UM - 22

GRAPHICAL REPRESENTATION OF INFORMATION RELATED WITH FLOODS

SATISH CHANDRA

DIRECTOR

STUDY GROUP

B.P. PARIDA

S.K. JAIN

D. CHALISGAONKAR

NATIONAL INSTITUTE OF HYDROLOGY

JAL VIGYAN BHAWAN

ROORKEE-247667 (U.P.)

INDIA

1986-87

CONTENTS

		PAGE
	List of Figures	iii
	List of Tables	iv
	Abstract	v
1.0	INTRODUCTION	1
2.0	DESCRIPTION OF EQUIPMENT	2
3.0	RUNNING GRIF ON VAX-11/780	3
4.0	PROCEDURES USED IN GRIF	5
	4.1 Summary of Statistics	5
	4.2 Outlier/Inlier Analysis	6
	4.3 Check for Persistence	8
	4.4 Plotting Position	8
5.0	PROBABILITY MODELS	10
	5.1 Two-parameter Normal Distribution	10
	5.2 Two-parameter Log-normal Distribution	11
	5.3 Two-parameter Gumbel (EV-1) Distribution	11
	5.4 Log-Pearson Type III Distribution	13
	5.5 Method of Power Transformation	14
6.0	DETAILED EXPLANATION OF COMPUTER PROGRAM	15
	6.1 Main Program	15
	6.2 Sub-programs	15
	6.2.1 Subroutine ORDER	15
	6.2.2 Subroutine MOMENT	15
	6.2.3 Subroutine LGMOM	16
	6.2.4 Subroutine NORM	16

6.2.5 Subroutine LGNB 16
6.2.6 Subroutine GUMB 17
6.2.7 Subroutine GUMLH 17
6.2.8 Subroutine LGPN 18
6.2.9 Subroutine BOX 18
6.2.1C Subroutine RANDT 18
6.2.11 Subroutine NENOPROB 19
6.2.12 Subroutine PRINT 19
6.2.13 Subroutine POWER 19
6.2.14 Subroutine PLOT 19
6.2.15 Subroutine PLOT1 20
6.2.16 Subroutine PLOT2 20
6.2.17 Subroutine OUTLIER 20

REFERENCES 21

APPENDICES

(A) Sample Input File (INPUT.DAT) A1 - A2
(B) Listing of Program B1 - B30
(C) Sample Output File (OUTPUT.DAT) C1 - C5
(D) Data File for Outlier/Inlier Analysis (OUTL.DAT) D1

LIST OF FIGURES

Figure No.	Title	Page
1	Flow Chart Showing Operation of GRIF	4

LIST OF TABLES

Table No.	Title	Page
1	Departures at Different Probability Levels for Outliers/Inliers	7

ABSTRACT

For a given catchment, information related with floods are many. Informations such as statistical summary, check for validity of randomness, presence of outliers/inliers, satisfactory design flood estimates, standard error of estimates and their confidence bands are of importance to any designer. Some of the information can be tabulated and some informations like the relationship between quantile estimate and return periods (or reduced variates) for a chosen probability model can be well represented graphically.

Generalised software package 'GRIF' (Graphical Representation of Information related with Floods) has therefore specifically been developed to assist the designer in obtaining necessary desired information from the observed annual peak floods. This package written in FORTRAN has the following features.

i) It runs in a user-freiendly mode and gives adequate flexibility to the designer for exercising his choice/options.

ii) It brings out statistical summary of data either in natural or log domain or even both.

iii) The designer has the option to go through the analysis for outlier/inliers, view the modifications and either accept or reject the analysis before going over to next module.

iv) Analysis for checking the persistence structure of data is available to the user.

v) It allows the designer to choose from amongst potential distribution with different parameter estimation techniques.

vi) Quantile estimates together with their standard errors at specified return periods with facility to compute quantiles to additionally specified return periods are available to the user.

vii) Options are also available to the user to see graphical plot of quantiles on the terminal.

Operational logic represented through a flow chart detailed description of various subroutines and procedures used alongwith a sample input and output are given in the user's manual

1.0 INTRODUCTION

Graphical Representation of Information related with Floods (GRIF) is a problem oriented generalised computer software for summarising the flood information through various statistics as well as through graphical representation such as bar charts, histograms and probability plots of quantiles. It consists of a main program and seventeen subroutines which are written in FORTRAN except for the Graphics subroutines.

GRIF is designed to allow the user to exercise several options while trying to derive relevant informations numerically as well as graphically from the observed annual peak floods and is flexible. Procedures/techniques adopted presently, exercising choice of probability models can be modified or deleted, and updated by addition of new subroutine(s). GRIF is practical and generally applicable. The results which are produced in a tabular form and graphically, can be interpreted easily by the user.

2.0 DESCRIPTION OF EQUIPMENT

This programame has been developed on VAX-11/780 system and written in FORTRAN-77 language. The grapahical part has been written using PLOT-10 IGL routines. The programame is very general and can be implemented on any other machine with slight modifications. A colour graphic terminal (TEK 4027) has been used to display graphs, bar chart and histogram. In case the IGL graphical routines are not available at the users' installation, the subroutines PLOT, PLOT1 and PLOT2 need be modified. If no graphical routines are available then the subroutines PLOT, PLOT1, and PLOT2 must be removed and all calls to it must be suppressed.

3.0 RUNNING GRIF ON VAX-11/780

After successful compilation and linking, the programme can be invoked by the DCL command 'RUN GRIF'. The data can be supplied from an interactive terminal or can be read from a disk file. The programme is interactive in nature and its flow depends upon the response of the user. The results are displayed on the user terminal and also written on a disk file (OUTPUT.DAT) for later reference and/or printing. The flow cart for the program is given in Figure 1.

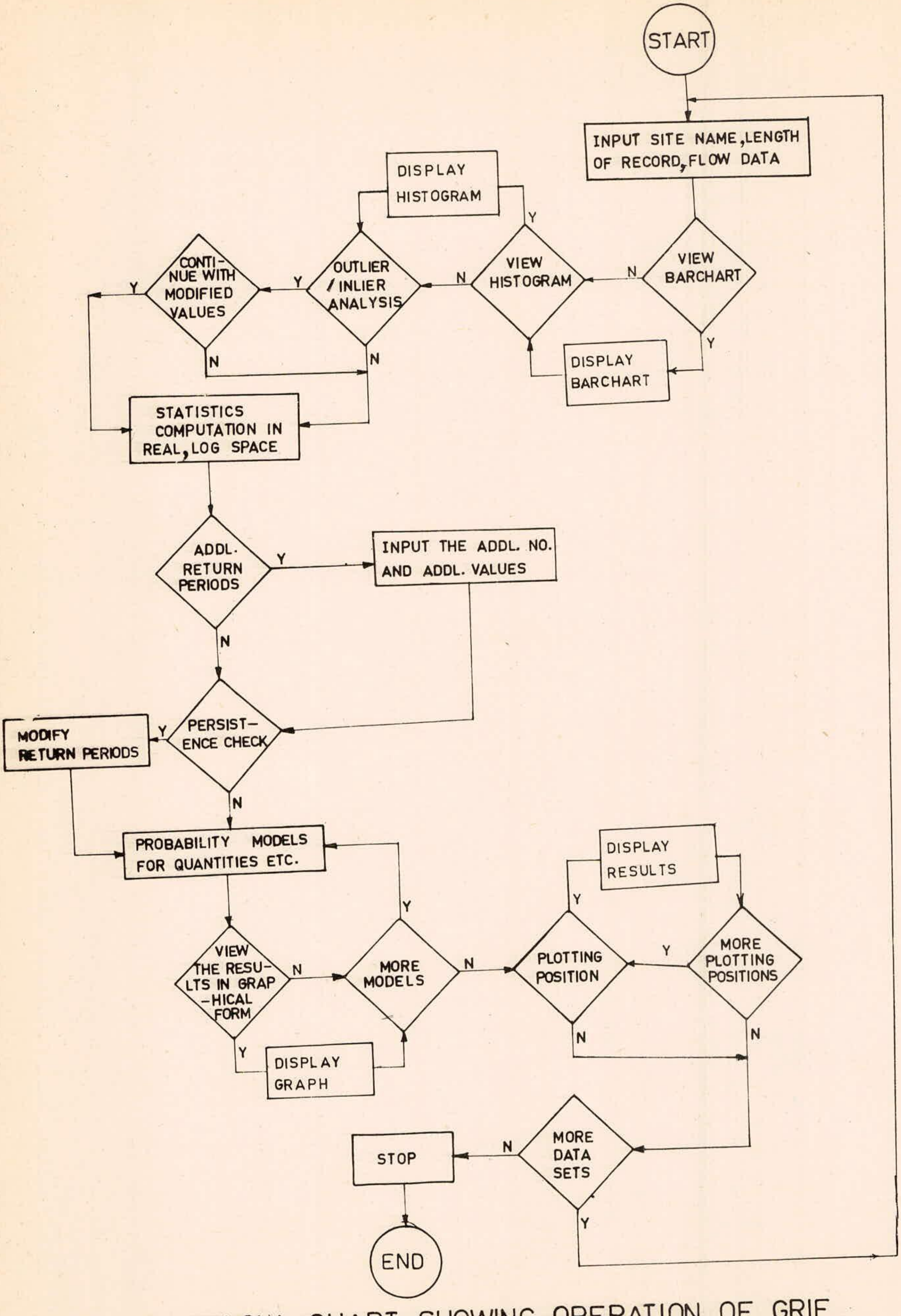

FIG. 1 FLOW CHART SHOWING OPERATION OF GRIF

4.0 PROCEDURE USED IN GRIF

4.1 Summary of Statistics

Following statistical parameters are calculated from the sample observations.

a) Sample Mean is regarded as an estimate of the variable which would be the most likely observed value next in the array of observations and is computed from $\bar{Q} = (\Sigma Q_i)/N$ ... (1)

b) Sample St. Deviation is the measure of dispersion of the various values of the variable Q_i, about the mean value $\bar{Q}$ and is obtained from

$$s_Q = (\Sigma[Q_i - \bar{Q})^2] / (N-1))^{0.5} \quad \text{... (2)}$$

c) Skewness is the measure of assymetry and is obtained from

$$C_s = N[\Sigma(Q_i - \bar{Q})^3 / s_Q^3] / (N-1)(N-2) \quad \text{... (3)}$$

d) Kurtosis is the measure of peakedness and is obtained

$$\text{from } C_K = N^2 \; \Sigma(Q_i - \bar{Q})^4 / s_Q^4 \, . \, (N-1)\,(N-2)\,(N-3) \quad \text{... (4)}$$

e) Coefficient of variation is the measure of dispersion of the variable about the mean expressed in dimensionless units. It is obtained from

$$C_v = (s_Q / \bar{Q}) \quad \text{... (5)}$$

f) Standard error of the mean indicating the reliability of the mean value, is obtained from

$$S_e(\bar{Q}) = s_Q / (N)^{0.5} \quad \text{... (6)}$$

g) Standard error of the standard deviation is obtained from

$$S_e(s_Q) = [(0.75 C_s^2 + 1)/2N]^{\frac{1}{2}} . \; s_Q \quad \text{... (7)}$$

Choice can also be expressed by the designer for computation of these statistics in the log-domain.

4.2 Outlier/Inlier Analysis

Statistical tests performed in the analysis for detection and modification of outliers/inliers is based on the study of Singh and Nakashima (1984) and are carried out in following steps.

a) Observed series (Q_i) is transformed to normality (z_i) with $z_i = (Q_i^{\lambda} - 1)/\lambda$ where, λ is the transformation parameter.

b) Transformed series (z_i) is standardised by $Z_i = (Z - \bar{z})/s_z$ where $\bar{z}$ and s_z are the mean and stad. daviation of transformed series.

c) Sample departure (D_i) for five lowermost and five upermost suspected values are computed by subtracting corresponding sample standard deviates (Z_i) from the standard normal deviates (Y_i) corresponding to i^{th} plotting $D_i = Y_i - Z_i$

d) The departures are then viewed through the first window representing the probability levels of 0.01 and 0.99 and 0.99 and are compared with the departures listed against these level in Table 1 for possible detection of any outlier and inlier from amongst the suspects.

e) The departure values for the detected outlier/inlier (if any) are then modified hence modifying the correspodig sample standard deviates. Destandardization and detransformation of the Z_i series gives a new Q_i series.

f) Steps from (a) to (e) are then repeated for each window i.e. 2

TABLE - 1

Departures at Different Probability Levels for Outliers/Inliers

P	Low 1 15-100	Low 2 20-100	Low 3 25-100	Low 4 30-100	Low 5 40-100	High 5 40-100	High 4 30-100	High 3 25-100	High 2 20-100	High 1 15-100
0.01	-0.6893	-0.4950	-0.4122	-0.3633	-0.3270	-0.3769	-0.4289	-0.5109	-0.5541	-1.0438
0.05	-0.5325	-0.3694	-0.3033	-0.2641	-0.2373	-0.2563	-0.2900	-0.3414	-0.4328	-0.6835
0.10	-0.4410	-0.2991	-0.2425	-0.2107	-0.1880	-0.1951	-0.2205	-0.2580	-0.3225	-0.5003
0.20	-0.3184	-0.2091	-0.1670	-0.1432	-0.1270	-0.1236	-0.1383	-0.1614	-0. 1966	-0.2951
0.30	-0.2210	-0.1408	-0.1103	-0.0933	-0.0819	-0.0737	-0.0818	-0.0942	-0.1120	-0.1586
0.40	-0.1319	-0.795	-0.0598	-0.0501	-0.0432	-0.0322	-0.0348	-0.0387	-0.0425	-0.0511
0.60	-0.0515	0.0428	0.0375	0.0339	0.0318	0.0432	0.0497	0.0599	0.0790	0.1321
0.70	0.1606	0.1123	0.0922	0.0808	0.0732	0.0817	0.0934	0.1096	0.1400	0.2212
0.80	0.2969	0.1974	0.1586	0.1369	0.1228	0.1265	0.1426	0.1663	0.2089	0.3166
0.90	0.5030	0.3213	0.2541	0.2172	0.1933	0.1865	0.2088	0.2411	0.2989	0.4376
0.95	0.6809	0.4309	0.4366	0.2853	0.2534	0.2348	0.2627	0.3000	0.3686	0.5285
0.99	1.0292	0.6433	0.4979	0.4182	0.3682	0.3233	0.3583	0.4073	0.4882	0.6787

through 6 for levels of probability pairs of 0.05, 0.95, 0.10, 0.90, 0.20, 0.80, 0.30, 0.70 and 0.40, 0.60.

