

PROGRAM NAME: HEC-2: Flood Plain Analysis

VERSION/DATE: 4.6.2 5/91

OPERATING SYSTEM: DOS

DISTRIBUTOR: HEC

Also see ProHEC2 by Dodson

DOCUMENTATION:

HEC-2: Water Surface Profiles User's Manual
September 1990
Revised: February 1991
Hydrologic Engineering Center US Army Corps of Engineers

Computing Water Surface Profiles with HEC-2 on a Personal Computer
TD-#26, 1992
Hydrologic Engineering Center US Army Corps of Engineers

ADDITIONAL DOCUMENTATION (sold separately):

"Hands-On" HEC-2 (Tutorial and Reference Guide)
by Dodson & Associates, Inc.
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(see ProHEC2 for more information)

SYSTEM REQUIREMENTS

Program requires 640k memory (521K free) and a hard disk. A math coprocessor is also highly recommended.

ABSTRACT

The program is intended for calculating water surface profiles for steady gradually varied flow in natural or man-made channels. Both subcritical and supercritical flow profiles can be calculated. The effects of various obstructions such as bridges, culverts, weirs, and structures in the floodplain may be considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. The computational procedure is generally known as the standard step method. The program is also designed for application in floodplain management and flood insurance studies to evaluate floodway encroachments. Also, capabilities are available for assessing the effects of channel improvements and levees on water surface profiles. Input and output may be either English or metric units.

SUPPLEMENTARY PROGRAMS

A data edit program (EDIT2) checks the data records for various input errors. An interactive summary printout program (SUMPO) and graphics program (PLOT2) are available for MS DOS computers. An input edit program (COED) is available with an HEC-2 input help file. All the supplementary programs are provided in the HEC-2 PC package.

PROGRAM DEVELOPMENT HISTORY

Computer program HEC-2, Water Surface Profiles, originated from a step-backwater program written in WIZ (a version of BASIC) by Bill S. Eichert in

1964. This early version was developed on a GE 225 system at the Corps of Engineers Tulsa District office. In 1966 the first FORTRAN version of HEC-2 was released by the Hydrologic Engineering Center (HEC) under the name "Backwater Any Cross Section."

As the name implied, Backwater Any Cross Section (unlike the other early backwater programs) was capable of computing water surface profiles in channels with irregularly shaped cross sections. This program represented a significant step in the development of modern computational techniques for hydraulic analysis.

The program was revised and expanded and in 1968 was released as HEC-2, Water Surface Profiles, the second in a series of generalized computer programs issued by the HEC. Since the first release of HEC-2 in 1968 the addition of new features and improvements have prompted the release of new versions in 1971, 1976 and 1988.

In 1984 Alfredo Montalvo adapted HEC-2 to the microcomputer (PC) environment. The PC release of HEC-2 has been accompanied by the introduction of PC based support programs, SUMPO and PLOT2.

The February 1991 release of HEC-2 (Version 4.6.0) includes the capability to simulate culvert hydraulics using the Federal Highway Administration's (FHWA) culvert procedures. The FHWA procedures were added to HEC-2 by Roy Dodson, Dodson & Associates, Houston, TX.

END

HEC-2

Water Surface Profiles

User's Manual

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HEC-2

Water Surface Profiles

User's Manual

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Chapter 1

Introduction

This manual documents Version 4.6 of HEC-2, released February 1991. Appendices provide sample applications, floodway options, bridge and culvert analysis. Input, output, and special notes are also presented in the Appendices.

1.1 Program Development

Computer program HEC-2, Water Surface Profiles, originated from a step-backwater program written in WIZ by Bill S. Eichert in 1964. This early version was developed on a GE 225 system at the Corps of Engineers Tulsa District office. In 1966 the first FORTRAN version of HEC-2 was released by the Hydrologic Engineering Center (HEC) under the name "Backwater Any Cross Section."

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The program was revised and expanded and in 1968 was released as HEC-2, Water Surface Profiles, the second in a series of generalized computer programs issued by the HEC. Since the first release of HEC-2 in 1968 the addition of new features and improvements have prompted the release of new versions in 1971, 1976 and 1988.

In 1984 Alfredo Montalvo adapted HEC-2 to the microcomputer (PC) environment. The PC release of HEC-2 has been accompanied by the introduction of PC based support programs, SUMPO and PLOT2.

The February 1991 release of HEC-2 (Version 4.6) includes the capability to simulate culvert hydraulics using the Federal Highway Administration's (FHWA) culvert procedures. The FHWA procedures were added to HEC-2 by Roy Dodson, Dodson and Associates, Houston, TX.

1.2 Overview of Program Capabilities

The program is intended for calculating water surface profiles for steady gradually varied flow in natural or man-made channels. Both subcritical and supercritical flow profiles can be calculated. The effects of various obstructions such as bridges, culverts, weirs, and structures in the floodplain may be considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. The computational procedure is generally known as the standard step method. The program is also designed for application in floodplain management and flood insurance studies to evaluate floodway encroachments. Also, capabilities are available for assessing the effects of channel improvements and levees on water surface profiles. Input and output may be either English or metric units.

1.3 Supplementary Programs

A data edit program (EDIT2) checks the data records for various input errors. An interactive summary printout program (SUMPO) and graphics program (PLOT2) are available for MS DOS computers. An input edit program (COED) is available with an HEC-2 input help file. All the supplementary programs are provided in the HEC-2 PC package.

1.4 Computer Equipment Requirements

Two versions of HEC-2 have been developed by HEC. A standard version of HEC-2 has been developed on the HARRIS 1000 computer. It may be used with minor modifications on most medium to large computers. A microcomputer version of HEC-2 has been developed for use on the IBM PC/XT microcomputer. FORTRAN source code for both versions and an executable module for the micro version are available.

Chapter 2

Theoretical Basis for Profile Calculation

2.1 General

This section describes methodology used in HEC-2 to calculate water surface profiles. Topics discussed include equations used for basic profile calculation, cross section subdivision for determining conveyance and velocity distribution, friction loss evaluation, iterative procedure for solving the basic equations and critical depth determination. Computational methodology for calculating flow through bridges is presented in Appendix III and the culvert procedure is described in Appendix IV. Methodology used by HEC-2 to determine and evaluate floodplain encroachments is contained in Appendix II.

2.2 Equations for Basic Profile Calculation

The following two equations are solved by an iterative procedure (the standard step method) to calculate an unknown water surface elevation at a cross section:

$$WS_2 - \frac{V_2^2}{2g} = WS_1 - \frac{V_1^2}{2g} + h_e \quad (1)$$

$$h_e = L \bar{S}_f + C \left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g} \right) \quad (2)$$

- where: WS_1, WS_2 = water surface elevations at ends of reach (see Figure 1)
- V_1, V_2 = mean velocities (total discharge \div total flow areas) at ends of reach
- β_1, β_2 = velocity coefficients for flow at ends of reach
- g = acceleration of gravity
- h_e = energy head loss
- L = discharge-weighted reach length
- S_f = representative friction slope for reach
- C = expansion or contraction loss coefficient

The discharge-weighted reach length, L , is calculated as:

$$L = \frac{L_{lob}\bar{Q}_{lob} + L_{ch}\bar{Q}_{ch} + L_{rob}\bar{Q}_{rob}}{\bar{Q}_{lob} + \bar{Q}_{ch} + \bar{Q}_{rob}} \quad (3)$$

where: L_{lob}, L_{ch}, L_{rob} = reach lengths specified for flow in the left overbank, main channel and right overbank, respectively

$\bar{Q}_{lob}, \bar{Q}_{ch}, \bar{Q}_{rob}$ = arithmetic average of flows at the ends of the reach for the left overbank, main channel, and right overbank, respectively

Determination of a representative friction slope, S_f , is discussed in Section 4 of this chapter. Selection of appropriate magnitudes for expansion and contraction coefficients is discussed in Chapter 3, Section 5 and Appendix III.

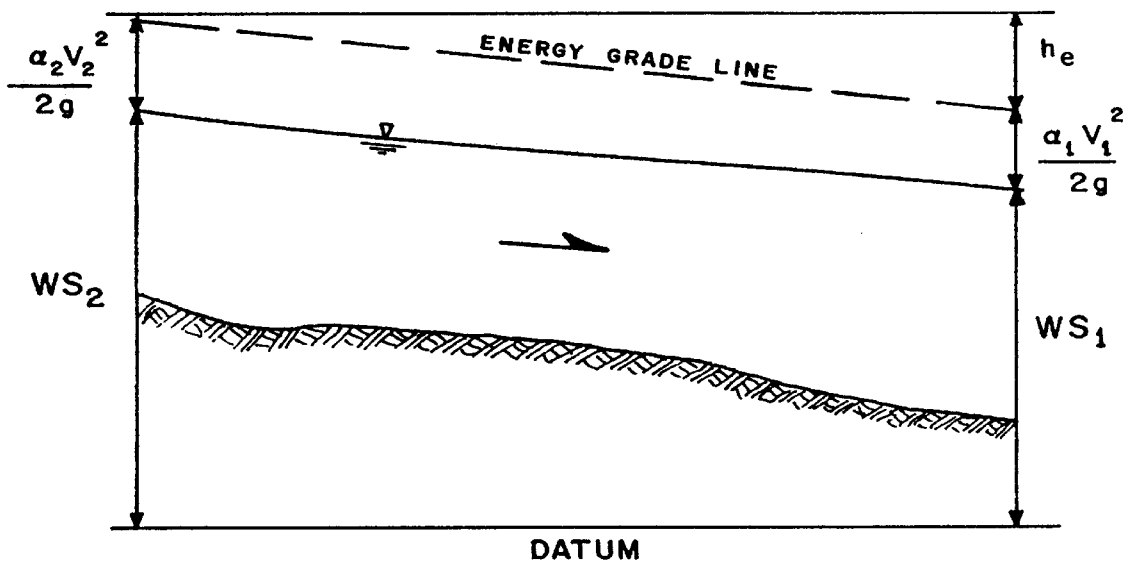


Figure 1
Representation of Terms in Energy Equation

2.3 Cross Section Subdivision

The determination of total conveyance and the velocity coefficient for a cross section requires that flow be subdivided into units for which the velocity is uniformly distributed. The approach used in HEC-2 is to subdivide flow in the **overbank** areas using the input cross section stations (X-coordinates) as the basis for subdivision. Conveyance is calculated within each subdivision by the following equation (based on English units):

$$k = \frac{1.486}{n} a r^{2/3} \quad (4)$$

- where: k = conveyance for subdivision
 n = Manning's $\rho n'$ for subdivision
 a = flow area for subdivision
 r = hydraulic radius for subdivision (area divided by wetted perimeter)

The total conveyance for the cross section is obtained by summing the incremental conveyances.

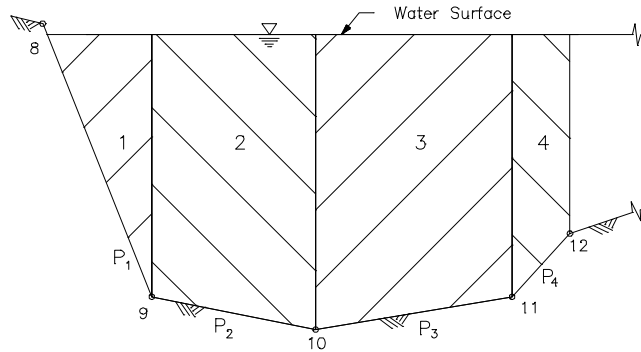


Figure 2
Incremental Areas in Subsections

Flow in the **main channel** is not subdivided, except when the roughness coefficient is changed within the channel area. HEC-2 has been modified to test the applicability of subdivision of roughness within the channel portion of a cross section, and if it is not applicable, the program will compute a composite $\rho n'$ value for the entire channel. The program determines if the channel portion of the cross section can be subdivided or if a composite channel $\rho n'$ value will be utilized based on the following criterion: if a channel side slope is steeper than 5H:1V and the cross section has been subdivided, a composite roughness $\rho n'_c$ will be computed [Equation 6-17, Chow, 1959]. The channel side slope used by HEC-2 is defined as the horizontal distance between adjacent NH stations within the channel over the difference in elevation of these two stations (see S_L and S_R of Figure 3).

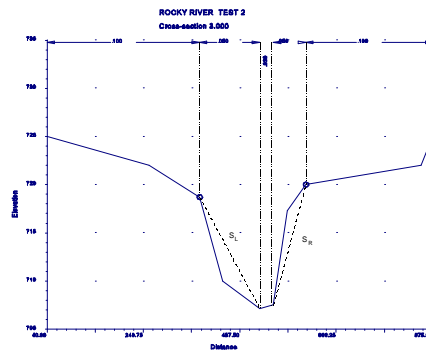


Figure 3
Definition of Bank Slope When Examining Conveyance Within the Channel

For the determination of pn_c' , the water area is divided imaginatively into N parts each with a known wetted perimeter P_i and roughness coefficient n_i .

$$n_c = \left[\frac{\sum_{i=1}^N P_i n_i^{1.5}}{P} \right]^{2/3} \quad (5)$$

- where: n_c = composite or equivalent coefficient of roughness
 P = wetted perimeter of cross section
 P_i = wetted perimeter of imaginary subdivision i
 n_i = coefficient of roughness for imaginary subdivision i

The computed composite pn_c' should be checked for reasonableness. The computed value is the channel pn' value (XNCH) in the detailed output and summary tables.

Channel subdivision is controlled in HEC-2 by the input variable SUBDIV specified in the third field of the J6 record.

2.4 Velocity Coefficient

The velocity coefficient, b , is computed based on the conveyance in the three flow elements: left overbank, right overbank, and channel. It is obtained with the following equation:

$$b = \frac{(A_t)^2 \left[\frac{(K_{lob})^3}{(A_{lob})^2} + \frac{(K_{ch})^3}{(A_{ch})^2} + \frac{(K_{rob})^3}{(A_{rob})^2} \right]}{(K_t)^3} \quad (6)$$

- where: A_t = total flow area of cross section
 A_{lob}, A_{ch}, A_{rob} = flow areas of left overbank, main channel and right overbank, respectively
 K_t = total conveyance of cross section
 K_{lob}, K_{ch}, K_{rob} = conveyances of left overbank, main channel and right overbank, respectively

2.5 Friction Loss Evaluation

Friction loss is evaluated in HEC-2 as the product of S_f , and L , where S_f is the representative friction slope for a reach and L is defined with Equation 3. Alternative expressions for S_f available in HEC-2 are as follows:

Average Conveyance Equation

$$\bar{S}_f = \left(\frac{Q_1}{K_1} \frac{Q_2}{K_2} \right)^2 \quad (7)$$

Average Friction Slope Equation

$$\bar{S}_f = \frac{S_{f_1} + S_{f_2}}{2} \quad (8)$$

Geometric Mean Friction Slope Equation

$$\bar{S}_f = \sqrt{S_{f_1} S_{f_2}} \quad (9)$$

Harmonic Mean Friction Slope Equation

$$\bar{S}_f = \frac{2 S_{f_1} S_{f_2}}{S_{f_1} + S_{f_2}} \quad (10)$$

Equation 7 is the 'default' equation used by the program; that is, it is used automatically unless a different equation is requested by input. The program also contains an option to select equations, depending on flow regime and profile type (e.g., S1, M1, etc.). Further discussion of the alternative methods for evaluating friction loss is contained in Chapter 4, Optional Capabilities.

2.6 Computation Procedure

The unknown water surface elevation at a cross section is determined by an iterative solution of Equations 1 and 2. The computational procedure is as follows:

1. Assume a water surface elevation at the upstream cross section (or downstream cross section if a supercritical profile is being calculated).
2. Based on the assumed water surface elevation, determine the corresponding total conveyance and velocity head.
3. With values from step 2, compute S_f and solve Equation 2 for h_e .
4. With values from steps 2 and 3, solve Equation 1 for WS_2 .
5. Compare the computed value of WS_2 with the values assumed in step 1; repeat steps 1 through 5 until the values agree to within .01 feet (or .01 meters).

Criteria used to assume water surface elevations in the iterative procedure varies from trial to trial. Generally the first trial is based on projecting the previous cross section's water surface elevation on the average of the friction slopes from the previous two cross sections. The second trial is an arithmetic average of the computed and assumed elevations from the first trial. The third and subsequent trials are generally based on a "secant" method of projecting the rate of change of the difference between computed and assumed elevations for the previous two trials to zero. The change from one trial to the next is constrained to a maximum of ± 50 percent of the assumed depth from the previous trial.

Once a 'balanced' water surface elevation has been obtained for a cross section, checks are made to ascertain that the elevation is on the 'right' side of the critical water surface elevation (e.g., above the critical elevation if a subcritical profile is being calculated). If the balanced elevation is on the 'wrong' side of the critical water surface elevation, critical depth is assumed for the cross section and a message to that effect is printed by the program. The program user should be aware of critical depth assumptions and determine the reasons for their occurrence, because in many cases they result from reach lengths being too long or from misrepresentation of the effective flow areas of cross sections.

For a subcritical profile, a preliminary check for proper flow regime involves the following equation:

$$\left(\frac{V^2}{2g} \right)_{test} = \frac{A_t}{2T} \quad (11)$$

where: $\left(\frac{V^2}{2g} \right)_{test}$ = velocity head that would exist if critical conditions existed at the balanced water surface elevation.

A_t = total flow area

T = water surface width

If the calculated velocity head, $\frac{V^2}{2g}$, is less than 94% of $\left(\frac{V^2}{2g} \right)_{te}$, the balanced water surface elevation will be accepted for the cross section. If the calculated velocity head is greater than 94 percent of the test value, the critical water surface elevation will be determined (by a procedure discussed in Section 2.6) so that a direct comparison of balanced elevation versus critical elevation can be made.

For a supercritical profile, critical depth is automatically calculated for every cross section, which enables a direct comparison between balanced and critical elevations.

2.7 Critical Depth Determination

Critical depth for a cross section will be determined if any of the following conditions are satisfied:

- (1) The supercritical flow regime has been specified.
- (2) Calculation of critical depth has been requested.
- (3) This is the first cross section and critical depth starting conditions have been specified.

- (4) The critical depth check for a subcritical profile indicates that critical depth needs to be determined to verify the flow regime associated with the balanced elevation.

The total energy head for a cross section is defined by:

$$H = WS + \frac{V^2}{2g} \quad (12)$$

where: H = total energy head

WS = water surface elevation

$\frac{bV^2}{2g}$ = velocity head

The critical water surface elevation is the elevation for which the total energy head is a minimum. The critical elevation is determined with an iterative procedure whereby values of WS are assumed and corresponding values of H are determined with Equation 12 until a minimum value for H is reached.

To speed the iteration process, a parabolic interpolation procedure is followed. The procedure basically involves determining values of H for three values of WS that are spaced at equal Δ WS intervals. The WS corresponding to the minimum value for H defined by a parabola passing through the three points (on the H versus WS plane) is used as the basis for the next assumption of a value for WS.

It is presumed that critical depth has been obtained when there is less than a 2.5 percent change in depth from one iteration to the next and provided the energy head has either decreased or has not increased by more than .01 feet. The tolerance of 2.5 percent may be changed by program input.

2.8 Program Limitations

The following assumptions are implicit in the analytical expressions used in the program:

- (1) Flow is steady,
- (2) Flow is gradually varied,
- (3) Flow is one dimensional (i.e., velocity components in directions other than the direction of flow are not accounted for),
- (4) River channels have 'small' slopes, say less than 1:10.

Flow is assumed to be steady because time-dependent terms are not included in the energy equation (Equation 1). Flow is assumed to be gradually varied because Equation 1 is based on the premise that a hydrostatic pressure distribution exists at each cross section. Flow is assumed to be one-dimensional because Equation 4 is based on the premise that the total energy head is the same for all points in a cross section. Small channel slopes are assumed because the pressure head which is a component of WS in Equation 1 is represented by the water depth measured vertically.

The program does not have the capability to deal with movable boundaries (i.e., sediment transport) and requires that energy losses be definable with the terms contained in Equation 2.

Chapter 3

Basic Data Requirements

3.1 General

A major portion of the programming in HEC-2 is devoted to providing a large variety of input and data manipulation options. The program objective is quite simple -- compute water surface elevations at all locations of interest for given flow values. The data needed to perform these computations include: flow regime, starting elevation, discharge, loss coefficients, cross section geometry, and reach lengths. The options available for providing and manipulating input are discussed in the following sections.

3.2 Flow Regime

Profile computations begin at a cross section with known or assumed starting conditions and proceed upstream for subcritical flow or downstream for supercritical flow. The direction of flow is specified on the J1 record (first job record) by setting variable IDIR equal to one for supercritical flow or zero (or blank) for subcritical flow. Subcritical profiles computed by the program (IDIR = 0) are constrained to critical depth or above, and supercritical profiles (IDIR = 1) are constrained to critical depth or below. The program will not allow profile computations to cross critical depth except for certain bridge analysis problems. In cases where flow passes from one flow regime to another as shown in Figure 4 below, it is necessary to compute the profile twice, alternately assuming subcritical and supercritical flow. Results of a subcritical profile (shown as p in Figure 4) computed for the

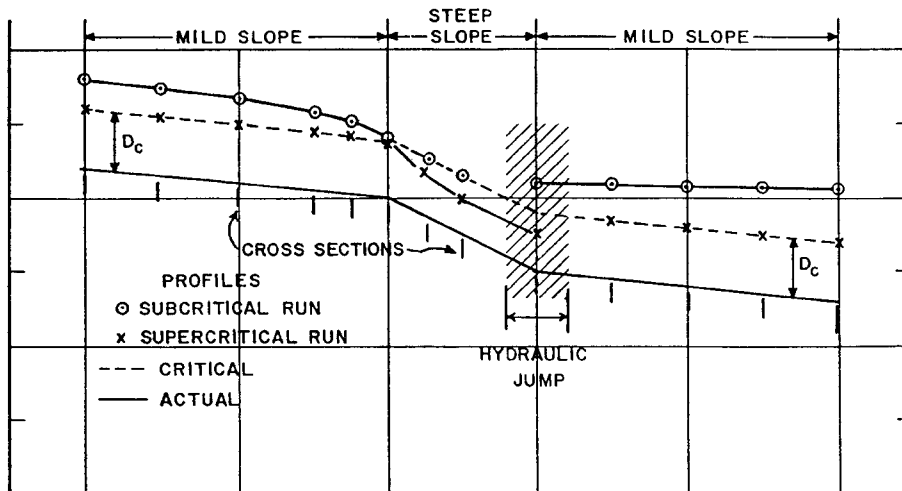


Figure 4
Profiles Calculated for Subcritical and Supercritical Flows

example stream would plot at critical depth (above the actual water surface profile) in the steep reach of stream. Results from a supercritical profile computation (shown as x in Figure 4) would plot at critical depth (below the actual water surface profile) for both mild reaches of the stream. The final plotted profile should incorporate computed results from both computations and an analysis of the hydraulic jump. HEC-2 does not contain the capability to determine the position of the hydraulic jump or energy losses associated with the jump.

3.3 Starting Elevation

The water surface elevation for the beginning cross section may be specified in one of four ways: (1) as critical depth, (2) as a known elevation, (3) by the slope area method, and (4) by a rating curve. By setting the variable STRT on the J1 record equal to minus one, critical depth will be computed and used as the starting water surface elevation. This method is appropriate at locations where critical or near critical conditions are known to exist for the range of discharges being computed (e.g., a waterfall, weir or a section of rapids). When a rating curve is available, the appropriate starting elevation can be specified by variable WSEL on the J1 record (or the entire rating curve may be entered with the JR record).

For beginning by the slope area method, STRT is set equal to the estimated slope of the energy grade line (must be a positive value). The flows computed for the fixed slope are compared with the starting flow and the depth is adjusted until the computed flow is within one percent of the starting flow. The water surface elevation thus determined may be used as the starting water surface elevation for subsequent water surface profile computations.

3.4 Discharge

Discharge may be specified and altered in several ways. The variable Q on the first job record (J1 record) specifies the starting discharge for single profile runs. When it is desired to change the discharge for a single profile run, the variable QNEW on the X2 record can be used to permanently change the discharge at any cross section.

An alternate procedure utilizes the QT records (discharge table) and may be used to specify from one to nineteen discharge values for single or multiple profile runs. QT records may be used to specify starting discharges and to permanently change discharges at any cross section in a data set. Variable INQ on the J1 record directs the program to the field of the QT record that contains the discharge for that profile. When a value of FQ is entered, all discharges on the X2 records and discharges in the specified INQ of the QT records are multiplied by the value.

3.5 Energy Loss Coefficients

Several types of loss coefficients are utilized by the program to evaluate head losses: (1) Manning's pn' or equivalent roughness heights pk' values for friction loss, (2) contraction and expansion coefficients to evaluate transition (shock) losses, and (3) bridge and culvert loss coefficients to evaluate losses related to weir shape, pier configuration, and pressure flow, and entrance and exit conditions.

Manning's pn' . Because Manning's pn' coefficient of roughness depends on such factors as type and amount of vegetation, channel configuration and stage, several options are available to vary pn' . When three pn' values are sufficient to describe the channel and overbank roughness, the first three fields of the NC record (pn' value - change) are used. Any of the pn' values may be permanently changed at any cross section by using another NC record. Often three values are not enough to adequately describe the lateral roughness variation in the cross section; in this case the NH record (pn' value - horizontal) is used. The number of pn' values used to describe the roughness is entered as variable NUMNH in the first field and the pn' values and corresponding cross section stations are entered in subsequent fields. These pn' values will be used for all subsequent cross sections unless changed by another NH record. Normally

the NH record pn' values should be redefined for each cross section with new geometry. If pn' values change within the channel, the criterion described in Section 2.3 is used to determine whether pn' values should be converted to a composite value using Equation 5.

Data indicating the variation of Manning's pn' with river stage may be used in the program. Manning's pn' and the corresponding stage elevation (beginning with the lowest elevation) are entered on the NV record (pn' value - vertical), beginning in the second and third fields, respectively. Variable NUMNV in Field 1 is the number of pn' values input on the NV records. This pn' value option applies only to the channel area.

If for subsequent jobs of the same run it is desired to modify the pn' values specified on the NC, NH, and NV records by a factor, variable FN on the J2 record may be used. The desired factor is entered as variable FN for each job. If the value of FN is negative, the factor is multiplied by the channel pn' values on the NC record but the overbank pn' values are not changed.

There are several references a user can access that shows Manning's pn' values for typical channels [USACE, 1959]; an extensive compilation of pn' values for streams and floodplains [Chow, 1959]; and, pictures of selected streams as a guide to pn' value determination [Fasken, 1963] [Barnes, 1967] are available.

Equivalent Roughness pk' . An equivalent roughness parameter pk' , commonly used in the hydraulic design of channels, is provided as an option for describing boundary roughness in HEC-2. Equivalent roughness, sometimes called "roughness height", is a measure of the linear dimension of roughness elements, but is not necessarily equal to the actual, or even the average, height of these elements. In fact, two roughness elements with different linear dimensions may have the same pk' value because of differences in shape and orientation [Chow, 1959].

The advantage of using equivalent roughness pk' instead of Manning's pn' is that pk' reflects changes in the friction factor due to stage, whereas Manning's pn' alone does not. This influence can be seen in the definition of Chezy's "C" (English units) for a rough channel [Equation 6, USACE, 1970]:

$$C = 32.6 \log_{10} \left[\frac{12.2R}{k} \right] \quad (13)$$

where: C = Chezy roughness coefficient

R = hydraulic radius (feet)

k = equivalent roughness (feet)

Note that as the hydraulic radius increases (which is equivalent to an increase in stage), the friction factor "C" increases. In HEC-2, pk' is converted to a Manning's pn' by using the above equation and equating the Chezy and Manning's equations [Equation 4, USACE, 1970] to obtain the following:

English Units:

$$n = \frac{1.486R^{1/6}}{32.6 \log_{10} \left[12.2 \frac{R}{k} \right]} \quad (14)$$

Metric Unit:

$$n = \frac{R^{1/6}}{18.0 \log_{10} \left[12.2 \frac{R}{k} \right]} \quad (15)$$

where: n = Manning's roughness coefficient

Again, this equation is based on the assumption that all channels (even concrete-lined channels) are "hydraulically rough." A graphical illustration of this conversion is available [USACE, 1970].

KH records can be used to describe the horizontal variation of $\rho k'$ in the same manner as NH records are used to describe Manning's $\rho n'$ values. Up to twenty values of $\rho k'$ can be specified for each cross section with the use of KH records. Normally, a set of KH records applies to a single cross section, and an NC record or another set of KH or NH records is used to define $\rho k'$ or $\rho n'$ values for the next cross section.

Tables and charts for determining $\rho k'$ values for concrete-lined channels are provided in EM 1110-2-1601 [USACE, 1970]. Values for riprap-lined channels may be taken as the theoretical spherical diameter of the median stone size. Approximate $\rho k'$ values [Chow, 1959] for a variety of bed materials, including those for natural rivers are shown in Table 1.

Table 1
Equivalent Roughness Values of Various Bed Materials

	k (Feet)
Brass, Cooper, Lead, Glass	0.0001 - 0.0030
Wrought Iron, Steel	0.0002 - 0.0080
Asphalted Cast Iron	0.0004 - 0.0070
Galvanized Iron	0.0005 - 0.0150
Cast Iron	0.0008 - 0.0180
Wood Stave	0.0006 - 0.0030
Cement	0.0013 - 0.0040
Concrete	0.0015 - 0.0100
Drain Tile	0.0020 - 0.0100
Riveted Steel	0.0030 - 0.0300
Natural River Bed	0.1000 - 3.0000

The values of $\rho k'$ (0.1 to 3.0 ft.) for natural river channels are normally much larger than the actual diameters of the bed materials to account for boundary irregularities and bed forms.

Contraction-Expansion Coefficients. Contraction or expansion of flow due to changes in the channel cross section is a common cause of energy losses within a reach. Whenever this occurs, the loss may be computed by specifying the contraction and expansion coefficients as variables CCHV and CEHV, respectively, on the NC record. The coefficients are multiplied by the absolute difference in velocity heads between the cross sections to give the energy loss caused by the transition. Where the change in river cross section is small, coefficients CCHV and CEHV are typically on the order of 0.1 and 0.3, respectively. When the change in effective cross section area is abrupt such as at bridges, CCHV and CEHV may be as high as 0.6 and 1.0, respectively. These values may be changed at any cross section by inserting a new NC record. These new values will be used until changed again by another NC record. For additional information concerning transition losses and for information on bridge loss coefficients see Appendix III.

3.6 Cross Section Geometry

Boundary geometry for the analysis of flow in natural streams is specified in terms of ground surface profiles (cross sections) and the measured distances between them (reach lengths). Cross sections are located at intervals along a stream to characterize the flow carrying capability of the stream and its adjacent floodplains. They should extend across the entire floodplain and should be perpendicular to the anticipated flow lines (approximately perpendicular to contour lines). Occasionally it is necessary to layout cross sections in a curved or dog-leg alignment to meet this requirement. Every effort should be made to obtain cross sections that accurately represent the stream and floodplain geometry. However, ineffective flow areas of the floodplain such as stream inlets, small ponds or indents in the valley floor should generally not be included in the cross section geometry.

Cross sections are required at representative locations throughout a stream reach and at locations where changes occur in discharge, slope, shape, or roughness, at locations where levees begin or end and at bridges or control structures such as weirs. Where abrupt changes occur, several cross sections should be used to describe the change regardless of the distance. Cross section spacing is also a function of stream size, slope, and the uniformity of cross section shape. In general, large uniform rivers of flat slope normally require the fewest number of cross sections per mile. The purpose of the study also affects spacing of cross sections. For instance, navigation studies on large relatively flat streams may require closely spaced (e.g., 500 feet) cross sections to analyze the effect of local conditions on low flow depths, whereas cross sections for sedimentation studies to determine deposition in reservoirs may be spaced at intervals of up to five or ten miles.

The choice of friction loss equation may also influence the spacing of cross sections. For instance, cross section spacing may be maximized when calculating an M1 profile with the average friction slope equation or when the harmonic mean friction slope equation is used to compute M2 profiles. The J6 record provides the option to let the program select the averaging equation (see Table 2, page 23).

Each cross section in an HEC-2 data set is identified and described by X1 and GR records. Variable SECNO on the X1 record is the cross section identification number which may correspond to stationing along the channel, mile points, or any fictitious numbering system, since it is only used to identify output and is not used in the computations. Each data point in the cross section is given a station number corresponding to the horizontal distance from a zero point on the left. The elevation and a corresponding station number of each data point are input as variables EL(I) and STA(I) on GR records. Up to 100 data points may be used to describe cross section geometry for most program applications. When the encroachment options are utilized, no more than 95 data points should be used, since they generate additional data points automatically to define the encroachment limits. The channel improvement option also should be used with less than 100 data points since it will generate data points (four or more depending on the geometry).

Cross section data is traditionally oriented looking downstream since the program considers the left side of the stream to have the lowest station numbers and the right side to have the highest. The left and right stations separating the channel from the overbank areas are specified as variables STCHL and STCHR on the X1 record. End points of a cross section that are too low (below the computed water surface elevation) will automatically be extended vertically and a note indicating the extension amount will be printed.

Numerous program options are available to allow the user to easily add or modify cross section data. For example, when the user wishes to repeat a surveyed cross section, a single X1 record may be input to identify the cross section and to provide reach length information. X1 record variables, PXSECR and PXSECE, allow the user to modify the horizontal and vertical dimensions of the repeated cross section data. Other program options to modify cross section data to model improved channel sections, encroachments and ineffective flow areas are described in detail in the following chapter.

3.7 HEC-2 Cross Section Adjustment Sequence

The following list describes the sequence of changes performed by HEC-2:

- 1. Read Cross Section Data, or Read Previous Data for Repeat Cross Section**

The previous section data was stored after the modifications listed in Items 2 and 3 below. The elevations and stations for this data are considered the original coordinates in the following.

- 2. Add X4 Data Points into the Cross Section Array**

X4 data should be in original cross section coordinates, for GR data; but adjusted for repeat section coordinates of the section as saved in Item 4, below.

- 3. Adjust Cross Section Coordinates Elevation and Station**

PXSECR (X1 record, Field 8 - X1.8) ratio is multiplied times the difference between the coordinate stations to compute new coordinates. Ratio is applied to the input section (GR and X4 data), or to the repeat section, as saved in Item 4. (Does not change X4 data in repeat section.)

PXSECE (X1.9) elevation adjustment is added to the elevations of every coordinate point. (Does not change X4 data in repeat section.)

- 4. Store the Adjusted Cross Section for Repeat Section Use**

The above adjustments are permanent, in that a repeat of the section will include the changes listed in Items 2 and 3.

- 5. Perform Channel Modifications Defined by CI Input**

CI input should be in original coordinate system, that is the center line station and invert elevation will be adjusted by the current cross section adjustments (Item 3 above).

CI adjustment is not a permanent change to the cross section in that a repeat of the section will not include the channel improvement.

6. Add X3 Encroachment Stations and Elevations

Two points are added to define the vertical wall of the left and or right encroachment. The elevation of the lower point is interpolated based on the cross section data. The input stations and elevations are in the adjusted coordinate system.

If elevations are also defined, the elevations for stations to the outside of the encroachment stations (left of the left encroachment and right of the right encroachment) will be raised to the defined elevation. If no elevation is given, the elevations are raised to 100,000.

7. Raise Elevation Based on ELSESED

All elevations within the channel below ELSESED (X3.2) are raised to that elevation. Cross section stations are added at the intercept of the ELSESED elevation with the cross section, making a horizontal invert at the ELSESED elevation.

8. Eliminate Any Duplicate Points

Any exactly duplicated point is eliminated from the cross section array.

9. Compute the Minimum Elevation, ELMIN, for the Section.

10. Begin Commutation of Water Surface Elevation, etc.

3.8 Reach Lengths

The measured distances between cross sections are referred to as reach lengths. The reach lengths for the left overbank, right overbank and channel used in computations are specified on the X1 record by variables XLOBL, XLOBR, and XLCH, respectively. Channel reach lengths are typically measured along the thalweg. Overbank reach lengths should be measured along the anticipated path of the center of mass of the overbank flow. Often these three values will be equal. There are, however, conditions where they will differ, such as at river bends, or where the channel meanders considerably and the overbanks are straight. Where the distances between cross sections for channel and overbanks are different, a discharge-weighted reach length is determined based on the discharges in the main channel and left and right overbank segments of the reach (see Equation 3, page 4).

Chapter 4

Optional Capabilities

4.1 General

HEC-2 has numerous optional capabilities that allow the program user to determine floodplains and floodways; to evaluate energy losses at obstructions such as weirs, culverts, and bridges; and to analyze improvements to drainage systems. Detailed descriptions of options associated with encroachments, bridges, and culverts are contained in Appendices II, III, and IV, respectively. Other program options include the capability to select from alternative friction loss equations; calculate critical depth; solve directly for Manning's pn' ; automatically insert program generated cross sections; specify ineffective flow areas; analyze tributary streams; perform multiple profile analysis in a single execution of the program; and analyze flow in ice covered streams. These options are described in detail in the following sections.

