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Technical Note

DESIGN-STORM UNIT-HYDROGRAPH COMPUTER PROGRAM

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ABSTRACT

The estimate of the design flood is one of the governing inputs for the selection and sizing of many infrastructures. While the design storm unit hydrograph approach is one of the most reliable method for the estimate of flood magnitude, its computation if done manually, is too tedious. A computer program should make the method usable to a number of practicing hydrologists.

INTRODUCTION

General

The design flood (flood hydrograph) is one of the most important parameters involved in determining the size of many infrastructures. Minimum bridge and culvert openings, sizing of spillways, sizing of dikes and other flood control structures are just few of the wide applications of **design flood**. The design flood, if underestimated, could result to overtopping the designed structure, thereby endangering the structure itself, properties and human lives. On the other hand, the design flood, if overestimated, would equate to unnecessary cost for the structure. Therefore, there is always a need for a good estimate of the design flood.

A number of methodologies are available to a consulting hydrologist in the estimate of the design flood. These are the following:

1. Flood Frequency Analysis
2. Regional Flood Study
3. Rational Formula
4. Design Storm Unit Hydrograph Approach

Flood Frequency Analysis

Annual maximum flows for a given stream are taken from streamflow records. This annual series is fitted into an extreme value type of distribution such as **Gumbel, Log Normal, Log Pearson Type III distribution.** A statistical analysis is then performed to determine the parameters of the distribution and eventually the flood magnitude of required return period. While this method yields the most reliable estimate of the design flood, its main disadvantage is the unavailability of reliable streamflow records. Neither will it yield a flood hydrograph needed for flood routing studies.

Regional Flood Study

In simplest terms, this is a multiple regression problem wherein a flood of a given return period is correlated with watershed parameters such as drainage area, length of streams, slope of stream, depth of precipitation of an identified durations and other hydrologic parameters.

Its disadvantage is similar to the flood frequency analysis.

Rational Formula

This is the simplest of all the methods used. It is based on a empirical formula, as follows:

$$Q = CIA$$

where

Q	=	Design discharge in m^3/sec
C	=	Coefficient of run off
I	=	Rainfall intensity at time of concentration in mm/hr
A	=	Catchment area in square kilometers

It is easy to use. All required data are easily available. The method, however, normally overestimates the magnitude of the design flood. Nor does it yield a flood hydrograph required for flood routing studies.

Design Storm Unit Hydrograph

In terms of arithmetical computation, this is the most difficult of the four (4) methods identified. The design storm unit hydrograph approach can be subdivided into the following subcomputations:

Design Storm Computation
Unit Hydrograph Derivation
Convolution Equation
Base Flow Correction

The common problems in this method are the following:

1. Although available in a number of foreign textbooks, the Lag Time Coefficient does not appear to be suited for local conditions. This coefficient will have a great bearing on the design discharge.

2. Unit hydrograph, derivable from a rainfall runoff record, cannot be computed for almost all Philippine Basin in the absence of a simultaneous rainfall runoff record.

3 The amount of computation involved is tedious.

DESIGN STORM UNIT HYDROGRAPH PROGRAM

Program Description

The aforementioned common problems were taken cared of by this computer program in the following manners:

- A regressed equation for the lag time coefficient using the drainage area, length of streams and slope was incorporated in the program. (Stevens and Templo, 1984).

- The US Soil Conservation System (SCS) Dimensionless hydrograph was used in the absence of the simultaneous rainfall runoff record.

- The tedious calculation is done by the computer.

The computer program, written in GWBASIC, runs in IBM PC, HP 150 and the TRS Model II Micrôcomputers. To improve readability of the results, excess rainfall, unit hydrograph and the design hydrograph are plotted in the printout.

The program flowchart is shown in Figure 1. The program listing in IBM PC GWBASIC is shown in the Appendix.

