measurement accuracy. In the case of estimating a maximum flood flow that washed out the gage, for example, it is much more important to recognize that all lower flows were exceeded by this event than to know the exact magnitude of this event. It should not be greatly discounted in the series, and certainly not eliminated from the series on the account of large measurement error.

Use of historical data.

When there is some pre-record information on streamflows available, it is possible to use this to adjust frequency computations. Usually such information will consist of one or more pre-record events that exceeded the maximum event of record. In such cases, a graphical approach can be used by assigning the largest historical event a plotting position based on the entire period of known history (which may include some years before the earliest known flood). Other events, including the largest recorded events, can be assigned plotting positions based on the entire historic period as long as such plotting positions for the large recorded events are larger than those based on the period of record alone. An analytic technique using this same procedure is described in reference 6. This technique is developed for use with samples drawn from a Gaussian normal distribution, but should be approximately correct and practical for the Pearson Type III distribution, using skew computed from recorded data. Alternative methods were not considered in this study.

In cases where it is simply known that the largest recorded event was not exceeded during a known pre-record period, its plotting position alone can be changed, or the equivalent effect can be computed analytically.

Routines for managing pre-record information as discussed herein are contained in the computer program described in Appendix F.

Flood estimates from rainfall and snowmelt.

Considerable study has been made by various researchers for deriving floods of known frequency from rainfall or snowmelt factors of known frequency. There is a cause and effect relationship that could be modeled mathematically if all of the necessary data were available and the intricate interrelationships were fully understood. In most natural drainage basins, great variations in soil and vegetation types and conditions, and extremely complex variations in storm rainfall, snowfall and snowmelt characteristics make very general assumptions necessary to any such modeling effort.

It is difficult to assign a frequency to any particular storm, unless a specific duration and areal extent is specified, and if that storm is transposed, the rainfall amount and frequency on any basin in the storm area will change. It is also difficult to assign runoff factors to a particular storm in order to compute a flood whose exceedence frequency is the same as that of the storm. For these reasons, the technique of computing many years of continuous runoff from precipitation with all of its variations appears to be most promising, even though the various pertinent factors are difficult to assess and model during dry periods.

In a great many cases, particularly for small areas, rainfall frequency estimates in combination with rainfall-runoff models offer the only practical approach to estimating runoff frequencies. This is true in regions where runoff records are not available for small areas and is particularly true for areas whose runoff characteristics have been greatly changed, such as irrigated areas, urban areas and airports. In these cases, the same frequency of rainfall should be used for all pertinent durations and area sizes, and average runoff factors should be used in order to obtain runoff of that frequency. This approach may be fairly reliable for basins with very low loss rates, particularly for paved areas. No tests were made of this in this study.

Where runoff records are available, they should be used as a primary basis of flood flow frequency estimates until such time as models such as continuous runoff computation models demonstrate reliable estimates of runoff frequency from rainfall or snowmelt data.

Where probable maximum, standard project or other types of extreme floods are computed from regional studies of rainfall or snowmelt potential, they can advantageously be used as a check or guide in the extrapolation of flood flow frequency curves. Exceedence frequencies of such events would vary with geographic location and other factors, so they can be used in only a very general way to assure that frequency-curve extrapolation does not indicate an unreasonable exceedence frequency for these large floods. This would be a judgment decision by experienced hydrologists.

Regional comparisons.

Frequency estimates or frequency statistics of flood flows can be compared over large regions for the purpose of estimating frequencies for ungaged locations and for improving the reliability of estimates based on gaged data at any particular location. Either estimates of flow for a given frequency or individual frequency statistics can be correlated with drainage basin characteristics. These characteristics should be features that would logically influence or relate to runoff and that can be obtained for ungaged areas.

If separate regional comparisons are made for flows corresponding to more than one frequency, such comparisons must be coordinated to assure consistency. On the other hand, if frequency statistics that are independent of each other are used as a basis of comparison, close coordination of the derived relationships is ordinarily not necessary. It is not obvious which technique is superior, but it is likely that correlations of moderate to large events would be more reliable than correlation of small or extremely large events, since causative hydrologic factors are more uniform and can be better delineated for moderate-size flood events.

A generally good approach to regional comparisons consists of making a multiple regression analysis relating each frequency characteristic in turn to basin characteristics, successively eliminating those basin characteristics that do not contribute appreciably incrementally to the correlation. After the best regression equation is obtained, residual errors that are obtained by subtracting values computed using station data from values computed using the regression equation can be plotted on a map, and isopleths or zones can be constructed if there appears to be some consistent geographic pattern. In this manner, it is possible to reduce errors of estimate appreciably.

XVII. CONCLUSIONS

Although split-record results in this study are not as definitive as was anticipated, there are sufficient clear-cut results to support definite recommendations. Conclusions that can be drawn are as follows:

a. Only method 2 (log-normal) and method 7 (log-Pearson III with regional skew)are not greatly biased in estimating future frequencies.

b. Method 7 gives somewhat more consistent results than method 2.

c. For methods 2 and 7, outlier technique "a" (retaining the outlier as recorded) is more accurate in terms of ratio of computed to observed frequencies than methods that give less weight to outliers.

d. For methods 2 and 7, zero-flow technique "b" (discarding zero flows and adjusting computed frequencies) is slightly superior to zero-flow technique "a".

e. Streamflows as represented by the 300 stations selected for this study are not substantially autocorrelated. Thus, records need not be continuous for use in frequency analysis.

f. Partial-duration frequencies are related to annual-event frequencies differently in different regions, and thus empirical regional relationships should be used rather than a single theoretical relationship.

Of particular significance is the conclusion that frequencies computed from theoretical functions in the classical manner must be adjusted to reflect more frequent extreme events if frequencies computed in a great number of cases are expected to average the same as would the true frequencies. For the recommended method, adjustment equal to the theoretical adjustment for estimates made from samples drawn from a normal population would be approximately correct.

Of interest from a research standpoint is the finding that split-record techniques in this application require more than 300 records of about 50 events each to be definitive, since random variations in the reserved data obscure the results.

In essence, then, regardless of the methodology employed, substantial uncertainty in frequency estimates from station data will exist, but the log Pearson III method with regional skew coefficients will produce unbiased estimates when the adjustment to expected probability is employed and will reduce uncertainty as much as or more than other methods tested.

It should be particularly noted that the treatment of Method 8 (best linear invariant Gumbel) in this study leaves much to be desired. Results for Method 8 as shown in the various tables and elsewhere have not been thoroughly checked for theoretical validity. This method uses an outlier detection and censoring technique unlike that used for the other methods and it is entirely possible that use of different outlier criteria might substantially change the results.

XVIII. RECOMMENDATIONS FOR FUTURE STUDY

It is considered that this study is an intial phase of a more comprehensive study that should include:

a. Differentiation in the treatment of outliers at the upper and lower end of a frequency curve.

b. Treatment of sequences composed of different types of events such as flood flows resulting from rainfall and those from snowmelt, or hurricane and non-hurricane floods.

c. Physical explanation for great differences in frequency characteristics among streams in a given region.

d. Development of systematic procedures for regional coordination of flood flow frequency estimates and applications to locations with recorded data as well as to locations without recorded data.

e. Development of procedures for deriving frequency curves for modified basin conditions such as by urbanization.

f. Development of a step-by-step procedure for deriving frequency curves for locations with various amounts and types of data such that progressively reliable results can be obtained on a consistent basis as the amount of effort expended is increased.

g. Preparation of a text on flood flow frequency determinations for use in training and practical application.

XIX. ACKNOWLEDGMENT

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Table 1
Streamflow Stations Used in Verification Analysis

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
01014000	ST. JOHN R BELOW FISH R, AT FORT KENT, ME.	5690.00	46	1926-1972
01023000	WEST BRANCH UNION RIVER AT AMHERST, ME.	148.00	53	1908-1972
01031500	PISCATAQUIS RIVER NEAR DOVER-FOXCROFT, ME.	297.00	70	1902-1972
01057000	LITTLE ANDROSCOGGIN RIVER NR SO. PARIS, ME.	76.20	51	1913-1972
01073000	OYSTER RIVER NEAR DURHAM, N.H.	12.10	37	1934-1971
01078000	SMITH RIVER NEAR BRISTOL, N.H.	85.80	53	1918-1971
01094000	SOUHEGAN RIVER AT MERRIMACK, N.H.	171.00	62	1909-1971
01106000	ADAMSVILLE BROOK AT ADAMSVILLE, R.I.	8.60	31	1940-1971
01135500	PASSUMPSIC RIVER AT PASSUMPSIC, VT.	436.00	43	1928-1971
01165500	MOSS BROOK AT WENDELL DEPOT, MASS.	12.30	55	1916-1971
01197500	HOUSATONIC RIVER NEAR GREAT BARRINGTON, MASS.	280.00	58	1913-1971
01329000	BATTEN KILL AT ARLINGTON, VT.	152.00	43	1928-1971
01396500	SOUTH BRANCH RARITAN RIVER NEAR HIGH BRIDGE N	65.30	53	1918-1971
01420500	BEAVER KILL AT COOKS FALLS, N. Y.	241.00	58	1913-1971
01472000	SCHUYLKILL RIVER AT POTTSTOWN, PA.	1147.00	44	1927-1971
01481000	BRANDYWINE CREEK AT CHADDS FORD, PA.	2870.00	52	1911-1971
01529500	CHOCTON RIVER NEAR CAMPBELL, N.Y.	470.00	53	1918-1971
01531500	SUSQUEHANNA RIVER AT TOWANDA, PA.	7797.00	78	1892-1971
01532000	TOWANDA CREEK NEAR MONROETON, PA.	215.00	58	1913-1971
01538000	WAPWALLOPEN CREEK NEAR WAPWALLOPEN, PA.	43.80	52	1919-1971
01543000	DR BR SINNEMAHONING CREEK AT STERLING RUN, PA	272.00	58	1913-1971
01556000	FRANKSTOWN BR JUNIATA R AT WILLIAMSBURG, PA.	291.00	55	1916-1971
01567000	JUNIATA RIVER AT NEWPORT, PA.	3354.00	73	1898-1971
01568000	SHERMAN CREEK AT SHERMANS DALE, PA.	200.00	42	1929-1971
01632000	NORTH F SHENANDOAH R AT COOTES STORE, VA.	210.00	47	1925-1972
01650500	NORTHWEST B ANACOSTIA R NR COLESVILLE, MD.	21.30	44	1923-1967
01671000	NORTH ANNA RIVER NEAR DOSWELL, VA.	439.00	45	1926-1971
02012500	JACKSON RIVER AT FALLING SPRING, VA.	411.00	48	1924-1972
02035000	JAMES RIVER AT CARTERSVILLE, VA.	6257.00	74	1898-1972
02039500	APPOMATTOX RIVER AT FARMVILLE, VA.	303.00	47	1925-1972
02066000	ROANOKE STAUNTON RIVER AT RANDOLPH, VA.	2977.00	72	1900-1972
02083500	TAR RIVER AT TARBORO, N. C.	2140.00	70	1896-1971
02085500	FLAT RIVER AT BAHAMA, N. C.	150.00	46	1925-1971
02086000	DIAL CREEK NEAR BAHAMA, N. C.	4.71	46	1925-1971
02094000	HORSEPEN CREEK AT BATTLE GROUND, N. C.	15.90	30	1925-1959

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
03528400	WHITE CREEK NEAR SHARPS CHAPEL, TENN.	2.68	33	1934-1967
03558000	TOCCOA RIVER NEAR DIAL, GA.	177.00	59	1912-1971
03571000	SEQUATCHIE RIVER NEAR WHITEWELL, TENN.	384.00	47	1920-1967
03604000	BUFFALO RIVER NEAR FLAT WOODS, TENN.	447.00	47	1920-1967
03999901	OHIO COSHOCTON,OHIO	7.16	31	1936-1967
03999902	BLACKBURG W-3,VIRGINIA	.03	33	1938-1971
04078500	EMBARRASS RIVER NEAR EMBARRASS, WIS.	395.00	48	1919-1967
04086500	CEDAR CREEK NEAR CEDARBURG, WIS.	121.00	37	1930-1967
04112500	RED CEDAR RIVER AT EAST LANSING, MICH.	355.00	63	1902-1971
04154000	CHIPPEWA RIVER NEAR MOUNT PLEASANT, MICH.	416.00	39	1932-1971
04166500	RIVER ROUGE AT DETROIT, MICH.	187.00	41	1930-1971
04186500	AUGLAIZE RIVER NEAR FORT JENNINGS, OHIO	332.00	46	1921-1971
04196500	SANDUSKY RIVER NEAR UPPER SANDUSKY, OHIO	298.00	49	1921-1971
04201500	ROCKY RIVER NEAR BEREA, OHIO	267.00	40	1923-1971
04212500	ASHTABULA RIVER NEAR ASHTABULA, OHIO	121.00	43	1924-1971
04216500	LITTLE TONAWANDA CREEK AT LINDEN, N.Y.	22.00	54	1912-1968
04234000	FALL CREEK NEAR ITHACA, N.Y.	124.00	46	1925-1971
04242500	EAST BRANCH FISH CREEK AT TABERG, N.Y.	189.00	48	1923-1971
04265000	GRASS RIVER AT PYRITES, N.Y.	335.00	46	1924-1971
04275000	EAST BRANCH AUSABLE R AT AU SABLE FORKS, N.Y.	198.00	47	1924-1971
04293500	MISSISQUOI RIVER NEAR RICHFORD, VT.	479.00	56	1911-1971
05062500	WILD RICE RIVER AT TWIN VALLEY, MINN.	888.00	50	1908-1971
05100000	PEMBINA RIVER AT NECHE, N. DAK.	3410.00	65	1903-1972
05106000	SPRAGUE CREEK NEAR SPRAGUE, MANITOBA	169.00	43	1928-1971
05129000	VERMILLION R BELOW VERMILION L NR TOWER,MINN.	483.00	49	1911-1971
05270500	SAUK RIVER NEAR ST. CLOUD, MINN.	925.00	45	1909-1971
05291000	WHETSTONE RIVER NEAR BIG STONE CITY, S. DAK.	389.00	45	1909-1971
05316500	REDWOOD RIVER NEAR REDWOOD FALLS, MINN.	697.00	46	1909-1971
05332500	NAMEKAGON RIVER NEAR TREGO, WIS.	503.00	54	1913-1967
05381000	BLACK RIVER AT NEILLSVILLE, WIS.	756.00	58	1904-1967
05394500	PRAIRIE RIVER NEAR MERRILL, WIS.	181.00	46	1913-1967
05415500	EAST FORK GALENA RIVER AT COUNCIL HILL, ILL.	20.10	30	1939-1969
05436500	SUGAR RIVER NEAR BRODHEAD, WIS.	527.00	58	1913-1971
05455000	RALSTON CREEK AT IOWA CITY, IOWA	3.01	47	1924-1971
05470000	SOUTH SKUNK RIVER NEAR AMES, IOWA	315.00	48	1920-1971

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
05495000	FOX RIVER AT WAYLAND, MO.	400.00	50	1921-1971
05532500	DES PLAINES RIVER AT RIVERSIDE, ILL.	635.00	58	1913-1971
05572000	SANGAMON RIVER AT MONTICELLO, ILL.	550.00	63	1907-1971
05587000	MACOUPIN CREEK NEAR KANE, ILL.	875.00	44	1920-1971
05597000	BIG MUDDY RIVER AT PLUMFIELD, ILL.	785.00	61	1908-1971
05999901	FENNIMORE W-3,WISCONSIN	.08	30	1937-1967
06037500	MADISON R NR WEST YELLOWSTONE, MONT.	420.00	53	1913-1967
06062500	TENMILE CREEK NEAR RIMINI, MONT.	32.70	53	1914-1967
06169000	HORSE CR AT INTERNATL. BOUNDARY, MONT.	73.50	46	1914-1961
06200500	SWEET GRASS CREEK ABOVE MELVILLE, MONT.	63.80	42	1913-1967
06216500	PRYOR CREEK NEAR BILLINGS, MONT.	435.00	42	1911-1967
06276500	GREYBULL RIVER AT MEETEETSE, WYO.	681.00	47	1920-1967
06334000	LITTLE MISSOURI RIVER NEAR ALZADA, MONT.	904.00	51	1911-1967
06606600	LITTLE SIOUX RIVER AT CORRECTIONVILLE, IOWA	2500.00	46	1918-1971
06609500	BOYER RIVER AT LOGAN, IOWA	871.00	42	1917-1971
06627000	NORTH PLATTE RIVER AT SARATOGA, WYO.	2840.00	62	1902-1967
06681000	WINTER CREEK NEAR SCOTTSBLUFF, NEBR.	0.00	40	1931-1971
06692000	BIRDWOOD CREEK NR HERSHEY, NEBR.	286.00	40	1931-1971
06724000	ST. VRAIN CREEK AT LYONS, COLO.	212.00	81	1887-1971
CFA add — 06755000	SOUTH CROW CREEK NEAR HECLA, WYO.	13.90	34	1932-1967
06813000	TARKIO RIVER AT FAIRFAX, MO.	508.00	49	1921-1970
06817500	NODAWAY RIVER NEAR BURLINGTON JUNCTION, MO.	1240.00	50	1921-1971
06853100	BEAVER CREEK NEAR ROSEMONT, NEBR.	.75	33	1938-1971
06869500	SALINE RIVER AT TESCOTT, KANS.	2820.00	53	1918-1971
06889500	SOLDIER CREEK NEAR TOPEKA, KANS.	290.00	43	1928-1971
06898000	THOMPSON RIVER AT DAVIS CITY, IOWA	701.00	40	1917-1971
06907000	LAMINE RIVER AT CLIFTON CITY, MO.	598.00	49	1921-1970
06917500	MARMATON RIVER NEAR FORT SCOTT, KANS.	408.00	47	1921-1971
06930000	BIG PINEY RIVER NEAR BIG PINEY, MO.	560.00	49	1921-1970
06999901	MC CREDIE,MISSOURI	.24	32	1940-1972
07016500	BOURBEUSE RIVER AT UNION, MO.	808.00	57	1914-1971
07037500	ST. FRANCIS RIVER NEAR PATTERSON, MO.	956.00	51	1920-1971
07052500	JAMES RIVER AT GALENA, MO.	987.00	50	1921-1971
07057000	BUFFALO R NR RUSH ARK.	1091.00	42	1928-1970
07098000	LITTLE BEAVER CREEK NEAR PIKES PEAK, COLO.	1.00	33	1916-1950

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
07098500	SACKETT CREEK NEAR PIKES PEAK, COLO.	.65	34	1916-1950
07101000	LION CREEK NEAR HALFWAY, COLO.	2.00	34	1916-1950
07101500	SHEEP CREEK NEAR HALFWAY, COLO.	.73	34	1916-1950
07111000	HUERFANO R AT MANZANARES CROSS,NR REDWING,COL	73.00	48	1923-1971
07182400	NEOSHO RIVER AT STRAWN, KANS.	2933.00	61	1901-1962
07196500	ILLINOIS RIVER NEAR TAHLEQUAH, OKLA.	959.00	37	1934-1971
07203000	VERMEJO RIVER NEAR DAWSON, N. MEX.	301.00	40	1928-1968
07205000	SIX MILE CREEK NEAR EAGLE NEST, N. MEX.	11.00	35	1930-1968
07218000	COYOTE CREEK NEAR GOLONDRINAS, N. MEX.	215.00	40	1928-1968
07332500	BLUE RIVER NEAR BLUE, OKLA.	476.00	36	1936-2957
07339000	MOUNTAIN FORK RIVER NEAR EAGLETOWN, OKLA.	787.00	42	1929-1971
07346000	CYPRESS CREEK NEAR JEFFERSON, TEX.	850.00	47	1912-1959
07363000	SALINE RIVER AT BENTON, ARK.	569.00	34	1937-1971
07365500	MIDDLE FK BAYOU D#ARBONNE NR BERNICE, LA.	178.00	30	1940-1970
07375500	TANGIPAHOA RIVER AT ROBERT, LA.	646.00	32	1938-1970
07382000	BAYOU COCODRIE NEAR CLEARWATER, LA.	240.00	35	1922-1970
08019000	LAKE FORK CREEK NEAR QUITMAN, TEX.	585.00	34	1924-1971
08041500	VILLAGE CREEK NEAR KOUNTZE, TEX.	861.00	37	1923-1971
08095000	NORTH BOSQUE RIVER NEAR CLIFTON, TEX.	972.00	48	1923-1971
08098227	BRUSHY CR WTRSHED Y-2 NR RIESEL, TEX.	.21	33	1938-1971
08098281	BRUSHY CREEK WTRSHED W-2 NEAR RIESEL, TEX	.20	34	1937-1971
08110000	YEGUA CREEK NEAR SOMERVILLE, TEX.	1008.00	47	1924-1971
08110500	NAVASOTA RIVER NEAR EASTERLY, TEX.	940.00	47	1924-1971
08148500	NORTH LLANO RIVER NEAR JUNCTION, TEX.	914.00	56	1915-1971
08150000	LLANO RIVER NEAR JUNCTION, TEX.	1874.00	56	1915-1971
08173000	PLUM CREEK NEAR LULING, TEX.	356.00	42	1929-1971
08189500	MISSION RIVER AT REFUGIO TEX.	643.00	32	1939-1971
08190000	NUECES RIVER AT LAGUNA, TEX.	764.00	49	1922-1971
08227000	SAGUACHE CREEK NEAR SAGUACHE, COLO.	595.00	60	1910-1971
08227500	NORTH CRESTONE CREEK NR CRESTONE, COLO.	10.70	36	1935-1971
08246500	CONEJOS RIVER NR MOGOTE, COLO.	282.00	63	1902-1971
08253500	SANTISTEVAN CREEK NR COSTILLA, N. MEX.	2.50	31	1937-1968
08263000	LATIR CREEK NEAR CERRO, N. MEX.	10.00	31	1937-1968
08271000	RIO LUCERO NEAR ARROYO SECO, N. MEX.	16.60	40	1910-1968
08302500	TESUQUE CR AB DIVERSIONS NR SANTA FE N MEX.	11.60	32	1935-1968

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
08380500	GALLINAS RIVER NR MONTEZUMA, N. MEX.	84.00	52	1914-1968
08388000	RIO RUIDOSO AT HONDO, N. MEX.	290.00	38	1930-1968
08477000	MIMBRES RIVER NEAR MIMBRES, N. MEX.	152.00	36	1930-1968
08999901	ALBUQUERQUE W-2,NEW MEXICO	.06	35	1938-1973
09085000	ROARING FORK AT GLENWOOD SPRINGS COLO.	1451.00	63	1905-1971
09097500	BUZZARD CREEK NEAR COLLBRAN, COLO.	139.00	50	1921-1971
09112500	EAST RIVER AT ALMONT COLO.	289.00	41	1917-1971
09201000	NEW FORK RIVER NR BOULDER, WYO.	552.00	53	1914-1967
09239500	YAMPA RIVER AT STEAMBOAT SPRINGS, COLO.	604.00	65	1903-1971
09255000	SLATER FORK NEAR SLATER, COLO.	161.00	41	1910-1971
09266500	ASHLEY CREEK NEAR VERNAL, UTAH	101.00	54	1913-1967
09304500	WHITE RIVER NEAR MEEKER, COLO.	762.00	62	1909-1971
09318000	HUNTINGTON CREEK NEAR HUNTINGTON, UTAH	188.00	63	1908-1971
09346000	NAVAJO RIVER AT EDITH, COLO.	172.00	37	1934-1971
09364500	ANIMAS RIVER AT FARMINGTON, N. MEX.	1360.00	54	1912-1967
09365500	LA PLATA RIVER AT HESPERUS, COLO.	37.00	57	1904-1971
09393500	SILVER CREEK NEAR SNOWFLAKE, ARIZ.	886.00	40	1928-1970
09403000	BRIGHT ANGEL CREEK NR GRAND CANYON, ARIZ.	101.00	47	1923-1970
09406000	VIRGIN RIVER AT VIRGIN, UTAH	934.00	62	1909-1971
09480500	SANTA CRUZ RIVER NEAR NOGALES, ARIZ.	533.00	41	1929-1970
09486000	RILLITO CREEK NEAR TUCSON, ARIZ.	918.00	56	1914-1970
09999901	SAFFORD W-2,ARIZONA	1.07	34	1938-1972
10113500	BLACKSMITH FORK AB U P + L CO DAM NR HYRUM U	260.00	57	1913-1971
10128500	WEBER RIVER NEAR OAKLEY, UT.	163.00	67	1904-1971
10174500	SEVIER RIVER AT HATCH, UTAH	340.00	46	1911-1971
10234500	BEAVER RIVER NEAR BEAVER, UTAH	82.00	58	1913-1971
10260500	DEEP CREEK NEAR HESPERIA, CALIF.	137.00	53	1905-1971
10267000	PINE CREEK AT DIVISION BOX NEAR BISHOP, CALIF	37.90	50	1921-1971
10286000	COTTONWOOD CREEK NEAR OLANCHA, CALIF.	39.90	63	1905-1971
10296000	WEST WALKER R BL LITTLE WALKER R NR COLEVILLE	180.00	33	1937-1970
10366000	TWENTYMILE CREEK NEAR ADEL,OREG.	194.00	41	1910-1971
10384000	CHEWAUCAN RIVER NEAR PAISLEY,OREG.	275.00	57	1911-1971
10393500	SILVIES RIVER NEAR BURNS,OREG.	934.00	62	1908-1971
10406500	TROUT CREEK NEAR DENIO,NEV. OREGON STATION	88.00	49	1921-1971
11055500	PLUNGE CREEK NEAR EAST HIGHLANDS,CALIF.	16.90	52	1919-1971

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
11104000	TOPANGA CREEK NEAR TOPANGA BEACH,CALIF.	18.00	41	1929-1971
11186000	KERN RIVER NEAR KERNVILLE, CALIF.	848.00	60	1911-1971
11215000	NORTH FORK KINGS RIVER NEAR CLIFF CAMP, CALIF	181.00	50	1921-1971
11259000	CHOWCHILLA R AT BUCHANAN DAMSITE NR RAYMD,CAL	235.00	41	1930-1971
11282000	MIDDLE TUOLUMNE RIVER AT OAKLAND REC. CAMP, C	73.50	55	1916-1971
11333500	NORTH FORK COSUMNES RIVER NEAR EL DORADO, CAL	205.00	53	1911-1971
11355500	HAT CREEK NEAR HAT CREEK, CALIF.	162.00	46	1925-1971
11381500	MILL CREEK NEAR LOS MOLINOS, CALIF.	131.00	43	1928-1971
11392500	MIDDLE FORK FEATHER RIVER NEAR CLIO, CALIF.	686.00	46	1925-1971
11464500	DRY CR NR CLOVERDALE, CALIF.	87.80	30	1941-1971
11476500	SF EEL R NR MIRANDA, CALIF.	537.00	31	1940-1971
11522500	SALMON R AT SOMES BAR, CALIF	751.00	46	1913-1971
12017000	NORTH RIVER NEAR RAYMOND, WASH.	219.00	44	1927-1971
12039500	QUINAULT RIVER AT QUINAULT LAKE, WASH.	264.00	57	1911-1971
12045500	ELWHA RIVER AT MCDONALD BR, NR PT ANGELES, WA	269.00	57	1897-1971
12097500	GREENWATER RIVER AT GREENWATER,WASH. 5	73.50	43	1929-1972
12133000	SOUTH FORK SKYKOMISH RIVER NEAR INDEX, WASH.	355.00	62	1902-1971
12209000	SOUTH FORK NOOKSACK R NEAR WICKERSHAM, WASH.	103.00	37	1934-1971
12305000	KOOTENAI RIVER AT LEONIA, IDAHO	11740.00	44	1927-1971
12307500	MOYIE RIVER AT EILEEN, IDAHO	755.00	46	1925-1971
12351000	BURNT FORK CREEK NEAR STEVENSVILLE, MONT.	74.00	33	1921-1967
12355500	FLATHEAD RIVER NEAR COLUMBIA FALLS, MONT.	1548.00	46	1910-1967
12370000	SWAN RIVER NEAR BIGFORK, MONT.	671.00	46	1921-1967
12401500	KETTLE RIVER NEAR FERRY, WASH.	2220.00	43	1928-1971
12408500	MILL CREEK NEAR COLVILLE, WASH.	83.00	32	1939-1971
12413000	COEUR D$ALENE RIVER AT ENAVILLE IDAHO	895.00	32	1939-1971
12451000	STEHEKIN RIVER AT STEHEKIN, WASH.	372.00	47	1910-1968
12457000	WENATCHEE RIVER AT PLAIN, WASH.	591.00	56	1910-1968
12500500	N F AHTANUM CR NR TAMPICO, WASH.	68.90	52	1909-1971
13011000	SNAKE RIVER AT MORAN, WHO.	824.00	65	1903-1971
13037500	SNAKE RIVER NEAR HEISE, IDAHO	5752.00	61	1910-1971
13069500	SNAKE RIVER NEAR BLACKFOOT, IDAHO	11310.00	61	1910-1971
13081500	SNAKE RIVER NR MINIDOKA, IDAHO	15700.00	75	1895-1971
13082500	GOOSE C AB TRAPPER CREEK, NR OAKLEY IDAHO	633.00	58	1911-1971
13120500	BIG LOST R AT HOWELL RANCH, NR CHILLY, IDAHO	450.00	63	1903-1971

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
13141500	CAMAS CREEK NEAR BLAINE IDAHO	648.00	47	1923-1971
13174500	OWYHEE RIVER NEAR GOLD CREEK, NEV.	209.00	43	1915-1970
13185000	BOISE RIVER NEAR TWIN SPRINGS, IDAHO	830.00	61	1910-1971
13214000	MALHEUR RIVER NEAR DREWSEY,OREG.	910.00	47	1920-1971
13261000	LITTLE WEISER R NR INDIAN VALLEY, IDAHO	81.90	39	1922-1971
13275500	POWDER RIVER NEAR BAKER,OREG.	219.00	53	1903-1968
13302500	SALMON RIVER AT SALMON, IDAHO	3760.00	57	1911-1971
13313000	JOHNSON CREEK AT YELLOW PINE, IDAHO	213.00	43	1928-1971
13330500	BEAR CREEK NEAR WALLOWA,OREG.	68.00	48	1923-1971
13338000	SOUTH FORK CLEARWATER R NR GRANGEVILLE, IDAHO	865.00	51	1910-1963
13351000	PALOUSE RIVER AT HOOPER,WASH.	2500.00	39	1897-1971
14010000	SO FK WALLA WALLA R NR MILTON,OREG.	63.00	49	1908-1971
14042500	CAMAS CREEK NEAR UKIAH,OREG.	121.00	47	1914-1971
14073000	TUMALO CREEK NEAR BEND,OREG.	47.30	58	1913-1971
14101500	WHITE RIVER BLW TYGH VALLEY,OREG.	368.00	54	1917-1971
14110000	KLICKITAT RIVER NEAR GLENWOOD, WASH.	360.00	61	1909-1971
14113000	KLICKITAT RIVER NEAR PITT, WASH.	1297.00	46	1909-1971
14146500	SALMON CREEK NEAR OAKRIDGE,OREG.	117.00	45	1912-1971
14178000	N SANTIAM R BL BOULDER CR NR DETROIT,OREG.	216.00	46	1906-1971
14210000	CLACKAMAS RIVER AT ESTACADA,OREG.	671.00	63	1908-1971
14226500	COWLITZ RIVER AT PACKWOOD, WASH.	287.00	51	1911-1971
14242500	TOUTLE RIVER NEAR SILVER LAKE, WASH.	474.00	49	1909-1971
14305500	SILETZ RIVER AT SILETZ,OREG.	202.00	55	1905-1971
14325000	SO FORK COQUILLE RIVER AT POWERS,OREG.	169.00	53	1916-1971
14328000	ROGUE RIVER ABOVE PROSPECT,OREG.	312.00	48	1923-1971
14372500	EAST FK ILLINOIS RIVER NR TAKILMA,OREG.	42.30	36	1927-1971
15026000	CASCADE CREEK NR PETERSBURG ALASKA	23.00	33	1917-1971
15040000	DOROTHY CREEK NR JUNEAU ALASKA	15.20	37	1929-1967
15072000	FISH CREEK NR KETCHIKAN ALASKA	32.10	50	1915-1971
16010000	KAWAIKOI STREAM NEAR WAIMEA	4.10	55	1915-1972
16049000	HANAPEPE R BELOW MANUAHI STREAM NR ELEELE HAW	18.80	44	1926-1972
16060000	S F WAILUA RIVER NR LIHUE HAWAII	22.40	59	1913-1972
16200000	N F KAUKONAHUA STRM AB RGT BR NR WAHIAWA HAW	1.38	48	1915-1972
16228000	MOANALUA STREAM NEAR HONOLULU HAWAII	2.73	46	1926-1972
16244000	PUKELE STREAM NEAR HONOLULU HAWAII	1.18	46	1926-1972

Table 1 Continued

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
16284000	WAIHEE STREAM NEAR HEEIA HAWAII	.93	34	1937-1972
16400000	HALAWA STREAM NR HALAWA HAWAII	4.62	47	1917-1972
16408000	WAIKOLU STR BLW PPLINE CRSNG NR KALAUPAPA HAW	3.68	48	1919-1972
16508000	HANAWI STREAM NEAR NAHIKU HAWAII	3.49	53	1914-1972
16570000	NAILIILIHAELE STREAM NR HUELO HAWAII	3.58	57	1913-1972
16620000	HONOKOHAU STRM NR HONOKOHAU HAWAII	4.11	56	1913-1972
16704000	WAILUKU RIVER AT PIIHONUA HAWAII	125.00	44	1928-1972

ZERO FLOW STATIONS

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
08098227	BRUSHY CR WTRSHED Y-2 NR RIESEL, TEX.	.21	33	1938-1971
08098239	BRUSHY CR WTRSHED Y NR RIESEL, TEX.	.48	32	1937-1971
08098263	BRUSHY CREEK WATERSHED W-1 NEAR RIESEL, TEX.	.28	34	1937-1971
08134000	NORTH CONCHO RIVER NR CARLSBAD, TEX.	1249.00	47	1924-1971
10258500	PALM CANYON CR NR PALM SPRINGS, CALIF.	94.00	35	1930-1971
10261000	WEST FORK MOJAVE R NR HESPERIA, CALIF.	74.80	48	1908-1971
11047000	ARROYO TRABUCO NR SAN JUAN CAPISTRANO, CALIF.	35.70	39	1931-1971
11047500	ALISO CREEK AT EL TORO,CALIF.	7.97	41	1930-1971
11096500	LITTLE TUJUNGA CREEK NEAR SAN FERNANDO,CALIF.	21.10	43	1928-1971
11126500	SANTA AGUEDA CREEK NEAR SANTA YNEZ, CALIF.	55.80	31	1940-1971
11140000	SISQUOC RIVER NEAR GAREY, CALIF.	472.00	31	1940-1971
11274500	ORESTIMBA CREEK NEAR NEWMAN, CALIF.	134.00	40	1931-1971
11312000	BEAR CREEK NEAR LOCKEFORD, CALIF.	47.60	41	1930-1971

Table 1 Continued
SPECIAL STATIONS

STATION NUMBER	STATION NAME	DRAINAGE AREA	YEARS OF RECORD	PERIOD OF RECORD
02102500	CAPE FEAR RIVER AT LILLINGTON, N. C.	3440.00	48	1923-1971
03203000	GUYANDOTTE RIVER AT MAN, W. VA.	762.00	38	1928-1967
03450000	BEETREE CREEK NEAR SWANNANOA, N. C.	5.46	45	1926-1971
03451500	FRENCH BROAD RIVER AT ASHEVILLE, N. C.	945.00	76	1895-1971
03540500	EMORY RIVER AT OAKDALE, TENN.	764.00	40	1927-1967
03574500	PAINT ROCK RIVER NEAR WOODVILLE, ALA.	320.00	36	1935-1971
03576250	LIMESTONE CR, U.S. HWY 72 NR ATHENS, ALA.	119.00	32	1939-1971
03584000	RICHLAND CREEK NEAR PULASKI, TENN.	366.00	33	1934-1967
03588500	SHOAL CREEK AT IRON CITY, TENN.	348.00	42	1925-1967
03599500	DUCK RIVER AT COLUMBIA, TENN.	1208.00	51	1904-1967
04106000	KALAMAZOO RIVER AT COMSTOCK, MICH.	1010.00	38	1932-1970
04119000	GRAND RIVER AT GRAND RAPIDS, MICH.	4900.00	71	1900-1971
04165500	CLINTON RIVER AT MOUNT CLEMENS, MICH.	734.00	37	1934-1971
04166500	RIVER ROUGE AT DETROIT, MICH.	187.00	41	1930-1971
05102500	RED RIVER OF THE NORTH AT EMERSON, MAN.	40200.00	59	1912-1971
05325000	MINNESOTA RIVER AT MANKATO, MINN.	14900.00	69	1902-1971
05331000	MISSISSIPPI RIVER AT ST. PAUL, MINN.	36800.00	104	1866-1971
05430500	ROCK RIVER AT AFTON, WIS.	3300.00	54	1913-1967
07340500	COSSATOT RIVER NEAR DE QUEEN ARK.	361.00	34	1937-1971
09480000	SANTA CRUZ RIVER NEAR LOCHIEL, ARIZ.	82.20	22	1948-1970
09481500	SONOITA CREEK NEAR PATAGONIA, ARIZ.	209.00	41	1929-1970
09482000	SANTA CRUZ RIVER AT CONTINENTAL, ARIZ.	1662.00	27	1939-1970
11203500	TULE RIVER NEAR PORTERVILLE, CALIF.	253.00	59	1901-1960
11210500	KAWEAH RIVER NEAR THREE RIVERS, CALIF.	519.00	58	1903-1961
14363000	APPLEGATE RIVER NEAR RUCH, OREG.	297.00	31	1911-1953
05066500	GOOSE RIVER AT HILLSBORO, N. DAK.	1203.00	42	1930-1972
05100000	PEMBINA RIVER AT NECHE, N. DAK.	3410.00	65	1903-1972
07099500	ARKANSAS RIVER NEAR PUEBLO, COLO.	4686.00	77	1894-1971
07124500	PURGATOIRE RIVER AT TRINIDAD, COLO.	795.00	59	1895-1971
08150000	LLANO RIVER NEAR JUNCTION, TEX.	1874.00	56	1915-1971
09342500	SAN JUAN RIVER AT PAGOSA SPRINGS, COLO.	298.00	42	1910-1971

Table 2

Numbers of Verification Stations by Zones and Area Size

USGS ZONE	Drainage area category (sq. mi.) 0-25	25-200	200-1000	1000+	Total
1	4	8	10	5	27
2	2	5	12	5	24
3	5	3	16	1	25
4	1	6	8	0	15
5	3	2	14	1	20
6	4	3	13	4	24
7	5	2	12	2	21
8	8	2	11	2	23
9	1	7	8	2	18
10	0	8	4	0	12
11	2	5	6	0	13
12	0	5	9	3	17
13	0	2	10	5	17
14	0	6	8	1	15
15	2	1	0	0	3
16	12	1	0	0	13
*	4	7	1	1	13
Total	53	73	142	32	300

*Zero-flow stations (zones 8, 10 & 11 only)

Table 3

Pre-Record Flows

Station Number	Years and Flows					
013965	1896	7560	1902	3840	1904	2670
014720	1902	53900				
015315	1865	188000				
015560	1889	35500				
015670	1889	209000				
015680	1927	44000				
016320	1924	17800				
020125	1913	50000				
020660	1878	130000				
021385	1916	34600				
022175	1902	19600				
023665	1929	220000				
024375	1892	98000				
030510	1888	21200				
031370	1913	40000				
033220	1832	767000				
034700	1867	43000	1875	55000	1896	46000
	1913	24000	1917	27000		
034855	1901	39000				
035580	1907	28000				
041540	1931	500				
068980	1885	30000				
069070	1905	90000	1907	70000		
070165	1897	44500				
070375	1915	100000				
070570	1915	164000	1927	110000		
071824	1885	75000				
071965	1916	112000	1927	60000		
073390	1915	92000	1925	67500		
073630	1927	110000				
081105	1899	90000				
081485	1889	84000				
081895	1914	33000	1938	33000		
081900	1913	210000				
091125	1913	1520	1916	3220		
092665	1912	880				
093045	1901	5000				
103935	1904	4730	1906	2100		
104065	1911	132				
115225	1912	23800				
120395	1910	52600				
120975	1912	2800				

Table 3 Continued

Station Number	Years and Flows					
121330	1897	70000				
123510	1920	347				
124130	1912	10500				
125005	1908	407				
133305	1915	755				
140100	1903	542	1907	418		
143280	1909	4400	1911	2940		
160100	1914	2240				

Zero Flow Stations

Station Number	Years and Flows	
102610	1907	12300
110965	1914	4100

Special Stations

Station Number	Years and Flows					
035840	1902	100000				
035995	1874	42000	1902	50700		
050665	1882	6700	1897	5700	1904	5300
	1916	4700				
053250	1881	90000				

TABLE 4

NUMBER OF STATIONS WHERE ONE OR MORE OBSERVED FLOOD EVENTS

EXCEEDS THE 1000-YR FLOW COMPUTED FROM COMPLETE RECORD

ZONE	STATION-YEARS OF RECORD	METHOD 1	2	3	4	5	6	7	8
1	1414	0	1	8	0	10	7	2	26
2	1074	0	3	9	0	10	7	1	19
3	1223	1	3	7	0	9	8	4	22
4	703	1	2	3	0	3	3	2	12
5	990	2	1	7	0	4	4	0	19
6	1124	0	2	4	0	4	4	1	18
7	852	1	2	5	1	3	4	3	17
8	969	1	1	10	0	3	3	1	19
9	920	3	0	4	0	3	3	1	16
10	636	1	0	2	0	1	1	0	10
11	594	1	1	6	0	4	4	0	11
12	777	0	2	2	0	2	2	2	9
13	911	1	0	1	0	4	2	2	14
14	761	0	0	3	0	4	1	1	15
15	120	0	0	0	0	0	0	0	2
16	637	1	0	4	0	4	3	0	12
17	495	1	0	2	0	0	0	0	12
TOTAL	14,200	14	18	77	1	68	56	20	253

Based on the 14,200 station-years of record, it might be expected that about 14 observed events would exceed the true 1000-year magnitudes.

TABLE 5

ADJUSTMENT RATIOS FOR 10-YEAR FLOOD

SAMPLE SIZE	ZONE 1		27 STATIONS		AVG 1/2 RECORD = 26 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.54	.38	.76	.29	.82	.57	.28	-1.85
10-YR	.75	.45	1.02	-.27	.95	.37	.34	4.56
1/2-REC	1.21	1.11	2.21	-1.04	2.01	1.01	1.03	4.49

	ZONE 2		24 STATIONS		AVG 1/2 RECORD = 22 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.48	.42	1.06	.64	1.03	.93	.41	-1.85
10-YR	1.01	.94	1.91	.68	1.60	1.31	.80	5.70
1/2-REC	1.33	1.33	2.76	-1.58	1.90	.49	.54	7.14

	ZONE 3		25 STATIONS		AVG 1/2 RECORD = 24 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.41	1.32	1.92	1.02	1.95	1.79	1.40	-1.85
10-YR	1.41	.81	1.80	.00	1.87	.96	1.01	5.39
1/2-REC	.98	.14	1.65	-1.88	1.17	.21	.39	4.80

	ZONE 4		15 STATIONS		AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.05	.94	1.20	.85	1.29	1.15	.94	-1.85
10-YR	-.52	-.50	.12	-.85	-.01	-.54	-.45	3.68
1/2-REC	.45	.02	1.63	-3.07	1.63	.46	.25	5.57

	ZONE 5		20 STATIONS		AVG 1/2 RECORD = 25 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.55	.35	1.03	.15	.98	.88	.47	-1.85
10-YR	.40	-.03	1.40	-.96	.61	.42	.19	7.37
1/2-REC	.81	-.40	2.91	-3.61	1.42	.99	.67	6.23

	ZONE 6		24 STATIONS		AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.80	.36	1.19	.15	1.11	.95	.45	-1.85
10-YR	1.43	.18	2.26	-.98	1.78	.96	.33	5.64
1/2-REC	1.08	-.45	2.94	-3.93	1.94	.07	-.04	6.14

	ZONE 7		21 STATIONS		AVG 1/2 RECORD = 20 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.15	1.19	1.69	1.29	1.62	1.59	1.29	-1.85
10-YR	1.58	1.36	2.34	.12	1.99	1.62	1.57	5.78
1/2-REC	1.97	1.00	2.45	-.74	2.07	.92	1.17	7.11

	ZONE 8		23 STATIONS		AVG 1/2 RECORD = 21 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.89	.79	1.71	.79	1.41	1.36	.79	-1.85
10-YR	-.66	-1.02	.29	-2.04	-.35	-.43	-1.02	4.52
1/2-REC	-.13	-.87	2.28	-3.08	.74	.66	-.87	7.88

TABLE 5 CONTINUED

ZONE 9 — 18 STATIONS — AVG 1/2 RECORD = 25 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	1.38	1.02	2.05	.96	1.96	1.78	1.10	-1.85
10-YR	1.95	1.54	2.54	.75	2.49	2.22	1.69	5.76
1/2-REC	.45	-.36	.97	-3.36	.45	-.07	-.27	4.07

ZONE 10 — 12 STATIONS — AVG 1/2 RECORD = 26 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	-.79	-.80	-.41	-.83	-.43	-.43	-.77	-1.85
10-YR	-.03	-.42	.90	-1.16	.71	.35	-.22	4.24
1/2-REC	.08	-1.27	1.24	-5.10	.58	-.27	-1.27	2.97

ZONE 11 — 13 STATIONS — AVG 1/2 RECORD = 23 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	1.29	1.21	1.89	1.20	1.93	1.75	1.11	-1.85
10-YR	1.11	1.03	2.21	.04	1.87	1.25	1.03	6.78
1/2 REC	.04	-.23	1.99	-2.93	1.20	1.20	-.23	5.32

ZONE 12 — 17 STATIONS — AVG 1/2 RECORD = 23 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	1.34	.73	1.34	.57	1.51	1.03	.80	-1.85
10-YR	.79	.41	.86	-.45	.92	-.44	.57	4.06
1/2-REC	.19	-.31	.54	-2.94	.92	-.35	-.19	2.81

ZONE 13 — 17 STATIONS — AVG 1/2 RECORD = 26 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	1.27	1.16	1.65	.96	1.77	1.52	1.19	-1.85
10-YR	.26	.22	.88	-.83	.67	.42	.38	4.60
1/2-REC	-.31	-1.52	.21	-4.89	.17	-.97	-1.12	2.88

ZONE 14 — 15 STATIONS — AVG 1/2 RECORD = 25 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	1.72	1.65	2.12	1.61	2.19	2.00	1.65	-1.85
10-YR	2.60	2.50	3.17	1.88	2.82	1.87	2.56	6.80
1/2-REC	.51	.61	1.83	-1.47	1.30	.29	.75	5.22

ZONE 15 — 3 STATIONS — AVG 1/2 RECORD = 20 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	2.47	2.47	2.74	2.55	2.66	2.28	2.28	-1.85
10-YR	1.27	1.27	1.58	1.27	1.58	1.58	1.27	2.65
1/2-REC	3.29	3.29	3.29	2.79	3.29	1.90	3.29	6.33

ZONE 16 — 13 STATIONS — AVG 1/2 RECORD = 24 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	.69	.75	1.03	.66	1.09	1.05	.75	-1.85
10-YR	.58	.42	.83	-.21	.76	.07	.42	4.24
1/2-REC	1.41	.07	1.68	-3.43	1.25	.64	.07	5.29

ALL ZONES — 287 STATIONS — AVG 1/2 RECORD = 23 YRS

METHOD	1	2	3	4	5	6	7	8
5-YR	.94	.79	1.38	.71	1.37	1.21	.81	-1.85
10-YR	.87	.52	1.52	-.29	1.26	.72	.60	5.27
1/2-REC	.77	.04	1.93	-2.66	1.34	.40	.17	5.36

Values shown are ratios by which the theoretical adjustment for Gaussian-distribution samples must be multiplied in order to convert from the computed 0.1 probability to average observed probabilities in the reserved data. See note table 7.