4.3 Check for Persistance

Possibility of any significant serial dependance in the normalized data (z_i) is checked through the computation of lag-one serial correlation co-efficient (ρ_1) from

$$\rho_1 = [\frac{1}{N-1} \sum_{i}^{N-1} (z_i - z)(z_{i+1} - \bar{z})] / [\frac{1}{N} \sum_{J}^{N} (z_i - z^{-2})]^{\frac{1}{2}} \quad \ldots (8)$$

For $\rho_1 > 0.2$ and lying within the 0.5% significance level i.e. inside $-\frac{1}{N-1} \pm 1.96 [\frac{(N-2)^2}{(N-1)^3}]^{\frac{1}{2}}$ necessary corrections in the standard normal variates hence in the return periods are carried out using the methodology suggested by Beran (1979) as given below -

$$y' = (1 - \rho_a)^{\frac{1}{2}} y \quad \ldots (9)$$

where y' = standard normal variate for the dependent series

y = standard normal variate for the independent series

ρ_a = average of the off diagonal correlation coefficient in correlation structure

$$[\rho_a = \frac{2\rho_1}{N(N-1)(1-\rho_1)} (N - 1 - \frac{\rho_1}{1-\rho_1}(1 - \rho_1^{N-1}))] \quad \ldots (10)$$

4.4 Plotting Positions

Formulae that are commonly used (i.e. Blom's, Weibull's, Gringorlen's and Cunnane's) besides an open option for the designer are available. The formulae are differentiated by the co-efficient 'C' in the generalised formula $G(Y_i)$ = probability of non-exceedence = $(i-C)/(N+1-2C)$ as,

Blom	C = 0.375
Weibull	C = 0.0
Gringorten	C = 0.44
Cunnane	C = 0.4

Selection of plotting position formulae is exercised by the designer through the entry of serial number corresponding to the designed formula when enquiry appears on the terminal.

5.0 PROBABILITY MODELS

Commonly used probability models alongwith common methods of parameter estimation are available to the user under six categories. Upon exercising of proper choice, the user obtains the quantile estimates for the predefined as well as for specified return periods alongwith the standard errors of estimates and the confidence bands for all the models. Computational procedure for each model is given below.

5.1 Two Parameter Normal Distribution

Method of Moments (MOM)

The choice is activated by calling SUBROUTINE NORM. Location and scale parameters $\bar{Q}$ and s_Q are computed from

$$\bar{Q} = (\Sigma Q_i)/N \qquad \ldots (11)$$

$$s_Q = [\Sigma (Q_i - \bar{Q})^2/(N-1)]^{1/2} \qquad \ldots (12)$$

The quantile estimate (Q_T) for any return period (T) is calculated from $Q_T = \bar{Q} + s_Q . K_T$ where K_T is the Frequency Factor or Standard normal variate for a given return period T.

Standard error (S_T) of the quantile estimate for a given return period. T is computed from $S_T = \delta \left(\frac{s_Q}{N}\right)^{0.5}$, where $\delta = (1.0+Q_T^2/2.0)^{1/2}$

Confidence bounds of the estmate Q_T for a given significance level 2α% is given by

$$Q_{TL} = Q_T - t_{(1-\alpha),\,(N-2)} . S_T \qquad \ldots (13)$$

$$Q_{TU} = Q_T + t_{(1-\alpha),\,(N-1)} . S_T \qquad \ldots (14)$$

are also computed, where, $t_{(1-\alpha)\,(N-2)}$ is the t statistics at $(1-\alpha)$ confidence level for (N-2) degrees of freedom, Q_{TL} and Q_{TU} are lower and upper bounds.

5.2 Two Parameter Log-Normal Distribution

Method of Moments

The choice is activated through the call of SUBROUTINE LGNB. Procedures are however similar to as that of (a) above except that Q_i are taken in the log-transformed domain and the standard error S_T computed is improved through the following relationship to obtain average standard error.

$$S_T = [Q_T(e^{S_T}-1) - Q_T(e^{-S_T}-1)]/2 \qquad \dots (15)$$

The estimated Q_T, Q_{TL} and Q_{TU} are detransformed through antilogs for arriving at values in the real domain.

5.3 Two Parameter Gumbel (EV-1) Distribution

(i) Method of Moments

The choice is activated upon call of SUBROUTINE GUMB .

The quantile estimate (Q_T) for any return period (T) is calculated by

$$Q_T = \bar{Q} + s_Q K_T \qquad \dots (16)$$

where

$$K_T = [0.5772+\ln(-\ln(1-\frac{1}{T}))]/1.2825$$

= frequency factor corresponding to any return period T.

Standard error (S_T) of the estimated Q_T is given by

$$S_T = \frac{s_Q}{\sqrt{N}} [1 + 1.1396K_T + 1.10 K_T^2]^{\frac{1}{2}} \qquad \dots (17)$$

and it's confidence bands are calculated from

$$Q_{TL} = Q_T - t_{(1-\alpha),(N-2)} \cdot S_T \qquad \dots (18)$$

$$Q_{TU} = Q_T + t_{(1-\alpha),(N-2)} \cdot S_T \qquad \dots (19)$$

ii) Method of Maximum Likelihood

The choice is activated by calling the SUBROUTINE GUMLH. Estimation of scale and location prameters α and β , can be achieved through solution of the folowing equations:

$$\beta = \frac{1}{\alpha} \ln [N / \sum^{N} e^{-\alpha Q_i}] \qquad \ldots(20)$$

$$\sum^{N} Q_i e^{-\alpha Q_i} - (\bar{Q} - \frac{1}{\alpha}) \sum^{N} e^{-\alpha Q_i} = 0 \qquad \ldots(21)$$

Equation (21) is solved using Taylor's series expansion as given by Panchang (1967), as it cannot be solved analytically.

If left hand side of equation (21) is represented as a function of i.e. F (α) then, the new value of α can be calculated from

$$F(\alpha_{j+1}) = F(\alpha_j) + \delta h_j . F'(\alpha_j) \qquad \ldots (22)$$

Where $F'(\alpha_j)$ = first order derivative of $F(\alpha)$ with respect to α

i.e. $$F'(\alpha) = - \sum^{N} Q_i^2 e^{-Q_i} + (\bar{Q} - 1/\alpha) \sum^{N} Q_i e^{-\alpha Q_i} - \frac{1}{\alpha^2} \sum^{N} e^{-\alpha Q_i} \qquad \ldots (23)$$

and $$\delta h_j = -F(\alpha_j)/F'(\alpha_j) \qquad \ldots (24)$$

and $$\alpha_{j+1} = \alpha_j + \delta h_j \qquad \ldots (25)$$

Quantile estimate (Q_T) for a desired return period T is computed from

$$Q_T = \beta - [\ln - (\ln(1 - \frac{1}{T}))]/\alpha \qquad \ldots (26)$$

Standard error (S_T) of Q_T is computed from

$$S_T = \frac{1}{\alpha} [(1.1086 + 0.5140 Y_T + 0.6079 Y_T^2)/N]^{1/2} \qquad \ldots (27)$$

and the confidence bands of Q_T for 2α% of significance level with (N-2) degrees of freedom are given by

$$Q_{TL} = Q_T - t_{(1-\alpha)\ (N-2)}\ S_T \qquad \ldots (28)$$

$$Q_{TU} = Q_T + t_{(1-\alpha)\ (N-2)}\ S_T \qquad \ldots (29)$$

5.4 Log - Pearson Type III Distribution

Method of Moments

The choice is exercised through call of SUBROUTINE LGPN

The location and scale parameters $\bar{Q}'$ and s_Q' are computed from log-transformed Q_i series.

Frequency factor K_T which is dependent on the shape parameter is computed using Wilson-Hilferty Transformation as

$$K_T = \frac{2}{C_s}\left[1 + \frac{Y_T \cdot C_s}{6} - \frac{C_s^2}{36}\right]^3 - \frac{2}{C_s} \qquad \ldots (30)$$

where,

C_s = co-efficient of Skewness of Q_i' series, and

Y_T = standard normal deviate corresponding return period T.

The quantile estimate (Q_T') for any return period T is computed from $Q_T' = \bar{Q}' + s_Q' . K_T$ and its value Q_T in natural domain

$$Q_T = \exp\ (Q_T')$$

Standard error estimates of Q_T is computed from

$$S_T' = \frac{s_Q}{\sqrt{N}}\ \left[\ 1 + K_T . C_s + \frac{K_T^2}{2}\left(\frac{3C_s^2}{4} + 1\right) + 3K_T . \nu_T \right.$$

$$\left. \left(C_s + \frac{C_s^3}{4}\right) + 3\ \nu_T^2\ \left(2 + 3C_s^2 + \frac{5C_s^4}{8}\right)\ \right]^{\frac{1}{2}} \qquad \ldots (31)$$

where

$$\nu_T = \frac{Y_T - 1}{6} + \frac{4(Y_T^3 - 6Y_T^4)}{6^3}\ C_s - \frac{3(Y_T^2 - 1)}{6^3}\ C_s^2 + \frac{4Y_T}{6^4}\ C_s^3$$

$$- \frac{10}{6^6}\ C_s^4 \qquad \ldots (32)$$

Y_T = standard normal deviate corresponding to return period of T yrs.

Average standard error S_T in linear units

$$= \frac{Q_T(e^{S'_T} - e^{-S'_T})}{2} \qquad \ldots (33)$$

Confidence bounds at 2α% significance level are calculated from

$$Q_{TU} = Q_T + t_{(1-\alpha)\,(N-3)}\, S_T \qquad \ldots (34)$$

$$Q_{TL} = Q_T - t_{(1-\alpha)(N-3)}\, S_T \qquad \ldots (35)$$

5.5 Method of Power Transformation

The choice is exercised by calling SUBROUTINE BOX. Here, transformation of data near to normality is done using the techniques suggested by Box and Cox (1964) such that the transformed series Z_i from the original Q_i series is given by,

$$Q_i = \frac{Q_i^{\lambda} - 1}{\lambda} \qquad \text{for } \lambda \neq 0 \qquad \ldots (36)$$

$$Z_i = \log Q_i \qquad \text{for } \lambda = 0 \qquad \ldots (37)$$

where λ = transformation parameter and can be computed using Newton-Raphson's Technique.

Computation of parameters, quantiles, standard error of quantiles and the confidence bounds at desired significance levels are computed through call of SUBROUTINE NORM. The estimates are finally detransformed i.e.

$Q_T = [(Z_T * \lambda) + 1]^{1/\lambda}$, so also the standard error of estimates and the bounds for obtaining the values in the natural domain.

6.0 DETAILED EXPLANATION OF COMPUTER PROGRAM

Much of the program is **explained** by comment cards and definition of variables. However, various subroutines used in the package are explained in details for reference such that suitable modification or improvement if needed can be incorporated in future by the user.

6.1 Main Program

Data inputs are read in the main programme through an interactive querry. The user has also the option of reading the data from a file (INPUT.DAT).

6.2 Sub-Programs

6.2.1 Subroutine ORDER (C)

This subroutine arranges the input data (Q) in decreasing order. It attaches each ordered data (AQ) with order no. (ORD), Return Period (RP), exceedence probability (PG), non-exceedence probability (P), according to assigned plotting position formula constant (C). It also picks maximum (BG) of data series, minimum (SML) of series and calculated range (RNG) of series.

Input - N(Integer); Q,C(Real)

6.2.2 Subroutine MOMENT (N,Q,AVG,STDV,VAR,CVN,SK,CURT)

This subroutine calculates statistical parameters, mean (AVG), Standard deviation (STDV), Variance (VAR), Co-efficient of variation (CVN) Coefficient of skewness (SKEW), Kurtosis (CURT), for the input data (Q) of length (N) used.

Input - N(Integer); Q(Real)

Output - AVG, STDV, VAR, CVN, SK, CURT (Real)

6.2.3 Subroutine LGMOM (AVGL, STDVL, VARL, CVNL, SKEWL, CURTL, IR)

This subroutine transforms the input peak flow (Q) of the corresponding year (IR) into values in natural log (ALQ) domain and then computes the statistical parameters such as, Mean (AVGL), Standard Deviation (STDVL), Variance (VARL), Co-efficient of Variance (CVNL), Co-efficient of Skewness (SKEWL), and Kurtosis (CURTL).

Input - IR, N(Integer); Q(Real)

Output - AVGL, STDVL, VARL, CVNL, CURTL (Real)

6.2.4 Subroutine NORM (NF, NV, RP, P, AVG, STDV, VAR, SN, VN, QN, FN, TITLE1)

This subroutine computes from N number of annual peak flow (Q) values, the mean (AVG), Standard Deviation (STDV), Variance (VAR) and there from estimates Quantiles (QN), Standard Errors (SN), the Confidence Band (QT1, QT2) at 5% significance level for different return periods (RP) or the probabilities of non exceedence (P). The reduced variates (FN) corresponding to P are also computed through sub-routine NENOPROB. The grapahics part is initiated through a simple querry for total no. of return period (NV) including the pre-assigned return period (NF).

Input - N,NV, NF(Integer), A, RP(Real), TITLE1(Alpha-numeric)

Output - P, AVG, STDV, VAR, SN, VN, QN, FN(Real)

6.2.5 Subroutine LGNB (NF, NV, RP, P, AVGL, STDVL, SL, VL, QL, FL, TITLE1)

It's operation is similar to subroutine NORM except that the computation is done in the log domain and detransformed to linearity at the end.

Input - N, NV, NF (Integer); Q, RP (Real); TITLE1 (Alpha-numeric)

Output - P, AVGL, STDVL, SL, VL, QL, FL (Real)

6.2.6 Subroutine GUMB (NF, NV, RP, P, AVG, STDV, VAR, SK, QR, SG, VG, QG, FG, TITLE1)

For parameter estimation and Gumbel Distribution this subroutine uses the method of moments to compute various statistical moments (AVG, STDV, VAR, SK) from the observed peak floods (Q) of N years and using them with frequency factor (FG), estimates the quantiles (QG), and their standard errors (SG) as well as the upper and lower bounds at 5% significance level (QT1, QT2) for all (NV) the return period (RP) including the specified ones (NF) at a given site (TITLE1). The prob. of non-exceedence (P) are computed using the Grin-gorten's plotting position and are used the compute the corresponding reduced variates for viewing the plot in screen.

Input - N, NF, NV (Integer); Q, RP, AVG, STDV, VAR, SK, QR(Real); TITLE1 (Alpha-numeric)

Output - SG, VG, QG, FG (Real)

6.2.7 Subroutine GUMLH (NF, NV, AVG, STDV, RP, P, ALPHA, BETA1, SGH, VGH, QGH, FGH, TITLE1)

This subroutine uses the method of maximum likelihood for estimation of scale (ALPHA) and location parameters (BETA1) using Gumbel distribution which is done through call of subroutine GUMBLS. Using the return periods (RP) it computes reduced variates (FGH) and combined with the estimated parameters it computes quantiles (QGH), their standard errors (SGH) and their lower and upper bounds at 5% significance level (QT1, QT2) for a given site (TITLE1) for all (NV) including the specified (NF) return periods.