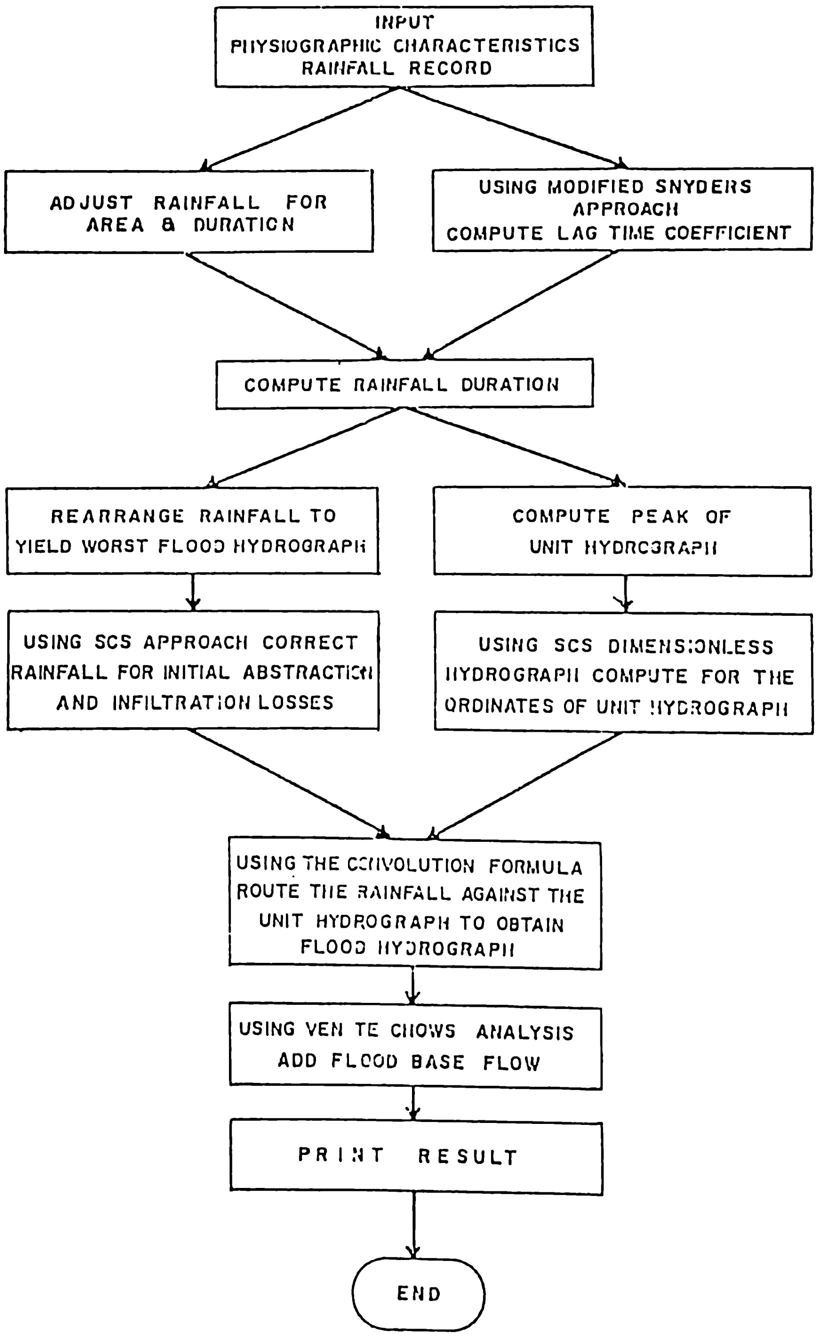


Figure 1. Flow Chart for the Design Storm Unit Hydrograph Approach

Program Input

The program requires data input in the following order:

A$ - Name of Project

N1 - No. of Points of the unit hydrograph. The SCS Dimensionless unit hydrograph adopted uses 16 points.

R1 - Ratio of Beginning Baseflow to peak hydrograph discharge; R1 = 0.01.

R2 - Ratio of Peak Baseflow to peak hydrograph discharge; R2 = 0.10.

R3 - Baseflow Recession coefficient; R3 = 0.975.

AA, BT, DB, BA, BL, BC, BS
- coefficients for the lag time coefficient regressed against the watershed parameters.

U(1) for I = 1 to N1
- ordinates of the SCS Dimensionless Unit Hydrograph.

B$ - Name of Road Section or Locality

C$ - Name of Waterway

A1 - Drainage Area in square kilometers

X1 - Length of Main Stream in kilometers (from highest point to outlet)

X2 - Length of Stream in kilometers (from centroid to outlet)

E1 - Elevation of Highest Point in Meters

E2 - Elevation of centroid of stream in meters

E3 - Elevation of outlet in meters

C1 - SCS Curve Number

C3 - Lag time coefficient control parameter

R6 - Rainfall Return Period

N6 - Number of rainfall time intervals

RA (1,I) I = 1, N6
- abscissa in hours of rainfall duration curves

RA (2,I) I = 1, N6
- ordinates in mm of rainfall duration curve

Program Output

The program tabulates and prints the unit hydrograph, design storm and discharge hydrograph (See Figure 2). To validate input, the data used are printed at the bottom of Figure 2.

The following are the symbols and abbreviations used in the output:

Description of Symbols

.	- Points representing the unit hydrograph
x	- Points representing the design storm
*	- Points representing the design hydrograph

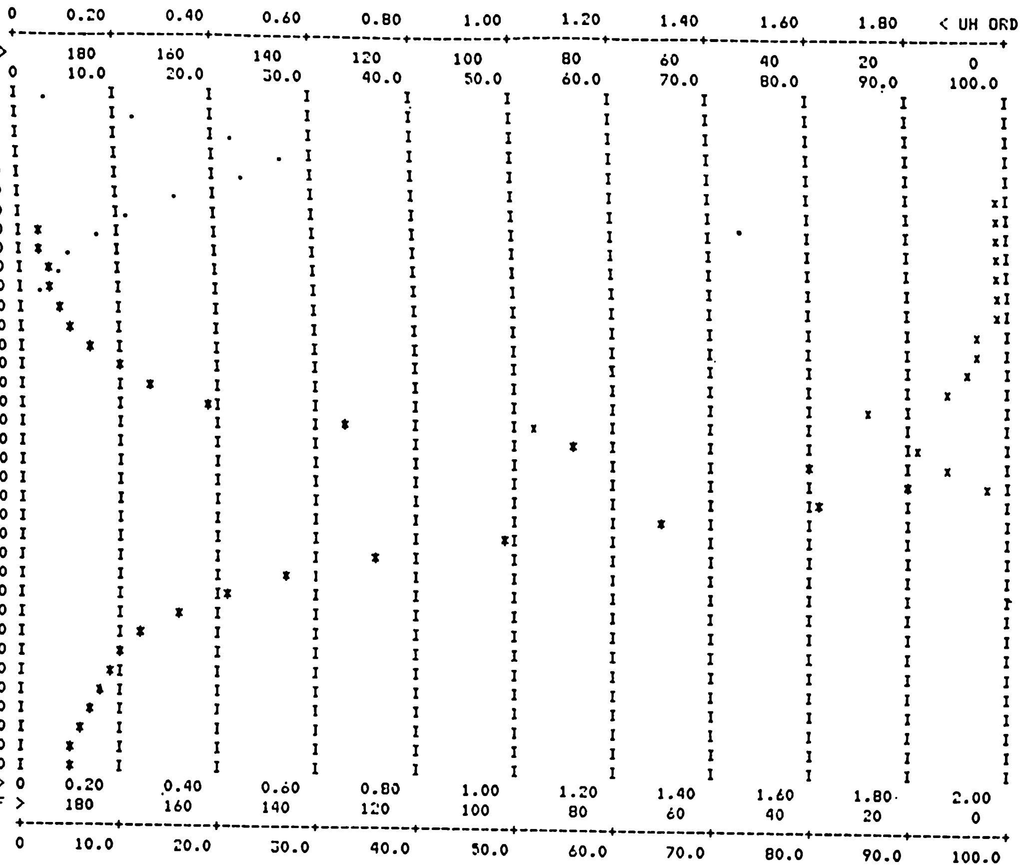
Description of Abbrevations

UH ORD m3/sec	- Unit Hydrograph Ordinates in Cumecs
ROFF mm	- Design Storm Ordinates in mm
DISCH m3/sec	- Design Hydrograph in Cumecs
RP	- Storm Return Period
#UH	- No. of Points in the Unit Hydrograph
RP BBF	- Ratio to Peak Discharge of Peak Baseflow
REC K	- Baseflow Recession Coefficient
D AREA	- Drainage Area in Square Kilometers
STR LN	- Length of Main Stream in Kilometer
LN CTD	- Length of Stream in km from Centroid to outlet
EL MAX	- Maximum Elevation of Stream in meters
EL CTD	- Elevation of Centroid Stream in meters
EL MIN	- Elevation of Stream outlet in meters
CN	- Curve Number

