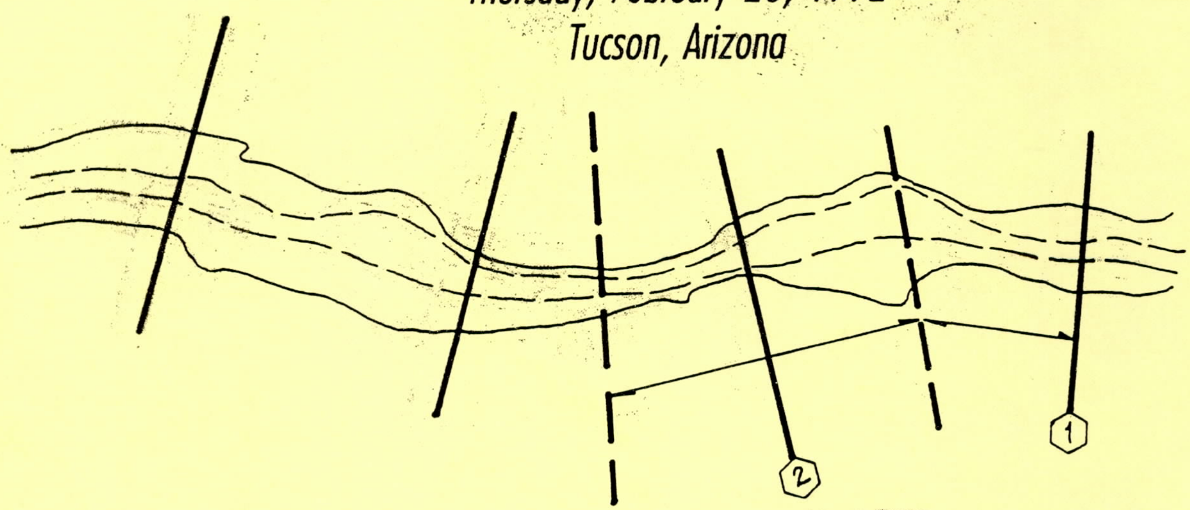
HEC-2 & HEC-1 Fundamentals and Review Procedures Technical Session

ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION

Presents

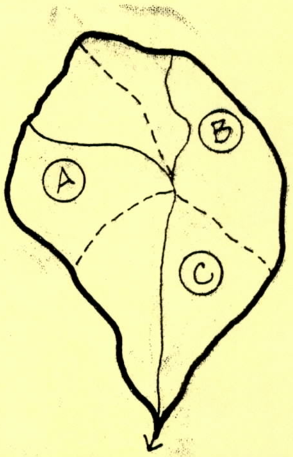
HEC-2 Fundamentals and Review Procedures Technical Session

Thursday, February 20, 1992
Tucson, Arizona

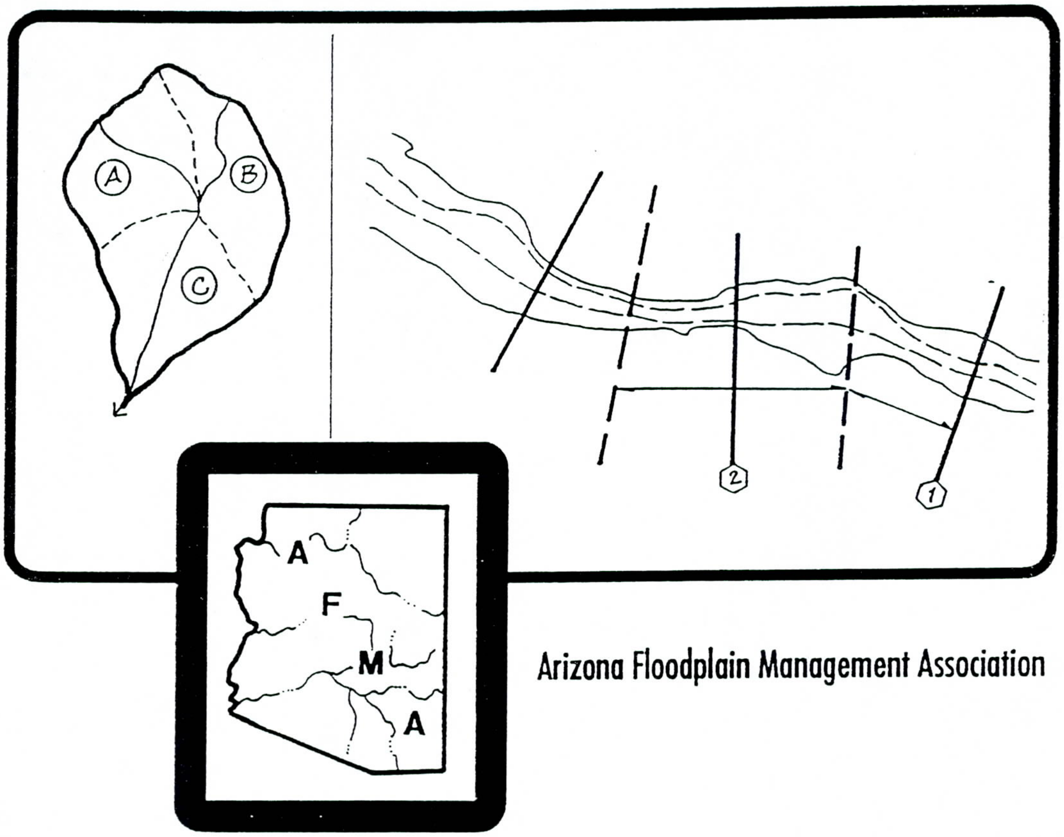


HEC-1 Fundamentals and Review Procedures Technical Session

Friday, February 21, 1992
Tucson, Arizona



HEC-1 & HEC-2
FUNDAMENTALS AND REVIEW PROCEDURES
TECHNICAL SESSIONS



Arizona Floodplain Management Association

Thursday and Friday
February 20-21, 1992
Tucson, Arizona

Arizona Floodplain Management Association
HEC-2/HEC-1 Fundamentals and Review Procedures
Technical Session Agendas
Tucson, Arizona

THURSDAY, FEBRUARY 20, 1992 **HEC-2**
1:00 TO 5:00 P.M.

1:00 - 1:15	Opening Remarks	Chuck Williams
1:15 - 1:30	Introduction	Jon Fuller
1:30 - 2:00	Program Input	Jon Fuller
2:00 - 3:00	Program Output	John Wise
3:00 - 3:15	Break	
3:15 - 4:00	Review Guidelines	John Wallace
4:00 - 4:30	Review Checklist and References	John Wallace
4:30 - 5:00	Discussion and Wrap-up	Chuck Williams

FRIDAY, FEBRUARY 21, 1992 **HEC-1**
8:00 A.M. TO 12:00 P.M.

8:00 - 8:15	Opening Remarks	Chuck Williams
8:15 - 8:30	Introduction	Tom Loomis
8:30 - 9:30	Watershed Modeling	Tom Loomis
9:30 - 10:00	Program Input	Pat Marum
10:00 - 10:15	Break	
10:15 - 10:45	Program Output	Pat Marum
10:45 - 11:30	Review Checklist and References	Amir Motamedi
11:30 - Noon	Discussion and Wrap-up	Chuck Williams

Outline for HEC2 Seminar
Part I: Introduction

I. Introduction

A. Goals and Objectives

1. ______________________________

2. ______________________________

3. ______________________________

B. Warning

1. To Beginners:

2. To Experts:

C. What is HEC2?

1. HEC2 Is:

a. Computer Program

b. Water Surf. Elev.

2. HEC2 Is Not:

a. ______________________________

b. ______________________________

II. Basic Hydraulics

A. Three Fundamental Principles:

1. Principle #1: Water down hill

2. Principle #2: ______________________________

a. Continuity

$Q_{in} = Q_{out} +$ ________

b. Energy

$E_{in} =$ ______ + Head Loss

OR

$WS_2 + a_2V_2^2/2g = WS_1 + a_1V_1^2/2g + h_e$

$h_e = (\_\_ \ \_\_) + C/2g(a_2V_2 - a_1V_1)$

c. Momentum

3. Principle #3: ______________________________

a. Gravity (Principle #1)

b. Inertia (Principle #2 & #3)

(1) Vectors

4. Hydraulics Vocabulary

   a. Froude Number: ratio of ______________

   b. Critical: F ___ 1

   c. Subcritical: F _<_ 1 (____tream Control)

   d. Supercritical: F _>_ 1 (____stream Control)

III. HEC2 Basics

A. How HEC2 Works

1. Inputs = ________________
   ____
   ____
   ____

2. Equations = ________________
   ____

3. Determines ______________________________

B. HEC2 Applications

1. Water Surface Elevations
2. Multiple Profiles
3. Channel Hydraulics
4. Bridge and Culvert Hydraulics
5. Floodway Determination
6. Encroachment Modeling
7. Channel Improvement Modeling
8. Split Flow (Side Wiers)
9. Tributary Profiles
10. Solving for Mannings "n"
11. Ice-Cover
12. Interface with Sediment Transport Models

C. Limitations of HEC2

1. Flow is Continuous (Principle #1)

   a. Steady Flow (Unsteady Flow)

2. One Dimensional (Principle #2)

   a. Length in Energy Equation

   b. Gradually Varied Flow

   c. Uniform Flow (Rapidly Varied)

   d. Horizontal Water Surface Elevation

3. Slope is Small

   a. Cosine of depth
   b. 10% rule

4. Rigid Channel Geometry

5. Garbage In = ________________

D. Food For Thought

1. Application in Arizona
    a. Steady Flow?
    b. One Dimensional?
    c. Low Slope?
    d. Rigid Channels?

2. Other Models Are Available

Part II: Program Input

IV. HEC2 Input

A. General Format of Input

1. Cards/Lines/Records
2. Fields

B. Title/Comment Cards

1. Optional, but Recommended

C. Job Cards - REQUIRED

1. J1: Starting Conditions

a. IDIR	J1.4:	Subcritical?
b. STRT	J1.5:	Starting Method
c. Q	J1.8:	Discharge
d. WSEL	J1.9:	Starting Water Surface

2. J2: Optional Job Control

3. J3: Output Control
   a. SUMPO Program

4. NC: Mannings "n" Values

D. Cross Section Records - REQUIRED

1. X1: General Cross Section Information

a. SECNO	X1.1:	Section Number
b. NUMST	X1.2:	Number of Geometry Stations
c. STCH*	X1.3:	Station of Channel Banks
d. XL*	X1.5:	Distances

2. GR: Cross Section Geometry

a. EL	GR.1:	Elevation of Point in Section
b. STN	GR.2:	Station of Point in Section

E. End Cards - REQUIRED

1. EJ - Ends Read Through Input, 1st Profile
2. ER - Ends Computations After Last Profile

V. Example of HEC2 Input

A. Problem Statement

You are chairman of the board of a major unnamed southwestern Savings and Loan. You plan to invest your client's retirement fund in a subdivision to be built along the portion of Main Stream shown in Figure 1. Some faceless bureaucrats are making you pay for a hydrologic analysis to determine floodplain limits. You have the following information:

- Q100 = 1000 cfs on Main Stream
- Q100 = 90 cfs on Tributary Creek
- Mannings' Roughness:
  - Channel = 0.024
  - Right Overbank = 0.050
  - Left Overbank = 0.045
- River Valley Slope = 0.01 ft/ft
- Cross Section Geometry (Figure 2)
- Reach Lengths: -

Reach Lengths			
Section	Channel	Right	Left
1	0	0	0
2	110	110	110
3	125	130	120
4	155	175	145
5	140	155	120

B. Goal(s) of Analysis

1. ______________________________

2. ______________________________

3. ______________________________

C. Data Entry

1. Where To Find Help

a. HEC2 Manual

b. HEC2 Vendors

c. Chuck Williams

D. How To Obtain Input

1. Data Sources

2. Review Input

5.2 C_ Record - Comments for Describing Data (optional)

Comment records for labeling a cross section must be placed immediately ahead of the first title (T1-T9) record. Comments will be printed in the data input list and in the detailed printout just ahead of the cross section whose number appears in Field 1 of records 3 - 100. Multiple comment records may be used to label a single cross section number.

RECORD NUMBER	FIELD	VARIABLE	VALUE	DESCRIPTION
1	0	IA	C_	Record identification characters (C, blank). Rest of record is blank.
2	0	IA	C_	Record identification character.
2	1	NUMCT	+	Number of data comment records to be printed. An unlimited number of comment records may be used.
3-unlimited	0	IA	C_	Record identification character.
	1	CNOS		Cross section number (Field 1 of X1 record) where title is to be printed. Cross section numbers (X1.1) referenced by comment records should be unique.
3-unlimited	2-10	COCD		Comment to be printed ahead of cross section number CNOS.

Example Application

```
C
C     3
C   100 Junction with Dry Creek
C   185 Spring Creek Gage
C   256 Study Limit
T1
.
.
.
ER
```

5.3 T1 - T9 Records - Title Records (optional)

5.3.1 T1, T2, T4 - T9 Records

Title record for output title. These records are entered before the J1 record. An unlimited number of title records may be input ahead of each J1 record.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	T1 or T2 etc.	Record identification characters.
1-10	none		Numbers and alphabetical characters.

5.3.2 T3 Record

Title record for output title. **The stream name should be entered in Fields 2 through 4 for output in the title of the summary tables and cross section and profile plots.**

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	T3	Record identification characters.
1		0	Not used.
2-4	TITLE		Title for summary tables and cross section and profile plots.
5-10	none		Numbers and alphabetical characters for title.

6 Job Control Records

6.1 J1 Record - Starting Conditions (required)

Job record specifying starting conditions and program options. This record is required for each job (profile).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	J1	Record identification characters.
1	ICHECK	-10	Do not print data records NC - EJ.
		0	Print data records NC - EJ before execution of first profile.
2	INQ	0	QT, ET or X5 records are not used.
		2-20	Field number on QT, ET and X5 records to be used for this profile (job).
3	NINV	0	Option to compute Manning's 'n' from known high water marks will not be used.
		1	Manning's 'n' will be computed from known high water marks. Enter known water surface elevation as variable WSELK on second field of X2 record (X2.2) for each cross section.
4	IDIR	0	Subcritical flow. Cross sectional data (GR records) are input starting at the downstream end of the stream.
		1	Supercritical flow. Cross sectional data are input starting at the upstream end.
5	STRT	-1	Start computations at critical depth.
		0	Start with known water surface elevation. Enter WSEL in field nine.
		+<1	Start by slope-area method. Enter estimated energy slope here. This starting option cannot be used in conjunction with encroachment Methods 3, 4, 5, and 6 at first cross section.

J1 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
		+>1	Number of rating curve (discharge elevation) pairs to be read on the following JR records to start the backwater.
6	METRIC	0	Input and output in English units.
		1	Input and output in Metric units.
7	HVINS	0	No interpolated cross sections to be generated by computer.
		+	Enter maximum allowable change in velocity head between cross sections. If this value is exceeded, interpolated cross sections will be inserted by the program.
8	Q	0	Discharge specified by QT record, INQ(J1.2) is two or greater.
		+	Starting river flow (cfs or cms).
9	WSEL	+	If STRT(J1.5) is zero enter known starting water surface elevation.
10	FQ	0	A factor of 1.0 will be used to multiply all discharges (QT, X2.1 and J1.8).
		+	Factor to multiply all flows by (QT, X2.1 and J1.8).

6.4 J2 Record - Optional Features

Optional record for first profile, **required** record for all subsequent profiles.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	J2	Record identification characters.
1	NPROF	0 or 1	Data records will be read NC - EJ.
		-1	Calls for **summary printout** for a single profile run.
		2-14	Profile number using cross section data from first profile. Up to 14 profiles can be computed using the initial cross section data records NC - EJ.
2	IPLOT	0	No cross sections will be plotted for this job unless individual plots are specified by using IPLOT on X1 record (X1.10).
		1	Line printer plots for **all** cross sections in this job.
		10	Same as above except, data points will be plotted only up to the water surface elevation.
3	PRFVS	0	Computer selects vertical scale of profile plot for current profile based on an elevation spread not exceeding 12 inches.
		+	Users selects vertical scale to be used for current profile. Enter number of elevation units per inch.
		-	No profile will be plotted.
4	XSECV	0	Computer selects vertical scale of cross section plot for each cross section individually.
		+	User selects vertical scale to be used for **all** cross sections. Enter number of elevation units per inch.

J2 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
5	XSECH	0	Computer selects horizontal scale of cross section plot for each cross section individually.
		+	User selects horizontal scale to be used for **all** cross sections. Enter number of horizontal units per line of output. If the vertical scale of the profile (PRFVS) is given, then the value of XSECH will be used for the horizontal scale of both the cross sections and **profiles**.
6	FN	0	A factor of 1.0 will be used.
		+	Factor to multiply all Manning's 'n' values by. (NC, NV and NH records).
		-	Factor to multiply NC channel 'n' values by (NC.3). NC record overbank 'n' values (NC.1 and .2). (All NV and NH 'n' values are modified).
7	ALLDC	-1	Critical depth will be computed for all cross sections using an allowable error of 2.5 percent of the depth.
		-	Same as ALLDC equal to negative one, except allowable error of ALLDC percent will be used.
		0	Critical depth will not be computed unless the actual depth is close to critical (except when low flow occurs for the special bridge method or when supercritical flow profiles are computed). An allowable error of 2.5 percent of the depth will be used.
		+	Same as ALLDC equal zero except, allowable error of ALLDC percent will be used.

J2 Record (continued)

Channel Modification Due to Excavation

Through the use of subroutine CHIMP the existing cross section (as described by GR records) may be modified by a trapezoidal channel excavation as specified by the use of the optional record CI and the eighth and ninth fields of the J2 record. A CI record should be located after the X1 record of the cross section where the improvement is to be initiated. The trapezoidal modification will start on the first cross section that has a CI record and will continue on each cross section until a CI record is read that has .01 for the channel bottom. Any changes in the variables on the CI record must be made by another CI record. Only those variables that change need to be shown on the CI record.

FIELD	VARIABLE	VALUE	DESCRIPTION
8	IBW	0	If a CI or IC record is read, the sixth field of the record will be used.
		6-10	Field number of field on CI record where channel bottom width is specified, or ice thickness factor on IC record. A negative value will create a TAPE16 file of adjusted cross section data in GR format. CI input is not required for this option.
9	CHNIM	0	Overbank 'n' values are unchanged.
		+	NH record (horizontal 'n' value variation) is to be simulated by the computer so that the channel 'n' value is used for a distance of CHNIM on each side of the left or right bank stations (which may be modified by the channel excavation described by the CI record). NH or NV records should not be used with this option.
10	ITRACE	0	No trace for this job unless specified by individual cross sections using ITRACE on X2 record (X2.10). Trace printout is used by programmers to debug the program, it is not recommended for general application.
		1	Minor trace for all cross sections.
		10	Major and minor trace for all cross sections. (Large amount of output.)
		15	Flow distribution printout for all cross sections (no major or minor trace for all cross sections).

7.6 QT Record - Table of Discharges for Multiple Profiles

Specifies a table of flows for use in computing a series of water surface profiles. The field of the flow being used for this job is specified by variable INQ(J1.2).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	QT	Record identification characters.
1	NUMQ	1-19	Total number of flows (maximum 19) entered on the QT records. If NUMQ is greater than nine, two QT records are required, and the first field of the second QT record should contain a Q(N) value.
2-20	Q(N)	+	Flow values to be used for multiple profiles. Variable INQ(J1.2) indicates which field is used for this job. INQ may range from 2 to 20.

7.2 NC Record - Starting Manning's 'n' Values and Shock Losses

Manning's 'n' and the expansion and contraction coefficients for transition (shock) losses are entered for starting each job, or for changing values previously specified. The NC record is required for the first cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	NC	Record identification characters.
1	XNL	0	No change in Manning's 'n' value for the left overbank.
		+	Manning's 'n' value for the left overbank.
2	XNR	0	No change in Manning's 'n' value for the right overbank.
		+	Manning's 'n' value for the right overbank.
3	XNCH	0	No change in Manning's 'n' value for the channel.
		+	Manning's 'n' value for the channel.
4	CCHV	0	No change in contraction coefficient.
		+	Contraction coefficient used in computing transition losses.
5	CEHV	0	No change in expansion coefficient.
		+	Expansion coefficient used in computing transition losses.
6-10			Not used.

8 Cross Section Records

8.1 X1 Record - General Items for Each Cross Section (required)

This record is required for each cross section (800 cross sections can be used for each profile) and is used to specify the cross section geometry and program options applicable to that cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	X1	Record identification characters.
1	SECNO	+	Cross section identification number.
		-	Start new tributary backwater at this cross section.
2	NUMST	0	**Previous** cross section is repeated for current section. GR records are not entered for this cross section.
		+	Total number of stations on the following GR records.
3	STCHL	0	NUMST(X1.2) is 0.
		+	The station of the left bank of the channel. Must be equal to one of the STA(N) on next GR records.
4	STCHR	0	NUMST(X1.2) is 0.
		+	The station of the right bank of the channel. Must be equal to one of the STA(N) on GR records and equal to or greater than STCHL.
5	XLOBL	+	Length of **left overbank** reach between current cross section and next downstream cross section. Zero for first cross section if IDIR = 0, (J1.4).
6	XLOBR	+	Length of **right overbank** reach between current cross section and next downstream cross section. Zero for first cross section if IDIR = 0.
7	XLCH	+	Length of **channel** reach between current cross section and next downstream cross section. Zero for first cross section if IDIR = 0.

X1 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
8	PXSECR	0	Cross section stations will not be changed by the factor PXSECR.
		+	Factor to modify the horizontal dimensions of a cross section. The distances between adjacent GR stations (STA) are multiplied by this factor to expand or narrow a cross section. The STA of the first GR point remains the same. The factor can apply to a repeated cross section or a current one. A factor of 1.1 will increase the horizontal distance between the GR stations by ten percent. (See X2.9 for station adjustment to BT data.) This factor will adjust data from CI records and NH or NK stations for repeat sections. It will not adjust data from X4 records in repeat cross sections.
9	PXSECE	0	Cross section elevations will not be changed.
		+ or -	Constant to be added (+ or -) to GR elevation data (either previous or current). Sediment elevation data (X3.2) input at current cross section is not modified by this factor. (See X2.7 for elevation change to BT data.) Will not adjust X4 records in repeat cross sections.
10	IPLOT	0	Current cross section will not be plotted unless all cross sections were requested by J2 record.
		1	Plot current cross section using all points.
		10	Plot current cross section using only those points up to the water surface elevation.

8.8 GR Record - Ground Profiles Elevations and Stations

This record specifies the elevation and station of each point in a cross section used to describe the ground profile, and is required for each X1 record unless NUMST (X1.2) is zero. The points outside of the channel determine the subdivision of the cross section which influences calculation of a discharge-weighted velocity head for the cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	GR	Record identification characters.
1	EL(1)	+ or -	Elevation of cross section point one at station STA(1). May be positive or negative.
2	STA(1)	+	Station of cross section point one.
3	EL(2)	+ or -	Elevation of cross section point two at STA(2).
4	STA(2)	+	Station of cross section point two.
5-10 etc.			

Continue with additional GR records using up to 100 points to describe the cross section. Stations must be in increasing order progressing from left to right across the cross section.

6.9 EJ Record - End of Job (required)

Required following data for the last cross section. This record is **only** used for the first profile of multiple profile jobs because the cross section data records are read for the first profile only. Each group of records beginning with the T1 record is considered a job.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	EJ	Record identification characters.
1-10			Not used.

6.10 ER Record - End of Run (required)

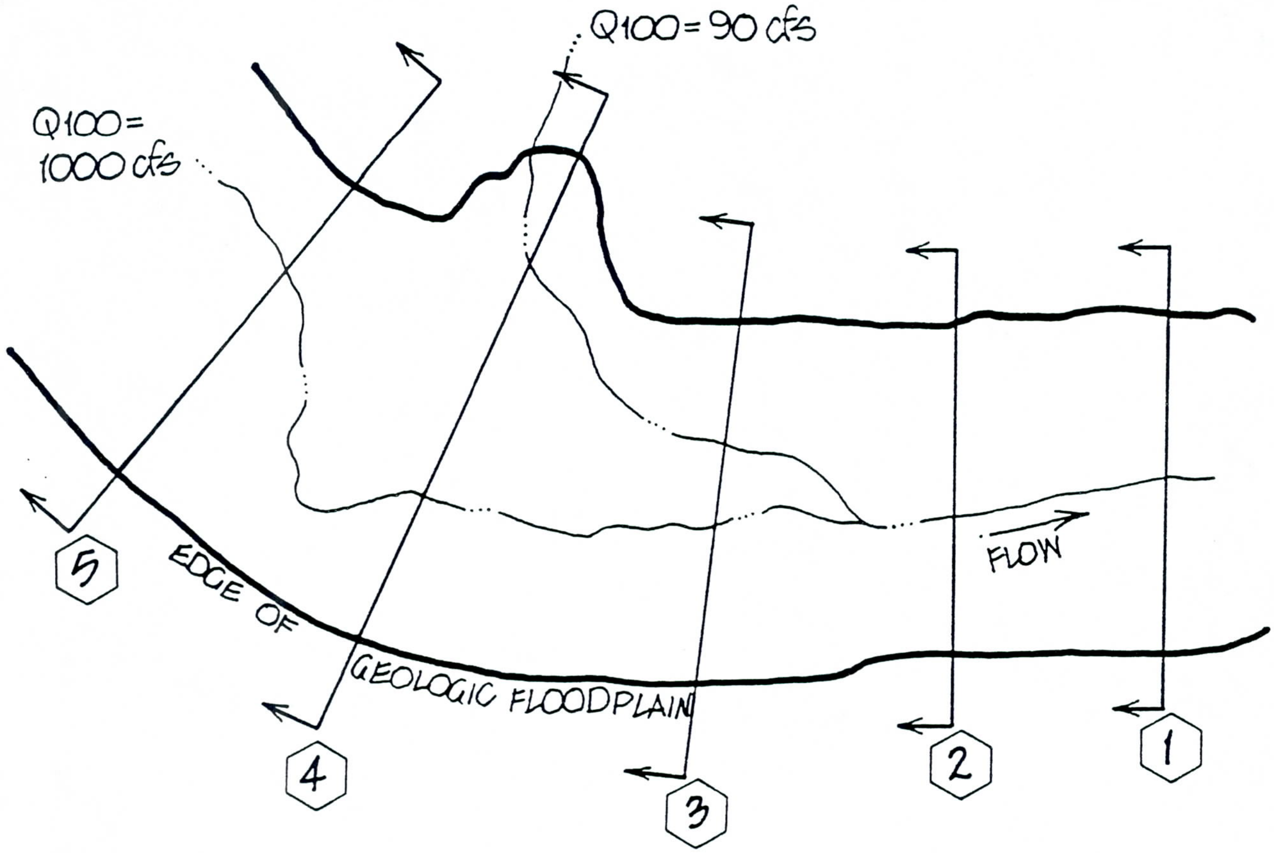
Required at the end of a run consisting of one or more jobs in order to end computation on stop command.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	ER	Record identification characters.
1-10			Not used.

```
T1  Sample Problem for AFMA Training Seminar
T2  Fuller 1/92  Subdivision on Main Stream  Q100=1000 cfs  Q2=50 cfs
T3      Sample Problem          Hydraulic Data Supplied by Client
J1             2               0    0.01                              94
J2     1
QT     2      50    1000
NC 0.045    0.05   0.024     0.1     0.3
X1     1       8     100     130
GR   100       0      90      20      89     100      85     104      85     124
GR    90     130      93     160     100     220
X1     2       0                     110     110     110               1
X1     3      15     130     160     120     130     125
GR   105       0      92      20      91      80      88      82      88      87
GR    90      90      90     130      87     135      87     155      91     160
GR    94     166      94     170      91     175      92     190     105     230
X1     4      12     200     250     145     175     155
GR   110       0      94      20      93      30      91      35      91      45
GR    93      50      92     200      89     205      89     245      93     250
GR    94     290     110     340
X1     5       8      50      75     120     155     140
GR   115       0      98      10      97      50      94      51      93      71
GR    96      75      98     280     115     320
EJ
T1  Sample Problem for AFMA Training Seminar
T2  Fuller 1/92  Subdivision on Main Stream  Q100=1000 cfs  Q2=50 cfs
T3       Sample  Q2
J1             3               0    0.01                              94
J2    15


ER
```

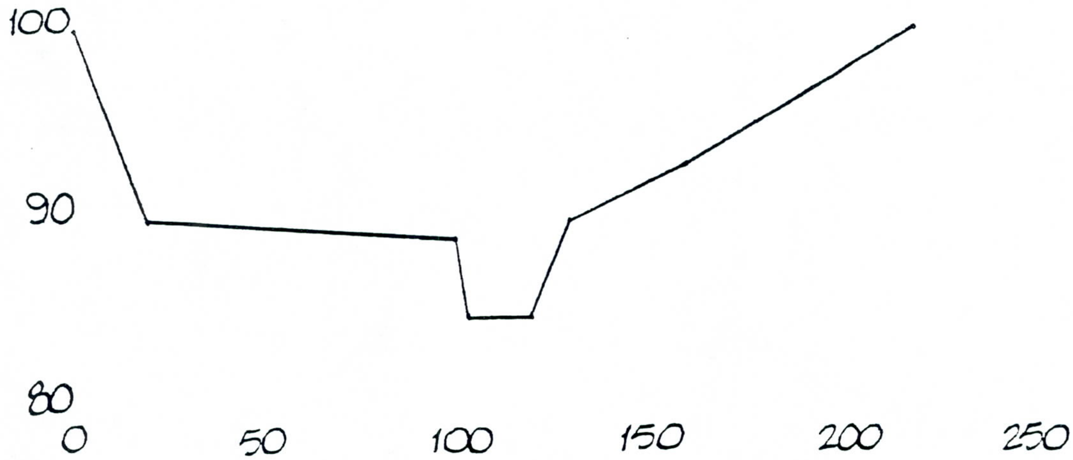
HEC 2 EXAMPLE



SUBJECT: HEC 2 EXAMPLE

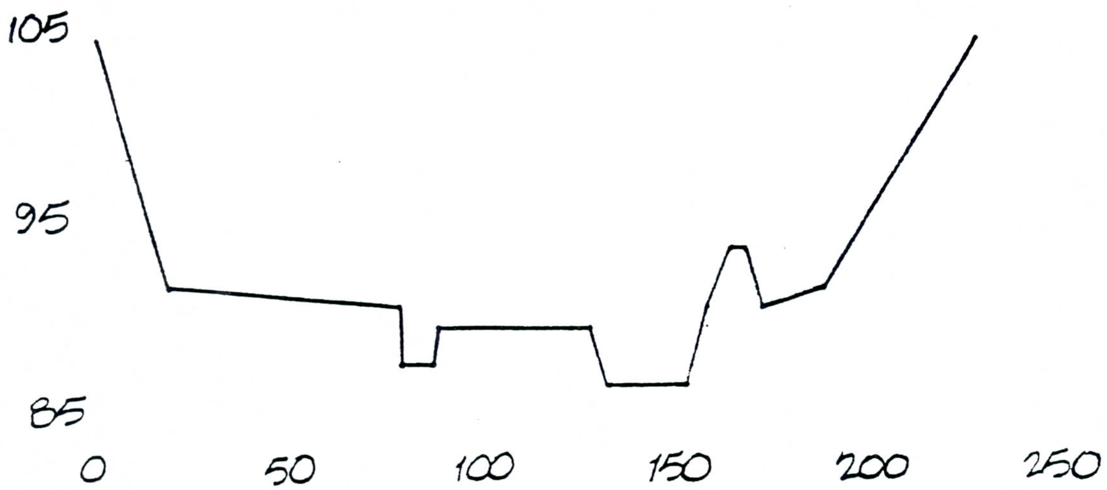
JOB NO.:

CROSS-SECTION #1



CROSS-SECTION #2, SAME AS #1 W/INCREASED ELEVATION BY 1 FOOT

CROSS-SECTION #3



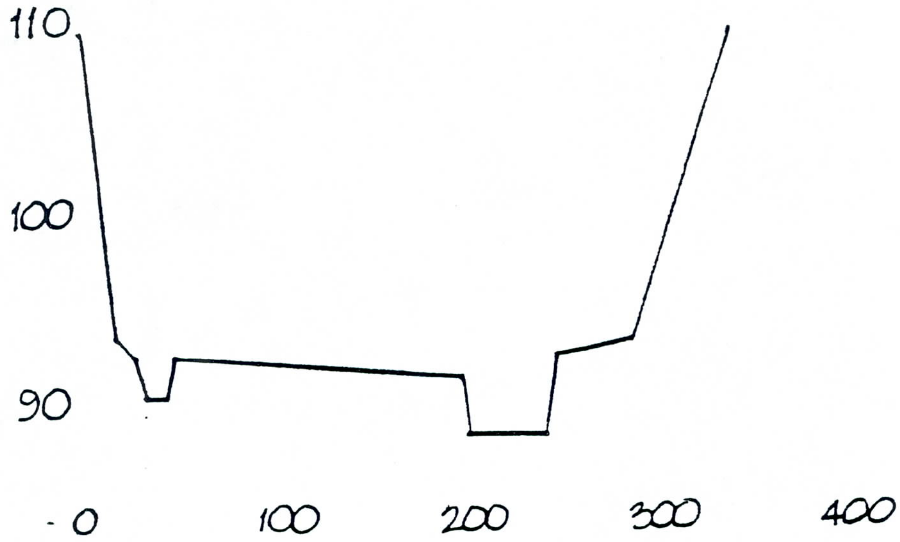
PREPARED BY: DATE: CHECKED BY: SHEET NO.: 1 OF 2

CBA
CELLA BARR ASSOCIATES
4911 EAST BROADWAY
TUCSON, ARIZONA 85711
(602) 750-7474
FAX (602) 750-7470

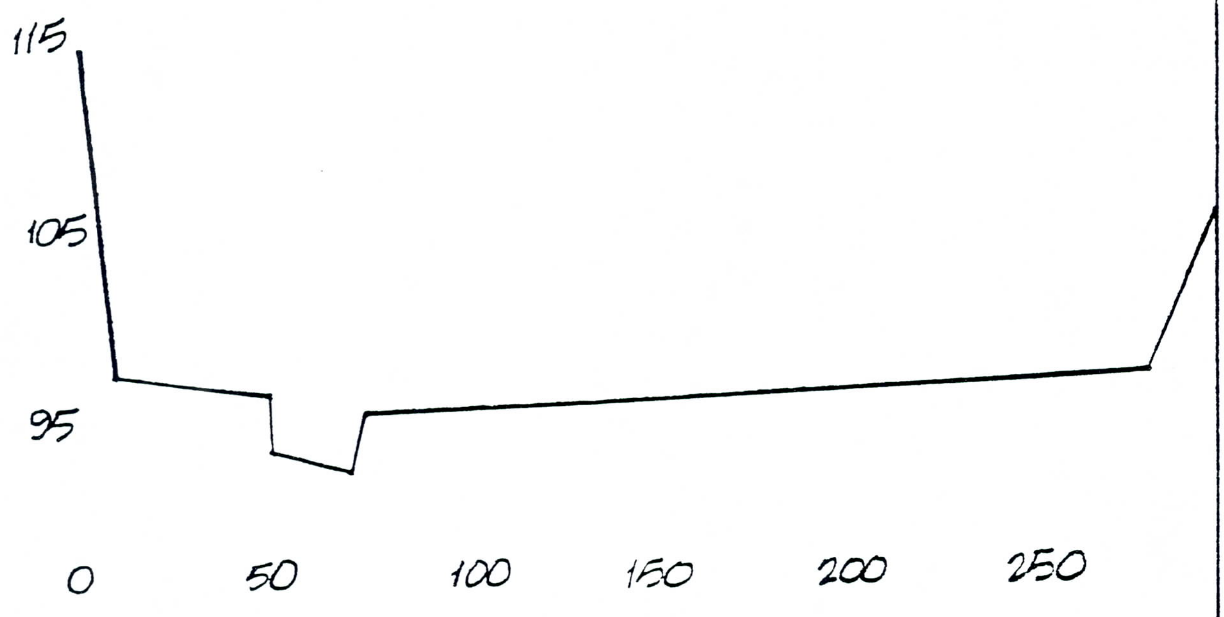
SUBJECT: HEC 2 EXAMPLE

JOB NO.:

CROSS-SECTION #4



CROSS-SECTION #5



PREPARED BY: DATE: CHECKED BY: SHEET NO.: 2 OF 2

CBA
CELLA BARR ASSOCIATES
4911 EAST BROADWAY
TUCSON, ARIZONA 85711
(602) 750-7474
FAX (602) 750-7470

```
1*****************************************************          ****************************************
 *  WATER SURFACE PROFILES                             *          *  U.S. ARMY CORPS OF ENGINEERS        *
 *  VERSION OF SEPTEMBER 1988                          *          *  THE HYDROLOGIC ENGINEERING CENTER   *
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END OF BANNER

1

12/29/91 19:14:13 PAGE 1

THIS RUN EXECUTED 12/29/91 19:14:14

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*************************************************
 HEC2 RELEASE DATED SEP 88 UPDATED SEPT 1989

 RROR CORR -  01,02,03
 MODIFICATION -
*************************************************
```

T1 Sample Problem for AFMA Training Seminar
T2 Fuller 1/92 Subdivision on Main Stream Q100=1000 cfs Q2=50 cfs
T3 Sample Problem Hydraulic Data Supplied by Client

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		2		0	0.01				94	

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	1									

QT	2	50	1000							
NC	0.045	0.05	0.024	0.1	0.3					
X1	1	8	100	130						
GR	100	0	90	20	89	100	85	104	85	124
GR	90	130	93	160	100	220				
X1	2	0			110	110	110		1	
X1	3	15	130	160	120	130	125			
	105	0	92	20	91	80	88	82	88	87
	90	90	90	130	87	135	87	155	91	160
GR	94	166	94	170	91	175	92	190	105	230
X1	4	12	200	250	145	175	155			
GR	110	0	94	20	93	30	91	35	91	45

```
GR       93        50        92       200        89       205        89       245        93       250
GR       94       290       110       340

X1        5         8        50        75       120       155       140
        115         0        98        10        97        50        94        51        93        71
         96        75        98       280       115       320
1
   12/29/91      19:14:13                                                                                   PAGE     2


   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST


*PROF 1

CCHV=     .100 CEHV=      .300
*SECNO 1.000
     1.000       .58     85.58     85.57     94.00     85.85       .27       .00       .00     89.00
       50.        0.       50.      . 0.        0.       12.        0.        0.        0.      90.00
       .00       .00      4.17       .00      .000      .024      .000      .000     85.00    103.42
   .009994        0.        0.        0.         0        17         0       .00     21.28    124.70
0
*SECNO 2.000
     2.000       .61     86.61       .00       .00     86.85       .24      1.00       .00     90.00
       50.        0.       50.        0.        0.       13.        0.        0.        0.      91.00 -
       .01       .00      3.93       .00      .000      .024      .000      .000     86.00    103.38
   .008259      110.      110.      110.         2         0         0       .00     21.35    124.74
0
*SECNO 3.000
     3.000       .62     87.62       .00       .00     87.85       .23      1.00       .00     90.00
       50.        0.       50.        0.        0.       13.        0.        0.        0.      91.00
       .02       .00      3.82       .00      .000      .024      .000      .000     87.00    133.96
   .007730      120.      125.      130.         3         0         0       .00     21.82    155.78
0
*SECNO 4.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     4.000       .36     89.36     89.36       .00     89.54       .18      1.47       .00     92.00
       50.        0.       50.        0.        0.       15.        0.        0.        0.      93.00
       .03       .00      3.40       .00      .000      .024      .000      .000     89.00    204.40
   .011926      145.      155.      175.         5        11         0       .00     41.06    245.45
0
*SECNO 5.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     5.000      1.05     94.05     94.05       .00     94.33       .28      1.60       .03     97.00
       50.        0.       50.        0.        0.       12.        0.        0.        0.      96.00
       .04       .00      4.28       .00      .000      .024      .000      .000     93.00     50.98
   .010993      120.      140.      155.        20        23         0       .00     21.41     72.40
0
1
PROFILE FOR STREAM  Sample Problem



PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA



ELEVATION    85.       90.        95.       100.       105.       110.       115.       120.       125.       130.
    SECNO    CUMDIS
```

```
 1.00    0.  IWE     L R         .          M         .         .         .         .         .         .         .
        20.  I E     L R         .          M         .         .         .         .         .         .         .
        40.  CIE      L.R        .         .M         .         .         .         .         .         .         .
        60.  CIWE     L.R        .         .M         .         .         .         .         .         .         .
        80.  CI E     L.R        .         .M         .         .         .         .         .         .         .
       100.  C IWE     L R       .         . M        .         .         .         .         .         .         .
 2.00  120.  C IWE     L R       .         . M        .         .         .         .         .         .         .
       140.  C I E     L R       .         .  M       .         .         .         .         .         .         .
       160.  C  IE     L R       .         .    M     .         .         .         .         .         .         .
       180.  C  IWE    L R       .         .     M    .         .         .         .         .         .         .
       200.  C  I E    L R       .         .      M   .         .         .         .         .         .         .
       220.  C   IE    L R       .         .       M  .         .         .         .         .         .         .
 3.00  240.  C   IWE   L R       .         .          M         .         .         .         .         .         .
       260.  C    IE   .L R      .         .          .M        .         .         .         .         .         .
       280.  C    IWE  .L R      .         .          .  M      .         .         .         .         .         .
       300.  C     IE  . L R     .         .          .   M     .         .         .         .         .         .
       320.  C     IE  . L R     .         .          .    M    .         .         .         .         .         .
       340.  C      WE .  L R    .         .          .     M   .         .         .         .         .         .
       360.  C      IE .  L R    .         .          .       M .         .         .         .         .         .
       380.  C       WE.   L R   .         .          .        M.         .         .         .         .         .
 4.00  400.  .       IE.   L R   .         .          .         M         .         .         .         .         .
       420.  .        IE    L R  .         .          .         .M        .         .         .         .         .
       440.  .         IWE    LR .         .          .         .  M      .         .         .         .         .
       460.  .         .I E    LR.         .          .         .   M     .         .         .         .         .
       480.  .         .  IWE   RL         .          .         .     M   .         .         .         .         .
       500.  .         .   IWE   RL        .          .         .      M  .         .         .         .         .
       520.  .         .    I E .R L       .          .         .        M.         .         .         .         .
 5.00  540.  .         .     I WE. R L     .          .         .         M         .         .         .         .
```

```
1
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 T1   Sample Problem for AFMA Training Seminar
 T2   Fuller 1/92  Subdivision on Main Stream  Q100=1000 cfs  Q2=50 cfs
 T3        Sample  Q2

 J1  ICHECK     INQ      NINV      IDIR      STRT     METRIC    HVINS      Q        WSEL       FQ

                 3                   0       0.01                                    94

 J2  NPROF     IPLOT     PRFVS     XSECV     XSECH      FN       ALLDC      IBW      CHNIM     ITRACE

      15



1
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   SECNO     DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL       OLOSS    BANK ELEV
   Q         QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID     ENDST


*PROF 2

CCHV=      .100 CEHV=      .300
*SECNO 1.000
3 CRITICAL DEPTH ASSUMED
    1.000     3.90     88.90     88.90     94.00     90.63      1.74      .00      .00     89.00
    1000.       0.     1000.        0.        0.       95.        0.       0.       0.     90.00
      .00      .00     10.57       .00      .000      .024      .000     .000     85.00    100.10
  .006754       0.        0.        0.         0        14         0      .00     28.57    128.67
```

0
*SECNO 2.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

2.000	3.94	89.94	89.94	.00	91.63	1.69	.73	.00	90.00
1000.	0.	1000.	0.	0.	96.	0.	0.	0.	91.00
.00	.00	10.44	.00	.000	.024	.000	.000	86.00	100.06
.006504	110.	110.	110.	3	5	0	.00	28.66	128.73

0
*SECNO 3.000

3265 DIVIDED FLOW

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.88

3.000	4.63	91.63	.00	.00	92.14	.51	.39	.12	90.00
1000.	220.	777.	2.	107.	121.	4.	1.	0.	91.00
.01	2.06	6.41	.58	.045	.024	.050	.000	87.00	42.57
.001835	120.	125.	130.	4	0	0	.00	129.08	184.36

0
*SECNO 4.000

3265 DIVIDED FLOW

3301 HV CHANGED MORE THAN HVINS

1

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = .58

4.000	2.71	91.71	91.64	.00	92.75	1.04	.45	.16	92.00
1000.	15.	985.	0.	8.	119.	0.	1.	1.	93.00
.01	1.84	8.26	.00	.045	.024	.000	.000	89.00	33.22
.005528	145.	155.	175.	6	11	0	.00	61.47	248.39

0
*SECNO 5.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

5.000	4.68	97.68	97.68	.00	98.44	.77	.57	.03	97.00
1000.	8.	780.	212.	9.	98.	144.	2.	1.	96.00
.02	.89	7.92	1.47	.045	.024	.050	.000	93.00	22.88
.003088	120.	140.	155.	20	11	0	.00	224.12	247.00

0
1
PROFILE FOR STREAM Sample Q2

PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

```
ELEVATION    85.       90.       95.      100.      105.      110.      115.      120.      125.      130.
    SECNO   CUMDIS

     1.00      0.  I       W RE         .         M         .         .         .         .         .         .         .
              20.  I       W R E        .         M         .         .         .         .         .         .         .
              40.  .I       W.RE        .         .M        .         .         .         .         .         .         .
              60.  .I       W.RE        .         .M        .         .         .         .         .         .         .
              80.  .I       W.R E       .         .M        .         .         .         .         .         .         .
             100.  . I       W RE       .         . M       .         .         .         .         .         .         .
     2.00    120.  . I       W RE       .         . M       .         .         .         .         .         .         .
             140.  C I       W RE       .         .  M      .         .         .         .         .         .         .
             160.  C  I      LWR E      .         .    M    .         .         .         .         .         .         .
             180.  C  I      LWR E      .         .     M   .         .         .         .         .         .         .
             200.  C  I      L W E      .         .      M  .         .         .         .         .         .         .
             220.  C    I    L RWE      .         .       M .         .         .         .         .         .         .
     3.00    240.  C    I    L RWE      .         .         M         .         .         .         .         .         .
             260.  C     I   .L WE      .         .         .M        .         .         .         .         .         .
             280.  C     I   .L W E     .         .         .  M      .         .         .         .         .         .
             300.  C      I  . LWRE     .         .         .   M     .         .         .         .         .         .
             320.  C      I  . LWRE     .         .         .    M    .         .         .         .         .         .
             340.  C      I  .  W E     .         .         .     M   .         .         .         .         .         .
             360.  C      I  .  W E     .         .         .       M .         .         .         .         .         .
             380.  C       I .  WLER    .         .         .        M.         .         .         .         .         .
     4.00    400.  .       I .  WL E    .         .         .         M         .         .         .         .         .
             420.  .        I.    W E   .         .         .         .M        .         .         .         .         .
             440.  .         I       WRE.         .         .         . M       .         .         .         .         .
             460.  .         .I      CWE          .         .         .  M      .         .         .         .         .
             480.  .         .  I     RW E        .         .         .    M    .         .         .         .         .
             500.  .         .   I     RLW E      .         .         .     M   .         .         .         .         .
             520.  .         .    I     .R LWE    .         .         .        M.         .         .         .         .
     5.00    540.  .         .     I    . R LW E  .         .         .         M         .         .         .         .
1
```

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THIS RUN EXECUTED 12/29/91 19:14:33

```
*****************************************************
  HEC2 RELEASE DATED SEP 88 UPDATED SEPT 1989


  ERROR CORR -  01,02,03
  MODIFICATION -
*****************************************************
```

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

Sample Problem

SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10*KS	VCH	AREA	.01K
	1.000	.00	.00	.00	85.00	50.00	85.58	85.57	85.85	99.94	4.17	12.00	5.00
*	1.000	.00	.00	.00	85.00	1000.00	88.90	88.90	90.63	67.54	10.57	94.60	121.68
	2.000	110.00	.00	.00	86.00	50.00	86.61	.00	86.85	82.59	3.93	12.73	5.50
*	2.000	110.00	.00	.00	86.00	1000.00	89.94	89.94	91.63	65.04	10.44	95.83	124.00
	3.000	125.00	.00	.00	87.00	50.00	87.62	.00	87.85	77.30	3.82	13.08	5.69
*	3.000	125.00	.00	.00	87.00	1000.00	91.63	.00	92.14	18.35	6.41	231.72	233.46

*	4.000	155.00	.00	.00	89.00	50.00	89.36	89.36	89.54	119.26	3.40	14.71	4.58
*	4.000	155.00	.00	.00	89.00	1000.00	91.71	91.64	92.75	55.28	8.26	127.60	134.50
*	5.000	140.00	.00	.00	93.00	50.00	94.05	94.05	94.33	109.93	4.28	11.68	4.77
	5.000	140.00	.00	.00	93.00	1000.00	97.68	97.68	98.44	30.88	7.92	251.95	179.96

Sample Problem

SUMMARY PRINTOUT TABLE 150

	SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
	1.000	50.00	85.58	.00	.00	-8.42	21.28	.00
*	1.000	1000.00	88.90	3.31	.00	-5.10	28.57	.00
	2.000	50.00	86.61	.00	1.03	.00	21.35	110.00
*	2.000	1000.00	89.94	3.33	1.04	.00	28.66	110.00
	3.000	50.00	87.62	.00	1.01	.00	21.82	125.00
*	3.000	1000.00	91.63	4.00	1.69	.00	129.08	125.00
*	4.000	50.00	89.36	.00	1.74	.00	41.06	155.00
*	4.000	1000.00	91.71	2.34	.08	.00	61.47	155.00
*	5.000	50.00	94.05	.00	4.68	.00	21.41	140.00
*	5.000	1000.00	97.68	3.63	5.97	.00	224.12	140.00

SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO= 1.000 PROFILE= 2 CRITICAL DEPTH ASSUMED

CAUTION SECNO= 2.000 PROFILE= 2 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 2.000 PROFILE= 2 MINIMUM SPECIFIC ENERGY

WARNING SECNO= 3.000 PROFILE= 2 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO= 4.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 4.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY
WARNING SECNO= 4.000 PROFILE= 2 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO= 5.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 5.000 PROFILE= 1 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 5.000 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL
CAUTION SECNO= 5.000 PROFILE= 2 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 5.000 PROFILE= 2 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 5.000 PROFILE= 2 20 TRIALS ATTEMPTED TO BALANCE WSEL

HEC-2 Technical Session (2/20/92)

PROGRAM OUTPUT

1. Options
2. Output Data Description
3. Special Notes
4. Channel Cross Section Output
   a. Cross-section Plot
   b. Profile Plot
5. Bridge/Culvert Output
   a. Special Bridge
   b. Normal Bridge
   c. Culvert
6. Graphics Plots - Samples

Chapter 6

Program Output

(1990 Version)

6.1 General

Computer program HEC-2 provides the user with a wide variety of output control options. Program output is generally written to output files(s), although on PC systems some output is directed to the monitor. Commonly used output options are shown in Appendix I, Sample Application of HEC-2. Table 4 summarizes output control options.

Table 4
Control of Program Output

Output	Control Records
Commentary	C
Input Data Listing*	J1.1
Detailed Output by Cross Section*	J5
Flow Distribution	J2.10, X2.10
Traces	J2.10, X2.10
Summary Tables*	J2.1, J3, J5
Profile Plots*	J2.3
Cross Section Plots	J2.2, X1.10
Archival Tape	AC
Storage-Outflow	J4

*These data are normal program output, but may be suppressed.

Appendix VI

Output Data Description

(1990 Version)

Output Data Description

This appendix contains a description of all output variables that apply to any cross section. Many of these variables can be selected for summary printout display.

Variable	Description
ACH	Cross section area of the channel.
ACULV	Gross area of culvert.
AEX	Area of channel improvement excavation in square feet at cross section.
ALOB	Cross section area of the left overbank.
ALPHA	Velocity head coefficient.
AREA	Cross section area.
AROB	Cross section area of the right overbank.
ASQ	The assumed **split flow** value used to compute the water surface elevation.
AV DEPTH	The average depth of flow for the normal depth section based on the total area divided by the water surface topwidth (split flow option).
AVG VELOCITY	The average velocity of the normal depth overflow reach (split flow option).
B	Stream width, used for ice stability analysis.
BANK ELEV LEFT/RIGHT	Left and right bank elevations.
BAREA	Net area of the bridge opening below the low chord. Entered on SB record.
B-S N	Value of composite Manning's 'n' for ice covered stream computed by Belokon-Sabaneev formula.
BW	The bottom width of the trapezoidal excavation.
C	Chezy's roughness coefficient, used in ice stability equation.
CASE	A variable indicating how the water surface elevation was computed. Values of -1, -2, -3, and 0 indicate assumptions of critical depth, minimum difference, a fixed change (X5 record), or a balance between the computed and assumed water surface elevations, respectively.
CCHV	Contraction coefficient.

Variable	Description
CEHV	Expansion coefficient.
CHRT	Chart number for FHWA culvert nomographs
CHSLOP	Channel slope.
CLASS	Identification number for following types of bridge/culvert flow.

Class	Type of Flow
1	Low Flow - Class A
2	Low Flow - Class B
3	Low Flow - Class C
6	Culvert Analysis, Inlet Control
7	Culvert Analysis, Outlet Control
10	Pressure Flow Alone
11,15	Weir and Low Flow - Class A
12	Weir and Low Flow - Class B
13	Weir and Low Flow - Class C
16	Culvert Analysis, Weir Flow & Inlet Control
17	Culvert Analysis, Weir Flow & Outlet Control
30	Pressure Flow and Weir Flow
59	Special Bridge Reverts to Normal Bridge Method
67	For Encroachment Methods 3 through 6

Variable	Description
CLSTA	The centerline station of the trapezoidal excavation.
CORAR	Area of the bridge deck subtracted from the total cross sectional area in the normal bridge method.
CRIWS	Critical water surface elevation.
CULVLN	Length of culvert barrel.
CUMDS	Cumulative channel distance from first cross section. (Units are based on J1.6 and J6.4 input).
CUNO	Number of identical culverts.
CUNV	Manning's 'n' value for culvert barrel.
CWSEL	Computed water surface elevation.
DEPTH	Depth of flow.
DIFEG	Difference in energy elevation for each profile.
DIFKWS	Difference in water surface elevation between known and computed.
DIFWSP	Difference in water surface elevation for each profile.
DIFWSX	Difference in water surface elevation between sections.

Variable	Description
DSSNO	The downstream section number where the split flow reach begins.
DSWS	The computed downstream water surface elevation (split flow option).
EG	Energy gradient elevation for a cross section which is equal to the computed water surface elevation CWSEL plus the velocity head HV.
EGIC	Energy grade elevation for inlet control when using culvert analysis option
EGLWC	The energy grade line elevation computed assuming low flow.
EGOC	Energy grade elevation for outlet control when using culvert analysis option.
EGPRS	The energy grade line elevation computed assuming pressure flow.
ELENCL	Elevation of left encroachment.
ELENCR	Elevation of right encroachment.
ELLC	Elevation of the bridge low chord. Equals ELLC entered on the X2 record if used, otherwise it equals maximum low chord in the BT table.
ELMIN	Minimum elevation in the cross section.
ELTRD	Elevation of the top of roadway. Equals ELTRD entered on the X2 record if used, otherwise it equals the minimum top of the road in the BT table.
ENDST	Ending station where the water surface intersects the ground on the right side.
ENTLC	Entrance loss coefficient for culvert analysis.
ERRAC	The percent error between the assumed discharge and computed discharge using the split flow option.
FRCH	Channel Froude number for uniform conditions.
H	Hydraulic radius, used in ice stability equation.
H3	Drop in water surface elevation from upstream to downstream sides of the bridge computed using Yarnell's equation assuming Class A low flow.
H4	Drop in water surface elevation from upstream to downstream using culvert analysis option.
HL	Energy loss due to friction.
HV	Discharge-weighted velocity head for a cross section.
IDC	Number of trials required to determine critical depth.
ICE N	Manning's 'n' value for floating ice entered on IC record.

Variable	Description
ICONT	Number of trails to determine the water surface elevation by the slope area method, or the number of trials to balance the energy gradient by the special bridge method, or the number of trials required to calculate encroachment stations by encroachment methods 5 and 6.
IHLEQ	Friction loss equation index.
ITRIAL	Number of trials required to balance the assumed and computed water surface elevations.
K*CHSL	Channel bed slope (times 1,000).
KRATIO	Ratio of the upstream to downstream conveyance.
L-BANK ELEV	Elevation of left bank station.
MAX DEPTH	The maximum depth that occurs on the normal depth overflow section (split flow option).
NICE	Manning's 'n' for underside of ice cover.
NITER	The number of iterations executed to compute split flow discharge.
OLOSS	Energy loss due to minor losses such as transition losses.
PCWSE	Previous computed water surface elevation.
PERENC	The target of encroachment requested on the ET record.
POWER	Channel stream power (lb/(ft*s) or N/(m*s)).
Q	Total flow in the cross section.
QCH	Amount of flow in channel.
QCHP	Percent of flow in the channel.
QCOMP	The computed split flow value based on the computed water surface elevation.
QCULV	Flow through culvert, using culvert analysis option.
QLOB	Amount of flow in the left overbank.
QLOBP	Percent of flow in the left overbank.
QLOW	Low flow at bridge, special bridge analysis. Pressure flow at the bridge, special bridge analysis.
QPR	Total pressure of low flow at the bridge.
QROB	Amount of flow in the right overbank.

Variable	Description
QROBP	Percent of flow in the right overbank.
QWEIR	Total weir flow at the bridge.
R-BANK ELEV	Elevation of right bank station.
RBEL	Right bank elevation.
RISE	Height of box culvert or diameter of pipe culvert.
SCL	Scale number for FHWA culvert nomographs.
SECNO	Identifying cross section number. Equal to the number in the first field of the X1 record.
SHEAR	Boundary shear stress within channel (lb/ft^2 or N/m^2).
SLOPE	Slope of the energy grade line for the current section.
SPAN	Width of box culvert.
SPGR	Specific gravity of floating ice. Entered on IC record.
SSTA	Starting station where the water surface intersects the ground on the left side of the cross section.
STENCL	The station of the left encroachment.
STENCR	The station of the right encroachment.
STCHL	Station of the left bank.
STCHR	Station of the right bank.
TABER	Percent of error between the total assumed **split flow** and total computed **split flow**.
TASQ	The total assumed **split flow** for the entire stream.
TCQ	The total computed **split flow** for the entire stream.
TELMX	Elevation of the lower of the end points of the cross section.
T/H (TH1)	Ratio of channel ice thickness and hydraulic radius, used in ice stability equation.
TIME	Travel time from the first cross section to the current cross section in hours.
TOF WIDTH	The width of the normal depth over flow section (split flow option).
TOP WIDTH	The width of the overflow section based on the computed water surface (split flow option).

Variable	Description
TOPWID	Width at the calculated water surface elevation.
TOTAL AREA	The total cross sectional area for a normal depth overflow reach (split flow option).
TRAPEZOID AREA	Net area of the bridge opening up to the low chord as defined by SS, BWP and BWC on the SB record. Should be close to BAREA on the SB record.
TVOLI	Total volume of ice in channel and overbanks.
TWA	Cumulative surface area (acres or 1000 square meters) of the stream (floodplain) from the first cross section.
USSNO	The upstream section number where the **split flow** reach ends.
USWS	The computed upstream water surface elevation (split flow option).
VCH	Mean velocity in the channel.
VEXR	Volume of channel improvement excavation in thousands of cubic yards in a reach (between two adjacent cross sections).
VEXT	Cumulative volume of channel improvement excavation in thousands of cubic yards up to the current cross section.
VLOB	Mean velocity in the left overbank.
VOL	Cumulative volume (acre-feet or 1000 cubic meters) of water in the stream from the first cross section.
VOLICH	Cumulative volume of ice in channel .
VOLIL	Cumulative volume of ice in left overbank.
VOLIR	Cumulative volume of ice in right overbank.
VROB	Mean velocity in the right overbank,
WEIRLN	Length of roadway for weir flow computations, defined by "BT" data and energy grade elevation.
WSELK	Known water surface elevation; for example, a high water mark.
WTN	Length weighted value of Manning's 'n' for the channel. Used when computing Manning's 'n' from high water marks.
X*K	Pariset's ice stability indicator (times 1000).
XFCH1	Froude number for ice stability analysis.
XICE1	Computed ice stability factor (Pariset' X).

Variable	Description
XLBEL	Left bank elevation.
XLCH	Distance in the channel between the previous cross section and the current cross section.
XLOBL	Distance in the left overbank between the previous cross section and the current cross section.
XLOBR	Distance in the right overbank between the previous cross section and the current cross section.
XNCH	Manning's 'n' for the channel area.
XNL	Manning's 'n' for the left overbank area.
XNR	Manning's 'n' for the right overbank area.
XSTAB1	Maximum ice stability factor X, for stable ice cover, from Pariset's ice stability function.
ZINCH	Composite 'n' value for ice covered channel computed with Belokon-Sabaneev formula.
ZITL	Ice thickness in left overbank.
ZITR	Ice thickness in right overbank.
ZITCH	Ice thickness in channel.
.01K	The total discharge (index Q) computed assuming $S^{1/2} = .01$.
10*KS	Slope of energy grade line (times 10,000).

Appendix V

Special Notes

(1990 Version)

This appendix explains special notes which commonly appear as part of the normal output. The special notes should be carefully reviewed to assure an accurate profile. If the reason the notes appear are not satisfactorily substantiated, the job may be rerun obtaining trace printout. (A programmers manual or source listing is required to interpret program traces).

Statement Number	Notes and Remarks
1221	NUMBER PROFILES TOO LARGE. The number of profiles calculated exceeds limit of fourteen.
1262	TAILWATER IS BELOW BRIDGE TRAPEZOID BOTTOM PROGRAM ABORTING AT SECTION X. The water surface elevation at the downstream cross section is below the trapezoid bottom specified on the SB record for this section. Remodel the invert of the downstream cross section to raise the water surface elevation or modify the SB trapezoid.
1340	RECORD NOT RECOGNIZED. First two columns in input record read did not correspond to any of the standard alphanumeric characters used to identify records.
1362	XKOR INCREASED TO 1.2. The orifice coefficient was zero or minus and was therefore changed to 1.2 since 1.0 is the minimum value. (SB.2)
1365	SB RECORD, BWP = 0. On the special bridge method record SB, the pier width omitted. If there are no piers, this is satisfactory. (SB.6)
1366	SB RECORD, BAREA = 0. On the special bridge method record SB, the area of the bridge when flowing full is omitted and therefore this job has been terminated. (SB.7)
1400	CCHV = , CEHV - . A change in contraction and expansion losses has been made. (NC.4 & .5)
1415	INQ EXCEEDS NUMQ. The field of the QT records to be used for the current Q, specified by variable INQ, contained no flow data. (INQ,J1.2)
1445	Q EXCEEDS 19. The number of discharges on the QT record exceed the maximum allowable number of nineteen.
1452	NV RECORDS EXCEED 4. The number of items specified on the NV record exceed the allowable.
1455	NV RECORD USED. A table of Manning's 'n' values for the channel and corresponding elevations, was used.

Statement Number	Notes and Remarks
1481	EL(N) DON'T INCREASE. The elevations on the NV records must increase when the channel roughness is varied with elevation and therefore, the job has been terminated.
1490	NH RECORD USED. Manning's 'n' value varied horizontally in accordance with values on NH record.
1518	NH RECORD STATIONS NOT INCREASING. The stations on the NH record specifying changes in Manning's roughness must increase and therefore, the job has been terminated.
1525	NH VALUES EXCEED 20. Manning's roughness coefficient specified on the NH record exceeded the allowable number.
1535	Q = 0. The discharge was not specified on the QT or J1 records.
1537	START TRIB COMP. Since a negative section number was used, the profile is to be computed on a tributary starting with the water surface elevation which was computed for the same (positive) section number on the main stem.
1553	STARTING NC RECORD OMITTED. The starting values on the NC record were not given. The roughness values assumed were very small (.00001).
1645	INT SEC ADDED BY RAISING SEC *X*, *Y*, FT AND MULTIPLYING BY *Z*. An intermediate cross section was calculated by the computer and inserted between two cross sections specified by input data.
1707	STCHL OF *X*, GREATER THAN *Y*. The station of the left bank is larger than the station of the right bank. The value of STCHL is changed to equal the first station of the cross section. (X1.3)
1740	CHIMP TEMPLATE DOES NOT INTERSECT CROSS SECTION, STMAX SET EQUAL TO *X*. The projected side slopes of the template do not cross the GR data.
1807	BT RECORDS EXCEED 100 PTS. Number of points describing the bridge (BT record) exceed allowable.
1857	BT RECORD, STA DON'T INCREASE. The roadway stations on the BT record should increase. Data should be corrected.
1860	XLCEL OF *X*, EXCEEDS RDEL OF *Y*. The low chord elevation of *X* exceeds the corresponding value of the top of roadway *Y*. Data should be corrected. (BT records)
1912	GR RECORDS, STATIONS DON'T INCREASE. The ground profile points do not increase in horizontal station. The station must be equal to, or greater than the previous station.
2020	NUMBER EL, STA, PTS EXCEED 100. The number of points used to describe the ground profile for the current cross section exceed the allowable. Additional GR points may have been generated by encroachment options.
2077	GR RECORDS MISSING. The GR records for a given X1 record with NUMST greater than zero were not given.

Statement Number	Notes and Remarks
2096	WSEL NOT GIVEN, AVG OF MAX, MIN USED. The starting water surface elevation was not given and therefore, has been assumed as halfway between the maximum and minimum elevation in the cross section. (J1.9)
2620	NO IMPROVEMENT MADE TO THIS SECTION. The subroutine CHIMP has been requested by the CI record and the excavation described will not cut the existing cross section.
2725	WSEL EXCEEDS LIMITS OF TABLE FOR MANNING's 'n'. An assumed water surface elevation fell outside the elevation limits which specified Manning's 'n' values on NV record. Table values were extrapolated for 'n' values.
2750	NUMBER OF COMPUTED POINTS EXCEED 100. The number of points added by subroutine CHIMP have caused the total to exceed one hundred. Reduce the number of points on the GR record.
2800	NATURAL Q1 = *A*, WSEL = *B*, EMC Q1 = *C*, WSEL = *D*, RATIO = *E*. See explanation in section 11.1, Appendix II.
3073	NEGATIVE SLOPE, WSEL = , EG = , PCWSE = , XEG = , WLEN = RESTART COMPUTATIONS AT SECNO = , USING 'n' VALUES COMPUTED FOR SECNO = . A negative slope of the energy gradient has been computed while trying to calculate roughness values that will exactly duplicate the observed high water marks. Due to this condition, the computations will start over again using the previous section's roughness values.
3075	SET S = SAVE. The computed slope at this section was negative or zero. The slope was set equal to the computed average slope between this and the previous section.
3170	NO ENCROACHMENT MORE THAN 800 XSEC. The number of cross sections for a given data set exceeded the maximum allowable for encroachment analysis.
3235	SLOPE TOO STEEP, EXCEEDS *X*. The computed slope of the energy grade line exceeded *X*, and critical depth has probably been crossed. If this cross section is a bridge, the special bridge method should be used in lieu of the normal bridge.
3265	DIVIDED FLOW. The area below the computed water surface elevation is divided into two or more segments by high ground. If this condition occurs for three or more cross sections consecutively, then separate profiles should be run up each leg of the divided flow as the water surface elevations are not necessarily identical at each cross section.
3280	CROSS SECTION EXTENDED *X* FEET (METERS). The cross section's ends have been projected vertically fifty feet (meters) in order to calculate the hydraulic properties of the cross section. Exactly *X* feet (meters) of this extension were used. If this vertical assumption could produce unreasonable results, the input data should be corrected.
3301	HV CHANGED MORE THAN HVINS. The difference between velocity heads computed for the current and previous cross sections exceeded the allowable specified by input as HVINS (or .5 feet if HVINS = 0, J1.7).

Statement Number	Notes and Remarks
3302	WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO =. The ratio (KRATIO) of the conveyance of this cross section to the conveyance of the previous section is outside the following range: 0.7<KRATIO<1.4. This could indicate that additional cross sections are required if the reach lengths are long.
3370	NORMAL BRIDGE, NRD = X, MIN ELTRD = Y, MAX ELLC = Z. The normal bridge method was used for this cross section. The number of points used in describing the bridge deck are given.
3377	BLOSS READ IN. The difference in water surface elevation between the previous and current cross section was given by input data. (X2.6)
3420	BRIDGE W.S. = X, BRIDGE VELOCITY = Y. The water surface elevation under the bridge is specified by *X* and the velocity through the bridge is *Y*.
3470	ENCROACHMENT STATIONS = W,X TYPE = Y TARGET = Z. The values of STENCL and STENCR (left and right encroachment stations) are *W* and *X*. The method used in determining these stations is method *Y* and the specified target (width or percent) for that method is *Z*. If the target is a percent, a ratio less than one is used instead of percent so that a percent target can be distinguished from a top width target.
3495	OVERBANK AREA ASSUMED NONEFFECTIVE, XLBEL = X, RBEL = Y. The effective area option (IEARA) was used and the computed water surface elevation was below at least one of the bank elevations specified by *X* and *Y* and therefore, this flow area was assumed noneffective. (X3.1)
3649	NUMBER SECTION EXCEED LIMIT. The number of cross sections for the given data set exceeds limit of eight hundred.
3685	20 TRIALS ATTEMPTED WSEL, CWSEL The number of trials in balancing the assumed and computed water surface elevations for the standard step procedure of backwater has reached twenty. Check the assumed water elevation for reasonableness.
3693	PROBABLE MINIMUM SPECIFIC ENERGY. This note is similar to 7185 except it is not certain (only probable), that critical depth has been crossed. It is known that no depth of flow assumed in any of the trials produced an energy grade line elevation as high as the minimum energy at critical depth.
3700	BRIDGE STENCL = X, STENCR = Y. The bridge profile has been encroached upon, the left and right encroachment stations are *X* and *Y*.
3710	WSEL ASSUMED BASED ON MIN DIFF. At the conclusion of twenty trials the assumed water surface elevation will be made equal to the elevation that came the closest to balancing. This condition usually occurs near the top of banks when the effective area option is used (IEARA = 10). Check results for reasonableness.
3720	ASSUMED CRITICAL DEPTH. Critical depth has been assumed for this cross section. This assumption should be verified by inspection of channel properties. Additional cross sections may need to be inserted in order to preserve the assumption of gradually varying flow.

Statement Number	Notes and Remarks
3790	DATA EPROR. JOB DUMPED. The computer detected an error in input and terminated that particular job (profile), but continued on with the next job of the input data.
3800	PREVIOUS ST GREATER THAN CURRENT. Either an input error caused the stations of the GR record to not increase or a programming error has been found.
3805	Q = 0. The discharge was not specified for this job.
3810	HT IS -. The height (HT), determined by subtracting the ground elevation from the assumed water surface elevation, has been found to be negative. Corrections for bridge deck (ELTRD - ELLC) used in the normal bridge method will have caused this note if any ELLC is greater than the corresponding ELTRD. If this is not the case a program error has been found, and a trace may be required to determine the source of the error.
3820	STA(N) GREATER STMAX. One of the stations of the points on the current ground profile records (GR) was greater than the maximum station for this profile.
3830	AROB OR ALOB IS - A negative area in the left or right overbank has been computed. A program error probably has been detected. A trace may be required to determine the program error.
3840	SECTION NOT HIGH ENOUGH. The computed water surface elevation exceeds the maximum specified on input records, therefore, the cross section ends have been vertically raised fifty feet.
3965	REACH OF - NOT EQUAL TO SECNO OF - The J4 record has been used to specify routing reaches which must be equal to the section numbers (SECNO) on the first field of the X1 record. The section numbers must also be in increasing order.
4020	80 TRIALS NOT ENOUGH FOR CRITICAL DEPTH. This note indicates a data error or program error has been detected. If no data error is detected, job may be rerun, with ITRACE equal to one, in order to obtain reason for failure of parabolic optimization process.
4478	FLOATING ICE COVER, ICE THICKNESS LOB = X, CH = Y, ROB = Z. Computations at this cross section include the hydraulic effects of a stationary floating ice cover. Ice cover thickness in left overbank is *X* feet or meters, channel thickness is *Y* feet or meters and right overbank thickness is *Z* feet or meters.
4575	CRITICAL DEPTH ASSUMED BELOW ELLC OF - EGLC = - EGC = - WSEL = -. Critical depth is being computed in a bridge section and the minimum energy below the low chord is less than the minimum energy above the top of the bridge.
4677	BRIDGE DECK DEFINITION ERROR AT STATIONS *X Y*. The low chord or top of road line, defined on the BT records for a normal bridge, has intersected the ground line as defined on the GR records. The program will not account for the bridge deck blockage between GR stations *X* and *Y*.
5020	SPECIAL BRIDGE. The input has specified that the bridge routine to be used for this cross section is the special bridge method.

Statement Number	Notes and Remarks
5070	VARIABLE ELCHU OR ELCHD ON Record SB NOT SPECIFIED. The elevations of the channel upstream and downstream of the bridge are not specified on input fields and have therefore, been assumed equal to the minimum elevation for the previous cross section. (SB.9 & .10)
5105	VARIABLE ELCHU ON SC CARD NOT SPECIFIED. The upstream invert elevation of the culvert is not specified in the input data (SC.9). ELCHU and ELCHD (SC.10) have been assumed equal to the minimum elevation of the previous cross section.
5110	ELCHU LESS THAN ELCHD. In the special culvert option, the upstream invert elevation is less than the downstream value (adverse slope). The profile analysis is aborted.
5115	SUPERCRITICAL FLOW--SPECIAL CULVERT OPTION NOT AVAILABLE. The profile is aborted because the special culvert option is only available for sub-critical flow. Change IDIR (J1.4) to zero.
5120	INCORRECT VALUE FOR FHWA CHART NUMBER. An incorrect value of the FHWA Chart Number (SC.8a) is entered. The profile is aborted. Correct the Chart Number.
5125	INCORRECT VALUE FOR FHWA SCALE NUMBER. An incorrect value of the FHWA Scale Number (SC.8b) is entered for the specified Chart Number (SC.8a). The profile is aborted. Correct the Chart or Scale Number.
5130	EGIC TOO LARGE; REDUCED TO *XXXX*. The energy gradient elevation (Culvert Inlet control flow) computed while assuming there is no weir flow is very high. This value is reduced to a more realistic value for the computation of weir flow.
5135	EGOC TOO LARGE; REDUCED TO *XXXX*. The energy gradient elevation (culvert outlet control flow) computed while assuming there is no weir flow is very high. This value is reduced to a more realistic value for the computation of Weir Flow.
5140	NORMAL DEPTH EXCEEDS CULVERT HEIGHT. The culvert normal depth exceeds the culvert height. It is therefore assumed equal to the culvert height.
5145	30 TRIALS OF NORMAL DEPTH NOT ENOUGH; POSSIBLY INVALID. After thirty iterations, the program cannot obtain a normal depth value within the predefined precision. The normal depth is assumed equal to the value obtained at the last iteration.
5150	EG OF *XXXX* LESS THAN XEG OF *XXXX*. The upstream energy gradient elevation of the culvert is less than the downstream value, indicating negative losses. The upstream energy gradient elevation is therefore assumed equal to the downstream energy gradient.
5155	20 TRIALS OF QWEIR NOT ENOUGH; POSSIBLY INVALID. While computing culvert flow and weir flow, the total discharge cannot be balanced with the actual discharge after 20 iterations.
5160	CULVERT BACKWATER, FROUDE > 1; JOB DUMPED. The culvert backwater routine starts with a super-critical flow condition. Therefore, the job has been terminated.

Statement Number	Notes and Remarks
5165	CULVERT BACKWATER, STEP < 0; JOB DUMPED. While computing the length for each iteration (step) the program has ended up with a negative value. Therefore, the job has been terminated.
5170	100 TRIALS OF CULVERT BACKWATER NOT ENOUGH. The culvert backwater profile requires more than 100 iterations. Therefore, the Inlet depth DEPIN is set equal to the Outlet depth DEPOUT.
5175	20 TRIALS OF QELTRD NOT ENOUGH; ASSUMED = *XXXX*. QELTRD is the maximum discharge through the culvert before any weir flow occurs. The program cannot obtain a correct value of QELTRD after 20 iterations.
5180	RISE (SC.5) LESS THAN OR EQUAL TO ZERO. The user has entered a rise or diameter value (SC.5) which is zero or negative. Therefore, the culvert has no cross-sectional area and cannot be analyzed.
5185	BOX SPAN (SC.6) LESS THAN OR EQUAL TO ZERO. The user has entered a Chart Number (SC.8a) which is within the range of 8 through 12. This indicates that a box culvert is to be analyzed. However, the user has entered a span (SC.6) value which is zero or negative. Therefore, the box culvert has no cross-sectional area and cannot be analyzed.
5227	DOWNSTREAM ELEV IS *X*, NOT *Y*, HYDRAULIC JUMP OCCURS DOWNSTREAM (IF LOW FLOW CONTROLS). The upstream momentum is so great that the water downstream of the bridge is supercritical and not subcritical.
5290	UPSTREAM ELEVATION IS *X* NOT *Y*, NEW BACKWATER REQUIRED. Since supercritical flow was assumed by input and since the bridge obstruction drowns out the supercritical flow upstream of the bridge, new backwater is required, from the bridge upstream.
5470	ERROR DS DEPTH WRONG SIDE CRITICAL. The calculated depth in the low flow routine was determined on the wrong side of critical depth. A trace may be required to determine cause.
6070	LOW FLOW BY NORMAL BRIDGE. When the pier width is specified as zero for the special bridge method and when low flow controls, the friction loss is computed using the normal bridge method instead of the special bridge method. (SB.6=0)
6110	EGLWC OF *X* LESS THAN XEG OF *Y*. The energy gradient elevation for the controlling low flow is less than the energy gradient for the previous cross section indicating negative losses. The energy gradient elevation for the current cross section is therefore, assumed equal to that for the previous energy gradient (no loss) and the run has been continued.
6180	SUPERCRITICAL FLOW, PRESSURE FLOW. Based on a comparison of EGPRS and EGLWC (the higher controls) the program concluded pressure flow. The solution of pressure flow in combination with supercritical flow is generally not compatible. The bridge model should be examined for possible input errors.

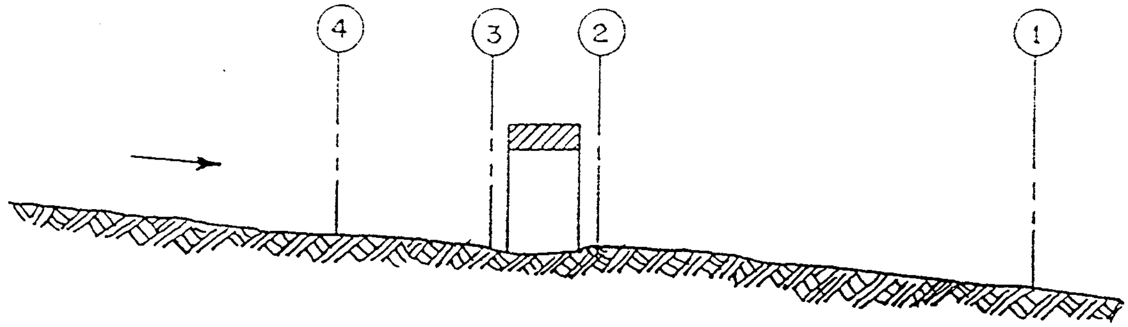
Statement Number	Notes and Remarks
6400	TRIAL AND ERROR FOR CHANNEL Q FAILED. For the low flow and weir flow combination, the discharge through the channel must be determined. In trying to determine the discharge through the channel by an iterative process, the assumed and computed discharges do not agree in fifty trials. The allowable error of one percent is too severe for the computation or a programming inadequacy has been detected.
6790	POSSIBLE INVALID SOLUTION 20 TRIALS OF EG NOT ENOUGH. In determining the energy grade line elevation for a combination of weir flow and low flow, the discharge computed for an assumed energy grade line elevation could not balance with the actual discharge to be used in the water surface profile determination. When this condition occurs, the job should be rerun using the trace feature and the cause of this failure determined.
6840	FLOW IS BY WEIR AND LOW FLOW. The minimum top of roadway in one or both overbank dips below the low chord over the bridge and the resulting water surface elevation, which is below the low chord over the bridge, was computed using Class A low flow under the bridge and weir flow in the low overbank.
6870	D.S. ENERGY OF *X* HIGHER THAN COMPUTED ENERGY OF *Y*. The energy grade line elevation of *X* for the previous (downstream) cross section is higher than the current cross section's computed energy grade line elevation of *Y*. The current energy grade line elevation was computed for a combination of weir and pressure flow. The energy grade line elevation for this cross section has been assumed equal to the previous energy elevation in order to eliminate negative losses. The weir coefficients used apparently were too efficient or a very long flat weir section has been encountered.
7185	MIN SPECIFIC ENERGY. The computer determined that it was impossible to proceed from the previous cross section to the current cross section without crossing critical depth and therefore, critical depth has been assumed for the current cross section. In other words, maximum losses cannot produce an energy elevation as high as the minimum energy at critical depth. If this note occurs for several consecutive cross sections, it is apparent that the wrong type of flow (IDIR) has been assumed for this segment of the profile. The cross sections should be reversed, IDIR changed and the profile rerun.
7230	SLOPE-AREA TRIALS EXCEED 100. In determining the starting water surface elevation using the slope of the energy grade line from input, one hundred trials were not sufficient to balance the calculated discharge with the actual discharge (Q). If this condition occurs, an error in the input data or a programming error has been encountered. Rerun with trace feature if input data appear satisfactory.
8190	PLOTTED POINTS (BY PRIORITY).. - - - ETC. This note gives the priority for plotting the values for the cross section. If two or more points are close enough together that a single space of the printer cannot distinguish between them, then only the last point plotted will be seen on the output. For instance, the energy gradient elevation (E) will hide the water surface elevation (W) for very small velocity heads.
8560	XSEC POINT - , *X*, EL, ST - *Y*, *Z*. The subscript computed for the current point was too low or too high to be plotted and is therefore, not shown on the cross section. The *X* indicates the type of point being plotted (*X* for ground point). The elevation and station of this point are printed out as *Y* and *Z*.

Statement Number	Notes and Remarks
8930	RDST NOT ON GR Record. The roadway station printed out here does not appear on the ground profile record (GR). For the normal bridge method all stations on the BT record must also appear on the GR record. This note can be ignored for the special bridge method.