TABLE 6

ADJUSTMENT RATIOS FOR 100-YEAR FLOOD

SAMPLE SIZE METHOD	ZONE 1		27 STATIONS		AVG 1/2 RECORD = 26 YRS			
5-YR	1.35	1.11	1.27	.39	1.61	1.12	.88	-.25
10-YR	1.50	1.10	2.05	-.25	2.42	1.73	.73	3.42
1/2-REC	2.83	2.84	3.90	-1.06	4.89	3.67	1.66	5.28

	ZONE 2		24 STATIONS		AVG 1/2 RECORD = 22 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.91	.79	1.05	.31	1.27	1.13	.63	-.25
10-YR	1.44	1.40	2.48	.63	2.41	2.07	1.37	5.40
1/2-REC	1.00	1.08	3.69	-.82	2.97	2.46	.14	7.16

	ZONE 3		25 STATIONS		AVG 1/2 RECORD = 24 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.80	1.18	1.76	.41	2.05	1.86	1.29	-.25
10-YR	2.42	1.15	2.43	-.04	2.84	1.62	1.32	4.79
1/2-REC	2.90	1.41	3.36	-1.12	3.71	2.76	2.30	5.53

	ZONE 4		15 STATIONS		AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.67	1.48	1.45	.59	2.27	2.02	1.64	-.25
10-YR	.67	.35	.56	-.48	1.07	.46	.42	1.50
1/2-REC	1.86	.48	1.54	-1.15	2.83	.88	1.03	3.81

	ZONE 5		20 STATIONS		AVG 1/2 RECORD = 25 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.03	.64	1.37	.24	1.19	1.12	.82	-.25
10-YR	1.22	.57	1.42	-.29	1.27	1.09	.80	5.65
1/2-REC	2.97	.21	4.38	-1.24	2.97	2.39	1.68	7.25

	ZONE 6		24 STATIONS		AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.15	.67	1.02	.04	1.17	.88	.76	-.25
10-YR	2.30	.55	1.67	-.27	1.78	1.10	.66	4.43
1/2-REC	1.20	-.23	3.22	-1.24	2.45	.79	.46	5.09

	ZONE 7		21 STATIONS		AVG 1/2 RECORD = 20 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.04	1.07	2.23	.28	2.20	2.16	1.20	-.25
10-YR	1.18	1.09	2.66	-.19	2.54	2.20	1.53	5.40
1/2-REC	3.10	.47	3.92	-.80	2.99	2.29	1.74	8.33

	ZONE 8		23 STATIONS		AVG 1/2 RECORD = 21 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.57	.27	2.08	.01	1.66	1.52	.27	-.25
10-YR	1.30	.14	1.59	-.35	1.15	.93	.14	4.17
1/2-REC	.82	-.32	4.36	-1.13	2.16	2.16	-.32	8.49

TABLE 6 CONTINUED

ZONE 9		18 STATIONS		AVG 1/2 RECORD = 25 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.07	1.33	1.90	.72	2.11	2.11	1.50	-.25
10-YR	2.45	2.23	3.21	.90	3.75	3.55	2.57	4.39
1/2-REC	1.07	.39	2.90	-1.72	3.78	2.38	.66	4.49

ZONE 10		12 STATIONS		AVG 1/2 RECORD = 26 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	-.10	-.10	.27	-.25	.29	.29	-.06	-.25
10-YR	.21	-.15	.96	-.59	1.06	.75	.15	2.55
1/2-REC	3.29	-.27	1.63	-1.79	2.42	1.32	-.27	4.40

ZONE 11		13 STATIONS		AVG 1/2 RECORD = 23 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	.68	.70	1.79	.11	1.58	1.54	.66	-.25
10-YR	2.41	1.51	4.14	.17	3.76	3.43	1.28	6.64
1/2-REC	.30	.79	5.40	-1.08	3.05	2.43	.50	9.77

ZONE 12		17 STATIONS		AVG 1/2 RECORD = 23 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.81	1.10	1.16	.44	1.56	1.19	1.19	-.25
10-YR	1.99	1.93	1.55	.13	2.27	1.04	2.11	2.60
1/2-REC	3.77	1.65	2.12	-1.33	4.39	2.57	1.86	1.82

ZONE 13		17 STATIONS		AVG 1/2 RECORD = 26 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.63	.87	1.12	.50	1.63	1.26	1.04	-.25
10-YR	.58	.37	1.27	-.28	1.41	1.25	.60	3.28
1/2-REC	1.01	-.07	2.20	-1.81	2.57	1.61	.81	2.69

ZONE 14		15 STATIONS		AVG 1/2 RECORD = 25 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.54	1.44	1.79	.65	2.43	2.21	1.44	-.25
10-YR	2.92	2.22	2.58	.23	3.53	1.98	2.32	5.16
1/2-REC	2.11	2.80	3.76	-1.52	4.40	3.10	2.80	5.37

ZONE 15		3 STATIONS		AVG 1/2 RECORD = 20 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	2.09	2.24	2.24	1.24	2.76	1.98	1.50	-.25
10-YR	.26	.26	.26	-.59	1.84	1.84	.26	1.72
1/2-REC	1.80	1.80	.93	-1.31	4.37	3.16	.93	.93

ZONE 16		13 STATIONS		AVG 1/2 RECORD = 24 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	.61	.55	.90	.18	1.30	1.22	.62	-.25
10-YR	1.87	1.23	1.63	-.59	1.83	.99	1.33	3.64
1/2-REC	4.21	1.17	3.96	-1.27	4.41	2.90	2.13	4.46

ALL ZONES		287 STATIONS		AVG 1/2 RECORD = 23 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.16	.90	1.45	.32	1.65	1.45	.94	-.25
10-YR	1.64	1.03	2.01	-.07	2.20	1.62	1.12	4.25
1/2-REC	2.12	.87	3.40	-1.23	3.35	2.30	1.14	5.66

Values shown are ratios by which the theoretical adjustment for Gaussian-distribution samples must be multiplied in order to convert from the computed 0.01 probability to average observed probabilities in the reserved data. See note table 7.

TABLE 7

ADJUSTMENT RATIOS FOR 1000-YEAR FLOOD

SAMPLE SIZE	ZONE 1		27 STATIONS		AVG 1/2 RECORD = 26 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	2.03	1.10	1.19	.21	2.12	1.44	.85	-.04
10-YR	2.30	.88	2.21	-.14	2.98	1.87	.52	4.06
1/2-REC	5.01	4.13	6.94	-.56	10.11	8.16	1.66	8.54

	ZONE 2		24 STATIONS		AVG 1/2 RECORD = 22 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.31	.83	1.18	.15	1.57	1.35	.68	-.04
10-YR	1.98	2.85	3.85	.64	4.45	3.66	2.07	7.41
1/2-REC	1.93	2.11	4.47	-.45	3.56	3.56	1.58	8.81

	ZONE 3		25 STATIONS		AVG 1/2 RECORD = 24 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	2.42	1.22	2.18	-.01	2.54	2.08	1.24	-.04
10-YR	6.06	2.20	3.06	-.14	3.89	1.82	2.20	7.11
1/2-REC	7.41	2.44	6.77	-.51	7.06	4.82	2.77	11.16

	ZONE 4		15 STATIONS		AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.88	1.50	1.46	.30	2.48	2.05	1.63	-.04
10-YR	1.24	.54	.47	-.14	1.13	.36	.71	1.33
1/2-REC	2.86	.80	2.11	-.48	3.60	3.60	2.40	2.81

	ZONE 5		20 STATIONS		AVG 1/2 RECORD = 25 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.84	.94	1.36	.49	1.92	1.45	1.32	-.04
10-YR	2.75	.56	2.90	-.14	2.43	2.00	.91	6.02
1/2-REC	5.51	1.39	5.76	-.52	5.89	5.30	3.22	11.70

	ZONE 6		24 STATIONS		AVG 1/2 RECORD = 23 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.91	.61	1.08	.07	1.54	1.13	.79	-.04
10-YR	3.99	.57	1.73	-.06	2.33	1.57	1.12	4.53
1/2-REC	2.88	1.38	2.47	-.48	2.06	1.63	1.24	8.92

	ZONE 7		21 STATIONS		AVG 1/2 RECORD = 20 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	1.19	.82	1.91	.19	2.18	1.89	1.40	-.04
10-YR	2.33	.96	3.58	.13	3.25	2.15	1.53	6.52
1/2-REC	5.99	1.48	5.36	.16	3.90	3.90	2.34	12.51

	ZONE 8		23 STATIONS		AVG 1/2 RECORD = 21 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.83	.09	1.28	-.01	.83	.83	.14	-.04
10-YR	2.79	.42	2.68	-.14	1.78	1.78	.42	5.90
1/2-REC	2.70	.84	7.62	-.41	3.54	3.54	1.32	13.61

	ZONE 9		18 STATIONS		AVG 1/2 RECORD = 25 YRS			
METHOD	1	2	3	4	5	6	7	8
5-YR	.90	1.30	1.37	.49	2.33	2.33	1.55	-.04
10-YR	3.61	3.59	3.22	.42	5.85	5.85	3.90	6.24
1/2-REC	3.59	.59	3.97	-.53	2.68	1.04	1.07	6.92

TABLE 7 CONTINUED

ZONE 10		12 STATIONS		AVG 1/2 RECORD = 26 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	.02	-.04	.25	-.04	.22	.22	-.04	-.04
10-YR	.44	-.14	.70	-.14	.67	.43	-.14	3.79
1/2-REC	7.21	.27	3.04	-.56	1.95	1.95	.27	4.50

ZONE 11		13 STATIONS		AVG 1/2 RECORD = 23 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.13	1.01	2.15	.20	2.13	1.78	.94	-.04
10-YR	4.31	2.44	5.95	.72	5.06	3.58	1.90	10.41
1/2-REC	1.74	.91	6.38	-.46	5.01	4.24	.91	15.65

ZONE 12		17 STATIONS		AVG 1/2 RECORD = 23 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	2.84	1.22	1.31	.45	2.03	1.51	1.27	-.04
10-YR	4.30	2.17	2.52	.10	4.27	1.40	2.17	3.37
1/2-REC	8.58	.75	.75	-.46	2.20	1.34	.75	4.59

ZONE 13		17 STATIONS		AVG 1/2 RECORD = 26 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.89	1.21	1.11	.32	1.92	1.79	1.21	-.04
10-YR	1.27	.36	1.39	-.14	1.77	1.77	.53	3.56
1/2-REC	4.01	-.57	2.83	-.57	3.65	2.43	.55	4.96

ZONE 14		15 STATIONS		AVG 1/2 RECORD = 25 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.91	1.45	1.56	.47	2.66	2.03	1.45	-.04
10-YR	5.41	2.35	2.81	-.14	4.63	2.17	2.35	5.56
1/2-REC	3.45	1.04	5.12	-.53	9.90	6.99	1.04	6.69

ZONE 15		3 STATIONS		AVG 1/2 RECORD = 20 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	2.67	3.00	2.54	-.04	3.51	1.25	1.77	-.04
10-YR	-.14	-.14	-.14	-.14	1.87	1.87	-.14	-.14
1/2-REC	2.17	2.17	-.38	-.38	6.15	6.15	-.38	-.38

ZONE 16		13 STATIONS		AVG 1/2 RECORD = 24 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	.69	.62	1.15	-.04	1.40	1.18	.69	-.04
10-YR	4.02	1.56	3.05	-.14	3.90	1.97	2.01	4.46
1/2-REC	8.74	2.37	7.24	-.51	8.30	6.21	3.76	7.24

ALL ZONES		287 STATIONS		AVG 1/2 RECORD = 23 YRS				
METHOD	1	2	3	4	5	6	7	8
5-YR	1.60	.95	1.40	.21	1.89	1.54	1.01	-.04
10-YR	3.13	1.40	2.66	.04	3.22	2.19	1.45	5.36
1/2-REC	4.66	1.49	4.81	-.45	4.99	4.02	1.68	8.80

Values shown are ratios by which the theoretical adjustment for Gaussian-distribution samples must be multiplied in order to convert from the computed 0.001 probability to average observed probabilities in the reserved data.

Table 7 Continued

Values in tables 5-7 are obtained as follows:

a. Compute the magnitude corresponding to a given exceedence probability for the best-fit function.

b. Count proportion of values in remainder of record that exceed this magnitude.

c. Subtract the specified probability from b.

d. Compute the Gaussian deviate that would correspond to the specified probability.

e. Compute the expected probability for the given sample size (record length used) and the Gaussian deviate determined in d.

f. Subtract the specified probability from e.

g. Divide f by c.

Table 8

STANDARD DEVIATION COMPARISONS

AVERAGE FOR ZONES 1 TO 16

COMPUTED PROBABILITY	METHOD 1	2	3	4	5	6	7	8
	AVERAGE OBSERVED PROBABILITIES							
.001	.0105	.0041	.0109	.0001	.0110	.0092	.0045	.0009
.01	.0232	.0153	.0315	.0023	.0309	.0244	.0170	.0015
.1	.1088	.1007	.1219	.0707	.1152	.1047	.1020	.0029
.5	.5090	.5149	.4576	.6152	.4713	.4950	.5108	.0037
	STANDARD DEVIATION OF OBSERVED PROBABILITIES FOR SPECIFIED COMPUTED PROBABILITIES							
.001	.0290	.0134	.0244	.0025	.0239	.0218	.0150	.0222
.01	.0430	.029	.045	.010	.043	.039	.032	.035
.1	.086	.084	.089	.074	.089	.084	.084	.067
.5	.132	.131	.142	.133	.133	.141	.130	.123

Note: Averages and standard deviations are of observed frequencies in the reserved portion of each record corresponding to computed mangitudes based on half records. Low standard deviations in relation to averages indicate more reliable estimates.

TABLE 9

ACCURACY RESULTS RATIOS

MAXIMUM (a), DECILE (b) AND MEDIAN (c) FLOWS

ZONE		METHOD 1	2	3	4	5	6	7	8
1	a	.56	.63	.60	.50	.66	.64	.56	.58
	b	.43	.46	.44	.35	.47	.46	.40	.41
	c	.46	.17	.65	.22	.61	.50	.20	.57
2	a	.45	.53	.57	.49	.55	.58	.48	.61
	b	.31	.33	.34	.28	.33	.34	.28	.36
	c	.45	.11	.69	.17	.62	.44	.12	.56
3	a	.57	.57	.61	.50	.60	.58	.56	.64
	b	.43	.38	.40	.30	.40	.39	.40	.40
	c	.36	.11	.57	.18	.56	.44	.13	.47
4	a	.48	.52	.51	.47	.56	.56	.55	.50
	b	.35	.30	.29	.23	.32	.32	.32	.28
	c	.38	.09	.63	.15	.55	.35	.11	.42
5	a	.58	.47	.55	.41	.56	.56	.53	.56
	b	.40	.33	.36	.28	.37	.37	.37	.38
	c	.43	.13	.69	.21	.59	.47	.16	.57
6	a	.52	.47	.50	.44	.50	.50	.48	.56
	b	.33	.31	.36	.23	.34	.35	.32	.38
	c	.40	.13	.59	.21	.59	.47	.15	.49
7	a	.57	.55	.62	.50	.60	.62	.58	.68
	b	.40	.34	.40	.30	.38	.38	.39	.49
	c	.44	.12	.76	.17	.68	.53	.15	.57
8	a	.49	.41	.59	.41	.50	.53	.41	.64
	b	.29	.27	.41	.25	.32	.36	.28	.46
	c	.42	.12	.75	.19	.60	.51	.14	.57
9	a	.54	.50	.56	.40	.56	.55	.53	.58
	b	.33	.29	.32	.22	.32	.31	.31	.35
	c	.43	.12	.60	.18	.55	.43	.13	.54
10	a	.59	.45	.49	.46	.51	.52	.47	.52
	b	.38	.24	.26	.18	.27	.27	.25	.28
	c	.29	.09	.52	.17	.46	.30	.09	.39
11	a	.39	.44	.58	.43	.49	.48	.41	.64
	b	.28	.36	.42	.35	.36	.38	.34	.50
	c	.42	.11	.75	.19	.66	.48	.15	.61
12	a	.61	.51	.47	.46	.52	.53	.51	.54
	b	.50	.45	.37	.36	.45	.43	.45	.40
	c	.21	.10	.46	.17	.45	.27	.12	.31
13	a	.47	.50	.48	.39	.53	.51	.52	.51
	b	.35	.27	.32	.21	.30	.30	.28	.32
	c	.24	.10	.54	.17	.56	.29	.10	.43
14	a	.53	.62	.58	.48	.66	.62	.61	.56
	b	.37	.40	.35	.28	.42	.39	.40	.31
	c	.43	.08	.69	.14	.65	.45	.12	.55
15	a	.57	.67	.44	.56	.65	.68	.54	.40
	b	.34	.43	.27	.39	.36	.36	.35	.21
	c	.59	.12	.71	.23	.71	.62	.18	.53

TABLE 9 CONTINUED

16	a	.70	.61	.66	.50	.70	.65	.62	.63
	b	.51	.43	.49	.33	.50	.47	.44	.42
	c	.43	.15	.65	.23	.60	.49	.17	.51
17	a	.39	.29	.59	.29	.36	.38	.29	.71
	b	.21	.20	.47	.15	.30	.34	.19	.63
	c	.41	.11	.86	.18	.65	.54	.12	.70
AVG	a	.53	.51	.56	.45	.56	.56	.51	.59
	b	.37	.34	.38	.27	.37	.37	.34	.40
	c	.40	.12	.65	.19	.59	.44	.14	.52

Values are root mean square differences between 1.0 and ratio of computed probability of flow in opposite half of record to plotting position. Thus, a value of zero would indicate a perfect forecast.

TABLE 10

ACCURACY RESULTS DIFFERENCES

MAXIMUM (a), DECILE (b) AND MEDIAN (c) FLOWS

		METHOD							
ZONE		1	2	3	4	5	6	7	8
1	a	.06	.06	.07	.05	.07	.07	.06	.07
	b	.10	.11	.12	.08	.13	.12	.10	.11
	c	.31	.13	.72	.25	.63	.34	.16	.97
2	a	.06	.06	.07	.05	.07	.07	.06	.06
	b	.07	.07	.09	.05	.09	.09	.07	.07
	c	.25	.10	.67	.17	.52	.28	.11	.65
3	a	.07	.07	.08	.06	.08	.08	.07	.07
	b	.10	.09	.12	.07	.12	.11	.10	.08
	c	.24	.10	.62	.22	.48	.29	.11	.61
4	a	.06	.06	.07	.05	.07	.07	.06	.06
	b	.09	.08	.10	.06	.10	.09	.08	.09
	c	.23	.09	.51	.15	.46	.25	.10	.47
5	a	.07	.07	.08	.06	.07	.07	.07	.06
	b	.09	.08	.09	.07	.10	.09	.09	.08
	c	.29	.11	.72	.22	.55	.34	.13	.87
6	a	.06	.06	.07	.06	.07	.08	.06	.07
	b	.08	.08	.09	.06	.09	.09	.08	.09
	c	.27	.12	.67	.22	.55	.31	.13	.78
7	a	.07	.07	.08	.07	.08	.08	.07	.07
	b	.10	.10	.12	.08	.12	.12	.10	.09
	c	.29	.11	.76	.16	.59	.30	.13	.71
8	a	.06	.06	.07	.05	.07	.07	.06	.05
	b	.07	.06	.08	.05	.08	.08	.06	.07
	c	.25	.11	.81	.18	.54	.33	.12	.94
9	a	.06	.06	.06	.05	.07	.07	.06	.06
	b	.09	.08	.09	.06	.09	.09	.08	.08
	c	.25	.11	.60	.17	.48	.28	.12	.67
10	a	.06	.06	.06	.06	.06	.06	.06	.06
	b	.07	.06	.07	.05	.07	.07	.06	.07
	c	.19	.08	.37	.15	.29	.18	.09	.39
11	a	.04	.04	.03	.04	.04	.03	.04	.04
	b	.09	.09	.11	.07	.10	.10	.08	.10
	c	.28	.10	.83	.24	.61	.35	.13	1.01
12	a	.07	.07	.08	.06	.08	.08	.07	.08
	b	.10	.09	.09	.07	.10	.09	.09	.09
	c	.19	.09	.40	.18	.38	.23	.10	.54
13	a	.05	.05	.05	.05	.05	.06	.05	.06
	b	.07	.06	.07	.05	.08	.07	.06	.07
	c	.17	.09	.46	.14	.36	.19	.10	.45
14	a	.05	.05	.06	.04	.06	.06	.05	.05
	b	.06	.06	.07	.05	.07	.07	.06	.06
	c	.26	.07	.62	.19	.56	.30	.10	.67
15	a	.08	.07	.08	.06	.09	.08	.07	.08
	b	.09	.10	.09	.08	.11	.10	.09	.07
	c	.35	.11	.73	.34	.74	.46	.15	.73

TABLE 10 CONTINUED

16	a	.08	.07	.08	.07	.08	.08	.07	.07
	b	.12	.11	.13	.08	.13	.12	.11	.10
	c	.27	.13	.66	.21	.53	.33	.14	.79
17	a	.05	.05	.05	.05	.06	.05	.05	.04
	b	.06	.05	.08	.04	.07	.07	.05	.07
	c	.24	.10	.97	.17	.57	.35	.11	.94
AVG	a	.062	.060	.067	.056	.070	.069	.061	.061
	b	.084	.080	.097	.063	.098	.094	.081	.082
	c	.254	.105	.657	.193	.518	.295	.120	.727

Values are root mean square difference between plotting position and computed probability in other half of record.

TABLE 11

CONSISTENCY RESULTS RATIOS

EXTREME (a), MAXIMUM (b), DECILE (c), AND MEDIAN (d) FLOWS

ZONE		METHOD 1	2	3	4	5	6	7	8
1	a	.85	.63	.49	.30	.42	.38	.32	.82
	b	.79	.54	.42	.25	.38	.35	.27	.72
	c	.56	.39	.33	.19	.28	.24	.19	.58
	d	.25	.19	.16	.14	.11	.10	.10	.29
2	a	.83	.54	.41	.28	.38	.37	.27	.68
	b	.67	.45	.39	.24	.33	.30	.23	.74
	c	.45	.31	.29	.18	.22	.20	.16	.60
	d	.22	.12	.10	.08	.07	.06	.06	.24
3	a	.90	.55	.44	.28	.38	.35	.29	.72
	b	.79	.48	.39	.24	.32	.29	.26	.73
	c	.57	.35	.31	.18	.25	.20	.20	.58
	d	.22	.14	.13	.10	.09	.09	.08	.26
4	a	.89	.52	.47	.26	.38	.35	.29	.80
	b	.71	.47	.41	.23	.34	.30	.26	.71
	c	.53	.34	.31	.17	.26	.22	.19	.53
	d	.17	.12	.12	.09	.08	.08	.06	.21
5	a	.90	.51	.46	.25	.39	.36	.28	.83
	b	.77	.42	.41	.20	.34	.31	.25	.71
	c	.52	.30	.31	.15	.24	.21	.18	.57
	d	.23	.15	.13	.11	.09	.09	.08	.24
6	a	.91	.49	.46	.22	.38	.32	.27	.79
	b	.75	.41	.42	.18	.33	.25	.23	.71
	c	.52	.31	.34	.14	.25	.20	.17	.58
	d	.21	.16	.13	.12	.10	.09	.08	.27
7	a	.88	.60	.48	.27	.42	.38	.33	.83
	b	.74	.52	.50	.24	.39	.34	.30	.82
	c	.57	.37	.39	.19	.29	.25	.21	.73
	d	.25	.16	.14	.11	.10	.07	.08	.29
8	a	.88	.52	.42	.23	.38	.34	.28	.66
	b	.71	.38	.39	.18	.31	.28	.21	.71
	c	.42	.26	.32	.13	.22	.20	.14	.61
	d	.18	.13	.09	.09	.07	.07	.07	.23
9	a	.87	.55	.49	.25	.40	.36	.31	.81
	b	.79	.45	.41	.20	.34	.30	.26	.75
	c	.52	.31	.31	.15	.24	.19	.18	.60
	d	.19	.12	.11	.08	.08	.08	.06	.25
10	a	.94	.51	.47	.21	.40	.34	.28	.80
	b	.80	.40	.38	.16	.33	.27	.22	.67
	c	.49	.24	.27	.12	.20	.16	.13	.51
	d	.18	.10	.09	.06	.06	.07	.05	.21
11	a	.80	.52	.44	.28	.37	.34	.26	.76
	b	.58	.38	.40	.22	.29	.26	.20	.80
	c	.31	.26	.27	.15	.18	.17	.14	.65
	d	.23	.14	.08	.09	.07	.06	.07	.26
12	a	.93	.59	.46	.27	.40	.34	.33	.76
	b	.81	.50	.38	.22	.35	.29	.28	.61
	c	.64	.37	.29	.17	.26	.22	.20	.49
	d	.15	.11	.11	.08	.07	.06	.06	.17

TABLE 11 CONTINUED

13	a	.82	.48	.38	.22	.33	.33	.27	.58
	b	.64	.37	.30	.17	.28	.27	.21	.47
	c	.41	.23	.22	.11	.17	.15	.13	.36
	d	.17	.11	.10	.07	.07	.06	.06	.17
14	a	.82	.61	.49	.30	.42	.38	.33	.91
	b	.72	.51	.40	.24	.37	.32	.27	.75
	c	.45	.31	.27	.16	.23	.19	.17	.50
	d	.17	.11	.09	.08	.06	.07	.06	.19
15	a	.95	.66	.50	.27	.44	.40	.33	.72
	b	.85	.59	.43	.25	.41	.34	.28	.65
	c	.71	.49	.37	.23	.35	.28	.24	.57
	d	.26	.19	.18	.16	.12	.13	.11	.32
16	a	.89	.59	.51	.27	.42	.36	.32	.83
	b	.91	.51	.47	.23	.39	.32	.28	.81
	c	.63	.37	.36	.19	.28	.24	.20	.60
	d	.23	.17	.16	.12	.11	.11	.09	.28
17	a	.89	.43	.44	.21	.39	.34	.24	.40
	b	.64	.27	.41	.14	.28	.25	.15	.77
	c	.29	.19	.32	.10	.19	.18	.10	.69
	d	.17	.12	.07	.09	.07	.06	.06	.20
AVG	a	.87	.54	.46	.26	.39	.35	.29	.75
	b	.74	.45	.41	.21	.34	.30	.24	.72
	c	.50	.32	.31	.16	.24	.21	.17	.58
	d	.21	.14	.12	.10	.08	.08	.07	.24

Values are root mean square difference between 1.0 and ratio of computed probabilities in 2 halves of record. Thus, a value of zero would indicate perfect consistency. The extreme flow is the maximum recorded flow multiplied by the square root of the ratio of maximum to median flows.

TABLE 12

CONSISTENCY RESULTS DIFFERENCES

EXTREME (a), MAXIMUM (b), DECILE (c), AND MEDIAN (d) FLOWS

ZONE		METHOD 1	2	3	4	5	6	7	8
1	a	.002	.003	.002	.008	.001	.003	.002	.003
	b	.019	.015	.009	.015	.007	.010	.008	.014
	c	.086	.061	.054	.031	.046	.040	.030	.073
	d	.153	.114	.105	.075	.071	.064	.060	.173
2	a	.003	.005	.001	.010	.001	.003	.003	.002
	b	.019	.016	.007	.016	.007	.010	.009	.011
	c	.065	.046	.046	.026	.036	.032	.023	.042
	d	.128	.066	.059	.041	.041	.037	.036	.129
3	a	.004	.008	.001	.015	.001	.002	.004	.001
	b	.026	.023	.008	.021	.008	.008	.012	.011
	c	.082	.054	.047	.030	.039	.033	.030	.046
	d	.124	.079	.082	.051	.052	.051	.042	.131
4	a	.005	.004	.000	.006	.001	.001	.002	.000
	b	.025	.016	.009	.013	.008	.009	.008	.011
	c	.074	.050	.044	.026	.039	.033	.028	.051
	d	.094	.066	.070	.041	.044	.046	.035	.113
5	a	.002	.009	.001	.010	.001	.002	.004	.002
	b	.020	.023	.007	.014	.008	.011	.012	.011
	c	.070	.049	.041	.023	.035	.033	.028	.044
	d	.138	.087	.084	.053	.058	.052	.047	.137
6	a	.003	.007	.002	.009	.002	.003	.004	.003
	b	.031	.021	.011	.014	.010	.009	.011	.017
	c	.076	.050	.051	.023	.041	.035	.027	.069
	d	.127	.092	.082	.058	.059	.054	.049	.159
7	a	.003	.006	.001	.011	.001	.003	.002	.001
	b	.028	.025	.012	.020	.012	.015	.013	.017
	c	.078	.059	.060	.030	.051	.047	.033	.052
	d	.142	.087	.085	.049	.058	.041	.047	.155
8	a	.004	.009	.002	.013	.001	.002	.005	.003
	b	.025	.023	.008	.018	.009	.009	.012	.014
	c	.058	.039	.043	.022	.034	.032	.021	.026
	d	.108	.070	.058	.040	.044	.039	.037	.131
9	a	.003	.006	.001	.011	.001	.005	.003	.002
	b	.023	.021	.011	.017	.009	.015	.011	.016
	c	.073	.045	.037	.023	.032	.029	.025	.056
	d	.107	.059	.063	.033	.041	.040	.032	.124
10	a	.002	.003	.000	.008	.000	.001	.001	.001
	b	.022	.014	.006	.012	.006	.006	.007	.008
	c	.064	.033	.029	.016	.026	.021	.018	.037
	d	.100	.049	.048	.026	.032	.036	.026	.101
11	a	.003	.005	.000	.007	.000	.000	.003	.000
	b	.015	.013	.003	.013	.005	.005	.007	.003
	c	.041	.034	.035	.022	.027	.026	.017	.052
	d	.125	.075	.052	.046	.043	.035	.040	.134
12	a	.004	.006	.002	.011	.001	.002	.003	.004
	b	.026	.022	.012	.018	.010	.011	.012	.020
	c	.075	.046	.033	.023	.031	.028	.025	.041
	d	.086	.063	.061	.039	.042	.034	.034	.088

TABLE 12 CONTINUED

13	a	.003	.004	.001	.011	.000	.005	.002	.001
	b	.015	.016	.006	.016	.005	.014	.008	.011
	c	.066	.039	.031	.021	.027	.027	.021	.045
	d	.089	.052	.056	.030	.036	.031	.028	.084
14	a	.002	.000	.000	.004	0.000	0.000	.000	.000
	b	.015	.008	.003	.010	.002	.003	.004	.004
	c	.063	.042	.034	.022	.032	.026	.023	.045
	d	.098	.063	.059	.041	.039	.040	.034	.104
15	a	.006	.002	.001	.004	.000	.003	.002	.000
	b	.031	.015	.010	.013	.008	.009	.009	.010
	c	.086	.059	.041	.030	.039	.034	.030	.047
	d	.160	.123	.115	.091	.078	.084	.067	.167
16	a	.002	.006	.001	.009	.000	.005	.003	.001
	b	.023	.019	.008	.017	.007	.011	.010	.013
	c	.118	.058	.058	.031	.047	.040	.032	.067
	d	.135	.291	.094	.055	.061	.060	.049	.154
17	a	.007	.012	0.000	.014	.001	.000	.006	.000
	b	.030	.020	.002	.015	.007	.006	.011	.001
	c	.040	.026	.031	.015	.025	.022	.014	.011
	d	.102	.067	.042	.042	.038	.034	.036	.114
AVG	a	.003	.006	.001	.010	.001	.002	.003	.002
	b	.023	.019	.008	.016	.008	.010	.010	.012
	c	.072	.047	.043	.025	.037	.033	.025	.048
	d	.119	.076	.072	.047	.049	.045	.041	.131

Values are root mean square difference between computed probabilities in 2 halves of record. Extreme flow is the maximum recorded flow multiplied by the square root of the ratio of maximum to median flows.

Table 13
Accuracy Results
Outlier Ratios for Maximum Flows

ZONE		METHOD 1	2	3	4	5	6	7
1	a	.60	.70	.64	.54	.73	.70	.59
	b	.70	.73	.66	.60	.76	.73	.62
	c	.73	.75	.68	.62	.78	.76	.66
	d	.76	.76	.71	.67	.79	.73	.71
2	a	.42	.61	.69	.54	.64	.66	.54
	b	.48	.64	.72	.56	.69	.70	.58
	c	.56	.69	.75	.59	.76	.72	.62
	d	.68	.75	.78	.65	.78	.78	.68
3	a	.44	.64	.62	.58	.62	.65	.61
	b	.68	.72	.70	.61	.73	.69	.71
	c	.73	.71	.71	.64	.72	.70	.71
	d	.74	.71	.70	.67	.72	.71	.72
4	a	.45	.48	.53	.38	.57	.57	.51
	b	.44	.51	.49	.36	.54	.57	.51
	c	.50	.53	.50	.37	.56	.59	.54
	d	.60	.56	.53	.41	.60	.55	.59
5	a	.66	.45	.59	.34	.60	.57	.52
	b	.55	.55	.59	.39	.59	.57	.62
	c	.58	.60	.60	.44	.62	.61	.64
	d	.60	.64	.63	.57	.67	.65	.64
6	a	.47	.49	.52	.52	.51	.53	.49
	b	.47	.50	.51	.51	.51	.55	.50
	c	.49	.51	.50	.51	.52	.53	.51
	d	.59	.57	.51	.54	.58	.55	.54
7	a	.56	.53	.60	.46	.59	.59	.53
	b	.58	.58	.60	.53	.59	.56	.60
	c	.56	.62	.69	.61	.65	.68	.64
	d	.62	.73	.79	.71	.82	.84	.77
8	a	.49	.39	.50	.43	.41	.44	.39
	b	.46	.38	.52	.44	.41	.46	.37
	c	.31	.41	.55	.46	.45	.46	.39
	d	.44	.49	.58	.48	.51	.55	.48
9	a	.53	.49	.54	.39	.55	.50	.50
	b	.54	.49	.52	.39	.55	.51	.52
	c	.64	.53	.53	.42	.60	.51	.56
	d	.73	.57	.56	.47	.66	.51	.60
10	a	.65	.51	.45	.44	.56	.56	.55
	b	.59	.56	.47	.43	.58	.59	.56
	c	.54	.56	.48	.44	.59	.61	.56
	d	.61	.59	.51	.46	.64	.60	.59
11	a	.45	.42	.52	.54	.28	.37	.36
	b	.53	.55	.66	.63	.53	.58	.46
	c	.64	.65	.76	.67	.65	.51	.59
	d	.68	.65	.86	.67	.68	.59	.65
12	a	.78	.58	.47	.46	.59	.56	.59
	b	.72	.60	.45	.46	.60	.55	.62
	c	.65	.63	.45	.51	.61	.52	.66
	d	.64	.65	.47	.56	.64	.51	.69

Table 13 Continued

13	a	.36	.63	.55	.48	.62	.58	.67
	b	.57	.66	.56	.51	.64	.63	.67
	c	.59	.68	.57	.52	.67	.68	.70
	d	.65	.70	.62	.61	.70	.69	.70
14	a	.56	.56	.55	.43	.61	.60	.55
	b	.54	.58	.56	.45	.61	.61	.57
	c	.50	.60	.56	.48	.62	.63	.60
	d	.49	.64	.58	.54	.66	.70	.63
15	a	.18	.28	.03	.07	.17	.28	.13
	b	.09	.39	.10	.27	.24	.20	.21
	c	.06	.46	.16	.49	.29	.42	.27
	d	.05	.50	.19	.67	.31	.44	.30
16	a	.59	.66	.60	.43	.74	.68	.68
	b	.71	.77	.66	.44	.85	.80	.79
	c	.79	.78	.67	.46	.84	.83	.78
	d	.85	.78	.73	.57	.82	.80	.79
17	a	.24	.26	.60	.29	.31	.36	.27
	b	.22	.27	.60	.27	.32	.39	.30
	c	.19	.25	.58	.26	.30	.38	.29
	d	.52	.21	.56	.23	.25	.34	.24
AVG	a	.53	.55	.57	.47	.58	.58	.54
	b	.57	.59	.59	.49	.62	.60	.58
	c	.58	.61	.60	.52	.64	.63	.60
	d	.65	.65	.64	.58	.68	.65	.64

Values are root mean square differences between 1.0 and ratio of computed probability of flow in opposite half of record to plotting position. Top value is for outlier method a, second for method b, third for method c, and bottom for outlier method d, as defined on page 15. A value of zero would indicate perfect forecasts.

Method 8 includes its unique technique for outliers and was therefore not included in this test.

Table 14
Accuracy Results
Outlier Differences for Maximum Flows

ZONE		METHOD 1	2	3	4	5	6	7
1	a	.063	.059	.067	.050	.072	.070	.059
	b	.058	.054	.060	.046	.064	.064	.054
	c	.054	.051	.056	.044	.060	.062	.051
	d	.045	.045	.050	.039	.054	.056	.046
2	a	.066	.071	.103	.052	.097	.093	.070
	b	.062	.066	.093	.049	.089	.090	.065
	c	.058	.058	.070	.044	.074	.068	.057
	d	.051	.048	.055	.040	.057	.054	.048
3	a	.070	.077	.091	.072	.091	.087	.077
	b	.070	.069	.074	.065	.077	.072	.069
	c	.066	.062	.064	.058	.068	.065	.062
	d	.054	.050	.052	.052	.055	.056	.051
4	a	.065	.077	.092	.065	.099	.090	.077
	b	.054	.053	.059	.049	.065	.066	.054
	c	.049	.045	.050	.041	.054	.060	.046
	d	.038	.032	.038	.031	.038	.047	.033
5	a	.032	.043	.031	.043	.036	.034	.042
	b	.026	.029	.028	.041	.028	.026	.028
	c	.025	.027	.027	.037	.027	.025	.027
	d	.026	.026	.027	.033	.027	.028	.026
6	a	.059	.057	.064	.063	.071	.076	.058
	b	.057	.055	.057	.061	.064	.069	.056
	c	.053	.051	.050	.055	.056	.051	.051
	d	.051	.046	.048	.049	.052	.049	.047
7	a	.054	.050	.076	.043	.083	.079	.050
	b	.048	.044	.049	.042	.052	.046	.045
	c	.046	.045	.050	.042	.052	.050	.046
	d	.050	.050	.055	.045	.058	.055	.051
8	a	.074	.074	.069	.070	.075	.071	.075
	b	.061	.062	.056	.064	.060	.067	.064
	c	.055	.056	.055	.058	.058	.062	.057
	d	.052	.051	.054	.052	.056	.060	.052
9	a	.073	.069	.074	.062	.079	.081	.070
	b	.065	.059	.064	.055	.068	.070	.060
	c	.062	.055	.060	.051	.063	.062	.055
	d	.056	.049	.054	.045	.056	.048	.050
10	a	.082	.078	.074	.078	.082	.076	.079
	b	.079	.075	.073	.075	.080	.075	.076
	c	.076	.072	.071	.071	.078	.073	.073
	d	.075	.071	.071	.067	.078	.080	.071
11	a	.018	.033	.031	.048	.020	.025	.033
	b	.028	.036	.036	.049	.030	.032	.036
	c	.033	.036	.039	.049	.034	.028	.037
	d	.036	.036	.042	.048	.037	.033	.036
12	a	.065	.060	.070	.058	.071	.070	.060
	b	.057	.051	.058	.051	.058	.052	.051
	c	.052	.048	.053	.046	.054	.048	.048
	d	.047	.045	.049	.042	.051	.043	.045

Table 14 Continued

13	a	.040	.055	.051	.064	.054	.055	.055
	b	.036	.050	.046	.060	.048	.049	.050
	c	.039	.045	.045	.055	.046	.040	.045
	d	.040	.041	.044	.050	.044	.038	.040
14	a	.064	.058	.066	.052	.071	.065	.059
	b	.061	.056	.064	.050	.068	.063	.057
	c	.055	.051	.056	.048	.060	.056	.052
	d	.044	.042	.046	.042	.048	.049	.042
15	a	.018	.025	.003	.008	.017	.049	.014
	b	.010	.031	.011	.024	.022	.032	.020
	c	.007	.034	.016	.036	.025	.033	.024
	d	.005	.036	.019	.041	.027	.033	.026
16	a	.059	.054	.073	.044	.078	.071	.055
	b	.058	.052	.065	.043	.071	.068	.053
	c	.050	.045	.046	.039	.053	.051	.046
	d	.039	.034	.032	.031	.037	.036	.035
17	a	.041	.048	.043	.052	.048	.053	.049
	b	.040	.048	.042	.049	.048	.053	.050
	c	.032	.043	.035	.046	.039	.048	.045
	d	.033	.031	.026	.038	.025	.037	.033
AVG	a	.061	.062	.071	.057	.074	.073	.062
	b	.056	.055	.060	.053	.063	.062	.055
	c	.052	.050	.054	.048	.057	.055	.051
	d	.047	.045	.048	.044	.051	.050	.045

Values are root mean square difference between plotting position of flow in one half of a record and computed probability in other half of record for that same flow. Top value is for outlier method a, second for method b, third for method c, and bottom for method d, as defined on page 14.

Method 8 includes its unique technique for outliers and was therefore not included in this test.

Table 15
Consistency Results
Outlier Ratios for Maximum Flows

ZONE		METHOD 1	2	3	4	5	6	7
1	a	.84	.64	.50	.30	.43	.37	.33
	b	.89	.62	.50	.30	.40	.37	.31
	c	.81	.61	.50	.32	.40	.37	.31
	d	.84	.60	.49	.35	.38	.37	.31
2	a	.86	.58	.43	.30	.40	.39	.30
	b	.83	.57	.44	.31	.39	.34	.30
	c	.94	.61	.42	.30	.38	.33	.32
	d	.91	.63	.39	.33	.37	.33	.32
3	a	.89	.57	.45	.29	.39	.35	.28
	b	.93	.59	.45	.30	.40	.36	.30
	c	.88	.60	.42	.31	.37	.37	.30
	d	.86	.60	.45	.33	.38	.35	.31
4	a	.87	.55	.51	.29	.39	.39	.31
	b	.86	.55	.46	.32	.39	.37	.31
	c	.91	.53	.45	.33	.36	.34	.29
	d	.93	.58	.44	.33	.41	.37	.32
5	a	.92	.57	.46	.27	.39	.35	.30
	b	.97	.58	.47	.30	.40	.34	.32
	c	.86	.59	.47	.32	.40	.35	.33
	d	.93	.60	.44	.34	.39	.34	.34
6	a	.97	.54	.44	.26	.40	.32	.30
	b	.93	.56	.45	.26	.41	.35	.31
	c	.91	.57	.46	.28	.38	.35	.32
	d	.93	.61	.46	.30	.40	.36	.33
7	a	.87	.64	.50	.28	.44	.40	.36
	b	.86	.62	.47	.28	.37	.32	.33
	c	.86	.58	.45	.28	.36	.32	.32
	d	.93	.65	.48	.31	.39	.36	.35
8	a	.93	.53	.47	.20	.40	.37	.28
	b	.82	.52	.40	.20	.37	.38	.28
	c	.74	.50	.40	.20	.37	.37	.27
	d	.79	.56	.46	.22	.37	.34	.30
9	a	.91	.58	.49	.26	.40	.35	.32
	b	.88	.58	.49	.28	.40	.38	.32
	c	.92	.61	.48	.30	.40	.39	.33
	d	.91	.65	.53	.33	.41	.36	.36
10	a	.90	.47	.48	.22	.39	.34	.26
	b	.83	.48	.46	.26	.36	.34	.26
	c	.93	.44	.43	.26	.40	.37	.24
	d	.98	.47	.42	.25	.40	.35	.26
11	a	.77	.47	.45	.22	.37	.32	.23
	b	.79	.45	.46	.21	.35	.30	.23
	c	.89	.52	.49	.22	.34	.29	.27
	d	.97	.55	.51	.30	.42	.37	.29
12	a	1.00	.59	.47	.27	.39	.34	.33
	b	.93	.59	.47	.29	.39	.35	.32
	c	.92	.60	.47	.31	.39	.38	.33
	d	.96	.62	.48	.34	.38	.35	.35

Table 15 Continued

13	a	.85	.54	.36	.22	.35	.34	.31
	b	.81	.54	.36	.23	.38	.29	.30
	c	.68	.54	.38	.23	.39	.31	.30
	d	.84	.54	.40	.24	.38	.35	.30
14	a	.82	.58	.49	.31	.41	.39	.31
	b	.84	.57	.44	.29	.40	.39	.31
	c	.88	.60	.46	.29	.41	.38	.32
	d	.90	.60	.46	.31	.39	.33	.32
15	a	.97	.58	.43	.07	.43	.38	.27
	b	.86	.65	.50	.17	.44	.36	.31
	c	.77	.67	.53	.31	.44	.40	.33
	d	.72	.69	.54	.37	.44	.41	.34
16	a	.84	.62	.52	.30	.44	.40	.34
	b	.96	.63	.57	.32	.43	.41	.34
	c	1.00	.63	.50	.31	.42	.40	.34
	d	.89	.67	.45	.30	.40	.41	.36
17	a	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	b	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	c	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	d	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AVG	a	.87	.56	.46	.27	.39	.36	.30
	b	.86	.56	.45	.28	.38	.35	.30
	c	.85	.56	.45	.29	.38	.35	.30
	d	.88	.59	.45	.31	.38	.35	.32

Values are root mean square difference between 1.0 and ratio of computed probabilities in 2 halves of record. Top value is for outlier method a, second for method b, third for method c, and bottom for method d, as defined on page 14. A value of zero would indicate perfect consistency.

Table 16
Consistency Results
Outlier Differences for Maximum Flows

ZONE		METHOD 1	2	3	4	5	6	7
1	a	.002	.003	.002	.008	.001	.002	.002
	b	.003	.002	.001	.006	.001	.001	.002
	c	.003	.002	.001	.006	.000	.002	.001
	d	.003	.002	.001	.006	.000	.001	.001
2	a	.003	.003	.001	.009	.001	.001	.002
	b	.003	.002	.001	.006	.000	.002	.001
	c	.003	.001	.001	.006	.000	.002	.001
	d	.003	.001	.001	.005	.000	.002	.001
3	a	.003	.008	.000	.016	0.000	.001	.005
	b	.003	.007	.000	.014	0.000	.001	.004
	c	.003	.004	.000	.010	0.000	.001	.002
	d	.003	.002	.000	.008	0.000	.001	.001
4	a	.006	.005	.000	.007	.001	.001	.002
	b	.006	.005	.000	.007	.001	.001	.002
	c	.006	.005	.000	.006	.001	.001	.002
	d	.006	.005	.000	.007	.001	.001	.002
5	a	.001	.012	.002	.011	.001	.002	.006
	b	.001	.004	.001	.008	.000	.002	.002
	c	.001	.005	.001	.010	.000	.002	.002
	d	.002	.006	.001	.011	.000	.002	.003
6	a	.002	.007	.000	.011	.001	.001	.003
	b	.002	.007	.000	.012	.001	.001	.004
	c	.003	.008	.001	.013	.001	.004	.004
	d	.003	.008	.001	.014	.001	.004	.004
7	a	.002	.004	.000	.009	.000	.002	.001
	b	.002	.003	.000	.007	.000	.002	.001
	c	.002	.003	.000	.007	.000	.002	.001
	d	.002	.003	.000	.008	.000	.002	.001
8	a	.003	.008	.000	.010	.001	.001	.004
	b	.003	.005	.000	.008	.000	.001	.002
	c	.003	.003	.000	.005	.000	.000	.001
	d	.003	.002	.000	.004	.000	.000	.001
9	a	.002	.006	.001	.013	.001	.006	.003
	b	.002	.004	.001	.010	.000	.005	.002
	c	.002	.004	.001	.010	.000	.004	.002
	d	.003	.004	.001	.010	.000	.001	.002
10	a	.002	.002	.000	.009	.000	.000	.001
	b	.003	.002	.000	.008	.000	.000	.001
	c	.003	.001	.000	.006	.000	.000	.001
	d	.003	.001	.000	.005	0.000	.002	.000
11	a	.001	.006	0.000	.007	.000	.000	.004
	b	.001	.007	0.000	.007	.000	.000	.004
	c	.001	.007	0.000	.007	.000	.000	.004
	d	.001	.007	0.000	.008	.000	.000	.004
12	a	.002	.003	.001	.009	.000	.003	.001
	b	.003	.002	.001	.009	.000	.003	.001
	c	.003	.002	.001	.009	.000	.004	.001
	d	.004	.002	.001	.010	.000	.004	.001

Table 16 Continued

13	a	.001	.003	.000	.009	.000	.000	.001
	b	.001	.002	.000	.007	.000	.000	.001
	c	.001	.001	.000	.005	.000	.000	.001
	d	.001	.001	.000	.003	0.000	0.000	.000
14	a	.001	.000	0.000	.004	0.000	.000	.000
	b	.001	.000	0.000	.003	0.000	0.000	.000
	c	.001	.000	0.000	.003	0.000	0.000	.000
	d	.001	.000	0.000	.003	0.000	0.000	.000
15	a	.010	.003	.001	.002	.000	.005	.002
	b	.009	.003	.001	.003	.000	.003	.003
	c	.008	.003	.001	.006	.000	.000	.003
	d	.008	.003	.001	.007	.000	.000	.003
16	a	.002	.002	.001	.007	.000	.001	.001
	b	.002	.002	.001	.007	.000	.001	.001
	c	.002	.002	.001	.007	.000	.001	.001
	d	.002	.002	.001	.007	.000	.001	.001
17	a	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	b	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	c	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	d	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AVG	a	.002	.005	.001	.009	.000	.002	.002
	b	.002	.004	.001	.008	.000	.002	.002
	c	.003	.003	.000	.007	.000	.002	.002
	d	.003	.003	.000	.007	.000	.002	.001

Values are root mean square difference between computed probabilities in 2 halves of record. Top value is for outlier method a, second for method b, third for method c, and bottom for method d, as defined on page 14.

Method 8 includes its unique technique for outliers and was therefore not included in this test.