FLOOD HYDROGRAPH FROM SYNTHETIC UNIT HYDROGRAPH
south cotabato highways project
SIQUIL TO LONDON SECTION OF SECTOR 3
WATERSHED 12

UH ORD M3/SEC	ROFF MM	DISCH M3/SEC	TIME HOUR
0.076		0.9	2.900
0.250		1.0	5.800
0.451		1.1	8.700
0.544		1.3	11.600
0.473		1.4	14.500
0.337		1.6	17.400
0.239		1.8	20.300
0.163		2.1	23.200
0.109		2.5	26.100
0.082	1.0	3.1	29.000
0.054	1.3	3.8	31.900
0.033	1.8	4.7	34.800
0.024	4.1	5.9	37.700
0.016	5.3	7.7	40.600
0.011	6.7	10.2	43.500
0.005	10.1	13.6	46.400
	27.8	19.0	49.300
	95.8	33.1	52.200
	16.4	56.4	55.100
	10.8	80.0	58.000
	3.5	90.4	60.900
		82.0	63.800
		65.1	66.700
		49.8	69.600
		36.8	72.500
		27.4	75.400
		21.4	78.300
		16.5	81.200
		12.9	84.100
		10.9	87.000
		9.2	89.900
		8.1	92.800
		7.0	95.700
		6.2	98.600
		5.9	101.500
		5.6	104.400

SM UHO . RO x DISCH *



RP	NUH	RP BBF	RP BFP	REC K	RGN CF	D AREA	STR LN	LN CTD	EL MAX	EL CTD	EL MIN	CN	HM SLP	LAG CT	TT PEK	UH DUR	MAX Q	MAX RO
50	16	0.0100	0.1000	0.9750	20.000	29.94	17.10	9.80	628	250	10	83.0	0.0245	1.056	11.60	2.90	90.41	95.78

Figure 2. Sample Program Output

HM SLP - Computed mean slope of watershed

LAG CT - Computed Lag Time Coefficient

TT PEK - Time to Peak in Hours

UH DUR - Time interval used in Unit Hydrograph

MAX Q - Design Discharge in Cumecs

MAX RO - Maximum Excess Rainfall in mm

PROGRAM SUBROUTINES

Slope of the Watershed, S4

$$\frac{\text{Length of waterway}}{S4} = \left.\frac{\text{Length of waterway}}{\text{Slope}}\right|_{\text{Highest pt. to centroid}} + \left.\frac{\text{Length of waterway}}{\text{Slope}}\right|_{\text{Centroid to Outlet}}$$

If the slope from highest point to centroid is more than twice the slope from centroid to outlet, S4 = slope from centroid to outlet.

Lag Time Coefficient, C2

The program has four (4) options in the determination of the lag time coefficient depending on the value of lag time coefficient control parameter, C3.

CASE 1. Simple Arithmetic Regression: C3 = O:

$$C2 = AC + BA * A1 + BL * X1 + BC * X2 + BS * S4$$

CASE 2. Curvilinear Regression : C3 = 10:

$$C2 = AA + BT * [EXP(DB) * (A1+1)^{BA} * (x1+1)^{BL} * (x2+1)^{BC} * (s4+1)^{BS}]$$

CASE 3. LOG - LOG Transformation : C3 = 20:

$$C2 = KK + MM * \exp\{\exp[DB + BA * \ln(\ln(A1 + 1)) + BS * \ln(\ln(S4 +))]\}$$

CASE 4. The user inputs directly the Lag Time Coefficient, C2

The program output was based on C3 = 20.

Lag Time, T1

$$T1 = 0.6868 * C2 \left[\frac{\text{Length of Stream} * \text{Length of Centroid to Outlet}}{\sqrt{\text{Slope of Waterway}}} \right]^{0.3}$$

Time to Peak, T2

$$T2 = 1.125 * T1$$

Time Increment for Unit Hydrograph, T3

$$T3 = T2/4$$

Unit Hydrograph Ordinate

$G(I);\ I = 1,2, \ldots\ldots N1$

$$G(I) = U(I) * \frac{1\ \text{MM} * 1000 * \text{A1 in Km2}}{\text{T3 in seconds} * \sum_{i=1}^{N1} U(I)}$$

Design Storm

Increment precipitation is computed from rainfall duration curve using time increment T3. It is then arranged to yield the worst condition if routed on the Unit hydrograph; i.e.; in the convolution equation, the sequence in the order of magnitude of the incremental rainfall should be in the same order of magnitude for the unit hydrograph

Excess Rainfall

Initial abstraction and soil infiltration are deducted from the design storm in order to yield the excess run off. This is computed using the US SCS Method.

$$S = \left[\frac{1000}{CN} - 10 \right] (25.4)$$

$$Ia = 0.2\ S$$

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)}$$

with $P > Ia$
$S > Ia + F$
$F \doteq Ia - Q$

where

S = Maximum Storage Potential of Soil in mm
F = Cumulative Infiltration Loss in mm
Q = Cumulative Runoff in mm
P = Cumulative Rainfall in mm

Convolution Equation

$$Q(K) = \sum_{i=1}^{K} G(K - I + 1); \; K = 1,2,\ldots N2$$

Baseflow Computation

Beginning baseflow and peak baseflow are assumed to be 0.01 and 0.10, respectively, of the convulated peak discharge.

Baseflow is assumed to increase linearly from the beginning of flow toward the convulated peak flow after which it is assumed to recede at the ratio of 0.975.