4.2 Multiple Profile Analysis

HEC-2 can in a single run compute up to 14 profiles using the same cross sectional data. Variables NPROF on the J2 record controls the reading of data records. For a multiple profile run, the NPROF for the first profile is set equal to one or left blank to read in cross section data records. For all remaining profiles NPROF equals the profile number, i.e., 2, 3, 4, ..., and only J1 and J2 are required (records NC through EJ are omitted). After the last profile of a multiple profile run, a summary printout will be generated which provides a concise summary of results for all profiles for each cross section.

4.3 Critical Depth

Several options related to the computation of critical depth are available in HEC-2. Critical depth may be requested for **each** cross section of a subcritical run by coding a value of -1 for variable ALLDC of the J2 record. As described previously in Section 6 of Chapter 2, the normal tolerance used to terminate critical depth trial calculations is 2.5 percent of the depth. Other tolerances may be specified by coding a **minus** percent value for variable ALLDC. For instance, if a user desires critical depth to be computed at each cross section with a tolerance of 1.5 percent, a value of -1.5 should be entered for ALLDC.

As indicated in Section 5 of Chapter 2, critical depth is calculated automatically for cross sections of subcritical profiles whenever the calculated velocity head exceeds a test velocity head. The tolerance normally used is also 2.5 percent of the depth. The user can specify an alternative tolerance to be used for the automatic calculation of critical depth by indicating a positive value for ALLDC.

4.4 Effective Flow Options

A series of program capabilities are available to restrict flow to the effective flow areas of cross sections. Among these capabilities are options to simulate sediment deposition, to confine flows to leveed channels, to block out road fills and bridge decks, and to analyze floodplain encroachments. These program options are illustrated in Figure 5 below.

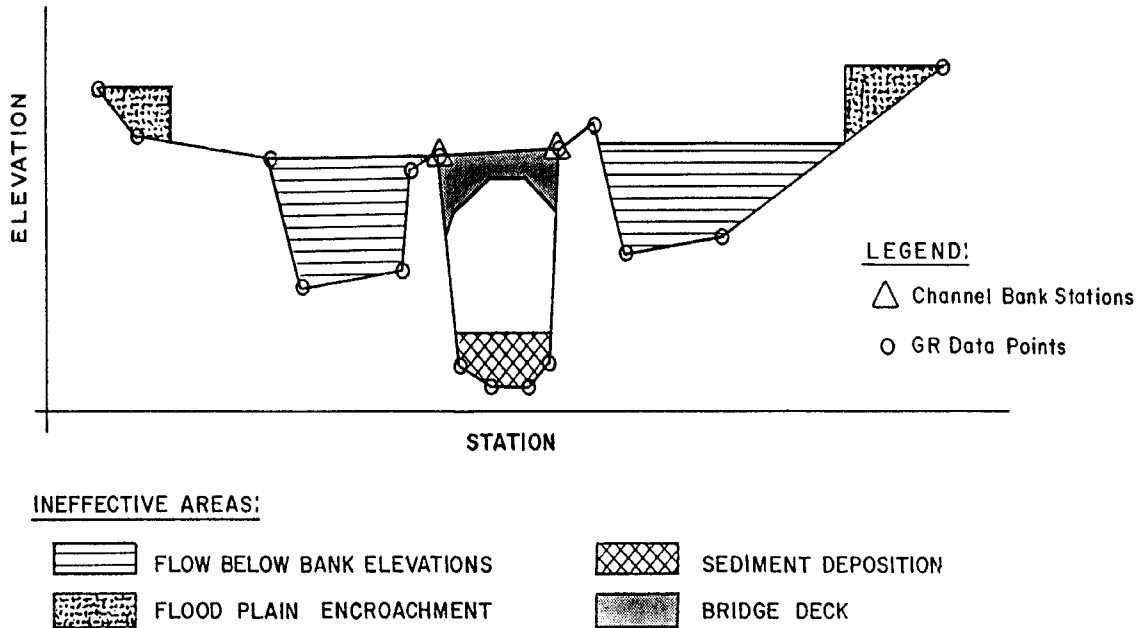


Figure 5
Types of Effective Flow Options

Sediment deposition may be specified by variable ELSESED on the X3 record. The specified elevation (ELSESED) is extended horizontally across the cross section and the area below this elevation is not considered by the program to carry flow.

Cross sections with low overbank areas or levees, require special consideration in computing water surface profiles because of possible overflow into areas outside the main channel. Normally the computations are based on the assumption that all area below the water surface elevation is effective in passing the discharge. However, if the water surface elevation at a particular cross section is less than the top of levee elevations, and if the water cannot enter or leave the overbanks upstream of that cross section, then the flow areas in these overbanks should not be used in the computations. Variable IEARA on the X3 record and the bank stations coded in fields three and four on the X1 record are used for this condition. By setting IEARA equal to ten the program will consider only flow confined by the levees, unless the water surface elevation is above the top of one or both of the levees; in this case flow area or areas outside the levee(s) will be included. If this option is employed and the water surface elevation is close to the top of a levee, it may not be possible to balance the assumed and computed water surface elevations due to the changing assumptions of flow area when just above and below the levee top. When this condition occurs, a note will be printed that states that the assumed and computed water surface elevations for the cross section cannot be balanced. A water surface elevation equal to the elevation which came closest to balancing will be adopted. It is then up to the program user to determine the appropriateness of the assumed water surface elevation and start the computation over again at that cross section if required.

It is important for the user to study carefully the flow pattern of the river where levees exist. If, for example, a levee were open at both ends and flow passed behind the levee without overtopping it, IEARA equals zero or blank should be used. Also, assumptions regarding effective flow areas may change with changes in flow magnitude. Where cross section elevations outside the levee are considerably lower than the channel bottom, it may be necessary to set IEARA equal to ten to confine the flow to the channel. For further information on this option see Appendix III, Section 2.3; Effective Area Option. The effective flow capabilities of the bridge and encroachment routines are described in the following paragraphs and in Appendices II and III, respectively.

4.5 Bridge Losses

Energy losses caused by structures such as bridges and culverts are computed in two parts. First, the losses due to expansion and contraction of the cross section on the upstream and downstream sides of the structure are computed in the standard step calculations. Secondly, the loss through the structure itself is computed by either the normal bridge, special bridge, or the culvert option.

The normal bridge method handles the cross section at the bridge just as it would any river cross section with the exception that the area of the bridge below the water surface is subtracted from the total area and the wetted perimeter is increased where the water surface elevation exceeds the low chord. The normal bridge method is particularly applicable for bridges without piers, bridges under high submergence, and for low flow through oval and arch culverts. Whenever flow crosses critical depth in a structure, the special bridge method should be used. The normal bridge method is automatically used by the computer, even though data was prepared for the special bridge method, for bridges without piers and under low flow control.

The special bridge method can be used for any bridge, but should be used for bridges with piers where low flow controls, for pressure flow, and whenever flow passes through critical depth when going through the structure. The special bridge method computes losses through the structure for low flow, weir flow and pressure flow or for any combination of these. Refer to Appendix III for a detailed explanation of HEC-2 bridge capabilities.

The culvert option is a new feature in Version 4.6. The special culvert method is similar to the special bridge method, except that the Federal Highway Administration (FHWA) standard equations for culvert hydraulics are used to compute losses through the structure. Refer to Appendix IV for a detailed explanation of the culvert capabilities.

4.6 Encroachment Options

Six methods of specifying encroachments for floodway studies can be used. Stations and elevations of the left and/or right encroachment (Method 1) can be specified for individual cross sections as desired. A floodway with a fixed top width (Method 2) can be specified which will be used for **all** cross sections until changed. The left and right encroachment stations are made equidistant from the centerline of the channel, which is halfway between the left and right banks stations. Encroachments can be specified by percentages (Method 3) which indicate the desired proportional reduction in the natural discharge carrying capacity of each cross section.

Encroachments can be determined so that each modified cross section will have the same discharge carrying capacity (at some higher elevation) as the natural cross section (Method 4). This higher elevation is specified as a fixed amount above the natural (e.g., 100-year) profile. The encroachments are determined so that an equal loss of conveyance (at higher elevation) occurs on each side of the channel, if possible.

Encroachment Method 5 is an optimization solution of encroachment Method 4. It determines water surfaces elevation differences between the natural and encroached conditions such that the target difference is obtained as near as possible.

Encroachment Method 6 is an optimization solution similar to Method 5; however, Method 6 optimizes on differences in the energy grade line elevations. Refer to Appendix II for a detailed explanation of Encroachment Methods 1 through 6.

4.7 Optional Friction Loss Equations

The friction loss between adjacent cross sections is computed as the product of the representative rate of friction loss (friction slope) and the weighted reach length. The program allows the user to select from the following previously defined (see page 7) friction loss equations:

- Average Conveyance
- Average Friction Slope
- Geometric Mean Friction Slope
- Harmonic Mean Friction Slope

Any of the above friction loss equations will produce satisfactory estimates provided that reach lengths are not too long. The advantage sought in alternative friction loss formulations is to be able to maximize reach lengths without sacrificing profile accuracy.

Equation 7, the average conveyance equation, is the friction loss formulation that has been standard in all HEC-2 source files since 1971. Previous HEC-2 source files utilized Equation 8, the average friction slope equation. Research [Reed/Wolfkill, 1976] indicates that Equation 8 is the most suitable for M1 profiles. (Suitability as indicated by Reed and Wolfkill is the most accurate determination of a known profile with the least number of cross sections.) Equation 9 is the standard friction loss formulation used in the U.S.G.S. step-backwater program WSPRO. Equation 10 has been shown by Reed and Wolfkill to be the most suitable for M2 profiles.

Another feature of this option is the capability of the program to select the most appropriate of the preceding four equations on a reach by reach basis depending on flow conditions (e.g., M1, S1, etc.) within the reach. It is anticipated that this capability may be incorporated into the program as a standard feature at sometime in the future. At present, however, the criteria shown in Table 2 below, do not select the best equation for friction loss analysis in reaches with significant lateral expansion, such as the reach below a contracted bridge opening.

The friction loss equation is controlled by variable IHLEQ on the J6 record as follows:

Value of IHLEQ (J6.1)	Friction Loss Equation Used
0	Average Conveyance (Equation 7)
1	Program selects equation based on flow conditions (Table 2).
2	Average Friction Slope (Equation 8)
3	Geometric Mean Friction Slope (Equation 9)
4	Harmonic Mean Friction Slope (Equation 10)

When using this option, it is informative to also use a J3 record to request printout of the variable IHLEQ to identify the equation used for each reach.

Table 2
Criteria Utilized to Select Friction Equation

Profile Type	Is friction slope at current cross section greater than friction slope at preceding cross section?	Equation Used
Subcritical (M1, S1)	Yes	8
Subcritical (M2)	No	10
Supercritical (S2)	Yes	8
Supercritical (M3,S3)	No	9

4.8 Channel Improvement

Cross section data may be modified automatically by the CHIMP option of the program to analyze improvements made to natural stream sections. The CHIMP option simulates channel improvement by trapezoidal excavation. This option is requested by the CI record which specifies the location of the centerline (CLSTA), the elevation of the improved invert (CELCH), a new channel reach length (XLCH), a new $\phi n'$ value (CNCH), the left side slope (XLSS), the right side slope (RSS) and a bottom width (BW). Up to five different bottom widths may be specified for the execution of a single run on each CI record. A maximum of three CI records may be used at each cross section. By using more than one CI record, a pilot channel can be defined. Figure 6 shows a sample application of the CHIMP option; note that improved section is modified only by excavation and not by fill. The old channel can be filled prior to the excavation by entering a negative channel bottom width.

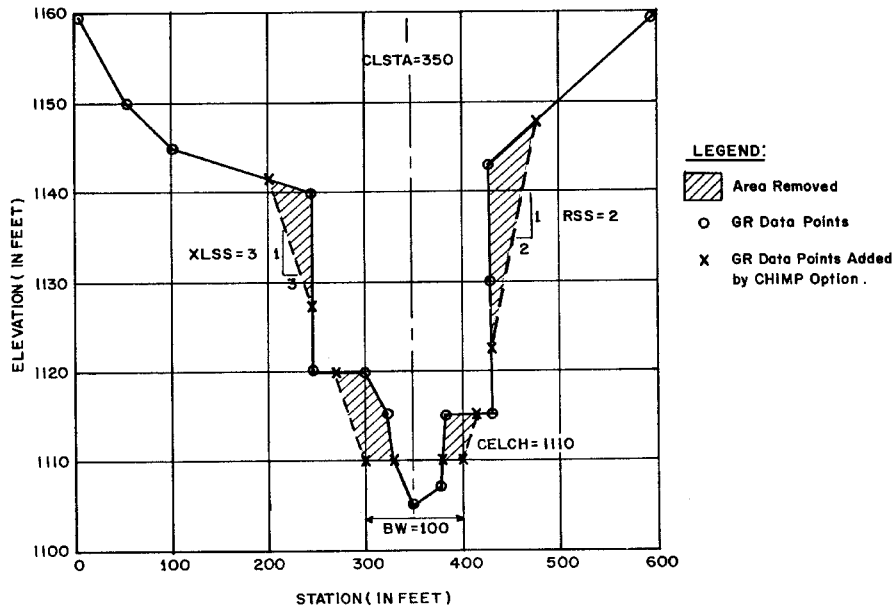


Figure 6
A Stream Cross Section Before and After CHIMP Modification

4.9 Interpolated Cross Sections

Occasionally it is necessary to insert cross sections between those specified by input, because the change in velocity head (ρHV) is too great to accurately determine the energy gradient. Additional cross sections may be coded manually or a program option may be requested to input interpolated cross sections. The option specified by the variable HVINS on the J1 record will insert up to three interpolated cross sections between two adjacent input cross sections. HVINS is the user specified maximum allowable change in velocity head between adjacent cross sections. When the program determines that ρHV between the current cross section and the previous cross section exceeds the user specified criterion, the program will automatically insert one to three cross sections (depending on the magnitude of $(\rho HV/HVINS) - 1$).

Interpolated cross sections are determined by raising or lowering and expanding or contracting the current cross section's shape. They are inserted uniformly between the two input cross sections. A proportion of the elevation difference determined from the minimum elevations of the two input cross sections is added (or subtracted) to the elevation coordinates (on GR records) of the current cross section.

The modification of the horizontal coordinates is a function of the ratio of the channel areas of the two input cross sections. The channel area (between bank stations) of the current cross section is determined with the depth of flow from the previous cross section.

Interpolated cross sections will be identified in the output by section numbers of 1.01, 1.02, and 1.03. The option will not add interpolated cross sections in the following cases: (1) if reach lengths between input cross sections are less than 50 feet, (2) if encroachments have been encountered in the run, or (3) if the previous cross section is a special bridge or special culvert cross section.

When there is a substantial difference in shape between the previous and current cross sections, interpolated cross sections generated automatically by the program may not be representative of the actual stream geometry. The user should always check the reasonableness of interpolated cross sections.

The number of interpolated cross sections added to each profile may vary with discharge; therefore, it is advisable not to request them for multiple profile runs because analysis should be made using exactly the same cross section data.

4.10 Tributary Stream Profiles

Subcritical profiles may be computed for tributary stream systems for single or multiple profiles in a single execution of the program. In general, data sets are arranged to compute profiles for the main stream (Reach 1) from the most downstream point to the study limit on the main stream. Data for a tributary stream (Reach 2), whose starting water surface elevation was determined when Reach 1 was calculated, follows the data for Reach 1. The first section number for Reach 2 is negative and refers to the section number in Reach 1 where the starting water surface elevation for Reach 2 was determined. When a negative section number (on the X1 record) is encountered the program will search its memory for the computed water surface elevation that corresponds to the negative section number. The program will then start computing the profile for Reach 2 with the previously determined water surface elevation.

Occasionally it may be desirable to calculate, in a single run, a profile for a stream system with a second order tributary (a tributary to a tributary). This may be accomplished if data for the tributary, with the tributary, is treated as a portion of the main stream. Then the main stream beyond the

junction of the two streams, is treated as a tributary. This is illustrated in the Figure 7; numbers 1 through 8 locate cross sections on the main stream, numbers 11 through 16 are cross sections on the first order tributary and numbers 21 through 22 are cross sections on the second order tributary.

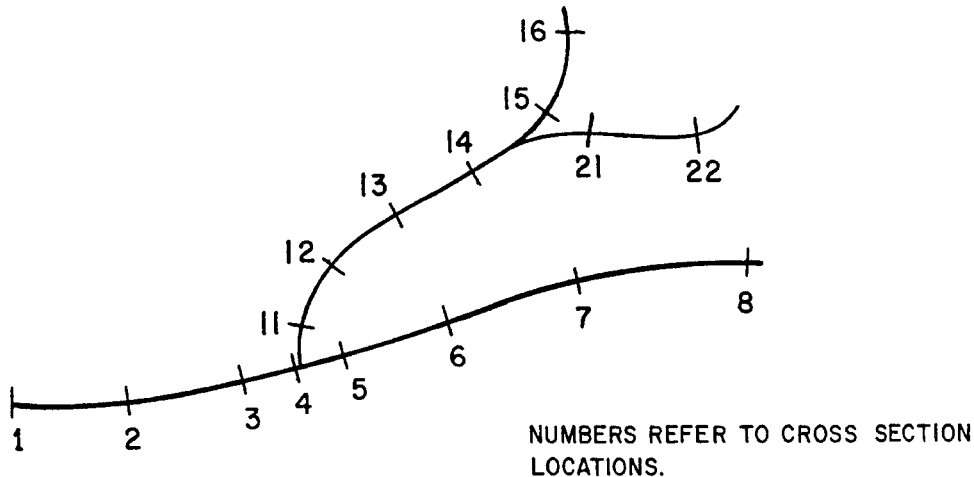


Figure 7
Second Order Stream System

The arrangement of cross section data (X1 and GR records) for the stream system in Figure 7 for a tributary analysis in a single execution of the program is as follows: 1, 2, 3, 4, 11, 12, 13, 14, 15, 16, -4, 5, 6, 7, 8, -14, 21, and 22.

Tributary stream profiles should not be calculated simultaneously with encroachment Methods 3 - 6 and the split flow option.

4.11 Solving for Manning's $\rho n'$

The program can be utilized in two ways to solve for Manning's $\rho n'$. HEC-2 can compute $\rho n'$ values automatically from high water data if the discharge, relative ratios of the $\rho n'$ values for the channel and overbanks and the water surface elevation at each cross section are known. The "best estimate" of $\rho n'$ for the first cross section must be entered on the NC record since it is not possible to compute an $\rho n'$ value for this cross section. The relative ratio of $\rho n'$ between channel and overbank is set by the first cross section and will be used for all subsequent cross sections unless another NC record is used to change this ratio. High water marks are used for the computed water surface elevation by setting variable NINV on the J1 record equal to one and entering the known water surface elevation as variable WSELK on the X2 record for each cross section. The average friction slope equation (see J6 record description) is utilized by the program to solve for $\rho n'$ values. If one of the other friction equations is to be utilized for profile analysis then the program-determined $\rho n'$ values should be verified using the appropriate friction equation. Because of the sensitivity of calculated results to slight errors in observed high water marks, a weighted $\rho n'$ (WTN) value is also calculated at each cross section. WTN is the length weighted channel $\rho n'$ calculated from the first cross section to the current cross section. When an adverse slope is encountered, computations restart using $\rho n'$ values from the previous section, but WTN computations continue.

Another method is to specify the discharge and an assumed set of $\rho n'$ values, and have the program compute a water surface profile which can be compared with the high water profile. For this method WSELK may be input on the X2 record, without entering the computations, so that it can be easily

compared with the computed water surface elevation on the output. The variable FN (J2.6 record) may be utilized to vary the assumed pn' values for multiple profile trials.

4.12 Storage-Outflow Data

The HEC-2 storage-outflow option can be used to generate HEC-1 [HEC, 1990] input data for hydrograph routing using the modified Puls method. The modified Puls method requires stream storage (acre feet or 1000's m^3) and corresponding discharges. Stream storages should be determined for a range of discharges which cover the anticipated range of flows for routed hydrographs.

The HEC-2 storage-outflow option will write the basic storage-outflow data in a file labeled TAPE7. The option provides HEC-1 KK records for each routing reach identified with the HEC-2 downstream and upstream section numbers. Corresponding storage and discharge values for each profile are written to HEC-1 SV and SQ records. HEC Training Document No. 30 describes the use of HEC-1 and HEC-2 for river routing.

It should be noted that the storage volumes computed by the program do not include any volumes blocked out as ineffective flow. If the reach for which storage-discharge data is being generated has ineffective flow areas, such as those normally located next to bridges, the storage data should be adjusted accordingly. In some cases, it may be convenient to use high roughness coefficients (pn' values) to block out these ineffective flow areas. This approach retains the storage volumes associated with these areas.

It is recommended that the HEC-2 interpolated cross section option not be used in conjunction with this option. Since the different number of cross sections for profiles in the same run could cause inconsistencies in incremented storage values. The J4 record controls use of this option.

4.13 Split Flow Option

The HEC-2 split flow option provides for the automatic determination of channel discharges and profiles in situations where flow is lost from the main channel. The split flow option can model flow over levees or weirs, overtopping of watershed divides, and flow splits created by diversion structures. This option allows the user to determine flow splits with weir, or normal depth analyses or by direct input of rating curves. Use of the split flow option is described in HEC Training Document 18, "Application of the HEC-2 Split Flow Option." The split flow option is compatible with all HEC-2 options except Encroachment Methods 3-6.

4.14 Ice Covered Streams

The HEC-2 ice cover analysis option provides the user with the capability to determine water surface profiles for streams with stationary floating ice cover. The option allows the user to input different ice thickness in the channel and left and right overbanks, a composite Manning's pn' value is determined by the Belokon-Sabaneev formula [USACE, 1982]. In addition to hydraulic analysis the option determines the potential for ice jams through the application of Pariset's ice stability function [Pariset/Gagon, 1966].

Chapter 5

Program Input

5.1 General

Fifty-three different records may be utilized to specify the many options and data input requirements for computer program HEC-2. These records are described in detail in Appendix VII. In general the various records may be classified into the following six categories: split flow, documentation, job control, change, cross section, and bridge/culvert data records. Records in each of the six categories are described briefly in the following sections.

5.2 Input Format

Data records are laid out in ten fields of eight columns each. One variable is used for each field except the first field, where the first two record columns are used for the record identification characters (i.e., T1, J1, GR). The format specification for each data record is A2, F6.0, 9F8.0. If decimal points are not indicated in the data, all numbers must be right justified within the field. Where the user desires to punch a decimal point it may appear anywhere within the field. All blank fields are read as zeroes. The program uses -1, 1, 10 and 15 to specify certain program options. Any number without a sign is considered positive.

Besides the fixed field format described above, the HEC-2 program also allows the use of free-format input. Free format input data is automatically converted to fixed format input and written to TAPE10. The TAPE10 file may be used for subsequent runs thereby providing faster executions and allowing more convenient review of input data.

5.3 Data Organization

Data sets for HEC-2 have a range encompassing, at a minimum, a single job (profile) with one cross section, to a run consisting of fourteen profiles with up to eight hundred cross sections. The minimum data set would require records T3, J1, NC, X1, GR, EJ, and ER. Multiple profile data sets using the same cross sections are constructed by successive sets of one or more title (T1 - T9) records, plus J1 and J2 records for each profile immediately following the EJ record. Table 3 illustrates the organization of data for a typical multiple profile run. Section 5.10 provides a sample problem illustrating basic input requirements.

5.4 Split Flow Records: **SF, JC, JP, TW, WS, WC, TN, NS, NG, TC, CS, CR, & EE**

These records are used to specify input data for the split flow analysis capability. All split flow data are entered ahead of all other HEC-2 data (AC, C, T1 etc.).

SF: Split Flow Record. The record is **required** when the split flow option is used. It must be the first record in the HEC-2 input file.

Table 3

**Typical HEC-2 Data Organization
(Multiple Profile Run)**

Record Type	Record Identification	Application
Split Flow	SF*, JC, JP, TW, WS, WC, TN, NS, NG, TC, CS,CT,EE*	All Profiles
Documentation	AC,C	All Profiles
Documentation Job Control	T1- T9 J1*, J2	First Profile
Job Control Change Cross Section	J3 - J6 NC*, NH, NV, KH, QT, ET, IC X1*, CI, X2, X3, X4, X5, GR*	All Profiles
Culvert (Special Culvert) Bridge (Special Bridge) Cross Section	SC* SB* X1*, X2*, X3, X4, X5, BT, GR	All Profiles
Change Cross Section	NC, NH, NV, KH, QT, ET, IC X1*, CI, X2, X3, X4, X5, GR	All Profiles
Cross Section Job Control	X1*, CI, X2, X3, X4, X5, GR EJ*	All Profiles
Documentation Job Control	T1 - T9 J1*, J2*	Second Profile
Documentation Job Control	T1 - T9 J1*, J2*	Last Profile
Job Control	ER*	Terminate Run

*Indicates required records

JC & JP: Optional Split Flow Job Records. These records may be used to input titles or initialize parameters for split flow analysis.

TW, WS, & WC: Weir Analysis Records. These records provide input for weir coefficients, elevation-station coordinates, and other data required for loss determination using the weir assumption.

TN, NS & NG: Normal Depth Analysis Records. These records provide input for normal depth parameters, elevation-station coordinates and other data required for loss determination using the normal depth assumption.

TC, CS, & CR: Rating Curve Analysis Record. These records provide input for analysis of split flows by input rating curves.

EE: End of Split Flow Analysis Record. This record is required to terminate a split flow analysis. The EE record is the last of the split flow records; it is input just ahead of the first regular HEC-2 data record (AC, C, T1 etc.).

5.5 Documentation Records: AC, C, T1 - T9

These records allow the user to document HEC-2 output to identify such items as stream name, study location, discharge frequency, data sources, or other pertinent information that will identify the unique character of a particular HEC-2 application.

AC: Archival Option. The optional AC record allows the user to document and create a computer readable record of input data and computed results in a compact form, labeled TAPE96. The archival file could be utilized with appropriate software to generate profile or cross section plots and to create new output tables using any of the 86 variables available for summary printout. Multiple AC records may be utilized to provide alphanumeric comments on the magnetic tape to document data sources, study assumptions or other pertinent information.

C: Comment Records. These optional records can be used to provide alphanumeric commentary in the data input list and in the standard cross section output. All the comments are provided at the head of the input data file. The comments are identified by a unique section number. The comments are printed with the associated section in program output.

T1 - T9: Title Records. One or more of these records should be used with each job (profile). Title information provided by these records is printed at the beginning of output for each profile. A portion of the T3 record is reserved for title information for summary printout tables and cross section and profile plots.

*** : Message in Input File Listing.** Messages, notes, explanation of data, etc., can be inserted anywhere in the input data set by placing the record identifier, *, in field zero of the line containing the information. The messages will be printed in the input listing, but will not be printed at any other location in the output. Blank lines may also be included in the input file and will be shown in the input listing, but will be disregarded by the program during execution.

5.6 Job Control Records: J1, JR, JS, J2 - J6, EJ & ER

These records control the processing of data, specify the level of printout, select various computation options, and terminate execution of the program. J1, JR, JS and J2 records apply only to a particular profile and must be input for each profile of a run. Job control records J3 through J6 pertain to all profiles in a run and are only input with job records for the first profile.

J1: Required Job Record. This job record is required for each profile to specify starting conditions, i.e., discharges, flow regime, water surface elevation, or energy slope. The J1 record also controls the printing of the data input list and options related to metric units, computer generated cross sections and the calculation of Manning's n from high water marks.

JR: Optional Job Record. This optional job record can be used to input a starting rating curve; up to 20 discharge-elevation values may be used.

JS: Optional Job Record. This optional job record may be used to specify assumed lost discharges for each reach defined in a split flow model. Normally this option is only used when the split flow option has experienced convergence problems.

J2: Required Job Record. This job record is **required** for each profile except the first of a multi-profile run. The use of the J2 record is optional for the first profile. This record controls the reading of data records, the plotting of cross sections and profiles, modification of Manning's pn' , the calculation of critical depth and simulates channel modification by trapezoidal excavation. The J2 record also controls the trace option, and requests flow distribution data.

J3: Optional Job Record. This job record is used on the first profile to select variables for summary printout. The user may select from a list of 86 variables to define summary output tables. The user also may choose from seven pre-defined tables to summarize data for bridges, encroachments, channel improvements, and floodways.

J4: Optional Job Record. This job record is used on the first profile to create a file (TAPE7) with modified-Puls routing data in the format required by computer program HEC-1.

J5: Optional Record. This job record is used to provide various levels of suppression of the cross section data and summary tables. This record is used with job records for the first profile.

J6: Optional Job Record. This job record is used for the following: to select various equations for computation of friction loss; to provide for transfer of control of disk/tape output units to system control records; to control subdivision of the channel for hydraulic computations; and, the labeling of profile plots.

EJ: End of Job Record. This **required** job control record follows data for the last cross section to be read. It serves to terminate the reading of data records. Only one EJ record is required for both **single** or multiple profile runs.

ER: End of Run Record. This **required** job control record terminates the execution of the program. The ER record follows the EJ record of a single profile run or follows the last J2 record of a multiple profile run.

5.7 Change Records: IC, NC, NH, NV, KH, QT, ET & CI

These records provide options to initialize and change values related to ice analysis, Manning's pn' , equivalent roughness pk' , discharge, cross section modification by encroachment, and channel improvement options. When initial values are changed they remain changed for all subsequent cross sections until another change record is encountered. Change records, IC - ET become effective at the cross section (X1 record) immediately following the change records. The CI record is input in the data set following the X1 record where the channel improvement option is to be initialized or changed.

IC: Ice Analysis Data. This optional record is used to specify ice thicknesses, pn' values, and specific gravity for the ice analysis option.

NC: Manning's pn' Description. This record is **required** to initialize pn' values and transition (shock) loss coefficients prior to data for the first cross section. Subsequent NC records may be utilized to permanently change values at any cross section within the data set.

NH: Horizontal Description of Manning's pn' . This optional record can be utilized to specify up to twenty pn' values that vary with horizontal distance across the cross section. Normally NH records apply to a single cross section and pn' values should be redefined by either another set of NH records or by an NC record for subsequent cross sections.

NV: Vertical Description of Manning's pn' . This optional record may be used to specify **channel pn'** values that vary with elevation. Like the NH record, NV records normally apply to a single cross section. Elevation-roughness data should encompass the full range of flow elevations expected (e.g., invert to maximum ground elevation).

KH: Equivalent Roughness pk' . This optional records can be used to specify up to twenty pk' values that vary with horizontal distance across a cross section. Similar in application to the NH record.

QT: Discharge Table. This optional record allows the user to input a table of up to 19 discharges for multiple profile runs. Subsequent QT records may be used to change discharge values at any cross section. The discharge value to be used for a particular run is specified by a variable on the J1 record.

ET: Encroachment Table. This optional record allows the user to input a table of up to nine encroachment specifications for multiple profile runs. The encroachment specification to be utilized for a particular profile corresponds with the field of the QT record selected by the J1 record.

CI: Optional Channel Improvement Record. This optional record allows a user to simulate the improvement of channels by excavation. Invert elevations, side slopes, pn' values and bottom widths may be specified by this option. Up to five different bottom widths may be specified for analysis during the execution of a multiple profile run. Up to three CI records may be used at a cross section. By using more than one CI record a pilot channel may be modeled.

5.8 Cross Section Records: X1, RC, X2 - X5 & GR

These records are the basic data that describe the geometric properties of a stream. Each set of X1 through X5 and GR records defines a single stream cross section. X1 and GR are required records that provide the basic geometric representation for a reach of stream. X2 through X5 records provide a series of options related to bridges, effective flow areas, additional geometric data, and high water elevations.

X1: Required Cross Section Record. An X1 record is required to input data for each cross section. Values on the X1 indicate the number of GR data points to be read on the following GR records and locate the cross section by indicating the distance to the immediate downstream cross section. Other values input on the X1 record locate the bank stations, raise or lower elevations on the GR records, allow skewing (expansion or contraction of the GR data, and request a line printer plot of the cross section data).

RC: Optional Rating Curve Record. This optional record provides the capability to input a rating curve. With this option the water surface elevation at the cross section where the option is employed is not determined by standard step computations but is based upon the input rating curve.

X2: Optional Cross Section Record. This record provides an array of options related to discharge, bridges, program traces, and calculation of Manning's pn' . An X2 record is required for each application of the special bridge or culvert option.

X3: Optional Cross Section Record. The X3 record provides various options to remove portions of the GR data from flow calculations. The removed or blocked out areas are referred to as ineffective flow areas. The X3 record allows the specification of such ineffective flow areas as: areas behind levees prior to overtopping; areas below a specified sediment elevation; filled areas; and areas behind specified encroachment stations.

X4: Optional Cross Section Record. This record allows additional ground points to be added to the elevation station data contained on the GR records. This option is useful when modifying GR data repeated from the previous cross section or when the effects of proposed obstructions such as levees, piers or buildings are to be examined.

X5: Optional Cross Section Record. This record is used to input water surface elevations at a cross section. Elevations or increments of elevation to be added to the water surface elevation of the previous cross section may be specified. The elevation specified for a particular profile corresponds with the field of the QT record selected by the J1 record.

GR: Ground Profile Record. This record inputs data that represents a profile of a stream taken perpendicular to the direction of flow. Up to one hundred pairs of elevation-station data may be utilized to describe the ground profile.

5.9 Bridge and Culvert Records: SB, SC & BT

These records are utilized to input data for bridge analysis by the normal bridge, the special bridge, and special culvert methods. X2 and X3 records are also used for bridge and culvert analysis.

SB: Special Bridge Record. This record is required to input coefficients for pier shape, orifice flow and weir flow for use by the special bridge method. Geometric properties of the bridge such as weir length, width of piers, and net area of the opening of the bridge can also be input on the SB record.

SC: Special Culvert Option. This record is required to input coefficients for entrance, exit, roughness, and weir flow. Geometric data such as elevation, shape, size and number of culverts are also input on SC records.

BT: Bridge Profile Record. The BT record is used to input bridge geometry for both normal bridge, special bridge, and culvert analysis. For analysis by the normal bridge method, BT records are utilized to describe the flow areas of the cross section that are blocked out by the bridge piers, bridge deck and approach fill. For the special bridge and special culvert methods, the BT records are used to define the weir profile.

5.10 Sample Problem Showing Basic Input

The following example illustrates the basic input required for most water surface profile computations. The output for this example is shown in Chapter 6. Chapter 4 describes optional capabilities which can be developed, with added input to a basic model like this example. Appendix I provides sample HEC-2 applications of optional program features.

The example data will compute two subcritical water surface profiles starting with a known water surface elevation. The discharges and starting elevations are shown in the profile plot, and the reach lengths are shown in the plan plot. Manning's n values are shown with the cross section plots. Contraction and expansion coefficients are 0.1 and 0.3, respectively.

Three cross sections are used. The first section illustrates the basic floodplain section, with three flow elements. The second section illustrates the cross section repeat capability. Prior to the third section the discharge is redefined and the Manning's n values are changed by varying them based on horizontal stations. The third section also illustrates the effective area option input to ignore the low overbank area until the elevation of the bank station is exceeded.