TABLE 17

ACCURACY RESULTS

ZERO-FLOW RATIOS FOR MAXIMUM FLOWS

(ZONE 17)

METHOD	ZERO-FLOW TECHNIQUE	
	A	B
1	.46	.51
2	.32	.30
3	.59	.59
4	.32	.30
5	.40	.40
6	.40	.41
7	.32	.31

Values are root-mean-square differences between 1.0 and ratio of computed probability of flow in opposite half of record to its plotting position. A value of zero would indicate perfect forecasts. Method 8 was not tested because logarithms are not used in its fitting computations and therefore zero flows are not a problem. Zero-flow techniques are described on page 14.

TABLE 18

ACCURACY RESULTS

ZERO-FLOW DIFFERENCES FOR MAXIMUM FLOWS

(ZONE 17)

METHOD	ZERO-FLOW TECHNIQUE	
	A	B
1	.057	.064
2	.057	.060
3	.059	.070
4	.057	.057
5	.062	.068
6	.055	.061
7	.059	.061

Values are root-mean-square differences between plotting position of flow in one half of a record and computed probability in the other half for that same flow. Method 8 was not tested because logarithms are not used in its fitting computations and therefore zero flows are not a problem. Zero-flow techniques are described on page 14.

TABLE 19

CONSISTENCY RESULTS

ZERO-FLOW RATIOS FOR MAXIMUM FLOWS

(ZONE 17)

METHOD	ZERO-FLOW TECHNIQUE	
	A	B
1	.89	.86
2	.43	.43
3	.44	.44
4	.21	.19
5	.39	.40
6	.34	.38
7	.24	.23

Values are root-mean-square difference between 1.0 and ratio of probabilities in 2 halves of record for maximum flows in opposite half of record. A value of zero would indicate perfect consistency. Method 8 was not tested because logarithms are not used in its fitting computation and therefore zero flows are not a problem. Zero-flow techniques are described on page 14.

TABLE 20

CONSISTENCY RESULTS

ZERO-FLOW DIFFERENCES FOR MAXIMUM FLOWS

(ZONE 17)

METHOD	ZERO-FLOW TECHNIQUE	
	A	B
1	.007	.007
2	.012	.008
3	.000	.000
4	.014	.012
5	.001	.000
6	.000	.001
7	.006	.004

Values are root-mean-square difference between computed probabilities in 2 halves of record for maximum flow in opposite half of record. Method 8 was not tested because logarithms are not used in its fitting computation and therefore zero flows are not a problem. Zero-flow techniques are described on page 14.

Table 21

Summary of Partial-Duration Ratios

Zone	Partial-duration frequencies for annual-event frequencies of						
	.1	.2	.3	.4	.5	.6	.7
1 (21 sta)	.094	.203	.328	.475	.641	.844	1.10
2 (17 sta)	.093	.209	.353	.517	.759	1.001	1.30
3 (19 sta)	.094	.206	.368	.507	.664	.862	1.18
4 (8 sta)	.095	.218	.341	.535	.702	.903	1.21
5 (17 sta)	.093	.213	.355	.510	.702	.928	1.34
6 (16 sta)	.134	.267	.393	.575	.774	1.008	1.33
7 (9 sta)	.099	.248	.412	.598	.826	1.077	1.42
8 (12 sta)	.082	.211	.343	.525	.803	1.083	1.52
9 (15 sta)	.106	.234	.385	.553	.765	.982	1.26
10 (12 sta)	.108	.248	.410	.588	.776	1.022	1.34
11 (12 sta)	.094	.230	.389	.577	.836	1.138	1.50
12 (12 sta)	.103	.228	.352	.500	.710	.943	1.21
13 (16 sta)	.095	.224	.372	.562	.768	.986	1.30
14 (14 sta)	.100	.226	.371	.532	.709	.929	1.22
15 (3 sta)	.099	.194	.301	.410	.609	.845	1.05
16 (13 sta)	.106	.232	.355	.522	.696	.912	1.27
Average	.099	.243	.366	.532	.733	.964	1.28
Langbein	.105	.223	.356	.510	.693	.917	1.20

Note: Data limited to 226 stations originally selected for the study.

Table 22

Summary of Autocorrelation Coefficients

Zone	No. of correl coefs. Neg	Pos	Extreme t value Min	Max
1	13	14	-1.39	1.27
2	10	14	-.67	2.36
3	13	12	-1.07	1.67
4	7	8	-.66	1.64
5	12	8	-1.34	1.67
6	8	16	-.68	1.67
7	13	8	-1.05	1.58
8	10	13	-.65	1.53
9	7	11	-.69	.80
10	4	8	-.68	1.45
11	11	2	-1.31	1.08
12	1	16	-.66	.85
13	7	10	-.14	.60
14	8	7	-.68	.67
15	0	3	+.16	.99
16	6	7	-.67	.84
Total	130	157	-.76	1.29

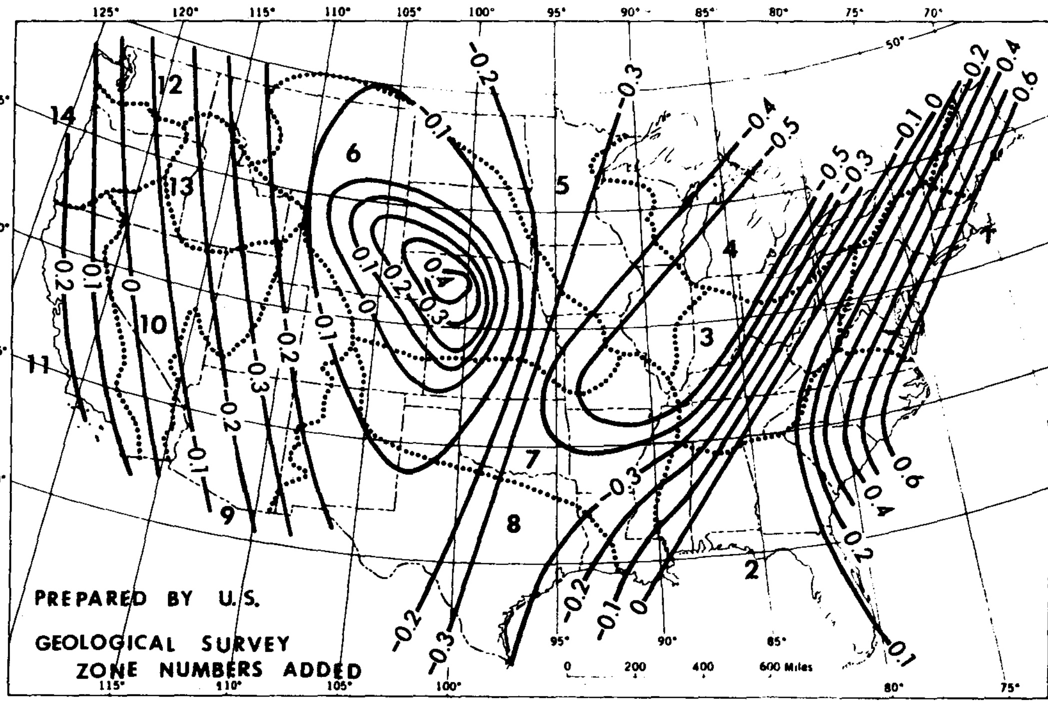


FIGURE 1

GENERALIZED SKEW COEFFICIENTS OF ANNUAL MAXIMUM STREAMFLOW LOGARITHMS

FIGURE 2

ACCURACY COMPARISON FOR 0.01

PROBABILITY ESTIMATE (TABLE 8)

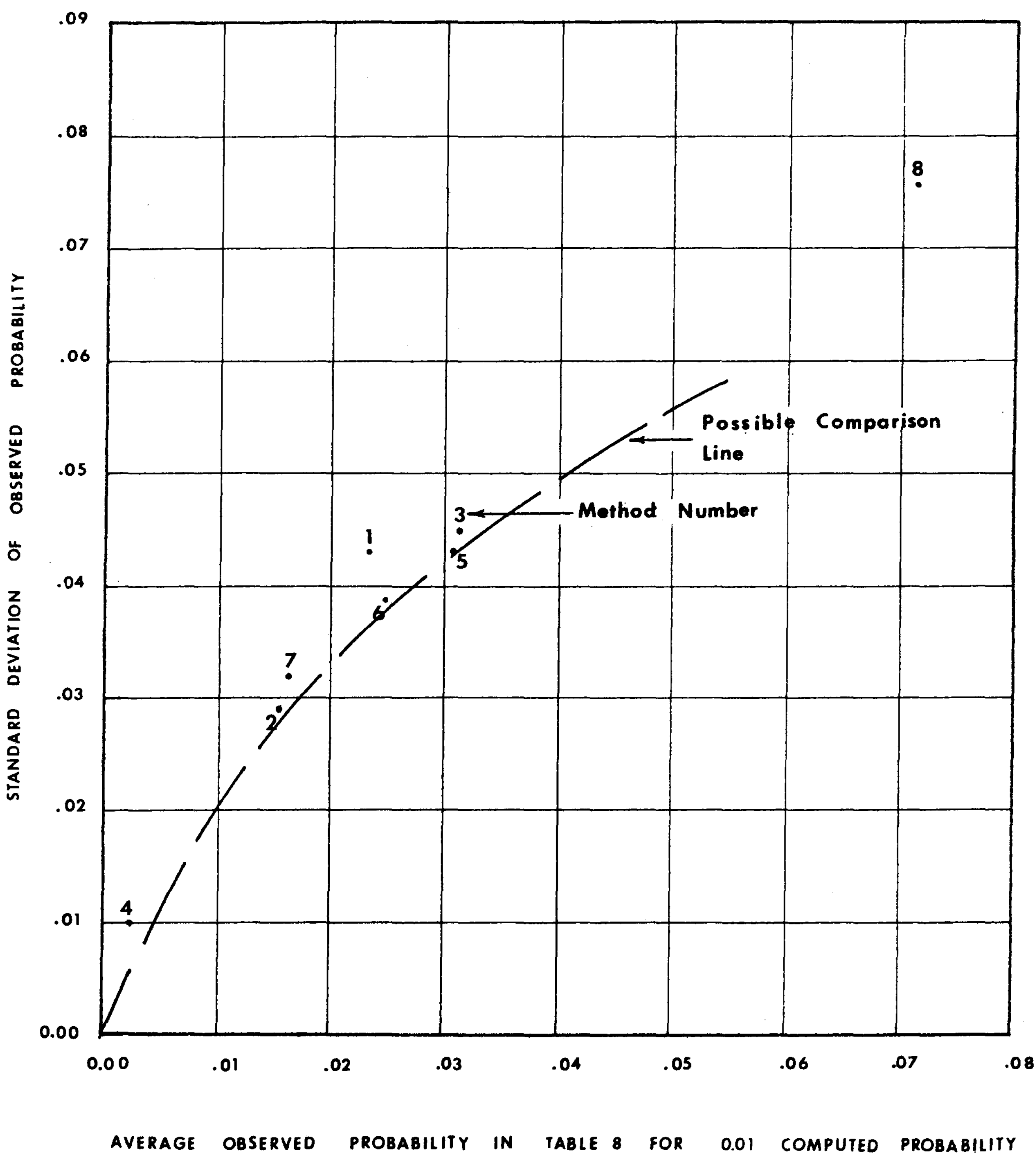


FIGURE 3

ACCURACY COMPARISON FOR MAXIMUM OBSERVED FLOW (TABLE 10)

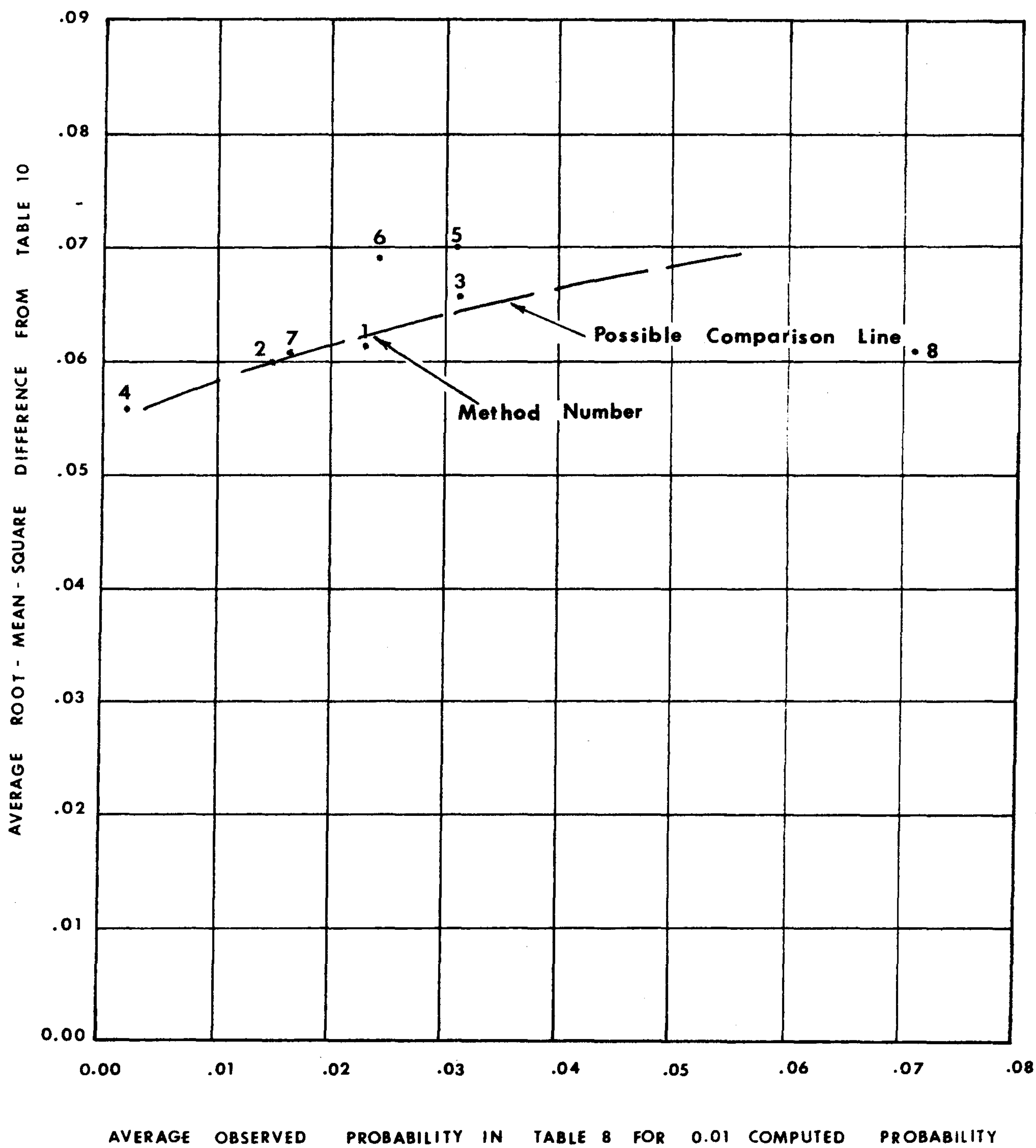
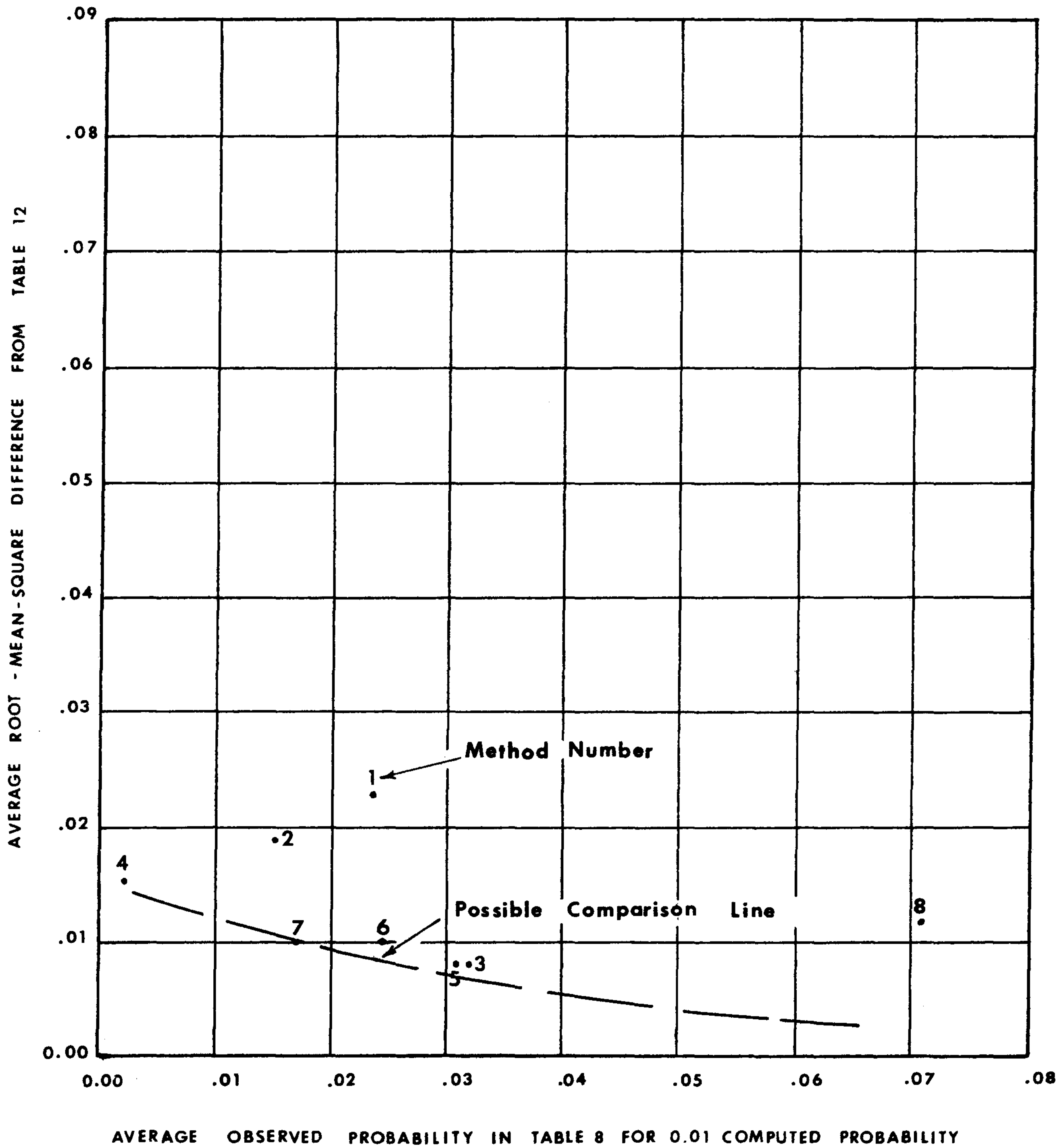


FIGURE 4

CONSISTENCY COMPARISON FOR MAXIMUM OBSERVED FLOW (TABLE 12)



APPENDIX A

THE EXPECTED PROBABILITY CONCEPT IN WATER RESOURCES DEVELOPMENT

CONSIDERATIONS OF RISK

In formulating a water resources project plan, it is necessary to evaluate conditions that will exist in the future with the project as contrasted with conditions that will exist in the future if the project is not constructed or if an alternative project is constructed. These evaluations must be made in terms of various objectives and must consider future variations of pertinent physical factors. Since these future variations cannot be predicted accurately, there is a chance element involved; and this chance element can greatly influence the evaluations. For example, whether or not a major flood of some extreme magnitude occurs during the lifetime of a project can greatly affect the value of a flood control project. This chance element represents a risk that must be taken, whether or not a project is constructed. It should be recognized that the risk can often be more serious in the event that a project is not constructed than if it is constructed.

The concept of mathematical expectation is highly useful in attaching some degree of certainty to an undertaking involving risk. The principle involved is that the value of an undertaking is equal to the sum of the cross-products of the value of each result with the corresponding probability that such a result will occur. Thus, if there is one chance in 10 that a flood within a certain range of magnitude will occur in any particular year, the annual value of protecting against floods within that range would be equal to the product of the probability of obtaining a flood within that range in any particular year and the benefits attained if the flood would occur within that range. This is the fundamental concept used in evaluating average annual flood damages or flood benefits.

CONSIDERATIONS OF UNCERTAINTY

The above principle of gambling based upon known risk could be applied to water resources development decisions if the probabilities associated with future floods were known accurately. However, such probabilities must be estimated from knowledge of past events. Where probabilities must be inferred from random sample data, they are uncertain, inasmuch as the sample might not and probably does not represent all of the future possibilities accurately. Thus, the probability estimates contain some degree of uncertainty, and mathematical expectation cannot be computed in a strict sense.

An important condition that results from this condition of uncertainty is that errors due to uncertainty do not necessarily compensate. For example, if our best estimate based on sample data is that a specified magnitude of flood will be exceeded on the average once in 100 years, it is possible that the true exceedence frequency could be three or four or more times per hundred years, but it can never be less than zero times per hundred years. The impact of errors in one direction due to uncertainty can be quite different from the impact of errors in the other direction. Thus, it appears obvious that we should not be content simply with being too high half the time and too low the other half of the time. We should consider the relative impacts of being too high or too low.

COMPUTATION OF UNCERTAINTY

The science of estimating population characteristics (probability characteristics of future events) has advanced greatly during the 20th century, particularly in regard to samples drawn from a Gaussian normal distribution. It is possible to delineate uncertainty with considerable accuracy when dealing with such samples. Fortunately, frequency curves of stream flows conform fairly closely to the logarithmic normal distribution in most regions; and it is therefore possible to delineate uncertainty of frequency or probability estimates of runoff if the logarithms are fitted to a normal distribution.

Figure 1 is a generalized representation of the range of uncertainty in probability estimates based on samples drawn from a normal population. The vertical scale could represent the logarithm of stream flow. The curves shown represent the likelihood that the true frequency corresponding to any particular magnitude exceeds the value shown on the frequency scale. The curve labeled .50 is very close to the curve that would ordinarily be used for deriving the best frequency estimate. It can be noted, for example, that a magnitude of 2 would be exceeded on the average 30 times per thousand events in accordance with the procedures normally used for making the best probability estimate. The figure also shows that there is a 5 percent chance that the true frequency is 150 or more times per thousand or a 5 percent chance that the true frequency is two times or less per thousand events.

THEORETICAL EXAMPLE

APPLICABILITY TO MULTIPLE ENTERPRISES

In this example, if 20 independent projects were undertaken and the best extimate for the frequency of the design magnitude of 2.0 in each case is three exceedences per hundred years, the total exceedences would be estimated at 60 per 100 years for all 20 projects. In actuality, however, we would expect that, due to sampling uncertainties, true frequencies corresponding to a magnitude of 2.0 would differ at the 20 projects and might be well represented by the following values at the 20 locations (corresponding to values of .025, .075, .125, ... 975 for the parameter of figure 1):

20	5	3	.9
12	5	2	.8
10	4	2	.5
8	4	2	.3
7	3	1	.1

This simply means that, while the best estimate of frequency from sample data in each case is 3 per 100 years, in one case out of 20, we would expect that the sample would contain unusually uniformly low values that mislead us into assigning a rare frequency to a common magnitude so that the true frequency would be about 20 instead of 3 per hundred years for that magnitude. Similarly, one case in 20 would have unusually variable high values that mislead us into assigning a common frequency to a rare magnitude so that the true frequency would be about 0.1 instead of 3.0 per hundred years for that magnitude. The remaining values in the above list could be similarly explained. The total of these values is about 90, which is 50 percent greater than the value obtained using the best probability estimate as the only true probability value in every case. If, however, the mathematically derived expected probability function were used, instead of the traditionally "best" estimate, we could read the expected probability curve of figure 1 to obtain the value of about 4.5 exceedences per 100 events. This value, when applied to each of the 20 enterprises, would yield a total estimate of 90. Thus, while the expected probability estimate would be wrong in the high direction more frequently than in the low direction, the heavier impacts of being wrong in the low direction would compensate for this. It can be noted, at this point, that expected probability is the average of all estimated-true probabilities.

APPLICATION

If a project were designed and operated for an indefinite period on the basis of known true probabilities, it can be demonstrated that the ratio of the actual return to the computed return on an investment will approach unity as the period of operation increases toward infinity. This is not the case where probabilities are not accurately known. However, if the expected probabilities as illustrated in figure 1 can be computed, then it can be demonstrated that the ratio of the actual return to the computed return on a large number of independent investments will approach unity as the periods of operation approach infinity and the number of investments (projects) approaches infinity. Thus, although there is an added chance element, it appears that the principles followed in undertaking projects involving risks where probabilities are known can also be applied where probabilities are not known but where uncertainty can be evaluated mathematically.

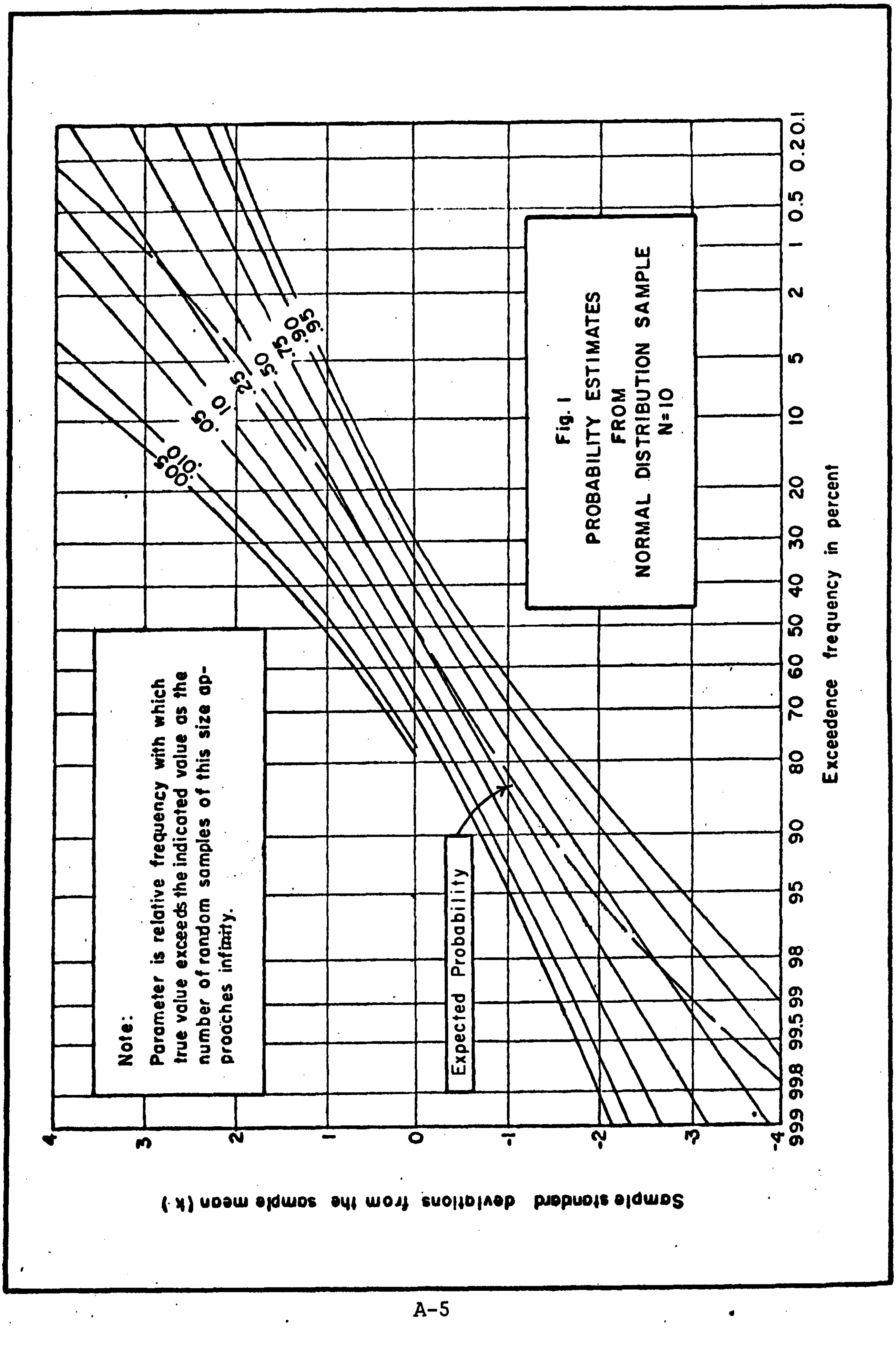


Fig. 1
PROBABILITY ESTIMATES
FROM
NORMAL DISTRIBUTION SAMPLE
N=10

APPENDIX B

COMPUTER PROGRAM FREQNCY

Origin of program.

This program was written at the Center for Research in Water Resources of The University of Texas at Austin by Tsann-Wang Yu, David Ford and Richard Smith with the assistance of Rajendra Juyal and under the direction of Leo R. Beard. Some of the routines for fitting frequency functions to data were obtained from the Central Technical Unit of the U.S. Soil Conservation Service. Research techniques and criteria contained in the program were developed in CRWR under the guidance of the Water Resources Council Work Group on Flood Flow Frequencies.

Purpose of the program.

This is the master computer program for conducting research under OWRR Grant No. 14-31-0001-9088, which funds a research project for determining the most consistent and reliable procedure or set of procedures for evaluating flood flow frequencies from streamflow data at the location for which estimates are desired.

The program accepts annual maximum streamflow data for any number of stations in turn and applies 8 different combinations of functions and fitting techniques to the complete record, each half record, a 5-event sample and a 10-event sample of each record. For half-record analyses, 2 different zero-flow techniques and 4 different outlier techniques are tested for methods 1 to 7. Method 8 (Best linear invariant Gumbel) has its built-in censoring technique for managing outliers, and zero flows are no problem with method 8, since logarithms of flows are not used in the fitting technique, as in other methods. Flows for specified frequencies and frequencies for specified flows are computed for each fitted function, and the numbers of events in the unused portion of the record above each established magnitude are counted. Results are written on tape for analysis in program VERIFY.

Statistics, computed frequency tables, data for use in VERIFY and other pertinent data are printed out for each method, and a plot of frequency data and points on the computed frequency function are printed for the Log Pearson III function and the Gumbel function fitted by the maximum likelihood method.

Methods.

As soon as data are read for a station, the year identification numbers are examined in sequence until 2 consecutive year numbers are reached. Any years preceding these are assumed to be pre-record flow estimates and are discarded after being identified in the print-out. Records are then divided into odd and even chronologic sequence numbers, omitting the first year for records having an odd number of years. Years of missing data are ignored. Also, 5-year and 10-year samples are selected for each record, starting with the earliest year of record and using maximum possible equal spacing between selected years. In cases where more than 5 (or 10) events occur, the earliest events are discarded.

Mathematical functions are fitted to the complete record and to each selected portion of records for each of the 8 methods being tested. In addition, 2 different zero-flow techniques and 4 different outlier techniques are used for those half-records where zero flows and/or outliers exist (except for method 8). Outliers are identified as maximum flows whose ratio to the second-largest flow exceeds the ratio of the second-largest to the eighth-largest flow, or as minimum flows whose ratio to the second-smallest flow is smaller than the ratio of the second-smallest to the eighth-smallest flow.

The first zero-flow technique is to use the flows as recorded for methods not using logarithms and adding 1 percent of the average annual peak flow to all values before taking the logarithms for those methods using the logarithms of flows. Of course, this quantity is subtracted later from computed flows. The second zero-flow technique is to discard all zero flows and adjust computed frequencies by the proportion of non-zero flows.

The first outlier technique is to retain the outlier as recorded. The second is to reduce it to the outlier criterion value (second-largest (smallest) value multiplied by the ratio of the second-largest (smallest) to the eighth-largest (smallest) value). The third is to reduce it to the second-largest (smallest) value multiplied by the square root of that ratio, and the last outlier technique is to discard the outlier completely.

For method 8, outliers at the upper end are discarded if the probability of occurrence in relation to the computed function is less than 0.1.

The 8 curve-fitting methods are as follows:

a. Log Pearson III. The technique used for this is that described in reference 6. The mean, standard deviation and skew coefficients for each data set are computed in accordance with the following equation:

$$\bar{X} = \frac{\Sigma X}{N} \qquad (1)$$

$$S^2 = \frac{\Sigma x^2}{N-1} \qquad (2)$$

$$g = \frac{N \Sigma x^3}{(N-1)(N-2)S^3} \qquad (3)$$

where:

X	=	logarithm of peak flow (incremented by 1% of the average annual peak flow only in cases of data sets having zero flows)
N	=	number of items in the data set
$\bar{X}$	=	mean logarithm
x	=	$X-\bar{X}$, deviation of a single event from the mean
S	=	standard deviation of logarithms
g	=	skew coefficient of logarithms

Flow logarithms are related to these statistics by use of the following equation:

$$X = \bar{X} + kS \quad (4)$$

Exceedence probabilities for specified values of k and values of k for specified exceedence probabilities are calculated by use of normal distribution routines available in computer libraries, with the transform to Pearson III deviates described in reference 6.

b. <u>Log Normal</u>. This method is identical to the Log Pearson III method except that the skew coefficient is not computed (a value of zero applies) and values of k are related to exceedence probabilities by use of the Gaussian normal distribution transform available in computer libraries.

c. <u>Gumbel</u>. This is the Fisher-Tippett extreme-value function, which relates magnitude linearly with the log of the log of the exceedence probability. Maximum-likelihood estimates of the mode and slope (location and scale parameters) are made by iteration, using procedures described by Harter and Moore in reference 28. The initial estimates of the location and scale statistics are obtained as follows:

$$M = \bar{X} - .045005\ S \quad (5)$$

$$B = .7797\ S \quad (6)$$

Magnitudes are related to these statistics as follows:

$$X = M + B\,(-\ln\,(-\ln P)) \quad (7)$$

where:

M	=	mode (location statistic)
B	=	slope (scale statistic)
X	=	magnitude
P	=	exceedence probability

Some of the computer routines used in this method were furnished by the Central Technical Unit of the Soil Conservation Service.

d. <u>Log Gumbel</u>. This technique is identical to the Gumbel technique, except that logarithms (base 10) of the flows are used. In data sets having zero values, 1% of the average annual maximum flow is added to each value before taking the logarithm. Of course, as in the case of the Log Pearson III method, this increment is later subtracted from computed values.

e. <u>Two-parameter Gamma</u>. This is identical to the 3-parameter Gamma method described below, except that the location parameter is set to zero. The shape parameter α is determined directly by solution of Morlund's expansion of the maximum-likelihood equation, which gives the following as an approximate estimate of α:

$$\alpha = \frac{1 + \sqrt{1 + \frac{4}{3}\left(\ln \bar{Q} - \frac{1}{N}\Sigma \ln Q\right)}}{4\left(\ln \bar{Q} - \frac{1}{N}\Sigma \ln Q\right)} - \Delta\alpha \qquad (8)$$

where:

$\bar{Q}$	=	average annual peak flow (incremented by 1% of average annual peak flow in cases of data sets having zero flows)
N	=	number of items in the data set
Q	=	peak flow (incremented by 1% of average annual peak flow in cases of data sets having zero flows)
$\Delta\alpha$	=	correction factor

β is estimated as follows:

$$\beta = \frac{1}{\alpha} \cdot \frac{1}{N} \Sigma Q \qquad (9)$$

f. Three-parameter Gamma. Computation of maximum-likelihood statistics for the 3-parameter Gamma distribution is accomplished using procedures described in reference 89. If the minimum flow is zero, or if the calculated lower bound is less than zero, the statistics are identical to those for the 2-parameter Gamma distribution. Otherwise, the lower bound, γ, is initialized at a value slightly smaller than the lowest value of record, and the maximum likelihood value of the lower bound is derived by iteration using criteria in reference 53. Then the parameters α and β are solved for directly using the equations above replacing Q with $Q-\gamma$. Probabilities corresponding to specified magnitudes are computed directly by use of a library gamma routine. Magnitudes corresponding to specified probabilities are computed by iteration using the inverse solution.

g. Regional Log Pearson III. This method is identical to the Log Pearson III method, except that the skew coefficient is taken from figure 1 instead of using the computed skew coefficient. Regionalized skew coefficients were furnished by the U.S. Geological Survey.

h. Best Linear Invariant Gumbel. This method is the same as for the Gumbel method, except that best linear invariant estimates (BLIE) are used for the function statistics instead of the maximum likelihood estimates (MLE). An automatic censoring routine is used for this method only; so there are not alternative outlier techniques tested for this method.

Statistics are computed as follows:

$$M = \Sigma(X \cdot U(N,J,I) \qquad (8)$$

$$B = \Sigma(X_1 \cdot V(N,J,I) \qquad (9)$$

where:

U = coefficient UMANN described in reference 43

V = coefficient BMANN described in reference 43

J = number of outliers deleted plus 1

I = order number of flows arranged in ascending-magnitude order

N = sample size as censored.

Since weighting coefficients U and V are available only for sample sizes ranging from 10 to 25, 5-year samples are not treated by this method, and records of more than 25 years are divided into chronological groups and weighted coefficients used in lieu of coefficients that might otherwise be obtained if more complete sets of weighting coefficients were available. Up to 2 outliers are censored at the upper end of the flow array. Each one is removed if sequential tests show that a value that extreme would occur by chance less than 1 time in 10 on the basis of the BLIE statistics. Details of this censoring technique are contained in reference 50. Weighting coefficients and most of the routines used in this method were furnished by the Central Technical Unit of the Soil Conservation Service.

Input.

Input for program FREQNCY is accomplished via the default input file (all READ n statements) and input tape 4 (all READ (4,n) statements.) Values read from the default file control the operation of the program; tape 4 contains streamflow records along with information such as USGS gage identification number.

For convenience, FREQNCY also reads from tape (identified as TAPE 7 in subroutine EXVAN) the weighting coefficients used to determine the best linear invariant estimators of Gumbel's mode and slope.

Variable locations for each input card in the default input file are shown by field number. Each card is divided into ten fields of eight columns each; each variable is read in integer form, right justified in the field, with no decimal points punched.

Card A, one card for entire computer run.

Field	Variable	Value	Description
1	KONTRL	1	Program will read one value of IPP, IDO, IPRINT. IFORM (indicator of distribution) will vary from 1 to 8.
		2	Program will read KMETH values of IFORM, IPP, IDO, IRPINT to be used for all stations.
2	KMETH	1-10	If KONTRL = 1, ignored If KONTRL = 2, number of values of IFORM, IPP, IDO, IPRINT to be read.
3	ILAST	≥0	Internal tape advance for tape 4. ILAST stations are read and wasted before first station to be included in this run is read. If end of file is encountered during advance, job will abort.

Card B, one card for each method (distribution) in the job if KONTRL is 2; otherwise only one card for entire job.

Field	Variable	Value	Description
1	IFORM	1-8	Indicator of distribution to be applied. Numbers correspond to order in section describing the distributions. Ignored if KONTL is 1.
2	IPP	1	Plotting position is M/N+1
		2	Plotting position is (M-0.3)/(N+0.4)
3	IDO	0	Plot only full record.
		1	Plot intermediate plots (split records)
4	IPRINT	0	Minimum print out: full record flows and frequencies and summary.
		1-3	Increase intermediate print out one step for each increase in IPRINT.

Data are read from tape 4 as follows:

Variable	Format	Description
IDSTA	I8	Station identification number
ISTAT	4A10,A5	Station location
	2X	
DA	F10.0	Drainage area in square miles
CONT	F7.0	Contributing drainage area
IYR	I8	Number of years of record
	22X	
RGLSKW	F5.2	Regional skew for Log Pearson III
IYRA(I)	I4	Year of flow
TIME(I)	A6	Date of peak flow in year I
Q(I)	F7.0	Peak flow of year I
	2X	

Actual read format is (I8,12X,4A10,A5,2X,F10.0,F7.0,I8.22XF5.2/(7(I4, A6,F7.0,2X)))

Output.

There is considerable flexibility in the amount of output obtainable from this program and in the storage media to which the output is directed. In the execution for this research project, only station identification and autocorrelation-coefficient summaries were printed on line. Because of the prohibitive bulk of computer output, the remainder was limited to primary output and directed to various tape units for later printing and use.

Primary (minimum) output consists of:

(a) Expected-probability, accuracy and consistency data on a separate tape for use as input to program VERIFY.

(b) Station identification, autocorrelation coefficients, chronologic and ordered data and plotting positions, and, for each method, computed statistics, the computed function and, if desired, a plotting of the data and computed function. Also, data described in (a) are directed to this tape as a check on the data for VERIFY.

The variable IPRINT produces increasing amounts of output as it varies from zero (for minimum output) to 3. This additional output consists of:

a. Data, plotting positions, computed statistics and computed functions for half-records.

b. Similar output for 5-year and 10-year samples of each record.

The program will normally produce graphic plots of complete records for the Log Pearson Type III and the Gumbel methods in order to demonstrate the relationship between observed data and computed function for two different ordinate and two different abscissa scales. Additional plots must be called for specifically.

Computer Program FREQNCY

Definitions of Variables

ACYA(IACY)	Computed frequencies for second half-record maximum, upper decile, median flows using statistics from first half record
ACYB(IACY)	Computed frequencies for first half-record maximum, upper decile, median flows using statistics from second half record
AK	Pearson Type III deviate
ALPHA	Shape parameter for 2- and 3-parameter gamma distributions
AMODE	Mode (location parameter) for Gumbel and log Gumbel distributions
AMQ	Mean of adjusted flows (after increment is added if necessary)
AMU	Geometric mean of (flow-lower bound)
AMX	Mean of logarithms of flows
AN	Floating point variation of N
ANM1	Floating point variation of N-1
ANM12	Floating point variation of (N-1)*(N-2)
B(I)	Desired probability values, adjusted for zero flow technique
BETA	Scale parameter for 2- and 3- parameter gamma distributions
BLANK	Alphanumeric blank space
C(I)	Adjusted autocorrelation coefficients of flows and logs of flows of complete and half records
CONT	Contributing drainage area
CORR(I)	Adjusted autocorrelation coefficients of flows of complete record
CSTY(I)	Combination of FREA- and FREB-arrays
DA	Drainage area

DELX	Increment used in iterative routines
DEV	Deviation of flow from mean
DIFF	Temporary variable representing a difference between two magnitudes
FREA(IFR)	Computed frequencies for full-record extreme, maximum, upper decile, median flows using statistics from first half-record
FREB(IFR)	Computed frequencies for full-record extreme, maximum, upper decile, median flows using statistics from second half-record
G	Calculated coefficient of skew
GAMMA	Location parameter of the lower boundary for 3-parameter gamma distribution
I	Temporary index or counter
IACY	Index for ACYA-, ACYB-arrays
IBELL	Counter of split record technique
IDEA	Outlier location indicator, 1 Indicates outlier on lower end of record 2 Indicates outlier on upper end of record 3 Indicates outlier on both ends of record
IDO	Plot control, if > 0 will plot complete record for all distributions
IDO1(I)	Input values of IDO (may vary from one distribution to another)
IDSTA	USGS station identification number
IER	Error message indicator for library statistical routines
IFORM	Indicator of distribution
IFORM1(I)	Input values of IFORM (for KONTRL=2)
IFR	Index for FREA-, FREB-arrays
IFREQ(I)	Interger variation of frequency values .001, .01, .1, .5 (for comparisons)

IFULL	Counter of number of stations read from tape 4
IGUMBL	Counter to prevent repeated reading of MANN'S weighing coefficients
ILAST	Indicator of number of stations to be skipped before input from tape 4 begins
IMTHD	Counter of number of methods (distributions) used in analysis
IN	Temporary variation of N
IOUT	Outlier indicator, if > 0 portion of record being tested has high or low outliers
IP	Index for XPT-array
IPP	Indicator of plotting position used, +1 calls for M/N+1, +2 calls for M-0.3/N+0.4
IPP1(I)	Input plotting position indicator (may vary from one distribution to another)
IPRINT	Print control
IPRINT1(I)	Input print control values
IREAD	Number of stations to be read from tape 4
ISCLE	Horizontal axis control for plot routine +1 calls for normally distributed probability scale, +2 calls for extreme-value (log-log) scale
ISTAT(AT)	Alphanumeric station identifier
ITMP	Temporary Variable
IYR	Number of years of data input (before blanks and historical data is omitted)
IYRA(I)	Year of peak flow
IYRM1	IYR-1
IZERO	Zero flow counter
J	Temporary index or counter

JSCLE	Vertical axis control for plot routine. +1 calls for arithmetic scale, +2 calls for logarithmic scale
JTMP	Temporary variable
JZERO	Counter of zero technique
K	Temporary index or counter
KMETH	For KONTRL=2, number of values of IFORM, IDO, IPRINT, IPP to be used for each station
KN	Temporary variable, variation of N
KONTRL	Indicator for input option, =1 IFORM varies from 1 to 8 under program control, =2 reads KMETH values of IFORM to use in analysis
KTMP	Temporary variable
L	Temporary index or counter
M	Temporary index
MN	Counter of outlier technique
N	Number of years of record in working array
NBLANK	Number of blank values of peak flow read from tape
ND2	N/2
NEVEN	Number of values in QEVEN-array
NIT	Number of comparisons of outlier and zero flow techniques possible
NITA	Number of outlier and zero flow techniques applied to first half-record
NITB	Number of outlier and zero flow techniques applied to second half-record
NJ	Number of calculated flows corresponding to probabilities specified in B array

NODD	Number of values in QODD-array
NPAIR	Number of values in half-record before historical records and blanks are removed
NSTORE	Total number of peak flows in complete record after historical data and blanks are omitted
NUMHI	Number of high outliers (computed in subroutine EXVAN)
NVAL(I)	Number of values to be plotted
PLOTP(I,J)	Plotting positions for flows in Q-array
PLT(I)	Plotting position of half-record maximum, upper decile, median flow
PXA	Temporary variable representing probability value
PXB	Temporary variable representing probability value
Q(I)	Working array containing complete record or a portion of complete record
QEVEN(I)	For half-record split, flows with even indices; for 5- or 10-year split, temporary storage of the 5 or 10 selected values
QMEAN	Mean of unadjusted flows
QNTY(I,J)	Observed and calculated flows to be plotted
QODD(I)	For half-record split, flows with odd indices; for 5- or 10-year split, temporary storage for remainder of record
QUE(I)	Temporary storage for Q-array during outlier routines
QXL(I,J)	Extreme, maximum, upper decile, and median flows of complete record and both half records
R(I,J)	Plotting positions and frequencies corresponding to flows in QNTY array. Used in plotting
RGLSKW	Regional skew coefficient for log Pearson III (method 7)

RTIO	Probability adjustment ratio. For JZERO=1, RTLO=1, for JZERO=2, RTIO=N/(N-IZERO)
RXXYY	Unadjusted coefficient of autocorrelation of logs of flows
RXY	Unadjusted coefficient of autocorrelation of flows
S	Standard deviation
SIGMA	Standard deviation of ln (flow-lower bound) values
SLOPE	Slope (scale parameter) for Gumbel and log Gumbel distributions
SOL	Solution in iterative search routines
STAR(I)	Array containing alphanumeric character*
SUMQ	Sum of values in Q-array
SUMQQ	Sum of squares of values in Q-array
SUMR	Sum of input flows with odd indices
SUMRR	Sum of squares of input flows with odd indices
SUMRS	Sum of cross products of input flows with even indices and input flows with odd indices
SUMS	Sum of input flows with even indices
SUMSS	Sum of squares of input flows with even indices
SUMX	Sum of logs of flows (values in X array)
SUMXX	Sum of squares of logs of flows
SUMXY	Sum of cross products of logs of input flows with even indices and input flows with odd indices
SUMY	Sum of logs of input flows with odd indices
SUMYY	Sum of squares of logs of input flows with odd indices
TAPE 4	Input data tape
TAPE 6	Output tape
TAPE 7	Input tape containing MANN's weighing coefficients

