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Frequency and Magnitudes of Monthly and Annual Flow Rates (As Determined By (a) A Normal Distribution (b) By Ranking (c) A Gamma Distribution And (d) By A Log Normal Distribution)

Roland W. Jeppson

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FREQUENCY AND MAGNITUDES OF MONTHLY AND ANNUAL FLOW RATES

As Determined By (a) A Normal Distribution
(b) By Ranking (c) A Gamma Distribution And
(d) By A Log Normal Distribution

A Computer Program of Generalized Use

by

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BACKGROUND OF PROGRAM

In developing a water resources atlas for the State of Utah it was necessary to determine the characteristics of stream flows within the State. The variations of stream flow for any given month from year to year as well as the variations from month to month throughout the year are important characteristics which were determined by analyzing the streamflow records to determine their probability distributions. The program which is described in the following pages was written to determine the monthly as well as annual runoff amounts which might be expected for any number of specified levels of probability.

Since all streamflow data does not follow the same distribution function, the program has been designed to fit the data to any or all of the following four distribution functions which are commonly used.

1. The normal distribution; 2. The distribution actually obtained from the data by ranking it from high to low; 3. The gamma distribution; and 4. The long-normal distribution.

The program has been written specifically to determine the monthly and annual runoff volumes in ac-ft and also in inches over the watershed. The program could, however, serve equally well for determining monthly and annual amounts of other quantities at specified levels of probabilities after very minor modifications.
Normal probability

The common bell shaped normal probability curve has the equation
\[ y = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{1}{2} \left( \frac{x - \mu}{\sigma} \right)^2}, \quad -\infty < x < \infty \quad \ldots \quad (1) \]

Under the assumption that the data follows a normal distribution, an estimate, \( \bar{x} \), of the mean \( \mu \) is the average of the observed data, and an estimate, \( s \), of the standard deviation, \( \sigma \), and the coefficient of skewness, \( g \), are given respectively by
\[
s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}} \quad g = \frac{n \sum_{i=1}^{n} (x_i - \bar{x})^3}{(n-1)(n-2)s^3} \quad \ldots \quad \ldots \quad (2) \]

where \( n \) is the number of observations.

The probability that the value of \( x \) will be equal to or less than a given specified amount is the area under the density function (1) to the left of that value of \( x \) and equals the integral of (1) from \( -\infty \) to the value. Since (1) requires a numerical integration, and because small data samples are used to estimate the parameters, \( \mu \) and \( \sigma \),
values of $x$ at specified levels of probable occurrence are commonly determined by

$$x = \bar{x} \pm st$$ \hspace{1in} (4)

where the values of $t$ are obtained from a table for the specified value of probability and the value of $n-1$ (degrees of freedom). The $t$ table is used because the statistic, $t = \frac{x - \bar{x}}{s}$, calculated from a sample of size $n$ from a normal distribution follows a $t$ distribution with $n-1$ degrees of freedom.

**Ranked distribution**

By listing data in order of its magnitude (either from high to low or from low to high) a data series or frequency series is obtained. By assuming that the record is representative of future events, the probability, $p$, of any event being equaled or exceeded, in this frequency series can be obtained by

$$p = \frac{m}{n+1}$$ \hspace{1in} (5)

where $m$ is the rank number, and $n$ is the total number of data points in the series. The curve obtained by plotting the probability against the magnitude of the event is the accumulated distribution curve of the actual data. The derivative would represent the actual density function of the data just as (1) represents the density function assuming a normal distribution.
Gamma distribution

The gamma distribution involves two parameters $r$ and $\lambda$ and the density function is defined by (see Parzen).

$$f(x) = \frac{\lambda}{\Gamma(r)} (\lambda x)^{r-1} e^{-\lambda x} \quad 0 < x < \infty$$

$$r > 0$$

$$\lambda > 0$$

The parameters $\lambda$ and $r$ can be estimated by noting that

$$\mu = \frac{r}{\lambda} \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad (7)$$

$$\sigma^2 = \frac{r}{\lambda^2} \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad (8)$$

giving the estimating equations $x = \frac{\bar{x}}{s^2}$ and $r = \frac{\bar{x}^2}{s^2}$. The gamma function $\Gamma(r)$ can be obtained by several relationships and/or from tables. In general, however, $\Gamma(r)$ can be calculated from the product power expansion

$$\Gamma(r) = \frac{1}{r} \prod_{k=1}^{\infty} \left( \frac{1 + \frac{1}{k}}{1 + \frac{r}{k}} \right)^r \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad (9)$$