Input - N, NV, NF (Integer); Q, RP, AVG, STDV(Real);
TITLE1 (Alpha-numeric)

Output - P, ALPHA, BETA1, FGH, QGH, SGH, VGH (Real)

6.2.8 Subroutine LGPN (NF, NV, RP, P, AVGL, STDVL, VARL, SQ, SPN, VPN, QPN, FPN, TITLE1)

This subroutine uses the Log-Pearson Type - III distribution and the method of moments for parameters estimation in the Log-domain.

It computes the quantiles (QPN) for various (NV) return periods (RP) including the pre-assigned (NF) ones from the frequency factor (FPN) as well as the standard error (SPN) of estimates and the confidence bands (QT1, QT2) at 5% significance level.

Input - N,NV, NF (Integer); RP, AVGL, STDVL, VARL,
SQ (Real); TITLLE1 (Alpha-numeric)

Output - P, SPN, VPN, QPN, FPN (Real)

6.2.9 Subroutine BOX (NF, NV, TQ, RP, P, AV, SD, AL, SKEW, SX, VX, QX, FX, TITLE1)

This subroutine uses the method of Power-Transformation for transforming the annual peak flow data (Q) through subroutine POWER and computes the quantiles (VX) for all (NV) the return period (RP) and their standard error (SX) as well as their 95% confidence bands (QT1, QT2).

Input - N, NV, NF (Integer); RP, AV, SD, SKEW (Real);
TITLE1 (Alpha-numeric)

Output - P, TQ, SX, VX, FX, AL (Real)

6.2.10 Subroutine RANDT (NV, AVG, AL, TQ, AV, SD, SKEW, R1, RP, RPM, TITLE1)

This subroutine tests for persistence in the annual peak flood series and makes necessary changes in the return period (RPM) depending on the significance of serial - correlation co-efficient by calling subroutine PERSM internally.

Input - N, NV (Integer); AVG, Q, RP (Real); TITLE1 (Alpha numeric)

Output - A1, TQ, AV, SD, SKEW, R1, RPM (Real)

6.2.11 Subroutine NENOPROB (GYY , YY)

This subroutine calculates the standard normal variates (YY) for a given probability of non-exceedence (GYY)

Input - GYY (Real)

Output - GYY (Real)

6.2.12 Subroutine PRINT (NF, NV, RI, FR,XQ, SE, QLL, QUL, TITLE1)

Results obtained from the frequency analysis such as : Return period (RI), Frequency Factor (FR), Estimated Quantiles (XQ), Standard Error of Estimates (SE), Confidence Bands (Lower-QLL, Upper-QUL) are printed for total number of return period values (NV) including the number of previously specified return period (NF) for a given site (TITLE1).

Input - NF, NV (Integer); RI, FR, XQ, SE, QLL, QUL (Real); TITLE1 (Alpha-numeric)

6.2.13 Subroutine POWER (N, X, AAL, ZZ, A3, VAR, S3, C3, AK3, AM3)

This subroutine transforms the flood data (X) near to normality to give ZZ values.

Input - N (Integer); X (Real)

Output - AAL, ZZ, A3, VAR, S3, C3, AK3, AM3 (Real)

6.2.14 Subroutine PLOT (NOY, NV, TITLE, TITLE3)

This subroutine, written for TEK-4027 terminal, plots NOY nos. of observed floods (Q_i) as well as computed quantiles against the reduced variates and also writes the method used (TITLE) for quantile estimation on the terminal screen. The minimum and maximum values on X and Y axis are input through X, X1, and Y, Y1 respectively. The labelling on X axis done through TITLE3.

Input - NOY, NV (Integer); X, Y, X1, Y1 (Real);
TITLE, TITLE3 (Alpha-numeric)

6.2.15 Subroutine PLOT1

This subroutiane specific to TEK-4027 terminal selects the ranges by itself and plots the histogram on the screen from N number of flood events (Q)

Input - N (Integer); Q (Real)

6.2.16 Subroutine PLOT2 (IR)

This subroutine specific to TEK 4027 plots the bar diagram of the yearwise (IR) flood events (Q) on the screen

Input - IR (Integer); Q (Real)

6.2.17 Subroutine OUTLIER (N, AT, BT, B, AL)

This subroutine tests for presence of any outlier/inlier in the observed sample (BT) through a statistical test on lowest five and highest five values from out of N values and if successful modifies them to the new values (AT). Pre-requisite to the test is that data be normally, distributed for which power transformation technique with a suitable value of transformation (AL) has been adopted and checks for deviations of data are carried out against simulated deviations (B).

Input - N (Integer); B, BT (Real)

Output - AL, AT (Real)

REFERENCES

1 Beron, M.A. (1979), 'The Effect of Dependence on the Assessment of Hydrologic Drought Severity', Proc. Intl. Symp. on Hydrological Aspects of Droughts, New Delhi, Vol. 1, pp. 103-111.

2 Box, G.E.P. and Cox, D.R. (1964), 'An Analysis of Transformations' (with discussion), Jr. of the Royal Stat. Society, Sec.B, Vol. 26, pp. 211-252.

3 Kite, G.W. (1977), "Frequency and Risk Analysis in Hydrology', W.R. Publications, Colorado 80161.

4 Panchang, G.M. (1967), 'Improved Precision of Future High Floods', Proc. Symp. on Floods and their Computations, Leningrad, Vol.1, pp. 51-59.

5 Singh, K.P. and M.Nakashima (1984), 'A New Methodology for Flood Frequency Analysis with Objective Detection and Modification of Outliers/Inliers', Frontiers in Hydrology, W.R. Publications, Colorado 80161, pp. 187-202.

APPENDIX - A SAMPLE INPUT FILE (INPUT.DAT)

```
       ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001
60
1915 19900.
1916 10400.
1917 10700.
1918 20100.
1919 8210.
1920 14300.
1921 8040.
1922 8210.
1923 13900.
1924 8390.
1925 18500.
1926 13000.
1927 16400.
1928 14500.
1929 13000.
1930 17200.
1931 13900.
1932 11900.
1933 13600.
1934 12400.
1935 18300.
1936 12900.
1937 18200.
1938 9900.
1939 10200.
1940 9020.
1941 11800.
1942 16100.
1943 16900.
1944 11800.
1945 13900.
1946 12300.
1947 15100.
1948 11900.
1949 11000.
1950 16000.
1951 11600.
1952 19900.
1953 18600.
1954 18000.
1955 13100.
1956 29100.
```

1957	10300.
1958	12200.
1959	15600.
1960	12700.
1961	13100.
1962	19200.
1963	19500.
1964	23000.
1965	6700.
1966	7130.
1967	14300.
1968	20600.
1969	25600.
1970	8180.
1971	34400.
1972	16100.
1973	10200.
1974	12300.