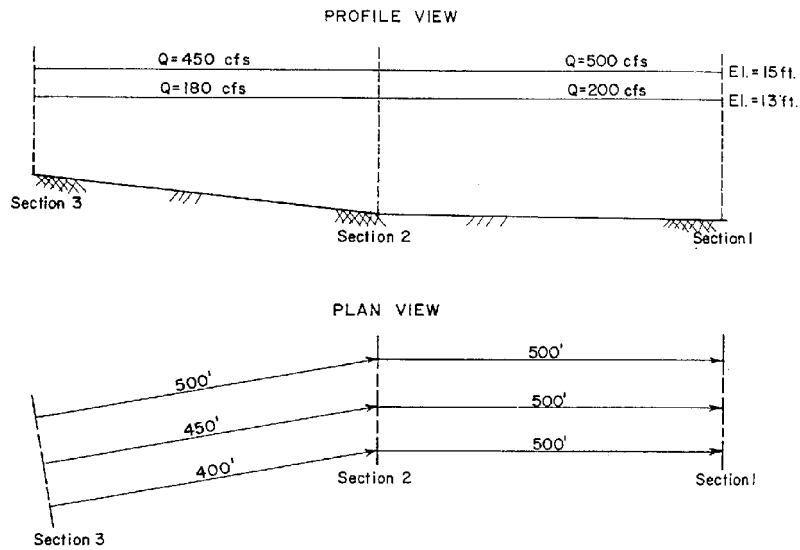


Figure 8
Sample Problem Profile and Plan Views

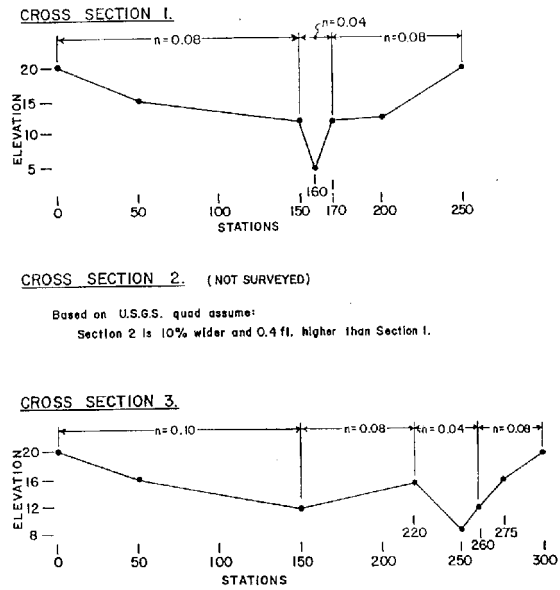


Figure 9
Sample Problem Cross Sections

Basic Input Example

```
T1  SAMPLE PROBLEM SHOWING BASIC INPUT
T2  First Profile, Q = 200 cfs  WSEL = 13 ft.
T3  Sample Creek
T4  Use as many Title records (T1-T9) as necessary to define the job.

*   Profile 1 reading field 2 of QT, starting at 13 ft. elevation.
*   Zero values indicate subcritical profile starting with known elevation.
J1      2          0          0          13

*   Manning's 'n' = .08 overbanks & .04 channel
*   Contraction coef. 0.1 and Expansion coef. 0.3
NC  .08      .08      .04      .1      .3

*   Discharge table with 2 flows: 200 cfs and 500 cfs
QT      2      200      500

*   Cross section 1 with 7 GR stations, and bank stations at 150 and 170.
*   Reach lengths to downstream section are not required for first section.
X1      1      7      150      170
GR      20      0      15      50      12      150      5      160      12      170
GR      15      200      20      250

*   Repeat cross section, 500 ft. reach lengths, expand 10%, raise 0.4 ft.
X1      2          500      500      500      1.1      .4

*   Revise Manning's 'n' values based on stations at Section 3
NH      4      .10      150      .08      220      .04      260      .08      300

*   Revise the discharges, starting with the next section (SECNO 3)
QT      2      180      450

*   Reach lengths: 500' left, 400' right, & 450' channel
X1      3      8      220      260      500      400      450

*   Effective area option to exclude low overbank area until flow exceeds
*   the bank elevation.
X3      10
GR      20      0      16      50      12      150      16      220      8      250
GR      12      260      16      275      20      300

*   EJ ends input of reach model.  Following data define added profiles.
EJ
T1  Second profile, only one title required

*   Read field 3 of QT records and start at elevation 15 ft.
J1      3          15

*   J2 record required subsequent profiles to define profile number.
J2      2
*   ER record ends the run.
ER
```

Chapter 6

Program Output

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 Applications 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*	J3, J5
Profile Plots*	J2.3
Cross Section Plots	J2.2, X1.10
Archival Tape (TAPE96)	AC
Storage-Outflow (TAPE7)	J4
Fixed Format Input (TAPE10)	FR
Modified Data File (TAPE16)	J2.8

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

The following output is from the Basic Input Example, presented in Chapter 5, page 34. The default output sequence is: (1) input listing for the first profile, (2) detailed output for the first profile, (3) printer plot for first profile, (4) input for the second profile, (5) output for the second profile, etc., and then (6) summary printout and error messages. There are no printer profile plots for the example because the program requires five, or more, cross sections before the profile plot is produced. The sections that follow provide a description of the default and optional output.

bbbbbbbbbbbbbbbbbbbb

* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 13:53:59 *

* 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
XXXXXXXX XXXX X XXXXX XXXXX
X X X X X X
X X X X X X
X X XXXXXXX XXXXX XXXXXXX

```

END OF BANNER

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06FEB91 13:53:59

PAGE 1

THIS RUN EXECUTED 06FEB91 13:53:59

HEC2 WATER SURFACE PROFILES
Version 4.6.0; February 1991

T1 SAMPLE PROBLEM SHOWING BASIC INPUT
T2 First Profile, Q = 200 cfs WSEL = 13 ft.
T3 Sample Creek
T4 Use as many Title records (T1-T9) as necessary to define the job.

Profile 1 reading field 2 of QT, starting at 13 ft. elevation.
Zero values indicate subcritical profile starting with known elevation.

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		2		0	0				13	
	Manning's 'n' = .08 overbanks & .04 channel Contraction coef. 0.1 and Expansion coef. 0.3									
NC	.08	.08	.04	.1	.3					
	Discharge table with 2 flows: 200 cfs and 500 cfs									
QT	2	200	500							
	Cross section 1 with 7 GR stations, and bank stations at 150 and 170. Reach lengths to downstream section are not required for first section.									
X1	1	7	150	170						
GR	20	0	15	50	12	150	5	160	12	170
GR	15	200	20	250						
	Repeat cross section, 500 ft. reach lengths, expand 10%, raise 0.4 ft.									
X1	2				500	500	500	1.1	.4	
	Revise Manning's 'n' values based on stations at Section 3									
NH	4	.10	150	.08	220	.04	260	.08	300	
	Revise the discharges, starting with the next section (SECNO 3)									
QT	2	180	450							
	Reach lengths: 500' left, 400' right, & 450' channel									
X1	3	8	220	260	500	400	450			
	Effective area option to exclude low overbank area until flow exceeds the bank elevation.									
X3	10									
GR	20	0	16	50	12	150	16	220	8	250
GR	12	260	16	275	20	300				

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PAGE 2

EJ ends input of reach model. Following data define added profiles.

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SECNO	DEPTH	CWSEL	CRISW	WSELK	EG	HV	HL	OLOSS	L-BANK	ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK	ELEV
TIME	VLOB	VCH	VROB	XLN	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	8.00	13.00	.00	13.00	13.07	.07	.00	.00	12.00
200.	5.	194.	1.	17.	90.	5.	0.	0.	12.00
.00	.28	2.15	.28	.080	.040	.080	.000	5.00	116.67
.000590	0.	0.	0.	0	0	0	.00	63.33	180.00

*SECNO 2.000

2.000	7.88	13.28	.00	.00	13.35	.06	.28	.00	12.40
200.	4.	195.	1.	15.	97.	4.	1.	1.	12.40
.07	.25	2.02	.25	.080	.040	.080	.000	5.40	132.38
.000517	500.	500.	500.	1	0	0	.00	64.40	196.79

1490 NH CARD USED

*SECNO 3.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 16.00 ELREA= 12.00

3.000	5.55	13.55	.00	.00	13.61	.06	.26	.00	16.00
180.	0.	178.	2.	0.	93.	4.	2.	1.	12.00
.14	.00	1.92	.39	.000	.040	.080	.000	8.00	229.22
.000649	500.	450.	400.	1	0	0	.00	36.56	265.78

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T1 Second profile, only one title required

Read field 3 of QT records and start at elevation 15 ft.

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		3							15	

J2 record required for subsequent profiles to define profile number.

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

ER record ends the run.

bbbbbbbbbbbbbbbbbbbb

SECNO	DEPTH	CWSEL	CRISW	WSELK	EG	HV	HL	OLOSS	L-BANK	ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK	ELEV
TIME	VLOB	VCH	VROB	XLN	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	10.00	15.00	.00	15.00	15.10	.10	.00	.00	12.00
500.	94.	378.	28.	150.	130.	45.	0.	0.	12.00
.00	.62	2.91	.62	.080	.040	.080	.000	5.00	50.00
.000660	0.	0.	0.	0	0	0	.00	150.00	200.00

*SECNO 2.000

2.000	9.92	15.32	.00	.00	15.41	.09	.30	.00	12.40
500.	89.	384.	27.	157.	141.	47.	4.	2.	12.40
.06	.57	2.72	.57	.080	.040	.080	.000	5.40	57.82
.000563	500.	500.	500.	1	0	0	.00	161.33	219.15

1490 NH CARD USED

*SECNO 3.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 16.00 ELREA= 12.00

3.000	7.60	15.60	.00	.00	15.70	.10	.29	.00	16.00
450.	0.	432.	18.	0.	164.	24.	7.	3.	12.00
.11	.00	2.63	.75	.000	.040	.080	.000	8.00	221.53
.000772	500.	450.	400.	0	0	0	.00	51.94	273.47

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 HEC2 WATER SURFACE PROFILES
 Version 4.6.0; February 1991

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

Sample Creek
 SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRWS	EG	10*KS	VCH	AREA
.01K												
	1.000	.00	.00	.00	5.00	200.00	13.00	.00	13.07	5.90	2.15	111.67
82.33	1.000	.00	.00	.00	5.00	500.00	15.00	.00	15.10	6.60	2.91	325.00
194.70												
	2.000	500.00	.00	.00	5.40	200.00	13.28	.00	13.35	5.17	2.02	115.43
87.92	2.000	500.00	.00	.00	5.40	500.00	15.32	.00	15.41	5.63	2.72	344.95
210.64												
	3.000	450.00	.00	.00	8.00	180.00	13.55	.00	13.61	6.49	1.92	97.46
70.64	3.000	450.00	.00	.00	8.00	450.00	15.60	.00	15.70	7.72	2.63	188.18
161.95												

bbbbbbbbbbbbbbbbbbbb

Sample Creek
 SUMMARY PRINTOUT TABLE 150

	SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
	1.000	200.00	13.00	.00	.00	.00	63.33	.00
	1.000	500.00	15.00	2.00	.00	.00	150.00	.00
	2.000	200.00	13.28	.00	.28	.00	64.40	500.00
	2.000	500.00	15.32	2.03	.32	.00	161.33	500.00
	3.000	180.00	13.55	.00	.26	.00	36.56	450.00
	3.000	450.00	15.60	2.05	.28	.00	51.94	450.00

bbbbbbbbbbbbbbbbbbbb

SUMMARY OF ERRORS AND SPECIAL NOTES

bbbbbbbbbbbbbbbbbbbb

6.2 Program Identification Block

Each execution of the program will print a program identification block in the upper left corner of the first page of output. Information contained in the block includes program version number and date.

6.3 Job Control Data

The first lines of output following the program identification block are title records (T1 - T9) for the first profile. Following the title information, input data on the J1 record and optional job records J2 through J6 (if used) are printed. Subsequent sets of T1 through J2 data are printed prior to execution of the respective profiles.

6.4 Input Data

A listing of the input data (records NC through EJ) is printed following the job control data for the first profile. This listing may be suppressed by coding a minus ten for variable ICHECK(J1.1) on the J1 record for the first profile.

6.5 Comments and Remarks

Comments to document data sources, study assumptions, or to label specific cross sections may be input with the data set. These comments will appear immediately ahead of the cross section they refer to in the input data listing and the cross section data. Remarks (*) only appear in the input listing in the same sequence they occupy in the input file.

6.6 Output Labels

In order to assist users with interactive terminals, unique labels are generated by the program at the beginning of each profile (e.g., *PROF 2) and at each cross section (e.g., *SECNO 21.100). With commonly available system text editors, these labels allow easy location of calculated data within the cross section data printout. The J5 record can be utilized to suppress all or portions of the cross section data printout to further facilitate the use of the program on interactive terminals.

6.7 Cross Section Data

Computed results are printed for each cross section following the data input list for the first profile and following the job control data for subsequent profiles. Headings listing the names of each of the 40 variables arranged in the same spatial order are printed periodically throughout the data. Appendix VI contains definitions of these variables.

```

02/06/91      13:53:59                                     PAGE
3

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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	XLN	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	8.00	13.00	.00	13.00	13.07	.07	.00	.00	12.00	
.200	5.	194.	1.	17.	90.	5.	0.	0.	12.00	
.00	.28	2.15	.28	.080	.040	.080	.000	5.00	116.67	
.000590	0.	0.	0.	0	0	0	.00	63.33	180.00	

Figure 10
Cross Section Output Display

6.8 Flow Distribution

The cross section data printout shows the distribution of flow in three subdivisions of the cross section: left overbank, channel and right overbank. Additional output showing the distribution of flow in overbanks of

the cross section may be requested by the user. When the flow distribution option is requested, the program prints out the lateral distribution of area, velocity, percent of total discharge, and depth for up to thirteen subdivisions of the cross section. Manning's bn' values are also shown if KH data is used. This program output is requested for all cross sections of a profile by setting variable ITRACE on the J2 record equal to fifteen. Flow distribution for a single cross section may be requested by setting ITRACE on the X2 record equal to fifteen. For additional information see Appendix II.

FLOW DISTRIBUTION FOR SECNO= 3.00 CWSEL= 723.00									
STA=	187.	260.	370.	500.	530.	600.	850.	858.	
PER Q=	.1	4.1	41.8	36.2	12.2	5.5	.0		
AREA=	36.7	291.5	1263.5	471.0	492.0	500.0	4.2		
VEL=	.2	1.0	2.3	5.4	1.7	.8	.2		
DEPTH=	.5	2.6	9.7	15.7	7.0	2.0	.5		
"n"=	.1003	.0475	.0485	.0288	.0513	.0508	.1009		

Figure 11
Flow Distribution Output Display

6.9 Special Notes

Special notes and error messages are printed at various locations in the cross section data to inform the user of various assumptions or options that have been used during computations. These notes should be carefully reviewed to assure an accurate profile. Special notes are described in Appendix V.

6.10 Program Trace

When modifying HEC-2 or installing it on different computer systems, programmers sometimes find it useful to print out important variables as they are computed to aid in checking, debugging and understanding the program. Two levels of program trace are available for this purpose. The minor trace prints values of variables, for each trial, used in the following computations:

- (1) Interpolated cross sections
- (2) Manning's bn' from known water surface elevations
- (3) Computed water surface elevation
- (4) Weir flow
- (5) Critical water surface elevation

The major trace, in addition to data printed for the minor trace, prints values of variables used in the computation of the hydraulic properties of each subarea of a cross section.

ITRACE on the J2 and X2 records is used to specify the desired level of trace. The minor trace may be called separately, ITRACE = 1, or in combination with the major trace, ITRACE = 10. If all cross sections are to be traced, the J2 record is used. If only individual cross sections are to be traced, the X2 records are used. The trace option can generate very large output files, for this reason this option is typically not used in normal applications.

6.11 Profile Plots

Profile plots are printed following the cross section data for jobs having five or more cross sections. These plots show the location of cross sections and elevations of critical depth, water surface, energy

grade line, channel invert, left and right bank elevations, and the lowest of the end stations of the cross section. The vertical and horizontal scales of a profile may be specified by J2 record variables PRFVS and XSECH, respectively. If these variables are omitted the program will automatically determine the appropriate scale values.

6.12 Cross Section Plots

Printer plots of any or all of the stream cross sections to any scale may be requested by using the J2 and X1 records. If all cross sections are to be plotted, set variable IPLOT on the J2.2 record equal to one or ten. If only certain cross sections are desired, IPLOT on the J2.2 record should be left blank and variable IPLOT on the X1.10 record should be set equal to one or ten for the cross section to be plotted. Vertical and horizontal scales of the plot may be specified constant for all cross sections in the job using variables XSECV (J2.4) and XSECH (J2.5). If the scale is not specified, the largest scale which is a multiple of one, two or five that produces three pages of output or less will be used. For some deep river cross sections, flow may occupy only a small portion of the total cross section. In this case it may be desirable to enlarge the scale and to print only the cross section points up to the water surface elevation. This may be done by using a value of ten for IPLOT instead of one.

6.13 Summary Data

Tables may be requested to summarize data in a tabular form for either single or multiple profile runs. The J3 record may be used to specify user- and pre-defined tables. User-defined tables of one to 13 variables may be specified from a list of 86 variables. User-defined tables may be specified to permit summary output that will conveniently print on 72 or 80 column terminals. Seven pre-defined tables are available to summarize data for bridges, culverts, encroachments, channel improvements, and flood hazard zones.

6.14 TAPE16 Scratch File for Writing Modified Data Input

Information reflecting changes to cross-sectional data and reach lengths resulting from channel modification and other program options can be written to an optional scratch file named TAPE16. This file can be used as a portion of the input file in subsequent runs, providing additional versatility in the use of program options. With this new file, encroachments can be analyzed and NH or KH records can be used to define roughness, thus avoiding some of the conflicts that would ordinarily occur between these options and the channel improvement option.

This option is implemented by entering any negative number in Field 8 of the J2 record. A TAPE16 file will be written containing information for each cross section of each profile. An example of an input file utilizing this feature and the corresponding TAPE16 file created by this input file is shown in Figures 12 and 13 respectively.

6.15 Archive File

The archive file TAPE96, written with the use of the AC record, provides 86 output variables for each section in standard numeric form. Note that this file contains all of the information found in the TAPE95 file in a formatted text form rather than a binary form. This feature allows other programs to easily access this information.

```

T1      Channel improvement option (CHIMP) and creation of TAPE16
T2      bottom width BW = 100
T3      CHIMP CREEK
J1      12                                     168.1

*      -7 in 8th field will cause TAPE16 file to be created

J2      -1                                     -1                                     -7
NC      .120      .120      .0377      0.1      0.3
QT      11      450      600      900      1200      1500      2300      5000      6700      9400
QT 15000      25000

*      Elevations of all stations will be decreased by 0.85 in TAPE16 for xsec 1

X1      1.05      38      18150      18448                                     1      -.85
GR 200.0      12000      180.0      12200      170.0      13000      170.0      13200      170.0      13500
GR 170.0      14000      170.0      14400      165.0      14500      170.0      14600      170.0      15950
GR 165.0      18149      165.0      18150      165.0      18151      165.0      18168      160.0      18179
GR 149.0      18188      155.0      18201      158.0      18209      159.8      18229      159.9      18234
GR 159.9      18237      160.0      18255      157.5      18259      157.0      18260      145.0      18282
GR 144.8      18308      144.8      18309      145.0      18310      145.0      18324      150.0      18341
GR 155.0      18353      162.0      18364      163.0      18429      164.0      18447      167.0      18448
GR 172.8      18449      180.0      19250      200.0      20600

*      Elevations will be increased by 3.14 compared to sec 1.05 of TAPE16

X1      1.55                                     1200      1300      3684                                     3.14

*      Channel improvement will change sec 1.55 information written to TAPE16

CI 18300      147.09      0.025      3      3      10      100      300      400

*      Elevations will be increased by 1.7 compared to sec 1.55 of TAPE16

X1      1.82                                     1400      1250      1450                                     1.7

*      Channel improvement shut off at sec 1.82

CI      .01      .01      .01      .01
EJ
ER

```

Figure 12
Input File Used to Create TAPE16 File

```

NC .1200      .12000      .03700      .10000      .30000
QT 11.      450.      600.      900.      1200.      1500.      2300.      5000.      6700.      9400.
QT15000.      25000.      0.      0.      0.      0.      0.      0.      0.      0.
X1 1.050      38      18150.0      18448.0      0.      0.      0.      0.
GR 199.1      12000.0      179.15      12200.0      169.15      13000.0      169.15      13200.0      169.15      13500.0
GR 169.1      14000.0      169.15      14400.0      164.15      14500.0      169.15      14600.0      169.15      15950.0
GR 164.1      18149.0      164.15      18150.0      164.15      18151.0      164.15      18168.0      159.15      18179.0
GR 148.1      18188.0      154.15      18201.0      157.15      18209.0      158.95      18229.0      159.05      18234.0
GR 159.0      18237.0      159.15      18255.0      156.65      18259.0      156.15      18260.0      144.15      18282.0
GR 143.9      18308.0      143.95      18309.0      144.15      18310.0      144.15      18324.0      149.15      18341.0
GR 154.1      18353.0      161.15      18364.0      162.15      18429.0      163.15      18447.0      166.15      18448.0
GR 171.9      18449.0      179.15      19250.0      199.15      20600.0
NC .1200      .12000      .02500      .10000      .30000
X1 1.550      43      18150.0      18448.0      1200.0      1300.0      3684.0
GR 202.3      12000.0      182.29      12200.0      172.29      13000.0      172.29      13200.0      172.29      13500.0
GR 172.3      14000.0      172.29      14400.0      167.29      14500.0      172.29      14600.0      172.29      15950.0
GR 167.3      18149.0      167.29      18150.0      167.29      18151.0      167.29      18168.0      162.29      18179.0
GR 151.3      18188.0      157.29      18201.0      160.29      18209.0      160.39      18210.1      154.09      18229.0
GR 152.4      18234.0      151.42      18237.0      147.09      18250.0      147.09      18255.0      147.09      18259.0
GR 147.1      18260.0      147.09      18282.0      147.09      18308.0      147.09      18308.0      147.09      18309.0
GR 147.1      18310.0      147.09      18324.0      147.09      18341.0      147.09      18350.0      148.09      18353.0
GR 151.8      18364.0      164.90      18403.4      165.29      18429.0      166.29      18447.0      169.29      18448.0
GR 175.1      18449.0      182.29      19250.0      202.29      20600.0
NC .1200      .12000      .02500      .10000      .30000
X1 1.820      38      18150.0      18448.0      1400.0      1250.0      1450.0
GR 204.0      12000.0      183.99      12200.0      173.99      13000.0      173.99      13200.0      173.99      13500.0
GR 174.0      14000.0      173.99      14400.0      168.99      14500.0      173.99      14600.0      173.99      15950.0
GR 169.0      18149.0      168.99      18150.0      168.99      18151.0      168.99      18168.0      163.99      18179.0
GR 153.0      18188.0      158.99      18201.0      161.99      18209.0      163.79      18229.0      163.89      18234.0
GR 163.9      18237.0      163.99      18255.0      161.49      18259.0      160.99      18260.0      148.99      18282.0
GR 148.8      18308.0      148.79      18309.0      148.99      18310.0      148.99      18324.0      153.99      18341.0
GR 159.0      18353.0      165.99      18364.0      166.99      18429.0      167.99      18447.0      170.99      18448.0
GR 176.8      18449.0      183.99      19250.0      203.99      20600.0
EJ

```

Figure 13
Example of TAPE16 File

An archival file can be used, with appropriate software, as a basis for further analysis. For example, additional profile plots can be generated; new output tables can be produced using any of the variables available for summary printout (J3 record); and cross section data can be verified. This may be particularly valuable when analysis is required to determine encroachment or floodways within the study area.

The Archival tape is structured as follows:

- Section A. Input data records
- Section B. Header block showing program version
- Section C. Number of output variables and cross sections
- Section D. Alphanumeric names of output variables
- Section E. Output variables for each cross section

THIS IS AN ARCHIVAL RUN ALL DATA AND RESULTS ARE SAVED ON UNIT 96

This indicates the unit number (in this example Unit 96) on which the file is written. It is the user's responsibility to provide the required job control statements to insure that the file written on Unit 96 will appear on magnetic tape or otherwise be saved by the system after execution.

The information written to the tape is formatted 130 character lines. This will allow the tape to be listed directly on a line printer. It should be noted that the file will contain characters in column one that are not intended as line printer carriage control. Thus for direct tape listing, the lines should be shifted one column.

6.16 Storage-Outflow

Storage-discharge data may be written to TAPE7 in a format for modified Puls routing using program HEC-1 . The J4 record defines the downstream and upstream section numbers for each routing reach. Training Document No. 30 describes the combined application of HEC-1 and HEC-2 for storage routing.

Chapter 7

References

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

Chow, Ven Te, *Open-Channel Hydraulics*, 1959.

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

Hydrologic Engineering Center, *HEC-1, Flood Hydrograph Package User's Manual*, September 1990.

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, 1966.

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.

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

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

U.S. Army Corps of Engineers, *Hydraulic Design of Flood Control Channels*, EM 1110-2-1601, 1970.

Chapter 8

Supplemental Material

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

- a. Eichert, Bill S., "Survey of Programs for Water Surface Profiles," HEC Technical Paper No. 11, 1968. (Published in the Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY 2, February 1970.)
- b. Eichert, Bill S., "Computer Determination of Flow Through Bridges," HEC Technical Paper No. 20, 1970. (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. Eichert, Bill S., "Critical Water Surface by Minimum Specific Energy Using the Parabolic Method," HEC Technical Paper No. 69, 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.

Appendix I

Sample Applications of HEC-2

Appendix I

Table of Contents

The following examples illustrate many of the input and output options available in HEC-2. These examples are contrived to show program features and may not represent realistic models of the actual streams.

Example Number	Sample HEC-2 Application	Page
1	Single Profile Run with Added Cross-Section Input Options and Several Output Options	I-1
2	Multiple Profile Run with Tributary Profiles, Normal and Special Bridge Input. Comments are Used to Annotate Input Options	I-9
3	Multiple Profile Run with Channel Improvement (CHIMP) Option	I-16
4	Multiple Profile Floodway with Encroachment Methods 1 through 5. Output is Limited to Flow Distributions and Floodway Summary Tables	I-20
5	Single Profile run with the Split Flow Option	I-28

Note: There are additional bridge examples in Appendix III and culvert examples in Appendix IV.

Example No. 1

Input

```

T1      Example 1: Single profile subcritical run
T2      Output options include: User design summary, flow distribution, suppress
T2      printer plot of profile, and cross-section printer plot.
T3      Bear Creek
T4      Input options include: Effective area option, encroachment method 1,
T5      add points, repeat cross section, and change discharge.
*       Starting with energy slope and estimated water surface elevation
J1      0.0092                7800 1756.02
*       Suppress profile printer plot (J2.3 = -1)
J2      -1
*       User designed output with variables and defined table (150)
J3      38      1      3      57      68      150

NC      .1      .1      .04      .1      .3

*       Use effective area option to only consider overbank when channel banks are
*       exceeded (X3.1 = 10).
*       Use left encroachment to block low overbank area beyond station 183 (X3.4&5)
X1      1.0      60      767      815      0      0      0
X3      10      183      1757
GR1767.0      0      1765.4      23      1763.5      49      1762.0      69      1759.1      87
GR1758.1      103      1756.9      113      1756.9      122      1753.2      127      1753.1      131
GR1757.7      140      1757.7      152      1755.0      160      1755.6      168      1755.6      171
GR1755.6      174      1754.7      177      1755.9      183      1756.0      190      1754.9      208
GR1754.7      220      1753.7      247      1753.3      282      1752.7      321      1750.9      352
GR1748.6      373      1747.2      391      1748.3      404      1752.1      434      1753.6      452
GR1753.7      477      1752.6      499      1753.2      532      1753.4      572      1753.9      613
GR1753.3      644      1754.4      677      1754.7      698      1755.6      728      1756.2      750
GR1755.7      767      1749.9      772      1749.3      775      1748.0      775      1747.4      778
GR1749.3      785      1749.7      789      1752.9      797      1755.5      807      1756.9      815
GR1755.3      827      1756.3      847      1756.2      866      1756.9      871      1759.5      877
GR1760.7      893      1762.0      918      1763.2      936      1764.3      963      1766.2      990

*       Request Effective Area option (X3.1 = 10)
X1      2.00      45      768      816      500      480      510
X3      10
GR1764.5      220      1764.2      224      1763.8      232      1763.4      240      1762.5      245
GR1761.2      248      1762.8      255      1762.4      260      1761.4      263      1761.4      267
GR1759.3      271      1758.5      285      1758.7      298      1758.6      315      1757.7      326
GR1755.8      336      1755.7      347      1755.8      358      1757.3      374      1757.3      411
GR1756.5      433      1756.4      459      1755.2      482      1753.5      508      1755.1      539
GR1755.8      550      1758.0      578      1759.0      606      1759.1      632      1760.1      666
GR1759.6      693      1759.4      718      1760.2      748      1759.5      760      1759.8      768
GR1755.5      771      1754.6      773      1753.6      776      1754.6      788      1755.4      795
GR1762.6      816      1761.9      828      1761.9      851      1762.5      893      1763.9      919

*       Channel & left bank 'n' value changed for next and following cross sections
NC      .085      .035
*       Flow distribution requested for section 3 (X2.10 = 15)
X1      3.00      59      1017      1068      620      550      610
X2
X3      10
GR1772.3      0      1772.7      78      1772.7      103      1771.8      112      1771.2      124
GR1771.5      164      1771.5      182      1771.3      210      1771.8      225      1769.2      247
GR1769.2      253      1768.3      275      1766.5      310      1765.1      322      1764.1      341
GR1763.1      381      1763.5      486      1764.4      502      1764.1      513      1764.5      534
GR1764.6      557      1764.8      591      1764.2      619      1762.3      647      1760.3      666
GR1760.5      684      1762.4      707      1765.3      735      1765.8      766      1766.0      796
GR1765.8      825      1765.6      860      1765.6      906      1765.8      940      1765.8      980
GR1766.1      991      1765.8      1017      1763.1      1025      1762.4      1032      1761.3      1034
GR1759.4      1053      1761.3      1059      1763.5      1068      1765.1      1093      1765.6      1116
GR1765.5      1134      1766.9      1156      1770.0      1169      1770.5      1188      1770.9      1218
GR1771.5      1234      1771.2      1258      1771.1      1290      1770.6      1330      1770.1      1365
GR1770.9      1390      1773.5      1415      1777.0      1442      1778.6      1465

```

* Cross-section plot to water surface requested for section 4 (X1.10 = 10)

X1	4.00	65	1248	1285	580	600	620		10
X3	10								
GR1775.9	254	1775.2	284	1775.0	314	1774.6	358	1774.5	373
GR1774.6	388	1773.8	407	1775.0	424	1775.0	441	1775.7	461
GR1775.7	465	1774.0	466	1774.0	474	1776.9	482	1775.0	488
GR1774.7	503	1773.5	506	1773.9	509	1773.9	512	1773.9	516
GR1772.2	518	1773.9	527	1772.5	543	1772.8	554	1772.9	565
GR1771.9	587	1771.3	619	1770.4	641	1770.6	658	1769.2	680
GR1765.9	697	1763.0	709	1763.7	713	1767.0	733	1768.5	747
GR1769.4	765	1769.4	798	1769.3	833	1768.9	865	1769.1	889
GR1769.0	907	1769.6	941	1769.2	974	1769.9	1006	1769.8	1032
GR1769.6	1060	1770.1	1088	1770.2	1126	1770.5	1159	1770.5	1187
GR1771.0	1198	1768.5	1207	1769.3	1221	1769.2	1248	1764.0	1257
GR1763.0	1263	1764.0	1267	1764.0	1275	1773.7	1285	1781.4	1302
GR1789.6	1320	1789.7	1332	1790.5	1352	1790.2	1373	1788.7	1396

* Cross section 5 is a repeat of cross section 4 raised 5 ft.

X1	5			600	650	670		5
X3	10							

* Manning's n values changed for next, and following sections

NC	.08	.09	.04						
X1	6	45	595	694	650	550	630		
GR1792.9	0	1791.0	75	1790.6	113	1789.4	164	1788.9	179
GR1787.1	184	1785.3	210	1784.7	263	1782.6	317	1781.0	323
GR1781.4	330	1780.3	339	1779.4	343	1778.4	346	1777.4	350
GR1779.8	353	1779.5	362	1780.0	369	1780.4	395	1779.9	398
GR1780.2	422	1779.1	452	1778.7	476	1778.2	499	1778.0	522
GR1778.0	550	1778.5	579	1779.0	595	1776.6	613	1774.1	626
GR1774.5	635	1775.3	643	1779.8	694	1780.3	705	1781.7	730
GR1784.9	785	1786.7	809	1787.7	817	1788.2	854	1788.5	878
GR1789.8	907	1792.0	937	1794.0	961	1795.3	987	1797.3	1015

* Add a point to GR array with X4 input.

X1	7.00	55	912	983	590	600	620		
X4	1	1785.1	800						
GR1798.3	0	1794.5	22	1792.4	44	1790.8	69	1788.1	108
GR1787.4	133	1786.3	164	1785.2	206	1784.1	244	1784.2	281
GR1784.0	316	1783.5	353	1783.6	388	1783.7	418	1782.0	438
GR1782.7	464	1782.6	479	1781.0	488	1781.1	496	1781.2	508
GR1783.1	516	1783.1	540	1781.6	550	1782.7	554	1782.7	558
GR1787.7	561	1786.6	564	1788.8	570	1789.2	584	1788.9	606
GR1787.3	621	1786.4	652	1785.6	680	1784.9	709	1785.3	740
GR1785.1	777	1784.9	806	1784.3	830	1783.9	853	1784.8	886
GR1784.6	912	1783.8	932	1780.6	954	1779.7	963	1777.2	970
GR1779.7	976	1784.5	983	1787.5	1004	1788.8	1024	1790.6	1050
GR1792.1	1077	1794.3	1108	1795.4	1138	1796.7	1169	1798.6	1217

* New discharge read on X2

X1	8.00	68	1089	1140	580	630	600		
X2	7000								
GR1803.0	0	1801.5	22	1799.8	36	1796.4	55	1794.1	70
GR1794.6	94	1793.7	123	1792.0	152	1791.1	182	1790.5	212
GR1790.0	249	1791.1	270	1792.2	283	1793.0	299	1792.6	324
GR1790.5	337	1789.3	343	1788.9	350	1789.4	375	1789.5	405
GR1789.0	436	1788.4	449	1788.2	461	1788.7	490	1789.2	518
GR1789.5	536	1789.7	548	1788.8	572	1788.4	590	1789.2	596
GR1787.4	599	1787.7	603	1787.6	606	1788.2	613	1788.5	635
GR1787.7	650	1787.5	673	1787.6	708	1787.0	738	1787.3	773
GR1787.1	809	1787.0	847	1787.3	886	1786.9	916	1786.8	946
GR1787.3	979	1787.9	1010	1788.2	1041	1788.4	1070	1788.0	1079
GR1789.5	1089	1788.7	1096	1784.6	1101	1784.3	1109	1784.7	1116
GR1784.6	1119	1785.3	1131	1790.3	1140	1790.8	1148	1791.5	1181
GR1792.3	1208	1792.3	1241	1792.9	1272	1793.6	1302	1794.6	1331
GR1795.8	1358	1798.9	1382	1802.7	1402				

EJ
ER

Output

```
*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 13:53:59 *
*****
```

```
*****
* 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 X
XXXXXXXX XXXX X XXXXX XXXXX
X X X X X X
X X X X X X
X X XXXXXXX XXXXX XXXXXXX
```

END OF BANNER

06FEB91 13:53:59

PAGE 1

THIS RUN EXECUTED 06FEB91 13:53:59

```
*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****
```

```
T1 Example 1: Single profile subcritical run
T2 Output options include: User design summary, flow distribution, suppress
T2 printer plot of profile, and cross-section printer plot.
T3 Bear Creek
T4 Input options include: Effective area option, encroachment method 1,
T5 add points, repeat cross section, and change discharge.
Starting with energy slope and estimated water surface elevation
```

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
					0.0092			7800	1756.02	
	Supress profile printer plot (J2.3 = -1)									
J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE

-1

User designed output with variables and defined table (150)

```
J3 VARIABLE CODES FOR SUMMARY PRINTOUT
38 1 3 57 68 150
NC .1 .1 .04 .1 .3
```

Use effective area option to only consider overbank when channel banks are exceeded (X3.1 = 10).
Use left encroachment to block low overbank area beyond station 183 (X3.4&5)

X1	1.0	60	767	815	0	815	0	0		
X3	10			183	1757					
GR	1767.0	0	1765.4	23	1763.5	49	1762.0	69	1759.1	87
GR	1758.1	103	1756.9	113	1756.9	122	1753.2	127	1753.1	131
GR	1757.7	140	1757.7	152	1755.0	160	1755.6	168	1755.6	171
GR	1755.6	174	1754.7	177	1755.9	183	1756.0	190	1754.9	208
GR	1754.7	220	1753.7	247	1753.3	282	1752.7	321	1750.9	352
GR	1748.6	373	1747.2	391	1748.3	404	1752.1	434	1753.6	452
GR	1753.7	477	1752.6	499	1753.2	532	1753.4	572	1753.9	613
GR	1753.3	644	1754.4	677	1754.7	698	1755.6	728	1756.2	750
GR	1755.7	767	1749.9	772	1749.3	775	1748.0	775	1747.4	778
GR	1749.3	785	1749.7	789	1752.9	797	1755.5	807	1756.9	815
GR	1755.3	827	1756.3	847	1756.2	866	1756.9	871	1759.5	877
GR	1760.7	893	1762.0	918	1763.2	936	1764.3	963	1766.2	990

Request Effective Area option (X3.1 = 10)

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PAGE 2

X1	2.00	45	768	816	500	480	510			
X3	10									
GR	1764.5	220	1764.2	224	1763.8	232	1763.4	240	1762.5	245
GR	1761.2	248	1762.8	255	1762.4	260	1761.4	263	1761.4	267
GR	1759.3	271	1758.5	285	1758.7	298	1758.6	315	1757.7	326
GR	1755.8	336	1755.7	347	1755.8	358	1757.3	374	1757.3	411
GR	1756.5	433	1756.4	459	1755.2	482	1753.5	508	1755.1	539
GR	1755.8	550	1758.0	578	1759.0	606	1759.1	632	1760.1	666
GR	1759.6	693	1759.4	718	1760.2	748	1759.5	760	1759.8	768
GR	1755.5	771	1754.6	773	1753.6	776	1754.6	788	1755.4	795
GR	1762.6	816	1761.9	828	1761.9	851	1762.5	893	1763.9	919

Channel & left bank 'n' value changed for next and following cross sections

```
NC .085 .035
Flow distribution requested for section 3 (X2.10 = 15)
X1 3.00 59 1017 1068 620 550 610
X2
X3 10
```

15

GR	1772.3	0	1772.7	78	1772.7	103	1771.8	112	1771.2	124
GR	1771.5	164	1771.5	182	1771.3	210	1771.8	225	1769.2	247
GR	1769.2	253	1768.3	275	1766.5	310	1765.1	322	1764.1	341
GR	1763.1	381	1763.5	486	1764.4	502	1764.1	513	1764.5	534
GR	1764.6	557	1764.8	591	1764.2	619	1762.3	647	1760.3	666
GR	1760.5	684	1762.4	707	1765.3	735	1765.8	766	1766.0	796
GR	1765.8	825	1765.6	860	1765.6	906	1765.8	940	1765.8	980
GR	1766.1	991	1765.8	1017	1763.1	1025	1762.4	1032	1761.3	1034
GR	1759.4	1053	1761.3	1059	1763.5	1068	1765.1	1093	1765.6	1116
GR	1765.5	1134	1766.9	1156	1770.0	1169	1770.5	1188	1770.9	1218
GR	1771.5	1234	1771.2	1258	1771.1	1290	1770.6	1330	1770.1	1365
GR	1770.9	1390	1773.5	1415	1777.0	1442	1778.6	1465		

Cross-section plot to water surface requested for section 4 (X1.10 = 10)

X1	4.00	65	1248	1285	580	600	620			10
X3	10									
GR	1775.9	254	1775.2	284	1775.0	314	1774.6	358	1774.5	373
GR	1774.6	388	1773.8	407	1775.0	424	1775.0	441	1775.7	461
GR	1775.7	465	1774.0	466	1774.0	474	1776.9	482	1775.0	488
GR	1774.7	503	1773.5	506	1773.9	509	1773.9	512	1773.9	516
GR	1772.2	518	1773.9	527	1772.5	543	1772.8	554	1772.9	565
GR	1771.9	587	1771.3	619	1770.4	641	1770.6	658	1769.2	680
GR	1765.9	697	1763.0	709	1763.7	713	1767.0	733	1768.5	747
GR	1769.4	765	1769.4	798	1769.3	833	1768.9	865	1769.1	889
GR	1769.0	907	1769.6	941	1769.2	974	1769.9	1006	1769.8	1032
GR	1769.6	1060	1770.1	1088	1770.2	1126	1770.5	1159	1770.5	1187
GR	1771.0	1198	1768.5	1207	1769.3	1221	1769.2	1248	1764.0	1257
GR	1763.0	1263	1764.0	1267	1764.0	1275	1773.7	1285	1781.4	1302
GR	1789.6	1320	1789.7	1332	1790.5	1352	1790.2	1373	1788.7	1396

Cross section 5 is a repeat of cross section 4 raised 5 ft.