Because of the slow converges of this product series, a numerical procedure by Davis has been used in the program to compute $\Gamma(r)$ for $r$ less than 2. For values of $r$ greater than or equal to 2, $\Gamma(r)$ is obtained by $\Gamma(r) = (r-1)(r-2)(r-3)\cdots(r-T_r) \Gamma(T_r)$ where

---


$T_r = r - [r-1]$, \([r-1]\) being the truncated value of the quantity, and 
$p(T_r)$ is obtained by the numerical procedure.

The gamma distribution is more versatile than the normal distribution and in many respects is more realistic for events such as rainfall and runoff, that have only positive values. Consequently, among others the gamma distribution (and also the incomplete gamma function, see Barger and Thom\(^3\)) have found wide application in predicting rainfall probabilities.

**Log-normal distribution**

The log-normal distribution is obtained by the transformation

\[ y = \ln x \]

and by assuming that the transformed data follow a normal distribution. Consequently, the procedures for determining a log-normal distribution are first to take the logarithm of the original data and thereafter follow the procedures used to fit a normal distribution to the data. Finally, the expected magnitudes at the specified probabilities are obtained as the antilogarithms. If logarithms to the base \(e\) are used, this last step can be accomplished by

\[ x = e^y \]  

(10)

where \( y \) is the magnitude obtained by eq. (4) using the transformed data.

---

FORTRAN IV PROGRAM

The program is designed to determine the expected runoff for each month in the year as well as the annual for the specified levels of probability, by any or all of the four distributions methods discussed earlier. The program assumes that the annual as well as the twelve monthly values are contained on the data cards. By a slight modification to the program the annual runoff could be computed.

After computing and printing the pertinent parameters for the distribution, the program prints the values of the runoff at each of the specified probability levels in units of ac-ft and also in terms of inches over the watershed contributing to the measured flow (see page 18 for sample of output). A listing of the FORTRAN IV program along with a description of the variable names used in the program is given beginning on page 11.
INPUT DATA REQUIRED BY PROGRAM

The proper order of the data cards required by the program are shown in figure 1. The first data card contains the number of probability levels and the percentage levels for which the runoff values are to be determined. (If the normal or log-normal distributions are called for, the number must be odd and the probability levels symmetric about the 50 percent level.) The next group of data cards contains the values from a t-table. The number of these cards equals the truncated number obtained by dividing the number of probability levels by two. Each of these cards in consecutive order contains the t-value for the specified probability levels working from the extremes toward the 50 percent level for 5, 10, 15, 20, 25, 30 and 60 degrees of freedom respectively. The next data card contains the FORMAT which is to be used to read the monthly and annual values of runoff, and the following card contains the name of the stream gaging station. The final card preceding the data is the control card. The number of the basin is in columns 1 and 2 (i.e. the first two digits of the USGS number). The station number is in columns 7 through 10 (i.e. the last four digits of the USGS number). The last two digits of the beginning year of record are in columns 14 and 15, and the final year of record in columns 19 and 20. In columns 21 through 30 the area (in square miles) of the watershed should be punched with the decimal point in column 25. The values punched in columns 35, 40, 45, 50, and 55 respectively determine whether the original data is listed, whether a normal distribution, ranking, a gamma distribution and/or a log normal distribution are to be used. If the distribution analysis is not wanted a zero should be given to the respective control parameter. If several stations of data are to be processed during the same access to the computer only the last two
of these cards should be placed before the data for subsequent stations.

A 99 in columns 4 and 5 on the two final cards terminates execution.