APPENDIX - B LISTING OF PROGRAM

```
C       GRAPHICAL REPRESENTATION OF INFORMATION RELATED WITH FLOODS
C
C                        *****  G R I F  *****
C
C             NATIONAL INSTITUTE OF HYDROLOGY ,ROORKEE
C
C       Q=ANNUAL MAXIMUM FLOOD(CUMECS)
C       ALQ=ANNUAL MAXIMUM FLOOD IN NATURAL LOG SPACE
C       PG=EXCEEDENCE PROBABILITY
C       IR=YEAR
C       R,RP=RETURN PERIOD
C       N=NO. OF DATA POINTS :NA=N+1:NN=NO. OF ASSIGNED RP:NU=N+NN
C       PARAMETERS::AUG=MEAN,STDV=STANDARD DEVIATION:VAR=VARIENCE
C       CVN=COFF. OF VARIATION,SKEW=SKEWNESS COFF
C       CURT=KURTOSIS,PARAMETERS IN LN SPACE-AVGL,STDVL,VAR,etc.;
C       BOX-COX...AL= LAMBDA,AV,SD,SQ;EV-1 LIKLEIHOOD..ALPHA,BETA1
C       XA,XK=STANDARD NORMAL DEVIATE;
C       QLN,WQ,GLQ,BLQ,PQ,QB,QE,QN,VQ1,EQB
C       ARE ESTIMATED FLOOD PEAK FROM DIFFERENT MODELS
C       ST=STANDARD ERROR OF ESTIMATED FLOOD
C       QT1, QT2 ARE UPPER AND LOWER LIMITS AT 95% SIGNIFICANCE
C       LEVEL(5% significance).
C

        CHARACTER ANS*1,HDG(5)*75,TITLE*1,TITLE1*8,METHOD*50,TITLE3*50
        CHARACTER*4 ZA,ZB*3,ZC
        DIMENSION RP(80),PG(80),P(80),SN(80),QN(80),
       1IR(80),VN(80),SL(80),VL(80),QL(80),TQ(80),SG(80),II(80),VG(80),
       2QG(80),SGH(80),VGH(80),QGH(80),SW(80),VW(80),QW(80),SPN(80)
       3,VPN(80),QPN(80),QX(80),SX(80),VX(80),FN(80),RR(80)
       4,RPM(80),AT(80),BT(80),CT(80),B(12,10),FL(80),FG(80),DT(80)
       5,FGH(80),FPN(80),FW(80),FX(80),CPL(5),
       6ET(80),R(8),GT(80),QRLOG(80),TTX(33),TTY(33)
        COMMON/YY/  GT,TEMP,GET,QRLOG
        COMMON/SKJ/ N,Q(80),XXX,YYY

        DATA CPL/0., 0.375, 0.44, 0.40, 0/
        DATA TTY/12.706,4.303,3.182,2.776,2.571,2.447,2.365,2.306,2.262,
       12.228,2.201,2.179,2.160,2.145,2.131,2.120,2.110,2.101,2.093,
       22.086,2.080,2.074,2.069,2.064,2.060,2.056,2.052,2.048,2.045,
       32.042,2.021,2.000,1.980/
        DATA TTX/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
       121,22,23,24,25,26,27,28,29,30,40,60,120/
        OPEN(UNIT=1,FILE='INPUT.DAT',STATUS='OLD')
        OPEN(UNIT=2,FILE='OUTL.DAT',STATUS='OLD')
        OPEN(UNIT=3,FILE='OUTPUT.DAT',STATUS='NEW')
        WRITE(6,802)
802     FORMAT(
```

```
     1/9X'****************************************************'
     1/9X'Welcome  to the  interactive session on  VAX-11/780'/
     2 9X'system  for GRAPHICAL REPRESENTATION OF INFORMATION'/
     3 9X'RELATED  WITH  FLOODS and other summary  statistics'/
     4 9x'derived from its attributes & modelling excercises.'/
     5 9X'Please keep  data  set ready for input through the'/
     6 9X'terminal according to the instructions.'/
     7 9X'****************************************************'/)
     DATA HDG/
     1'     WEIBULL formula     (for any prob. distribution)',
     1'     BLOM    formula     (for normal distribution)',
     1'     GRINGORTEN formula  (for EV1,Exp.distribution)',
     1'     CUNNANE formula     (for any prob. distribution)'
     1'     Any other            plotting position formula'/
     WRITE(6,843)
843  FORMAT(3X'The data may be read from the data file, or may be'
     1/3X'input through the terminal. Type "D" if data is to be read'
     2/3x' from the data file INPUT.DAT otherwise type any other
     3 character : ',$)
     READ(5,4) ANS
     NC=5
     IF(ANS.EQ.'D'.OR.ANS.EQ.'d') NC=1
111  IF(NC.EQ.5) WRITE(6,10)
10   FORMAT(3X'Input river name, gauging site name and years of'/
     13X,'record (all in one line within 80 characters)')
     READ(NC,4) TITLE1
4    FORMAT(A)
     IF (NC.EQ.5) WRITE(NC,9)
9    FORMAT(3X,'Input "N", the no. of data sets being input.'/
     13X,'For each data set firs. input year and then input the'/
     13X,'corresponding peak flood value(cumecs)'/)
     READ(NC,*) N,(IR(I),Q(I),I=1,N)
     WRITE(6,919)
919  FORMAT(/' Do you want to view the BAR CHART of flood events (Y/N)
     1 : ',$)
     READ(5,4)ANS
     IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT2(IR)
     WRITE(6,199)
199  FORMAT(/' Do you want to view the HISTOGRAM of floods (Y/N) : ',$)
     READ(5,4)ANS
     IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT1
     DO 11 M=1,12
     READ(2,*) (B(M,J),J=1,10)
19   FORMAT(10(1X,F6.3),/)
11   CONTINUE
     WRITE(6,1)
1    FORMAT(/' Do you want to see the input data set input (Y/N) : ',$)
     READ(5,4) ANS
     IF(ANS.EQ.'Y'.or.ans.EQ.'y') THEN
     WRITE(3,2) N,(IR(I),Q(I),I=1,N)
```

```
      WRITE(6,2) N,(IR(I),Q(I),I=1,N)
2     FORMAT(/3X'Number of data sets input = 'I3//10X'Year',7X,'ANNUAL
     1 FLOOD'/22X'(Cumecs)'/10X'-----------------------'/
     1(10X,I5,4X,F10.2))
      WRITE(6,803)
      WRITE(3,803)
      ENDIF
803   FORMAT(10X'-----------------------'/)
      DO 9911 I=1,N
      II(I)=IR(I)
      AT(I)=Q(I)
      CT(I)=Q(I)
      BT(I)=Q(I)
      DT(I)=Q(I)
      ET(I)=Q(I)
9911  CONTINUE
      NF=8
      IN=N
      WRITE(6,999)
999   FORMAT(/' Do you want to analyse the input data for outliers (Y/N)
     1 : ',$)
      READ(5,4) ANS
      IF(ANS.EQ.'Y'.or.ans.eQ.'y') THEN
      WRITE(6,211)
211   FORMAT(/' The analysis is done by suspecting five lowest and
     1 highest'/' values of the series as outlier/inlier and viewing
     1 them through'/' the window for outlier/inlier check. If the
     1 suspicion is confirmed'/' the historic values are modified.')
212   KK=KK+1
      CALL OUTLIER(N,AT,BT,B,AL)
      WRITE(6,809)
809   FORMAT(/3X,'The new peak flow series with the modified values of'
     1/' the outliers/inliers is as follows :'/)
214   WRITE(6,21)((IR(I),AT(I)),I=1,N)
21    FORMAT(//10X'Year'7X'Peak Flow'/22X' (Cumecs)'/
     110X'-----------------------'//,
     1(10X,I5,4X,F10.2))
      WRITE(6,808)
808   FORMAT(10X'-----------------------'//)
      WRITE(6,9998)
9998  FORMAT(/' Do you want to go through the analysis with the new data
     1 set (Y/N) : ',$)
      READ(5,4) ANS
      IF(ANS.NE.'Y'.OR.ANS.NE.'y') GO TO 1000
      DO 9921 I=1,N
9921  Q(I)=AT(I)
      GO TO 260
      ENDIF
1000  N=IN
      DO 270 I=1,N
      IR(I)=II(I)
```

```
270     AT(I)=CT(I)
260     WRITE(6,8)
        CALL MOMENT(N,Q,AVG,STDV,VAR,CVN,SK,CURT)
        WRITE(6,801)
        WRITE(3,801)
        CALL LGMOM(AVGL,STDVL,VARL,CVNL,SKEWL,CURTL,1R)
        NV=NF+NN
        DATA R/2.0,5.0,10.0,25.0,50.0,100.0,500.0,1000.0/
        DO 5 I=1,NV
        RP(I)=R(I)
5       RPM(I)=0.0
        WRITE(6,561)
561     FORMAT(/
        1' This programme makes peak flood estimates corresponding to'/
        2' pre-assigned return periods of'//
        15x'2, 5, 10, 25, 50, 100, 500, and 1000 Years.'//
        1' Do you want to make peak flood estimates for any other return
        1 period (Y/N) : '$)
        READ(5,4)ANS
        IF(ANS.EQ.'Y'.or.ans.eQ.'y') THEN
        WRITE(6,501)
501     FORMAT(/' Please give number of return-period years in addition to'/
        1' the above 8 periods for which peak flood estimates is required ',$)
        READ(5,*) NN
        NV=NF+NN
        WRITE(6,831)NN
831     FORMAT(' Please give the additional'i3' return-period values')
        READ(5,*) (RR(J),J=1,NN)
        NG=NF+1
        DO 50 I=NG,NV
        J=I-NF
50      RP(I)=RR(J)
        ENDIF
        WRITE(6,899)
899     FORMAT(/' Do you want to test the annual peak flood series for
        1 persistance (Y/N) :'$)
        READ(5,4) ANS
        IF(ANS.NE.'Y'.or.ans.ne.'y') GOTO 549
        CALL RANDT(NV,AVG,AL,TQ,AV,SD,SKEW,R1,RP,RPM,TITLE1)
549     DO 45 I=1,NV
        PG(I)=1.0/RP(I)
45      P(I)=1.0-PG(I)
        WRITE(6,6) (I,RP(I),P(I),PG(I),I=1,NF)
        WRITE(3,6) (I,RP(I),P(I),PG(I),I=1,NF)
        IF(NV.EQ.NF) GOTO 822
        WRITE(6,821) (I,RP(I),P(I),PG(I),I=NG,NV)
        WRITE(3,821) (I,RP(I),P(I),PG(I),I=NG,NV)
6       FORMAT(/3X'For pre-assigned values of return periods '//
        13X'SERIAL '4X'RETURN PERIOD'4X'NON-EXCEEDANCE'4X
        1'EXCEEDANCE'/6X'NO'8X'(Years)'9X'PROBABILITY'5X'PROBABILITY'/
```

```
      13X'----------------------------------------------------------'/
      1(4X,I3,6X,F11.2,7X,F10.6,4X,F10.6))
821   FORMAT(/3X'For the additionally required return periods : '/
      14X,I3,6X,F11.2,7X,F10.6,4X,F10.6)
822   WRITE(6,806)
      WRITE(3,806)
806   FORMAT(3X'------------------------------------------------------
      1------'/)
      TTT1=N-2
      TTT2=N-3
      IF(TTT1.GT.TTX(33)) THEN
       XXX=TTY(33)
       GO TO 1744
      ENDIF
      DO 1711 I=1,33
      IF(TTT1.EQ.TTX(I)) THEN
       XXX=TTY(I)
       GO TO 1744
      ENDIF
      IF(TTT1.LT.TTX(I)) THEN
       XXX=TTY(I)-(TTX(I)-TTT1)*(TTY(I)-TTY(I-1))/(TTX(I)-TTX(I-1))
       GO TO 1744
      ENDIF
1711  CONTINUE
1744  DO 1712 I=1,33
      IF(TTT2.EQ.TTX(I)) THEN
       YYY=TTY(I)
       GO TO 1745
      ENDIP
      IF(TTT2.LT.TTX(I)) THEN
       YYY=TTY(I)-(TTX(I)-TTT1)*(TTY(I)-TTY(I-1))/(TTX(I)-TTX(I-1))
       GO TO 1745
      ENDIF
      IF(TTT2.GT.TTX(33)) THEN
       YYY=TTY(33)
       GO TO 1745
       ENDIF
1712  CONTINUE
1745  WRITE(6,16)
      WRITE(3,16)
16    FORMAT(/3X'The estimates of peak flows for different return'
      1/3x'periods by different probability models follow'/)
      CALL NORM(NF,NV,RP,P,AVG,STDV,VAR,SN,VN,QN,FN,TITLE1)
      CALL LGNB(NF,NV,RP,P,AVGL,STDVL,SL,VL,QL,FL,TITLE1)
      CALL GUMB(NF,NV,RP,P,AVG,STDV,VAR,SK,CURT,SG,VG,QG,FG,TITLE1)
      CALL GUMLH(NF,NV,AVG,STDV,RP,P,ALPHA,BETA1,SGH,VGH,QGH,FGH,
      1TITLE1)
      CALL LGPN(NF,NV,RP,P,AVGL,STDVL,VARL,SKEWL,SPN,VPN,QPN,FPN,
      1TITLE1)
      CALL BOX(NF,NV,TQ,RP,P,AV,SD,AL,SKEW,SX,VX,QX,FX,TITLE1)
```

```
12      WRITE(6,101)
101     FORMAT(3X'Input case No. for choice of plotting position:'/
        15X'Case1., WEIBULL        (1939)  plotting position (C=0.000)'.
        25X'Case2., BLOM           (1958)  plotting position (C=0.375)',
        35X'Case3., GRINGORTON     (1963)  plotting position (C=0.440)'/
        45X'Case4., CUNNANE        (1978)  plotting position (C=0.400)'/
        55X'Case5,  ANY OTHER              plotting position (C=?.?)'//
        65x'Your choice : '$)
        READ(5,*) ICSE
        IF((ICSE.NE.1).OR.(ICSE.NE.2).OR.(ICSE.NE.3).OR.(ICSE.NE.4).OR
        1(ICSE.NE.5))GO TO 888
        C=CPL(ICSE)
        IF(ICSE.EQ.5) THEN
548     WRITE(6,546)
546     FORMAT(/' Input the value of constant "C" (of your option)'/
        1' in the plotting position formulae:  n=(1-2c)/(m-c)'/)
        READ(5,*)C
        ENDIF
547     WRITE(6,538) HDG(ICSE)
538     FORMAT(/3X'You have chosen the following plotting position'/
        13X'method for the current analysis :'/A75)
        CALL ORDER(C,SML)
        WRITE(6,545)
545     FORMAT(/' Do you want to try any other plotting position formul
        1 (Y/N) :'$)
        READ(5,4) ANS
        IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') GO TO 12
8       FORMAT(/3X'Estimates of statistical parameters of the annual'/
        13X'flood peak series follow'/)
801     FORMAT(/3X'Estimates of statistical parameters of the'/
        13X'NATURAL-LOG TRANSFORMED annual flood peak series'/)
888     WRITE(6,813)
813     FORMAT(//' Do you want to analyse another data set (Y/N) : '$)
        READ(5,4) ANS
        IF(ANS.EQ.'Y'.or.ans.eq.'y') GO TO 111
        ZA=CHAR(27)// CHAR(91) // CHAR(49)// CHAR(109)
        ZB=CHAR(27)//CHAR(35)//'6'
        ZC=CHAR(27)//CHAR(91)//CHAR(48)//CHAR(109)
        TYPE *,ZA,ZB,' tHANK yOU AND bA-BYE',ZC
        END
C
        SUBROUTINE ORDER(C,SML)
C       THIS SUBROUTINE ARRANGES THE ANNUAL PEAK FLOOD SERIES IN THE