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PAGE 3

X1	5				600	650	670		5
X3	10								

Manning's n values changed for next, and following sections

NC	.08	.09	.04							
X1	6	45	595	694	650	550	630			
GR	1792.9	0	1791.0	75	1790.6	113	1789.4	164	1788.9	179
GR	1787.1	184	1785.3	210	1784.7	263	1782.6	317	1781.0	323
GR	1781.4	330	1780.3	339	1779.4	343	1778.4	346	1777.4	350
GR	1779.8	353	1779.5	362	1780.0	369	1780.4	395	1779.9	398
GR	1780.2	422	1779.1	452	1778.7	476	1778.2	499	1778.0	522
GR	1778.0	550	1778.5	579	1779.0	595	1776.6	613	1774.1	626
GR	1774.5	635	1775.3	643	1779.8	694	1780.3	705	1781.7	730
GR	1784.9	785	1786.7	809	1787.7	817	1788.2	854	1788.5	878
GR	1789.8	907	1792.0	937	1794.0	961	1795.3	987	1797.3	1015

Add a point to GR array with X4 input.

X1	7.00	55	912	983	590	600	620			
X4	1	1785.1	800							
GR	1798.3	0	1794.5	22	1792.4	44	1790.8	69	1788.1	108
GR	1787.4	133	1786.3	164	1785.2	206	1784.1	244	1784.2	281
GR	1784.0	316	1783.5	353	1783.6	388	1783.7	418	1782.0	438
GR	1782.7	464	1782.6	479	1781.0	488	1781.1	496	1781.2	508
GR	1783.1	516	1783.1	540	1781.6	550	1782.7	554	1782.7	558
GR	1787.7	561	1786.3	564	1788.8	570	1789.2	584	1788.9	606
GR	1787.3	621	1786.4	652	1785.6	680	1784.9	709	1785.3	740
GR	1785.1	777	1784.9	806	1784.3	830	1783.9	853	1784.8	886
GR	1784.6	912	1783.8	932	1780.6	954	1779.7	963	1777.2	970
GR	1779.7	976	1784.5	983	1787.5	1004	1788.8	1024	1790.6	1050
GR	1792.1	1077	1794.3	1108	1795.4	1138	1796.7	1169	1798.6	1217

New discharge read on X2

X1	8.00	68	1089	1140	580	630	600			
X2	7000									
GR	1803.0	0	1801.5	22	1799.8	36	1796.4	55	1794.1	70
GR	1794.6	94	1793.7	123	1792.0	152	1791.1	182	1790.5	212
GR	1790.0	249	1791.1	270	1792.2	283	1793.0	299	1792.6	324
GR	1790.5	337	1789.3	343	1788.9	350	1789.4	375	1789.5	405
GR	1789.0	436	1788.4	449	1788.2	461	1788.7	490	1789.2	518
GR	1789.5	536	1789.7	548	1788.8	572	1788.4	590	1789.2	596
GR	1787.4	599	1787.7	603	1787.6	606	1788.2	613	1788.5	635
GR	1787.7	650	1787.5	673	1787.6	708	1787.0	738	1787.3	773
GR	1787.1	809	1787.0	847	1787.3	886	1786.9	916	1786.8	946
GR	1787.3	979	1787.9	1010	1788.2	1041	1788.4	1070	1788.0	1079
GR	1789.5	1089	1788.7	1096	1784.6	1101	1784.3	1109	1784.7	1116
GR	1784.6	1119	1785.3	1131	1790.3	1140	1790.8	1148	1791.5	1181
GR	1792.3	1208	1792.3	1241	1792.9	1272	1793.6	1302	1794.6	1331
GR	1795.8	1358	1798.9	1382	1802.7	1402				

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PAGE 4

SECNO	DEPTH	CWSEL	CRISW	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

3265 DIVIDED FLOW

3470 ENCROACHMENT STATIONS= 183.0 990.0 TYPE= 1 TARGET= -183.000
ELENCL= 1757.00 ELENCR= 100000.00

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 1755.70 ELREA= 1756.90

1.000	8.82	1756.02	.00	1756.02	1756.48	.46	.00	.00	1755.70
7800.0	5993.5	1806.5	.0	1668.2	196.8	.0	.0	.0	1756.90
.00	3.59	9.18	.00	.100	.040	.000	.000	1747.20	183.00
.009381	0.	0.	0.	0	0	0	.00	614.26	809.97

*SECNO 2.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 1759.80 ELREA= 1762.60

2.000	7.26	1760.76	.00	.00	1761.30	.54	4.80	.03	1759.80
7800.0	5807.6	1992.4	.0	1562.5	202.8	.0	20.9	6.6	1762.60
.03	3.72	9.82	.00	.100	.040	.000	.000	1753.50	268.22
.009726	500.	510.	480.	2	0	0	.00	542.41	810.63

*SECNO 3.000

3.000	7.05	1766.45	.00	.00	1767.25	.81	5.87	.08	1765.80
7800.0	4893.2	2712.7	194.2	1431.9	239.8	102.0	45.9	16.4	1763.50
.05	3.42	11.31	1.90	.085	.035	.100	.000	1759.40	310.46
.009340	620.	610.	550.	2	0	0	.00	838.40	1148.87

FLOW DISTRIBUTION FOR SECNO= 3.00 CWSEL= 1766.45

STA=	310.	381.	486.	534.	591.	647.	666.	684.	707.	766.	1017.	1068.	1149.
PER Q=	6.2	15.4	4.1	3.3	6.0	6.3	7.8	7.3	3.5	2.8	34.8	2.5	
AREA=	156.7	330.3	109.2	103.0	144.0	97.8	108.8	114.9	100.5	166.8	239.8	102.0	
VEL=	3.1	3.6	2.9	2.5	3.3	5.0	5.6	4.9	2.7	1.3	11.3	1.9	
DEPTH=	2.2	3.1	2.3	1.8	2.6	5.1	6.0	5.0	1.7	.7	4.7	1.3	

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PAGE 5

SECNO	DEPTH	CWSEL	CRISW	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

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 1769.20 ELREA= 1773.70

4.000	8.70	1771.70	.00	.00	1772.66	.96	5.36	.04	1769.20
7800.0	5062.0	2738.0	.0	1514.8	220.2	.0	69.5	26.6	1773.70
.08	3.34	12.43	.00	.085	.035	.000	.000	1763.00	597.46
.008724	580.	620.	600.	3	0	0	.00	685.49	1282.94

*SECNO 5.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 1774.20 ELREA= 1778.70

5.000	8.88	1776.88	.00	.00	1777.69	.81	5.02	.01	1774.20
7800.0	5166.3	2633.7	.0	1628.3	226.3	.0	94.6	36.2	1778.70
.11	3.17	11.64	.00	.085	.035	.000	.000	1768.00	588.21
.007434	600.	670.	650.	3	0	0	.00	694.91	1283.12

*SECNO 6.000

6.000	7.73	1781.83	.00	.00	1782.94	1.11	5.16	.09	1779.00
7800.0	2657.9	5069.6	72.6	739.8	498.0	40.4	117.8	44.4	1779.80
.13	3.59	10.18	1.80	.080	.040	.090	.000	1774.10	319.90
.008786	650.	630.	550.	2	0	0	.00	412.29	732.19

*SECNO 7.000

3265 DIVIDED FLOW

3301 HV CHANGED MORE THAN HVINS

7.000	9.56	1786.76	.00	.00	1787.19	.42	4.18	.07	1784.60
7800.0	5012.0	2764.2	23.8	1726.9	351.9	17.9	140.9	52.4	1784.50
.17	2.90	7.86	1.33	.080	.040	.090	.000	1777.20	150.95
.005562	590.	620.	600.	2	0	0	.00	770.94	998.84

*SECNO 8.000

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PAGE 6

SECNO	DEPTH	CWSEL	CRISW	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	

3265 DIVIDED FLOW

8.000	6.11	1790.41	.00	.00	1790.75	.34	3.55	.01	1789.50
7000.0	5245.8	1754.2	.0	1801.9	223.3	.1	168.5	63.2	1790.30
.21	2.91	7.85	.01	.080	.040	.090	.000	1784.30	218.62
.006707	580.	600.	630.	3	0	0	.00	842.54	1141.77


```

1080. . . . . X . W . E . .
1085. . . . . X . W . E . .
481090. . . . . .X . W . E . .
1095. . . . . .X . W . E . .
1100. . . . . .X . W . E . .
1105. . . . . .X . W . E . .
1110. . . . . .X . W . E . .
1115. . . . . .X . W . E . .
1120. . . . . .X . W . E . .
491125. . . . . .X . W . E . .
1130. . . . . .X . W . E . .
1135. . . . . .X . W . E . .
1140. . . . . .X . W . E . .
1145. . . . . .X . W . E . .
1150. . . . . .X . W . E . .
1155. . . . . .X . W . E . .
501160. . . . . .X . W . E . .
1165. . . . . .X . W . E . .
1170. . . . . .X . W . E . .
1175. . . . . .X . W . E . .
1180. . . . . .X . W . E . .
511185. . . . . .X . W . E . .
1190. . . . . .X . W . E . .
1195. . . . . .X . W . E . .
521200. . . . . .X . W . E . .
531205. . . . . X . . . W . E . .
1210. . . . . .X . W . E . .
1215. . . . . .X . W . E . .
541220. . . . . .X . W . E . .
1225. . . . . .X . W . E . .
1230. . . . . .X . W . E . .
1235. . . . . .X . W . E . .
1240. . . . . .X . W . E . .
1245. . . . . .X . W . E . .
551250. . . . . .X . W . E . . BANK.
561255. . . . . .X . W . E . .
1260. . X . . . . . W . E . .
581265. XXXXXXXXXXXX . . . . . W . E . .
1270. . X . . . . . W . E . .
591275. . X . . . . . W . E . .
1280. . . . . X . . . W . E . .
601285. . . . . . . . . W . E . . BANK.

```

NRD= 0 ELLC= 9999999.00 ELTRD= 9999999.00

EL(I),STA(I)	1775.90	1774.60	1775.70	1774.70	1772.20	1771.90	1765.90	1769.40	1769.00	1769.60	1771.00	1771.00	1763.00	1789.60																																									
254.00	388.00	465.00	503.00	518.00	587.00	697.00	765.00	907.00	1060.00	1198.00	1263.00	1320.00	1775.20	1773.80	1774.00	1773.50	1773.90	1773.90	1772.50	1770.40	1763.70	1769.30	1769.20	1770.20	1769.30	1764.00	1789.70																												
284.00	407.00	466.00	506.00	527.00	619.00	709.00	798.00	941.00	1088.00	1207.00	1267.00	1332.00	1775.00	1775.00	1774.00	1773.90	1772.50	1770.60	1767.00	1760.70	1763.00	1769.30	1769.20	1770.20	1769.30	1764.00	1790.50	1775.00	1775.00	1774.00	1773.90	1772.80	1770.60	1767.00	1768.90	1769.90	1770.50	1769.20	1764.00	1773.00	1790.20	1373.00	1774.50	1775.70	1775.00	1773.90	1772.90	1769.20	1768.50	1769.10	1032.00	1187.00	1257.00	1302.00	1396.00

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THIS RUN EXECUTED 06FEB91 13:53:59

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

Bear Creek

SUMMARY PRINTOUT

SECNO	CWSEL	EG	ALPHA	FRCH
1.000	1756.02	1756.48	1.68	.76
2.000	1760.76	1761.30	1.79	.79
3.000	1766.45	1767.25	2.68	.92
4.000	1771.70	1772.66	3.04	.87
5.000	1776.88	1777.69	2.96	.81
6.000	1781.83	1782.94	1.93	.80
7.000	1786.76	1787.19	1.97	.62
8.000	1790.41	1790.75	1.83	.66

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Bear Creek

SUMMARY PRINTOUT TABLE 150

SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRWS	EG	10*KS	VCH	AREA	.01K
1.000	.00	.00	.00	1747.20	7800.00	1756.02	.00	1756.48	93.81	9.18	1865.06	805.34
2.000	510.00	.00	.00	1753.50	7800.00	1760.76	.00	1761.30	97.26	9.82	1765.29	790.93
3.000	610.00	.00	.00	1759.40	7800.00	1766.45	.00	1767.25	93.40	11.31	1773.78	807.10
4.000	620.00	.00	.00	1763.00	7800.00	1771.70	.00	1772.66	87.24	12.43	1734.96	835.08
5.000	670.00	.00	.00	1768.00	7800.00	1776.88	.00	1777.69	74.34	11.64	1854.59	904.64
6.000	630.00	.00	.00	1774.10	7800.00	1781.83	.00	1782.94	87.86	10.18	1278.22	832.15
7.000	620.00	.00	.00	1777.20	7800.00	1786.76	.00	1787.19	55.62	7.86	2096.67	1045.90
8.000	600.00	.00	.00	1784.30	7000.00	1790.41	.00	1790.75	67.07	7.85	2025.36	854.71

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Bear Creek

SUMMARY PRINTOUT TABLE 150

SECNO	Q	CWSEL	DIPWSP	DIPWSX	DIPKWS	TOPWID	XLCH
1.000	7800.00	1756.02	.00	.00	.00	614.26	.00
2.000	7800.00	1760.76	.00	4.74	.00	542.41	510.00
3.000	7800.00	1766.45	.00	5.69	.00	838.40	610.00
4.000	7800.00	1771.70	.00	5.26	.00	685.49	620.00
5.000	7800.00	1776.88	.00	5.17	.00	694.91	670.00
6.000	7800.00	1781.83	.00	4.95	.00	412.29	630.00
7.000	7800.00	1786.76	.00	4.94	.00	770.94	620.00
8.000	7000.00	1790.41	.00	3.65	.00	842.54	600.00

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SUMMARY OF ERRORS AND SPECIAL NOTES

Example No. 2

Input

```

C
C 16
C 1 X3 CARD UTILIZED TO SPECIFY SEDIMENT ELEVATION (X3.2)
C 2 X5 CARD UTILIZED TO SPECIFY WATER SURFACE ELEVATIONS
C 3 START TRIBUTARIES AT CROSS SECTION 3
C 3.1 X5 CARD UTILIZED TO SPECIFY DIFFERENCE IN CWSEL BETWEEN
C 3.1 SECTIONS 3 AND 3.1 FOR INQS 2,3 AND 4
C 4 EFFECTIVE AREA OPTION USED TO CONFINE FLOW TO BRIDGE OPENING
C 4 UNTIL WEIR FLOW CAN BE EXPECTED (X3.8,X3.9=58)
C 5 BT CARDS DEFINE WEIR PROFILE ONLY ,SINCE PIER IS SPECIFIED THIS
C 5 SPECIAL BRIDGE CAN NOT REVERT TO THE NORMAL BRIDGE ROUTINE
C 6 HIGH WATER ELEVATION OF 59.06 (X2.2)
C 15 WEIR LENGETH DEFINED BY SB.4, BT CARDS ARE NOT REQUIRED
C 15 NO PIER DEFINED ON SB CARD,NORMAL BR. TO BE USED FOR LOW FLOW
C 16 HIGH WATER ELEVATION OF 59.06 (X2.2)
C 24.1 X4 CARD PROVIDES ADDITIONAL GR DATA TO MODEL BRIDGE PIERS
C 24.2 X1 CARD REPEATS GR AND X4 DATA,X2 CARD REPEATS BT DATA
C 26 HIGH WATER ELEVATION OF 59.06 (X2.2)
T1 Example 2, Special and Normal Bridge plus tributary stream profile
T2 Comments used to annotate input data
T3 WOODY CREEK
T4 (See test data file HEC205.DAT for example input)
J1 2 0.0016 45
J2 -1
J3 38 1 9 5 33 55 26 56 42 4
J3 58 62 100 105
* Detailed output omitted by J5 record input.
J5 -10
QT 9 6000 10000 14000 14000 16000 18000 20000 24000 28000
NC 0.06 0.06 0.035 0.1 0.3
X1 1 15 550 670
X3 10 36
GR 55 0 50 100 45 250 44 500 43 550
GR 35 570 33 575 38 600 39 640 45 670
GR 46 750 43.5 800 44 1050 49 1100 55 1200
X1 2 14 450 540 1700 2050 1900
X3 10 37.5
X5 9 48.5 49.59 51 51 51.2 51.5 51.7 52.4 53
GR 60 0 50 100 47 200 46 400 45 450
GR 36.8 460 37 480 38 510 47 540 49 700
GR 48 750 46 800 49 1000 60 1200
X1 3 14 650 745 1900 1900 2000
GR 65 0 55 50 52 100 53 300 55 400
GR 52 600 50 650 45 660 40.8 700 41 740
GR 53 745 51 890 52 1000 65 1200
X1 3.1 400 400 400 0.95 0.5
X5 -3 0.6 1 1.05
NC 0.06 0.06 0.035 0.3 0.5
X1 4 21 600 700 1600 1600 1600
X3 10 58 58
GR 70 0 63 100 57.5 250 55 400 54 500
GR 53.5 600 45 610 44 625 44.5 640 46 650
GR 47.5 660 47 670 47 695 55 700 55.5 750
GR 54.5 775 53 825 55 900 57.5 950 63 1000
GR 70 1100

```

SB	1.25	1.5	3.0		82.5	6	1014	0.67	45	45
X1	5				50	50	50			
X2			1	57	60					
X3	10							61	61	
BT	7	0	65		500	61		600	60	
BT	700	60		800	61		1000	63		1100
BT	70									
X1	6	12	350	440	250	250	250		-.3	
X2		59.56								
X3	10									
GR	75	0	60	50	56	300	54.5	350	45	370
GR	46	400	48	420	56	440	58	600	55	650
GR	56	700	75	850						

* Negative section number indicates tributary starting with Section 3 WSEL.

* The water surface elevation will be used with the following input data.

NC	0.06	0.06	0.035	0.1	0.3					
X1	-3	14	650	745						
X3	10									
GR	65	0	55	50	52	100	53	300	55	400
GR	52	600	50	650	45	660	40.8	700	41	740
GR	53	745	51	890	52	1000	65	1200		
X1	13.1				400	400	400	0.95	0.5	
X5	-3	0.6	1	1.05						
NC	0.06	0.06	0.035	0.3	0.5					
X1	14	21	600	700	1600	1600	1600			
X3	10							58	58	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000
GR	70	1100								
SB		1.5	3.0	300	76.5		1014	0.67	45	45
X1	15				50	50	50			
X2			1	57	60					
X3	10							61	61	
X4	10	44	622.9	57	623	57	624.9	46	647.9	57
X4	648	57	649.9	47	674	57	674.1	57	676	47
X4	676.1									
X1	16	12	350	440	250	250	250		- .3	
X2		59.56								
X3	10									
GR	75	0	60	50	56	300	54.5	350	45	370
GR	46	400	48	420	56	440	58	600	55	650
GR	56	700	75	850						
NC	0.06	0.06	0.035	0.1	0.3					
X1	-3	14	650	745						
X3	10									
GR	65	0	55	50	52	100	53	300	55	400
GR	52	600	50	650	45	660	40.8	700	41	740
GR	53	745	51	890	52	1000	65	1200		
X1	23.1				400	400	400	0.95	0.5	
X5	-3	0.6	1	1.05						
NC	0.06	0.06	0.035	0.3	0.5					
X1	24	21	600	700	1600	1600	1600			
X3	10							58	58	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000
GR	70	1100								
X1	24.1				1	1	1			
X3	10							60	60	
X4	10	44	622.9	57	623	57	624.9	46	647.9	57
X4	648	57	649.9	47	674	57	674.1	57	676	47
X4	676.1									
BT	16	0	70	70	100	63	63	250	62	57.5
BT	400	61.5	55	500	61	54	600	60	53.5	600
BT	60	57	700	60	57	700	60	55	750	60.5
BT	55.5	775	60.5	54.5	825	61	53	900	62	55
BT	950	62.5	57.5	1000	63	63	1100	70	70	
X1	24.2				50	50	50			
X2							1			
X3	10							60	60	
X1	25	21	600	700	1	1	1			
X3	10							61	61	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000

GR	70	1100								
X1	26	12	350	440	250	250	250			-.3
X2		59.56								
X3	10									
GR	75	0	60	50	56	300	54.5	350	45	370
GR	46	400	48	420	56	440	58	600	55	650
GR	56	700	75	850						
EJ										
T1	Title input is optional; however,									
J1		3			0.0016					48
J2	2		-1							
T1	One or more Title records are required for each profile.									
J1		6			0.0016					50
J2	3		-1							
ER										

Output

```
*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 12:58:27 *
*****
```

```
*****
* 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 X X X
XXXXXXXX XXXX X XXXXX XXXXX
X X X X X X
X X X X X X
X X XXXXXXX XXXXX XXXXXXX

```

END OF BANNER

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PAGE 1

THIS RUN EXECUTED 06FEB91 12:58:27

```
*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****
```

```
T1 Example 2, Special and Normal Bridge plus tributary stream profile
T2 Comments used to annotate input data
T3 WOODY CREEK
T4 (See test data file HEC205.DAT for example input)
```

```
J1 ICHECK INQ NINV IDIR STRT METRIC HVINS Q WSEL FQ
          2          0.0016          45
J2 NPROF IPLOT PRFVS XSECV XSECH FN ALLDC IBW CHNIM ITRACE
          -1
```

```
J3 VARIABLE CODES FOR SUMMARY PRINTOUT
38 1 9 5 33 55 26 56 42 4
58 62 100 105
Detailed output omitted by J5 record input.
```

```
J5 LPRNT NUMSEC *****REQUESTED SECTION NUMBERS*****
-10 -10
```

QT	9	6000	10000	14000	14000	16000	18000	20000	24000	28000
NC	0.06	0.06	0.035	0.1	0.3					
X3 CARD UTILIZED TO SPECIFY SEDIMENT ELEVATION (X3.2)										
X1	1	15	550	670						
X3	10	36								
GR	55	0	50	100	45	250	44	500	43	550
GR	35	570	33	575	38	600	39	640	45	670
GR	46	750	43.5	800	44	1050	49	1100	55	1200

X5 CARD UTILIZED TO SPECIFY WATER SURFACE ELEVATIONS										
X1	2	14	450	540	1700	2050	1900			
X3	10	37.5								
X5	9	48.5	49.59	51	51	51.2	51.5	51.7	52.4	53
GR	60	0	50	100	47	200	46	400	45	450
GR	36.8	460	37	480	38	510	47	540	49	700
GR	48	750	46	800	49	1000	60	1200		

START TRIBUTARIES AT CROSS SECTION 3										
X1	3	14	650	745	1900	1900	2000			
GR	65	0	55	50	52	100	53	300	55	400
GR	52	600	50	650	45	660	40.8	700	41	740
GR	53	745	51	890	52	1000	65	1200		
X5 CARD UTILIZED TO SPECIFY DIFFERENCE IN CWSEL BETWEEN SECTIONS 3 AND 3.1 FOR INQS 2,3 AND 4										
X1	3.1				400	400	400	0.95	0.5	
X5	-3	0.6	1	1.05						
NC	0.06	0.06	0.035	0.3	0.5					
EFFECTIVE AREA OPTION USED TO CONFINE FLOW TO BRIDGE OPENING UNTIL WEIR FLOW CAN BE EXPECTED (X3.8,X3.9=58)										
X1	4	21	600	700	1600	1600	1600			
X3	10							58	58	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000
GR	70	1100								
SB	1.25	1.5	3.0		82.5	6	1014	0.67	45	45

BT CARDS DEFINE WEIR PROFILE ONLY ,SINCE PIER IS SPECIFIED THIS SPECIAL BRIDGE CAN NOT REVERT TO THE NORMAL BRIDGE ROUTINE

X1	5			50	50	50				
X2		1	57	60						
X3	10						61	61		
BT	7	0	65		500	61	600	60		
BT	700	60		800	61		1000	63		1100
BT	70									

HIGH WATER ELEVATION OF 59.06 (X2.2)

X1	6	12	350	440	250	250	250			- .3
X2		59.56								
X3	10									
GR	75	0	60	50	56	300	54.5	350	45	370
GR	46	400	48	420	56	440	58	600	55	650
GR	56	700	75	850						

Negative section number indicates tributary starting with Section 3 WSEL.
The water surface elevation will be used with the following input data.

NC	0.06	0.06	0.035	0.1	0.3					
X1	-3	14	650	745						
X3	10									
GR	65	0	55	50	52	100	53	300	55	400
GR	52	600	50	650	45	660	40.8	700	41	740
GR	53	745	51	890	52	1000	65	1200		

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X1	13.1				400	400	400	0.95	0.5	
X5	-3	0.6	1	1.05						
NC	0.06	0.06	0.035	0.3	0.5					
X1	14	21	600	700	1600	1600	1600			
X3	10							58	58	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000
GR	70	1100								

SB		1.5	3.0	300	76.5		1014	0.67	45	45
WEIR LENGETH DEFINED BY SB.4 , BT CARDS ARE NOT REQUIRED										
NO PIER DEFINED ON SB CARD,NORMAL BR. TO BE USED FOR LOW FLOW										
X1	15				50	50	50			
X2			1	57	60					
X3	10							61	61	
X4	10	44	622.9	57	623	57	624.9	46	647.9	57
X4	648	57	649.9	47	674	57	674.1	57	676	47
X4	676.1									

HIGH WATER ELEVATION OF 59.06 (X2.2)

X1	16	12	350	440	250	250	250			- .3
X2		59.56								
X3	10									
GR	75	0	60	50	56	300	54.5	350	45	370
GR	46	400	48	420	56	440	58	600	55	650
GR	56	700	75	850						

NC	0.06	0.06	0.035	0.1	0.3					
X1	-3	14	650	745						
X3	10									
GR	65	0	55	50	52	100	53	300	55	400
GR	52	600	50	650	45	660	40.8	700	41	740
GR	53	745	51	890	52	1000	65	1200		

X1	23.1				400	400	400	0.95	0.5	
X5	-3	0.6	1	1.05						
NC	0.06	0.06	0.035	0.3	0.5					
X1	24	21	600	700	1600	1600	1600			
X3	10							58	58	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000
GR	70	1100								

X4 CARD PROVIDES ADDITIONAL GR DATA TO MODEL BRIDGE PIERS										
X1	24.1				1	1	1			
X3	10							60	60	
X4	10	44	622.9	57	623	57	624.9	46	647.9	57
X4	648	57	649.9	47	674	57	674.1	57	676	47
X4	676.1									
BT	16	0	70	70	100	63	63	250	62	57.5
BT	400	61.5	55	500	61	54	600	60	53.5	600
BT	60	57	700	60	57	700	60	55	750	60.5
BT	55.5	775	60.5	54.5	825	61	53	900	62	55
BT	950	62.5	57.5	1000	63	63	1100	70	70	
X1 CARD REPEATS GR AND X4 DATA, X2 CARD REPEATS BT DATA										
X1	24.2				50	50	50			
X2							1			
X3	10							60	60	
X1	25	21	600	700	1	1	1			
X3	10							61	61	
GR	70	0	63	100	57.5	250	55	400	54	500
GR	53.5	600	45	610	44	625	44.5	640	46	650
GR	47.5	660	47	670	47	695	55	700	55.5	750
GR	54.5	775	53	825	55	900	57.5	950	63	1000
GR	70	1100								

	HIGH WATER ELEVATION OF 59.06 (X2.2)									
X1	26	12	350	440	250	250	250			- .3
X2		59.56								
X3	10									
GR	75	0	60	50	56	300	54.5	350	45	370
GR	46	400	48	420	56	440	58	600	55	650
GR	56	700	75	850						

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T1 Title input is optional; however,

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		3			0.0016				48	
J2	NPROF	IPLT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	2		-1							

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T1 One or more Title records are required for each profile.

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		6			0.0016				50	
J2	NPROF	IPLT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	3		-1							

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THIS RUN EXECUTED 06FEB91 12:58:57

 HEC-2 WATER SURFACE PROFILES
 Version 4.6.0; Febraury 1991

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

WOODY CREEK

SUMMARY PRINTOUT

	SECNO	CWSEL	WSELK	10*KS	K*CHSL	VLOB	VCH	VROB	ELMIN	TOPWID	KRATIO	IHLQ
	1.000	45.60	45.00	16.08	.00	1.21	5.96	1.41	36.00	794.33	.00	.00
	1.000	46.92	48.00	15.87	.00	1.82	6.68	1.95	36.00	886.99	.00	.00
	1.000	48.37	50.00	15.99	.00	2.38	7.50	2.54	36.00	944.80	.00	.00
*	2.000	48.50	.00	11.53	.79	1.40	6.02	.92	37.50	751.67	1.18	.00
*	2.000	49.59	.00	15.50	.79	2.05	7.54	1.51	37.50	897.06	1.01	.00
*	2.000	51.20	.00	14.90	.79	2.59	8.16	2.18	37.50	952.00	1.04	.00
	3.000	51.18	.00	20.01	1.65	.78	7.48	.22	40.80	155.62	.76	.00
	3.000	52.99	.00	25.54	1.65	1.28	9.50	1.44	40.80	696.48	.78	.00
	3.000	54.53	.00	28.10	1.65	2.06	10.94	2.52	40.80	926.84	.73	.00
*	3.100	51.78	.00	21.46	1.25	.85	7.77	.31	41.30	168.48	.97	.00
*	3.100	53.99	.00	21.82	1.25	1.38	9.02	1.64	41.30	733.19	1.08	.00
	3.100	56.00	.00	18.51	1.25	2.05	9.31	2.47	41.30	955.84	1.23	.00
	4.000	55.06	.00	16.99	1.69	.00	6.98	.00	44.00	100.00	1.12	.00
	4.000	57.35	.00	21.44	1.69	.00	9.18	.00	44.00	100.00	1.01	.00
	4.000	58.89	.00	14.25	1.69	2.37	8.18	2.47	44.00	750.59	1.14	.00
	5.000	55.24	.00	15.86	.00	.00	6.84	.00	44.00	100.00	1.04	.00

	5.000	58.56	.00	15.11	.00	.00	8.27	.00	44.00	100.00	1.19	.00
*	5.000	62.25	.00	3.67	.00	1.69	4.87	1.78	44.00	872.70	1.97	.00
	6.000	55.54	59.56	29.45	2.80	1.03	8.71	.00	44.70	134.29	.73	.00
	6.000	59.51	59.56	11.05	2.80	1.60	7.03	1.78	44.70	668.13	1.17	.00
*	6.000	62.25	59.56	8.12	2.80	2.10	6.94	2.25	44.70	710.27	.67	.00
	-3.000	51.18	.00	19.98	.00	.78	7.48	.00	40.80	123.74	.73	.00
	-3.000	52.99	.00	28.06	.00	1.34	9.96	.00	40.80	425.85	1.17	.00
	-3.000	54.53	.00	28.18	.00	2.06	10.95	2.52	40.80	926.01	.67	.00

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	SECNO	CWSEL	WSELK	10*KS	K*CHSL	VLOB	VCH	VROB	ELMIN	TOPWID	KRATIO	IHLEQ
*	13.100	51.78	.00	21.46	1.25	.85	7.77	.31	41.30	168.48	.96	.00
*	13.100	53.99	.00	21.82	1.25	1.38	9.02	1.64	41.30	733.19	1.13	.00
	13.100	56.01	.00	18.34	1.25	2.05	9.28	2.46	41.30	956.17	1.24	.00
	14.000	55.06	.00	16.99	1.69	.00	6.98	.00	44.00	100.00	1.12	.00
	14.000	57.35	.00	21.45	1.69	.00	9.19	.00	44.00	100.00	1.01	.00
	14.000	58.88	.00	14.31	1.69	2.37	8.19	2.47	44.00	750.27	1.13	.00
	15.000	55.12	.00	34.75	.00	.00	7.42	.00	44.00	94.20	.70	.00
	15.000	58.39	.00	36.83	.00	.00	8.90	.00	44.00	100.00	.76	.00
*	15.000	62.31	.00	5.06	.00	1.99	4.02	2.10	44.00	874.90	1.68	.00
	16.000	55.77	59.56	26.40	2.80	1.11	8.38	.86	44.70	218.53	1.15	.00
*	16.000	59.75	59.56	9.83	2.80	1.56	6.72	1.76	44.70	682.08	1.94	.00
	16.000	62.31	59.56	7.93	2.80	2.09	6.88	2.24	44.70	710.92	.80	.00
	-3.000	51.18	.00	19.98	.00	.78	7.48	.00	40.80	123.74	1.15	.00
	-3.000	52.99	.00	28.06	.00	1.34	9.96	.00	40.80	425.85	1.94	.00
	-3.000	54.53	.00	28.18	.00	2.06	10.95	2.52	40.80	926.01	.80	.00
*	23.100	51.78	.00	21.46	1.25	.85	7.77	.31	41.30	168.48	.96	.00
*	23.100	53.99	.00	21.82	1.25	1.38	9.02	1.64	41.30	733.19	1.13	.00
	23.100	56.01	.00	18.34	1.25	2.05	9.28	2.46	41.30	956.17	1.24	.00
	24.000	55.06	.00	16.99	1.69	.00	6.98	.00	44.00	100.00	1.12	.00
	24.000	57.35	.00	21.45	1.69	.00	9.19	.00	44.00	100.00	1.01	.00
	24.000	58.88	.00	14.31	1.69	2.37	8.19	2.47	44.00	750.27	1.13	.00
*	24.100	55.00	.00	36.76	.00	.00	7.53	.00	44.00	94.19	.68	.00
*	24.100	57.21	.00	101.41	.00	.00	10.15	.00	44.00	100.00	.46	.00
*	24.100	57.18	.00	259.61	.00	.00	16.24	.00	44.00	100.00	.23	.00
	24.200	55.23	.00	34.03	.00	.00	7.33	.00	44.00	94.21	1.04	.00
	24.200	57.72	.00	101.41	.00	.00	10.15	.00	44.00	100.00	1.00	.00
	24.200	58.48	.00	259.61	.00	.00	16.24	.00	44.00	100.00	1.00	.00
*	25.000	55.41	.00	14.82	.00	.00	6.70	.00	44.00	100.00	1.52	.00
*	25.000	58.38	.00	15.81	.00	.00	8.38	.00	44.00	100.00	2.53	.00
*	25.000	63.63	.00	2.32	.00	1.49	4.09	1.57	44.00	917.97	10.59	.00
	26.000	55.70	59.56	27.27	2.80	1.07	8.47	.82	44.70	207.31	.74	.00
	26.000	59.34	59.56	11.98	2.80	1.63	7.25	1.79	44.70	656.67	1.15	.00
*	26.000	63.64	59.56	4.83	2.80	1.89	5.70	1.98	44.70	725.88	.69	.00