Figure 1. Sample of input control cards.
LIST OF VARIABLE NAMES

CK       an array of numbers supplied by a data statement which are 
          used to numerically approximate the gamma function.
RPIE     parameter used in computing gamma function.
GAMMA1   parameter used in computing gamma function.
FMT      an array which stores the FORMAT which is read in at 
          execution time.
NAME     an array used to store the name of the station being processed.
R        a two dimensional array used to store the monthly run data.
AV       an array used to store the average values of runoff for each 
          month.
STD      an array used to store the standard deviation of runoff for 
          each month.
SKEW     an array used to store the coefficient of skewness of runoff 
          for each month.
P        an array containing the desired levels of probability.
T        a two dimensional containing the values from a t-table.
RUN      a two dimensional array used to store data for convenience 
          in output.
RUN1     an array used to store data for convenience in output.
PLEV     an array used to store the probability level of ranked data, 
          and also intermediate probability level from the gamma 
          distribution.
XR       a two dimensional array used to store runoff values for 
          convenience in output.
FXR      a two dimensional array used to store density function values 
          for convenience in output.
AMBA     an array used to store the values of the \( \lambda \) parameter of the 
          gamma distribution.
GAMMA  an array used to store the values of the gamma function.

RPAR  an array used to store the values of r parameter of the gamma distribution.

NPRB  the number of probability levels.

NPH  the number of probability levels on each side of 50 percent.

NB  the basin number.

NSTA  the station number.

NYRB  the beginning year of the data.

NYRE  the ending year of the data.

AREA  the area of the watershed drainage area in square miles.

NPRINT  Controls output--if equal to zero original data is not printed.

LNOR  if equal to zero log normal distribution analysis is not performed.

NGAMMA  if equal to zero gamma distribution analysis is not performed.

NRANK  if equal to zero rank distribution analysis is not performed.

NORMAL  if equal to zero normal distribution analysis is not performed.

NN & FN  number of years of record.

RLANGR  a function subroutine used for Lagrange's interpolation or extrapolation based on a second degree polynomial.

Note: The additional variables used in the program used for convenience in computation and are defined in the FORTRAN statements in which they appear.
LISTING OF SOURCE PROGRAM

C C

DOUBLE PRECISION CK(26),KPI,GAMMA1,AMBAX

REAL FMT(17),NAME(12)
REAL R(6,13),AV(13),STD(13),SKEW(13),P(11),T(5,7),RUN(13,5)
3RUN(13,5),PELV(67),X2(10,13),FRT(10,13),AMBA(13),GAMMA(13),RPAR(13)

COMPUTES THE DATA NEEDED TO PLOT THE BAR GRAPHS OF MONTHLY RUNOFF

DATA (CK(I),I=1,26)/1.0,5777156549015329,-6558780715202538,
$-0.042002635304052,1.166386113822915,-0.0421977345555443,
$0.0096219715278770,-0.0071269432466863,-0.0011651675918591,-0.00215241
$0.67411499,-0.001280652823882,-0.00001234134578079,-0.000012504394821,
$1.1330272320E=6,-2.056338417E=-7,6.116095E=-9,5.02007E=-9,
$1.1812746E=-9,1.043427E=-10,7.7823E=-12,-3.6968E=-12,5.1E=-13,
$3.06E=-14,-5.4E=-15,1.4E=-15,1.0E=-16
READ (5,100) NPH,NPRB,(P(1),I=1,NPRB)

10 DO 10 I=1,NPH
10 READ(5,127) (T(I,J),J=1,7)
127 FORMAT(I7,I0,5T)
110 FORMAT(15,11F5.1)

100 READ(5,100) FMT(I),I=1,12

99 READ(5,100) (NAME(I),I=1,12)

59 READ(5,100) (NAME(I),I=1,12)

READ(5,101) NB,NSTA,NYRB,NYRE,AREA,NPRINT,NORMAL,LRANK,NGAMMA,LNOR

101 FORMAT(15,F10.2,5F15)

IF(NB .EQ. 99) GO TO 99

CONV=0.01875/AREA

NYRBM=NYRB-1

NN=NYRE-NYRB+1

NN5=NN/5

FN=NN

FN1=FN-1.0

FN2=FN-2.0

4 DO 4 J=1,13

4 AV(J)=0.0

IF(NPRINT .EQ. 0) GO TO 2

WRITE(6,103) NB,NSTA,(NAME(I),I=1,12)

WRITE(6,104)

104 FORMAT(1H,129)

MARCH APRIL MAY JUNE JULY AUG. SE

$FT" ANNUAL"

2 DO 1 I=1,NN

READ(5,FMT) IT,(R(I,J),J=1,13)