C       DECREASING ORDER OF MAGNITUDE AND COMPUTES RETURN PERIOD,
C       EXCEEDANCE AND NON-EXCEEDANCE PROBABILITY AS PER CHOICE OF
C       PLOTTING POSITION OPTED FOR.
        COMMON /SKJ/ N,Q(80),XXX,YYY
        DIMENSION OQ(80),ORD(80),RP(80),ORQ(80),PG(80),P(80),YY(80)
C       SORTING OF DATA SET
        DO 5 I=1,N
```

```
5       OQ(I)=Q(I)
        K=N-1
10      DO 11 I=1,K
        IF(OQ(I).GE.OQ(I+1)) GO TO 11
        AMAX=OQ(I)
        OQ(I)=OQ(I+1)
        OQ(I+1)=AMAX
11      CONTINUE
C       ORDERING OF DATA SET AND RETURN PERIOD CALCULATIONS
        K=K-1
        IF(K.GT.1)GO TO 10
        TN=N+1.0-2.0*C
        J=0
        NX=N-1
        DO 13 I=1,NX
        IF(OQ(I).EQ.OQ(I+1))GO TO 13
        J=J+1
        ORD(J)=I
        RP(J)=TN/(I-C)
        PG(J)=1.0/RP(J)
        P(J)=1.0-PG(J)
        ORQ(J)=OQ(I)
        PR=P(J)
        CALL NENOPROB(PR,X)
        YY(J)=X
13      CONTINUE
        J=J+1
        IF(OQ(N-1).EQ.OQ(N))GO TO 15
        ORD(J)=N
        RP(J)=TN/(N-C)
        PG(J)=1.0/RP(J)
        P(J)=1.0-PG(J)
        ORQ(J)=OQ(N)
        PR=P(J)
15      CALL NENOPROB(PR,X)
        YY(J)=X
        WRITE(6,21)(ORD(I),RP(I),P(I),ORQ(I),PG(I),YY(I),I=1,J)
        WRITE(3,21)(ORD(I),RP(I),P(I),ORQ(I),PG(I),YY(I),I=1,J)
21      FORMAT(/2X'ORDER'2X'RETURN',3X'NON-EXCEED.',
        14X'ORDERED',4X'EXCEEDANCE',3X'REDUCED'/4X'NO.',2X'PERIOD',
        22X'PROBABILITY',4X'PEAK FLOWS',2X'PROBABILITY',2X'VARIATES'
        3/8X'(Years)',18X'(Cumecs)'/' ---------------------------------
        1-------------------------------------'/
        6(2X,F3.0,2X,F5.1,6X,F8.6,3X,F10.3,7X,F8.6,2X,F7.4))
        WRITE(6,12)
        WRITE(3,12)
12      FORMAT(' ---------------------------------------------------
        1-------'/)
        BG=ORQ(1)
        SML=ORQ(J)
```

```
      RNG=BG-SML
      NDT=N/2
      RNDT=NDT
      RN=N
      DNT=RN/2.0
      IF(DNT.EQ.RNDT)GO TO 535
      NMED=N/2+1
      QMED=ORQ(NMED)
      GO TO 534
535   NT=N/2
      QMED=(ORQ(NT)+ORQ(NT+1))/2.0
      QMOD=3.0*QMED-2.0*AVG
534   WRITE(6,532)BG,SML,RNG,QMED,QMOD
      WRITE(3,532)BG,SML,RNG,QMED,QMOD
532   FORMAT(/5X'Range of values in the peak flow series are:-'/
     15X'MAXIMUM DISCHARGE = ',F8.0,'Cumecs'/
     25X'MINIMUM DISCHARGE = ',F8.0,'Cumecs'/
     35X'DISCHARGE(RANGE)  = ',F8.0,'Cumecs'/
     45X'MEDIAN VALUE      = ',F8.0,'Cumecs'/
     55X'MODE VALUE        = ',F8.0,'Cumecs')
      RETURN
      END
C
      SUBROUTINE MOMENT(N,Q,AVG,STDV,VAR,CVN,SK,CURT)
C     STATISTICAL PARAMETER ESTIMATION OF THE ANNUAL PEAK FLOOD
C     SERIES BY MOMENT METHOD.
      DIMENSION Q(80)
      S1=0.0
      S2=0.0
      S3=0.0
      S4=0.0
      SUM=0.0
      DO 200 I=1,N
200   SUM=SUM+Q(I)
      AVG=SUM/N
      SUM=0.0
      SU1=0.0
      SU2=0.0
      DO 210 I=1,N
      AA=Q(I)-AVG
      AB=AA*AA
      SUM=SUM+AB
      SU1=SU1+AA*AB
      SU2=SU2+AB*AB
210   CONTINUE
      VAR=SUM/(N-1)
      STDV=SQRT(VAR)
      SK=(SU1*N)/(N-1)/(N-2)
      SK=SK/(STDV**3)
      CURT=SU2*N/(N-1)*N/(N-2)/(N-3)
```

```
      CURT=CURT/(STDV**4)
      CVN=STDV/AVG
      DO 124 I=1,N
      S2=S2+(AVG-Q(I))**2
      S3=S3+(Q(I)-S1)**3
124   S4=S4+(Q(I)-S1)**4
      U2=S2/(N-1.0)
      U3=S3*N/((N-1.0)*(N-2.0))
      U4=(S4*(N**2))/((N-1.0)*(N-2.0)*(N-3.0))
      SIGMA=SQRT(U2)
C     COEFFICIANT OF VARIATION(CVN)
      SEM=STDV/(N**0.5)
      SED=SK*SK
      SED=0.75*SED
      SED=SED+1.0
      SED=SQRT(SED)
      SED=SED*SIGMA/((2.0*N)**0.5)
      SESA=6*N*(N-1)
      SESB=(N-2)*(N+1)*(N+3)
      SESC=SESA/SESB
      WRITE(6,14) AVG,VAR,STDV,SK,CURT,CVN,SEM,SED
      WRITE(3,14) AVG,VAR,STDV,SK,CURT,CVN,SEM,SED
14    FORMAT(/
      15X'MEAN                                = 'F12.4/
      25X'VARIANCE                            = 'F16.4/
      35X'STANDARD DEVIATION                  = 'F12.4/
      45X'SKEWNESS COEFF                      = 'F12.4/
      55X'COEFF OF KURTOSIS                   = 'F12.4/
      65X'COEFF OF VARIATION                  = 'F12.4/
      75X'STANDARD ERROR OF MEAN              = 'F12.6/
      85X'STANDARD ERROR OF STANDARD DEVIATION = 'F12.6/)
      RETURN
      END

      SUBROUTINE GUMB(NF,NV,RP,F,AVG,STDV,VAR,SK,QR,SG,VG,QG,FG,
      1TITLE1)
C     ESTIMATION OF ANNUAL FLOOD PEAK FOR REQUIRED RETURN PERIOD BY
C                             GUMBEL DISTRIBUTION.
C
      CHARACTER*80 TITLE1, ANS*1
      DIMENSION RP(80),FG(80),QG(80),SG(80),QT1(80),QT2(80)
      1,F(80),VG(80),Z(80),QA(80),FS(80),QB(80)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      COMMON/YY/Z,QA,FS,QB
      CHARACTER*50 METHOD,TITLE3
      DATA METHOD/'GUMBEL distribution '/
      DATA TITLE3/'Discharse in 10000 Cumecs ------>'/
      WRITE(6,528)
      WRITE(3,528)
528   FORMAT(/3X'Estimates of peak flood using EV-1 distribution
```

```
      1 (Method of Moments)'/)
      DO 25 I=1,NV
      FG(I)=-(0.5772+ALOG(-ALOG(1.-1./RP(I))))/1.2825
      QG(I)=AVG+STDV*FG(I)
      SG(I)=VAR*(1.0+SK*FG(I)+(QR-1.0)*FG(I)*FG(I)/4.0)/N
      VB(I)=SG(I)*N
      SG(I)=SQRT(SG(I))
      QT1(I)=QG(I)-XXX*SG(I)
      QT2(I)=QG(I)+XXX*SG(I)
      QB(I)=QG(I)/10000.
      FS(I)=-ALOG(-ALOG(1.-1./RP(I)))
25    CONTINUE
      N1=N-1
      DO 125 K=1,N1
      JJ=N-K
      DO 125 L=1,JJ
      IF(Q(L).LE.Q(L+1)) GO TO 125
      VAL=Q(L)
      Q(L)=Q(L+1)
      Q(L+1)=VAL
125   CONTINUE
      DO 150 I=1,N
      QA(I)=Q(I)/10000.
150   CONTINUE
      ANN=N+0.12
      DO 151 I=1,N
      AI=I
      P(I)=(AI-0.44)/ANN
      Z(I)=-ALOG(-ALOG(P(I)))
151   CONTINUE
      CALL PRINT(NF,NV,RP,FG,QG,SG,QT1,QT2,TITLE1)
      WRITE(6,214)
214   FORMAT(/' Do you want to view the graph on the screen (Y/N) :'$)
      READ(5,215) ANS
215   FORMAT(A)
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT(N,NV,METHOD,TITLE3)
216   RETURN
      END
C
      SUBROUTINE PRINT(NF,NV,RI,FR,XQ,SE,QLL,QUL,TITLE1)
C
C     RESULTS OF FREQUENCY ANALYSIS ARE PRINTED THRU THIS SUBROUTINE
C
      CHARACTER*80 TITLE1
      COMMON /SKJ/ N,Q(80),XXX,YYY
      DIMENSION RI(N),FR(N),XQ(N),SE(N),QLL(N),QUL(N)
      WRITE(6,999)TITLE1
      WRITE(3,999)TITLE1
999   FORMAT(3X,A/)
```

```
      WRITE(6,101) (I,RI(I),FR(I),XQ(I),SE(I),QLL(I),QUL(I),I=1,NF)
      WRITE(3,101) (I,RI(I),FR(I),XQ(I),SE(I),QLL(I),QUL(I),I=1,NF)
101   FORMAT(3x'-----------------------------------------------------------
     1---------------------'/
     23X'SERIAL',2X'RETURN',3X'FREQUENCY',4X'COMPUTED',3X
     3'STANDARD',6X'95% CONFINED BAND'/4X'NO.',4X'PERIOD',3X'FACT
     4OR'7X'PEAKFLOW',4X'ERROR',7X'LOWER',7X'UPPER'/11X'(Years)'
     5,15X'(Cumecs)',3X'(Cumecs)'3X'(Cumecs)',5X'(Cumecs)'/
     63X'--------------------------------------------------------
     1---------------------'/
     8(4X,I3,4X,F6.0,3X,F7.4,3X,F10.0,2X,F8.0,3X,F10.0,2X,F10.0))
      IF(NF.EQ.NV) GO TO 103
      NH=NF+1
      WRITE(6,102) (I,RI(I),FR(I),XQ(I),SE(I),QLL(I),QUL(I),I=NH,NV)
      WRITE(3,102) (I,RI(I),FR(I),XQ(I),SE(I),QLL(I),QUL(I),I=NH,NV)
102   FORMAT(/6X'For additionally requested return period values'//
     1(4X,I3,4X,F6.0,3X,F7.4,3X,F10.0,2X,F8.0,3X,F10.0,2X,F10.0))
103   WRITE(6,104)
      WRITE(3,104)
104   FORMAT(3X'-----------------------------------------------------------
     1---------------------'/)
      RETURN
      END
C
      SUBROUTINE LGPN(NF,NV,RP,P,AVGL,STDVL,VARL,SQ,SPN,VPN,QPN,FPN,
     1TITLE1)
C
C     THIS SUBROUTINE ESTIMATES PEAK FLOOD FOR THE REQUIRED RETURN
C     PERIOD USING LOG-PEARSON III (3-PARAMETER) DISTRIBUTION.
C
      DIMENSION P(80),RP(80),FPN(80),QPN(80),QT1(80),QT2(80)
     1,SPN(80),VPN(80),G(80),Z(80),QA(80),FL(80),QB(80)
      CHARACTER*80 TITLE1, METHOD*50,TITLE3*50,ANS*1
      COMMON/YY/Z,QA,FL,QB
      COMMON /SKJ/ N,Q(80),XXX,YYY
      DATA METHOD/'3P LOG PEARSON III'/
      DATA TITLE3/'Discharge in LOG10----->'/
      WRITE(6,68)
      WRITE(3,68)
 .8   FORMAT(/' Estimates of peak flood using LOG-PEARSON III
     1 distribution (3-PARAMETER)'/)
      DO 70 I=1,NV
      PR=1.-1./RP(I)
      CALL NENOPROB(PR,X)
      FL(I)=X
      FPN(I)=2/SQ*(1.+FL(I)*SQ/6-SQ**2/36)**3-2/SQ
      QPN(I)=AVGL+STDVL*FPN(I)
      QPN(I)=EXP(QPN(I))
      SLOPE= (X*X-1.0)/6.0 + 4.*(X**3-6.0*X)*SQ/216.0
     1 - 3.0*(X*X-1.0)*SQ*SQ/216.0 + 4.0*X*SQ**3/1296.0
     2 - 10.0*SQ**4/(1296.0*36)  !46656
```

```
      B1=1.0+FPN(I)*SQ+ FPN(I)**2*0.5*(0.75*SQ*SQ+1.0)
      B2=3.0*FPN(I)*SLOPE*(SQ+0.25*SQ*SQ*SQ)
      B3=3.0*SLOPE*SLOPE*(2.0+3.0*SQ*SQ+5.0*SQ*SQ*SQ*SQ/8.0)
      ST=VARL*(B1+B2+B3)
      VPN(I)=EXP(ST)*QPN(I)
      ST=SQRT(ST/N)
      ST=QPN(I)*(EXP(ST)-EXP(-ST))/2.0
      SPN(I)=ST
      QT1(I)=QPN(I)-YYY*ST
      QT2(I)=QPN(I)+YYY*ST
      QB(I)=ALOG10(QPN(I))
70    CONTINUE
      N1=N-1
      DO 125 K=1,N1
      JJ=N-K
      DO 125 L=1,JJ
      IF(Q(L).LE.Q(L+1)) GO TO 125
      VAL=Q(L)
      Q(L)=Q(L+1)
      Q(L+1)=VAL
125   CONTINUE
      DO 27 I= 1,N
      QA(I)=ALOG10(Q(I))
27    CONTINUE
      ANN=n+0.25
      DO 31 I=1,N
      G(I)=(I-0.375)/ANN
      GG=G(I)
      CALL NENOPROB(GG,ZZ)
      Z(I)=ZZ
31    CONTINUE
      CALL PRINT(NF,NV,RP,FPN,QPN,SPN,QT1,QT2,TITLE1)
      WRITE(6,28)
28    FORMAT(/' Do you want to view the graph on the screen (Y/N) :'$)
      READ(5,29) ANS
29    FORMAT(A)
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT(N,NV,METHOD,TITLE3)
30    RETURN
      END

      SUBROUTINE BOX(NF,NV,TQ,RP,P,AV,SD,AL,SKEW,SX,VX,QX,FX,TITLE1)
C
C     THIS SUBROUTINE TRANSFORMS THE INPUT ANNUAL PEAK FLOOD SERIES
C     USING BOX-COX TRANSFORMATION AND THEN ESTIMATES THE PEAK FLOOD
C     FOR THE REQUIRED RETURN PERIOD FROM THE TRANSFORMED SERIES.
C
C     This subroutine uses transformation Y=(X**LAMDA-1)/LAMDA
C     It searches LAMDA such that skewness coeff. of the
C     transformed series is < 0.02.
C
```

```
      CHARACTER*80 TITLE1, ANS*1, METHOD*50,TITLE3*50
      DIMENSION TQ(80),RP(80),P(80),QB(80),QT1(80),ST(80),QX(80)
     1,QT2(80),FX(80),VX(80),SX(80),G(80),Z(80),QA(80),FN(80),QC(80)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      COMMON/YY/Z,QA,FN,QC
      DATA METHOD/'POWER TRANSFORMATION
      DATA TITLE3/'Discharge in 10000 Cumec------>'/
      WRITE(6,506)
      WRITE(3,506)
506   FORMAT(/3X'Frequency analysis by POWER TRANSFORMATION method.
      CALL POWER(N,Q,AL,TQ,AV,VR,SD,SKEW,AKURT,AMOM5)
      WRITE(6,14)AL
      WRITE(3,14)AL
14    FORMAT(/3X'Values of LAMDA = 'F11.8)
      WRITE(6,67)SKEW
      WRITE(3,67)SKEW
67    FORMAT(/3X'Skewness of the transformed series = ',F12.8)
      WRITE(6,444)
444   FORMAT(/' Do you want the transformed series to be tabulated (Y/N) :
     1'$)
      READ(5,445)ANS
445   FORMAT(A)
      IF(ANS.NE.'Y'.OR.ANS.NE.'y')GO TO 446
      WRITE(6,175) (I,Q(I),TQ(I),I=1,N)
      WRITE(3,175) (I,Q(I),TQ(I),I=1,N)
175   FORMAT(/3X'SERIAL'5X'PEAK FLOW'3X'TRANSFORMED PEAK FLOW'/
     15X'No.'7X'(Cumec)'6X'(Cumecs)'/3X'-----------------------
     3---------------'/(5X,I3,6X,F9.1,6X,F12.6))
      WRITE(6,519)
      WRITE(3,519)
519   FORMAT(3X'--  ---------------------------------------'/)
446   WRITE(6,1)AV,SD,VR,SKEW,AKURT,AMOM5
      WRITE(3,1)AV,SD,VR,SKEW,AKURT,AMOM5
1     FORMAT(/3X'For the power transformed series :'/
     13X'AVERAGE    = 'F12.6/3X'STND DEV    = 'F12.6/
     23X'VARIANCE   = 'F12.6/3X'SKEWNESS    = 'F12.6/
     33X'KURTOSIS   = 'F12.6/3X'5TH MOMENT = 'F12.6/)
      SEM=SD/(N**0.5)
      SED=SQRT(0.75*SKEW*SKEW+1.0)
      SED=SED*SD/((2.0*N)**0.5)