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Appendix
Program Listing

```
10 CLEAR
15 '     *****************************
17 '     VERSION XYZ JAN 29 1988 2:30 PM
20 'fldhyd :computes DESIGN DISCHARGE
25 '*****************************
30 'USING SYNTHETIC UNIT HYDROGRAPH
40 'FROM BASIN PARAMETERS
689 DEFSNG A-Z
690 DIM A(40),B(40),BG(10),C(2,20),D(20),E(50),F(40),G(40),K(20)
695 DIM M(40),P(40),Q(40),R(40),R$(20),RA(2,20),RB(2,20),S(40),SC(10),S$(20)
697 DIM T(20),U(40),Z(40)
700 DIM BB(40),FF(40),GG(40),PP(40),QQ(40),RR(40),SS(40)
710  IT = 0
712 N7 = 8
715 EP = EXP(1)
720 GOSUB 9000
725 '
730 ' READ CONTROLS FOR READING AND PRINTING
732 '
740 READ I1,I2,I3,I4
741 BC= 0
742 KK = 0
743 MM =0
744 AA =0
745 BT = 0
746 N7 = 8
750 ON I1 GOTO 850,845,825,810
780 '
790 ' READ ALL INPUT DATA
792 '
805 READ A$
810 READ N1,R1,R2,R3,C3,SM'''''',CM
815 IF C3 = 0 THEN READ AC,BA,BL,BC,BS
817 IF C3 = 10 THEN READ AA,BT,DB,BA,BL,BC,BS
818 IF C3 = 20 THEN READ KK,MM,DB,BA,BL,BC,BS
820 FOR I =1 TO N1  : READ U(I) : NEXT I
825 IF I4  = 0 THEN  : READ B$ : READ C$ : READ A1,X1,X2,E1,E2,E3,C1,C3
840 READ R6,N6 : FOR  I =1 TO N6 :  READ RA(1,I),RA(2,I) : NEXT I
845 IF I4 = 1  AND N7 >= 7 THEN READ B$
850 IF I4 = 1 THEN READ C$ :READ A1,X1,X2,E1,E2,E3,C1,C3
980 ' ***8888888***********
990 ' COMPUTE SYNTHETIC UNIT HYDROGRAPH
1000 ' ************************************
1010 '
1015 ' IADATA WATERWAY#4
1020 S1 = 0
1030 FOR I =1 TO N1
1040 S1 = S1+U(I)
1050 NEXT I
1060 S2 = (E1-E2)/((X1-X2)*1000)
1070 S3 =(E2-E3)/(X2*1000)
1080 S4 = ((X1-X2)*(1/S2) +X2*(1/S3))/X1
1090 S4 = 1/S4
1100 IF S2/S3 > SM THEN S4 =S3
```

```
1110 IF C3 = 0 THEN C2 = AC+BA*A1+BL*X1+BC*X2+BS*S4
1112 G1 = (A1+1)^BA
1114 G2 = (X1+1)^BL
1116 G3 = (X2+1)^BC
1118 G4 = (S4+1)^BS
1119 IF C3 = 10 THEN C2 = AA+BT*(EXP(DB)*G1*G2*G3*G4-1)
1120 G1 = BA*LOG(LOG(A1+EP))
1122 G2 = BL*LOG(LOG(X1+EP))
1124 G3= BC*LOG(LOG(X2+EP))
1125 G4 = BS*LOG(LOG(S4+EP))
1126 G5 = DB + G1+G2+G3+G4
1127 IF C3  = 20 THEN C2 = KK+MM*(EXP(EXP(G5))-EXP(1))
1129 IF C3 <> 0 AND C3 <> 10 AND C3 <> 20 THEN C2 = C3
1130 IF C2 < CM THEN C2 = CM
1135 T1 = .6868*C2*(X1*X2/S4^.5)^.38
1140 T2 = 1.125*T1
1150 T3  = T2/4
1152 IF T3 < .1 AND T3 > .01 THEN  : D3 =-3 : GOTO 1160
1154 IF T3 < 1 AND T3 >9.999999E-02 THEN  : D3 = -2 : GOTO 1160
1156 IF T3 <10 AND T3 > 1! THEN  : D3 = -1  : GOTO 1160
1158 IF T3 > 10 THEN D3 = 0
1160 I5 = T3*(1/10^D3) +.5
1162 I5 = INT(I5)
1167 T3 = I5*10^D3
1172 T2 = T3*4
1180 S5 = 1000*A1/(T3*3600)
1200 FOR I =1 TO N1
1210 G(I) = U(I)*S5/S1
1220 NEXT I
1225 PRINT "SYN OK"
1350 '*****************
1360 'COMPUTE INC RAINFALLL
1370 '*********************
1380 '
1382 PRINT "GOING TO SUB 3000"
1390 GOSUB 3000
1392 PRINT "SUB 3000  OK"
1400 '
1520 '
1530 '
1540 'CONSTRUCT DESIGN STORM
1550 '*****************8
1551 '
1552 FOR J =1 TO N2 : Z(J) =P(J) : NEXT J
1554 FOR I =1 TO N2
1556 BP = 0
1558 FOR J =1 TO N2
1560 IF BP < Z(J) THEN  : BP = Z(J) : KM = J
1562 NEXT J
1564 Z(KM) = 0
1566 P(I) = BP
1568 NEXT I
1569 '
1570 FOR J =1 TO N1 : M(J) = 0 : Z(J) = G(J) :NEXT J
```

```
1580 FOR I =1 TO N1
1590 BG = 0
1600 FOR J =1 TO N1
1610 IF BG  < G(J) AND Z(J) > 0 THEN  BG = G(J) : M(I)  =J
1620 NEXT J
1630 KM = M(I)
1640 Z(KM) = 0
1650 NEXT I
1660 IF N1 >= N2 THEN 1750
1670 N3 = N2 -N1
1710 FOR I =1 TO N3
1720 S(I) = P(N2-I+1)
1730 NEXT I
1740 GOTO 1760
1750 IF N1 > N2 THEN N5 .= N2
1760 IF N1 <= N2 THEN N5 =N1
1765 FOR I =1 TO N5