1 IF(NPRINT .GT. 0) WRITE(6,102) IT,(R(I,J),J=1,13)

10 DO 1 J=1,13

1 AV(J)=AV(J)+R(I,J)

103 FORMAT(1H,25)

DATA FOR STATION,13,1H=14,12A6)

102 FORMAT(1H,14)

4F9.0,9F10.0

IF(NORMAL .EQ. 0) GO TO 48

WRITE(6,153)

153 FORMAT(1H,30)

BASED ON A NORMAL DISTRIBUTION

DO 5 J=1,13

5 AV(J)=AV(J)/FN

WRITE(6,132) NB,NSTA,(NAME(I),I=1,12)

132 FORMAT(1H,44)

STD. DEV. AND COEF. OF SKEW. FOR STATION,13,1H=

$14,12A6)
WRITE (6, 104)
WRITE (6, 124) (AV(J), J=1,13)
124 FORMAT (1H, 4H HAVE ..., 4F9.0, 9F10.0)
DO 6 J=1,13
SX2=0.0
SX3=0.0
AVE=AV(J)
6 FORMAT (1H, 5=1,13)
SX=R(1,J)-AVE
SX=X*5
SX2=SX2+SXX
7 SX3=SX3+SX*5X
VAR=SX2/FN1
STD(J)=SORT(VAR)
6 SKEW(J)=FN*SX3/(FN1*FN2*VAR*STD(J))
WRITE (6, 105) (STD(J), J=1,13)
105 FORMAT (1H, 4H STD ..., 4F9.0, 9F10.0)
WRITE (6, 106) (SKEW(J), J=1,13)
106 FORMAT (1H, 4H SKEW ..., 4F9.0, 9F10.0)
WRITE (6, 108) NB, NSTA
108 FORMAT (1H0, 65HTABLE OF RUNOFF VALUES AT INDICATED PROBABILITY LEVEL
$ FOR STATION ..., 13=1,14)
WRITE (6, 109)
109 FORMAT (1H, 12H PROB LEVEL OCT., NOV., DEC., JAN., FEB.,
$ MARCH, APRIL, MAY, JUNE, JULY, AUG., SEPT.
$ ANNUAL)
IF (NN5 .GT. 0) GO TO 9
WRITE (6, 107) NN
107 FORMAT (1H, 15, 56H LESS THAN 5 YEARS OF RECORD, SO LEVELS ARE NOT DETERMINED)
GO TO 11
9 IF (NN5 .GT. 7) NN5=7
DO 8 1=1,NPH
FAC=T(1,NN5)
DO 12 J=1,13
FACD=FAC*STD(J)
RUN1(J)=AV(J)+FACD
12 RUN(J)=AV(J)+FACD
WRITE (6, 111) P(I), (RUN1(J), J=1,13)
DO 23 J=1,13
23 RUN1(J)=CONV*RUN1(J)
8 WRITE (6, 112) (RUN1(J), J=1,13)
112 FORMAT (1H, 4H IN ..., 4F9.3, 9F10.3)
111 FORMAT (1H, 4F9.0, 9F10.0)
WRITE (6, 111) P(NPH), (AV(J), J=1,13)
DO 51 J=1,13
51 RUN1(J)=CONV*AV(J)
WRITE (6, 112) (RUN1(J), J=1,13)
DO 13 I=1,NPH
13 WRITE (6, 111) P(I), (RUN(J,IM), J=1,13)
DO 24 J=1,13
24 IF (LRANK .EQ. 0) GO TO 47
11 DO 22 J=1,13
M=NN

14 M=M/2
IF (M) 22+22+16

16 K=NN-M
JJ=1

17 J=JJ
18 L=1+M
IF (R(L,J)-R(1,J)) 21*21+20

20 B=R(1,J)
R(L,J)=B
T=1-M
IF (I-1) 21*18+18

21*JJ=JJ+1
IF (JJ=K) 17*17+14

22 CONTINUE
WRITE (6, 154)

154 FORMAT (HO, 73IH PROBABILITIES BASED ON RANKING)
WRITE (6, 113) NB, NSTA, (NAME(I), I=1,12)

II3 FORMAT (HO, 75H RANKED VALUES OF RUNOFF FOR STATION, I3, I1H-1, I4, I2A6)
WRITE (6, 109)