      SESA=6.0*N*(N-1)
      SESB=(N-2)*(N+1)*(N+3)
      SESC=SESA/SESB
      SESK=SQRT(SESC)
      WRITE(6,200)SEM,SED,SESK
      WRITE(3,200)SEM,SED,SESK
200   FORMAT(3X'STANDARD ERROR OF MEAN                    = ',F12.6/
     13X'STANDARD ERROR OF STANDARD DEVIATION   = ',F12.6/
     23X'STANDARD ERROR OF SKEWNESS COEFFICIENT = ',F12.6/)
      ALINV=1.0/AL
```

```
      DO 90 I=1,NV
      PR=1.-1./RP(I)
      CALL NENOPROB(PR,X)
      FX(I)=X
      FN(I)=FX(I)
      QB(I)=AV+SD*FX(I)
      ST(I)=SD*SQRT((1.0+FX(I)*FX(I)/2.0)/N)
      VX(I)=VR*(1+FX(I)**2/2.)
      VX(I)=(VX(I)*AL+1.)
      VX(I)=VX(I)**ALINV
      STL=(ST(I)*AL+1.0)
      QBL=(QB(I)*AL+1.0)
      SX(I)=STL**ALINV
      QX(I)=QBL**ALINV
      QT1(I)=QB(I)-XXX*ST(I)
      QT2(I)=QB(I)+XXX*ST(I)
      QT1(I)=(QT1(I)*AL+1.0)**ALINV
      QT2(I)=(QT2(I)*AL+1.0)**ALINV
      SX(I)=QT2(I)-QX(I)
      QC(I)=QX(I)/10000.
90    CONTINUE
      N1=N-1
      DO 124 K=1,N1
      JJ=N-K
      DO 125 L=1,JJ
      IF(Q(L).LE.Q(L+1)) GO TO 125
      VAL=Q(L)
      Q(L)=Q(L+1)
      Q(L+1)=VAL
125   CONTINUE
124   CONTINUE
      DO 700 I=1,N
      QA(1)=Q(I)/10000.
700   CONTINUE
      ANN=N+0.25
      DO 701 I=1,N
      G(I)=(I-0.375)/ANN
      GG=G(I)
      CALL NENOPROB(GG,ZZ)
      Z(I)=ZZ
701   CONTINUE
      CALL PRINT(NF,NV,RP,FX,QX,SX,QT1,QT2,TITLE1)
      WRITE(6,702)
702   FORMAT(/' Do you want to view the graph on the screen (Y/N) :'$)
      READ(5,165) ANS
165   FORMAT(A)
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT(N,NV,METHOD,TITLE3)
166   RETURN
      END
C
```

```
      SUBROUTINE RANDT(NV,AVG,AL,TQ,AV,SD,SKEW,R1,RP,RPM,TITLE1)
C
C     THIS SUBROUTINE TESTS THE INPUT ANNUAL PEAK FLOOD SERIES FOR
C     PERSISTANCE BY COMPETING THE LAG 1 SERIAL CORRELATION AND
C     IDENTIFYING IT FOR BEING SIGNIFICANT OR NOT
C
      CHARACTER*80 TITLE1
      DIMENSION RP(80),TQ(80),RPM(80)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      Q(N+1)=Q(1)
      S=0.0
      S1=0.0
      S2=0.0
      DO 57 I=1,N
57    S1=S1+Q(I)/N
      DO 67 I=1,N
67    S2=S2+(Q(I)-S1)**2
      DO 77 I=1,N
77    S=S+(Q(I)-AVG)*(Q(I+1)-AVG)
      U2=S2/(N-1)*N
      SIGMA=SQRT(U2)
      R1=(S/(S2*(N-2)))*N
      D2=((N-2)/(N-1))*((N-2)/(N-1))*(1./(N-1))
      DS=SQRT(D2)
      C=1.96*DS
      C1=1./(N-1.)
      CU=C-C1
      CL=-cu
      WRITE(6,507)TITLE1
      WRITE(3,507)TITLE1
507   FORMAT(/A)
      WRITE(6,59)R1,CL,CU
      WRITE(3,59)R1,CL,CU
59    FORMAT(/
     15X'SERIAL CORRELATION COEFFICIENT LAG 1 = ',F7.4/
     25X'Its lower significant level value    = ',F7.4/
     35X'Its upper significant level value    = ',F7.4/)
      IF(R1.GE.CU) GO TO 66
      IF(CL.GT.R1) GO TO 102
      IF((R1.GE.CL).AND.(R1.LT.CU)) GO TO 101
66    WRITE(6,61)
      WRITE(3,61)
61    FORMAT(/5X'LAG 1 SERIAL CORRELATION Coefficient is highly'/
     15X'significant. Return periods are to be modified :'/)
      GO TO 200
102   WRITE(6,62)
62    FORMAT(/5X'LAG 1 SERIAL CORRELATION COEFFICIENT is'/
     15X'not significant. You may use any of the methods'/
     25X'of frequency analysis for random variables.'/)
      GO TO 100
```

```
101     WRITE(6,65)
65      FORMAT(/5X'LAG 1 SERIAL CORRELATION COEFFICIENT is'/
        15X'only somewhat significant. The return periods modified'/
        25X'for persistence are as follows:-'/)
200     CALL PERSM(NV,AL,TQ,AV,SD,SKEW,RP,RPM,VR)
100     RETURN
        END
C
        SUBROUTINE NORM(NF,NV,RP,P,AVG,STDV,VAR,SN,VN,QN,FN,TITLE1)
C
C       ESTIMATED PEAK FLOOD VALUES USING NORMAL DISTRIBUTION
        CHARACTER*80 TITLE1,ANS*1
        CHARACTER*50 METHOD,TITLE3
        DIMENSION P(80),RP(80),QN(80),QT1(80),QT2(80),FX(80)
        1,FN(80),SN(80),VN(80),G(80),Z(80),QA(80),QB(80)
        COMMON/YY/Z,QA,FX,QB
        COMMON /SKJ/ N,Q(80),XXX,YYY
        DATA METHOD/'NORMAL DISTRIBUTION'/
        DATA TITLE3/'Discharge in 10000 Cumec ---->'/
        WRITE(6,516)
        WRITE(3,516)
516     FORMAT(/3X'Quantile estimates using NORMAL
        1distribution (Method of Moments)'/)
        DO 130 I=1,NV
        P(I)=1-(1/RP(I))
        PR=P(I)
        CALL NENOPROB(PR,X)
        FN(I)=X
        FX(I)=FN(I)
        QN(I)=AVG+STDV*FN(I)
        VN(I)=VAR*(1.+X**2./2.)
        STT=SQRT((VAR/N)*(1.0+X*X/2.0))
        SN(I)=STT
        QT1(I)=QN(I)-XXX*STT
        QT2(I)=QN(I)+XXX*STT
        QB(I)=(QN(I)/10000.)
130     CONTINUE
        N1=N-1
        DO 124 K=1,N1
        JJ=N-K
        DO 125 L=1,JJ
        IF(Q(L).LE.Q(L+1)) GO TO 125
        VAL=Q(L)
        Q(L)=Q(L+1)
        Q(L+1)=VAL
125     CONTINUE
124     CONTINUE
        DO 78 I=1,N
        QA(I)=Q(I)/10000.
78      CONTINUE
```

```
      ANN=N+0.25
      DO 77 I=1,N
      G(I)=(I-.375)/ANN
      GG=G(I)
      CALL NENOPROB(GG,ZZ)
      Z(I)=ZZ
77    CONTINUE
      CALL PRINT(NF,NV,RP,FN,QN,SN,QT1,QT2,TITLE1)
      WRITE(6,610)
610   FORMAT(/' Do you want to view the graph on the screen (Y/N) :'$)
      READ(5,555) ANS
555   FORMAT(A)
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT(N,NV,METHOD,TITLE3)
615   CONTINUE
612   RETURN
      END
C
      SUBROUTINE LGMOM(AVGL,STDVL,VARL,CVNL,SKEWL,CURTL,TR)
C
C     STATISTICAL PARAMETER ESTIMATION BY MOMENTS METHOD AFTER
C     THE NATURAL-LOG TRANSFORMATION OF THE INPUT ANNUAL PEAK FLOW
C     SERIES.
      COMMON /SKJ/ N,Q(80),XXX,YYY
      CHARACTER*1 ANS
      DIMENSION IR(80),ALQ(80)
      DO 67 I=1,N
      ALQ(I)=ALOG(Q(I))
67    CONTINUE
      WRITE(6,69)
69    FORMAT(/' Do you want the transformed series tabulated (Y/N) '$)
      READ(5,79)ANS
79    FORMAT(A)
      IF(ANS.NE.'Y'.OR.ANS.EQ.'y') GO TO 73
      WRITE(6,70)
      WRITE(3,70)
      WRITE(6,68)(IR(I),Q(I),ALQ(I),I=1,N)
      WRITE(3,68)(IR(I),Q(I),ALQ(I),I=1,N)
70    FORMAT(/4X'Year'6X'PEAK FLOW'5X'LN(transformed)'/
     115X'(Cumecs)'9X'(Cumecs)'/
     23X'-------------------------------------------'/)
68    FORMAT(3X,I4,5X,F8.0,5X,F10.3)
      WRITE(6,71)
      WRITE(3,71)
71    FORMAT(3X'-------------------------------------------'/,
     13X'For LN(Transformed)PEAK FLOOD series:-'/)
73    CALL MOMENT(N,ALQ,AVGL,STDVL,VARL,CVNL,SKEWL,CURTL)
      RETURN
      END
```

```
      SUBROUTINE LGNB(NF,NV,RP,P,AVGL,STDVL,SL,VL,QL,FL,TITLE1)
C     ESTIMATION OF FLOOD BY LOG NORMAL METHOD-TAKING THE NATURAL
C     LOG OF ANNUAL PEAK FLOWS(METHOD OF MOMENTS)
C
      CHARACTER*80 TITLE1, ANS*1
      DIMENSION P(80),RP(80),QL(80),QT1(80),QT2(80),FX(80),QB(80)
     1,DELTA(80),SL(80),VL(80),FL(80),G(80),Z(80),QA(80)
      COMMON/YY/Z,QA,FX,QB
      COMMON /SKJ/ N,Q(80),XXX,YYY
      CHARACTER*50 METHOD,TITLE3
      DATA METHOD/'LOG NORMAL     MOM'/
      DATA TITLE3/'Discharge in LN----->'/
      WRITE(6,513)
513   FORMAT(/3X'This subroutine estimates peak flood for the'/
     13X'required return period using LOG-NORMAL distribution'/
     23X'after taking NATURAL LOG transformation by method of moments'/)
      DO 141 I=1,NV
141   FL(I)=0.0
      DO 140 I=1,NV
      PR=P(I)
      CALL NENOPROB(PR,X)
      FL(I)=X
      FX(I)=FL(I)
      QL(I)=AVGL+STDVL*FL(I)
      QL(I)=EXP(QL(I))
      DELTA(I)=SQRT(1.0+FL(I)**2/2.0)
      SL(I)=DELTA(I)*(STDVL/(N**0.5))
      SL(I)=QL(I)*((EXP(SL(I))-1.0)-(EXP(-SL(I))-1.0))/2.0
      VL(I)=SL(I)*N**0.5
      QT1(I)=QL(I)-XXX*SL(I)
      QT2(I)=QL(I)+XXX*SL(I)
      QB(I)=ALOG(QL(I))
140   CONTINUE
      N1=N-1
      DO 125 K=1,N1
      JJ=N-K
      DO 125 L=1,JJ
      IF(Q(L).LE.Q(L+1)) GO TO 125
      VAL=Q(L)
      Q(L)=Q(L+1)
      Q(L+1)=VAL
125   CONTINUE
      DO 160 I=1,N
      QA(I)=ALOG(Q(I))
160   CONTINUE
      ANN=N+0.25
      DO 165 I=1,N
      G(I)=(I-0.375)/ANN
      GG=G(I)
      CALL NENOPROB(GG,ZZ)
      Z(I)=ZZ
```

```
165   CONTINUE
      WRITE(6,516)
      WRITE(3,516)
516   FORMAT(/3X'Quantile estimates using LOG-NORMAL
     1distribution (Method of Moments)'/)
      CALL PRINT(NF,NV,RP,FL,QL,SL,QT1,QT2,TITLE1)
      WRITE(6,101)
101   FORMAT(/' Do you want to view the graph on the screen (Y/N) :'$)
      READ(5,555) ANS
555   FORMAT(A)
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y') CALL PLOT(N,NV,METHOD,TITLE3)
102   RETURN
      END
C
      SUBROUTINE GUMLH(NF,NV,AVG,STDV,RP,P,ALPHA,BETA1,SGH,VGH,QGH,FGH
     1,TITLE1)
C     COMPUTATION OF T YEAR FLOOD,ALONG WITH EXTERNAL TYPE1 DISTRIBUTION
C                 PARAMETER ESTIMATION BY MAXIMUM LIKELIHOOD.  .
C
      CHARACTER*80 TITLE1
      DIMENSION QGH(80),SGH(80),RP(80),P(80),QT1(80),QT2(80),
     1AQ(80),FGH(80),VGH(80)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      CALL GUMBLS(AVG,STDV,ALPHA,BETA1)
      STDVG=1.2825/ALPHA
      AVGG=BETA1+0.45*STDVG
      DO 148 I=1,NV
      FGH(I)=-ALOG(-ALOG(1.0-1.0/RP(I)))
      QGH(I)=BETA1+FGH(I)/ALPHA
      SGH(I)=SQRT(1.1086+0.5140*FGH(I)+0.6079*FGH(I)*FGH(I))
      VGH(I)=(SGH(I)/ALPHA)**2
      SGH(I)=SGH(I)*SQRT(1.0/(N*ALPHA*ALPHA))
      QT1(I)=QGH(I)-XXX*SGH(I)
      QT2(I)=QGH(I)+XXX*SGH(I)
148   CONTINUE
      WRITE(6,150)ALPHA,AVGG,BETA1,STDVG
      WRITE(3,150)ALPHA,AVGG,BETA1,STDVG
      CALL PRINT(NF,NV,RP,FGH,QGH,SGH,QT1,QT2,TITLE1)
150   FORMAT(/3X'Estimates of peak flood using EV-1 distribution
     1 (Method of Maximum likelihood)'/,
     16X'ALPHA = 'F10.4,15X'MEAN    = 'F10.2/
     26X'BETA  = 'F10.4,15X'STND DV = 'F10.2/)
      RETURN
      END
C
      SUBROUTINE GUMBLS(AVG,STDV,ALPHA,BETA)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      ALPHA=1.2825/STDV
      BETA=AVG-0.45*STDV
      AML=ALPHA
```

```
      INO=0
141   INO=INO+1
      A=1.0/(AML**2)
      B=AVG-1.0/AML
      C=0.0
      D=0.0
      E=0.0
      DO 142 I=1,N
      TE=EXP(-AML*Q(I))
      C=C+TE
      D=D+TE*Q(I)
      E=E+TE*Q(I)**2
142   CONTINUE
      FCN=D-B*C
      FPN=B*D-E-A*C
      AS=AML-(FCN/FPN)
      DELTA=ABS(AS*0.1E-2)
      IF((ABS(AS-AML).LT.DELTA).OR.(INO.GT.35))GO TO 144
      AML=AS
      GO TO 141
144   ALPHA=AS
      BETA=(1.0/ALPHA)*ALOG(N/C)
      RETURN
      END

      SUBROUTINE PRB(T,PROB)
      PI=3.1415927
      A=1.0/(SQRT(2.0*PI))
      B=(2.0*T/(4.0*45.0))
      PROB=A*B*(7.0+32.0*EXP(-(T*T)/32.0)+12.0*EXP(-(T*T)/8.0)
     1+32.0*EXP(-9.0*(T*T)/32.0)+7.0*EXP(-(T*T)/2.0))
      PROB=PROB+0.5
      RETURN
      END

      SUBROUTINE NENOPROB(GYY,YY)
C     THIS SUBROUTINE USES PROBABILITY OF NON EXCEEDANDCE
C     AND CALCULATES THE REDUCED VARIATES FOR A SAMPLE
C     WHICH IS NORMALLY DISTRIBUTED N(MEU,SIGMA)
      DIMENSION GY(72),Y(72)
      N=72
      DATA GY/.5,.5199,.5398,.5596,.5793,.5987,.6179,.6368,.6554,
     1.6736,.6915,.7088,.7257,.7422,.7580,.7734,.7881,.8023,.8159,
     2.8289,.8413,.8513,.8643,.8749,.8849,.8944,.9032,.9115,.9192,
     3.9265,.9332,.9394,.9452,.9565,.9554,.9599,.9641,.9678,.9713,
     4.9744,.9772,.9798,.9821,.9842,.9861,.9878,.9893,.9906,.9918,
     5.9929,.9938,.9946,.9953,.9960,.9965,.9970,.9974,.9978,.9981,
     6.99854,.9987,.9990,.9993,.9995,.9997,.99977,.99984,.99989,
     7.99993,.99995,.99997,.999995/
      DATA Y/.00,.05,.1,.15,.2,.25,.3,.35,.4,.45,.5,.55,.6,.65,.7,
```

```
      1.75,.8,.85,.9,.95,1.0,1.05,1.1,1.15,1.2,1.25,1.3,1.35,1.4,1.45
     2,1.5,1.55,1.6,1.65,1.7,1.75,1.8,1.85,1.9,1.95,2.0,2.05,2.1,2.15
     3,2.2,2.25,2.3,2.35,2.4,2.45,2.5,2.55,2.6,2.65,2.7,2.75,2.8,2.85
     4,2.9,2.95,3.0,3.1,3.2,3.2,3.4,3.5,3.6,3.7,3.8,3.9,4.0,4.4172/
      IF(GYY.GT..99997.OR.GYY.LT..00003)GO TO 70
      IF(GYY-0.5)60,10,20
60    GYY=1.0-GYY
      DO 80 I=2,N
      II=I-1
      IF(GYY.GT.GY(I)) GO TO 80
      GO TO 90