TAPE 20	Output tape for program verify
TEMP	Temporary variable
TEMP4	Temporary variable
TEMP7	Temporary variable
TIME(I)	Date of Peak flow
TMP	Temporary variable
TVL(I)	Chance that a correlation coefficient, CORR(I), is accidental
U(I)	Temporary storage for full-record flows during split record tests
X(I)	Logarithms of flows
XPT(IP)	Observed frequencies in remainder of record for flows with computed frequencies of .001, .01, .1, .5
XX	Temporary variable used in iteration routines
YY	Temporary variable used in iteration routines

```
      PROGRAM FREQNCY(INPUT,OUTPUT,TAPE6,TAPE4,TAPE7,TAPE20)
      DIMENSION Q(130),X(130),PLOTP(2,130),B(13),QNTY(2,130),R(2,130),
     1       NVAL(2),U(130),TIME(130),QODD(130),QEVEN(65),IFORM1(10),
     2       IDO1(10),IPP1(10),IPRINT1(10),IYRA(130),STAR(17),
     3       TVL(27),QXL(3,4),ISTAT(5),C(9),CORR(27),XPT(16),PLT(3),
     4       ACYA(24),ACYB(24),CSTY(64),QUE(130),FREA(32),FREB(32),
     5       IFREQ(4)
      COMMON /AR1/ Q,N
      COMMON /AR2/ ALPHA,BETA
      COMMON /AR3/ GAMMA
      COMMON /AR4/ PLT,PLOTP,IPP
      COMMON /AR5/ QODD,NODD,QEVEN,NEVEN
      COMMON /AR8/ AMU,SIGMA,AK
      COMMON /AR12/ IGUMBL
      COMMON /AR13/ QXL
      COMMON /AR15/ AMX,S,G
      COMMON /AR16/ SLOPE,AMODE
      COMMON /AR17/ AMQ
      DATA (STAR(J),J=1,17)/17*8H********/
      DATA BLANK/6H      /
      DATA IFREQ/1,10,100,500/
C
C                               TAPE  4 = INPUT DATA TAPE
C                               TAPE  6 = OUTPUT TAPE
C                               TAPE  7 = MANNS WEIGHING COEFFICIENTS
C                               TAPE 20 = SAVE TAPE FOR PROGRAM VERIFY
C
C
C                               THE FOLLOWING INTERNATIONAL MATHEMATICAL
C                               AND STATISTICAL LIBRARY ROUTINES ARE USED
C                               IN THIS PROGRAM----
C                               MDNRIS -  COMPUTES THE INVERSE NORMAL
C                                         PROBABILITY DISTRIBUTION FUNCTION
C                               MDNOR -   COMPUTES THE NORMAL PROBABILITY
C                                         DENSITY FUNCTION
C                               MDGAM -   COMPUTES THE INCOMPLETE GAMMA
C                                         PROBABILITY DISTRIBUTION FUNCTION
      IGUMBL=0
      REWIND 20
      PRINT 2170
      WRITE (6,2150)
      WRITE (6,2170)
C                               READ INPUT CONTROL FROM FIRST CARD
      READ 1680, KONTRL,KMETH,ILAST,IREAD
C                               DATA INPUT FROM TAPE
      IFULL=0
         IF (ILAST.EQ.0) GO TO 20
C                               READ AND WASTE TAPE UP TO DESIRED STATION
      DO 10 J=1,ILAST
      READ (4,1690) IDSTA,ISTAT,DA,CONT,IYR,RGLSKW,(IYRA(I),TIME(I),
```

```
     1       Q(I),I=1,IYR)
        IF (EOF,4) 30,10
 10   CONTINUE
C                               READ DATA FOR ONE STATION
C                               PROGRAM ALWAYS BRANCHES TO STEP 20 TO READ
C                               NEXT STATION
 20   CONTINUE
      IMTHD=0
      IFULL=IFULL+1
         IF (IFULL.GT.IREAD) GO TO 30
      READ (4,1690) IDSTA,ISTAT,DA,CONT,IYR,RGLSKW,(IYRA(I),TIME(I),
     1       Q(I),I=1,IYR)
         IF (EOF,4) 30,40
 30   CONTINUE
C                               END OF PROGRAM -- WRITE END OF FILE MARKS
C                               ON TAPES AND SAVE THEM FOR PROGRAM VERIFY
      END FILE 20
      END FILE 6
      CALL SAVEPF (4L7959,6LTAPE20,4L1166,ITMP)
         IF (ITMP.LE.0) PRINT 1920
         IF (ITMP.GT.0) PRINT 1930, ITMP
C                               ORDER AND PRINT AUTOCORRELATION
C                               COEFFICIENTS AND T VALUES FOR ALL STATIONS
C                               ANALYZED THIS RUN
      CALL ORDER (IREAD,CORR)
      CALL ORDER (IREAD,TVL)
      PRINT 1670, IREAD,(CORR(I),TVL(I),I=1,IREAD)
      STOP
 40   CONTINUE
C                               BEGIN ANALYSIS OF DATA FOR ONE STATION
      DO 50 I=1,IYR
      QUE(I)=Q(I)
 50   CONTINUE
C                               QUE ARRAY IS TEMPORARY STORAGE FOR INPUT
C                               FLOWS (IYR VALUES)
C
C                               CALCULATE SERIAL CORRELATION COEFFICIENTS
      ITMP=0
      IYRM1=IYR-1
      DO 60 I=1,IYRM1
      QODD(I)=Q(I)
      QEVEN(I)=Q(I+1)
 60   CONTINUE
      DO 120 K=1,3
         GO TO (70,80,90), K
 70   CONTINUE
      M=1
      J=1
         GO TO 100
 80   CONTINUE
```

```
      M=1
      J=2
         GO TO 100
 90   CONTINUE
      M=2
      J=2
 100  CONTINUE
      NPAIR=0
      SUMR=0.
      SUMS=0.
      SUMX=0.
      SUMY=0.
      SUMRS=0.
      SUMXY=0.
      SUMRR=0.
      SUMSS=0.
      SUMXX=0.
      SUMYY=0.
      DO 110 I=M,IYRM1,J
      TEMP=QODD(I)
      TMP=QEVEN(I)
      SUMR=SUMR+TEMP
      SUMRR=SUMRR+(TEMP*TEMP)
      SUMS=SUMS+TMP
      SUMSS=SUMSS+(TMP*TMP)
      SUMRS=SUMRS+(TEMP*TMP)
      IF (TEMP.LT..1) TEMP=.1
      IF (TMP.LT..1) TMP=.1
      TEMP=ALOG10(TEMP)
      TMP=ALOG10(TMP)
      SUMX=SUMX+TEMP
      SUMY=SUMY+TMP
      SUMXX=SUMXX+(TEMP*TEMP)
      SUMYY=SUMYY+(TMP*TMP)
      SUMXY=SUMXY+(TEMP*TMP)
      NPAIR=NPAIR+1
 110  CONTINUE
      AN=NPAIR
      ITMP=ITMP+1
      C(ITMP)=AN
      TEMP4=SUMRS-SUMR*SUMS/AN
      TEMP=SUMRR-SUMR*SUMR/AN
      TMP=SUMSS-SUMS*SUMS/AN
      RXY=TEMP4*TEMP4/(TEMP*TMP)
      TEMP7=SUMXY-SUMX*SUMY/AN
      TEMP=SUMXX-SUMX*SUMX/AN
      TMP=SUMYY-SUMY*SUMY/AN
      RXXYY=TEMP7*TEMP7/(TEMP*TMP)
      TEMP4=TEMP4/ABS(TEMP4)
      TEMP7=TEMP7/ABS(TEMP7)
```

```
      ITMP=ITMP+1
      C(ITMP)=TEMP4*SQRT(ABS(1.-(((AN-1.)*(1.-RXY))/(AN-2.))))
      ITMP=ITMP+1
      C(ITMP)=TEMP7*SQRT(ABS(1.-(((AN-1.)*(1.-RXXYY))/(AN-2.))))
  120 CONTINUE
      TEMP=C(2)
      CORR(IFULL)=TEMP
      TMP=1.
      IF (TEMP.LT.0.) TMP=-1.
      TVL(IFULL)=SQRT(TEMP**2*(AN-3.)/(1.-TEMP**2))*TMP
C                               REMOVE BLANK DATA SO MACHINE WILL NOT STOP
      NBLANK=0
      DO 160 I=1,IYR
      TEMP=Q(I)
         IF (.NOT.TEMP) 130,140
  130 CONTINUE
         IF (TEMP.GT.-999.) GO TO 150
      TIME(I)=BLANK
  140 CONTINUE
      NBLANK=NBLANK+1
         GO TO 160
  150 CONTINUE
      Q(I-NBLANK)=TEMP
  160 CONTINUE
      N=IYR-NBLANK
C                               OMIT HISTORIC RECORDS AND TEMPORARILY
C                               STORE THEM IN QODD ARRAY
      NODD=0
      I=1
  170 CONTINUE
      J=I+1
      ITMP=IYRA(J)-IYRA(I)
         IF (ITMP.EQ.1) GO TO 190
      N=N-1
      NODD=NODD+1
      QODD(NODD)=Q(J)
      DO 180 K=1,N
      IYRA(K)=IYRA(J)
      Q(K)=Q(J)
      J=J+1
  180 CONTINUE
         GO TO 170
  190 CONTINUE
      DO 200 I=1,N
      U(I)=Q(I)
  200 CONTINUE
      NSTORE=N
C                               U ARRAY IS STORAGE FOR UNORDERED INPUT
C                               FLOWS LESS BLANKS AND HISTORIC RECORDS
      CALL ORDER (N,Q)
```

```
         IF (IFULL.GT.1) WRITE (6,1710) STAR,STAR
      PRINT 2160
      PRINT 1700, IDSTA,ISTAT
      WRITE (6,1700) IDSTA,ISTAT
      WRITE (6,1720) IYR,NBLANK,N
C                               PRINT SERIAL CORRELATION COEFFICIENTS
      WRITE (6,1770) C
      WRITE (6,1730)
      CALL POSIT (N)
C                               PRINT DATE, ORIGINAL INPUT FLOWS, ORDERED
C                               FLOWS AND PLOTTING POSITIONS
      WRITE (6,1740) (TIME(I),QUE(I),Q(I),I,PLOTP(1,I),PLOTP(2,I),I=1,N)
         IF (N.EQ.IYR) GO TO 210
      ITMP=N+1
      WRITE (6,1750) (TIME(I),QUE(I),I=ITMP,IYR)
         IF (NODD.EQ.0) GO TO 210
C                               IF ANY HISTORIC RECORDS WERE OMITTED, PRINT
C                               THEM HERE
      WRITE (6,1760) (QODD(I),I=1,NODD)
 210  CONTINUE
      IFORM=0
C                               READ PROGRAM CONTROL FROM CARDS
         GO TO (220,250), KONTRL
 220  CONTINUE
C                               KONTRL=1
C                               READ IPP,IDO,IPRINT ONE TIME.
C                               IFORM VARIES FROM 1 TO 9
         IF (IFULL.GT.1) GO TO 240
      READ 1680, ITMP,IPP,IDO,IPRINT
      KMETH=9
      DO 230 J=1,9
      IFORM1(J)=J
 230  CONTINUE
 240  CONTINUE
      IMTHD=IMTHD+1
      IFORM=IFORM+1
         IF (IFORM.GT.9) GO TO 20
         GO TO 280
 250  CONTINUE
C                               KONTRL=2
C                               READ KMETH VALUES FOR EACH STATION.
      IMTHD=IMTHD+1
         IF (IMTHD.GT.KMETH) GO TO 20
         IF (IFULL.GT.1.OR.IMTHD.GT.1) GO TO 270
      DO 260 I=1,KMETH
      READ 1680, IFORM1(I),IPP1(I),IDO1(I),IPRINT1(I)
 260  CONTINUE
 270  CONTINUE
      IFORM=IFORM1(IMTHD)
      IDO=IDO1(IMTHD)
```

```
      IPP=IPP1(IMTHD)
      IPRINT=IPRINT1(IMTHD)
  280 CONTINUE
      ITMP=IFULL*IMTHD
         IF (ITMP.EQ.1) WRITE (20) KMETH,IREAD,(IFORM1(K),K=1,KMETH)
      WRITE (6,2050) STAR
C                              PRINT APPROPRIATE TITLE FOR METHOD
         IF (IFORM.EQ.1) WRITE (6,2060)
         IF (IFORM.EQ.2) WRITE (6,2070)
         IF (IFORM.EQ.3) WRITE (6,2080)
         IF (IFORM.EQ.4) WRITE (6,2140)
         IF (IFORM.EQ.5) WRITE (6,2100)
         IF (IFORM.EQ.6) WRITE (6,2110)
         IF (IFORM.EQ.7) WRITE (6,2130)
         IF (IFORM.EQ.8) WRITE (6,2090)
         IF (IFORM.EQ.9) WRITE (6,2120)
         IF (IFORM.GT.1) PRINT 2160
         IF (IFORM.EQ.1) PRINT 2060
         IF (IFORM.EQ.2) PRINT 2070
         IF (IFORM.EQ.3) PRINT 2080
         IF (IFORM.EQ.4) PRINT 2140
         IF (IFORM.EQ.5) PRINT 2100
         IF (IFORM.EQ.6) PRINT 2110
         IF (IFORM.EQ.7) PRINT 2130
         IF (IFORM.EQ.8) PRINT 2090
C                              DO LOOP FOR SPLIT RECORD TESTS
      DO 1620 IBELL=1,5
      IZERO=0
         GO TO (290,310,320,400,440), IBELL
  290 CONTINUE
C                              NO SPLIT IN RECORD
      WRITE (6,2190)
      N=NSTORE
      DO 300 I=1,N
      Q(I)=U(I)
  300 CONTINUE
      CALL ORDER (N,Q)
      IF (IMTHD.EQ.1) CALL CHOOSE (Q,N,1)
      CALL POSIT (N)
         GO TO 460
C                              FOR IBELL=2, SELECT  5 EVENLY SPACED YEARS.
  310 NEVEN=5
         IF (IFORM.EQ.8) GO TO 1620
         IF (IPRINT.GE.2) WRITE (6,2200)
         GO TO 330
C                              FOR IBELL=3, SELECT 10 EVENLY SPACED YEARS.
  320 NEVEN=10
         IF (IPRINT.GE.2) WRITE (6,2210)
  330 CONTINUE
      NODD=NSTORE-NEVEN
```

```
      ITMP=(NSTORE-1)/NEVEN
      L=1
      J=1
      K=1
      DO 350 I=1,NSTORE
         IF (I.NE.K) GO TO 340
      QEVEN(L)=U(I)
      K=K+ITMP
      L=L+1
         GO TO 350
 340  QODD(J)=U(I)
      J=J+1
 350  CONTINUE
         IF (L.EQ.NEVEN) GO TO 370
      QODD(J)=QEVEN(1)
      DO 360 I=1,NEVEN
      QEVEN(I)=QEVEN(I+1)
 360  CONTINUE
 370  CONTINUE
      CALL ORDER (NEVEN,QEVEN)
      CALL ORDER (NODD,QODD)
      CALL POSIT (NODD)
         IF (IPRINT.LT.2.OR.IMTHD.GT.1) GO TO 380
      WRITE (6,2020) (QEVEN(I),I=1,NEVEN)
      WRITE (6,2030) (QODD(I),PLOTP(1,I),PLOTP(2,I),I=1,NODD)
 380  CONTINUE
      N=NEVEN
      DO 390 I=1,N
      Q(I)=QEVEN(I)
 390  CONTINUE
         GO TO 460
C                             SPLIT RECORD INTO 2 HALVES
 400  ND2=NSTORE/2
      AN=NSTORE
      TEMP=ND2
      TMP=AN/2
      NEVEN=ND2
      NODD=ND2
      KN=NSTORE
      IF (TMP.GT.TEMP) KN=NSTORE-1
      J=0
      DO 410 I=2,KN,2
      J=J+1
      QEVEN(J)=U(I)
 410  CONTINUE
      KN=NSTORE-1
      IF (TMP.GT.TEMP) KN=NSTORE-2
      J=0
      DO 420 I=1,KN,2
      J=J+1
```

```
      QODD(J)=U(I)
  420 CONTINUE
C                              ORDER HALF-RECORDS, CALCULATE PLOTTING
C                              POSITIONS, AND DETERMINE MAXIMUM, UPPER
C                              DECILE, AND MEDIAN FLOWS
      CALL POSIT (NODD)
      CALL ORDER (NODD,QODD)
      CALL ORDER (NEVEN,QEVEN)
      IF (IMTHD.EQ.1) CALL CHOOSE (QODD,NODD,2)
      IF (IMTHD.EQ.1) CALL CHOOSE (QEVEN,NEVEN,3)
C                              SET Q ARRAY = QEVEN ARRAY FOR IBELL=4
         IF (IPRINT.GE.1) WRITE (6,2220)
      N=ND2
      DO 430 I=1,N
      Q(I)=QEVEN(I)
  430 CONTINUE
         IF (IPRINT.LT.1.OR.IMTHD.GT.1) GO TO 460
      WRITE (6,2040) (QEVEN(I),QODD(I),PLOTP(1,I),PLOTP(2,I),I=1,N)
         GO TO 460
  440 CONTINUE
C                              SET Q ARRAY = QODD ARRAY FOR IBELL=5
      N=ND2
         IF (IPRINT.GE.1) WRITE (6,2230)
      DO 450 I=1,N
      Q(I)=QODD(I)
  450 CONTINUE
  460 CONTINUE
      JZERO=1
      DO 470 I=1,N
      IF (Q(I).LE.0.) IZERO=IZERO+1
  470 CONTINUE
      RTIO=1.0
      IOUT=1
         IF (IBELL.LT.4) GO TO 680
C                              ZERO AND OUTLIER TESTS FOR HALF-RECORDS
      DO 480 I=1,N
      QUE(I)=Q(I)
  480 CONTINUE
      IN=N
      JZERO=0
C                              TEST HALF-RECORD FOR ZEROES
  490 JZERO=JZERO+1
         IF (JZERO.EQ.1) GO TO 500
C                              FOR SECOND ZERO FLOW TECHNIQUE, DROP ZERO
C                              FLOWS.  TEST FOR OUTLIERS ONLY ON UPPER
C                              END OF RECORD
      IOUT=1
      IDEA=0
      AN=N
      TMP=N-IZERO
```

```
      RTIO=AN/TMP
      N=TMP
      IN=N
         IF (IFORM.EQ.8) GO TO 680
         GO TO 520
C                                 SKIP OUTLIER TESTS FOR BLIE
 500  IDEA=0
         IF (IFORM.NE.8) GO TO 510
      NITA=1
      NITB=1
      IF (IBELL.EQ.4.AND.IZERO.GT.1) NITA=2
      IF (IBELL.EQ.5.AND.IZERO.GT.1) NITB=2
         GO TO 680
 510  CONTINUE
C                                 TEST FOR OUTLIERS ON LOWER END
         IF ((Q(N)*Q(N-7)).GE.(Q(N-1)*Q(N-1))) GO TO 520
      ITMP=IMTHD*JZERO
         IF (IBELL.EQ.4.AND.ITMP.EQ.1) WRITE (6,1940)
         IF (IBELL.EQ.5.AND.ITMP.EQ.1) WRITE (6,1950)
      IOUT=4
      IDEA=IDEA+1
 520  CONTINUE
C                                 TEST FOR OUTLIERS ON UPPER END
         IF ((Q(1)/Q(2)).LE.(Q(2)/Q(8))) GO TO 530
      ITMP=IMTHD*JZERO
         IF (IBELL.EQ.4.AND.ITMP.EQ.1) WRITE (6,1960)
         IF (IBELL.EQ.5.AND.ITMP.EQ.1) WRITE (6,1970)
      IOUT=4
      IDEA=IDEA+2
 530  CONTINUE
         IF (JZERO.EQ.2) GO TO 540
      ITMP=1
      IF (IZERO.GE.1) ITMP=2
      ITMP=ITMP*IOUT
      IF (IBELL.EQ.4) NITA=ITMP
      IF (IBELL.EQ.5) NITB=ITMP
 540  MN=0
 550  MN=MN+1
         IF (IOUT.NE.4) GO TO 680
         GO TO (620,560,560), IDEA
 560  CONTINUE
         GO TO (670,570,580,590), MN
 570  CONTINUE
C                                 TREAT OUTLIER BY CONSTRAINING TO RATIO
      Q(1)=Q(2)*Q(2)/Q(8)
         GO TO 610
 580  CONTINUE
C                                 TREAT OUTLIER BY CONSTRAINING TO SQRT OF
C                                 RATIO
      Q(1)=Q(2)*SQRT(Q(2)/Q(8))
```

```
         GO TO 610
 590  CONTINUE
C                                TREAT OUTLIER BY OMISSION OF VALUE
      N=N-1
      DO 600 I=1,N
      Q(I)=Q(I+1)
 600  CONTINUE
 610     IF (IDEA.LT.3) GO TO 660
 620  CONTINUE
         GO TO (670,630,640,650), MN
 630  CONTINUE
C                                TREAT OUTLIER BY CONSTRAINING TO RATIO
      Q(N)=Q(N-1)*Q(N-1)/Q(N-7)
         GO TO 660
 640  CONTINUE
C                                TREAT OUTLIER BY CONSTRAINING TO SQRT OF
C                                RATIO
      Q(N)=Q(N-1)*SQRT(Q(N-1)/Q(N-7))
         GO TO 660
 650  CONTINUE
C                                TREAT OUTLIER BY OMISSION OF VALUE
      N=N-1
 660  CONTINUE
 670  CONTINUE
         IF (IPRINT.LT.3) GO TO 680
         IF (IOUT.GT.1.AND.MN.EQ.1) WRITE (6,1980)
         IF (MN.EQ.2) WRITE (6,1990)
         IF (MN.EQ.3) WRITE (6,2000)
         IF (MN.EQ.4) WRITE (6,2010)
 680  CONTINUE
      IF (IBELL.LT.4) MN=1
C                                CALCULATE MEAN OF FLOWS
      AN=N
      ANM1=N-1
      ANM12=(N-1)*(N-2)
      SUMQ=0.0
      DO 690 I=1,N
      SUMQ=SUMQ+Q(I)
 690  CONTINUE
      QMEAN=SUMQ/AN
C                                SET UP DESIRED PROBABILITIES
      R(2,1)=.001
      R(2,2)=.003
      R(2,3)=.01
      R(2,4)=.03
      R(2,5)=.1
      R(2,6)=.3
      R(2,7)=.5
      R(2,8)=.7
      R(2,9)=.9
```

```
      R(2,10)=.97
      R(2,11)=.99
      R(2,12)=.997
      R(2,13)=.999
C                                ADJUST TO EXPECTED PROBABILITY FOR ZERO
C                                TECHNIQUES.  FOR FIRST ZERO TECHNIQUE
C                                RTIO=1.0.  FOR SECOND TECHNIQUE RTIO IS
C                                RATIO  OF TOTAL NO. FLOWS TO NO. OF NONZERO
C                                FLOWS.
      B(1)=1.-(.001*RTIO)
      B(2)=1.-(.003*RTIO)
      B(3)=1.-(.01*RTIO)
      B(4)=1.-(.03*RTIO)
      B(5)=1.-(.1*RTIO)
      B(6)=1.-(.3*RTIO)
      B(7)=1.-(.5*RTIO)
      B(8)=1.-(.7*RTIO)
      B(9)=1.-(.9*RTIO)
      B(10)=1.-(.97*RTIO)
      B(11)=1.-(.99*RTIO)
      B(12)=1.-(.997*RTIO)
      B(13)=1.-(.999*RTIO)
      SUMQ=0.
      SUMQQ=0.
      SUMX=0.
      SUMXX=0.
C                                IF DISTRIBUTION USES LOGS OF FLOWS AND IF
C                                THERE ARE ZERO FLOWS ON RECORD
C                                ADD ONE PERCENT OF MEAN TO ALL FLOWS FOR
C                                FIRST ZERO TECHNIQUE.
      DO 710 I=1,N
      TEMP=Q(I)
         IF (IFORM.EQ.3.OR.IFORM.EQ.8) GO TO 700
      IF (JZERO.EQ.1.AND.IZERO.GE.1) TEMP=TEMP+(.01*QMEAN)
      X(I)=ALOG10(TEMP)
      SUMX=SUMX+X(I)
      SUMXX=SUMXX+X(I)*X(I)
 700  Q(I)=TEMP
      SUMQ=SUMQ+TEMP
      SUMQQ=SUMQQ+(TEMP*TEMP)
 710  CONTINUE
C                                CALCULATE MEAN OF ADJUSTED FLOWS AND MEAN
C                                OF LOGS OF ADJUSTED FLOWS
      AMQ=SUMQ/AN
      AMX=SUMX/AN
C                                BRANCH TO VARIOUS DISTRIBUTIONS
         GO TO (730,720,790,790,890,890,730,790,890), IFORM
 720  CONTINUE
C                                LOG NORMAL (2 PARAMETER)
      G=0.0
```

```
C                                   LOG PEARSON TYPE III
  730  CONTINUE
       NJ=13
       JSCLE=2
       ISCLE=1
       TEMP=0.
       TMP=0.
       DO 740 I=1,N
       DEV=X(I)-AMX
       TEMP=TEMP+(DEV*DEV)
       TMP=TMP+(DEV*DEV*DEV)
  740  CONTINUE
       S=SQRT(TEMP/ANM1)
       IF (IFORM.EQ.1) G=(AN*TMP)/(ANM12*(S**3))
       IF (IFORM.EQ.7) G=RGLSKW
       DO 780 J=1,13
          IF (B(J).LE.0.) GO TO 760
       CALL MONRIS (B(J),AK,IER)
          IF (G.EQ.0.) GO TO 750
       AK=(2./G)*((((((G/6.)*(AK-G/6.))+1.)**3)-1.)
  750  CONTINUE
       TEMP=(10.**(AMX+(AK*S)))
       IF (JZERO.EQ.1.AND.IZERO.GE.1) TEMP=TEMP-(.01*QMEAN)
C                                   IF FLOWS HAVE BEEN INCREMENTED BY ONE
C                                   PERCENT OF MEAN, SUBTRACT THIS INCREMENT
          IF (TEMP.GE.0.) GO TO 770
  760  TEMP=0.
  770  QNTY(2,J)=TEMP
  780  CONTINUE
          GO TO 1160
  790  CONTINUE
       NJ=11
       JSCLE=1
       ISCLE=2
       R(2,10)=.99
       R(2,11)=.999
       B(10)=1.-(.99*RTIO)
       B(11)=1.-(.999*RTIO)
          IF (IFORM.EQ.8) GO TO 830
          IF (IFORM.EQ.4) GO TO 810
C                                   CALCULATE GUMBEL MODE AND SLOPE BY METHOD
C                                   OF MOMENTS TO USE AS INITIAL ESTIMATES FOR
C                                   HARTERS ROUTINE
C
C                                   GUMBEL (MLE)
       S=SQRT((AN/ANM1)*((SUMQQ/AN)-(AMQ*AMQ)))
       TMP=AMQ-(.45005*S)
       TEMP=.7797*S
C                                   REVERSE ORDER OF FLOWS
       ITMP=N
```

```
      DO 800 I=1,N
      TIME(I)=Q(ITMP)
      ITMP=ITMP-1
  800 CONTINUE
C                                   CALL ROUTINE FOR HARTERS ESTIMATES
      CALL MAVK (1.,1.,1,TMP,TEMP,0,0,TIME,N,N)
         GO TO 850
C                                   LOG GUMBEL (MLE)
  810 S=SQRT((AN/ANM1)*((SUMXX/AN)-(AMX*AMX)))
      TMP=AMX-(.45005*S)
      TEMP=.7797*S
C                                   REVERSE ORDER OF FLOWS
      ITMP=N
      DO 820 I=1,N
      TIME(I)=X(ITMP)
      ITMP=ITMP-1
  820 CONTINUE
C                                   CALL ROUTINE FOR HARTERS ESTIMATES
      CALL MAVK (1.,1.,1,TMP,TEMP,0,0,TIME,N,N)
      JSCLE=2
         GO TO 850
C                                   GUMBEL (BLIE)
  830 ITMP=N
      NUMHI=0
C                                   REVERSE ORDER OF FLOWS
      DO 840 I=1,N
      TIME(I)=Q(ITMP)
      ITMP=ITMP-1
  840 CONTINUE
C                                   CALL ROUTINE FOR MANNS ESTIMATES
      CALL EXVAN (TIME,N,NUMHI)
  850 CONTINUE
      DO 880 I=1,11
         IF (B(I).LE.0.) GO TO 860
      TMP=-ALOG(-ALOG(B(I)))
      TEMP=AMODE+(SLOPE*TMP)
      IF (IFORM.EQ.4) TEMP=10.**TEMP
C                                   IF FLOWS HAVE BEEN INCREMENTED BY ONE
C                                   PERCENT OF MEAN, SUBTRACT THIS INCREMENT
      IF (JZERO.EQ.1.AND.IZERO.GE.1.AND.IFORM.EQ.4) TEMP=TEMP-(.01*
     1        QMEAN)
         IF (TEMP.GE.0.) GO TO 870
  860 TEMP=0.
  870 QNTY(2,I)=TEMP
  880 CONTINUE
         GO TO 1160
  890 CONTINUE
C                                   2 PARAMETER GAMMA (MLE)
      JSCLE=1
      ISCLE=1
```

```
      SUMX=0.
      DO 900 I=1,N
      TEMP=Q(I)/AMQ
      Q(I)=TEMP
      X(I)=ALOG(TEMP)
      SUMX=SUMX+X(I)
 900  CONTINUE
      AMX=SUMX/AN
         IF (IFORM.EQ.6.OR.IFORM.EQ.9) GO TO 910
C                               USE NORLUNDS EXPANSION OF MAX. LIKELIHOOD
C                               FUNCTION TO CALCULATE SCALE AND SHAPE
C                               PARAMETERS FOR 2 PARAMETER GAMMA
      DIFF=-AMX
      ALPHA=(1.+SQRT(1.+((4./3.)*DIFF)))/(4.*DIFF)
      ALPHA=ALPHA-CORRECT(ALPHA)
      BETA=1./ALPHA
         GO TO 1000
 910  CONTINUE
C                               DETERMINE MAX. LIKELIHOOD ESTIMATORS FOR
C                               LOCATION PARAMETER OF LOWER BOUND FOR
C                               3 PARAMETER GAMMA OR 3 PARAMETER LOG NORMAL
C                               BY ITERATIVE SEARCH
      SOL=.9999*Q(N)
         IF (SOL.GT.0.) GO TO 920
      SOL=0.
         GO TO 990
 920  M=0
      DELX=SOL/5.
      IF (IFORM.EQ.6) TMP=F(SOL)
      IF (IFORM.EQ.9) TMP=H(SOL)
      K=0
 930  K=K+1
         IF (K.GT.200) GO TO 980
      SOL=SOL-DELX
      IF (IFORM.EQ.6) TEMP=F(SOL)
      IF (IFORM.EQ.9) TEMP=H(SOL)
         IF (ABS(TEMP).LE.1.E-4) GO TO 980
         IF (TEMP*TMP.LT.0.) GO TO 940
      TMP=TEMP
         GO TO 930
 940  XX=SOL+DELX
      YY=SOL
 950  SOL=(XX+YY)/2.
      M=M+1
         IF (M.GT.200) GO TO 980
      IF (IFORM.EQ.6) TEMP=F(SOL)
      IF (IFORM.EQ.9) TEMP=H(SOL)
         IF (ABS(TEMP).LE.1.E-4) GO TO 980
         IF (TMP*TEMP) 960,980,970
 960  YY=SOL
```

```
        GO TO 950
 970   XX=SOL
        GO TO 950
 980   CONTINUE
C                                    CONSTRAIN LOWER BOUND TO BE .GE. 0
 990   IF (SOL.LE.0.) SOL=0.
        IF (IFORM.EQ.9) GO TO 1110
      GAMMA=SOL
      TMP=F(GAMMA)
 1000 CONTINUE
C                                    INVERSE OF GAMMA FUNCTION BY ITERATIVE
C                                    SEARCH
      NJ=7
      R(2,1)=.001
      R(2,2)=.01
      R(2,3)=.1
      R(2,4)=.5
      R(2,5)=.9
      R(2,6)=.99
      R(2,7)=.999
      B(1)=1.-(RTIO*.999)
      B(2)=1.-(RTIO*.99)
      B(3)=1.-(RTIO*.9)
      B(4)=1.-(RTIO*.5)
      B(5)=1.-(RTIO*.1)
      B(6)=1.-(RTIO*.01)
      B(7)=1.-(RTIO*.001)
      XX=Q(1)/BETA
      DO 1090 I=1,7
        IF (B(I).LE.0.) GO TO 1080
      PXB=B(I)
      DELX=XX/31.
      CALL MDGAM (XX,ALPHA,PXA,IER)
      PXA=1.-PXA
      IF (PXB.LT.PXA) DELX=-DELX
      K=0
 1010 K=K+1
        IF (K.LE.250) GO TO 1020
      WRITE (6,2240) IFORM,B(I)
        GO TO 1090
 1020 YY=XX-DELX
      IF (YY.LE..01*DELX) YY=0.0
      CALL MDGAM (YY,ALPHA,PXA,IER)
      PXA=1.-PXA
      DIFF=PXA-PXB
      IF (DELX.LT.0.) DIFF=-DIFF
        IF (DIFF.GT.0.) GO TO 1030
      XX=YY
        GO TO 1010
 1030   IF (DELX.GT.0.) GO TO 1040
```

```
      TEMP=YY
      YY=XX
      XX=TEMP
      ITMP=0
 1040 TEMP=(XX+YY)/2.
      ITMP=ITMP+1
         IF (ITMP.GT.30) GO TO 1070
      CALL MOGAM (TEMP,ALPHA,PXA,IER)
      PXA=1.-PXA
      PXA=PXB-PXA
         IF (ABS(PXA).LE.PXB*.0001) GO TO 1070
         IF (PXA) 1050,1070,1060
 1050 YY=TEMP
         GO TO 1040
 1060 XX=TEMP
         GO TO 1040
 1070 XX=TEMP
      IF (IFORM.EQ.5) TEMP=TEMP*BETA*AMQ
      IF (IFORM.EQ.6) TEMP=(TEMP*BETA+GAMMA)*AMQ
C                                IF FLOWS HAVE BEEN INCREMENTED BY ONE
C                                PERCENT OF MEAN, SUBTRACT THIS INCREMENT
      IF (JZERO.EQ.1.AND.IZERO.GE.1) TEMP=TEMP-(.01*QMEAN)
         IF (TEMP.GE.0.) GO TO 1090
 1080 TEMP=0.
      QNTY(2,I)=TEMP
 1090 CONTINUE
      DO 1100 I=1,N
      Q(I)=Q(I)*AMQ
 1100 CONTINUE
         GO TO 1160
C                                3 PARAMETER LOG NORMAL (MLE)
 1110 CONTINUE
      NJ=13
      JSCLE=2
      ISCLE=1
      AK=SOL
      TEMP=H(AK)
      DO 1140 I=1,13
         IF (B(I).LE.0.) GO TO 1120
      CALL MDNRIS (B(I),TMP,IER)
      TEMP=(AMU*EXP(SIGMA*TMP))+AK
      TEMP=TEMP*AMQ
C                                IF FLOWS HAVE BEEN INCREMENTED BY ONE
C                                PERCENT OF MEAN, SUBTRACT THIS INCREMENT
      IF (JZERO.EQ.1.AND.IZERO.GE.1) TEMP=TEMP-(.01*QMEAN)
         IF (TEMP.GE.0.) GO TO 1130
 1120 TEMP=0.
 1130 QNTY(2,I)=TEMP
 1140 CONTINUE
      DO 1150 I=1,N
```

```
      Q(I)=Q(I)*AMQ
 1150 CONTINUE
 1160 CONTINUE
C                           CHECK IF CALCULATED STATISTICS AND/OR
C                           ESTIMATORS OF DISTRIBUTION PARAMETERS ARE
C                           TO BE PRINTED.
         IF (IBELL.EQ.1) GO TO 1170
         IF (IBELL.LE.3.AND.IPRINT.LT.2) GO TO 1320
         IF (MN.GT.1.AND.IPRINT.LT.3) GO TO 1320
         IF (IBELL.GE.4.AND.IPRINT.LT.1) GO TO 1320
 1170 CONTINUE
C                           PRINT CALCULATED STATISTICS AND/OR
C                           ESTIMATORS OF DISTRIBUTION PARAMETERS.
         GO TO (1190,1190,1200,1200,1210,1220,1190,1230,1180), IFORM
 1180 WRITE (6,1830) AMODE,SLOPE,NUMHI
         GO TO 1240
 1190    IF (IFORM.LT.7) WRITE (6,1780) AMQ,AMX,S,G
         IF (IFORM.EQ.7) WRITE (6,1790) AMQ,AMX,S,G
         GO TO 1240
 1200 WRITE (6,1820) AMODE,SLOPE
         GO TO 1240
 1210 WRITE (6,1840) ALPHA,BETA
         GO TO 1240
 1220 WRITE (6,1850) ALPHA,BETA,GAMMA
         GO TO 1240
      WRITE (6,1860) AMU,AK,SIGMA
         GO TO 1240
 1230 WRITE (6,1830) AMODE,SLOPE,NUMHI
 1240 WRITE (6,1800)
C
C                           PRINT PROBABILITIES AND CORRESPONDING
C                           CALCULATED FLOWS
C
      WRITE (6,1810) (QNTY(2,J),R(2,J),J=1,NJ)
C                           PLOT IF THIS IS FULL RECORD WITH LOG
C                           PEARSON III OR GUMBEL (MLE)
         IF (IBELL.EQ.1.AND.IFORM.EQ.1) GO TO 1280
         IF (IBELL.EQ.1.AND.IFORM.EQ.3) GO TO 1280
C                           PLOT IF IDO.EQ.1 AND THIS IS FULL RECORD
      ITMP=IBELL*IDO
         IF (ITMP.EQ.1) GO TO 1280
         GO TO 1320
         IF (IBELL.EQ.5) GO TO 1260
C                           SET UP VALUES FOR PLOT IF DESIRED
      DO 1250 I=1,NODD
      QNTY(1,I)=QODD(I)
 1250 CONTINUE
         GO TO 1300
 1260 CONTINUE
      DO 1270 I=1,NEVEN
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      QNTY(1,I)=QEVEN(I)
 1270 CONTINUE
         GO TO 1300
 1280 CONTINUE
      DO 1290 I=1,N
      QNTY(1,I)=Q(I)
 1290 CONTINUE
 1300 CONTINUE
      DO 1310 I=1,N
      R(1,I)=PLOTP(IPP,I)
 1310 CONTINUE
      NVAL(1)=N
      NVAL(2)=NJ
C
C                                CALL PLOT ROUTINE
C
      IF (JSCLE.EQ.1) CALL ARITH (2,NVAL,QNTY,R,ISCLE)
      IF (JSCLE.EQ.2) CALL PLOG (2,NVAL,QNTY,R,ISCLE)
 1320 CONTINUE
C
C                                FILL ARRAYS TO SAVE DESIRED VALUES ON
C                                TAPE
         GO TO (1330,1350,1350,1380,1490), IBELL
C
C                                ENTIRE RECORD FLOWS
C
 1330 IP=0
      DO 1340 I=1,16
      XPT(I)=0.0
 1340 CONTINUE
         GO TO 1600
 1350 I=0
      IF (IBELL.EQ.3) IP=4
C
C                                5 OR 10 SELECTED FLOWS
C
C                                OBSERVED FREQ. IN REMAINDER OF RECORD
C                                FOR FLOWS WITH COMPUTED FREQ. OF .001,.01,
C                                .1,.5
      DO 1370 J=1,4
      IP=IP+1
 1360 I=I+1
         IF (I.GT.NJ) GO TO 1600
      ITMP=1000.*R(2,I)+0.1
         IF (IFREQ(J).NE.ITMP) GO TO 1360
      CALL BIGGER (QNTY(2,I),XPT(IP),IBELL)
 1370 CONTINUE
         GO TO 1600
C
C                                FIRST HALF RECORD FLOWS
```

```
C
 1380     IF (MN.NE.1) GO TO 1430
          GO TO (1390,1420), JZERO
 1390 CONTINUE
      IFR=0
      IACY=0
      I=0
      IP=8
C                               OBSERVED FREQ. IN REMAINDER OF RECORD
C                               FOR FLOWS WITH COMPUTED FREQ. OF .001,.01,
C                               .1,.5
      DO 1410 J=1,4
      IP=IP+1
 1400 I=I+1
         IF (I.GT.NJ) GO TO 1600
      ITMP=1000.*R(2,I)+0.1
         IF (IFREQ(J).NE.ITMP) GO TO 1400
      CALL BIGGER (QNTY(2,I),XPT(IP),IBELL)
 1410 CONTINUE
         GO TO 1430
 1420 IFR=16
      IACY=12
 1430 CONTINUE
C                               COMPUTED FREQ. FOR OPPOSITE HALF RECORD
C                               MAX.,DECILE,MEDIAN
      DO 1440 J=2,4
      IACY=IACY+1
      CALL INVERSE (QXL(2,J),ACYA(IACY),IFORM)
 1440 CONTINUE
C                               COMPUTED FREQ. FOR FULL-RECORD EXTREME,
C                               MAX.,DECILE,MEDIAN
      DO 1450 J=1,4
      IFR=IFR+1
      CALL INVERSE (QXL(1,J),FREA(IFR),IFORM)
 1450 CONTINUE
      ITMP=MN*JZERO
         IF (ITMP.NE.1) GO TO 1470
C                               COMPLETELY FILL FREA ARRAY WITH FIRST 4
C                               VALUES
      DO 1460 J=8,32,4
      FREA(J-3)=FREA(1)
      FREA(J-2)=FREA(2)
      FREA(J-1)=FREA(3)
      FREA(J)=FREA(4)
 1460 CONTINUE
         GO TO 1600
 1470    IF (JZERO.EQ.1.OR.MN.NE.1) GO TO 1600
      DO 1480 J=24,32,4
      FREA(J-3)=FREA(17)
      FREA(J-2)=FREA(18)
```