113 FNP=JN*JN+1.0
DO 26 I=1,NN
PLEV(I)=FNP*FLOAT(I)

25 WRITE (6, 142) PLEV(I), (R(I,J), J=1,13)

142 FORMAT (HO, 75H RANKED VALUES OF RUNOFF FOR STATION, I3, I1H-1, I4, I2A6)
WRITE (6, 109)

42 IF (NGamma .EQ. 0) GO TO 401

J=J+1
GO TO 27

26 PI=PLEV(J-1)
P2=PLEV(J)
P3=PLEV(J+1)
DO 29 K=1,13

29 RUN1(K)=LANGR(PO+PI, P2, P3, R(J-1,K), R(J,K), R(J+1,K))
WRITE (6, 111) PO, (RUN1(K), K=1,13)
DO 30 K=1,13

30 RUNI(K)=CONV*RUN1(K)
WRITE (6, 112) (RUN1(K), K=1,13)

47 IF (NGamma .EQ. 0) GO TO 247

486 FORMAT (HO, 79H STATION, I2, I1H-1, I4, I16H NAME OF STATION, I2A6)
WRITE (6, 421)

421 FORMAT (HO, 82H RUNOFF IN AC-FT AND INCHES FOR GIVEN PROBABILITY LEVELS USING A GAMMA DISTRIBUTION)
WRITE (6, 420) (PI, I=1,NPRB)

420 FORMAT (1H, 5HPRUB, F10.2, 4F12.2, 6F11.2)
WRITE (6, 422)

422 FORMAT (1H, 5HMONTH)
DO 400 J=1,13
IF (LRANK .EQ. 0) GO TO 401
RMINI=R1(N+J)
RMAXI=R1(J)
GO TO 402

401 RMINI=R1(J)
RMAXI=R1(J)
DO 403 I=2,NN
IF(R1(J),G1, RMAXI) RMAXI=R1(J)
403 IF(R1(J),L1, RMINI) RMINI=R1(J)
402 IF (NORMAL G1, 0) GO TO 404

AV(J)=R1(J)
SX2=AV(J)*AV(J)
DO 405 I=2,NN
AV(J)=AV(J)+R1(J)
405 SX2=5X2+R1(J)*R1(J)
AVE=AV(J)/F
VAR=(5X2-AVE*AV(J))/(FN-1.0)
AV(J)=AVE
GO TO 410

404 VAR=STD(J)*STD(J)
410 RINIC=RMINI-2.* (AV(J)-RMINI)/FN
IF (RINIC L1, 0.0) RINIC=0.0
AVE=AV(J)-RINIC
AMBA(J)=AVE/VAR
RPAR(J)=AVE*AMBA(J)
RBEGG=RMINI-RINIC
IF(RPAR(J) GT 1.0) GO TO #73
RPAR(J)=1.0
AMBA(J)=1.0/AVE
473 RPAR1=RPAR(J)-1.0
NRDIF=RPAR(J)-1.0
RRPR=RPAR(J)-FLOAT(NRDIF)
RPIE=1.0
GAMMA1=0.0
DO 415 I=1,26
RPIE=RPIE*RRPR
415 GAMMA1=GAMMA1+CD(1) RPIE
GAMMA1=1.0/GAMMA1
IF (NRDIF .LE. 0.0) GO TO 407
DO 416 I=1,NRDIF
416 GAMMA1=GAMMA1*(FLCAT(NRDIF-1)+RRPR)

407 GAMMA(J)=GAMMA1
RPIE=AMBA(J)
GAMMA1=DLOG(RPIE/GAMMA1)
RDIF=(RMAXI-RMINI)/9.
C 407 RDIF=(RMAXI-RMINI)/9.
DO 408 I=1,10
XR(1,J)=RBEGG+FLOAT(1-1)*RDIF
AMBA=RDIF*XR(1,J)
RPE=GAMMA1+RPAR1*DLOG(AMBA)-AMBA
408 FXR(1,J)=EXP(RPE)
PLEV(1)=0.0
RDIF1=54.166667*RDIF
RDIF2=4.166667*RDIF
XR1=XR(1,J)*XR(1,J)
XR2=XR(2,J)*XR(2,J)
DEN=XR1*XR(2,J)-XR(1,J)*XR2
ACOEF=(FXR(1,J)*XR(2,J)-FXR(2,J)*XR(1,J))/DEN
5X3=0,0
AVE=AV(J)
DO 34 I=1,NPH
Sx=R(I,J)-AVE
SXX=Sx*5X
Sx2=Sx2+5XX
Sx3=Sx3+5X*SXX
VAR=Sx2/FN1
STD(J)=SRT(VAR)
SKLW(J)=XI*5X3/(FN1*FN2*VAR*SID(J))