1770 L = M(I)
1780 S(N2-L+1) = P(I)
1790 NEXT I
1800 '
1810 '*****************
1820 '  COMPUTE EXCESS AND RUNOFF
1830 '***************************
1840 '
1850 S6 = 1000/C1 -10
1860 S6 = S6*25.4
1870 S7 = 0
1875 FOR I =1 TO N2
1880 S7 =S7 + S(I)
1900 IF S7  < .2*S6 THEN 1960
1910 E(I) = (S7-.2*S6)^2/(S7+.8*S6)
1920 IF I =1 THEN 1992
1930 R(I) = E(I)- E(I-1)
1940 F(I) = S(I)-R(I)
1950 GOTO 1996
1960 F(I) =S(I)
1970 E(I) = 0
1980 R(I) = 0
1990 GOTO 1996
1992 R(I) = E(I)
1994 F(I) = S(I) -R(I)
1996 NEXT I
1998 R5 = 0
2000 FOR I =1 TO N2
2002 IF R5 >R(I) THEN 2006
2004 R5 = R(I)
2006 NEXT I
2008 F3 = 0
2010 FOR I =1 TO N2
2012 IF F3 > F(I) THEN 2016
2014 F3 = F(I)
2016 NEXT I
2018 S9 = 0
```

```
2020 FOR I=1 TO N2
2022 IF S9 > S(I) THEN 2026
2024 S9 = S(I)
2026 NEXT I
2028 '
2030 '
2040 ' *******************
2050 ' COMPUTE DIRECT DISCHARGE'
2060 ' *********************
2070 '
2080 N4 = N1 + N2 -1
2090 N4 = INT(N4)
2091 FOR K =1 TO N4
2092 K2 = 1
2093 Q(K) =0
2094 IF K <= N1 THEN 2100
2096 K2 = K-N1 +1
2100 FOR I =K2 TO K
2110 Q(K) = Q(K)+G(K-I+1)*R(I)
2120 NEXT I
2140 NEXT K
2150 '
2160 '**************************
2170 '   COMPUTE BASEFLOW
2180 '************************
2190 '
2200 Q1 = 0
2210 FOR K =1 TO N4
2220 IF Q1 >Q(K) THEN 2250
2230 Q1 = Q(K)
2240 K1 = K
2250 NEXT K
2260 '
2270 B2 = R1*Q1
2280 B3 = R2*Q1
2290 X3 = K1
2300 X4 = X3*T3
2310 B4 = (LOG(B3)-LOG(B2))/X4
2320 FOR I =1 TO K1
2330 X5 = I
2340 X6 = B4*T3*X5
2360 B(I) = B2*EXP(X6)
2370 Q(I) = Q(I) +B(I)
2380 NEXT I
2382 Q1 = Q1+B(K1)
2390 K = K1+1
2400 FOR I =K TO N4
2410 B(I) = B(I-1)*R3
2420 Q(I) =Q(I)+B(I)
2430 NEXT I
2440 '
2450 '  PRINT DISCHARGE
2460 '********************
2470 '
```

```
2520 IF I2 = 1 THEN GOSUB 4000
2530 IF I2 = 2 THEN GOSUB 5000
2535 IF I2 = 3 THEN GOSUB 7000
2540 IF I3=1 OR I3 = 2 THEN GOSUB 6000
2870 '
2880 '************************
2890 '   GOTO NEXT OPERATION
2900 '************************8
2910 '
2911  FOR I =1 TO N1 : G(I) = 0 : NEXT I
2912 FOR I =1 TO N5 : M(I) = 0 : NEXT I
2913 FOR I =1 TO N2 : P(I) = 0 : NEXT I
2914 FOR I =1 TO N4 : B(I) = 0 : R(I)=0 : S(I) = 0 : F(I)=0 : NEXT I
2918 '
2920 READ N7,I4
2925 IF N7 <= 0 OR N7 >= 10 THEN 50000
2930 ON N7 GOTO 740,805,810,815,820,825,840,845,850
2990 '
3000 ' SUBROUITNE COMPUTES PRECIP INC AND AR COORR
3010 '
3012  FOR I =1 TO N6 : RB(1,I) = RA(1,I) : RB(2,I)= RA(2,I) : NEXT I
3020  T4 = 0
3030 I6 = 0
3035 IF A1 <= 26.88 THEN 3182
3060 IF A1  > 200 THEN 3110
3070 D1 = 1.1752 - .14703*LOG(LOG(A1))
3080 D2 = .018164 -.0152473*LOG(LOG(A1))
3090 P1 = -.0158705 + .0133222*LOG(LOG(A1))
3100 GOTO 3143
3110 IF A1 > 1000 THEN 3124
3120 D1 = 1.86034 -.55795*LOG(LOG(A1))
3122 GOTO 3130
3124 D1 = 3.20735-1.25494*LOG(LOG(A1))
3130 D2 = .1788491-.116165 *LOG(LOG(A1))
3140 P1 = -.1016328 +.0647571*LOG(LOG(A1))
3143 FOR I= 1 TO N6
3150 P2 = LOG(RB(2,I) +EP)
3160 K(I) = D1 +(D2 +P1*P2)*LOG(LOG(RB(2,I)+EP))
3170 RB(1,I) = RB(1,I)+K(I)
3172 NEXT I
3180 '
3182 L1 = LOG(RB(1,1))
3184 L2 = LOG(RB(2,1))
3190 FOR  I= 2 TO N6
3195 IF T3 > RB(2,I) THEN 3360
3200 '
3210 C(2,I) = (LOG(RB(1,I))-L1)/(LOG(RB(2,I))-L2)
3220 C(1,I) = LOG(RB(1,I))-C(2,I)*LOG(RB(2,I))
3230 C(1,I) = EXP(C(1,I))
3250 IF I6 = 0 THEN : N9 .=RB(2,I)/T3:D(I) = RB(2,I)-N9*T3: GOTO 3260
3252 N9  = (RB(2,I)-RB(2,I-1))/T3 +  D(I-1)
3260 N9 = INT(N9+.001)
3270 D(I) = RB(2,I)-RB(2,I-1)-N9*T3
3280 FOR J =1 TO N9
```

```
3290 I6 = I6+1
3300 T4 = T4+T3
3310 A(I6) = C(1,I)*T4^C(2,I)