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      FREA(J-1)=FREA(19)
      FREA(J)=FREA(20)
 1480 CONTINUE
         GO TO 1600
C
C                                 SECOND HALF RECORD FLOWS
C
 1490    IF (MN.NE.1) GO TO 1540
         GO TO (1500,1530), JZERO
 1500 IFR=0
      IACY=0
      I=0
      IP=12
C                                 OBSERVED FREQ. IN REMAINDER OF RECORD
C                                 FOR FLOWS WITH COMPUTED FREQ. OF .001,.01,
C                                 .1,.5
      DO 1520 J=1,4
      IP=IP+1
 1510 I=I+1
         IF (I.GT.NJ) GO TO 1600
      ITMP=1000.*R(2,I)+0.1
         IF (IFREQ(J).NE.ITMP) GO TO 1510
      CALL BIGGER (QNTY(2,I),XPT(IP),IBELL)
 1520 CONTINUE
         GO TO 1540
 1530 IFR=16
      IACY=12
 1540 CONTINUE
C                                 COMPUTED FREQ. FOR OPPOSITE HALF RECORD
C                                 MAX.,DECILE,MEDIAN
      DO 1550 J=2,4
      IACY=IACY+1
      CALL INVERSE (QXL(3,J),ACYB(IACY),IFORM)
 1550 CONTINUE
C                                 COMPUTED FREQ. FOR FULL-RECORD EXTREME,
C                                 MAX.,DECILE,MEDIAN
      DO 1560 J=1,4
      IFR=IFR+1
      CALL INVERSE (QXL(1,J),FREB(IFR),IFORM)
 1560 CONTINUE
      ITMP=MN*JZERO
         IF (ITMP.NE.1) GO TO 1580
      DO 1570 J=8,32,4
      FREB(J-3)=FREB(1)
      FREB(J-2)=FREB(2)
      FREB(J-1)=FREB(3)
      FREB(J)=FREB(4)
 1570 CONTINUE
         GO TO 1600
 1580    IF (JZERO.EQ.1.OR.MN.NE.1) GO TO 1600
```

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      DO 1590 J=24,32,4
      FREB(J-3)=FREB(17)
      FREB(J-2)=FREB(18)
      FREB(J-1)=FREB(19)
      FREB(J)=FREB(20)
 1590 CONTINUE
 1600 CONTINUE
         IF (IBELL.LT.4) GO TO 1620
C
C                                REPLACE Q ARRAY FOR NEXT OUTLIER TECHNIQUE
      DO 1610 I=1,IN
      Q(I)=QUE(I)
 1610 CONTINUE
      N=IN
         IF (IOUT.EQ.4.AND.MN.LT.4) GO TO 550
         IF (IZERO.GE.1.AND.JZERO.EQ.1) GO TO 490
C                                STATEMENT 760 IS END OF SPLIT RECORD DO
C                                LOOP
 1620 CONTINUE
      J=1
      DO 1630 I=1,64,2
      CSTY(I)=FREA(J)
      J=J+1
 1630 CONTINUE
      J=1
      DO 1640 I=2,64,2
      CSTY(I)=FREB(J)
      J=J+1
 1640 CONTINUE
      NIT=8
      ITMP=NITA*NITB
      IF (ITMP.EQ.1.OR.ITMP.EQ.2.OR.ITMP.EQ.4) NIT=ITMP
      IF (NITA.EQ.2.AND.NITB.EQ.2) NIT=2
      IF (NITA.EQ.4.AND.NITB.EQ.4) NIT=4
      WRITE (20) IDSTA,NSTORE,NITA,NITB,NIT,XPT,PLT,ACYA,ACYB,CSTY
      WRITE (6,2180) ((QXL(I,J),J=1,4),I=1,3)
C
C                                PRINT DATA THAT WAS WRITTEN ON TAPE
C
      WRITE (6,1870) XPT,PLT
      WRITE (6,1880)
      J=1
      DO 1650 K=1,2
      DO 1650 KTMP=1,4
      JTMP=J+2
      WRITE (6,1900) (KTMP,K,(ACYA(I),ACYB(I),I=J,JTMP))
      J=JTMP+1
 1650 CONTINUE
      WRITE (6,1890)
      J=1
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```
      DO 1660 K=1,2
      DO 1660 KTMP=1,4
      JTMP=J+7
      WRITE (6,1910) KTMP,K,(CSTY(I),I=J,JTMP)
      J=JTMP+1
 1660 CONTINUE
C                              RETURN TO READ INFORMATION ON NEXT DISTR.
C                              TO BE USED OR NEXT STATION TO BE PROCESSED
         GO TO (240,250), KONTRL
 1670 FORMAT  (////,18X,*AUTOCORRELATION COEFFICIENTS AND T VALUES FOR *
     1,I3,* STATIONS*,/,/(F30.3,F28.2))
 1680 FORMAT (10I8)
 1690 FORMAT  (I8,12X,4A10,A5,2X,F10.0,F7.0,I8,22X,F5.2/(7(I4,A6,F7.0,2X
     1)))
 1700 FORMAT  (38X,I8,5X,4A10,A5)
 1710 FORMAT  (2(/,17A8))
 1720 FORMAT  (/,5X,*TOTAL NO. OF VALUES READ          =*,I8,/,5X,*NO. OF
     1BLANK VALUES                     =*,I8,/,5X,*NO. OF VALUES USED FOR ANALYS
     2IS =*,I8)
 1730 FORMAT       (5X,*DATE OF*,6X,*OBSERVED*,6X,*ORDERED*,7X,*RANK*,5X,
     1*PLOTTING POSITION*,/,5X,*PEAK FLOW*,4X,*PEAK FLOW*,5X,*PEAK FLOW*
     2, 14X,*M/N+1*,8X,*M-0.3/N+0.4*)
 1740 FORMAT  (5X,A6  ,7X,F10.0,4X,F10.0,4X,I4  ,5X,F8.5,5X,F8.5)
 1750 FORMAT  (5X,A6,7X,F10.0)
 1760 FORMAT  (5X,*FLOWS OMMITED AS HISTORIC RECORDS*,/,5X,/(F10.0))
 1770 FORMAT  (22X,*AUTOCORRELATION COEFFICIENTS*,/,26X,*NO. PAIRS*,4X,*
     1FLOW*,6X,*LOG OF FLOW*,/,5X,*COMPLETE RECORD*,F12.0,2F12.5,/,5X,*H
     2ALF RECORD*,4X,F12.0,2F12.5,/,  5X,*OTHER HALF*,5X,F12.0,2F12.5,/)
 1780 FORMAT  (5X,*ARITHMETIC MEAN      =*,F12.5,/,5X,*MEAN OF LOGS.
     1  =*,F12.5,/,5X,*STANDARD DEVIATION  =*,F12.5,/,5X,*COEFFICIENT OF
     2 SKEW =*,F12.5,/)
 1790 FORMAT  (5X,*ARITHMETIC MEAN      =*,F12.5,/,5X,*MEAN OF LOGS.
     1  =*,F12.5,/,5X,*STANDARD DEVIATION  =*,F12.5,/,5X,*COEFFICIENT OF
     2 SKEW =*,F12.5,5X,*(REGIONAL SKEW)*,/)
 1800 FORMAT  (9X,*FLOW*,7X,*PROBABILITY*)
 1810 FORMAT  (4X,F10.0,6X,F9.3)
 1820 FORMAT  (5X,*HARTERS MAXIMUM LIKELIHOOD ESTIMATORS OF GUMBEL MODE
     1AND SLOPE*,/,5X,*MODE  =*,F12.5,/,5X,*SLOPE =*,F12.5,/)
 1830 FORMAT  (5X,*MANNS BEST LINEAR INVARIANT ESTIMATORS OF GUMBEL MODE
     1 AND SLOPE*,/,5X,*MODE*,17X,*=*,F12.5,/,5X,*SLOPE*,16X,*=*,F12.5,/
     2,5X,*NO. OF HIGH OUTLIERS =*,I6)
 1840 FORMAT  (5X,*ESTIMATORS FOR 2 PARAMETER GAMMA DISTRIBUTION*,/,5X,
     1 *SHAPE PARAMETER =*,F12.5,/,5X,*SCALE PARAMETER =*,F12.5,/)
 1850 FORMAT  (5X,*ESTIMATORS FOR 3 PARAMETER GAMMA DISTRIBUTION*,/,5X,
     1*SHAPE PARAMETER                          =*,F12.5,/,5X,*SCALE PARAMET
     2ER                    =*,F12.5,/,5X,*LOCATION PARAMETER OF LOWER
     3  BOUNDARY=*,F12.5,/)
 1860 FORMAT  (5X,*ESTIMATORS FOR 3 PARAMETER LOG NORMAL DISTRIBUTION*,/
     1,5X,*POPULATION GEOMETRIC MEAN OF (K-K0)        = *,F12.5,/,5X,*LOW
     2ER BOUNDARY OF THE DISTRIBUTION OF K   = *,F12.5,/,5X,*STANDARD DE
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     3VIATION OF THE LN(K-K0) VALUES = *,F12.5,/)
 1870 FORMAT  (/,5X,*OBSERVED FREQUENCIES IN REMAINDER OF RECORD FOR COM
     1PUTED FLOWS WITH*,/,5X,*FREQUENCIES OF*,7X,*   .001*,7X,*   .01*,7X
     2,*    .1*,7X,*    .5*,/,5X,*5-YR SAMPLE*,10X,4(F6.4,7X,),/,5X,*10-
     3YR SAMPLE*,9X,4(F6.4,7X),/,5X,*HALF RECORD*,10X,4(F6.4,7X),/,5X,
     4 *OTHER HALF*,11X,4(F6.4,7X),/,41X,*MAX*,9X,*DECILE*,7X,*MEDIAN*,/
     5,5X,*PLOTTING POS*,22X,3(F6.4,7X),/)
 1880 FORMAT (5X,*HALF-RECORD COMPUTED FREQUENCIES OF OPPOSITE HALF-RECO
     1RD FLOWS*,/,6X,*OUTLIER     ZERO*,35X,*MAXIMUM*,15X,*MEDIAN*,18X,*
     2DECILE*,/,5X,*TECHNIQUE  TECHNIQUE*)
 1890 FORMAT (/,5X,*HALF-RECORD FREQUENCY ESTIMATES OF FULL-RECORD FLOWS
     1*,/,        ,6X,*OUTLIER     ZERO*,12X,*EXTREME*,16X,*MAXIMUM*,15X,
     2*MEDIAN*,18X,*DECILE*,/,5X,*TECHNIQUE  TECHNIQUE*)
 1900 FORMAT (I10,I10,F38.4, F8.4,2(F15.4,F8.4))
 1910 FORMAT (2I10,4(F15.4,F8.4))
 1920 FORMAT  (5X,*CALCULATED VALUES SAVED -- TAPE OPERATION SUCCESSFUL*
     1)
 1930 FORMAT  (5X,*TAPE OPERATION NOT SUCCESSFUL, ERROR MESSAGE NO.*,I6)
 1940 FORMAT  (5X,*TESTS INDICATE OUTLIER ON LOWER END OF RECORD -- FIRS
     1T HALF-RECORD*)
 1950 FORMAT   (5X,*TESTS INDICATE OUTLIER ON LOWER END OF RECORD -- SEC
     1OND HALF-RECORD*)
 1960 FORMAT  (5X,*TESTS INDICATE OUTLIER ON UPPER END OF RECORD -- FIRS
     1T HALF-RECORD*)
 1970 FORMAT   (5X,*TESTS INDICATE OUTLIER ON UPPER END OF RECORD -- SEC
     1OND HALF-RECORD*)
 1980 FORMAT  (5X,*OUTLIER(S) TREATED BY USING VALUE AS LARGEST (OR SMAL
     1LEST) OF RECORD*,)
 1990 FORMAT  (5X,*OUTLIER(S) TREATED BY CONSTRAINING TO GIVEN RATIO(S)*
     1)
 2000 FORMAT  (5X,*OUTLIER(S) TREATED BY CONSTRAINING TO SQUARE ROOT OF
     1GIVEN RATIO(S)*)
 2010 FORMAT  (5X,*OUTLIER(S) TREATED BY OMITTING VALUE(S)*)
 2020 FORMAT  (/,12X,*SELECTED FLOWS*,/(12X,F10.0))
 2030 FORMAT  (/,12X,*OBSERVED FLOW*,8X,*PLOTTING POSITION*,/,34X,*M/N+1
     1*,7X,*M-0.3/N+0.4*,/(12X,F10.0,10X,F10.5,5X,F10.5))
 2040 FORMAT  (/,12X,*OBSERVED FLOW*,8X,*PLOTTING POSITION*,/,12X,*EVEN*
     1,9X,*ODD*,6X,*M/N+1*,7X,*M-0.3/N+0.4*,/(6X,F10.0,1X,F10.0,4X,F8.5,
     27X,F8.5))
 2050 FORMAT  (17A8)
 2060 FORMAT (/,56X,*LOG PEARSON TYPE III*,/)
 2070 FORMAT (/,61X,*LOG NORMAL*,/)
 2080 FORMAT  (/,61X,*GUMBEL (MLE)*,/)
 2090 FORMAT  (/,51X,*GUMBEL (BEST LINEAR INVARIANT)*,/)
 2100 FORMAT (/,56X,*GAMMA (2 PARAMETER)*,/)
 2110 FORMAT (/,56X,*GAMMA (3 PARAMETER)*,/)
 2120 FORMAT (/,54X,*LOG NORMAL (3 PARAMETER)*,/)
 2130 FORMAT  (/,50X,*LOG PEARSON TYPE III (FIXED SKEW)*,/)
 2140 FORMAT  (/,58X,*LOG GUMBEL (MLE)*,/)
 2150 FORMAT  (1H0)
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2160 FORMAT (1H1)
2170 FORMAT  (1H1,43X,*FLOOD FREQUENCY RESEARCH PROJECT CALCULATIONS*,/
    1,38X,*COMPLETE RECORDS, HALF RECORDS, 5-YR, AND 10-YR, SAMPLES*,//
    2)
2180 FORMAT  (/,5X,*FLOWS*,16X,*EXTREME*,8X,*MAX*,9X,*DECILE*,7X,*MEDIA
    1N*,/,5X,*FULL-RECORD*,10X,4(F6.0,7X),/,5X,*HALF RECORD*,10X,4(F6.0
    2,7X),/,5X,*OTHER HALF*,11X,4(F6.0,7X))
2190 FORMAT  (5X,*ENTIRE RECORD USED TO CALCULATE DISTRIBUTION PARAMETE
    1RS*,/,5X,*PREDICTED VALUES COMPARED WITH OBSERVED VALUES FROM ENTI
    2RE RECORD*)
2200 FORMAT  (5X,*5  YEARS OF RECORD USED TO CALCULATE DISTRIBUTION PAR
    1AMETERS*,/,5X,*PREDICTED VALUES COMPARED WITH OBSERVED VALUES FORM
    2 REMAINDER OF RECORD*)
2210 FORMAT  (5X,*10 YEARS OF RECORD USED TO CALCULATE DISTRIBUTION PAR
    1AMETERS*,/,5X,*PREDICTED VALUES COMPARED WITH OBSERVED VALUES FORM
    2 REMAINDER OF RECORD*)
2220 FORMAT  (5X,*FIRST HALF-RECORD USED TO CALCULATE DISTRIBUTION PARA
    1METERS*,/,5X,*PREDICTED VALUES COMPARED WITH OBSERVED VALUES FROM
    2OTHER HALF-RECORD*)
2230 FORMAT  (5X,*SECOND HALF-RECORD USED TO CALCULATE DISTRIBUTION PAR
    1AMETERS*,/,5X,*PREDICTED VALUES COMPARED WITH OBSERVED VALUES FROM
    2 OTHER HALF-RECORD*)
2240 FORMAT  (5X,*-----CAUTION----- FOR DISTR. NO. *,I6,* VALUE FOR PROB.
    1 =*,F12.3,* NOT FOUND IN 250 ITERATIONS*)
     END
     SUBROUTINE EXVAN (YI,NN,NUMHI)
     DIMENSION YI(130),XA(130),XYZ(130),XSUM1(100),XSUM2(100),IINN1(4),
    1       IINN4(4),UMANN(25,3,25),BMANN(25,3,25),YP10(100)
     COMMON /AR12/ IGUMBL
     COMMON /AR16/ SLOPE,AMODE
     IGUMBL=IGUMBL+1
        IF (IGUMBL.GT.1) GO TO 10
     REWIND 7
     READ (7) (((UMANN(I,J,K),BMANN(I,J,K),K=1,25),J=1,3),I=10,25),
    1       (YP10(L),L=4,100)
10   CONTINUE
     JKL=9
     DO 20 I=1,NN
     XA(I)=YI(I)
     XYZ(I)=YI(I)
20   CONTINUE
     MPASS=NN
     NNX=0
     NNY=0
     YSUM1=0.0
     YSUM2=0.0
     DO 30 I=1,10
     XSUM1(I)=0.0
     XSUM2(I)=0.0
30   CONTINUE
```

```
      NUMHI=0
      SUMU=0.0
      SUMB=0.0
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      AX=0.0
      BX=0.0
      SUM5=0.0
      SUM6=0.0
      SUM7=0.0
      SUM8=0.0
      AAA=0.0
      BBB=0.0
         IF (NN.GT.25.AND.NN.LE.50) GO TO 90
         IF (NN.GT.50.AND.NN.LE.75) GO TO 140
         IF (NN.GT.75.AND.NN.LE.100) GO TO 100
      DO 40 I=1,NN
      SUMU=SUMU+XA(I)*UMANN(NN,1,I)
      SUMB=SUMB+XA(I)*BMANN(NN,1,I)
40    CONTINUE
      BBB=SUMB
      AAA=SUMU
         IF (YP10(NN).GT.(XA(NN)-SUMU/SUMB)) GO TO 480
      NNN=NN-1
      DO 50 I=1,NNN
      SUM1=SUM1+XA(I)*UMANN(NN,2,I)
      SUM2=SUM2+XA(I)*BMANN(NN,2,I)
50    CONTINUE
      AAA=SUM1
      BBB=SUM2
         IF (YP10(NNN).GT.(XA(NNN)-SUM1)/SUM2) GO TO 70
      NNN=NN-2
      DO 60 I=1,NNN
      SUM3=SUM3+XA(I)*UMANN(NN,3,I)
      SUM4=SUM4+XA(I)*BMANN(NN,3,I)
60    CONTINUE
      AAA=SUM3
      BBB=SUM4
70    DO 80 I=1,NNN
      AX=AX+XA(I)*UMANN(NNN,1,I)
      BX=BX+XA(I)*BMANN(NNN,1,I)
80    CONTINUE
      NUMHI=NN-NNN
      AMODE=AAA
      SLOPE=BBB
      MPASS=NN-NUMHI
      RETURN
90    XNN=NN
```

```
      NP=2
      INN=NN/2
      IINN1(1)=1
      IINN1(2)=1+INN
      IINN4(1)=INN
      IINN4(2)=NN
         GO TO 160
100   XNN=NN
      NP=4
         IF (NN.EQ.95) GO TO 130
         IF (NN.EQ.98) GO TO 110
         IF (NN.EQ.99) GO TO 120
      INN=NN/4
      IINN1(1)=1
      IINN1(2)=1+INN
      IINN1(3)=1+INN*2
      IINN1(4)=1+INN*3
      IINN4(1)=INN
      IINN4(2)=INN*2
      IINN4(3)=INN*3
      IINN4(4)=NN
         GO TO 160
110   IINN1(1)=1
      IINN1(2)=25
      IINN1(3)=49
      IINN1(4)=74
      IINN4(1)=24
      IINN4(2)=48
      IINN4(3)=73
      IINN4(4)=98
         GO TO 160
120   IINN1(1)=1
      IINN1(2)=25
      IINN1(3)=50
      IINN1(4)=75
      IINN4(1)=24
      IINN4(2)=49
      IINN4(3)=74
      IINN4(4)=99
         GO TO 160
130   IINN1(1)=1
      IINN1(2)=24
      IINN1(3)=47
      IINN1(4)=71
      IINN4(1)=23
      IINN4(2)=46
      IINN4(3)=70
      IINN4(4)=95
         GO TO 160
140   XNN=NN
```

```
      NP=3
         IF (NN.EQ.74) GO TO 150
      INN=NN/3
      IINN1(1)=1
      IINN1(2)=1+INN
      IINN1(3)=1+INN*2
      IINN4(1)=INN
      IINN4(2)=INN*2
      IINN4(3)=NN
         GO TO 160
 150  IINN1(1)=1
      IINN1(2)=25
      IINN1(3)=50
      IINN4(1)=24
      IINN4(3)=74
 160  DO 190 K=1,NP
      NZC=0
      YSUM1=0.0
      YSUM2=0.0
      INN6=IINN4(K)-1
      INN9=IINN4(K)-IINN1(K)+1
      XNN9=INN9
      ISEE1=IINN1(K)
      ISEE2=IINN4(K)
      DO 170 I=ISEE1,INN6
      INN7=I+1
      DO 170 J=INN7,ISEE2
         IF (YI(I).LE.YI(J)) GO TO 170
      TEMP1=YI(I)
      YI(I)=YI(J)
      YI(J)=TEMP1
 170  CONTINUE
      DO 180 I=ISEE1,ISEE2
      NZC=NZC+1
      XA(I)=YI(I)
      YSUM1=YSUM1+XA(I)*UMANN(INN9,1,NZC)
      YSUM2=YSUM2+XA(I)*BMANN(INN9,1,NZC)
 180  CONTINUE
      XSUM1(K)=YSUM1*(XNN9/XNN)
      XSUM2(K)=YSUM2*(XNN9/XNN)
 190  CONTINUE
         IF (NP.EQ.3) GO TO 240
         IF (NP.EQ.4) GO TO 310
      BBB=XSUM2(1)+XSUM2(2)
      AAA=XSUM1(1)+XSUM1(2)
         IF (YP10(NN).GT.(XYZ(NN)-AAA)/BBB) GO TO 480
         IF (XA(NN).GE.XA(INN)) GO TO 200
      IDOT1=1
         GO TO 220
 200  IDOT1=2
```

```
      IF (XA(NN-1).GE.XA(INN)) GO TO 230
210   IDOT2=1
      GO TO 400
220   IF (XA(INN-1).GE.XA(NN)) GO TO 210
230   IDOT2=2
      GO TO 400
240   AAA=XSUM1(1)+XSUM1(3)+XSUM1(2)
      IF (YP10(NN).GT.(XYZ(NN)-AAA)/BBB) GO TO 480
      BBB=XSUM2(1)+XSUM2(2)+XSUM2(3)
      IF (XA(NN).GE.XA(2*INN).AND.XA(NN).GE.XA(INN)) GO TO 250
      IF (XA(2*INN).GE.XA(NN).AND.XA(2*INN).GE.XA(INN)) GO TO 260
      IDOT1=1
      GO TO 280
250   IDOT1=3
      IF (XA(NN-1).GE.XA(2*INN).AND.XA(NN-1).GE.XA(INN)) GO TO 300
      IF (XA(2*INN).GE.XA(INN)) GO TO 290
      IDOT2=1
      GO TO 400
260   IDOT1=2
      IF (XA(2*INN-1).GE.XA(NN).AND.XA(2*INN-1).GE.XA(INN)) GO TO 290
      IF (XA(NN).GE.XA(INN)) GO TO 300
270   IDOT2=1
      GO TO 400
280   IF (XA(INN-1).GE.XA(NN).AND.XA(INN-1).GE.XA(2*INN)) GO TO 270
      IF (XA(NN).GE.XA(2*INN)) GO TO 300
290   IDOT2=2
      GO TO 400
300   IDOT2=3
      GO TO 400
310   AAA=XSUM1(1)+XSUM1(2)+XSUM1(3)+XSUM1(4)
      BBB=XSUM2(1)+XSUM2(2)+XSUM2(3)+XSUM2(4)
      IF (YP10(NN).GT.(XYZ(NN)-AAA)/BBB) GO TO 480
      IF (XA(NN).GE.XA(3*INN).AND.XA(NN).GE.XA(2*
     1    INN).AND.XA(NN).GE.XA(INN)) GO TO 320
      IF (XA(3*INN).GE.XA(NN).AND.XA(3*INN).GE.XA(2*INN).AND.XA(3*
     1    INN).GE.XA(INN)) GO TO 360
      IF (XA(2*INN).GE.XA(NN).AND.XA(2*INN).GE.XA(3*INN).AND.XA(2*
     1    INN).GE.XA(INN)) GO TO 370
      IDOT1=1
      GO TO 380
320   IDOT1=4
      IF (XA(NN-1).GE.XA(3*INN).AND.XA(NN-1).GE.XA(2*INN).AND.XA(NN-
     1    1).GE.XA(INN)) GO TO 390
      IF (XA(3*INN).GE.XA(NN-1).AND.XA(3*INN).GE.XA(2*INN).AND.XA(3*
     1    INN).GE.XA(INN)) GO TO 350
      IF (XA(2*INN).GE.XA(NN-1).AND.XA(2*INN).GE.XA(3*INN).AND.XA(2*
     1    INN).GE.XA(INN)) GO TO 340
330   IDOT2=1
      GO TO 400
340   IDOT2=2
```

```
      GO TO 400
350   IDOT2=3
      GO TO 400
360   IDOT1=3
      IF (XA(3*INN-1).GE.XA(NN).AND.XA(3*INN-1).GE.XA(2*INN).AND.XA(3*
     1     INN-1).GE.XA(INN)) GO TO 350
      IF (XA(NN).GE.XA(3*INN-1).AND.XA(NN).GE.XA(2*
     1     INN).AND.XA(NN).GE.XA(INN)) GO TO 390
      IF (XA(2*INN).GE.XA(NN).AND.XA(2*INN).GE.XA(3*INN-1).AND.XA(2*
     1     INN).GE.XA(INN)) GO TO 340
      GO TO 330
370   IDOT1=2
      IF (XA(2*INN-1).GE.XA(NN).AND.XA(2*INN-1).GE.XA(3*INN).AND.XA(2*
     1     INN-1).GE.XA(INN)) GO TO 340
      IF (XA(NN).GE.XA(3*INN).AND.XA(NN).GE.XA(2*INN-
     1     1).AND.XA(NN).GE.XA(INN)) GO TO 390
      IF (XA(3*INN).GE.XA(NN).AND.XA(3*INN).GE.XA(2*INN-1).AND.XA(3*
     1     INN).GE.XA(INN)) GO TO 350
      GO TO 330
380   IF (XA(INN-1).GE.XA(NN).AND.XA(INN-1).GE.XA(3*INN).AND.XA(INN-
     1     1).GE.XA(2*INN)) GO TO 330
      IF (XA(NN).GE.XA(3*INN).AND.XA(NN).GE.XA(2*
     1     INN).AND.XA(NN).GE.XA(INN-1)) GO TO 390
      IF (XA(3*INN).GE.XA(NN).AND.XA(3*INN).GE.XA(2*INN).AND.XA(3*
     1     INN).GE.XA(INN-1)) GO TO 350
      GO TO 340
390   IDOT2=4
400   NNX=NN-1
      XNX=NNX
      NZN=NN-1
      XZN=NZN
      INN9=IINN4(IDOT1)-IINN1(IDOT1)+1
      XNN9=INN9
      INN8=INN9-1
      XNN8=INN8
      NZC=0
      IUP=IINN4(IDOT1)-1
      ISEE1=IINN1(IDOT1)
      DO 410 I=ISEE1,IUP
      NZC=NZC+1
      SUM1=SUM1+XA(I)*UMANN(INN9,2,NZC)
      SUM2=SUM2+XA(I)*BMANN(INN9,2,NZC)
      SUM5=SUM5+XA(I)*UMANN(INN8,1,NZC)
      SUM6=SUM6+XA(I)*BMANN(INN8,1,NZC)
410   CONTINUE
      SSUM1=SUM1*(XNN8/XNX)
      SSUM2=SUM2*(XNN8/XNX)
      SSUM5=SUM5*(XNN8/XNX)
      SSUM6=SUM6*(XNN8/XNX)
      AX=(XNN/XNX)*(AAA-XSUM1(IDOT1))+SSUM5
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```
      BX=(XNN/XNX)*(BBB-XSUM2(IDOT1))+SSUM6
      AAA=(XNN/XNX)*(AAA-XSUM1(IDOT1))+SSUM1
      BBB=(XNN/XNX)*(BBB-XSUM2(IDOT1))+SSUM2
      IYES=Ø
         IF (YP1Ø(NZN).GT.(XYZ(NZN)-AAA)/BBB.AND.NN.GT.5Ø) GO TO 45Ø
         IF (YP1Ø(NZN).GT.(XYZ(NZN)-AAA)/BBB.AND.NN.LE.5Ø) GO TO 46Ø
      NNX=NN-2
      XNX=NNX
      IF (IDOT1.EQ.IDOT2) IYES=1
      INN9=IINN4(IDOT2)-IINN1(IDOT2)+1
      XNN9=INN9
      INN8=IINN4(IDOT2)-IINN1(IDOT2)-IYES
      XNN8=INN8
      IUP=IINN4(IDOT2)-(1+IYES)
      ISEE1=IINN1(IDOT2)
      NZC=Ø
      DO 42Ø I=ISEE1,IUP
      NZC=NZC+1
      SUM3=SUM3+XA(I)*UMANN(INN9,2+IYES,NZC)
      SUM4=SUM4+XA(I)*BMANN(INN9,2+IYES,NZC)
      SUM7=SUM7+XA(I)*UMANN(INN8,1,NZC)
      SUM8=SUM8+XA(I)*BMANN(INN8,1,NZC)
42Ø   CONTINUE
      SSUM3=SUM3*(XNN8/XNX)
      SSUM4=SUM4*(XNN8/XNX)
      SSUM7=SUM7*(XNN8/XNX)
      SSUM8=SUM8*(XNN8/XNX)
         IF (IYES.EQ.1) GO TO 43Ø
      AX=(XZN/XNX)*(AX-XSUM1(IDOT2))+SSUM7
      BX=(XZN/XNX)*(BX-XSUM2(IDOT2))+SSUM8
      AAA=(XZN/XNX)*(AAA-XSUM1(IDOT2))+SSUM3
      BBB=(XZN/XNX)*(BBB-XSUM2(IDOT2))+SSUM4
         GO TO 44Ø
43Ø   AX=(XZN/XNX)*(AX-SSUM5)+SSUM7
      BX=(XZN/XNX)*(BX-SSUM6)+SSUM8
      AAA=(XZN/XNX)*(AAA-SSUM1)+SSUM3
      BBB=(XZN/XNX)*(BBB-SSUM2)+SSUM4
44Ø      IF (YP1Ø(NNX).GT.(XYZ(NNX)-AAA)/BBB.AND.NN.GT.5Ø) GO TO 45Ø
         IF (YP1Ø(NNX).GT.(XYZ(NNX)-AAA)/BBB.AND.NN.LE.5Ø) GO TO 46Ø
      NUMHI=2
         GO TO 47Ø
45Ø   CONTINUE
46Ø   CONTINUE
      NUMHI=NN-(NNX+NNY)
47Ø   AMODE=AAA
      SLOPE=BBB
      MPASS=NN-NUMHI
         GO TO 49Ø
48Ø   AMODE=AAA
      SLOPE=BBB
```

```
 490  CONTINUE
      RETURN
      END
      SUBROUTINE MAVK (SS1,SS2,LORS,UU,BB,M1,M2,T,M,N)
C     IEEVP HARTER ITERATIVE ESTIMATION EXTREME-VALUE PARAMETERS REV MAY
      DIMENSION T(130),U(550),B(550),Z(130),X(56),Y(55)
      COMMON /AR16/ SLOPE,AMODE
C     INPUT
C     N=SAMPLE SIZE (BEFORE CENSORING),N=100 OR LESS AS DIMENSIONED
C     SS1=0 IF LOCATION PARAMETER U IS KNOWN
C     SS1=1 IF LOCATION PARAMETER U IS TO BE ESTIMATED
C     SS2=0 IF SCALE PARAMETER B IS KNOWN
C     SS2=1 IF SCALE PARAMETER B IS TO BE ESTIMATED
C     LORS=0 FOR DISTRIBUTION OF SMALLEST VALUES
C     LORS=1 FOR DISTRIBUTION OF LARGEST VALUES
C     T(I)=I-TH ORDER STATISTIC OF SAMPLE (I=1,N)
C       (SUBSTITUTE BLANK CARDS FOR UNKNOWN CENSORED OBSERVATIONS)
C     M=NUMBER OF OBSERVATIONS REMAINING AFTER CENSORING
C     B(1)=INITIAL ESTIMATE (OR KNOWN VALUE) OF B
C     U(1)=INITIAL ESTIMATE (OR KNOWN VALUE) OF U
C     M1=NUMBER OF OBSERVATIONS CENSORED FROM BELOW
C     M2=NUMBER OF OBSERVATIONS CENSORED FROM ABOVE
C     OUTPUT
C     N,SS1,SS2,LORS,M,U(1),B(1),M1,M2--SAME AS FOR INPUT
C     U(J)=ESTIMATE AFTER J-1 ITERATIONS (OR KNOWN VALUE) OF U
C     B(J)=ESTIMATE AFTER J-1 ITERATIONS (OR KNOWN VALUE) OF B
C       (MAXIMUM VALUE OF J AS PRESENTLY DIMENSIONED IS 550)
C     EL=NATURAL LOGARITHM OF LIKELIHOOD FOR U(J),B(J)
C     REFERENCE
C     HARTER, H. LEON AND MOORE, ALBERT H., MAXIMUM-LIKELIHOOD ESTIMA-
C       TION, FROM DOUBLY CENSORED SAMPLES, OF THE PARAMETERS OF THE
C       FIRST ASYMPTOTIC DISTRIBUTION OF EXTREME VALUES, SUBMITTED FOR
C       PUBLICATION
      U(1)=UU
      B(1)=BB
      EN=N
      N1=M1+1
      N2=N-M2
      EM=M
      EM1=M1
      EM2=M2
      ELNM=0.
      DO 10 I=N1,N
      EI=I
      ELNM=ELNM+ALOG(EI)
 10   CONTINUE
      M9=0
         IF (M2.NE.0) GO TO 20
      M2=1
      M9=1
```

```
20    DO 30 I=1,M2
      EI=I
      ELNM=ELNM-ALOG(EI)
30    CONTINUE
      IF (M9.EQ.1) M2=0
40    DO 640 J=2,550
      JJ=J-1
      X(1)=U(JJ)
         IF (SS1) 660,280,50
50    LS=0
      DO 250 L=1,55
      LP=L+1
      LL=L-1
      X(LP)=X(L)
         IF (LORS) 660,60,110
60    Y(L)=-(EN-EM1-EM2)/B(JJ)
      DO 70 I=N1,N2
      Z(I)=(T(I)-X(L))/B(JJ)
      Y(L)=Y(L)+EXP(Z(I))/B(JJ)
70    CONTINUE
         IF (M1) 660,90,80
80    FL=EXP(Z(N1)-EXP(Z(N1)))
      FU=1.-EXP(-EXP(Z(N1)))
      Y(L)=Y(L)-EM1*FL/(B(JJ)*FU)
90       IF (M2) 660,160,100
100   Y(L)=Y(L)+EM2*EXP(Z(N2))/B(JJ)
         GO TO 160
110   Y(L)=(EN-EM1-EM2)/B(JJ)
      DO 120 I=N1,N2
      Z(I)=(T(I)-X(L))/B(JJ)
      Y(L)=Y(L)-EXP(-Z(I))/B(JJ)
120   CONTINUE
         IF (M1) 660,140,130
130   Y(L)=Y(L)-EM1*EXP(-Z(N1))/B(JJ)
140      IF (M2) 660,160,150
150   FL=EXP(-Z(N2)-EXP(-Z(N2)))
      FU=EXP(-EXP(-Z(N2)))
      Y(L)=Y(L)+EM2*FL/(B(JJ)*(1.-FU))
160      IF (Y(L)) 170,270,180
170   LS=LS-1
         IF (LS+L) 210,190,210
180   LS=LS+1
         IF (LS-L) 210,200,210
190   X(LP)=X(L)-.01*ABS(X(L))
         GO TO 250
200   X(LP)=X(L)+.01*ABS(X(L))
         GO TO 250
210      IF (Y(L)*Y(LL)) 230,270,220
220   LL=LL-1
         GO TO 210
```

```
230   X(LP)=X(L)+Y(L)*(X(L)-X(LL))/(Y(LL)-Y(L))
          IF (ABS(X(LP))-1.E-4) 260,260,240
240       IF (ABS(X(LP)-X(L))-1.E-4) 270,270,250
250   CONTINUE
          GO TO 270
260   U(1)=-U(1)
          GO TO 40
270   U(J)=X(LP)
          GO TO 290
280   U(J)=U(JJ)
290   B(J)=B(JJ)
          IF (SS2) 660,520,300
300   LS=0
      X(1)=B(J)
      DO 500 L=1,55
      LL=L-1
      LP=L+1
      X(LP)=X(L)
          IF (LORS) 660,310,360
310   Y(L)=-(EN-EM1-EM2)/X(L)
      DO 320 I=N1,N2
      Z(I)=(T(I)-U(J))/X(L)
      Y(L)=Y(L)-Z(I)/X(L)+Z(I)*EXP(Z(I))/X(L)
320   CONTINUE
          IF (M1) 660,340,330
330   FL=EXP(Z(N1)-EXP(Z(N1)))
      FU=1.-EXP(-EXP(Z(N1)))
      Y(L)=Y(L)-EM1*Z(N1)*FL/(X(L)*FU)
340       IF (M2) 660,410,350
350   Y(L)=Y(L)+EM2*Z(N2)*EXP(Z(N2))/X(L)
          GO TO 410
360   Y(L)=-(EN-EM1-EM2)/X(L)
      DO 370 I=N1,N2
      Z(I)=(T(I)-U(J))/X(L)
      Y(L)=Y(L)+Z(I)/X(L)-Z(I)*EXP(-Z(I))/X(L)
370   CONTINUE
          IF (M1) 660,390,380
380   Y(L)=Y(L)-EM1*Z(N1)*EXP(-Z(N1))/X(L)
390       IF (M2) 660,410,400
400   FL=EXP(-Z(N2)-EXP(-Z(N2)))
      FU=EXP(-EXP(-Z(N2)))
      Y(L)=Y(L)+EM2*Z(N2)*FL/(X(L)*(1.-FU))
410       IF (Y(L)) 420,510,430
420   LS=LS-1
          IF (LS+L) 460,440,460
430   LS=LS+1
          IF (LS-L) 460,450,460
440   X(LP)=.99*X(L)
          GO TO 490
450   X(LP)=1.01*X(L)
```

```
      GO TO 490
460      IF (Y(L)*Y(LL)) 480,510,470
470   LL=LL-1
      GO TO 460
480   X(LP)=X(L)+Y(L)*(X(L)-X(LL))/(Y(LL)-Y(L))
490      IF (ABS(X(LP)-X(L))-1.E-4) 510,510,500
500   CONTINUE
510   B(J)=X(LP)
520      IF (LORS) 660,530,580
530   EL=ELNM-(EN-EM1-EM2)*ALOG(B(J))
      DO 540 I=N1,N2
      Z(I)=(T(I)-U(J))/B(J)
      EL=EL+Z(I)-EXP(Z(I))
540   CONTINUE
         IF (M1) 660,560,550
550   FU=1.-EXP(-EXP(Z(N1)))
      EL=EL+EM1*ALOG(FU)
560      IF (M2) 660,650,570
570   EL=EL-EM2*EXP(Z(N2))
         GO TO 650
580   EL=ELNM-(EN-EM1-EM2)*ALOG(B(J))
      DO 590 I=N1,N2
      Z(I)=(T(I)-U(J))/B(J)
      EL=EL-Z(I)-EXP(-Z(I))
590   CONTINUE
         IF (M1) 660,610,600
600   EL=EL-EM1*EXP(-Z(N1))
610      IF (M2) 660,650,620
620   FU=EXP(-EXP(-Z(N2)))
      EL=EL+EM2*ALOG(1.-FU)
         IF (ABS(U(J)-U(JJ))-1.E-4) 630,630,640
630      IF (ABS(B(J)-B(JJ))-1.E-4) 650,650,640
640   CONTINUE
650   AMODE=U(J)
      SLOPE=B(J)
660   RETURN
      END
      SUBROUTINE CHOOSE (Q,N,ICHOSE)
C
C                              SUBROUTINE TO DETERMINE EXTREME,MAXIMUM,
C                              UPPER DECILE,AND MEDIAN FLOWS
C
      DIMENSION Q(130),PLOTP(2,130),QXL(3,4),PLT(3)
      COMMON /AR4/ PLT,PLOTP,IPP
      COMMON /AR13/ QXL
      AN=N
      L=(AN/2.)+0.5
      Q50=Q(L)
      QXL(ICHOSE,4)=Q50
      PLT(3)=PLOTP(IPP,L)
```

```
      L=(AN/10.)+.5
      QXL(ICHOSE,3)=Q(L)
      PLT(2)=PLOTP(IPP,L)
      Q1=Q(1)
      QXL(ICHOSE,2)=Q1
      PLT(1)=PLOTP(IPP,1)
      QEXT=Q1*SQRT(Q1/Q50)
      QXL(ICHOSE,1)=QEXT
      RETURN
      END
      SUBROUTINE BIGGER (A,OBS,IBELL)
C
C                                 DETERMINES OBSERVED FREQ (OBS) BY COUNTING
C                                 NUMBER OF VALUES GREATER THAT A.
C
      DIMENSION QODD(130),QEVEN(65)
      COMMON /AR5/ QODD,NODD,QEVEN,NEVEN
      NUMBIG=0
         GO TO (10,20,20,20,50), IBELL
 10   CONTINUE
      RETURN
 20   DO 40 J=1,NODD
      TEMP=QODD(J)-A
         IF (TEMP) 40,40,30
 30   NUMBIG=NUMBIG+1
 40   CONTINUE
      AN=NODD
         GO TO 80
 50   DO 70 J=1,NEVEN
      TEMP=QEVEN(J)-A
         IF (TEMP) 70,70,60
 60   NUMBIG=NUMBIG+1
 70   CONTINUE
      AN=NEVEN
 80   CONTINUE
      TEMP=NUMBIG
      OBS=TEMP/AN
      RETURN
      END
      SUBROUTINE ORDER (N,Q)
C
C                                 SUBROUTINE FOR RANKING OF ARRAY Q IN
C                                 DESCENDING ORDER
C
      DIMENSION Q(130)
      NA=N-1
      DO 20 J=1,NA
      M=J
      MA=J+1
      DO 10 I=MA,N
```

```
      IF (Q(I).GT.Q(M)) M=I
   10 CONTINUE
      TEMP=Q(J)
      Q(J)=Q(M)
      Q(M)=TEMP
   20 CONTINUE
      RETURN
      END
      SUBROUTINE POSIT (N)
C
C                                COMPUTATION OF PLOTTING POSITIONS
C
      DIMENSION PLT(3),PLOTP(2,130)
      COMMON /AR4/ PLT,PLOTP,IPP
      AN=N
      DEN=AN+1.0
      DEN2=AN+0.4
      DO 10 I=1,N
      TEMP=I
      PLOTP(1,I)=TEMP/DEN
      PLOTP(2,I)=(TEMP-0.3)/DEN2
   10 CONTINUE
      RETURN
      END
      SUBROUTINE INVERSE (Q,PROB,IFORM)
C
C                                GIVEN DISTRIBUTION PARAMETERS FROM MAIN
C                                PROGRAM, THIS SUBROUTINE COMPUTES PROB. OF
C                                EXCEEDANCE (PROB) OF FLOOD OF MAGNITUDE Q.
C
      COMMON /AR2/ ALPHA,BETA
      COMMON /AR3/ GAMMA
      COMMON /AR8/ AMU,SIGMA,AK
      COMMON /AR15/ AMX,S,G
      COMMON /AR16/ SLOPE,AMODE
      COMMON /AR17/ AMQ
         GO TO (10,10,30,40,50,60,10,30,70), IFORM
   10 CONTINUE
C                                LOG NORMAL AND LOG PEARSON III
      AK=(ALOG10(Q)-AMX)/S
      IF (IFORM.EQ.1.AND.G.EQ.0.) Y=AK
         IF (IFORM.EQ.1.AND.G.EQ.0.) GO TO 20
      IF (IFORM.EQ.2) Y=AK
         IF (IFORM.EQ.2) GO TO 20
      IF (IFORM.EQ.7.AND.G.EQ.0.) Y=AK
         IF (IFORM.EQ.7.AND.G.EQ.0.) GO TO 20
      THIRD=1./3.
      TEMP=(AK*G+2.)/2.
      TMP=(ABS(TEMP))**THIRD*(TEMP/ABS(TEMP))
      Y=((6./G)*(TMP-1.))+G/6.
```

```
 20   CONTINUE
      CALL MDNOR (Y,PROB)
         GO TO 80
 30   CONTINUE
C                                  GUMBEL (MLE AND BLIE)
      X=(Q-AMODE)/SLOPE
      PROB=EXP(-EXP(-X))
         GO TO 80
 40   CONTINUE
C                                  LOG GUMBEL (MLE)
      TEMP=ALOG10(Q)
      X=(TEMP-AMODE)/SLOPE
      PROB=EXP(-EXP(-X))
         GO TO 80
 50   CONTINUE
C                                  2 PARAMETER GAMMA
      Y=Q/(AMQ*BETA)
      CALL MDGAM (Y,ALPHA,PROB,IER)
         IF (IER.NE.0) PRINT 90, IER,Y,ALPHA,PROB,BETA,AMQ,Q
         GO TO 80
 60   CONTINUE
C                                  3 PARAMETER GAMMA
      TEMP=Q/AMQ
      Y=(TEMP-GAMMA)/BETA
      CALL MDGAM (Y,ALPHA,PROB,IER)
         IF (IER.NE.0) PRINT 90, IER,Y,ALPHA,PROB,BETA,AMQ,Q,GAMMA
         GO TO 80
 70   CONTINUE
C                                  3 PARAMETER LOG NORMAL
      TEMP=Q/AMQ
      Y=(ALOG((TEMP-AK)/AMU))/SIGMA
      CALL MDNOR (Y,PROB)
 80   CONTINUE
      PROB=1.-PROB
      RETURN
 90   FORMAT  (5X,I4,2X,7(F12.5,1X))
      END
      FUNCTION F (X)
C
C                                  CALCULATION OF LOCATION PARAMETER OF THE
C                                  LOWER BOUNDARY FOR GAMMA 3,  REFERENCE--
C                                  MARKOVIC, PG.9.
C
      DIMENSION Q(130)
C                                  NOTE THAT Q-ARRAY CONTAINS VALUES DIVIDED
C                                  BY THE ARITHMETIC MEAN
      COMMON /AR1/ Q,N
      COMMON /AR2/ ALPHA,BETA
      AN=N
      SUM=0.
```

```
      SUMINV=0.
      DIFF=1.0-X
      DO 10 I=1,N
      TEMP=Q(I)
      SUM=SUM+ALOG(TEMP-X)
      SUMINV=SUMINV+(1./(TEMP-X))
 10   CONTINUE
      TEMP=SQRT(1.+((4./3.)*(ALOG(DIFF)-(SUM/AN))))
      F=(1.+TEMP)-((1.+TEMP)-(4*(ALOG(DIFF)-(SUM/AN))))*(DIFF*(SUMINV/
     1       AN))
      ALPHA=(1.+TEMP)/(4.*(ALOG(DIFF)-(SUM/AN)))
      ALPHA=ALPHA-CORRECT(ALPHA)
      BETA=DIFF/ALPHA
      RETURN
      END
      FUNCTION H (X)
C
C                                 CALCULATION OF LOCATION PARAMETER OF THE
C                                 LOWER BOUNDARY FOR LOG NORMAL 3.  REFERENCE
C                                 -- MARKOVIC.
C
      DIMENSION Q(130)
      COMMON /AR1/ Q,N
      COMMON /AR8/ AMU,SIGMA,AK
      AN=N
      SUMDIFF=0.
      SUMLOG=0.
      SUMLOG2=0.
      DO 10 I=1,N
      DIFF=Q(I)-X
      SUMDIFF=SUMDIFF+DIFF
      TEMP=ALOG(DIFF)
      SUMLOG=SUMLOG+TEMP
      SUMLOG2=SUMLOG2+(TEMP*TEMP)
 10   CONTINUE
      H=(SUMDIFF*((SUMLOG2/AN)-((SUMLOG/AN)**2)-(SUMLOG/AN)))+(SUMLOG/
     1       SUMDIFF)
      AMU=EXP(SUMDIFF/AN)
      SUM=0.
      DO 20 I=1,N
      SUM=SUM+((ALOG(Q(I)-X)-(SUMDIFF/AN))**2)
 20   CONTINUE
      SIGMA=SQRT(SUM/AN)
      RETURN
      END
      FUNCTION CORRECT (ALPHA)
C
C                                 CORRECTION FACTOR FOR COMPUTATION OF MLE
C                                 OF THE SHAPE PARAMETERS OF GAMMA FUNCTIONS
C                                 WITH 2 AND 3 PARAMETERS.  CORRECTION IS
```

```
C                                NECESSARY DUE TO ERROR IN ALPHA RESULTING
C                                FROM USING ONLY ONE TERM IN NORLUND≠S
C                                EXPANSION.  REFERENCE -- MARKOVIC, PG. 9.
C
      DIMENSION ALFA(18),DELTA(18)
      DATA ALFA/.2,.3,.4,.5,.6,.7,.8,.9,1.0,1.1,1.2,1.3,1.5,1.7,1.9,2.3,
     1      3.2,5.6/
      DATA DELTA/.034,.029,.025,.021,.017,.014,.012,.011,.009,.008,.007,
     1      .006,.005,.004,.003,.002,.001,.0/
         IF (ALPHA.LT.5.6) GO TO 10
      CORRECT=0.0
      RETURN
 10   CONTINUE
         IF (ALPHA.LT..2) GO TO 30
      DO 20 I=2,18
         IF (ALPHA.GE.ALFA(I)) GO TO 20
      TMP=ALFA(I-1)
      TEMP=DELTA(I-1)
      CORRECT=TEMP-((ALPHA-TMP)*((TEMP-DELTA(I))/(TOP-TMP)))
      RETURN
 20   CONTINUE
 30   CONTINUE
      CORRECT=(.05*(.3-ALPHA))+.029
      RETURN
      END
      SUBROUTINE PLOG (NVAR,NVAL,QNTY,P,ISCLE)
C
C                                PLOT ROUTINE FOR LOG SCALE
C
      DIMENSION NVAL(2),QNTY(2,130),P(2,130),ISCL(3),NLIN(3),SYMBL(100),
     1      PRB(100)
      DOUBLE PRECISION CNST
      DATA STAR,ZERO/1H*,1HX/
C              DETERMINE RANGE OF MAGNITUDE TO BE PLOTTED
      PRINT 150
      QMAX=0.
      QMIN=999999.
      DO 20 J=1,NVAR
      NQ=NVAL(J)
      DO 10 I=1,NQ
      IF (QNTY(J,I).LT.QMIN) QMIN=QNTY(J,I)
      IF (QNTY(J,I).GT.QMAX) QMAX=QNTY(J,I)
 10   CONTINUE
 20   CONTINUE
         IF (QMAX.GT.1.) GO TO 30
      PRINT 160
      RETURN
 30   CONTINUE
      IF (QMIN.LT.QMAX*.0001) QMIN=QMAX*.0001
      IFCTR=1
```

```
         IF (QMIN.GT.1.) GO TO 40
      TMP=500000./QMAX
      TEMP=1./QMIN
      ITP=ALOG10(TMP)
      ITMP=ALOG10(TEMP)
      IF (TEMP.GT.1.) ITMP=ITMP+1
      IF (ITMP.GT.ITP) ITMP=ITP
      IFCTR=10**ITMP
      PRINT 170, IFCTR
C              SET UPPER LIMIT OF GRID
 40   CONTINUE
      ITP=ALOG10(QMAX)
      TMP=QMAX/10.**ITP
      ITMP=10
      IF (TMP.LE.5.) ITMP=5
      IF (TMP.LE.2.) ITMP=2
         IF (ITMP-5) 70,60,50
 50   CONTINUE
      J=1
         GO TO 80
 60   CONTINUE
      J=2
         GO TO 80
 70   CONTINUE
      J=3
 80   CONTINUE
      ITMP=ITMP*10**ITP*IFCTR
      ISCAL=ITMP
      QMX=ITMP
      TEMP=IFCTR
      QMX=QMX/TEMP
C              SET LOWER LIMIT OF GRID
      TEMP=ALOG10(QMIN)
      IP=TEMP
      IF (TEMP.LT.0.) IP=IP-1
      TMP=QMIN/10.**IP
      ITEMP=1
      IF (TMP.GT.2.) ITEMP=2
      IF (TMP.GT.5.) ITEMP=5
      TEMP=ITEMP
      TMP=IFCTR
      TEMP=TEMP*10.**IP+.000001
      ITEMP=TEMP*TMP
C              ESTABLISH SCALE AND SPACING
      TMP=ITMP/ITEMP
      CNST=10.**(-.05)
      QMN=QMX/SQRT(CNST)
      LINES=ALOG10(TMP)*20.+1.1
      IF (LINES.LT.21) LINES=21
      ISCL(1)=10
```

```
      ISCL(2)=5
      ISCL(3)=2
      NLIN(1)=6
      NLIN(2)=8
      NLIN(3)=6
      M=1
      N=1
      K=0
      DO 130 I=1,LINES
      IF (I.NE.1) ISCAL=-1
      QMN=QMN*CNST
      K=K+1
         IF (K.LE.NLIN(J)) GO TO 90
      K=1
      J=J+1
      IF (J.GT.3) J=1
      IF (ISCL(J).EQ.10) ITP=ITP-1
      TMP=ITP
      TEMP=IFCTR
      TP=ISCL(J)
      ISCAL=TP*10.**TMP*TEMP+.5
      IF (ISCAL.GE.1000000) ISCAL=-2
C              ESTABLISH POINTS TO PLOT ON LINE I
 90   CONTINUE
      NPNT=0
 100  CONTINUE
         IF (M.GT.NVAL(1)) GO TO 110
         IF (QNTY(1,M).LE.QMN.AND.I.LT.LINES) GO TO 110
      NPNT=NPNT+1
      PRB(NPNT)=P(1,M)
      SYMBL(NPNT)=STAR
      M=M+1
         GO TO 100
 110  CONTINUE
         IF (N.GT.NVAL(2)) GO TO 120
         IF (QNTY(2,N).LE.QMN.AND.I.LT.LINES) GO TO 120
      NPNT=NPNT+1
      PRB(NPNT)=P(2,N)
      SYMBL(NPNT)=ZERO
      N=N+1
         GO TO 110
 120  CONTINUE
      IF (ISCLE.EQ.1) CALL PNORM (I,LINES,NPNT,PRB,SYMBL,ISCAL)
      IF (ISCLE.EQ.2) CALL LOGLG (I,LINES,NPNT,PRB,SYMBL,ISCAL)
 130  CONTINUE
      PRINT 140
      RETURN
 140  FORMAT (/,/,/)
 150  FORMAT  (1HQ)
 160  FORMAT  (17H0VALUES TOO SMALL)
```

```
 170  FORMAT  (25H0QUANTITIES MULTIPLIED BY I6/)
      END
      SUBROUTINE ARITH (NVAR,NVAL,QNTY,P,ISCLE)
C
C                                 PLOT ROUTINE FOR ARITHMETIC SCALE
C
      DIMENSION NVAL(2),QNTY(2,130),P(2,130),SYMBL(100),PRB(100)
      DATA STAR,ZERO/1H*,1HX/
C               DETERMINE RANGE OF MAGNITUDE TO BE PLOTTED
      PRINT 100
      QMAX=0.
      QMIN=999999.
      DO 20 J=1,NVAR
      NQ=NVAL(J)
      DO 10 I=1,NQ
      IF (QNTY(J,I).LT.QMIN) QMIN=QNTY(J,I)
      IF (QNTY(J,I).GT.QMAX) QMAX=QNTY(J,I)
 10   CONTINUE
 20   CONTINUE
         IF (QMAX.GT.1.) GO TO 30
      PRINT 110
      RETURN
 30   CONTINUE
      LINES=51
      NLIN=10
      TMP=ALOG10(QMAX)
      I=TMP
      IF (TMP.LT.0.) I=I-1
      TMP=QMAX/10.**I
      NTRVL=2
      IF (TMP.GT.2) NTRVL=4
      IF (TMP.GT.4) NTRVL=5
      IF (TMP.GT.5) NTRVL=10
      TMP=NTRVL
      QMX=TMP*10.**I
      DLTQ=QMX*.02
      QMN=QMX+DLTQ*.5
      M=1
      N=1
      K=0
      ISCAL=QMX+.5
      ISC=ISCAL
      ITMP=QMX*.2+.5
      DO 80 I=1,LINES
      IF (I.NE.1) ISCAL=-1
      QMN=QMN-DLTQ
      K=K+1
         IF (K.LE.NLIN) GO TO 40
      K=1
      ISC=ISC-ITMP
```

```
      ISCAL=ISC
 40   CONTINUE
      IF (ISCAL.GE.1000000) ISCAL=-2
C             ESTABLISH POINTS TO PLOT ON LINE I
      NPNT=0
 50   CONTINUE
         IF (M.GT.NVAL(1)) GO TO 60
         IF (QNTY(1,M).LE.QMN.AND.I.LT.LINES) GO TO 60
      NPNT=NPNT+1
      PRB(NPNT)=P(1,M)
      SYMBL(NPNT)=STAR
      M=M+1
         GO TO 50
 60   CONTINUE
         IF (N.GT.NVAL(2)) GO TO 70
         IF (QNTY(2,N).LE.QMN.AND.I.LT.LINES) GO TO 70
      NPNT=NPNT+1
      PRB(NPNT)=P(2,N)
      SYMBL(NPNT)=ZERO
      N=N+1
         GO TO 60
 70   CONTINUE
      IF (ISCLE.EQ.1) CALL PNORM (I,LINES,NPNT,PRB,SYMBL,ISCAL)
      IF (ISCLE.EQ.2) CALL LOGLG (I,LINES,NPNT,PRB,SYMBL,ISCAL)
 80   CONTINUE
      PRINT 90
      RETURN
 90   FORMAT (/,/,/)
 100  FORMAT  (1HQ)
 110  FORMAT  (17H0VALUES TOO SMALL)
      END
      SUBROUTINE PNORM (I,N,NPNT,PRB,SYMBL,ISCAL)
C
C                           PLOT ROUTINE FOR NORMAL PROBABILITY SCALE
C
      DIMENSION GRID(132),PLOT(132),PROB(11),PLT(11),PRB(100),SYMBL(100)
      DATA BLANK,PER,DASH/1H ,1H.,1H-/
         IF (I.GT.1) GO TO 20
      DO 10 J=8,132
      GRID(J)=BLANK
 10   CONTINUE
      GRID(8)=PER
      GRID(15)=PER
      GRID(23)=PER
      GRID(32)=PER
      GRID(44)=PER
      GRID(60)=PER
      GRID(70)=PER
      GRID(80)=PER
      GRID(96)=PER
```

```
      GRID(108)=PER
      GRID(117)=PER
      GRID(125)=PER
      GRID(132)=PER
 20   CONTINUE
         IF (ISCAL+1) 50,30,50
 30   CONTINUE
      DO 40 J=8,132
      PLOT(J)=GRID(J)
 40   CONTINUE
         GO TO 70
 50   CONTINUE
      DO 60 J=8,132
      PLOT(J)=DASH
 60   CONTINUE
 70   CONTINUE
         IF (NPNT.LE.0) GO TO 90
      DO 80 K=1,NPNT
      P=1-PRB(K)
      CALL MDNRIS (P,X,IER)
      M=70.5+X*20.
      IF (M.LT.8) M=8
      IF (M.GT.132) M=132
      PLOT(M)=SYMBL(K)
 80   CONTINUE
 90   CONTINUE
         IF (ISCAL.GE.0) PRINT 100, ISCAL,(PLOT(J),J=8,132)
         IF (ISCAL.LT.0) PRINT 110, (PLOT(J),J=8,132)
         IF (I.EQ.N) PRINT 120
      RETURN
 100  FORMAT  (1XI6,125A1)
 110  FORMAT  (7X125A1)
 120  FORMAT  (6X4H99.9 3X4H99.7 5X2H99 7X2H97 10X2H90 14X2H70 8X2H50
     1  7X2H30 14X2H10 11X1H3 8X1H1 6X2H.3 5X2H.1/50X39HEXCEEDENCE FREQU
     2ENCY PER HUNDRED EVENTS)
      END
      SUBROUTINE LOGLG (I,N,NPNT,PRB,SYMBL,ISCAL)
C
C                               PLOT ROUTINE FOR LOG-LOG SCALE (EXTREME-
C                               VALUE PROBABILITY SCALE FOR GUMBLE)
C
      DIMENSION GRID(132),PLOT(132),PRB(100),SYMBL(100)
      DATA BLANK,PER,DASH/1H ,1H.,1H-/
         IF (I.GT.1) GO TO 20
      DO 10 J=8,132
      GRID(J)=BLANK
 10   CONTINUE
      GRID(13)=PER
      GRID(18)=PER
      GRID(27)=PER
```

```
      GRID(35)=PER
      GRID(43)=PER
      GRID(51)=PER
      GRID(67)=PER
      GRID(83)=PER
      GRID(98)=PER
      GRID(114)=PER
      GRID(128)=PER
 20   CONTINUE
         IF (ISCAL+1) 50,30,50
 30   CONTINUE
      DO 40 J=8,132
      PLOT(J)=GRID(J)
 40   CONTINUE
         GO TO 70
 50   CONTINUE
      DO 60 J=8,132
      PLOT(J)=DASH
 60   CONTINUE
 70   CONTINUE
         IF (NPNT.LE.0) GO TO 90
      DO 80 K=1,NPNT
      TMP=ALOG10(1.-PRB(K))
      TMP=ALOG10(-TMP)
      M=27.5-TMP*30.
      IF (M.LT.8) M=8
      IF (M.GT.132) M=132
      PLOT(M)=SYMBL(K)
 80   CONTINUE
 90   CONTINUE
         IF (ISCAL.GE.0) PRINT 100, ISCAL,(PLOT(J),J=8,132)
         IF (ISCAL.LT.0) PRINT 110, (PLOT(J),J=8,132)
         IF (I.EQ.N) PRINT 120
      RETURN
100   FORMAT (1XI6,125A1)
110   FORMAT (7X125A1)
120   FORMAT (10X4H99.9 3X2H99 6X2H90 6X2H70 6X2H50 7X2H30 13X2H10
     1 15X1H3 14X1H1 14X2H.3 12X2H.1 /50X39HEXCEEDENCE FREQUENCY PER HUN
     2DRED EVENTS)
      END
```

APPENDIX C

COMPUTER PROGRAM VERIFY

Origin of program.