80    CONTINUE
90    P=GY(I)-GY(II)
      Q=GYY-GY(II)
      R=((Y(I)-Y(II))*Q)/P
      YY=0.0-(Y(II)+R)
      GO TO 50
10    YY=0.0
20    DO 30 I=2,N
      II=I-1
      IF(GYY.GT.GY(I)) GOTO 30
      GO TO 40
30    CONTINUE
40    P=GY(I)-GY(II)
      Q=GYY-GY(II)
      R=((Y(I)-Y(II))*Q)/P
      YY=Y(II)+R
      GO TO 50
70    YY=10.0
C     SOME UNREAL ISTIC VALUE CHOSEN SAY 10 IN THIS CASE
C     TO INDICATE THAT THE PROB. VALUE DOESN'T LIE WITHIN
C     THE RANGE(0.00003<PR.>0.99997)
50    RETURN
      END

      SUBROUTINE PERSM(NV,AL,TQ,AV,SD,SKEW,RP,RPM,VR)
C
C     THIS SUBROUTINE MODIFIES THE VALUES OF INPUT RETURNPERIODS
C     IF THE PERSISTANCE-TEST DIPICTS SUCH REQUIRMENTS
C
      DIMENSION TQ(80),RP(80),RPM(80)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      CALL POWER(N,Q,AL,TQ,AV,VR,SD,SKEW,AKURT,AMOM5)
      SUM=0.0
      SU=0.0
      DO 400 J=1,N-1
      JJ=J+1
      PP=(TQ(J)-AV)
      RR=(TQ(JJ)-AV)
400   SUM=SUM+(PP*RR)
```

```
      ANU=SUM/(N-1.)
      DO 405 J=1,N
405   SU=SU+(TQ(J)-AV)**2
      DNU=SU/N
      R1=ANU/DNU
      R2=1.0-R1
      IF(R1.GT.0.2)GO TO 450
      WRITE(6,13)R1
      WRITE(3,13)R1
13    FORMAT('  R1 = 'F10.7)
      GO TO 900
450   RA=(2*R1/(N*(N-1)*R2))*(N-1-(R1/R2)*(1.0-R1**(N-1)))
      WRITE(6,224)R1,RA
      WRITE(3,224)R1,RA
224   FORMAT(/3X'R1 = 'F10.7,3X'RA = 'F10.7/)
      IF(RA.GE.1.0)GO TO 900
      DO 200 I=1,NV
200   RPM(I)=RP(I)/((1.0-RA)**0.5)
      WRITE(6,18)(I,RP(I),RPM(I),I=1,NV)
18    FORMAT(3X'Sl.No.',3X,'Given return periods',3X,'Modified return
     1 periods'/3X'-----------------------------------------------------
     1------'/(3X,I5,10X,F10.1,10X,F10.1))
      GO TO 1
900   DO 2 I=1,NV
2     RPM(I)=RP(I)
      WRITE(6,901)
901   FORMAT(/'Test is not significant. Return periods not modified.')
1     RETURN
      END
C
      SUBROUTINE BKS(NK,A,CSK,AAVG,STD,AKUR,am5)
      DIMENSION A(80)
      SUM=0.0
      DO 200 I=1,NK
200   SUM=SUM+A(I)
      AAVG=SUM/NK
      SUM=0.0
      SU1=0.0
      SU2=0.0
      DO 210 I=1,NK
      AA=A(I)-AAVG
      AB=AA*AA
      SUM=SUM+AB
      SU1=SU1+AA*AB
      SU2=SU2+AB*AB
210   CONTINUE
      STD=SQRT(SUM/(NK-1))
      SKEW=(SU1*NK)/(NK-1)/(NK-2)
      CSK=SKEW/(STD**3)
      AKU=SU2*NK/(NK-1)*NK/(NK-2)/(NK-3)
```

```
      AKUR=AKU/(STD**4)
      U5=0
      DO 600 I=1,NK
600   U5=U5+(A(I)-AAVG)**5
      AM5=U5/(NK-1)*NK/(NK-2)*NK/(NK-3)*NK/(NK-4)
      AM5=AM5/(STD**5)
      RETURN
      END
C
      SUBROUTINE PLOT(NOY,NV,TITLE,TITLE3)
      COMMON/YY/X,Y,X1,Y1
      DIMENSION X(80),Y(80),X1(80),Y1(80),MP1(25),MP2(25)
      CHARACTER*50 TITLE,TITLE3, ANS*1
      CHARACTER*4 TMP1(13),TMP2(13)
      YMAX=Y(1)
      YMIN=Y(1)
      DO 30  I=1,NOY
      IF (YMAX.GE.Y(I)) GOTO 10
      YMAX=Y(I)
10    IF (YMIN.LE.Y(I)) GOTO 30
      YMIN=Y(I)
30    CONTINUE
      IF (YMIN.GE.0) THEN
      YYMIN=-YMAX/5
      ELSE
      YYMIN=YMIN+YMIN/5
      ENDIF
      IF (YMAX.LE.0) THEN
      YYMAX=-YMIN/5
      ELSE
      YYMAX=YMAX+YMAX/5
      ENDIF
      XXMAX=7.0
      XXMIN=-8.0
      K=0
      DO J=1,50,4
      K=K+1
      TMP1(K)=TITLE(J:(J+3))
      DECODE(4,100,TMP1(K)) MP1(K)
100   FORMAT(A4)
      ENDDO
      K=0
      DO J=1,50,4
      K=K+1
      TMP2(K)=TITLE3(J:(J+3))
      DECODE(4,100,TMP2(K))  MP2(K)
      ENDDO

      CALL GRSTRT(4027,1)
      CALL WINDOW(XXMIN,XXMAX,YYMIN,YYMAX)
```

```
      CALL VWPORT(XXMIN,XXMAX,YYMIN,YYMAX)
      CALL GRAIN(0.0)
      CALL TXAM
      CALL TXGAP(-99.0,-99.0)
      CALL NEWPAG
      CALL MOVE(-6.0,YYMAX)
      CALL LINCLR(1)
      CALL DRAW(-6.0,YYMIN)
      CALL TXTCLR(5)
      CALL MOVE(-8.0,0.0)
      CALL DRAW(7.0,0.0)
      IXDIV=-6
      DO 80 I=1,13
      DIV=IXDIV+I
      CALL MOVE(DIV,YYMAX/100.0)
      CALL DRAW(DIV,-YYMAX/100.0)
      IDIV=DIV
      CALL TXICUR(9)
      CALL INUMBR(IDIV,3)
80    CONTINUE
      YDIV=0
      DO 90 I=1,50
      R=I
      DIV=YDIV+R/5
      CALL MOVE(-5.90,DIV)
      CALL DRAW(-6.05,DIV)
      CALL MOVE(-6.10,DIV)
      CALL TXICUR(6)
      CALL RNUMBR(DIV,1,3)
90    CONTINUE
      CALL TXANGL(90.0)
      CALL TXICUR(5)
      CALL MOVE(-7.0,YYMAX/2)
      CALL TEXT(25,MP2)
      CALL TXANGL(.15)
      CALL TXICUR(2)
      CALL MOVE(2.0,YYMIN)
      CALL TEXT(28,'Reduced Variates ---------->')
      CALL TXICUR(7)
      CALL MOVE (-5.0,YYMAX*8/9)
      CALL TEXT(16,'TYPE OF METHOD: ')
      CALL TEXT(25,MP1)
      CALL TXTCLR(0)
      DO I=1,NOY
      CALL MOVE(X(I),Y(I))
      CALL TEXT(1,'*')
      ENDDO
      CALL TXTCLR(2)
      DO I=1,Nv
      CALL MOVE(X1(I),Y1(I))
```

```
      CALL TEXT(1,'.')
      ENDDO
110   CALL LINCLR(1)
      CALL SKIP
      CALL POLY(NV,X1,Y1)
160   FORMAT(I1)
      CALL GRSTOP
96    WRITE(6,95)
95    FORMAT(5X,' To continue press <RET>')
      READ *
      TYPE*,' !WOR 0'
      RETURN
      END
C
      SUBROUTINE POWER(N,X,AAL,ZZ,A3,VAR,S3,C3,AK3,AM3)
      DIMENSION X(80),Y(80),Z(80),AL(50),SK(80),ZZ(80)
      AL(1)=1.0
      AL(2)=-1.0
      DO 10 I=1,N
      Z(I)=((X(I)**AL(1))-1.0)/AL(1)
10    Y(I)=((X(I)**AL(2))-1.0)/AL(2)
      CALL BKS(N,Z,C1,A1,S1,AK1,AM1)
      CALL BKS(N,Y,C2,A2,S2,AK2,AM2)
      SK(1)=C1
      SK(2)=C2
      IC=3
40    DLAM=-SK(IC-1)*(AL(IC-1)-AL(IC-2))/(SK(IC-1)-SK(IC-2))
      AL(IC)=AL(IC-1)+DLAM
      DO 20 I=1,N
20    ZZ(I)=((X(I)**AL(IC))-1.0)/AL(IC)
      CALL BKS(N,ZZ,C3,A3,S3,AK3,AM3)
      SK(IC)=C3
      SS=ABS(SK(IC)-SK(IC-1))
      IF(SS.LE.0.001) GO TO 30
      IC=IC+1
      GO TO 40
30    CALL BKS(N,ZZ,C3,A3,S3,AK3,AM3)
      AAL=AL(IC)
      VAR=((S3**2)*(N-1))/N
      RETURN
      END

      SUBROUTINE OUTLIER(N,AT,BT,B,AL)
      DIMENSION BT(80),TQ(80),ZZ(80),PR(80),Y(80),D(80),P(80),R(80),
     1B(12,10),AT(80),IP(10),XX(10)
      NNN=N-4
      NN=N-1
      DO 915 K=1,NN
      JJ=N-K
      DO 915 L=1,JJ
```

```
      IF(BT(L).LE.BT(L+1))GO TO 915
      TEMP=BT(L)
      BT(L)=BT(L+1)
      BT(L+1)=TEMP
915   CONTINUE
      WRITE(6,911)
911   FORMAT(/3X,'Following five lowest and five highest values of'
     13X,'the series are suspected as outliers/inliers:-'//)
      WRITE(6,*)(BT(I),I=1,5),(BT(J),J=NNN,N)
      WRITE(6,912)
912   FORMAT(/3X,'These are being taken for modification.'/)
      DO 9112 I=1,5
9112  XX(I)=BT(I)
      IN=NNN
      DO 9913 I=6,10
      XX(I)=BT(IN)
      IN=IN+1
9913  CONTINUE
      DO 9915 I=1,10
      TA=XX(I)
      DO 9910 J=1,N
      IF(TA.EQ.AT(J))GO TO 9917
      GO TO 9910
9917  IP(I)=J
      GO TO 9915
9910  CONTINUE
9915  CONTINUE
      CALL POWER(N,BT,AL,TQ,AV,VR,SD,SKEW,AKURT,AMOM5)
      DO 20 I=1,N
      ZZ(I)=(TQ(I)-AV)/SD
      PR(I)=(I-0.375)/(N+0.25)
      PRI=PR(I)
      CALL NENOPROB(PRI,X)
      Y(I)=X
      D(I)=Y(I)-ZZ(I)
20    CONTINUE
      DO 50 M=1,12
      DO 61 J=1,5
      DO 61 I=1,5
      IF((M.EQ.2).OR.(M.EQ.4))GO TO 31
      IF((M.EQ.6).OR.(M.EQ.8))GO TO 31
      IF((M.EQ.10).OR.(M.EQ.12))GO TO 31
      IF(D(I).LE.B(M,J))D(I)=B(M,J)
      GO TO 41
31    IF(D(I).GE.B(M,J))D(I)=B(M,J)
41    D(I)=D(I)
      ZZ(I)=Y(I)-D(I)
      TQ(I)=(ZZ(I)*SD)+AV
      P(I)=((TQ(I)*AL)+1)**(1/AL)
      BT(I)=P(I)
```

```
61      CONTINUE
        DO 71 J=6,10
        DO 71 K=NNN,N
        IF((M.EQ.2).OR.(M.EQ.4))GO TO 81
        IF((M.EQ.6).OR.(M.EQ.8))GO TO 81
        IF((M.EQ.10).OR.(M.EQ.12))GO TO 81
        IF(D(K).LE.B(M,J))D(K)=B(M,J)
        GO TO 91
81      IF(D(K).GE.B(M,J))D(K)=B(M,J)
91      D(K)=D(K)
        ZZ(K)=Y(K)-D(K)
        TQ(K)=(ZZ(K)*SD)+AV
        R(K)=(TQ(K)*AL+1)**(1/AL)
        BT(K)=R(K)
71      CONTINUE
        CALL POWER(N,BT,AL,TQ,AV,VR,SD,SKEW,AKURT,AMOM5)
        DO 22 I=1,N
        ZZ(I)=(TQ(I)-AV)/SD
        PR(I)=(I-0.375)/(N+0.25)
        PP=PR(I)
        CALL NENOPROB(PP,YI)
        Y(I)=YI
        D(I)=Y(I)-ZZ(I)
22      CONTINUE
50      CONTINUE
        DO 9918 I=1,5
9918    XX(I)=BT(I)
        INN=NNN
        DO 9919 I=6,10
        XX(I)=BT(INN)
        INN=INN+1
9919    CONTINUE
        WRITE(6,9921)
        WRITE(3,9921)
9921    FORMAT(/3X,'Modified values of inliers/outliers are :-'/)
        WRITE(6,*)(XX(I),I=1,10)
        WRITE(3,*)(XX(I),I=1,10)
        DO 9920 K=1,10
9920    AT(IP(K))=XX(K)
        RETURN
        END

        SUBROUTINE PLOT1
        COMMON /SKJ/ N,Q(80),XXX,YYY
        DIMENSION XMIN(11),XMAX(12),IFREQ(12),RFREQ(12)
        DO 5 I=1,11
5       IFREQ(I)=0.0
        XMIN(1)=-1000
        XMAX(1)=0.0
        AA=100
```

```
      L=1
      DO 8 J=2,N
      IF(Q(J).LT.Q(L)) GOTO 8
      L=J
8     CONTINUE
      QMAX=Q(L)
      IF(QMAX.LE.1000) GOTO 10
      IF((QMAX.GT.1000).AND.(QMAX.LE.25000)) GOTO 11
      IF((QMAX.GT.25000).AND.(QMAX.LT.75000)) GOTO 12
      GOTO 13
10    DO 15 I=2,11
      XMAX(I)=AA*(I-1)
15    XMIN(I)=AA*(I-2)
      GOTO 13
11    AA=AA*25
      GOTO 10
12    AA=AA*75
      GOTO 10
13    DO 2 I=1,N
      DO 2 J=1,11
      IF((Q(I).LT.XMAX(J)).AND.(Q(I).GE.XMIN(J)))
      1IFREQ(J)=IFREQ(J)+1
2     CONTINUE
      DO 3 I=1,11
3     RFREQ(I)=IFREQ(I)/FLOAT(N)
      XXMAX=XMAX(11)+XMAX(11)/FLOAT(10)
      XXMIN=-XMAX(11)/FLOAT(10)
      YYMIN=-IFREQ(11)
      CALL GRSTRT(4027,1)
      CALL WINDOW(XXMIN,XXMAX,-10.0,60.0)
      CALL TXGAP(-99.0,-99.0)
      CALL MOVE(0.0,60.0)
      CALL DRAW(0.0,-10.0)
      CALL MOVE(XXMIN,0.0)
      CALL DRAW(XXMAX,0.0)
      CALL TXICUR(8)
      CALL TXAM
      DO I=1,11
      CALL MOVE(XMAX(I),0.5)
      CALL DRAW(XMAX(I),-0.5)
      CALL MOVE(XMAX(I),-.5)
      IF(XMAX(I).EQ.0.0) THEN
      IXX=0
      GOTO 55
      ELSE
      IXX=XMAX(I)/FLOAT(100)
      ENDIF
55    CALL INUMBR(IXX,3)
      ENDDO
      CALL MOVE(XXMAX/3,-7.0)
```

```
      CALL TEXT(18,'FLOW IN CUMECS -->')
      CALL TXICUR(2)
      DO I=1,11
      CALL MOVE(XMAX(I),0.0)
      FREQ=IFREQ(I)
      CALL DRAW(XMAX(I),FREQ)
      CALL DRAW(XMAX(I+1),FREQ)
      CALL DRAW(XMAX(I+1),0.0)
      CALL MOVE((XMAX(I)+XMAX(I+1))/2,FREQ+2)
      IF(I.EQ.11) GO TO 65
      CALL INUMBR(IFREQ(I),3)
      CALL MOVE(XMAX(I+1),0.0)
      ENDDO
      call txicur(5)
65    call txangl(90.0)
      call move(xxmin/2,30.0)
      call text(14,'FREQUENCIES-->')
      CALL GRSTOP
      TYPE *,' Hit <RET> to continue'
      READ *
      TYPE *,'!WOR 0'
      RETURN
      end

      SUBROUTINE PLOT2(IYEAR)
      COMMON /SKJ/ N,Q(80),XXX,YYY
      DIMENSION  IYEAR(80)
      XMAX=IYEAR(1)
      XMIN=IYEAR(1)
      YMAX=Q(1)
      DO 40 I=1,N
10    IF (XMAX.GE.IYEAR(I)) GOTO 20
      XMAX=IYEAR(I)
20    IF(YMAX.GE.Q(I))  GOTO 30
      YMAX=Q(I)
30    IF(XMIN.LE.IYEAR(I)) GO TO 40
      XMIN=IYEAR(I)
40    CONTINUE
      DIFF=IYEAR(2)-IYEAR(1)
      XXMAX=DIFF*(N+4)
      YYMAX=YMAX+YMAX/FLOAT(5)
      XXMIN=-XXMAX/FLOAT(10)
      YYMIn=-YYMAX/FLOAT(10)
      CALL GRSTRT(4027,1)
      CALL WINDOW(XXMIN,XXMAX,YYMIN,YYMAX)
      CALL TXICUR(5)
      CALL TXAM
      CALL MOVE(0.0,YYMAX)
      CALL DRAW(0.0,YYMIN)
      CALL MOVE(XXMIN,0.0)
```

```
CALL DRAW(XXMAX,0.0)
CALL TXGAP(-99.0,-99.0)
CALL MOVE(XXMAX/2,YYMIN)
CALL TXICUR(2)
CALL TEXT(10,'YEARS --->')
CALL TXICUR(5)
DO  KK=1,N,10
CALL MOVE(DIFF*KK,0.0)
CALL DRAW(DIFF*KK,YYMIN/FLOAT(4))
CALL MOVE(DIFF*KK,yymin/2)
CALL INUMBr(Iyear(kk),4)
ENDDO
CALL TXANGL(90.)
DO  Kk=1,N
CALL MOVE(DIFF*KK,0.0)
CALL DRAW(DIFF*KK,Q(KK))
CALL MOVE(DIFF*KK,Q(KK)+Q(KK)/FLOAT(20))
IQ=Q(KK)/FLOAT(100)
CALL INUMBR(iq,5)
ENDDO
CALL TXICUR(5)
CALL MOVE(XXMIN/2,YYMAX/2)
CALL TEXT(23,'FLOW IN 100 CUMECS --->')
CALL GRSTOP
TYPE *,' Hit <RET> to continue'
READ *
TYPE *,'!WOR 0'
RETURN
END
```