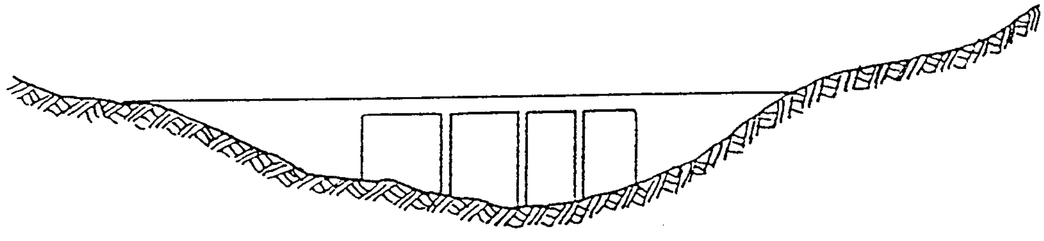
Channel Cross-Section Output

Refer to Sample HEC-2 Model in Input Section for:

- Output
- Cross-Section Plot
- Profile Plot



A. Channel Profile and Section Locations



B. Bridge Cross Section on Natural Floodway

C. Portion of Cross Sections 2 & 3 Effective for Low Flow and Pressure Flow

Figure 7
Cross Sections Near Bridges

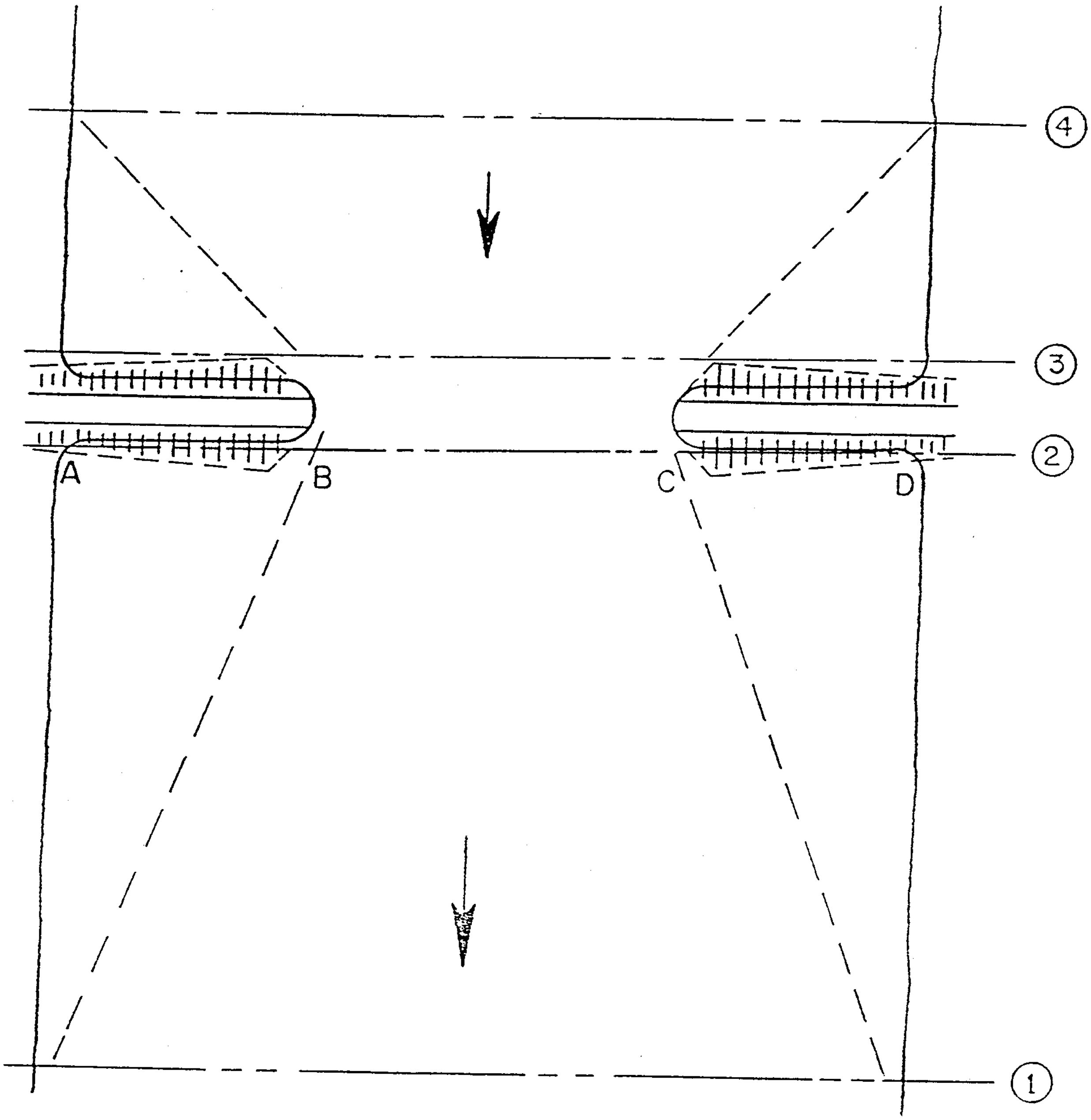
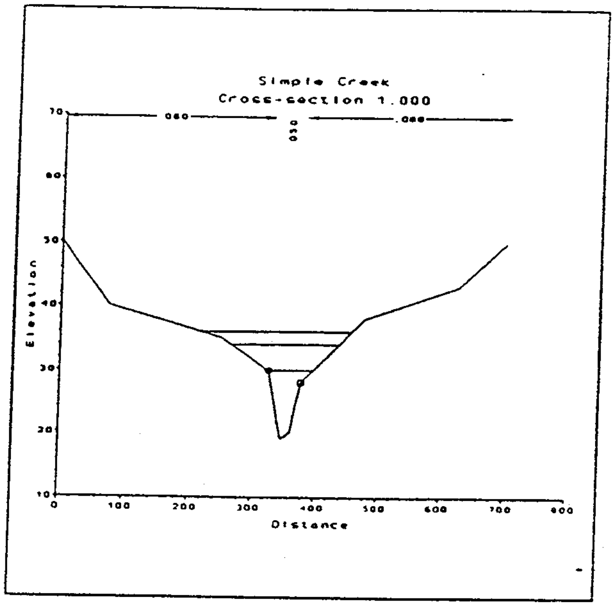
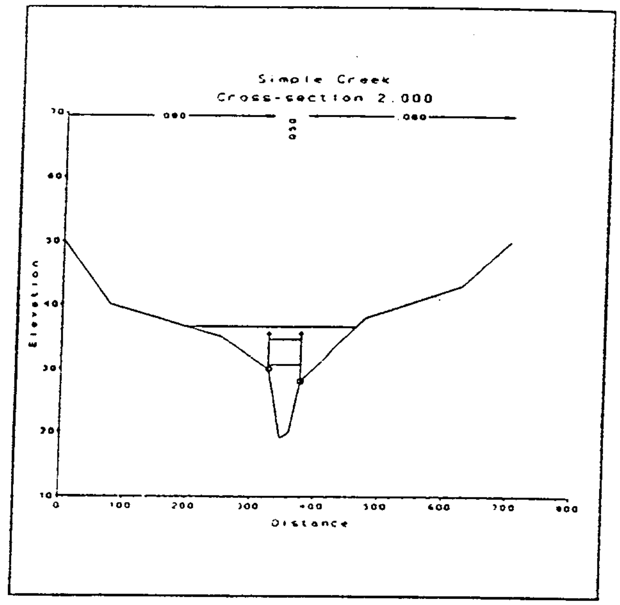


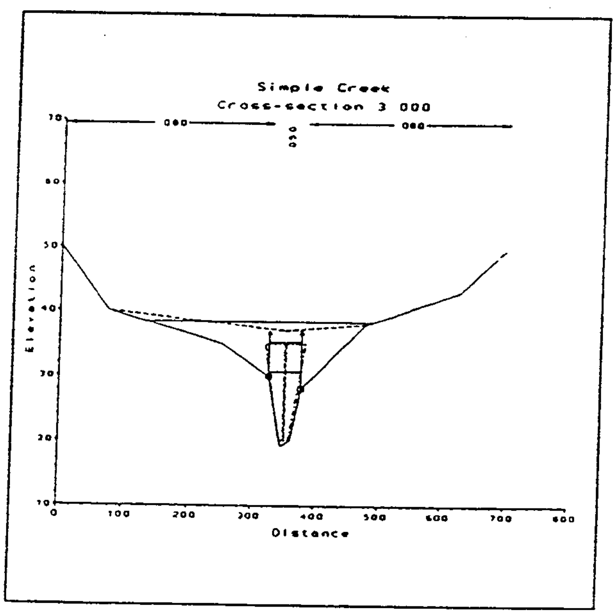
Figure 6
Cross Section Locations in the Vicinity of Bridges



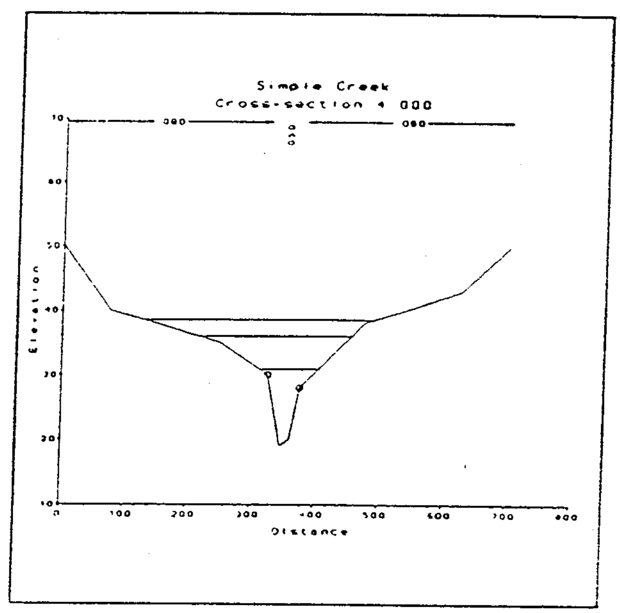
Downstream Natural Section



Downstream from Bridge

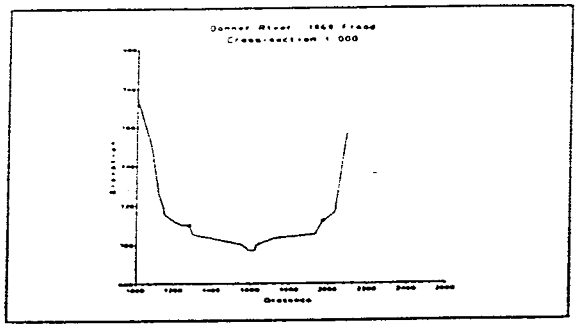


Upstream from Bridge plus Bridge Data

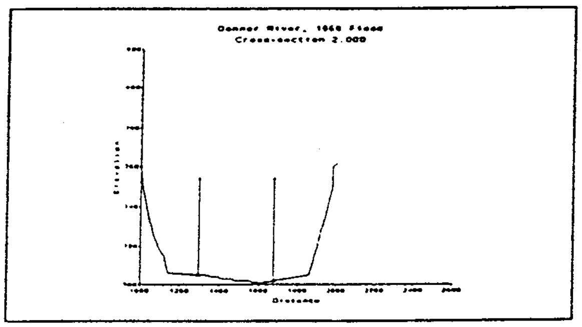


Upstream Natural Section

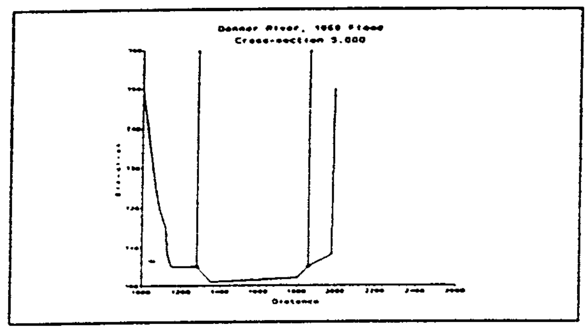
Figure 8
Special Bridge Example Cross Sections



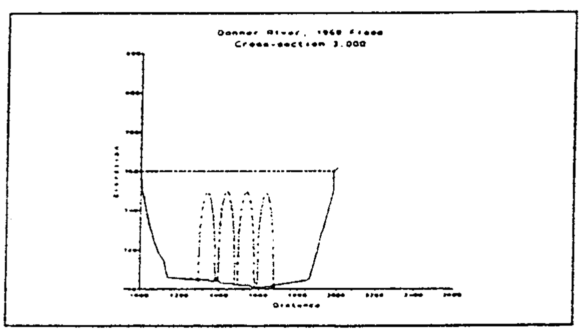
Downstream Natural Section



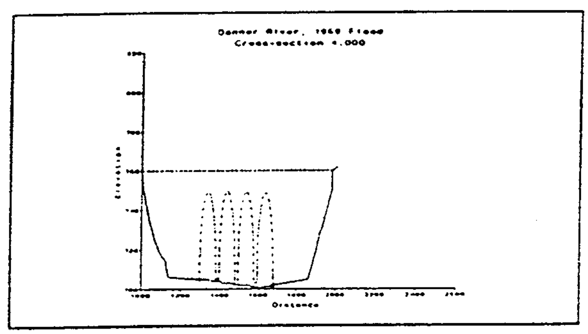
Downstream from Bridge



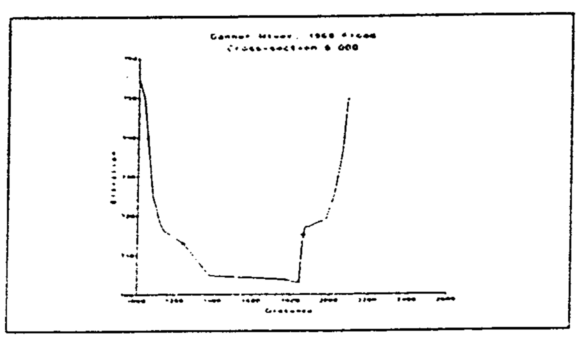
Upstream from Bridge



Downstream Bridge Section



Upstream Bridge Section



Upstream Natural Section

Figure 10
Normal Bridge Example Cross Sections

```
*******************************************
*  HEC-2 WATER SURFACE PROFILES           *
*                                         *
*  Version     4.5.0;  September 1990     *
*                                         *
*  RUN DATE    29AUG90    TIME   16:02:27 *
*******************************************

                                        ************************************
                                        *  U.S. ARMY CORPS OF ENGINEERS    *
                                        *  HYDROLOGIC ENGINEERING CENTER   *
                                        *  609 SECOND STREET, SUITE D      *
                                        *  DAVIS, CALIFORNIA 95616-4687    *
                                        *       (916) 756-1104             *
                                        ************************************

                      X     X  XXXXXXX   XXXXX               XXXXX
                      X     X  X        X     X             X     X
                      X     X  X        X                         X
                      XXXXXXX  XXXX     X          XXXXX     XXXXX
                      X     X  X        X                   X
                      X     X  X        X     X             X
END OF BANNER         X     X  XXXXXXX   XXXXX              XXXXXXX

                              ooooooooooooooooooooo

   29AUG90       16:02:27
                                                                          PAGE   1
 ************************************                THIS RUN EXECUTED 29AUG90    16:02:27
 HEC-2 WATER SURFACE PROFILES

 Version     4.5.0;  September 1990
 ************************************

T1    SPECIAL BRIDGE EXAMPLE
T2    Low flow profile
T3     Simple Creek

J1  ICHECK    INQ     NINV    IDIR    STRT    METRIC   HVINS    Q      WSEL     FQ

               2
   Request the Speical Bridge Summary Tables on J3.                        30

J3  VARIABLE CODES FOR SUMMARY PRINTOUT

     100       105

NC    .08      .08      .05      .3       .5
QT     3       2000     4500     6000
X1     1        10      325      375       0       0       0
GR    50         0       40       75      35     250      30      325     19     345
GR    20       360       28      375      38     475      43      625     50     700
   New NC contraction and expantion coefficients go here if they are changed for
   the bridge calculations.  Expansion loss would be evaluated at Section 2.

X1     2                                 240     240     240
   Effective area option to control the flow to the bridge width up to elev. 36.
X3    10                                                            36      36

   Special Bridge input between downstream and upstream sections

SB   1.05      1.6      2.6               15       2     565       1.6      20      20

   Remaining bridge input is provided with the upstream section.
X1     3                                  60      60      60
   X2 input for Special Bridge, Max. low-chord elev., and Min. top-of-road elev.
X2                       1       35       37
   Effective area option to control the flow to the bridge width up to elev. 37.
X3    10                                                            37      37
   Bridge Table to define top-of-road profile.  Low chord values are not
   required because the bridge has a pier width for low-flow calculations.
   Low chord values are required for standard step low-flow solution.
BT    -6         0       50               75      40               350      37
BT             475       38              625      43               700      50

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  29AUG90       16:02:27
                                                                          PAGE   2
X1     4                                  60      60      60
   New NC contraction and expansion coefficients go here if they were change
   for the bridge.   The new coefficients would apply to the following sections.

                              ooooooooooooooooooooo

  29AUG90       16:02:27
                                                                          PAGE   3
   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG      HV      HL      OLOSS    L-BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH     AROB    VOL     TWA      R-BANK ELEV
   TIME      VLOB      VCH       VROB      XNL       XNCH    XNR     WTN     ELMIN    SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC     ICONT   CORAR   TOPWID   ENDST
*PROF 1

CCHV=     .300 CEHV=     .500
*SECNO 1.000
   1.000     11.00     30.00      .00      30.00    30.47     .47     .00     .00     30.00
  2000.0        .0    1980.2     19.8         .0    357.5    20.0      .0      .0     28.00
     .00       .00      5.54      .99       .000     .050    .080    .000   19.00    325.00
 .002853        0.        0.       0.          0        0       0     .00   70.00    395.00
```

*SECNO 2.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 36.00 ELREA= 36.00

2.000	11.68	30.68	.00	.00	31.08	.40	.59	.02	30.00
2000.0	.0	2000.0	.0	.0	391.7	.0	2.1	.3	28.00
.01	.00	5.11	.00	.000	.050	.000	.000	19.00	325.00
.002146	240.	240.	240.	0	0	0	.00	50.00	375.00

SPECIAL BRIDGE

SB XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
1.05	1.60	2.60	.00	15.00	2.00	565.00	1.60	20.00	20.00

*SECNO 3.000
CLASS A LOW FLOW

3420 BRIDGE W.S.= 30.59 BRIDGE VELOCITY= 6.31 CALCULATED CHANNEL AREA= 317.

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD	WEIRLN
.00	31.12	.04	0.	2000.	565.	555.	35.00	37.00	0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 37.00 ELREA= 37.00

3.000	11.72	30.72	.00	.00	31.12	.40	.04	.00	30.00
2000.0	.0	2000.0	.0	.0	393.6	.0	2.7	.4	28.00
.02	.00	5.08	.00	.000	.050	.000	.000	19.00	325.00
.002112	60.	60.	60.	0	0	0	.00	50.00	375.00

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PAGE 4

29AUG90 16:02:27

SECNO Q TIME SLOPE	DEPTH QLOB VLOB XLOBL	CWSEL QCH VCH XLCH	CRIWS QROB VROB XLOBR	WSELK ALOB XNL ITRIAL	EG ACH XNCH IDC	HV AROB XNR ICONT	HL VOL WTN CORAR	OLOSS TWA ELMIN TOPWID	L-BANK ELEV R-BANK ELEV SSTA ENDST
*SECNO 4.000									
4.000	11.90	30.90	.00	.00	31.26	.36	.12	.01	30.00
2000.0	2.8	1954.1	43.1	6.0	402.3	42.0	3.2	.5	28.00
.02	.47	4.86	1.03	.080	.050	.080	.000	19.00	311.55
.001874	60.	60.	60.	2	0	0	.00	92.42	403.97

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PAGE 5

29AUG90 16:02:27

T1 PRESSURE FLOW PROFILE

J1 ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	3							34	

J2 NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
2									

oooooooooooooooooooo

PAGE 6

29AUG90 16:02:27

SECNO Q TIME SLOPE	DEPTH QLOB VLOB XLOBL	CWSEL QCH VCH XLCH	CRIWS QROB VROB XLOBR	WSELK ALOB XNL ITRIAL	EG ACH XNCH IDC	HV AROB XNR ICONT	HL VOL WTN CORAR	OLOSS TWA ELMIN TOPWID	L-BANK ELEV R-BANK ELEV SSTA ENDST

*PROF 2

CCHV= .300 CEHV= .500

*SECNO 1.000									
1.000	15.00	34.00	.00	34.00	34.70	.70	.00	.00	30.00
4500.0	180.2	3966.1	353.6	120.0	557.5	180.0	.0	.0	28.00
.00	1.50	7.11	1.96	.080	.050	.080	.000	19.00	265.00
.002603	0.	0.	0.	0	0	0	.00	170.00	435.00

*SECNO 2.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 36.00 ELREA= 36.00

2.000	15.54	34.54	.00	.00	35.46	.92	.65	.11	30.00
4500.0	.0	4500.0	.0	.0	584.7	.0	4.0	.8	28.00
.01	.00	7.70	.00	.000	.050	.000	.000	19.00	325.00
.002859	240.	240.	240.	2	0	0	.00	50.00	375.00

SPECIAL BRIDGE

SB XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
1.05	1.60	2.60	.00	15.00	2.00	565.00	1.60	20.00	20.00

*SECNO 3.000
PRESSURE FLOW

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	TRAPEZOID AREA	ELLC	ELTRD	WEIRLN
36.12	35.56	.11	0.	4500.	565.	555.	35.00	37.00	0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 37.00 ELREA= 37.00

3.000	16.31	35.31	.00	.00	36.12	.81	.66	.00	30.00
4500.0	.0	4500.0	.0	.0	623.3	.0	4.8	.7	28.00
.01	.00	7.22	.00	.000	.050	.000	.000	19.00	325.00
.002310	60.	60.	60.	2	0	0	.00	50.00	375.00

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                                                    oooooooooooooooooooo

   29AUG90     16:02:27                                                                              PAGE    7

    SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
    Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
    TIME       VLOB       VCH        VROB.      XNL        XNCH       XNR        WTN        ELMIN      SSTA
    SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

 *SECNO 4.000
     4.000      16.97      35.97        .00        .00      36.35        .38        .10        .13      30.00
    4500.0      396.5     3583.4      520.1      277.4      656.3      318.1        6.1         .9      28.00
       .01       1.43       5.46       1.64       .080       .050       .080       .000      19.00     215.93
   .001233        60.        60.        60.          2          0          0        .00     238.94     454.76

                                                    oooooooooooooooooooo

   29AUG90     16:02:27                                                                              PAGE    8

T1   PRESSURE AND WEIR FLOW PROFILE

J1   ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL.     FQ

               4                                                           36

J2   NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

     3

                                                    oooooooooooooooooooo

   29AUG90     18:02:27                                                                              PAGE    9

    SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
    Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
    TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
    SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

 *PROF 3

 CCHV=      .300 CEHV=      .500
 *SECNO 1.000
     1.000      17.00      36.00        .00      36.00      36.66        .66        .00        .00      30.00
    6000.0      532.8     4771.3      696.0      280.0      657.5      320.0         .0         .0      28.00
       .00       1.90       7.26       2.17       .080       .050       .080       .000      19.00     215.00
   .002173         0.         0.         0.          0          0          0        .00     240.00     455.00

 *SECNO 2.000
     2.000      17.62      36.62        .00        .00      37.16        .54        .46        .04      30.00
    6000.0      643.5     4598.6      757.9      354.8      688.5      371.4        7.4        1.4      28.00
       .01       1.81       6.68       2.04       .080       .050       .080       .000      19.00     193.33
   .001732       240.       240.       240.          2          0          0        .00     267.86     461.19

 SPECIAL BRIDGE

 SB  XK         XKOR       COFQ       RDLEN      BWC        BWP        BAREA      SS         ELCHU      ELCHD
      1.05       1.60       2.60        .00      15.00       2.00     565.00       1.60      20.00      20.00

 *SECNO 3.000
 PRESSURE AND WEIR FLOW,  Weir Submergence Based on TRAPEZOIDAL Shape

  EGPRS      EGLWC      H3         QWEIR      QPR        BAREA     TRAPEZOID   ELLC       ELTRD      WEIRLN
                                                                   AREA
     39.42      37.83        .04       765.      5182.       565.       555.      35.00      37.00       303.

     3.000      19.40      38.40        .00        .00      38.71        .31       1.55        .00      30.00
    6000.0      973.5     4094.5      932.1      645.4      777.7      542.8        9.7        1.8      28.00
       .02       1.51       5.27       1.72       .080       .050       .080       .000      19.00     130.89
   .000915        60.        60.        60.          2          0          2        .00     356.21     487.10

 *SECNO 4.000
     4.000      19.47      38.47        .00        .00      38.77        .30        .05        .00      30.00
    6000.0      986.3     4073.1      940.7      659.3      781.2      550.8       12.4        2.3      28.00
       .02       1.50       5.21       1.71       .080       .050       .080       .000      19.00     128.40
   .000891        60.        60.        60.          1          0          0        .00     360.83     489.23

                                                    oooooooooooooooooooo

   29AUG90     16:02:27                                                                              PAGE   10

                                                                       THIS RUN EXECUTED 29AUG90    16:02:32
 ************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.5.0;  September 1990
 ************************************

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

Simple Creek

SUMMARY PRINTOUT TABLE  100

      SECNO     EGLWC     ELLC      EGPRS     ELTRD     QPR       QWEIR     CLASS     H3        DEPTH     CWSEL     VCH       EG

      3.000     31.12     35.00       .00     37.00   2000.00       .00      1.00      .04     11.72     30.72      5.08     31.12
      3.000     35.56     35.00     36.12     37.00   4500.00       .00     10.00      .11     18.31     35.31      7.22     36.12
      3.000     37.83     35.00     39.42     37.00   5182.04    765.35     30.00      .04     19.40     38.40      5.27     38.71
```

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29AUG90 16:02:27

Simple Creek

SUMMARY PRINTOUT TABLE 105

SECNO	CWSEL	HL	OLOSS	TOPWID	QLOB	QCH	QROB
1.000	30.00	.00	.00	70.00	.00	1980.22	19.78
1.000	34.00	.00	.00	170.00	180.25	3966.11	353.64
1.000	36.00	.00	.00	240.00	532.78	4771.26	695.96
2.000	30.68	.59	.02	50.00	.00	2000.00	.00
2.000	34.54	.65	.11	50.00	.00	4500.00	.00
2.000	36.62	.46	.04	267.86	643.54	4598.57	757.88
3.000	30.72	.04	.00	50.00	.00	2000.00	.00
3.000	35.31	.66	.00	50.00	.00	4500.00	.00
3.000	38.40	1.55	.00	356.21	973.47	4094.47	932.06
4.000	30.90	.12	.01	82.42	2.84	1954.11	43.05
4.000	35.97	.10	.13	238.94	396.47	3583.39	520.14
4.000	38.47	.05	.00	360.83	986.26	4073.07	940.67

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29AUG90 16:02:27

SUMMARY OF ERRORS AND SPECIAL NOTES

```
*********************************************
* WATER SURFACE PROFILES                    *
*                                           *
* Version 4.5.0; September 1990             *
*                                           *
* RUN DATE    21AUG90    TIME    07:43:14   *
*********************************************
```

```
*************************************
* U.S. ARMY CORPS OF ENGINEERS      *
* HYDROLOGIC ENGINEERING CENTER     *
* 609 SECOND STREET, SUITE D        *
* DAVIS, CALIFORNIA 95616-4687      *
*       (916) 756-1104              *
*************************************
```

```
X     X  XXXXXXX   XXXXX               XXXXX
X     X  X        X     X             X     X
X     X  X        X                         X
XXXXXXX  XXXX     X          XXXXX     XXXXX
X     X  X        X                   X
X     X  X        X     X             X
X     X  XXXXXXX   XXXXX              XXXXXXX
```

END OF BANNER

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21AUG90 07:43:14


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**********************************
HEC2 WATER SURFACE PROFILES

Version 4.5.0; September 1990
**********************************
```

THIS RUN EXECUTED 21AUG90 07:43:14

T1 Multiple Arch Railroad Bridge (Normal Bridge Example)
T3 Donner River, 1969 Flood

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0	3	0	0	0.0025	0	0	0	715	0

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	-1	0	-1	0	0	0	0	0	0	0

NC	0.055	0.060	0.035	0.3	0.5					
QT	5	41000	105000	130000	285000	530000				
X1	1	20	1280	1970						
GR	775	1000	750	1080	725	1120	720	1140	715	1150
GR	714	1170	712	1200	711	1220	710	1240	710	1280
GR	705	1300	700	1560	697	1590	697	1620	700	1630
GR	703.1	1720	705	1930	712	1970	716	2030	757	2090

Limit flow width with EFFECTIVE AREA OPTION

X1	2	65	1295	1676	400	400	400			
X3	10									
GR	760	1000	750	1010	734	1043	732	1049	730	1056
GR	727	1063	725	1070	723	1076	722	1081	720	1090
GR	718	1100	717	1104	715.5	1116	715	1120	710	1130
GR	706	1142	705	1295	705	1300	705	1311	705	1323
GR	705	1338	704.5	1352	704	1365	704	1375	704	1380
GR	704	1394	704	1399	703	1409	703	1423	703	1437
GR	703	1451	703	1463	702.5	1474	702	1478	702	1493
GR	702	1498	702	1508	702	1522	702	1536	702	1548
GR	701.5	1562	701	1572	701	1577	701	1592	701	1596
GR	701	1600	701	1608	701	1621	701.5	1633	701.5	1647
GR	701.5	1660	702	1671	702	1676	705	1860	709	1869
GR	710	1874	716	1890	719	1897	721	1903	725	1910
GR	728	1918	730	1927	750	1980	760	1981	762	2010

Note: on the first GR row of this section, the values 755 and 755 are printed raised above the columns headed 1049 and 730. In the table they are placed in the cells where 1049 and 730 appear, so those two cells each show a single value.

California Northern R.R. Bridge (River Mile 15.434)

NC			.025							
X1	3				1	1	1			
BT	-64	1000	760	760	1010	760	750	1043	760	734
BT		1049	760	732	1056	760	730	1063	760	727
BT		1070	760	725	1076	760	723	1081	760	722
BT		1090	760	720	1100	760	718	1104	760	717

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21AUG90 07:43:14

BT		1116	760	715.5	1120	760	715	1130	760	710
BT		1142	760	706	1295	760	705	1300	760	728
BT		1311	760	741	1323	760	747	1338	760	750
BT		1352	760	747	1365	760	739	1375	760	727
BT		1380	760	704	1394	760	704	1399	760	728
BT		1409	760	741	1423	760	748	1437	760	750
BT		1451	760	747	1463	760	739	1474	760	726
BT		1478	760	702	1493	760	702	1498	760	729
BT		1508	760	740	1522	760	748	1536	760	750
BT		1548	760	747	1562	760	739	1572	760	727
BT		1577	760	701	1592	760	701	1596	760	728
BT		1600	760	732	1608	760	740	1621	760	747
BT		1633	760	749	1647	760	747	1660	760	740
BT		1671	760	727	1676	760	702	1860	760	705
BT		1869	760	709	1874	760	710	1890	760	716
BT		1897	760	719	1903	760	721	1910	760	725
BT		1918	760	728	1927	760	730	1980	760	750
BT		1981	760	760						

Repeat BT and GR data from downstream face of bridge

X1	4									
X2					20	20	20			
							1			
NC			.035							

```
               Limit flow width with EFFECTIVE AREA OPTION
X1        5       12      1230     1860        1        1        1
X3       10                                                             760      760
GR      750     1000       725     1070      720     1090      715     1120      708     1130
GR      705     1150       705     1230      701     1350      702     1800      705     1860
GR      708     1980       750     1990

X1        6       20      1240     1860      110      110      110
GR      755     1000       750     1030      725     1080      718     1120      717     1130
GR      716     1140       715     1180      713     1240      705     1380      704     1760
GR      703     1840       715     1860      717     1870      717     1890      718     1930
GR      719     1980       725     2020      730     2040      735     2060      750     2090
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  21AUG90      07:43:14
   SECNO      DEPTH     CWSEL     CRIWS     WSELK       EG        HV        HL      OLOSS   L-BANK ELEV
   Q          QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA     R-BANK ELEV
   TIME       VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN   SSTA
   SLOPE      XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID  ENDST

*PROF 1

CCHV=      .300 CEHV=      .500
*SECNO 1.000
     1.000     18.67    715.67       .00    715.00    717.74      2.07       .00       .00    710.00
  105000.0    1937.1  102874.3     188.5     518.1    8835.2     101.3        .0        .0    712.00
       .00      3.74     11.64      1.86      .055      .035      .060      .000    697.00   1148.65
   .002520        0.        0.        0.         0         0         3       .00    876.46   2025.11

*SECNO 2.000

3301 HV CHANGED MORE THAN HVINS

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      755.00 ELREA=      755.00
     2.000     14.92    715.92    715.92       .00    722.64      6.72      1.63      2.33    705.00
  105000.0        .0  105000.0        .0        .0    5047.4        .0      66.6       5.8    702.00
       .01       .00     20.80       .00      .000      .035      .000      .000    701.00   1295.00
   .007661      400.      400.      400.         4        15         0       .00    381.00   1676.00

*SECNO 3.000

3301 HV CHANGED MORE THAN HVINS

3370 NORMAL BRIDGE, NRD=  64 MIN ELTRD=    760.00 MAX ELLC=    750.00

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     3.000     16.30    717.30    717.30       .00    724.90      7.60       .01       .44    705.00
  105000.0        .0  105000.0        .0        .0    4746.1        .0      66.7       5.8    702.00
       .01       .00     22.12       .00      .000      .025      .000      .000    701.00   1102.82
   .006107        1.        1.        1.        20        19         0  -5549.82    790.21   1893.02

*SECNO 4.000
```

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```
  21AUG90      07:43:14
   SECNO      DEPTH     CWSEL     CRIWS     WSELK       EG        HV        HL      OLOSS   L-BANK ELEV
   Q          QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA     R-BANK ELEV
   TIME       VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN   SSTA
   SLOPE      XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID  ENDST

3301 HV CHANGED MORE THAN HVINS

3370 NORMAL BRIDGE, NRD=  64 MIN ELTRD=    760.00 MAX ELLC=    750.00

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
     4.000     19.59    720.59    717.30       .00    725.73      5.13       .09       .74    705.00
  105000.0        .0  105000.0        .0        .0    5774.5        .0      69.1       6.2    702.00
       .01       .00     18.18       .00      .000      .025      .000      .000    701.00   1087.34
   .003427       20.       20.       20.        26        19         0  -7163.23    814.43   1901.77

*SECNO 5.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   2.79

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      760.00 ELREA=      760.00
     5.000     25.14    726.14       .00       .00    727.01       .87       .00      1.28    705.00
  105000.0        .0  105000.0        .0        .0   14064.3        .0      69.3       6.2    705.00
       .01       .00      7.47       .00      .000      .035      .000      .000    701.00   1280.00
   .000441        1.        1.        1.         3         0         0       .00    580.00   1860.00

*SECNO 6.000
     6.000     23.23    726.23       .00       .00    727.07       .84       .05       .01    713.00
  105000.0    4712.5   97502.4    2785.0    1537.9   12831.1    1194.4     106.7       3.1    715.00
       .01      3.06      7.60      2.33      .055      .035      .060      .000    703.00   1077.54
   .000568      110.      110.      110.         2         0         0       .00    947.37   2024.91
```

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THIS RUN EXECUTED 21AUG90 07:43:24

****

HEC2 WATER SURFACE PROFILES

Version 4.5.0; September 1990

****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

Donner River, 1969 Flood

SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10*KS	VCH	AREA	.01K
	1.000	.00	.00	.00	697.00	105000.00	715.67	.00	717.74	25.20	11.64	9454.60	20918.40
*	2.000	400.00	.00	.00	701.00	105000.00	715.92	715.92	722.64	76.61	20.80	5047.44	11996.08
*	3.000	1.00	760.00	750.00	701.00	105000.00	717.30	717.30	724.90	61.07	22.12	4746.14	13436.58
*	4.000	20.00	760.00	750.00	701.00	105000.00	720.59	717.30	725.73	34.27	18.18	5774.50	17935.29
*	5.000	1.00	.00	.00	701.00	105000.00	726.14	.00	727.01	4.41	7.47	14064.30	50020.34
	6.000	110.00	.00	.00	703.00	105000.00	726.23	.00	727.07	5.68	7.60	15563.41	44057.65

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Donner River, 1969 Flood

SUMMARY PRINTOUT TABLE 150

	SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
	1.000	105000.00	715.67	.00	.00	.67	876.46	.00
*	2.000	105000.00	715.92	.00	.25	.00	381.00	400.00
*	3.000	105000.00	717.30	.00	1.37	.00	790.21	1.00
*	4.000	105000.00	720.59	.00	3.30	.00	814.43	20.00
*	5.000	105000.00	726.14	.00	5.55	.00	580.00	1.00
	6.000	105000.00	726.23	.00	.09	.00	947.37	110.00

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SUMMARY OF ERRORS AND SPECIAL NOTES

```
CAUTION SECNO=    2.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    2.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=    3.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=    3.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=    3.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=    4.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

WARNING SECNO=    5.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```

Chapter 4

Examples of the Special Culvert Method

This chapter presents four examples of culvert models using the Special Culvert Method. The following examples are included:

1) A road crossing with a single box culvert.

2) A road crossing with a single pipe culvert.

3) A road crossing with multiple box culverts.

4) A road crossing with multiple pipe culverts.

4.1 Example of Box Culvert Analysis

As an example of the application of a special culvert model of a box culvert, the culvert illustrated in Figure 4.1 is considered. The culvert underneath the roadway is a 10' X 6' concrete box culvert, fifty feet in length. A Manning's 'n' value of 0.013 is assumed for the culvert. At both ends of the culvert are a vertical headwall and 45-degree wing walls. According to Table 3.9 of this appendix, Scale 1 of FHWA chart 8 is appropriate for this type of culvert. According to Table 3.4 of this appendix, the entrance loss coefficient for this type of entrance is about 0.4, assuming that the top edge of the entrance is not rounded.

A concrete apron extends about five feet past the end of the culvert. The roadway on either side of the channel is not elevated. The drop in invert elevation is 0.1 foot through the culvert, so the slope of the culvert invert is 0.2%.

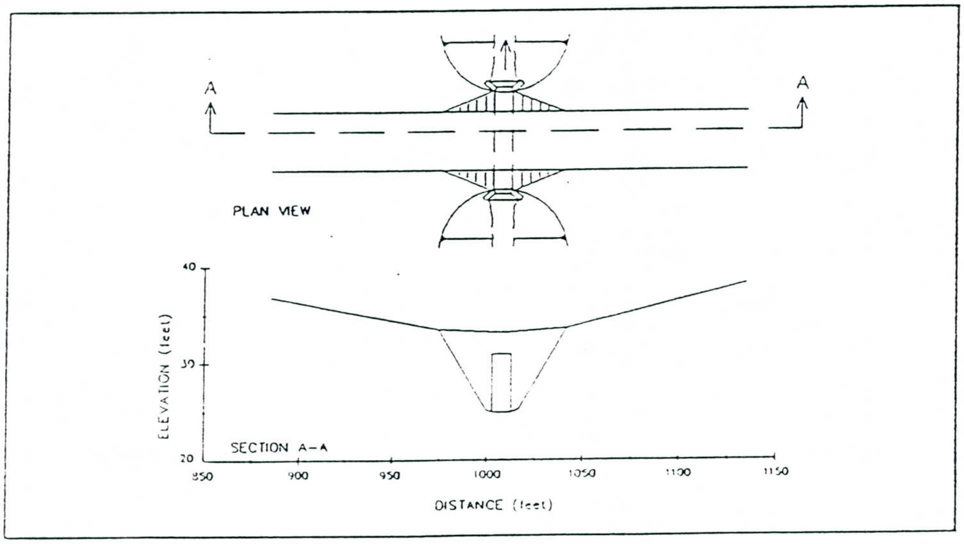

Figure 4.1
Illustration of Box Culvert Example

Cross-section 1 of the special culvert model is located downstream of the culvert crossing at a distance determined by the 4:1 flow expansion rule. The flow expands from a top width of ten feet in the culverts to a maximum of about sixty feet downstream, the spacing between cross-sections 1 and 2 should be about 4 X (30 - 5) = 100 feet.

Cross-section 2 is located at the downstream end of the culvert. The n-value is changed at cross-section 2 because the concrete apron extends past the downstream end of the culvert. The effective area option is used at cross-section 2 to restrict flow to the portion of the cross-section in and directly above the culvert opening until the roadway is overtopped. Both of the test elevations on the X3 record at cross-section 2 are set at thirty-two. These elevations are computed by subtracting the expected head loss through the culvert (about 1.3 feet) from the top-of-road elevations for the left and right sides of the road (each of which is 33.3).

The weir flow coefficient is set at 3.0. This is the recommended value for roadway embankments. The fill over the culvert is assumed to be similar to a roadway embankment.

The downstream channel flow-line elevation is equal to 24.9 for this example. The upstream flow-line elevation is 0.1 foot higher. These values are entered in Fields 9 and 10 of the SC record.

```
   20AUG90      14:03:37                                                              PAGE    1


                                                         THIS RUN EXECUTED 20AUG90    14:03:38
 ***********************************
 HEC-2 WATER SURFACE PROFILES

 Version    4.5.0;  September 1990
 ***********************************

T1       SINGLE BOX CULVERT EXAMPLE - SPECIAL CULVERT METHOD
T3       Dodson Cr., 10X6 BOX              Profile 1

J1  ICHECK    INQ      NINV     IDIR     STRT     METRIC    HVINS     Q      WSEL      FQ

               2                        .00015                              30.0

J2  NPROF    IPLOT    PRFVS    XSECV    XSECH      FN      ALLOC     IBW     CHNIM    ITRACE

     1                  -1


           USE J3 RECORDS TO REQUEST CUSTOM SUMMARY TABLE
         AND REGULAR SPECIAL CULVERT SUMMARY TABLES 101 AND 105

J3  VARIABLE CODES FOR SUMMARY PRINTOUT

     38        66        42        1         2        43        26        4        58
    101       105

        USE NC RECORD TO SET REGULAR CHANNEL LOSS COEFFICIENTS

NC      0.1       0.1       0.04      0.1       0.3
QT        3       150        300      400

        CROSS-SECTION 1 OF SPECIAL CULVERT MODEL - DOWNSTREAM OF CULVERT
X1        1        10        975      1042
GR     37.1       865       36.6       903        35       939      33.7       975      24.9      1000
GR     24.9      1011       34.1      1042      35.7      1074      35.7      1106      38.7      1145

        USE NC RECORD TO SET EXPANSION AND CONTRACTION COEFFICIENTS FOR CULVERT

NC                                      0.3       0.5

        CROSS-SECTION 2 OF SPECIAL CULVERT MODEL - AT DOWNSTREAM CULVERT FACE
          LEFT AND RIGHT BANKS REDEFINED TO LIMIT FLOW TO WIDTH OF CULVERT
NH        3       0.1        975      0.04      1042       0.1      1135
X1        2        10       1003      1013       100       100       100
        USE X3 RECORD TO RESTRICT EFFECTIVE FLOW AREA TO CULVERT WIDTH
X3       10                                                                   32.5      32.5
GR     36.9       885       34.9       938      33.5       975      25.2      1003        25      1003
GR       25      1013       25.3      1013      33.7      1042      35.8      1085      38.3      1135

        SC RECORD DEFINES A SINGLE 10X6 CONCRETE BOX CULVERT
```

Figure 4.2a
Box Culvert Example Output

Cross-section 3 is located at the upstream end of the culvert. The effective area option is also used at cross-section 3 to restrict flow to the portion of the cross-section in and directly above the culvert until the roadway is overtopped. The test elevations on the X3 record at cross-section 3 are set at the top-of-road elevations for the left and right sides of the road (each of which is 33.3).

Cross-section 4 is located upstream of the culvert at a distance determined using the 1:1 contraction rule. Since the flow must contract from a total top width of about one hundred and twenty feet at cross-section 4 to a top width of ten feet in the culvert, the spacing between cross-sections 3 and 4 should be about 60 - 5 = 55 feet.

```
     20AUG90       14:03:37                                                                  PAGE    2

 SC     1.013       0.4        3.0                 6.0       10.0       50        8.1        25       24.9

          CROSS-SECTION 3 OF SPECIAL CULVERT MODEL - AT UPSTREAM CULVERT FACE
          USE NH FOR N-VALUES AT CROSS-SECTION 3 BECAUSE OF CONCRETE APRON
 NH       3         0.1        975       0.04      1042       0.1       1135
 X1       3          10       1003       1013        50        50         50
 X2                              2                 33.3
 X3      10                                                                       33.7       33.7
 BT      -8         885       36.9                  938      34.8                  975       33.5
 BT                1003       33.3                 1013      33.3                 1042       33.7
 BT                1085       35.8                 1135      38.3
 GR    36.9         885       34.9        938      33.5       975       25.2      1003       25.1      1003
 GR    25.1        1013       25.3       1013      33.7      1042       35.8      1085       38.3      1135

 NC     0.1         0.1       0.04

          CROSS-SECTION 4 OF SPECIAL CULVERT MODEL - UPSTREAM OF CULVERT
 X1       4          10        975       1042        25        25         25
 GR    37.1         865       36.6        903        35       939       33.7       975       25.1      1000
 GR    25.1        1011       34.1       1042      35.7      1074       37.2      1106       38.7      1145
```

Figure 4.2b

Box Culvert Example Output (continued)

```
     20AUG90       14:03:37                                                                  PAGE    3

      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG        HV        HL       OLOSS     L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH       AROB      VOL      TWA       R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH      XNR       WTN      ELMIN     SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC       ICONT     CORAR    TOPWID    ENDST

 *PROF 1

 CCHV=      .100 CEHV=      .300
 *SECNO 1.000
       1.000      5.40      30.30        .00      30.00     30.31       .02       .00       .00      33.70
       150.0        .0      150.0         .0         .0     149.9        .0        .0        .0      34.10
         .00       .00       1.00        .00       .000      .040      .000      .000     24.90     984.66
     .000151        0.         0.         0.          0         0         4       .00     44.53    1029.19

 CCHV=      .300 CEHV=      .500
 1490 NH CARD USED
 *SECNO 2.000

 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE.  KRATIO =   .47

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      32.50 ELREA=      32.50

       2.000      5.27      30.27        .00        .00     30.40       .13       .03       .06      25.20
       150.0        .0      150.0         .0         .0      52.7        .0        .2        .1      25.30
         .01       .00       2.85        .00       .000      .040      .000      .000     25.00    1003.00
     .000682      100.       100.       100.          2         0         0       .00     10.00    1013.00


 SPECIAL CULVERT

 SC  CUNO      CUNV     ENTLC      COFQ      RDLEN      RISE      SPAN    CULVLN    CHRT      SCL       ELCHU     ELCHD
       1       .013       .40      3.00        .00      6.00     10.00     50.00      8         1       25.00     24.90

 CHART   8 - BOX CULVERT WITH FLARED WINGWALLS; NO INLET TOP EDGE BEVEL
 SCALE   1 - WINGWALLS FLARED 30 TO 75 DEGREES

 1490 NH CARD USED
 *SECNO 3.000

 SPECIAL CULVERT OUTLET CONTROL

 EGIC =     29.355  EGOC =     30.454  PCWSE=     30.272  ELTRD=     33.300
 SPECIAL CULVERT
```

Figure 4.2c

Box Culvert Example Output

```
 20AUG90        14:03:37                                                                                         PAGE    4

  SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
  Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
  TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
  SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST


   EGIC      EGOC        H4      QWEIR     QCULV      VCH     ACULV     ELTRD     WEIRLN
  29.35     30.45       .05        0.      150.     2.870     60.0     33.30        0.


3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      33.70 ELREA=      33.70

    3.000      5.23     30.33       .00       .00     30.45       .13       .06       .00     25.20
    150.0        .0     150.0        .0        .0      52.3        .0        .3        .1     25.30
      .01       .00      2.87       .00      .000      .040      .000      .000     25.10   1003.00
  .000684       50.       50.       50.         0         0         0       .00     10.00   1013.00

*SECNO 4.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  2.14

    4.000      5.38     30.48       .00       .00     30.49       .02       .01       .03     33.70
    150.0        .0     150.0        .0        .0     151.1        .0        .4        .1     34.10
      .02       .00       .99       .00      .000      .040      .000      .000     25.10    984.36
  .000150       25.       25.       25.         2         0         0       .00     45.17   1029.53
```

Figure 4.2d
Box Culvert Example Output (continued)

```
 20AUG90        14:03:37                                                                                         PAGE    5

T1      SINGLE BOX CULVERT EXAMPLE - SPECIAL CULVERT METHOD
T3      Dodson Cr., 10X6 BOX            Profile 2

J1   ICHECK     INQ       NINV      IDIR      STRT     METRIC    HVINS      Q        WSEL      FQ

                  3                         .00015                                  32.0

J2   NPROF     IPLOT     PRFVS     XSECV     XSECH      FN       ALLDC     IBW      CHNIM     ITRACE

       2                   -1
```

Figure 4.2e
Box Culvert Example Output (continued)

```
 20AUG90        14:03:37                                                                                         PAGE    6
  SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
  Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
  TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
  SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST
*PROF 2

CCHV=      .100 CEHV=      .300
*SECNO 1.000
    1.000      7.40     32.30       .00     32.00     32.32       .02       .00       .00     33.70
    300.0        .0     300.0        .0        .0     251.2        .0        .0        .0     34.10
      .00       .00      1.19       .00      .000      .040      .000      .000     24.90    978.99
  .000151        0.        0.        0.         0         0         4       .00     56.93   1035.92

CCHV=      .300 CEHV=      .500
1490 NH CARD USED
*SECNO 2.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   .40

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      32.50 ELREA=      32.50

    2.000      7.20     32.20       .00       .00     32.47       .27       .03       .12     25.20
    300.0        .0     300.0        .0        .0      72.0        .0        .4        .1     25.30
      .01       .00      4.17       .00      .000      .040      .000      .000     25.00   1003.00
  .000964      100.      100.      100.         2         0         0       .00     10.00   1013.00

SPECIAL CULVERT

SC  CUNO        CUNV      ENTLC      COFQ     RDLEN      RISE      SPAN    CULVLN     CHRT       SCL        ELCHU      ELCHO
     1          .013       .40       3.00      .00       6.00     10.00     50.00      8          1         25.00      24.90

CHART  8 - BOX CULVERT WITH FLARED WINGWALLS; NO INLET TOP EDGE BEVEL
SCALE  1 - WINGWALLS FLARED 30 TO 75 DEGREES

1490 NH CARD USED
*SECNO 3.000

SPECIAL CULVERT OUTLET CONTROL

EGIC =     32.037  EGOC =     33.024  PCWSE=     32.203  ELTRD=     33.300
SPECIAL CULVERT
```

Figure 4.2f
Box Culvert Example Output (continued)

```
20AUG90        14:03:37                                                                          PAGE   7

  SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
  Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
  TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
  SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

  EGIC       EGOC      H4        QWEIR     QCULV     VCH       ACULV     ELTRD     WEIRLN
  32.04      33.02     .58       0.        300.      3.902     60.0      33.30     0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       33.70 ELREA=       33.70

  3.000      7.69      32.79     .00       .00       33.02     .24       .55       .00       25.20
  300.0      .0        300.0     .0        .0        76.9      .0        .5        .1        25.30
  .01        .00       3.90      .00       .000      .040      .000      .000      25.10     1003.00
  .000756    50.       50.       50.       0         0         0         .00       10.00     1013.00

*SECNO 4.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  2.70

  4.000      7.98      33.08     .00       .00       33.10     .02       .01       .07       33.70
  300.0      .0        300.0     .0        .0        289.9     .0        .6        .1        34.10
  .02        .00       1.03      .00       .000      .040      .000      .000      25.10     976.81
  .000104    25.       25.       25.       2         0         0         .00       61.68     1038.48
```

Figure 4.2g
Box Culvert Example Output (continued)

```
20AUG90        14:03:37                                                                          PAGE   8

T1        SINGLE BOX CULVERT EXAMPLE - SPECIAL CULVERT METHOD
T3        Dodson Cr., 10X6 BOX          Profile 3

J1   ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
                4                             .00015                                  34.0

J2   NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE
     15                   -1
```

Figure 4.2h
Box Culvert Example Output (continued)

```
20AUG90        14:03:37                                                                          PAGE   9

  SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
  Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
  TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
  SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST
*PROF 3

CCHV=      .100 CEHV=      .300
*SECNO 1.000
  1.000      8.42      33.32     .00       34.00     33.34     .03       .00       .00       33.70
  400.0      .0        400.0     .0        .0        312.5     .0        .0        .0        34.10
  .00        .00       1.28      .00       .000      .040      .000      .000      24.90     976.09
  .000149    0.        0.        0.        0         0         4         .00       63.27     1039.36

CCHV=      .300 CEHV=      .500
1490 NH CARD USED
*SECNO 2.000
  2.000      8.33      33.33     .00       .00       33.36     .03       .01       .00       25.20
  400.0      125.3     150.4     124.3     111.5     83.3      111.3     .7        .1        25.30
  .02        1.12      1.81      1.12      .040      .040      .040      .000      25.00     975.57
  .000149    100.      100.      100.      0         0         0         .00       65.16     1040.73
SPECIAL CULVERT

SC  CUNO      CUNV      ENTLC     COFQ      RDLEN     RISE      SPAN      CULVLN    CHRT      SCL       ELCHU     ELCHD
    1         .013      .40       3.00      .00       6.00      10.00     50.00     8         1         25.00     24.90

CHART  8 - BOX CULVERT WITH FLARED WINGWALLS; NO INLET TOP EDGE BEVEL
SCALE  1 - WINGWALLS FLARED 30 TO 75 DEGREES

1490 NH CARD USED
*SECNO 3.000
SPECIAL CULVERT

  EGIC       EGOC      H4        QWEIR     QCULV     VCH       ACULV     ELTRD     WEIRLN
  33.31      34.39     .62       87.       316.      1.585     60.0      33.30     85.

  3.000      8.85      33.95     .00       .00       33.98     .02       .62       .00       25.20
  400.0      131.1     140.3     128.5     131.6     88.5      129.8     1.1       .2        25.30
  .03        1.00      1.59      .99       .040      .040      .040      .000      25.10     963.06
  .000103    50.       50.       50.       2         0         0         .00       84.10     1047.16
```

Figure 4.2i
Box Culvert Example Output (continued)

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SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
*SECNO 4.000									
4.000	8.86	33.96	.00	.00	33.98	.02	.00	.00	33.70
400.0	.0	400.0	.0	.9	346.3	.0	1.3	.3	34.10
.04	.04	1.15	.00	.100	.040	.000	.000	25.10	967.94
.000113	25.	25.	25.	0	0	0	.00	73.56	1041.50

Figure 4.2j
Box Culvert Example Output (continued)

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THIS RUN EXECUTED 20AUG90 14:03:40

****

HEC-2 WATER SURFACE PROFILES

Version 4.5.0; September 1990

****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

Dodson Cr., 10X6 BOX

SUMMARY PRINTOUT

	SECNO	CUMDS	ELMIN	CWSEL	CRIWS	Q	VCH	TOPWID	KRATIO
	1.000	.00	24.90	30.30	.00	150.00	1.00	44.53	.00
	1.000	.00	24.90	32.30	.00	300.00	1.19	56.93	.00
	1.000	.00	24.90	33.32	.00	400.00	1.28	63.27	.00
*	2.000	100.00	25.00	30.27	.00	150.00	2.85	10.00	.47
*	2.000	100.00	25.00	32.20	.00	300.00	4.17	10.00	.40
	2.000	100.00	25.00	33.33	.00	400.00	1.81	65.16	1.00
	3.000	150.00	25.10	30.33	.00	150.00	2.87	10.00	1.00
	3.000	150.00	25.10	32.79	.00	300.00	3.90	10.00	1.13
	3.000	150.00	25.10	33.95	.00	400.00	1.59	84.10	1.20
*	4.000	175.00	25.10	30.48	.00	150.00	.99	45.17	2.14
*	4.000	175.00	25.10	33.08	.00	300.00	1.03	61.68	2.70
	4.000	175.00	25.10	33.96	.00	400.00	1.15	73.56	.96

Figure 4.2k
Box Culvert Example Output (continued)

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Dodson Cr., 10X6 BOX

SUMMARY PRINTOUT TABLE 101

SECNO	EGOC	EGIC	H4	ELTRD	QCULV	QWEIR	CLASS	DEPTH	CWSEL	VCH	EG
3.000	30.45	29.35	.05	33.30	150.00	.00	7.00	5.23	30.33	2.87	30.45
3.000	33.02	32.04	.58	33.30	300.00	.00	7.00	7.69	32.79	3.90	33.02
3.000	34.39	33.31	.62	33.30	315.60	87.11	17.00	8.85	33.95	1.59	33.98

Figure 4.2l
Box Culvert Example Output (continued)

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Dodson Cr., 10X6 BOX

SUMMARY PRINTOUT TABLE 105

SECNO	CWSEL	HL	OLOSS	TOPWID	QLOB	QCH	QROB
1.000	30.30	.00	.00	44.53	.00	150.00	.00
1.000	32.30	.00	.00	56.93	.00	300.00	.00
1.000	33.32	.00	.00	63.27	.00	400.00	.00
* 2.000	30.27	.03	.06	10.00	.00	150.00	.00
* 2.000	32.20	.03	.12	10.00	.00	300.00	.00
2.000	33.33	.01	.00	65.16	125.34	150.40	124.26
3.000	30.33	.06	.00	10.00	.00	150.00	.00
3.000	32.79	.55	.00	10.00	.00	300.00	.00
3.000	33.95	.62	.00	84.10	131.12	140.33	128.54
* 4.000	30.48	.01	.03	45.17	.00	150.00	.00
* 4.000	33.08	.01	.07	61.68	.00	300.00	.00
4.000	33.96	.00	.00	73.56	.04	399.96	.00

Figure 4.2m
Box Culvert Example Output (continued)

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SUMMARY OF ERRORS AND SPECIAL NOTES

WARNING SECNO= 2.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO= 2.000 PROFILE= 2 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO= 4.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO= 4.000 PROFILE= 2 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

Figure 4.2n
Box Culvert Example Output (continued)

4.2 Example of Pipe Culvert Analysis

This example deals with a roadway crossing over a reinforced concrete pipe culvert. As shown in Figure 4.3, the culvert is a 84-inch reinforced concrete pipe 50 feet in length. A Manning's 'n' value of 0.013 is assumed for the culvert. At both ends of the culvert are a vertical headwall and 45-degree wing walls. According to Table 3.9 of this appendix, Scale 1 of FHWA Chart 1 is appropriate for this type of culvert. According to Table 3.6 of this appendix, the entrance loss coefficient for this type of entrance is about 0.5, assuming that the top edge of the entrance is not rounded.

A concrete apron extends about 5 feet past the end of the culvert. The roadway on either side of the channel is not elevated. The drop in invert elevation is 0.1 foot through the culvert, so the slope of the culvert invert is 0.2%.

Cross-section 1 of the special culvert model is located downstream of the culvert crossing at a distance determined by the 4:1 flow expansion rule.

Cross-section 2 is located at the downstream end of the culvert. The n-value is changed at cross-section 2 because the concrete apron extends past the downstream end of the culvert. The effective area option is used at cross-section 2 to restrict flow to the portion of the cross-section in and directly above the culvert opening until the roadway is overtopped. Both of the test elevations on the X3 record at cross-section 2 are set at 32.9. These elevations are computed by subtracting the expected head loss through the culvert (about 0.8 feet) from the top-of-road elevations for the left and right sides of the road (each of which is 33.7).

The weir flow coefficient is set at 3.0. This is the recommended value for roadway embankments. The fill over the culvert is assumed to be similar to a roadway embankment.

The downstream channel flow-line elevation is equal to 25 for this example. The upstream flow-line elevation is 0.1 foot higher. These values are entered in fields 9 and 10 of the SC record.

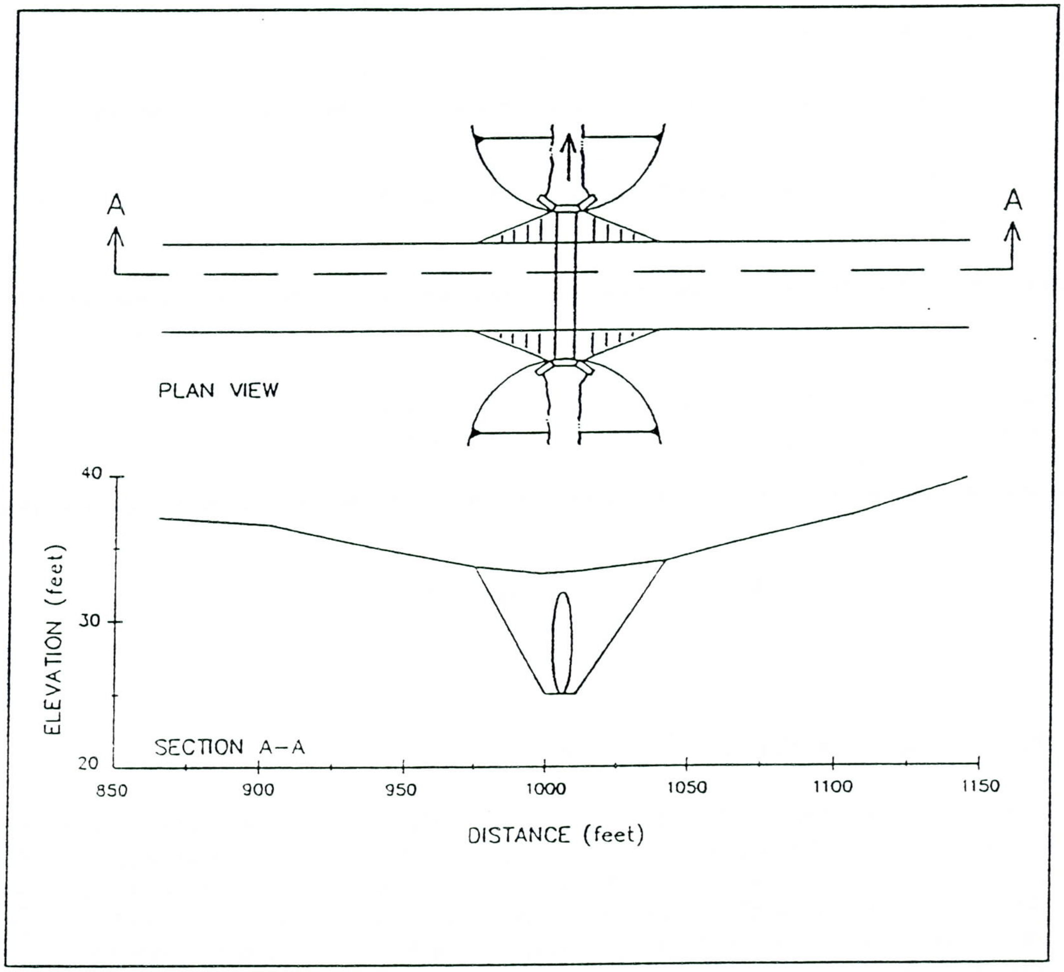

Figure 4.3
Pipe Culvert Example

Cross-section 3 is located at the upstream end of the culvert. The effective area option is also used at cross-section 3 to restrict flow to the portion of the cross-section in and directly above the culvert until the roadway is overtopped. The test elevations on the X3 record at cross-section 3 are set at the top-of-road elevations for the left and right sides of the road (each of which is 33.7).

Cross-section 4 is located upstream of the culvert at a distance determined using the 1:1 contraction rule.

```
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                                                                                      PAGE    1
**************************************
HEC-2 WATER SURFACE PROFILES                                  THIS RUN EXECUTED 20AUG90    13:11:31

Version   4.5.0;  September 1990
**************************************

T1        SINGLE PIPE CULVERT EXAMPLE - SPECIAL CULVERT METHOD
T3        Dodson Cr., 7 ft. Pipe           Profile 1

J1   ICHECK    INQ      NINV     IDIR     STRT      METRIC    HVINS     Q        WSEL      FQ
                2                         .00015                                 31.0
J2   NPROF     IPLOT    PRFVS    XSECV    XSECH     FN        ALLDC     IBW      CHNIM     ITRACE
      1                  -1

          USE J3 RECORDS TO REQUEST CUSTOM SUMMARY TABLE
          AND REGULAR SPECIAL CULVERT SUMMARY TABLES 101 AND 105
J3   VARIABLE CODES FOR SUMMARY PRINTOUT
      38       66
     101      105        42        1        2        43        26        4        58

          USE NC RECORD TO SET REGULAR CHANNEL LOSS COEFFICIENTS
NC     0.1      0.1      0.04      0.1      0.3
QT      3       200      280       400

        CROSS-SECTION 1 OF SPECIAL CULVERT MODEL - DOWNSTREAM OF CULVERT
X1      1        10       975      1042
GR    37.1      865      36.6       903      35       939      33.7      975      24.9     1000
GR    24.9     1011      34.1      1042     35.7     1074      35.7     1106      38.7     1145
        USE NC RECORD TO SET EXPANSION AND CONTRACTION COEFFICIENTS FOR CULVERT
NC                                  0.3      0.5
        CROSS-SECTION 2 OF SPECIAL CULVERT MODEL - AT DOWNSTREAM CULVERT FACE
          LEFT AND RIGHT BANKS REDEFINED TO LIMIT FLOW TO WIDTH OF CULVERT
NH      3        .1       975       .04     1042        .1      1145
X1      2        12      1003      1010      100       -100      100
        USE X3 RECORD TO RESTRICT EFFECTIVE FLOW AREA TO CULVERT WIDTH
X3     10
GR    37.1      865      36.6       903      35       939      33.7      32.2      32.2     1000
GR     25      1003       25       1010      25       1011     34.1      975        25      1074
GR    37.2     1106      38.7      1145                                  1042      35.7

        SC RECORD DEFINES A SINGLE 84-INCH CONCRETE PIPE CULVERT
```

Figure 4.4a
Pipe Culvert Example Output

```
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                                                                                  PAGE    2
SC    1.013      0.5       3.0                7.0                50       1.1      25.1      25.0
NH      3        .1        975      .04      1042        .1      1145
        CROSS-SECTION 3 OF SPECIAL CULVERT MODEL - AT UPSTREAM CULVERT FACE
X1      3        12       1003      1010       50        50        50
X2                          2                 33.7
X3     10
BT    -10       865       37.1                903       36.6               33.7      33.7
BT              975       33.7               1003       33.7               939        35
BT             1042       34.1               1074       35.7              1010       33.7
BT             1145       38.7                                            1106       37.2
GR    37.1      865       36.6       903       35        939      33.7      975      25.1     1000
GR    25.1     1003       25.1      1010      25.1      1011      34.1     1042      35.7     1074
GR    37.2     1106       38.7      1145

NC     0.1      0.1       .04

        CROSS-SECTION 4 OF SPECIAL CULVERT MODEL - UPSTREAM OF CULVERT
X1      4        10        975      1042       25        25        25
GR    37.1      865       36.6       903       35        939      33.7      975      25.1     1000
GR    25.1     1011       34.1      1042      35.7      1074      37.2     1106      38.7     1145
```

Figure 4.4a
Pipe Culvert Example Output

```
 20AUG90      13:11:31                                                                                    PAGE    3

   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

 *PROF 1

 CCHV=      .100 CEHV=      .300
 *SECNO 1.000
    1.000      6.16     31.06       .00     31.00     31.08       .02       .00       .00     33.70
    200.0        .0     200.0        .0        .0     185.5        .0        .0        .0     34.10
      .00       .00      1.08       .00      .000      .040      .000      .000     24.90    982.51
  .000151        0.        0.        0.         0         0         3       .00     49.24   1031.75

 CCHV=      .300 CEHV=      .500
 1490 NH CARD USED
 *SECNO 2.000

 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   .31

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=        32.20 ELREA=      32.20

    2.000      5.92     30.92       .00       .00     31.28       .36       .04       .17     25.00
    200.0        .0     200.0        .0        .0      41.5        .0        .3        .1     25.00
      .01       .00      4.83       .00      .000      .040      .000      .000     25.00   1003.00
  .001574      100.      100.      100.         2         0         0       .00      7.00   1010.00

 SPECIAL CULVERT

 SC  CUNO    CUNV    ENTLC    COFQ    RDLEN    RISE    SPAN    CULVLN   CHRT    SCL    ELCHU    ELCHD
      1      .013     .50     3.00     .00     7.00     .00    50.00     1       1     25.10    25.00

 CHART  1 - CONCRETE PIPE CULVERT; NO BEVELED RING ENTRANCE
 SCALE  1 - SQUARE EDGE ENTRANCE WITH HEADWALL

 1490 NH CARD USED
 *SECNO 3.000

 SPECIAL CULVERT OUTLET CONTROL

 EGIC =     30.854  EGOC =     31.559  PCWSE=     30.921  ELTRD=     33.700
 SPECIAL CULVERT
```

Figure 4.4c
Pipe Culvert Example Output (continued)

```
 20AUG90      13:11:31                                                                                    PAGE    4

   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

    EGIC      EGOC        H4     QWEIR     QCULV       VCH     ACULV     ELTRD    WEIRLN
    30.85     31.56       .30        0.      200.     4.668      38.5     33.70        0.

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=        33.70 ELREA=      33.70

    3.000      6.12     31.22       .00       .00     31.56       .34       .28       .00     25.10
    200.0        .0     200.0        .0        .0      42.8        .0        .3        .1     25.10
      .01       .00      4.67       .00      .000      .040      .000      .000     25.10   1003.00
  .001410       50.       50.       50.         0         0         0       .00      7.00   1010.00

 *SECNO 4.000

 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  3.54

    4.000      6.55     31.65       .00       .00     31.66       .01       .01       .10     33.70
    200.0        .0     200.0        .0        .0     208.3        .0        .4        .1     34.10
      .02       .00       .96       .00      .000      .040      .000      .000     25.10    980.96
  .000112       25.       25.       25.         2         0         0       .00     52.60   1033.56
```

Figure 4.4d
Pipe Culvert Example Output (continued)

```
20AUG90        13:11:31                                                                 PAGE  5

T1     SINGLE PIPE CULVERT EXAMPLE - SPECIAL CULVERT METHOD
T3     Dodson Cr., 7 ft. Pipe          Profile 2

J1   ICHECK    INQ     NINV     IDIR     STRT     METRIC    HVINS     Q      WSEL     FQ

               3                         .00015                              32.5

J2   NPROF     IPLOT   PRFVS    XSECV    XSECH    FN        ALLDC     IBW    CHNIM    ITRACE

     2                 -1
```

Figure 4.4e
Pipe Culvert Example Output (continued)

```
20AUG90        13:11:31                                                                 PAGE  6

     SECNO     DEPTH    CWSEL    CRIWS    WSELK    EG      HV      HL      OLOSS    L-BANK ELEV
     Q         QLOB     QCH      QROB     ALOB     ACH     AROB    VOL     TWA      R-BANK ELEV
     TIME      VLOB     VCH      VROB     XNL      XNCH    XNR     WTN     ELMIN    SSTA
     SLOPE     XLOBL    XLCH     XLOBR    ITRIAL   IDC     ICONT   CORAR   TOPWID   ENDST

*PROF 2

CCHV=    .100 CEHV=    .300
*SECNO 1.000
     1.000     7.19     32.09    .00      32.50    32.11   .02     .00     .00      33.70
     280.0     .0       280.0    .0       .0       239.7   .0      .0      .0       34.10
     .00       .00      1.17     .00      .000     .040    .000    .000    24.90    979.57
     .000149   0.       0.       0.       0        0       4       .00     55.66    1035.23

CCHV=    .300 CEHV=    .500
1490 NH CARD USED
*SECNO 2.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO =   .28

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      32.20 ELREA=      32.20

     2.000     6.87     31.87    .00      .00      32.40   .53     .04     .25      25.00
     280.0     .0       280.0    .0       .0       48.1    .0      .3      .1       25.00
     .00       .00      5.82     .00      .000     .040    .000    .000    25.00    1003.00
     .001876   100.     100.     100.     2        0       0       .00     7.00     1010.00

SPECIAL CULVERT

SC  CUNO   CUNV    ENTLC   COFQ    RDLEN   RISE    SPAN    CULVLN   CHRT   SCL    ELCHU    ELCHD
    1      .013    .50     3.00    .00     7.00    .00     50.00    1      1      25.10    25.00

CHART   1 - CONCRETE PIPE CULVERT; NO BEVELED RING ENTRANCE
SCALE   1 - SQUARE EDGE ENTRANCE WITH HEADWALL

1490 NH CARD USED
*SECNO 3.000

SPECIAL CULVERT OUTLET CONTROL

EGIC =    32.358  EGOC =    32.844  PCWSE=    31.875  ELTRD=    33.700
```

Figure 4.4f
Pipe Culvert Example Output (continued)

```
 20AUG90        13:11:31                                                                              PAGE     7

   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

 SPECIAL CULVERT

     EGIC       EGOC        H4       QWEIR      QCULV       VCH       ACULV      ELTRD     WEIRLN
    32.36      32.84       .50         0.       280.      5.499      38.5      33.70         0.

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       33.70 ELREA=       33.70

     3.000       7.27      32.37        .00        .00      32.84        .47        .44        .00      25.10
     280.0         .0      280.0         .0         .0       50.9         .0         .4         .1      25.10
       .01        .00       5.50        .00       .000       .040       .000       .000      25.10    1003.00
   .001554        50.        50.        50.          0          0          0        .00       7.00    1010.00

 *SECNO 4.000

 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  4.02

     4.000       7.87      32.97        .00        .00      32.99        .02        .01        .14      33.70
     280.0         .0      280.0         .0         .0      283.4         .0         .5         .1      34.10
       .01        .00        .99        .00       .000       .040       .000       .000      25.10     977.12
   .000096        25.        25.        25.          2          0          0        .00      61.00    1038.11
```

Figure 4.4g
Pipe Culvert Example Output (continued)

```
 20AUG90        13:11:31                                                                              PAGE     8

 T1       SINGLE PIPE CULVERT EXAMPLE - SPECIAL CULVERT METHOD
 T3       Dodson Cr., 7 ft. Pipe          Profile 3

 J1   ICHECK     INQ      NINV      IDIR      STRT      METRIC     HVINS      Q        WSEL       FQ

                  4                         .00015                                    33.5

 J2   NPROF     IPLOT     PRFVS     XSECV     XSECH      FN        ALLDC      IBW      CHNIM     ITRACE

       15                   -1
```

Figure 4.4h
Pipe Culvert Example Output (continued)

```
 20AUG90        13:11:31                                                                              PAGE     9

   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

 *PROF 3

 CCHV=      .100 CEHV=      .300
 *SECNO 1.000
     1.000       8.37      33.27        .00      33.50      33.30        .03        .00        .00      33.70
     400.0         .0      400.0         .0         .0      309.7         .0         .0         .0      34.10
       .00        .00       1.29        .00       .000       .040       .000       .000      24.90     976.22
   .000153         0.         0.         0.          0          0          3        .00      62.99    1039.21

 CCHV=      .300 CEHV=      .500
 1490 NH CARD USED
 *SECNO 2.000
     2.000       8.28      33.28        .00        .00      33.31        .03        .01        .00      25.00
     400.0      152.1      104.2      143.7      123.5       58.0      125.3         .7         .1      25.00
       .02       1.23       1.80       1.15       .040       .040       .040       .000      25.00     976.19
   .000139       100.       100.       100.          0          0          0        .00      63.04    1039.23

 SPECIAL CULVERT

 SC  CUNO       CUNV     ENTLC      COFQ      RDLEN      RISE      SPAN      CULVLN     CHRT       SCL        ELCHU      ELCHD
       1        .013       .50      3.00        .00      7.00       .00      50.00        1         1         25.10      25.00

 CHART   1 - CONCRETE PIPE CULVERT; NO BEVELED RING ENTRANCE
 SCALE   1 - SQUARE EDGE ENTRANCE WITH HEADWALL

 1490 NH CARD USED
 *SECNO 3.000
 SPECIAL CULVERT

     EGIC       EGOC        H4       QWEIR      QCULV       VCH       ACULV      ELTRD     WEIRLN
    34.18      36.01       1.17       133.       266.      1.430      38.5      33.70        96.

     3.000       9.36      34.46        .00        .00      34.48        .02       1.17        .00      25.10
     400.0      156.8       93.8      149.4      163.2       65.6      161.8        1.1         .2      25.10
       .03        .96       1.43        .92       .040       .040       .040       .000      25.10     953.61
   .000075        50.        50.        50.          1          0          0        .00      95.83    1049.45
```

Figure 4.4i
Pipe Culvert Example Output (continued)

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SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST
*SECNO 4.000									
4.000	9.37	34.47	.00	.00	34.48	.02	.00	.00	33.70
400.0	.6	399.4	.1	8.1	380.5	1.3	1.3	.3	34.10
.04	.07	1.05	.04	.100	.040	.100	.000	25.10	953.79
.000083	25.	25.	25.	0	0	0	.00	95.53	1049.32

Figure 4.4j
Pipe Culvert Example Output (continued)

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THIS RUN EXECUTED 20AUG90 13:11:34

****
HEC-2 WATER SURFACE PROFILES

Version 4.5.0; September 1990
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

Dodson Cr., 7 ft. Pipe

SUMMARY PRINTOUT

	SECNO	CUMDS	ELMIN	CWSEL	CRIWS	Q	VCH	TOPWID	KRATIO
	1.000	.00	24.90	31.06	.00	200.00	1.08	49.24	.00
	1.000	.00	24.90	32.09	.00	280.00	1.17	55.66	.00
	1.000	.00	24.90	33.27	.00	400.00	1.29	62.99	.00
*	2.000	100.00	25.00	30.92	.00	200.00	4.83	7.00	.31
*	2.000	100.00	25.00	31.87	.00	280.00	5.82	7.00	.28
	2.000	100.00	25.00	33.28	.00	400.00	1.80	63.04	1.05
	3.000	150.00	25.10	31.22	.00	200.00	4.67	7.00	1.06
	3.000	150.00	25.10	32.37	.00	280.00	5.50	7.00	1.10
	3.000	150.00	25.10	34.46	.00	400.00	1.43	95.83	1.36
*	4.000	175.00	25.10	31.65	.00	200.00	.96	52.60	3.54
*	4.000	175.00	25.10	32.97	.00	280.00	.99	61.00	4.02
	4.000	175.00	25.10	34.47	.00	400.00	1.05	95.53	.95

Figure 4.4k
Pipe Culvert Example Output (continued)

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Dodson Cr., 7 ft. Pipe

SUMMARY PRINTOUT TABLE 101

SECNO	EGOC	EGIC	H4	ELTRD	QCULV	QWEIR	CLASS	DEPTH	CWSEL	VCH	EG
3.000	31.56	30.85	.30	33.70	200.00	.00	7.00	6.12	31.22	4.67	31.56
3.000	32.84	32.36	.50	33.70	280.00	.00	7.00	7.27	32.37	5.50	32.84
3.000	36.01	34.18	1.17	33.70	265.68	132.80	17.00	9.36	34.46	1.43	34.48

Figure 4.4l
Pipe Culvert Example Output (continued)

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Dodson Cr., 7 ft. Pipe

SUMMARY PRINTOUT TABLE 105

	SECNO	CWSEL	HL	OLOSS	TOPWID	QLOB	QCH	QROB
	1.000	31.06	.00	.00	49.24	.00	200.00	.00
	1.000	32.09	.00	.00	55.66	.00	280.00	.00
	1.000	33.27	.00	.00	62.99	.00	400.00	.00
*	2.000	30.92	.04	.17	7.00	.00	200.00	.00
*	2.000	31.87	.04	.25	7.00	.00	280.00	.00
	2.000	33.28	.01	.00	63.04	152.14	104.20	143.66
	3.000	31.22	.28	.00	7.00	.00	200.00	.00
	3.000	32.37	.44	.00	7.00	.00	280.00	.00
	3.000	34.46	1.17	.00	95.83	156.79	93.82	149.39
*	4.000	31.65	.01	.10	52.60	.00	200.00	.00
*	4.000	32.97	.01	.14	61.00	.00	280.00	.00
	4.000	34.47	.00	.00	95.53	.58	399.36	.06

Figure 4.4m
Pipe Culvert Example Output (continued)

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SUMMARY OF ERRORS AND SPECIAL NOTES

```
WARNING SECNO=   2.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=   2.000  PROFILE=  2  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=   4.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=   4.000  PROFILE=  2  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```

Figure 4.4n
Pipe Culvert Example Output (continued)

4.3 Multiple Culverts Example

This example deals with a situation where the roadway crossing consists of two 72-inch reinforced concrete pipe culverts. As illustrated on Figure 4.5, the culverts are 50 feet in length. A Manning's 'n' value of 0.013 is assumed for the culverts. At each end of the culverts is a vertical headwall and 45-degree wingwalls. According to Table 3.8 of this Appendix, Scale 1 of FHWA Chart 1 is appropriate for this type of culvert. According to Table 3.5 of this Appendix, the entrance loss coefficient for this type of entrance is about 0.5, assuming that the top edge of the entrance is not rounded.

A concrete apron extends about five feet past the end of the culvert. The roadway on either side of the channel is not elevated. The drop in invert elevation is 0.1 foot through the culvert, so the slope of the culvert invert is 0.2%. Elevated roadway approach embankments extend into the floodplain on each side of the bridge.

Cross-section 1 of the special culvert model is located downstream of the culvert crossing at a distance determined by the 4:1 flow expansion rule.

Cross-section 2 is located at the downstream end of the culvert. The n-value is changed at cross-section 2 because the concrete apron extends past the downstream end of the culvert. The effective area option is used at cross-section 2 to restrict flow to the portion of the cross-section in

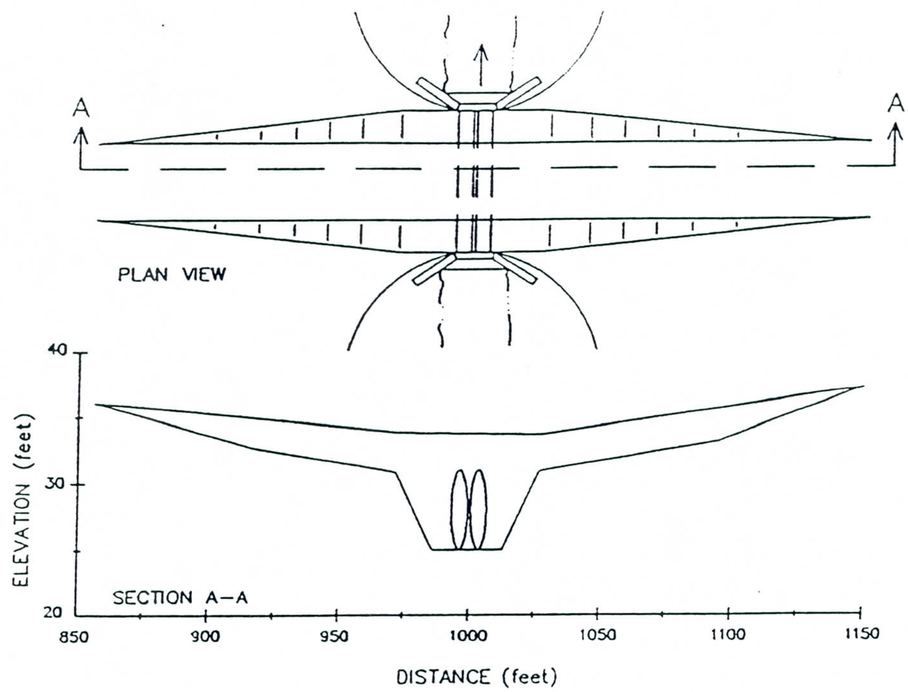

Figure 4.5
Illustration of Multiple Culverts Example

and directly above the culvert opening until the roadway is overtopped. Both of the test elevations on the X3 record at cross-section 2 are set at 32.5. These elevations are computed by subtracting the expected head loss through the culvert (about 1.3 feet) from the top-of-road elevations for the left and right sides of the road (each of which is 33.8).

The weir flow coefficient is set at 3.0. This is the recommended value for roadway embankments. The fill over the culvert is assumed to be similar to a roadway embankment.

The downstream channel flow-line elevation is equal to twenty-five for this example. The upstream flow-line elevation is 0.1 foot higher. These values are entered in fields 9 and 10 of the SC record.

Cross-section 3 is located at the upstream end of the culvert. The effective area option is also used at cross-section 3 to restrict flow to the portion of the cross-section in and directly above the culvert until the roadway is overtopped. The test elevations on the X3 record at cross-section 3 are set at the top-of-road elevations for the left and right sides of the road (each of which is 33.8).

Cross-section 4 is located upstream of the culvert at a distance determined using the 1:1 contraction rule.

The results of a multi-profile HEC-2 run for this example may be found in Figure 4.6. Solutions for culvert flow and combination culvert flow and weir flow conditions are determined by the HEC-2 program.