This program was written by Leo R. Beard, Technical Director of the Center for Research in Water Resources, The University of Texas at Austin, under the guidance of the Work Group on Flood Flow Frequencies, Hydrology Committee of the Water Resources Council.

Purpose of the program.

This program is designed to accept split-record output data from the program FREQNCY, and to compute accuracy and consistency criteria for evaluating a number of flood flow frequency techniques.

Methods.

Verification analysis is made in two steps. The first step uses data from program FREQNCY only for the first outlier technique and the first zero-flow technique and is for the purpose of establishing an average expected-probability adjustment coefficient for each basic method used. This adjustment accounts for the difference in average frequencies in the true populations at a large number of stations and the average frequencies computed from sample data for those populations using unique best estimates of the function parameters in each case. This adjustment has been developed theoretically for the Gaussian Normal distribution and was reported on by Leo R. Beard in "Probability Estimates Based on Small Normal Distribution Samples," Journal of Geophysical Research, Volume 65, Number 7, July 1960. In this program, expected probability for the normal distribution is computed by the following equation:

$$X = \bar{X} + t_{n-1}\sqrt{\frac{n+1}{n}}\,S \qquad (1)$$

in which

X = magnitude having exceedence probability equal to that of Student's t

t = Student's t

n = Number of events in the sample

$\bar{X}$ = Mean of sample values

S = Standard deviation estimated from sample values

The normal probability estimate for the Gaussian distribution is:

$$X = \bar{X} + kS \qquad (2)$$

in which X is a magnitude having exceedence probability equal to that of a normally distributed k value. For the same value of X, values of exceedence probabilities of computed k and t quantities are computed. For sample sizes of 5, 10 and half-record length, flows are computed for probabilities of .5, .1, .01 and .001, and observed exceedence frequencies of these magnitudes in the remainder of the record are compared with the frequencies computed in accordance with the above equations. For each magnitude, the difference between observed probability and the probability of k is divided by the difference between the probability of t and the probability of k, and the average ratio for each sample size and method is established for the aggregate of all stations. These average ratios are to be used to develop expected-probability adjustment criteria for each frequency technique.

The second step uses output data from program FREQNCY for all outliers and zero-flow techniques in turn and makes the verfication analysis for establishing the relative accuracy and consistency of the various flood flow frequency techniques. Relative accuracy is measured by the root mean square difference between 1.0 and the ratio of the expected plotting position of the largest, decile and median events in one half of the record to the computed expected probabilities for each of those magnitudes in turn using data in the other half of the record. If any ratio exceeds 1.0, its reciprocal is used. The expected-probability is estimated by use of the following equation:

$$P = P_k + C(P_t - P_k)$$

in which

P_t = Expected exceedence probability for a Gaussian distribution

P_k = Normal computed exceedence probability for a Gaussian distribution

C = Coefficient (FCTR) derived in step 1 for the particular distribution being employed

Relative consistency is measured as the root-mean-square difference between 1.0 and the ratio of the smaller to the larger computed frequency (not adjusted for expected probability) from data for the two halves of each record for magnitudes of the median, upper decile, maximum and extreme full-record values. The extreme value is defined as the maximum value multiplied by the square root of the ratio of the maximum value to the median value.

Input.

Control of the program operation is by one card for each type of operation and method. Variables are right-justified in 8-column fields as follows:

Cols 1-8	IOPER--Type of operation, 1 for expected-probability calibration and 2 for verification analysis
Cols 9-16	METHOD--Method of curve fitting (see Definitions)
Cols 17-24	FCTR--Multiplier of expected-probability adjustment (derived from earlier pass when IOPER = 1 and used only when IOPER = 2)

a blank card will cause the computer run to end.

All other input is in binary mode from tape 10, which is the output tape for program FREQNCY. If the specified method identification number on an input card is not contained on tape 10, program VERIFY will abort.

Output.

The output for step 1 (IOPER) = 1) for a specified method consists of average computed frequencies (adjusted for expected probability) for all record halves, average relative exceedence frequencies for the other half in each case, and the ratio of these two averages for magnitudes corresponding to the extreme, maximum, upper decile and median magnitudes for the full record in each case. From these ratios, a value of FCTR for step 2 can be selected, giving substantial weight to the ratio corresponding to the maximum flow.

The output for step 2 (IOPER = 2) for each method in turn consists of accuracy and consistency data (as described in the section on Methods) for all half records for each outlier and zero-flow technique in turn for magnitudes corresponding to the maximum, upper decile and median events in the other record half in each case. For those half-records having outliers, a separate summary is made for all 4 outlier techniques used in program FREQNCY, and for those half-records having zero flows, a separate summary is made for the two zero-flow techniques used in program FREQNCY. For those half-records having both zero flows and outliers, a separate summary is made for all 8 combinations of zero-flow and outlier techniques.

Definitions of Variables
Program VERIFY

ACYA(I) - Array of probabilities computed from half record for full record flows as follows:

Zero-flow technique	Outlier technique	Full-record flows Maximum	Decile	Median
A	A	1	2	3
A	B	4	5	6
A	C	7	8	9
A	D	10	11	12
B	A	13	14	15
B	B	16	17	18
B	C	19	20	21
B	D	22	23	24

ACYB(I) - Same as ACYA for other half of record

ANYR - Average number of years per record

CSTY(I) - Ratios of smaller to larger computed probabilities for the 2 record halves arranged similar to ACYA, except that a column of extreme values precedes the column of maximum values, thus making a total of 32 items in the array.

FA - Observed relative exceedence frequency in other half of record for flow corresponding to computed probability of .001 in one half of the record.

FAA - Same as FA with record halves reversed

FAB - Observed relative exceedence frequency in remainder of record for flow corresponding to computed probability of .001 in 5-year sample

FAC - Same as FAB for 10-year sample

FB - Same as FA for computed probability of .01

FBA - Same as FB with record halves reversed

FBB - Same as FAB for .01 probability

FBC	-	Same as FBB for 10-year sample
FC	-	Same as FA for computed probability of .1
FCA	-	Same as FC with record halves reversed
FCB	-	Same as FAB for .1 probability
FCC	-	Same as FCB for 10-year sample
FD	-	Same as FA for computed probability of .5
FDA	-	Same as FD with record halves reversed
FDB	-	Same as FAB for .5 probability
FDC	-	Same as FDB for 10-year sample
TEMP	-	Temporary variable
IJ	-	Temporary index
IM	-	Method iteration number in run
IMTHD	-	Method iteration number on tape
IOPER	-	Indicator for type of run (1 for expected-probability calibration and 2 for verification analysis)
IST(I)	-	Station identification number in read sequence
ISTA	-	Station identification number
ITMP	-	Temporary index
ITP	-	Temporary index
IX	-	Subscript for zero-flow and outlier technique
J	-	Temporary index
L	-	Temporary index
M	-	Temporary index
METHOD	-	Method identification number 1 for Log Pearson III 2 for Log Normal 3 for Gumbel 4 for Log Gumbel 5 for 2-parameter Gamma 6 for 3-parameter Gamma 7 for Log Pearson with regional skew 8 for Gumbel with best linear invariant fit

N	-	Number of years of record used
NIT	-	Total number of zero-flow and outlier technique combinations employed in both halves of record
NITA	-	Same as NIT for one half of record
NITB	-	Same as NITA for other half of record
NMTHD	-	Number of methods for which values are on tape 10
NPLA(I)	-	Number of half records for which verification results were obtained subscripted as follows: 1-All record halves 2,3,4,9-All record halves with outliers 5,10-All record halves with zero flows 6,7,8,11-All record halves with zero flows and outliers
NSTA	-	Total number of stations in run
NYR	-	Total number of years in all records for run
PPA(I)	-	Plotting positions for maximum, decile and median events in half record
PPL	-	Plotting position for largest event in half record
PPM	-	Plotting position for median event in half record
PPX	-	Plotting position for upper decile event in half record
RA	-	Ratio of observed relative exceedence frequencies in one half to computed expected-probability for extreme flow magnitude in other half of record (magnitude equal to maximum multiplied by square root of ratio of maximum to median)
RB	-	Same as RA for maximum flow
RC	-	Same as RA for upper-decile flow
RD	-	Same as RA for median flow
SCSTY(I,J)	-	Average root-mean-square error of ratio of smaller to larger computed exceedence probabilities in 2 halves of record. The I subscript corresponds to identification for NPLA and the J subscript corresponds to full-record flow magnitudes as follows:

1-Extreme flow

2-Maximum flow

3-Upper-decile flow

4-Median flow

SFA - Summation of FA

SFAB - Summation of FAB

SFAC - Summation of FAC

SFB - Summation of FB

SFBB - Summation of FBB

SFBC - Summation of FBC

SFC - Summation of FC

SFCB - Summation of FCB

SFCC - Summation of FCC

SFD - Summation of FD

SFDB - Summation of FDB

SFDC - Summation of FDC

SPLA(I,J) - Average root-mean-square difference between computed expected probability from one half of record and expected plotting position for flow in other half of record, with I subscript corresponding to the subscript of NPLA and J subscript corresponding to:

1-Maximum flow

2-Upper decile flow

3-Median flow

SPPL - Summation and average of PPL

SPPM - Summation and average of PPM

SPPX - Summation and average of PPX

TEMP - Temporary variable

TMP - Temporary variable

TSFA - Expected probability corresponding to computed probability of .001 for samples from a normal distribution

TSFB	-	Expected probability corresponding to computed probability of .01 for samples from a normal distribution
TSFC	-	Expected probability corresponding to computed probability of .1 for samples from a normal distribution
TSFD	-	Expected probability corresponding to computed probability of .5 for samples from a normal distribution
Y	-	Temporary variable

```
      PROGRAM VERIFY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,PUNCH)
      DIMENSION IST(300),ACYA(24),ACYB(24),CSTY(64),SPLA(10,3),NPLA(10),
     1      PPA(3),SCSTY(10,4),MTHD(10),VAR(131,8,30),IVAR(5,8,30),
     2      NPLB(10),SCSTD(10,4),SPLD(10,3),CSTYD(32),CSTYR(32),
     3      SMX(4),SMXX(4),SUMAA(4),SUMA(4)
      SUMA(K)=0.
      SUMAA(K)=0.
      NIP=0
      NX=0
      IM=0
      WRITE (6,770)
      REWIND 10
      NIV=0
      DIV=0.
      READ (10) NMTHD,NSTA,(MTHD(K),K=1,NMTHD)
      WRITE (6,20) NMTHD,NSTA,(MTHD(K),K=1,NMTHD)
 20   FORMAT (/* NMTHD=*I2,3X*NSTA=*I3,3X*METHODS*10I4)
 30   CONTINUE
      READ (5,610) IOPER,METHOD,FCTR
      IF (IOPER.LE.0) STOP
      WRITE (6,40) IOPER,METHOD,FCTR
 40   FORMAT (* IOPER=*I2,3X*METHOD=*I2,3X*FCTR=*F6.3)
      DO 50 K=1,NMTHD
      IMTHD=K
         IF (METHOD.EQ.MTHD(K)) GO TO 60
 50   CONTINUE
      WRITE (6,780)
      STOP
 60   CONTINUE
      IM=IM+1
C           INITIATE SUMS
      NYR=0
         IF (IOPER.EQ.2) GO TO 70
      SFA=0.
      SFAB=0.
      SFAC=0.
      SFB=0.
      SFBB=0.
      SFBC=0.
      SFC=0.
      SFCB=0.
      SFCC=0.
      SFD=0.
      SFDB=0.
      SFDC=0.
         GO TO 110
 70   CONTINUE
      SPPM=0.
      SPPL=0.
      SPPX=0.
```

```
      DO 80 I=1,4
      SMX(I)=0.
      SMXX(I)=0.
   80 CONTINUE
      DO 100 I=1,10
      DO 90 K=1,3
      SPLD(I,K)=0.
      SPLA(I,K)=0.
   90 CONTINUE
      DO 100 K=1,4
      SCSTD(I,K)=0.
      SCSTY(I,K)=0.
      NPLA(I)=0
  100 CONTINUE
  110 CONTINUE
      DO 380 JI=1,NSTA
C           READ DATA FOR SPECIFIED METHOD
         IF (IM.GT.1) GO TO 130
      DO 120 J=1,NMTHD
      READ (10) (IVAR(I,J,JI),I=1,5),(VAR(I,J,JI),I=1,131)
  120 CONTINUE
      NX=NX+IVAR(2,IMTHD,JI)
  130 CONTINUE
      L=IMTHD
      ISTA=IVAR(1,L,JI)
      N=IVAR(2,L,JI)
      NITA=IVAR(3,L,JI)
      NITB=IVAR(4,L,JI)
      NIT=IVAR(5,L,JI)
      FAB=VAR(1,L,JI)
      FBB=VAR(2,L,JI)
      FCB=VAR(3,L,JI)
      FDB=VAR(4,L,JI)
      FAC=VAR(5,L,JI)
      FBC=VAR(6,L,JI)
      FCC=VAR(7,L,JI)
      FDC=VAR(8,L,JI)
      FA=VAR(9,L,JI)
      FB=VAR(10,L,JI)
      FC=VAR(11,L,JI)
      FD=VAR(12,L,JI)
      FAA=VAR(13,L,JI)
      FBA=VAR(14,L,JI)
      FCA=VAR(15,L,JI)
      FDA=VAR(16,L,JI)
      IST(JI)=ISTA
      IF (N/2*2.LT.N) N=N-1
      NYR=NYR+N
         IF (IOPER.EQ.1) GO TO 270
      PPL=VAR(17,L,JI)
```

```
      PPX=VAR(18,L,JI)
      PPM=VAR(19,L,JI)
      DO 140 I=1,24
      J=I+19
      K=I+43
      ACYA(I)=VAR(J,L,JI)
      ACYB(I)=VAR(K,L,JI)
 140  CONTINUE
         IF (METHOD.EQ.8) GO TO 230
         IF (NITA.NE.4) GO TO 170
      SMP=PPL+SMP
      NIV=NIV+1
      KA=0
      DO 160 I=1,10,3
      KA=KA+1
      TP=N/2-1
      Y=ACYA(I)
      TMP=Y
         IF (Y.LT..00001) GO TO 150
      TMP=1.-Y
      CALL MDNRIS (TMP,TEMP,IER)
      TEMP=TEMP*SQRT((TP+1.)/(TP+2.))
      CALL MDTD (TEMP,TP,TMP,IER)
      TMP=TMP*.5
 150  CONTINUE
      SUMAA(KA)=SUMAA(KA)+(PPL-TMP)**2
      SUMA(KA)=SUMA(KA)+TMP
 160  CONTINUE
 170  CONTINUE
         IF (NITB.NE.4) GO TO 230
      SMP=PPL+SMP
      NIV=NIV+1
      JA=0
      DO 190 I=1,10,3
      JA=JA+1
      TP=N/2-1
      Y=ACYB(I)
      TMP=Y
         IF (Y.LT..00001) GO TO 180
      TMP=1.-Y
      CALL MDNRIS (TMP,TEMP,IER)
      TEMP=TEMP*SQRT((TP+1.)/(TP+2.))
      CALL MDTD (TEMP,TP,TMP,IER)
      TMP=TMP*.5
 180  CONTINUE
      SUMAA(JA)=SUMAA(JA)+(PPL-TMP)**2
      SUMA(JA)=SUMA(JA)+TMP
 190  CONTINUE
         GO TO 230
 200  CONTINUE
```

```
      DIV=NIV
      NIV=NIV/7
      NIP=NIP+1
         IF (NIP.GE.2) GO TO 230
      SMP=SMP/DIV
      DO 210 I=1,4
      SUMA(I)=SUMA(I)/DIV
      SUMAA(I)=SQRT(SUMAA(I)/DIV)
 210  CONTINUE
      PRINT 220, SMP,(SUMA(K),K=1,4),(SUMAA(K),K=1,4),NX,NIV
 220  FORMAT (1H1,*  AVERAGE PLOT POS FOR MAX FLOW*F10.4,//,*  AVERAGE C
     1OMP FREQUENCY FOR OUTLIERS*,/,35X,*A*,F10.4,/,35X,*B*,F10.4,/,35X,
     2 *C*,F10.4,/,35X,*D*,F10.4,//,*  ROOT MEAN SQUARE DIFFERENCE BETWE
     3EN COMP PROB AND PLOT POS*,/,35X,*A*,F10.4,/,35X,*B*,F10.4,/,35X,*
     4C*,F10.4,/,35X,*D*,F10.4,//,5X,* STATION YEARS OF RECORD*,I10,/,5X
     5,* NUMBER OF HALF RECORDS*,I10)
 230  CONTINUE
      DO 240 I=1,64
      K=67+I
      CSTY(I)=VAR(K,L,JI)
 240  CONTINUE
      J=0
      DO 250 I=1,63,2
      J=J+1
      CSTYD(J)=(CSTY(I)-CSTY(I+1))**2
 250  CONTINUE
      J=0
      DO 260 I=1,63,2
      J=J+1
      TMP=CSTY(I)
      TP=CSTY(I+1)
      TEMP=TMP
      IF (TMP.LT.TP) TMP=TP
      IF (TEMP.LT.TP) TP=TEMP
         IF (TMP.GT.0.) GO TO 255
      TMP=1.
      TP=1.
 255  CSTYR(J)=(1.-TP/TMP)**2
 260  CONTINUE
         GO TO 280
C           OBSERVED FREQUENCY FOR COMPUTED SHORT-RECORD FLOWS
 270  CONTINUE
      SFA=SFA+FA+FAA
      SFB=SFB+FB+FBA
      SFC=SFC+FC+FCA
      SFD=SFD+FD+FDA
      SFAB=SFAB+FAB
      SFBB=SFBB+FBB
      SFCB=SFCB+FCB
      SFDB=SFDB+FDB
```

```
      SFAC=SFAC+FAC
      SFBC=SFBC+FBC
      SFCC=SFCC+FCC
      SFDC=SFDC+FDC
         GO TO 380
  280 CONTINUE
      PPA(1)=PPL
      PPA(2)=PPX
      PPA(3)=PPM
      SMX(1)=SMX(1)+FA+FAA
      SMX(2)=SMX(2)+FB+FBA
      SMX(3)=SMX(3)+FC+FCA
      SMX(4)=SMX(4)+FD+FDA
      SMXX(1)=SMXX(1)+FA**2+FAA**2
      SMXX(2)=SMXX(2)+FB**2+FBA**2
      SMXX(3)=SMXX(3)+FC**2+FCA**2
      SMXX(4)=SMXX(4)+FD**2+FDA**2
C                     TWO RECORD HALVES
      DO 370 L=1,2
C            NUMBER OF ZERO AND OUTLIER TECHNIQUES FOR EACH HALF RECORD
      ITP=NITA
      IF (L.EQ.2) ITP=NITB
      IF (METHOD.EQ.8) ITP=1
      IF (METHOD.EQ.8) NIT=1
      J=0
      M=0
C                     ITERATIONS PER RECORD HALF
      DO 360 I=1,ITP
      IX=I
         IF (ITP.NE.2.OR.I.EQ.1) GO TO 290
      IX=5
      J=12
      M=16
  290 CONTINUE
         IF (NITA.LT.NITB.AND.L.EQ.1) GO TO 320
         IF (NITA.GE.NITB.AND.L.EQ.2) GO TO 320
C            SUM SQUARES OF CONSISTENCY ERRORS
      DO 310 K=1,4
      M=M+1
      TEMP=CSTYR(M)
      TEMPA=CSTYD(M)
         IF (I.NE.1) GO TO 300
      IF (NIT.EQ.2.OR.NIT.EQ.8) SCSTY(9,K)=SCSTY(9,K)+TEMP
      IF (NIT.EQ.2.OR.NIT.EQ.8) SCSTD(9,K)=SCSTD(9,K)+TEMPA
      IF (NIT.EQ.4) SCSTY(10,K)=SCSTY(10,K)+TEMP
      IF (NIT.EQ.4) SCSTD(10,K)=SCSTD(10,K)+TEMPA
  300 CONTINUE
         IF (IX.NE.1.AND.IX.NE.5.AND.NIT.EQ.8) GO TO 310
      SCSTY(IX,K)=SCSTY(IX,K)+TEMP
      SCSTD(IX,K)=SCSTD(IX,K)+TEMPA
```

```
 310  CONTINUE
      IF (IX.EQ.1.OR.IX.EQ.5.OR.NIT.NE.8) NPLB(IX)=NPLB(IX)+1
         IF (I.NE.1) GO TO 320
      IF (NIT.EQ.2.OR.NIT.EQ.8) NPLB(9)=NPLB(9)+1
      IF (NIT.EQ.4) NPLB(10)=NPLB(10)+1
 320  CONTINUE
      DO 350 K=1,3
      J=J+1
      Y=ACYA(J)
      IF (L.EQ.2) Y=ACYB(J)
      TMP=Y
         IF (Y.LT..00001) GO TO 330
C           EXPECTED-PROBABILITY ADJUSTMENT
      TP=N/2-1
      TMP=1.-Y
      CALL MDNRIS (TMP,TEMP,IER)
      TEMP=TEMP*SQRT((TP+1.)/(TP+2.))
      CALL MDTD (TEMP,TP,TMP,IER)
      TMP=TMP*.5
 330  CONTINUE
      Y=Y+FCTR*(TMP-Y)
C           SUM SQUARES OF ACCURACY ERRORS
      TEMP=Y/PPA(K)
      IF (TEMP.LT..1) TEMP=.1
      TEMP=(ALOG10(TEMP))**2
      TEMPA=(Y-PPA(K))**2
         IF (I.NE.1) GO TO 340
      IF (ITP.EQ.2.OR.ITP.EQ.8) SPLA(9,K)=SPLA(9,K)+TEMP
      IF (ITP.EQ.2.OR.ITP.EQ.8) SPLD(9,K)=SPLD(9,K)+TEMPA
      IF (ITP.EQ.4) SPLA(10,K)=SPLA(10,K)+TEMP
      IF (ITP.EQ.4) SPLD(10,K)=SPLD(10,K)+TEMPA
 340  CONTINUE
         IF (IX.NE.1.AND.IX.NE.5.AND.ITP.EQ.8) GO TO 350
      SPLA(IX,K)=SPLA(IX,K)+TEMP
      SPLD(IX,K)=SPLD(IX,K)+TEMPA
 350  CONTINUE
      IF (IX.EQ.1.OR.IX.EQ.5.OR.ITP.NE.8) NPLA(IX)=NPLA(IX)+1
C           COUNT ITEMS SUMMED
         IF (I.NE.1) GO TO 360
      IF (ITP.EQ.2.OR.ITP.EQ.8) NPLA(9)=NPLA(9)+1
      IF (ITP.EQ.4) NPLA(10)=NPLA(10)+1
 360  CONTINUE
 370  CONTINUE
C           PLOTTING POSITIONS OF SELECTED EVENTS,TOTAL FOR ALL STATIONS
      SPPL=SPPL+PPL
      SPPX=SPPX+PPX
      SPPM=SPPM+PPM
 380  CONTINUE
C           IDENTIFY STATIONS USED
         IF (IM.EQ.1) WRITE (6,390) NSTA,(IST(J),J=1,NSTA)
```

```
 390  FORMAT (1H0 I5,1X24HSTATIONS USED AS FOLLOWS /(10I12))
         IF (IOPER.EQ.1) WRITE (6,400)
 400  FORMAT (1H036X46 HCALIBRATION FOR EXPECTED PROBABILITY (IOPER=1))
         IF (IOPER.EQ.2) WRITE (6,410) FCTR
 410  FORMAT (1H038X36 HVERIFICATION RESULTS (IOPER=2) FCTR=F6.3)
C             IDENTIFY METHOD
         GO TO (420,430,440,450,460,470,480,490), METHOD
 420  CONTINUE
      WRITE (6,650)
         GO TO 500
 430  CONTINUE
      WRITE (6,660)
         GO TO 500
 440  CONTINUE
      WRITE (6,670)
         GO TO 500
 450  CONTINUE
      WRITE (6,680)
         GO TO 500
 460  CONTINUE
      WRITE (6,690)
         GO TO 500
 470  CONTINUE
      WRITE (6,700)
         GO TO 500
 480  CONTINUE
      WRITE (6,710)
         GO TO 500
 490  CONTINUE
      WRITE (6,720)
 500  CONTINUE
         IF (IOPER.EQ.1) GO TO 590
      TMP=NSTA*2
      IZONE=IST(1)/1000000
      DO 510 I=1,4
      TEMP=SMX(I)/TMP
      SMX(I)=SQRT((SMXX(I)-SMX(I)**2/TMP)/TMP)
      SMXX(I)=TEMP
 510  CONTINUE
      PUNCH 520, IZONE,METHOD,TMP,SMX,SMXX
 520  FORMAT (2I4,9F8.4)
      PRINT 530, SMX,SMXX
 530  FORMAT (* STANDARD ERROR OF OBSERVED FREQUENCIES IN OTHER HALF OF
     1RECORD FOR COMPUTED */1X * FREQUENCIES OF * 6X*.001* 7X*.01* 8X*.1
     2* 8X*.5*/F28.4,3F10.3/* AVG OBS FREQ* F15.4,3F10.3/)
C             AVERAGE PLOTTING POSITION
      TMP=NSTA
      SPPL=SPPL/TMP
      SPPX=SPPX/TMP
      SPPM=SPPM/TMP
```

```
C             AVERAGE ACCURACY AND CONSISTENCY`ERRORS
      DO 570 I=1,10
      TMP=NPLA(I)
         IF (TMP.LE.0.) GO TO 550
      DO 540 K=1,3
      SPLD(I,K)=SQRT(SPLD(I,K)/TMP)
      SPLA(I,K)=SQRT(SPLA(I,K)/TMP)
  540 CONTINUE
  550 CONTINUE
      TMP=NPLB(I)
         IF (TMP.LE.0) GO TO 570
      DO 560 K=1,4
      SCSTD(I,K)=SQRT(SCSTD(I,K)/TMP)
      SCSTY(I,K)=SQRT(SCSTY(I,K)/TMP)
  560 CONTINUE
  570 CONTINUE
C             PRINT ACCURACY AND CONSISTENCY RESULTS
      WRITE (6,730) (SPLA(1,K),K=1,3),(SPLA(10,K),K=1,3),((SPLA(I,K),
     1       K=1,3),I=2,4),(SPLA(9,K),K=1,3),(SPLA(5,K),K=1,3)
      WRITE (6,740) (SPLD(1,K),K=1,3),(SPLD(10,K),K=1,3),((SPLD(I,K),
     1       K=1,3),I=2,4),(SPLD(9,K),K=1,3),(SPLD(5,K),K=1,3)
      WRITE (6,750) (SCSTY(1,K),K=1,4),(SCSTY(10,K),K=1,4),((SCSTY(I,K),
     1       K=1,4),I=2,4),(SCSTY(9,K),K=1,4),(SCSTY(5,K),K=1,4)
      WRITE (6,760) (SCSTD(1,K),K=1,4),(SCSTD(10,K),K=1,4),((SCSTD(I,K),
     1       K=1,4),I=2,4),(SCSTD(9,K),K=1,4),(SCSTD(5,K),K=1,4)
      PUNCH 580, NSTA,METHOD,IST(1),FCTR,NPLA,(SPLA(1,K),K=1,3),
     1       (SPLA(10,K),K=1,3),((SPLA(I,K),K=1,3),I=2,4),(SPLA(9,K),
     2       K=1,3),(SPLA(5,K),K=1,3),(SPLD(1,K),K=1,3),(SPLD(10,K),
     3       K=1,3),((SPLD(I,K),K=1,3),I=2,4),(SPLD(9,K),K=1,3),
     4       (SPLD(5,K),K=1,3),(SCSTY(1,K),K=1,4),(SCSTY(10,K),K=1,
     5       4),((SCSTY(I,K),K=1,4),I=2,4),(SCSTY(9,K),K=1,4),
     6       (SCSTY(5,K),K=1,4),(SCSTD(1,K),K=1,4),(SCSTD(10,K),K=1,
     7       4),((SCSTD(I,K),K=1,4),I=2,4),(SCSTD(9,K),K=1,4),
     8       (SCSTD(5,K),K=1,4)
  580 FORMAT (2I8,I16,F8.4/10I8/(10F8.4))
         GO TO 30
C             AVERAGE OBSERVED FREQUENCIES IN OTHER HALF OF RECORDS
  590 CONTINUE
      TMP=NSTA*2
      SFA=SFA/TMP
      SFB=SFB/TMP
      SFC=SFC/TMP
      SFD=SFD/TMP
C             EXPECTED-PROBILITY ADJUSTMENT FOR GAUSSIAN DISTRIBUTION
      TEMP=NYR
      ANYR=TEMP/TMP
      TP=ANYR-1
      TMPA=.001
      TMP=.999
      CALL MDNRIS (TMP,TEMP,IER)
```

```
      TEMP=TEMP*SQRT((TP+1.)/(TP+2.))
      CALL MDTD (TEMP,TP,TSFA,IER)
      TSFA=TSFA*.5
      TMPB=.01
      TMP=.99
      CALL MDNRIS (TMP,TEMP,IER)
      TEMP=TEMP*SQRT((TP+1.)/(TP+2.))
      CALL MDTD (TEMP,TP,TSFB,IER)
      TSFB=TSFB*.5
      TMPC=.1
      TMP=.9
      CALL MDNRIS (TMP,TEMP,IER)
      TEMP=TEMP*SQRT((TP+1.)/(TP+2.))
      CALL MDTD (TEMP,TP,TSFC,IER)
      TSFC=TSFC*.5
      TSFD=.5
C           RATIOS OF OBSERVED TO EXPECTED FREQUENCIES, HALF RECORDS
      RA=(SFA-TMPA)/(TSFA-TMPA)
      RB=(SFB-TMPB)/(TSFB-TMPB)
      RC=(SFC-TMPC)/(TSFC-TMPC)
      AR=(RA+RB+RC)/3
      A=RA
      B=RB
      C=RC
      WRITE (6,620) ANYR,AR,SFD,TSFC,SFC,RC,TSFB,SFB,RB,TSFA,SFA,RA
C           AVERAGE OBSERVED FREQUENCIES FOR 5-YEAR SAMPLES
      TMP=NSTA
      SFAB=SFAB/TMP
      SFBB=SFBB/TMP
      SFCB=SFCB/TMP
      SFDB=SFDB/TMP
C           RATIOS OF OBSERVED TO EXPECTED FREQUENCIES,5-YEAR SAMPLES
      RA=(SFAB-TMPA)/.023
      RB=(SFBB-TMPB)/.040
      RC=(SFCB-TMPC)/.054
      RD=RC
      RE=RB
      RF=RA
         IF (METHOD.NE.8) WRITE (6,630) SFDB,SFCB,RC,SFBB,RB,SFAB,RA
C           AVERAGE OBSERVED FREQUENCIES FOR 10-YEAR SAMPLES
      SFAC=SFAC/TMP
      SFBC=SFBC/TMP
      SFCC=SFCC/TMP
      SFDC=SFDC/TMP
C           RATIO OF OBSERVED TO EXPECTED FREQUENCIES,10-YEAR SAMPLES
      RA=(SFAC-TMPA)/.0072
      RB=(SFBC-TMPB)/.017
      RC=(SFCC-TMPC)/.027
      RG=RC
      RH=RB
```

```
      RI=RA
      RA=A
      RB=B
      RC=C
      WRITE (6,640) SFDC,SFCC,RG,SFBC,RH,SFAC,RI
      PUNCH 600, NSTA,METHOD,IST(1),ANYR,RD,RG,RC,RE,RH,RB,RF,RI,RA
600   FORMAT (2I8,I16,/10F8.4)
         GO TO 30
610   FORMAT  (2I8,F8.0,2I8)
620   FORMAT  (47H0EXCEEDENCE FREQUENCIES FOR AVG HALF-RECORD OF F5.2,
     1 5X * AVG ADJ = * F7.3/3X
     2 15HTHEORETICAL.50 3X 8HOBSERVED,F5.3,2X 16HADJUSTMENT RATIO /15X
     3F4.3,10XF5.3,F16.3/15X  F4.3,10XF5.3,F16.3/14X F5.3, 10X F5.3,F16.
     43)
630   FORMAT (33H0EXCEEDENCE FREQ FOR 5-YR RECORDS /3X 15HTHEORETICAL .5
     10 3X 8HOBSERVED F5.3,2X 16HADJUSTMENT RATIO /15X 4H.154 10X F5.3,F
     216.3/15X 4H.050 10X F5.3,F16.3/15X 4H.024 10X F5.3,F16.3)
640   FORMAT (34H0EXCEEDENCE FREQ FOR 10-YR RECORDS /3X 15HTHEORETICAL .
     150 3X 8HOBSERVED F5.3,2X 16HADJUSTMENT RATIO/15X 4H.127 10X F5.3,F
     216.3/15X 4H.027 10X F5.3,F16.3/ 15X,5H.0082 10X F5.3,F16.3)
650   FORMAT (53X 15HLOG PEARSON III)
660   FORMAT (55X 10HLOG NORMAL)
670   FORMAT (57X 6HGUMBEL)
680   FORMAT (55X 10HLOG GUMBEL)
690   FORMAT (52X 17H2-PARAMETER GAMMA)
700   FORMAT (52X 17H3-PARAMETER GAMMA)
710   FORMAT (43X 34HLOG PEARSON III WITH REGIONAL SKEW)
720   FORMAT (46X 28HBEST LINEAR INVARIANT GUMBEL)
730   FORMAT (*  ROOT MEAN SQUARE LOGARITHM OF RATIO OF COMPUTED PROBABI
     1LITY IN OTHER HALF OF RECORD TO PLOTTING POSITION OF HALF-RECORD F
     2LOWS*/* (ACCURACY RESULTS)*/4X16HZERO-FLOW METHOD6X    14HOUTLIER
     3METHOD 15X3HMAX 14X6HDECILE 14X6HMEDIAN/* ALL HALF RECORDS *
     4  /12X1HA 19X1HA F25.3,2F20.3/* OUTLIERS AND NO ZERO FLOWS*/12X1HA
     5 19X1HA F25.3,2F20.3/12X1HA 19X1HB F25.3,2F20.3/12X1HA 19X1HC F25.
     63,2F20.3/12X1HA 19X1HD F25.3,2F20.3/* ZERO FLOWS*/ 12X1HA 19X1HA F
     725.3,2F20.3/12X1HB 19X1HA F25.3,2F20.3)
740   FORMAT (* ROOT MEAN SQUARE DIFFERENCE BETWEEN PLOT POS AND COMPUTE
     1D PROB IN OTHER HALF OF RECORD (ACCURACY RESULTS)*/4X16HZERO-FLOW
     2METHOD                       6X    14HOUTLIER METHOD 15X3HMAX 14X6HDECI
     3LE 14X6HMEDIAN/* ALL HALF RECORDS *         /12X1HA 19X1HA F25.3,2F
     420.3/* OUTLIERS AND NO ZERO FLOWS*/12X1HA 19X1HA F25.3,2F20.3/12X1
     5HA 19X1HB F25.3,2F20.3/12X1HA 19X1HC F25.3,2F20.3/12X1HA 19X1HD F2
     65.3,2F20.3/* ZERO FLOWS*/ 12X1HA 19X1HA F25.3,2F20.3/12X1HB 19X1HA
     7 F25.3,2F20.3)
750   FORMAT (* ROOT MEAN SQUARE DIFFERENCE BETWEEN 1.0 AND RATIO OF PRO
     1BABILITIES IN 2 HALVES OF RECORD (CONSISTENCY RESULTS)*/ 4X16HZERO
     2-FLOW METHOD  6X14HOUTLIER METHOD 11X7HEXTREME 17X3HMAX 14X6HDECIL
     3E  14X6HMEDIAN/* ALL HALF RECORDS* /12X1HA 19X1HA F25.3,3F20.3/
     4     * OUTLIERS AND NO ZERO FLOWS*/12X1HA 19X1HA F25.3,3F20.3 /12X1
     5HA 19X1HB F25.3,3F20.3/12X1HA 19X1HC F25.3,3F20.3/12X1HA 19X1HD F2
```

```
    65,3,3F20,3/* ZERO FLOWS*/12X1HA 19X1HA F25,3,3F20,3/12X1HB 19X1HA
    7F25,3,3F20,3)
760  FORMAT (* ROOT MEAN SQUARE DIFFERENCE BETWEEN COMPUTED PROBABILITI
    1ES FOR 2 HALVES OF RECORD (CONSISTENCY RESULTS)*/        4X16HZERO
    2-FLOW METHOD  6X14HOUTLIER METHOD 13X7HEXTREME  17X3HMAX 14X6HDECI
    3LE 14X6HMEDIAN/* ALL HALF RECORDS* /12X1HA 19X1HA F25,3,3F20,3/
    4    * OUTLIERS AND NO ZERO FLOWS*/12X1HA 19X1HA F25,3,3F20,3 /12X1
    5HA 19X1HB F25,3,3F20,3/12X1HA 19X1HC F25,3,3F20,3/12X1HA 19X1HD F2
    65,3,3F20,3/* ZERO FLOWS*/12X1HA 19X1HA F25,3,3F20,3/12X1HB 19X1HA
    7F25,3,3F20,3)
770  FORMAT (1H1 50X 21HVERIFICATION ANALYSIS)
780  FORMAT  (27H0METHOD IDENTIFIER IN ERROR)
     END
```

APPENDIX D

COMPUTER PROGRAM PARE

Origin of program.

This program was written by Leo R. Beard, Technical Director of the Center for Research in Water Resources, The University of Texas at Austin.

Purpose of the program.

The program will accept records of daily flows at any number of long-record stations, establish annual maximum events and partial-duration events for each year at each station, perform summaries of each for later analysis and compute the average exceedence frequencies of partial-duration events for each of 7 annual-event magnitudes as follows: those exceeded on the average 10, 20, 30, 40, 50, 60 and 70 percent of the years. The program is used to analyze data in each of 16 USGS geographic zones in order to establish an average relationship for each zone and for all zones. Other groupings such as by size of drainage area can also be studied.

Methods.

Since data on tape came from two different USGS sources, two different initial processing operations are necessary. For zones 9 through 16, data for October through December of each year are given after data for January through September of the following calendar year. It is therefore necessary to transpose these to the start of the data array. For zones 1 through 8, data are consecutive for water years of October through September, and such a transposition is not necessary. In all zones, however, 31 items per month are given for all months, and it is necessary to eliminate the items for days beyond the end of months having less than 31 days. This operation is performed using a special routine for identifying leap years.

Annual maximum events are selected and stored in one array (QMX) while partial-duration events separated by at least 5 + Ln (DA) days, during which flows drop below 75 percent of the smaller flow in each adjacent pair, are selected and stored in the QX array for each year. The 5 largest values in each QX array for a station are stored in the order of magnitude for each successive year in the QP array.

For each station, magnitudes corresponding to specified exceedence frequencies of .1, .2, .3, .4, .5, .6 and .7 events per year are interpolated between annual-event magnitudes using M/(N+1) plotting positions. Then the QX array is searched to count the number of events larger than each of these magnitudes. The frequency per year for each of these is divided by the corresponding specified exceedence frequency of the annual-event magnitudes to obtain ratios for print-out. These are temporarily stored in the R array and accumulated in the RT array, which is used later to compute and print out the average ratio for all stations in each computer run.

Input.

Program operation is controlled by card input with the following data on each successive card:

Cols 1-8	ISTA - USGS station identification number
Cols 9-16	IPRT - Print-control indicator. Value greater than zero calls for supplementary print-out of all peak flows for each year. Value of 2 also calls for print-out of daily flows from tape.
Cols 17-24	IFILE - Positive number calls for all stations in the USGS zone corresponding to that number.

Other data used by the program are read from tape 10, one year per record (130 characters per line), each record containing the station number (I10) calendar year number (I10), consecutive flow data (F10.3) for 372 days (31 days per month with dummy values for excess days) and drainage area in square miles (F 10.3).

Output.

Basic output for each station from the program consists of a list of annual maximum flows in the order of magnitude, a list of the 5 largest partial-duration flows in the order of magnitude for each year, and 7 ratios, each consisting of the number of partial-duration flows per year exceeding magnitudes corresponding to the observed annual-event magnitudes exceeded .1, .2, .3, .4, .5, .6 and .7 times per year.

Basic output for the job is the 7 averages of these ratios for all stations in the job.

Supplementary output called by a value greater than zero for IPRT is all of the partial-duration flows for each year. With a value of 2 for IPRT, the complete daily flows for each year are printed out in the 31-day-per-month format with rows of 9's for excess days at the end of shorter months.