33 CONTINUE
WRITE(6,115) NB,NSTA
115 FORMAT(10H0,12x'THE FOLLOWING IS OBTAINED ASSUMING A LOG-NORMAL DIST

$RIBUTION FOR STATION 13,1H-14')
WRITE(6,134) (AV(J),J=1,13)
134 FORMAT(1H+4H AVE,A5,9F9.4,9F10.4)
WRITE(6,135) (STD(J),J=1,13)
135 FORMAT(1H+4HSTD,A5,4F9.4,9F10.4)
WRITE(6,108) NB,NSTA

136 FORMAT(1H+4HSK,4F9.4,9F10.5)
WRITE(6,109)
DO 35 I=1,NPH
FAC=T(I*NN5)
35 CONTINUE
331 FACD=FAC*STD(J)
RUN1(J)=EXP(AV(J)+FACD)
WRITE(6,111) P(I),(RUN1(J),J=1,13)
36 CONTINUE
37 RUN1(J)=CONV*RUN1(J)
WRITE(6,112) (RUN1(J),J=1,13)
38 CONTINUE
39 RUN1(J)=CONV*RUN1(J)
WRITE(6,111) P(NPH1),(RUN1(J),J=1,13)
39 CONTINUE
40 RUN1(J)=CONV*RUN1(J)
WRITE(6,112) (RUN1(J),J=1,13)
41 RUN(J,IN)=CONV*RUN(J,IN)
40 WRITE(6,112) (RUN(J,IN),J=1,13)
GO TO 50
99 STOP
END

FUNCTION RLANGR(PG,PI,P2,P3,R1,R2,R3)
A1=(PO-P2)*(PO-P3)*R1/(P1-P2)*(P1-P3)
A2=(PO-P1)*(PO-P3)*R2/(P2-P1)*(P2-P3)
A3=(PO-P1)*(PO-P2)*R3/(P3-P1)*(P3-P2)
RLANGR=A1+A2+A3
RETURN
END
<table>
<thead>
<tr>
<th>YEAR</th>
<th>OCT.</th>
<th>NOV.</th>
<th>DEC.</th>
<th>JAN.</th>
<th>FEB.</th>
<th>MARCH</th>
<th>APRIL</th>
<th>MAY</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUG.</th>
<th>SEPT.</th>
<th>ANNUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>332.</td>
<td>360.</td>
<td>283.</td>
<td>300.</td>
<td>282.</td>
<td>361.</td>
<td>348.</td>
<td>156.</td>
<td>159.</td>
<td>79.</td>
<td>67.</td>
<td>133.</td>
<td>112.</td>
</tr>
<tr>
<td>1954</td>
<td>1600.</td>
<td>1260.</td>
<td>1140.</td>
<td>1130.</td>
<td>736.</td>
<td>930.</td>
<td>954.</td>
<td>1640.</td>
<td>1940.</td>
<td>1500.</td>
<td>1260.</td>
<td>1010.</td>
<td>1500.</td>
</tr>
<tr>
<td>1958</td>
<td>964.</td>
<td>841.</td>
<td>768.</td>
<td>676.</td>
<td>605.</td>
<td>585.</td>
<td>746.</td>
<td>2360.</td>
<td>1690.</td>
<td>1130.</td>
<td>924.</td>
<td>781.</td>
<td>1227.</td>
</tr>
</tbody>
</table>

**Original Data for Station 10-230 (Big Creek Near Randolph)**

**Listing of Output**
### TABLE OF RUNOFF VALUES

Based on a normal distribution, the table below shows the runoff values for Station 10-230 (Big Creek near Randolph) at various probability levels. The values are given for each month from October to September, along with the annual values.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>2063</td>
<td>1697</td>
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**THE FOLLOWING IS OBTAINED ASSUMING A LOG-NORMAL DISTRIBUTION FOR STATION 10-230**