```
   20AUG90       14:52:29                                                                              PAGE    1

                                                                          THIS RUN EXECUTED 20AUG90    14:52:29
 ************************************
 HEC-2 WATER SURFACE PROFILES

 Version    4.5.0; September 1990
 ************************************

 T1      MULTIPLE PIPE CULVERTS EXAMPLE - SPECIAL CULVERT METHOD
 T3      Dodson Cr., 2-7 ft PIPES       Profile 1

 J1   ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q        WSEL      FQ

                 2                             .00015                                 30.0

 J2   NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW      CHNIM     ITRACE

         1                 -1

         USE J3 RECORDS TO REQUEST CUSTOM SUMMARY TABLE
         AND REGULAR SPECIAL CULVERT SUMMARY TABLES 101 AND 105

 J3   VARIABLE CODES FOR SUMMARY PRINTOUT

        38        66        42         1         2        43        26        4         58
       101       105

         USE NC RECORD TO SET REGULAR CHANNEL LOSS COEFFICIENTS

 NC      0.1       0.1       0.04      0.1       0.3
 QT       3        250       400       500

         CROSS-SECTION 1 OF SPECIAL CULVERT MODEL - DOWNSTREAM OF CULVERTS
 X1       1         8        972       1027
 GR     36.1       856       32.7       917      30.9       972      24.8      986       24.8      1013
 GR      31        1027      33.2      1095      37.2      1150

         USE NC RECORD TO SET EXPANSION AND CONTRACTION COEFFICIENTS FOR CULVERTS

 NC                                     0.3       0.5

         CROSS-SECTION 2 OF SPECIAL CULVERT MODEL - AT DOWNSTREAM CULVERT FACE
         LEFT AND RIGHT BANKS ARE REDEFINED TO LIMIT FLOW TO WIDTH OF CULVERT
 NH       3        0.1       972       0.04      1027       0.1      1150
 X1       2         10       993       1007       200       200       200
         USE X3 RECORD TO RESTRICT EFFECTIVE FLOW AREA TO CULVERT WIDTH
 X3      10                                                                   32.3      32.3
 GR     36.1       856       32.7       917      30.9       972       25       986        25       993
 GR      25        1007       25       1013       31        1027      33.2     1095       37.2      1150

         SC RECORD DEFINES DUAL 72-INCH CONCRETE PIPE CULVERTS
```

Figure 4.6a
Multiple Culverts Example Output

```
   20AUG90       14:52:29                                                                            PAGE    2
 SC     2.013      0.5       3.0                 6.0                           50       1.1       25.1      25.0

         CROSS-SECTION 3 OF SPECIAL CULVERT MODEL - AT UPSTREAM CULVERT FACE
 NH       3        0.1       972       0.04      1027       0.1      1150
 X1       3         10       993       1007       50         50       50
 X2                           2                  33.7
 X3      10                                                                   33.7      33.7
 BT      -8        856       36.1                 917      34.8                972       33.9
 BT                993       33.8                1007      33.8               1027       33.7
 BT                1095      35.7                1150      37.2
 GR     36.1       856       32.7       917      30.9       972      25.1      986       25.1      993
 GR     25.1       1007      25.1      1013       31        1027      33.2     1095       37.2      1150

 NC      0.1       0.1       0.04
 X1       4         8        972       1027       50         50       50
 GR     36.1       856       32.7       917      30.9       972      25.1      986       25.1      1013
 GR      31        1027      33.2      1095      37.2      1150
```

Figure 4.6b
Multiple Culverts Example Output (continued)

```
20AUG90        14:52:29                                                                                          PAGE    3

SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

*PROF 1

CCHV=      .100 CEHV=      .300
*SECNO 1.000
   1.000      5.49      30.29        .00      30.00      30.31       .02        .00        .00      30.90
   250.0        .0      250.0         .0         .0      217.0        .0         .0         .0      31.00
     .00       .00       1.15        .00       .000       .040      .000       .000      24.80     973.39
 .000152        0.         0.         0.          0          0         4        .00      52.01    1025.40

CCHV=      .300 CEHV=      .500
1490 NH CARD USED
*SECNO 2.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   .41

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       32.30 ELREA=       32.30

   2.000      5.28      30.28        .00        .00      30.45       .18        .06        .08      25.00
   250.0        .0      250.0         .0         .0       73.9        .0         .7         .2      25.00
     .02       .00       3.38        .00       .000       .040      .000       .000      25.00     993.00
 .000904      200.       200.       200.          2          0         0        .00      14.00    1007.00

SPECIAL CULVERT

SC  CUNO      CUNV      ENTLC      COFQ      RDLEN      RISE      SPAN      CULVLN     CHRT      SCL       ELCHU      ELCHD
     2        .013       .50       3.00       .00       6.00       .00      50.00       1         1        25.10      25.00

CHART  1 - CONCRETE PIPE CULVERT; NO BEVELED RING ENTRANCE
SCALE  1 - SQUARE EDGE ENTRANCE WITH HEADWALL

1490 NH CARD USED
*SECNO 3.000

SPECIAL CULVERT OUTLET CONTROL
```

Figure 4.6c
Multiple Culverts Example Output (continued)

```
20AUG90        14:52:29                                                                                          PAGE    4

SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

EGIC       EGOC       H4         QWEIR      QCULV      VCH        ACULV      ELTRD      WEIRLN
29.67      30.66       .21         0.       250.      3.315       56.5      33.70         0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       33.70 ELREA=       33.70

   3.000      5.39      30.49        .00        .00      30.66       .17        .20        .00      25.10
   250.0        .0      250.0         .0         .0       75.4        .0         .8         .2      25.10
     .02       .00       3.32        .00       .000       .040      .000       .000      25.10     993.00
 .000843       50.        50.        50.          0          0         0        .00      14.00    1007.00

*SECNO 4.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  2.47

   4.000      5.60      30.70        .00        .00      30.72       .02        .01        .05      30.90
   250.0        .0      250.0         .0         .0      226.1        .0         .9         .2      31.00
     .03       .00       1.11        .00       .000       .040      .000       .000      25.10     972.49
 .000138       50.        50.        50.          2          0         0        .00      53.79    1026.28
```

Figure 4.6d
Multiple Culverts Example Output (continued)

```
20AUG90        14:52:29                                                                                          PAGE    5
T1      MULTIPLE PIPE CULVERTS EXAMPLE - SPECIAL CULVERT METHOD
T3      Dodson Cr., 2-7 ft PIPES      Profile 2

J1   ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
               3                             .00015                                  32.0
```

Figure 4.6e
Multiple Culverts Example Output (continued)

```
20AUG90        14:52:29                                                                                        PAGE    6

   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

*PROF 2

CCHV=     .100 CEHV=     .300
*SECNO 1.000
     1.000      6.94     31.74       .00     32.00     31.77       .03       .00       .00     30.90
     400.0       1.1     398.1        .6      10.9     295.8       8.6        .0        .0     31.00
       .00       .10      1.35       .09      .100      .040      .100      .000     24.80    946.21
   .000148        0.        0.        0.         0         0         4       .00    103.78   1049.99

CCHV=     .300 CEHV=     .500
1490 NH CARD USED
*SECNO 2.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   .37

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       32.30 ELREA=       32.30

     2.000      6.68     31.68       .00       .00     31.96       .28       .06       .13     25.00
     400.0        .0     400.0        .0        .0      93.5        .0        .9        .3     25.00
       .01       .00      4.28       .00      .000      .040      .000      .000     25.00    993.00
   .001054      200.      200.      200.         2         0         0       .00     14.00   1007.00

SPECIAL CULVERT

SC  CUNO      CUNV     ENTLC     COFQ      RDLEN     RISE      SPAN      CULVLN    CHRT      SCL       ELCHU     ELCHD
      2       .013      .50      3.00       .00      6.00       .00      50.00       1         1       25.10     25.00

CHART   1 - CONCRETE PIPE CULVERT; NO BEVELED RING ENTRANCE
SCALE   1 - SQUARE EDGE ENTRANCE WITH HEADWALL

1490 NH CARD USED
*SECNO 3.000

SPECIAL CULVERT OUTLET CONTROL

EGIC =     31.330  EGOC =     33.161  PCWSE=     31.678  ELTRD=     33.700
SPECIAL CULVERT
```

Figure 4.6f

Multiple Culverts Example Output (continued)

```
20AUG90        14:52:29                                                                                        PAGE    7

   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

   EGIC      EGOC      H4        QWEIR     QCULV     VCH       ACULV     ELTRD     WEIRLN
   31.33     33.16     1.28      0.        400.      3.637     56.5      33.70     0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       33.70 ELREA=       33.70

     3.000      7.86     32.96       .00       .00     33.16       .21      1.20       .00     25.10
     400.0        .0     400.0        .0        .0     110.0        .0       1.1        .3     25.10
       .02       .00      3.64       .00      .000      .040      .000      .000     25.10    993.00
   .000614       50.       50.       50.         0         0         0       .00     14.00   1007.00

*SECNO 4.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  3.04

     4.000      8.11     33.21       .00       .00     33.23       .02       .01       .06     30.90
     400.0      11.9     378.3       9.8      79.8     364.1      75.4       1.4        .4     31.00
       .03       .15      1.04       .13      .100      .040      .100      .000     25.10    907.86
   .000067       50.       50.       50.         2         0         0       .00    187.27   1095.13
```

Figure 4.6g

Multiple Culverts Example Output (continued)

```
20AUG90     14:52:29
                                                                                    PAGE   8
T1    MULTIPLE PIPE CULVERTS EXAMPLE - SPECIAL CULVERT METHOD
T3    Dodson Cr., 2-7 ft PIPES     Profile 3

J1   ICHECK    INQ      NINV     IDIR     STRT     METRIC    HVINS     Q      WSEL      FQ
                4                         .00015                               35.0

J2   NPROF    IPLOT    PRFVS    XSECV    XSECH     FN       ALLDC     IBW    CHNIM    ITRACE
      15                -1
```

Figure 4.6h
Multiple Culverts Example Output (continued)

```
20AUG90     14:52:29
                                                                                    PAGE   9
  SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG      HV      HL      OLOSS    L-BANK ELEV
  Q        QLOB     QCH      QROB     ALOB     ACH     AROB    VOL     TWA      R-BANK ELEV
  TIME     VLOB     VCH      VROB     XNL      XNCH    XNR     WTN     ELMIN    SSTA
  SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC     ICONT   CORAR   TOPWID   ENDST
*PROF 3

CCHV=      .100 CEHV=     .300
*SECNO 1.000
    1.000    7.64    32.44      .00    35.00   32.48     .03     .00      .00     30.90
    500.0     5.6    489.7      4.7     36.4   334.3    32.2      .0       .0     31.00
      .00     .15     1.46      .15     .100    .040    .100    .000    24.80    924.82
  .000149      0.       0.       0.        0       0       4     .00   146.81   1071.63
CCHV=      .300 CEHV=     .500
1490 NH CARD USED
*SECNO 2.000
    2.000    7.48    32.48      .00      .00   32.51     .03     .03      .00     25.00
    500.0   168.3    178.6    153.2    153.5   104.6   141.0     1.8       .7     25.00
      .04    1.10     1.71     1.09     .042    .040    .042    .000    25.00    923.91
  .000144    200.     200.     200.        0       0       0     .00   148.64   1072.55
SPECIAL CULVERT

SC  CUNO    CUNV    ENTLC    COFQ    RDLEN    RISE    SPAN    CULVLN    CHRT    SCL    ELCHU    ELCHD
      2     .013     .50     3.00     .00     6.00     .00     50.00      1      1     25.10    25.00
CHART   1 - CONCRETE PIPE CULVERT; NO BEVELED RING ENTRANCE
SCALE   1 - SQUARE EDGE ENTRANCE WITH HEADWALL

1490 NH CARD USED
*SECNO 3.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.60
SPECIAL CULVERT

     EGIC     EGOC      H4     QWEIR    QCULV     VCH    ACULV    ELTRD   WEIRLN
    32.35    34.48     1.65      43.     459.   1.209     56.5    33.70      87.

    3.000     9.05    34.15      .00      .00   34.16      .01     1.65      .00     25.10
    500.0    180.2    153.3    166.5    299.1   126.8    285.8      2.5       .9     25.10
      .06      .60     1.21      .58     .049    .040     .049     .000    25.10    890.90
  .000056      50.      50.      50.        1       0        0      .00   217.23   1108.13
```

Figure 4.6i
Multiple Culverts Example Output (continued)

```
20AUG90     14:52:29
                                                                                    PAGE   10
  SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG      HV      HL      OLOSS    L-BANK ELEV
  Q        QLOB     QCH      QROB     ALOB     ACH     AROB    VOL     TWA      R-BANK ELEV
  TIME     VLOB     VCH      VROB     XNL      XNCH    XNR     WTN     ELMIN    SSTA
  SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC     ICONT   CORAR   TOPWID   ENDST
*SECNO 4.000
    4.000    9.05    34.15      .00      .00   34.17     .02     .00      .00     30.90
    500.0    27.9    445.8     26.2    148.5   416.1   146.0     3.3      1.1     31.00
      .07     .19     1.07      .18     .100    .040    .100    .000    25.10    890.91
  .000059     50.      50.      50.        0       0       0     .00   217.22   1108.12
```

Figure 4.6j
Multiple Culverts Example Output (continued)

20AUG90 14:52:29 PAGE 11

THIS RUN EXECUTED 20AUG90 14:52:32

```
**************************************
HEC-2 WATER SURFACE PROFILES
Version 4.5.0; September 1990
**************************************
```

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

Dodson Cr., 2-7 ft PIPES

SUMMARY PRINTOUT

	SECNO	CUMDS	ELMIN	CWSEL	CRIWS	Q	VCH	TOPWID	KRATIO
	1.000	.00	24.80	30.29	.00	250.00	1.15	52.01	.00
	1.000	.00	24.80	31.74	.00	400.00	1.35	103.78	.00
	1.000	.00	24.80	32.44	.00	500.00	1.46	146.81	.00
*	2.000	200.00	25.00	30.28	.00	250.00	3.38	14.00	.41
*	2.000	200.00	25.00	31.68	.00	400.00	4.28	14.00	.37
	2.000	200.00	25.00	32.48	.00	500.00	1.71	148.64	1.02
	3.000	250.00	25.10	30.49	.00	250.00	3.32	14.00	1.04
	3.000	250.00	25.10	32.96	.00	400.00	3.64	14.00	1.31
*	3.000	250.00	25.10	34.15	.00	500.00	1.21	217.23	1.60
*	4.000	300.00	25.10	30.70	.00	250.00	1.11	53.79	2.47
*	4.000	300.00	25.10	33.21	.00	400.00	1.04	187.27	3.04
	4.000	300.00	25.10	34.15	.00	500.00	1.07	217.22	.97

Figure 4.6k
Multiple Culverts Example Output (continued)

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Dodson Cr., 2-7 ft PIPES

SUMMARY PRINTOUT TABLE 101

	SECNO	EGOC	EGIC	H4	ELTRD	QCULV	QWEIR	CLASS	DEPTH	CWSEL	VCH	EG
	3.000	30.66	29.67	.21	33.70	250.00	.00	7.00	5.39	30.49	3.32	30.66
	3.000	33.16	31.33	1.28	33.70	400.00	.00	7.00	7.86	32.96	3.64	33.16
*	3.000	34.48	32.35	1.65	33.70	458.93	43.14	17.00	9.05	34.15	1.21	34.16

Figure 4.6l
Multiple Culverts Example Output (continued)

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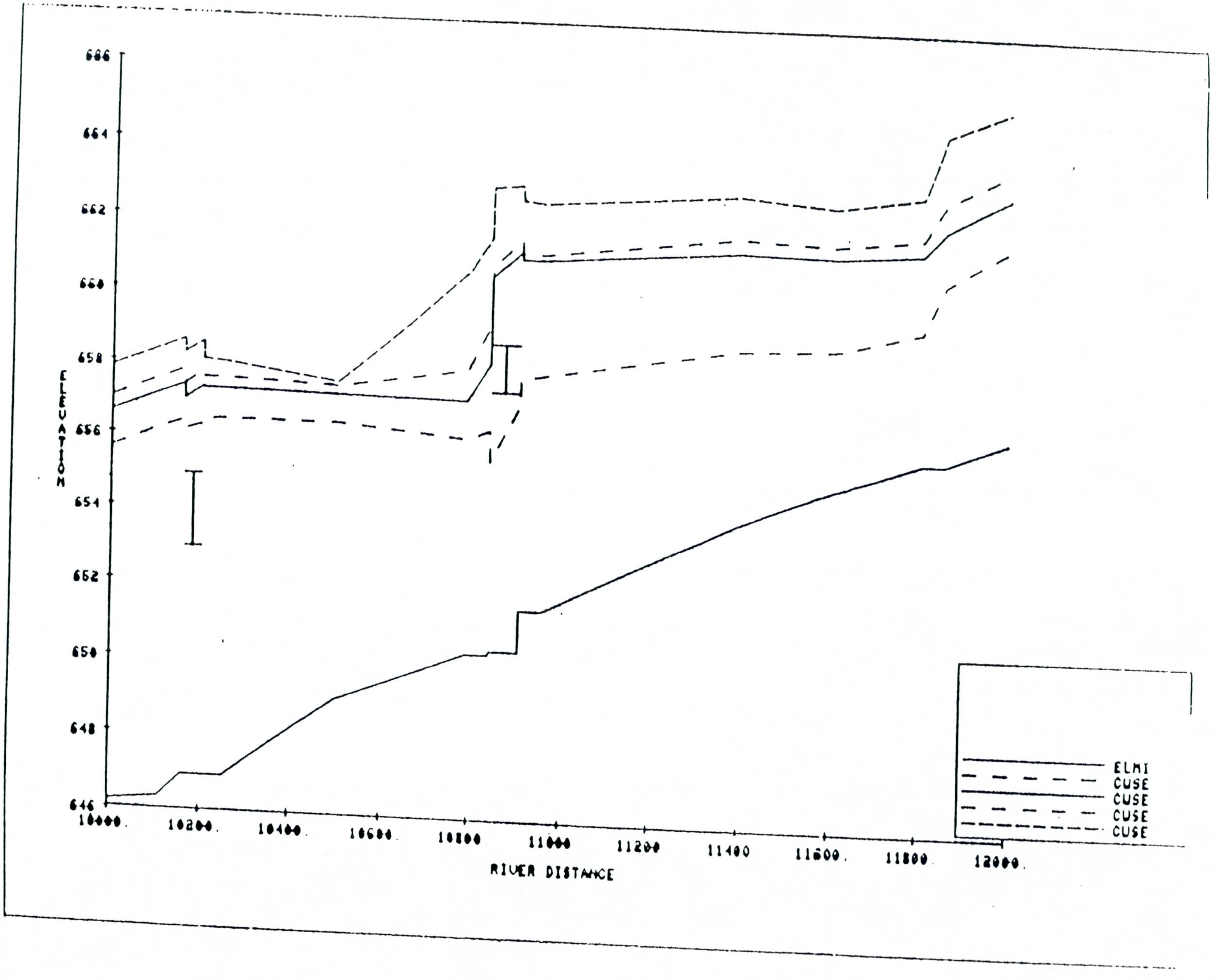
Dodson Cr., 2-7 ft PIPES

SUMMARY PRINTOUT TABLE 105

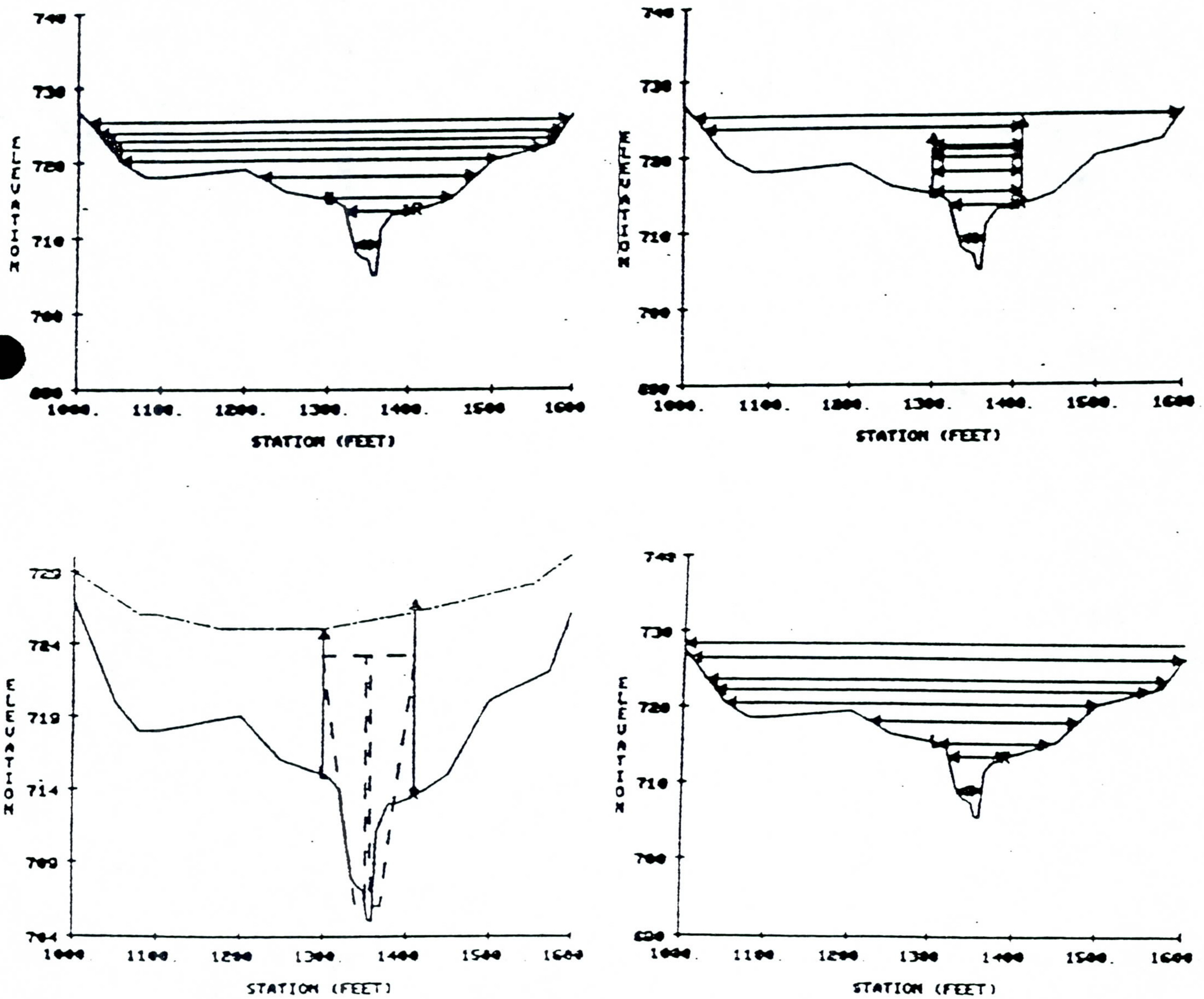
	SECNO	CWSEL	HL	OLOSS	TOPWID	QLOB	QCH	QROB
	1.000	30.29	.00	.00	52.01	.00	250.00	.00
	1.000	31.74	.00	.00	103.78	1.11	398.09	.80
	1.000	32.44	.00	.00	146.81	5.56	489.74	4.70
*	2.000	30.28	.06	.08	14.00	.00	250.00	.00
*	2.000	31.68	.06	.13	14.00	.00	400.00	.00
	2.000	32.48	.03	.00	148.64	168.27	178.56	153.18
	3.000	30.49	.20	.00	14.00	.00	250.00	.00
	3.000	32.96	1.20	.00	14.00	.00	400.00	.00
*	3.000	34.15	1.65	.00	217.23	180.25	153.27	166.48
*	4.000	30.70	.01	.05	53.79	.00	250.00	.00
*	4.000	33.21	.01	.06	187.27	11.92	378.29	9.79
	4.000	34.15	.00	.00	217.22	27.95	445.81	26.24

Figure 4.6m
Multiple Culverts Example Output (continued)


666
664
662
660
658
656
654
652
650
648
646
ELEVATION
10000.
10200.
10400.
10600.
10800.
11000
11200
11400
11600.
11800
12000.
RIVER DISTANCE
ELMI
CUSE
CUSE
CUSE
CUSE

```
CALL.H2PLOT(I-XSECPL.DEV-GCSTK4.GEOM-SB2.COMP-SB95)
 ***************************************
 *HEC-2 CROSS-SECTION PLOTTING PROGRAM *
 *VERSION AA, JANUARY 28. 1980         *
 ***************************************

 ENTER: VARIABLE/SEPARATOR/VALUE OR STRING
I>GO
```

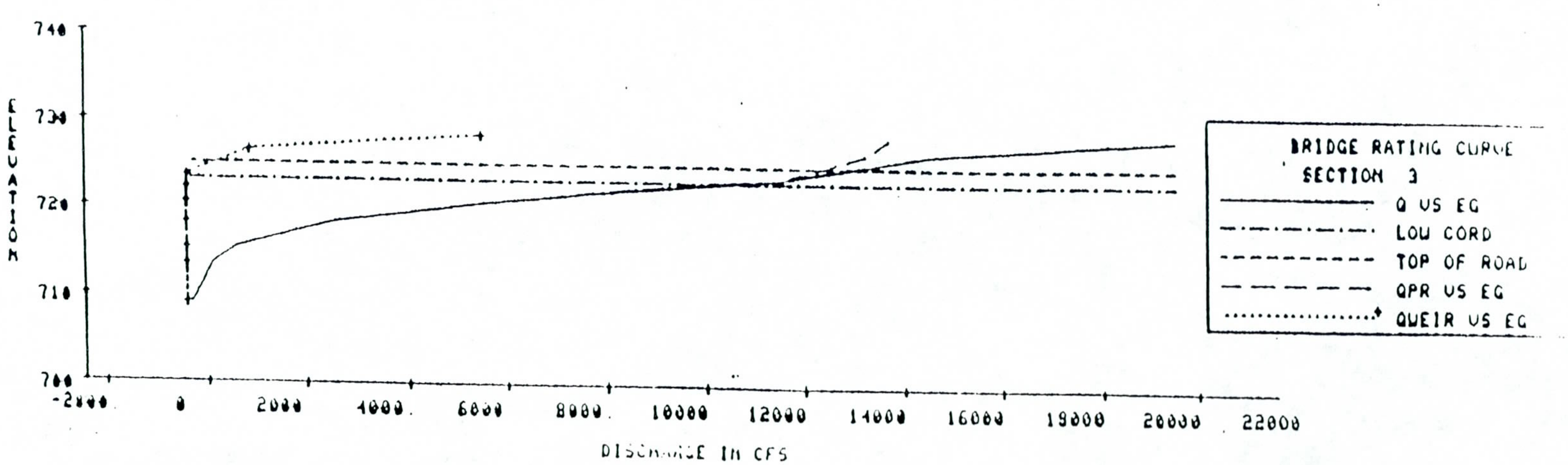


```
C>CALL,H2PLOT(I=XSECPL,DEV=GCSTK4 COMP=SB95,
 ****************************************
 *HEC-2 CROSS-SECTION PLOTTING PROGRAM  *
 *VERSION AA, JANUARY 28, 1980          *
 ****************************************

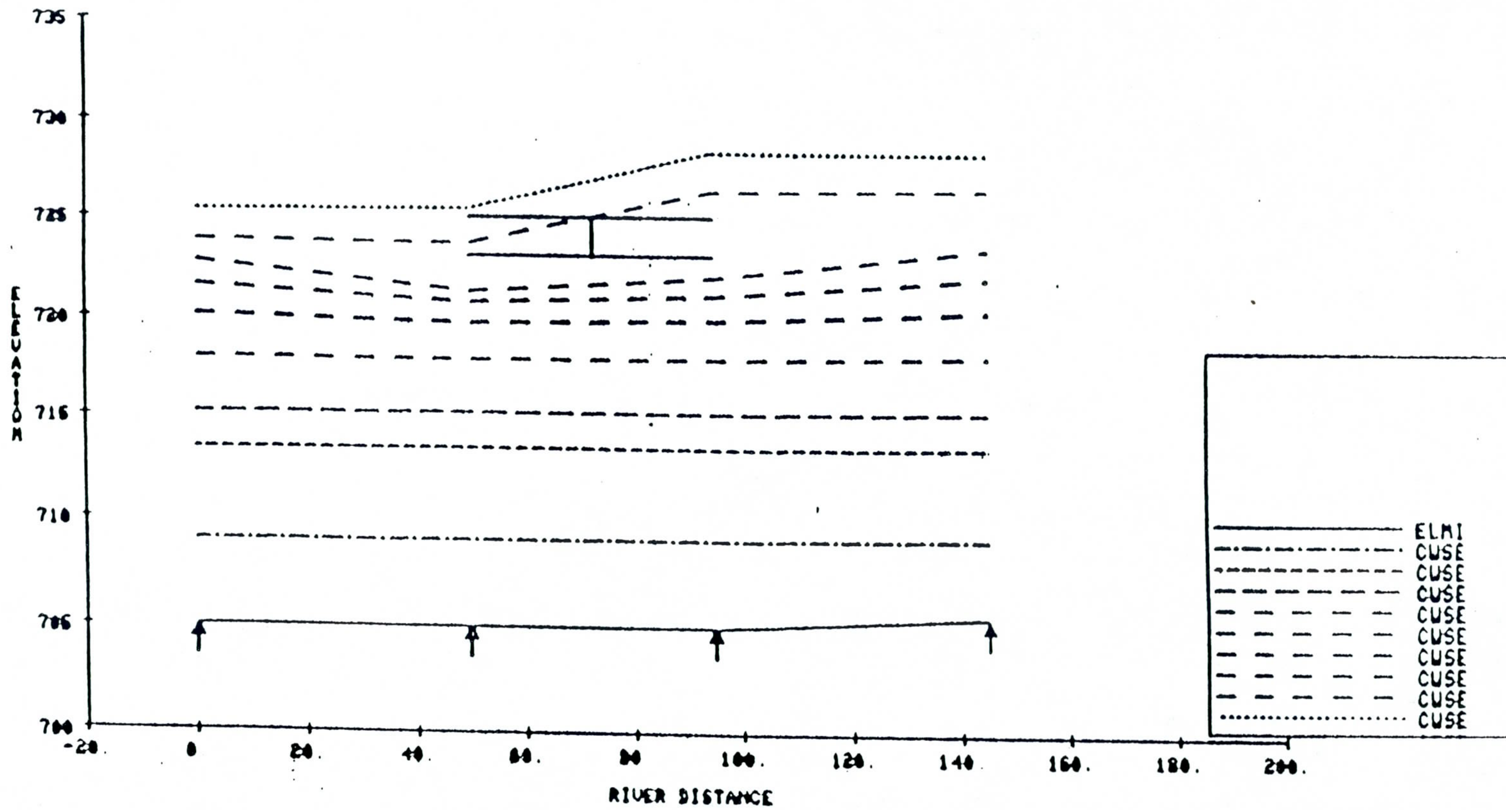
 ENTER  VARIABLE/SEPARATOR/VALUE OR STRING
I>XLBL,DISCHARGE IN CFS
 ENTER  VARIABLE/SEPARATOR/VALUE OR STRING
I>PLOT

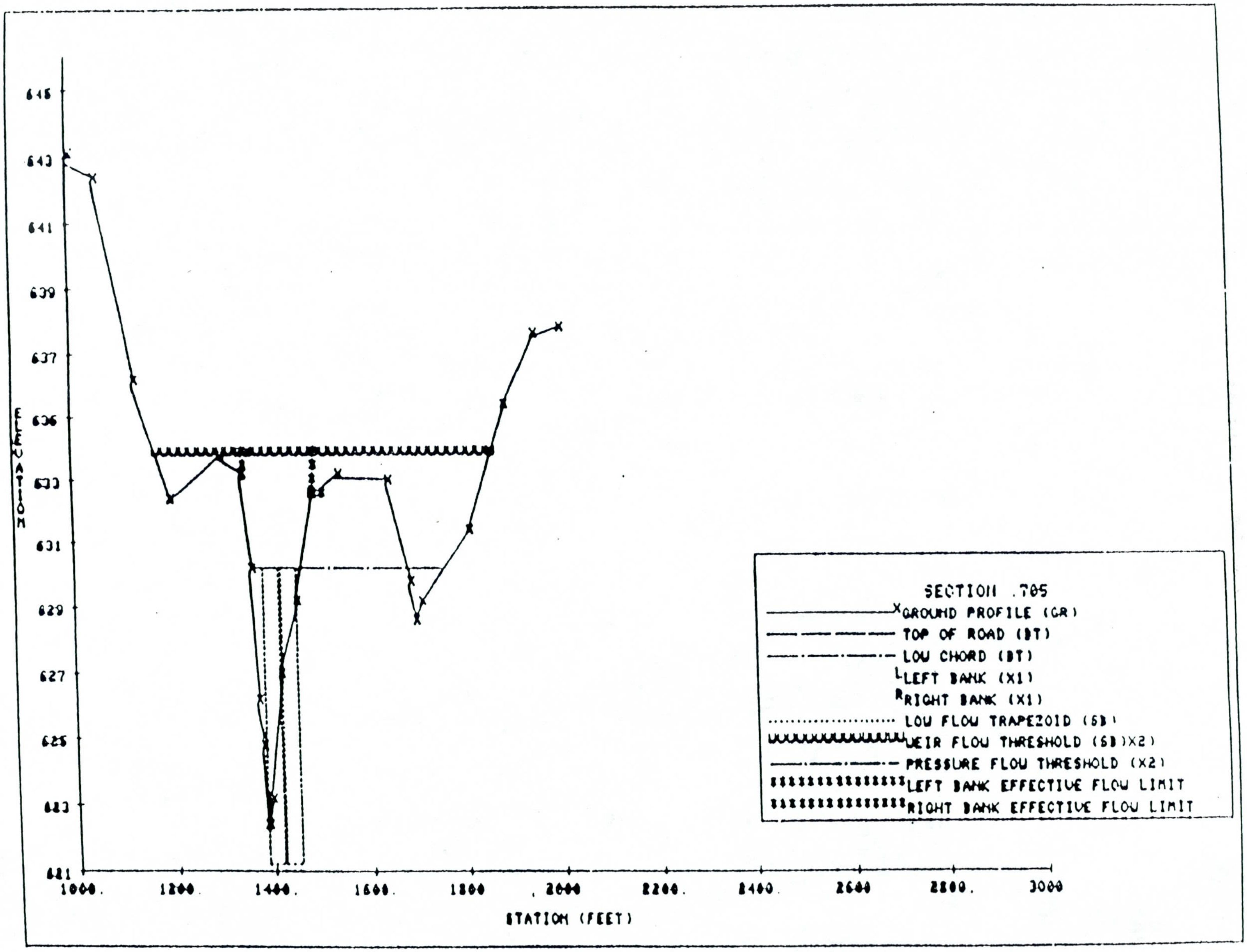
 EXISTING CURVE SPECS. TO ELIMINATE CURVE, ENTER 'NULL' FOR SYMBOL + LINE OPTS

 CURVE   1      PLOTS DATA FOR:     GROUND PROFILE (GR)
                 XVAR=   0 .      YVAR=   0 .      SYMBOL= DEFA        , LINE= DEFA          , CHARAC SIZE=      10
 **********ENTER- CURVE, XVAR, YVAR, SYMBOL, LINE, CHARACTER SIZE, VARDES**********
I>1,43,3,...Q US EG
 CURVE   2      PLOTS DATA FOR:     TOP OF ROAD (BT)
                 XVAR=   0 .      YVAR=   0 .      SYMBOL= DEFA        , LINE= DEFA            CHARAC SIZE=      10
 **********ENTER- CURVE, XVAR, YVAR, SYMBOL, LINE, CHARACTER SIZE, VARDES**********
I>2,43,41,...LOW CORD
 CURVE   3      PLOTS DATA FOR:     LOW CHORD (BT)
                 XVAR=   0 .      YVAR=   0 .      SYMBOL= DEFA        , LINE= DEFA            CHARAC SIZE=      10
 **********ENTER- CURVE, XVAR, YVAR, SYMBOL, LINE, CHARACTER SIZE, VARDES**********
I>3,43,40,...TOP OF ROAD
 CURVE   4      PLOTS DATA FOR:     CHANNEL IMPROVEMENT (CI)
                 XVAR=   0 .      YVAR=   0 .      SYMBOL= DEFA        , LINE= DEFA          , CHARAC SIZE=      10
 **********ENTER- CURVE, XVAR, YVAR, SYMBOL, LINE, CHARACTER SIZE, VARDES**********
I>4,47,3,...QPR US EG
 CURVE   5      PLOTS DATA FOR:     LEFT BANK (X1)
                 XVAR=   0 .      YVAR=   0 .      SYMBOL= DEFA        , LINE= DEFA          , CHARAC SIZE=      14
 **********ENTER- CURVE, XVAR, YVAR, SYMBOL, LINE, CHARACTER SIZE, VARDES**********
I>5,46,3,C+,D9,,QWEIR US EG
 CURVE   6      PLOTS DATA FOR:     RIGHT BANK (X1)
                 XVAR=   0 .      YVAR=   0 .      SYMBOL= DEFA        , LINE= DEFA          , CHARAC SIZE=      14
 **********ENTER- CURVE, XVAR, YVAR, SYMBOL, LINE, CHARACTER SIZE, VARDES**********
I>ALL
 ENTER  VARIABLE/SEPARATOR/VALUE OR STRING
I>GO
```



```
C)CALL,H2PLOT(I=PROFPL,DEV=GCSTK4,COMP=SB95)
 ****************************************
 *HEC-2 PROFILE PLOTTING PROGRAM        *
 *VERSION AA, JANUARY 28, 1980          *
 ****************************************
 ENTER: VARIABLE/SEPARATOR/VALUE OR STRING
I)SECNO,1,BRIDGE,1
 ENTER: VARIABLE/SEPARATOR/VALUE OR STRING
I)GO
```




SECTION .705
GROUND PROFILE (GR)
TOP OF ROAD (BT)
LOW CHORD (BT)
LEFT BANK (X1)
RIGHT BANK (X1)
LOW FLOW TRAPEZOID (SB)
WEIR FLOW THRESHOLD (SB)X2)
PRESSURE FLOW THRESHOLD (X2)
LEFT BANK EFFECTIVE FLOW LIMIT
RIGHT BANK EFFECTIVE FLOW LIMIT
ELEVATION
STATION (FEET)
645
643
641
639
637
635
633
631
629
627
625
623
621
1000.
1200.
1400.
1600.
1800.
2000
2200.
2400.
2600
2800.
3000

4

HEC-2 REVIEWER'S GUIDELINES AND CHECKLISTS

TABLE OF CONTENTS

PART I

HEC-2 REVIEWERS CHECKLIST

HEC 2 REVIEWER'S CHECKLIST

INPUT CHECKLIST

1. **TOPOGRAPHY AND CROSS-SECTION GEOMETRY**

   A. Review individual cross-section plots (see Figure 1Ai). Is the topography of the channel and floodplain accurately reflected in the geometry of the cross-sections (see Figure 1Aii)?

   B. Are the cross-sections properly oriented (i.e., perpendicular) with the direction of flow suggested by the topography (see Figure 1B)?

2. **PROFILE PLOTS**
   Review the following for abrupt changes, adverse grade or other anomalies (see Figure 2):

   A. Channel bed profile

   B. Top of bank profiles

3. **DISCHARGE**

   A. What discharge was used and how was it derived (see Figure 3A)?

   B. Is there existing discharge data which may be more appropriate or required for regulatory purposes (see Figure 3B/4B)?

   C. Are there any tributaries at which a change in discharge might be expected (see Figure 3C)?

   D. Are there multiple discharges (ie., multiple profile run)? What return interval (event) do the discharge(s) represent (see Figure 3D)?

4. **STARTING WATER SURFACE**

   A. What method was used to establish the starting water surface elevation; known, slope area, critical or other? Is this method appropriate based on available information on flow regime and topography (see Figure 4A)?

   B. Is there a known starting water surface from a downstream (for subcritical) or upstream (for supercritical) location which should be used (see Figure 3B/4B)?

5. MAPPING

Review the mapped floodlimits (if prepared) shown on the topographic mapping used to develop the model.

A. Compare the topwidths from the output to the actual topwidths shown on the mapping.

B. Compare the water surface elevations from the output to the elevations at the intersection of the floodlimits and cross-section locations as shown on the mapping.

C. Perform a random check of intermediate flood elevations based on interpolation between cross-sections and corresponding intersecting ground elevations. Do the floodlimits extend to the ground elevations expected based on the interpolated water surface elevations?

D. Check the mapping to ensure that embayments such as slackwater areas have been properly indicated where inundated.

E. Other anomolies: Check the mapping for any extreme or otherwise unusual variations in floodplain delineations which seem inconsistent with either the topography as shown on aerial/topographic mapping or with the HEC-2 model results.

HEC 2 REVIEWER'S CHECKLIST

OUTPUT CHECKLIST (refer to sample HEC-2 input/output for items 1 through 3)

1. **KEY HYDRAULIC PARAMETERS**
   Check the following parameters for consistency and reasonableness:

   A. flow depth,
   B. velocity,
   C. velocity head,
   D. area,
   E. topwidth
   F. channel slope
   G. energy slope

   These parameters should be constant or vary gradually from cross-section to cross-section. Note any unusual variations and any extreme values which do not seem realistic or are inconsistent with known conditions regarding the stream reach.

2. **FLOW DISTRIBUTION**

   A. Check the flow distribution from cross-section to cross-section. Does the distribution in any one area (i.e., left overbank, channel, right overbank) vary dramatically from one cross-section to the next?

   B. Does the distribution of flow between channel and overbanks seem reasonable (e.g., if majority of flow is in one overbank is this what you would expect based on the input review)?

3. **ERROR AND WARNING MESSAGES**
   Review both detailed and summary output for messages. Some common messages to look for include:

   A. Are there consistent warning messages indicating profile defaulting to critical depth? If so modeling of the alternative flow regime (i.e., subcritical vs. supercritical) may be warranted.

   B. Are there any extended cross-section messages (these messages indicate the computed vertical floodplain limits exceed the limits of the cross-section)? If so are the implications of this significant and can the cross-sections be extended or otherwise modified to account for the additional flow area?

C. Are there any divided flow messages? If so these areas may warrant separate modeling efforts (see 4 below).

D. Are there any messages indicating change in velocity head exceeding allowable limit? If so, are they significant?

E. Are there any other messages (see OUTPUT section of notebook for listing of all messages and most common).

4. **SPECIAL CONDITIONS**

Based on the foregoing review determine whether the model input or output suggests any of the following special flow conditions (see also Figures 7A through 7E from Input Checklist section):

A. Bridges and/or culverts? Has the proper method been used (i.e., normal, special or culvert)? Refer to HEC Training Document #18 for method application guidelines.

B. Levees? Is flow confined within levees allowing overbank flow only above the levee crest stage? If so have ineffective flow areas been modeled (e.g., using X3 encroachments)?

C. Distributary or alluvial fan conditions? Does the output indicate consistent occurance of flows diverging from a common path without rejoining downstream or do flow characteristics indicate a gradually expanding pattern of flow with little or no boundary definition? If so a distributary type flow pattern may predominate making modeling by HEC-2 impractical or impossible.

D. Split and/or divided flow? Flow overtopping a divide as side weir flow? Have these areas been accounted for using split flow modeling or other approximation to account for lost flow? Refer to HEC Training Document #?? for method application guidelines.

E. Islands? Do the model results indicate isolated flood free areas within the floodplain? If so check the modeling in these areas again to insure that these areas are truly above the surrounding floodwater elevations. The occurence of islands may indicate a flow pattern similar to split or divided flow where the two (or more) separate flow paths around the island must be modeled separately to accruately determine flow profiles.

5. **ROUGHNESS COEFFICEINTS AND OTHER LOSSES**

A. What Manning's roughness coefficeints were used for the channel and overbank areas? Review available aerial and/or ground photography. Are the coefficients realistic and representative (see Figure 5A)?

B. Is there a need to model more than three distinct areas within each cross-section (i.e., left overbank, channel and right overbank)? Does aerial photography or field review indicate braided channel areas or other areas where the roughness appears to vary within the overbank or channel (see Figure 5B)?

C. What expansion and contraction losses are specified? Are these reasonable? (see Figure 5C)

6. **INEFFECTIVE FLOW AREAS**

A. Are areas such as expansion or contraction "shadow" areas (e.g., areas outside the main flow conveyance zone approaching or exiting a bridge) modeled as ineffective (see Figure 6A)?

B. Are there depressions such as overbank excavations, reflected as ineffective flow areas (see Figure 6B)?

7. **SPECIAL CONDITIONS**

Based on review of the input data note the existence or any indication of the possible existence of the following conditions for further investigation when reviewing the output:

A. Bridges and/or culverts (see Figure 7A)?

B. Levees (see Figure 7B)?

C. Distributary or alluvial fan conditions (see Figure 7C) ?

D. Split and/or divided flow (see Figure 7D)?

E. Islands (see Figure 7E) ?

PART II

HEC-2 REVIEWERS CHECKLIST FORM

HEC2 REVIEWER'S CHECKLIST: MODEL INPUT (page 1 of 2)				
ITEM		**HEADING**	**CHKD**	**COMMENTS**
I		TOPOGRAPHY		
	A	Section Geometry		
	B	Section Orientation		
II		PROFILE PLOTS		
	A	Channel Bed		
	B	Top of Bank		
III		DISCHARGE		
	A	Value/Method		
	B	Known Value		
	C	Multiple Runs		
	D	Tributaries		

HEC2 REVIEWER'S CHECKLIST: MODEL INPUT (page 2 of 2)				
ITEM		**HEADING**	**CHKD**	**COMMENTS**
IV		STARTING WSEL		
	A	Value/Method		
	B	Known Value		
V		ROUGHNESS COEFF.		
	A	Values		
	B	Multiple Values		
	C	Exp/Cont Losses		
VI		INEFF. FLOW AREAS		
	A	Shadow Zones		
	B	Depressions		
VII		SPECIAL CONDITIONS		
	A	Bridges		
	B	Levees		
	C	Dist./Braided		
	D	Split/Divided		
	E	Islands		

HEC2 REVIEWER'S CHECKLIST: MODEL OUTPUT (page 1 of 2)				
ITEM		**HEADING**	**CHKD**	**COMMENT**
I		HYD. PARAMETERS		
	A	Flow Depth		
	B	Velocity		
	C	Vel. Head		
	D	Area		
	E	Topwidth		
	F	Channel Slope		
	G	Energy Slope		
II		FLOW DISTRIBUTION		
	A	Section to Section		
	B	Channel v. Overbank		

HEC2 REVIEWER'S CHECKLIST: MODEL OUTPUT (page 2 of 2)				
ITEM		**HEADING**	**CHKD**	**COMMENT**
III		ERR/WARNING MESS.		
	A	Critical Depth		
	B	Extended X-Section		
	C	Divided Flow		
	D	Chng in Vel. Head		
	E	Other		
IV		SPECIAL CONDITIONS		
	A	Bridges		
	B	Levees		
	C	Dist./Braided		
	D	Split/Divided		
	E	Islands		
V		MAPPING		
	A	Topwidths		
	B	WSEL v. Contours		
	C	Intermediate WSELs		
	D	Embayments		
	E	Other anomolies		

PART III

FIGURES 1Ai THROUGH 7E

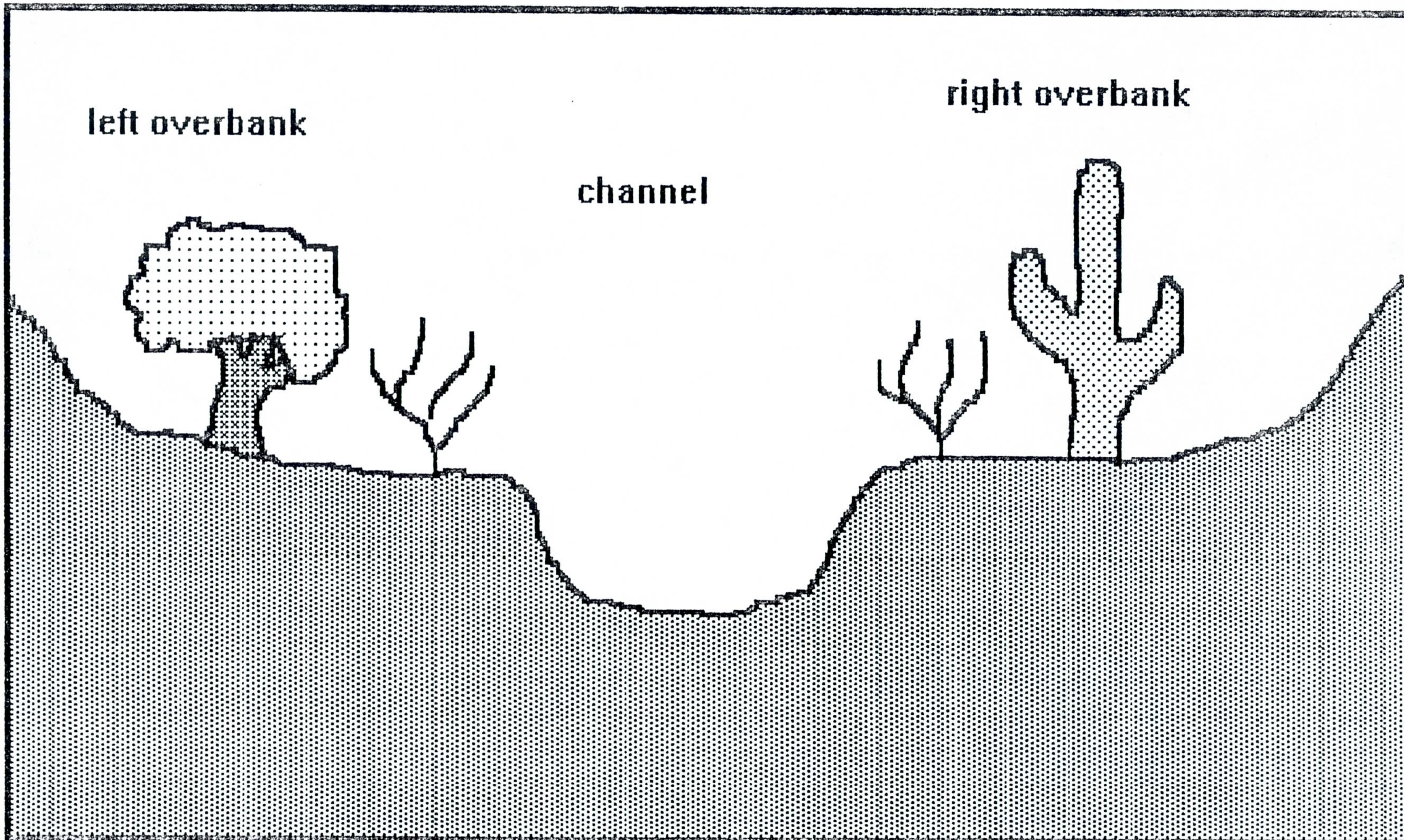


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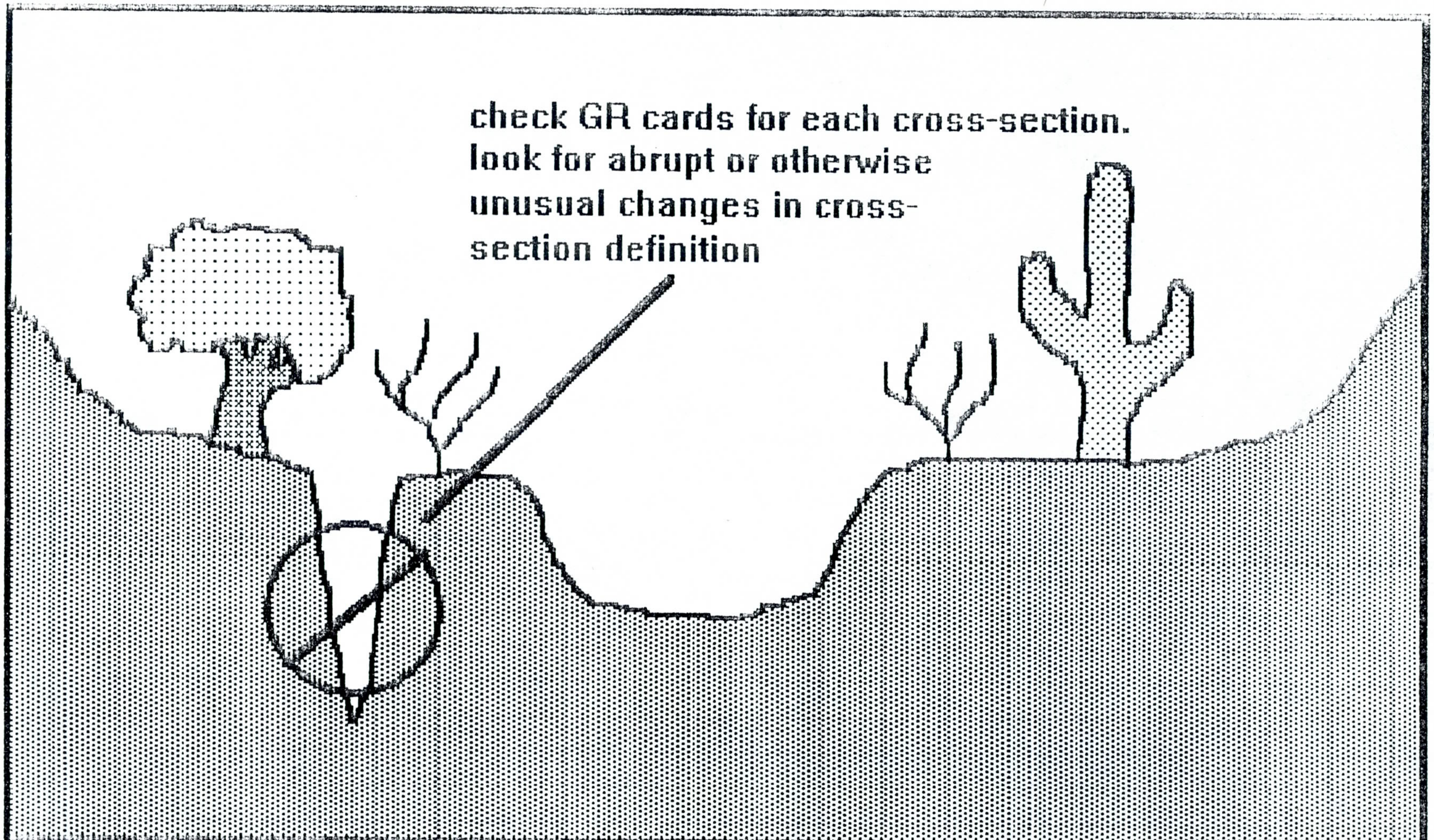
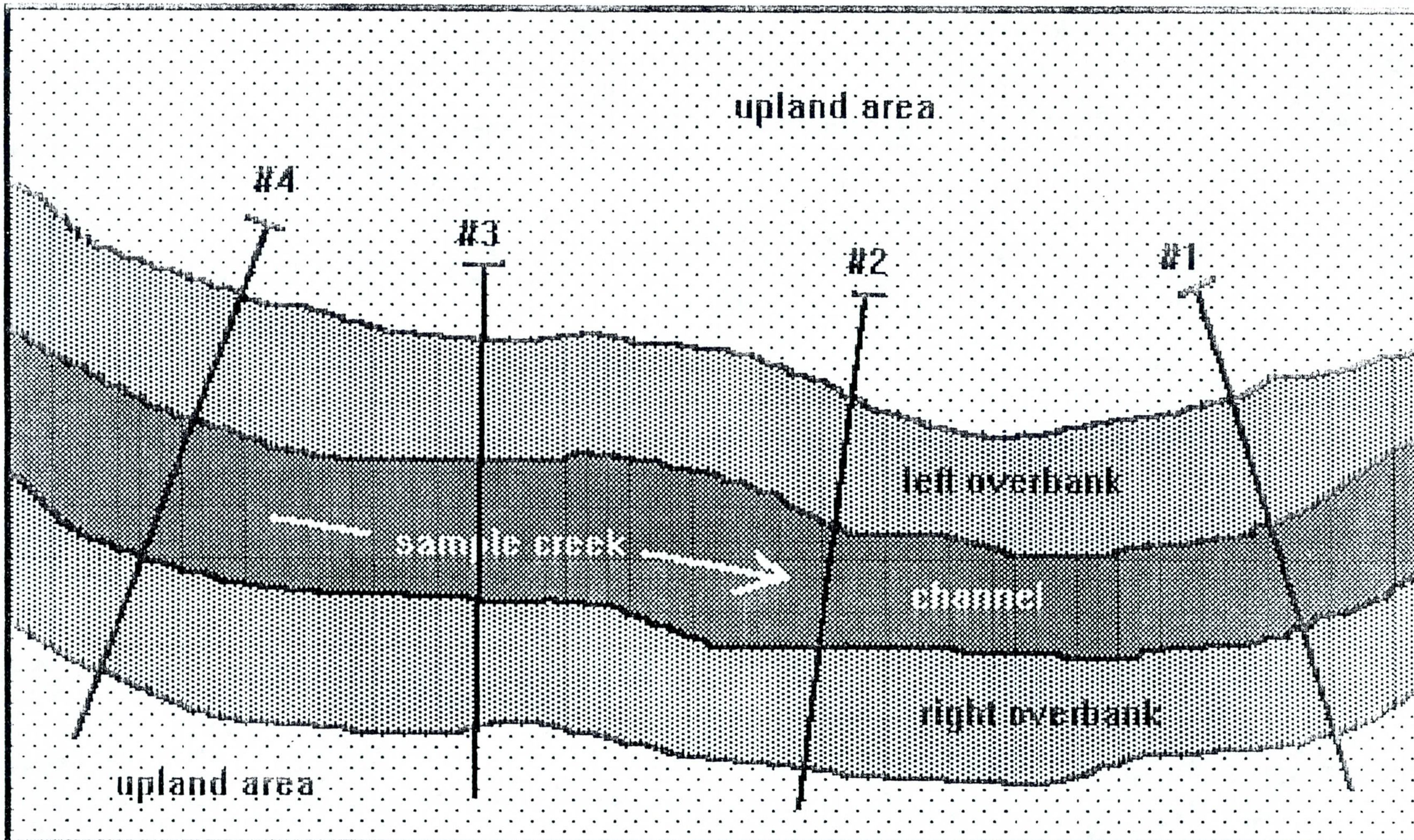
FIGURE 1Ai TYPICAL SECTION SHOWING CHANNEL AND OVERBANKS



ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION	FIGURE 1Aii TYPICAL SECTION SHOWING POSSIBLE CROSS-SECTION ERROR



ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION	FIGURE 1B TYPICAL PLAN VIEW SHOWING CROSS-SECTION ALIGNMENTS

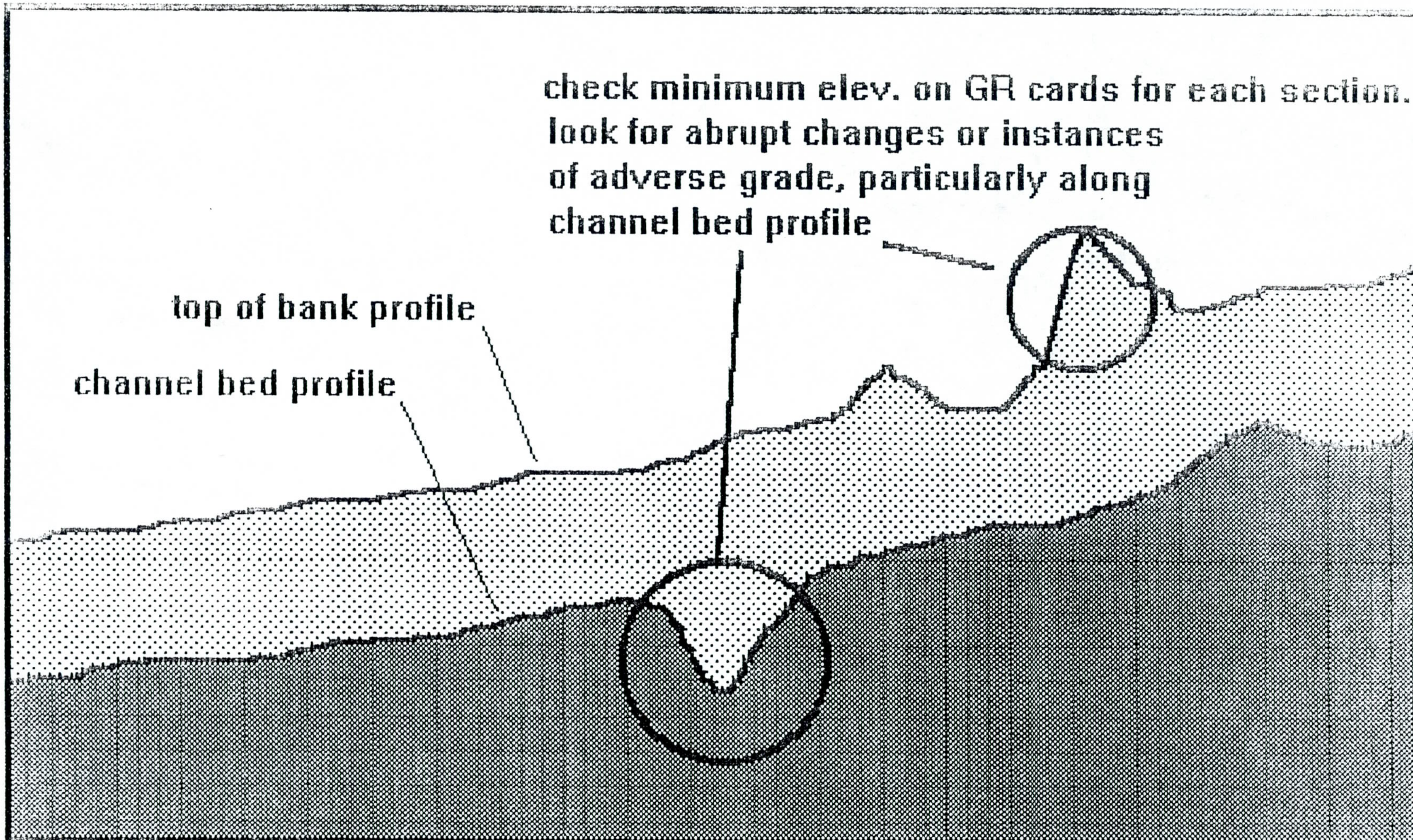


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FIGURE 2 BED AND BANK PROFILES SHOWING UNUSUAL FEATURES/VARIATIONS

```
T1      Sample HEC-2 Model for HEC-2 Workshop
T2      Arizona Floodplain Management Association
T3      February 20 and 21, Ramada Inn, Tucson, Arizona
J1     0     2     0     0   .01     0     0     0    90     0
J2     1     0    -1     0     0     0    -1     0     0    15
J3    38     8    26    10    25     4    33     5    43    13
J3    14    15
NC.045  .050  .024    .1    .3
QT     1  1000
X1     1     8   100   130     0     0     0     0     0     0
GR100        0    90    20    89   100    85   104    85   124
GR 90      130    93   160   100   220
```

check QT (field 3) or J1 (field 8) for discharge value

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FIGURE 3A SAMPLE HEC-2 INPUT SHOWING LOCATION OF DISCHARGE VALUE

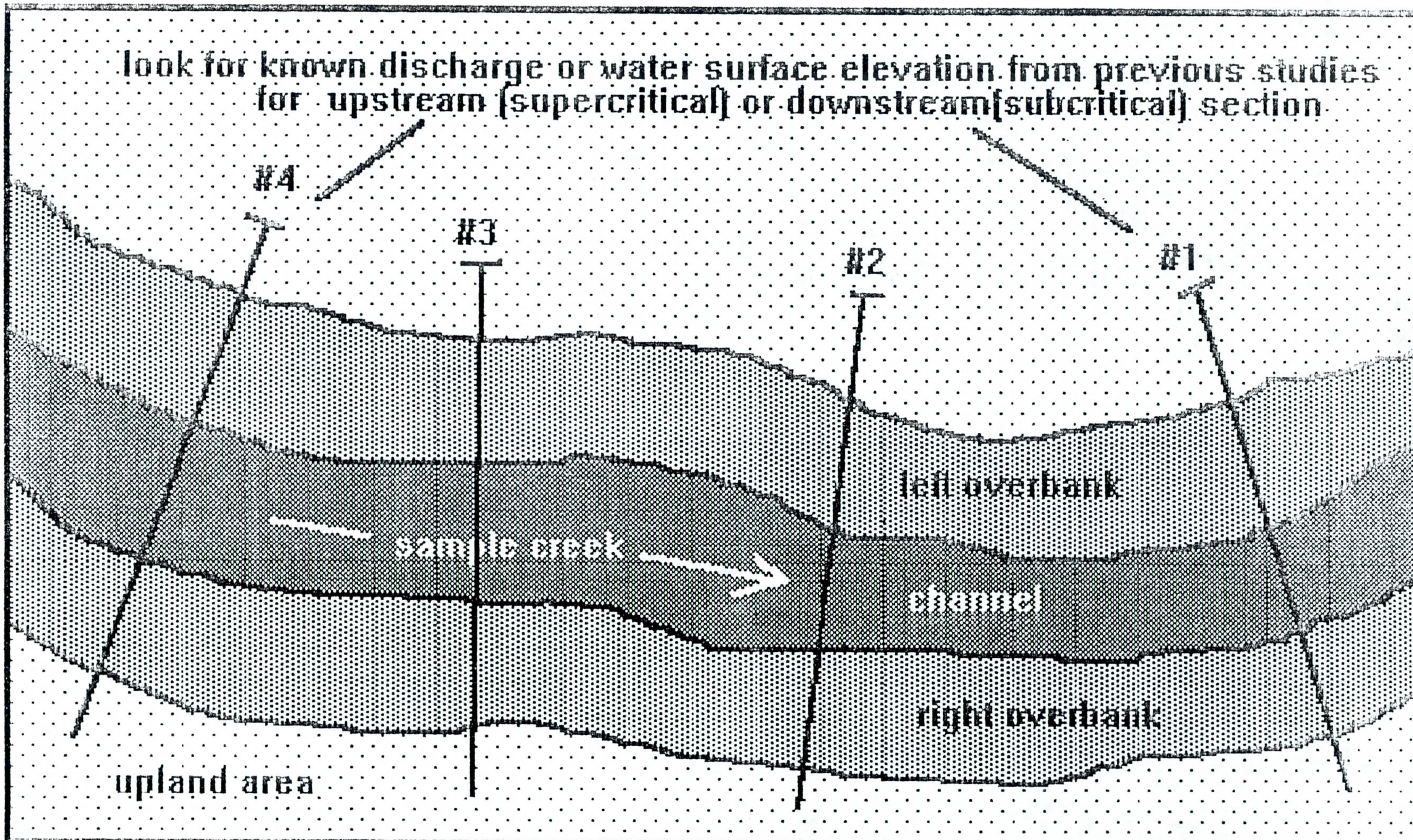

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FIGURE 3B/4B REVIEW PREVIOUS STUDIES
FOR DISCHARGE/WSEL INFORMATION

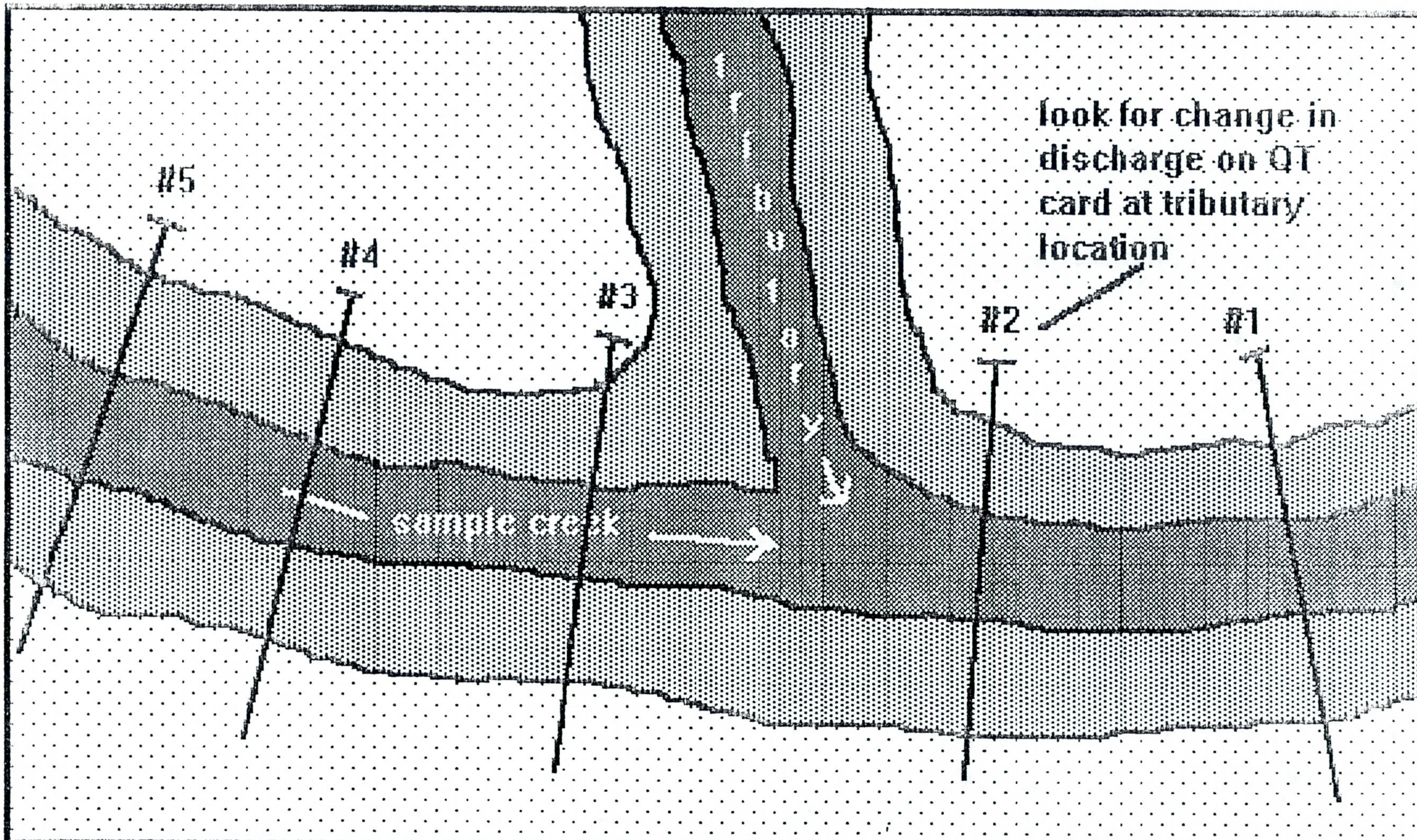

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FIGURE 3C TYPICAL PLAN VIEW SHOWING TRIBUTARY TO MAIN STREAM