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WOODY CREEK

SUMMARY PRINTOUT TABLE 100

	SECNO	EGLWC	ELLC	EGPRS	ELTRD	QPR	QWEIR	CLASS	H3	DEPTH	CWSEL	VCH	EG
	5.000	55.96	57.00	.00	60.00	6000.00	.00	1.00	.18	11.24	55.24	6.84	55.96
	5.000	58.95	57.00	59.62	60.00	10000.00	.00	10.00	.37	14.56	58.56	8.27	59.62
*	5.000	61.54	57.00	64.69	60.00	12540.73	3388.55	30.00	.13	18.25	62.25	4.87	62.45

*	15.000	56.75	57.00	.00	60.00	6000.00	.00	59.00	.00	11.12	55.12	7.42	55.98
*	15.000	59.59	57.00	59.62	60.00	10000.00	.00	10.00	.00	14.39	58.39	8.90	59.62
*	15.000	62.33	57.00	64.68	60.00	12548.82	3442.20	30.00	.00	18.31	62.31	4.02	62.45

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WOODY CREEK

SUMMARY PRINTOUT TABLE 105

	SECNO	CWSEL	HL	OLOSS	TOPWID	QLOB	QCH	QROB

*	3.100	51.78	.83	.02	168.48	16.56	5981.34	2.10
*	3.100	53.99	.94	.02	733.19	554.42	8738.88	706.71
	3.100	56.00	.90	.05	955.84	2868.51	10697.73	2433.76

	4.000	55.06	3.04	.05	100.00	.00	6000.00	.00
	4.000	57.35	3.46	.10	100.00	.00	10000.00	.00
	4.000	58.89	2.59	.07	750.59	3260.18	10165.85	2573.97

	5.000	55.24	.15	.00	100.00	.00	6000.00	.00
	5.000	58.56	.96	.00	100.00	.00	10000.00	.00
*	5.000	62.25	2.87	.00	872.70	4789.71	7686.46	3523.82

	6.000	55.54	.53	.22	134.29	30.82	5969.18	.00
	6.000	59.51	.32	.15	668.13	1089.15	7330.64	1580.20
*	6.000	62.25	.13	.13	710.27	3187.18	8958.11	3854.71

*	13.100	51.78	.83	.02	168.48	16.56	5981.34	2.10
*	13.100	53.99	.99	.04	733.19	554.42	8738.88	706.71
	13.100	56.01	.90	.05	956.17	2885.87	10672.47	2441.66

	14.000	55.06	3.04	.05	100.00	.00	6000.00	.00
	14.000	57.35	3.46	.10	100.00	.00	10000.00	.00
	14.000	58.88	2.58	.07	750.27	3254.97	10174.60	2570.44

*	15.000	55.12	.12	.05	94.20	.00	6000.00	.00
	15.000	58.39	.96	.00	100.00	.00	10000.00	.00
*	15.000	62.31	2.87	.00	874.90	5705.60	6101.16	4193.24

	16.000	55.77	.75	.11	218.53	45.81	5921.15	33.04
*	16.000	59.75	.43	.21	682.08	1168.88	7152.66	1678.46
	16.000	62.31	.16	.15	710.92	3210.47	8915.18	3874.35

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SUMMARY OF ERRORS AND SPECIAL NOTES

NOTE	SECNO=	2.000	PROFILE=	1	WSEL BASED ON X5 CARD
NOTE	SECNO=	2.000	PROFILE=	2	WSEL BASED ON X5 CARD
NOTE	SECNO=	2.000	PROFILE=	3	WSEL BASED ON X5 CARD
NOTE	SECNO=	3.100	PROFILE=	1	WSEL BASED ON X5 CARD
NOTE	SECNO=	3.100	PROFILE=	2	WSEL BASED ON X5 CARD
WARNING	SECNO=	5.000	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	6.000	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
NOTE	SECNO=	13.100	PROFILE=	1	WSEL BASED ON X5 CARD
NOTE	SECNO=	13.100	PROFILE=	2	WSEL BASED ON X5 CARD
WARNING	SECNO=	15.000	PROFILE=	1	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	15.000	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	16.000	PROFILE=	2	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
NOTE	SECNO=	23.100	PROFILE=	1	WSEL BASED ON X5 CARD
NOTE	SECNO=	23.100	PROFILE=	2	WSEL BASED ON X5 CARD
WARNING	SECNO=	24.100	PROFILE=	1	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	24.100	PROFILE=	2	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	24.100	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	25.000	PROFILE=	1	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	25.000	PROFILE=	2	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	25.000	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING	SECNO=	26.000	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

Example No. 3

Input

```

T1      Example 3: Channel Improvement (CHIMP)
T2      1ST PROFILE IS NATURAL (IBW=8 on J2.8), (BW=.01 on CI.8)
T3      RABBIT CREEK
T4      (Example 3 based on test data file HEC212.DAT)
T5      Field 12 (Second field of second QT) read for discharge.
J1      12                                168.1
J2      1                                -1                                8
J3      120
*      Suppress detailed output, except for the last two cross sections.
J5      -10                               0                               2.2
NC      .120                               .120                               .037                               0.1                               0.3
QT      11                                450                                600                                900                                1200                                1500                                2300                                5000                                6700                                9400
QT 15000  25000

*      No CI input for first section; therefore, this section is always natural.
X1      1.05                               38                               18150                               18448                                1                                -.85
GR 200.0  12000                               180.0                               12200                               170.0                               13000                               170.0                               13200                               170.0                               13500
GR 170.0  14000                               170.0                               14400                               165.0                               14500                               170.0                               14600                               170.0                               15950
GR 165.0  18149                               165.0                               18150                               165.0                               18151                               165.0                               18168                               160.0                               18179
GR 149.0  18188                               155.0                               18201                               158.0                               18209                               159.8                               18229                               159.9                               18234
GR 159.9  18237                               160.0                               18255                               157.5                               18259                               157.0                               18260                               145.0                               18282
GR 144.8  18308                               144.8                               18309                               145.0                               18310                               145.0                               18324                               150.0                               18341
GR 155.0  18353                               162.0                               18364                               163.0                               18429                               164.0                               18447                               167.0                               18448
GR 172.8  18449                               180.0                               19250                               200.0                               20600

*      CI input provides center station, elevation, channel 'n' value, and
*      side slopes of 3 on 1.
X1      1.55                                1200                               1300                               3684                                3.14
CI 18300  147.09                               0.025                               3                                3                                10                                100                                300                                400

*      CI input of -1 provides center station and elevation based on existing cross
*      section. Blank fields indicate no change from previous CI input.
X1      1.82                                1400                               1250                               1450                                1.7
CI      -1                                -1                                0.025

*      No CI indicates no change from previous input.
X1      2.1                                1400                               1250                               1450                                1.76

*      CI input changes center station, elevation, 'n' value and side slopes.
X1      2.2                                528                               528                               528                                0.5
CI 18400  150                               0.015                               4                                2                                100                                100                                300                                400

*      The Channel improvement is stopped at this cross section. (BW = 0.01)
X1      2.3                                600                               600                               600                                1
CI      0.01                               0.01                                0.01                                0.01                                0.01
EJ
T1      CHANNEL IMPROVEMENT: IBW=6, BW=10 UNTIL SEC 2.2, BW=100 AT SEC 2.2
J1      12                                168.1
J2      2                                -1                                6                                30
T1      CHANNEL IMPROVEMENT: IBW=7, BW=100 and CHNIM=30 (J2.9)
J1      12                                168.1
J2      3                                -1                                7                                30
T1      CHANNEL IMPROVEMENT: IBW=9, BW=300 and CHNIM=20 (J2.9)
J1      12                                168.1
J2      4                                -1                                9                                20

```


ER

Output

```
*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 08:38:43 *
*****
```

```
*****
* 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 X X X
XXXXXXXX XXXX X XXXXX XXXXX
X X X X X X
X X X X X X X
X X XXXXXXX XXXXX XXXXXXX
```

END OF BANNER

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PAGE 1

THIS RUN EXECUTED 06FEB91 08:38:43

```
*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****
```

```
T1 Example 3: Channel Improvement (CHIMP)
T2 1ST PROFILE IS NATURAL (IBW=8 on J2.8), (BW=.01 on CI.8)
T3 RABBIT CREEK
T4 (Example 3 based on test data file HEC212.DAT)
T5 Field 12 (Second field of second QT) read for discharge.
```

```
J1 ICHECK INQ NINV IDIR STRT METRIC HVINS Q WSEL FQ
      12 168.1
J2 NPROF IPLOT PRFVS XSECV XSECH FN ALLDC IBW CHNIM ITRACE
      1 -1 8
```

```
J3 VARIABLE CODES FOR SUMMARY PRINTOUT
120
Supress detailed output, except for the last two cross sections.
```

```
J5 LPRNT NUMSEC *****REQUESTED SECTION NUMBERS*****
-10 0 2.2
```

```
NC .120 .120 .037 0.1 0.3
QT 11 450 600 900 1200 1500 2300 5000 6700 9400
QT 15000 25000
```

```
No CI input for first section; therefore, this section is always natural.
X1 1.05 38 18150 18448 1 - .85
GR 200.0 12000 180.0 12200 170.0 13000 170.0 13200 170.0 13500
GR 170.0 14000 170.0 14400 165.0 14500 170.0 14600 170.0 15950
GR 165.0 18149 165.0 18150 165.0 18151 165.0 18168 160.0 18179
GR 149.0 18188 155.0 18201 158.0 18209 159.8 18229 159.9 18234
GR 159.9 18237 160.0 18255 157.5 18259 157.0 18260 145.0 18282
GR 144.8 18308 144.8 18309 145.0 18310 145.0 18324 150.0 18341
GR 155.0 18353 162.0 18364 163.0 18429 164.0 18447 167.0 18448
GR 172.8 18449 180.0 19250 200.0 20600
```

CI input provides center station, elevation, channel 'n' value, and side slopes of 3 on 1.

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PAGE 2

X1	1.55				1200	1300	3684	3.14	
CI	18300	147.09	0.025	3	3	10	100	300	400

CI input of -1 provides center station and elevation based on existing cross section. Blank fields indicate no change from previous CI input.

X1	1.82				1400	1250	1450	1.7	
CI	-1	-1	0.025						

No CI indicates no change from previous input.

X1	2.1				1400	1250	1450	1.76	
----	-----	--	--	--	------	------	------	------	--

CI input changes center station, elevation, 'n' value and side slopes.

X1	2.2				528	528	528	0.5	
CI	18400	150	0.015	4	2	100	100	300	400

The Channel improvement is stopped at this cross section. (BW = 0.01)

X1	2.3				600	600	600	1	
CI					0.01	0.01	0.01	0.01	0.01

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		12							168.1	
J2	NPROF	IFLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
		3	-1					7	30	

*SECNO 2.200
 CHIMP CLSTA= 18400.00 CELCH= 150.00 BW= 100.00 STCHL= 18150.00 STCHR= 18509.18
 EXCAVATION DATA
 AEX= 2783.0SQ-FT VEXR= 38.0K*CU-YD VEXT= 156.7K*CU-YD

2136 NH VALUES .120 18120.000 .015 18539.180 .120 20600.000

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

2.200	21.12	171.12	.00	.00	171.54	.42	.09	.03	171.25
25000.0	.0	25000.0	.0	.0	4824.0	.0	762.7	129.7	179.59
.33	.00	5.18	.00	.000	.015	.000	.000	150.00	18168.29
.000080	528.	528.	528.	2	0	0	.00	323.95	18492.24

*SECNO 2.300

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = .26

2.300	17.27	169.32	.00	.00	172.48	3.16	.12	.82	172.25
25000.0	.0	25000.0	.0	.0	1752.7	.0	808.0	133.3	174.25
.34	.00	14.26	.00	.000	.015	.000	.000	152.05	18174.43
.001224	600.	600.	600.	3	0	0	.00	194.72	18369.15

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T1 CHANNEL IMPROVEMENT: IBW=9, BW=300 and CHNIM=20 (J2.9)

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
									168.1	
J2	NPROF	IPLT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	4		-1					9	20	

*SECNO 2.200
 CHIMP CLSTA= 18400.00 CELCH= 150.00 BW= 300.00 STCHL= 18150.00 STCHR= 18611.01
 EXCAVATION DATA
 AEX= 6658.3SQ-FT VEXR= 117.8K*CU-YD VEXT= 696.4K*CU-YD

2136 NH VALUES .120 18130.000 .015 18631.010 .120 20600.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.80

2.200	19.27	169.27	.00	.00	169.46	.20	.03	.00	171.25
25000.0	.0	25000.0	.0	.0	7022.6	.0	1137.8	113.7	180.51
.59	.00	3.56	.00	.000	.015	.000	.000	150.00	18172.38
.000031	528.	528.	528.	0	0	0	.00	416.14	18588.52

*SECNO 2.300

3301 HV CHANGED MORE THAN HVINS

3685 20 TRIALS ATTEMPTED WSEL,CWSEL

3693 PROBABLE MINIMUM SPECIFIC ENERGY

3720 CRITICAL DEPTH ASSUMED

2.300	16.04	168.09	168.09	.00	172.29	4.20	.06	1.20	172.25
25000.0	.0	25000.0	.0	.0	1520.3	.0	1196.6	117.8	174.25
.60	.00	16.44	.00	.000	.015	.000	.000	152.05	18177.15
.001840	600.	600.	600.	20	10	0	.00	185.03	18362.18

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THIS RUN EXECUTED 06FEB91 08:39:01

 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

RABBIT CREEK

SUMMARY PRINTOUT TABLE 120

	SECNO	CWSEL	EG	VCH	10*KS	DEPTH	TOPWID	CLSTA	BW	STCHL	XLBEL	STCHR	RBEL
	2.200	174.70	175.34	6.60	10.80	23.65	1956.44	.00	.01	18150.00	171.25	18448.00	173.25
*	2.200	173.23	173.54	4.48	.54	23.23	1313.75	18400.00	100.00	18150.00	171.25	18509.18	179.59
*	2.200	171.12	171.54	5.18	.80	21.12	323.95	18400.00	100.00	18150.00	171.25	18509.18	179.59
*	2.200	169.27	169.46	3.56	.31	19.27	416.14	18400.00	300.00	18150.00	171.25	18611.01	180.51
	2.300	175.35	176.05	6.90	12.27	23.30	1789.17	.00	.01	18150.00	172.25	18448.00	174.25
*	2.300	172.50	173.96	9.69	5.78	20.45	417.45	.00	.01	18150.00	172.25	18448.00	174.25
*	2.300	169.32	172.48	14.26	12.24	17.27	194.72	.00	.01	18150.00	172.25	18448.00	174.25
*	2.300	168.09	172.29	16.44	18.40	16.04	185.03	.00	.01	18150.00	172.25	18448.00	174.25

SUMMARY OF ERRORS AND SPECIAL NOTES

WARNING SECNO=	1.550	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=	1.550	PROFILE=	4	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=	2.200	PROFILE=	2	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=	2.200	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=	2.200	PROFILE=	4	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=	2.300	PROFILE=	2	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
WARNING SECNO=	2.300	PROFILE=	3	CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
CAUTION SECNO=	2.300	PROFILE=	4	CRITICAL DEPTH ASSUMED
CAUTION SECNO=	2.300	PROFILE=	4	PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=	2.300	PROFILE=	4	20 TRIALS ATTEMPTED TO BALANCE WSEL

Example No. 4

Input

```

T1      Example 4: Floodway Analysis, METHODS 1, 2, 3, 4 and 5.
T2      Existing conditions profile, no encroachment.
T3      NORTH BUFFALO CREEK
T4      (Data based on HEC214.DAT)
J1          2                                698.3
* Flow distribution requested for first profile (J2.10 = 15)
J2      1          -1                                15
* Floodway Summary Tables requested.
J3      110      115      200
* Detailed output suppressed. Flow distribution will be displayed.
J5      -10      -10
* Channel will be subdivided when 'n' values change within channel (J6.3 = -1)
J6          -1
NC      .12      .12      .055      .1      .3
* Discharge Table (QT) has 1% chance flow in all fields.
QT      7      8000      8000      8000      8000      8000      8000      8000

* First profile is natural, ET.2 is blank. (J1.2 = 2 reads QT & ET field 2)
* Method 1 encroachment stations are in fields 9 & 10 (ET.3 = 9.1)
* Method 2 is 250 foot wide floodway centered on channel (ET.4 = 250.2)
* Method 3 is a 12% conveyance reduction (ET.5 = 12.3)
* Method 4 is a one-foot rise to compute encroachments (ET.6 = 10.4)
* Method 5 is the same one-foot rise, but with multiple cycles (ET.7 = 10.5)
ET          9.1      250.2      12.3      10.4      10.5          360      610
X1 29900      23      460      508      0      0      0      1      0      0
GR 712.0      0      708.0      10      703.2      28      701.2      35      699.2      42
GR 697.2      57      695.2      71      693.2      110      691.2      150      691.0      400
GR 689.2      460      681.2      470      681.2      495      689.2      508      691.2      512
GR 693.2      530      695.2      563      697.2      570      699.2      580      701.2      595
GR 703.2      601      709.0      612      712.0      630

* Method 1 must be defined for each cross sections. The other methods continue
ET          9.1          145      385
NH      5      0.12      75      0.10      245      0.055      285      0.10      457      0.12
NH      590
X1 33700      22      245      285      3000      3000      3800      1      0      0
GR 713.0      0      709.2      20      705.2      35      703.2      50      701.2      63
GR 699.2      75      697.2      90      695.2      130      695.2      240      693.2      245
GR 685.0      250      685.0      280      693.2      285      695.2      292      695.2      410
GR 697.2      457      699.2      500      701.2      510      703.2      535      705.2      560
GR 708.7      573      713.0      590

ET          9.1          100      330
NH      6      0.12      48      0.10      115      0.04      140      0.06      160      0.10
NH      360      0.12      410
X1 35100      19      115      150      1000      1500      1400      1      0      0
GR 714.0      0      710.1      23      706.7      36      705.2      48      703.2      64
GR 701.2      76      699.2      92      689.2      115      686.0      116      686.0      136
GR 689.2      140      691.2      145      693.2      150      695.2      160      695.2      360
GR 697.2      370      699.2      375      709.2      395      714.2      410

ET          9.1          100      340
NC 0.12      0.12      0.055      0.1      0.3
X1 36950      22      193      233      1600      1600      1850      1      0      0
X3      10          705.5      705.5

```


GR 715.0	0	709.2	25	707.2	31	705.2	40	703.2	50
GR 701.2	61	699.2	87	697.2	180	693.2	193	688.0	198
GR 688.0	228	693.2	233	695.2	245	697.2	250	697.2	290
GR 699.2	310	701.2	370	703.2	410	705.2	445	707.2	465
GR 709.2	500	715.2	512						

SB	0.9	1.5	2.9	28	1.5	1050	2.4	688	688
----	-----	-----	-----	----	-----	------	-----	-----	-----

* A value of 0.01 added to input will transfer encroachment stations to the
 * BT record for weir flow calculations.

ET		9.11	250.21	12.31	10.41	10.51		100	340
X1 37000				50	50	50			
X2		1	704	706					
X3 10							706	706	
BT 16	0	715	715	25	712	709.2	31	710	707.2
BT 40	709	705.2	50	709	703.2	61	708.5	701.2	87
BT 706.5	699.2	180	706	697.2	290	706	697.2	310	706
BT 699.2	370	708	701.2	410	708.5	703.2	445	709	705.2
BT 465	710	707.2	500	712	709.2	512	715.2	715.2	

ET		9.1						100	340
X1 37110				110	110	110		0.2	

ET		9.1						10	240
X1 40150	22	95	145	2800	2800	3040			
GR 720.2	0	719.2	22	717.2	30	715.2	40	713.2	50
GR 711.2	58	709.2	70	699.2	95	693	105	693	135
GR 699.2	145	701.2	150	701.2	220	703.2	240	705.2	255
GR 707.2	270	709.2	290	711.2	310	713.2	325	715.2	350
GR 717.2	370	719.2	390						

EJ

T1	Method 1 floodway profile								
J1	3							699.3	
J2	2	-1							
T1	Method 2 floodway profile								
J1	4							699.3	
J2	3	-1							
T1	Method 3 floodway profile								
J1	5							699.3	
J2	4	-1							
T1	Method 4 floodway profile								
J1	6							699.3	
J2	5	-1							
T1	Method 5 floodway profile								
J1	7							699.3	
J2	6	-1							

ER

GR	689.2	460	681.2	470	681.2	495	689.2	508	691.2	512
GR	693.2	530	695.2	563	697.2	570	699.2	580	701.2	595
GR	703.2	601	709.0	612	712.0	630				

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PAGE 2

Method 1 must be defined for each cross sections. The other methods continue

ET			9.1						145	385
NH	5	0.12	75	0.10	245	0.055	285	0.10	457	0.12
NH	590									
X1	33700	22	245	285	3000	3000	3800	1	0	0
GR	713.0	0	709.2	20	705.2	35	703.2	50	701.2	63
GR	699.2	75	697.2	90	695.2	130	695.2	240	693.2	245
GR	685.0	250	685.0	280	693.2	285	695.2	292	695.2	410
GR	697.2	457	699.2	500	701.2	510	703.2	535	705.2	560
GR	708.7	573	713.0	590						

ET			9.1						100	330
NH	6	0.12	48	0.10	115	0.04	140	0.06	160	0.10
NH	360	0.12	410							
X1	35100	19	115	150	1000	1500	1400	1	0	0
GR	714.0	0	710.1	23	706.7	36	705.2	48	703.2	64
GR	701.2	76	699.2	92	689.2	115	686.0	116	686.0	136
GR	689.2	140	691.2	145	693.2	150	695.2	160	695.2	360
GR	697.2	370	699.2	375	709.2	395	714.2	410		

ET			9.1						100	340
NC	0.12	0.12	0.055	0.1	0.3					
X1	36950	22	193	233	1600	1600	1850	1	0	0
X3	10							705.5	705.5	
GR	715.0	0	709.2	25	707.2	31	705.2	40	703.2	50
GR	701.2	61	699.2	87	697.2	180	693.2	193	688.0	198
GR	688.0	228	693.2	233	695.2	245	697.2	250	697.2	290
GR	699.2	310	701.2	370	703.2	410	705.2	445	707.2	465
GR	709.2	500	715.2	512						

SB	0.9	1.5	2.9		28	1.5	1050	2.4	688	688
----	-----	-----	-----	--	----	-----	------	-----	-----	-----

A value of 0.01 added to input will transfer encroachment stations to the BT record for weir flow calculations.

ET			9.11	250.21	12.31	10.41	10.51		100	340
X1	37000				50	50	50			
X2		1	704	706						
X3	10							706	706	
BT	16	0	715	715	25	712	709.2	31	710	707.2
BT	40	709	705.2	50	709	703.2	61	708.5	701.2	87
BT	706.5	699.2	180	706	697.2	290	706	697.2	310	706
BT	699.2	370	708	701.2	410	708.5	703.2	445	709	705.2
BT	465	710	707.2	500	712	709.2	512	715.2	715.2	

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ET			9.1						100	340
X1	37110			110	110	110			0.2	
ET			9.1						10	240
X1	40150	22	95	145	2800	2800	3040			
GR	720.2	0	719.2	22	717.2	30	715.2	40	713.2	50
GR	711.2	58	709.2	70	699.2	95	693	105	693	135
GR	699.2	145	701.2	150	701.2	220	703.2	240	705.2	255
GR	707.2	270	709.2	290	711.2	310	713.2	325	715.2	350
GR	717.2	370	719.2	390						

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SECNO	DEPTH	CWSEL	CRWS	WSELK	EG	HV	HL	OLOSS	L-BANK	ELEV			
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK	ELEV			
TIME	VLOB	VCH	VROB	XLN	XNCH	XNR	WTN	ELMIN	SSTA				
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST				
FLOW DISTRIBUTION FOR SECNO= 29900.00 CWSEL= 698.30													
STA=	49.	57.	71.	110.	150.	400.	460.	508.	512.	530.	563.	570.	575.
PER Q=	.0	.2	2.1	4.1	33.6	10.0	45.7	.6	1.8	1.7	.1	.0	
AREA=	4.5	29.4	159.9	244.0	1800.0	492.0	728.8	32.4	109.8	135.3	14.7	3.0	
VEL=	.3	.7	1.0	1.3	1.5	1.6	5.0	1.5	1.3	1.0	.6	.3	
DEPTH=	.5	2.1	4.1	6.1	7.2	8.2	15.2	8.1	6.1	4.1	2.1	.5	
FLOW DISTRIBUTION FOR SECNO= 33700.00 CWSEL= 702.17													
STA=	57.	130.	240.	245.	285.	410.	457.	522.					
PER Q=	6.5	18.7	1.0	43.6	21.5	6.2	2.6						
AREA=	325.1	766.8	39.9	645.8	878.4	280.6	196.4						
VEL=	1.6	1.9	2.0	5.4	2.0	1.8	1.0						
DEPTH=	4.4	7.0	8.0	16.1	7.0	6.0	3.0						
FLOW DISTRIBUTION FOR SECNO= 35100.00 CWSEL= 703.67													
STA=	60.	115.	140.	150.	160.	360.	384.						
PER Q=	6.3	39.5	6.3	4.1	41.7	1.9							
AREA=	291.6	433.6	124.7	94.7	1693.2	121.9							
VEL=	1.7	7.3	4.0	3.5	2.0	1.3							
DEPTH=	5.3	17.3	12.5	9.5	8.5	5.1							

FLOW DISTRIBUTION FOR SECNO= 36950.00 CWSSEL= 705.70

STA=	38.	87.	180.	193.	233.	245.	290.	310.	370.	450.
PER Q=	3.2	15.4	3.7	52.9	4.0	9.3	3.3	5.9	2.3	
AREA=	197.2	697.8	136.5	682.1	138.0	387.7	150.1	330.2	194.0	
VEL=	1.3	1.8	2.1	6.2	2.3	1.9	1.8	1.4	.9	
DEPTH=	4.0	7.5	10.5	17.1	11.5	8.6	7.5	5.5	2.4	

FLOW DISTRIBUTION FOR SECNO= 37000.00 CWSSEL= 706.66

STA=	33.	87.	180.	193.	233.	245.	290.	310.	370.	445.	460.
PER Q=	3.8	16.1	3.6	49.7	3.9	9.5	3.5	6.6	3.2	.0	
AREA=	246.4	786.7	149.0	720.4	149.5	430.7	169.2	387.6	264.5	10.7	
VEL=	1.2	1.6	1.9	5.5	2.1	1.8	1.6	1.4	1.0	.3	
DEPTH=	4.6	8.5	11.5	18.0	12.5	9.6	8.5	6.5	3.5	.7	

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SECNO	DEPTH	CWSSEL	CRISW	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

FLOW DISTRIBUTION FOR SECNO= 37110.00 CWSSEL= 706.77

STA=	34.	87.	180.	193.	233.	245.	290.	310.	370.	445.	459.
PER Q=	3.7	16.1	3.6	50.0	3.9	9.5	3.4	6.6	3.1		.0
AREA=	241.5	778.2	147.8	716.7	148.4	426.6	167.4	382.1	257.6		9.4
VEL=	1.2	1.7	2.0	5.6	2.1	1.8	1.6	1.4	1.0		.3
DEPTH=	4.5	8.4	11.4	17.9	12.4	9.5	8.4	6.4	3.4		.7

FLOW DISTRIBUTION FOR SECNO= 40150.00 CWSSEL= 710.46

STA=	62.	70.	95.	145.	150.	220.	240.	255.	270.	290.	303.
PER Q=	.0	3.2	69.1	1.5	18.2	4.3	2.0	1.1	.5		.0
AREA=	4.7	156.4	810.8	51.3	647.9	165.1	93.8	63.8	45.1		7.9
VEL=	.4	1.7	6.8	2.3	2.3	2.1	1.7	1.3	.9		.4
DEPTH=	.6	6.3	16.2	10.3	9.3	8.3	6.3	4.3	2.3		.6

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T1 Method 1 floodway profile

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
									699.3	
		3								
J2	NPROF	IPLLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
		2		-1						

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T1 Method 2 floodway profile

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
									699.3	
		4								
J2	NPROF	IPLLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
		3		-1						

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T1 Method 3 floodway profile

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
									699.3	
		5								
J2	NPROF	IPLLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
		4		-1						

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T1 Method 4 floodway profile

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
									699.3	
		6								
J2	NPROF	IPLLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
		5		-1						

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T1 Method 5 floodway profile

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		7							699.3	
J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	6		-1							

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THIS RUN EXECUTED 06FEB91 09:22:14

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

NORTH BUFFALO CREEK

SUMMARY PRINTOUT TABLE 110

SECNO	CWSEL	DIFKWS	EG	TOPWID	QLOB	QCH	QROB	PERENC	STENCL	STCHL	STCHR	STENCR
29900.000	698.30	.00	698.50	526.75	4001.78	3654.36	343.85	.00	.00	460.00	508.00	.00
29900.000	699.30	1.00	699.84	220.75	1939.17	5432.97	627.85	250.00	360.00	460.00	508.00	610.00
29900.000	699.30	1.00	699.83	221.75	1952.64	5420.90	626.46	250.00	359.00	460.00	508.00	609.00
29900.000	699.30	1.00	699.49	352.80	4284.74	3715.26	.00	.12	155.20	460.00	508.00	508.00
29900.000	699.30	1.00	699.50	335.10	4170.57	3829.43	.00	.16	172.90	460.00	508.00	508.00
29900.000	699.30	1.00	699.48	364.84	4373.39	3626.61	.00	.10	143.16	460.00	508.00	508.00
33700.000	702.17	.00	702.40	465.45	2091.73	3490.15	2418.12	.00	.00	245.00	285.00	.00
33700.000	704.54	2.37	704.82	240.00	1954.04	4082.66	1963.30	240.00	145.00	245.00	285.00	385.00
33700.000	704.46	2.29	704.72	250.00	1998.17	3994.61	2007.22	250.00	140.00	245.00	285.00	390.00
33700.000	703.16	.99	703.41	304.61	1928.63	3735.99	2335.38	.12	126.51	245.00	285.00	431.12
33700.000	703.33	1.16	703.60	289.24	1872.39	3832.96	2294.65	.17	131.68	245.00	285.00	420.92
33700.000	703.17	1.00	703.45	287.74	1863.63	3876.30	2260.06	.15	131.64	245.00	285.00	419.38
35100.000	703.67	.00	704.01	323.66	507.39	3666.99	3825.61	.00	.00	115.00	150.00	.00
35100.000	705.78	2.11	706.09	230.00	315.53	3872.88	3811.59	230.00	100.00	115.00	150.00	330.00
35100.000	705.75	2.08	706.23	213.89	809.26	4513.06	2677.68	250.00	7.50	115.00	150.00	257.50
35100.000	704.60	.94	705.00	232.61	10.41	4018.62	3970.97	.12	113.71	115.00	150.00	346.32
35100.000	705.01	1.34	705.28	228.61	.00	3501.73	4498.27	.14	115.00	115.00	150.00	343.61
35100.000	704.66	1.00	705.04	237.98	53.17	3958.12	3988.72	.11	111.28	115.00	150.00	349.27
36950.000	705.70	.00	706.04	412.30	1779.05	4234.96	1986.00	.00	.00	193.00	233.00	.00
36950.000	707.35	1.65	707.68	240.00	1617.12	4462.44	1920.43	240.00	100.00	193.00	233.00	340.00
36950.000	707.72	2.02	708.02	250.00	1783.99	4326.31	1889.70	250.00	88.00	193.00	233.00	338.00
36950.000	706.65	.95	707.05	229.07	1563.86	4645.78	1790.36	.12	101.86	193.00	233.00	330.93
36950.000	707.04	1.34	707.42	227.30	1551.59	4602.02	1846.39	.15	105.09	193.00	233.00	332.39
36950.000	706.70	1.00	707.17	194.52	1407.98	4905.23	1686.79	.17	117.78	193.00	233.00	312.30
37000.000	706.66	.00	706.91	426.17	1881.13	3978.04	2140.83	.00	.00	193.00	233.00	.00
37000.000	707.83	1.18	708.14	240.00	1647.94	4394.24	1957.82	240.00	100.00	193.00	233.00	340.00
37000.000	708.11	1.45	708.38	250.00	1810.97	4272.79	1916.24	250.00	88.00	193.00	233.00	338.00
37000.000	707.26	.60	707.61	229.07	1609.10	4551.35	1839.55	.12	101.86	193.00	233.00	330.93
37000.000	707.57	.91	707.91	227.30	1586.74	4525.46	1887.79	.14	105.09	193.00	233.00	332.39
37000.000	707.26	.60	707.68	194.52	1444.69	4825.89	1729.42	.05	117.78	193.00	233.00	312.30

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SECNO	CWSEL	DIFKWS	EG	TOPWID	QLOB	QCH	QROB	PERENC	STENCL	STCHL	STCHR	STENCR
37110.000	706.77	.00	707.03	424.84	1872.14	4001.12	2126.73	.00	.00	193.00	233.00	.00
37110.000	707.94	1.17	708.25	240.00	1642.70	4405.85	1951.45	240.00	100.00	193.00	233.00	340.00
37110.000	708.20	1.44	708.48	250.00	1804.34	4285.95	1909.71	250.00	88.00	193.00	233.00	338.00
37110.000	707.41	.65	707.74	247.14	1635.34	4435.28	1929.38	.12	96.79	193.00	233.00	343.93
37110.000	707.72	.95	708.03	249.14	1632.20	4379.98	1987.82	.14	98.22	193.00	233.00	347.36
37110.000	707.61	.84	707.82	404.35	1944.35	3809.06	2246.59	.00	41.25	193.00	233.00	445.60
40150.000	710.46	.00	710.98	240.09	259.86	5530.99	2209.15	.00	.00	95.00	145.00	.00
40150.000	711.41	.95	711.90	182.82	311.72	5658.96	2029.32	230.00	10.00	95.00	145.00	240.00
40150.000	711.42	.96	711.89	187.86	307.58	5575.27	2117.15	250.00	.01	95.00	145.00	245.00
40150.000	711.65	1.19	712.20	127.22	.00	5886.32	2113.68	.12	95.00	95.00	145.00	222.22
40150.000	711.72	1.27	712.27	126.45	.00	5885.04	2114.96	.13	95.00	95.00	145.00	221.45
* 40150.000	711.37	.91	712.72	51.53	.00	7982.71	17.29	.31	95.00	95.00	145.00	146.53

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SUMMARY OF ERRORS AND SPECIAL NOTES

WARNING SECNO= 40150.000 PROFILE= 6 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

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Floodway width summary: NORTH BUFFALO CREEK
Profile No. 2

Section Number	Elevation Increase	Top Width	Left Sta		Right Sta		Right Encroach Station
			Left Encroach Station	Distance From Center	Center Station	Distance From Center	
29900.000	1.00	250.00	360.00	124.00	484.00	126.00	610.00
33700.000	2.37	240.00	145.00	120.00	265.00	120.00	385.00
35100.000	2.11	230.00	100.00	32.50	132.50	197.50	330.00
36950.000	1.65	240.00	100.00	113.00	213.00	127.00	340.00
37000.000	1.18	240.00	100.00	113.00	213.00	127.00	340.00
37110.000	1.17	240.00	100.00	113.00	213.00	127.00	340.00
40150.000	.95	230.00	10.00	110.00	120.00	120.00	240.00

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Floodway width summary: NORTH BUFFALO CREEK
Profile No. 3

Section Number	Elevation Increase	Top Width	Left Sta		Right Sta		Right Encroach Station
			Encroach Station	Distance From Center	Distance From Center	Encroach Station	
29900.000	1.00	250.00	359.00	125.00	484.00	125.00	609.00
33700.000	2.29	250.00	140.00	125.00	265.00	125.00	390.00
35100.000	2.08	250.00	7.50	125.00	132.50	125.00	257.50
36950.000	2.02	250.00	88.00	125.00	213.00	125.00	338.00
37000.000	1.45	250.00	88.00	125.00	213.00	125.00	338.00
37110.000	1.44	250.00	88.00	125.00	213.00	125.00	338.00
40150.000	.96	244.99	.01	119.99	120.00	125.00	245.00

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Floodway width summary: NORTH BUFFALO CREEK
Profile No. 4

Section Number	Elevation Increase	Top Width	Left Sta		Right Sta		Right Encroach Station
			Encroach Station	Distance From Center	Distance From Center	Encroach Station	
29900.000	1.00	352.80	155.20	328.80	484.00	24.00	508.00
33700.000	.99	304.61	126.51	138.49	265.00	166.12	431.12
35100.000	.94	232.61	113.71	18.79	132.50	213.82	346.32
36950.000	.95	229.07	101.86	111.14	213.00	117.93	330.93
37000.000	.60	229.07	101.86	111.14	213.00	117.93	330.93
37110.000	.65	247.14	96.79	116.21	213.00	130.93	343.93
40150.000	1.19	127.22	95.00	25.00	120.00	102.22	222.22

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Floodway width summary: NORTH BUFFALO CREEK
Profile No. 5