3320 IF I6 = 1 THEN 3345
3330 P(I6)  = A(I6) - A(I6-1)
3335 IF I6 >=N1+5 THEN 3450
3340 GOTO 3350
3345 P(I6) = A(I6)
3350 NEXT J
3360 L1 = LOG(RB(1,I))
3362 L2 = LOG(RB(2,I))
3364 NEXT I
3370 N9 = N1-I6+5
3380 FOR I =1 TO N9
3390 I6 = I6+1
3400 T4 = T4+T3
3410 A(I6) = C(1,N6)*T4^C(2,N6)
3420 P(I6) = A(I6)-A(I6-1)
3430 NEXT I
3450 N2 = I6
3460 RETURN
4000 '
4010 '  SUBROUT PRINT UHG RAIN STORM LOSS RUNOFF BASE FLOW AND DISCHG
4020 '
4021 LPRINT CHR$(12)
4022 FOR IZ =1 TO 4 :' LPRINT :NEXT IZ
4023 LPRINT : LPRINT "DISCHARGE FLOOD HYDROGRAPH "
4024 LPRINT TAB(1) A$ :LPRINT TAB(1) B$;
4025 LPRINT TAB(1) C$
4026 LPRINT :LPRINT:LPRINT
4030 LPRINT TAB(1)"  TIME";:LPRINT TAB(8)"UH ORD";:LPRINT TAB(15)"  RAIN";
4040 LPRINT TAB(22)" STORM";:LPRINT TAB(29)"P LOSS";:LPRINT TAB(36)"RUNOFF";
4050 LPRINT TAB(43)" B FLOW";:LPRINT TAB(50)"  DISCH";:LPRINT TAB(57)"   TIME"
4060 LPRINT TAB(1)"  HOUR";:LPRINT TAB(8)" M3/SEC";:LPRINT TAB(15)"     MM";
4070 LPRINT TAB(22)"    MM";:LPRINT TAB(29)"    MM ";:LPRINT TAB(36)"    MM";
4080 LPRINT TAB(43)" M3/SEC";:LPRINT TAB(50)" M3/SEC";:LPRINT TAB(57)"   HOUR"
4090 LPRINT
4100 T4 = 0
4110 FOR I =1 TO N4
4120 T4 = T4+T3
4130 LPRINT TAB(1) USING"###.##";T4;
4135 IF G(I) >= .001 THEN LPRINT TAB(8)  USING"#.###";G(I);
4140 IF P(I) >= 1 THEN LPRINT TAB(15) USING"###.##";P(I);
4145 IF S(I) >= 1 THEN LPRINT TAB(22) USING"###.##";S(I);
4150 IF F(I) >= .1 THEN LPRINT TAB(29) USING"###.##";F(I);
4155 IF R(I) >= .1 THEN LPRINT TAB(36) USING"####.##";R(I);
4160 LPRINT TAB(43) USING"####.##";B(I);:LPRINT TAB(50) USING"####.##";Q(I);
4170 LPRINT TAB(57) USING"###.##";T4
4175 NEXT I
4180 LPRINT
4190 RETURN
5000 '
5010 ' SUBROUTINE  PRINT AND PLOT UHG, RUNOFF AND DISCHARGE
5020 '
```

```
5022 LPRINT CHR$(12)
5023  LPRINT CHR$(13)
5024 LPRINT
5026 LPRINT TAB(1)"FLOOD HYDROGRAPH FROM SYNTHETIC UNIT HYDROGRAPH ";
5028 LPRINT TAB(1) A$:LPRINT TAB(1) B$:LPRINT TAB(1) C$
5029 LPRINT
5030 BG(1) = G(3)
5040 BG(2) = R5
5050 BG(3)  =Q1
5060 FOR I =1 TO 3
5070 IF BG(I)<= 1 THEN  SC(I)   =100  : GOTO 5210
5080 IF BG(I)<= 2 THEN  SC(I)   =50  : GOTO 5210
5090 IF BG(I)<= 5 THEN  SC(I)   =20  : GOTO 5210
5100 IF BG(I)<= 10 THEN  SC(I)   =10  : GOTO 5210
5110 IF BG(I)<= 20 THEN  SC(I)   =5  : GOTO 5210
5120 IF BG(I)<= 50 THEN  SC(I)   =2  : GOTO 5210
5130 IF BG(I)<= 100 THEN  SC(I)   =1  : GOTO 5210
5140 IF BG(I)<= 200 THEN  SC(I)   =.5: GOTO 5210
5150 IF BG(I)<= 500 THEN  SC(I)   =.2: GOTO 5210
5160 IF BG(I)<= 1000 THEN  SC(I)   =.1: GOTO 5210
5170 IF BG(I)<= 2000 THEN  SC(I)   =.05: GOTO 5210
5180 IF BG(I)<= 5000 THEN  SC(I)   =.02: GOTO 5210
5190 IF BG(I)<= 10000 THEN  SC(I)   =.01: GOTO 5210
5200 LPRINT TAB(1)" NOT FORMATTED FOR DISCHARGES GREATER THAN 100000";:STOP
5210 NEXT I
5212 SC(1) = SC(1)*.5
5214 SC(2) = SC(2)*.5
5220 LPRINT TAB(1)"UH ORD";:LPRINT TAB(8)" ROFF";:LPRINT TAB(13)"  DISCH";
5230 LPRINT TAB(21)"   TIME";:LPRINT TAB(29)"0";
5240 FOR I =1 TO 9 : LPRINT TAB(20+I*10)USING"######.##";I*10/SC(1);:NEXT I
5250 LPRINT TAB(120)"   < UH ORD"
5260 LPRINT TAB(1)"M3/SEC";:LPRINT TAB(8)"  MM ";:LPRINT TAB(13)"  M3/SEC";
5270 LPRINT TAB(21)"   HOUR";:LPRINT TAB(29)"+";
5280 FOR I =1 TO 10: LPRINT TAB(20+I*10)"---------+";:NEXT I
5290 LPRINT
5300 LPRINT TAB(20)"  R OFF > ";:LPRINT TAB(30) USING"#########";90/SC(2);
5310 FOR I =1 TO 9 : LPRINT TAB(30+I*10)USING"#########";(90-I*10)/SC(2);:NEXT I
5320 LPRINT
5330 LPRINT TAB(20)" DISCH >";:LPRINT TAB(29)"0";