```
T1      Sample HEC-2 Model for HEC-2 Workshop
T2      Arizona Floodplain Management Association
T3      February 20 and 21, Ramada Inn, Tucson, Arizona
J1      0     2     0     0   .01     0     0     0    90     0
J2      1     0    -1     0     0     0    -1     0     0    15
J3     38     8    26    10    25     4    33     5    43    13
J3     14    15
NC.045  .050  .024    .1    .3
QT      4  1000  2000  3000  4000
X1      1     8   100   130     0     0     0     0     0     0
GR100         0    90    20    89   100    85   104    85   124
GR  90      130    93   160
```

check QT card for multiple discharge values or check end of HEC-2 deck for additional J1/J2 card sets which indicate a multiple profile run. J2 card provides additional information on multiple profile run job control.

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FIGURE 3D SAMPLE HEC-2 INPUT SHOWING MULTIPLE PROFILE INFORMATION

T1	Sample HEC-2 Model for HEC-2 Workshop									
T2	Arizona Floodplain Management Association									
T3	February 20 and 21, Ramada Inn, Tucson, Arizona									
J1	0	2	0	0	.01	0	0	0	90	0
J2	1	0	-1	0	0	0	-1	0	0	15
J3	38	8	26	10	25	4	33	5	43	13
J3	14	15								
NC	.045	.050	.024	.1	.3					
QT	1	1000								
X1	1	8	100	130	0	0	0	0	0	0
GR	100	0	90	20	89	100	85	104	85	124
GR	90	130	93	160						

check J2 card (fields 5 and 9) for starting water surface information

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FIGURE 4A SAMPLE HEC-2 INPUT SHOWING STARTING WSEL INFORMATION

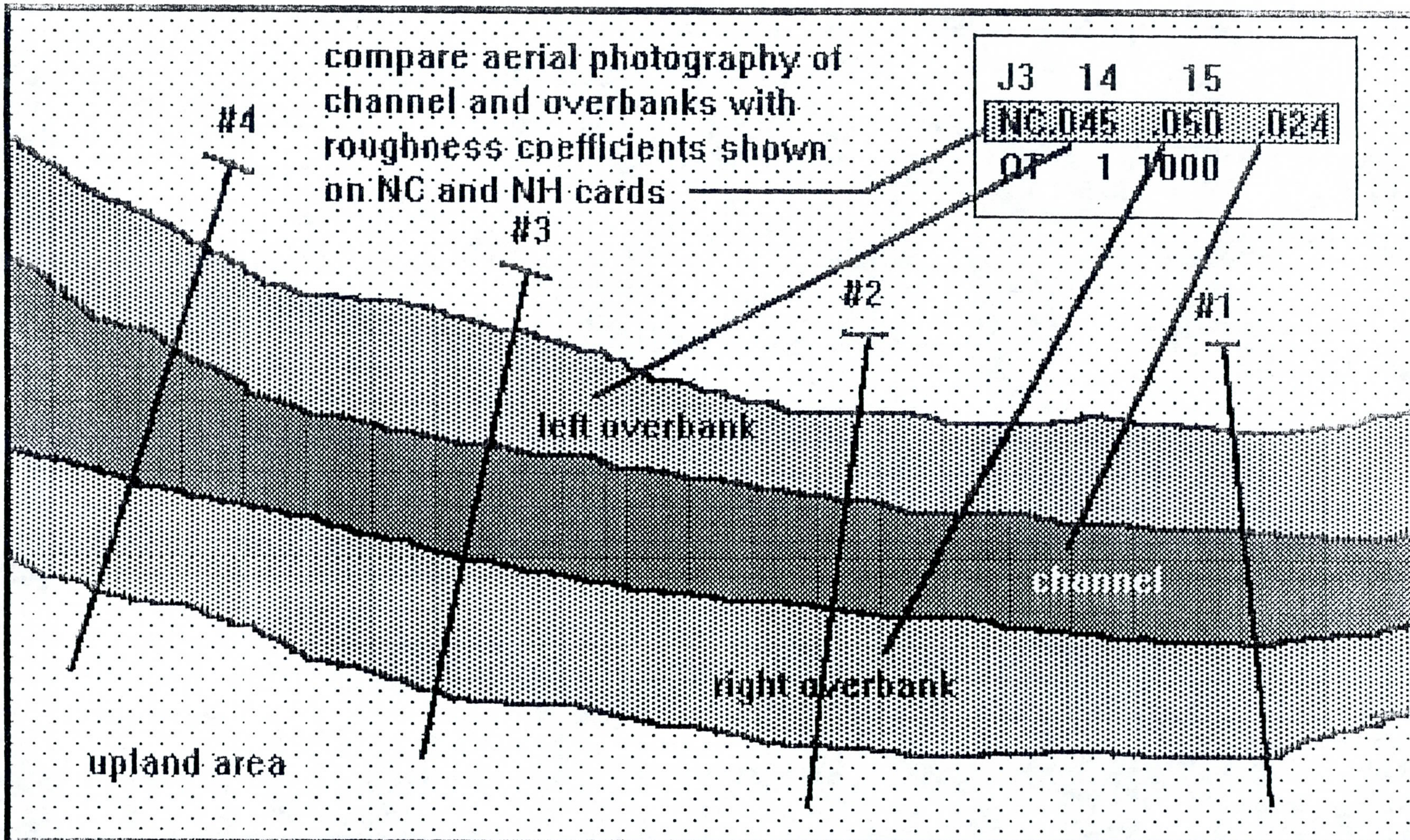

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FIGURE 5A TYPICAL PLAN VIEW SHOWING FLOODPLAIN ROUGHNESS ELEMENTS

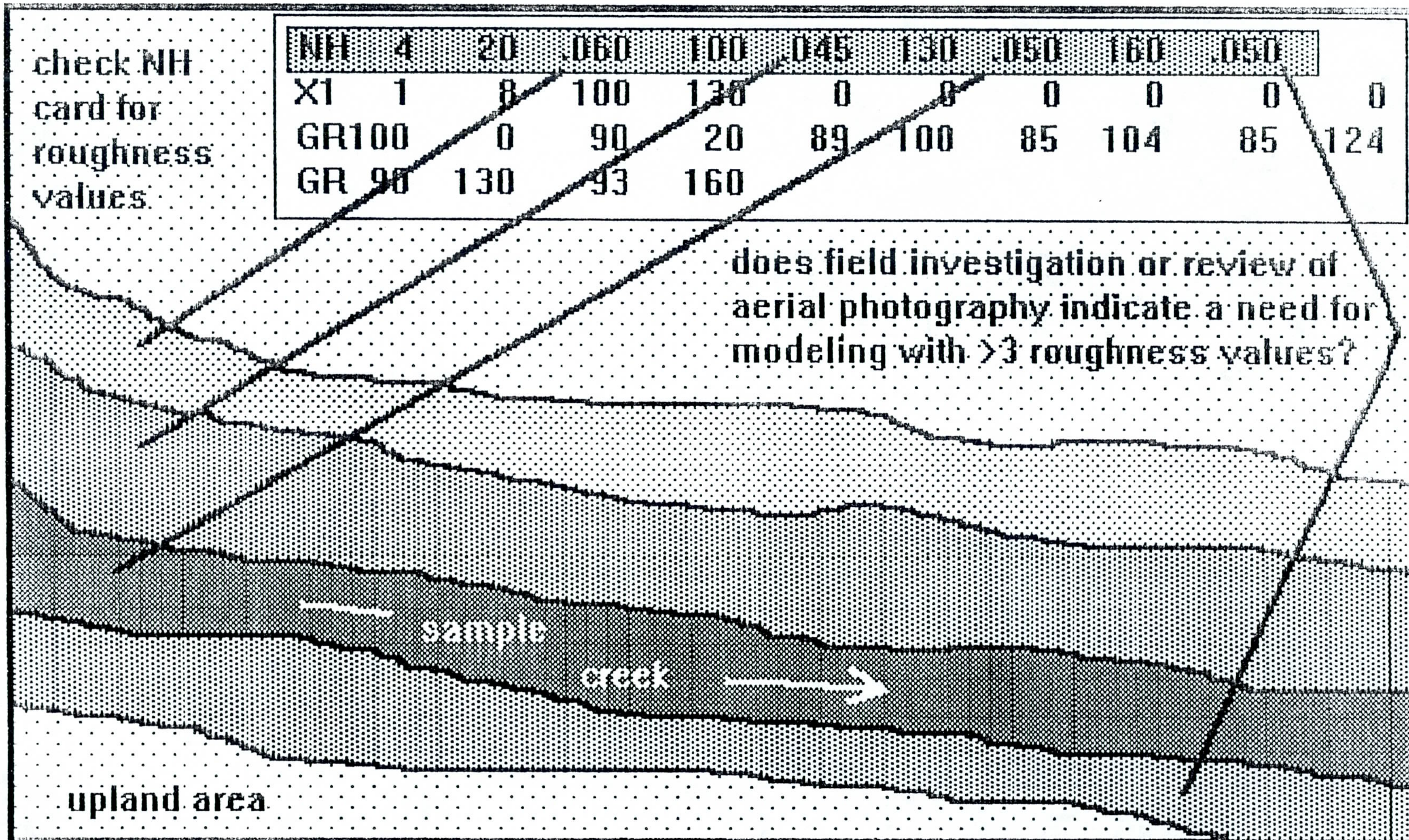

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FIGURE 5B TYPICAL PLAN VIEW SHOWING MORE THAN THREE ROUGHNESS ZONES

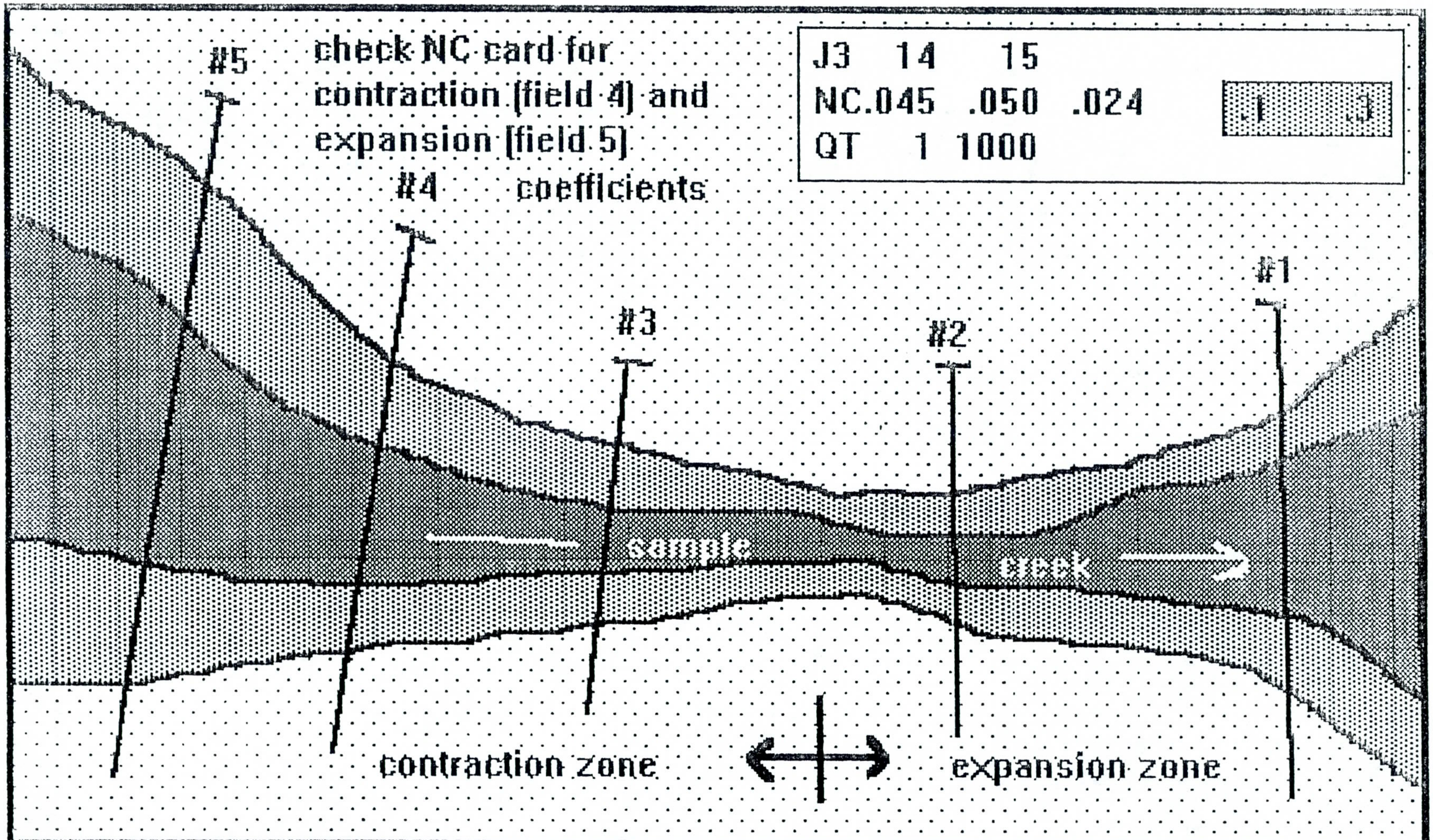

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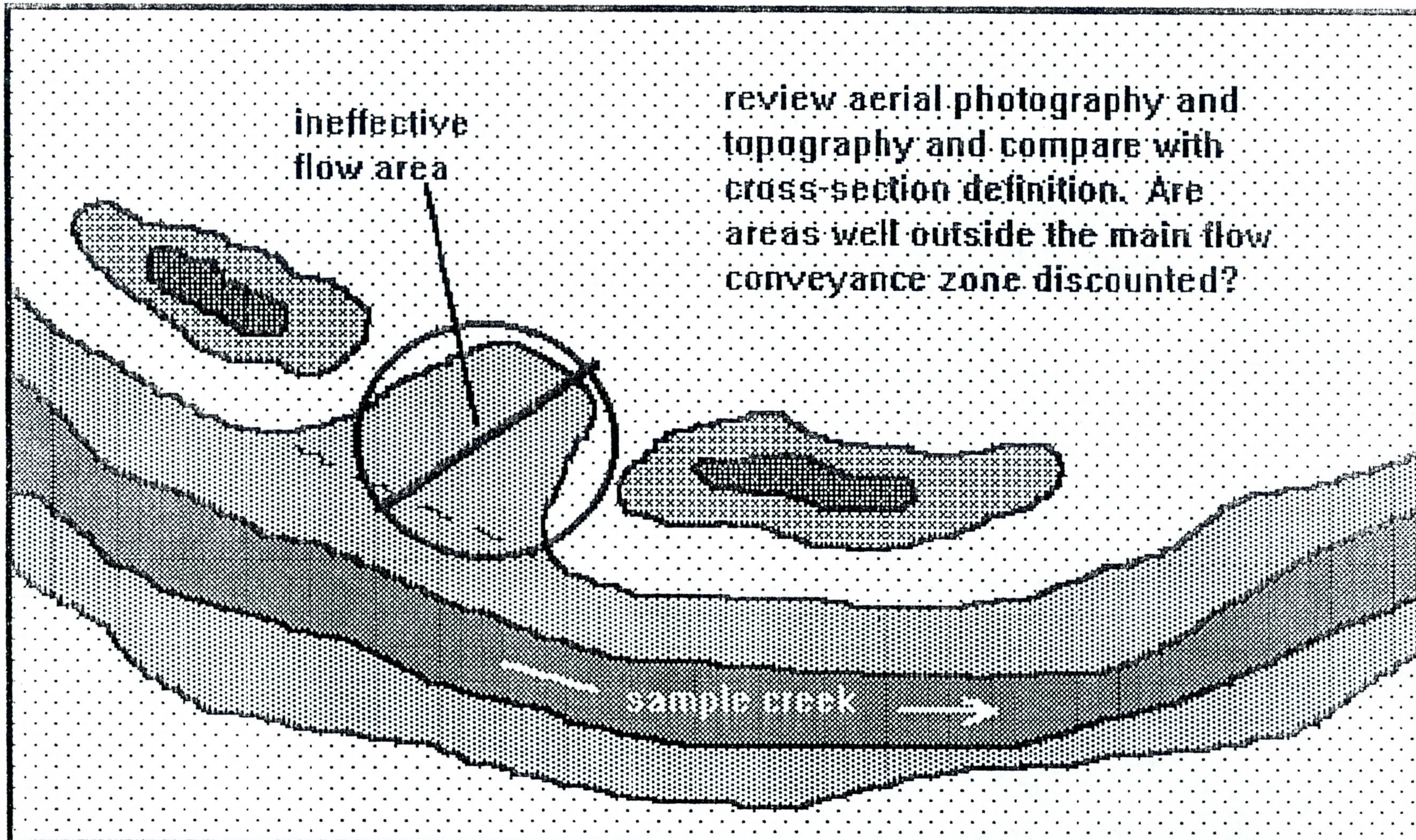
FIGURE 5C PLAN VIEW SHOWING CONTRACTION AND EXPANSION ZONES



ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION	FIGURE 6A	PLAN VIEW SHOWING EXAMPLE INEFFECTIVE FLOW AREA

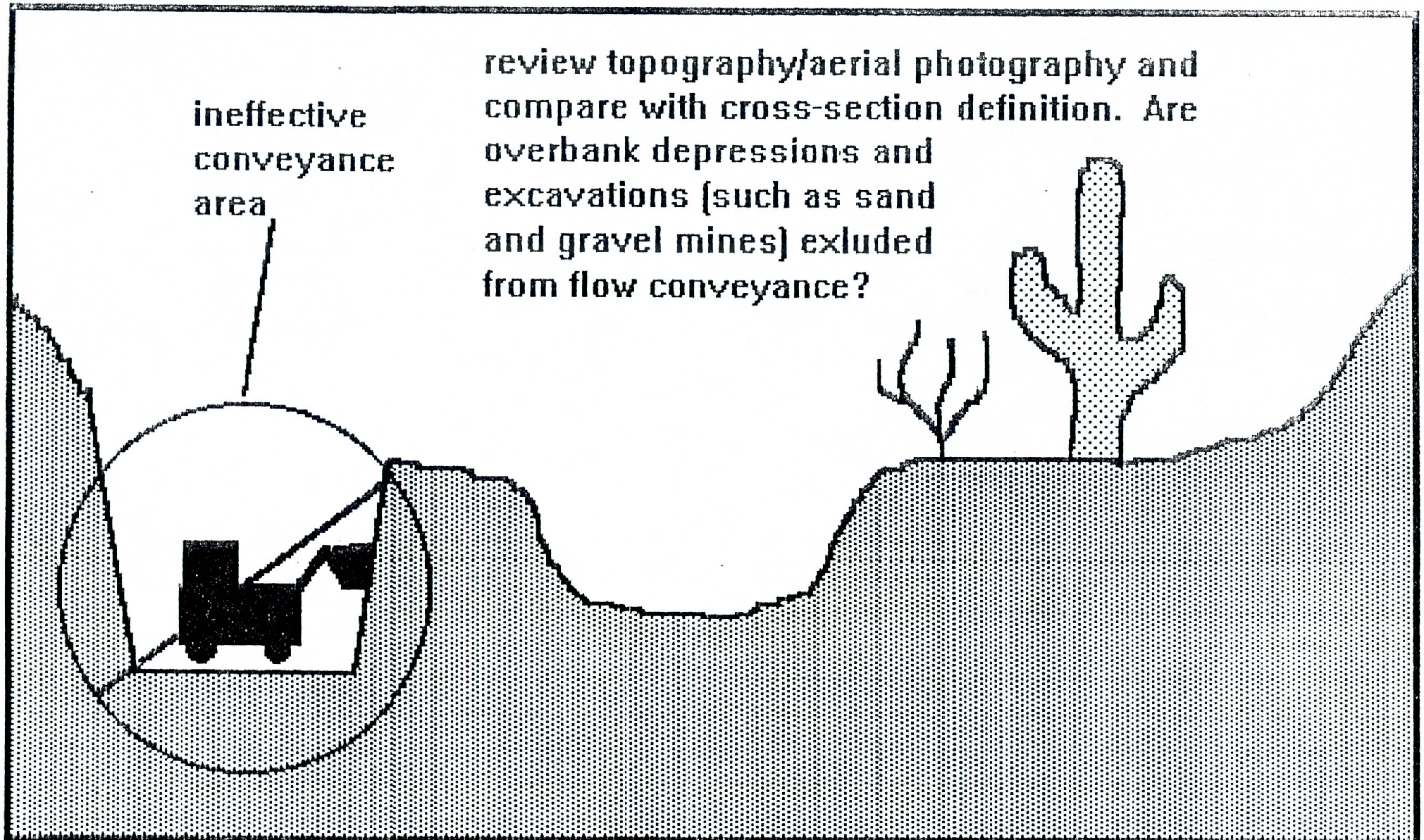


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FIGURE 6B TYPICAL SECTION SHOWING INEFFECTIVE OVERBANK AREA

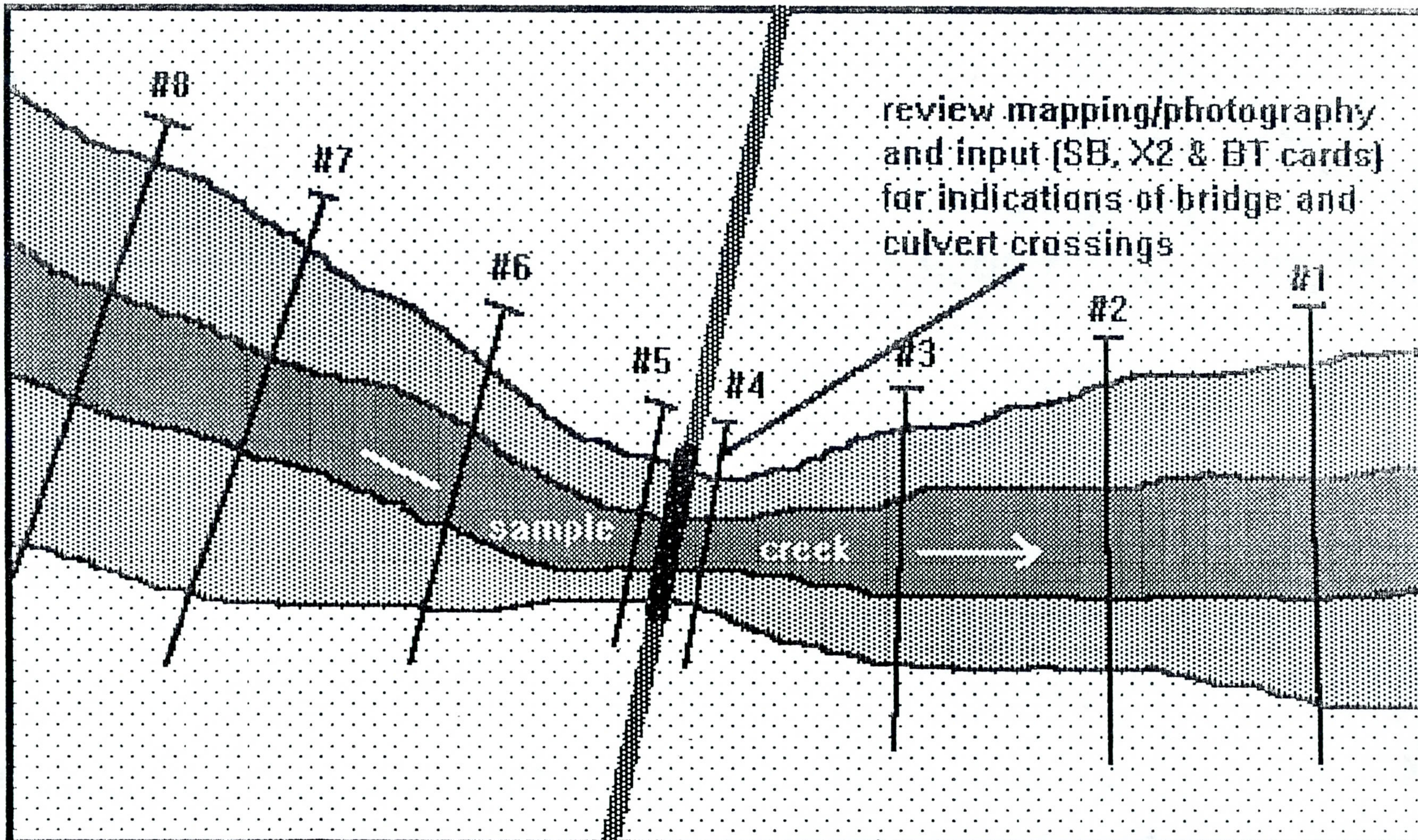

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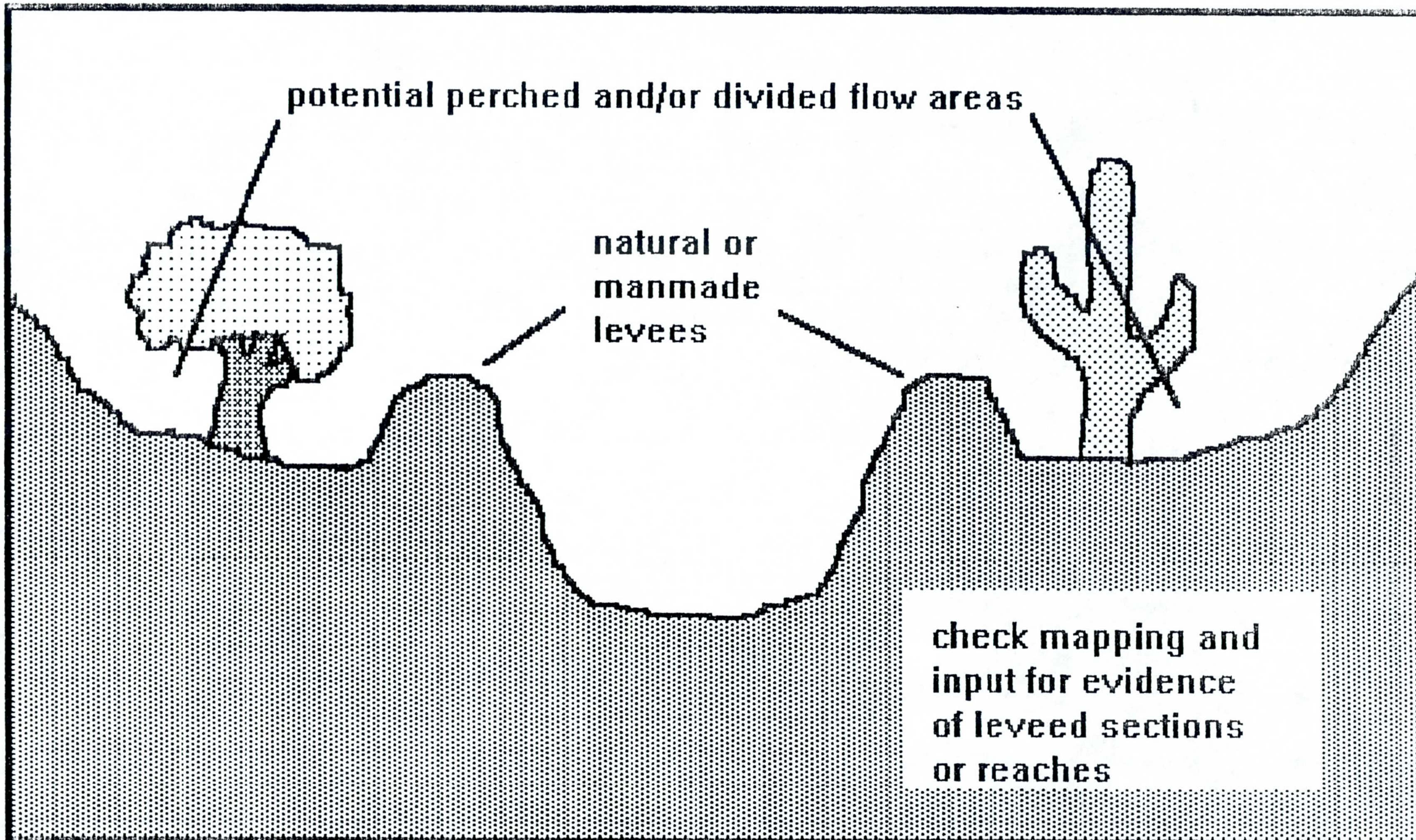
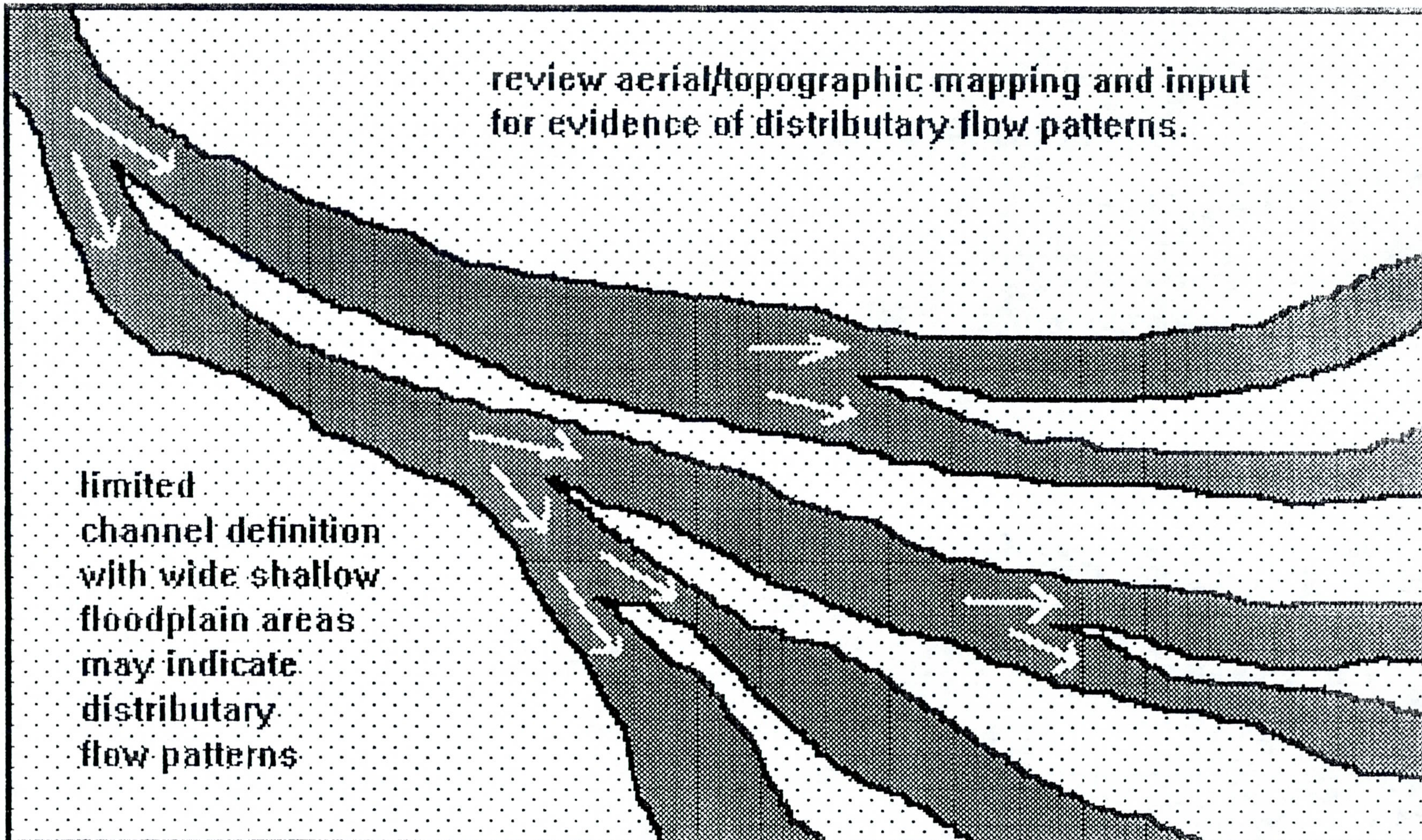
FIGURE 7A PLAN VIEW SHOWING BRIDGE CROSSING LOCATION



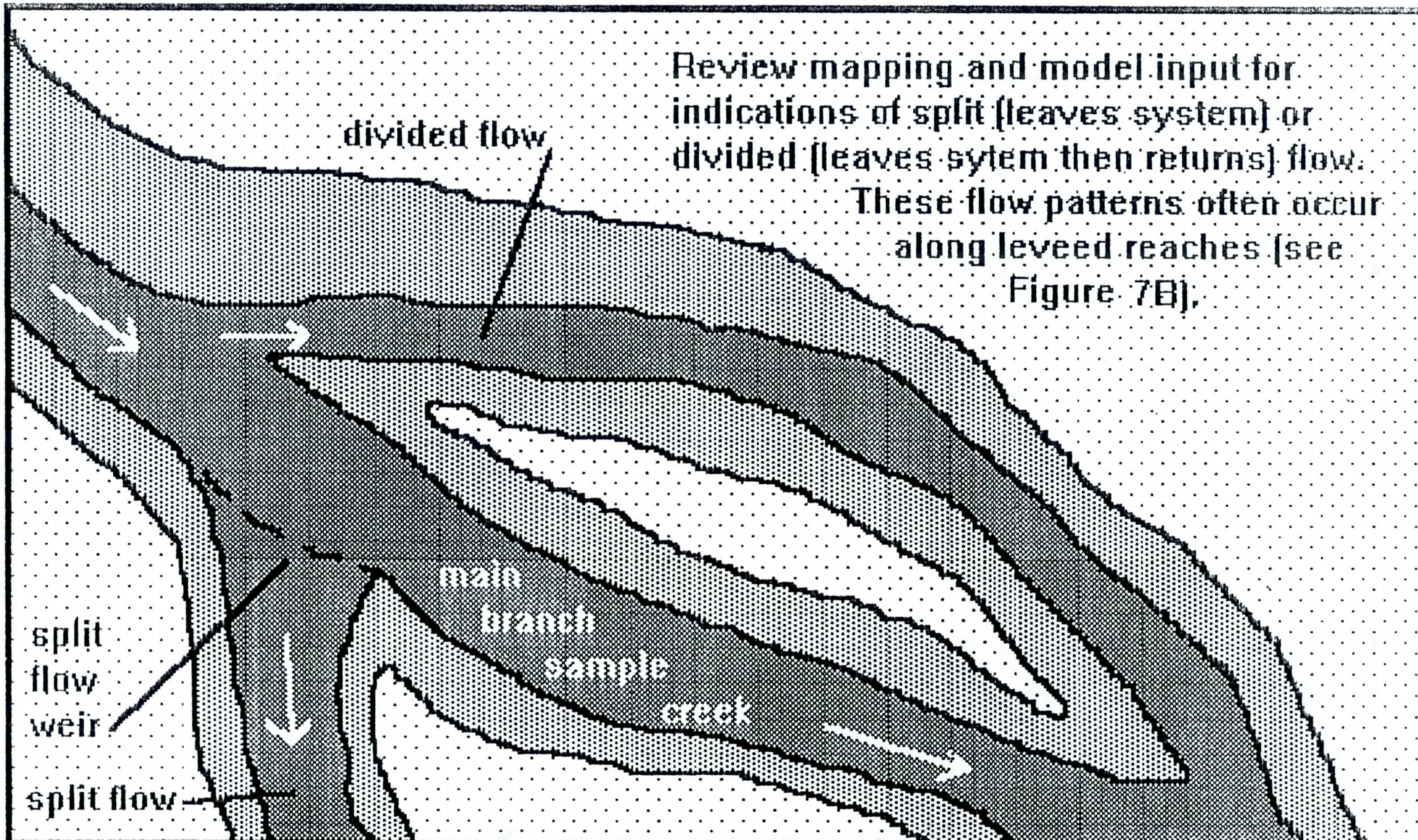
ARIZONA FLOODPLAIN
MANAGEMENT ASSOCIATION

FIGURE 7B TYPICAL SECTION
SHOWING LEVEED CHANNEL REACH



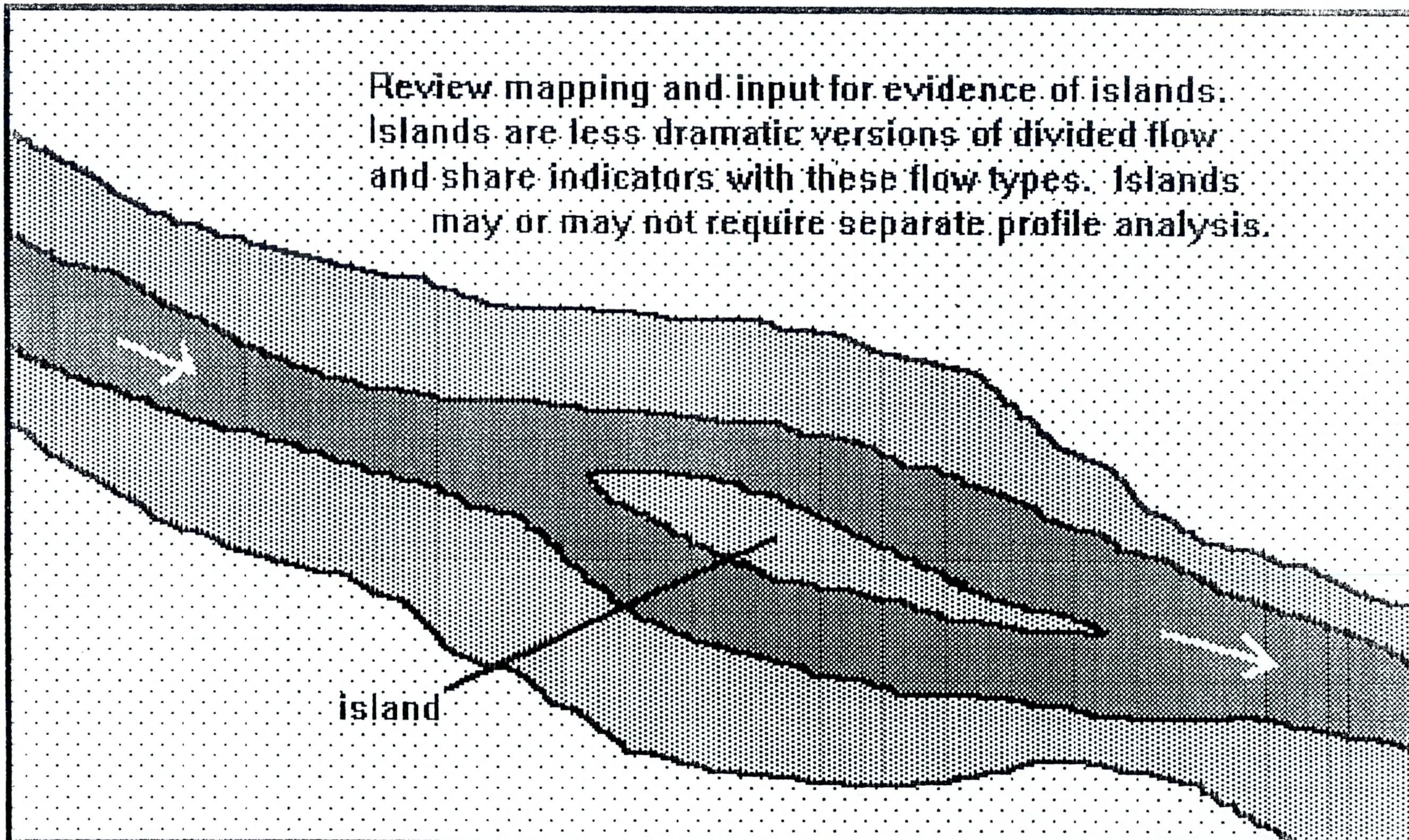
ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION

FIGURE 7C PLAN VIEW SHOWING DISTRIBUTARY FLOW PATTERN



ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION

FIGURE 7D PLAN VIEW SHOWING SPLIT AND DIVIDED FLOW PATTERNS



ARIZONA FLOODPLAIN MANAGEMENT ASSOCIATION

FIGURE 7E PLAN VIEW SHOWING ISLAND WITHIN FLOODPLAIN

PART IV

EXAMPLE HEC-2 INPUT/OUTPUT

```
1*******************************************
 *  HEC-2 WATER SURFACE PROFILES           *
 *                                         *
 *  Version   4.6.0;  February 1991        *
 *                                         *
 *  RUN DATE    10FEB92    TIME   11:00:39 *
 *******************************************
```

SAMPLE HEC-2 INPUT/OUTPUT: This sample HEC-2 input/output describes and discusses Items 1 through 3 of the Output Checklist. Various shaded boxes discuss the pertinent checklist item.

```
X     X  XXXXXXX   XXXXX              XXXXX
X     X  X        X     X            X     X
X     X  X        X                        X
XXXXXXX  XXXX     X          XXXXX    XXXXX
X     X  X        X                  X
X     X  X        X     X            X
X     X  XXXXXXX   XXXXX             XXXXXXX
```

1
10FEB92   11:00:39   PAGE 1

THIS RUN EXECUTED 10FEB92   11:00:39

```
************************************
HEC-2 WATER SURFACE PROFILES

Version   4.6.0;  February 1991
************************************
```

T1 Sample HEC-2 Model for HEC-2 Workshop
T2 Arizona Floodplain Management Association; Winter 1992
T3 February 20 and 21, Ramada Inn, Tucson, Arizona

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0	2	0	0	.01	0	0	0	90	0

J2	NPROF	IPLOT	PREVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	1	0	-1	0	0	0	-1	0	0	15

J3 VARIABLE CODES FOR SUMMARY PRINTOUT

38	1	8	26	10	25	4	33	5	43

```
     13          14          15

NC     0.045       0.050       0.024        0.1         0.3
QT         1        1000
X1         1           8         100         130           0           0           0           0           0           0
GR       100           0          90          20          89         100          85         104          85         124
GR        90         130          93         160         100         220

X1         2           9         100         130           0           0           0           0           0           0
GR       101           0          91          20          90         100          86         104          86         124
GR        91         130          94         160         101         220          89         225

X1         3          15         130         160           0           0           0           0           0           0
GR       105           0          92          20          91          80          88          82          88          87
GR        90          90          90         130          87         135          87         155          91         160
GR        94         166          94         170          91         175          92         190         105         230

X1         4          12         200         250           0           0           0           0           0           0
GR       110           0          94          20          93          30          91          35          91          45
GR        93          50          92         200          89         205          89         245          93         250
GR        94         290         110         340

X1         5           8          50          75           0           0           0           0           0           0
GR       115           0          98          10          97          50          94          51          93          71
GR        96          75          98         280         115         320
1
   10FEB92      11:00:39                                                                                  PAGE     2


    SECNO       DEPTH       CWSEL       CRIWS       WSELK       EG          HV          HL          OLOSS       L-BANK ELEV
    Q           QLOB        QCH         QROB        ALOB        ACH         AROB        VOL         TWA         R-BANK ELEV
    TIME        VLOB        VCH         VROB        XNL         XNCH        XNR         WTN         ELMIN       SSTA
    SLOPE       XLOBL       XLCH        XLOBR       ITRIAL      IDC         ICONT       CORAR       TOPWID      ENDST


*PROF 1

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS

CCHV=      .100 CEHV=      .300
*SECNO 1.000
3720 CRITICAL DEPTH ASSUMED
      1.000       3.90      88.90       88.90       90.00       90.63       1.73         .00         .00       89.00
     1000.0         .0     1000.0          .0          .0        94.8         .0          .0          .0       90.00
        .00        .00      10.55         .00        .000        .024       .000        .000       85.00      100.10
    .006721         0.         0.          0.           0          14          4         .00       28.58      128.68


FLOW DISTRIBUTION FOR SECNO=       1.00            CWSEL=      88.90

STA=       100.       130.
  PER Q=      100.0
   AREA=       94.8
    VEL=       10.6
  DEPTH=        3.3

*SECNO 2.000
```

3265 DIVIDED FLOW ←

3280 CROSS SECTION 2.00 EXTENDED .94 FEET ←

```
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     2.000       3.94      89.94      89.94        .00      91.63
1.69       .00        .00      90.00
    1000.0         .0      999.9         .1         .0       95.8
 .2         .0         .0      91.00
       .00        .00      10.44        .49       .000       .024
.050      .000      86.00     100.06
   .006511         0.         0.         0.          0          5
  0        .00      29.05     225.00

FLOW DISTRIBUTION FOR SECNO=      2.00        CWSEL=     89.94

STA=     100.      130.      225.
  PER Q=    100.0        .0
   AREA=     95.8        .2
    VEL=     10.4        .5
  DEPTH=      3.3        .0

1
   10FEB92      11:00:39
                                                PAGE    3
```

OUTPUT CHECKLIST ITEMS 3B AND 3C: Review output at each cross-section for extended cross-section or divided flow messages. Either message may mean model revisions are needed (see HEC-2 Reviewer's Checklist for more information).

OUTPUT CHECKLIST ITEM 3D: Review detailed output for "HV changed more than HVINS" message. This message indicates the change in velocity head ($V^2/2g$) was greater than that specified on J1, field 7, or the default value, (0.5.) Intermediate cross-sections may be warranted.

1.5?

```
    SECNO      DEPTH      CWSEL      CRIWS      WSELK       EG         HV
     HL        OLOSS       L-BANK ELEV
     Q         QLOB       QCH        QROB       ALOB       ACH
AROB      VOL        TWA       R-BANK ELEV
    TIME       VLOB       VCH        VROB       XNL        XNCH
XNR       WTN        ELMIN      SSTA
    SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

*SECNO 3.000
```

3301 HV CHANGED MORE THAN HVINS ←

```
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     3.000       3.78      90.78      90.78        .00      91.86       1.07        .00        .06      90.00
    1000.0      144.3      855.7         .0       53.2       96.1         .0         .0         .0      91.00
       .00       2.71       8.91        .00       .045       .024       .000       .000      87.00      80.14
   .004758         0.         0.         0.          0         11          0        .00      79.59     159.73

FLOW DISTRIBUTION FOR SECNO=      3.00        CWSEL=     90.78

STA=      80.       82.       87.       90.      130.      160.
  PER Q=       .5       6.3       1.6       6.1      85.6
   AREA=      2.6      13.9       5.4      31.4      96.1
    VEL=      1.9       4.5       3.0       1.9       8.9
  DEPTH=      1.4       2.8       1.8        .8       3.2

*SECNO 4.000
```

```
3265 DIVIDED FLOW

7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
   4.000      2.65     91.65     91.65       .00     92.75      1.10       .00       .01     92.00
  1000.0      13.6     986.4        .0       7.5     116.2        .0        .0        .0     93.00
     .00      1.81      8.49       .00      .045      .024      .000      .000     89.00     33.38
 .006011        0.        0.        0.         0        16         0       .00     60.97    248.31

FLOW DISTRIBUTION FOR SECNO=      4.00          CWSEL=     91.65

STA=      33.      35.      45.      47.     250.
  PER Q=       .1      1.2       .1     98.6
   AREA=       .5      6.5       .5    116.2
    VEL=      1.1      1.9      1.1      8.5
  DEPTH=       .3       .6       .3      2.4
```

```
1
   10FEB92       11:00:39                                                      PAGE     4


    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST
```

```
*SECNO 5.000
```
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
```
    5.000       4.66      97.66      97.66       .00      98.45
 .79        .00        .03      97.00
   1000.0        7.7      783.8      208.5       8.7       98.0
141.1         .0         .0      96.00
      .00        .89       8.00       1.48      .045      .024
.050       .000      93.00      23.63
  .003170         0.         0.         0.         0        11
  0         .00     221.44     245.07
```

OUTPUT CHECKLIST ITEM 3A: Look for consistent messages indicting profile defaulting to critical depth. If so modeling by alternative regime may be warranted.