Section Number	Elevation Increase	Top Width	Left Sta		Right Sta		Right Encroach Station
			Encroach Station	Distance From Center	Distance From Center	Encroach Station	
29900.000	1.00	335.11	172.90	311.10	484.00	24.00	508.00
33700.000	1.16	289.24	131.68	133.32	265.00	155.92	420.92
35100.000	1.34	228.61	115.00	17.50	132.50	211.11	343.61
36950.000	1.34	227.30	105.09	107.91	213.00	119.39	332.39
37000.000	.91	227.30	105.09	107.91	213.00	119.39	332.39
37110.000	.95	249.14	98.22	114.78	213.00	134.36	347.36
40150.000	1.27	126.45	95.00	25.00	120.00	101.45	221.45

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Floodway width summary: NORTH BUFFALO CREEK
Profile No. 6

Section Number	Elevation Increase	Top Width	Left Sta		Right Sta		Right Encroach Station
			Encroach Station	Distance From Center	Distance From Center	Encroach Station	
29900.000	1.00	364.84	143.16	340.84	484.00	24.00	508.00
33700.000	1.00	287.74	131.64	133.36	265.00	154.38	419.38

35100.000	1.00	237.99	111.28	21.22	132.50	216.77	349.27
36950.000	1.00	194.52	117.78	95.22	213.00	99.30	312.30
37000.000	.60	194.52	117.78	95.22	213.00	99.30	312.30
37110.000	.84	404.35	41.25	171.75	213.00	232.60	445.60
40150.000	.91	51.53	95.00	25.00	120.00	26.53	146.53

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FLOODWAY DATA, NORTH BUFFALO CREEK
PROFILE NO. 2

STATION	----- FLOODWAY -----			WATER SURFACE ELEVATION		
	WIDTH	SECTION AREA	MEAN VELOCITY	WITH FLOODWAY	WITHOUT FLOODWAY	DIFFERENCE
29900.000	221.	2025.	3.9	699.3	698.3	1.0
33700.000	240.	2619.	3.1	704.6	702.2	2.4
35100.000	230.	2746.	2.9	705.8	703.7	2.1
36950.000	240.	2684.	3.0	707.3	705.7	1.6
37000.000	240.	2798.	2.9	707.9	706.7	1.2
37110.000	240.	2778.	2.9	708.0	706.8	1.2
40150.000	183.	2008.	4.0	711.4	710.5	.9

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FLOODWAY DATA, NORTH BUFFALO CREEK
PROFILE NO. 3

STATION	FLOODWAY			WATER SURFACE ELEVATION		
	WIDTH	SECTION AREA	MEAN VELOCITY	WITH FLOODWAY	WITHOUT FLOODWAY	DIFFERENCE
29900.000	222.	2034.	3.9	699.3	698.3	1.0
33700.000	250.	2692.	3.0	704.5	702.2	2.3
35100.000	214.	2198.	3.6	705.7	703.7	2.0
36950.000	250.	2860.	2.8	707.7	705.7	2.0
37000.000	250.	2955.	2.7	708.1	706.7	1.4
37110.000	250.	2931.	2.7	708.2	706.8	1.4
40150.000	188.	2049.	3.9	711.4	710.5	.9

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FLOODWAY DATA, NORTH BUFFALO CREEK
PROFILE NO. 4

STATION	FLOODWAY			WATER SURFACE ELEVATION		
	WIDTH	SECTION AREA	MEAN VELOCITY	WITH FLOODWAY	WITHOUT FLOODWAY	DIFFERENCE
29900.000	353.	3337.	2.4	699.3	698.3	1.0
33700.000	305.	2794.	2.9	703.2	702.2	1.0
35100.000	233.	2467.	3.2	704.6	703.7	.9
36950.000	229.	2439.	3.3	706.7	705.7	1.0
37000.000	229.	2579.	3.1	707.3	706.7	.6
37110.000	247.	2703.	3.0	707.4	706.8	.6
40150.000	127.	1682.	4.8	711.7	710.5	1.2

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FLOODWAY DATA, NORTH BUFFALO CREEK
PROFILE NO. 5

STATION	FLOODWAY			WATER SURFACE ELEVATION		
	WIDTH	SECTION AREA	MEAN VELOCITY	WITH FLOODWAY	WITHOUT FLOODWAY	DIFFERENCE
29900.000	335.	3193.	2.5	699.3	698.3	1.0
33700.000	289.	2728.	2.9	703.3	702.2	1.1
35100.000	229.	2513.	3.2	705.0	703.7	1.3
36950.000	227.	2513.	3.2	707.0	705.7	1.3
37000.000	227.	2632.	3.0	707.6	706.7	.9
37110.000	249.	2790.	2.9	707.7	706.8	.9
40150.000	126.	1684.	4.8	711.7	710.5	1.2

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FLOODWAY DATA, NORTH BUFFALO CREEK
PROFILE NO. 6

STATION	FLOODWAY			WATER SURFACE ELEVATION		
	WIDTH	SECTION AREA	MEAN VELOCITY	WITH FLOODWAY	WITHOUT FLOODWAY	DIFFERENCE
29900.000	365.	3433.	2.3	699.3	698.3	1.0
33700.000	288.	2671.	3.0	703.2	702.2	1.0
35100.000	238.	2545.	3.1	704.7	703.7	1.0
36950.000	195.	2191.	3.7	706.7	705.7	1.0
37000.000	195.	2300.	3.5	707.3	706.7	.6
37110.000	404.	3601.	2.2	707.6	706.8	.8

40150.000 52. 875. 9.1 711.4 710.5 .9

Example No. 5

Input

```

SF      Example 5:  SPLIT FLOW data are entered first
TW      Right bank levee between Sections 3 and 4
WS      2          3          4          -1          3.4
WC      26         460        28
TW      Right bank floodway over-flow weir between Sections 2 and 3
WS      2          2          3          -1          2.7
WC      19         370        21
TW      Right bank levee between Sections 1 and 2
WS      2          1          2          -1          3.4
WC      19         520        24
EE
T1      Example 5:  SPLIT FLOW reach data follow Split Flow EE record
T2      One profile with 40,000 cfs
T3      RED FOX RIVER
J1      0          .005          40000          20          0
* NC only used to define contraction and expansion coefficients
NC      0          0          0          .1          .3
* NH record used to define Manning's 'n' values for Section 1
NH      5          .1          415          .050          650          .030          710          .050          1020          .1
NH      1635
X1      1          11          650          710          0          0          0
X3      622          752
GR      25         20          18          110          17          415          14          650          1          675
GR      0          690          1          710          13          710          14          1020          14          1590
GR      25         1635
NH      4          .100          415          .050          575          .030          640          .100          1250
X1      2          10          575          640          600          600          600
X3      525          735
GR      25         30          20          110          20          200          17          415          10          575
GR      4          580          4          615          18          640          18          1195          25          1250
NC      .100          .050          .030
X1      3          10          390          600          500          500          500
X3      390          600
X4      1          17.2          390
GR      25         40          22          260          18.7          370          15          420          7.1          500
GR      7.5         530          17.3          560          20          600          22          850          25          875
NH      5          .100          130          .050          330          .036          460          .050          610          .100
NH      700
X1      4          8          330          460          700          700          700
X3      300          600
GR      26         30          24          130          23          330          9.5          370          10          400
GR      22         460          22          610          26          700
EJ
ER

```

Output

```
*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 11:02:02 *
*****
```

```
*****
* 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 X X X
XXXXXX XXXX X XXXXX XXXXX
X X X X X X
X X X X X X
X X XXXXXXX XXXXX XXXXXXX

```

END OF BANNER

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PAGE 1

THIS RUN EXECUTED 06FEB91 11:02:02

```
*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****
```

SPLIT FLOW BEING PERFORMED

SF Example 5: SPLIT FLOW data are entered first

TW Right bank levee between Sections 3 and 4
 WS 2 3 4 -1 3.4
 WC 26 460 28

TW Right bank floodway over-flow weir between Sections 2 and 3
 WS 2 2 3 -1 2.7
 WC 19 370 21

TW Right bank levee between Sections 1 and 2
 WS 2 1 2 -1 3.4
 WC 19 520 24

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PAGE 2

T1 Example 5: SPLIT FLOW reach data follow Split Flow EE record
 T2 One profile with 40,000 cfs
 T3 RED FOX RIVER

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0				.005			40000	20	0
NC only used to define contraction and expansion coefficients										
NC	0	0	0	.1	.3					
NH record used to define Manning's 'n' values for Section 1										
NH	5	.1	415	.050	650	.030	710	.050	1020	.1
NH	1635									
X1	1	11	650	710	0	0	0			
X3				622		752				
GR	25	20	18	110	17	415	14	650	1	675
GR	0	690	1	710	13	710	14	1020	14	1590
GR	25	1635								
NH	4	.100	415	.050	575	.030	640	.100	1250	

X1	2	10	575	640	600	600	600			
X3				525		735				
GR	25	30	20	110	20	200	17	415	10	575
GR	4	580	4	615	18	640	18	1195	25	1250
NC	.100	.050	.030							
X1	3	10	390	600	500	500	500			
X3				390		600				
X4	1	17.2	390							
GR	25	40	22	260	18.7	370	15	420	7.1	500
GR	7.5	530	17.3	560	20	600	22	850	25	875
NH	5	.100	130	.050	330	.036	460	.050	610	.100
NH	700									
X1	4	8	330	460	700	700	700			
X3				300		600				
GR	26	30	24	130	23	330	9.5	370	10	400
GR	22	460	22	610	26	700				

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

*PROF 1

CCHV= .100 CEHV= .300

1490 NH CARD USED

*SECNO 1.000

3470 ENCROACHMENT STATIONS=	622.0	752.0	TYPE=	1	TARGET=	130.000				
1.000	20.42	20.42	.00	20.00	25.84	5.42	.00	.00	14.00	
23659.0	1094.2	20355.7	2209.1	174.7	1020.1	308.7	.0	.0	13.00	
.00	6.26	19.95	7.16	.050	.030	.050	.000	.00	622.00	
.005018	0.	0.	0.	0	0	3	.00	130.00	752.00	

1490 NH CARD USED

*SECNO 2.000

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.53

3470 ENCROACHMENT STATIONS=	525.0	735.0	TYPE=	1	TARGET=	210.000				
2.000	20.95	24.95	.00	.00	28.13	3.18	2.06	.22	10.00	
25930.6	5180.5	19016.8	1733.3	693.4	1172.5	661.4	27.8	2.3	18.00	
.01	7.47	16.22	2.62	.050	.030	.100	.000	4.00	525.00	
.002571	600.	600.	600.	2	0	0	.00	210.00	735.00	

*SECNO 3.000

3280 CROSS SECTION 3.00 EXTENDED 1.49 FEET

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.49

3470 ENCROACHMENT STATIONS=	390.0	600.0	TYPE=	1	TARGET=	210.000				
3.000	19.39	26.49	.00	.00	29.47	2.98	1.32	.02	17.20	
39615.7	.0	39615.7	.0	.0	2858.5	.0	58.7	4.8	100000.00	
.02	.00	13.86	.00	.000	.030	.000	.000	7.10	390.00	
.002686	500.	500.	500.	3	0	0	.00	210.00	600.00	

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

1490 NH CARD USED

*SECNO 4.000

3280 CROSS SECTION 4.00 EXTENDED 2.30 FEET

3301 HV CHANGED MORE THAN HVINS

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = .67

3470 ENCROACHMENT STATIONS=	300.0	600.0	TYPE=	1	TARGET=	300.000				
4.000	18.80	28.30	.00	.00	32.59	4.29	2.73	.39	23.00	
40000.0	987.1	32222.0	6790.9	156.7	1776.5	882.0	104.3	8.8	22.00	
.03	6.30	18.14	7.70	.050	.036	.050	.000	9.50	300.00	
.006117	700.	700.	700.	3	0	0	.00	300.00	600.00	

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TW Right bank levee between Sections 3 and 4

ASQ	QCOMP	ERRAC	TASQ	TCQ	TABER	NITER	DSWS	USWS	DSSNO	USSNO
384.29	387.88	.93	384.29	387.88	.93	17	26.487	28.299	3.000	4.000

TW Right bank floodway over-flow weir between Sections 2 and 3

ASQ	QCOMP	ERRAC	TASQ	TCQ	TABER	NITER	DSWS	USWS	DSSNO	USSNO
13685.15	13670.57	.11	14069.44	14058.45	.08	17	24.954	26.487	2.000	3.000

TW Right bank levee between Sections 1 and 2

ASQ	QCOMP	ERRAC	TASQ	TCQ	TABER	NITER	DSWS	USWS	DSSNO	USSNO
2271.58	2296.01	1.07	16341.03	16354.46	.08	17	20.419	24.954	1.000	2.000

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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

RED FOX RIVER

SUMMARY PRINTOUT TABLE 150

SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRWS	EG	10*KS	VCH	AREA	.01K
1.000	.00	.00	.00	.00	23658.97	20.42	.00	25.84	50.18	19.95	1503.61	3339.84
* 2.000	600.00	.00	.00	4.00	25930.56	24.95	.00	28.13	25.71	16.22	2527.26	5113.90
* 3.000	500.00	.00	.00	7.10	39615.71	26.49	.00	29.47	26.86	13.86	2858.55	7644.48
* 4.000	700.00	.00	.00	9.50	40000.00	28.30	.00	32.59	61.17	18.14	2815.18	5114.48

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RED FOX RIVER

SUMMARY PRINTOUT TABLE 150

SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
1.000	23658.97	20.42	.00	.00	.42	130.00	.00
* 2.000	25930.56	24.95	.00	4.54	.00	210.00	600.00
* 3.000	39615.71	26.49	.00	1.53	.00	210.00	500.00
* 4.000	40000.00	28.30	.00	1.81	.00	300.00	700.00

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SUMMARY OF ERRORS AND SPECIAL NOTES

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

WARNING SECNO= 3.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

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

Appendix II

Floodway Encroachment Calculations

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Appendix II

Floodway Encroachment Calculations

1 Introduction

The evaluation of the impact of floodplain encroachments on water surface profiles can be of substantial interest to planners, land developers, and engineers. It is also a significant aspect of flood insurance studies. HEC-2 contains six optional methods for specifying floodplain encroachments. Each method is illustrated in the following paragraphs. Also program options related to encroachment determinations, data organization, and encroachment output will be covered.

2 Encroachment Method 1

With Method 1 the user specifies the exact location of the encroachment for a given cross section. Stations and elevations which apply to all profiles of the left and/or right encroachment, are specified on the X3 record for individual cross sections as desired. Encroachment stations for individual cross sections can also be specified differently for each profile by using the ET record. A 9.1 in the INQ field (J1.2) of the ET record would indicate that Method 1 is being used (for current cross section only), and the left and right encroachment stations are specified on Fields 9 and 10 of the ET record.

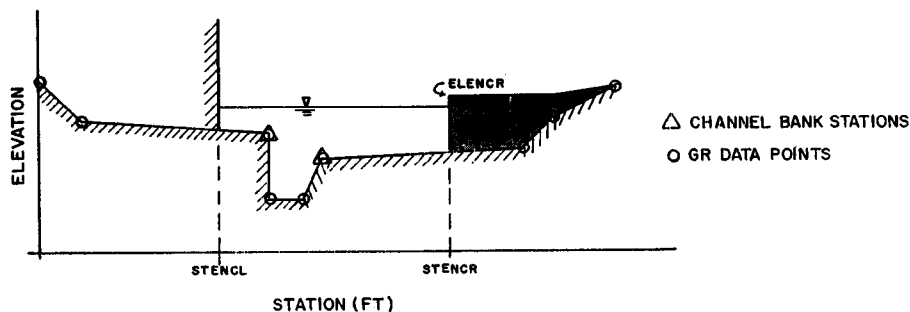


Figure 1
Encroachment Method 1

3 Encroachment Method 2

Method 2 utilizes a fixed top width. The top width (ENCFP) can be specified on an ET or X3 record which will be used for the current and **all subsequent cross sections** until changed by another X3 or ET record. The left and right encroachment stations are made equal distance from the centerline of the

channel, which is halfway between the left and right bank stations. A 200.2 in the INQ (J1.2) of the ET record would indicate a 200 foot width will be used for Method 2. No provision is made to insure that all of the channel area is retained as flow area.

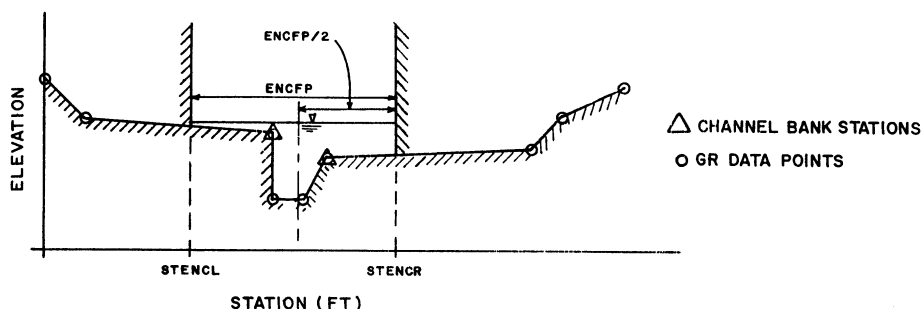


Figure 2
Encroachment Method 2

4 Encroachment Method 3

Method 3 calculates encroachment stations for a specified percent reduction (PERENC) in the natural conveyance of each cross section. One-half of PERENC is eliminated on each side of the cross section (if possible) as long as the encroachments do not infringe on the main channel. If one-half PERENC exceeds either overbank conveyance, the program will attempt to make up the difference on the other side. If the percent reduction in cross section conveyance cannot be accommodated by both overbank areas combined, the encroachment stations are made equal to the

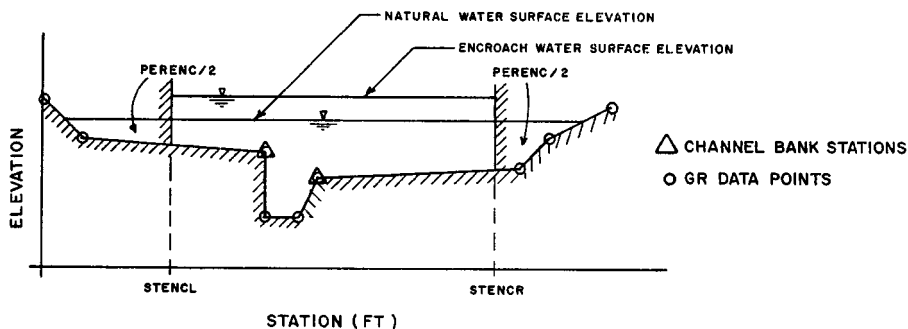


Figure 3
Encroachment Method 3

stations of left and right channel banks. This method requires that the first profile (of a multiple profile run) must be a natural (unencroached) profile. Subsequent profiles of multiple profile runs may be utilized for Method 3 encroachments. The amount of conveyance reduction is requested by percentages specified on the ET record. The percentage can be changed by inserting another ET record ahead of the appropriate cross section. A 10.3 in the INQ field (J1.2) of the ET record for the second profile would indicate that 10 percent of the conveyance based on the natural profile (first profile) will be eliminated - 5 percent from each overbank. An alternate scheme to **equal** conveyance reduction is conveyance

reduction in **proportion** to the distribution of natural overbank conveyance. For instance, if the natural cross section had twice as much conveyance in the left overbank as in the right overbank, a 10.3 value would reduce 5 percent conveyance in each overbank, whereas a -10.3 value would reduce 6.7 percent from the left overbank and 3.3 percent from the right overbank.

5 Encroachment Method 4

Method 4 computes encroachment stations so that conveyance within the encroached cross section (at some higher elevation) is equal to the conveyance of the natural cross section at the natural water level. This higher elevation is specified as a fixed amount above the natural (e.g., 100 year) profile. The encroachment stations are determined so that an equal loss of conveyance (at the higher elevation) occurs on each overbank, if possible. If half of the loss cannot be obtained in one overbank, the difference will be made up, if possible, in the other overbank, except that encroachments will not be allowed to fall within the main channel.

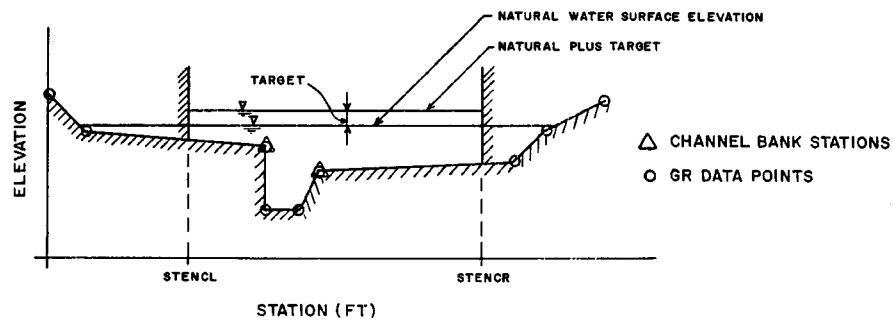


Figure 4
Encroachment Method 4

A 10.4 in the INQ field (J1.2) of the ET record indicates that a 1 foot rise (value is in tenths of a foot on the left side of the decimal point) will be used to determine the encroachments based on equal conveyance. An alternate scheme to **equal** conveyance reduction is to reduce conveyance in **proportion** to the distribution of natural overbank conveyance (a value of -10.4). See Method 3 for an explanation of this. Also, the first profile must be for natural (unencroached) conditions and subsequent profiles can be computed for different targets.

6 Encroachment Method 5

Method 5 operates much like Method 4 except that an optimization scheme is used to obtain the target difference in water surface elevation between natural and encroached conditions. A maximum of 21 trials is allowed in attempting a solution. The routine uses the percent reduction in conveyance as the objective function to be optimized to obtain the desired target. Convergence is usually obtained in three of four trials. The number of trials processed is printed under the variable name ICONT. Equal conveyance reduction is attempted in each overbank. Input for Method 5 is specified on the ET record in the same fashion as for Method 4. A 10.5 value in the INQ field (J1.2) of the ET

record would indicate a target of 1 foot difference in water surface elevations. This method can be changed before any cross section, like Methods 1 through 4. Also, as with Methods 3 and 4, the first profile must be for natural (unencroached) conditions and subsequent profiles can be computed for different targets.

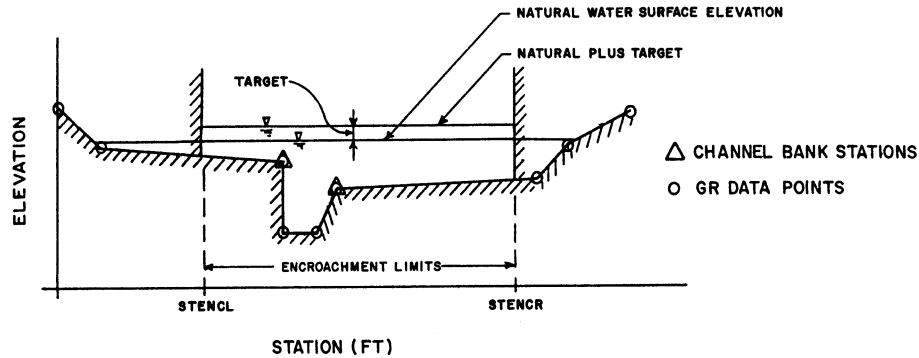


Figure 5
Encroachment Method 5

7 Encroachment Method 6

Method 6 operates in the same manner as Method 5 except that the optimization is based on obtaining a target difference in energy grade line elevation between natural and encroached conditions. Input for Method 6 is specified on the ET record and can be changed before any cross section, like Methods 1 through 5. A 10.6 in the INQ field (J1.2) of the ET record would indicate a floodway with a target of 1 foot difference in energy elevations. Also, the first profile must be for natural (unencroached) conditions and subsequent profiles can be computed for different targets.

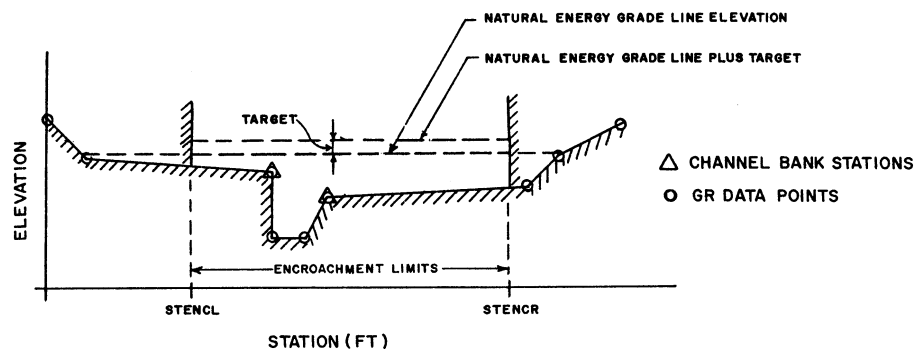


Figure 6
Encroachment Method 6

8 Bridge Encroachments

Each of the six methods can be used to evaluate the effect of encroachments on bridges (BT records). Bridge encroachments for special bridge analysis must be requested by adding a .01 to the

code on the ET record for the encroachment Methods 1 through 6. Thus, 9.11, 100.21, 10.31, 10.41, 10.51, or 10.61 would request the bridge encroachments for Method 1 through 6, while 9.1, 100.2, 10.3, 10.4, 10.5, or 10.6 would not encroach BT records. The following table describes how each method handles encroachments on special bridges.

Table 1
Encroachments on Special Bridges

Method	Special Bridge Encroachments
1	Bridge encroachments defined by target values of Method 1.
2	Bridge encroachments defined by target values of Method 2.
3 - 6	Bridge encroachments defined by encroachments determined at the cross section immediately downstream of the bridge.

Without this option, the program will not calculate encroachments on special bridge or special culvert models. For normal bridge models BT data encroachments are handled in the same manner as GR data encroachments.

9 Flow Distribution Option

This option is recommended when computing floodway encroachments. With flow distribution the program prints out the lateral distribution of area, velocity, and discharge in the overbank subareas (formed by points on the GR record) for each cross section. Because the distribution of discharge is given as a percent, it can also be considered a percentage-distribution of conveyance.

The flow distribution option is called by setting the variable ITRACE (J2.10 or X2.10) equal to 15. If the number of subareas carrying flow in the overbanks is less than 11, the distribution using all subareas will be printed. Otherwise, the distribution will be based on sub-areas that carry more than 3 percent of the flow. An example of flow distribution is shown in Figure 11, on page 40.

10 Encroachment Data Organization

The table on the following page illustrates a possible organization of data records for an encroachment analysis. Only the variables directly associated with encroachment analysis are shown in the table. For this example, three profiles are calculated with the first profile as the natural profile. Both profiles two and three are initiated with encroachment Method 4; other methods are then used for subsequent cross sections.

11 Computer Output for Floodway Calculations

11.1 Notes in Normal Output

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 percent, a ratio less than one is used instead of percent so that a percent target can be distinguished from a topwidth target.

2800 Natural Q1 = A, WSEL = B, ENC Q1 = C, WSEL = D, Ratio = E. This note is printed out for encroachment Methods 3 through 6. The index discharge (Q assuming $S^{1/2} = .01$) is equal to A for the natural profile at the water elevation of B. The index discharge for the encroached cross section is equal to C at elevation D. Elevation D is equal to B for Method 3, but is higher for Methods 4 through 6. The reduction ratio of $1-(C/A)$ is shown as E. This ratio for Method 3 is normally equal to the target for Note 3470 which is based on the input percentage on the ET record. E will be less than the target when the overbanks do not carry the target percentage of flow. The ratio is normally equal to zero for Methods 4 through 6 (the target on Note 3470 will be the equivalent ratio for Method 3), since there is no reduction in the flow carrying capability except for the raise in water elevation from B to D. When the reduction ratio, E, is negative, there is an increase in the index Q using only the channel area.

11.2 Floodway Summary Table

There are three pre-defined summary tables for floodway calculations. The tables are described in the following section. All three tables are shown in Example No. 4 output in Appendix I.

Summary Table 110 (Encroachment Data Table). Summary Table 110, requested on the J3 record, provides information relating to encroachment analysis. The column headings for Table 110 are described below.

- a. SECNO - cross section number
- b. CWSEL - computed water surface elevation
- c. DIFKWS - the difference between the computed water surface elevations for each profile and the first profile (which should be the natural profile for encroachment options)
- d. EG - energy grade line elevation
- e. TOPWID - cross section width at the calculated water surface elevation
- f. QLOB - amount of flow in the left overbank
- g. QCH - amount of flow in the channel
- h. QROB - amount of flow in the right overbank
- i. PERENC - the target of encroachment requested on ET record

Table 2
Encroachment Data Organization

Card	Values	Comments
T1 - T3		Title information (natural profile)
J1	INQ(J1.2 = 2) WSEL(J1.9)	Read second field of ET and QT record. Starting water surface elevation is specified here.
J2	ITRACE(J2.10 = 15)	Request flow distribution for natural profile.
J3	IVAR(J3.1 = 110), IVAR(J3.2 = 200)	Summary Table 110 and 200 will be requested for summary printout.
NC QT		
ET	ENCFP(ET.2 = 0) ENCFP(ET.3 = 8.4) ENCFP(ET.4 = 10.4)	First profile is natural profile. Second profile is Method 4 with .8 foot rise. Third profile is Method 4 with one foot rise.
X1 GR X1 GR		
ET	ENCFP(ET.2 = 0) ENCFP(ET.3 = 7.4) ENCFP(ET.4 = 5.41)	First profile is natural profile (no change). Second profiles is changes to 7.4. Third profile is changed to 5.41. Bridge encroachment stations (for the BT records) will be the same as the downstream encroachments.
X1 GR		
SB		
ET	ENCFP(ET.2 = 0) ENCFP(ET.3 = 7.11) (ET.7 = STENCL) (ET.8 = STENCR) ENCFP(ET.4 = 0)	First profile is natural profile (no change). Second profile is changed to Method 1 for bridge. Bridge encroachments (for both BT and GR records are specified in the seventh and eighth fields of the ET record. Continue previous encroachment instructions.
X1 X2 BT		
ET	ENCFP(ET.2 = 0) ENCFP(ET.3 = 15.3) ENCFP(ET.4 = 10.5)	First profile is natural profile (no change). Second profile is changed to Method 3. Third profile is changed to Method 5.
X1 GR X1 GR		
EJ		End of data.
T1 - T3		Title information (Method 4 encroachment).
J1	INQ(J1.2 = 3) STRT(J1.5 = 0) WSEL(J1.9)	Read third fields of ET and QT records. Slope area method of starting should not be used for encroachment profile. Starting water surface elevation specified here.
J2	NPROF(J2.1 = 2)	Second profile.
T1 - T3		Title information (Method 4 encroachment).
J1	INQ(J1.2 = 4) STRT(J1.5 = 0) WSEL(J1.9)	Read fourth field of ET and QT records. Slope area method should not be used. Starting water surface elevation specified area.
J2	NPROF(J2.1 = 3)	Last profile.
ER		End of run.

- j. STENCL - the station of the left encroachment
- k. STCHL - the station of left bank
- l. STCHR - the station of right bank
- m. STENCR - the station of the right encroachment

Summary Table 115. A floodway distance table that provides the stations for left and right encroachment, and the center line (halfway between bank stations), plus the distance from the center station to left and right encroachment stations. These data facilitate transfer of encroachment station locations to plan maps.

Summary Table 200 (FIA Table 1). A floodway table similar to FIA Table 1 which summarizes information on floodway widths, mean velocities and water surface elevations as required for flood insurance studies. The water surface elevations and the difference rounded to a tenth of a foot for output display.

Appendix III

Application of HEC-2 Bridge Routines

Appendix III

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EXHIBITS

- A Special Bridge Example - Computer Run
- B Normal Bridge Example - Computer Run
- C Input Loss Example - Computer Run

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Chapter 1

Bridge Loss Calculations

1.1 Introduction

HEC-2 computes energy losses caused by structures such as bridges and culverts in two parts. One part consists of the losses that occur in reaches immediately upstream and downstream from the bridge where contraction and expansion of the flow is taking place. The second part consists of losses at the structure itself and is calculated with either the normal bridge method or the special bridge method. As an alternative to having the program compute the losses, it is possible to input a loss (or water surface elevation) determined externally from the program.

1.2 Contraction and Expansion Losses

Losses due to contraction and expansion of flow between cross sections are determined by standard step profile calculations. Manning's equation is used to calculate friction losses, and all other losses are described in terms of a coefficient times the absolute value of the change in velocity head between adjacent cross sections. When the velocity head increases in the downstream direction, a contraction coefficient is used; and when the velocity head decreases, an expansion coefficient is used.

1.3 Normal Bridge Method

The normal bridge method handles a bridge cross section in the same manner as a natural river cross section, except that the area of the bridge below the water surface is subtracted from the total area, and the wetted perimeter is increased where the water is in contact with the bridge structure. The bridge deck is described either by entering the constant elevations of the top of roadway and low chord as variables ELTRD and ELLC respectively on the X2 record, or by specifying a table of roadway stations and elevations, and corresponding low chord elevations, on the BT records. When only ELLC and ELTRD are used, these elevations are extended horizontally until they intersect the ground line defined on the GR records. Pier losses are accounted for by the loss of area and the increased wetted perimeter of the piers as described in terms of cross section coordinates, usually on the GR record.

1.4 Special Bridge Method

The special bridge method computes losses through the structure for either low flow, pressure flow, weir flow, or for a combination of these. The profile through the bridge is calculated using hydraulic formulas to determine the change in energy and water surface elevation through the bridge.

Low Flow. The procedure used for low flow calculations in the special bridge method depends on whether the bridge has piers. **Without piers**, the low flow solution is accomplished by standard step calculations as in the normal bridge method. The transfer to the normal bridge method is necessary because the equations used in the special bridge method **for low flow** are based on the obstruction width due to the piers.

Without piers, the special bridge solution would indicate that no losses would occur. For a bridge **with piers**, the program goes through a momentum balance for cross sections just outside and inside the

bridge to determine the class of flow. The momentum calculations are handled by employing the following momentum relations based on the equations proposed by Koch-Carstanjen [Eichert/Peters, 1970] [Koch-Carstanjen, 1962].

$$n_{p1} + \frac{Q^2}{g(A_1)^2} \left(A_1 - \frac{C_D}{2} A_{p1} \right) = m_2 + \frac{Q^2}{gA_2} = m_3 - m_{p3} \quad (\text{III-1})$$

- where: A_1, A_3 = flow areas at upstream and downstream sections, respectively
- A_2 = flow area (gross area - area of piers) at a section within constricted reach
- A_{p1}, A_{p3} = obstructed areas at upstream and downstream sections, respectively
- $\bar{y}_1, \bar{y}_2, \bar{y}_3$ = vertical distance from water surface to center of gravity of A_1, A_2, A_3 , respectively
- m_1, m_2, m_3 = $A_1\bar{y}_1, A_2\bar{y}_2$ and $A_3\bar{y}_3$, respectively
- m_{p1}, m_{p3} = $A_{p1}\bar{y}_{p1}$ and $A_{p3}\bar{y}_{p3}$, respectively
- C_D = drag coefficient equal to 2.0 for square pier ends and 1.33 for piers with semicircular ends
- $\bar{y}_{p1}, \bar{y}_{p2}$ = vertical distance from water surface to center of gravity of A_{p1} and A_{p3} , respectively
- Q = discharge
- g = gravitational acceleration

The three parts of the momentum equation represent the total momentum flux in the constriction expressed in terms of the channel properties and flow depths upstream, within and downstream of the constricted section. If each part of this equation is plotted as a function of the water depth, three curves are obtained (Figure 1) representing the total momentum flux in the constriction for various depths at each location. The desired solutions (water depths) are then readily available for any class of flow. The momentum equation is based on a trapezoidal section and therefore requires a trapezoidal approximation of the bridge opening. A logic diagram for the momentum calculation is shown in Figure 2.