5340 FOR I=1 TO 10 :LPRINT TAB(20+I*10) USING"#######.#";I*10/SC(3);:NEXT I
5350 LPRINT
5360 '
5370 T4 = 0
5380 FOR J =1 TO N4
5390 T4 = T4+T3
5400 FOR I =1 TO 13 : T(I) = 0 : NEXT I
5410 S$(1) ="."
5420 S$(2) = "x"
5430 S$(3) = "*"
5432 T(1)= INT(G(J)*SC(1)-1)
5434 T(2)= INT(100-R(J)*SC(2)-1)
5436 T(3)= INT(Q(J)*SC(3)-1)
5440 FOR I =4 TO 13 : S$(I)="I":T(I)= 10*(I-3)-1:NEXT I
5450 FOR K =4 TO 13
```

```
5455 IF T(K) >= 99 THEN 5490
5460 IF T(1) = T(K) THEN S$(K) = S$(1)
5470 IF T(2) = T(K) THEN S$(K) = S$(2)
5480 IF T(3) = T(K) THEN S$(K) = S$(3)
5490 NEXT K
5495 IF T(2) >= 99 THEN T(2) = -1
5500 FOR I =1 TO 13 :Z(I)=T(I) : R$(I) = S$(I):NEXT I
5510 IDX = 13
5520 M  = 0
5530 FOR I = 1 TO 13
5550 M =M+1
5560 MT = 1000000!
5570 FOR K =1 TO 13
5580 IF MT > Z(K) THEN MT = Z(K) : MK = K
5590 NEXT K
5600 IF MT > 100 THEN 5640
5610 T(M) = MT
5620 S$(M) = R$(MK)
5630 Z(MK) = 1000000!
5640 NEXT I
5650 IF G(J) >= .001 THEN LPRINT TAB(1) USING"##.###";G(J);
5655 IF R(J) >=1 THEN LPRINT TAB(8) USING"###.#";R(J);
5660 LPRINT TAB(13) USING"#####.#";Q(J);:LPRINT TAB(21) USING"###.###";T4;
5670 LPRINT TAB(29)"I";
5680 FOR I =1 TO IDX
5682 IF T(I) < 1 THEN 5696
5684 IF I <= 1 THEN 5694
5686 IF T(I) = T(I-1) THEN 5696
5688 IF I <= 2 THEN 5694
5690 IF T(I) = T(I-2) THEN 5696
5692 IF I <= 3 THEN 5694
5693 IF T(I) = T(I-3) THEN 5696
5694 LPRINT TAB(30+T(I));S$(I);
5696 NEXT I
5698 LPRINT
5700 NEXT J
5710 LPRINT TAB(1)"SM UHO";:LPRINT TAB(8)"  RO";:LPRINT TAB(13)"  DISCH";
5720 LPRINT TAB(22)" UHO >";:LPRINT TAB(29)"0";
5730 FOR I =1 TO 10 : LPRINT TAB(20+I*10) USING"#####.##";I*10/SC(1);:NEXT I
5740 LPRINT
5750 LPRINT TAB(1)"   .   ";:LPRINT TAB(8)"   x ";:LPRINT TAB(13)"  *  ";
5760 LPRINT TAB(22)" R OFF >";:LPRINT TAB(30)USING"#######";(90)/SC(2);
5770 FOR I =1 TO 9 : LPRINT TAB(30+I*10)USING"#######";(90-I*10)/SC(2);:NEXT I
5775 LPRINT
5780 LPRINT TAB(29)"+";
5790 FOR I =1 TO 10  :LPRINT TAB(20+I*10)"---------+";:NEXT I
5800 LPRINT
5810 LPRINT TAB(20)"   DIS> ";:LPRINT TAB(29)"0";
5820 FOR I =1 TO 10 :LPRINT TAB(20+I*10)  USING"#######.#";I*10/SC(3);:NEXT I
5830 LPRINT
5840 LPRINT
5850 RETURN
6000 '
6012 LPRINT CHR$(13)
```

```
6022 IF I3 <> 2 THEN 6027
6023 LPRINT
6024 LPRINT TAB(1)"FLOOD HYDROGRAPH FROM SYNTHETIC UHG : DESIGN Q FOR";
6025 LPRINT TAB(52) A$;:LPRINT TAB(64) B$;:LPRINT TAB(83)" ";:LPRINT TAB(84) C$
6027 LPRINT TAB(1)"RP";
6030 LPRINT TAB(5) "#UH";:LPRINT TAB(8)" RP BBF";:LPRINT TAB(15)" RP BFP";
6040 LPRINT TAB(22)" REC K";:LPRINT TAB(29)" RGN CF";:LPRINT TAB(36)" D AREA";
6050 LPRINT TAB(43)" STR LN";:LPRINT TAB(50)" LN CTD";:LPRINT TAB(57)" EL MAX";
6070 LPRINT TAB(64)" EL CTD";:LPRINT TAB(71)" EL MIN";:LPRINT TAB(78)" CN ";
6080 LPRINT TAB(85)" HM SLP";:LPRINT TAB(92)" LAG CT";:LPRINT TAB(99)" TT PEK";
6090 LPRINT TAB(106)" UH DUR";:LPRINT TAB(113)" MAX Q";
6095 LPRINT TAB(120)"MAX RO"
6100 '
6105 LPRINT TAB(1) USING"###";R6;
6110 LPRINT TAB(5) USING"###";N1;:LPRINT TAB(8) USING"##.####";R1;
6120 LPRINT TAB(15) USING"##.####";R2;:LPRINT TAB(22) USING"##.####";R3;
6130 LPRINT TAB(29) USING"###.###";C3;:LPRINT TAB(36) USING"####.##";A1;
6140 LPRINT TAB(43) USING"####.##";X1;:LPRINT TAB(50) USING"####.##";X2;
6150 LPRINT TAB(57) USING"######";E1;:LPRINT TAB(64) USING"######";E2;
6160 LPRINT TAB(71) USING"#####";E3;:LPRINT TAB(78) USING"#####.#";C1;
6170 LPRINT TAB(85) USING"##.####";S4;:LPRINT TAB(92) USING"###.###";C2;
6180 LPRINT TAB(99) USING"##.##";T2;:LPRINT TAB(106) USING"##.##";T3;