```
FLOW DISTRIBUTION FOR SECNO=      5.00          CWSEL=     97.66

STA=      24.      50.      75.     245.
  PER Q=       .8     78.4     20.8
   AREA=      8.7     98.0    141.1
    VEL=       .9      8.0      1.5
  DEPTH=       .3      3.9       .8
```

THIS RUN EXECUTED 10FEB92 11:00:42

****

HEC-2 WATER SURFACE PROFILES

Version 4.6.0; February 1991

****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

February 20 and 21, Rama

SUMMARY PRINTOUT

	SECNO	CWSEL	DEPTH	VCH	HV	AREA	TOPWID	K*CHSL	10*KS	Q	QLOB	QCH	QROB
*	1.000	88.90	3.90	10.55	1.73	94.76	28.58	.00	67.21	1000.00	.00	1000.00	.00
*	2.000	89.94	3.94	10.44	1.69	95.97	29.05	1000.00	65.11	1000.00	.00	999.91	.09
*	3.000	90.78	3.78	8.91	1.07	149.27	79.59	1000.00	47.58	1000.00	144.33	855.67	.00
*	4.000	91.65	2.65	8.49	1.10	123.70	60.97	2000.00	60.11	1000.00	13.65	986.35	.00
*	5.000	97.66	4.66	8.00	.79	247.77	221.44	4000.00	31.70	1000.00	7.71	783.84	208.45

OUTPUT CHECKLIST ITEM 1: Review the hydraulic variables in the summary output for consistency and reasonableness. These parameters should be constant or vary gradually from cross-section to cross-section.

OUTPUT CHECKLIST ITEM 2: Using the summary printout (or detailed printout for each cross-section) check the flow distribution from cross-section to cross-section and within each cross-section (i.e., channel vs. overbanks). Flow distribution ordinarily should not vary greatly from one section to the next or within a section.

1
10FEB92 11:00:39

PAGE 6

SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO= 1.000 PROFILE= 1 CRITICAL DEPTH ASSUMED

CAUTION SECNO= 2.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 2.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

CAUTION SECNO= 3.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 3.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

CAUTION SECNO= 4.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 4.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

CAUTION SECNO= 5.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 5.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

PART V

REFERENCES

HEC-2

Water Surface Profiles

User's Manual

September 1990

Hydrologic Engineering Center
US Army Corps of Engineers
609 Second Street
Davis, CA 95616

(916) 756-1104

CPD-2A

Chapter 5

References and Bibliography

American Iron and Steel Institute (AISI), *Modern Sewer Design*, Washington, D.C., 1980. This book is an excellent reference on practical hydraulics.

Bonner, Vernon R., *Computing Water Surface Profiles with HEC-2 on a Personal Computer*, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Training Document 26.

Bradley, Joseph, *Hydraulics of Bridge Waterways*, Hydraulic Design Series No. 1, Federal Highway Administration, U.S. Department of Transportation, revised Second Edition, March 1978.

Brater, Ernest F. and Horace Williams King, *Handbook of Hydraulics*, McGraw-Hill, Inc., New York, 1976. This book is not a good place to start learning about hydraulics, but we keep coming back to it for information not easily available elsewhere.

Bureau of Public Roads (BPR), *Hydraulic Charts for the Selection of Highway Culverts*, Hydraulic Engineering Circular No. 5, U.S. Department of Commerce, December 1965. The methods and charts in this publication form the basis for much of the information in later FHWA publications.

Chow, Ven Te, *Open Channel Hydraulics*, McGraw-Hill, Inc., New York, 1959. This is the classic text on flow in open channels.

Davis, Calvin Victor and Kenneth E. Sorensen, Editors, *Handbook of Applied Hydraulics*, McGraw-Hill, Inc., New York, 1969. This is a handy reference for certain hydraulic information.

Eichert, Bill S. and John C. Peters, *Computer Determination of Flow Through Bridges*, Technical Paper No. 20, U.S. Army Corps of Engineers, Hydrologic Engineering Center, 1970.

Eichert, Bill S. and John Peters, *Computer Determination of Flow Through Bridges*, Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY 7, July 1970.

Featherstone, R. E. and C. Nalluri, *Civil Engineering Hydraulics*, Granada Publishing Limited, London, 1982. This book is fairly theoretical, but with many examples.

Federal Highway Administration (FHWA), *Hydraulic Design of Improved Inlets for Culverts*, Hydraulic Engineering Circular No. 13, U.S. Department of Transportation, August 1972. The methods and charts in this publication form the basis for some of the information presented in the FHWA's "Hydraulic Design of Highway Culverts" (FHWA 1985).

Federal Highway Administration (FHWA), *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Hydraulic Engineering Circular No. 14, U.S. Department of Transportation, December 1975.

Federal Highway Administration (FHWA), *Capacity Charts for the Hydraulic Design of Highway Culverts*, Hydraulic Engineering Circular No. 10, U.S. Department of Transportation, March 1978. This is a good reference on culvert hydraulics and design. The capacity charts can be used to check the results of the HEC-2 Special Culvert Option.

Federal Highway Administration (FHWA), *Hydraulic Design of Highway Culverts*, Hydraulic Design Series No. 5, U.S. Department of Transportation, September 1985. This is an invaluable reference for hydraulic engineers. If you design or analyze culverts, you need this book. The hydraulic charts in this publication can be used to check the results of the HEC-2 Special Culvert Option.

French, Richard H., *Open Channel Hydraulics*, McGraw-Hill, Inc. New York, 1985. This is a comprehensive, up-to-date text on open-channel flow.

Portland Cement Association, *Handbook of Concrete Culvert Pipe Hydraulics*, 1964.

Shearman, J.O., et al, *Bridge Waterways Analysis Model: Research Report*, Report No. FHWA/RD-86/108, U.S. Department of Transportation, Federal Highway Administration, July 1986.

ZELENSKY, PAUL N., *Approximate Method for Computing Backwater Profiles in Corrugated Metal Pipes*, Federal Highway Administration, Offices of Research & Development, Report No. FHWA-RD-76-42, April 1976. This report presents an approximate method for backwater computations in structural plate corrugated metal pipes with 6 x 2 inch corrugations.

Chapter 6

References

a. "Backwater Curves in River Channels," Engineering Manual 1110-2-1409, U.S. Army Corps of Engineers, 7 December 1959.

b. "Computer Determination of Flow Through Bridges," Eichert, B.S. and Peters, J.C., ASCE, J. Hyd. Div., Vol. 96, No. HY7, July 1970.

c. Koch-Carstanjen, "Von de Bewegung des Wassers und Den Dabei Auftretenden Kraften, Hydrofynamim, Berlin 1962. A partial translation appears in Appendix I, "Report on Engineering Aspects of Flood of March 1938," U.S. Army Engineer Office, Los Angeles, May 1939.

d. "Handbook of Concrete Culvert Pipe Hydraulics," Portland Cement Association, 1964.

e. "Handbook of Hydraulics," Horace W. King and Ernest F. Brater, Fifth Edition, McGraw - Hill Book Company, 1963.

f. "HEC-2, Water Surface Profiles," Programmers Manual, The Hydrologic Engineering Center, September 1982.

g. "Hydraulic Design of Reservoir Outlet Structures," Engineering Manual 1110-2-1602, U.S. Army Engineers, 1 August 1963.

h. "Hydraulic Design of Spillways," Engineering Manual 1110-2-1603, U.S. Army Corps of Engineers, 31 March 1965, Plate 33.

i. "Hydraulics of Bridge Waterways," Hydraulic Design Series No. 1, Joseph Bradley, Federal Highway Administration, U.S. Department of Transportation, revised Second Edition, March 1978.

j. "Open Channel Hydraulics," Ven Te Chow, McGraw - Hill Book Company, 1959.

k. "Water Surface Profiles," IHD Volume 6, The Hydrologic Engineering Center, July 1975.

Chapter 7

References

1. U.S. Army Corps of Engineers, EM-1110-2-1409, "Backwater Curves in River Channels", 7 December 1959.

2. Chow, Ven Te, "Open-Channel Hydraulics", 1959.

3. Fasken, Guy B., "Guide for Selecting Roughness Coefficient 'n' Values for Channels", Soil Conservation Service, December 1963.

4. Barnes, Harry H., Jr., "Roughness Characteristics of Natural Channels", Geological Survey Water-Supply Paper 1849, 1967.

5. Reed, J.R. and A.J. Wolfkill, "Evaluation of Friction Slopes Models," River 76, Symposium on Inland Waterways for Navigation Flood Control and Water Diversions, Colorado State University, 1976.

6. U.S. Army Corps of Engineers, EM 1110-2-1612, "Ice Engineering Manual", 15 October 1982.

7. Pariset, E., R. Hausser, and A. Gagon, "Formation of Ice Covers and Ice Jams in Rivers," Journal of the Hydraulics Division, ASCE 92:1-24.

8. HEC-1, Flood Hydrograph Package User's Manual, September 1990.

9. Department of the Army, Corps of Engineers. "Hydraulic Design of Flood Control Channels," Engineer Manual EM 1110-2-1601. Office of the Chief of Engineers. 1970.

Chapter 8

Supplemental Material

The following supporting publications and illustrations are available from HEC for computer program HEC-2, Water Surface Profiles:

a. HEC Technical Paper No. 11, Survey of Programs for Water Surface Profiles (1968) by Bill S. Eichert. (Published in the Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY 2, February 1970).

b. HEC Technical Paper No. 20, Computer Determination of Flow Through Bridges (1970) by Bill S. Eichert and John Peters. (Published in the Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY 7, July 1970).

c. "Water Surface Profiles", IHD Volume 6, (out of print).

d. HEC Technical Paper No. 69, Critical Water Surface by Minimum Specific Energy Using the Parabolic Method, Bill S. Eichert, 1969. (out of print)

e. HEC Training Document No. 5, Floodway Determination Using Computer Program HEC-2, January 1988.

f. HEC Training Document No. 18, Application of the HEC-2 Split Flow Option, April 1982.

g. HEC Training Document No. 26, Computing Water Surface Profiles with HEC-2 on a Personal Computer, February 1990.

h. HEC Training Document No. 30, River Routing with HEC-1 and HEC-2, July 1990.

PART VI

ADDITIONAL CHECKLIST FORMS

CONTIGUOUS STUDY CHECK

PREPARED BY ____________ FIS ____________ DATE ____________

CRITERIA	AGREEMENT		COMMENTS
	YES	NO	
____________ CONTIGUOUS STUDY ____________ LOCATION WRT CURRENT STUDY ____________ FLOODING SOURCE			
A — MAPS AND PROFILES			
1 - FLOODWAY WIDTHS			
2 - BFE'S & ZONE VALUES			
3 - 100 & 500 YR FLOOD BDY'S			
4 - CORPORATE LIMITS			
B — NARRATIVES			
1 - DISCHARGES			
2 - METHODOLOGIES			
____________ CONTIGUOUS STUDY ____________ LOCATION WRT CURRENT STUDY ____________ FLOODING SOURCE			
A — MAPS AND PROFILES			
1 - FLOODWAY WIDTHS			
2 - BFE'S & ZONE VALUES			
3 - 100 & 500 YR FLOOD BDY'S			
4 - CORPORATE LIMITS			
B — NARRATIVES			
1 - DISCHARGES			
2 - METHODOLOGIES			

Exhibit 1

Engineer:
Study:

Date
Stream:

ROUGHNESS COEFFICIENT CHECK

SECNO	XNL	XNCH	XNR	CCHV	CEHV	REMARKS

CROSS-SECTION LOCATION

______________________ ENGINEER

______________________ DATE

______________________ COMMUNITY

______________________ STREAM

REACH LENGTH

COMPARE XLOBL AND XLOBR WITH XLCH

Note cross sections where it seems unreasonable

SPACING

CHECK EITHER Ku/Kd OR Su/Sd (100-YEAR ONLY)

Note Cross sections where either

0.7 > Ku/Kd > 1.4 and H1 > 1.0' and XLCH > 1,000'

or

0.5 > Su/Sd > 2.0 and H1 > 1.0' and XLCH > 1,000'

If all the flow is contained within the channel, this check can be ignored.

ALIGNMENT

CHECK THAT ALL CROSS SECTIONS SPAN THE ENTIRE EFFECTIVE FLOW AREA AND THAT THEY ARE PERPENDICULAR TO THE FLOOD FLOW

Note cross sections that should be lengthened and/or those which, if realigned properly, would make a significant change in floodway/flood boundary width.

LOCATION

CHECK FOR CROSS SECTIONS LOCATED:

At changes in discharge, slope, shape or roughness
Where levees begin and end
At structures (see bridge checks)

Note between which two cross sections a new cross section might be added

DEFINITE CHANGES

CROSS SECTIONS TO BE MODIFIED, AND HOW:

CROSS SECTIONS TO BE ADDED (BETWEEN WHICH TWO CROSS SECTIONS):

BRIDGE INVENTORY CHECK

Engineer ______________________ Date ________________ Page ____ of ____

Study ______________________ Stream ______________________

Bridge/Street Name	Profile	Work Map Base	HEC-2[1]	USGS Quads	Community Base Map	Other Sources

[1] — or other hydraulic model

NORMAL BRIDGE CHECK

Date: ____________ Page ____ of ____

Engineer: ____________ Study: ____________

Stream: ____________ Bridge Name: ____________

	SECNO	XLCH	CWSEL	EG	X3ELV	SLOPE	TOPWID			
1										
2										
3										
4										
5										
6										
								XLCEL	LRDEL	RRDEL

	OK	NOK
Type of Flow Check —		
Slope Check —		
Bridge Deck Check —		
X3 Elevations Check —		
Manning's "n" & Con. Exp. loss coeff. Check —		
Distance Check —		
Error Messages —		

Comments —

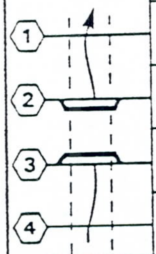
Exhibit 6

SPECIAL BRIDGE CHECK

Date: ______________ Page ____ of ____

Engineer: ______________________ Study: ______________________

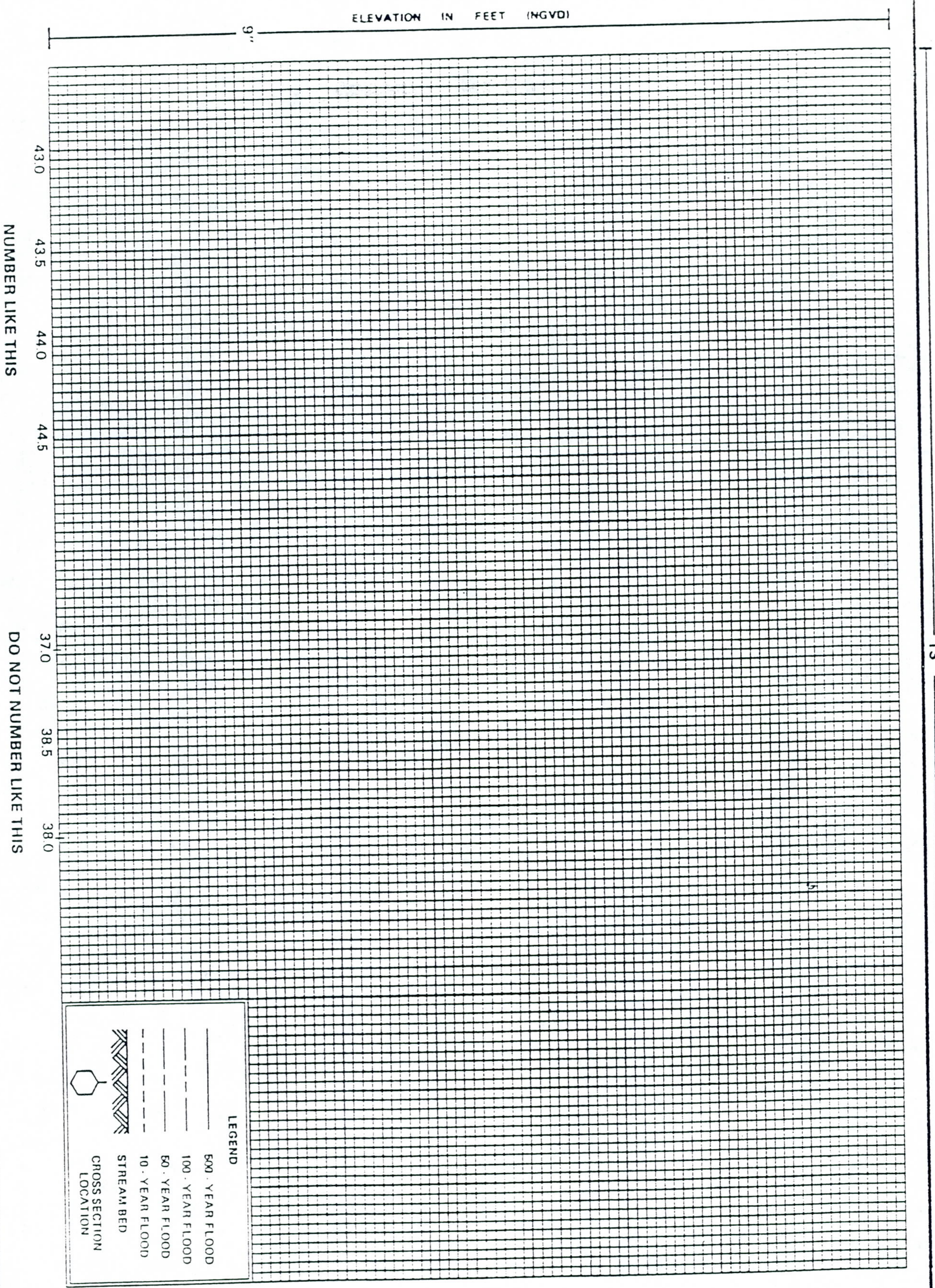
Stream: ______________________ Bridge Name: ______________________

	SECNO	XLCH	CWSEL	EG	X3ELV	TOPWID	WRLEN CHWID			
1										
2										
3										
4										
XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	TRAPA	SS	ELCHU	ELCHD
EGPRS	EGLWC	QWEIR	QPR	QLOW	QT	ELLC	ELTRD	XLCEL	LRDEL	RRDEL

	OK	NOK
SB Card Values Check —		
Weir Length Check (for weir flow) —		
EGLWC Check (for low flow) —		
ELLC & ELTRD Check —		
X3 Elevations Check —		
Manning's "n" & Con./Exp. loss coeff. Check —		
Distance Check —		
Encroachment Check —		

Error Messages —

Comments —



FEDERAL EMERGENCY MANAGEMENT AGENCY

FLOOD PROFILES

Exhibit 8

AGREEMENT TABLE

COMMUNITY ______________________________ DATE: __________

STREAM ______________________________ PREPARED BY ______________________ PAGE ____ OF ____

Physical Feature	# x-sec	abc x-sec	Cumulative Channel Distance				Distance B/X-Sec (profiles)		Floodway Width			Base Flood Elevation		
			table	profile	printout	maps	maps	printout	table	maps	printout	table	profile	printout

Exhibit 9

Advances in Hydrologic Engineering

January 1992

Training at HEC

The FY 1992 training program is underway. The **Hydrologic Engineering in Planning** course continues to be in high demand with thirty-six students attending during 18-22 November. The course provides the planning professionals with an overview of hydrologic analytical methods used in flood damage studies.

The next course was the **Real-Time Water Control**, which was 9-20 December. This year the water control software is operating on UNIX workstations. The computer workshops were conducted with our classroom PC's connected through a ETHERNET to INTERGRAPH and MIPS workstations.

Openings still remain for the **Flood Warning Preparedness** and **Hydrologic Engineer Role in Planning** courses. People interested in the courses should contact the Hunstville Training Division at (205) 722-5822 for registration information.

HEC has also presented several workshops for the field during the first months of this fiscal year. An HEC-5 workshop on water supply was conducted in Atlanta, sponsored by South Atlantic Division. An HEC-1 workshop was presented to Corps, TVA, and others in Nashville, sponsored by the District; and an HEC-2 workshop was presented in Fort Wayne, IA, sponsored by the Detroit District. (Bonner)

HEC Training Schedule for 1992

Course Title	Date	Tuition
Flood Plain Hydrology	9-20 Mar 92	$ 1,850
Flood Warning Preparedness	6-10 Apr 92	$ 1,210
Hydrologic Data Management	11-15 May 92	$ 1,570
Hydrologic Engineer Role in Planning	22-26 Jun 92	$ 1,570
Advanced HEC-1	14-18 Sep 92	$ 1,295

HEC Patriarch Al Onodera Announces Retirement

Alfred Onodera, affectionately known as "Big Al" to his colleagues at HEC, has announced that he has selected February 1, 1992 as his retirement date. Upon his retirement, Al will have completed more than thirty-five years of Federal service. He began his federal service as a paratrooper with the 101st Airborne Division. Upon his return to civilian life, Al joined the Corps Sacramento District as a draftsman.

Al was a member of the original group headed by Leo Beard when HEC was established as a part of the Sacramento District in July 1964. During his twenty-seven plus years with HEC, Al has worked as an Engineering Technician and Computer Specialist. He has helped HEC and the Corps to implement its hydrologic and administrative software on virtually every computer and operating system ever made!

Al has indicated that he will continue his interest in water resources as he intends to visit many of the beaches in the South Pacific during his retirement. He has promised to send post cards to keep the Corps informed about his findings on beach erosion. (Hayes)

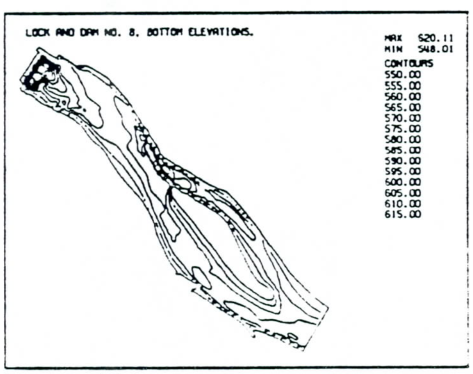
Training Assistance for Bolivian Engineers

The US Agency for International Development (US AID) sponsored a Corps of Engineers review of water resources activities and professionals in Bolivia. Mobile District staff identified and prioritized several potential programs. It was recommended that an immediate effort should be made to transfer appropriate analytical technology to Bolivian engineers involved with water resource development activities. US AID requested the Corps Mobile District to provide hydrologic and hydraulic training specifically on the Corps HEC-1 and HEC-2 computer programs. A cooperative agreement has been developed and approved between the Government of Bolivia, US AID and the Corps to provide the technology transfer.

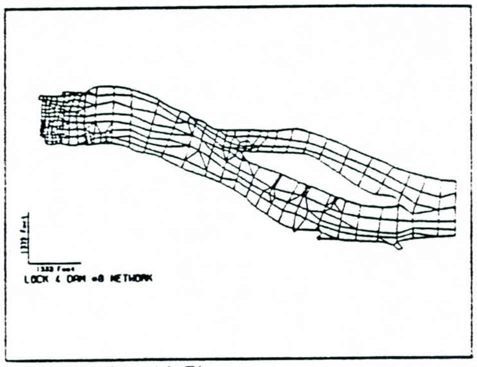
HEC is assisting the Mobile District by presenting training in computer programs HEC-1 and HEC-2 to engineers in Bolivia. Around February 1992, Alfredo Montalvo will join two Mobile staff engineers in presenting two one-week workshops on HEC-2. Approximately one month later, David Goldman will join the Mobile team to present two HEC-1 workshops. The one-year project also includes translation of the program user's manuals into Spanish and continued application assistance after the workshops by the Mobile District staff. An initial application for the programs will be to develop the flows and stages to design bridge crossings in Bolivia. (Bonner)

2-D Hydraulics Modeling Update

HEC has recently negotiated an agreement with PLOTWORKS, Inc. (Ramona, CA) whereby we can provide executable programs linked with the PLOT88 graphics library free of charge to Corps of Engineer offices. This means that graphic displays created by the RMA-2 system of two-dimensional hydrodynamics programs will be readily available from applications run on MS-DOS PC's. Numerous output devices are supported, including: HP pen plotters, screen output, laserjet printers, AutoCad* files, and files that can be imported to WordPerfect* as graphics images (as was done here). The RMA-2 system is the hydrodynamics component of the TABS-2 sediment transport modeling system supported by WES. An extended memory version of this system will be developed shortly; this will allow the analysis of systems with more than 500 elements, depending upon the computer memory available to the user. This agreement will provide Corps offices with an interim means for applying RMA-2, using in-house hardware, until HEC finalizes NexGen UNIX Workstation graphics issues. (Gee)



Contour Plot

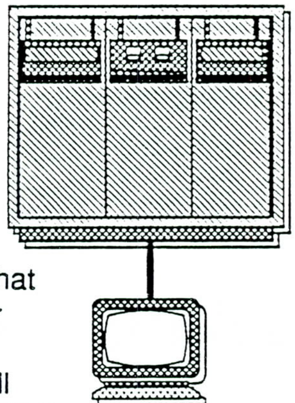

Network (Mesh) Plot

*Autocad is a registered trademark of Autodesk, Inc. Sausalito, CA.

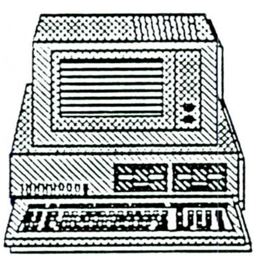
WordPerfect is a registered trademark of the WordPerfect Corporation, Orem, UT.

HEC Computer Resources Changing

Where have all the mainframes gone: long time forgotten (by many). Now it is PC's, workstations and supercomputers; times are a changin'. HEC is rapidly moving into the "workstation and PC" network capability for its computational resources. Our ol'blue HARRIS 1000 is due to be unplugged in mid-February 1992. Does that mean we will ignore our friends working on the HARRIS? No! HEC will continue to support HARRIS users (and other Corps computers) as the field-office demand indicates. We have made arrangements with Sacramento District to use their HARRIS, via CDCNET, to support that software. Copies of all our current HARRIS software will still be available.

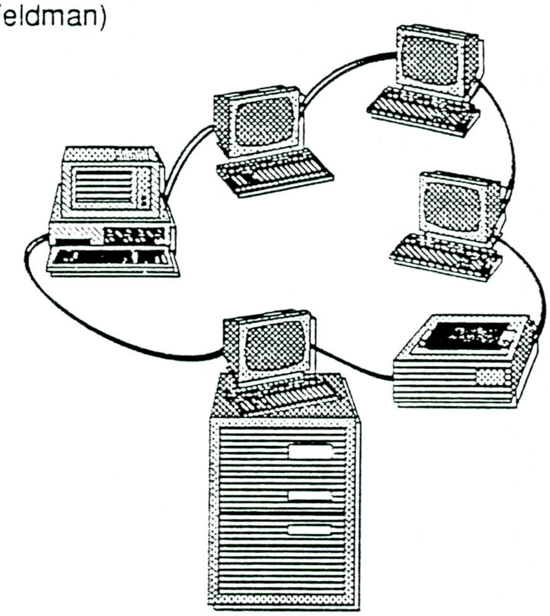


The current thrust in HEC's computational resources is toward workstations and high-performance PC's. Workstations offer the greatest potential for increased performance because of their speed, graphics, and multitasking/multiuser capabilities. HEC's latest purchase was a CDC 4330 with the graphics conversion kit (a potent MIPS machine) off the Corps CEAP contract for about $25,000. Our latest PC's are 33 mhz 486s with hardware caching, powerful and cheap at about $3,000. Most of our machines are on a LAN which includes the device interface to CDCNET. Thus, an engineer can sit at a PC and have access to workstations at HEC, larger CDC mainframes, WES's supercomputer, Districts and Divisions, and beyond.



This increased workstation power comes at some expense: UNIX. UNIX is unfriendly, but powerful. We are currently developing the next generation of HEC software to run in the UNIX X-Windows (and DOS Windows) environment. The user will be shielded from the rigors of UNIX as much as possible. The X-Windows workstation environment will come first, and the PC transfer will be made after that. (Who knows what PC Windows capabilities will be then; we're guessing it will be close to the workstation X-Windows.) Transfer of code from one workstation to another will be more difficult than for DOS machines. The CPU chips used are different between hardware manufacturers (e.g., SUN and CDC) so the transfer needs to be made at the source code level and recompiled. UNIX is becoming more and more standard so that may not even be a problem in the not so distant future.

Yes, computer resources are rapidly changing. HEC is developing new software to bring these computational capabilities to the hydrologic engineering community. (Feldman)



HEC Computer Program Activities

New Program Release - HEC-IFH

HEC is now making a provisional release of a new computer program for the personal computer. The program, "Interior Flood Hydrology (HEC-IFH)", can be used to analyze flood damage reduction measures for leveed interior areas.

Projects that include flood damage reduction measures such as levees and floodwalls usually involve special problems associated with isolated interior areas. Storm runoff patterns are altered and remedial measures are often required to prevent increased or residual flooding in the interior due to natural flow blockage. Hydrologic analyses are needed to characterize the interior area flood hazard and to evaluate the performance of the potential flood damage reduction measures and plans. The HEC-IFH program services this need. HEC-IFH is a comprehensive interactive program that is operational on 386 class personal computers with 3 MB of extended (4 MB total) memory. It is particularly powerful for performing long, historical period simulations and makes extensive use of a menu-driven user interface, statistical and graphical data representations, and data summaries. Annual or partial series interior elevation-frequency relationships can be derived directly for various alternative configurations of interior features such as gravity outlets, pumps, and diversions.

The program consists of two analysis components, one for Continuous Simulation Analysis (CSA) and one for Hypothetical Event Analysis (HEA). This first, provisional release will consist of the CSA portion of the package and is **limited** to Corps' offices. Single events may also be entered and analyzed independently using the CSA version. Release of the final, complete package is planned for March 1992. Corps offices can obtain a copy of the provisional release (CSA, version 1.0) by contacting HEC. (Dotson)

HEC-1

Use of the kinematic wave runoff with the multiratio option does not combine hydrographs appropriately in Version 4.0 of HEC-1 (see the description of the JR record in the HEC-1 User's Manual). The problem can be detected by noting that the basin area is not totaled correctly in the runoff summary output.

The kinematic wave option does not have this problem when used in the stream network option (i.e., when the multiratio capability is not applied). Consequently, each storm that would have been used via the multiratio approach can be simulated individually with the stream network option.

The error has been corrected in the large-array (extended memory) version of HEC-1 (Version 4.0.1E, September 1991). A correction to Version 4.0 will be made and released in the near future. (Goldman)

HEC-5Q

The new water quality version of "Simulation of Flood Control and Conservation Systems," HEC-5Q has recently been released. The new version includes the March 1991 water quantity routines from HEC-5, an option for flow augmentation, and the capability for up to 200 layers in the reservoir water quality analysis. The new version is about five times faster than the previous release for PC equipment. A 386 class of personal computer with at least 2Mb of extended memory is required to execute HEC-5Q.

The long awaited flow augmentation option of HEC-5Q was finally made operational. This option provides the water control manager the capability to evaluate the relative value of a "best" water quality reservoir operation versus the "best" water quantity conservation operation. The manager can then assess if an improved water quality condition is worth the modified operation of the system.

Briefings on HEC-5Q and/or start-up assistance on project applications is funded by Water Operations Technical Support (WOTS) at no cost to Corps of Engineers offices. HEC-5Q is available from HEC for Federal government offices and is available from several vendors for non-Federal offices. A list of vendors is available by calling HEC. (Willey)

New Publications

New Technical Papers at HEC

Papers in this series have resulted from technical activities of HEC. Versions of some of these have been published in technical journals or in conference proceedings. The purpose of this series is to make the information available for use in the Center's training program and for distribution within the Corps of Engineers.

- TP-130 Estimating Sediment Delivery and Yield on Alluvial Fans
- TP-131 Hydrologic Aspects of Flood Warning - Preparedness Programs
- TP-132 Twenty-Five Years of Developing, Distributing, and Supporting Hydrologic Engineering Computer Programs
- TP-133 Predicting Deposition Patterns in Small Basins
- TP-134 Annual Extreme Lake Elevations by Total Probability Theorem
- TP-135 A Muskingum-Cunge Channel Flow Routing Method for Drainage Networks
- TP-136 Prescriptive Reservoir System Analysis Model - Missouri River System Application

The publications of HEC are available to public and private organizations and to individuals at the cost of reproduction and distribution. Technical Papers are $2 per copy. Corps of Engineers offices and other federal agencies may receive the publications at no cost.

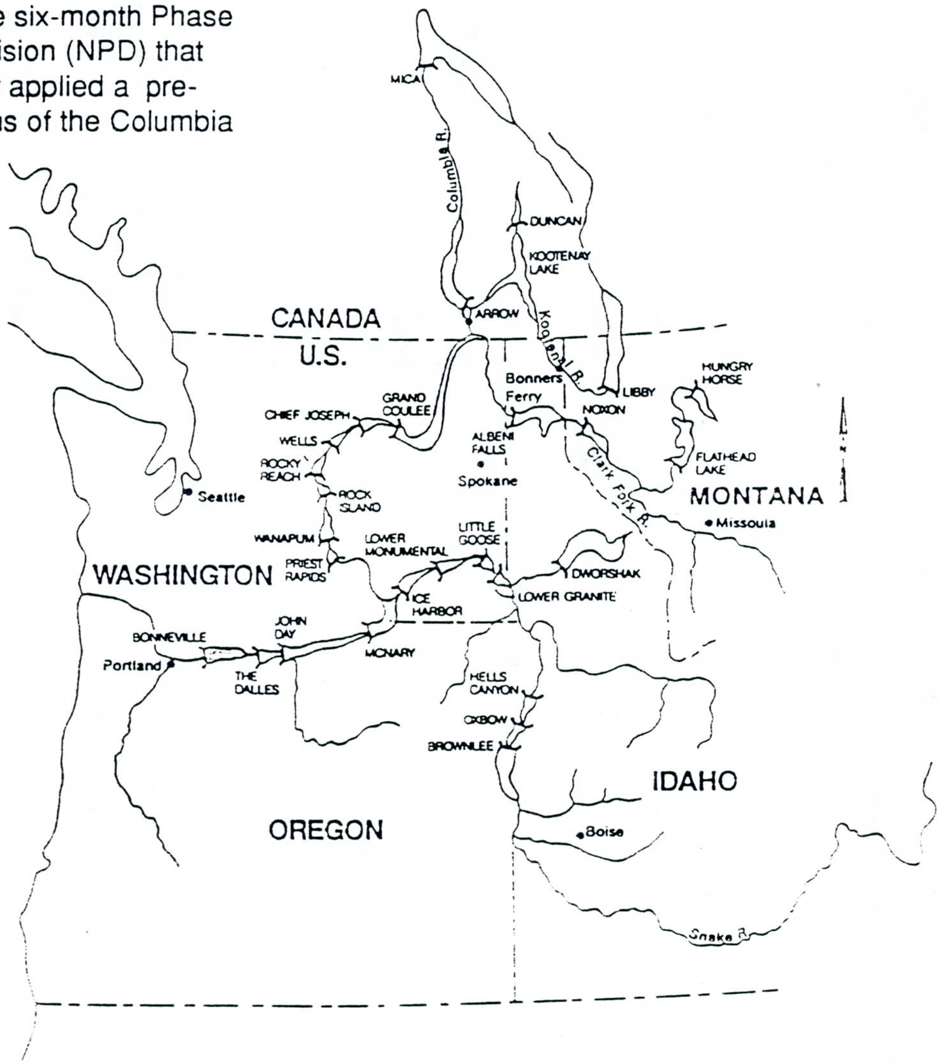
To order HEC publications, send your request, together with payment made payable to: FAO-USAED, Sacramento. (Tomita)

Send to:

Hydrologic Engineering Center
U.S. Army Corps of Engineers
609 Second Street
Davis, CA 95616-4687

Columbia River System Analysis Model - Phase I

HEC has completed the six-month Phase I study for North Pacific Division (NPD) that developed and successfully applied a preliminary model for operations of the Columbia River reservoir system. The study is part of a two-phase effort of HEC (overall project and model development) and the Institute for Water Resources (IWR) (economic concepts and penalty function development). The system was analyzed using the HEC Prescriptive Reservoir Model (HEC-PRM) originally developed for study of the Missouri River mainstem reservoir system. The model represents the Columbia River system as a network and uses network-flow programming to optimally allocate the system water. A one-year second phase study is anticipated to begin in the fourth quarter of this year. The Phase I report for the study is now available. The document number is PR-16 and the cost is $7. (Burnham)



US Army Corps of Engineers

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DEPARTMENT OF THE ARMY
Hydrologic Engineering Center, Corps of Engineers
609 Second Street
Davis, CA 95616-4687

JOHN WISE
CELLA BARR ASSOCIATES
4911 EAST BROADWAY
TUCSON AZ 85711

21 November 1991

Hydrologic Engineering Center Software Distribution
Domestic

Since October 1988, the Hydrologic Engineering Center (HEC) has not directly distributed software to non-Federal offices. To help meet the need for these services, HEC has transferred documentation and executable software for MS-DOS computers to the National Technical Information Service (NTIS) for general distribution. Additionally, computer programs HEC-1 and HEC-2 have been provided to PC-Trans and McTrans, which distribute software for state and federal highway agencies.

To promote a wider distribution and additional user support of HEC software, a list of vendors has been developed. These vendors have obtained their software from HEC and have indicated their distribution and support services. The list is divided into categories to assist in locating a vendor that provides an appropriate service for your needs. The vendors are listed by the following categories:

1. Government-Sponsored Distributors
2. Vendors Providing Programs Plus Other Services
   (Distributors of program source code are included in this category)
3. Vendors Providing Modified (Enhanced) Programs
   (Distributors of executable programs for computers other than MS-DOS are included)

All vendors, except Category 3, provide the programs and documentation they received from HEC. Category 3 vendors have developed supplemental program capabilities and, in some cases, additional or replacement documentation. To obtain HEC software not listed, or if you have difficulty obtaining HEC software, please contact us at: (916) 756-1104, office hours are: 7:30 a.m. to 4:15 p.m. Pacific Time.

All office hours listed for the vendors are local times.

US Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, California
USA 95616

(916) 756-1104 FAX (916) 756-8250

1. Government-Sponsored Distributors:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650
FAX (703) 321-8547

Contact: Ordering
Office Hours: 8 a.m. - 5 p.m.

Software Available:	HEC-1 (PB91-505222)	$130.00
	HEC-2 (PB91-506550)	$130.00
	HEC-5 (PB92-500263)	$230.00
	HEC-6 (PB92-500255)	$130.00
	COED (AD-A204 559)	$55.00
	HECWRC (AD-A204 571)	$50.00
	HMR52 (AD-A204 563)	$50.00
	MLRP (AD-A204 565)	$50.00
	STATS (AD-A204 567)	$50.00
	WQRRS (PB91-509984)	$180.00
Services Available:	Distribution	

McTrans Center
University of Florida
512 Weil Hall
Gainesville, FL 32611-2083
(904) 392-0378
FAX (904) 392-3224

Contact: Mike Tootle
Office Hours: 7 a.m. - 5 p.m.

Software Available:	HEC-1 (w/o GSS drivers)	$90.00
	HEC-1 (with GSS drivers)	$150.00
	HEC-2	$70.00
	GSS Drivers only	$60.00
Services Available:	Distribution	

Transportation Center (PC-TRANS)
University of Kansas
2011 Learned Hall
Lawrence, KS 66045
(913) 864-5658
FAX (913) 864-3199

Contact: Carl Thor
Office Hours: 8 a.m. - 5 p.m.

Software Available:	HEC-1 (with GSS drivers)	$160.00
	HEC-2	$72.50
	GSS Drivers only	$72.50
Services Available:	Distribution; Telephone Hotline	

The GSS drivers are software packages for specific plotters, printers and graphics adapters. The HECDSS DSPLAY graphics programs requires the GSS drivers to create graphical displays. The GSS drivers are products of Graphic Software Systems, Inc., 9590 S.W. Gemini Drive, Beaverton, OR 97005.

2. Vendors Providing Programs (Distribution) Plus Other Services:

Advanced Hydrologic
PO Box 278
Pittsford, NY 14534
(716) 248-3215

Contact: John Gauthier
Office Hours: 6:30 a.m. - 11 p.m.

Software Available: HEC-2
Other Services: Telephone Hotline

Albert H. Halff Associates, Inc.
4000 Fossil Creek Blvd.
Fort Worth, TX 76137
(817) 847-1422 FAX: ext. 232

Contact: Mr. Lynn Lovell
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HEC-6, FDA, HECWRC, HMR52
Other Services: Engineering Assistance (HEC-2 & FDA only); Training (HEC-2 only)

Bowen Engineering
216 F Street
Davis, CA 95616
(916) 758-1028

Contact: Teresa Bowen
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-2, HEC-5, FDA
Other Services: Engineering Assistance; Training (HEC-5 only)

Carter & Burgess, Inc.
1100 Macon Street
Fort Worth, TX 76102
(817) 335-2611

Contact: James Amick
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HMR52

CEDRA Corporation
65 West Broad Street
Rochester, NY 14614
(716) 232-6998

Contact: Amy Harrington
Office Hours: 9 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-3, HEC-5, HEC-6, HECDSS, STORM

CivilSoft
1592 N. Batavia, Suite 1A
Orange, CA 92667
(714) 974-1864

Contact: Sales Department
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-6, COED
Other Services: Source Code Distribution (HEC-1 & HEC-2 only; PC's only; MS/PC DOS systems)

Consulting Engineering Services
14780 S.W. Osprey Drive, Suite 285
Beaverton, OR 97007
(503) 646-4509

Contact: Anthony Weiler
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Telephone Hotline; Engineering Assistance

David J. Newton Associates, Inc.
1201 SW 12th Avenue, Suite 620
Portland, OR 97205
(503) 228-7718

Contact: Mary Ann Tawney
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2

DeVries & Associates
324 Encina Avenue
Davis, CA 95616
(916) 757-1035
(916) 757-8901 (messages)

Contact: Dr. Johannes DeVries
Office Hours: 12 noon - 6 p.m.

Software Available: HEC-1, HEC-2, HEC-3, HEC-6, HECWRC
Other Services: Engineering Assistance; Training; Source Code Distribution (HEC-1, HEC-2, & HEC-3 only)

deRES Consultants
PO Box 1615
Coolidge, AZ 85228
(602) 723-5126

Contact: Darde G. de Roulhac
Office Hours: 9 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2

Dewberry & Davis
8401 Arlington Blvd.
Fairfax, VA 22031-4666
(703) 849-0338
(703) 849-0307

Contact: Moe Khine/Vernon Hagen
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HECWRC
Other Services: Engineering Assistance; Distribution Only for HEC-5

Engineering Data Systems
Clock Tower West
Dubuque, IA 52001
800-369-6344
(319) 556-8392

Contact: Randy Dymond
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Telephone Hotline; Engineering Assistance

Ensign & Buckley Consulting Engineers
3327 Longview Drive
Sacramento, CA 95660-5895
(916) 971-3961

Contact: Gary Parker
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2

ERC\EDGe
3325 Perimeter Hill Drive
Nashville, TN 37211
800-476-5770
(615) 333-0630 (TN)

Contact: Byron Hinchey
Office Hours: 7 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HECWRC, HMR52
Other Services: Telephone Hotline; Engineering Assistance (HEC-1 & HEC-2 only)

ETC Engineers, Inc.
1510 South Broadway
Little Rock, AR 72202
(501) 375-1786

Contact: Mizan Rahman
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HECWRC, HMR52
Other Services: Telephone Hotline; Engineering Assistance; Training; Distribution Only for HEC-5, HECWRC & HMR52

FTN Associates, Ltd.
#3 Innwood Circle, Suite 220
Little Rock, AR 72211
(501) 225-7779

Contact: Marc Johnson
Office Hours: 9 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HECDSS, HECWRC, WQRRS
Other Services: Engineering Assistance, Distribution Only for HEC-5

German-Wong & Associates Inc.
201 Lathrop Way, Suite F
Sacramento, CA 95815
(916) 646-4262
FAX (916) 646-4874

Contact: John German
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-2
Other Services: Engineering Assistance

GKY & Associates, Inc.
5411-E Backlick Road
Springfield, VA 22151
(703) 642-5080

Contact: Stuart Stein
Office Hours: 9 a.m. - 5:30 p.m.

Software Available: HEC-1, HEC-2
Other Services: Telephone Hotline; Engineering Assistance; Training

Gregory L. Morris & Associates
256 San Justo Street
PO Box 5635
San Juan, PR 00902
(809) 723-8005

Contact: Gregory Morris
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-6
Other Services: Engineering Assistance

Haner, Ross & Sporseen, Inc.
15 Southwest 82nd Drive
Gladstone, OR 97027
(503) 657-1384

Contact: J.H. (Jim) Greenman
Office Hours: M-Th 7:30 a.m. - 5:30 p.m.
F 7:30 a.m. - 11:30 a.m.

Software Available: HEC-1, HEC-2, HEC-6
Other Services: Telephone Hotline; Engineering Assistance

Hydraulic Enhancements
2204 Bracyridge Road
Greensboro, NC 27407
(919) 574-0706
Computer Bulletin Board: (919) 852-7375 (24 hours a day)

Contact: Scott Edelman/Eric Lintz
Office Hours: 7 a.m. - 6 p.m.

Software Available: HEC-2
Other Services: Telephone Hotline; Engineering Assistance; Training

HydroTel International
PO Box 32171
Lafayette, LA 70593-2171
(318) 981-5450

Contact: Dr. Nosrat Maghsoudi
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-6
Other Services: Engineering Assistance; Training

Iowa Institute of Hydraulic Research
University of Iowa
Iowa City, IA 52242
(319) 335-5229

Contact: Forrest Holly, Jr.
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-6
Other Services: Engineering Assistance

Joseph E. Bonadiman & Associates, Inc.
P.O. Box 5852
San Bernardino, CA 92412
(714) 885-3806

Contact: Dennis Jackson
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-6
Other Services: Telephone Hotline;
HEC-1 & HEC-2 versions for ALPHA-MICRO computer systems also available

Law Engineering, Inc.
7616 LBJ Freeway, Suite 600
Dallas, TX 75251
(214) 934-0800

Contact: Mark Walter
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Engineering Assistance, Training

Liberty Computers Ltd.
326 Kingsberry Drive
Annapolis, MD 21401
(301) 757-3487

Contact: Arden Weiss
Office Hours: Anytime

Software Available: HEC-2, HEC-5

OTAK, Inc.
17355 S.W. Boones Ferry Road
Lake Oswego, OR 97035
(503) 635-3618

Contact: Seth Jelen
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, WQRRS
Other Services: Telephone Hotline; Engineering Assistance; Training; Distribution Only for WQRRS

Pate Engineers, Inc.
13403 Northwest Freeway, Suite 160
Houston, TX 77040-6071
(713) 462-3178

Contact: Alan McKee
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Engineering Assistance

Pennsylvania State University
Department of Civil Engineering
212 Sackett Building
University Park, PA 16802

Contact: Art Miller
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HEC-6
Other Services: Training

Placer County Flood Control District
1144 B Avenue
Auburn, CA 95603
(916) 889-7592

Contact: Dennis Huff
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Targeted for local, city, county & other public agencies. For these groups limited phone support and training.

Rampone Engineering Inc.
PO Box 287
Beech Grove, IN 46107
(317) 788-1880

Contact: Richard Rampone
Office Hours: 9 a.m. - 4:30 p.m.

Software Available: HEC-1, HEC-2
Other Services: Telephone Hotline; Engineering Assistance; Training; Distribution Only for HEC-1

Resource Consultants, Inc.
402 West Mountain Avenue
PO Box Q
Fort Collins, CO 80522
(303) 482-8471

Contact: David Frick
Office Hours: 8 a.m.- 5 p.m.

Software Available: HEC-1, HEC-2, HEC-6, COED, FDA, HECWRC
Other Services: Telephone Hotline; Engineering Assistance; Source Code Distribution for HEC-2 Only (PC's only; MS/PC DOS systems)

RiverTech, Inc.
23332 Mill Creek Drive, Suite 100
Laguna Hills, CA 92653
(714) 586-6121

Contact: Douglas Hamilton
Office Hours: 7 a.m. - 6 p.m.

Software Available: HEC-1, HEC-2, HEC-6
Other Services: Telephone Hotline; Engineering Assistance; Training

Sear-Brown Group
85 Metro Park
Rochester, NY 14623
(716) 475-1440 (messages are taken during non-office hours)
FAX (716) 272-1814

Contact: Paul Way
Office Hours: 7:30 a.m.- 5:30 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HEC-6, COED, FDA, HECWRC, HMR52, HYCOST, PAS, WQRRS
Other Services: Engineering Assistance; Telephone Hotline (not for HECWRC, or HMR52)

Shannon Engineering Associates, Inc.
PO Box 1043
Avon, CT 06001-1043
(203) 678-7228

Contact: Thomas Shannon
Office Hours: 3:30 a.m. - 4:30 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HEC-6, COED, FDA, HECWRC, HMR52, HYCOST, HYDPAR, MLRP, PAS, STATS, UHCOMP

Skibitzke Engineers & Associates, Inc.
2920 North 24th Avenue, #6
Phoenix, AZ 85015
(602) 257-4699

Contact: Craig Smith
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-6, FDA
Other Services: Telephone Hotline; Engineering Assistance; Training

Simons, Li & Associates, Inc.
PO Box 2712
Tucson, AZ 85702-2712
(602) 884-9594

Contact: Robert Smolinsky
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-6

SouthWest Engineering
5426 W. Vegas Drive
Las Vegas, NV 89108
(702) 648-9700

Contact: Mark Jones/Chip Maxfield
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2

Spectrum Engineering
3302 Fourth Avenue, North
Billings, MT 59101
(406) 259-2412

Contact: Gary Rome
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-4, HEC-5, HEC-6, FDA, WQRRS
Other Services: Telephone Hotline; Engineering Assistance; Video Tape; Distribution Only for HEC-5

Steve H. Blair, P.E.
Consulting Engineer
1644 Birdhaven Way
Pittsburg, CA 94565
(510) 709-1425

Contact: Steve Blair
Office Hours: 9 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Engineering Assistance

Sweetland Engineering & Assoc., Inc.
600 Science Park Road
State College, PA 16803
(814) 237-6518

Contact: Todd Pysher
Office Hours: 8:30 a.m. - 4:30 p.m.

Software Available: HEC-1, HEC-2, HEC-5

Systech Engineering, Inc.
3744 Mt. Diablo Road, Suite 101
Lafayette, CA 94549
(415) 284-7544

Contact: Luis Gomez
Office Hours: 8:30 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, WQRRS
Other Services: Telephone Hotline; Engineering Assistance

Texas A&M University
Water Resources Engineering
Civil Engineering Department
College Station, TX 77843
(409) 845-4550

Contact: Wesley James
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Telephone Hotline; Engineering Assistance; Training

University of Colorado at Denver
Dept. of Civil Engineering
1200 Larimer Street, Box 113
Denver, CO 80204
(303) 798-4936 (Hot Line)
(303) 556-2849; (303) 556-2871

Contact: Dr. James C.Y. Guo
Office Hours: 1:00 - 5 p.m.
(Tuesday & Thursday)

Software Available: HEC-1, HEC-2, HEC-5, HEC-6, HMR52
Other Services: Engineering Assistance (HEC-1 only);
Telephone Hotline (HEC-2, HEC-5, & HMR52 only)

University of Texas at Austin
Continuing Engineering Studies
College of Engineering
ECJ 10.324 - RM 2.612
Austin, TX 78712
(512) 471-3506

Contact: Gloria Griggs
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Training

Utah State University
Engineering & Software Services
Logan, UT 84322-8200
(801) 750-3187
FAX (801) 750-3663
TELEX 3729283

Contact: Daniel H. Hoggan
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Engineering Assistance; Video Tape; Training

Water Engineering & Technology, Inc.
PO Box 5000
Davis, CA 95617
(916) 758-3611
FAX (916) 758-6551

Contact: Robert MacArthur
Office Hours: 7:30 a.m. - 5 p.m.

Software Available: HEC-6
Other Services: Telephone Hotline; Training

Water Engineering & Technology, Inc.
419 Canyon Avenue, Suite 225
Fort Collins, CO 80521-2671
(303) 482-8201

Contact: Mark Peterson
Office Hours: 9 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Other Services: Engineering Assistance; Training

Water Resources Publications
PO Box 2841
Littleton, CO 80161-2841
(800) 736-2405
(303) 790-1836

Contact: Ms. Branka McLaughlin
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-3, HEC-5, HEC5Q, HECDSS, HECWRC, WQRRS

WEST Consultants, Inc.
2111 Palomar Airport Road, Suite 180
Carlsbad, CA 92009-1419
(619) 431-8113

Contact: David Williams/Jeff Bradley
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HEC-6, COED, HECWRC, HMR52
Other Services: Engineering Assistance;
Training (HEC-2, HEC-6 & COED only)

Winkley/Alexander, Inc.
1101 Highway 360, South, Suite E-230
Austin, TX 78767
(512) 328-3242

Contact: Scot Alexander
Office Hours: 9 a.m. - 4 p.m.

Software Available: HEC-2
Other Services: Telephone Hotline; Engineering Assistance

3. Vendors Providing Modified (Enhanced) Programs:

BOSS Corp.
6612 Mineral Point Road
Madison, WI 53705-4238
(608) 258-9910
FAX (608) 258-9943
TELEX 401242

Contact: Technical Support
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-2, HEC-6, HMR52
Services Available: Distribution; Telephone Hotline; Engineering Assistance; Video Tape (HMR52 Only)

CH2M Hill
2525 Airpark Drive
Redding, CA 96001
(916) 243-5831

Contact: Kenneth Iceman
Office Hours: 8 a.m. - 5 p.m.

Software Available: WQRRS (DEC Digital Equipment only)
Services Available: Distribution; Telephone Hotline; Engineering Assistance

Digital Software, Inc.
5510 Munford Road
PO Box 52149
Raleigh, NC 27612
(919) 787-7144

Contact: W.F. Johnson
Office Hours: 9 a.m. - 4 p.m.

Software Available: HEC-1 & HEC-2 (Data General AOS/VS Systems)
Services Available: Distribution

Dodson & Associates, Inc.
5629 FM 1960 West, Suite 314
Houston, TX 77069
(713) 440-3787
FAX (713) 440-4742

Contact: Roy D. Dodson
Office Hours: 7 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-4, HEC-5, HEC-6, HMR52, PAS, STORM
Services Available: Distribution; Telephone Hotline; Engineering Assistance; Video Tape (HEC-1, HEC-2 & PAS only); Training (HEC-1, HEC-2 & PAS only); Distribution for STORM only

Eichert Engineering
PO Box 3108
El Macero, CA 85618
(916) 756-6391
FAX (916) 753-1436

Contact: Bill S. Eichert
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-5
Services Available: Distribution; Telephone Hotline; Engineering Assistance; Training

Haestad Methods, Inc.
37 Brookside Road
Waterbury, CT 06708
800-727-6555 or (203) 755-1666 (CT)
Bulletin Board: (203) 756-1921
FAX (203) 597-1488
TELEX (910) 240-2251

Contact: Technical Support/Sales
Office Hours: 8:45 a.m. - 5:15 p.m.

Software Available: HEC-1, HEC-2, HEC-3, HEC-4, HEC-5, HEC-6, HECWRC, HMR52, STATS
Services Available: Distribution; Telephone Hotline; Engineering Assistance; Video Tape; Training

Hydrotech Microsystems
PO Box 40184
Portland, OR 97240-0184
(503) 257-6926

Contact: William Britton
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2, HEC-5, HECWRC (Apple Macintosh Only)
Services Available: Distribution; Telephone Hotline

John E. Harms Jr. & Associates, Inc.
90 Governor Ritchie Highway
PO Box 5
Pasadena, MD 21122
(301) 647-6000

Contact: Robert Noeth, Jr./Oner Yucel
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-2 (Apple Macintosh Only)
Services Available: Distribution; Engineering Assistance; Training

Northwest Hydraulic Consultants Inc.
22017 - 70th Avenue South
Kent, WA 98032
(206) 872-0218

Contact: Jeff Johnson
Office Hours: 8 a.m. - 4 p.m.

Software Available: HEC-2, HEC-6
Services Available: Distribution; Engineering Assistance; Source Code Distribution

Stephen Dedalus Incorporated
1150 S.E. Maynard Road, Suite 100
Cary, NC 27511
(919) 467-7072

Contact: Ed Odom
Office Hours: 8 a.m. - 5 p.m.

Software Available: HEC-1, HEC-2
Services Available: Distribution (UNIX Workstations, e.g., HP/Apollo, Silicon Graphics, IBM, DEC, and Sony)

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Announcing three short courses offered at Arizona State University

FLOOD PLAIN HYDROLOGY USING HEC-1

- APRIL 6 - 10, 1992

FLOOD PLAIN HYDRAULICS USING HEC-2

- APRIL 27 - MAY 1, 1992

UNSTEADY FLOW MODELING USING DAMBRK AND DWOPER

- MAY 11 - 15, 1992

Flood Plain Hydrology Using HEC-1

April 6 - 10, 1992

Presenters: L. Mays and D. Ford

This short course is intended for individuals with a need to solve hydrologic problems related to hydrologic design and analysis, and to flood plain management and flood insurance programs. Participants should have some experience in hydrology. Previous experience with HEC-1 is not required.

The course format consists of lectures and discussions followed by workshops. These practical application based workshops are designed around realistic problems and consist of developing HEC-1 input for workshop problems. Participants will have "hands-on" use of the program on PC's. A copy of the computer program will be available, on diskette, for each participant to bring back to the work place. Questions from participants and open discussions are encouraged during lectures, as well as during workshop sessions.

The HEC-1 computer program will be the primary educational vehicle for this course. Other computer programs for urban rainfall-runoff analysis and storm water detention design and analysis (ILLUDAS) and for flood flow frequency analysis (HECWRC) will be discussed.

Program

- Input procedure for the HEC-1 computer program
- Applications of the HEC-1 computer program
- Hydrologic analysis including unit hydrograph development, loss rate methods, flood routing in reservoirs and rivers, etc.
- Development of design storms
- Flood flows under modified conditions
- Design and analysis of urban storm water detention basins
- Coordinated flood flow determination for a stream system
- Flood flow frequency analysis using the U.S. Army Corps of Engineers HECWRC computer program and the U.S. Water Resources Council Method
- ILLUDAS (Illinois Urban Drainage Area Simulator)

Arizona State University vigorously pursues affirmative action and equal opportunity in its employment, activities and programs.

I wish to attend:

☐ **Flood Plain Hydrology Using HEC-1** (2154) Fee $815
April 6 - 10, 1992
Monday - Thursday 8:15 am to 5:30 pm
Friday 8:15 am to 12:30 pm

☐ **Flood Plain Hydraulics Using HEC-2** (2186) Fee $815
April 27 - May 1, 1992
Monday - Thursday 8:15 am to 5:30 pm
Friday 8:15 am to 12:30 pm

☐ **Unsteady Flow Modeling Using DAMBRK and DWOPER** (2179) Fee $815
May 11 - 15, 1992
Monday - Thursday 8:15 am to 5:30 pm
Friday 8:15 am to 12:30 pm

First Name ____ Last Name ____ Badge ____

Position ____

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City / State ____ Zip Code ____

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Mail to: Center for Professional Development
College of Engineering and Applied Sciences
Arizona State University
Tempe, AZ 85287-7506
Phone: 602/965-1740
FAX: 602/965-8296

Fee and Location

The registration fee of **$815 per course** includes all costs of instruction, lecture notes, copies of the software, parking and refreshment breaks. It does not include meals or hotel accommodations. The courses will be held at the Arizona State University Engineering Center in the city of Tempe. Area hotels include:

Sheraton Tempe Mission Palms, 602/894-1400
Holiday Inn, 602/968-3451
Howard Johnson, 602/967-9431

The Center for Professional Development reserves the right to change instructors and to cancel or reschedule a program in the event of insufficient enrollment or unforeseen circumstances.

Refunds and Cancellations

The registration fee is fully refundable one week prior to the first day of each program. Registrants who do not attend and do not cancel are subject to the complete fee. Participant substitutions may be made at any time at no charge, prior to the seminar.

Enrollment

Early enrollment is advised. Enrollment is limited and will be accepted in the order of receipt at the Center. Fees may be paid by check or money order, or by a billing to your organization. Please make all remittances payable, in U.S. funds, to Arizona State University. Payments by VISA, MasterCard and American Express are also accepted.

Enroll by phone, FAX, or mail:

Phone: 602/965-1740
FAX: 602/965-8296
Mail to: Center for Professional Development
College of Engineering and Applied Sciences
Arizona State University
Tempe, AZ 85287-7506

For further information about the program content or enrollment procedure, contact us at the phone number listed above.

Unsteady Flow Modeling Using DAMBRK and DWOPER

May 11 - 15, 1992

Presenters: L. Mays and D. Fread

This short course is intended for individuals involved with work relating to open channel hydraulic analysis and design, flood forecasting, dam safety analysis, reservoir operation, etc. Participants should also possess a background in steady flow open channel hydraulics.

The course consists of detailed lectures and workshops. The workshops are designed around realistic problems and consist of developing the DAMBRK and DWOPER input for workshop problems. Participants will have "hands-on" use of the program on PC's. A copy of the computer program will be available, on diskette, for each participant to take back to the work place. Questions from participants and open discussion are encouraged during lectures as well as during the workshop sessions.

Program

- Development of the mathematical model for dynamic routing with topics on derivation of Saint-Venant equations, finite difference approximations, solution technique, initial and boundary conditions
- DAMBRK model description including cross sections, frictional resistance, breach formation, lateral inflows, etc.
- DAMBRK input procedure description
- Applications of DAMBRK (Teton Dam failure, Buffalo Creek Dam failure, multiple dam application, bridge embankment failure simulation)
- Trouble shooting DAMBRK and limitations of DAMBRK
- Simplified Dam Break (SMPDBK) model description
- Breach analysis (BREACH) model description
- Dynamic Wave Operational Model (DWOPER) model description and capabilities including tributary junctions, internal boundaries, and gate operations
- DWOPER input and output and detailed descriptions of applications
- Storm sewer and network options in DWOPER
- New developments and the FLDWAV model

Flood Plain Hydraulics Using HEC-2

April 27 - May 1, 1992

Presenters: L. Mays and V. Bonner

This short course is intended for individuals having some experience in open channel flow hydraulics. Previous experience with HEC-1 or HEC-2 is not required.

The course consists of lectures and discussions, followed by workshops. These workshops are designed around real problems and utilize practical applications. The HEC-2 computer program, developed at the U.S. Army Corps of Engineers Hydrologic Engineering Center, is the primary educational vehicle for this course. Workshops involve "hands-on" use of the program on PC's. A copy of the computer program will be available, on diskette, for each participant to take back to the work place. Questions from the participants and open discussions are encouraged during lectures, as well as during workshop sessions. **Participants will need to bring a hand calculator.**

Program

- Open channel flow
  - Energy concepts
  - Gradually varied flow theory
  - Backwater analysis methods
- HEC-2 computer program
  - General program features
  - Input preparation
  - Output analysis
  - Normal and special bridge methods
  - Floodway determination
  - Channel improvements
  - Several applications
- Water surface profiles
  - Channel and overbank changes
  - Flow through bridges
  - Special modeling problems
  - Floodway determination
  - Channel design concepts
  - Case Studies

Presenters

Larry W. Mays (Course Director), Department Chair - Civil Engineering, Arizona State University. Dr. Mays has recently joined the faculty ranks of ASU after thirteen years at the University of Texas at Austin. In Texas, he was also the Director of the Center for Research in Water Resources. He has published extensively in the areas of water resources and hydrology. He co-authored the book *Applied Hydrology* by V.T. Chow, D.R. Maidment and L.W. Mays, and was an editor of Reliability Analysis of Water Distribution Systems published by the American Society of Civil Engineers. In addition he has consulted both in the U.S. and internationally, and has served as an expert witness on several drainage and floodplain cases. He has had extensive experience teaching hydrology, hydraulics and unsteady flow modeling, and in the application of HEC-1, HEC-2, HEC-6, DAMBRK, and DWOPER computer codes. He is a registered professional engineer in eight states and a registered professional hydrologist with the American Institute of Hydrology.

David Ford, Consulting Hydrologist - Sacramento, California. Dr. Ford has more than 15 years of experience in hydrologic engineering and specializing in the application of U.S. Army Corps of Engineers HEC-1 computer code. He is a registered professional engineer in Texas and California and is a part time faculty member at the California State University - Sacramento and the University of California - Davis. Dr. Ford received his B.S., M.S. and Ph.D. degrees for the University of Texas at Austin.

Danny L. Fread, Director - Hydrologic Research Laboratory, U.S. National Weather Service, NOAA, Washington, D.C. Dr. Fread has had more than 23 years experience in the development of software for modeling unsteady flow in rivers and reservoirs. His DAMBRK and DWOPER computer programs are used extensively throughout the U.S. and in many countries for the modeling of unsteady flows. Dr. Fread has published extensively on unsteady flow modeling and has had extensive experience in teaching the use of his computer programs.

Vernon Bonner, Hydraulic Engineer - U.S. Army Corps of Engineers' Hydraulic Engineering Center, Davis, California. Mr. Bonner has spent 20 years with the Hydrologic Engineering Center and 7 years with the California State Department of Water Resources. He has been intimately involved with the development, application and up-dating of HEC-2. He is a registered professional engineer in California.

Winter 1992

Course Catalog

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DSS Applications for HEC Models

Wednesday-Friday, January 8-10

This course provides instruction on use of DSS and extensive opportunities for hands-on practice with various applications of the program. DSS provides a wide array of output options to optimize the use of HEC models and to enhance one's presentation of output information. *Non-credit.*

(Section 913E600) Sacramento: University Extension Sacramento Center / Wednesday-Friday, 8 a.m.-5 p.m. / January 8-10 / $550 (includes course materials & 1 dinner) / Pre-enroll by January 2.

Computational Fluid Dynamics

Friday & Saturday, January 10 & 11

For information call (916) 757-8899.

Scanning Electron Microscopy

Sunday-Friday, February 2-7

Scanning Electron Microscopy offers practical training for using electron microscopy in the physical sciences. Lecture and lab sessions teach analytic procedures, specific applications and instrument operations. During lab sessions experts are available to discuss specific applications or problems related to your work. *Non-credit.*

(Section 913C101) Davis: Ramada Inn / Sunday, 4-8 p.m. (registration & reception), Monday-Thursday, 8 a.m.-5 p.m., & Friday, 8 a.m.-1 p.m. / February 2-7 / $1,095 ($945 if you register prior to December 5) (includes course materials, lab supplies, reception & banquet / Pre-enroll by December 5.

Reservoir Operations: Microcomputer Applications with Computer Program HEC-5

Monday-Friday, February 10-14

The course covers reservoir operations for flood control, hydropower, pumped storage and conservation, and features hands-on computer experience with analysis of workshop results. Participants solve a variety of reservoir operation problems and gain practical experience in using the model for operating on existing reservoir systems, in designing systems or analyzing reservoir operations. *Non-credit.*

(Section 913E601) Sacramento: University Extension Sacramento Center / Monday-Thursday, 8 a.m.-4:30 p.m., Monday dinner, 6 p.m.-8:30 p.m., Friday, 8 a.m.-12 noon / February 10-14 / $750 (includes course materials & 1 dinner) / Pre-enroll by February 3.

Water Surface Profile Computation Using Program HEC-2 on Microcomputers

Monday-Friday, March 30-April 3

This intensive one-week course covers hydraulic engineering techniques for flood plain studies. Emphasis is on the computation of water surface profiles in rivers using the computer program HEC-2, developed by the Hydraulic Engineering Center in Davis. Lectures and workshops provide a background in hydraulic principles and experience in using the program. *Non-credit.*

(Section 913E602) Sacramento: University Extension Sacramento Center / Monday-Thursday, 8 a.m.-4:30 p.m., Monday dinner, 6 p.m.-8:30 p.m., Friday, 8 a.m.-12 noon / March 30-April 3 / $750 (includes course materials, diskettes & 1 dinner) / Pre-enroll by March 23.

Freezing Technology Short Course

Monday-Thursday, February 3-6

Intended for management and supervisory personnel, quality control personnel, and line supervisors in the frozen foods industry, this course is designed to train operating personnel to make better on-the-job decisions by better understanding the "whys" of what they do. Limited to 50 enrollees. Early enrollment is advised. *Non-credit.*

(Section 913E301) Davis: University Club, UCD / Monday-Thursday, 8 a.m.-5 p.m. / February 3-6 / $450 (includes course materials & lunches) / Pre-enroll by January 27.

Better Process Control School

Monday-Thursday, March 16-19

This FDA-approved school is being held in conjunction with the California Cannery Inspection Authority and U.S. Food and Drug Administration. Technical instruction in the school is given by staff members of the University of California, the National Food Processors Association, and select industry experts. Instruction includes lectures, discussions and examinations. Certificates are awarded to those who satisfactorily complete the course. *Non-credit.*

(Section 913E300) Davis: Freeborn Hall, UCD / Monday, 8:30 a.m.-5:30 p.m. (registration begins at 8 a.m.), Tuesday & Wednesday, 8 a.m.-5 p.m., & Thursday, 8 a.m.-3 p.m. / March 16-19 / $450 (includes text & lunches) / Pre-enroll by March 9.

Food Product Development/ Ingredient Technology

Monday-Wednesday, March 16-18

This course examines changing consumer eating and buying trends, regulatory constraints, and potential profitability of new products. It stresses a coordinated approach that integrates the business aspect of successful new product development and marketing with science, technology, regulation and innovative thinking. *Non-credit.*

(Section 913E302) Davis: University Club, UCD / Monday & Tuesday, 8 a.m.-5 p.m., Wednesday, 8 a.m.-4 p.m. / March 16-18 $499 (includes course materials, 3 lunches & 1 dinner) / Pre-enroll by March 9.

For Additional References

see Part V of

HEC-2 Reviewer's Guidelines and Checklists

U.S. ARMY CORPS OF ENGINEERS HEC-1

FLOOD HYDROGRAPH PACKAGE

INTRODUCTORY COURSE FOR FUNDAMENTAL UNDERSTANDING OF HEC-1

February 21, 1992

8:00- 8:15 **OPENING REMARKS** Chuck Williams

8:15- 8:30 **I. INTRODUCTION** Tom Loomis

A. Course Outline.

B. Choice of a Hydrologic Model.

C. History of HEC-1.

D. When to use HEC-1.

8:30- 9:30 **II. WATERSHED MODELING** Tom Loomis

A. Example of a typical watershed: East Fork Cave Creek.

B. Watershed breakdown and sub-basin delineation.

C. Precipitation and rainfall distributions.

D. Rainfall losses.

E. Time of concentration and lag time.

F. Hydrograph generation.

G. Hydrograph channel routing.

H. Channel routing considerations.

I. Hydrograph operations.

9:30-10:00 **III. PROGRAM INPUT** Pat Marum

A. General.

B. Job initialization records.

C. Job type records.

D. Hydrograph generation records.

E. Precipitation records.

F. Hydrograph transformation and diversion records.

G. Hydrograph routing records.

H. Sample input file.

10:00-10:15 **BREAK**

10:15-10:45 **IV. PROGRAM OUTPUT** Pat Marum

A. General

B. Output options.

C. Sub-basin output

D. Hydrograph routing.

E. Hydrograph combining.

F. Summary tables.

G. Sample problem and appropriate support documentation.

10:45-11:30 **V. REVIEWER'S CHECKLIST AND REFERENCES** Amir Motamedi

A. Checklist.

B. References.

11:30-12:00 **VI. DISCUSSION AND WRAP-UP** Chuck Williams

A. ADWR: Instructions For Organizing and Submitting Technical Documentation For Flood Study, September, 1991.

B. Where to go for help.

INTRODUCTION

This session is intended to be a review of watershed modeling and to present common coding errors made using computerized methods such as HEC-1 and TR20. This is **not** a replacement for a detailed course such as the 1-week short course on HEC-1 offered by ASU, or similiar courses sponsored by the SCS for TR20. It is intended to be a supplement to such courses and will present a more practical side to the use of computerized methods. This session will be centered around HEC-1 since the trend in the state is toward the use of simulation models such as S-graphs, the Clark unit hydrograph, or the Kinematic Wave method. These methods, and associated loss methods, cannot be readily applied using TR20. We have assumed a basic knowledge of watershed modeling and surface water hydrology. Detailed knowledge of HEC-1 is not necessary.

Introduction - The history of HEC-1 will be discussed as well as when the use of modeling techniques is appropriate.

Watershed Modeling - Description of how a watershed model is developed.

HEC-1 Program Input and Output Overview

Reviewer's Checklist and References

CHOICE OF A HYDROLOGIC METHOD

1. When to use modeling techniques.

   - Valid statistical information is not available.
   - The study watershed is ungaged.
   - Combining, routing, and diverting of hydrographs is necessary.
   - Evaluating design alternatives.
   - Forecasting of future conditions.

2. When approximate methods are appropriate:

   - Rational method.

     Watershed areas less than 80 acres.
     Routing and combining of hydrographs is not necessary.
     Peak discharges are needed, not runoff volumes.

   - TR-55.

     Watershed areas with a T_c greater than 10 min. and less than 2 hours.
     24 hour duration storm.
     Single hydrograph generation.
     Channel hydrograph routing is not necessary.

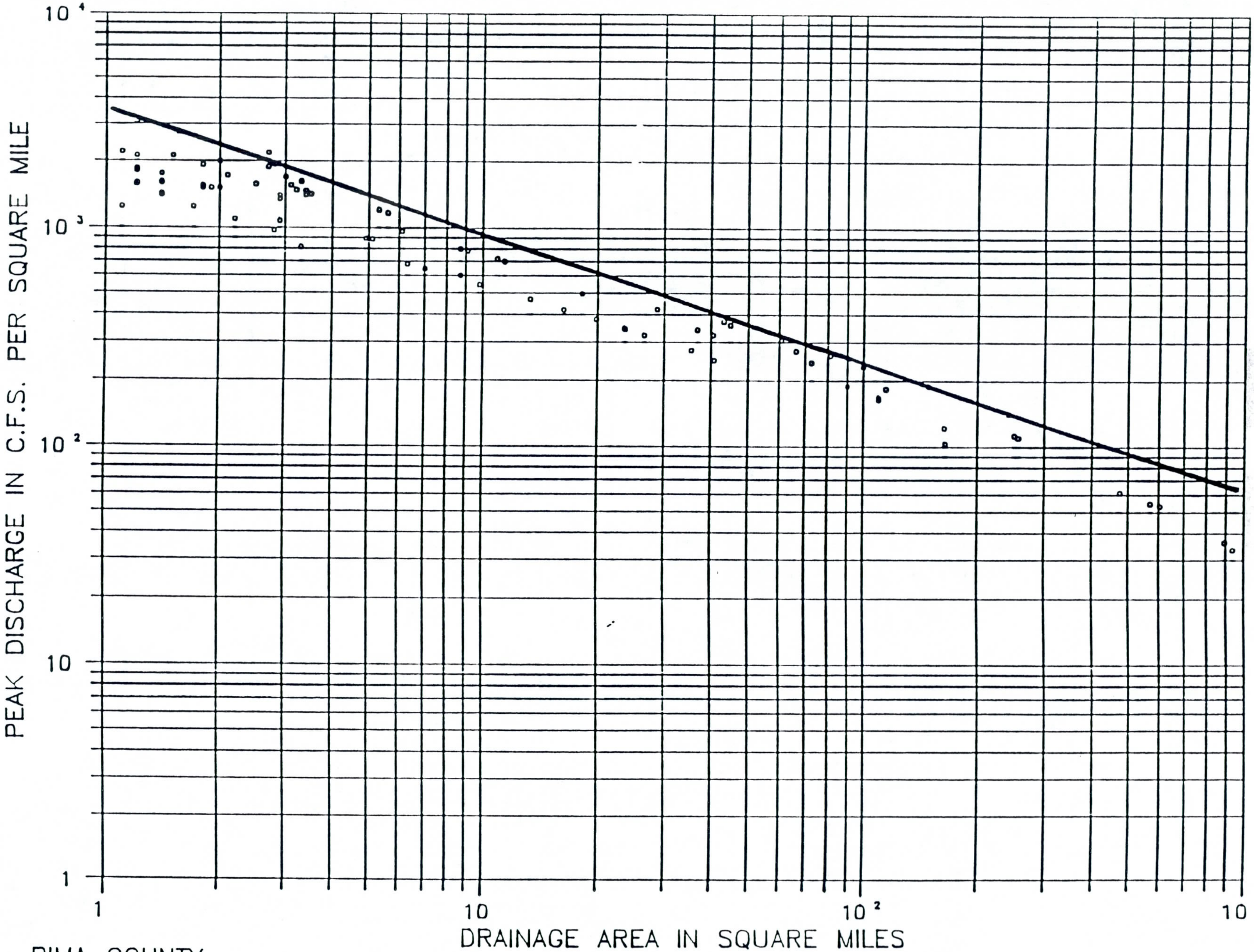
   - Envelope curves.

     Checking reasonableness of discharges estimated by other methods.

3. Computer models commonly used in Arizona.

   - HEC-1.
   - SCS TR-20.
   - SCS TR-55.
   - City of Tucson Method
   - Pima County Peak Method

BASED ON F.I.S. STUDIES OF RECORD

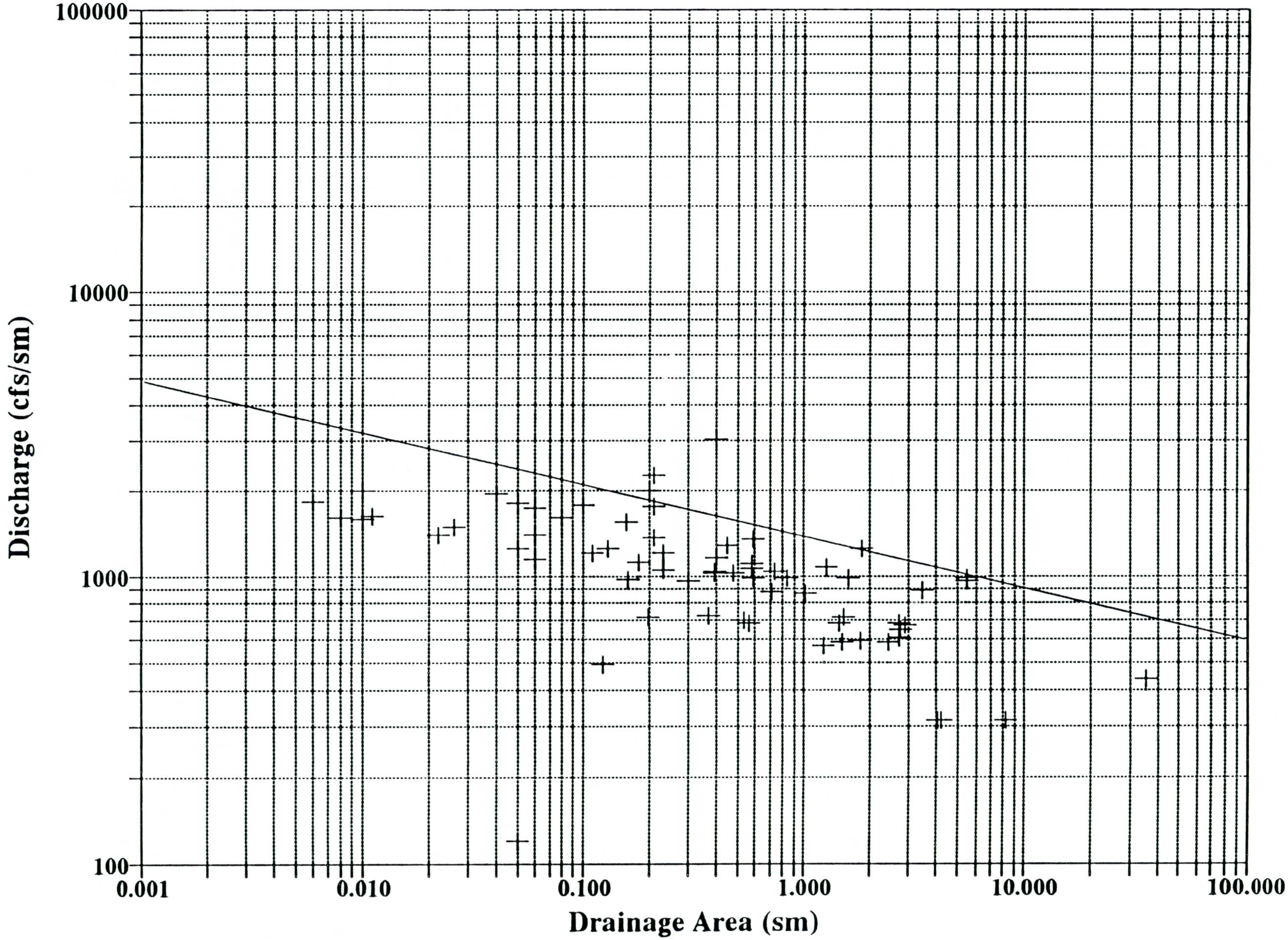


PIMA COUNTY
ENVELOPE CURVE

ENVELOPE CURVE FOR BULLHEAD CITY, AZ

100-Yr, 24-Hr, Existing Condition

Based on Subdivision and Public Works Drainage Reports of Record



HISTORY OF HEC-1

- **1967** Program was originally developed by HEC.

- **1968** First version of the *Package* program was released.

- **1973** Input and output capabilities were revised. The program was expanded, revised and republished.

- **1981** Major Revision:

    1. Input formats were revised.
    2. Dam Break Analysis was added.
    3. Project optimization was added.
    4. Kinematic Wave capability was added.

- **1984** The PC (microcomputer) version was released, short the flood damage and ogee spillway capabilities.

- **1988** Significant improvements made:

    1. Green-Ampt infiltration function was added.
    2. Kinematic Wave runoff computations were improved.
    3. All main-frame computer options made available in the PC version.
    4. Error using Green-Ampt with JD records.

- **1990** Various improvements made:

    1. Muskingum-Cunge channel routing was added.
    2. Improved detention basin modeling.
    3. Interface to HEC Data Storage System (DSS).
    4. Error using JR record with Kinematic Wave runoff. Hydrographs do not combine properly.

- **1991** 80386/486 specific extended/expanded memory version.

WHY HEC-1 WAS DEVELOPED

1. Designed to simulate the surface runoff response of a river basin to precipitation.

2. Accomplished by representing the basin as a **system** of hydrologic and hydraulic components.

3. These components may represent:

   - A surface runoff entity (a sub-basin).
   - A stream channel.
   - A reservoir.

4. The components are represented by:

   - A set of parameters which describe the characteristics of the component.
   - Mathematical relationships which describe the physical process involved.

5. The **BOTTOM LINE:**

   - To compute streamflow hydrographs at desired locations in the river basin.

THEORETICAL ASSUMPTIONS OF HEC-1

1. HEC-1 is a deterministic, lumped, unsteady model.

2. It forecasts results and does not consider the randomness of variables.

3. The hydrologic processes can be represented by model parameters which reflect **average** conditions within a subarea.

4. If the parameters don't meet this criteria, then:

   - Spacial Parameters - Break down the watershed into smaller sub-basins.

   - Temporal Parameters - Decrease the computation time interval.

KEY LIMITATIONS OF HEC-1

1. Only a single storm can be applied. Provisions are not made for soil moisture recovery during periods of no precipitation.

2. Model results are in terms of discharge rates and runoff volumes, not stage.

3. Streamflow routings are performed by hydrologic routing methods and do n reflect the full Saint-Venant equations.

4. Reservoir routings are based on modified Puls techniques. One can:

   - Simulate outflow over a spillway.
   - Simulate outflow through a low level outlet.
   - Specify a schedule of releases over time.

WHAT HEC-1 IS USED FOR TODAY IN ARIZONA

- Watershed planning.
- Flood Insurance Studies.
- LOMR's, CLOMR's, and LOMA's.
- PMF dam safety and design studies.
- Retention and detention basin design

WATERSHED MODELING

- EXAMPLE OF A TYPICAL WATERSHED
- SUB-BASIN DELINEATION
- PRECIPITATION AND RAINFALL DISTRIBUTIONS
- RAINFALL LOSSES
- TIME OF CONCENTRATION AND LAG TIME
- HYDROGRAPH GENERATION
- HYDROGRAPH CHANNEL ROUTING
- CHANNEL ROUTING CONSIDERATIONS
- HYDROGRAPH OPERATIONS

WATERSHED BREAKDOWN AND SUB-BASIN DELINEATION

1. Time of Concentration and Lag Time.

- T_c is the travel time, during the corresponding period of most intense rainfall, for a flood wave to travel from the hydraulically most distant point in the sub-basin.

- T_L is usually defined as the time from the center of mass of rainfall to the hydrograph time of peak, or to the center of mass of runoff.

$$T_L = 0.6 * T_c \text{ (for SCS method)}$$

- The minimum basin size is a function of T_c and NMIN.

NMIN = Integer number of minutes for tabulation interval.

NMIN $<=$ $0.15 * T_c$ (must be evenly divisible by 60).

NQ = Integer number of hydrograph ordinates.

NMIN*NQ must be at **least** as long as the storm duration.

The **BOTTOM LINE**:

- The minimum sub-basin area and corresponding T_c should correlate with the governing time interval for the modeling program and storm duration used.

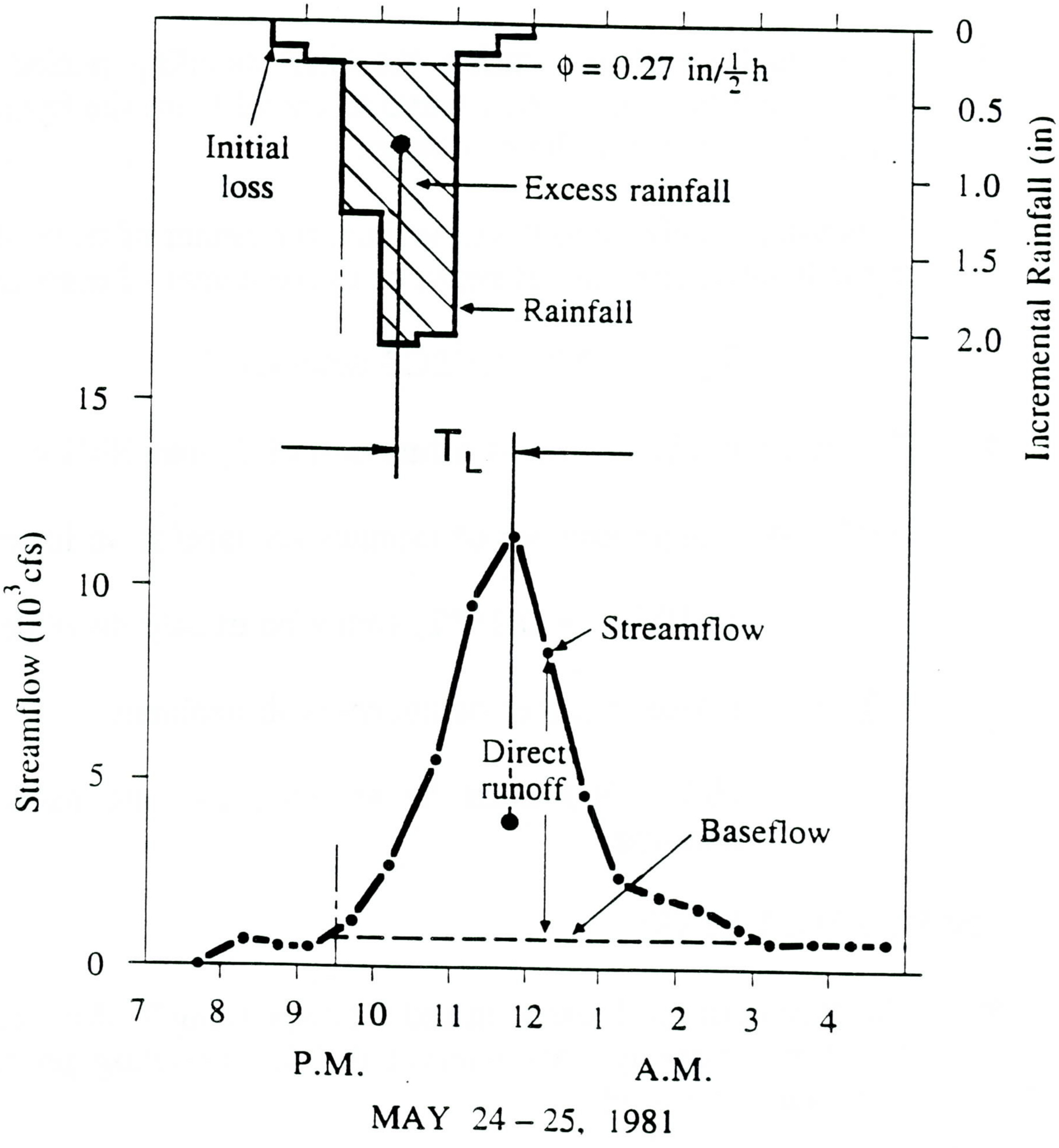
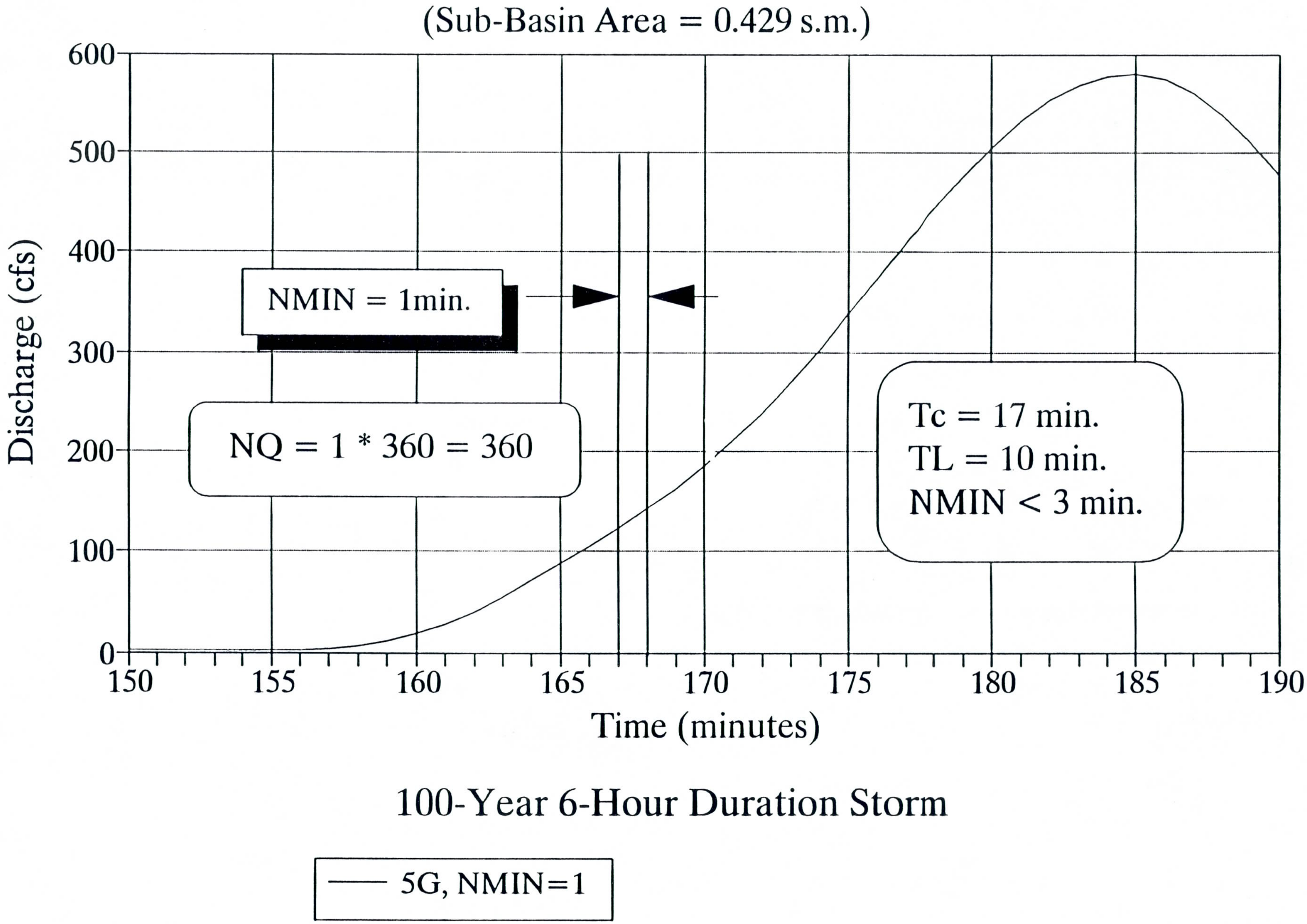
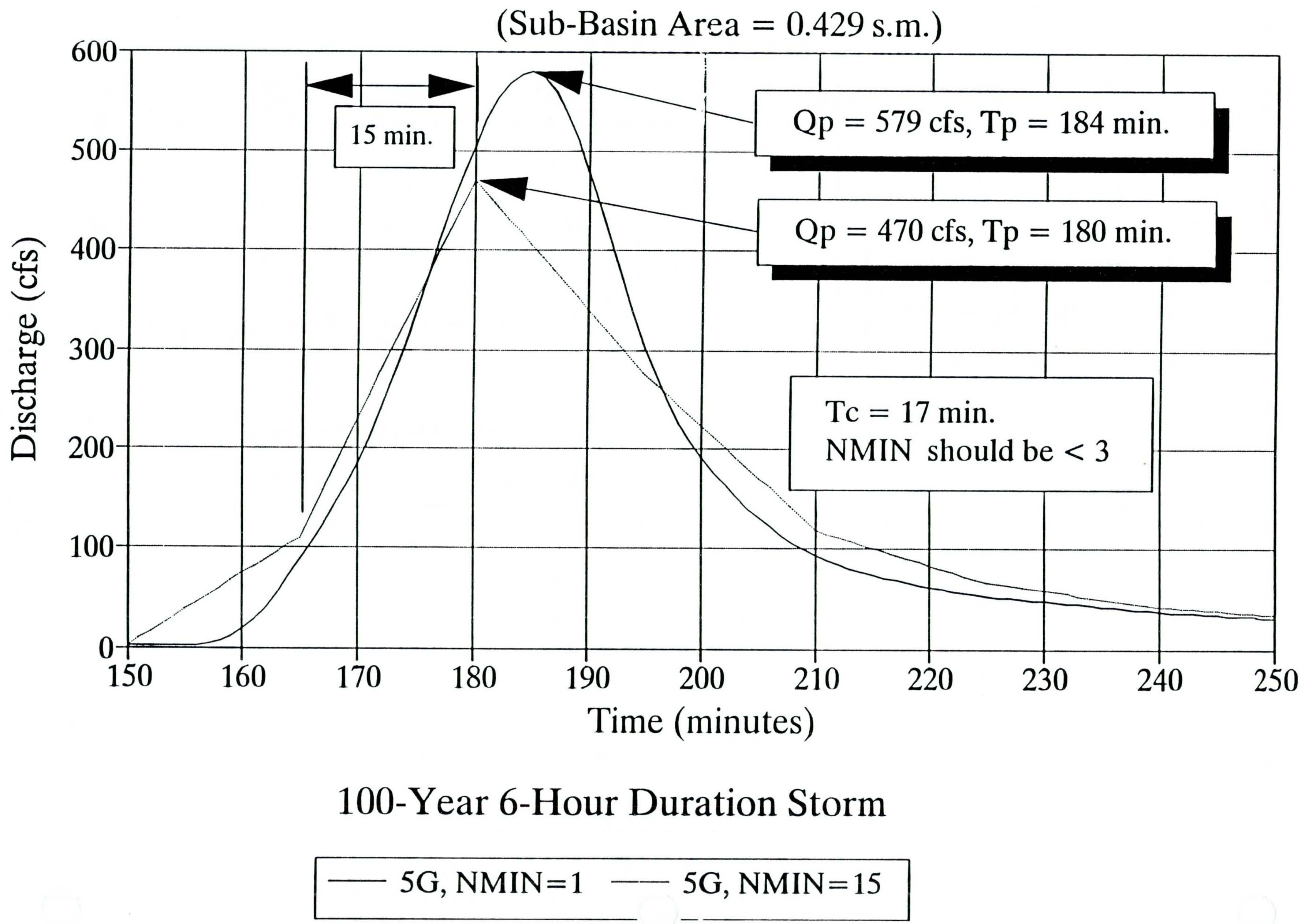

0
0.5
1.0
1.5
2.0
Incremental Rainfall (in)
ϕ = 0.27 in/$\frac{1}{2}$h
Initial loss
Excess rainfall
Rainfall
15
10
5
0
Streamflow (10^3cfs)
T_L
Streamflow
Direct runoff
Baseflow
7
8
9
10
11
12
1
2
3
4
P.M.
A.M.
MAY 24 – 25, 1981

FIGURE 5.3.1

MOON VALLEY WASH
SUB-BASIN 5G



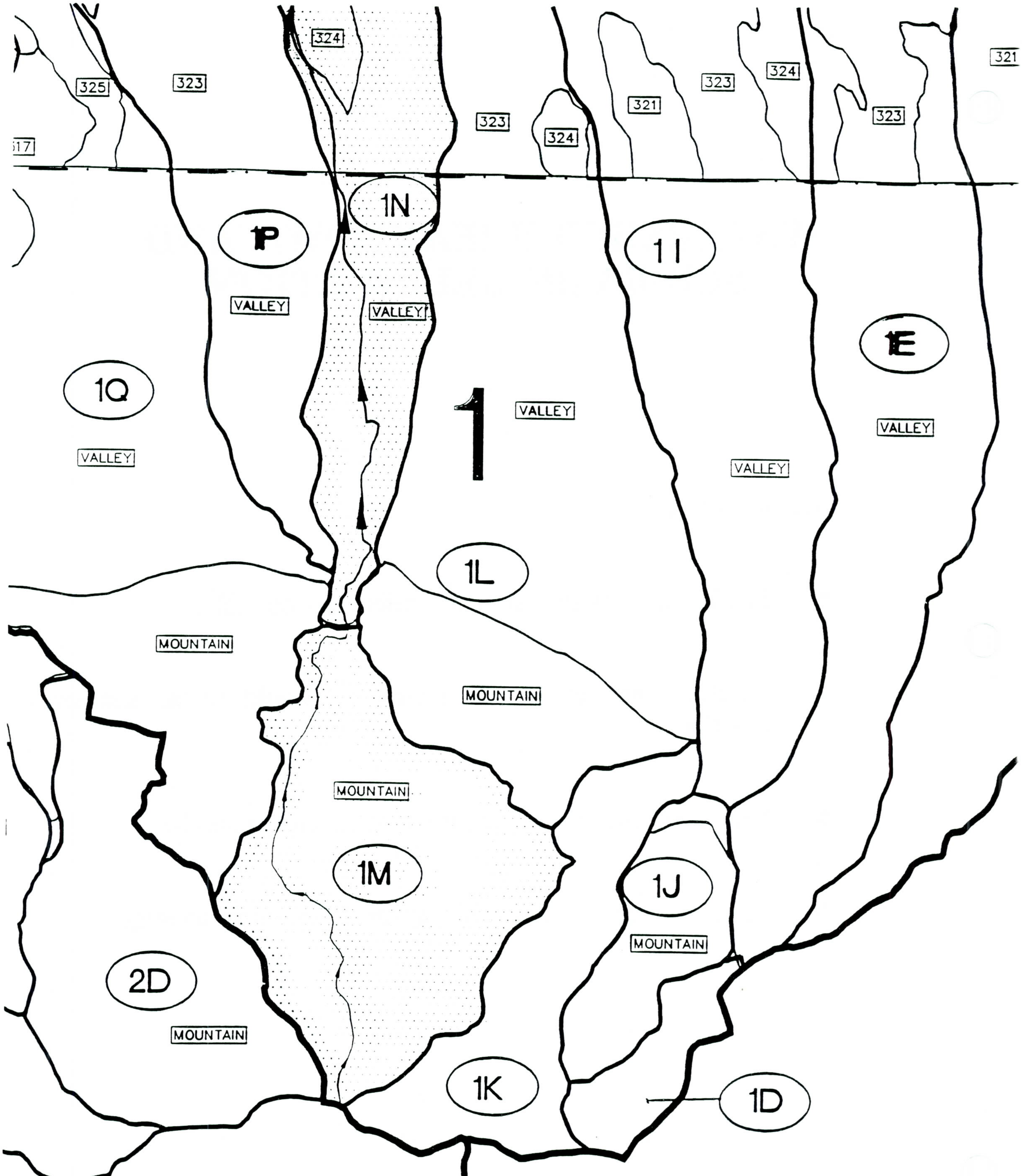
MOON VALLEY WASH
SUB-BASIN 5G



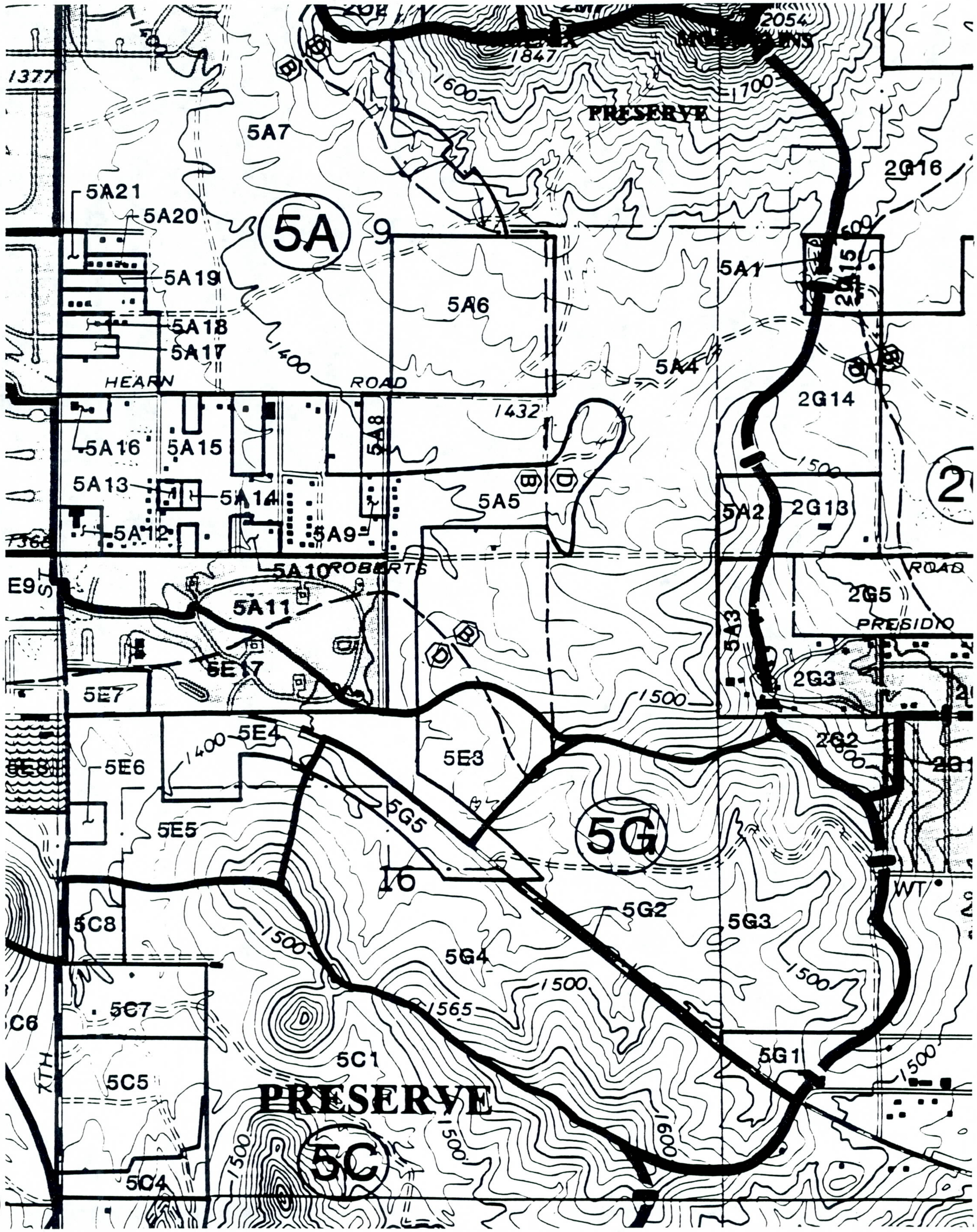
WATERSHED BREAKDOWN AND SUB-BASIN DELINEATION

2. **Homogeneity.**

- Sub-basin areas should be as uniform as possible.
- Landuse and surface characteristics should be as similiar as possible.
- Soils and vegetation characteristics should be similiar.
- Select a target sub-basin area to strive for as an average.



SAMPLE SUB-BASIN SOIL AND TERRAIN CHARACTERISTICS MAP, GILA BEND, AZ



SAMPLE SUB-BASIN LANDUSE MAP FOR MOON VALLEY WASH

WATERSHED BREAKDOWN AND SUB-BASIN DELINEATION

3. **Appropriate routing lengths.**

- Sub-basin delineation should consider channel reach route lengths.

  $NSTPS = L/(V_{avg} * NMIN)$

- Each reach length should be long enough that the NSTPS >= 1.0

  $L = NSTPS * (V_{avg} * NMIN)$

  For $V_{avg} = 5$ fps, NMIN = 5 min.:

  $L = 1*5*60*5 = 1500$ feet.

4. **Concentration points.**

- Confluences of washes.
- Significant structures.
- Jurisdictional boundaries.

PRECIPITATION, AND RAINFALL DISTRIBUTIONS

1. **Actual rainfall versus design rainfall.**

   - Actual rainfall is random and highly variable.
   - Design rainfall is a point precipitation derived by frequency analysis.
   - Total rainfall (point precipitation) can be obtained from a rainfall atlas.
   - Temporal distributions are used to simulate the variation in rainfall over for a design storm.
   - Spatial distribution.

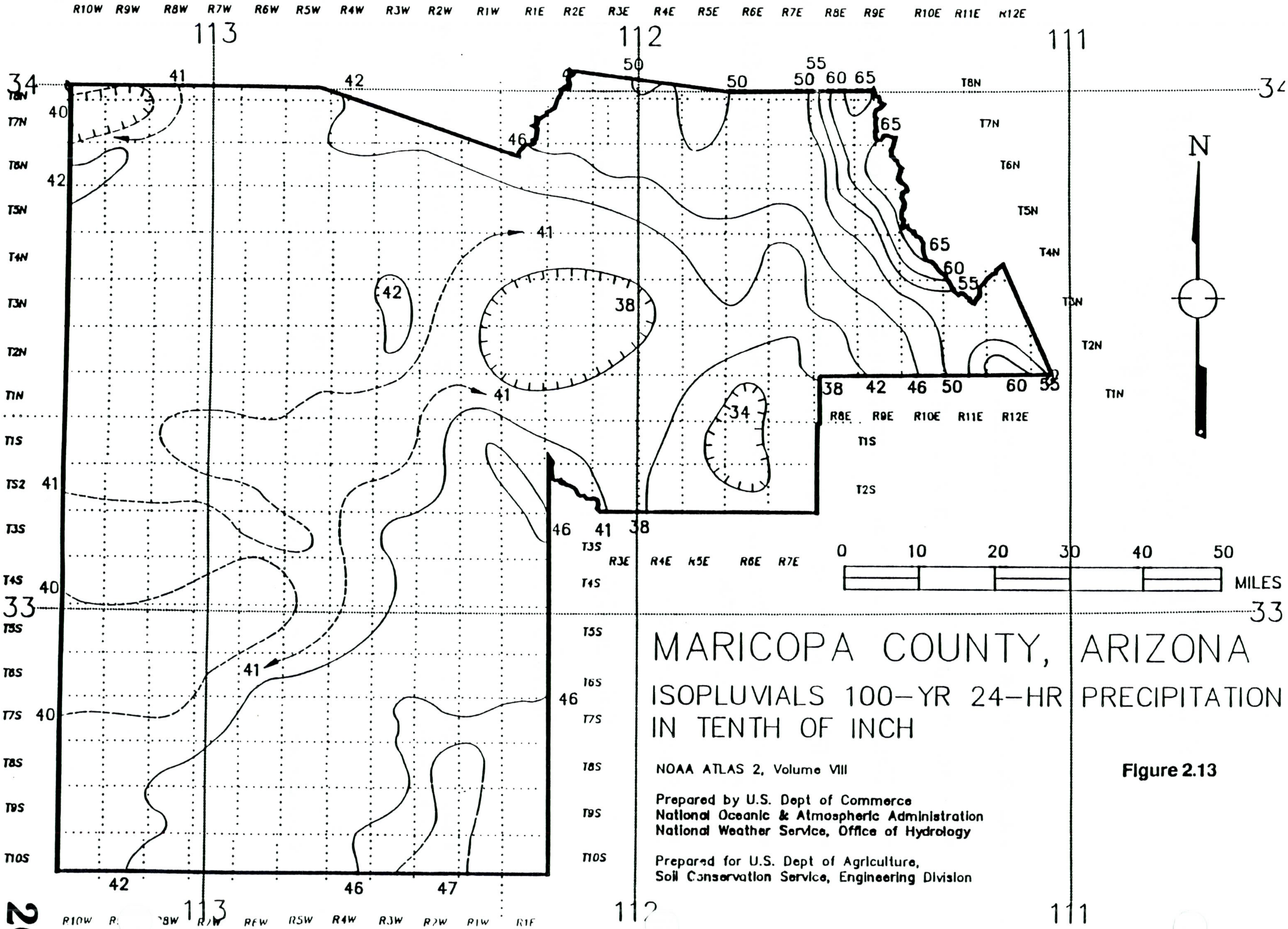
     Point precipitation is assumed to fall evenly over the sub-basin.

     Spatial distribution is simulated using areal reduction curves.

2. **Rainfall atlas's used in Arizona are the NOAA Atlas II, 1973 and the forthcoming new state atlas.**

3. **Choice of a design storm duration is highly dependant on the characteristics of rainfall patterns for the study region.**

4. **The apparent cyclic nature of precipitation in Arizona.**



MARICOPA COUNTY, ARIZONA

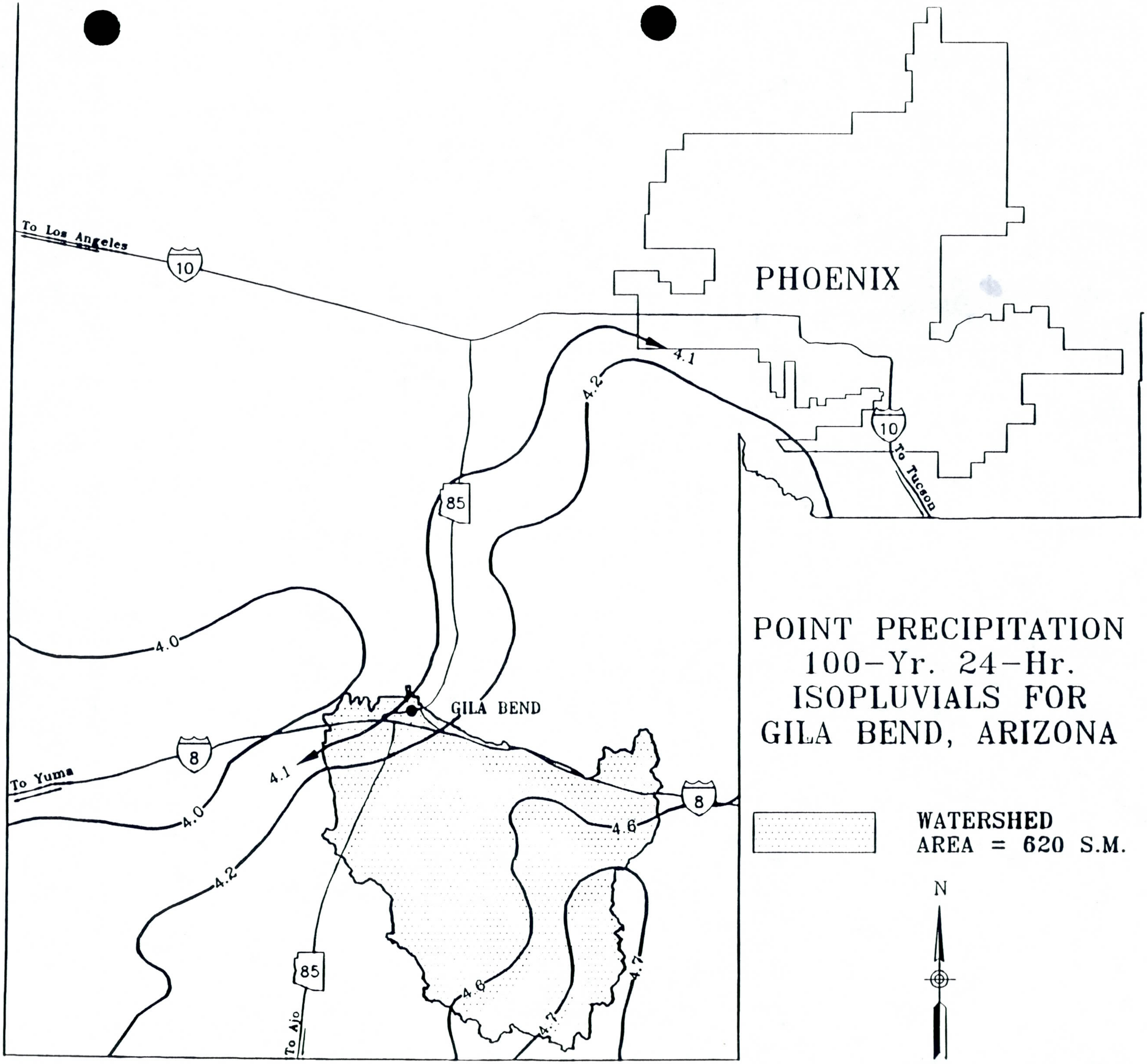
ISOPLUVIALS 100-YR 24-HR PRECIPITATION IN TENTH OF INCH

NOAA ATLAS 2, Volume VIII

Prepared by U.S. Dept of Commerce
National Oceanic & Atmospheric Administration
National Weather Service, Office of Hydrology

Prepared for U.S. Dept of Agriculture,
Soil Conservation Service, Engineering Division

Figure 2.13



POINT PRECIPITATION
100–Yr. 24–Hr.
ISOPLUVIALS FOR
GILA BEND, ARIZONA

WATERSHED
AREA = 620 S.M.

FROM NOAA Hydro - 40 (1984)
(Walnut Gulch ARS Experimental Watershed)

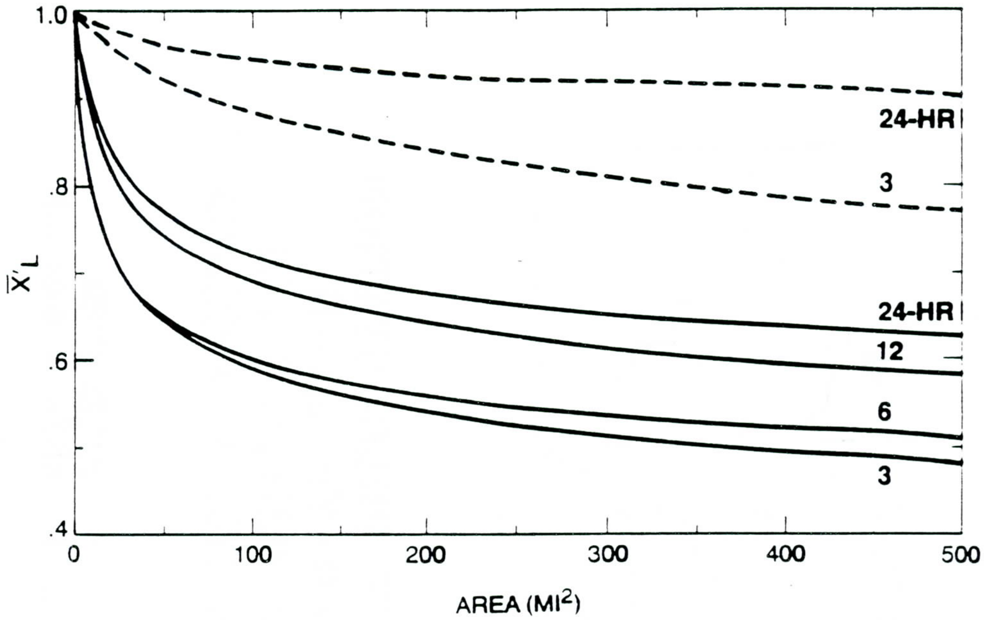


Figure 14.—$\bar{X}'_L$ (2.54-yr depth-area ratio, see sec. 4.3) for 3-, 6-, 12-, and 24-hr in southeast Arizona. Dashed lines are 3-hr and 24-hr Chicago $\bar{X}'_L$ (from TR 24)

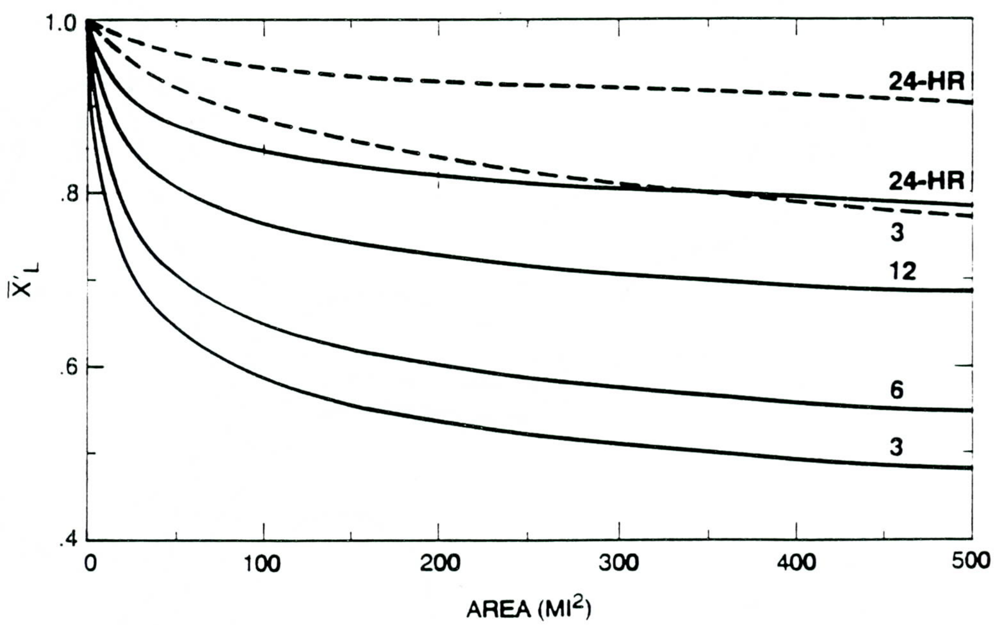
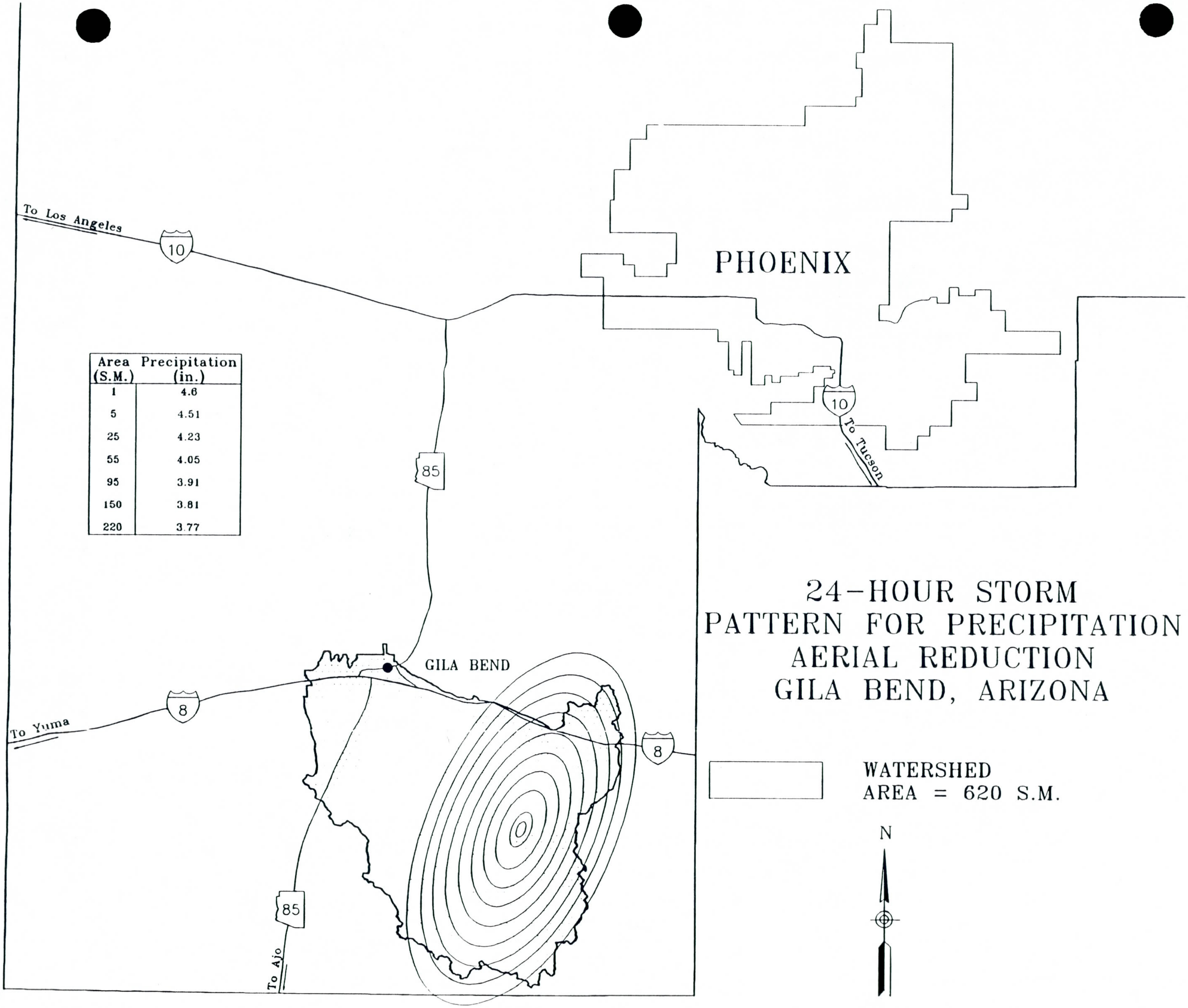


Figure 15.—Same as figure 14, but for central Arizona.

be attributed to a mixture of storm types, but still different from these found in the central Plains.

The recorder-pair data for distances greater than 15 mi contain little information on the structure of 1- and 2-hr storms. This is supported by the low



Area (S.M.)	Precipitation (in.)
1	4.6
5	4.51
25	4.23
55	4.05
95	3.91
150	3.81
220	3.77

24-HOUR STORM
PATTERN FOR PRECIPITATION
AERIAL REDUCTION
GILA BEND, ARIZONA

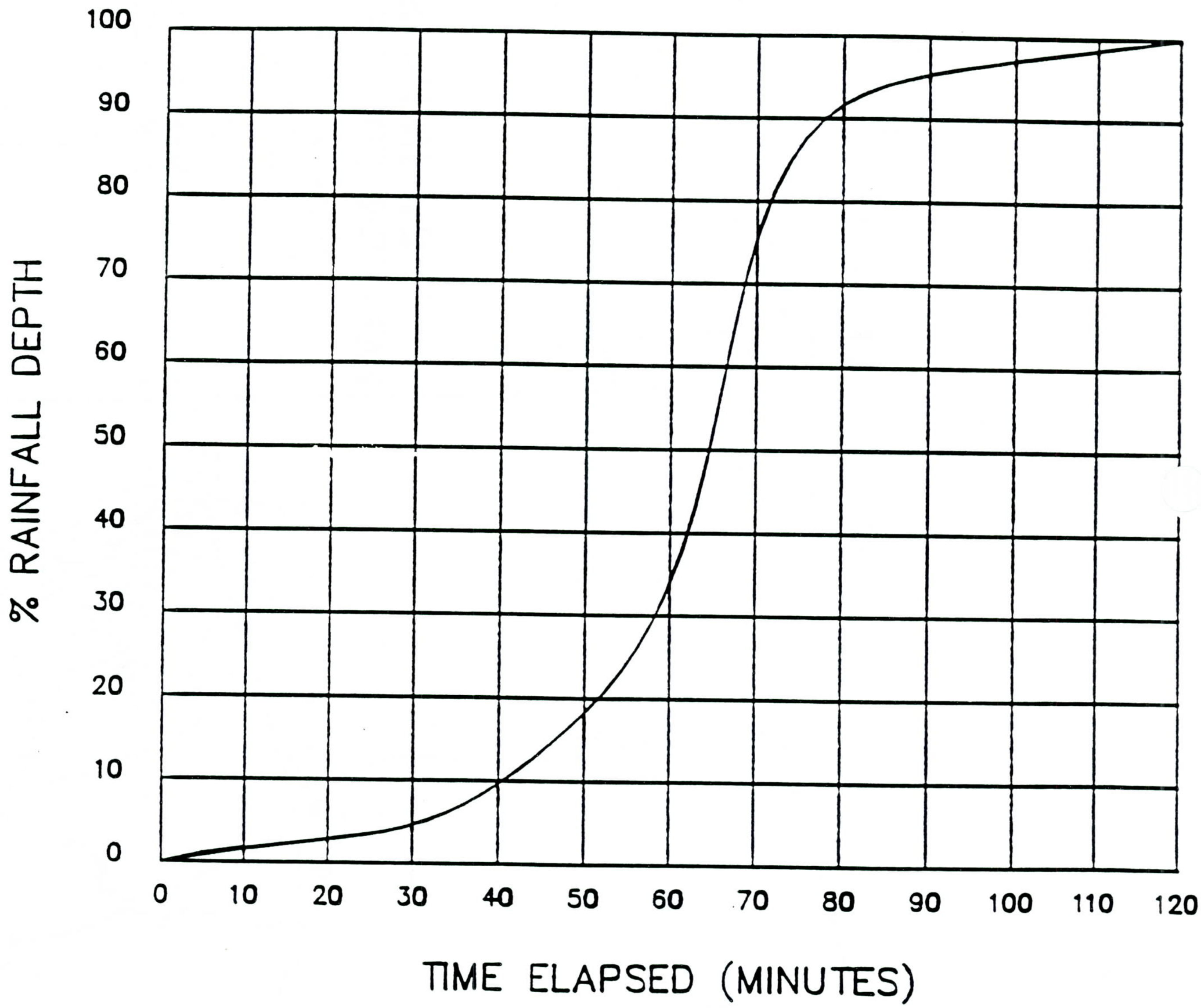


Figure 2.16
2-Hour Mass Curve for Retention Design

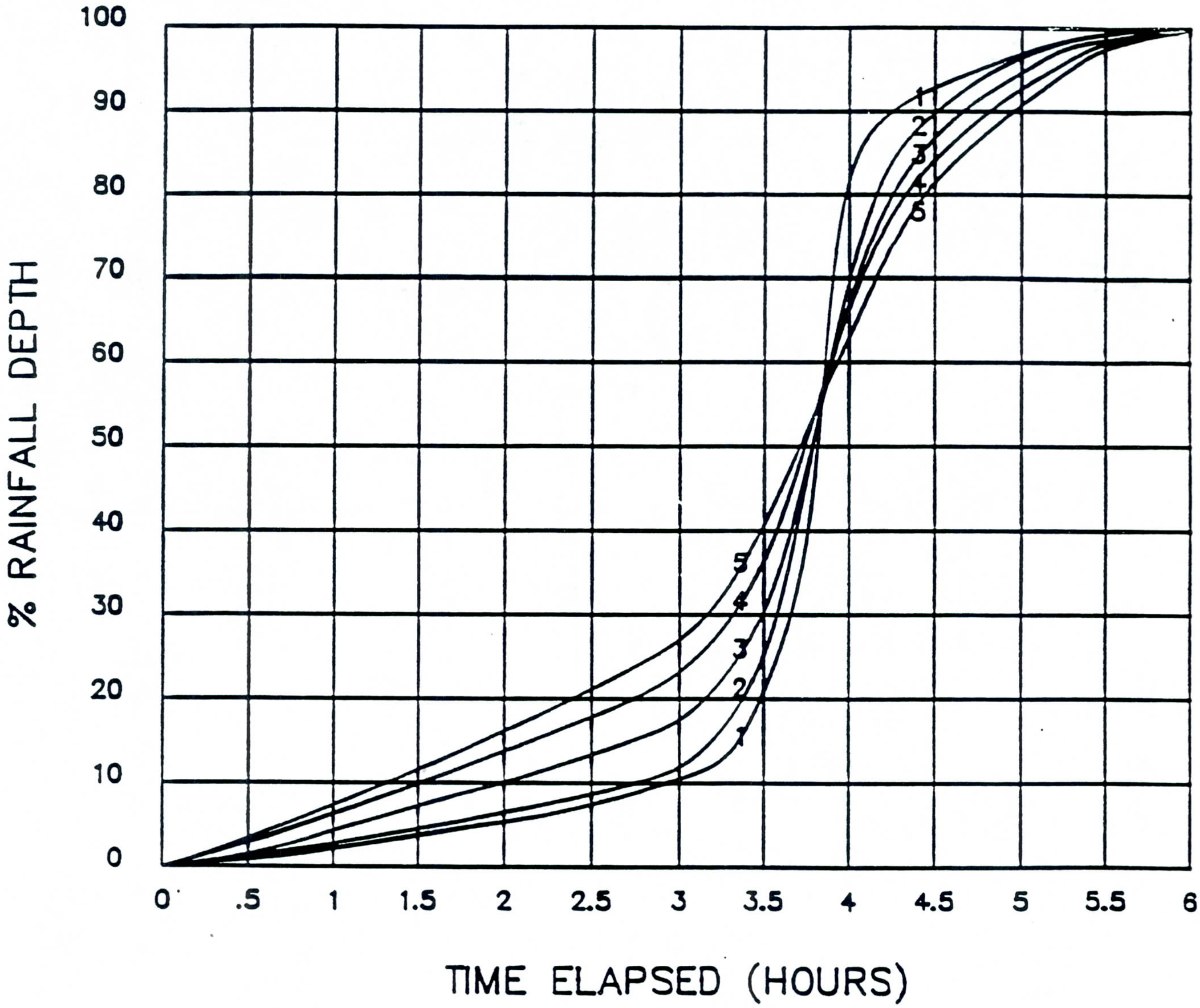
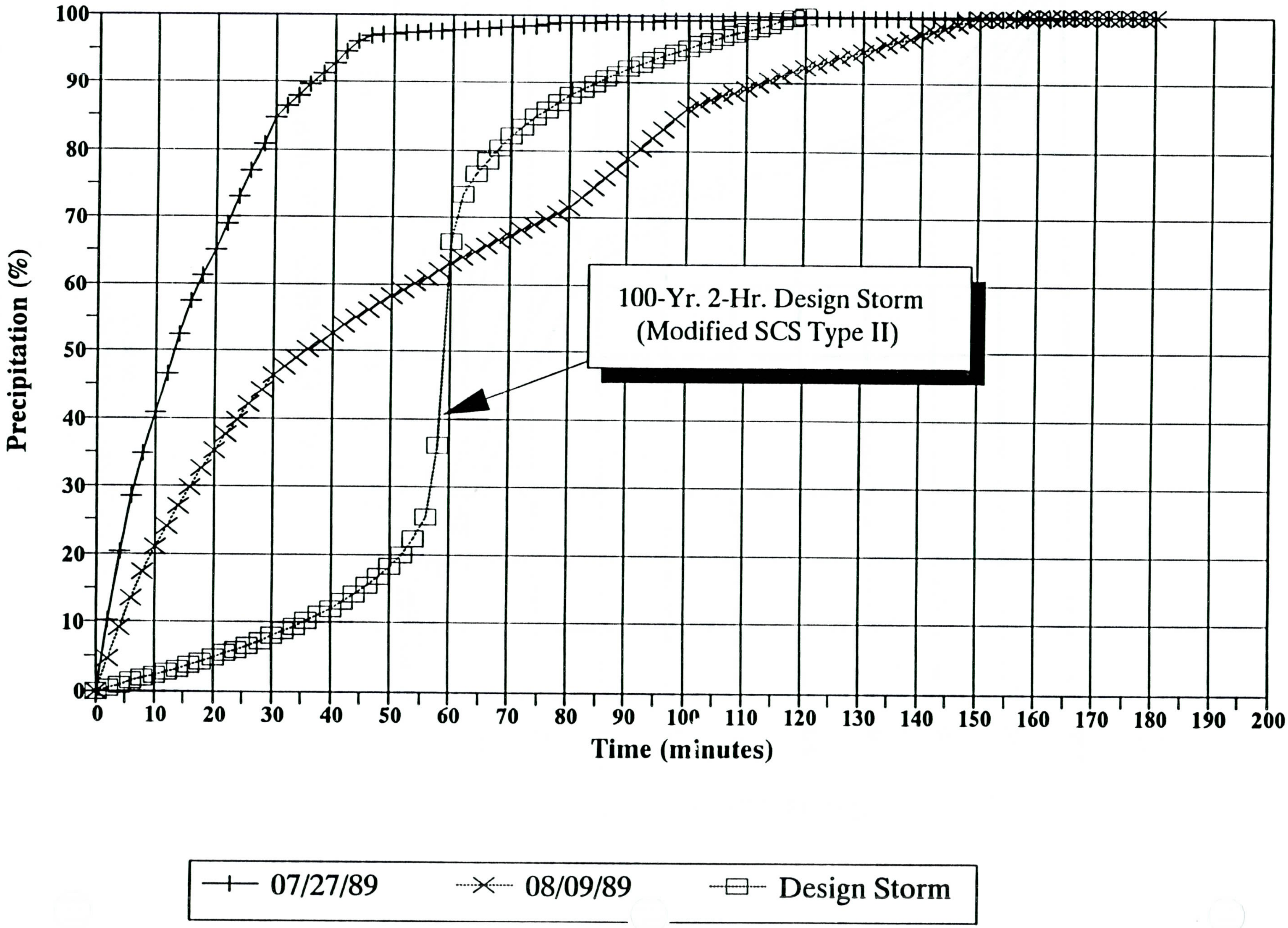


Figure 2.17
6-Hour Mass Curves for Maricopa County

FIGURE 1: Yuma Rainfall Distributions
July and August, 1989 and Design Storm



RAINFALL LOSSES

1. Loss rates are applied to the sub-basin by averaging parameter values assigned to each landuse and soil class present.

2. SCS curve numbers (empirically based).

3. Initial and uniform loss (empirically based).

4. Green-Ampt Loss Equation (physically based, can be derived using principles of continuity and momentum).

5. Developed watershed versus undeveloped.

   - Percent impervious must be taken into account.

     Most curve number values for urban landuses are adjusted for % impervious. A common error when using SCS methods is to apply a % impervious correction when this is already accounted for in the curve number. For example, using sub-basin 5E which consists of 1/4 acre lots:

     CN = 83 for SCS hydrologic soil group C.
     % Impervious for this landuse is 38%, per TR55.
     Q_{100} = 446 cfs using the CN value alone.
     Q_{100} = 855 cfs using the CN value and applying the % impervious.

   - Soil moisture condition on the watershed must be considered.

TIME OF CONCENTRATION AND LAG TIME.

1. The unit hydrograph method is generally very sensitive to the T_c value. A common coding error when using the SCS method under HEC-1 is to input the T_c instead of T_L. An example of the effects of an error of this type follows:

   Sub-basin 5G: $T_L = 0.17$ hours, $T_c = 0.28$ hours

   $Q_{100} = 579$ cfs using T_L correctly.
   $Q_{100} = 459$ cfs using the T_c value incorrectly.

2. T_c values should be checked closely to ensure that average velocities through the watershed are reasonable.

HYDROGRAPH GENERATION

1. Unit Hydrograph.

- SCS dimensionless unit hydrograph.
- Clark unit hydrograph.
- Snyder unit hydrograph.
- User input.

2. S-Graph Method.

A dimensionless form of the unit hydrograph generally developed by reconstituting observed floods. An S-Graph is selected and then a unit hydrograph is created externally to HEC-1.

3. Kinematic Wave.

HYDROGRAPH CHANNEL ROUTING

1. Physical data required.

- Channel hydraulic information representative of each reach.

  An 8-point cross section or cross section description.

  Reach length.

  Average reach slope.

  Manning's roughness estimates for the overbanks and the channel.

- An estimate of travel time through the reach approximating the fully developed flow wave travel time.

2. Routing methods available.

- *Normal depth* (modified puls) - For natural or inproved channels.

- *Muskingum* - For natural channels. Has two coefficients, X and K. Values of X vary from 0.0 to 0.5. The parameter K is the wave travel time through the reach.

- *Muskingum-Cunge* - Simulation of full dynamic wave routing.

- *Kinematic wave* - For improved channels and culverts, no attenuation. Generally not appropriate for friction slopes less than 1%.

- *Modified Att-Kin* - For natural or improved channels using a 2-pass method consisting of a storage route followed by a kinematic wave route.

- Simulation of transmission losses.

CHANNEL ROUTING CONSIDERATIONS

1. **Number of routing steps.**

NSTPS is generally equal to: L/(V*avg**NMIN)

The hydrograph attenuation associated with storage approximations based on NSTPS can vary dramatically if a reasonable value is not selected. An example is the channel reach downstream of sub-basin 1M from the Gila Bend study:

Sub-Basin 1M: Area = 2.19 sm, Q_{100} = 2018 cfs, T_p = 12.60 hours,

Routing Method = Normal depth, L = 28,600', S = 1.7%, NMIN = 3 min.

NSTPS = 33 (correct), Q_{100} = 1635 cfs, T_p = 14.25 hours

NSTPS = 3 (incorrect), Q_{100} = 1134 cfs, T_p = 14.30 hours

Travel Time (correct) = 14.25-12.60 = 1.65 hours

NSTPS = 1.65*60/3 min. = 33 steps.

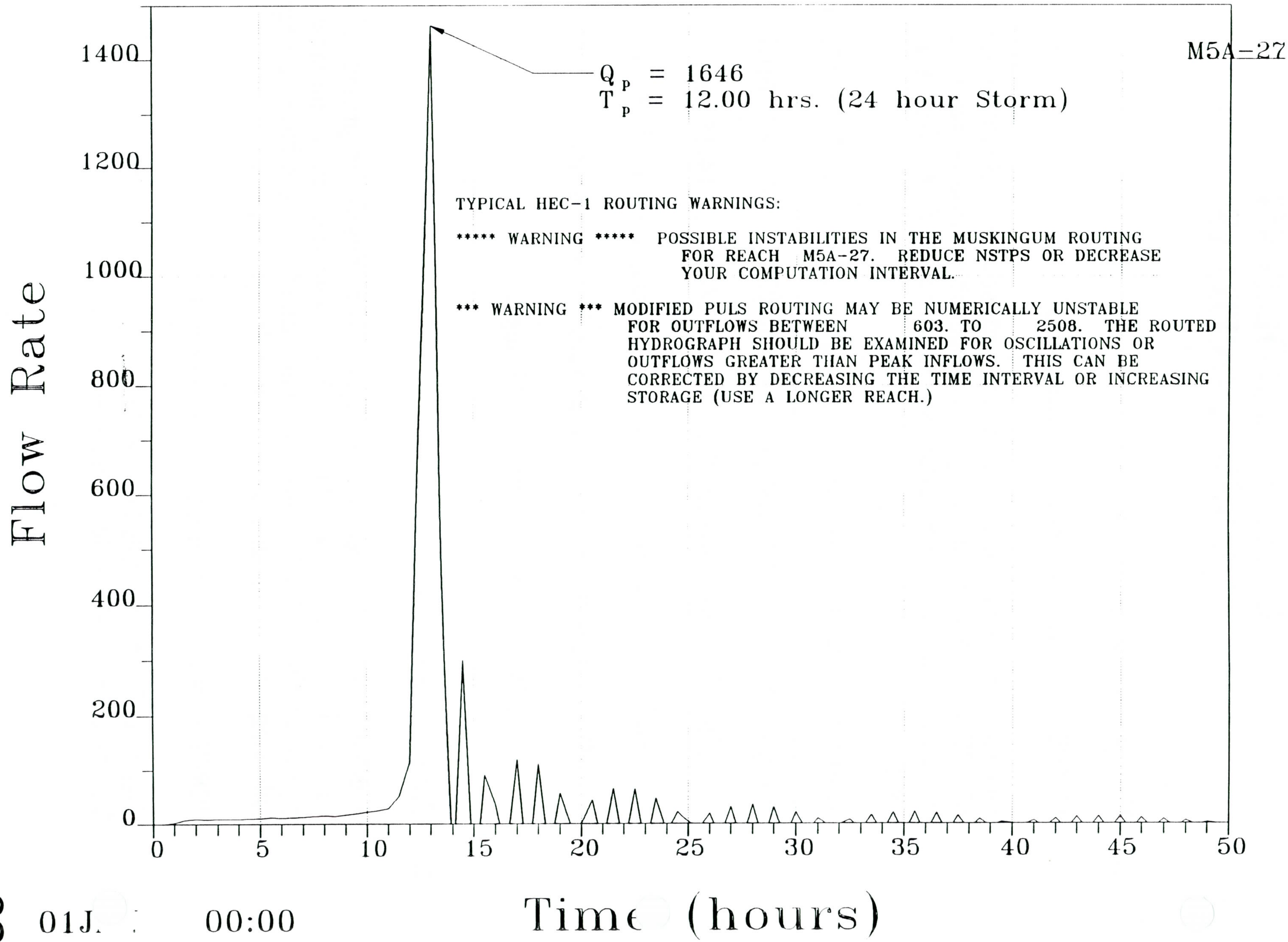
2. **Transmission losses.**

A common error in applying this option is to neglect to provide a value in field 4 of the RL record. This is the bottom elevation of the cross section typical of the reach. Using the Gila Bend 1M sub-basin example, the following are the results if an error of this type is made:

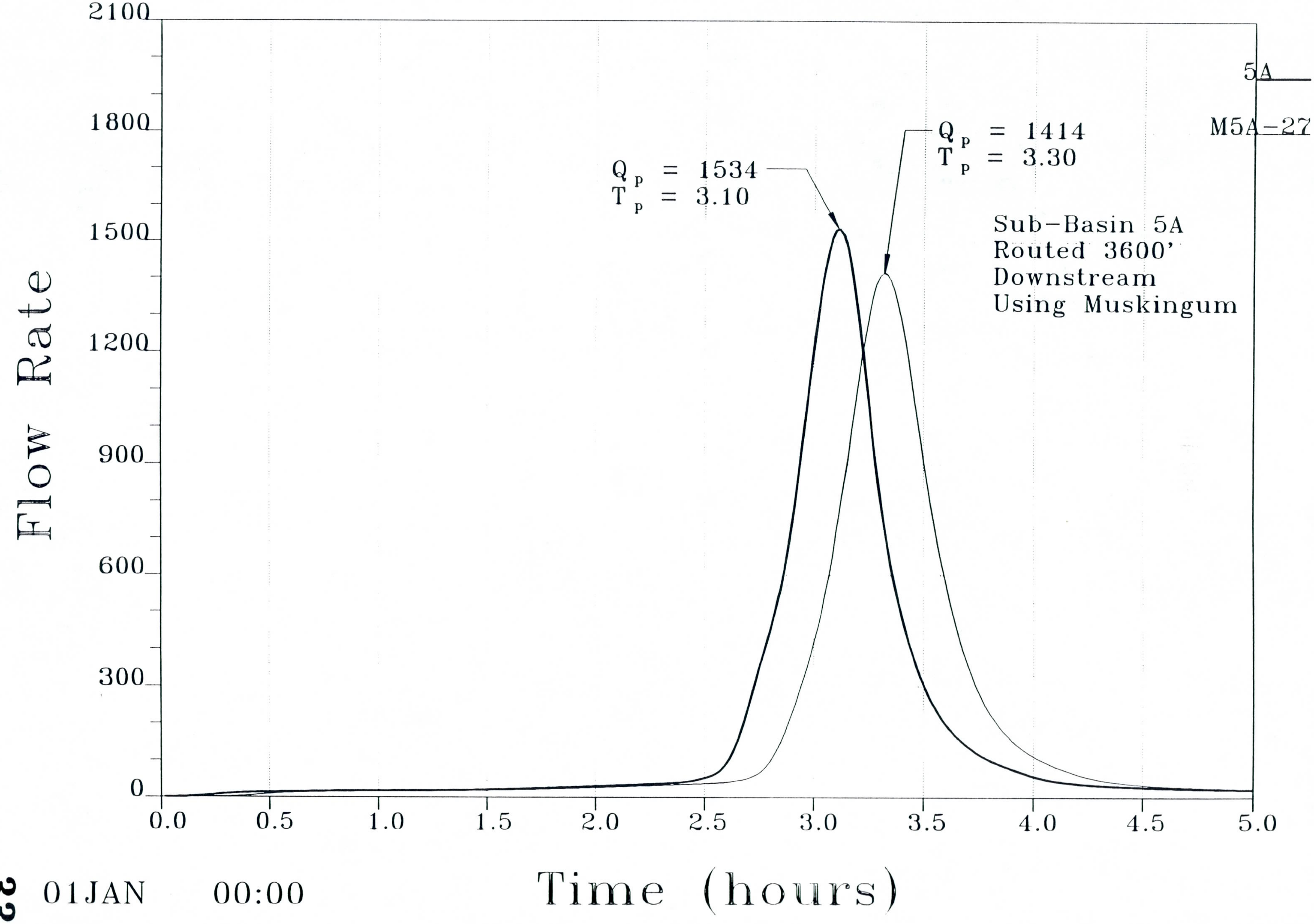
PERCRT = Percolation rate in cfs/acre = 1.7

Q_{100} = 1635 cfs if applied correctly.
Q_{100} = 1749 cfs if applied incorrectly.

MOON VALLEY WASH SUB-BASIN 5A ROUTED



MOON VALLEY WASH SUB-BASIN 5A



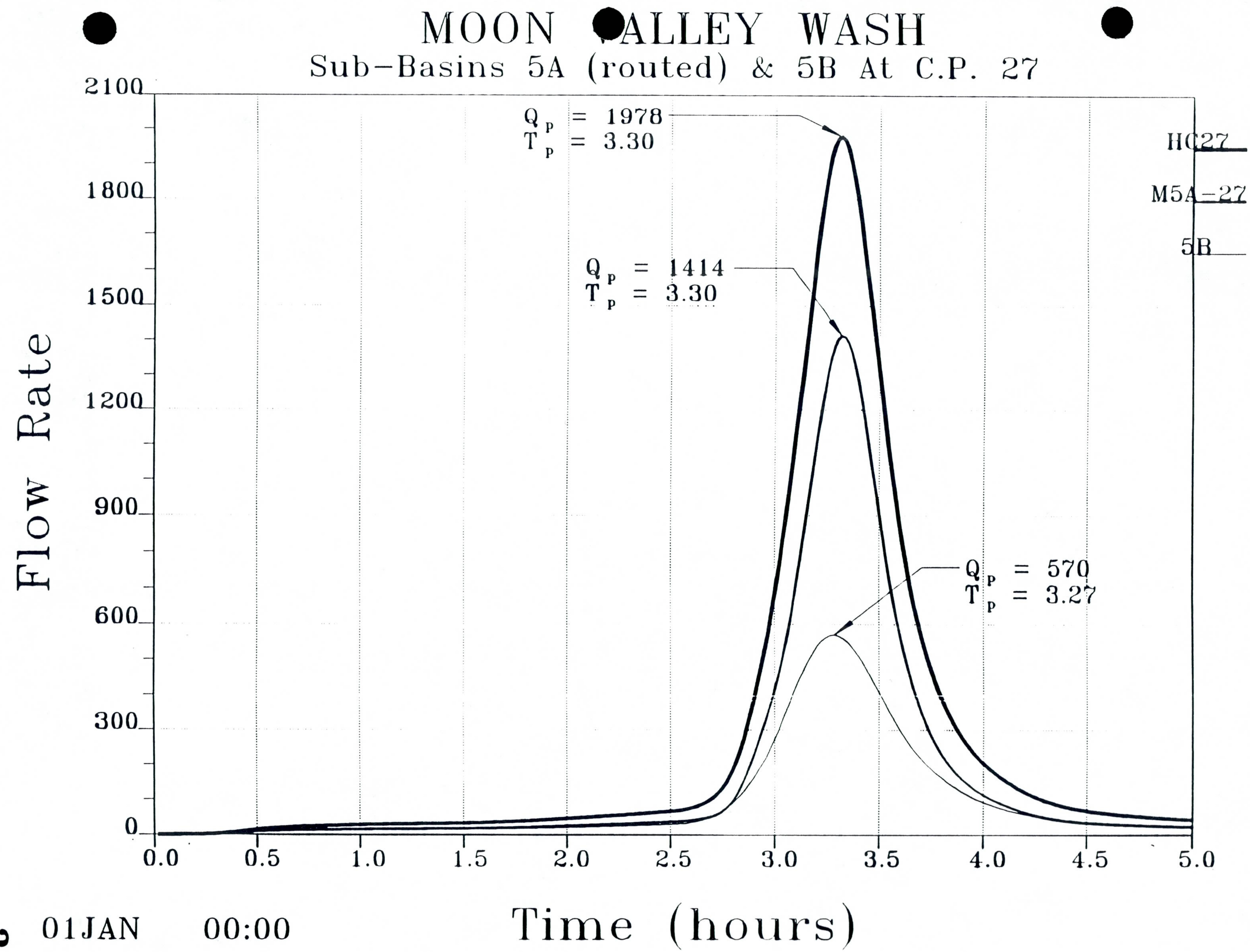
01JAN 00:00

HYDROGRAPH OPERATIONS

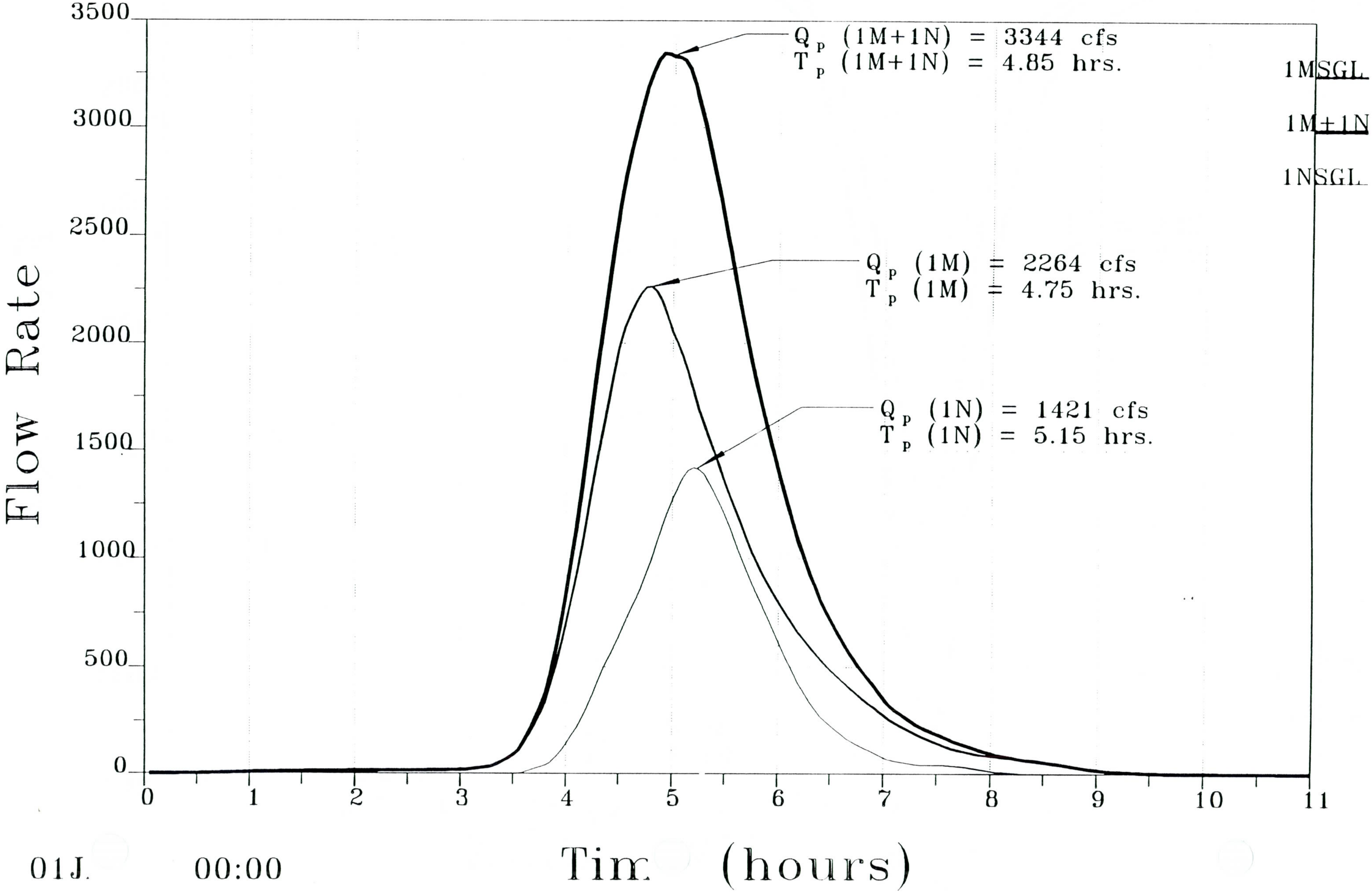
1. Combining hydrographs.

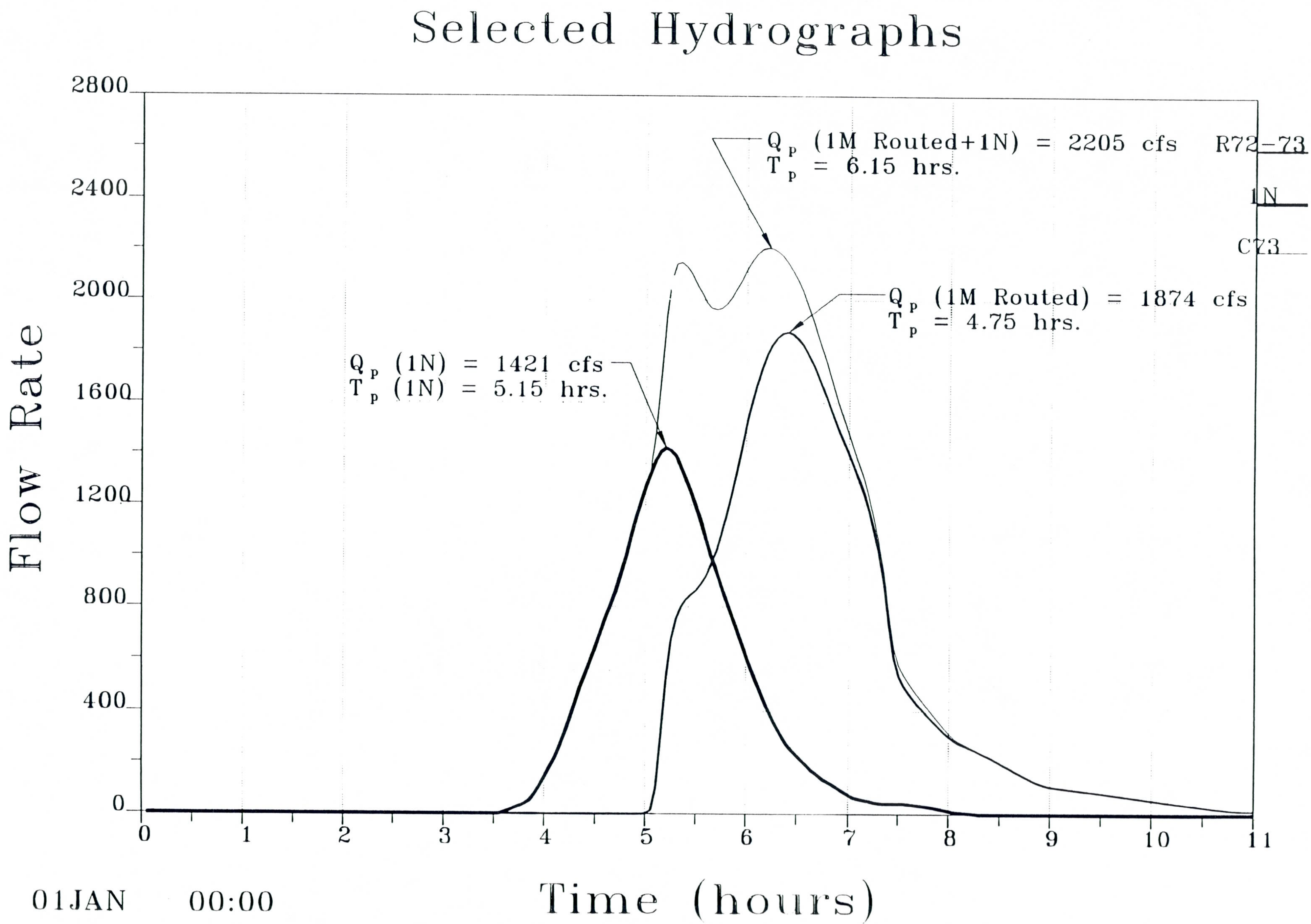
2. Diverting hydrographs.

3. Routing hydrographs.


MOON VALLEY WASH
Sub-Basins 5A (routed) & 5B At C.P. 27
Flow Rate
Time (hours)
2100
1800
1500
1200
900
600
300
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Q p = 1978
T p = 3.30
Q p = 1414
T p = 3.30
Q p = 570
T p = 3.27
HC27
M5A-27
5B
01JAN 00:00

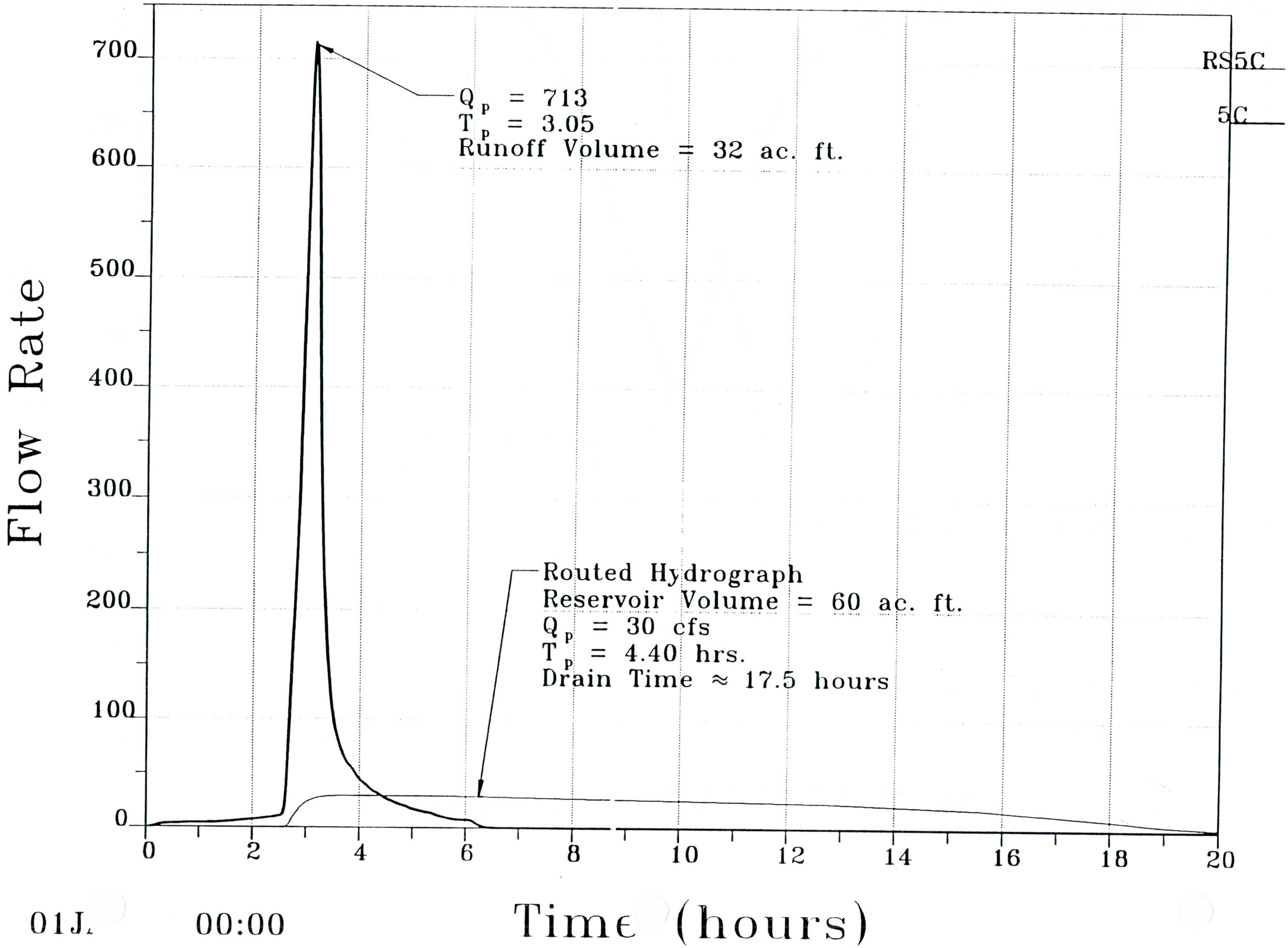
Selected Hydrographs




Selected Hydrographs
Flow Rate
2800
2400
2000
1600
1200
800
400
0
Q p (1M Routed+1N) = 2205 cfs
T p = 6.15 hrs.
Q p (1M Routed) = 1874 cfs
T p = 4.75 hrs.
Q p (1N) = 1421 cfs
T p (1N) = 5.15 hrs.
R72-73
1N
C73
0
1
2
3
4
5
6
7
8
9
10
11
Time (hours)
01JAN 00:00

MOON VALLEY WASH

Sub-Basin 5C Routed Through Detention Basin

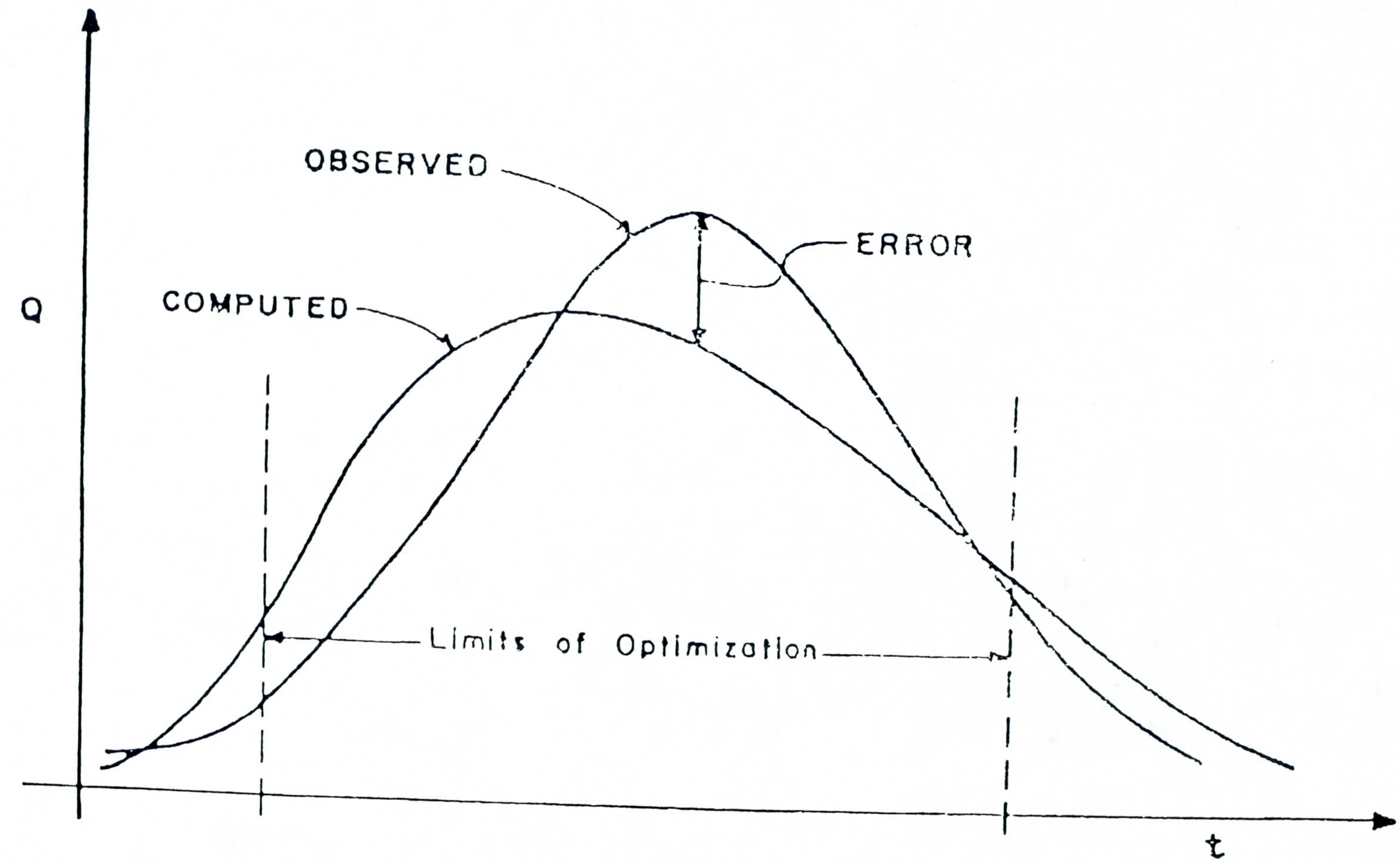


TYPICAL WATERSHED MODELING PROCESS

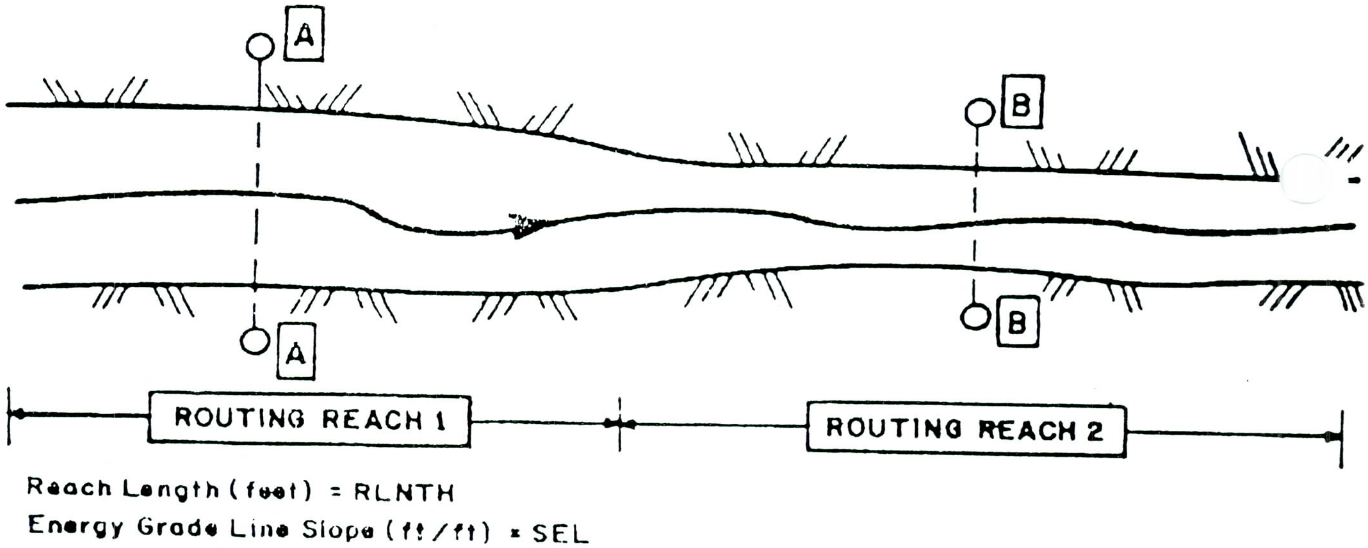
- Preparation of base mapping.
- Preliminary sub-basin delineation.
- Field Reconnaissance.
- Final sub-basin delineation.
- Determine statistical parameters.
- Determine physical parameters.

  Sub-basin areas.
  Time of Concentration and Lag Time.
  Rainfall losses.
  Landuse and terrain classifications.
  Routing parameters.

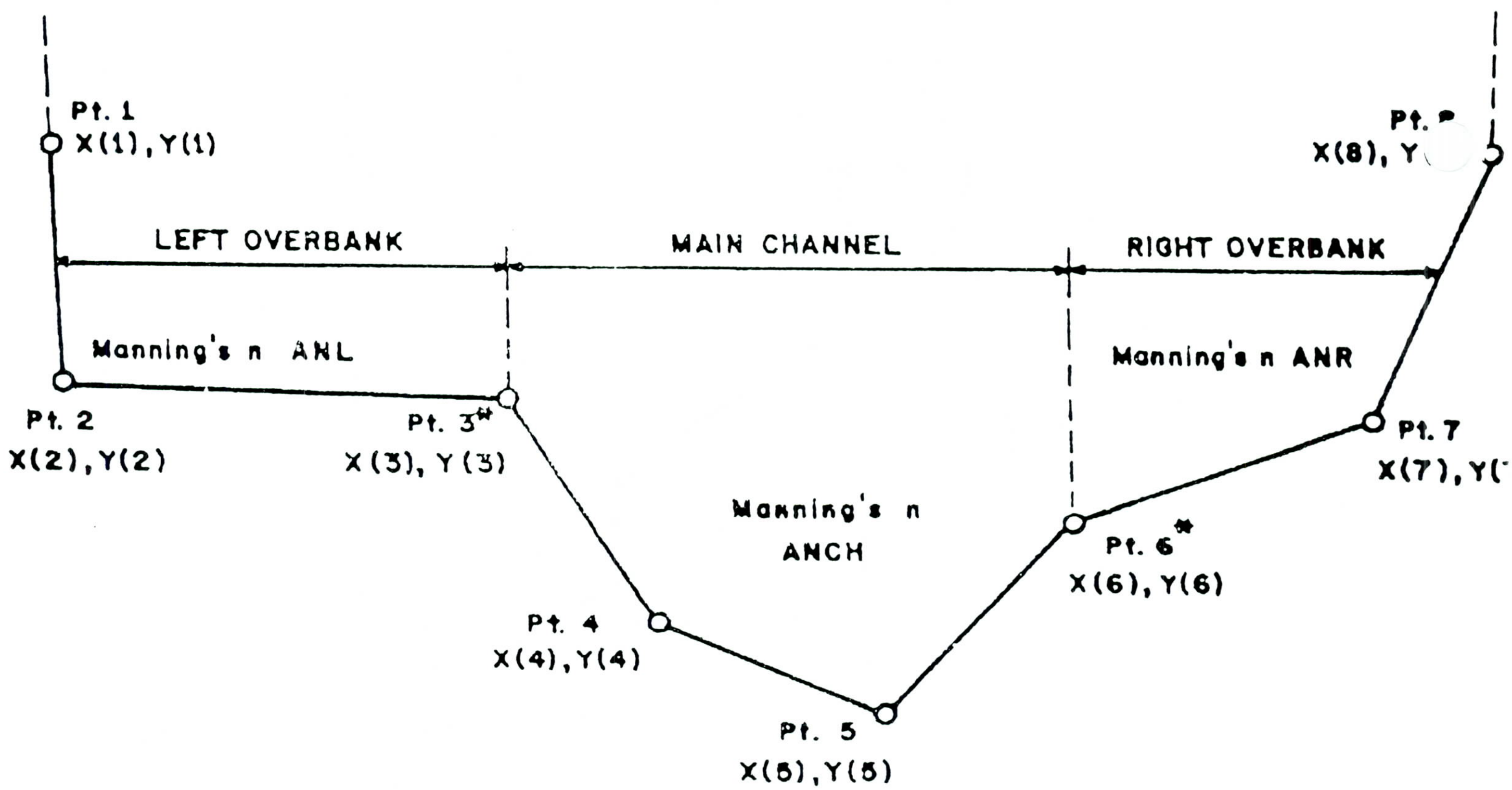
- Prepare routing diagram.
- Prepare HEC-1 input file.
- Debug and calibrate model.
- Final report.



OBSERVED
ERROR
COMPUTED
Q
Limits of Optimization
t



REPRESENTATIVE CROSS SECTION FOR ROUTING REACH



* NOTE: Coordinate Station Points 3 and 6 are taken as left and right bank stations, respectively.

Figure 3.10 Normal Depth Storage-Outflow Channel Routing

Table 10.1
HEC-1 Input Data Identification Scheme

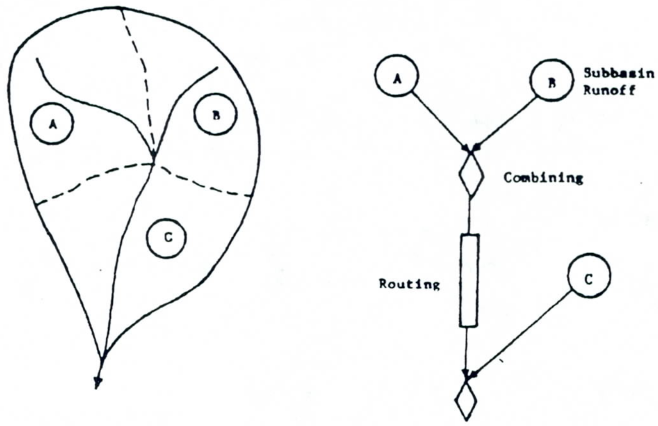
Data Category	Record Identification	Description of Data
Job Initialization	ID	Job IDentification
	IT	Job Time Control
	IM	Metric Units
	IO	General Output Controls
	IN	Time Control for Input Data Arrays
Variable Output Summary	VS	Stations to be summarized
	VV	Variables to be summarized
Optimization	OU	Unit Graph and Loss Rate Controls
	OR	Routing Controls
	OS	Flood Control System Optimization
	OO	System Optimization Objective Function
Job Type	JP	Multi-Plan Data
	JR	Multi-Ratio Data
	JD	Depth-Area Data
Job Step Control	KK	Stream Station Identification
	KM	Alphanumeric Message Record
	KO	Output Control for This Station
	KF	Format for Punched Output
	KP	Plan Number
Hydrograph Transformation	HC	Combine Hydrographs
	HQ/HE	Stage(Elevation)/Discharge Rating Curve
	HL	Local flow computation option
	HS	Initial Storage for Given Reservoir Releases
	HB	Hydrograph Balance Option
Hydrograph Data	QO	Observed Hydrograph
	QI	Direct Input Hydrograph
	QS	Stage Hydrograph
	QP	Pattern Hydrograph
Basin Data	BA	Basin Area
	BF	Base Flow Characteristics
	BR	Retrieve Runoff Data from ATODTA File
	BI	Input Hydrograph from Prior Job
Precipitation Data	PB	Basin-Average Total Precipitation
	PI	Incremental Precipitation Time Series
	PC	Cumulative Precipitation Time Series
	PG	Gage Storm Total Precipitation
	PI/PC	Incremental/Cumulative Precipitation Time Series for Recording Gage
	PR	Recording Gages to be Weighted
	PT	Storm Total Gages to be Weighted
	PW	Weightings for Precipitation Gages
	PH	Hypothetical Storm's Return Period
	PM	Probable Maximum Precipitation Option
	PS	Standard Project Precipitation Option
Loss Rate Data Function	LE	HEC's Exponential Rainfall Loss Rate Function
	LM	HEC's Exponential SnowMelt Function
	LU	Initial and Uniform Rates
	LS	SCS Curve Number
	LH	Holtan's Function
	LG	Green and Ampt Loss Rate
Unit Hydrograph Data	UI	Direct Input Unit Hydrograph
	UC	Clark Unit Hydrograph
	US	Snyder Unit Hydrograph
	UD	SCS Dimensionless Unit Hydrograph
	UA	Time-Area Data
	UK	Kinematic Overland
	RK	Kinematic Wave Channel (collector, main)
	RD	Muskingum-Cunge "Diffusion" channel (collector, main)

Table 10.1
HEC-1 Input Data Identification Scheme (continued)

Data Category	Record Identification	Description of Data
Melt Data	MA	Zone Area and Snow Content Data
	MC	Melt Coefficient
	MD	Dewpoint Data
	MS	Solar Radiation Data
	MT	Temperature Data
	MW	Wind Data
Routing Data	RN	No Routing for Current Plan
	RL	Channel Loss Rates
	RD	Muskingum-Cunge "Diffusion" channel
	RK	Kinematic Wave Channel
	RM	Muskingum Parameters
	RT	Straddle/Stagger Parameters
	RS	Storage Routing Option, follow with SV and SQ records if Modified Puls is used
	RC	Channel Characteristics for Normal Depth Storage Routing
	RX	Cross-Section X Coordinates
	RY	Cross-Section Y Coordinates
Storage Routing Data	SL	Low-Level Outlet Characteristics
	ST	Top of Dam Characteristics
	SW	Width/Elevation for Non-Level Top of Dam
	SE	Geometry
	SS	Spillway Characteristics
	SGO	Gee or Trapezoidal Spillway Option
	SQ	Discharge/Elevation Tailwater Rating
	SE	Curve for SG record
	SV	Reservoir Volume
	SQ	Discharge,
	SA	Surface Area, and
	SE	Water Surface Elevation Data
	SB	Dam Breach Characteristics
	SO	Optimization Parameters
	SD	Cost $ Function Corresponding to SV Data
Diversion Data	DR	Retrieve Diverted Flow
	DT	Flow Diversion Characteristics
	DI	Variable Diversion Q as Function of
	DQ	Inflow
	DO	Diversion Size Optimization Data
	DD	Cost $ Function for Diversion
Pumping Withdrawal Data	WP	Pump Characteristics
	WR	Pump flow Retrieval
	WO	Pump Size Optimization Data
	WC	Capacity Function for Pump
	WD	Cost $ Function for Pump
Flood Damage Data	EC	Identifies Flood Damage Option
	CN	Damage Category Names
	PN	Plan Names
	WN	Watershed Name
	TN	Township Name
For Each Damage Reach	WT	Watershed and Township Location
	FR	Frequency Data
	QF	Discharges for FR data
	SF	Stages for Rating Curve with QS
	QS	Discharges for SQ data
	SD	Stages for Damage Data, DG
	QD	Discharges for Damage Data, DG
	DG	Damage Data
	EP	End of Plan Identifier
End of Job	ZZ	Required to end job

10.3 Hydrologic/Hydraulic Simulation Options

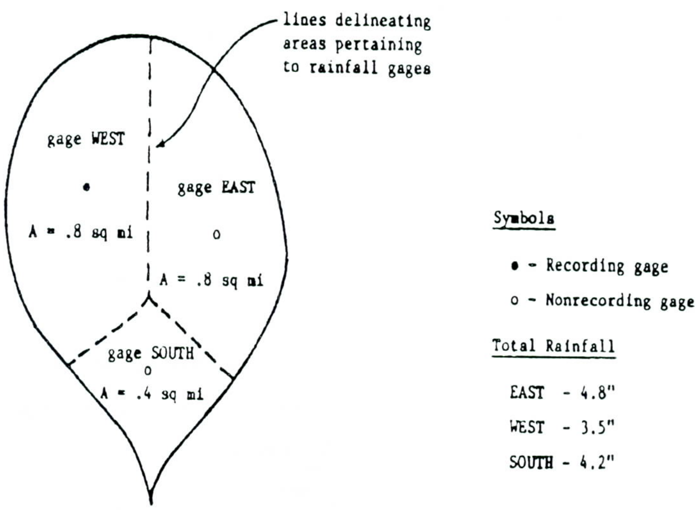
The HEC-1 program has a number of alternative methods available for simulating some aspects of the hydrologic/hydraulic processes (as referred to in the center column of Table 10.2). The different methods were also noted in the several data types available for one data category. For example, loss rates may be calculated by any of 5 different methods: exponential, initial/constant, SCS, Green and Ampt or Holtan. The general sequence of model building operations was shown in Figure 10.1.



	Card ID	Description
	ID	Title
	IT	Time interval and beginning time
	IO	Output Control option for whole job
Runoff from Subbasin A	KK	Subbasin A
	BA	Area
	BF	Baseflow
	P_	Select precipitation method, use IN if necessary
	L_	Select one loss rate method
	U_	Select one rainfall excess transformation method
Subbasin runoff B	KK	
	BA	Similar to above for Subbasin A
	BF	
	P_,L_,U_	
Combine A + B	KK	Station Name
	KM	Combine runoff from A and B (message option)
	HC	Indicate 2 hydrographs are to be combined
Route (A+B) to C	KK	Station name
	RL	Channel loss optional
	R_	Select one routing method
Subbasin C runoff	KK	
	BA	Similar to above for Subbasin A
	BF	
	P_,L_,U_	
Combine Routed (A+B) with C	KK	Station name
	HC	Indicate 2 hydrographs are to be combined
	KK	
	IN	Compare computed and observed flows
	QO	
	ZZ	

Figure 10.1 Example Input Data Organization for a River Basin

There are a number of methods available for specifying rainfall hyetographs in the stream network computation as described in Section 3 and Table 10.4. Historical gage data can be input to the subbasin runoff computation as shown in Figure 10.2. The gage data consists of PG records for nonrecording gages and PG and PI or PC records for recording gages. These data are usually grouped toward the beginning of the data set before the first KK-record runoff computation. Within each KK-record group, the (PR, PW) and (PT, PW) records are used to specify which gages and corresponding weightings are to be used for computation of that subbasin's average precipitation. **Note that a recording gage can be used as both a storm total and a recording gage station.** This is indicated by using gage WEST of PT and PW records in Figure 10.2. If the storm total value is not specified on the PG record for the recording station (as is the case for the Figure 10.2 example), the program sums the incremental values on the PI records to compute that value.



DATA INPUT

	Card ID	Data			
	ID				
	IT				
	PG	EAST	4.8		
Rainfall gage data	PG	SOUTH	4.2		
	PG	WEST			
	PI	.02	.05	etc.	recording gage
	.				
	.	readings for storm			
	.				
	KK	3-gage basin			
	BA	2.0			
Gage weightings for	PT	WEST	EAST	SOUTH	
basin-average total	PW	.4	.4	.2	
Gage weightings for	PR	WEST			
basin-average recorder	PW	1			
	L				
	U				

Figure 10.2 Precipitation Gage Data for Subbasin-Average Computation

Table 10.4

Precipitation Data Input Options

Type of Storm Data	Record Identification
Basin-Average Storm Depth and Time Series	PB and/or (PI or PC)
Recording and Nonrecording Gages	PG for all nonrecording gages PG and (PI or PC) for all recording gages PR, PW, PT, PW for each subbasin
Synthetic Storm from Depth-Duration Data	PH
Probable Maximum Storm	PM
Standard Project Storm	PS
Depth-Area with Synthetic Storm	JD, PH, or PI/PC

Table 10.5

Hydrograph Input or Computation Options

	Hydrograph Derivation Options and Records			
Type of Data	**Input Hydrograph**	**SAM***	**Unit Graph**	**Kinematic Wave**
Inflows or Precipitation	QI	P_, M_	P_, M_	P_, M_
Basin Area	BA	BR	BA	BA
Base Flow	--	--	BF	BF
Loss Rate			LE, LM, LU, LS, LG or LH	LE, LM, LU, LS, LG or LH
Overland Flow Routing			UI, UC, US, UA or UD	UK, RK or RD

* Spatial data management and analysis files

Table 10.6

Runoff and Routing Optimization Input Data Options

Type of Data	Runoff Optimization	Routing Optimization
Optimization Control	OU	OR
Basin Characteristics	BA, L_, U_, and BF	
Pattern Hydrograph		QP
Observed Data	P_, M_, QO	QI, QO

Table 10.7

Channel and Reservoir Routing Methods Input Data Options
(without spillway and overtopping analysis)

		Modified Puls		
Type of Data	Muskingum/ Muskingum-Cunge	Given Storage Outflow	Normal-Depth Storage Outflow	Kinematic Wave
Routing Control	RM/RD	RS	RS	RK
Storage Discharge Relationships	--	SV/SQ*	--	--
Rating-Curve	--	SQ/SE*	--	--
Channel Hydraulic Characteristics	/RC, RX, RY**	--	RC, RX, RY	RK

* These data may be computed from options listed in Table 10.8

**Optional for Muskingum-Cunge

Table 10.8

Spillway Routing, Dam Overtopping, and Dam Failure
Input Data Options

Type of Data	Type of Spillway Analysis			
	Given Rating Curve	**Weir Coefficients**	**Trapezoid**	**Ogee**
Routing control	RS	RS, SS	RS, SG	RS, SG
Rating curve input	SQ, SE	--	--	--
Reservoir Area-Storage-Elevation	SA or SV, SE	SA or SV, SE	SA or SV, SE	SA or SV, SE
Spillway and Low Level Outlet Specs	SS (first field only)	SS, SL	SS	SS
Trapezoidal and Ogee Specs & Tailwater	--	--	SG, SQ, SE	SG, SQ, SE
Dam Overtopping Data	ST** SW, SE***	ST** SW, SE	ST** SW, SE	ST** SW, SE
Dam Failure Data	SB*	SB*	SB*	SB*
+Breach Outflow Submergence	SQ, SE or RC, RX, RY	SQ, SE or RC, RX, RY	SQ, SE or RC, RX, RY	SQ, SE or RC, RX, RY

* Used for dam failure only, SB and ST Records required for dam failure.

** Required to obtain special summary printout for spillway adequacy and dam overtopping (ID only).

*** The SW, SE are used for non-level top of dam. The discharges computed with this option are added to discharges computed with the above options.

\+ Must follow SB record, specifies downstream channel rating curve.

Table 10.9

Flood Damage Analysis Input Data Options

Type of Data	Record Identification
Economic Analysis Delimiter	EC
Damage Reach ID	KK
Damage Category	CN, WN*, PN*, TN*
Flow Frequency & Flow Damage Data	FR, QF, DG, QD, or FR, QF, SQ, QS, DG, SQ
Stage Frequency & Stage Damage Data	FR, SR, DG, SD or FR, SF, SQ, QS, DG, QD

* Optional records

Table 10.10

Flood Control Project Optimization
Input Data Options

	Stream Network Data			Economic Data
Type of Data	Pump	Reservoir	Diversion	Local Protection Project
Optimization		OS		
Target Penalty		OO		
Discount Factor + Size Constraint	WO	SO	DO	LO
Cost	WC, WD	SD*	DC, DD	LC, LD
Damage Pattern				DU, DL
Degree of Protection				DP

* Used with SE, SA or SV records for storage routing

Table 10.11

Hydrograph Transformation, Comparisons and I/O

	Transformation	Comparison	I/O
Combination	HC		
Adjust Hydrograph Ordinates	BA or HB		
Local Flow	HL, QO		
Compute Storage, Given Reservoir Releases	HS, QO		
Compute Stage	*HQ, HE		
Compare with Observations		QO or HL	
Write to Disk			*KO, KF
Read or Write from Scratch Files			*KO or BI

* The use of these options must be in combination with some other hydrograph computation

Table 11.1

HEC-1 Error Messages

Error No.	Message	Subroutine
1	**INVALID RECORD IDENTIFICATION CODE, OR RECORD OUT OF SEQUENCE** Program does not recognize the record identification code in columns 1 and 2. Some records must be read in a designated sequence. Refer to Input Description and Section 10 of Users Manual. Program allows up to 30 input errors before terminating.	INPUT
2	**NUMBER OF ORDINATES CANNOT EXCEED xxx.** Number of ordinates, NQ, on IT record must be reduced to the stated limit.	OUTPUT
3	**(NPLAN*NTRIO) CANNOT EXCEED xxx AND (NPLAN*NTRIO*NQ) CANNOT EXCEED xxx.** Number of plans, ratios, or hydrograph ordinates must be reduced to stated limit.	OUTPUT
4	**NO HYDROGRAPH AVAILABLE TO ROUTE.** No hydrograph has been given to initiate network diagram.	PREVU
5	**TOO MANY HYDROGRAPHS. COMBINE MORE OFTEN.** Space for stream network diagram is limited, so maximum number of branches is limited to 9.	PREVU
6	**TRIED TO COMBINE MORE HYDROGRAPHS THAN AVAILABLE.** Network diagram has fewer branches than are to be combined at this point.	PREVU
7	**DIMENSION EXCEEDED ON RECORD NO. nn **xx RECORD **.** Too many values were read from given record. Check input description.	ECONO
8	**xx RECORD ENCOUNTERED WHEN yy RECORD WAS EXPECTED FOLLOWING RECORD NO. nnn.** Record No. nnn indicated that the next record would be a yy record, but an xx record was read instead. A record may be missing or out of sequence.	ECONO
9	**QF OR SF RECORD MISSING.** New flow- or stage-frequency data are required for each damage reach.	ECONO
10	**QD OR SD RECORD MISSING.** New flow- or stage-damage data are required for each damage reach.	ECONO
11	**SQ RECORD MUST PRECEDE QS RECORD.** See Input Description.	ECONO
12	**SQ AND/OR QS MISSING.** A stage-flow curve is required to convert flows to stages or vice versa.	ECONO
13	**FIRST PLAN AT EACH STATION MUST BE PLAN 1. (EP-RECORD MAY BE MISSING).** Damage calculations assume that PLAN 1 is the existing condition. Frequencies are given for PLAN 1 and flows for the other plans produced by the same ratio are assumed to have the same frequencies. See Section 8 of Users Manual.	ECONO
14	**PEAK FLOW/STAGE DATA FOR LOCATION xxxxx NOT FOUND.** Station name on KK record is not the same as station name used in hydrologic calculations. When an SF record is used, peak stages must have been calculated in the hydrologic portion of HEC-1.	ECONO
15	**INSUFFICIENT DATA FOR STORAGE ROUTING.** May also indicate redundant data. Storage routing requires storage and outflow data. With some options stages are required. See Input Description.	RESOUT

Table 11.1
HEC-1 Error Messages (continued)

Error No.	Message	Subroutine
16	ARRAY ON RECORD NO. nnn (xx) EXCEEDS DIMENSION OF KK. Attempted to read more data from xx record than was dimensioned in program.	REDARY
17	NUMBER OF PUMPS EXCEEDS nn--RECORD NO. ***** IGNORED. Attempted to read more pump data than dimensioned. For multiplan runs, number of pumps can be reset to zero by reading a blank WP record.	INPUT
18	NO TOTAL-STORM STATION WEIGHTS. Weighting factors are required to average total storm precipitation.	BASIN
19	NO RECORDING STATION WEIGHTS. Weighting factors are required to average temporal distribution of precipitation.	BASIN
20	PRECIPITATION STATION xxxxx NOT FOUND. Station name given on PR or PT record does not match names given on PG records.	BASIN
21	TIME INTERVAL TOO SMALL FOR DURATION OF PMS OR SPS. Standard project storm has a duration of 96 hours. Probable maximum storm duration varies from 24 to 96 hours, depending on given data. The given combination of time interval and storm duration causes the number of ordinates to exceed the program dimensions. Use a larger time interval or shorter storm.	BASIN
22	NO PREVIOUS DIVERSION HYDROGRAPHS HAVE BEEN SAVED. Attempted to retrieve a diversion hydrograph before the diversion has been computed.	DIVERT
23	DIVERSION HYDROGRAPH NOT FOUND FOR STATION xxxxx. Station name on DR record does not match names given on previous DT records.	DIVERT
24	INITIAL VALUES OF TC AND R. For optimization run, given values of TC and R on UC record must both be positive or both negative.	INVAR
25	STATION xxxxx NOT FOUND ON UNIT nn. Station name on BI record does not match names of hydrographs stored on unit nn.	READQ
26	SPILLWAY CREST IS ABOVE MAXIMUM RESERVOIR ELEVATION. Program cannot compute spillway discharge. Maximum reservoir elevation is assumed to be highest stage given with storage data.	RESOUT
27	VARIABLE NUMBER (nn) EXCEEDS SIZE OF VAR ARRAY. Variable numbers given on DO, SO, WO, and LO records must be in the range 1-10.	SETOPT
28	HYDROGRAPH STACK FULL. COMBINE MORE OFTEN. Storage space for hydrographs is full. Required storage can be reduced by using more combining points in the stream network.	STACK
29	ONLY ONE DATA POINT FOR INTERPOLATION. Program cannot interpolate from one piece of data. More ratios or frequencies are required for damage calculations.	AKIMAI
30	X VALUES ARE NOT UNIQUE AND/OR INCREASING FOR CUBIC SPLINE INTERPOLATION. The cubic spline interpolation routine requires that the independent variable be unique and monotonically increasing, i.e.. X_j $X_{j\ 1}$ for all j.	AKIMA
31	xx RECORD MUST FOLLOW yy RECORD (INPUT LINE NO. nn). An xx record was expected to be after the yy record. See Input Description for xx and yy records. nn is sequence number of yy record.	INPUT

Table 11.1
HEC-1 Error Messages (continued)

Error No.	Message	Subroutine
32	**NUMBER OF STORAGE VALUES AND NUMBER OF OUTFLOW VALUES ARE NOT EQUAL.** Number of values given on SA or SV records must be the same as the number of flows on the SQ record unless elevations (SE record) are given for both storage and outflow. The number of values is determined by the last non-zero value on the record.	RESOUT
33	**PLAN NUMBER (nn) ON KP-RECORD (NO. ii) IS GREATER THAN NUMBER OF PLANS (mm) DECLARED ON JP-RECORD.** Number of plans for this run is declared on JP record. Plan number must be a positive integer less or than equal to value on JP record.	INPUT
34	**HYDROGRAPH STACK IS EMPTY.** Attempted to combine more hydrographs than have been saved (HC record), or attempted to route an upstream hydrograph when no hydrographs have been saved (e.g., RK record with "yes" option in kinematic wave runoff). Use *DIAGRAM record to check stream network.	STACK
35	**PLAN NUMBER nn (ON KP-RECORD NO. iii) HAS ALREADY BEEN COMPUTED FOR STATION xxxxxxxxx.** Duplicate plan numbers may not be used within a KK record segment of the input set. The plan number is set to 1 when a KK record is read. Only K_ or I_ record may be present between the KK record and a KP record for PLAN 1. This does not preclude the first KP record from being for any other plan (see Input Description for KP record).	INPUT
36	**ACCUMULATED AREA IS ZERO. ENTER AREA FOR COMBINED HYDROGRAPH IN FIELD 2 OF HC-RECORD.** Basin area for a combined hydrograph was calculated as zero. This will result in an error when computing an interpolated hydrograph for the depth area option (JD-Record). Basin area to be used to calculate the interpolated hydrograph should be entered in Field 2 of the HC Record.	MANE2
37	**OPERATION CANNOT BE DETERMINED FROM RECORDS IN KK-RECORD GROUP BEGINNING WITH RECORD NO. XXX.** The records specified in a KK-record group were not complete and it is likely that data needs to be specified on additional records.	HEC1
38	**X-COORDINATE **** IS NEGATIVE** The station distance values on the RX record must be greater than zero.	
39	**CROSS-SECTION X-COORDINATES ARE NOT INCREASING ****,**** **The station distances on the RX record must increase from the beginning station (left overbank) to the ending station (right overbank).	
40	**CATEGORY NUMBER ON DG-RECORD IS NOT IN RANGE 1 TO XXX** Number of categories, ICAT, must be less than or equal to ten.	

Appendix A

HEC-1
Input Description

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HEC-1 Input Description

Introduction

1 Introduction

1.1 Organization of this Input Description

This input description is organized into three major types of data: 1) job description and initialization data, 2) hydrograph calculation data, and 3) economic analysis data. This corresponds to the general sequence of data necessary to build the digital model of a river basin as described in the next subsection on Input Data Structure.

The first group (pages A-6 through A-18), JOB DESCRIPTION AND INITIALIZATION DATA, begins with the I records and goes through the V records. The ID and IT records are required and are described first. The other records are optional and are described in a recommended input sequence, i.e., I, J, O, V records as desired.

The second group (pages A-19 through A-97), HYDROGRAPH CALCULATION DATA, comprises all of the data necessary to simulate the various river basin processes. The input data in this group are organized ALPHABETICALLY, beginning with the B records and ending with the W records. The required and recommended order to input these data are described in the next subsection, Input Data Structure.

The third group (pages A-98 through A-112), ECONOMIC ANALYSIS DATA, consists of data to be supplied after all of the hydrologic and hydraulic calculations are completed. These data are optional and begin with the EC record and are organized in the recommended sequence of input.

The last record described is the REQUIRED ZZ RECORD, page A-113, to end the job.

1.2 Input Data Structure

The input data set is divided into three sections - job description and initialization data, hydrograph calculation data, and economic analysis data.

The first section begins with an ID record. This section contains an alphanumeric description of the job, sets the job type, output control, time interval and time span, and the type of units to be used.

Section two contains data for calculating hydrographs. Each hydrograph calculation begins with a KK record, and the records following the KK record provide information on how the hydrograph is to be calculated.

The third section begins with an EC record. All data following the EC record are for calculation of expected annual damages.

Finally the job is terminated by a ZZ record. Data for a new job beginning with an ID record may follow immediately after the ZZ record.

The record sequence for a typical job is shown. A dash, -, is used to indicate the second character of a record identification which will be selected at the option of the user.