Definitions of Variables

DA	-	Drainage area in square miles
EOF	-	End-of-file mark on tape
I	-	Temporary index
IFILE	-	Positive number calls for all stations in the USGS zone corresponding to that number
IFLW	-	Sequence number of adopted peak flows within each year
ILAG	-	Number of days since last higher flow
IPRT	-	Positive value greater than zero calls for supplementary print-out of all peak flows for each year. Value of 2 also calls for print-out of daily flows from tape
IST(30)	-	Station identification number
ISTA	-	Station identification number, card input
ISTN	-	Station number, tape input
ITEMP	-	Temporary variable
ITMP	-	Temporary variable
ITP	-	Temporary variable
IX	-	Temporary index
IY	-	Temporary index
IYR	-	Calendar year number
J	-	Temporary index
K	-	Temporary index
LAG	-	Required days of separation between adopted peaks
N	-	Number of partial-duration flows exceeding annual-event flow of specified frequency
NB	-	Number of blank days in record of flows on tape
NDAYS	-	Number of days in February of current year from tape
NFLW	-	Number of maximum flows to be retained each year for later analysis
NSTA	-	Total number of stations analyzed

NYR	-	Total number of years of complete record at current station
Q(500)	-	Consecutive daily flows
QMAX	-	Maximum flow for year
QMIN	-	Minimum flow since last adopted peak
QMX(100)	-	Maximum annual flows
QP(500)	-	Adopted partial-duration flows for all years (NFLW values for each year) in descending order of magnitude within each consecutive year
QX(25)	-	Adopted partial-duration flows within current year
R(30,7)	-	Ratio of number of partial-duration flows exceeding exceedence probability of specified annual-event flow to (number of years of record times that exceedence probability).
RT(7)	-	Total for all stations of R values
TEMP	-	Temporary variable
TMP	-	Temporary variable
TP	-	Temporary variable

```
      PROGRAM PARE(INPUT,OUTPUT,TAPE10,TAPE6=OUTPUT)
C              PARTIAL DURATION RELATIONSHIP DEVELOPMENT PROGRAM
C              READ DATA TAPE 10
      DIMENSION QMX(100),QX(50),Q(500),QP(500),R(30,7),RT(7),IST(30),
     1        IDATA(15)
      DO 20 I=1,7
      RT(I)=0.
 20   CONTINUE
      NFLW=5
      NSTA=0
      PRINT 30
 30   FORMAT   (1H1)
      PRINT 40
 40   FORMAT   (31X,58HRELATION OF PARTIAL DURATION TO ANNUAL MAXIMUM FR
     1EQUENCIES )
 50   CONTINUE
      READ 60, ISTA,IPRT,IFILE
 60   FORMAT   (3I8)
C              END OF JOB
         IF (ISTA.LE.0.AND.IFILE.LE.0) GO TO 430
C              COMPUTE DAYS OF SEPARATION BETWEEN PEAKS
 70   CONTINUE
      ILAG=99
      LAG=10
      NYR=0
C              FIRST YEAR OF NEW STATION DATA ALREADY READ
         IF (NSTA.GT.0) GO TO 110
 80   CONTINUE
      READ (10,100) ISTN,IYR,(Q(I),I=93,464),DA
         IF (EOF,10) 90,110
 90   CONTINUE
      IFILE=-999
         GO TO 350
 100  FORMAT   (2I10,11F10.3/,27(13F10.3/),10F10.3,/,20X,F10.3)
 110  CONTINUE
         IF (ISTN.EQ.ISTA) GO TO 120
C              END OF STATION DATA
         IF (NYR.GT.15) GO TO 350
      NYR=0
      IF (IFILE.GT.0) ISTA=ISTN
         IF (IFILE.GT.0) GO TO 70
C              DATA FOR STATION TO BE SKIPPED
         GO TO 50
C              ARRANGE DAILIES CONSECUTIVELY STARTING OCT 1
 120  CONTINUE
      NDAYS=28
      IF (IYR/4*4.EQ.IYR) NDAYS=29
      IF (IYR.EQ.1900) NDAYS=28
      ISTA=ISTN
      ITP=ISTA/1000000
```

```
          IF (IFILE.LE.0) GO TO 130
      IF (DA.GT.0) LAG=ALOG(DA)+5.
 130  CONTINUE
          IF (ITP.LE.8) GO TO 200
C             MOVE LAST 3 MONTHS TO START OF WATER YEAR
C             OCT,NOV
      J=371
      DO 140 I=1,61
      J=J+1
      Q(I)=Q(J)
 140  CONTINUE
C             DEC
      J=433
      DO 150 I=62,92
      J=J+1
      Q(I)=Q(J)
 150  CONTINUE
          IF (IPRT.EQ.2) PRINT 160, ISTN,IYR,(Q(I),I=1,371)
 160  FORMAT    (/1X,2I10,11F10.3/(1X,13F10.3)/)
C             MAR,APR
      ITP=124+NDAYS
      ITMP=184+NDAYS
      NB=3
      IF (NDAYS.EQ.29) NB=2
      DO 170 I=ITP,ITMP
      IX=I+NB
      Q(I)=Q(IX)
 170  CONTINUE
C             MAY,JUNE
      NB=NB+1
      ITP=185+NDAYS
      ITMP=245+NDAYS
      DO 180 I=ITP,ITMP
      IX=I+NB
      Q(I)=Q(IX)
 180  CONTINUE
C             JULY-SEPT
      NB=NB+1
      ITP=246+NDAYS
      NDAYS=337+NDAYS
      DO 190 I=ITP,NDAYS
      IX=I+NB
      Q(I)=Q(IX)
 190  CONTINUE
         GO TO 260
C             OCT,NOV
 200  CONTINUE
      J=92
      DO 210 I=1,61
      J=J+1
```

```
      Q(I)=Q(J)
  210 CONTINUE
C             DEC-FEB
      J=154
      DO 220 I=62,152
      J=J+1
      Q(I)=Q(J)
  220 CONTINUE
C             MAR-APR
      IX=123+NDAYS
      IY=IX+1
      IX=IX+61
      J=247
      DO 230 I=IY,IX
      J=J+1
      Q(I)=Q(J)
  230 CONTINUE
C             MAY-JUNE
      IY=IX+1
      IX=IX+61
      J=309
      DO 240 I=IY,IX
      J=J+1
      Q(I)=Q(J)
  240 CONTINUE
C             JULY-SEPT
      IY=IX+1
      IX=IX+92
      J=371
      DO 250 I=IY,IX
      J=J+1
      Q(I)=Q(J)
  250 CONTINUE
         IF (IPRT.EQ.2) PRINT 160, ISTN,IYR,(Q(I),I=1,IX),DA
C             SELECT PEAK FLOWS SEPARATED BY LAG DAYS WITH 25 PERCENT SAG
C             BETWEEN
      NDAYS=IX
  260 CONTINUE
      QMAX=0.
      IFLW=0
      IF (NYR.EQ.0) QMIN=Q(1)
      DO 280 I=1,NDAYS
      TMP=Q(I)
C             IF DATA MISSING,SKIP ENTIRE YEAR
         IF (TMP.LT.0.OR.TMP.GT.999998.) GO TO 80
C             QMAX IS LARGEST FLOW FOR YEAR
      IF (TMP.GT.QMAX) QMAX=TMP
      ILAG=ILAG+1
      IF (TMP.LT.QMIN) QMIN=TMP
      TP=999999.
```

```
      IF (IFLW.GT.0) TP=QX(IFLW)
C           REPLACE EARLIER PEAK IF CRITERIA NOT SATISFIED
         IF (TMP.GT.TP.AND.ILAG.LT.LAG.AND.IFLW.GT.0) GO TO 270
         IF (TMP.GT.TP.AND.QMIN/.75.GT.TP.AND.IFLW.GT.0) GO TO 270
         IF (TMP.LT.QMIN/.75.OR.ILAG.LT.LAG) GO TO 280
C           ADOPT NEW PEAK IF CRITERIA SATISFIED
      IFLW=IFLW+1
  270 CONTINUE
      QX(IFLW)=TMP
      QMIN=TMP
      ILAG=0
  280 CONTINUE
      NYR=NYR+1
         IF (IFLW.GE.NFLW) GO TO 300
C           WHERE INSUFFICIENT PEAKS IN YEAR,USE ZERO FOR REMAINDER
      ITP=IFLW+1
      DO 290 I=ITP,NFLW
      QX(I)=0.
  290 CONTINUE
      IFLW=NFLW
C           ARRANGE PEAKS IN ORDER OF MAGNITUDE FOR EACH YEAR
  300 CONTINUE
      ITP=IFLW-1
      DO 320 I=1,ITP
      ITMP=IFLW-I
      DO 310 J=1,ITMP
         IF (QX(J).GE.QX(J+1)) GO TO 310
      TMP=QX(J)
      QX(J)=QX(J+1)
      QX(J+1)=TMP
  310 CONTINUE
  320 CONTINUE
         IF (IPRT.GE.1) PRINT 330, (QX(I),I=1,IFLW)
  330 FORMAT   (/,48X,23H PARTIAL DURATION FLOWS /(15F8.0))
C           STORE PEAKS IN QP AND QMX ARRAYS FOR ALL YEARS
      ITEMP=(NYR-1)*NFLW
      DO 340 I=1,NFLW
      ITEMP=ITEMP+1
      QP(ITEMP)=QX(I)
  340 CONTINUE
      QMX(NYR)=QMAX
         GO TO 80
C           ARRANGE ANNUAL PEAKS IN ORDER OF MAGNITUDE
  350 CONTINUE
      ITMP=NYR-1
      DO 370 I=1,ITMP
      ITP=I+1
      DO 360 K=ITP,NYR
         IF (QMX(I).GE.QMX(K)) GO TO 360
      TEMP=QMX(I)
```

```
      QMX(I)=QMX(K)
      QMX(K)=TEMP
  360 CONTINUE
  370 CONTINUE
      NSTA=NSTA+1
      IST(NSTA)=ISTA
C             COUNT PARTIAL-DURATION PEAKS LARGER THAN VALUES CORRESPONDIN
C             G TO ANNUAL EXCEEDENCE PROBABILITIES OF .1,.2,.3,.4,.5,.6, A
C             ND .7
      TEMP=NYR+1
      TMP=0.
      DO 390 I=1,7
C             INTERPOLATE ANNUAL MAX VALUE EXCEEDED WITH SPECIFIED FREQ
      TMP=TMP+.1
      ITP=TEMP*TMP
      TP=ITP
      TP=TEMP*TMP-TP
      Q(I)=QMX(ITP)*(1.-TP)+QMX(ITP+1)*TP
      TP=Q(I)
C             COUNT PARTIAL DURATION EXCEEDENCES
      N=0
      DO 380 J=1,ITEMP
      IF (QP(J).GE.TP) N=N+1
  380 CONTINUE
      TP=N
      R(NSTA,I)=TP/TEMP
      RT(I)=RT(I)+TP/TEMP
  390 CONTINUE
      WRITE (6,400) ISTA,(QMX(I),I=1,NYR)
      WRITE (6,410) (QP(I),I=1,ITEMP)
  400 FORMAT  (4H0STA I10/21H ANNUAL MAXIMUM FLOWS/(10F12.0))
  410 FORMAT  (23H0PARTIAL DURATION FLOWS/(5F12.0))
      WRITE (6,420) (R(NSTA,I),I=1,7)
  420 FORMAT  (7H0RATIOS 7F8.3)
      PRINT 30
      IF (IFILE.GT.0) ISTA=ISTN
         IF (IFILE) 430,50,70
C             SUM FOR ALL STATIONS
  430 CONTINUE
      TMP=NSTA
      DO 440 I=1,7
      RT(I)=RT(I)/TMP
  440 CONTINUE
      PRINT 450
  450 FORMAT   (/////)
      WRITE (6,460)
  460 FORMAT  (///,43X,28HPARTIAL-DURATION FREQUENCIES /42X,31HFOR ANNUA
     1L-EVENT FREQUENCIES OF   /21X,63HSTATION     .100      .200      .300
     2  .400      .500      .600      .700      /)
      WRITE (6,470) ((IST(I),(R(I,K),K=1,7)),I=1,NSTA)
```

```
470  FORMAT   (20X,I8,7F8.3)
     WRITE (6,480) (RT(I),I=1,7)
480  FORMAT   (/,18X,10HAVG RATIOS ,7F8.3)
     STOP
     END
```

APPENDIX E

ANNOTATED BIBLIOGRAPHY OF FLOOD FREQUENCY ANALYSIS

1. Aitchison, J., Brown, J.A.A., The Lognormal Distribution, Cambridge, England, Cambridge University Press, 176 p., 1957.

2. Alexander, G.N., Karoly, A., and Susts, A.B., "Equivalent Distributions with Application to Rainfall as an Upper Bound to Flood Distributions," Journal Hydrology (Australia), Vol. 9, No. 3 & 4, pp. 322-371, Nov. 1969.

   It was shown that, using known hydro-statistical relationships between rainfall, losses and floods, the same distribution type cannot in practice be used over the complete range for both rainfall and floods. A moment-ratio diagram was used to give a graphical measure of distribution types.

3. Alexander, G.N., "Estimation of the 10,000 Year Flood," Commission Internationale Des Grands Barrages, Madrid, pp. 1327-1350, 1973.

4. Alexander, G.N., "Flood Flow Estimation, Probability and the Return Period," Inst. Engrs., Australia Jour., Vol. 29, pp. 263-278, 1957.

5. Beard, Leo R., "Probability Estimates Based on Small Normal-Distribution Samples," Journal of Geophysical Research, July 1960.

   Develops a relationship between theoretical expected probabilities and probabilities computed from the normal distribution and maximum-likelihood statistics.

6. Beard, L. R., Statistical Methods in Hydrology, U.S. Army Corps of Engineers, Civil Works Investigation Project CW-151, 1962.

   This paper details extensively the logarithmic Pearson Type III distribution and many considerations in the selection and use of data and application of frequency estimates.

7. Benson, M.A., "Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain," USGS Water Supply Paper, 1580-B, 63 p., 1962.

Relations between flood peaks and hydrologic factors in a humid region with limited climatic variation, but a diversity of terrain were described in this report. Statistical multiple-regression techniques were used. Many topographic and climatic factors were evaluated and their relations to flood peaks were examined.

8. Bernier, J., "On the Application of Various Limit Laws of Extreme Values to the Problem of Floods," La Houille Blanche, Vol. 11, pp. 718-725, 1956.

9. Bowers, C.E., Pabst, A.F., and Larson, S.P., "Computer Program for Statistical Analysis of Annual Flood Data by the Log Pearson Type III Method," Available from the National Technical Information Service as PB-119-541, Computer Program No. 1, 32 p., Jan. 1971.

This paper is an explanation of the log-Pearson Type III distribution and its use as a uniform method establishing of flood flow frequencies. The example used illustrated the input and output data for annual floods on two Minnesota streams. The computer program used was written in Fortran IV language and was included in the appendix.

10. Brown, T.L., Sammons, W.H., "Flood Peaks from Small Southwest Range Watershed," Discussion, Jour. Hydro. Div., Proc. ASCE, Vol. 97, No. HY1, Jan. 1971.

The authors discuss the outlier problem and give several approaches to its solution. These include maximum likelihood estimations, best linear unbiased estimations and best linear invariant estimations with and without single and double censoring.

11. Carrigan, P.H., "A Flood-Frequency Relation Based on Regional Record Maxima," USGS Professional Paper, 434F, 22 p., 1971.

Techniques of analysis are introduced to increase the sample size by taking into account the random variations of flood intensity in both time and space. The recurrence interval for the maximum annual flood in the region was estimated by a computer-simulation model.

12. Criff, R.W., and Rantz, S.E., A Comparison of Methods Used in Flood-Frequency Studies for Coastal Basins in California, USGS Water Supply Paper 1580-E, 1965.

Six methods of analysis were studied: index-flood method, multiple correlation, logarithmic normal distribution, extreme-value probability distribution (Gumbel method), Pearson Type III distribution, and the gamma distribution.

13. Dalinsky, J.D., "An Unconventional Approach to Flood Frequency Analysis," Int'l. Assoc. Hydro. Scien. Bull., Vol. 15, No. 3, pp. 55-59, Sept. 1970.

It is suggested that flood-frequency analysis be based on regional rainfall analyses since rainfall data are more reliable and easier to measure and rainfall is stochastic.

14. Dalrymple, Tate, Flood Frequency Analysis, USGS Water Supply Paper, 1543-A, 80 p., 1960.

15. Eagleson, P.S., "Dynamics of Flood Frequency," A.G.U. Water Resources Research, Vol. 8, No. 4, pp. 878-898, August, 1972.

Density functions for climatic and catchment variables are used to derive a probability mass function of peak streamflow from a given catchment. The exceedence probability for a flood peak of given magnitude is then related to the annual exceedence interval of this flood.

16. Elderton, W.P., "Frequency Curves and Correlation," 4th Edition, Harren Press, Washington, D.C., 272 p., 1953.

This book considers different aspects of frequency distributions with special emphasis on Pearson's System of frequency-curves. Also considered are method of moments correlation techniques, partial correlation, and methods to calculate standard errors.

17. Fleming, G., and Franz, D.D., "Flood Frequency Estimating Techniques for Small Watersheds," ASCE Proceedings, Jour. Hydr. Div., Vol. 97, No. HY9, Pap. 8383, pp. 1441-1460, Sept. 1971.

Digital computer simulation, regional flood frequency analysis, Potter's statistical procedure, and an arbitrarily standardized version of the rational method were used in comparative tests on eleven small watersheds. For the streams tested, digital simulation using the Hydrocomp Simulation Program was most successful in reproducing the flood frequency curves determined from the historic streamflow.

18. Frost, J. and Clarke, R.T., "Estimating the T-Year Flood by the Extension of Records of Partial Duration Series," Int'l Assoc. Hydro. Scien. Bull., Vol. 17, pp. 209-217, 1972.

The primary approach to flood-frequency analysis discussed in this paper is the partial duration series, in which a stochastic model is formulated for discharges exceeding a threshold. An extension of the partial duration series method may be used in the commonly-encountered situation in which (a) an estimation must be made for a gaging site with short record, and (b) a longer record is available for a nearby gaging site.

19. Gill, M.A., "Analysis of Probability and Risk Equations," ASCE Proceedings, Jour. Hydr. Div., Vol. 98, No. HY5, pp. 969-971, May 1971.

Approximate versions of the probability equation used for determining design floods are proposed.

20. Gilroy, E.J., "The Upper Bound of a Log-Pearson Type III Random Variable with Negatively Skewed Logarithms," USGS Professional Paper 800-B, pp. B273-B275, 1972.

This paper examines the effect of negative skew coefficients on the values derived from the Pearson Type III distribution. All derivations are presented in an appendix.

21. Glos, E., and Krause, R., "Estimating the Accuracy of Statistical Flood Values by Means of Long-Term Discharge Records and Historical Data," in Floods and Their Computation, Int'l Assoc. Hydro. Scien. Pub. Vol. 1, No. 84, pp. 114-151, 1969.

Long-term records were divided into parts of various length to estimate the relationship between accuracy and length of record. The results showed validity for a limited range of coefficient of variation from 0.4 to 0.7.

22. Greenwood, J.S., and Durand, D., "Aids for Fitting the Gamma Distribution by Maximum Likelihood," Technometrics, Vol. 2, No. 1, pp. 55-65, 1960.

23. Hardison, C.H., "Accuracy of Streamflow Characteristics," USGS Professional Paper 650-D, pp. D210-D214, 1969.

This paper proposes accuracy goals for each streamflow characteristic and includes curves and tables to aid in setting such goals.

24. Hardison, C.H., "Generalized Skew Coefficients of Annual Peak Floods in the United States and Their Application," Water Resources Research, Vol.10, No. 3, June 1974.

A map of average skew coefficients was developed in this paper to provide for areal variation in generalized skew coefficients without abrupt changes from region to region.

25. Hardison, C.H., and Jennings, M.E., "Bias in Computed Flood Risk," ASCE Proceedings, Jour. Hydr. Div., Vol. 98, No. HY3, pp. 415-427, March 1972.

This paper shows how flood risk can be computed for both gaged and ungaged sites at which the population of annual peaks can be assumed to follow a log-Pearson Type III distribution.

26. Hardison, C.H., "Estimation of 100-Year Flood Magnitude at Ungaged Sites," Open-file report, U.S. Dept. of Interior, Geological Survey.

A simple technique for estimating the 100-year peak flood discharge at ungaged sites was presented in this report.

27. Harter, H.L., "A New Table of Percentage Points of the Pearson Type III Distribution," Technometrics, Vol. 11, No. 1, pp. 171-187, Feb. 1969.

A five-decimal-place table of the percentage points of the Pearson Type III distribution is given and a description of the computation method is included in the paper. Applications are discussed, including estimating return periods of floods.

28. Harter, H.L., "Some Optimization Problems in Parameter Estimation," Proceedings of the Symposium on Optimizing Methods in Statistics, Ohio State University, Columbus, Ohio, June 1971.

The author offers some observations concerning three problems with which he has had experience. They are: (1) iterative procedures for maximum likelihood estimation, based on complete or censored samples, of the parameters of various populations; (2) optimum spacings of quantities for linear estimation; and (3) optimum choice of order statistics for linear estimation.

29. Harter, H.L., and Moore, A.H., "A Note on Estimation from a Type I Extreme-Value Distribution," Technometrics, Vol. 9, No. 2, pp. 325-331, May 1967.

Maximum likelihood was used for estimating the parameters of the Gumbel distribution.

30. Heras, R., "Practical Methods of Estimating Maximum Floods (French)," Floods and Their Computation, Int'l. Assoc. Hydro. Scien., Vol. 1, No. 84, pp. 492-504, 1969.

This report contains a summary of different methods (direct, empirical, statistical, and hydrometric), which in general are used simultaneously to compare different results and to try to estimate the highest flood values with the maximum possible accuracy.

31. Hiemstra, L.A.V. and Reich, B.M., "Engineering Judgment and Small Area Flood Peaks," Hydrol. Pap. 19, Colorado State University, Fort Collins, 1967.

Five methods of flood prediction are presented in order to enhance the development of flood predictions in small basins and on ungaged basins. The "Rational" formula, the Bureau of Public Roads method, and the Tacitly Maximized Peak technique show superiority in that they overestimate floods from the samples.

32. Hoyt, W.G., and Langbien, W.B., Floods, Princeton University Press, New Jersey, 469 p., 1955.

33. Inter-Agency Committee on Water Resources, Subcommittee on Hydrology, Methods of Flow Frequency Analysis, Bulletin 13, 1966.

A description is given of the methods most commonly used by Federal Agencies for making frequency studies of runoff at individual streamflow stations. There are numerous references included in the report.

34. Jacquet, J., and Bernier, J., "Determination of Maximum Flood Flow and Probability of its Being Exceeded, Using Incomplete Information (French)," in Floods and Their Computation, Vol. 1, Int'l. Assoc. Hydro. Scien., Pub. No. 84, pp. 419-431, 1969.

Flood probabilities are calculated on the basis of a stochastic process with the use of rainfall and runoff coefficients. The methodology is explained and it is compared to classical methods.

35. Jennings, M.E., and Benson, M.A., "Frequency Curves for Annual Flood Series with Some Zero Events or Incomplete Data," A.G.U. Water Resources Research, Vol. 5, No. 1, pp. 276-280, Feb. 1969.

This report describes a method for solving the problem of zero peaks. The probability of occurrence of a nonzero peak is combined with the conditional probability of exceeding a given flood magnitude, given that a nonzero peak has occurred.

36. Johnson, N.L. and Kotz, S., Continuous Univariate Distributions-1, Houghton Mifflin Co., Boston, Massachusetts, 300 p., Vol 1, 1970.

37. Johnson, N.L., and Kitz, S., Continuous Univariate Distributions-2, Houghton Mifflin Co., Boston, Massachusetts, 306 p., Vol. 2, 1970.

38. Kibler, D.F., and Yevjevich, V., "Effects of Sampling Interval, Periodicity, Dependence and Skewness on Extreme Values," Proc. Int'l. Symp. Colo. State Univ., Fort Collins, Vol. 1, Paper 67, pp. 537-545, Sept. 1967.

The validity of extreme value theory was tested by studying the effects of sampling interval, periodicity, dependence, and skewness on the frequency distributions of extreme values. Results are presented as a series of graphical plots.

39. Kirby, W., "Flood Estimation in the Presence of Outliers," U.S. Dept. of Interior, Geological Survey, Open-file Report, Arlington, Virginia, 1971.

This paper presents a computational method of reducing distortion of estimates based on a sample that contains an improbably large outlier.

40. Kirby, W., "On the Random Occurrence of Major Floods," A.G.U. Water Resources Research, Vol. 5, No. 4, pp. 778-784, 1969.

A simple model of the random occurrence of floods is developed and analyzed in this paper. It is suggested that for many purposes the Poisson process constitutes a good model.

41. Kuksin, I.Y., "Methods of Estimating Maximum Discharge of Given Probability," Soviet Hydrol. Selec. Pap., Issue No. 2, pp. 157-160, 1968.

The gamma-distribution and the 3-parameter gamma distribution commonly used in the USSR, were compared with the log-normal curve, binomial curve and the Fisher-Tippet curve that are used elsewhere to estimate flood discharge probabilities. The best estimates were given by Gumbels' methods based on a theory of the extreme terms of a sample.

42. Langbein, W.B., "Annual Floods and the Partial Duration Series," Transactions, American Geophysical Union, Vol. 30, p. 879, 1949.

Develops theoretical relation between the exceedences frequency of any particular annual maximum event and the frequency of all events above the magnitude of that event, assuming that a large number of random events occur each year.

43. Leclerc, G. and Schaske, J.C., Jr., "Derivation of Hydrologic Frequency Curves," Available from the National Technical Information Service as PB-209-761, Ralph M. Parsons Lab. Report No. 142, 151 p. Jan 1972.

An assessment is made of a new approach to the derivation of hydrologic frequency curves. This approach consists of making the rainfall process the primary input to the derivation of frequency curves rather than using streamflow records as does the classic approach.

44. Leese, Marvin N., "Use of Censored Data in the Estimation of Gumbel Distribution Parameters for Annual Maximum Flood Series," Water Resources Research, Vol. 9, No. 6, pp. 1534-1542, Dec. 1973.

Maximum likelihood equations for the estimation of Gumbel distribution parameters from censored samples are derived; expressions for their large-sample standard errors are also given.

45. Mann, N.R., "Best Linear Invariant Estimation for Weibull Parameters Under Progressive Censoring," Technometrics, Vol. 13, No. 3, pp. 521-533, August 1971.

Best linear invariant estimators of log reliable life are derived for a model in which failure times have a two-parameter Weibull distribution and removal of some surviving items from life test is allowed at the time of any failure.

46. Mann, N.R., "Estimators and Exact Confidence Bounds for Weibull Parameters Based on a Few Ordered Observations," Technometrics, Vol. 12, No. 2, pp. 345-361, May 1970.

The problem of obtaining exact confidence bounds for the shape parameter and for reliable life is considered in detail in this paper when a two-parameter Weibull distribution is assumed. Analytically derived bounds for both these parameters from only a few observations compare well with those derived by Monte Carlo procedures using all the ordered observations.

47. Mann, N.R., "Exact Three-Order-Statistic Confidence Bounds on Reliable Life for a Weibull Model with Progressive Censoring," Jour. of the American Statistical Association, Vol. 64, pp. 306-315, March 1969.

48. Mann, N.R. and Saunders, S.C., "On Evaluation of Warranty Assurance When Life has Weibull Distribution," Biometrika, Vol. 56, No. 3, pp. 615-625, 1969.

The warranty period, which must satisfy an assurance criterion at the prescribed probability level regardless of the true parameter values within the distribution, was calculated from a small preliminary sample of life lengths by using a two-parameter Weibull distribution model.

49. Mann, N.R., "Point and Interval Estimation Procedures for the Two-Parameter Weibull and Extreme-Value Distributions," Technometrics, Vol. 10, No. 2, pp. 231-256, May 1968.

Point estimators of parameters of the first asymptolic distribution of smallest values, or, the extreme-value distribution, are surveyed and compared. The investigation is applicable to the estimation of Weibull parameters, since the logarithms of variates having the two-parameter Weibull distribution are variates from the extreme-value distribution.

50. Mann, N.R., "Tables for Obtaining the Best Linear Invariant Estimates of Parameters of the Weibull Distribution," Technometrics, Vol. 9, No. 4, pp. 629-645, Nov. 1967.

Tables are given for estimating log reliable life, where the estimator is best among linear estimators with expected loss invariant under translations, after a censored life-test situation is considered and the assumption of a Weibull distribution for failure times is made.

51. Mann, N.R., and Fertig, K.W., "Tables for Obtaining Weibull Confidence Bounds and Tolerance Bounds Based on Best Linear Invariant Estimates of Parameters of the Extreme-Value Distribution," Technometrics, Vol. 15, No. 1, pp. 87-101, Feb., 1973.

Tables are given for obtaining confidence bounds for the two parameters and the 90th, 95th, and 99th percentiles of the two-parameter Weibull or extreme-value distribution. Discussion is included concerning other methods of obtaining confidence and tolerance bounds for these distributions.

52. Mann, N.R., "Warranty Periods Based on Three Ordered Sample Observations from a Weibull Population," IEEE Transactions on Reliability, Vol. R-19, No. 4, Nov. 1970.

Investigation is made of using Weibull failure data to determine warranty periods for lots to be manufactured in the future.

53. Markovic, R.D., "Probability Functions of Best Fit to Distributions of Annual Precipitation and Runoff," Hydrology Paper No. 8, Colorado State University, Fort Collins, Colo., Aug. 1965.

Five probability functions--Normal, Log-normal with 2, Log-normal with 3, Gamma with 2 and Gamma with 3 parameters--are fitted to each individual observed distribution of 2056 selected precipitation and river gaging stations in the Western United States and Southwestern Canada. As a result of this study, it has been found that all five probability functions investigated are applicable.

54. Matalas, N.C., Wallis, J.R., "Eureka! It Fits a Pearson Type 3 Distribution," Water Resources Research, Vol. 9, No. 2, pp. 281-289, April 1973.

Under the assumption that a random variable is distributed as Pearson Type 3, a comparison was made between moment and maximum likelihood estimates of the parameter values of the distribution and the variate values at specified probability levels.

55. McGinnis, David, "The Effects of Anomalous Precipitation on Extreme-Value Analysis," Ph.D. Dissertation, Pennsylvania State University, Civil Engineering Department, Dec. 1971.

Best linear invariant estimates, best linear unbiased estimates and maximum likelihood estimates of the Gumbel distribution are used to establish the existence of patterns in rainfall for 77 Pennsylvania watersheds.

56. McGuiness, J.L., and Brakensick, D.L., Simplified Techniques for Fitting Frequency Distributions to Hydrologic Data, US ARS, Agricultural Handbook, Vol. 259, 42 p., 1964.

57. Melentijevich, M., "Estimation of Flood Flows Using Mathematical Statistics," in Floods and Their Computation, Vol. 1, Int'l. Assoc. Hydro. Scien. Pub. No. 84, pp. 164-174, 1969.

Statistical errors of estimation of the parameters of the distribution of the frequency of floods are illustrated on a numerical example by fitting a log-normal distribution to annual values of extreme flow of the Danube and Drina Rivers for different lengths of record.

58. Ott, Ronald F., "Streamflow Frequency Using Stochastically Generated Hourly Rainfall," Ph.D. Dissertation, Stanford University, 1972.

The main purpose of this research was to investigate flood determination techniques commonly used in practice today by use of synthetic long-term records. Six commonly used methods of frequency analyses were used. These included the Gumbel, log-Gumbel, normal, log-Pearson Type III and the log-Pearson using Beard's plotting positions.

59. Potter, W.D., Simplification of the Gumbel Method for Computing Probability Curves, U.S. Soil Conservation Service, Tech. Paper 78, 22 p., 1949.

60. Potter, W.D., "Upper and Lower Frequency Curves for Peak Rates of Runoff," A.G.U. Trans. Vol. 39, No. 1, pp. 100-105, 1958.

61. Powell, R.W., A Simple Method of Investigating Flood Frequency, Civil Eng. Vol. 13, pp. 105-107, 1943.

62. Reich, B.M., "Flood Frequency Analysis with Short Records," International Higher Hydrological Course, Geography Dept., Moscow State Tomonosov University, USSR, June 1973.

The Log-Pearson Type III flood frequency method was compared to the classical Gumbel analysis to determine greater reliability when rising short records. In 24 out of 29 cases the Gumbel analyses of short records gave 1000-year estimates that were within 25% of corresponding long record estimates, while the Log-Pearson Type III method gave similar results in only 14 cases.

63. Reich, B.M., "Flood Series Compared to Rainfall Extremes," A.G.U. Water Resources Research, Vol. 6, No. 6, pp. 1655-1667, Dec. 1970.

Annual series of maximum instantaneous flood peaks from 26 Pennsylvanian watersheds smaller than 200 square miles were analyzed by the Gumbel, log-Gumbel and log-Pearson Type III methods, with the straight line Gumbel showing general applicability. No usable relationships could be found between the extreme value statistics of rainfall and floods.

64. Reich, B.M., "General Report on Session 9: Flood Computation," International Symposium on River Mechanics, Int'l. Assn. for Hydraulic Research, Bangkok, Thailand, Jan. 1973.

This report covers several papers on floods. They include: 1) Recent research in runoff estimates from small rural watersheds, 2) Computing flood frequency in humid Eastern U.S.A., 3) Effect of dams on flood frequency, 4) A general formula for determination of peak flood, 5) Flood computations for the Hawaiian Islands, 6) A typhoon flood computation model in Taiwan, 7) Design peak flood computation for major and multipurpose reservoirs on Marmada River and 8) Assessment of 1966 peak discharge of the Meking at Vientiane.

65. Reich, B.M., "Purpose and Performance of Peak Predictions," Proc. of Int'l. Hydro. Symp., Colo. State Univ., Vol. 1, Paper 70, pp. 565-572, Sept. 1967.

Five current methods for estimating flood peaks expected from ungaged rural drainages of small areas are discussed. Diagrams and statistics illustrate the uncertainties involved and show which methods under- or over-predict flood discharges.

66. Reich, B.M., and Hiemstra, L.A.V., Tacitly Maximized Small Watershed Flood Estimates, Journ. Hydraulics Division, ASCE, Vol. 91, No. HY3, Proc. Paper 4339, May 1965 and Vol. 92, HY4, July 1966.

67. Sammons, W.H., Elements for Detecting Outliers in Samples from a Known Cumulative Probability Distribution, Dept. of Agriculture Soil Conservation Service, Central Technical Unit, 7 pages, September, 1971.

68. Sammons, W.H., "Volume-Duration Probability Analyses of Runoff Stream-Flow Data," Trans. of the ACAE, Vol. 10, No. 1, pp. 15-20, 1967.

The volume-duration-probability analyses used in this paper for areas less than a thousand square miles, relate the water year maximum 1, 3, 7, 15, 30, 60, 90, 120, 183, and 274-day discharge to their probability of occurrence. The gamma (two-parameter) distribution is the principal method employed in the analysis.

69. Shane, R.M., "A Statistical Analysis of Base-Flow Flood Discharge Data," University Microfilms, Ann Arbor, Michigan, Order No. 67-1409, Ph.D. Dissertation, 106 p., 1966.

A probability model was developed and equations were derived that relate design flow to several commonly used measures of risk. The uncertainty of a prediction due to the inherent random nature of flood occurrences was separated from the uncertainty due to a finite length of record.

70. Shane, R.M., and W.R. Lynn, "Mathematical Model for Flood Risk Evaluation," Proc. Amer. Soc. Civil Engrs., Vol. 90, No. HY6, pp. 1-20, November 1965.

71. Singh, Krishan P., and Sinclair, Robert A., "Two-Distribution Method for Flood-Frequency Analysis," Journal of the Hydraulics Division, ASCE, Jan. 1972.

72. Snyder, W.M., "Fitting of Distribution Functions by Nonlinear Least Squares," A.G.U. Water Resources Research, Vol. 8, No. 6, pp. 1423-1432, December 1972.

All parameters of a distribution and seemingly most common distributions can be fitted by this common technique, and therefore, special methods adapted to particular distributions are eliminated. Problems with plotting position and sample outliers vanish with this method of fitting.

73. Strupczewski, W., Determination of Probability Distribution of Maximum Discharges on the Basins of All Observed Floods, in <u>Floods and Their Computation</u>, Vol. 1, Int'l. Assoc. Hydro. Scien., Publ. No. 84, pp. 41-51, 1969.

74. Styner, W.A., and Sammons, W.H., "Comparative Frequency Analysis of Ten Selected USGS Stream Gages Using 2-Parameter Gamma Log-Normal, Log Extreme Value, Arithmetic Normal and Arithmetic Extreme Value Frequency Distributions," Dept. of Agriculture Soil Conservation Service, Central Technical Unit, 47 pages, March 1967.

75. Thom, H.C.S., A Note on the Gamma Distribution: Monthly Weather Rev., Vol. 86, No. 4, pp. 117-122, 1958.

76. Thomas, D.M., Log-Pearson Type III Frequency Analysis by Computer, Techniques of Water-Resources Investigations of the United States Geological Survey, 1968.

77. Todorovic, P. and Zelenhasic, E., "A Stochastic Model for Flood Analysis," Water Resources Research, Vol. 6, No. 6, pp. 1640-1648, Dec. 1970.

78. Todorovic, P., On Extreme Problems in Hydrology, Joint Sta. Meeting, Amer. Stat. Assoc. and Inst. of Math. Stat., CSU, Fort Collins, 1971.

79. Todorociv, P., and Woolhiser, D.A., "On the Time When the Flood Occurs," A.G.U. Water Resources Research, Vol. 8, No. 6, pp. 1433-1438, Dec. 1972.

80. Todorovic, P. and Rousselle, J., "Some Problems of Flood Analysis," Water Resources Research, Vol. 7, No. 5, pp. 1144-1150, Oct. 1971.

A model was developed for nonidentically distributed exceedences on the assumption that only those exceedences during a particular season may be considered identically distributed. From this hypothesis the distribution function of the maximum flood peak exceedence in an arbitrary interval of time was determined. The theoretical and observed results agree reasonably well.

81. U.S. Dept. of Interior, Bureau of Reclamation, Office of Chief Engineer, Determination of Flood Flow Frequencies with the Use of the Log-Pearson Type III method, Electronic Computer Program Description, No. HY173, Denver, Colo., 1969.

This is the description of a program used to compute a log-Pearson Type III frequency curve from known records of annual-maximum flood flows at one stream gaging station.

82. U.S. Dept. of Interior, Bureau of Reclamation, Flood Hydrology Section, Flood Flow Frequency Procedures Used by the Bureau of Reclamation, Division of Planning Coordination Engineering and Research Center, Denver, Colo., 1971.

83. U.S. Dept. of Interior, Bureau of Reclamation, Hazen Type Frequency Analysis, Users Manual and Programmers Manual, Flood Hydrology Section, Engineering and Research Center, Denver, Colo, 1973.

84. U.S. Dept. of Interior, Bureau of Reclamation, "Water Studies," Vol. IV, Part 5, Flood Hydrology, Chap. 6.4, Frequency Studies, 1949.

Consideration is given in this chapter, first to mathematical methods of frequency determinations; then briefly to graphical methods. Particular emphasis is placed on requirements that must be satisfied to insure significance in the results.

85. Wallis, J.R., Matalas, N.C., "Relative Importance of Decision Variables in Flood Frequency Analysis," IBM, Thomas J. Watson Research Center, Yorktown Heights, N.Y.

Monte Carlo simulations were used to assess flood and over-design losses that result from differing choices of assumed frequency distribution, plotting position, criterion of best fit and length of record.

86. Ward, J.K.G., "Frequency Analysis of Floods and Droughts," Inst. Eng. Aust., Civl. Eng. Trans. Vol. CEIO, No. 1, pp. 7-14, Apr. 1968.

A method is presented for statistical analysis of floods and droughts for rivers having reasonably long streamflow records. Results of the analyses conducted can be applied to ungaged streams for flood frequency predictions.

87. Water Resources Council, Hydrology Committee, A Uniform Technique for Determining Flood Flow Frequencies, Bull. 15, Washington, D.C., 1967.

This bulletin sets forth a uniform technique for determining flood flow frequencies. This technique, the Pearson Type III method, is discussed fully and should commend itself for use by State, local government and private engineers.

88. Weiss, L.L., A Nomogram for Log-Normal Frequency Analysis, Trans. A.G.U., Vol. 38, pp. 33-37, 1957.

89. "Estimation of Maximum Floods," World Meteorological Organization Technical Note No. 98, Geneva, Switzerland, 1968.

In addition to physical analysis, statistical methods and their application to storm and flood events are discussed. Statistical analysis and techniques used in various countries in flood frequency analysis are outlined.

90. Yevjevich, V., New Vistas for Flood Investigations, Piene: Loro Previsione E Difesa del Suilo, Quaderno N, 169, Roma Accademia Nazionale dei Lincei, 1972.

A wide variety of problems related to floods are examined in this paper. These include: statistical inference for flood events, probability distribution of floods, flood prediction, and extraction of information on floods from runoff data and precipitation data.

91. Yevjevich, V.M., Probability and Statistics in Hydrology: Water Resources Publications, Ft. Collins, 1972.

92. Zelenhasic, E., Theoretical Probability Distributions for Flood Peaks. Hydrol. Pap. 42, Colo. State Univ., Fort Collins, 1970.

A stochastic model is presented for interpretation, analysis, and prediction of the largest flood peak discharge above a given base level concerning a time interval [o,t] at a given location on a river. A comparison indicated that this model gives better results than Gumbel's method.

APPENDIX F

COMPUTER PROGRAM FLOFREQ

Origin of program.

This program was written at the Center for Research in Water Resources of The University of Texas at Austin by David Ford under the direction of Leo R. Beard. Techniques and criteria contained in the program were developed in CRWR under the guidance of the Water Resources Council Work Group on Flood Flow Frequencies and through the auspices of the Office of Water Resources Research.

Purpose of the program.

Based on the research conducted under OWRR Grant No. 14-31-0001-9088, this program was designed to accept annual streamflow data and evaluate flood flow frequencies using the Log Pearson III function. The program applies criteria developed through this research to evaluate streamflow records containing zero flows, outliers, and historical records, should they exist.

Station identification information, statistics, and computed frequency tables are printed for each station. In addition, a table of input flows, ordered flows, and plotting positions and a plot of frequency data and points on the computed frequency function may be printed.

Methods.

Program FLOFREQ is designed to accept annual peak flow data either from magnetic tape or from punched cards. After the peak flow data is input, a punched card with the station identification number, regional skew coefficient, and any historical data, if it exists, is read. The station number read with peak flow data and the station number input with skew coefficient and historical data are compared to ensure proper order of input. A search is then made to check for years of missing data. These are ignored in development of the frequency curve.

A count is made of zero flows and of outliers on the lower end of the record. For this test, outliers are identified as flows with logarithms more than 2.5 standard deviations less than the mean of the logarithms of the recorded flows. All zero flows and outliers are discarded and the computed frequencies are adjusted by the proportion of non-zero, non-outlier flows.

Information on pre-record flows may be specified either by supplying magnitudes of the historical flows or by indicating that maximum recorded flows have not been exceeded during a given period. These cases are handled as follows:

a. Magnitudes of historical flows are specified.

Only pre-record flow magnitudes that exceed the maximum recorded flow are accepted for special treatment. For each pre-record flow, the plotting position (exceedence frequency) obtained from the formula (M-.3)/(NT+.4) is converted to a Gaussian deviate. For all recorded flows, the larger exceedence frequency of that computed from the above formula or the formula (M-.3)/(N+.4) is converted to a Gaussian deviate. In these formulas, NT is the total years of record and pre-record, and N is the number of years of record.

The mean and standard deviation of all Gaussian deviates are computed and divided by the standard deviation of Gaussian deviates computed for recorded flows using the second formula above. This divisor is approximately 1.0 and adjusts for slight bias that might exist in the plotting position computation and transformation. The standard deviation of all flow logarithms (including pre-record values) is then computed and divided by the de-biased standard deviation of Gaussian deviates. This gives essentially a "best-fit" standard deviation for the normal distribution for the incomplete sample. The mean logarithm of all flows is then decreased by the product of this standard deviation and the mean of all Gaussian deviates. This gives essentially a best-fit mean for the normal distribution for the incomplete sample.

b. Information regarding the non-exceedence of maximum flows is specified.

The largest flow of record is then the largest flow for the entire period of record and pre-record information. It's plotting position is computed accordingly, and the procedure for computing mean and standard deviation as described in the preceding paragraph is followed.

When no historical information is input (NHIST is 0 or blank) the year identification numbers are examined in sequence until 2 consecutive year numbers are reached. Any years preceding these are assumed to be pre-record flow estimates. If pre-record flow estimates are found under this criterion, computation of the plotting positions, mean, and standard deviation is as in section a above. Otherwise the mean and standard deviation for each data set are computed in accordance with the following equations:

$$\bar{X} = \frac{\Sigma X}{N} \quad (1)$$

$$S^2 = \frac{\Sigma x^2}{N-1} \quad (2)$$

where X = logarithm of a single peak flow magnitude

x = deviation of the logarithm of a single magnitude from the mean logarithm of flow magnitude

$\bar{X}$ = mean logarithm

S = standard deviation of logarithms

N = number of items in the data set

In all cases, regardless of existence of or lack of pre-record information, the skew coefficient is calculated, based on recorded data as follows:

$$g = \frac{N\Sigma x^3}{(N-1)(N-2)S^3} \qquad (3)$$

This value is then used in computation of Pearson deviates. As an option, a regional skew value may be used rather than the calculated value. Flow logarithms are related to these statistics by use of the following equation:

$$X = \bar{X} + kS$$

where

X = logarithm of a peak flow

K = Pearson Type III deviate

The frequency curve is established using this equation by computing flows corresponding to specified exceedence frequencies as follows:

a. Where zeros or outliers at the lower end exist, specified exceedence frequencies are multiplied by the ratio of total number of years of record to the number of non-zero, non-outlier years of record.

b. These exceedence frequencies are converted to k values corresponding to expected-probability exceedence frequencies by solving for student's t corresponding to the exceedence frequency, multiplying the t value by (N+1)/N and using the approximate Pearson Type III transform given in reference 6 of the main report.

Input.

Input for program FLOFREQ is accomplished via punched card input file (TAPE5) and magnetic tape (TAPE4). As an option, the magnetic tape input may be omitted, with all data then being read from punched card input. Generally, values read from punched input control the operation of the program, provide the skew coefficient to be used and indicate historical flow data, if any. Values read from magnetic tape (or from punched input on option) include USGS station identification information and the peak flow data.

Variable locations for each input card are shown by field number. Each card is divided into ten fields of eight columns each. Unless otherwise specified, each variable must be right justified in the field, with no decimal points punched.

Card A, one card for entire computer job.

Field	Variable	Value	Description
1	NPUT	≤0	Peak flow data is to be read from magnetic tape.
		>0	Peak flow data is to be read from punched cards.
2	NSKIP	≥0	Internal tape advance for TAPE4. NSKIP stations are read and wasted before first station to be included in this job is read. If NPUT > 0, this value is ignored.
3	NREAD	≥0	Number of stations to be read and analyzed this job.
4	IPLOT	≥0	Input flows, ordered flows, plotting positions and a plot of discharge vs. expected probability of exceedence will be included in output.
		<0	Table of flows, plotting positions and plot are suppressed.
5-10	IUNIT	Alphanumeric	Descriptor of units of discharge (left justified)

Card B*, one card per station if NPUT > 0. Otherwise, card is omitted.

Field	Variable	Value	Description
1	IDSTA	≥0	USGS station identification number
2	IYR	≥0	Number of years of record to be input, including missing data.
3-7	ISTAT	Alphanumeric	Station identification description

Card C*, one card for each five years of record if NPUT > 0. Otherwise, card is omitted.

Field	Variable	Value	Description
1,3,5,7,9	IYRA(I)		Year of peak flow
2,4,6,8,10	Q(I)		Peak flow magnitude. Decimal point is assumed at right of field unless punched. If data is missing, leave blank.

Card D*, one card per station

Field	Variable	Value	Description
1	ITMP	≥0	Temporary variable. Must match IDSTA (station identification number) punched on Card B or job will terminate.
2	SKW	≤-99	Calculated skew coefficient is to be used.
		>-99	Value of SKW is to be used as skew coefficient. Decimal point is assumed at right of field unless punched.
3	NHIST	>0	Number of years of historical (pre-record) data to be input. Data on cards C should be record data only
		0 or blank	All flows in years prior to first 2 consecutive years are treated as historical data.
		<0	Indicates that ABS(NHIST) recorded values are known not to have been exceeded in historical period. Data on cards C should be record data only.
4	IYRHS	≥0	Earliest year of historical data. Ignored if NHIST is 0 or blank.
5-10	QH(I)	≥0	Historical peak flow magnitudes. Decimal point is assumed at right of field unless punched.

*When flow data are read from cards, cards B, C and D are provided together for each station in turn.

Data are read from TAPE4 as follows

Variable	Format	Description
IDSTA	I8	Station identification number
ISTAT	4A10,A5	Alphanumeric station identification
IYR	I8	Number of years of record
IYRA(1)	I4	Year of first peak flow
Q(1)	F7.0	First peak flow magnitude
IYRA(2)		Year of second peak flow
Q(2)		Second peak flow magnitude
etc.		

Format for USGS tape is (I8,12X,4A10,A5,19X,I8,27X,/(I4,6X,F7.0,2X)

Output.

A sample of the output from program FLOFREQ follows the attached source program listing. This output consists of:

(a) Station number and identification, chronological and ordered data and plotting positions

(b) Computed statistics, the input regional skew coefficient, the computed function, and, if desired, a plotting of the observed data and the computed function.