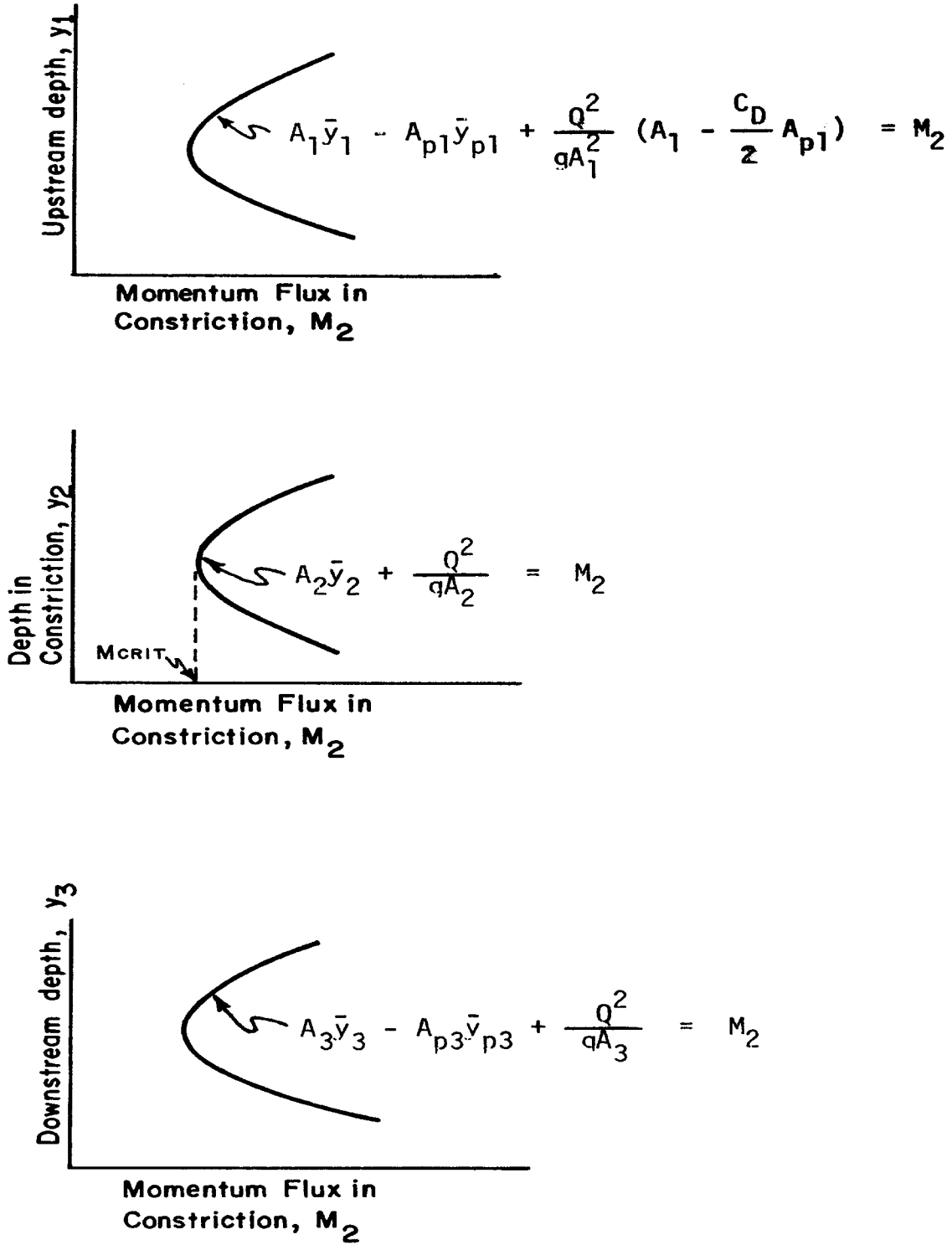
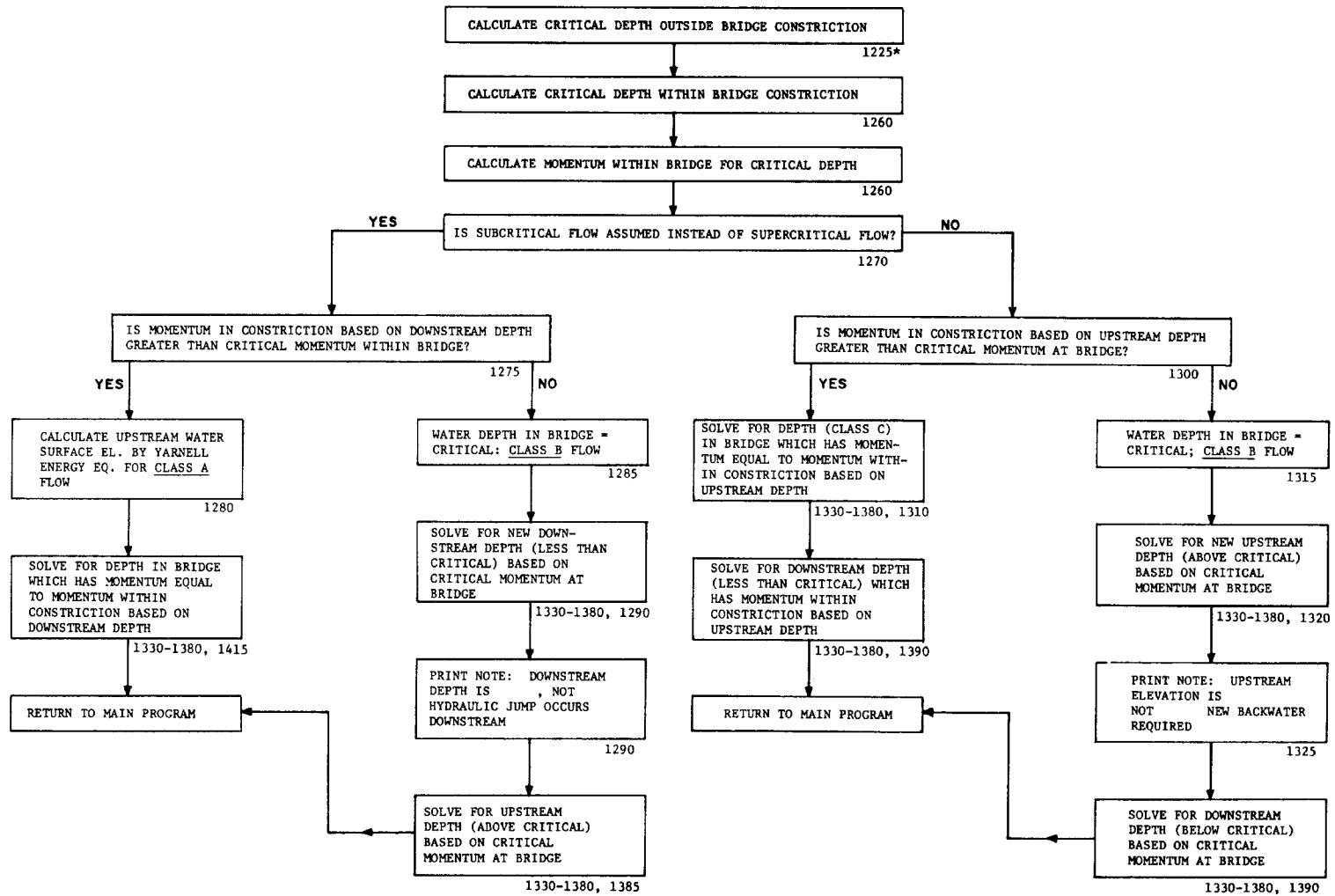


Figure 1
Momentum Curves from Special Bridge Method

SUBPROGRAM BLFLO, LOW FLOW CONTROL



*Numbers refer to statement numbers in source deck of computer program

General Program Logic for Low Flow Calculations

Class A low flow occurs when the water surface through the bridge is above critical depth, i.e., subcritical flow. The special bridge method uses the Yarnell equation for this class of flow to determine the change in water surface elevation through the bridge. As in the momentum calculations, a trapezoidal approximation of the bridge opening is used to determine the areas.

$$H_3 = 2K (K + 10\omega - 0.6) (\alpha + 15\alpha^4) \frac{V_3^2}{2g} \quad (\text{III-2})$$

where: H_3 = drop in water surface from upstream to downstream sides of the bridge

K = pier shape coefficient

ω = ratio of velocity head to depth downstream from the bridge

α = $\frac{\text{obstructed area}}{\text{total unobstructed area}}$

V_3 = velocity downstream from the bridge

The computed upstream water surface elevation is simply the downstream water surface elevation plus H_3 . With the upstream water surface elevation known, the program computes the corresponding velocity head and energy elevation for the upstream section.

Class B low flow can exist for either a subcritical or supercritical profile. For either profile, class B low flow occurs when the profile passes through critical depth in the bridge constriction. For a **subcritical profile**, critical depth is determined in the bridge, a new downstream depth (below critical) and the upstream depth (above critical) are calculated by finding the depths whose corresponding momentum fluxes equal the momentum flux in the bridge for critical depth. With this solution, Statement 5227 DOWNSTREAM ELEV IS X, NOT Y, HYDRAULIC JUMP OCCURS DOWNSTREAM is printed with the elevation X as the supercritical elevation. The program does not provide the location of the hydraulic jump. A supercritical profile could be computed starting at the downstream section with a water surface elevation X. For a **supercritical profile**, the bridge is acting as a control and is causing the upstream water surface elevation to be above critical depth. Momentum equations are again used to recompute an upstream water surface elevation (above critical) and a downstream elevation below critical depth. For this situation, the Statement 5920 UPSTREAM ELEVATION IS X NOT Y, NEW BACKWATER REQUIRED is printed indicating a subcritical profile should be calculated upstream from the bridge starting at elevation X.

Class C low flow is computed for a supercritical profile where the water surface profile stays supercritical through the bridge constriction. The downstream depth and the depth in the bridge are computed by the momentum equations based on the momentum flux in the constriction and the upstream depth.

Pressure Flow. The pressure flow computations use the orifice flow equation of U.S. Army Engineer Manual 1110-2-1602, "Hydraulic Design of Reservoir Outlet Structures," [USACE, 1963]:

$$Q = A \sqrt{\frac{2gH}{K}} \quad (\text{III-3})$$

where: H = difference between the energy gradient elevation upstream and tailwater elevation downstream

K = total loss coefficient

A = net area of the orifice

g = gravitational acceleration

Q = total orifice flow

The total loss coefficient K, for determining losses between the cross sections immediately upstream and downstream from the bridge, is equal to 1.0 plus the sum of loss coefficients for intake, intermediate piers, friction, and other minor losses. The section on loss coefficients provides values for the total loss coefficient and shows the derivation of the equation and the definition of the loss coefficient.

Weir Flow. Flow over the bridge and the roadway approaching the bridge is calculated using the standard weir equation:

$$Q = CLH^{3/2} \quad (\text{III-4})$$

where: C = coefficient of discharge

L = effective length of weir controlling flow

H = difference between the energy grade line elevation and the roadway crest elevation

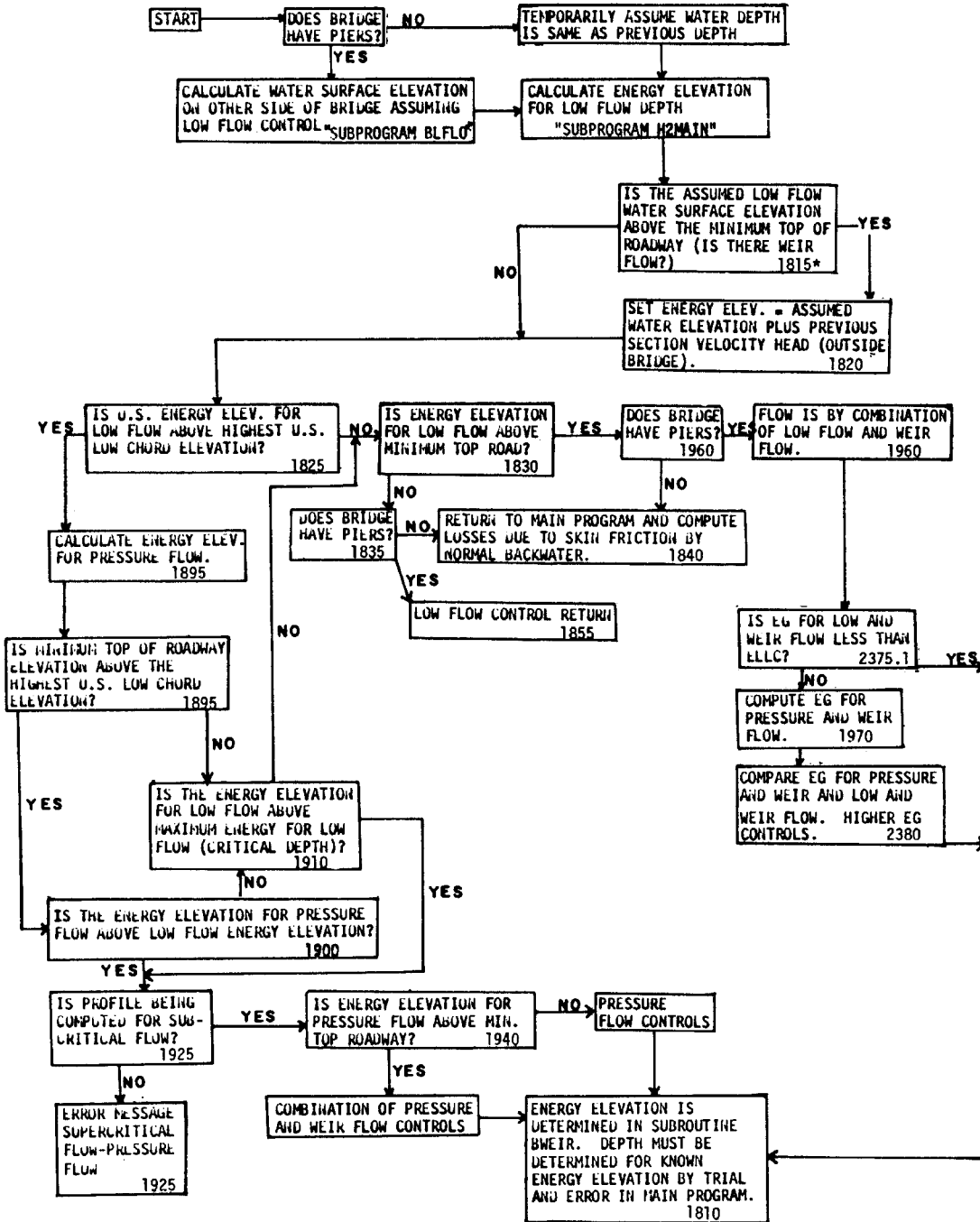
Q = total flow over the weir

The approach velocity is included by using the energy grade line elevation in lieu of the upstream water surface elevation for computing the head, H. Values for the coefficient of discharge 'C' are presented in the section on loss coefficients. Where submergence by tailwater exists, the coefficient 'C' is reduced by the program [Bradley, 1978]. Submergence corrections are based on a trapezoidal weir shape or optionally an ogee spillway shape. A total weir flow, Q, is computed by subdividing the weir crest into segments, computing L, H, a submergence correction and Q for each segment, and summing the incremental discharges.

Combination Flow. Sometimes combinations of low flow or pressure flow occur with weir flow. In these cases a trial and error procedure is used, with the equations just described, to determine the amount of each type of flow. The procedure consists of assuming energy elevations and computing the total discharge until the computed discharge equals, within 1 percent, the discharge desired.

Decision Logic. The general flow diagram for the special bridge method is shown in Figure 3. By following the decision logic associated with a bridge solution, the program user can determine what adjustment could be made in the program input to alter the computed solution. A discussion of the logic sequence is provided to assist the user in interpreting the program solutions.

GENERAL FLOW DIAGRAM
SPECIAL BRIDGE METHOD



*Numbers refer to statement numbers in subprogram BWEIR.

Figure 3
Special Bridge Method General Logic Diagram

The first step in the special bridge method is to assume low flow conditions and estimate the water surface elevation on the other side of the bridge. How that estimate is made depends on whether the bridge has piers. If there are bridge piers, the program goes through the momentum equations to determine class of flow and water surface elevation. Without piers, the program temporarily assumes the water depth is the same on both sides of the bridges.

The program then checks for weir flow by comparing the estimated water surface elevation to the minimum top of road elevation (ELTRD). If it is possible that weir flow exists, the program estimates an energy elevation based on the velocity head at the previous section.

The program then compares the estimated low flow energy elevation to the maximum elevation of the bridge low chord (ELLC). If the low flow energy elevation (EGLWC) is greater than the low chord elevation (ELLC) the program will calculate an energy elevation assuming pressure flow (EGPRS). If the low flow energy elevation is less than ELLC, the program concludes that low flow controls and checks again to determine if weir flow exists. If there is weir flow, the program will check for piers. **With piers**, a trial and error solution will be made for low flow (by the Yarnell equation) and weir flow (by the weir equation). **Without piers**, the normal bridge solution (standard step calculation with adjustments in area and wetted perimeter) will be used to compute the upstream elevation. If weir flow did not exist, the program would check for piers and then solve for a low flow solution. **With piers**, the low flow solution would be based on the momentum or the Yarnell equation; and without piers, the solution would be computed using standard step calculations.

Had the energy elevation required for pressure flow (EGPRS) been calculated, the program would go on to compare the low flow energy elevation EGLWC with EGPRS. Figure 4 illustrates the comparison of EGLWC and EGPRS.

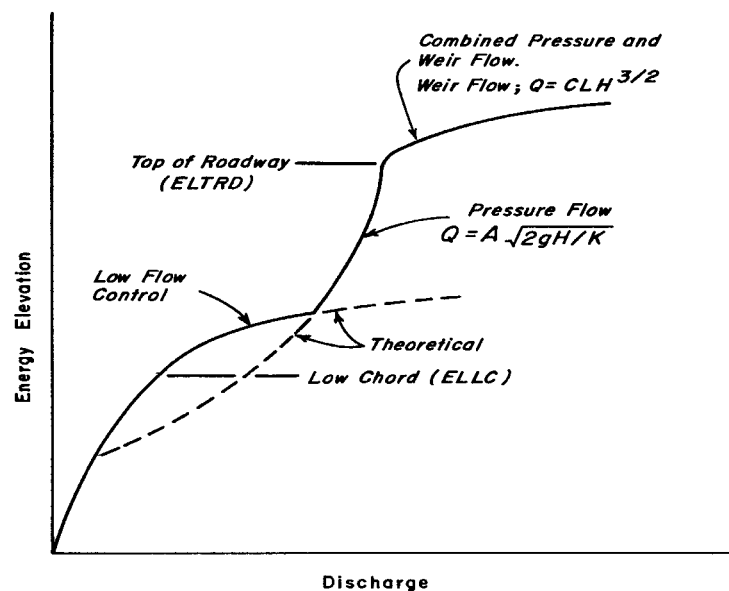


Figure 4
Typical Discharge Rating Curve for Bridge Culvert

One exception to the direct comparisons of the two energy elevations is when the minimum elevation of the top of road (ELTRD) is less than the maximum elevation of the low chord (ELLC). For this type of bridge, a combination of weir flow and low flow can occur. The low flow energy elevation (EGLWC) is compared to the estimated maximum energy elevation for low flow control (1.5 times depth plus invert elevation), rather than EGPRS, because the low road elevation would cause weir flow to exist prior to the occurrence of pressure flow. Depth is defined here as the difference between the low chord (ELLC) and the invert elevation (ELMIN).

At critical depth, 1.5 times the depth represents the minimum specific energy that could occur for a rectangular section. If critical depth occurred just at the maximum low chord elevation, it would produce the maximum possible energy elevation for low flow. Therefore, an energy elevation greater than that value would have to be for pressure flow. For the energy range between the low chord and the maximum low flow energy, the program will compute the energy elevations for low and weir flow and pressure and weir flow. The higher of the two energy elevations will control. Energy elevations below the maximum low chord are for low flow or low and weir flow for this type of bridge.

Based on the previous checks, the bridge routine has differentiated between low flow and pressure flow. With either type of flow, the program checks against the minimum top of road elevation (ELTRD) to determine if weir flow also exists. If the energy elevation is greater than ELTRD, a trial and error solution is made to determine the distribution of flow. The computed weir flow is listed under QWEIR and the flow under the bridge is given under QPR regardless of whether it is low flow or pressure flow. The flow diagram for computing the combination flow solution is shown in Figure 5. Up to 20 iterations are made to balance the total discharge to within 1 percent of the given discharge.

Important parameters in the decision logic of the special bridge method are the two test elevations ELLC and ELTRD. Because they play such an important role in the bridge analysis, **it is recommended they always be coded as input on fields four and five of the X2 record.**

1.5 Input Losses

One other method of computing water surface profiles through bridges is to input the bridge loss. The loss used could be just the "structure" loss, or it could be the total loss between any two adjacent cross sections. Differences in water surface elevations can be read on the X5 record for each discharge profile. The field read on the X5 record is called by variable INQ on the second field of the J1 record.

For control structures, the known water surface elevations as provided by a rating curve can be read on an X5 record for multiple profiles or an X2 record for a single profile job. However, for a given X5 record, the data must consist entirely of either known water surface elevations or of differences in water surface elevation. Both types of input cannot be placed on the same record.

Chapter 2

General Modeling Guidelines

2.1 Introduction

Considerations in modeling the geometry of a reach of river in the vicinity of a bridge are essentially the same for both the normal bridge method and the special bridge method. Suggested techniques are presented in this section and are applied in subsequent examples on bridge coding.

2.2 Cross Section Locations

Figure 6 shows in plan view the basic configuration of cross sections for computing losses through bridges. For ease of discussion, assume a subcritical profile starting downstream from the bridge.

Cross section 1 is sufficiently downstream from the bridge that flow is not affected by the bridge. The flow has fully expanded, and the basic input problem is to determine how far downstream from the bridge the cross section should be located. A rule of thumb is to locate the downstream cross section about four times the average length of the side constriction caused by the bridge abutments. Therefore, cross section 1 would be located downstream from the bridge four times the distance AB or CD shown in Figure 6. Because the constriction of flow may vary with the discharge, the downstream reach length should represent the average condition if a range of discharges are used in the model.

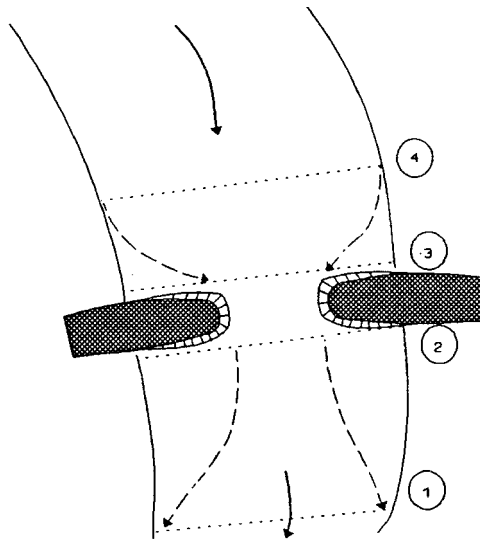


Figure 6
Cross Section Locations in the Vicinity of Bridges

Locating cross section 1 based on a 4:1 expansion of flow downstream from the bridge may provide a reach length to cross section 2 that is too long for a reasonable estimate of friction loss. If intermediate cross sections are required, the 4:1 expansion rate could be used to locate the lateral extent of intermediate cross sections. The user should carefully review the program output to determine if an adequate number of cross sections are used. A change in conveyance of more than 30 percent between the two cross sections and a relatively long reach would indicate a need for intermediate cross sections.

Cross section 2 is a river cross section immediately (i.e., within a foot or two) downstream from the bridge. The cross section should represent the effective¹ flow area just outside the bridge and its location could be considered as the downstream face of the bridge. It is important to work with effective flow area because it is assumed in the application of the energy equation that the mean downstream velocity for each subsection can be determined from Manning's equation. The method used to define the effective area at this cross section is discussed under effective flow area. The standard step solution at cross section 2 would include determination of the expansion loss from cross section 2 to cross section 1.

The bridge loss occurring from cross section 2 to cross section 3 is determined by either the special bridge method with the SB record or by standard step calculations through one or two cross sections that define the bridge opening (normal bridge method). The selection of the bridge routine and the input requirements are presented in a subsequent cross section.

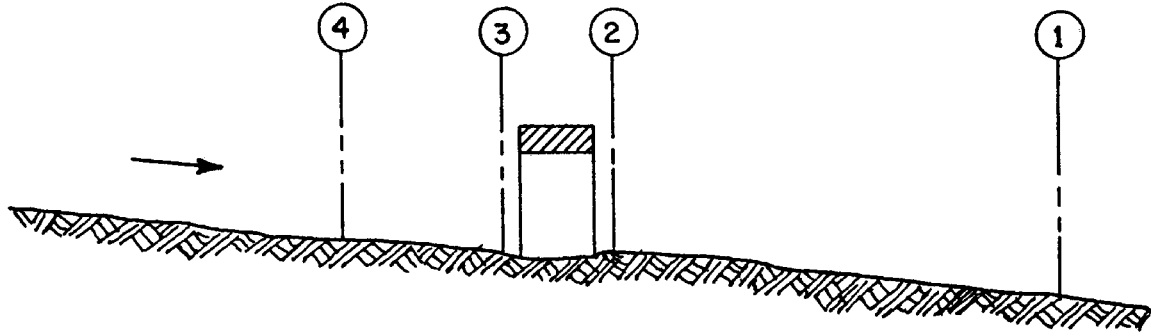
Cross section 3 represents the effective flow area just upstream from the bridge. The reach lengths from cross section 2 to cross section 3 are generally equal to the width of the bridge. The energy elevation computed by the special bridge method is applied to this cross section or, for the normal bridge method, a standard step solution from a cross section in the bridge to this cross section provides the energy elevation. The energy loss computed between cross sections 2 and 3 represents the loss through the bridge structure itself.

Cross section 4 is an upstream cross section where the flow lines are approximately parallel and the full cross section is effective. Because the flow contraction can occur over a shorter distance than the flow expansion, the reach length between cross sections 3 and 4 can be about one times the average bridge opening between the abutments (distance B-C in Figure 6). However, this criterion for locating the upstream cross section may result in too short a reach length for situations where the ratio of the width of the bridge opening to the width of the floodplain is small. An alternative criterion would be to locate the upstream cross section a distance equal to the bridge contraction (distance AB or CD in Figure 6). The program will compute the contraction portion of the bridge loss over this reach length by the standard step calculations.

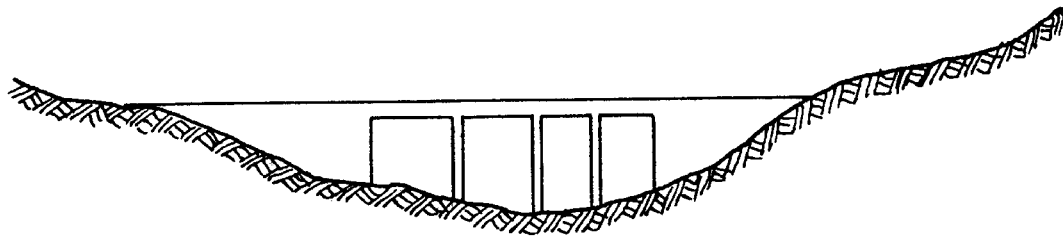
2.3 Effective Area Option

A basic problem in setting up the bridge routines is the definition of effective flow area near the bridge structure. Referring to Figure 6, the dashed lines represent the effective flow boundary for low flow and pressure flow conditions. Therefore, for cross sections 2 and 3, ineffective flow areas to either side of the bridge opening (along distance AB and CD) should not be included for low flow or pressure flow. The elimination of the ineffective overbank areas can be accomplished by redefining the geometry at cross sections 2 and 3 (as shown in part C of Figure 7) or by using the natural ground profile and requesting the program's effective area option to eliminate the use of the overbank area. By redefining the cross section, a fixed boundary is used at the sides of the cross section to contain the flow, when in fact a solid boundary is not physically there. The use of the effective area option does not add wetted perimeter to the flow boundary above the given ground profile.

¹ Effective flow is that portion of flow where the main velocity is normal to the cross section and in the downstream direction.



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

The bridge example shown in Figure 7 is a typical situation where the bridge spans the entire floodway and its abutments obstruct the natural floodway. This is the same situation as was shown in plan view in Figure 6. The cross section numbers and locations are the same as those discussed in "Cross Section Locations" (see Section 2.2). The input problem is to convert the natural ground profile at cross sections 2 and 3 from the cross section shown in part "B" to that shown in part "C" of Figure 7.

The effective area option of the program (IEARA = 10, Field 1, X3 record) is used to keep all the flow in the channel until the elevations associated with the left and/or right bank stations are exceeded by the computed water surface elevation. The program will allow the controlling elevations of the left and right bank stations to be specified by the user. This is done by reading in effective area elevations (ELLEA and ELREA) in Fields 8 and 9 of the X3 record. If these elevations are not read in, elevations specified on the GR records for the left and right bank stations will be used.

The effective area option applies to the left and right bank stations; therefore, those stations should coincide with the abutments of the bridge. For cross sections 2 and 3, the left and right bank stations should line up with the bridge abutments. An X3 record would be used with these cross sections to call for the effective area option and to designate effective area elevations for the left and right bank stations. The given elevations would correspond to an elevation where weir flow would just start over the bridge. For the downstream cross section, the threshold water surface elevation for weir flow is not usually known on the initial run, so an estimate must be made. An elevation anywhere between the low chord and top-of-road elevation could be used; so an average of the two elevations might be a reasonable estimate.

Using the effective area option to define the effective flow area allows the entire overbank to become effective as soon as the effective area elevations are exceeded. The assumption is that under weir flow conditions, the water can generally flow across the whole bridge length and the entire overbank in the vicinity of the bridge would be effectively carrying flow up to and over the bridge. If it is more reasonable to assume only part of the overbank is effective for carrying flow when the bridge is under weir flow, then the cross section should be redefined for cross sections 2 and 3 to eliminate the portion of the overbank area considered ineffective even under weir flow conditions.

Cross section 3, just upstream from the bridge, is usually coded in the same manner as cross section two. In many cases the cross sections are identical. The only difference generally is the elevation to use for the effective area option. For the upstream cross section, the elevation usually would be the low point of the top-of-road (ELTRD).

Using the effective area option in the manner just described for the two cross sections on either side of the bridge provides for a constricted section when all of the flow is going under the bridge. When the water surface is higher than the control elevations used, the entire cross section is used. The program user should check the computed solutions on either side of the bridge section to insure they are consistent with the type of flow. That is, for low flow or pressure flow solutions, the printout should show the effective area restricted to the main channel. When the bridge data indicates weir flow, the solution should show that the entire cross section is effective.

2.4 Selection of Methods

When selecting the method of computing the water surface profile through a bridge, there are three basic choices: (1) determine the change in water surface elevation or the water surface elevation by an "external" technique and input the results into the program, (2) calculate the energy loss based on friction using the standard step method - normal bridge method, or (3) calculate the energy loss by previously discussed formulas of the special bridge method. Each method should be considered and the following discussion provides some basic guidelines. For the analysis of culverts, the special culvert option is recommended, see Appendix IV.

Input Losses. The following are examples of when a change or known water surface elevation might be read into the program:

1. If a structure acts as a hydraulic control and a rating curve is available, reading in the known water surface elevation is the easiest and surest way to establish proper water surface elevations.
2. The use of observed data to estimate losses through a bridge can also be an expeditious method of establishing the losses.
3. An alternate computation technique can be used such as the Bureau of Public Roads (BPR) procedure [Bradley, 1978] for determining the loss for low flow conditions. The calculated loss can then be read in. Care must be taken to insure the loss calculated by an alternate method is properly used in the program. For example, the BPR technique provides the increase in water surface elevation above the normal water surface elevation without the bridge. Therefore, it includes the effects of contraction and expansion losses and the loss caused by the structure, but it does not reflect the normal friction loss that would occur without the bridge.

Normal Bridge Method. The use of the standard step method for computing losses is most applicable when friction losses are the predominate consideration. The following examples are some typical cases where the normal bridge method might be used.

1. For long culverts under low flow conditions, the standard step method is the most suitable approach. Several sections can be taken through the culvert to model changes in grade or shape or to model a very long culvert.
2. In cases where the bridge and abutments are a small obstruction to the flow, the normal bridge method can be used.
3. Because the special bridge method requires a trapezoidal approximation of the bridge opening for low flow solutions, the normal bridge method could be used where the flow area cannot be reasonably approximated by a trapezoid (see Section 5.2, page III-33).

Special Bridge Method. The special bridge method is capable of solving a wide range of flow problems. The following are situations where the method is applicable.

1. The special bridge method will determine the class of low flow based on a trapezoidal approximation of a bridge with piers. If a bridge opening can be reasonably modeled by a trapezoid, the program will determine when the profile goes through critical depth and what the corresponding water surface elevation is on either side of the bridge.
2. Pressure flow is computed using the orifice equation. The orifice coefficient can be computed to account for friction; therefore, the special bridge method would be suitable for pressure flow through long culverts.
3. Weir flow is computed in the special bridge method; therefore, dams and weirs can be modeled as well as bridges. When computing pressure flow or weir flow, the program user might consider whether the bridge deck could survive such conditions.
4. Combinations of low or pressure flow and weir flow can be computed using the hydraulic formulas. An iterative procedure solves the combination flow problem for a variety of conditions. For low flow and weir flow solutions the bridge must have piers for the program to handle the low flow part of the combination flow. Otherwise the program will revert to the normal bridge method.

Chapter 3

Loss Coefficients

3.1 Introduction

After the cross sections are located and the method of solution is determined, the program user has to select coefficients associated with the method chosen. For the normal bridge method the Manning's 'n' values are used to determine the friction loss. The contraction and expansion losses caused by the bridge are estimated using contraction and expansion coefficients.

3.2 Contraction and Expansion Coefficients

These coefficients are used to compute energy losses associated with changes in the shape of river cross sections (or effective flow areas). The loss due to expansion of flow is usually much larger than the contraction loss, and losses from short abrupt transitions are larger than losses from gradual transitions. The transition loss is computed by multiplying a coefficient times the absolute difference in velocity heads between cross sections. If the values for the coefficients are being redefined to account for contraction and expansion through a bridge, the new values are read on the NC record prior to the section where the change in velocity head is evaluated. Referring back to Figure 6, on a subcritical profile, the new values should be read in just before section two and changed back to the original values after section four. Typical values are shown below.

Table 1
Contraction and Expansion Coefficients

	Contraction	Expansion
No transition loss computed	0.0	0.0
Gradual transitions	0.1	0.3
Bridge sections	0.3	0.5
Abrupt transitions	0.6	0.8

The maximum value for the expansion coefficient would be one (1.0).

3.3 Special Bridge Coefficients

When using the special bridge method, coefficients must be read in for the Yarnell equation, the orifice equation, and the weir equation. The following discussion provides suggested values and methods for estimating the required coefficients.

Pier Shape Coefficient XK is used in Yarnell's energy equation for computing the change in water surface elevation through a bridge for class A low flow. Because the calculation is based on the presence of piers, both the coefficient and a total width (BWP) must be read on the SB record. If there are no piers, both variables can be left blank and the program will use a standard step solution for low flows. The following table gives values of XK for various pier shapes.

Pier Shape	XK
Semicircular nose and tail	0.90
Twin-cylinder piers with connecting diaphragm	0.95
Twin-cylinder piers without diaphragm	1.05
90° triangular nose and tail	1.05
Square nose and tail	1.25

The Yarnell equation is a semi-empirical equation based on hydraulic model data. As such, it probably should not be applied in cases where the flow obstruction is something other than a pier; for example, the fill separating twin circular culverts.

Loss Coefficient XKOR is used in the orifice flow equation,

$$Q = A \sqrt{\frac{2gH}{K}} \quad (\text{III-5})$$

This form of the equation can be derived by applying the energy equation from a point just downstream from the bridge (2) to a point just upstream (1), see Figure 6.

$$y_1 + Z_1 + \alpha_1 \frac{V_1^2}{2g} = y_2 + Z_2 + \alpha_2 \frac{V_2^2}{2g} + H_L \quad (\text{III-6})$$

where: y = depth of water

Z = invert elevation

$\alpha \frac{V^2}{2g}$ = velocity head

H_L = head loss

Defining the head (H) on the orifice as the difference between the upstream energy elevation and the downstream water surface elevation (the definition used in HEC-2) produces:

$$H = \left(y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} \right) - (y_2 + Z_2) \quad (\text{III-7})$$

Substituting H from Equation III-7 into Equation III-6 produces:

$$H = \frac{\alpha_2 V_2^2}{2g} + H_L \quad (\text{III-8})$$

Head loss (H_L) through the bridge can be defined in terms of the bridge velocity head and loss coefficient K_b . The example to a point just downstream can be defined by an expansion coefficient K_e and the change in velocity head.

$$H_L = K_b \frac{V_b^2}{2g} + K_e \left(\frac{V_b^2}{2g} - \frac{\alpha_2 V_2^2}{2g} \right) \quad (\text{III-9})$$

where: b = subscript designating the bridge

The head loss equation (Equation III-9) then can be used to define H_L in Equation III-8:

$$H = \frac{\alpha_2 V_2^2}{2g} + K_b \left(\frac{V_b^2}{2g} \right) + K_e \left(\frac{V_b^2}{2g} - \frac{\alpha_2 V_2^2}{2g} \right) \quad (\text{III-10})$$

If the expansion coefficient (K_e) is taken as 1.0, the equation can be rewritten into the form of the orifice equation by adding the continuity equation ($Q = VA$).

$$Q = A \sqrt{\frac{2gH}{K}} \quad (\text{III-11})$$

where: $K = K_b + 1$

The loss coefficient used in the program's orifice equation can be related to the loss coefficient C from another commonly used orifice flow equation:

$$Q = CA \sqrt{2gH} \quad (\text{III-12})$$

The conversion ($XKOR=1/C^2$) can be used for tabulated values of C. However, care must be taken to insure the definition of H used in the various formulations is applicable.