```
  ID          Job identification

  IT          Time specification

  I-*         Additional initialization data

  J-*         Job type

  O-*         Optimization

  VV*,VS*     Variable output summary tables

( KK          Hydrograph computation identification )
(                                                   )
(             KK-record groups describing RUNOFF,   )
( .           ROUTING, COMBINING, etc., components  )
( .           are repeated as necessary to simulate )
( .           the processes and connectivity of a   )
( .           river basin.  See following pages.    )

EC*           Economic data identification

. (See section on economic data)

ZZ            End-of-job record
```

*Optional records

Data input for RUNOFF calculations will be retained and used for subsequent runoff calculations until new data are read. Thus the data used in calculating runoff need only be read once, unless they are to be changed for a new basin. A typical record sequence for computing subbasin rainfall-runoff is:

```
(     KK              Hydrograph computation identification   )
(                                                             )
(     BA              Basin area                              )
(                                                             )
(     BF*             Base flow data                          )
(                                                             )
(     P-              Precipitation data                      )
(                                                             )
(     L-              Loss data                               )
(                                                             )
(     U-              Unit graph or kinematic wave data       )

(     KK              Hydrograph computation identification   )
(                                                             )
(     BA                                                      )
(                                                             )
(     BF*                   If BF, P-, L-, U-records          )
(                                                             )
(     P-*                   do not appear, data from          )
(                                                             )
(     L-*                   previous calculation will         )
(                                                             )
(     U-*                   be used.                          )

(     KK              Etc.                                    )
(                                                             )
```

For hydrograph ROUTING the record sequence is:

```
(     KK              Hydrograph computation identification   )
(                                                             )
(     R-              Routing option                          )
(                                                             )
(     S-*             Reservoir data or dam-break analysis    )
```

*Optional records

For DIVERSIONS the record sequence is:

```
(   KK        Hydrograph computation identification   )
(                                                     )
(   DT        Diversion identification                )
(                                                     )
(   DI        Inflow to diversion point               )
(                                                     )
(   DQ        Diverted flow                           )

(   KK        Etc., for other parts of stream         )
(             network                                 )
 .
 .
 .
(   KK        Hydrograph computation identification   )
(                                                     )
(   DR        Retrieve diversion hydrograph           )

(   KK        Etc., for routing/combining of return   )
(             flow                                    )
 .
 .
 .
```

Each input record is described in detail on the following pages. Variable locations on each record are shown by field numbers which indicate the relative position of the data on the record.

When data are entered in FIXED FORMAT the record is divided into ten fields of eight columns each, except field one. Variables occurring in field one may only occupy columns 3-8 because columns 1 and 2 are reserved for the record identification characters. Integer and alphanumeric values must be right justified in their fields.

Data may also be entered in FREE FORMAT where fields are separated by a comma or one or more spaces. Successive commas are used to indicate blank fields. When entering time series data (flow, precipitation, etc.), more (or less) than 10 values can be placed on a record.

1.3 Input Control Records

The following records may be used to control the format and printing of the input data. An input comment record is also described which may be inserted anywhere in the input data stream.

RECORD IDENTIFICATION	DESCRIPTION OF INPUT CONTROL
*LIST	Causes echo print of input data following this record until a *NOLIST record is encountered. *LIST is the default assumption.
*NOLIST	Stops echo print listing of input data until a *LIST record is encountered.
*FREE	Indicates a free format will be used for the input following this record and before a *FIX record is encountered. Fields may be separated by a comma or by one or more spaces. Successive commas would indicate blank fields. When entering time-series data (flow, precipitation, etc.), more (or less) than 10 values may be placed on a record. Default is fixed format.
*FIX	Indicates a standard HEC fixed format (10 8-column fields) will be used for the data following this record and before a *FREE record is encountered. Default is fixed format.
*	This is a COMMENT record that is printed only with the input echo listing. The comment occupies columns 3 through 80. Any number of comment records may be inserted at any point in the input data stream.
*DIAGRAM	Causes a diagram of the stream network to be printed. In multiple job runs this option is reset so a diagram is generated only for those jobs which contain this record.

NOTE - The asterisk (*) must be in column 1 and followed by the remainder of the identification. If column 2 is blank, it is assumed to be a COMMENT record.

2 Job Initialization (I Records)

The ID and IT records are required to begin the job. The other records (IM AND IO) are only used if those options are desired.

2.1 ID Record - Job Title Information**

At least one ID record is required but any number may be used as desired to title the output from this job. The title information is contained in columns 3-80 inclusive and any characters or symbols may be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	ID	Record identification.
1-10	ITLS	AN	Job title information.

**Required

2.2 IT Record - Time Specification**

The IT record is used to define time interval, starting date and time, and length of hydrographs calculated by the program.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	IT	Record identification.
1	NMIN	+	Integer number of minutes in tabulation interval. Minimum value is one minute.
2	IDATE[1]	+	Day, month, and year of the beginning of the first time interval (e.g., 17MAR78 is input for March 17, 1978). Required to specify pathname part D when using DSS.
3	ITIME[1]	+	Integer number for hour and minute of the beginning of the first time interval (e.g., 1645 is input for 4:45 pm).
4	NQ	+	Integer number of hydrograph ordinates to be computed (300 maximum). If end date and time are specified in Fields 5 and 6, NQ will be computed from the beginning and end dates and times.
5	NDDATE	+	Day, month, and year of last ordinate (used to compute NQ).
6	NDTIME	+	Integer number for time of last ordinate (used to compute NQ).
7	ICENT	+	Integer number for century of IDATE (e.g., 1800, default 1900)

[1]CAUTION - IDATE and ITIME are the time of initial flow conditions. No runoff calculations are made from precipitation preceding this time. The first runoff computation is for the end of the first period (ITIME+NMIN); thus, the first precipitation value specified should be for the precipitation that fell between ITIME and ITIME+NMIN.

Use 3-character code for month: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC. Use of any other code for month means this is not a date, and days will be numbered consecutively from the given day. Default is day = 1

**Required

2.3 IN Record - Time Interval for Input Data

The IN record is used to define time interval and starting time for time series data which are read into the program on PC, PI, QO, QI, QS, MD, MS, MT and MW records.

FIELD	VARIABLE	VALUE	DESCRIPTION
1	JXMIN	+	Integer number of minutes in tabulation interval.
2	JXDATE	+	Day, month, year at beginning of the first time interval (e.g., March 17, 1978 is input as 17MAR78).
3	JXTIME	+	Hour and minute at the beginning of the first time interval (e.g., 4:45 pm is input as 1645).

If an IN record is not used the time interval and starting time for all time series will be the values specified on the IT record.

IN records may appear anywhere (exception: not after JD and before PI) in the input stream. The same time interval and starting time will be used for all time series data until these values are reset by reading new values on an IN record.

When time series data are read from PC, PI, QO, QS, QP, MD, MS, MT, or MW records, values to be used by the program are computed using linear interpolation to match the tabulation interval specified on the IT record.

For times preceding or following the given ordinates, the first or last value is repeated as necessary to define NQ (IT-4) ordinates.

Data on PC, QI, QO, QP and QS records are **instantaneous** values. The first value will occur at JXDATE and JXTIME.

Data on PI, MD, MS, MT and MW records are **cumulative** or average values over a time interval. The first value on these records is for the time interval beginning at JXDATE, JXTIME and ending at JXTIME + JXMIN.

2.4 IO Record - Output Control

The IO record is used to control output for the entire job. The KO record may be used to change output control for each hydrograph calculation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	IO	Record identification.
1	IPRT	0,1,2	Print all output.
		3	Print input data and intermediate and master summaries.
		4	Print input data and master summary.
		5	Print job specification and master summary only.
2	IPLT	0,1	No printer plots for entire job unless overridden temporarily by a KO record for any station operation.
		2	Plot every computed hydrograph for entire job unless overridden by a KO record for any station.
3	QSCAL	0 or, Blank	Program will choose scale for streamflow plots.
		+	Desired scale for streamflow plots in units per ten printer characters (e.g., one hundred for one hundred cfs per ten characters).

2.5 IM Record - Metric Units

This record is required if input is in metric units. Include one record with IM beginning in column 1. No other fields on the record are presently used.

3 Job Type Option (J Records)

J records are required only if one of the following special jobs is desired.

3.1 JP Record - Multiplan

Required only if more than one plan is being analyzed or if performing single event damage.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	JP	Record identification.
1	NPLAN[1]	+	Number of plans desired (NPLAN = 1 for single event damage calculation).

NOTE: The product NPLAN*NRATIO (NRATIO is the number of ratios as defined on JR record) cannot exceed forty-five. The product NPLAN*NRATIO*NQ (NQ defined on IT record) cannot exceed 4,800. These limits may be changed if the dimensions are changed as noted in the HEC-1 Programmers Manual.

[1]Must be greater than or equal two for economic analysis.

3.2 JR Record - Multiratio

Required only if multiple ratios are desired for each plan. If performing single event damage then a single ratio may be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	JR	Record identification.
1	IRTIO	PREC	Indicates ratios are to be taken of precipitation (default).
		FLOW	Indicates ratios are to be taken of runoff.
2	RTIO(1)	+	Ratio by which all hydrograph or precipitation ordinates of each subarea are to be multiplied for all plans.
3	RTIO(2)	+	Same as above for up to nine ratios as desired. Ratios **must** be in ascending order for use in economic calculations.

3.3 JD Record - Depth/Area Storm

Required only if stream system is to be simulated using a consistent depth/area relationship. Each JD record may be followed by a set of PC or PI records giving the precipitation pattern to be used for that depth and area. If no pattern is given following any of the second through ninth JD records, the previous pattern will be used. A maximum of nine depth-area storms (maximum of nine JD records) may be used.

Precipitation patterns may be generated using the hypothetical storm option. The convention for specifying hypothetical storms with a JD, PH record combination is somewhat different than for gage rainfall (i.e. with PI or PC records). In this case only a single PH record following the first JD record is required for all depth area storms. The variable PNHR(I) on the PH record (see page A-51) specifies the depth duration data for point rainfall. This point rainfall may be adjusted for a partial to annual series correction (variable PFREQ on the PH record) and for a point to areal rainfall correction (see page 13 in this manual). The areal correction is made by using the value TRDA on the JD record in place of the variable TRSDA on the PH record. Consequently, a different storm is obtained by applying the areal correction for the area specified on the JD records to the point precipitation. The total storm depth is obtained from the adjusted rainfall on the PH record and need not be specified as STRM on the JD record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	JD	Record identification.
1	STRM	+	Average precipitation in inches (mm). Not required with hypothetical storm.
2	TRDA	+	Area in square miles (sq km).

4 Optimization Option (O Records)

4.1 OU Record - Unit Graph and Loss Rate Optimization[1]

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OU	Record identification.
1	IFORD	0,1 or Blank	Begin optimization at first simulated value.
		+I	Begin optimization at Ith simulated value.
2	ILORD	0, or Blank	End optimization at last simulated value.
		+I	End optimization at Ith simulated value.

4.2 OR Record - Routing Optimization

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OR	Record identification.
1	IFORD	0,1 or Blank	Begin optimization at first simulated value.
		+I	Begin optimization at Ith simulated value.
2	ILORD	0, or Blank	End optimization at last simulated value.
		+I	End optimization at Ith simulated value.

[1]ZZ record at the end of each optimization required if summary of multiple optimizations are desired.

6.2 BF Record - Base Flow Characteristics

Base flow parameters (STRTQ, QRCSN, and RTIOR) will be assumed equal to zero unless this record is supplied. Once this record is supplied, all following subbasins will be assumed to have these values unless overridden by another BF record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BF	Record identification.
1	STRTQ	+	Flow at start of storm in cfs (cu m/s). Will be receded in same manner as QRCSN below.
		-	When negative, this is cfs/sq mi (cu m/s/sq km) which will be multiplied by subbasin area, TAREA, to determine STRTQ.
2	QRCSN	+	Flow in cfs (cu m/s) below which base flow recession occurs in accordance with the recession constant RTIOR. QRCSN is that flow where the straight line (in semilog paper) recession deviates from the falling limb of the hydrograph.
		-	When negative, it is the ratio by which the peak discharge is multiplied to compute QRCSN.
3	RTIOR	+	Ratio of recession flow, QRCSN to that flow occurring one hour later. Must be greater than or equal to one.

NOTE - The definition of RTIOR has been changed from the 1973 version of HEC-1. The old value is QA/QB in the following equation:

New RTIOR = (QA/QB)**(1/DT)

Where QB is a recession flow occurring DT hours after recession flow QA.

6.3 BI Record - Read Hydrograph from a File

A BI record is used to identify a hydrograph on a file created earlier by HEC-1. The hydrograph is read from this file and converted to the time interval and starting time for the current job.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BI	Record identification.
1	ISTA	AN	Station name for hydrograph to be read from file on unit IQIN (default is ISTAQ on KK record).
2	IQIN	21 or 22	Unit number (specify 21 or 22) for file which contains HEC-1 data to be retrieved from a previous simulation. This option allows HEC-1 to be restarted from the point where a previous simulation saved the HEC-1 data via the IOUT option on the KO record, Field 5.

11.3 MT Record - Temperature Time Series

These data are required for any snowfall/melt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MT	Record identification.
1	TEMPR(1)	+	Air temperature for first interval in degrees F (°C) at bottom of lowest elevation zone. Will be adjusted to each zone by use of TLAPS (MC-1).
2	TEMPR(2)	+	Air temperature as above for second interval.
3	TEMPR(3)	+	Etc.

11.4 MS Record - Energy Budget Shortwave Radiation

The MS, MD, and MW records are only used for the energy budget snowmelt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MS	Record identification.
1	SOL(1)	+	Shortwave radiation in Langleys during first interval.
2	SOL(2)	+	Shortwave radiation during second interval.
3	SOL(3)	+	Etc.

11.5 MD Record - Energy Budget Dew Point

The MS, MD, and MW records are only used for the energy budget snowmelt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MD	Record identification.
1	DEWPT(1)	+	Dew point during first interval in degrees F (°C) at bottom of lowest elevation zone. Will be adjusted to each zone by use of 0.2 TLAPS (MC-1).
2	DEWPT(2)	+	Dew point as above for second interval.
3	DEWPT(3)	+	Etc.

11.6 MW Record - Energy Budget Wind Speed

The MS, MD, and MW records are only used for the energy budget snowmelt simulation. See IN record description for discussion of time interval and number of values.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MW	Record identification.
1	WIND(1)	+	Wind speed in mi/hr (km/hr) at fifty feet (fifteen meters) above surface, average for basin during first interval.
2	WIND(2)	+	Wind speed as above for second interval.
3	WIND(3)	+	Etc.

12 Precipitation Data (P Records)

Precipitation data can be input as either precipitation gage data or subbasin-average precipitation.

A typical record sequence for GAGE data is as follows:

```
        ID
        IT            Etc., for job initialization

        PG            Non-recording gage (total storm precipitation)
        PG            Non-recording gage (total storm precipitation), etc.
        PG            This is a recording gage if the PG record is followed
                      by PI or PC records.
        PI
        .
        .