Definitions of Variables
Program FLOFREQ

AK	-	Pearson Type III deviate
AMQ	-	Arithmetic mean of peak flows
AMX	-	Mean of logarithms of flows
B(I)	-	Probability of exceedence values adjusted for zero flows and outliers
G	-	Coefficient of skew used to compute frequency curve (G=GCAL or G=SKW)
GCAL	-	Computed, coefficient of skew
I	-	Temporary counter or index
IDSTA	-	USGS station identification number
IER	-	Error indicator for statistical subroutines (MDSTI and MDNOR)
IHD	-	Number of input historical flows omitted as less than maximum flow of record
IPLOT	-	Output control. Negative value suppresses table of flows and plotting positions and plot of frequency data and points on computed frequency curve
ISTAT(5)	-	Alphanumeric station identifier
ITMP	-	Temporary variable
IUNIT(4)	-	Alphanumeric descriptor of units of discharge
IYR	-	Number of years of peak flow data input, including missing data
IYRA(I)	-	Year of peak flow
IYRHS	-	Earliest year of historical record
IZERO	-	Number of zero flows and outliers
J	-	Temporary index or counter
K	-	Temporary index or counter
N	-	Number of years of record input less blanks, zero flows and outliers

NBLANK	-	Number of missing (blank) peak flows
NHIST	-	Indicator for historical peak flows. Positive value indicates NHIST historical values are to be input. Zero indicates no historical values are to be input and all values prior to first consecutive years of record of input peak flow data are to be treated as historical data. Negative value indicates that it is known that the maximum value of the input peak flow data is the ABS(NHIST) largest value since year IYRHS
NPUT	-	Indicator of form of input of peak flow data. If > 0, peak flow data is to be input from punched cards. Otherwise, input is from magnetic tape.
NQH	-	Total number of peak flows (input record plus historical flows)
NREAD	-	Number of stations to be analyzed this run
NSKIP	-	Program tape advance. For NPUT ≤ 0, NSKIP stations are read and wasted before analysis begins
NSTA	-	Counter of number of stations analyzed
NT	-	Number of peak flow values input, less missing data
NVAL(I)	-	For plot routine, number of values to be plotted as observed or computed flows
NYRH	-	Length of period of record beginning with year of earliest historical data
PLOTP(I,J)	-	Plotting positions of observed flows
PPH	-	Plotting position (M-0.3/N+0.4) based on length of record defined by earliest historical data
PPHB	-	Plotting position (M/N+1) based on length of record defined by earliest historical data
PPR	-	Plotting position (M-0.3/N+0.4) based on length of period of actual recorded data
PPRB	-	Plotting position (M/N+1) based on length of period of actual recorded data

Q(I)	-	Array of recorded peak flow data arranged in descending magnitude
QH(I)	-	Array of historical peak flow data arranged in descending magnitude
QNTY(I,J)	-	Array of flow magnitudes for plotting
R(I,J)	-	Array of plotting positions and probability values for plotting
RTIO	-	Probability adjustment ratio. When zero flows and/or outliers exist, the probability of exceedence is adjusted by ratio of total number of flows to number of non-zero, non-outlier flows
S	-	Standard deviation of logs of flows
SKW	-	Input skew coefficient. If SKW > -99. This value is used to compute frequency curve. Otherwise computed skew coefficient (GCAL) is used.
SMSQH	-	Sum of squares of normal deviates of plotting positions of historical flows
SMSQQ	-	Sum of squares logarithms of flows (including historical data)
SMSQR	-	Sum of squares of normal deviates of plotting positions based on length of period of actual recorded data
STAR(17)	-	Array of alphanumeric character*
SUMH	-	Sum of normal deviates of plotting positions based on length of period of actual recorded data
SUMQH	-	Sum of logarithms of flows (including historical data)
TEMP	-	Temporary variable
TEMPA	-	Temporary variable
TMP	-	Temporary variable
TP	-	Temporary variable
U(I)	-	Array of input peak flows
X(I)	-	Array of logarithms of peak flows

```
      PROGRAM FLOFREQ(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE4)
      DIMENSION Q(130),X(130),PLOTP(2,130),QNTY(2,130),R(2,130),U(130),
     1       IYRA(130),STAR(17),B(13),NVAL(2),ISTAT(5),QH(8),IYRH(8),
     2       IUNIT(4)
      DATA (STAR(J),J=1,17)/17*8H********/
C
C                                 TAPE4 - INPUT DATA TAPE
C                                 TAPE5 - LOGICAL CARD INPUT UNIT
C                                 TAPE6 - LOGICAL PRINTER OUTPUT UNIT
C
      WRITE (6,660)
C                                 SET UP DESIRED PROBABILITIES
C                                 OF EXCEEDENCE
      R(2,1)=.001
      R(2,2)=.003
      R(2,3)=.01
      R(2,4)=.03
      R(2,5)=.1
      R(2,6)=.3
      R(2,7)=.5
      R(2,8)=.7
      R(2,9)=.9
      R(2,10)=.97
      R(2,11)=.99
      R(2,12)=.997
      R(2,13)=.999
C                                 **CARD A**
C                                 PROGRAM CONTROL PARAMETERS
C                                 ONE CARD PER RUN
      READ (5,540) NPUT,NSKIP,NREAD,IPLOT,IUNIT
      NSTA=0
         IF (IUNIT(1).NE.10H          ) GO TO 10
      IUNIT(1)=10HCUBIC FEET
      IUNIT(2)=10H PER SECON
      IUNIT(3)=10HD
      IUNIT(4)=10H
C                                 PROGRAM ALWAYS BRANCHES TO STEP 20 TO READ
C                                 NEXT STATION
 10   CONTINUE
      IHD=0
C                                 INITIALIZE ARRAYS
      DO 20 I=1,130
      Q(I)=0.
      U(I)=0.
      IYRA(I)=0.
      R(1,I)=0.
      DO 20 J=1,2
      PLOTP(J,I)=0.
      QNTY(J,I)=0.
 20   CONTINUE
```

```
      DO 30 I=1,8
      QH(I)=0.
 30   CONTINUE
C                              CHECK TYPE OF INPUT
         IF (NPUT.GT.0) GO TO 70
C                              PEAK FLOW DATA INPUT FROM TAPE
         IF (NSKIP.LE.0.OR.NSTA.GT.0) GO TO 50
C                              READ AND WASTE TAPE UP TO DESIRED STATION
      DO 40 J=1,NSKIP
      READ (4,550) IDSTA,ISTAT,IYR,(IYRA(I),U(I),I=1,IYR)
         IF (EOF,4) 60,40
 40   CONTINUE
C                              READ DATA FOR ONE STATION
 50   READ (4,550) IDSTA,ISTAT,IYR,(IYRA(I),U(I),I=1,IYR)
         IF (EOF,4) 60,80
 60   STOP
C                              PEAK FLOW DATA INPUT FROM CARDS
C                              ONE SET PER STATION
C                              **CARD B**
 70   READ (5,560) IDSTA,IYR,ISTAT
C                              **CARD C**
      READ (5,570) (IYRA(I),U(I),I=1,IYR)
         IF (EOF,5) 60,80
 80   NSTA=NSTA+1
C                              **CARD D**
C                              READ STATION NO.,SKEW COEFF.,HISTORICAL
C                              DATA FROM CARD.
C                              ONE CARD PER STATION (REGARDLESS OF FORM OF
C                              INPUT OF PEAK FLOW DATA)
      READ (5,630) ITMP,SKW,NHIST,IYRHS,(IYRH(I),QH(I),I=1,3)
         IF (NHIST.GT.3) READ (5,680) (IYRH(I),QH(I),I=4,NHIST)
C                              IF INPUT STATION NO. DOES NOT MATCH STATION
C                              NO. READ WITH PEAK FLOW DATA, TERMINATE JOB
         IF (IDSTA.EQ.ITMP) GO TO 90
      WRITE (6,600)
      STOP
 90   CONTINUE
C
      DO 100 I=1,IYR
      Q(I)=U(I)
 100  CONTINUE
C                              IF BLANKS WERE READ REMOVE THEM
C                              AND SHIFT Q ARRAY.  UPDATE N
      NBLANK=0
      DO 130 I=1,IYR
      TEMP=Q(I)
C                              THE FOLLOWING STATEMENT MAY BE INVALID
C                              FOR CERTAIN FORTRAN COMPILERS.
C                              FOR UNIV. OF TEXAS FORTRAN (RUN 60.2)
C                              COMPILER IT WILL TEST FOR BLANK (NO PUNCH)
```

```
          IF (.NOT.TEMP) 120,110
  110   CONTINUE
        NBLANK=NBLANK+1
          GO TO 130
  120   CONTINUE
        Q(I-NBLANK)=TEMP
  130   CONTINUE
        N=IYR-NBLANK
          IF (NHIST.NE.0) GO TO 160
C                             IF NHIST=0 PROGRAM ROUTINE FOR DETERMINING
C                             HISTORICAL DATA WILL BE USED
C                             TEST DATA FOR NON-CONSECUTIVE YEARS OF
C                             RECORD.  THESE ARE TREATED AS HISTORICAL
C                             DATA.
        IYRHS=IYRA(1)
        I=1
  140   CONTINUE
        J=I+1
        ITMP=IYRA(J)-IYRA(I)
          IF (ITMP.EQ.1) GO TO 160
        N=N-1
        IYR=IYR-1
        NHIST=NHIST+1
C                             PUT NON-CONSECUTIVE YEARS IN QH AND IYRH
C                             ARRAYS.  THESE WILL BE TREATED BY SAME
C                             ALGORITHM USED IF HIST. DATA IS INPUT
C                             VIA CARD D.
        QH(NHIST)=Q(I)
        IYRH(NHIST)=IYRA(I)
        DO 150 K=1,N
        IYRA(K)=IYRA(J)
        Q(K)=Q(J)
        U(K)=U(J)
        J=J+1
  150   CONTINUE
          GO TO 140
  160   CONTINUE
C                             CALL ROUTINE TO ORDER FLOWS
        CALL ORDER (Q,N)
        NT=N
C                             TEST FOR ZERO FLOWS
        IZERO=0
        DO 180 I=1,N
        TP=Q(I)
          IF (TP.GT.0) GO TO 170
        IZERO=IZERO+1
          GO TO 180
  170   X(I)=ALOG10(TP)
  180   CONTINUE
        N=N-IZERO
```

```
      NVAL(1)=N
      IOUT=0
         GO TO 200
C                                    TEST FOR OUTLIERS ON LOWER END OF RECORD
C                                    FOR TEST OUTLIER IS DEFINED AS FLOW LESS
C                                    2.5 STANDARD DEVIATIONS BELOW MEAN OF LOGS
C                                    OF NON-ZERO FLOWS
 190     IF (X(N).GT.TEMP) GO TO 230
      ITMP=N-1
C                                    REMOVE NO MORE THAN NT/3 VALUES AS OUTLIERS
         IF (ITMP.LE.2*NT/3) GO TO 230
      N=ITMP
      IOUT=IOUT+1
 200  TMP=0.
C                                    COMPUTE MEAN AND STANDARD DEVIATION
      DO 210 I=1,N
      TMP=TMP+X(I)
 210  CONTINUE
      AMX=TMP/FLOAT(N)
      TMP=0.
      DO 220 I=1,N
      TMP=TMP+(X(I)-AMX)**2
 220  CONTINUE
      TP=SQRT(TMP/FLOAT(N-1))
      TEMP=AMX-2.5*TP
         GO TO 190
C                                    DETERMINE RATIO OF TOTAL NO. OF FLOWS TO
C                                    NO. OF NONZERO FLOWS
 230  RTIO=FLOAT(NT)/FLOAT(N)
C                                    NVAL(1) POINTS WILL BE PLOTTED AS OBSERVED
C                                    DATA.
C                                    N IS THE TOTAL NUMBER OF RECORDED PEAK
C                                    FLOWS LESS BLANKS, ZEROES, AND OUTLIERS.
C                                    NT IS THE TOTAL NUMBER OF RECORDED FLOWS
C                                    LESS ZEROES.
C                                    ADJUST PROBABILITIES FOR ZERO FLOWS
C                                    AND/OR OUTLIERS
      B(1)=1.-(.001*RTIO)
      B(2)=1.-(.003*RTIO)
      B(3)=1.-(.01*RTIO)
      B(4)=1.-(.03*RTIO)
      B(5)=1.-(.1*RTIO)
      B(6)=1.-(.3*RTIO)
      B(7)=1.-(.5*RTIO)
      B(8)=1.-(.7*RTIO)
      B(9)=1.-(.9*RTIO)
      B(10)=1.-(.97*RTIO)
      B(11)=1.-(.99*RTIO)
      B(12)=1.-(.997*RTIO)
      B(13)=1.-(.999*RTIO)
```

```
      SUMH=0.
      SMSQR=0.
      SMSQH=0.
      SUMQH=0.
      SMSQQ=0.
      TEMPA=NT
C                               IF THERE IS NO HISTORICAL DATA JUMP TO 270
C                               HISTORICAL DATA ROUTINE
         IF (NHIST) 350,400,240
  240 TEMP=Q(1)
C                               SHIFT U AND IYRA ARRAYS AND INSERT QH AND
C                               IYRH
      ITMP=IYR+NHIST
      J=IYR
      DO 250 I=1,IYR
      IYRA(ITMP)=IYRA(J)
      U(ITMP)=U(J)
      ITMP=ITMP-1
      J=J-1
  250 CONTINUE
      DO 260 I=1,NHIST
      IYRA(I)=IYRH(I)
      U(I)=QH(I)
  260 CONTINUE
      IYR=IYR+NHIST
C                               OMIT HISTORICAL FLOWS LESS THAN MAXIMUM
C                               FLOW OF CONTINUOUS RECORD
      DO 280 I=1,NHIST
      TMP=QH(I)
         IF (TMP.GT.TEMP) GO TO 270
      IHD=IHD+1
         GO TO 280
  270 QH(I-IHD)=TMP
  280 CONTINUE
      NHIST=NHIST-IHD
C                               IF ALL HIST. DATA IS LESS THAN MAX.
C                               PEAK OF CONTINUOUS RECORD, NHIST = -1
      IF (NHIST.LE.0) NHIST=-1
         IF (NHIST.LT.0) GO TO 350
C                               CALL ROUTINE TO ORDER INPUT HISTORICAL
C                               FLOWS
      IF (NHIST.GT.1) CALL ORDER (QH,NHIST)
C                               NYRH IS LENGTH OF ENTIRE PERIOD OF
C                               KNOWLEDGE (INCLUDING BOTH CONTINUOUS
C                               RECORD AND HIST. DATA)
      NYRH=IYRA(IYR)-IYRHS+1-NBLANK
      NQH=NT+NHIST
      TEMP=NYRH
      DO 320 I=1,NQH
      J=I-NHIST
```

```
      TMP=I
C                                     CALCULATE PLOTTING POSITIONS USING FULL
C                                     PERIOD OF RECORD (INCLUDING HISTORICAL
C                                     DATA)
      PPH=(TMP-.3)/(TEMP+.4)
      PPHB=TMP/(TEMP+1.)
         IF (J.GT.N) GO TO 290
      IF (J.LE.0) TP=ALOG10(QH(I))
      IF (J.GT.0) TP=ALOG10(Q(J))
      SMSQQ=SMSQQ+TP**2
      SUMQH=SUMQH+TP
         IF (J.LE.0) GO TO 310
 290  TMP=J
C                                     CALCULATE PLOTTING POSITIONS USING LENGTH
C                                     OF PERIOD OF RECORDED FLOWS
      PPR=(TMP-.3)/(TEMPA+.4)
      PPRB=TMP/(TEMPA+1.)
         IF (J.GT.N) GO TO 300
      TMP=1.-PPR*RTIO
      CALL MDNRIS (TMP,TP,IER)
      SMSQR=SMSQR+TP**2
 300  IF (PPHB.LT.PPRB) PPHB=PPRB
      IF (PPH.LT.PPR) PPH=PPR
 310  PLOTP(2,I)=PPH
      PLOTP(1,I)=PPHB
         IF (J.GT.N) GO TO 320
      TMP=1.-PPH*RTIO
      CALL MDNRIS (TMP,TP,IER)
      SUMH=SUMH+TP
      SMSQH=SMSQH+TP**2
 320  CONTINUE
C                                     REPOSITION Q-ARRAY AND ADD HISTORICAL FLOWS
      TP=N
      TMP=N+NHIST
      J=N
      ITMP=N+NHIST
      DO 330 I=1,N
      Q(ITMP)=Q(J)
      X(ITMP)=X(J)
      J=J-1
      ITMP=ITMP-1
 330  CONTINUE
      DO 340 I=1,NHIST
      Q(I)=QH(I)
      X(I)=ALOG10(QH(I))
 340  CONTINUE
         GO TO 390
C                                     CONTROL PASSES TO HERE IF IT IS KNOWN THAT
C                                     ABS(NHIST) HIGHEST FLOWS OF RECORD HAVE NOT
C                                     BEEN EXCEEDED
```

```
 350  NYRH=IYRA(IYR)-IYRHS+1-NBLANK
      DO 380 I=1,NT
      TMP=I
      PPH=(TMP-.3)/(TEMPA+.4)
      PPHB=TMP/(TEMPA+1.)
         IF (I.GT.N) GO TO 370
      TEMP=1.-PPH*RTIO
      CALL MDNRIS (TEMP,TP,IER)
      SMSQR=SMSQR+TP**2
         IF (I.GT.-NHIST) GO TO 360
      TP=NYRH
      PPH=(TMP-.3)/(TP+.4)
      PPHB=TMP/(TP+1.)
      TEMP=1.-PPH*RTIO
      CALL MDNRIS (TEMP,TP,IER)
 360  SMSQH=SMSQH+TP**2
      SUMH=SUMH+TP
      TP=ALOG10(Q(I))
      SUMQH=SUMQH+TP
      SMSQQ=SMSQQ+TP**2
 370  PLOTP(2,I)=PPH
      PLOTP(1,I)=PPHB
 380  CONTINUE
      TP=N
      TMP=TP
 390  TEMP=(SMSQH-SUMH**2/TMP)/TMP
      TEMPA=SMSQR/TP
      SMSQH=SQRT(TEMP/TEMPA)
      SMSQQ=SQRT((SMSQQ-SUMQH**2/TMP)/TMP)
C                                  DETERMINE MEAN AND STANDARD DEVIATION
      S=SMSQQ/SMSQH
      AMX=SUMQH/TMP-S*SUMH/TMP
         GO TO 420
C                                  CALCULATE PLOTTING POSITIONS
 400  TP=NT+1
      TEMP=0.
      TEMPA=FLOAT(NT)+0.4
      DO 410 I=1,NT
      PLOTP(1,I)=FLOAT(I)/TP
      PLOTP(2,I)=(FLOAT(I)-.3)/TEMPA
         IF (I.GT.N) GO TO 410
      TEMP=TEMP+X(I)
 410  CONTINUE
C                                  DETERMINE ARITHMETIC MEAN AND MEAN OF LOGS
      AMX=TEMP/FLOAT(N)
 420  J=0
      TEMP=0.
      TMP=0.
      TEMPA=0.
      IF (NHIST.GT.0) J=NHIST
```

```
      DO 430 I=1,N
      J=J+1
      TP=X(J)-AMX
      TEMP=TEMP+TP**2
      TMP=TMP+TP**3
      TEMPA=TEMPA+Q(I)
 430  CONTINUE
      AMQ=TEMPA/FLOAT(N)
C                               DETERMINE STANDARD DEVIATION FOR CASE WITH
C                               NO HISTORICAL FLOW DATA
      TP=SQRT(TEMP/FLOAT(N-1))
      IF (NHIST.EQ.0) S=TP
      TEMP=(N-1)*(N-2)
C                               CALCULATE SKEW COEFFICIENT
      GCAL=(FLOAT(N)*TMP)/(TEMP*TP**3)
C                               IF INPUT SKEW COEFF. LE -99., USE
C                               CALCULATED SKEW COEFF. OTHERWISE USE
C                               INPUT SKEW COEFF.
      G=GCAL
      IF (SKW.GT.-99.) G=SKW
      TP=N-1
      NVAL(2)=13
      DO 440 J=1,13
      IF (B(J).LE.0.) NVAL(2)=NVAL(2)-1
 440  CONTINUE
      ITMP=NVAL(2)
      DO 490 J=1,ITMP
      TMP=B(J)
      TEMP=0.
         IF (TMP.LE.0.) GO TO 480
C                               ADJUST TO EXPECTED PROBABILITY
      TEMPA=-1.
         IF (TMP-.5) 460,470,450
 450  TMP=1.-TMP
      TEMPA=1.
 460  TMP=TMP*2
C                               CALL ROUTINE FOR INVERSE STUDENT*S T
      CALL MDSTI (TMP,TP,TEMP,IER)
      TEMP=TEMP*SQRT((TP+2.)/(TP+1.))
      TEMP=TEMP*TEMPA
 470  AK=TEMP
C                               APPROX. TRANSFORM FROM NORMAL DEVIATE TO
C                               PEARSON TYPE III DEVIATE
      IF (G.NE.0.) AK=(2./G)*(((((G/6.)*(TEMP-G/6.))+1.)**3)-1.)
C                               REVERSE TRANSFORM
      TEMP=(10.**(AMX+(AK*S)))
 480  IF (TEMP.LE.0.) TEMP=0.
      QNTY(2,J)=TEMP
 490  CONTINUE
C                               PRINT CALCULATED STATISTICS, CALCULATED
```

```
C                                  FLOWS,AND CORR. PROBABILITIES
            IF (NSTA.GT.1) WRITE (6,590) STAR,STAR
         ITMP=N
         IF (NHIST.GT.0) ITMP=ITMP+NHIST
         WRITE (6,580) IDSTA,ISTAT,IYR,NBLANK,ITMP
            IF (IPLOT.LT.0) GO TO 500
         ITMP=NT
         IF (NHIST.GT.0) ITMP=ITMP+NHIST
         NVAL(1)=ITMP
         WRITE (6,670) (IYRA(I),U(I),Q(I),I,PLOTP(1,I),PLOTP(2,I),I=1,ITMP)
         ITP=ITMP+1
            IF (IYR.GT.ITMP) WRITE (6,610) (IYRA(I),U(I),I=ITP,IYR)
            IF (IHD.GT.0) WRITE (6,640) IHD
            IF (IOUT.GT.0) WRITE (6,690) IOUT
         WRITE (6,650) STAR
  500    TEMP=QNTY(2,13)
         ITMP=NVAL(2)
         IF (TEMP.GE.1.) WRITE (6,620) AMQ,AMX,S,GCAL,G,(QNTY(2,J),R(2,J),
     1        J=1,ITMP)
         IF (TEMP.LT.1.) WRITE (6,620) AMQ,AMX,S,GCAL,G,(QNTY(2,J),R(2,J),
     1        J=1,ITMP)
C
C                                  CALL PLOT ROUTINE
C
            IF (IPLOT.LT.0) GO TO 520
         ITMP=NVAL(1)
         DO 510 I=1,ITMP
         QNTY(1,I)=Q(I)
         R(1,I)=PLOTP(2,I)
  510    CONTINUE
         WRITE (6,530) IUNIT
         CALL PLOG (2,NVAL,QNTY,R)
C                                  IF MORE STATIONS ARE TO BE ANALYZED GO
C                                  BACK TO BEGINNING
  520       IF (NSTA.LT.NREAD) GO TO 10
C
  530    FORMAT  (///,40X,13HDISCHARGE IN 4A10)
  540    FORMAT  (1X,I7,3I8,4A10)
  550    FORMAT   (I8,12X,4A10,A5,19X,          I8,27X,     /(7(I4,6X,F7.0,2
     1X)))
  560    FORMAT  (1X,I7,I8,4A10,A5)
  570    FORMAT  (1X,I7,F8.0,4(I8,F8.0))
  580    FORMAT  (38X,I8,5X,4A10,A5,///,5X,24HTOTAL NO. OF VALUES READ,8X,1
     1H=,I8,/,5X,19HNO. OF BLANK VALUES,13X,1H=,I8,/,5X,33HNO. OF VALUES
     2 USED FOR ANALYSIS =,I8,//)
  590    FORMAT    (2(/,17A8))
  600    FORMAT  (5X,35HDATA OUT OF ORDER -- JOB TERMINATED)
  610    FORMAT (I11,F14.0)
  620    FORMAT  (/,56X,15HLOG PEARSON III,/,5X,21HARITHMETIC MEAN      =,F1
     12.5,/,5X,21HMEAN OF LOGS,        =,F12.5,/,5X,21HSTANDARD DEVIATION
```

```
     2  =,F12.5,/,5X,21HCOEFFICIENT OF SKEW =,F12.5,5X,11HCHANGED TO F12
     3,5,//,9X,4HFLOW,7X,20HEXPECTED PROBABILITY,/,20X,16H   OF EXCEEDEN
     4CE,/(F14.0,F16.3))
 630  FORMAT  (1X,I7,F8.0,2I8,3(I8,F8.0))
 640  FORMAT  (I11,49H PRE-RECORD FLOWS LESS THAN MAXIMUM RECORDED FLOW)
 650  FORMAT   (17A8)
 660  FORMAT  (1H1,50X,33HFLOOD FLOW FREQUENCY COMPUTATIONS,///)
 670  FORMAT  (5X,7HYEAR OF ,6X,8HOBSERVED,6X,7HORDERED,7X,4HRANK,5X,17H
     1PLOTTING POSITION,/,5X,9HPEAK FLOW,4X,9HPEAK FLOW,5X,9HPEAK FLOW,1
     24X,5HM/N+1,8X,11HM-0.3/N+0.4,/(I11,F14.0,F14.0,I10,F12.5,F15.5))
 680  FORMAT  (5(I8,F8.0))
 690  FORMAT  (I11,56H OUTLIERS ON LOWER END OF RECORD (TREATED AS ZERO
     1FLOWS))
      END
      SUBROUTINE PLOG (NVAR,NVAL,QNTY,P)
C
C     -----------------------------------------------------------------
C     FUNCTION                     - PROVIDES A LINE-PRINTER PLOT OF
C                                  MAGNITUDE VS. PROBABILITY OF
C                                  EXCEEDENCE.
C     USAGE                        - CALL PLOG (NVAR,NVAL,QNTY,P)
C     PARAMETERS       NVAR        - NUMBER OF FUNCTIONS TO BE PLOTTED.
C                                  CURRENTLY LIMITED TO 2.
C                   NVAL     - NUMBER OF VALUES TO BE PLOTTED
C                              ON EACH CURVE.
C                   QNTY     - INPUT MAGNITUDE. VALUES MUST BE
C                              ARRANGED IN ORDER OF DECREASING
C                              MAGNITUDE.
C                   P        - INPUT PROBABILITIES.
C     PRECISION                    - SINGLE
C     -----------------------------------------------------------------
C
      DIMENSION NVAL(2),QNTY(2,130),P(2,130),ISCL(3),NLIN(3),SYMBL(100),
     1      PRB(100),GRID(132),PLOT(132)
      DOUBLE PRECISION CNST
      INTEGER GRID,PLOT,SYMBL
      DATA ISTAR,IX,IPER,IDASH,IBLANK/1H*,1HX,1H.,1H-,1H /
      WRITE (6,220)
      DO 10 J=8,132
      GRID(J)=IBLANK
 10   CONTINUE
      GRID(8)=IPER
      GRID(15)=IPER
      GRID(23)=IPER
      GRID(32)=IPER
      GRID(44)=IPER
      GRID(60)=IPER
      GRID(70)=IPER
      GRID(80)=IPER
      GRID(96)=IPER
```

```
      GRID(108)=IPER
      GRID(117)=IPER
      GRID(125)=IPER
      GRID(132)=IPER
C             DETERMINE RANGE OF MAGNITUDE TO BE PLOTTED
      QMAX=0.
      QMIN=999999.
      DO 30 J=1,NVAR
      NQ=NVAL(J)
      DO 20 I=1,NQ
      IF (QNTY(J,I).LT.QMIN) QMIN=QNTY(J,I)
      IF (QNTY(J,I).GT.QMAX) QMAX=QNTY(J,I)
 20   CONTINUE
 30   CONTINUE
         IF (QMAX.GT.1.) GO TO 40
      WRITE (6,230)
      RETURN
 40   CONTINUE
      IF (QMIN.LT.QMAX*.0001) QMIN=QMAX*.0001
      IFCTR=1
         IF (QMIN.GT.1.) GO TO 50
      TMP=500000./QMAX
      TEMP=1./QMIN
      ITP=ALOG10(TMP)
      ITMP=ALOG10(TEMP)
      IF (TEMP.GT.1.) ITMP=ITMP+1
      IF (ITMP.GT.ITP) ITMP=ITP
      IFCTR=10**ITMP
      WRITE (6,240) IFCTR
C             SET UPPER LIMIT OF GRID
 50   CONTINUE
      ITP=ALOG10(QMAX)
      TMP=QMAX/10.**ITP
      ITMP=10
      IF (TMP.LE.5.) ITMP=5
      IF (TMP.LE.2.) ITMP=2
         IF (ITMP-5) 80,70,60
 60   CONTINUE
      JJ=1
         GO TO 90
 70   CONTINUE
      JJ=2
         GO TO 90
 80   CONTINUE
      JJ=3
 90   CONTINUE
      ITMP=ITMP*10**ITP*IFCTR
      ISCAL=ITMP
      QMX=ITMP
      TEMP=IFCTR
```

```
      QMX=QMX/TEMP
C              SET LOWER LIMIT OF GRID
      TEMP=ALOG10(QMIN)
      IP=TEMP
      IF (TEMP.LT.0.) IP=IP-1
      TMP=QMIN/10.**IP
      ITEMP=1
      IF (TMP.GT.2.) ITEMP=2
      IF (TMP.GT.5.) ITEMP=5
      TEMP=ITEMP
      TMP=IFCTR
      TEMP=TEMP*10.**IP+.000001
      ITEMP=TEMP*TMP
C              ESTABLISH SCALE AND SPACING
      TMP=ITMP/ITEMP
      CNST=10.**(-.05)
      QMN=QMX/SQRT(CNST)
      LINES=ALOG10(TMP)*20.+1.1
      IF (LINES.LT.21) LINES=21
      ISCL(1)=10
      ISCL(2)=5
      ISCL(3)=2
      NLIN(1)=6
      NLIN(2)=8
      NLIN(3)=6
      M=1
      N=1
      K=0
      DO 210 I=1,LINES
      IF (I.NE.1) ISCAL=-1
      QMN=QMN*CNST
      K=K+1
         IF (K.LE.NLIN(JJ)) GO TO 100
      K=1
      JJ=JJ+1
      IF (JJ.GT.3) JJ=1
      IF (ISCL(JJ).EQ.10) ITP=ITP-1
      TMP=ITP
      TEMP=IFCTR
      TP=ISCL(JJ)
      ISCAL=TP*10.**TMP*TEMP+.5
      IF (ISCAL.GE.10000000000) ISCAL=-2
100   CONTINUE
      NPNT=0
110   CONTINUE
         IF (M.GT.NVAL(1)) GO TO 120
         IF (QNTY(1,M).LE.QMN.AND.I.LT.LINES) GO TO 120
      NPNT=NPNT+1
      PRB(NPNT)=P(1,M)
      SYMBL(NPNT)=ISTAR
```

```
      M=M+1
         GO TO 110
  120 CONTINUE
         IF (N.GT.NVAL(2)) GO TO 130
         IF (QNTY(2,N).LE.QMN.AND.I.LT.LINES) GO TO 130
C                ESTABLISH POINTS TO PLOT ON LINE I
      NPNT=NPNT+1
      PRB(NPNT)=P(2,N)
      SYMBL(NPNT)=IX
      N=N+1
         GO TO 120
  130 CONTINUE
         IF (ISCAL+1) 160,140,160
  140 DO 150 J=8,132
      PLOT(J)=GRID(J)
  150 CONTINUE
         GO TO 180
  160 DO 170 J=8,132
      PLOT(J)=IDASH
  170 CONTINUE
  180    IF (NPNT.LE.0) GO TO 200
      DO 190 KK=1,NPNT
      TEMP=1.-PRB(KK)
      CALL MDNRIS (TEMP,X,IER)
      MM=70.5+X*20.
      IF (MM.LT.8) MM=8
      IF (MM.GT.132) MM=132
      PLOT(MM)=SYMBL(KK)
  190 CONTINUE
  200    IF (ISCAL.GE.0) WRITE (6,260) ISCAL,(PLOT(J),J=8,132)
         IF (ISCAL.LT.0) WRITE (6,270) (PLOT(J),J=8,132)
  210 CONTINUE
      WRITE (6,280)
      WRITE (6,250)
      RETURN
  220 FORMAT  (1HQ)
  230 FORMAT  (17H0VALUES TOO SMALL)
  240 FORMAT  (25H0QUANTITIES MULTIPLIED BY I6/)
  250 FORMAT   (1HR)
  260 FORMAT  (1X,I10,125A1)
  270 FORMAT  (11X,125A1)
  280 FORMAT (10X4H99.9 3X4H99.7 5X2H99 7X2H97 10X2H90 14X2H70 8X2H50
     1  7X2H30 14X2H10 11X1H3 8X1H1 6X2H.3 5X2H.1/50X39HEXCEEDENCE FREQU
     2ENCY PER HUNDRED EVENTS,///)
      END
      SUBROUTINE ORDER (Q,N)
C
C     ------------------------------------------------------------------
C
C     FUNCTION                    - NUMERICAL RANKING
```

```
C      USAGE                          = CALL ORDER (Q,N)
C      PARAMETERS      Q              = INPUT VECTOR CONTAINING VALUES TO
C                                       BE RANKED. ON OUTPUT THIS VECTOR
C                                       IS ARRANGED IN ORDER OF DECREASING
C                                       MAGNITUDE.
C                    N              = NUMBER OF VALUES TO BE RANKED.
C      PRECISION                      = SINGLE
C      -------------------------------------------------------------------
C
       DIMENSION Q(130)
       NA=N-1
       DO 20 J=1,NA
       M=J
       MA=J+1
       DO 10 I=MA,N
       IF (Q(I).GT.Q(M)) M=I
 10    CONTINUE
       TEMP=Q(J)
       Q(J)=Q(M)
       Q(M)=TEMP
 20    CONTINUE
       RETURN
       END
       SUBROUTINE MDSTI (Q,F,X,IER)
C
C      -------------------------------------------------------------------
C
C      FUNCTION                   - INVERSE STUDENT*S T DISTRIBUTION
C      USAGE                      - CALL MDSTI (Q,F,X,IER)
C      PARAMETERS    Q            - INPUT PROBABILITY IN THE EXCLUSIVE RANGE
C                                   (0,1). (THE SUM OF THE AREAS IN BOTH TAILS
C                                   OF THE T DISTRIBUTION.)
C                    F        - DEGREES OF FREEDOM FOR T DISTRIBUTION (REAL
C                                   NUMBER NOT LESS THAN 1). INPUT
C                    X        - VALUE SUCH THAT THE PROBABILITY OF THE
C                                   ABSOLUTE VALUE OF T BEING GREATER THAN X IS
C                                   Q.
C                    IER      - ERROR INDICATOR
C                               TERMINAL ERROR = 128+N
C                                   N = 1 MEANS THAT F(DEGREES OF FREEDOM) IS
C                                   LESS THAN 1
C                                   N = 2 MEANS THAT Q IS OUT OF THE EXCLUSIVE
C                                   RANGE (0,1).
C                                   N = 3 MEANS THAT AN ERROR OCCURRED IN
C                                   SUBROUTINE MDNRIS, THE INVERSE NORMAL PDF
C      PRECISION                  - SINGLE
C      -------------------------------------------------------------------
C
       IER=0
          IF (F.GE.1.) GO TO 10
```

```
C                                            TERMINAL ERROR F .LT. 1
      IER=129
         GO TO 80
   10    IF (Q.LE.0.0.OR.Q.GE.1.0) GO TO 60
C                                            EXACT INTEGRAL FOR 2 DEGREES OF
C                                            FREEDOM
         IF (ABS(F-2.0).GT..000001) GO TO 20
      X=SQRT(2.0/(Q*(2.0-Q))-2.0)
         GO TO 90
   20 HPI=1.5707963267949
C                                            EXACT INTEGRAL FOR 1 DEGREE OF
C                                            FREEDOM
         IF (ABS(F-1.0).GT..000001) GO TO 30
      A=Q*HPI
      X=1./TAN(A)
         GO TO 90
C                                            EXPANSION FOR N GREATER THAN 2
   30 A=1.0/(F-0.5)
      B=48.0/(A*A)
      C=((20700.*A/B-98.)*A-16.)*A+96.36
      D=((94.5/(B+C)-3.0)/B+1.0)*SQRT(A*HPI)*F
      XX=D*Q
      Y=XX**(2.0/F)
         IF (Y.GT.A+.05) GO TO 50
      Y=((1.0/(((F+6.0)/(F*Y)-0.089*D-0.822)*(F+2.0)*3.0)+0.5/(F+4.0))*
     1       Y-1.0)*(F+1.0)/(F+2.0)+1.0/Y
   40 X=SQRT(F*Y)
         GO TO 90
C                                            ASYMPTOTIC INVERSE EXPANSION ABOUT
C                                            NORMAL
   50 X=.5*Q
      CALL MDNRIS (X,XX,IER)
         IF (IER.NE.0) GO TO 70
      Y=XX*XX
      IF (F.LT.5.) C=C+0.3*(F-4.5)*(XX+0.6)
      C=(((.05*D*XX-5.0)*XX-7.0)*XX-2.0)*XX+B+C
      Y=(((((0.4*Y+6.3)*Y+36.)*Y+94.5)/C-Y-3.0)/B+1.0)*XX
      Y=A*Y*Y
      D=Y
      Y=.05*Y*Y+Y
      IF (Y.GT..002) Y=EXP(D)-1.0
         GO TO 40
C                                            Q IS OUT OF RANGE
   60 IER=130
         GO TO 80
C                                            ERROR OCCURRED IN SUBROUTINE MDNRIS
   70 IER=131
   80 CONTINUE
      CALL UERTST (IER,6HMDSTI )
   90 RETURN
```

```
      END
      SUBROUTINE MERFI (P,Y,IER)
C
C     -----------------------------------------------------------------
C
C     FUNCTION       MERFI  - COMPUTE THE INVERSE ERROR FUNCTION,
C                MERFCI - COMPUTE THE INVERSE COMPLEMENTED
C                            ERROR FUNCTION,
C                MDNRIS - COMPUTE THE INVERSE GAUSSIAN INTEGERAL,
C
C     USAGE                  - CALL MERFI(P,X,IER)
C                        - CALL MERFCI(P,X,IER)
C                        - CALL MDNRIS(P,X,IER)
C     PARAMETERS     P       - INPUT VALUE
C                              FOR MERFI P MUST BE BETWEEN -1,0 AND 1,0
C                              FOR MERFCI P MUST BE BETWEEN 0,0 AND 2,0
C                              FOR MDNRIS P MUST BE BETWEEN 0,0 AND 1,0
C                X       - OUTPUT RESULT OF COMPUTATION,
C                IER     - ERROR INDICATOR
C                          TERMINAL ERROR = 128+N
C                            N=1 INDICATES P LIES OUTSIDE THE LEGAL
C                            DOMAIN, PLUS OR MINUS INFINITY IS GIVEN AS
C                            THE RESULT (SIGN IS THE SIGN OF THE FUNCTION
C                            VALUE OF THE NEAREST LEGAL ARGUMENT),
C     PRECISION              - SINGLE
C     LANGUAGE               - FORTRAN
C     -----------------------------------------------------------------
C
      DIMENSION A(65),C(17),D(25),E(23)
      EQUIVALENCE (A(24),C(1)), (A(41),D(1)), (A(1),E(1))
      DATA E/,992885376618940,,120467516143104,,016078199342100,
     1      ,002686704437162,,000499634730235,,000098898218599,
     2      ,000020391812764,,000004327271618,,000000938081413,
     3      ,000000206734721,,000000046159699,,000000010416680,
     4      ,000000002371501,,000000000543928,,000000000125549,
     5      ,000000000029138,,000000000006795,,000000000001591,
     6      ,000000000000374,,000000000000088,,000000000000021,
     7      ,000000000000005,,000000000000001/
      DATA C/,912158803417554,-,016266281867664,,000433556472949,
     1      ,000214438570074,,000002625751076,-,000003021091050,-
     2      ,000000012406062,,000000062406609,-,000000000540125,-
     3      ,000000001423208,,000000000034384,,000000000033585,-
     4      ,000000000001458,-,000000000000810,,000000000000053,
     5      ,000000000000020,-,000000000000002/
      DATA D/,956679709020493,-,023107004309065,-,004374236097508,-
     1      ,000576503422651,-,000010961022307,,000025108547025,
     2      ,000010562336068,,000002754412330,,000000432484498,-
     3      ,000000020530337,-,000000043891537,-,000000017684010,-
     4      ,000000003991289,-,000000000186932,,000000000272923,
     5      ,000000000132817,,000000000031834,,000000000001670,-
```

```
      6       .000000000002036,-.000000000000965,-.000000000000220,-
      7       .000000000000010,.000000000000013,.000000000000006,
      8       .000000000000001/
       DATA H1,H2,H3,H4,R2/-1.5488130423733,2.5654901231478,-
      1       .55945763132983,2.2879157162634,-1.4142135623731/
       DATA XINF/377677777777777777778/
C      INVERSE ERROR FUNCTION ENTRY
       INT=1
       X=P
          GO TO 10
C      INVERSE COMPLEMENTED ERROR FUNCTION ENTRY
       ENTRY MERFCI
       INT=2
       X=1.-P
          GO TO 10
C      INVERSE GAUSSIAN INTEGRAL ENTRY
       ENTRY MDNRIS
       INT=3
       X=1.-P-P
 10    IER=0
       SIGMA=SIGN(1.,X)
          IF (.NOT.(X.GT.-1..AND.X.LT.1.)) GO TO 90
       Z=ABS(X)
          IF (Z.GT..8) GO TO 50
       W=Z*Z/.32-1.
       N=22
       IPP=1
       L=1
 20    LB2=1
       X3=1.
       X4=W
       X6=A(IPP)
 30    X6=X6+A(IPP+LB2)*X4
       X5=X4*W*2.-X3
       X3=X4
       X4=X5
       LB2=LB2+1
          IF (LB2.LE.N) GO TO 30
          GO TO (40,70), L
 40    Y=Z*X6*SIGMA
          IF (INT.NE.3) GO TO 100
          GO TO 80
 50    B=SQRT(-ALOG(1.-Z*Z))
          IF (X.GT..9975) GO TO 60
       W=H1*B+H2
       IPP=24
       L=2
       N=16
          GO TO 20
 60    W=H3*B+H4
```

```
      IPP=41
      N=24
      L=2
         GO TO 20
   70 Y=B*X6*SIGMA
         IF (INT.NE.3) GO TO 100
   80 Y=R2*Y
         GO TO 100
   90 Y=SIGMA*XINF
      IER=129
      CALL UERTST (IER,6HMERFI )
  100 RETURN
      END
      SUBROUTINE UERTST (IER,NAME)
C
C     ------------------------------------------------------------------
C
C     FUNCTION             - ERROR MESSAGE GENERATION
C     USAGE                - CALL UERTST(IER,NAME)
C     PARAMETERS   IER     - ERROR PARAMETER, TYPE + N  WHERE
C                            TYPE= 128 IMPLIES TERMINAL ERROR
C                                   64 IMPLIES WARNING WITH FIX
C                                   32 IMPLIES WARNING
C                            N    = ERROR CODE RELEVANT TO CALLING ROUTINE
C                  NAME   - INPUT SCALAR CONTAINING THE NAME OF THE
C                            CALLING ROUTINE AS A 6-CHARACTER LITERAL
C                            STRING.
C     ------------------------------------------------------------------
C
      DIMENSION ITYP(2,4),IBIT(4)
      INTEGER WARN,WARF,TERM,PRINTR
      EQUIVALENCE (IBIT(1),WARN), (IBIT(2),WARF), (IBIT(3),TERM)
      DATA ITYP/10HWARNING   ,10H          ,10HWARNING(WI,10HTH FIX)   ,
     1      10HTERMINAL  ,10H          ,10HNON-DEFINE,10HD          /
     2      ,IBIT/32,64,128,0/
      DATA PRINTR/6LOUTPUT/
      IER2=IER
         IF (IER2.GE.WARN) GO TO 10
C                                  NON-DEFINED
      IER1=4
         GO TO 40
   10    IF (IER2.LT.TERM) GO TO 20
C                                  TERMINAL
      IER1=3
         GO TO 40
   20    IF (IER2.LT.WARF) GO TO 30
C                                  WARNING(WITH FIX)
      IER1=2
         GO TO 40
C                                  WARNING
```

```
 30    IER1=1
C                                         EXTRACT *N*
 40    IER2=IER2-IBIT(IER1)
C                                         PRINT ERROR MESSAGE
       WRITE (PRINTR,50) (ITYP(I,IER1),I=1,2),NAME,IER2,IER
       RETURN
 50    FORMAT (26H *** I M S L(UERTST) ***  ,2A10,4X,A6,4X,I2,
     1     8H (IER = ,I3,1H))
       END
```

FLOOD FLOW FREQUENCY COMPUTATIONS

CAPE FEAR RIVER AT LILLINGTON, N. C.

2102500

TOTAL NO. OF VALUES READ = 48
NO. OF BLANK VALUES = 1
NO. OF VALUES USED FOR ANALYSIS = 47

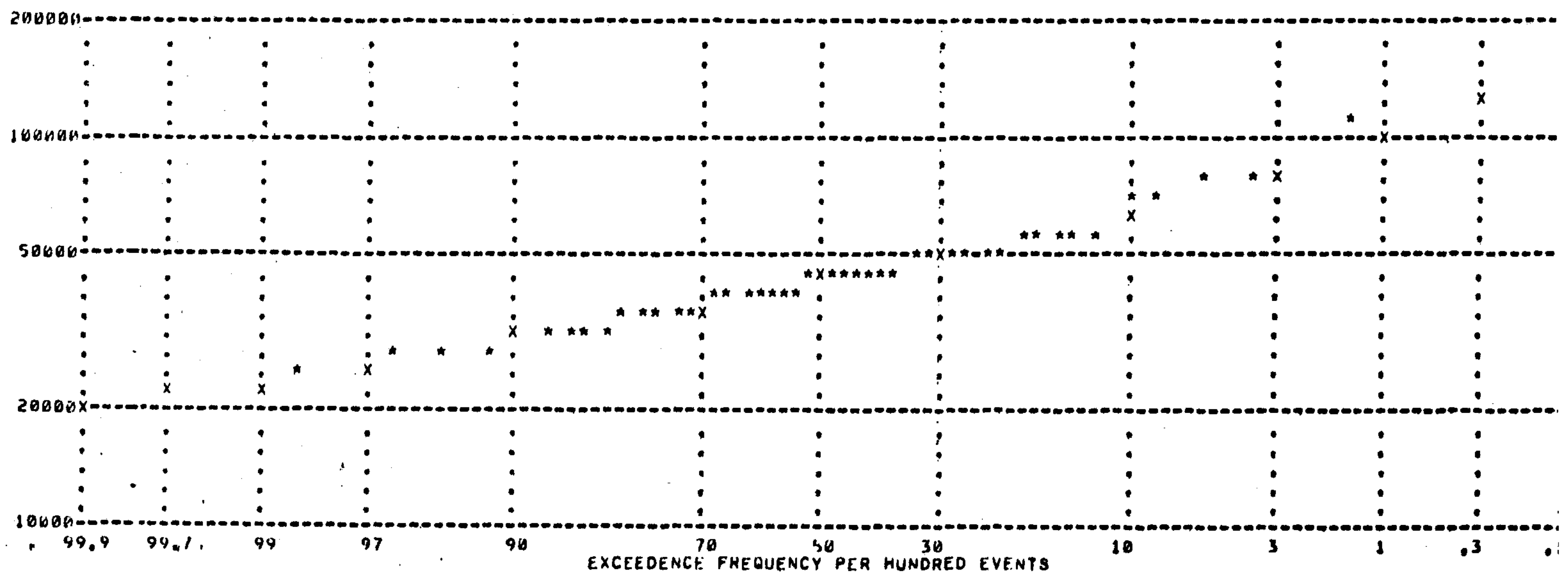
YEAR OF PEAK FLOW	OBSERVED PEAK FLOW	ORDERED PEAK FLOW	RANK	PLOTTING POSITION M/N+1	M-0.3/N+0.4
1924	52400	107000	1	.02083	.01477
1925	46200	84000	2	.04167	.03586
1926	27300	77100	3	.06250	.05696
1927	33200	73200	4	.08333	.07806
1928	84000	67700	5	.10417	.09916
1929	67700	57500	6	.12500	.12025
1930	107000	56500	7	.14583	.14135
1931	29200	56500	8	.16667	.16245
1932	50900	54400	9	.18750	.18354
1933	29200	53400	10	.20833	.20464
1934	40000	52400	11	.22917	.22574
1935	41000	50900	12	.25000	.24684
1936	73200	49900	13	.27083	.26793
1937	34800	49900	14	.29167	.28903
1938	47000	49400	15	.31250	.31013
1939	47500	47500	16	.33333	.33122
1940	32000	47500	17	.35417	.35232
1941	31600	47000	18	.37500	.37342
1942	30800	46500	19	.39583	.39451
1943	40900	46500	20	.41667	.41561
1944	42300	46200	21	.43750	.43671
1945	-0	44100	22	.45833	.45781
1946	54400	42300	23	.47917	.47890
1947	39600	42300	24	.50000	.50000
1948	49900	42300	25	.52083	.52110
1949	53400	41800	26	.54167	.54219
1950	36500	41300	27	.56250	.56329
1951	34800	41000	28	.58333	.58439
1952	77100	40900	29	.60417	.60549
1953	44100	40000	30	.62500	.62658
1954	56500	40000	31	.64583	.64768
1955	49900	39600	32	.66667	.66878
1956	46500	37200	33	.68750	.68987
1957	41800	36500	34	.70833	.71097
1958	46500	36500	35	.72917	.73207
1959	40000	36500	36	.75000	.75316
1960	47500	34800	37	.77083	.77426
1961	36500	34800	38	.79167	.79536
1962	56500	33200	39	.81250	.81646
1963	42300	32000	40	.83333	.83755
1964	42300	31600	41	.85417	.85865
1965	57500	31300	42	.87500	.87975
1966	49400	30800	43	.89583	.90084
1967	26400	29200	44	.91667	.92194
1968	36500	29200	45	.93750	.94304
1969	31300	27300	46	.95833	.96414
1970	37200	26400	47	.97917	.98523

LOG PEARSON III

```
ARITHMETIC MEAN        = 46040.42553
MEAN OF LOGS.          =     4.64319
STANDARD DEVIATION     =      .12839
COEFFICIENT OF SKEW =         .73878     CHANGED TO        .40000
```

FLOW	EXPECTED PROBABILITY OF EXCEEDENCE
143369	.001
120813	.003
99520	.010
82491	.030
65617	.100
56702	.300
43119	.500
37062	.700
30321	.900
26160	.970
23579	.990
21464	.997
19943	.999

DISCHARGE IN CUBIC FEET PER SECOND



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16. Abstract Through the use of computer analysis, techniques were developed that will yield greater reliability and consistency than has heretofore been available in flood flow frequency determinations from data on natural streamflows available at the location for which each frequency estimate is to be computed.

300 U.S. Geological Survey streamflow stations with records 40 years or longer and unregulated flow were selected and analyzed using Log Pearson III, Log Normal, Gumbel, Log Gumbel, Two-Parameter Gamma, Three-Parameter Gamma, Log Pearson III with regional skew and Best Linear Invariant Gumbel distribution techniques. Zero-flow and outlier techniques were also considered. The results indicate the Log Pearson III method with regional skew coefficients will produce unbiased estimates when the adjustment to expected probability is employed and will reduce uncertainty as much or more than the other methods tested. (Smith-Texas)

17a. Descriptors *Flood frequency, *Flood forecasting, *Statistical methods, *Frequency analysis, *Statistical models, *Stochastic processes, *Regression analysis, Stochastic hydrology, Flood flow, Maximum probable flood, Historic floods, Streamflow forecasting, Streamflow, Runoff, Frequency distribution, Runoff forecasting

17b. Identifiers Log Pearson III with regional skew, Log Pearson III, Log Normal, Gumbel, Log Gumbel, 2-Parameter Gamma, 3-Parameter Gamma, Best Linear Invariant Estimates, Computer Analysis, Outlier techniques, Zero Flows, Split-Record testing, Partial duration

17c. COWRR Field & Group 02 E, 10

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