6190 LPRINT TAB(112) USING"####.##";Q1;:LPRINT TAB(120) USING"###.##";R5
6194 FOR  IZ = 1 TO 4:LPRINT :NEXT IZ
6200 RETURN
9000 '
9010 'SUB READS DATA TO CHECK FOR FORMAT
9020 '
9030 READ I1,I2,I3,I4
9040 ON I1 GOTO 9155,9150,9125,9100
9090 READ A$
9100 READ N1,R1,R2,R3,C3,SM
9110 IF C3 = 0 THEN READ AC,BA,BL,BC,BS
9115 IF C3 =10 THEN  READ AA,BT,DB,BA,BL,BC,BS
9117 IF C3 = 20 THEN READ AA,BT,DB,BA,BL,BC,BS
9120 FOR I =1 TO N1 :READ U(I) :NEXT I
9125 IF I4 =0 THEN READ B$,C$:READ A1,X1,X2,E1,E2,E3,C1,C3
9150 READ R6,N6 : FOR I =1 TO N6 : READ RA(1,I),RA(2,I) : NEXT I
9155 IF I4=1 AND N7 >= 7  THEN READ B$
9160 IF I4 =1 THEN READ C$,A1,X1,X2,E1,E2,E3,C1,C3
9180 READ N7,I4
9190 IF N7 = 0 OR N7 >= 10 THEN RESTORE : RETURN
9200 ON N7 GOTO 9030,9090,9100,9110,9120,9125,9150,9155,9160
10000 DATA 0,2,1,1
10010 DATA south cotabato highways project
10020 DATA 16,.01,.1,.975,20,2
10030 DATA -.090546,1.09006,.656590,.000159,-.422831,.061844,3.52643
10040 DATA .14,.46,.83,1,.87,.62,.44,.3,.2,.15,.1,.06,.045,.03,.02,.01
10050 'ATA  50,10,15.1,.0833,23.0,.16667,29.7,.25,44.2,.5,59.0,1,86.10,2,104.2,3
,137.3,6,168.1,12,191.9,24
10060 'ATA 25,10,13.3,.08333,20.2,.16667,26.1,.25,38.9,.5,51.8,1,75.5,2,91.3,3,1
20.1,6,147.0,12,167.6,24
10065 DATA 10,10,10.8,.08333,16.5,.16667,21.3,.25,31.6,.5,42.2,1,61.3,2,74.0,3,9
7.00,6,118.5,12,134.9,24
```

```
10070 DATA  SECTION 2 OF SECTOR 3
10210 DATA WS15,.27,.75,.25,300,80,10,83,20,9,1
10220 DATA WS16,4.99,5.1,2,480,300,10,83,20,9,1
10230 DATA WS17,6.88,7.0,4.7,402,353,10,83,20,9,1
10240 DATA WS18,.37,1.1,.35,300,200,10,83,20,9,1
10250 DATA WS19,.71,1.6,.5,300,250,10,83,20,9,1
10260 DATA WS20,6.3,6.27,3.2,405,332,10,83,20,9,1
10270 DATA WS21,.08,0.35,.15,250,130,100,83,20,9,1
10280 DATA WS22,.15,.85,.35,280,70,20,83,20,9,1
10290 DATA WS23,0.19,0.8,.3,280,70,20,83,20,9,1
10300 DATA WS24,0.68,1.00,.5,300,100,20,83,.20,9,1
10310 DATA WS25,1.68,3.9,1.60,400,210,20,83,20,9,1
10320 DATA WS26,.45,1.35,.55,300,100,10,83,20,9,1
10330 DATA WS27,1.08,3.3,1.3,480,200,15,83,20,9,1
10340 DATA WS28,.45,2.3,1.1,350,150,15,83,20,9,1
10350 DATA WS29,2.56,3.21,2.20,405,200,10,83,20,9,1
10360 DATA WS30,2.40,4.68,2.2,400,200,10,83,20,9,1
10362 DATA WS31,.64,2.0,0.9,360,160,10,83,20,9,1
10364 DATA WS32,1.09,2.4,1.1,300,200,10,83,20,9,1
10370 DATA WS33,1.44,3.45,1.45,300,220,10,83,20,9,1
10380 DATA WS34,1.41,3.2,1.5,250,130,10,83,20,9,1
10390 DATA WS35,.44,1.00,.5,150,60,10,83,20,9,1
10400 DATA WS36,.37,1.0,.35,150,60,20,83,20,9,1
10410 DATA WS37,.18,1.3,.5,150,60,20,83,20,9,1
10420 DATA WS38,.72,3,1.2,250,150,10,83,20,9,1
10430 DATA WS39,.53,1.6,.7,195,80,10,83,20,9,1
10440 DATA WS40,.37,1.4,.6,194,100,10,83,20,9,1
10450 DATA WS41,.17,0.8,.3,150,60,10,83,20,9,1
10460 DATA WS42,.51,1.7,.9,194,90,10,83,20,9,1
10470 DATA WS43,0.94,2.6,.8,194,80,10,83,20,9,1
10480 DATA WS44,38.56,14.55,6.9,710,250,8,83,20,9,1
10490 DATA WS45,.56,1.3,.5,100,50,10,83,20,9,1
10500 DATA WS46,2.00,3.65,1.65,290,150,10,83,20,9,1
10510 DATA WS47,.47,1.4,.4,150,60,10,83,20,9,1
10520 DATA WS48,.19,0.95,.25,150,60,20,83,20,9,1
10530 DATA WS49,.22,0.9,.3,150,60,15,83,20,9,1
10540 DATA WS50,1.54,3.35,1.2,428,140,10,83,20,9,1
10550 DATA WS51,1.26,2.50,.9,290,100,10,83,20,9,1
10560 DATA WS52,.22,.7,.2,105,55,15,83,20,9,1
10570 DATA WS53,3.95,5.05,2.05,534,200,15,83,20,9,1
10580 'ATA WS54,6.12,3.9,2.8,534,200,10,83,20,9,1
10590 'ATA WS55,.51,.5,.2,105,50,10,83,20,9,1
```