        KK            Subbasin runoff computation
        BA
        BF
    (   PT            Specification of stations and weightings for   )
    (   PW            computation of the storm total precipitation   )
    (   PR            and its time patter for this subbasin.  If     )
    (   PW            recording stations are to be used in the       )
    (                 computation of subbasin-average TOTAL          )
    (                 precipitation, their gage identification must  )
    (                 also be on the PT record.                      )
        L-
        U-

        KK            Etc.
        .
        .
```

PG and PG+PI/PC record combinations can be included at any point in the data set following the IT record. It is usually convenient to group them together as a precipitation data bank before the first KK record. Different storms can then be simulated by simply inserting different data banks, as long as the gage identification and weightings are the same.

Subbasin-average precipitation can be specified using historical storm data (PB and PI/PC records) or synthetic storm data (PM, PS or PH records).

12 **Precipitation Data (P Records)** (continued)

A typical record sequence is as follows:

```
ID
IT

KK
.
.
.
PB             Subbasin-average precipitation specified as
PI             part of this subbasin runoff computation.
.
.
.
KK
.
PM, PS or PH   Synthetic storm data for this subbasin.
.
.
.
.
```

Once precipitation data has been specified for a subbasin runoff computation, those data will be used for subsequent runoff calculations until changed by reading new precipitation data.

12.1 PB/PI/PC Records - Storm Total and Distribution Option

These records are used if the basin-average, storm total precipitation is known along with a time pattern with which to distribute the storm total. They must be included in the KK record group for a runoff calculation.

12.1.1 PB Record - Basin Average Precipitation

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PB	Record identification.
1	STORM	0	Total storm, basin-average precipitation will be computed from values given on the following PI or PC records.
		+	Total storm, basin-average precipitation in inches (mm). If this value is given, the following PI or PC records' values for PRCPR will be used as a distribution pattern for the STORM amount.

12.1.2 PI Record - Incremental Precipitation Time Series

PI records contain an incremental precipitation time distribution. They are only used after a PG, PB or JD record which identifies the distribution. The interval length and starting time for the first interval will be as specified on the last IN record which has been read. The program reads all consecutive PI records and interpolates incremental precipitation values for the computation time interval and time period specified on the IT record. If an IN record is not specified the parameters on the IT record will be used. A maximum of 300 values can be specified on up to thirty records. A negative one may be used to signify missing data when using more than one recording gage in conjunction with PG records. The precipitation will be computed based on the weighted average of the remaining stations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PI	Record identification.
1	PRCPR(1)	+	Precipitation in inches (mm) during the firs time interval identified on the preceding IN record, i.e. from JXTIME (IN record) to JXTIME+JXMIN.
2	PRCPR(2)	+	Etc.

12.6.2 PT Record - Storm Total Stations to be Weighted

Basin-average total precipitation is computed as (WTR*PRCPN)/(SUM OF WTR) for all stations used. Recording gages can also be used in this computation of subbasin-average storm total precipitation; if used, their gage identification must be specified on the PT record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PT	Record identification.
1	ISTN(1)	AN	Alphanumeric station identification for total storm station. Must correspond to one of the station names on a previous PG record.
2-10	ISTN(I)	AN	Etc., up to ten stations corresponding to weightings on following PW record.

12.6.3 PW Record - Weightings for Precipitation Stations

This record is used to specify weights to be assigned to precipitation gages. If used, this record must follow immediately after a PR and/or PT record. If no PW record is used, each gage on the PR or PT record will have the same relative weight.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PW	Record identification.
1	WTR(1)	+	Relative weight in any units for the station name specified in Field 1 on the previous PR or PT record.
2-10	WTR(I)	+	Etc., corresponding to stations on previous PR record and/or PT record.

13 Hydrograph Time-Series Data (Q Records)

These records contain hydrograph time series data. The first value on the record is at the starting time specified on the previous IN record. Subsequent values are spaced at the time interval specified on the IN record. The program reads all consecutive Q records and interpolates values for the computation time interval and time period specified on the IT record. If the computation time period extends before or beyond the Q data supplied, the first or last value will be repeated as necessary to produce a hydrograph for the full time period.

13.1 QO Record - Observed Hydrograph

These records are used to input an observed hydrograph for an optimization job (OU or OR records) or for comparing the computed with an observed flow at any point in a river network. For optimization jobs, QO records are included in the data for runoff calculation. For comparison of hydrographs, QO records are separated from other data with a KK record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QO	Record identification.
1	QO(1)	+	Observed flow in cfs (cu m/s) at the beginning of the first period.
2	QO(2)	+	Etc.

12.4 PM Record - Probable Maximum Precipitation (Eastern United States)

This record is used for automatic computation of a Probable Maximum Storm (PMS) according to the outdated Hydrometeorological Report No. 33. This capability has been retained in HEC-1 to allow recomputation of hydrographs according to the old HMR No. 33 method.

NOTE - **Hydrometeorological Report No. 33 has been superseded by HMR No. 51 and** No. 52. Computer program HMR52 (HEC, 1984) may be used to calculate PMS hyetographs.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PM	Record identification.
1	PMS	+	Probable maximum index precipitation from HYDROMET Report 33.
2	TRSPC	0	TRSPC defaults to the Hop Brook factor (reference EC-1110-2-163). The adjustment is automatically made by the program. The precipitation is adjusted based on drainage area size using the following criteria.

HOP Brook Adjustment Factor

Drainage Area sq mi	Precipitation Reduction	Adjustment Factor
1000	10	.90
500	10	90
200	10	.89
100	13	.87
50	15	.85
10 OR LESS	20	.80

		+	Direct input of the transposition coefficient as desired (use 1.0 if no adjustment is desired).

12.4 PM Record - Probable Maximum Precipitation (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
3	TRSDA	0	Defaults to TAREA (BA-1).
		+	Drainage area in square miles (sq km) for which storm is transposed. Transposition drainage area is used to compute the storm reduction coefficient (TRSPC) for probable maximum storm. TRSDA may be different from the actual subbasin area TAREA (BA-1). Example: It is desired to center a PMS over a five hundred square miles watershed and calculate the corresponding runoff for a two hundred square mile subbasin of that watershed. For this condition TAREA=200 and TRSDA=500.
4	SWD	NO	Precipitation will be distributed according to EM 1110-2-1411 (default).
		YES	Precipitation will be distributed according to Southwestern Division criteria (see Table 3.1, page 11).
5	R6	+	Maximum 6-hour precipitation in percent of index PMS.
6	R12	+	Maximum 12-hour percentage of PMS.
7	R24	+	Maximum 24-hour percentage of PMS.
8	R48	+	Maximum 48-hour percentage of PMS (optional).
9	R72	+	Maximum 72-hour percentage of PMS (optional).
10	R96	+	Maximum 96-hour percentage of PMS (optional).

Duration of the computed PMS will correspond to the last non-zero percentage entered. Minimum duration is twenty-four hours.

12.3 PH Record - Hypothetical Storms

These records are used to compute a hypothetical storm over a subbasin. The total storm will be automatically distributed according to the specified depth/duration data. A triangular precipitation distribution is constructed such that the depth specified for any duration occurs during the central part of the storm.

The duration of the storm will be the duration for the last non-zero depth which is specified. The first non-zero depth specified will be the most intense portion of the storm. Depths must be specified for all durations between these limits.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PH	Record identification.
1	PFREQ	50,20, 10	Storm frequency in percent. Rainfall will be converted to annual-series rainfall for fifty, twenty, and ten percent storms. No conversion is made for any other frequency (see Table 3.3, page 13).
		Blank	No conversion is made from partial-duration to annual series.
2	TRSDA	+	Storm area to be used in computing reduction of point rainfall depths per TP-40.
		0, or Blank	Basin area from BA record will be used to compute reduction of point rainfall depths, for the stream network option or from the JD record (TRDA) for the depth area option.
3	PNHR(1)	+	5-minute duration depth for PFREQ storm.
4	PNHR(2)	+	15-minute duration depth for PFREQ storm.
5	PNHR(3)	+	60-minute duration depth for PFREQ storm.
6	PNHR(4)	+	2-hour duration depth for PFREQ storm.
7	PNHR(5)	+	3-hour duration depth for PFREQ storm.

12.3 **PH Record - Hypothetical Storms** (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
8	PNHR(6)	+	6-hour duration depth for PFREQ storm.
9	PNHR(7)	+	12-hour duration depth for PFREQ storm.
10	PNHR(8)	+	24-hour duration depth for PFREQ storm.

Continue on second PH record (if needed).

FIELD	VARIABLE	VALUE	DESCRIPTION
1	PNHR(9)	+	2-day duration depth for PFREQ storm.
2	PNHR(10)	+	4-day duration depth for PFREQ storm.
3	PNHR(11)	+	7-day duration depth for PFREQ storm.
4	PNHR(12)	+	10-day duration depth for PFREQ storm.

12.1.3 PC Record - Cumulative Precipitation Time Series

PC records contain a cumulative precipitation distribution. They are only used after a PG, PB or JD record which identifies the distribution. The interval of ordinates and time of first mass curve ordinate are as specified on previous IN record. If an IN record is not specified the parameters on the IT recorded will be used. The program reads all consecutive PC records and interpolates incremental precipitation values for the computation time interval and time period specified on the IT record. A maximum of 300 values can be specified on up to thirty records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PC	Record identification.
1	PRCPR(1)	+	Cumulative precipitation at beginning of storm.
2	PRCPR(2)	+	Cumulative precipitation at end of first period.
3	PRCPR(3)	+	Cumulative precipitation at end of second period.
4	PRCPR(4)	+	Etc.

12.2 PG Record - Storm Total Precipitation for a Station (Gage)

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PG	Record identification.
1	ISTAN	AN	Station identification.
2	PRCPN	0	Total storm precipitation will be computed from following PI or PC records.
		+	Total storm precipitation in inches (mm) for above station.
3	ANAPN	+	Normal annual precipitation for above station. Used to compute basin mean precipitation by weighted average of station normal precipitation.
		0 or Blank	Weighting by normal annual precipitation will not be performed.
4	ISTANX	AN	Station to be replaced by station identified in Field 1.

All precipitation gages are total-storm stations. Some stations may also have temporal distributions associated with the storm-total precipitation. These stations are also called recording stations when referring to the temporal pattern. The temporal distribution is defined on PI or PC records immediately following a PG record.

Up to seventy stations may be entered on PG records. However, precipitation time series (PI or PC records) can be stored for only fifteen stations. If more stations are required, additional PG records may be entered later in the input stream and the data from those records will replace data for the station identified by ISTANX.

PR, PT and PW records are used within each KK, BA, etc., record series to specify weightings of precipitation station data to compute the subbasin-average precipitation distribution.

4.3 OS Record - Flood Control System Optimization

When HEC-1 is used to determine optimal sizes of flood control system components, initial estimates for sizes of the components are entered on the OS record. The following records are used later in the input set to refer to variables initialized on the OS record:

- DO Diversion
- SO Reservoir
- WO Pump
- LO Local protection projects and uniform degree of protection

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OS	Record identification.
1	VAR(1)	+	Size of flood control system component. Reservoir volume in acre-ft (1,000 cu m), diversion, and pump in cfs (cu m/sec), local protection in cfs (cu m/sec) or feet (meters), uniform degree of protection in percent. Size will not be optimized.
		0	Zero capacity indicates component will be ignored during simulation.
		-	Initial estimates of component; size will be optimized.
2-10	VAR(I)	+,-	Similar to Field 1. Up to ten values.

4.4 OF Record - Fixed Facility Costs

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OF	Record identification.
1	FCAP	+	Capital cost of system facilities other than those to be optimized (fixed facilities). Same dollar units as system components.
2	FDCNT	+	Equivalent annual cost of FCAP. Same dollar units as system components.
		+.0000	Discount factor (capital recover factor) to compute equivalent annual cost from capital cost. (Example .05)
3	FAN	+	Equivalent annual cost of operation, maintenance power and replacement of FCAP system facilities.
		+.0000	Proportion of capital cost that will be required for annual operation, maintenance, power and replacement.

4.5 OO Record - System Optimization Objective Function

Used to modify objective function.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	OO	Record identification.
1	ANORM	0	Default value of 0.1 will be used.
		+	Proportion of target flow for normalized objective function. May wish to reduce if target flow deviation is excessive. Do not reduce to below .02.
2	CNST	0	Default value of 1.0 will be used.
		+	Relative weight between net benefits and performance target deviation in objective function.

5 User-Defined Output Tables (V Records)

VS and VV records define tables which may be used to display selected time series output. Each table may contain up to ten columns of data as defined on one pair of VS/VV records. Up to five tables may be output by using five successive pairs of VS/VV records.

5.1 VS Record - Stations Desired

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	VS	Record identification.
1	ISTA(1)	AN	Station identification corresponding to ISTAQ on KK record where special output summary is desired. Variable to be printed is described by SMVAR(1) on the VV record.
2	ISTA(2)	AN	Same as above for up to ten stations; same station must be repeated in order to print several time series for the same station.

5.2 VV Record - Information Desired

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	VV	Record identification.
1	SMVAR(1)	+	Numeric code describing the first column of output, identified as V.PR where V is the variable to be printed in the table, P is the plan number, and R is the ratio number (corresponding to ISTA(1) on a VS record). Values of V correspond to: 1. Observed flow 2. Calculated flow 3. Rainfall values 4. Rainfall loss values 5. Rainfall excess value 6. Storage values 7. Stage values
2	SMVAR(2)	+	Same as above corresponding to ISTA(2). Up to ten values.

6 Basin Runoff Data (B Records)

These records are required for direct input of a hydrograph or for computing runoff from precipitation on a basin/subbasin.

6.1 BA Record - Subbasin Area

Required for subbasin runoff computation or direct input of a hydrograph on QI records. If QI records are used, they should follow the BA record and an IN record if necessary. The next hydrograph computation specification record (KK) should follow the last QI record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BA	Record identification.
1	TAREA	+	Drainage area in square miles (sq km).
2	SNAP	+	Normal annual precipitation for the drainage area above. Will be overridden by computed normal annual for snowmelt zone, if used.
		0 or Blank	Weighting by basin normal annual precipitation will not be performed.
3	RATIO	+	Multiply each hydrograph ordinate by this value.

6.2 BF Record - Base Flow Characteristics

Base flow parameters (STRTQ, QRCSN, and RTIOR) will be assumed equal to zero unless this record is supplied. Once this record is supplied, all following subbasins will be assumed to have these values unless overridden by another BF record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BF	Record identification.
1	STRTQ	+	Flow at start of storm in cfs (cu m/s). Will be receded in same manner as QRCSN below.
		-	When negative, this is cfs/sq mi (cu m/s/sq km) which will be multiplied by subbasin area, TAREA, to determine STRTQ.
2	QRCSN	+	Flow in cfs (cu m/s) below which base flow recession occurs in accordance with the recession constant RTIOR. QRCSN is that flow where the straight line (in semilog paper) recession deviates from the falling limb of the hydrograph.
		-	When negative, it is the ratio by which the peak discharge is multiplied to compute QRCSN.
3	RTIOR	+	Ratio of recession flow, QRCSN to that flow occurring one hour later. Must be greater than or equal to one.

NOTE - The definition of RTIOR has been changed from the 1973 version of HEC-1. The old value is QA/QB in the following equation:

New RTIOR = (QA/QB)**(1/DT)

Where QB is a recession flow occurring DT hours after recession flow QA.

6.3 BI Record - Read Hydrograph from a File

A BI record is used to identify a hydrograph on a file created earlier by HEC-1. The hydrograph is read from this file and converted to the time interval and starting time for the current job.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	BI	Record identification.
1	ISTA	AN	Station name for hydrograph to be read from file on unit IQIN (default is ISTAQ on KK record).
2	IQIN	21 or 22	Unit number (specify 21 or 22) for file which contains HEC-1 data to be retrieved from a previous simulation. This option allows HEC-1 to be restarted from the point where a previous simulation saved the HEC-1 data via the IOUT option on the KO record, Field 5.

7 Diversion Data (D Records)

Streamflow may be diverted or retrieved at any stream station operation (KK record series).

7.1 DR Record - Retrieve Previously Diverted Flow

The DR record is used to retrieve a hydrograph which was created by a previous diversion. This hydrograph can then be treated like any other hydrograph in the system. Retrieval of a diversion hydrograph is a separate operation, so the DR record must be preceded by a KK record which identifies the hydrograph which has been retrieved.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DR	Record identification.
1	ISTAD	AN	Station name corresponding to the name given a previously diverted flow with a DT record.

7.2 DT/DI/DQ Records - Flow Diversion

Flow diversion is considered to be a separate operation, so the D records must be preceded by a KK record which identifies the hydrograph which remains after diversion. Diversions are specified as a function of main channel flow on the DI/DQ records.

For multiplan simulations (JP record), diversion data (DI and DQ records) must be supplied for all plans. If no water is be diverted for a particular plan, then the DQ record would contain only zeroes. Diversion hydrographs are saved for all plans using the name in Field 1 of the DT record.

7.2.1 DT Record - Diversion Identifier

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DT	Record identification.
1	ISTAD	AN	Name to be assigned to the diverted flow for future retrieval purposes with DR record.
2	DSTRMX	+	Maximum volume of diverted flow in acre-feet (1,000 cu m) (not used if zero or blank).
3	DVRSMX	+	Peak flow (cfs) that can be diverted in any computation period. (Default: 1×10^{10})

7.2.2 DI Record - Diversion Inflow Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DI	Record identification.
1	DINFLO(1)	+	Inflow (cfs, cu m/s) to the diversion station, corresponding to DIVFLO(1) (DQ record), the flow to be diverted.
2-10	DINFLO(I)		Etc., up to twenty values (two records) corresponding to the amount of flow to be diverted on the DQ records.

7.2.3 DQ Record - Diversion Outflow Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DQ	Record identification.
1	DIVFLO(1)	+	Rate of flow (cfs, cu m/s) to be diverted, corresponding to the main channel flow rate (before diversion) on DINFLO, DI records.
2-10	DIVFLO(I)	+	Etc., up to twenty values (two records) corresponding to values on DI records.

7.3 DO Record - Diversion Optimization

Data required for optimization of diversion capacity are:

Diversion Identification	DT record
Diverted Flow vs. Inflow	DI, DQ records
Cost vs. Capacity	DC, DD records
Cost Factors, Range	DO record

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DO	Record identification.
1	IOPTD	+	Number of field on OS record which contains capacity of diversion (overrides DSTRMX on DT record).
		0, or Blank	Diversion capacity is not optimized.
2	DANCST	+	Proportion of capital cost of diversion that will be required for annual operation and maintenance.
3	DDSCNT	+	Discount factor (capital recovery factor) to compute equivalent annual cost from capital cost.
4	DVRMX	+	Maximum permissible capacity of diversion in cfs (cu m/sec). Used as a constraint on optimization.
5	DVRMN	+	Minimum permissible capacity of diversion cfs (cu m/sec). Used as a constraint on optimization.

7.4 DC Record - Diversion Capacity Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DC	Record identification.
1	DCAP(1)	+	Diversion capacity in cfs (cu m/sec) corresponding to costs on DD record.
2-10	DCAP(I)	+	Etc., up to ten values.

7.5 DD Record - Diversion Cost Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DD	Record identification.
1	DCST(1)	+	Diversion capital cost corresponding to capacity on DC record.
2-10	DCST(I)	+	Etc., up to ten values.

8 Hydrograph Transformation (H Records)

These records describe operations which combine or reshape hydrographs.

8.1 HB Record - Hydrograph Balance

This record is required only if it is desired to balance the current hydrograph according to these specified volumes/durations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HB	Record identification.
1	NQB(1)	+	Number of ordinates to be included in the shortest duration.
2	SUMB(1)	+	Sum of flows corresponding to duration NQB(1) shortest duration.
3	NQB(2)	+	Number of ordinates for the next larger duration (including the prior duration).
4	SUMB(2)	+	Sum of flows corresponding to duration NQB(2).
5-10			Pairs of numbers and sums, up to five durations.

8.2 HC Record - Combine Hydrographs

Hydrograph combination is considered as a separate operation, so the HC record must be preceded by a KK record which identifies the resulting hydrograph. The HC record indicates the number of hydrographs which will be combined.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HC	Record identification.
1	ICOMP	2-5	Indicates ICOMP hydrographs will be combined at this stream station. Default is two.
2	TAREA	+	For depth-area jobs (JD records), this field may be used to set the cumulative basin area for the combined hydrograph. This option is useful when combining diversion hydrographs. The area associated with a diversion hydrograph is zero when combined with another hydrograph. This option may also be useful to set the area when combining a hydrograph brought in with a BI record.
		0	Use basin area calculated by program to compute interpolated hydrographs.

8.3 HL Record - Local Flow

HL records are used in conjunction with observed QO records to compute local flow. The local flow is the difference between the last computed hydrograph and the observed flows. Note that the current hydrograph now corresponds to the observed flows. The last computed hydrograph is removed from the stack and is no longer available for computations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HL	Record identification.
1	TAREA	+	Basin area (sq mi) corresponding to observed hydrograph.

8.4 HQ/HE Records - Rating Table for Stage Hydrograph

HQ and HE records may be included in any hydrograph calculation to compute stages from the computed hydrograph.

8.4.1 HQ Record - Flows for Rating Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HQ	Record identification.
1-10	QSTG	+	Flows in cfs (cu m/sec) corresponding to stages on HE record. Up to twenty values on two records.

8.4.2 HE Record - Stages for Rating Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HE	Record identification.
1-10	STGQ	+	Stages in feet (meters) corresponding to flows on HQ record. Up to twenty value on two records.

8.5 HS Record - Calculate Reservoir Storage from Inflow and Outflow

The HS record must be followed by the desired reservoir releases on QO records or read in from the DSS database using a ZR record (e.g., ZR=QO....). Reservoir storage is calculated as a result of the inflow to this location and the prescribed releases on QO records. Those QO records are then used as the hydrograph for the next downstream KK calculation. See Example Problem #14.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	HS	Record identification.
1	STR	+	Initial storage in acre-feet at the beginning of the simulation.

9 Job Step Control (K Records)

9.1 KK Record - Station Computation Identifier**

The KK record must be repeated at the beginning of each station computation (i.e., subbasin runoff, routing, combining, diversion, etc.).

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KK	Record identification.
1	ISTAQ	AN	Stream station location identification. Must be a unique identifier for entire run when used in conjunction with a damage reach in economic analysis.
2-10	NAME	AN	Station description.

9.2 KM Record - Message

The message on the KM record will be printed at the beginning of the output for each stations or plan. There is no limit on the number of KM records. KM records may not be interspersed in certain record sequences such as precipitation records or kinematic wave records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KM	Record identification.
1-10	ITLS	AN	Station- or computation-description message.

**Required

9.3 KO Record - Output Control Option

Use this record to temporarily override output control specified on IO record until the next KK record is read.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KO	Record identification.
1	JPRT	0 or Blank	Use print control specified on IO record.
		1,2	Print all output for this station.
		3	Print input data and summaries for this computation.
		4	Print basin input data only for this computation.
		5	No printout for this computation.
2	JPLT	0 or Blank	Use plot control specified on IO record.
		1	No printer plots for this computation.
		2	Plot computed hydrograph for this computation.
3	QSCAL	0 or Blank	Use plot scale specified on IO record.
		+	Desired scale for streamflow plot in units per ten printer characters (e.g., one hundred for one hundred cfs per ten characters).
4	IPNCH	0	No hydrograph is to be saved on Unit 7 for this station.

9.3 KO Record - Output Control Option (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
		+	Hydrograph computed at this station is to be saved on Unit 7. See Fields 6, 7, and 8 below for optional definition of beginning and ending ordinate and time interval. A KF record may be used to specify format for the Unit 7 file. Default format is (2HQI,I6,9I8). See Table 13.1.
5	IOUT	0	No hydrograph written to tape/disk file for this station.
		21 or 22	Unit number (specify 21 or 22) for tape/disk file on which to save HEC-1 data in order to restart the simulation at this location in a subsequent progra execution. The program restart option . activated on the BI record. See Fields 6, 7, and 8 below for optional definition of beginning and ending ordinates and time interval. The file will be saved under the name "TAPE21" or "TAPE22", depending on the unit number specified.
6	ISAV1	+	First ordinate of hydrograph to be saved on Unit 7, 21, or 22. Default is 1.
7	ISAV2	+	Last ordinate of hydrograph to be saved on Unit 7, 21, or 22. Default is NQ (IT-4).
8	TIMINT	+	Time interval in hours for hydrograph to be saved on Unit 7, 21, or 22. Ordinates will be interpolated from current hydrograph. Default is time interval specified on IT record (IT-1).

9.4 KF Record - Unit 7 Output Format

Use this record to specify format for the hydrographs on Unit 7. (See KO-4.) This format will be used until a new KF record is read. Default format is (2HQI,I6,9I8). KF record should not be used unless format is to be changed. This record can only be used in *FIX format.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KF	Record identification.
1	FLOTQ	YES	Convert hydrograph to floating point (decimal) numbers before writing.
		NO	Write hydrograph in integer format (default).
2-10	IFMT	AN	Alphanumeric format specification for output. This format must be consistent with the choice of integer or floating point indicated in Field 1. Parentheses must be included. Example: (2HQI,F6.2,9F8.2)

9.5 KP Record - Plan Label

This record is required to identify (number) a plan in a multiplan run. If hydrograph computation data is provided before (or without) a KP record, it is assumed to be plan 1. The data provided after a KP record need only be that required to change what was computed in the previous plan. All plans not specifically identified with a KP record are assumed to be the same as the first plan processed. See following example.

```
KK
KP 1
.
.  Data for PLAN 1
.
KP 3
.
.  Data for PLAN 3
.
   *Data for PLAN 2 is not provided and thus will be the same as
   PLAN 1
KK
```

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KP	Record identification.
1	ISTM	+	Plan number identifier.

10 Loss Rate Data (L Records)

One of four different rainfall loss rate procedures may be used for a subbasin runoff computation. A different loss rate may be used for each subbasin and/or plan. Snowmelt loss rate (LM record) may be used in conjunction with the exponential (LE record) or uniform (LU record) loss rates.

10.1 LU Record - Initial and Uniform Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LU	Record identification.
1	STRTL	0,+	Initial rainfall/snowmelt loss in inches (mm) for snow free ground. If operating in the optimization mode (OU record), this variable will be fixed at this value and not optimized.
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
2	CNSTL	0,+ or - STRTL	Uniform rainfall/snowmelt loss in inches/hour (mm/hr) which is used after the starting loss is completely satisfied. See Field 1 for meaning of VALUE.
3	RTIMP	+	Percent of drainage basin that is impervious. No losses are computed for this portion of the basin.
4-6			Specify loss rate variables similar to Fields 1-3 for second kinematic subcatchment.

10.2 LE Record - HEC Exponential Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LE	Record identification.
1	STRKR	+,0	Initial value of STRKR in inches/hour (mm/hr) for HEC's exponential rain loss rate function. If doing an optimization (OU record), this variable will not be optimized and will be fixed at this value.
		-1	For optimization only (OU record previously supplied), program assumes a starting value and then optimizes.
		-	For optimization only (OU record previously supplied), program uses this (after sign change) as the starting value for the optimization.
2	DLTKR	0,+ or -	DLTKR is the amount in inches (mm) of initial accumulated RAIN loss during which the loss coefficient is increased. See Field 1 for meaning of value.
3	RTIOL	0,+ or -	Rate of change of the rain loss-rate parameter computed as the ratio of STRKR to a value of STRKR after ten inches (ten mm) of accumulated loss. See Field 1 for an explanation of the values.
4	ERAIN	0,+ or -	Exponent of precipitation for loss rate function. See Field 1 for meaning of value.
5	RTIMP	+	Percent of subbasin which is impervious. 100 percent runoff will be computed for this portion of the subbasin.
6-10			Specify loss rate variables similar to Fields 1-5 above, for the second kinematic subcatchment. UK record is used. No optimization may be performed.

10.3 LM Record - HEC Exponential Snowmelt Loss Rate

This record is used in conjunction with the LE or LU records to compute the loss rate for snowmelt. Only the exponential loss can be used with the optimization option.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LM	Record identification.
1	STRKS	+,0	Initial value of STRKS in inches/hour (mm/hr) for HEC exponential snowmelt loss rate function. When used with LE record, or uniform meltwater loss rate, inches/hour (mm/hour) when used with LU record. If doing an optimization (OU record) this variable will not be optimized and will be fixed at this value.
		-1	For optimization of exponential loss only (OU record previously supplied), program assumes a starting VALUE and then optimizes.
		-	For optimization of exponential loss only (OU record previously supplied), program uses this (after sign change) as the starting VALUE for the optimization.
2	RTIOK	0,+ or -	Rate of change of the snowmelt loss-rate parameter computed as the ratio STRKS to a value of STRKS after ten inches (ten mm) of accumulated loss. See Field 1 for the meaning of VALUE. Not used for uniform meltwater loss rate.

10.4 LG Record - Green and Ampt Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LG	Record identification.
1	IA	0,+	Initial loss inches (mm).
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above except program uses this value (after sign change) as the starting point for the optimization.
2	DTHETA	+ or -	Volumetric moisture deficit. (If value equal to zero method reduces to initial loss equal to IA and constant loss, equal to XKSAT, see LU record.) See Field 1 for meaning of value.
3	PSIF	+ or -	Wetting front suction inches (mm). (If value equal to zero method reduces to initial loss equal to IA and constant loss equal XKSAT, see LU record.) See Field 1 for meaning of value.
4	XKSAT	+ or -	Hydraulic conductivity at natural saturation inches per hour (mm/hour). See Field 1 for meaning of value.
5	RTIMP	+	Percent of subbasin which is impervious. One hundred percent runoff will be computed for this portion of the subbasin.
6-10			Specify loss rate variables similar to Fields 1-5 above, for the second kinematic subcatchment. UK record is used. No optimization may be performed.

10.5 LH Record - Holtan Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LH	Record identification.
1	FC	0,+	Holtans long term equilibrium loss rate in inches/hour (mm/hr) for rainfall/snowmelt losses on snowfree ground. If this is an optimization job (OU record supplied), this variable will be fixed at this value and not optimized.
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above except program uses this value (after sign change) as the starting point for the optimization.
2	GIA	0,+ or -	Infiltration rate in inches/hour per (inch**BEXP) or mm/hr per (mmm***BEXP) of available soil moisture storage capacity (i.e., 1 - soil moisture). See Field 1 for meaning of VALUE.
3	SAI	0,+ or -	Initial value of SA available soil moisture capacity in inches (mm). See Field 1 for meaning of VALUE.
4	BEXP	0,+ or -	Exponent of available soil moisture storage, SA. Default value is 1.4. See Field 1 for meaning of VALUE.
5	RTIMP	+	Percent of drainage basin that is impervious. No losses are computed for this portion of the basin. This variable is not optimized.
6-10			Repeat Fields 1-5 for second kinematic subcatchment if used.

10.6 LS Record - SCS Curve Number Loss Rate

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LS	Record identification.
1	STRTL	+	Initial rainfall abstraction in inches (mm) for snow free ground. For an optimization job (OU record) this variable is fixed at the given value.
		0	Initial abstraction will be computed as 0.2*(1000-10*CRVNBR)/CRVNBR. For an optimization job, initial abstraction will vary with CRVNBR.
		-1	For optimization only (OU record previously supplied), program will assume a starting value and then optimize.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
2	CRVNBR	0,+	SCS curve number for rainfall/snowmelt losses on snow-free ground. If this is an optimization job (OU record supplied), this variable will be fixed at this value and not optimized.
		-	Same as (-1) above but program uses this value (after sign change) as the starting point for the optimization.
3	RTIMP[1]	+	Percent of drainage basin that is impervious. No losses are computed for this portion of the basin.
4-6			Specify loss rate variables similar to Fields 1-3 for second kinematic subcatchment if used.

[1]This factor should only be used for directly connected impervious areas not already accounted for in the curve number land use.

11 Snowmelt Data (M Records)

M records are required only if snowfall/melt computations are to be made. Snow computations are accomplished in separate, equally incremented, elevation zones within each subbasin. Melt may be computed by the degree-day or energy-budget method.

11.1 MA Record - Elevation Zone Data

These records are required for snowfall/melt simulation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MA	Record identification.
1	AREA(1)	+	Drainage area in sq mi (sq km) in Zone 1 (lowest zone).
2	SNO(1)	+	Average water equivalent in inches (mm) of snowpack at start of this job (first interval of NQ) in Zone 1, corresponding to AREA(1).
3	ANAP(1)	+	Normal annual precipitation in inches (mm) for Zone 1, corresponding to AREA (1).

NOTE - Up to ten records, one for each zone. Zones must be in equal elevation increments corresponding to lapse rate coefficient TLAPS (MC-1).

11.2 MC Record - Melt Coefficient

This record is required for any snowfall/melt simulation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	MC	Record identification.
1	TLAPS	+	Temperature lapse in degrees F (°C) per elevation zone. All zones must have same increment of elevation.
2	COEF	+	Snowmelt coefficient, usually about 0.07 for degree-day method and 1.0 for energy-budget method.
		-1	For optimization only (OU record previously supplied), program assumes a starting value and then optimizes.
		-	For optimization only (OU record previously supplied), program uses this (after sign change) as the starting value for optimization.
3	FRZTP	+ or -	Index temperature at which snow will melt in degrees F (°C). Precipitation will be assumed to fall as snow at temperature of FRZTP+2°F (FRZTP+2°C) and below.

13.2 QI Record - Direct Input Hydrograph

These records are used to input a hydrograph directly (without rainfall-runoff computations) at any point in a river network.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QI	Record identification.
1	QI(1)	+	Hydrograph ordinate in cfs (cu m/s) at beginning of first period.
2	QI(2)	+	Etc.

13.3 QS Record - Stage Hydrograph

These records are used to input a stage hydrograph for comparison with the computed hydrograph. A rating table, on HQ and HE RECORDS, must also be supplied. Comparison of hydrographs is a distinct operation which must be separated from other operations with a KK RECORD.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QS	Record identification.
1	QS(1)	+	Stage in feet (m) at the beginning of the first time interval.
2	QS(2)	+	Etc.

13.4 QP Record - Pattern Hydrograph

These records are used to input a pattern hydrograph for which local inflow will be distributed in a routing optimization job (OR record) only.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QP	Record identification.
1	QP(1)	+	Pattern hydrograph for local inflow which will be adjusted for volume in routing coefficient derivation.
2	QP(2)	+	Etc.

14 Routing Data (R Records)

Routing of streamflows may be accomplished by several different methods. One of the following methods should be selected and put in the record set immediately after the streamflows to be routed have been computed. Also see Table 10.7 for input data requirements for alternative routing methods.

General information (use if desired)

RN indicates NO routing, **used only with multiPLAN.**
RL **channel losses**, may be used in conjunction with any of routing methods.

Routing Methods (choose one)

RD **Muskingum-Cunge** "diffusion" (RC, RX, RY optional)
RK **Kinematic Wave**
RM **Muskingum**
RT **Straddle/Stagger**
RS **Storage** (modified Puls, normal depth, or level pool, see summary of options on RS record)

Routing is considered to be a separate operation, so the R records must be preceded by a KK record which identifies the routed hydrograph.

14.1 RN Record - No Routing Option for this Plan

The RN record is used in a multiplan job to indicate that no routing occurs for this plan.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RN	Record identification.

14.2 RL Record - Channel Loss

Channel infiltration/percolation losses may be computed in conjunction with any of the routing methods. If desired, include the RL record with the desired routing method records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RL	Record identification.
1	QLOSS	+	Constant channel loss in entire routing in cfs (cu m/sec). This value is subtracted from every ordinate of the inflow hydrograph.
2	CLOSS	+	Ratio of remaining flow (after QLOSS) which is lost for entire routing. Each inflow hydrograph ordinate (after QLOSS is subtracted) is multiplied by (1-CLOSS).
3	PERCRT	+	Percolation rate cfs/acre (cu m/sec-acre) for wetted surface area of channel. This option is used in conjunction with storage routing and requires SA or SV/SE records.
4	ELVINV	+	Average invert elevation of channel L used to compute flow surface area for PERCRT.

14.3 RD Record - Muskingum-Cunge Routing

The RD record can be used by itself or in conjunction with RC, RX, and RY records to specify an eight point cross-section. When utilizing the eight-point cross-section option, fields 1-8 of the RD record do not need to be filled out. All of the necessary routing information is taken from the RC, RX, and RY records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RD	Record identification.
1	L	+	Channel length (ft).
2	S	+	Channel slope (ft/ft).
3	N	+	Channel roughness (Manning's n).
4			Not used.
5	SHAPE	TRAP	Trapezoidal channel, includes triangular and rectangular (default).
		DEEP	Deep rectangular (square) channel. Flow depth is approximately equal to channel width.
		CIRC	Circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.
6	WD	+	Channel bottom width or diameter (ft). Default value is zero.
7	Z	+	Side slopes, if required. Defaults equals one when WD, RD-6, is zero.
8			Not used. This field is only used in conjunction with kinematic wave subbasin runoff, see UK record.

14.4 RK Record - Kinematic Wave Channel Routing

This record is used for kinematic wave routing of a previously computed hydrograph. For channel routing in conjunction with runoff calculation, see the section on UK and RK records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RK	Record identification.
1	L	+	Channel length (feet or meters).
2	S	+	Channel slope (ft/ft).
3	N	+	Channel roughness.
4			Not used. This field is only used with the UK/RK record combination.
5	SHAPE	TRAP,0, Blank	Trapezoidal channel (including triangular and rectangular). (Default)
		DEEP	Deep rectangular (square) channel. Flow depth is approximately equal to channel width.
		CIRC	Circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.
6	WD	+	Channel bottom width or diameter (feet or meters). (Default value is zero.)
7	Z	+	Side slopes, if required (default value is 1.0 when WD, RK-6, is zero). (1 vertical to Z horizontal.)
8			Not used. This field is only used with kinematic wave subbasin runoff, see UK record.
9	NDXMIN	+	Integer number of routing increments (default five, maximum of fifty). This variable is used in the finite difference solution. The greater the number of routing steps the more accurate the solution. **This variable is not required.** HEC-1 will compute a routing increment that is probably accurate enough for most purposes.

14.5 RM Record - Muskingum Routing

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RM	Record identification.
1	NSTPS	+	Integer steps (equal to number of subreaches) for the Muskingum routing.
		-1	Number of steps will be optimized. OR record must have been previously supplied.
2	AMSKK	+	Muskingum K coefficient in hours for entire reach[1]. The program will automatically compute the subreach Muskingum K as AMSKK/NSTPS. AMSKK, etc., must be within the following limits:

$$\frac{1}{2(1-X)} \leq \frac{(AMSKK*60.)}{(NMIN * NSTPS)} \leq \frac{1}{2X}$$

Where NMIN is the number of minutes in the computation interval.

FIELD	VARIABLE	VALUE	DESCRIPTION
		-1	Muskingum K coefficient will be optimized. OR record must have been previously supplied.
3	X	+	Muskingum X coefficient for Muskingum routing or working R&D routing.
		-1	Muskingum X coefficient will be optimized. OR records must have been previously supplied.

[1]NOTE - The Muskingum K coefficient input is DIFFERENT than in the pre-1981 versions of HEC-1. It is now input as the TOTAL K for the routing reach, not the K for the subreach.

14.6 RT Record - Straddle\Stagger Routing

NOTE - The variables used for this routing method are dependent on the computation time interval. The user should make proper adjustments when using different time intervals.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RT	Record identification.
1	NSTPS	+	Integer number of routing steps to be used for routing by Tatum method.
		0	LAG method.
		-1	If number of steps for Tatum method is to be derived by the program. OR record must have been previously supplied.
		1	If routing by Straddle-Stagger method.
2	NSTDL	+	Integer number of ordinates to be averaged in the Straddle-Stagger routing.
		-1	If straddle is to be derived by the program. OR record must have been previously supplied.
		2	If routing by the Tatum method with or without derivation.
3	LAG	+	Integer number of intervals hydrograph is to be lagged.
		-1	If lag is to be derived by the program. OR record must have been previously supplied.
		0	Tatum

14.7 RS Record - Storage Routing

This record is required to perform a storage-discharge routing. The record contains the starting conditions for the routing. A storage-discharge relation may be input directly on the SV and SQ records, or computed from surface area and elevation on SA and SE records and stage-discharge data on SE and SQ records, or computed from channel characteristics on RC, RX and RY records. Thus, storage routing may be accomplished by one of the following sequences of records:

Channel Routing: (choose one method)

RS,RC,RX,RY	Normal depth storage
RS,SV,SQ	Modified Puls

Reservoir Routing: RS + volume + outflow

Volume: (choose one method)

SV (SE optional)	Known volume
SA,SE	Compute volume

Outflow: (choose one method)

SQ (SE optional)	Known outflow (and rating)
SS, (SL and ST optional) requires SE record on outflow volume specifications.	Computed weir spillway
SS, (SL and ST optional) SG, SQ, SE	Computed ogee or trapezoidal spillway outflow

14.7 RS Record - Storage Routing (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RS	Record identification.
1	NSTPS	+	Number of steps to be used in the storage routing. Usually about equal to (reach length/ average velocity)/time interval (NMIN). NSTPS is usually equal to 1 for a reservoir.
2	ITYP	STOR	Storage (acre-feet or 1000 cu m) for the beginning of the first time period is specified in next field (default).
		FLOW	Discharge (cfs or cu m/s) for the beginning of the first time period is specified in the next field.
		ELEV	Elevation in (feet or meters) for the beginning of the first time period is specified in the next field.
3	RSVRIC	+	Storage (acre-ft or 1000 cu m), discharge (cfs or cu m/s), or elevation (ft or m), as indicated by previous field ITYP, corresponding to the desired starting condition at the beginning of the first time period IDATE/ITIME (IT-2/IT-3).
		-1	The initial outflow will be set to the initial inflow.
4	X	0	Working R&D method not used.
		+	Wedge storage coefficient (Muskingum X) to be used in a working R&D routing using a computed or given storage-discharge relationship.

14.8 RC Record - Normal-Depth Channel Routing

This record is used in combination with the RX and RY records to describe the channel in a routing reach. Manning's equation is used to compute a table of storage and outflow values for use in modified puls routing. These values are based on uniform subcritical flow in the reach. An RS record is required to provide initial conditions for modified puls routing.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RC	Record identification.
1	ANL	+	Left overbank Manning's n value.
2	ANCH	+	Channel Manning's n value.
3	ANR	+	Right overbank Manning's n value.
4	RLNTH	+	Reach length, in feet (m), for which computations are represented.
5	SEL	+	Energy grade line slope in ft/ft (m/m) for normal flow rate computations. If unknown, may be estimated as equal to channel or floodplain slope.
6	ELMAX	+	Maximum elevation for which storage and outflow values are to be computed (default is maximum elevation on RY record).

14.9 RX Record - Cross Section X Coordinates[1]

Left bank and right bank of channel are assumed to be located at points 3 and 6, respectively, of the cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RX	Record identification.
1	X(1)	+	Horizontal station, in feet (m), of first point in cross section on the LEFT OVERBANK. Corresponds to first elevation Y(1) on RY record.
2	X(2)	+	Similar to above for another point on LEFT OVERBANK. Corresponds to second elevation Y(2) on RY record.
3	X(3)	+	Similar to above for LEFT BANK of CHANNEL.
4	X(4)	+	Similar to above for a point in CHANNEL.
5	X(5)	+	Similar to above for another point in CHANNEL.
6	X(6)	+	Similar to above for RIGHT BANK of CHANNEL.
7	X(7)	+	Similar to above for a point on RIGHT OVERBANK.
8	X(8)	+	Similar to above for another point on RIGHT OVERBANK.

[1]All eight points must be used. Stationing (x distance) must continuously increase.

14.10 RY Record - Cross Section Y Coordinates

Left bank and right bank of channel are assumed to be located at points 3 and 6, respectively, of the cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RY	Record identification.
1	Y(1)	+	Vertical elevation, in feet (m), of first point in cross section on the LEFT OVERBANK. Corresponds to first station on RX record. Must be a positive value.
2	Y(2)	+	Similar to above for another point on the LEFT OVERBANK. Corresponds to second station on RX record.
3	Y(3)	+	Similar to above for LEFT BANK of CHANNEL.
4	Y(4)	+	Similar to above for a point in CHANNEL.
5	Y(5)	+	Similar to above for another point in CHANNEL.
6	Y(6)	+	Similar to above for RIGHT BANK of CHANNEL.
7	Y(7)	+	Similar to above for a point on RIGHT OVERBANK.
8	Y(8)	+	Similar to above for another point on RIGHT OVERBANK.

15 Storage Routing Data (S Records)

S records are used to provide storage and outflow data for storage routing.

STORAGE data can be input in two ways:

1. Storage volume on SV records
2. Surface area and elevation on SA and SE records

OUTFLOW data can be input in three ways:

1. Discharge on SQ records
2. Weir and orifice data on SS and SL records
3. Ogee spillway data on SL, SS, SG, SQ, and SE records

When spillway data (weir or ogee) are provided, the program computes a steady flow rating curve, then interpolates from that rating curve during the routing calculation. Elevation data may be input for storage or outflow by following SV or SQ records with SE records.

15.1 SV/SA Records - Reservoir Storage Data

One of these sets of records is required in order to compute the storage relationship for a reservoir routing. If the storage volumes are not known, they may be computed by the conic method using surface area-elevation information.

15.1.1 SV Record - Reservoir Volume

These records are to be used if the reservoir volumes are known. Do not use if SA records are supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SV	Record identification.
1-10	RCAP(I)	+	Reservoir storage in acre-feet (1,000 cubic meters), up to twenty values on two records.

15.1.2 SA Record - Reservoir Surface Area Option

These records are used if the reservoir volumes (SV record) are not known. Do not use if SV records are supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SA	Record identification.
1-10	RAREA(I)	+	Reservoir surface area in acres (1,000 square meters), up to twenty values on two records.

15.2 SE Record - Elevation

SE records may be used immediately after SV, SA, or SQ records to specify elevations for the values on those records.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SE	Record identification.
1-10	ELEV(I)	+	Elevation in feet (m) corresponding to value in same field on preceding SV, SA, or SQ record (up to twenty values on two records). Note that the SE record must follow an SV or SA record.

15.3 SQ Record - Discharge

The SQ record gives outflow data for storage routing. Values should correspond to storage data, or if elevation data are provided for both storage and outflow, the program will interpolate discharges for the given storages.

The SQ and SE records are also used to specify tailwater data for the ogee spillway option.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SQ	Record identification.
1-10	DISQ(I)	+	Discharge in cfs (cu m/s) up to twenty values on two records.

15.4 SL Record - Low-Level Outlet

This record is necessary to describe flow through a low-level outlet. An SS record is also required if the SL record is used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SL	Record identification.
1	ELEVL	+	Centerline elevation, in feet (m), of downstream end of low-level outlet. This low-level outlet may be used with the weir, trapezoidal, or ogee spillways.
2	CAREA	+	Cross-sectional area, a, in square feet (sq m), in the low-level outlet orifice equation as described below for COQL.
3	COQL	+	Discharge coefficient, c, in orifice equation, q=ca(2gh)**e, for the low-level outlet.
4	EXPL	+	Exponent, e, of head h in orifice equation for low-level outlet as described in previous two fields. Usually equals 0.5.

15.5 SS Record - Spillway Characteristics

This record is used to compute flow for weir or ogee spillways. If the dam overtopping summary is requested (ST record), the spillway crest elevation should be provided on this record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SS	Record identification.
1	CREL	+	Spillway crest elevation, in feet (m). This crest elevation is also required in the weir, trapezoidal, and ogee spillway computations.
2	SPWID	+	Spillway length, in feet (m) corresponding to L in the WEIR equation as described below for COQW or the bottom width of the TRAPEZOIDAL spillway or the length of the OGEE spillway.
3	COQW	+	Discharge coefficient, c, in the spillway WEIR flow equation q=clh**e.
4	EXPW	+	Exponent e of head, h, in spillway WEIR flow equation. Usually equals 1.5.

15.6 ST Record - Top-of-Dam Overflow

This record is used to compute flow over the top of a dam. Flow computed using the weir coefficients specified on this record is added to outflow computed from the spillway (SQ, SS, SL, or SG records). Use of this record calls for the dam overtopping summary (spillway crest elevation should be provided on SS record). This record is required if the non-level top-of-dam option (SW/SE records) is used. The discharge over the top of dam is added to the discharge elevation relationship generated by the program (SL, SS, SG options) or specified by the user (SQ, SE option).

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	ST	Record identification.
1	TOPEL	+	Elevation, in feet (m), of the top of the dam at which overtopping begins.
2	DAMWID	+	Length, in feet (m), of the top-of-dam which is actively being overtopped - corresponds to one in the weir equation q=clh**e. Does not include spillway.
3	COQD	+	Discharge coefficient, c, in the above weir equation. If SQ/SE records include flow over top of dam, Field 3 should be zero.
4	EXPD	+	Exponent, e, in the above weir equation. Usually equals 1.5.

15.7 SW/SE Records - Non-Level Top-of-Dam Option

If a non-level top-of-dam has a significant impact on the flow over the top of the dam, the following records should be used to describe the geometry of the top of the dam. These records are used in addition to the ST record.

15.7.1 SW Record - Non-Level Crest Lengths

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SW	Record identification.
1-10	WIDTH(I)	+	Accumulated dam crest length at or below corresponding elevation on SE record (up to ten values).

15.7.2 SE Record - Non-Level Crest Elevations

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SE	Record identification.
1-10	ELVW(I)	+	Elevation in feet (m) for corresponding crest length on SW record (up to 10 values).

15.8 SG Record - Trapezoidal and Ogee Spillway

This record is used only if a trapezoidal or ogee spillway is to be simulated in detail (see users manual for details). Tailwater rating curve must be provided on SQ and SE records which follow immediately after SG record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SG	Record identification.
1	IABCOA	0 or Blank	Abutment contraction coefficients are to be based on adjacent EARTH non-overflow section.
		10	Abutment contraction coefficients are to be based on adjacent CONCRETE non-overflow sections.
2	ISPITW	0	Spillway tailwater will be given on SQ/SE records.
		10	Spillway tailwater will be computed using specific energy equation. The low-level outlet tailwater will be on SQ/SE records in either case.
3	ISPCTW	0 or Blank	Both spillway and low-level outlet cause submergence of low level outlet.
		10	Low-level outlet discharges only shall be used in computing low-level outlet submergence.
4	NGATES	+	Number of spillway gates, i.e., spillway openings (or intermediate piers plus one). Used in computation of pier losses.
5	SS	0	For ogee spillway.
		+	Side slope of trapezoidal spillway. Slope is horizontal over vertical, e.g., 2.0 for two to one side slopes.

15.8 **SG Record - Trapezoidal and Ogee Spillway** (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
6	DESHD	+	Design head for ogee spillway, in feet (m).
7	APEL	+	Apron elevation, in feet (m), at base of spillway.
8	APWID	+	Spillway apron width, in feet (m).
9	APLOSS	+	Approach-channel head loss in feet (m), at the design head.
10	PDPTH	+	Approach depth for ogee spillway, in feet (minimum of ten percent of design head).

NOTE - SQ and SE records to define the tailwater must follow this SG record. If a low-level outlet is specified, it should precede the SG record to prevent error message.

15.9 SB Record - Dam-Breach Simulation

This record is required only to simulate a dam breach. Both an SB and an ST record are required for dam breach calculations.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SB	Record identification.
1	ELBM	+	Elevation, in feet (m), of the bottom of the breach when breach is at maximum size.
2	BRWID	+	Width, in feet (m), of the bottom of the breach when breach is at maximum size.
3	Z	+	Side slope of breach (z horizontal to one vertical).
4	TFAIL	+	Time, in hours, for breach to develop to maximum size.
5	FAILEL	+	Elevation, in feet (m), of water surface which will cause dam to fail (begins breach computation).

NOTE - Tables and plots of dam-breach hydrographs for each plan are generated automatically when IPRNT (IO-1 or KO-1) is less than four. Those tables and plots show how well the breach hydrograph is represented by the normal time interval specified on the IT record.

Dam-breach outflow submergence. Tailwater submergence effects on outflow from the breach may be taken into account by inserting SQ/SE or RC/RX/RY records immediately after the SB record. The RC/RX/RY records depict a cross-section representative of the downstream flow restriction condition. A normal depth rating curve is calculated from the cross-section data for use in the submergence calculation.

15.10 SO Record - Reservoir Volume Optimization

Data required for determining optimum volume of a reservoir are:

Low-Level Outlet data	SL record
Spillway data	SS record
Volume vs. Elevation data	SV, SE records
Costs vs. Volume data	SD record
Cost Factors, Range	SO record

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SO	Record identification.
1	IOPTR	+	Number of field on OS record which contains reservoir volume (overrides CREL on SS record).
		0, or Blank	Reservoir volume is not to be optimized. To be used during initial data set testing and to fix size of the reservoir.
2	RANCST	+	Proportion (decimal) of capital cost of reservoir that will be required for annual operation and maintenance.
3	RDSCNT	+	Discount or capital recovery factor (decimal) to compute equivalent annual cost from capital cost.
4	CAPMX	+	Maximum permissible storage capacity of reservoir in acre-feet (1,000 cu m). Used as a constraint on optimization.
5	CAPMN	+	Minimum permissible storage capacity of reservoir in acre-feet (1,000 cu m). Used as a constraint on optimization.

15.11 SD Record - Reservoir Cost

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SD	Record identification.
1	RCST(1)	+	Reservoir capital cost corresponding to storage on SV record.
2-10	RCST(I)	+	Etc., up to ten values.

16 Unit Graph/Kinematic Data (U Records)

Five different methods are available to transform rainfall/snowmelt excesses into runoff. Choose one technique for each subbasin.

16.1 UI Record - Given Unit Graph

The given unit hydrograph must have been derived for the time interval on the IT record (IT-1, IT-2). For example, if the time interval is fifteen minutes, then a fifteen minute unit hydrograph must be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UI	Record identification.
1	QUNGR(1)	+	Unit hydrograph flow in cfs (cu m/sec) at end of first interval.
2	QUNGR(2)	+	Same for second interval.
3	QUNGR(3)	+	Etc., up to one hundred and fifty values on successive UI records.

16.2 UC Record - Clark Unit Graph

Clark's time-area data is supplied on UA records if desired or a synthetic time-area curve is used if the UA record is not supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UC	Record identification.
1	TC	+	TC is the time of concentration in hours for the Clark unit hydrograph. Neither TC nor R are to be optimized. The value of R, Field 2, must also be positive. Value of variable is fixed at the given value. TC must be greater than or equal to NMIN (IT-1).
		-1	TC and R will both be optimized and the value of R (Field 2) must also be -1. The program will supply the starting value for the optimization scheme. OU record must have been previously supplied.
		-2	Ratio R/(TC+R) is to be read in the next field (2) and held constant. TC and R will both be optimized but the specified ratio will not be changed. Field 2 must be a positive ratio R/(TC+R). OU record must have been supplied.
		-X	Where X is the desired starting value for TC in the optimization and the starting value of R, Field 2, must also be supplied as a negative number. Cannot be equal to -1 or -2. X (when converted to minutes) must be greater than or equal to NMIN (IT-1). OU record must have been supplied.

16.2 UC Record - Clark Unit Graph (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
2	R	+	R is the Clark storage coefficient in hours. No optimization of TC or R unless TC is equal to -2. If TC is -2, this field contains the constant value for the ratio R/(TC+R). R must be greater than or equal to 0.5 NMIN.
		-Y	Where Y is the desired starting value for R in the optimization and the starting value of TC must also be supplied as a negative number. Cannot be -1. R (when converted to minutes) must be greater than or equal to 0.5 NMIN.

16.3 US Record - Snyder Unit Graph

A time-area curve may be supplied on UA records, following this record if desired.

If it is desired to optimize the Snyder coefficient, an OU record must have been previously supplied. Optimization is accomplished using the Clark function to compute a continuous unit graph and then estimate the Snyder parameters.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	US	Record identification.
1	TP	+	Snyder's standard lag in hours. If in the optimization mode (OU record previously supplied), this variable is fixed at the given value and not optimized.
		-1	For optimization only (OU record previously supplied). Program will assume a starting value and optimize.
		-	Same as (-1) above except program uses this value (after a sign change) as the starting point for the optimization.
2	CP	+ or -	Snyder's peaking coefficient, CP. See Field 1 for meaning of VALUE.

16.4 UA Record - Time-Area Data

This time-area data may be used with either the Clark or Snyder methods. This data may be in any units, since area is scaled to the subbasin area and time is scaled to time of concentration. The areas contribute to runoff at the basin outlet at equally spaced time intervals. A synthetic time-area curve will be used if the UA record is not supplied.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UA	Record identification.
1	QCLK(1)	+	Area in any units, that contributes at time zero (usually area of reservoir, if any) at concentration point.
2	QCLK(2)	+	Total area contributing runoff during first time interval. The time intervals may be of any length, but the same equal interval must be used for all points on this time area relationship, QCLK(I).
3	QCLK(3)	+	Cumulative area contributing runoff during second such interval.
4	QCLK(4)	+	Etc., up to 150 values.

16.5 UD Record - SCS Dimensionless Unit Graph

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UD	Record identification.
1	TLAG	+	SCS lag in hours. If in the optimization mode (OU record previously supplied), this variable is fixed at the given value and not optimized.
		-1	For optimization only (OU record previously supplied) program will assume a starting value and optimize.
		-	Same as (-1) above except program uses this value (after a sign change) as the starting point for the optimization.

16.6 UK/RK or UK/RD Records - Kinematic Wave or Muskingum-Cunge Excess Transformation

At least one UK record and one RK or RD record are required to define characteristics for kinematic wave routing of precipitation excess to the subbasin outlet. UK records may be used with RK or RD records, but RK and RD records cannot be intermixed. A maximum of two UK records and three RK or three RD records can be used.

16.6.1 UK Record - Kinematic Overland Flow

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	UK	Record identification.
1	L	+	Overland flow length (ft) (m).
2	S	+	Representative slope (ft/ft) (m/m).
3	N	+	Roughness coefficient, see users manual.
4	A	+	Percentage of subbasin area that this element represents (percent).
5	NDXMIN	+	Integer number of routing increments for overland flow plane (default five, maximum of fifty). This variable is used in the finite difference solution. The greater the number of routing steps the more accurate the solution. **This variable is not required.** HEC-1 will compute a routing increment that is probably accurate enough for most purposes.

If the percentage in Field 4 is less than one hundred, a second UK record must be supplied to describe another subcatchment contributing to the same collector system (RK record). The percentages for two subcatchments must add up to one hundred. Two separate subcatchments are typically used to describe the pervious and impervious portions of a subbasin.

The first and second loss rates specified on a previous L record will be used for the first and second UK subcatchments, respectively.

16.6.2 RK/RD Record - **Subcatchment Kinematic Wave or Muskingum-Cunge Collector/Main Channels**

Overland flow (from the UK record) is routed to the subbasin outlet through channels described on RK or RD records. UK record(s) may be followed by up to two RK or two RD records representing successive collector channels and one RK or one RD record representing the main channel. **RK and RD records cannot be mixed**, one method must be used for all collector/main channels within the same subbasin. The outflow from the first collector channel is inflow to the second, etc. The RD record may be used in conjunction with the RC, RX, RY records to specify an eight point cross-section for main channel routing only.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	RK	Record identification.
1	L	+	Channel length (feet or meters).
2	S	+	Channel slope (ft/ft).
3	N	+	Channel roughness (Manning's n).
4	CA	+	Contributing area to a typical collector (sq mi or sq km). On the last RK record (main channel) the contributing area is assumed to be TAREA (BA-1).
5	SHAPE	TRAP	Trapezoidal channel, includes triangular and rectangular (default).
		DEEP	Deep rectangular (square) channel. Flow depth is approximately equal to channel width.
		CIRC	Circular channel shape. This cross section only approximates flow in a pipe or culvert. Flow depths are allowed to exceed the pipe diameter.
6	WD	+	Channel bottom width or diameter (feet or meters). (Default value is zero.)
7	Z	+	Side slopes, if required. Default = 1 when WD, RK-6, is zero.

16.6.2 RK/RD Record - Subcatchment Kinematic Wave or Muskingum-Cunge Collector/Main Channels (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
8	UPSTQ		This field is only used for main channels.
		YES	Upstream hydrograph will be routed through main channel, in addition to lateral inflow from this subbasin.
		NO	Do not route upstream hydrograph (default).
9	NDXMIN	+	Kinematic wave routing only. Integer number of routing increments for collector/main channels (default two, maximum of fifty). This variable is used in the finite difference solution. The greater the number of routing steps the more accurate the solution. **This variable is not required.** HEC-1 will compute a routing increment that is probably accurate enough for most purposes.

NOTE: Fields 1-9 are not used for RD main channel routing with RC/RX/RY records.

17.3 WO Record - Pump Optimization

Data required for optimization of pump capacity are:

Storage Routing data	RS, S records
Pump Operation data	WP record
Cost vs. Capacity	WC, WD record
Cost Factors, Range	WO record

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WO	Record identification.
1	IOPTP	+	Number of field on OS record which contains pump capacity (overrides PUMPQ on WP record).
		0, or Blank	Pump capacity on WP record is used.
2	PANCST	+	Proportion of capital cost of pump that will be required for annual operation and maintenance.
3	PDSCNT	+	Discount or capital recovery factor (decimal) to compute equivalent annual cost from capital cost.
4	PWRCST	+	Average annual power cost for capacity on OS or WP record. Cost is computed as a function of volume pumped for each size pump during the optimization.
5	PMPMX	+	Maximum permissible capacity of pumping plant in cfs (cu m/sec). Used as a constraint on optimization.
6	PMPMN	+	Minimum permissible capacity of pumping plant in cfs (cu m/sec). Used as a constraint on optimization.

17.4 WC Record - Pump Capacity Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WC	Record identification.
1	PCAP(1)	+	Pump capacity in cfs (cu m/sec) corresponding to PCST(1) on following WD record.
2-10	PCAP(I)	+	Etc., up to ten values.

17.5 WD Record - Pumping Plant Cost Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WD	Record identification.
1	PCST(1)	+	Pumping plant capital cost corresponding to capacity on WC record.
2-10	PCST(I)	+	Etc., up to ten values.

18 Economic Data

Data for economic evaluation of flood damage is placed in the data set following the last hydrograph calculation and before the ZZ record. The first record in the economic data is an EC record, and all records between the EC and ZZ records are economic-data records. The economic data may be used to calculate expected annual damage, single event damage, or adjusted flow or stage frequency curves.

A typical sequence for economic data is:

EC	Identifies following records as containing economic data
CN	Damage category names
PN*	Plan names
WN*	Watershed names
TN*	Township names
KK	Station identification to a unique KK record station in the previous river network simulation data
WT*	Watershed and township identification
FR	Frequency data
QF,SF*	Flows for frequency data
SQ*	Stages for rating curve
QS*	Flows for rating curve
QD,SD*	Flows or stages for damage data (only required for damage calculations)
DG	Damage data (only required for damage calculations)
KK, Etc.	For other damage centers in the river network

*Optional records

18.1 EC Record - Economic Data**

This record is required as the first record of economic data. It indicates that following records will contain data for calculation of expected annual damages.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	EC	Record identification.

18.2 CN Record - Damage Category Names**

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	CN	Record identification.
1	NCAT	+	The number of different damage categories (or types), e.g., urban, rural, utility, etc. Dimensioned for ten categories.
2	NMCAT	AN	Alphanumeric name for first damage category. Damage data (DG records) must be identified by the order input here.
3-10	NMCAT	AN	Repeat as required by NCAT (CN-1). If NCAT is 10, the tenth name must be in Field 2 of the next record.

**These records are REQUIRED for flood damage analysis.

18.3 PN Record - Plan Names

This record is used for description of the plans. One record is used for each plan. A maximum of five plans (PN records) may be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	PN	Record identification.
1	IPLN	+	Plan number to which this description applies.
2-10	NMPLN	AN	Alphanumeric description of above plan number (may use remainder of record).

18.4 WN Record - Watershed Name

WN, TN, and WT records may be used to identify damage reaches by watershed and township. If this option is used expected annual damages will be listed in summary tables according to watershed and township.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WN	Record identification.
1	NWAT	+	Number of watershed names to read. Dimensioned for fifteen watersheds.
2	WID	AN	Alphanumeric name for first watershed.
3-10	WID	AN	Repeat for each watershed as required by NWAT (WN-1). If NWAT is greater than nine, the tenth name must be in Field 3 of the next record.

18.5 TN Record - Township Name

See WN record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	TN	Record identification.
1	NTWN	+	Number of township names to read. Dimensioned for fifteen townships.
2	TID	AN	Alphanumeric name for first township.
3-10	TID	AN	Repeat for each township as required by NTWN (TN-1). If NTWN is greater than nine, the tenth name must be in Field 3 of the next record.

18.6 KK Record - Station Computation Identifier**

The KK record must be repeated at the beginning of each damage reach.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	KK	Record identification. Default value for pathname part B if FR record not used (DSS use only).
1	ISTAQ	AN	Stream station location identification. It must correspond identically to the station identification used on the KK record in the hydrologic calculations, see page A-32.
2-10	NAME	AN	Station description.

**Required

18.7 WT Record - Watershed and Township Identification

This record is used to identify the watershed and township for the stream station given on the KK record. Watershed and township designations will be the same for all stations until a new WT record is read.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	WT	Record identification.
1	IWAT	+	Integer corresponding to watershed name on WN record.
2	ITWN	+	Integer corresponding to township name on TN record.

18.8 FR Record - Frequency Data**

This record is required for the first station. These frequency values will be used until changed by a new FR record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	FR	Record identification.
1		+	Pathname part B (DSS use only).
2	NFRQ	+	Number of exceedence frequency values to be read on FR records. Dimensioned for eighteen.
3	PFREQ	+	Exceedence frequency values (in percent). Must be in descending order (99,90,.....,10, etc.).
4-10	PFREQ	+	Repeat as required by NFRQ (FR-2). If there are more than eight values, the ninth value must be in the first field of the next record.

**Required

18.9 QF Record - Flows for Frequency Curve

This record is required for each station if SF record is not provided.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QF	Record identification.
1			Not used.
2			Not used.
3-10	QFRQ	+	Peak flow values corresponding to exceedence frequencies on FR record. Repeat as required by NFRQ (FR-2). If there are more than eight values the ninth value must be in the first field of the next record.

18.10 SF Record - Stages for Frequency Curve

This record should be used only if peak stage have been calculated in the hydrologic portion of HEC-1. This record is required for each station if QF record is not provided.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SF	Record identification.
1			Not used.
2			Not used.
3-10	SFRQ	+	Peak stages corresponding to exceedence frequencies on FR record. Repeat as required by NFRQ (FR-2). If there are more than eight values, the ninth value must be in the first field of the next record.

18.11 SQ Record - Stages for Rating Curve

A stage-flow rating curve is required when stage-damage data are provided and stages are not computed in the river network simulation.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SQ	Record identification.
1			Not used.
2	NSTG	+	Number of stage values to be read on SQ records. Dimensioned for eighteen.
3-10	STGQ	+	Stage values corresponding to flows on QS records. Values must be in ascending order. Repeat as required by NSTG (SQ-2). If there are more than eight values, the ninth value must be in the first field of the next record.

18.12 QS Record - Flows for Rating Curve

This record must be preceded by an SQ record.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QS	Record identification.
1			Not used.
2			Not used.
3-10	QSTG	+	Flow values corresponding to stages on the SQ record. Repeat as required by NSTG (SQ-2). If there are more than eight values, the ninth value must be in the first field of the next record.

18.13 SD Record - Stages for Damage Data

Do not use this record if flow-damage data are to be used or if damages are not to be computed. Provide one SD record for each station. If stage-damage data change for each plan, a new SD record must be provided for each plan.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	SD	Record identification.
1			Not used.
2	NDMG	+	Number of stage values to be read. Dimensioned for eighteen.
3-10	SDMG	+	Stage values corresponding to damage on DG record. Values must be in ascending order. Repeat as required by NDMG (SD-2). If there are more than eight values, the ninth value must be in field one of the next record.

18.14 QD Record - Flows for Damage Data

This record is required if SD record is not provided and damages are to be calculated. If flow-damage data change for each plan, a new QD record must be provided for each plan.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	QD	Record identification.
1			Not used.
2	NDMG	+	Number of flow values to be read, dimensioned for eighteen.
3-10	QDMG	+	Flow values corresponding to damages on DG record. Values must be in ascending order. Repeat as required by NDMG (QD-2). If more than eight values are to be read, the ninth value must be in field one of the next record.

18.15 DG Record - Damage Data**

Damage data must be provided for each station if damages are to be calculated. One (two if NDMG is greater than eight) record is required for each damage category.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DG	Record identification.
1			Not used.
2			A **three digit number** containing the PLAN and damage category in columns 14-16. Do not leave imbedded blanks.
	IPLN	+	Column 14 contains the one digit PLAN number to which this data applies.
		0	If column 14 is zero, the same data is used for all plans.
	ICAT	+	Columns 15 and 16 contain the 2-digit damage category number, e.g., 01, 02, ... or 10.
3-10	DAMG	+	Damage values for category ICAT corresponding to stage (SD) or flow (QD). Repeat as required by NDMG (SD-2 or QD-2). If more than eight values are to be read, the ninth value must be in field one of the next record.

**Required

18.16 EP Record - End of Plan

This record is required to indicate the end of data for a plan. The current plan will be evaluated and new data will be read for the next plan. If there are no additional data, the last data set read will be used to compute expected annual damages for any plan which has not been evaluated.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	EP	Record identification.

The following data conventions must be followed in using the EP record:

- The frequency curve (FR and QF/SF records) **cannot** be changed.
- The stages for a rating curve (SQ record) **cannot** be changed.
- The discharges for a rating curve (QS record) **can** be changed.
- The damage data (SD/QD and DG records) **can** be changed.
- Labels such as Plan Name (PN) and Damage Category Name (CN) **can** be changed. Plan Names could be specified for all plans in the first group of data (for the first plan).

18.17 LO Record - Optimize Local-Protection Project

Data required for optimization of a local protection project or uniform degree of protection are:

Damage Data with Improvements	DU, DL records
Cost vs. Capacity Table	LC, LD records
Cost Factors, Range	LO record

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LO	Record identification.
1	IOPTLP	+	Number of field on OS record which contains capacity of local protection project.
		-	Number of field on OS record which contains uniform degree of protection.
2	XANCST	+	Proportion of local protection project capital cost that will be required for annual operation and maintenance.
3	XDSCNT	+	Discount factor (capital recovery factor) to compute equivalent annual cost from capital cost.
4	LPMX	+	Maximum permissible design capacity of local protection project in same units as QD or SD record. This is the design level associated with lower pattern damage function on DL records. Used as a constraint on optimization.
5	XLPMN	+	Minimum permissible design capacity of local protection project in same units as QD or SD record. This is the design level associated with upper pattern damage function on DU records. Used as a constraint on optimization.

18.18 LC Record - Local-Protection Capacity Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LC	Record identification.
1	XLCAP(1)	+	Local project design capacity in same units as QD or SD record.
2-10	XLCAP(I)	+	Etc., up to ten values.

18.19 LD Record - Local-Protection Cost Table

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	LD	Record identification.
1	XLCST(1)	+	Capital cost of local protection project corresponding to capacity on LC record.
2-10	XLCST(I)	+	Etc., up to ten values.

18.20 DU Record - Upper Pattern Damage Table

Pattern damage table for minimum design level (XLPMN) for local protection project.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DU	Record identification.
1			Not used.
2	ICAT	+	Damage category number.
3-10	TUDAMG	+	Damage values for category ICAT corresponding to stage (SD) or flow (QD) values. Repeat as required by NDMG (SD-2 or QD-2). If more than eight values are to be read, the ninth value must be in Field 1 on the next record.

18.21 DL Record - Lower Pattern Damage Table

Pattern damage table for maximum design level (XLPMX) for local protection project.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DL	Record identification.
1			Not used.
2	ICAT	+	Damage category number.
3-10	TLDAMG	+	Damage values for category ICAT corresponding to stage (SD) or flow (QD) values. Repeat as required by NDMG (SD-2 or QD-2). If more than eight values are to be read, the ninth value must be in Field 1 on the next record.

18.22 DP Record - Degree of Protection

Degree of protection and target level are used as performance constraints on optimization of a flood control system.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	DP	Record identification.
1	DGPRT	+	Target degree of protection for this location in percent exceedence frequency.
2	TRGT	+	Target level for degree of protection corresponding to exceedence frequency, DGPRT, above. TRGT is elevation in feet (meters) if SF record is used, or TRGT is flow in cfs (cu m/sec) if QF record is used.

19 End-of-Job (ZZ Record**)

This record identifies the end of an HEC-1 job and causes summary computations and printout to occur. Another job may be started with another ID, IT, etc., record series if desired. If another job does not follow, the control is passed back to the computer operating system.

FIELD	VARIABLE	VALUE	DESCRIPTION
Col 1+2	ID	ZZ	Record identification.

**Required

20 HEC-1 INPUT RECORD SUMMARY FIELD

ID	1	2	3	4	5	6	7	8	9	10	Page
*LIST											A-5
*NOLIST											A-5
*FREE											A-5
*FIX											A-5
* (comment beginning in Column 3)											A-5
*DIAGRAM											A-5
ID	ITLS										A-6
IT	NMIN	IDATE	ITIME	NQ	NDDATE	NDTIME	ICENT				A-7
IN	JXMIN	JXDATE	JXTIME								A-8
IO	IPRT	IPLT	QSCAL								A-9
IM											A-9
JP	NPLAN										A-10
JR	IRTIO	RTIO	. . .								A-11
JD	STRM	TRDA									A-12
OU	IFORD	ILORD									A-13
OR	IFORD	ILORD									A-13
OS	VAR	. . .									A-14
OF	FCAP	FDCNT	FAN								A-15
OO	ANORM	CNST									A-16
VS	ISTA	. . .									A-17
VV	SMVAR	. . .									A-18
BA	TAREA	SNAP	RATIO								A-19
BF	STRTQ	QRCSN	RTIOR								A-20
BI	ISTA	IQIN									A-21
DR	ISTAD										A-22
DT	ISTAD	DSTRMX	DVRSMX								A-23
DI	DINFLO	. . .									A-24
DQ	DIVFLO	. . .									A-24
DO	IOPTD	DANCST	DDSCNT	DVRMX	DVRMN						A-25
DC	DCAP	. . .									A-26
DD	DCST	. . .									A-26

20 HEC-1 INPUT RECORD SUMMARY FIELD (continued)

ID	1	2	3	4	5	6	7	8	9	10	Page
HB	NQB	SUMB	NQB	SUMB	. . .						A-27
HC	ICOMP	TAREA									A-28
HL	TAREA										A-29
HQ	QSTG	. . .									A-29
HE	STGQ	. . .									A-29
HS	STR										A-30
KK	ISTAQ	NAME	. . .								A-31
KM	ITLS	. . .									A-31
KO	JPRT	JPLT	QSCAL	IPNCH	IOUT	ISAV1	ISAV2	TIMINT			A-32
KF	FLOTQ	IFMT	. . .								A-34
KP	ISTM										A-35
LU	STRTL	CNSTL	RTIMP	*repeat for second kinematic wave subcatchment							A-36
LE	STRKR	DLTKR	RTIOL	ERAIN	RTIMP	*					A-37
LM	STRKS	RTIOK									A-38
LS	STRTL	CRVNBR	RTIMP	*							A-39
LH	FC	GIA	SAI	BEXP	RTIMP	*					A-40
LG	IA	DTHETA	PSIF	XKSAT	RTIMP						A-41
MA	AREA	SNO	ANAP								A-42
MC	TLAPS	COEF	FRZTP								A-43
MT	TEMPR	. . .									A-44
MS	SOL	. . .									A-44
MD	DEWPT	. . .									A-45
MW	WIND	. . .									A-45
PB	STORM										A-48
PI	PRCPR	. . .									A-49
PC	PRCPR	. . .									A-50
PG	ISTAN	PRCPN	ANAPN	ISTANX							A-51
PH	PFREQ	TRSDA	PNHR	. . .							A-52
PM	PMS	TRSPC	TRSDA	SWD	R6	R12	R24	R48	R72	R96	A-54
PS	SPFE	TRSPC	TRSDA	SWD							A-56
PR	ISTR	. . .									A-57
PT	ISTN	. . .									A-58
PW	WTR	. . .									A-58
QO	QO	. . .									A-59
QI	QI	. . .									A-60
QS	QS	. . .									A-60
QP	QP	. . .									A-61

20 **HEC-1 INPUT RECORD SUMMARY FIELD** (continued)

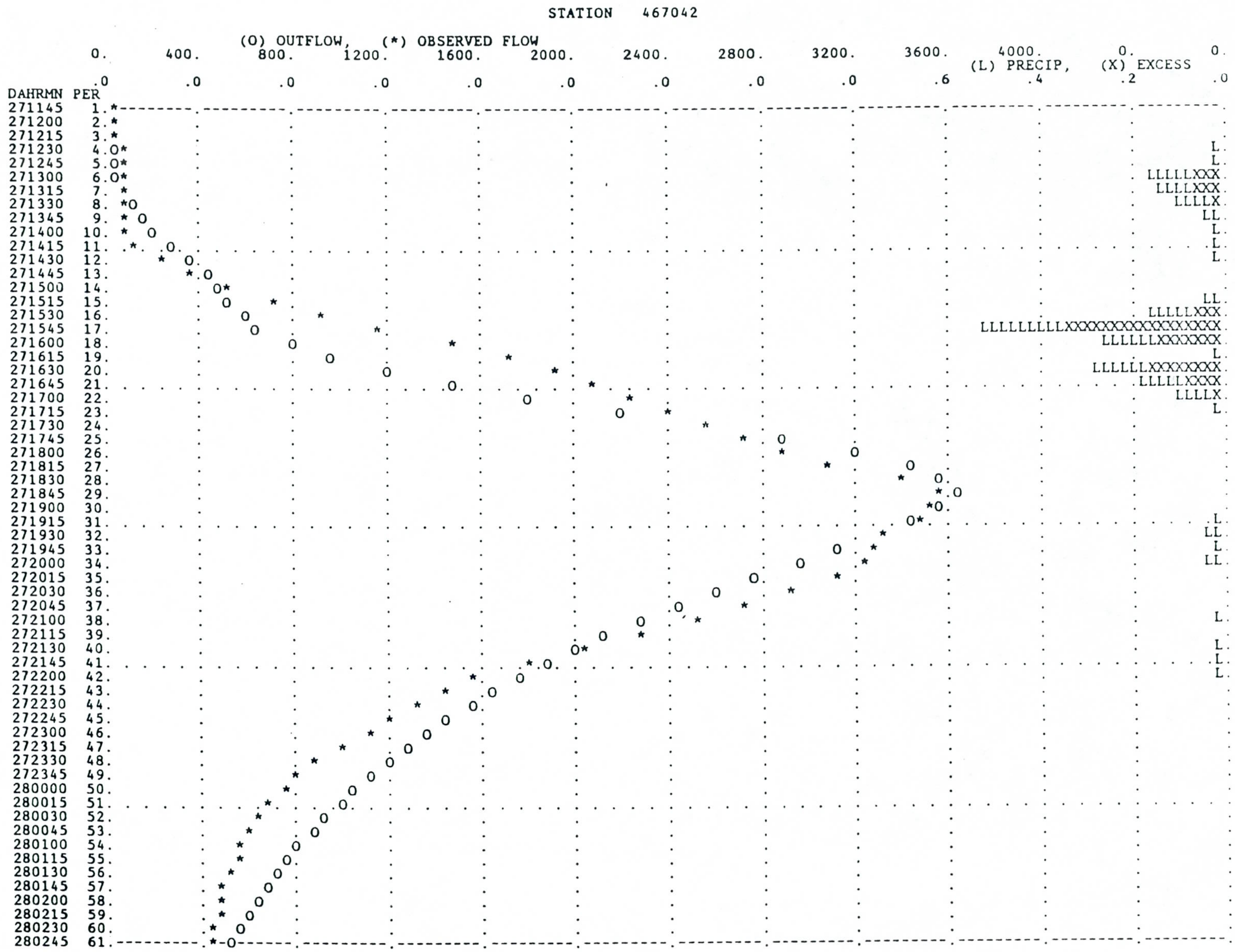
ID	1	2	3	4	5	6	7	8	9	10	Page
RN											A-62
RL	QLOSS	CLOSS	PERCRT	ELVTNV							A-63
RD	L	S	N		SHAPE	WD	Z	UPSTQ			A-64
RM	NSTPS	AMSKK	X								A-65
RS	NSTPS	ITYP	RSVRIC	X							A-66
RC	ANL	ANCH	ANR	RLNTH	SEL	ELMAX					A-68
RX	X	. . .									A-69
RY	Y	. . .									A-70
RK	L	S	N	---	SHAPE	WD	Z	---	NDXMIN		A-71
RT	NSTPS	NSTDL	LAG								A-72
SV	RCAP	. . .									A-74
SA	RAREA	. . .									A-74
SE	ELEV	. . .									A-75
SQ	DISQ	. . .									A-75
SL	ELEVL	CAREA	COQL	EXPL							A-76
SS	CREL	SPWID	COQW	EXPW							A-77
ST	TOPEL	DAMWID	COQD	EXPD							A-78
SW	WIDTH	. . .									A-79
SE	ELVW	. . .									A-79
SG	IABCOA	ISPITW	ISPCTW	NGATES	SS	DESHD	APEL	APWID	APLOSS	PDPTH	A-80
SB	ELBM	BRWID	Z	TFAIL	FAILEL						A-82
SO	IOPTR	RANCST	RDSCNT	CAPMX	CAPMN						A-83
SD	RCST	. . .									A-84
UI	QUNGR	. . .									A-85
UC	TC	R									A-86
US	TP	CP									A-88
UA	QCLK	. . .									A-89
UD	TLAG										A-90
UK	L	S	N	A	DX						A-91
RK	L	S	N	CA	SHAPE	WD	Z	UPSTQ	DX		A-92
WP	PMPON	PUMPQ	PMPOFF	ISTAD							A-94
WR	ISTAD										A-95
WO	IOPTP	PANCST	PDSCNT	PWRCST	PMPMX	PMPMN					A-96
WC	PCAP	. . .									A-97
WD	PCST	. . .									A-97

20 **HEC-1 INPUT RECORD SUMMARY FIELD** (continued)

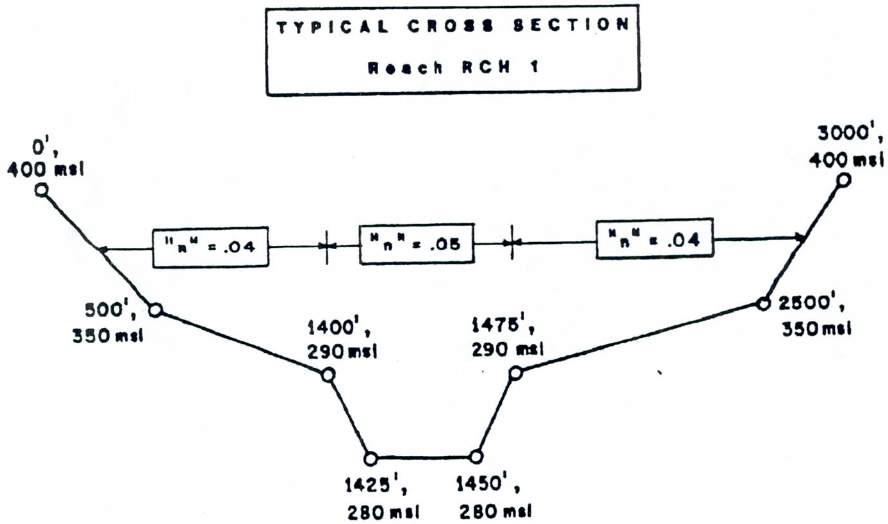
ID	1	2	3	4	5	6	7	8	9	10	Page
EC											A-99
CN	NCAT	NMCAT	. . .								A-99
PN	IPLN	NMPLN									A-100
WN	NWAT	WID	. . .								A-101
TN	NTWN	TID	. . .								A-101
KK	ISTAQ	NAME	. . .								A-102
WT	IWAT	ITWN									A-103
FR	---	NFRQ	PFREQ	. . .							A-103
QF	---	---	QFRQ	. . .							A-104
SF	---	---	SFRQ	. . .							A-104
SQ	---	NSTG	STGQ	. . .							A-105
QS	---	---	QSTG	. . .							A-105
SD	---	NDMG	SDMG	. . .							A-106
QD	---	NDMG	QDMG	. . .							A-106
DG	---	IPLN	DAMG	. . .							A-107
EP											A-108
LO	IOPTLP	XANCST	XDSCNT	LPMX	XLPMN						A-109
LC	XLCAP	. . .									A-110
LD	XLCST	. . .									A-110
DU	---	ICAT	TUDAMG	. . .							A-111
DL	---	ICAT	TLDAMG	. . .							A-111
DP	DGPRT	TRGT									A-112
ZZ											A-113