APPENDIX-C SAMPLE OUTPUT FILE (OUTPUT.DAT)

Number of data sets input = 60

Year	ANNUAL FLOOD (Cumecs)
1915	19900.00
1916	10400.00
1917	10700.00
1918	20100.00
1919	8210.00
1920	14300.00
1921	8040.00
1922	8210.00
1923	13900.00
1924	8390.00
1925	18500.00
1926	13000.00
1927	16400.00
1928	14500.00
1929	13000.00
1930	17200.00
1931	13900.00
1932	11900.00
1933	13600.00
1934	12400.00
1935	18300.00
1936	12900.00
1937	18200.00
1938	9900.00
1939	10200.00
1940	9020.00
1941	11800.00
1942	16100.00
1943	16900.00
1944	11800.00
1945	13900.00
1946	12300.00
1947	15100.00
1948	11900.00
1949	11000.00
1950	16000.00
1951	11600.00
1952	19900.00
1953	18600.00
1954	18000.00
1955	13100.00
1956	29100.00
1957	10300.00
1958	12200.00
1959	15600.00
1960	12700.00
1961	13100.00
1962	19200.00
1963	19500.00

1964	23000.00
1965	6700.00
1966	7130.00
1967	14300.00
1968	20600.00
1969	25600.00
1970	8180.00
1971	34400.00
1972	16100.00
1973	10200.00
1974	12300.00

Modified values of inliers/outliers are :-

4959.664	6065.614	6946.141	7265.872	7698.670
21607.42	23000.04	23939.78	26117.64	29396.80

MEAN	=	14554.6670
VARIANCE	=	27320380.0000
STANDARD DEVIATION	=	5226.8901
SKEWNESS COEFF	=	1.3557
COEFF OF KURTOSIS	=	6.0458
COEFF OF VARIATION	=	0.3591
STANDARD ERROR OF MEAN	=	674.788574
STANDARD ERROR OF STANDARD DEVIATION	=	735.880066

Estimates of statistical parameters of the
NATURAL-LOG TRANSFORMED annual flood peak series

MEAN	=	9.5285
VARIANCE	=	0.1138
STANDARD DEVIATION	=	0.3374
SKEWNESS COEFF	=	0.1962
COEFF OF KURTOSIS	=	3.2592
COEFF OF VARIATION	=	0.0354
STANDARD ERROR OF MEAN	=	0.043559
STANDARD ERROR OF STANDARD DEVIATION	=	0.031242

For pre-assigned values of return periods

SERIAL NO	RETURN PERIOD (Years)	NON-EXCEEDANCE PROBABILITY	EXCEEDANCE PROBABILITY
1	2.00	0.500000	0.500000
2	5.00	0.800000	0.200000
3	10.00	0.900000	0.100000
4	25.00	0.960000	0.040000
5	50.00	0.980000	0.020000
6	100.00	0.990000	0.010000
7	500.00	0.998000	0.002000
8	1000.00	0.999000	0.001000

The estimates of peak flows for different return periods by different probability models follow

Quantile estimates using NORMAL distribution (Method of Moments)

ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001

SERIAL NO.	RETURN PERIOD (Years)	FREQUENCY FACTOR	COMPUTED PEAKFLOW (Cumecs)	STANDARD ERROR (Cumecs)	95% CONFINED BAND LOWER (Cumecs)	UPPER (Cumecs)
1	2.	0.0000	14555.	675.	13204.	15906.
2	5.	0.8419	18955.	785.	17383.	20527.
3	10.	1.2818	21255.	911.	19431.	23078.
4	25.	1.7512	23708.	1074.	21558.	25858.
5	50.	2.0543	25293.	1190.	22910.	27675.
6	100.	2.3269	26717.	1299.	24116.	29318.
7	500.	2.8833	29626.	1532.	26558.	32693.
8	1000.	3.1000	30758.	1626.	27503.	34013.

Quantile estimates using LOG-NORMAL distribution (Method of Moments)

ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001

SERIAL NO.	RETURN PERIOD (Years)	FREQUENCY FACTOR	COMPUTED PEAKFLOW (Cumecs)	STANDARD ERROR (Cumecs)	95% CONFINED BAND LOWER (Cumecs)	UPPER (Cumecs)
1	2.	0.0000	13746.	599.	12546.	14945.
2	5.	0.8419	18261.	926.	16407.	20115.
3	10.	1.2818	21183.	1246.	18689.	23678.
4	25.	1.7512	24818.	1722.	21371.	28266.
5	50.	2.0543	27491.	2114.	23259.	31724.
6	100.	2.3269	30139.	2531.	25073.	35206.
7	500.	2.8833	36364.	3603.	29151.	43577.
8	1000.	3.1000	39122.	4113.	30886.	47357.

Estimates of peak flood using EV-1 distribution (Method of Moments)

ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001

SERIAL NO.	RETURN PERIOD (Years)	FREQUENCY FACTOR	COMPUTED PEAKFLOW (Cumecs)	STANDARD ERROR (Cumecs)	95% CONFINED BAND LOWER (Cumecs)	UPPER (Cumecs)
1	2.	-0.1643	13696.	608.	12479.	14913.
2	5.	0.7195	18315.	1094.	16125.	20506.
3	10.	1.3046	21374.	1496.	18378.	24369.
4	25.	2.0439	25238.	2029.	21176.	29300.
5	50.	2.5924	28105.	2432.	23235.	32974.
6	100.	3.1368	30950.	2836.	25272.	36629.
7	500.	4.3949	37526.	3777.	29965.	45087.
8	1000.	4.9357	40353.	4183.	31979.	48727.

Estimates of peak flood using EV-1 distribution (Method of Maximum likelihood)

ALPHA = 0.0003 MEAN = 14509.88

BETA = 12269.5635 STND DV = 4978.48

ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001

SERIAL NO.	RETURN PERIOD (Years)	FREQUENCY FACTOR	COMPUTED PEAKFLOW (Cumecs)	STANDARD ERROR (Cumecs)	95% CONFINED BAND LOWER (Cumecs)	UPPER (Cumecs)
1	2.	0.3665	136[illegible].	588.	12514.	14870.
2	5.	1.4999	18092.	903.	16284.	19900.
3	10.	2.2504	21005.	1158.	18686.	23325.
4	25.	3.1985	24686.	1301.	21681.	27691.
5	50.	3.9019	27416.	1763.	23888.	30945.
6	100.	4.6002	30127.	2026.	26071.	34182.
7	500.	6.2136	36390.	2641.	31102.	41678.
8	1000.	6.9073	39083.	2908.	33261.	44904.

Estimates of peak flood using LOG-PEARSON III distribution (3-PARAMETER)

ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001

SERIAL NO.	RETURN PERIOD (Years)	FREQUENCY FACTOR	COMPUTED PEAKFLOW (Cumecs)	STANDARD ERROR (Cumecs)	95% CONFINED BAND LOWER (Cumecs)	UPPER (Cumecs)
1	2.	-0.0327	13595.	641.	12311.	14879.
2	5.	0.8308	18193.	975.	16241.	20145.
3	10.	1.3008	21320.	1391.	18535.	24104.
4	25.	1.8169	25374.	2234.	20902.	29847.
5	50.	2.1582	28472.	3098.	22268.	34675.
6	100.	2.4706	31637.	4161.	23307.	39967.
7	500.	3.1246	39448.	7472.	24488.	54408.
8	1000.	3.3852	43073.	9312.	24429.	61717.

Frequency analysis by POWER TRANSFORMATION method.

Values of LAMDA = -0.19403985

Skewness of the transformed series = -0.00009051

For the power transformed series :
AVERAGE = 4.340634
STND DEV = 0.052948
VARIANCE = 0.002757
SKEWNESS = -0.000091
KURTOSIS = 3.120473
5TH MOMENT = 0.613147

STANDARD ERROR OF MEAN = 0.006836
STANDARD ERROR OF STANDARD DEVIATION = 0.004834
STANDARD ERROR OF SKEWNESS COEFFICIENT = 0.308694

ST. MARYS RIVER AT STILLWATER-STATION NO. 01E0001

SERIAL NO.	RETURN PERIOD (Years)	FREQUENCY FACTOR	COMPUTED PEAKFLOW (Cumecs)	STANDARD ERROR (Cumecs)	95% CONFINED BAND LOWER (Cumecs)	UPPER (Cumecs)
1	2.	0.0000	13598.	1243.	12477.	14841.
2	5.	0.8419	18184.	2073.	16360.	20257.
3	10.	1.2818	21311.	2943.	18784.	24254.
4	25.	1.7512	25382.	4353.	21769.	29735.
5	50.	2.0343	28508.	5614.	23963.	34122.
6	100.	2.3269	31719.	7052.	26146.	38771.
7	500.	2.8833	39722.	11204.	31339.	50926.
8	1000.	3.1000	43477.	13409.	33675.	56886.

APPENDIX - D   DATA FILE FOR OUTLIER/INLIER ANALYSIS (OUTL.DAT)

.010	-.689	-.495	-.412	-.363	-.327	-.376	-.428	-.510	-.654	-1.053
.99	1.029	.643	.497	.418	.368	.323	.358	.407	.488	.678
.05,	-.532	-.369	-.303	-.264	-.237	-.256	-.290	-.341	-.432	-.683
.95,	.680	.430	.336	.285	.253	.234	.262	.300	.368	.528
.10,	-.441	-.299	-.242	-.210	-.188	-.195	-.220	-.258	-.322	-.500
.90,	.503	.321	.254	.217	.193	.186	.208	.241	.298	.437
.20,	-.318	-.209	-.167	-.143	-.127	-.123	-.138	-.161	-.199	-.295
.80,	.296	.197	.158	.136	.122	.126	.142	.166	.208	.316
.30,	-.221	-.140	-.110	-.093	-.081	-.073	-.081	-.094	-.112	-.151
.70,	.160	.112	.092	.080	.073	.081	.093	.109	.140	.221
.40,	-.131	-.079	-.059	-.050	-.043	-.032	-.034	-.038	-.042	-.051
.60,	.051	.042	.037	.033	.031	.043	.049	.059	.079	.132