```
                                                         STATION     GAGE

                         (I) INFLOW,   (O) OUTFLOW,   (*) OBSERVED FLOW
         0.      200.      400.      600.      800.     1000.     1200.     1400.        0.        0.        0.        0.        0.
DAHRMN PER
120715   1I*O-------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
120730   2I*O       .         .         .         .         .         .         .         .         .         .         .         .
120745   3I*O       .         .         .         .         .         .         .         .         .         .         .         .
120800   4I*O       .         .         .         .         .         .         .         .         .         .         .         .
120815   5I*O       .         .         .         .         .         .         .         .         .         .         .         .
120830   6I *       .         .         .         .         .         .         .         .         .         .         .         .
120845   7I  *      .         .         .         .         .         .         .         .         .         .         .         .
120900   8I    *    .         .         .         .         .         .         .         .         .         .         .         .
120915   9I       *O.         .         .         .         .         .         .         .         .         .         .         .
120930  10I         . *O      .         .         .         .         .         .         .         .         .         .         .
120945  11I . . . . . . . .*O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121000  12I         .         *O        .         .         .         .         .         .         .         .         .         .
121015  13I         .         .*O       .         .         .         .         .         .         .         .         .         .
121030  14I         .         *O        .         .         .         .         .         .         .         .         .         .
121045  15I         .      * O.         .         .         .         .         .         .         .         .         .         .
121100  16I         .    * O  .         .         .         .         .         .         .         .         .         .         .
121115  17I         .  *O     .         .         .         .         .         .         .         .         .         .         .
121130  18I         .* O      .         .         .         .         .         .         .         .         .         .         .
121145  19I         . * O     .         .         .         .         .         .         .         .         .         .         .
121200  20I         .     * O .         .         .         .         .         .         .         .         .         .         .
121215  21I . . . . . . . . . . . * .O. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121230  22I         .         .         .    * O  .         .         .         .         .         .         .         .         .
121245  23I         .         .         .         .     *O  .         .         .         .         .         .         .         .
121300  24I         .         .         .         .         .     *   .         .         .         .         .         .         .
121315  25I         .         .         .         .         .         . O*      .         .         .         .         .         .
121330  26I         .         .         .         .         .         .     O*  .         .         .         .         .         .
121345  27I         .         .         .         .         .         .      O *.         .         .         .         .         .
121400  28I         .         .         .         .         .         .    O*   .         .         .         .         .         .
121415  29I         .         .         .         .         .         O*        .         .         .         .         .         .
121430  30I         .         .         .         .         .    O*   .         .         .         .         .         .         .
121445  31I . . . . . . . . . . . . . . . . . . . . . . . .O* . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121500  32I         .         .         .         .    *    .         .         .         .         .         .         .         .
121515  33I         .         .         .         O*        .         .         .         .         .         .         .         .
121530  34I         .         .         .      *  .         .         .         .         .         .         .         .         .
121545  35I         .         .         .  *      .         .         .         .         .         .         .         .         .
121600  36I         .         .         O*        .         .         .         .         .         .         .         .         .
121615  37I         .         .      *O .         .         .         .         .         .         .         .         .         .
121630  38I         .         .    *    .         .         .         .         .         .         .         .         .         .
121645  39I         .         . *O      .         .         .         .         .         .         .         .         .         .
121700  40I         .         *O        .         .         .         .         .         .         .         .         .         .
121715  41I . . . . . . . . .*O . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
121730  42I         .        *.         .         .         .         .         .         .         .         .         .         .
121745  43I         .       * .         .         .         .         .         .         .         .         .         .         .
121800  44I         .      *  .         .         .         .         .         .         .         .         .         .         .
121815  45I         .      *  .         .         .         .         .         .         .         .         .         .         .
121830  46I         .     *   .         .         .         .         .         .         .         .         .         .         .
121845  47I         .     *   .         .         .         .         .         .         .         .         .         .         .
121900  48I         .    O*   .         .         .         .         .         .         .         .         .         .         .
121915  49I         .    *    .         .         .         .         .         .         .         .         .         .         .
121930  50I         .   O*    .         .         .         .         .         .         .         .         .         .         .
121945  51I . . . . . . * . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
122000  52I         .  O*     .         .         .         .         .         .         .         .         .         .         .
122015  53I         .  *      .         .         .         .         .         .         .         .         .         .         .
122030  54I         . O *     .         .         .         .         .         .         .         .         .         .         .
122045  55I         . O*      .         .         .         .         .         .         .         .         .         .         .
122100  56I         .O*       .         .         .         .         .         .         .         .         .         .         .
122115  57I         .O*       .         .         .         .         .         .         .         .         .         .         .
122130  58I---------.*--------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
```



(-) LIMITS OF OPTIMIZATION



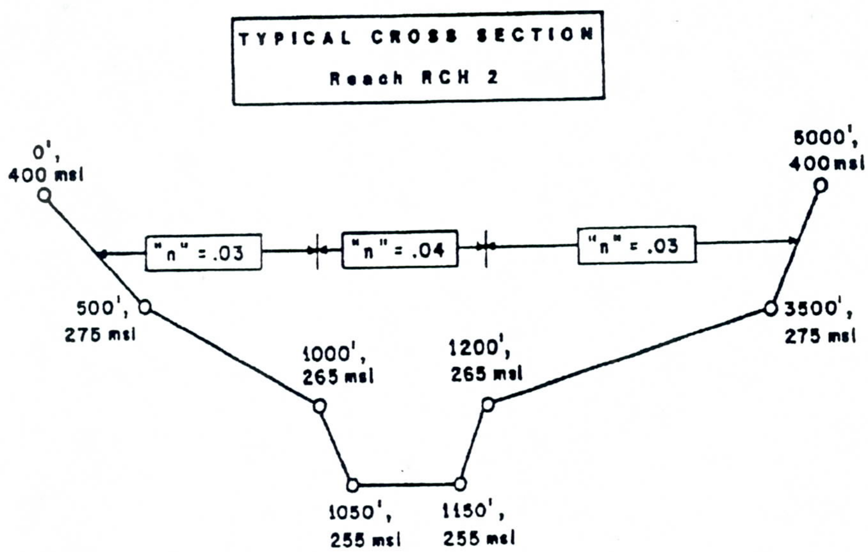
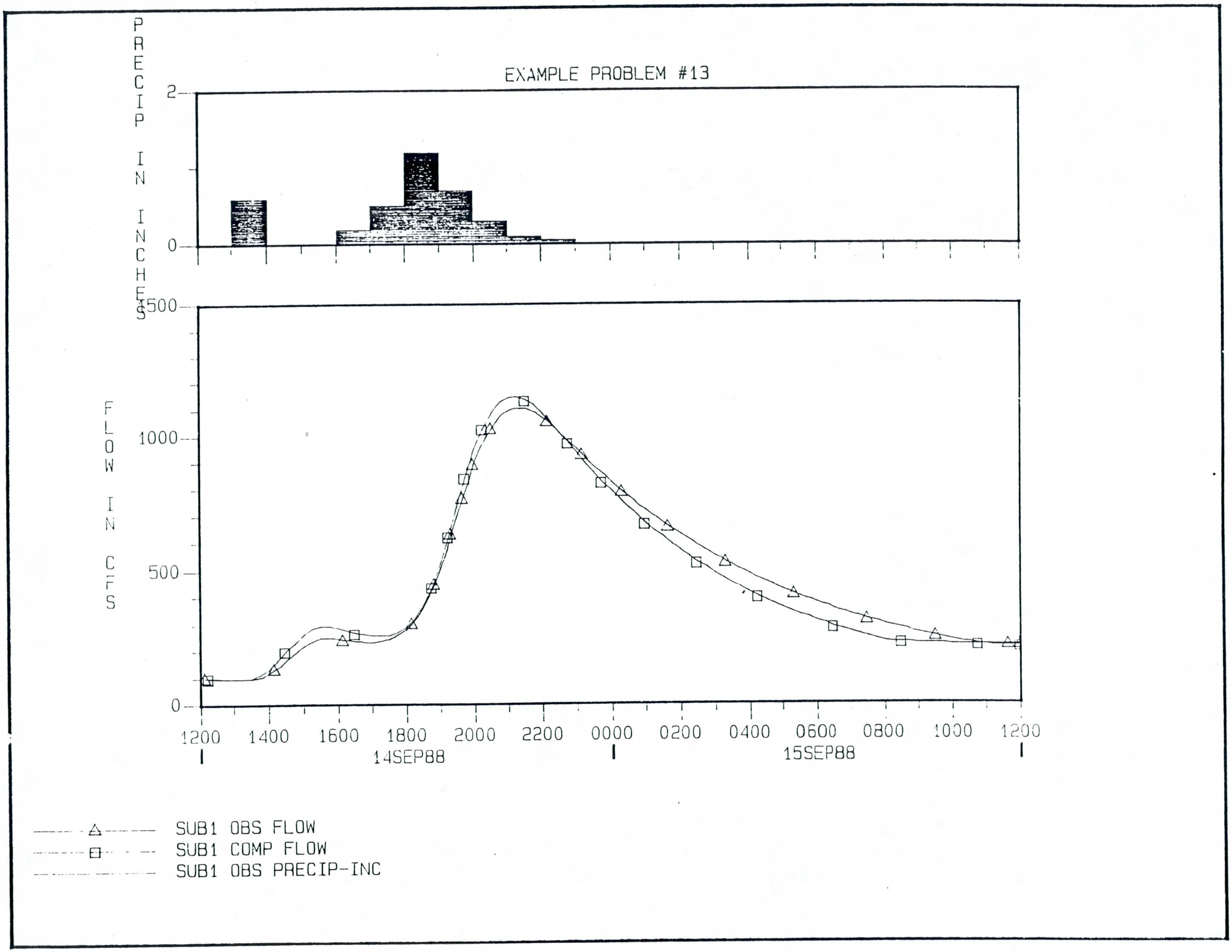


Figure 12.6 Bear Creek Downstream Cross Sections


EXAMPLE PROBLEM #13
PRECIP IN INCHES
2
0
FLOW IN CFS
1500
1000
500
0
1200 1400 1600 1800 2000 2200 0000 0200 0400 0600 0800 1000 1200
14SEP88
15SEP88
SUB1 OBS FLOW
SUB1 COMP FLOW
SUB1 OBS PRECIP-INC

Subbasin 2 (SUB2) is heavily urbanized with commercial and residential land use. The channel from CP1 to CP2 is a concrete lined trapezoidal channel with the following dimensions:

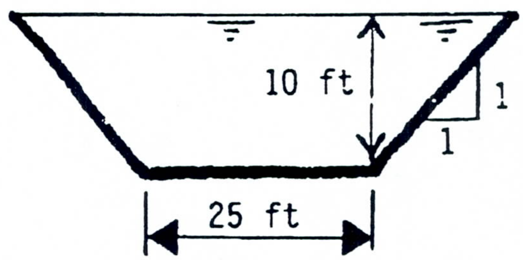


Figure 12.11 Trapezoidal Channel

Both subbasins 1 and 3 are completely undeveloped. The channel between CP2 and CP3 is in its natural state. A representative 8-point cross section has been fit to match the main channel and overbank flows through the reach as shown below:

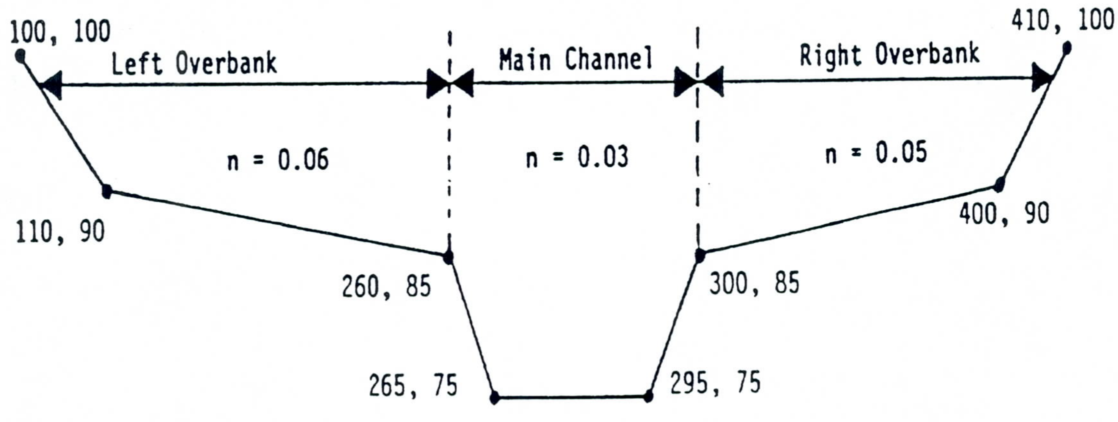


Figure 12.12 8-point Cross Section

Listings of the required input data and the resulting output are shown in Table 12.15. For the channel routing from CP1 to CP2, it is only necessary to have an RD record. Use of the RD record by itself means that the channel geometry can be described with a simple geometric element, such as a trapezoid. For the routing reach between CP2 and CP3, it is necessary to also include RC, RX, and RY records to describe the geometry through this reach. When using the 8-point cross-section option, the RD record only serves to indicate a Muskingum-Cunge channel routing is being performed. All of the necessary information is obtained from the RC, RX, and RY records.

```
                                                        STATION    ROUT2

                         (I) INFLOW,   (O) OUTFLOW
         0.     2000.     4000.     6000.     8000.    10000.    12000.    14000.        0.        0.        0.        0.        0.
DAHRMN PER
181100   1I---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
181115   2I         .         .         .         .         .         .         .         .         .         .         .         .
181130   3OI        .         .         .         .         .         .         .         .         .         .         .         .
181145   4OI        .         .         .         .         .         .         .         .         .         .         .         .
181200   5O I       .         .         .         .         .         .         .         .         .         .         .         .
181215   6O   I     .         .         .         .         .         .         .         .         .         .         .         .
181230   7O      I  .         .         .         .         .         .         .         .         .         .         .         .
181245   8O         .I        .         .         .         .         .         .         .         .         .         .         .
181300   9O         .      I  .         .         .         .         .         .         .         .         .         .         .
181315  10.O        .         .  I      .         .         .         .         .         .         .         .         .         .
181330  11. .O. . . . . . . . . . . . .I . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
181345  12.     O   .         .         .      I  .         .         .         .         .         .         .         .         .
181400  13.       O .         .         .         .   I     .         .         .         .         .         .         .         .
181415  14.         O         .         .         .         .I        .         .         .         .         .         .         .
181430  15.         .  O      .         .         .         .     I   .         .         .         .         .         .         .
181445  16.         .    O    .         .         .         .         I         .         .         .         .         .         .
181500  17.         .        O.         .         .         .         .I        .         .         .         .         .         .
181515  18.         .         .    O    .         .         .         I         .         .         .         .         .         .
181530  19.         .         .         .O        .         .       I .         .         .         .         .         .         .
181545  20.         .         .         .      O  .   I     .         .         .         .         .         .         .         .
181600  21. . . . . . . . . . . . . . . . . . . . . O . . . .I. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
181615  22.         .         .         .         .     OI  .         .         .         .         .         .         .         .
181630  23.         .         .         .         .  I     O.         .         .         .         .         .         .         .
181645  24.         .         .         .        I.         O         .         .         .         .         .         .         .
181700  25.         .         .         .     I   .         O         .         .         .         .         .         .         .
181715  26.         .         .         .  I      .        O.         .         .         .         .         .         .         .
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181800  29.         .         .   I     .         .   O     .         .         .         .         .         .         .         .
181815  30.         .         . I       .         . O       .         .         .         .         .         .         .         .
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190100  57.   IO    .         .         .         .         .         .         .         .         .         .         .         .
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U.S. ARMY CORPS OF ENGINEERS HEC-1
FLOOD HYDROGRAPH PACKAGE

REVIEW CHECKLIST

February 21, 1992

HEC-1 INPUT

I. JOB INITIALIZATION RECORDS:

A. ID RECORDS: Records need to be complete, have dates and project name on them.

B. IT RECORD:

1. **NMIN:** The time step for tabulation/computation should be smaller than 0.29 * LAG of the smallest time of concentration calculated for the sub-basins, yet large enough to be able to account for the entire simulation.

   Also, 60/NMIN should be an integer.

2. **IDATE, ITIME:** No runoff will be computed prior to date and time specified on these records. The first precipitation value specified should be for the precipitation that fell between ITIME and ITIME+NMIN.

3. **NQ:** There should be enough ordinances to cover entire storm duration AND runoff hydrograph.

C. IN RECORD:

1. **JXMIN:** Compare this value to the time series records used in the program(PC,PI, QO, QS, QP, MD, MS, MT, OR MW.) to make sure it has been used correctly.

   NOTE: *If an IN record is not used, the NMIN value on the IT record will be used.*

D. IO RECORD:

1. **IPRT:** Level 3 or lower is suggested for all review, since some error messages may not be printed on higher output levels.

E. JR RECORD:

1. **IRTIO:** Check if and why it is being used.
2. **RTIO:** Check if and why it is being used.

F. JD RECORD:

1. **STRM:** Check areal reduction for the area in TRDA.
2. **TRDA:** Check areal reduction.

   NOTE: *for HEC-1 versions prior to 1990, the stage shown on the summary table is for the LAST JD card only, and may not necessarily be the correct one.*

   NOTE: *JD option will not provide the best results when used in conjunction with the diversion cards in split flow situations.*

II. BASIN DATA:

A. BA RECORD:

1. **TAREA:** check basin area.
2. **RATIO:** check if and why this field is used.

B. BF RECORD:

NOTE: *BF record should be set to zero, or it will be carried over to next sub-basin.*

III. HYDROGRAPH TRANSFORMATION:

A. HC RECORD:

1. **TAREA:** this field could be used in conjunction with JD records in the split flow areas. check to see if total area used is correct.

NOTE: *No more than 5 hydrographs can be combined at each time.*

NOTE: *No more than 9 hanging hydrographs can be carried on a schematic diagram.*

NOTE: *TAREA can only be used in conjunction with the JD record.*

IV. LOSS RATE DATA:

A. LU RECORD:

1. **STRTL:** this value is the SUM of surface retention losses (IA) AND initial soil losses.
2. **RTIMP:** NO losses will be calculated for this area, HEC-1 assumes ALL this area is connected and at the outlet of the sub-basin.

B. LG RECORD:

1. **IA:** surface retention losses only, NO initial soil losses.
2. **DTHETA:** check to see if initial soil moisture condition is dry, normal or saturated. WHY?
3. **RTIMP:** NO losses will be calculated for this area, HEC-1 assumes ALL this area is connected and at the outlet of the sub-basin.

C. LS RECORD:

1. **STRTL:** initial rainfall abstraction, if left blank, will be computed from CRVNBR.
2. **CRVNBR:** check to see if it needs adjustments for the storm duration specified. 1986 TR-55 CN are for 24 hour storm duration.
3. **RTIMP:** NO losses will be calculated for this area. HEC-1 assumes ALL this area is connected and at the outlet of the sub-basin. This factor should only be used for directly connected impervious areas not already accounted for in the curve number land use.

V. PRECIPITATION DATA:

A. PB RECORD:

1. **STORM:** check total rainfall. Is it arealy reduced. Check with Depth-Frequency-Duration curves.

B. PI RECORD:

NOTE: *check against IN record. Check distribution.*

C. PC RECORD:

NOTE: *check against IN record. Check distribution.*

VI. ROUTING DATA:

A. RL RECORD:

1. **ELJNV:** this must be specified. Transmission losses will NOT be calculated otherwise.

NOTE: *check transmission losses for the reach. The loss should be representative of the entire cross section for the average inundation area for the storm being modeled. Main channel usually is associated with high infiltration losses; over bank losses are relatively less.*

B. RD RECORD:

1. **L:** Reach lengths should be reasonable. Too short of a reach length may cause instability in the routing calculations. Too long of a length makes finding a representative cross section impossible.
2. **S:** Slopes should be as uniform as possible. If not, try dividing the reach into more uniform reaches.
3. **N:** channel roughness is dependent on the depth of the flow. Make sure a representative cross section of the routing reach is considered when estimating roughness coefficients.

NOTE: *Cross section should have enough capacity.*

C. RK RECORD:

1. **L:** Reach lengths should be reasonable. Too short of a reach length may cause instability in the routing calculations. Too long of a length makes finding a representative cross section impossible.
2. **S:** Slopes should be as uniform as possible. If not, try dividing the reach into more uniform reaches.
3. **N:** channel roughness is dependent on the depth of the flow. Make sure a representative cross section of the routing reach is considered when estimating roughness coefficients.

4. **NDXMIN, DX:** For HEC-1 versions prior to 1988:

Kinematic wave routing may not be providing correct results. Check results for stability.

For interim release of HEC-1 in 1988; the DX field in the RK card must be used to divide routing reaches, results must be checked for percent error.

For 1990 version of HEC-1, NDXMIN field of the RK card could be used to divide routing reaches, however the program generally does a good job at approximating the reach length.

D. RM RECORD:

1. **NSTPS:** check number of subreaches.
2. **AMSKK:** check Muskingum K to make sure it is within limits specified. Relationship 2KX NMIN K must hold.
3. **X:** This value should be representative of channel geometry. Value of 0.5 will cause the least attenuation while a value of 0.1 will cause the most.

E. RS RECORD:

NOTE: *RS record can be used for reservoir routing and Channel Routing.*

1. **NSTEPS:** number of steps in storage routing. Is usually equal to 1 for reservoir routing. Will effect travel time and attenuation if changed.
2. **ITIPE, RSVRIC:** check for initial condition!

F. RC RECORD:

1. **ANL, ANCH, ANR:** check if n values are reasonable, if right and left n values are placed correctly. Only three n values are allowed: pts. 1-3; 3-6; 6-8.
2. **L:** Reach lengths should be reasonable. Too short of a reach length may cause instability in the routing calculations. Too long of a length makes finding a representative cross section impossible.

G. RX AND RY RECORDS:

1. Check to see if cross section is reasonable (typical) for the routing reach.
2. Will the cross section hold (convey) the entire flow. If not, HEC-1 will extend the cross section VERTICALLY, which is not suitable for arid regions with flat over banks.
3. all 8 stations on the RX records must be used, and stationing must continually increase.

H. SV RECORD:

1. **RCAP:** storage in ACRE-FEET !!

J. SA RECORD:

1. **RAREA:** surface area in ACRES !!

K. SE RECORD:

1. **ELEV:** check that the referenced elevations match the corresponding storage/area in the stage-storage-discharge curve.

VII. SPILLWAY RECORDS:

A. SQ RECORD:

1. **DISQ:** discharge in cfs. Can be used with the SE record for SV records, or a separate set of SE records. Check with stage-storage-discharge curves.

B. SL RECORD:

1. **ELEVL:** centerline of the upstream end of the low-level outlet.

NOTE: *extreme caution must be used when using this option, since the program may show outflows exceeding inflows (or when there isn't an inflow!) At times. Using a pre-developed rating curve may be better for these situations.*

This method will essentially use inlet control equations. If outlet control is dominant, other methodology should be used.

VIII. HYDROGRAPH GENERATION RECORDS:

A: **NOTE:** *ALL UNIT GRAPHS MUST HAVE BEEN DERIVED FOR THE SAME TIME INTERVAL ON THE IT RECORD.*

B. UC RECORD:

1. **TC:** Time of concentration in HOURS! Check to see if reasonable, compare with like basins.
2. **R:** Storage coefficient in hours.

C. UA RECORD:

since this indicates the shape (geometry) of the sub-basin, check to see if they are reasonable. HEC-1 has default synthetic time area if UA record is not provided.

D. UD RECORD:

1. **TLAG:** in HOURS! (or 0.6 * Tc)

E. UK/RK RECORD:

1. **NOTE:** *at least one UK and one RK card are needed to define the characteristics of the basin.*
2. **L:** is the OVERLAND length. should be from the sub-basin boundaries to the point where washes become more defined.
3. **S:** representative slope of the overland flow.
4. **N:** this is the overland friction coefficient, values are in ranges above 0.1
5. **A:** check percentage!

6. **NDXMIN:** for 1991 version, check output for percent error.

   for interim 1988 version, change DX and check results at the output, percent error should be examined for accuracy.

7. If more than one UK card is being used, the percentage on field 4 of all the UK cards for that sub-basin must add up to 100.

8. Use of Kinematic wave runoff with multi-ratio option does not combine hydrographs appropriately. This is for version 4.0 of HEC-1. This could be corrected by using separate input files for each storm. (per USACOE HEC)

HEC-1 OUTPUT

1 – check you have the right model.

I. AREA:

Check the accuracy of the total drainage area. Normally, for basins with a single outlet, the easiest way is to check the last number on the "area" column in the summary table. For basins with several outlets, the contributing area for each outlet may have to be added together and then checked for accuracy.

If gages such as USGS stage gages are present in the area, the HEC- 1 area above the gage concentration point should be compared to USGS published reports. Previous studies of the area may also prove useful for comparison of areas.

When a diverted hydrograph is returned, the area associated with it must also be returned.

II. PEAK RUNOFF:

Since HEC-1 does not have a summary table showing specific yield (cfs/sq. mile), it is recommended that reviewers develop this information themselves. This column could be used to compare flows from one sub-basin with another. Since specific yield depends on many factors such as area, slope, losses, etc., this comparison may be difficult. However, large differences in specific yield should alert the reviewer to check the input for discrepancies.

III. ERRORS:

All error messages must be checked. Output level 3 or less must be entered on the IO record for all error messages to appear. The HEC-1 manual contains a section explaining the error messages and how to correct them.

IV. DIAGRAM:

Check the schematic. Follow the diagram on the watershed map and see if it is correct.

A. Make sure there are no "hanging hydrographs" left.

B. Make sure that all of the diverted hydrographs have been accounted for.

C. Make sure that all of the subareas are attached and are being combined in the proper sequence. All upstream subareas must be combined before routing through a downstream channel.

V. LOSSES:

Look through the output for each sub-basin. Check the total rainfall, total losses and total runoff. If zero or a very small number is noticed in any of these columns, the input for that sub-basin must be examined. It is possible to drop a loss card (i.e. LS, LU, LG,...) and not get an error statement in the output. Check the loss columns for inconsistency. Inconsistencies in estimated losses must be examined.

VI. ROUTING:

A. Check the applicability of the routing methodology applied.

B. Check that the outflow is not greater than the inflow.

C. Check for instability in the outflow hydrograph. This can be done by using level 1 output or by plotting the hydrograph.

D. Check to see that the flow is contained within the channel. HEC-1 will normally extend the banks vertically if the channel cross- section area is not large enough.

E. Check travel time. Travel time can be translated back to velocity or wave celerity. If the travel time is too long or too short, examine the input parameters for the routing. Routing steps in the input can be checked against the output velocity.

F. Attenuation: Except for the kinematic wave option, other routing procedures will normally result in some attenuation of the peak flow. This attenuation should be checked for reasonableness.

G. Routing will not only attenuate the flow, but will also delay the peaks and therefore will separate them in time. This separation of peaks will have a substantial effect when combining hydrographs and therefore the resulting peak at the outlet. Choosing short reaches or using large computational time intervals will cause the peak time to default to the nearest time interval. The cumulative effect of this is noticeable in the results.

VII. TIME TO PEAK (Tp):

Check the time to peak column on the summary table:

A. For large areas (greater that 1 square mile), one expects larger differences in Tps for the resulting hydrographs. If all the Tps appear to coincide or are very close, the computational time interval or NMIN the on the IT record must be examined or changed.

B. Check that the Tps occurs after the most intense portion of the rainfall period (usually about half the duration of the rainfall).

VIII. VOLUMES:

Check the output to determine if the volume of runoff is reasonable. This may prove to be somewhat difficult since there are very few “yard sticks” developed for comparing runoff volumes. Experience and published reports should be relied upon to determine if the runoff volumes are reasonable.

GENERAL

I. Compare the peaks flows and specific yields to available data for the area. Inconsistencies in these may indicate to the reviewer errors in the HEC-1 input.

II. Keep the sub-basin areas as uniform as possible. Otherwise, it is easy to over-estimate the peaks for small sub-basins and under-estimate the peaks for large sub-basins.

III. Separate mountainous areas from the adjacent valleys. Most of the peak is generated from hill slopes and attenuated or lost in the valley. Mixing the two may cause incorrect results.

IV. Peaks are most affected by the time of concentration. Volumes are most sensitive to loss functions.

V. When comparing HEC-1 results with other results, make sure adjustments are made properly. For example, losses should not be adjusted where time of concentration is the major cause of the differences.

VI. There are problems involved with the use of pre 1990 kinematic wave option of HEC-1. For the interim version of HEC-1 (1989), the DX column of the RK record should be used to obtain more accurate results. 1990 version of HEC-1 has apparently solved the problems with the kinematic wave routing.

VII. Theoretically, kinematic wave routing WILL NOT attenuate the peak flow. If any attenuation is noticed in the results, it is due to numerical errors.

VIII. Time of concentration and lag time are not interchangeable. It is important to use them properly since peak flows are extremely sensitive to these parameters.

IX. Weighted curve numbers already include imperviousness. Indicating a percent imperviousness on the RTIMP column in conjunction with weighted curve numbers will result in these areas being accounted for twice.

X. Manning's Friction Coefficient for routing must be used properly for main channel v.s. overbank. If sheet flow is present, the n values must be adjusted accordingly.

XI. When comparing existing v.s. proposed conditions, all the model parameters must be adjusted accordingly. Proposed storm sewer pipe flows are more efficient than surface flows and can increase peak discharges. For more frequent storms, where depth of flow is small, introducing street networks may effect the flow paths. This may require a re-examination of sub-basin boundaries.

XII. Many different methods have been used to model the affect of retention criteria now used in many parts of Arizona. These include reducing the rainfall total, reducing the sub-basin area, increasing the initial abstraction among others. One possible way suggested is to first run the model using the frequency/duration specified by the criteria (i.e. 100yr, 2 hour; 10 year, 24 hour, etc.). The volume estimated by this model can then be diverted from the sub-basins for the design storm.

XIII. When using the JD card, HEC-1 will perform as many separate runs as there are JD records, using the rainfall specified on each JD card. (NOTE: different precipitation patterns can be identified for each JD card.) Based on the contributing area for each sub-basin, HEC-1 will interpolate between hydrographs (not rainfalls) to produce the hydrograph for that concentration point. Diverted hydrographs do not have an area associated with them. Therefore, when this hydrograph reaches a concentration point, the area for that hydrograph is ignored. One way to remedy this is to manually recalculate the area above the concentration point and include that in the second field of the HC card for the concentration point.

XIV. If NMIN on the IT record is changed, all the dependent parameters such as the unit hydrographs (UI), Muskingum K value (RM) and all NSTEPS must be adjusted accordingly.

XV. If rainfall records are changed, all the rainfall dependent parameters such as the Papadakis Time of concentration must be adjusted accordingly.

ARIZONA DEPARTMENT OF WATER RESOURCES
15 South 15th Avenue, Phoenix, Arizona 85007
Telephone (602) 542-1553
Fax (602 256-0506

FIFE SYMINGTON
Governor

ELIZABETH ANN RIEKE
Director

November 18, 1991

Floodplain Administrator and Engineering Professionals

The Arizona Department of Water Resources, under the authority of ARS 45-3605(a) established State Standard 1-90 "Requirement for Flood Study Technical Documentation" in August 1990. The purpose of this standard was to ensure that technical backup materials for flood studies would be available in the future.

Attached is a revised copy of State Standard Attachment 1-90 "Instructions for Organizing and Submitting Technical Documentation." This revised version incorporates comments we have received over the past year from the various communities, counties and consultants that has followed this standard. The documentation standard has resulted in substantially reducing FEMA turn around times in several recent LOMR and restudy cases.

There has been some confusion over when the State Standard should apply. As a State Standard it was targeted for those studies performed by communities, counties or others that would be reviewed by the state or submitted to the Federal Emergency Management Agency. Communities and counties could adopt the Standard for studies submitted only to them at their discretion. Contractors working under contract with FEMA may elect to use the Standard or may be directed by FEMA to use Appendix 6 of FEMA-37 " Guidelines for Study Contractors." The Standard can be applied to any level study or revision by including only those sections of the documentation that are applicable. For example, a LOMR that did not involve revised hydrology would simply note in Section 3 - Hydrology the source of flow rates being used. None of the subsections of Section 3 would need to be present in the TDN.

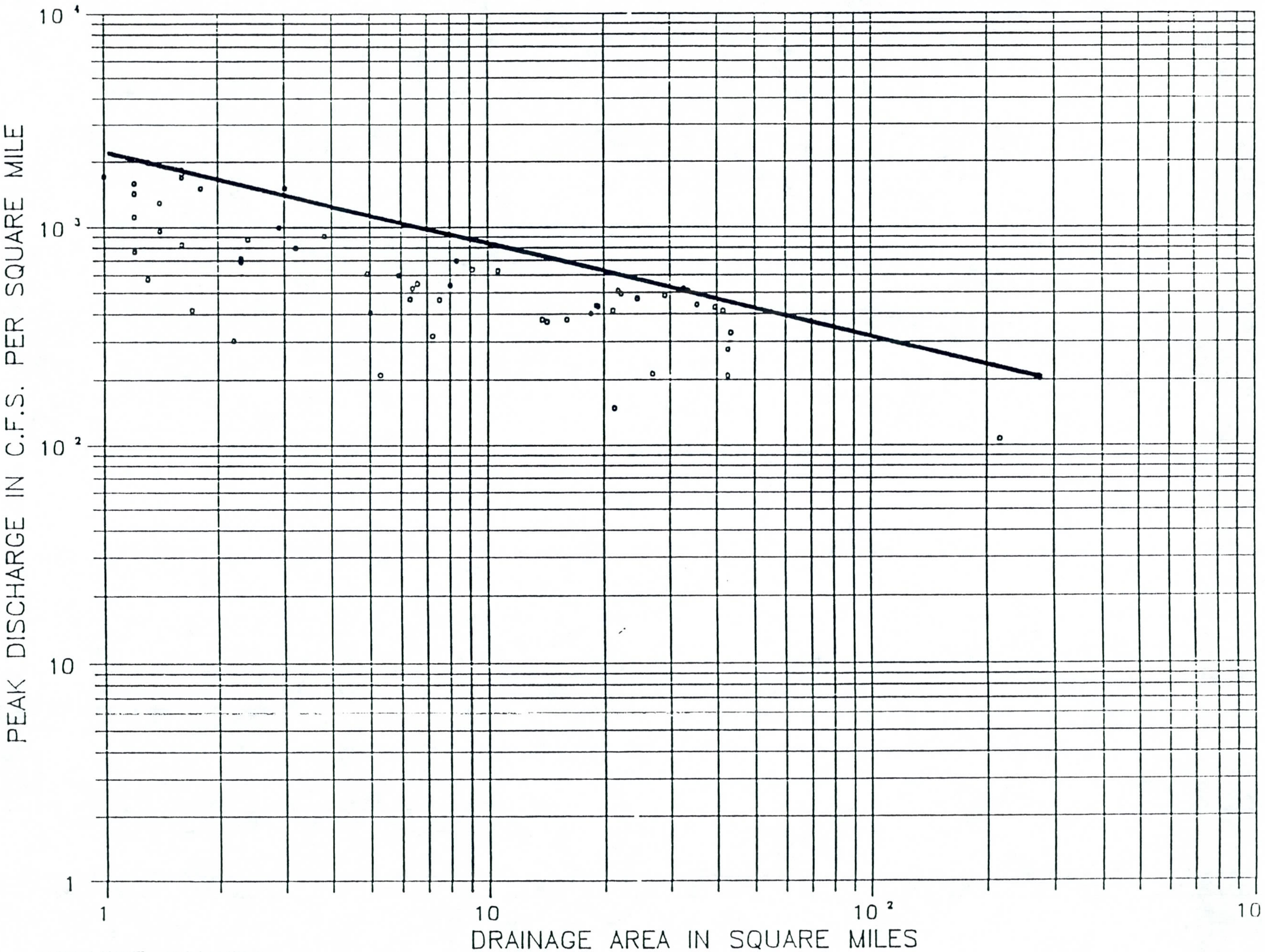
The Department, for archival purposes, requests that a copy of the Technical Documentation Notebook be forwarded to the Department after it is finalized and accepted by all agencies. This will insure that the technical back-up for all future studies is available.

Please call me at 542-1541 if you have any questions or need any additional information. Corrections and proposed revisions to the Standard are always welcome.

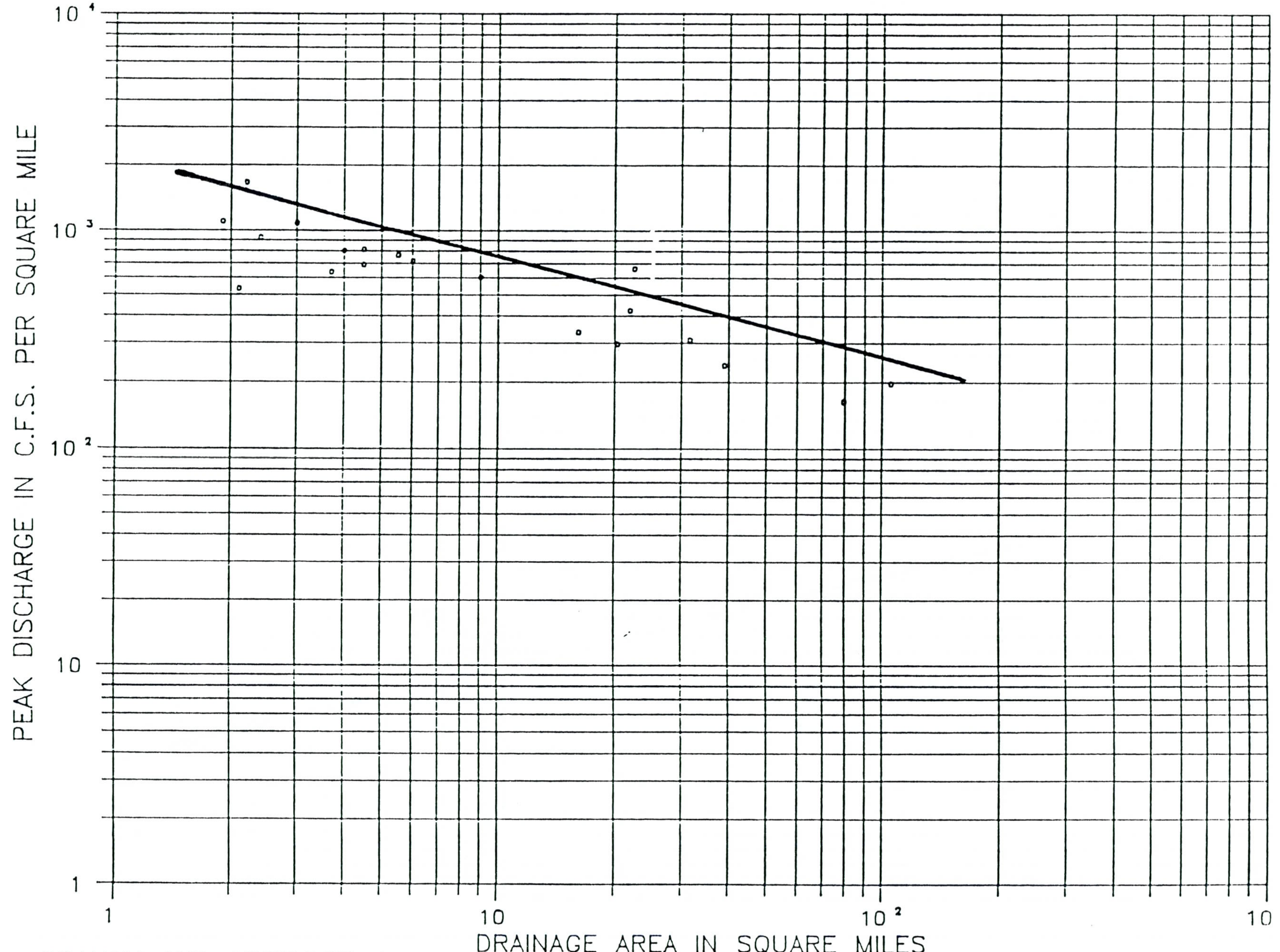
Sincerely,

James R. Morris, P.E., Chief
Flood Engineering Section

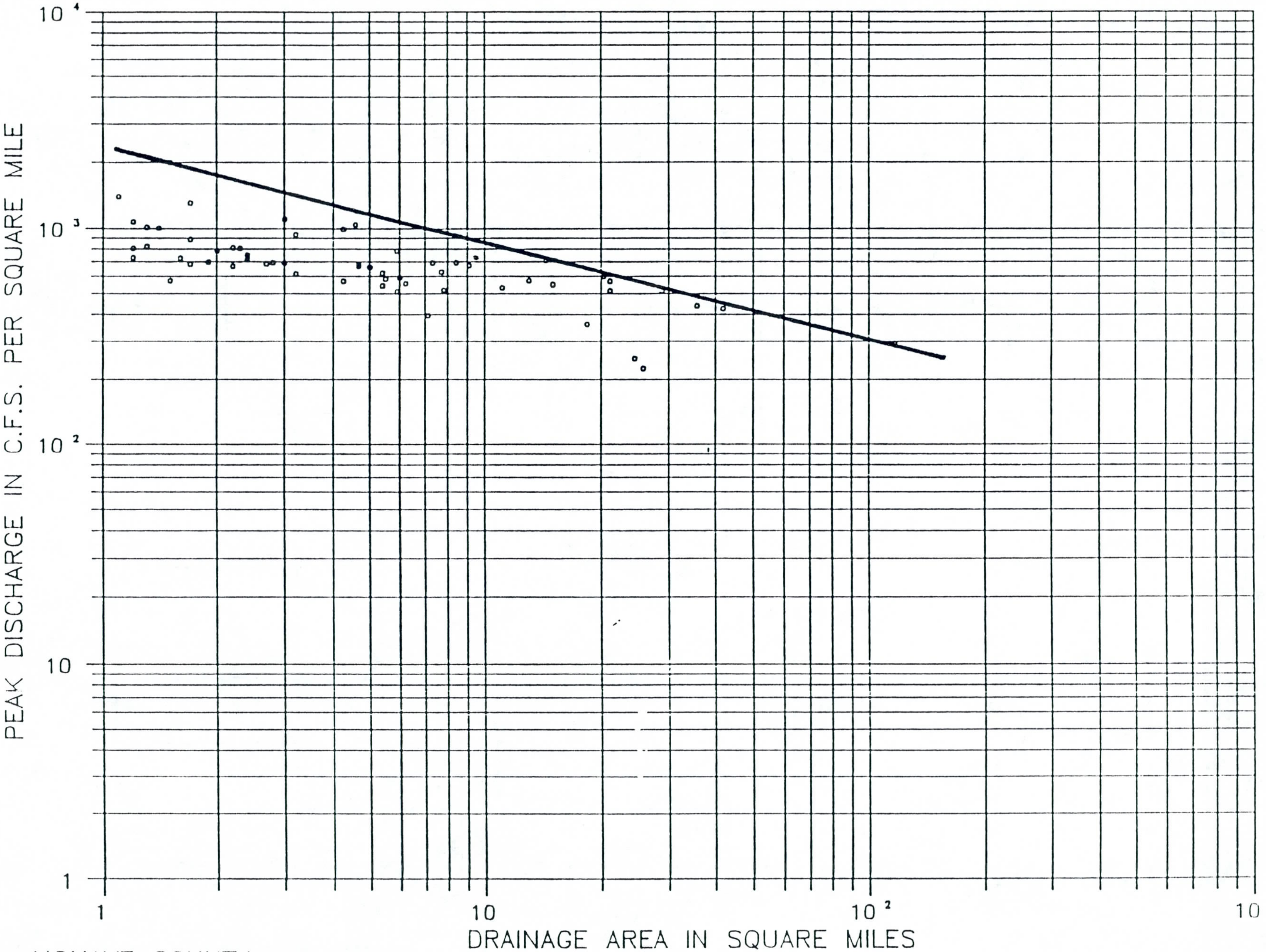
JRM/ms
Attachments



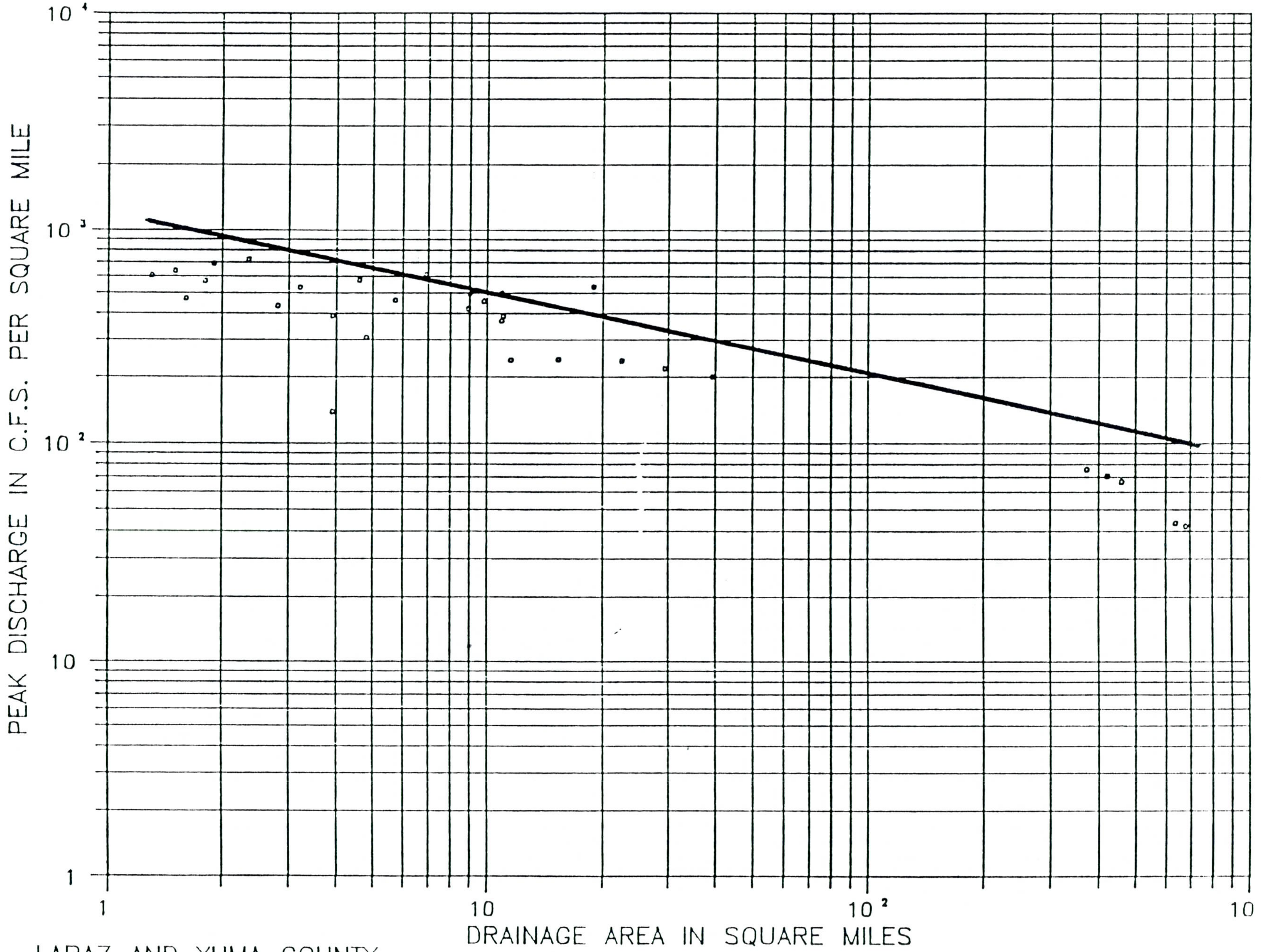
COCHISE COUNTY
ENVELOPE CURVE



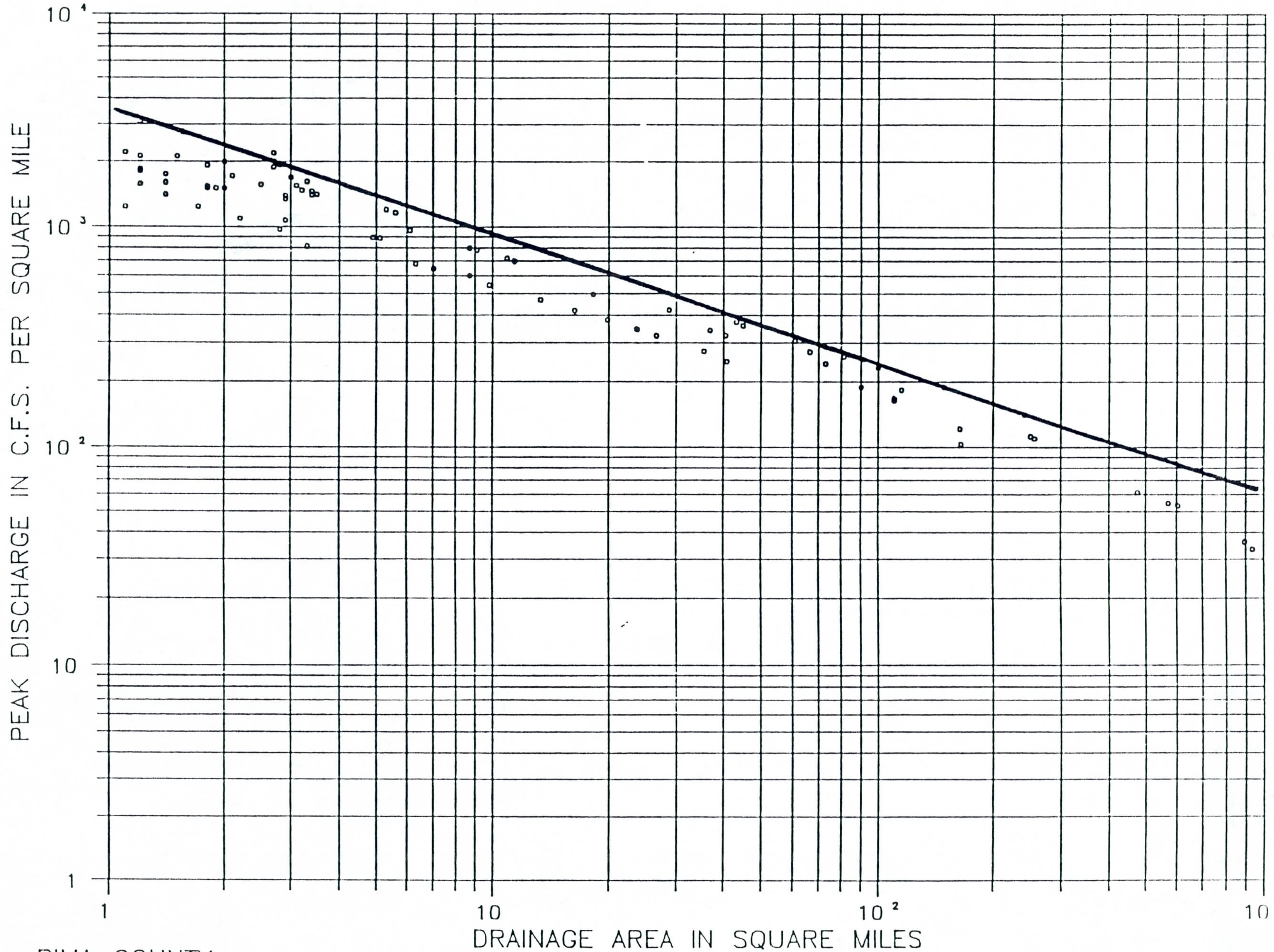
GRAHAM AND GREENLEE COUNTY
ENVELOPE CURVE



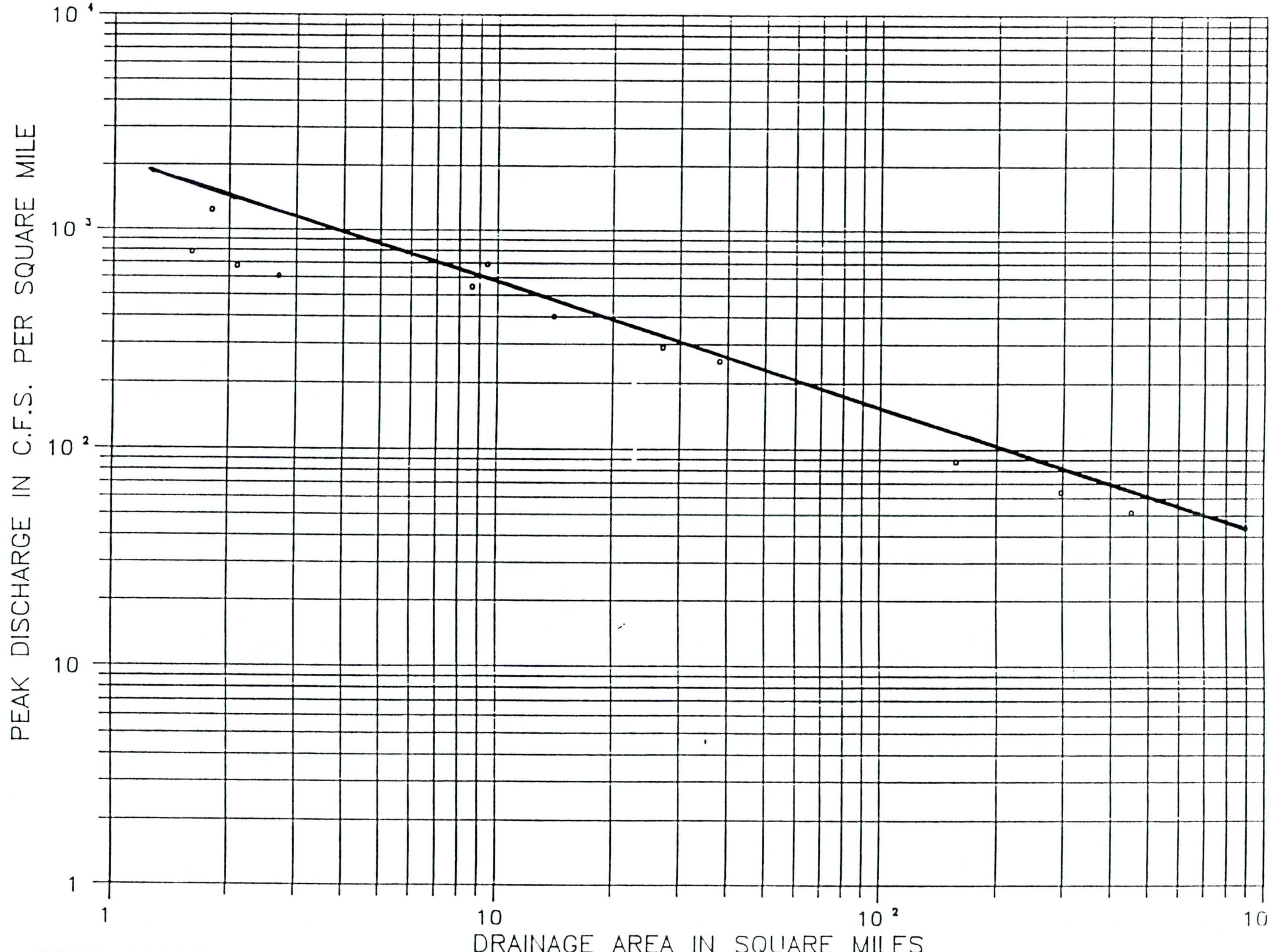
MOHAVE COUNTY
ENVELOPE CURVE



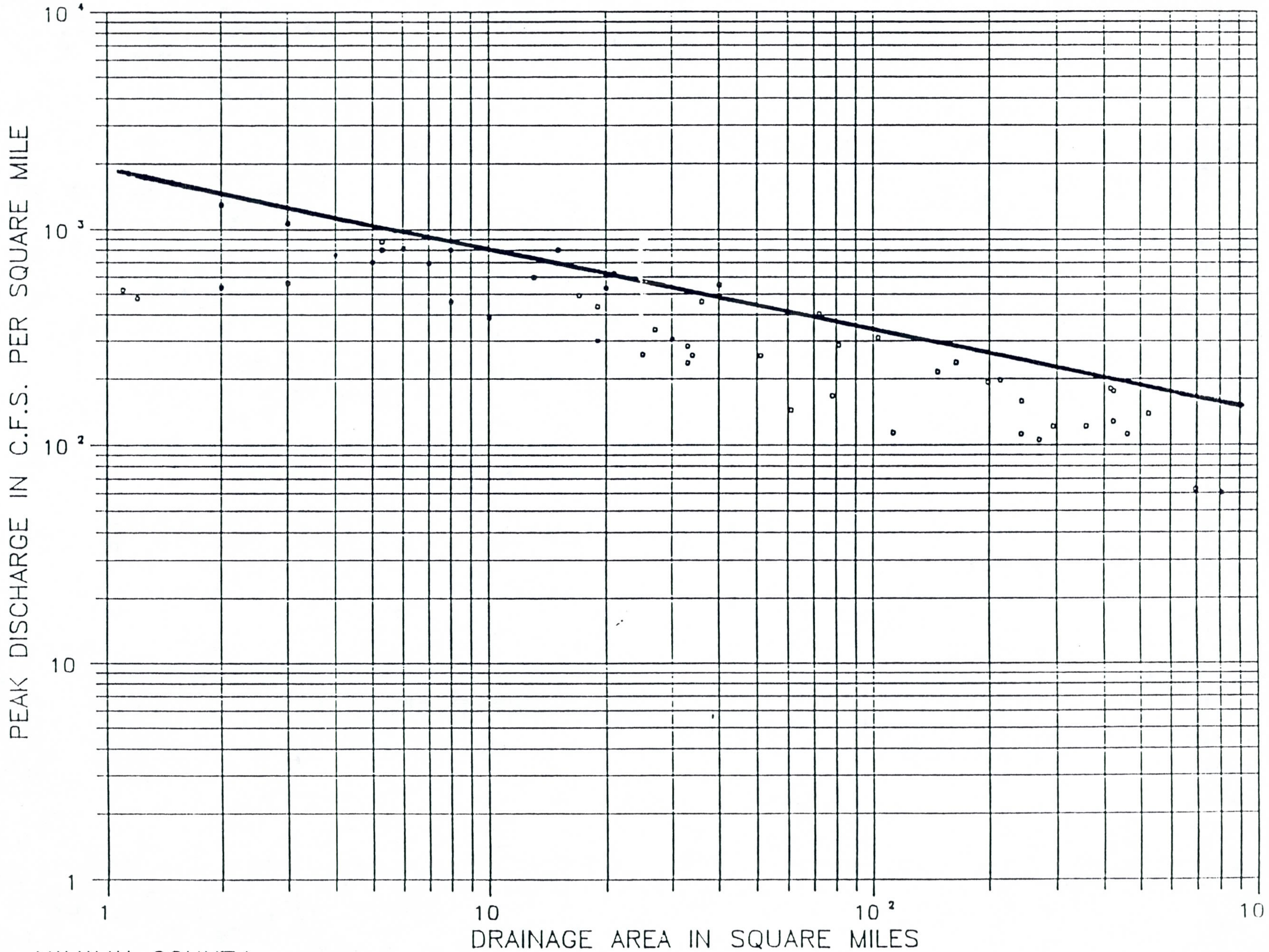
LAPAZ AND YUMA COUNTY
ENVELOPE CURVE



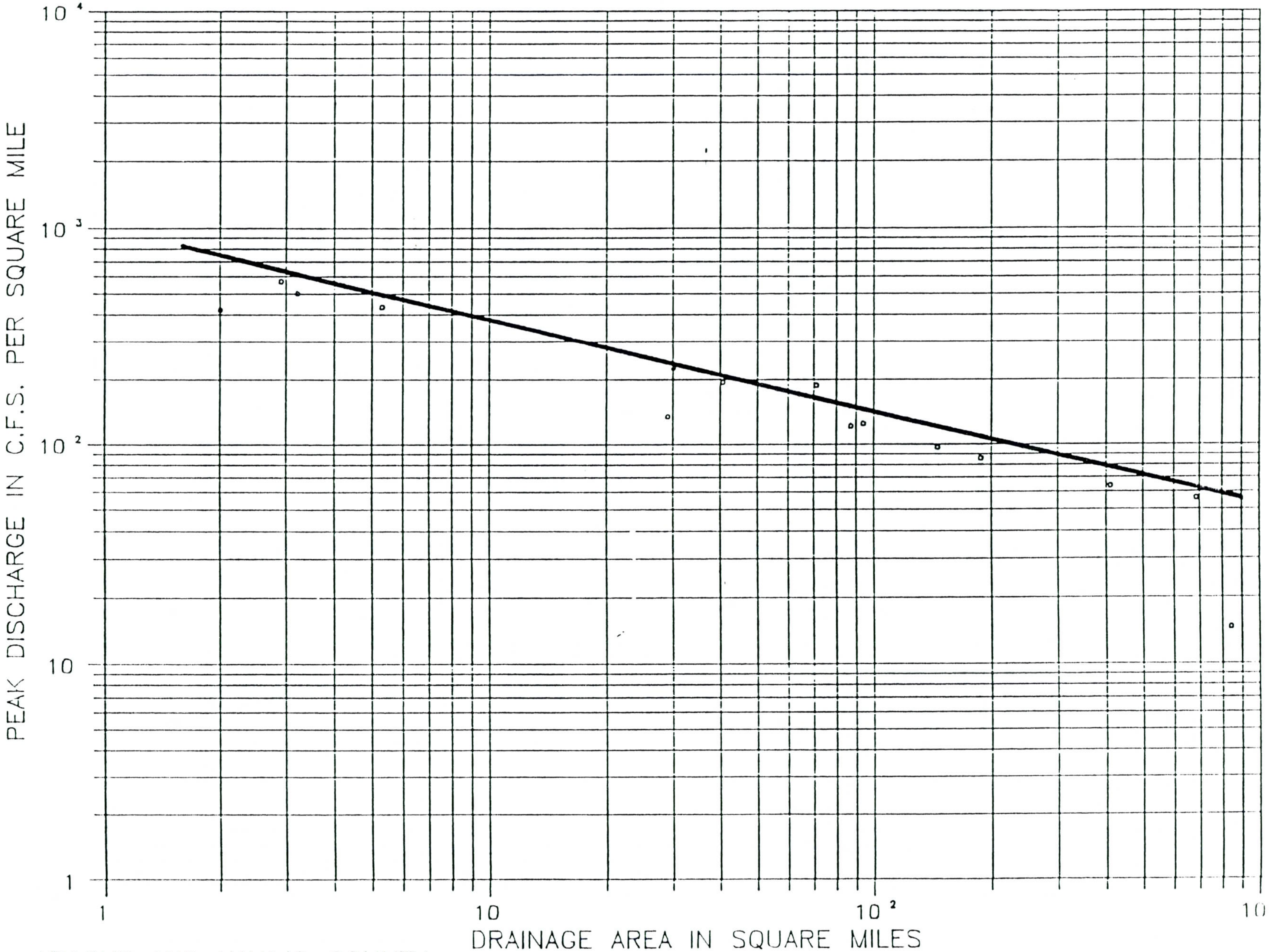
PIMA COUNTY
ENVELOPE CURVE



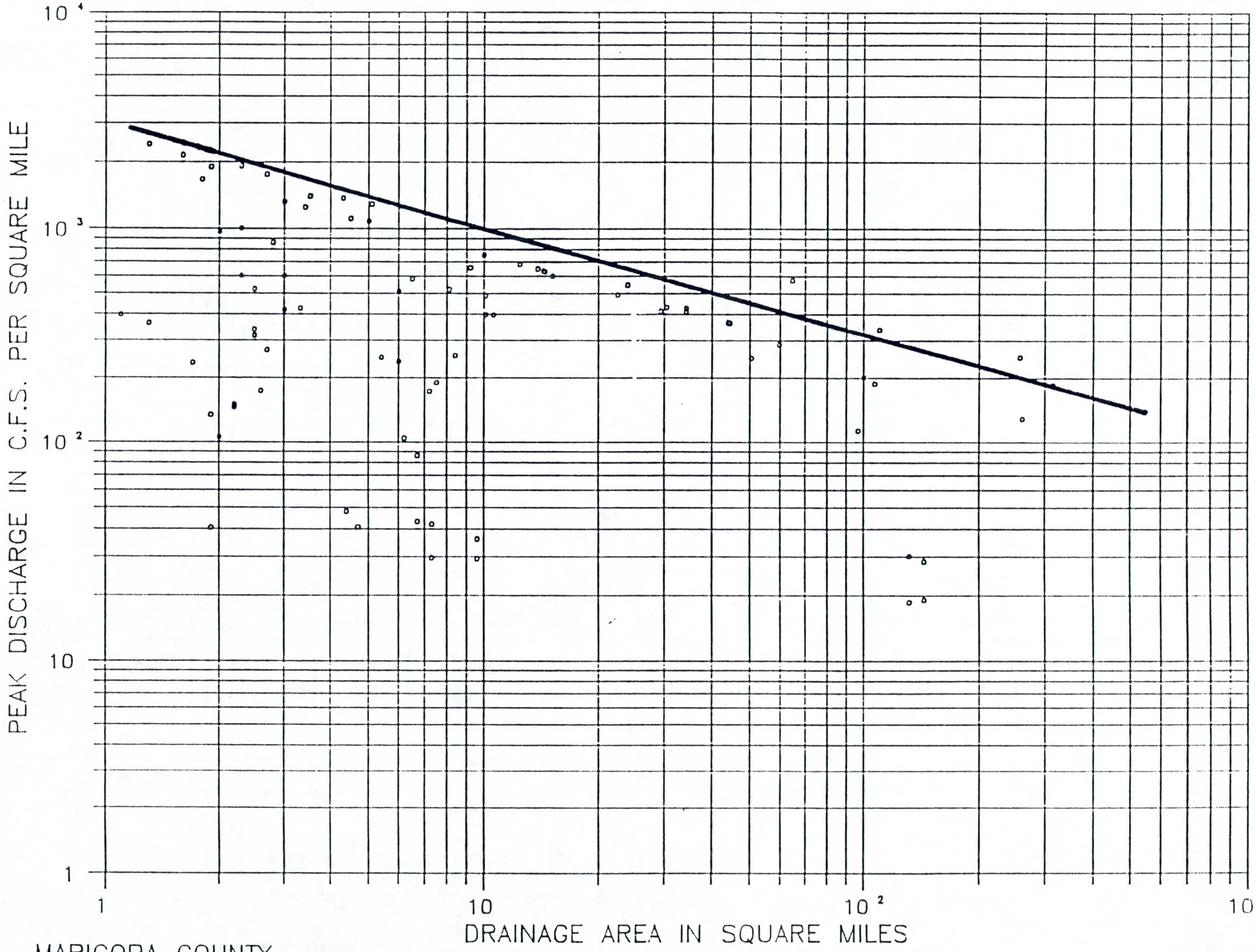
PINAL COUNTY
ENVELOPE CURVE



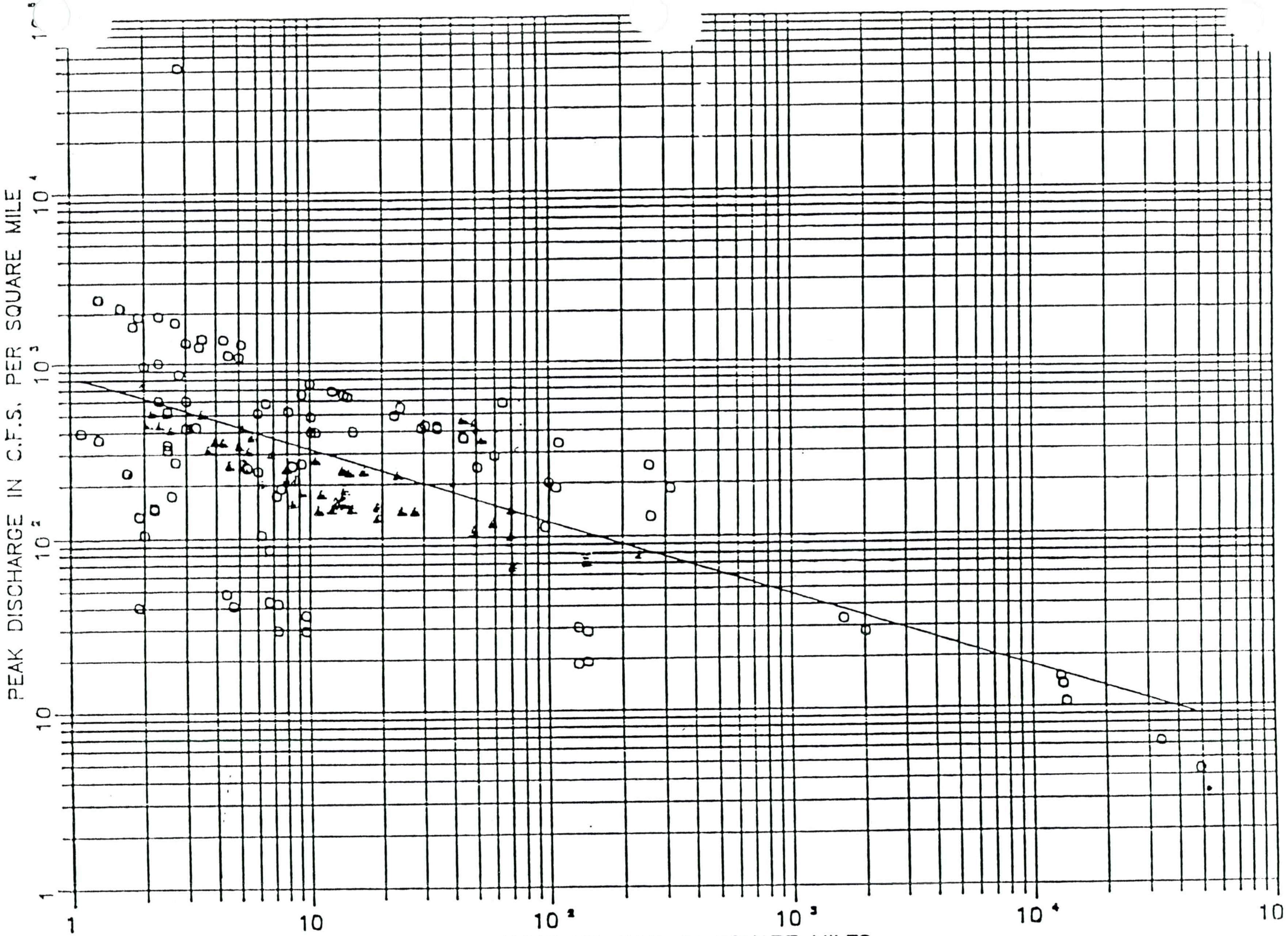
YAVAYAI COUNTY
ENVELOPE CURVE



APACHE AND NAVAJO COUNTY
ENVELOPE CURVE



MARICOPA COUNTY
ENVELOPE CURVE



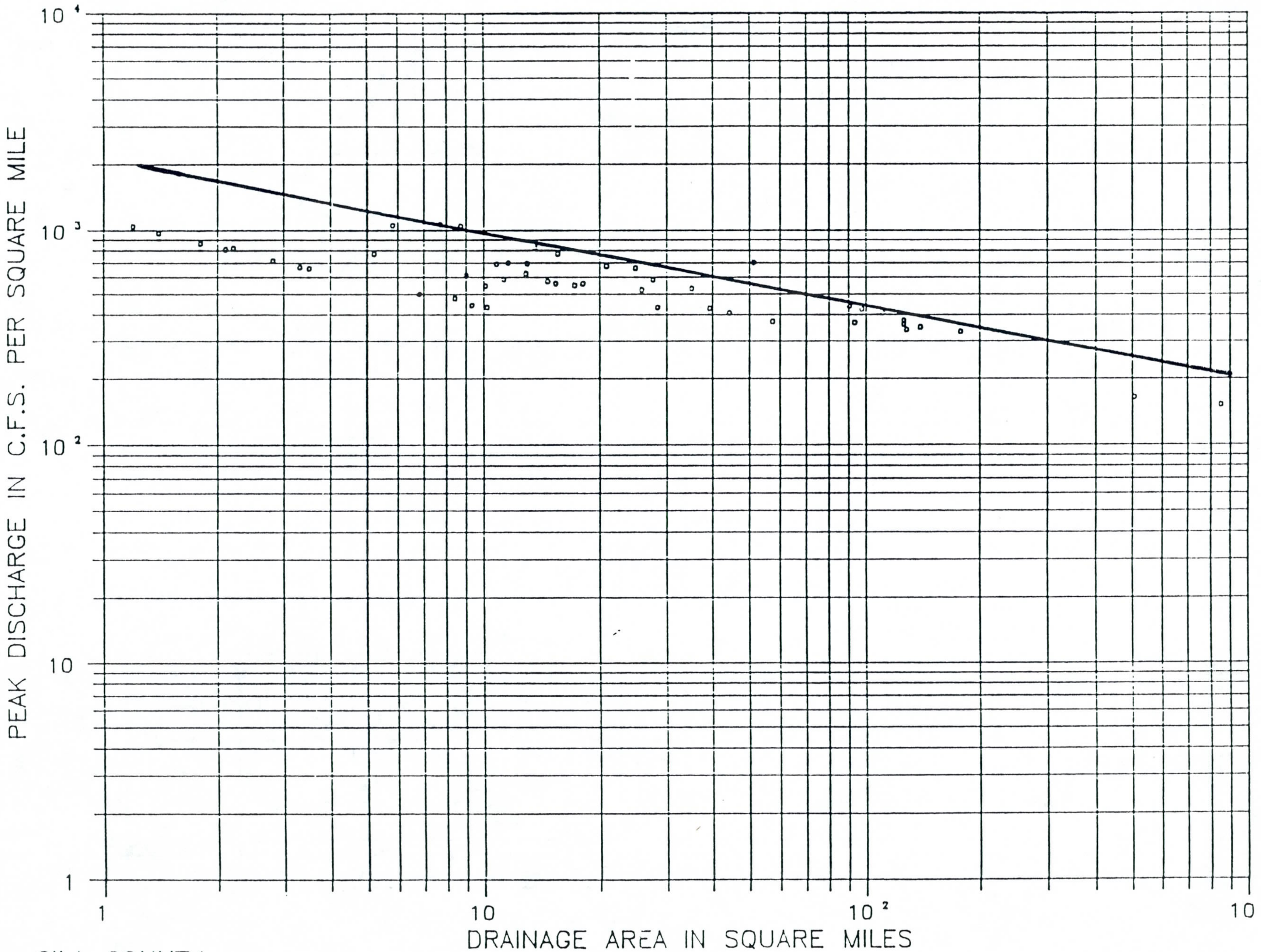
Maricopa County
JRM 01/11/89
Power Function PK/SQM = 828.9 DA ** −0.42

Source: Arizona Department of Water Resources

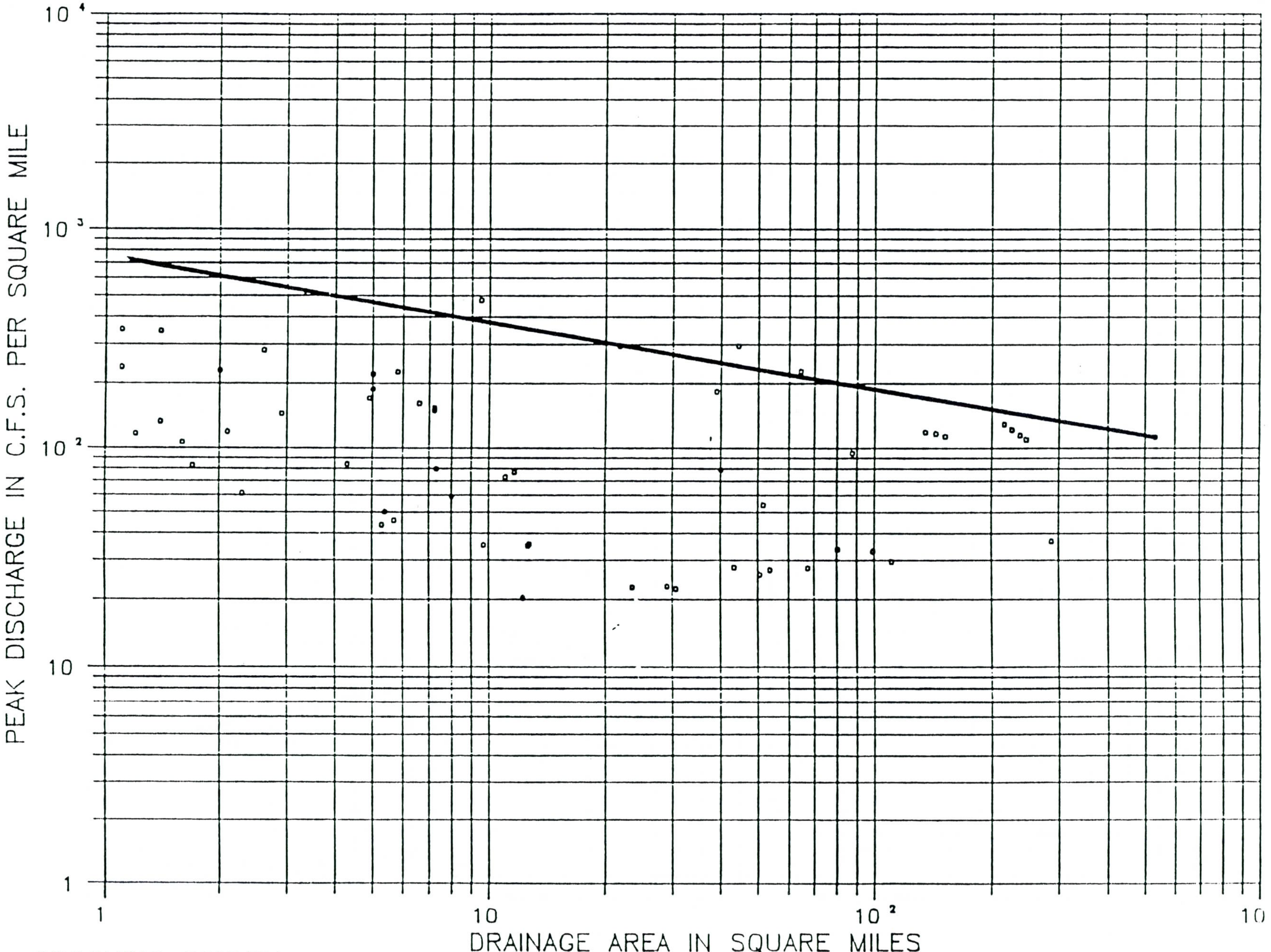
o - Existing Data
▲ - URS Data

FIGURE 4

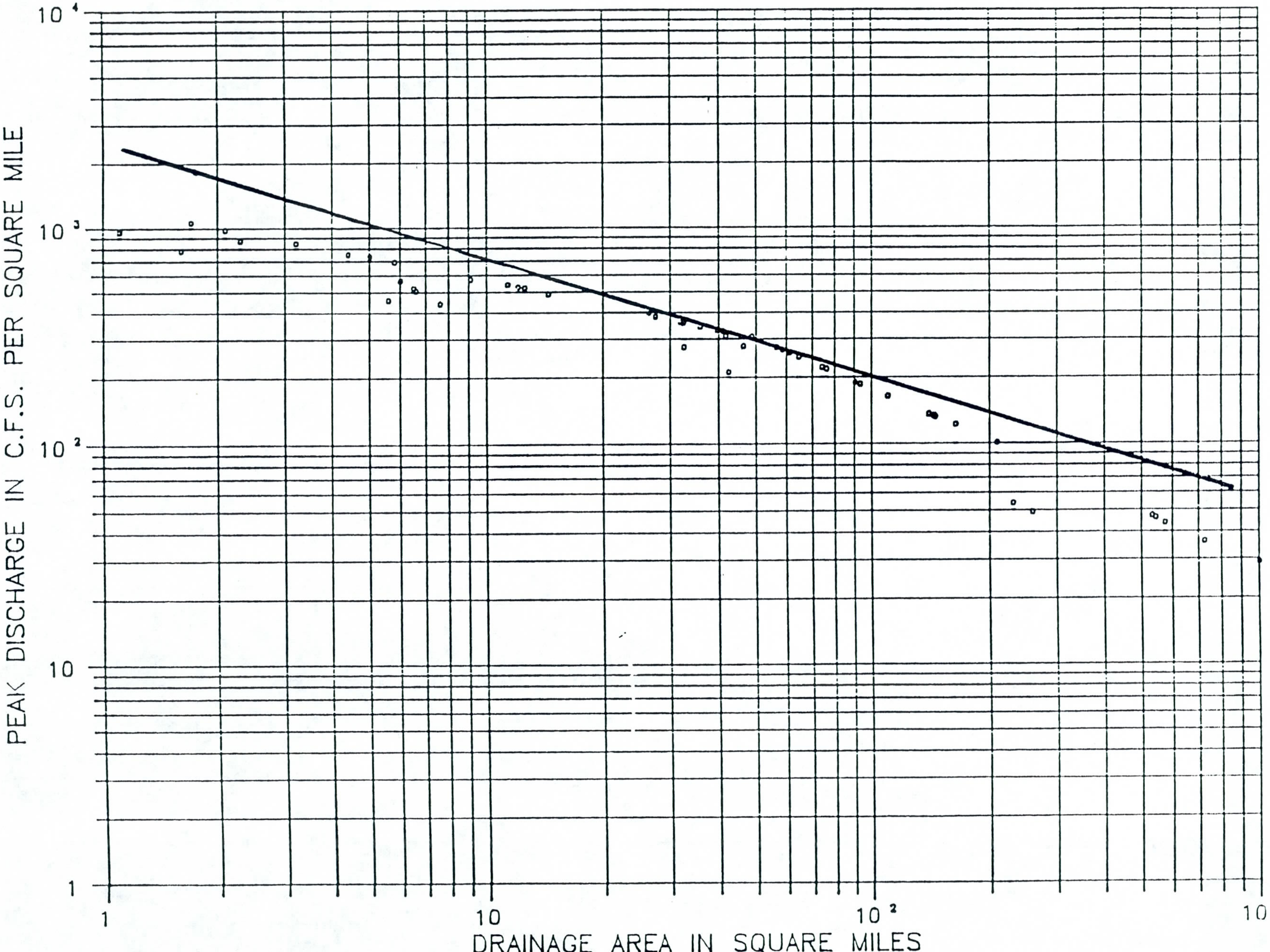
Comparison of 100-yr Discharges



GILA COUNTY
ENVELOPE CURVE



COCONINO COUNTY
ENVELOPE CURVE



SANTA CRUZ COUNTY
ENVELOPE CURVE

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Note: Additional data for the HEC-1 review checklist was provided by:

- Burgess & Niple, Inc.
- HDR Engineering, Inc.
- Flood Control District of Maricopa County
- McLaughlin-Kmetty Engineers, Ltd.
- Yavapai County Flood Control District

Sample U.S. Army Corps of Engineers HEC Newsletter (January, 1992) "Advances in Hydrologic Engineering" - refer to HEC-2 Discussion Section.

List of HEC software suppliers/vendors is included in publication entitled "Hydrologic Engineering Center Software Distribution - Domestic" (November 21, 1992) - refer to HEC-2 Discussion Section.

US Army Corps of Engineers
Hydrologic Engineering Center

GENERALIZED COMPUTER PROGRAM

HEC-1

Flood Hydrograph Package

User's Manual

September 1990

CPD-1A
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