The Bureau of Public Roads [Bradley, 1978] shows experimental values for C for fully submerged conditions to vary from 0.7 to 0.9. A value of 0.8 is recommended as being applicable for the average two to four lane concrete girder bridge. The definition of H is consistent with that used in HEC-2. In the absence of calibration data, a value of 1.56 for XKOR ($C = 0.8$) would be applicable to most bridges and short culverts. For longer culverts, the coefficient can be calculated by the sum of XKOR as shown.

$$XKOR = k_e + k_f + 1 \quad (\text{III-13})$$

where: k_e = entrance loss coefficient
 k_f = friction loss coefficient

The coefficient for friction loss (k_f) can be computed from Manning's equation by equating two equations for friction loss in the culvert.

$$k_f \frac{V_b^2}{2g} = S_f \cdot L \quad \text{(III-14)}$$

where: S_f = the average friction slope
 L = the length of the culvert

Manning's equation for the velocity in the culvert is rearranged to define S_f .

$$V_b = \frac{1.49}{n} R^{2/3} S_f^{1/2}$$

$$S_f = \frac{V_b^2 n^2}{2.22 R^{4/3}} \quad \text{(III-15)}$$

By substituting Equation III-15 for Equation III-14, the coefficient k_f can be defined based on culvert parameters.

$$k_f = \frac{V_b^2 n^2}{2.22 R^{4/3}} \cdot L \cdot \frac{2g}{V_b^2}$$

$$k_f = \frac{29n^2 L}{R^{4/3}} \quad \text{(III-16)}$$

Typical values of the coefficients are shown below:

Description	k
Intake (k_e)	0.1 to 0.9
Intermediate piers	0.05
Friction (Manning's equation)	k_f
	$XKOR = \sum k + 1$

where: English $k_f = 29n^2 L / R^{4/3}$

Metric $k_f = 19.6n^2 L / R^{4/3}$

King's Handbook [King/Brater, 1963], in its discussion on pipe culverts gives an entrance loss of .1 for a flush inlet, and 0.15 for a projecting inlet for concrete pipes. Inlet loss coefficients as high as 0.9 for a projecting entrance and corrugated metal pipes are indicated. All the coefficients were applied to the velocity head for the pipe (also see Appendix III for additional information on entrance and exit coefficients).

For multiple culverts, an equivalent coefficient can be computed to apply in cases where all culverts are flowing full.

$$Q = \sqrt{2gh} AT \sqrt{\frac{1}{K_{equiv}}} \quad (III-17)$$

$$\text{where: } K_{equiv} = \frac{AT^2}{\left[\sum_{i=1}^n \sqrt{\frac{A_i^2}{K_i}} \right]^2}$$

- AT = total area
- A_i = area of individual culvert
- K_i = coefficient for individual culvert
- n = number of culverts

Coefficient of Discharge, COFQ is used in the standard weir equation: $Q = CLH^{3/2}$. Under free flow conditions (discharge independent of tailwater) the coefficient of discharge 'C', ranges from 2.5 to 3.1 (1.39 - 1.72 metric) for broad-crested weirs depending primarily upon the gross head on the crest ('C' increases with head). Increased resistance to flow caused by obstructions such as trash on bridge railings, curbs, and other barriers would decrease the value of 'C'. With submerged flow (discharge affected by tailwater), the coefficient 'C' should be reduced. This is done automatically by the program using the Waterways Experiment Station Design Chart 1114. The correction is based on model studies with a low ogee crest weir.

Tables of weir coefficients 'C' are given for broad-crested weirs in King's Handbook with the value of 'C' varying with measured head 'H' and breadth of weir. For rectangular weirs with a breadth of 15 feet and a 'H' of 1 foot or more, the given value is 2.63. Trapezoidal shaped weirs generally have a larger coefficient with typical values ranging from 2.7 to 3.08.

Hydraulics of Bridge Waterways [Bradley, 1978] provides a curve of 'C' versus the head on the roadway. The roadway section is shown as a trapezoid and the coefficient rapidly changes from 2.9 for a very small 'H' to 3.03 for H = 0.6 feet. From there, the curve levels off near a value of 3.05.

With very little prototype data available, it seems the assumption of a rectangular weir for flow over the bridge deck (assuming the bridge can withstand the forces) and a coefficient of 2.6 would be reasonable. If the weir flow is over the roadway approaches to the bridge, a value of 3.0 would be consistent with available data. If weir flow occurs a combination of bridge and roadway, an average coefficient (weighted by weir length) could be used.

Chapter 4

Examples of Input Preparation

4.1 Introduction

Example problems using the two bridge methods and direct input of bridge loss are provided to illustrate input preparation. The special bridge method is used for a "typical bridge with piers" and the normal bridge method is used for an arch bridge. A simple example illustrates use of the X5 record to read in a change in water surface elevation. Chapter 5, "Bridge Problems and Suggested Approaches", presents the modifications of basic input requirements for some typical bridge problems such as multiple bridge openings, perched bridges, low water bridges and others.

4.2 Special Bridge Example

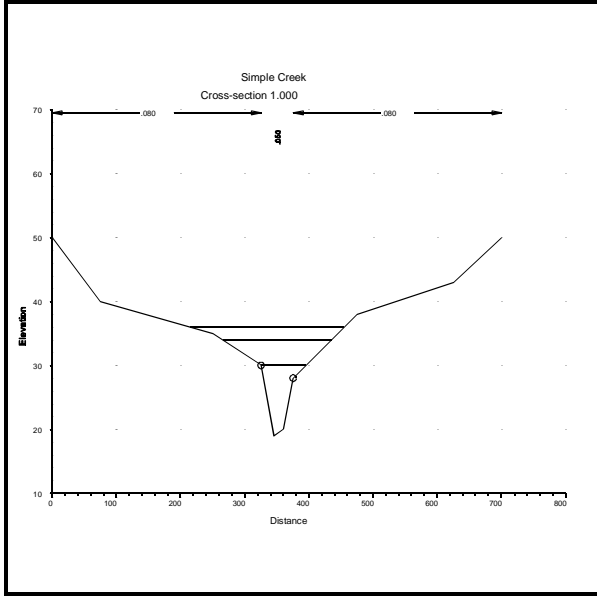
The example problem cross sections, with computed water surface elevations, are shown in Figure 8. The bridge spans the entire floodway and has abutments that constrict the natural flow. To simplify input, it will be assumed that the reach has a constant cross sectional shape and has a bed slope of zero. Other pertinent data is shown on the figure. The following discussion describes the input problem and the input is shown in Figure 9. A computer run with the data set is given in Exhibit A.

The problem is set up for a multiple profile run using the QT record. Manning's 'n' values are read on the NC record and contraction and expansion coefficients of 0.3 and 0.5 were selected.

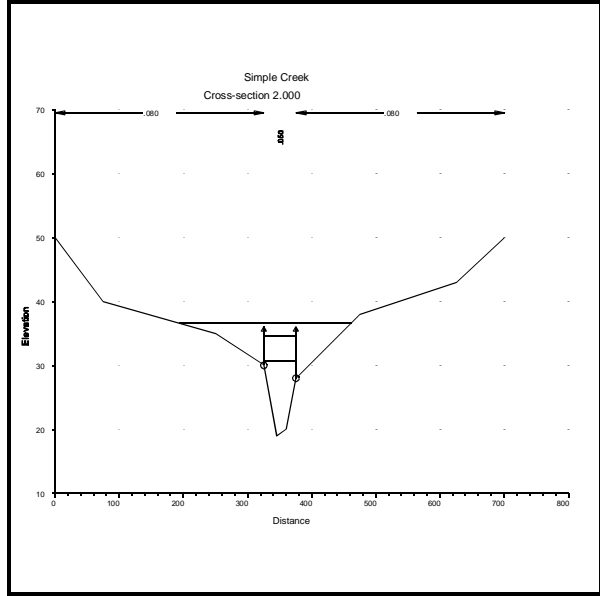
Cross Section 1 is the downstream cross section located where the flow has fully expanded back onto the floodplain. The section will be repeated as cross section 2; therefore, the left and right bank stations are selected to be consistent with the bridge opening. The section is located downstream using the 4:1 expansion of the flow as previously presented. The reach lengths for the first section are set to zero as this is the section where the profile is being initiated. The GR records are used to describe the natural ground section in the usual manner.

Cross Section 2 is immediately downstream from the bridge. The reach lengths between sections one and two are set equal to four times the average abutment length (60 feet \pm) for a total reach length of 240 feet. Because the natural section was considered applicable, the ground profile was repeated.

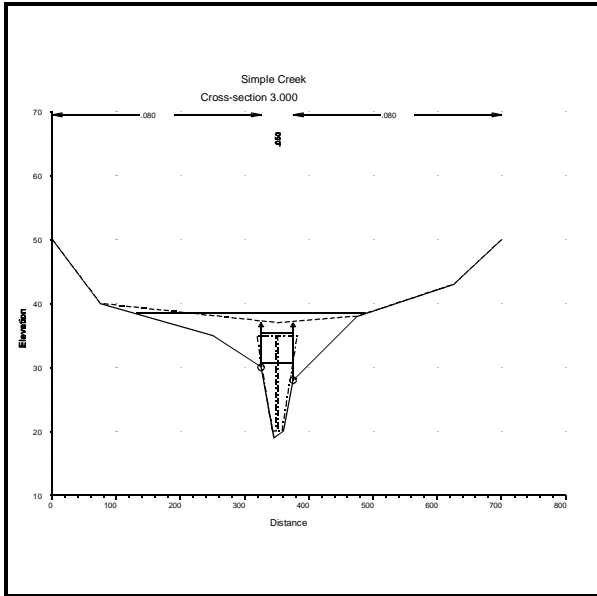
The effective area option is used at cross section 2 to confine the flow to the bridge opening when flow through the bridge is low flow or pressure flow. The left and right bank stations have already been set consistent with the abutment locations. All that is required is the X3 record with a ten in the first field and the selection of an elevation above which weir flow can be expected over the bridge. For the initial data input, the elevation at cross section 2 corresponding to weir flow is generally unknown, so an estimate must be made. In the example, water cannot flow around the bridge so weir flow must pass over the bridge. A reasonable estimate for the downstream elevation (i.e., at cross section 2) is an elevation midway between the low chord and top of road elevations, or 36 feet in this example. The limiting elevations for the effective area option are entered in Fields 8 and 9 of the X3 record.



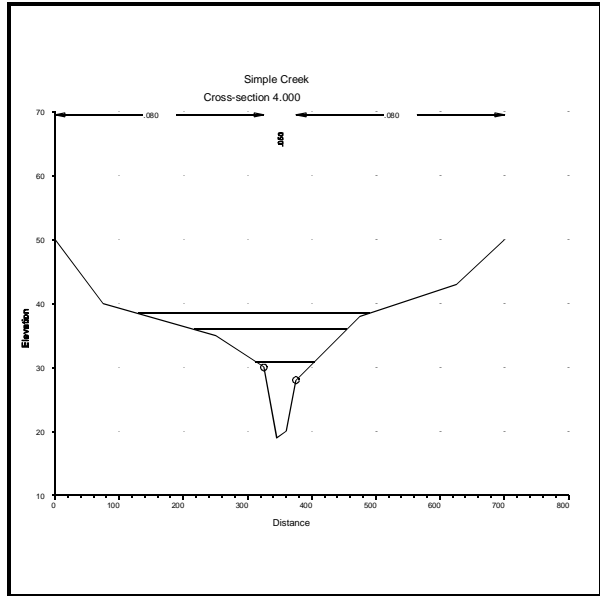
Downstream Natural Section



Downstream from Bridge



Upstream from Bridge plus Bridge Data



Upstream Natural Section

Figure 8
Special Bridge Example Cross Sections


```

T1    SPECIAL BRIDGE EXAMPLE
T2    Low flow profile
T3    Simple Creek
J1    2                                30
* Request the Speical Bridge Summary Tables on J3.
J3    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 expansion 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

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.
EJ
T1    PRESSURE FLOW PROFILE
J1    3                                34
J2    2
T1    PRESSURE AND WEIR FLOW PROFILE
J1    4                                36
J2    3
ER

```

**Figure 9
Special Bridge Example Input**

Record SB defines bridge characteristics for the special bridge method. The first three variables are the coefficients for computing class A low flow, pressure flow, and weir flow, respectively. The first field contains the pier shape coefficient for the Yarnell equation. The shape of the piers is the basis for selecting the coefficient as shown on page 19. For the example, twin-cylinder piers without diaphragm require a coefficient of 1.05. For a bridge without piers, the first field can be left blank.

For the pressure flow calculations, the value of XKOR is used in the orifice equation. Based on the typical value suggested by the Bureau of Public Roads, a value of 1.6 was selected.

The weir flow coefficient, COFQ, is used to calculate weir flow. In the example, most of the weir flow would occur over the bridge rather than the road, so a value of 2.6 was selected.

The variable RDLEN was not used because it is only applicable for a horizontal weir with a crest length RDLEN. To define the weir profile for the example problem the BT records are used.

Six variables on the SB record provide the data to model the bridge opening. Five variables define the bridge for low flow calculations with the momentum and Yarnell equations. The bottom width of the trapezoid (BWC) and the side slope (SS) provide the basic trapezoid. Variable BWP gives

the total width of piers and ELCHU and ELCHD give the upstream and downstream elevations for the invert of the trapezoid. The sixth variable, BAREA, provides the net area of the bridge opening for calculating pressure flow.

In making a trapezoidal approximation of a bridge opening, dimensions should be chosen so that the corresponding water surface elevation versus area curve duplicates as closely as possible the elevation versus area curve for the actual bridge opening. If the area-elevation relation cannot be preserved over the complete range of elevations, emphasis should be placed on the range of elevations to be used in the problem. If low flows are to be run, then the elevation-area curve corresponding to the trapezoid should be appropriate for the lower depths in the bridge section. For high flows, the small depths would not be as important. To check the trapezoidal area for large flows, the user should compare the program computed output variable TRAPEZOID AREA to the net bridge area (BAREA) based on the actual bridge. The two areas should be close, especially if flows near the bridge's low flow capacity are being computed.

The variables ELCHU and ELCHD define the upstream and downstream invert elevations for the trapezoidal area. If the trapezoid invert is the same as the minimum elevation (ELMIN) for the previous cross section (cross section 2 in this example), then the elevations can be left blank on the SB record. In some cases, the invert elevation must be set higher than ELMIN to give a better bridge model (elevation-area curve) at higher discharges. In those cases, the invert elevations can be read on the SB record.

For the example problem, the invert elevation for the trapezoid was set at 20 feet, slightly higher than the actual elevation. A bottom width of 15 feet and side slopes of 1.6 give a reasonable trapezoidal approximation. Total net area based on the trapezoidal model is 555 square feet.

The variable BAREA is the net area under the bridge to be used in the orifice equation. Once the program has determined that flow through the bridge is by pressure flow, the trapezoidal approximation is no longer used, and flow calculations are made using the orifice equation. The total open area under the bridge (BAREA) is used for the pressure flow calculations. Based on the given bridge geometry, an area of 565 square feet is entered in Field 7 of the SB record.

Cross Section 3, immediately upstream from the bridge, is a repeat of cross section two for this example. The reach lengths for this section are the length of the water course through the bridge.

Following the X1 record for cross section 3 is an X2 record. This record is required with the special bridge method to call the special bridge method (IBRID = 1 in Field 3) and to give test elevations for pressure flow and weir flow (ELLC and ELTRD in Fields 4 and 5). The maximum elevation on the low chord of the bridge, ELLC, is used by the program to check if there is a possibility of pressure flow. The low point of the top of road, ELTRD, is used to test if weir flow exists. Even though the program can scan the BT records to find these elevations, it is good practice to always specify them on the X2 record. Also, the need for low chord elevations on the BT records is eliminated when coding a bridge with piers for the special bridge method. The effective area option is defined for cross section 3 in the same manner as for cross section 2. For the upstream side of the bridge, the elevations for the control of effective area are set to the minimum top of road (ELTRD). As in cross section 2, the X3 records has a ten in the first field and the control elevations in Fields 8 and 9.

The BT records, necessary to define the weir for the special bridge method are placed with input records for cross section 3. Because the bridge in the example problem has piers, the program will remain with the special bridge method for all solutions. That is, the program cannot revert to the normal bridge method for the given input. This is important to check when coding the BT records because it can simplify input. If the program remains in the special bridge method, all that is needed on the BT records is specification of road stations and elevations to define the weir. In defining the weir under these circumstances, road stations do not have to be consistent with the GR record stations.

Without a pier, the special bridge method will use standard step calculations for low flow and for combination weir and low flow solutions (the weir equation would not be used). When standard step calculations are made, the program computes conveyance by segments across the section; therefore, the BT stations under these conditions would have to line up with GR stations and both top of road and low chord elevations would have to be given. The BT records in the example show the minimum required data for the example problem.

Cross section 3 is a repeat section, so there are no GR records. If GR records were used with cross section 3, they would follow the BT records.

Cross Section 4 completes the model for the example problem. It is a full flow section located upstream from the bridge beyond the zone of flow contraction. The reach length is estimated by a one to one ratio of the average abutment constriction on the flow. In the example, the distance is 60 feet. Because the same ground geometry is used, no GR records are read.

If the contraction and expansion coefficients, read on the NC record, were to be changed to lower values for subsequent profile calculations proceeding upstream from cross section 4, the new values would be read in after section four and before the next X1 record.

The coded input for this problem was run on HEC-2. The program output is shown in Exhibit A.

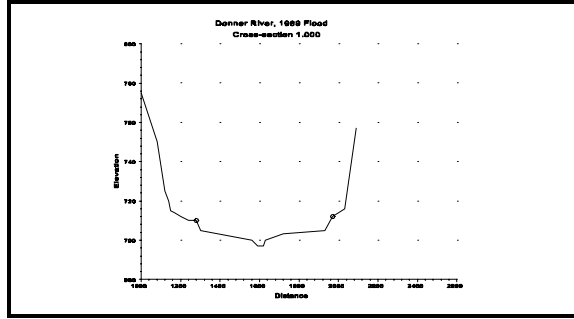
4.3 Normal Bridge Method Example

The second example, an arch bridge, will be modeled using the normal bridge method. Again, the problem is fairly simple and intended to illustrate the basic input requirements. The geometric data are shown in Figure 10 and the complete data listing is shown in Figure 11. The computer solution for the problem is shown in Exhibit B. Discussion of the input follows.

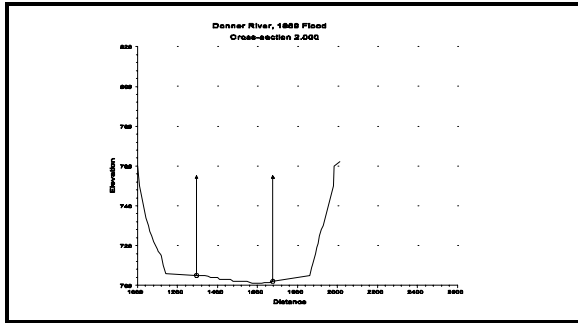
A single profile is to be calculated with Manning's 'n' values defined on the NC record. The starting 'n' values define the natural channel and overbanks. Contraction and expansion coefficients of 0.3 and 0.5, respectively, were selected.

The first two cross sections represent the same modeling situation discussed under the special bridge method example. **Cross Section 1** is the downstream section located where the flow has fully expanded onto the floodplain. It is located 400 feet downstream from the bridge based on the 4:1 expansion of the flow as previously presented. **Cross Section 2** is just downstream from the bridge and represents the contacted effective flow leaving the bridge. The X3 record is used, as before, to call the effective area option and to extend the elevation of channel control for cases where all the flow is going through the bridge.

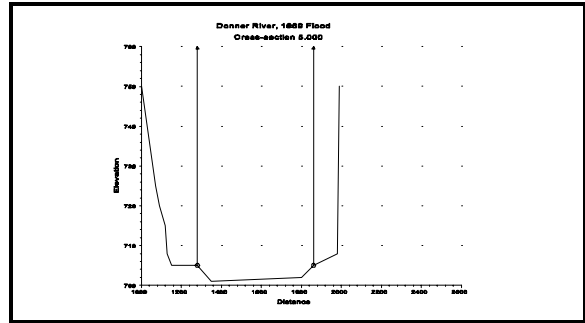
Input for the normal bridge method differs from input for the special bridge at this point. After cross section 2, located immediately downstream from the bridge, comes **cross section 3** representing a section through the bridge. For the bridge the Manning's 'n' value for the channel should change. Therefore, the NC record is read in prior to cross section 3 with a channel 'n' value of 0.025 for the bridge.



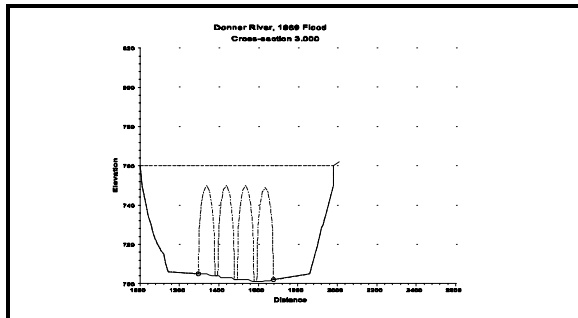
Downstream Natural Section



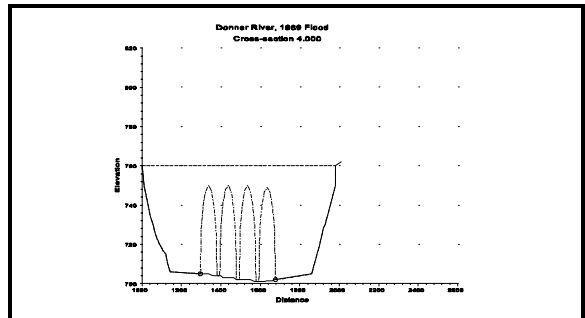
Downstream from Bridge



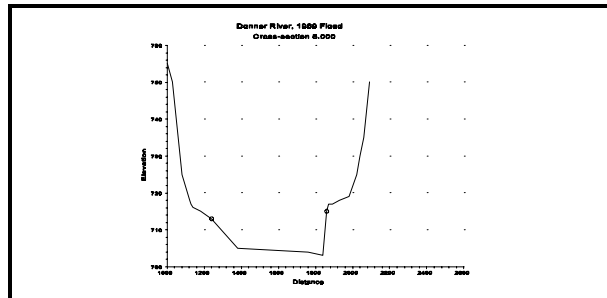
Upstream from Bridge



Downstream Bridge Section



Upstream Bridge Section



Upstream Natural Section

Figure 10
Normal Bridge Example Cross Sections

```

T1      Multiple Arch Railroad Bridge (Normal Bridge Example)
T3      Donner River, 1969 Flood
J1      0      3      0      0      0.0025      0      0      0      715      0
J2      -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
*
*      California Northern R.R. Bridge (River Mile 15.434)
*
NC      .025
X1      3
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
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      20      20      20
X2
NC      .035
*
*      Limit flow width with EFFECTIVE AREA OPTION
X1      5      12      1280 1860 1 1 1
X3      10
GR 750 1000 725 1070 720 1090 715 1120 708 1130
GR 705 1150 705 1280 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
EJ
ER

```

Figure 11
Normal Bridge Example Input

After changing the 'n' value for the bridge, the bridge is described using the BT records, as shown in Figure 10.

The **BT records** for the normal bridge method should only have stations that are used on the GR records. Consistent stationing is required because the program computes the conveyance of the cross section incrementally for each GR station. To properly correct the area and wetted perimeter for the presence of the bridge, the given BT stations must coincide with the GR stations. For GR stations between given BT stations, the program will linearly interpolate the road elevation (variable RDEL) and low chord elevation (variable XCEL) to calculate the incremental conveyance.

For bridge stations in the overbank areas, the low chord elevation (XCEL) is usually set equal to the ground point elevation (EL on the GR record). In the channel area, the low chord elevation defines the low chord of the bridge. For the example problem, the low chord elevations define the bottom of the arches. The top of road elevations define the road profile for the cross section.

As cross section 3 is just inside the bridge on the downstream side, **cross section 4** is located inside the bridge at the upstream end. This section is a repeat section of the downstream bridge section. The cross section elevations were not changed; however, the bridge can be modeled with a slope by adding an incremental elevation in Field 9 of the X1 record. The BT records for this cross section are also repeated from cross section 3 by using the X2 record with a one in Field 7 (variable REPBT). If the bridge had been modeled with a slope, the same incremental elevation adjustment used on the X1 record would be applied by the program to the low chord elevations on the BT record. The top of road elevations are not changed by the program. The standard step solution from cross section 3 to cross section 4 determines friction and expansion or contraction losses through the bridge. If only friction losses should be computed, the values for the contraction and expansion coefficients should be redefined to very small values just before cross section 4. After cross section 4, the values can be reset to calculate shock losses.

Cross Section 5 represents the effective flow area just upstream from the bridge. The Manning's 'n' value must first be changed back to represent the channel. An NC record with the channel 'n' value is read in just before cross section 5. This cross section could be modeled as a repeat of cross section 4, but without the BT records. The effective area option is again used to maintain the flow in the channel up to the top of road elevation (X3 record with ten in Field 1 and control elevations in Fields 8 and 9).

The last cross section for the bridge model is a cross section upstream from the zone of contraction for the bridge. **Cross section 6** represents the full floodplain and is located 110 feet upstream, determined by using a one on one contraction rate. The ground section is redefined by GR records. This cross section completes the geometric model for the normal bridge method.

4.4 Input Bridge Loss Example

Bridge losses can be read into the program by two different methods. A bridge loss in terms of a change in water surface elevation can be read on the X2 record (variable BLOSS on Field 6) or on the X5 record. The X5 record will be demonstrated in this example because it can be used for multiple profiles, where as only a single loss can be read on the X2 record.

The example used with the special bridge method will be repeated here. However, instead of modeling the bridge, the calculation will involve only cross sections 1 through 4 (see Figure 8) and the bridge loss will be input at cross section 4. It is assumed for the application that the bridge loss has been determined externally from the program.

The input is a repeat of that for the previous special bridge example (Figures 8 and 9) up through the first cross section. This is followed by input for the far upstream cross section 4. An X5 record is added to the usual data at cross section 4.

The X5 record can be used in two ways. Either a water surface elevation or a change in water surface can be defined. The choice is indicated on the record by the sign used (plus or minus) with the variable N on the first field. The variable indicates the number of values to be specified on the X5 record. A positive N indicates water surface elevations and a negative N indicates increments of water surface elevation. The latter is used in this example.

On multiple profile runs, the variable INQ (Field 2 of the J1 record) tells the program which field of the QT record to read. The same procedure is used to read the X5 record. In this example, each field to be read on the QT record has a corresponding bridge loss to be read on the X5 record. The first field of the X5 record shows the number of values to be read. The value in the first field is negative to indicate that changes in water surface elevation are to be read. The changes in the example are the computed results from the special bridge example. The computer run is shown in Exhibit C.

```

T1 BRIDGE PROBLEM WITH INPUT LOSS
T2 X5 input for WSEL change from Special Bridge Example
T3 SIMPLE CREEK
T4 LOW FLOW PROFILE
J1 2 30
NC .08 .08 .05 .3 .5
QT 3 2000 4500 6000 0 0 0
X1 1 10 325 375
GR 50 0 40 75 35 250 30 325 19 345
GR 20 360 28 375 38 475 43 625 50 700
BT 475 38 625 43 700 50

* All bridge sections eliminated. Total loss defined on X5 record.
* Losses computed in Special Bridge Example.
X1 4 360 360 360
X5 -3 0.90 1.97 2.47
EJ
T1 PRESSURE FLOW PROFILE
J1 3 34
J2 2
T1 PRESSURE AND WEIR FLOW PROFILE
J1 4 36
J2 3
ER

```

Figure 12
Input Bridge Loss Example Input

Chapter 5

Bridge Problems and Suggested Approaches

5.1 Introduction

The examples presented in the previous section were for relatively simple structures so that fundamental principles of input preparation should be emphasized. However, many bridges are more complex than the one illustrated, and the following discussion is intended to show how HEC-2 can be used to calculate profiles for some of the types of bridges that are frequently encountered. The discussion here will be an extension of the previous examples and will address only those aspects of input preparation that have not been discussed previously.

5.2 Multiple Bridge Opening

Many bridges have more than one opening for flood flow, especially over very wide floodplains. Multiple culverts, bridges with side relief openings, and separate bridges over a divided channel are all examples of multiple bridge openings. With more than one bridge opening, and possible different control elevations, the problem can be very complicated. Some general considerations follow.

For low flow situations, the normal bridge method is more applicable than the special bridge method. The SB record cannot be used to model more than one trapezoidal bridge opening. Modeling two or more separate bridge openings as one trapezoidal section with wide piers (variable BWP) is generally unsatisfactory because the semi-empirical Yarnell equation has not been calibrated for such flow conditions.

Pressure flow can be modeled with the special bridge method, however, only one controlling elevation (ELLC) can be used. Therefore, if the maximum low chord elevation (variable ELLC) is the same on all bridge openings, or if the flow is high enough to inundate all the openings, the orifice equation can be used. Chapter 3, "Loss Coefficients", provides a method of computing an equivalent coefficient for multiple culverts.

If flow through some of the culverts is low flow while flow through other culverts is pressure flow, the program cannot provide a direct solution with the special bridge method. To use the special bridge method, the openings would have to be modeled separately and a "divided flow" approach would be required [Chow, 1959]. A normal bridge solution could be directly obtained if the distribution of flow based on conveyance was reasonable and if one water surface elevation could be assumed for the entire bridge section.

Computer determination of low flow by the normal bridge method and pressure flow by the special bridge method can be obtained in a multiple profile run. By coding the bridge input using the special bridge without a pier, the program will use the normal bridge method for low flow solutions. The BT records would have to be coded consistent with requirements for the normal bridge method. For the higher discharges where pressure flow occurs, the solution would be obtained from the orifice equation in the special bridge method.

5.3 Dams and Weirs

Flow over uncontrolled dams and weirs can be modeled with the special bridge method. Weir flow is calculated over weirs defined by either the stations and road elevations on BT records or by a fixed weir length (RDLEN) and elevation (ELTRD) defined on records SB and X2, respectively. To use the special bridge method where all flow is weir flow requires the same basic data as for a bridge. Recalling the calculation sequence, the special bridge method assumes low flow and then pressure flow prior to determining that weir flow exists. On the SB record, it is necessary to input some arbitrarily small values for the variables defining the trapezoid and the orifice area (variables BWC, BAREA, and SS). The small areas defined by the trapezoid and BAREA will cause the program to solve for a combination of pressure flow and weir flow. With a very small orifice area, the pressure flow will be negligible and a weir flow solution will have been achieved.

5.4 Perched Bridges

A perched bridge is one for which the road approaching the bridge is at the floodplain ground level, and only in the immediate area of the bridge does the road rise above ground level to span the watercourse. A typical flood flow situation with this type of bridge is to have low flow under the bridge and overbank flow around the bridge. Because the road approaching the bridge is usually not much higher than the surrounding ground, the assumption of weir flow is often not justified. A solution based on standard step calculations would be better than a solution based on weir flow with correction for submergence. Therefore, this type of bridge should generally be modeled using the normal bridge method, especially when a large percentage of the total discharge is in the overbank areas.

5.5 Low Water Bridges

A low water bridge is designed to carry only low flows under the bridge. Flood flows are carried over the bridge and road. When modeling this bridge for flood flows, the anticipated solution is a combination of pressure and weir flow, which implies using the special bridge method. However, with most of the flow over the top of the bridge, the correction for submergence may introduce considerable error. If the tailwater is going to be high, it may be better to use the normal bridge method. In fact, if almost all the water is over the top, the bridge may be modeled as a cross section over the top of the bridge, ignoring the flow under the bridge.

5.6 Bridges on a Skew

Skewed bridge crossings are generally handled by making adjustments to the bridge dimensions to define an equivalent cross section perpendicular to the flow lines. The adjustments can be made in the normal bridge method by multiplying the actual dimensions of the bridge by the cosine of the skew angle. The cosine of the angle is coded on the X1 record (variable PXSECR in Field 8) for the cross section coordinates on GR records and on the X2 record (variable BSQ in Field 9) for the data on the BT records. If the special bridge method is used, the data coded on the SB record must be adjusted prior to input. There is no internal method in the program to adjust the data on the SB record.

In the publication "Hydraulics of Bridge Waterways" [Bradley, 1978] the effect of skew on low flow is discussed. In model testing, skewed crossings with angles up to 20 degrees showed no objectionable flow patterns. For increasing angles, flow efficiency decreased.

A graph illustrating the impact of skewness indicates that using the projected length is adequate for angles up to 30 degrees for small flow contractions.

5.7 Parallel Bridges

With the construction of divided highways, a common modeling problem involved parallel bridges. For new highways, these bridges are often identical structures. The hydraulic losses through the two structures has been shown to be between one and two times the loss for one bridge [Bradley, 1978]. The model results [Bradley, 1978] indicate the loss for two bridges ranging from 1.3 to 1.55 times the loss for one bridge crossing, over the range of bridge spacings tested. Presumably if the two bridges were far enough apart, the losses for the two bridges would equal twice the loss for one. For the program user faced with a dual bridge problem, computing a single bridge loss and then adjusting it with criteria [Bradley, 1978] may be the most expedient approach. If both bridges are modeled, care should be exercised in depicting the expansion of flow between the bridges.

Chapter 6

References

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U.S. Army Corps of Engineers, *Hydraulic Design of Spillways*, EM 1110-2-1603, 31 March 1965, Plate 33.

Exhibit A

Special Bridge Example

Computer Run

```

*****
*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 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

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X X XXXXXXX XXXXX XXXXX
X X X X X X X X
X X X X X X X X
XXXXXXXX XXXX X XXXXX XXXXX
X X X X X X X X
X X X X X X X X
X X XXXXXXX XXXXX XXXXXXX

```

END OF BANNER

06FEB91 16:02:27

PAGE 1

THIS RUN EXECUTED 06FEB91 16:02:27

```

*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****

```

T1 SPECIAL BRIDGE EXAMPLE
T2 Low flow profile
T3 Simple Creek

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
									30	
Request the Speical Bridge Summary Tables on J3.										
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 expansion coefficients go here if they are changed for the bridge calculations. Expansion loss would be evaluated at Section 2.

X1	2			240	240	240				
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				1	35	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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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.

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PAGE 3

SECNO	DEPTH	CWSEL	CRISW	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								
	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	28.00
	.00	.00	5.54	.99	.000	.050	.080	.000	19.00
	.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	COFO	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

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

*SECNO 4.000	11.90	30.90	.00	.00	31.26	.36	.12	.01	30.00	
4.000	2.8	1954.1	43.1	6.0	402.3	42.0	3.2	.5	28.00	
2000.0	.02	4.47	4.86	1.03	.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

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								

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PAGE 6

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

*PROF 2

CCHV=	.300	CEHV=	.500							
*SECNO 1.000	15.00	34.00	.00	34.00	34.70	.70	.00	.00	30.00	
1.000	180.2	3966.1	353.6	120.0	557.5	180.0	.0	.0	28.00	
4500.0	.00	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	.6	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	COFO	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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PAGE 7

SECNO	DEPTH	CWSEL	CRISW	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	215.83	
.001233	60.	60.	60.	2	0	0	.00	238.94	454.76	

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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								

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PAGE 9

SECNO	DEPTH	CWSEL	CRISW	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	COFO	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 AREA	ELLC	ELTRD	WEIRLN
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

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PAGE 10

THIS RUN EXECUTED 06FEB91 16:02:32

 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

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	16.31	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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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	92.42	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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SUMMARY OF ERRORS AND SPECIAL NOTES

Exhibit B

Normal Bridge Example

Computer Run

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*****
* WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 07:43:14 *
*****

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

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X X X X X X
X X X X X X
X X XXXXXXX XXXXX XXXXXXX

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END OF BANNER

06FEB91 07:43:14

PAGE 1

THIS RUN EXECUTED 06FEB91 07:43:14

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*****
HEC2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****

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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							755	755	
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

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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PAGE 2

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			20	20	20			
X2						1			
NC			.035						

Limit flow width with EFFECTIVE AREA OPTION									
X1	5	12	1280	1860	1	1	1		
X3	10							760	760
GR	750	1000	725	1070	720	1090	715	1120	708
GR	705	1150	705	1280	701	1350	702	1800	705
GR	708	1980	750	1990					1860
X1	6	20	1240	1860	110	110	110		
GR	755	1000	750	1030	725	1080	718	1120	717
GR	716	1140	715	1180	713	1240	705	1380	704
GR	703	1840	715	1860	717	1870	717	1890	718
GR	719	1980	725	2020	730	2040	735	2060	750

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PAGE 3

SECNO	DEPTH	CWSEL	CRISW	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	WIN	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 ELLE= 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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PAGE 4

SECNO	DEPTH	CWSEL	CRISW	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	WIN	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 ELLE= 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	8.1	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

HEC2 WATER SURFACE PROFILES
Version 4.6.0; February 1991

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	CRWS	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

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

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

Exhibit C

Input Loss Example

Computer Run

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*****
*****
* HEC-2 WATER SURFACE PROFILES *
* *
* *
* Version 4.6.0; February 1991 *
* *
* *
* RUN DATE 06FEB91 TIME 07:50:10 *
* *
*****
*****

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

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END OF BANNER

06FEB91 07:50:10

PAGE 1

THIS RUN EXECUTED 06FEB91 07:50:10

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*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
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T1 BRIDGE PROBLEM WITH INPUT LOSS
T2 X5 input for WSEL change from Special Bridge Example
T3 SIMPLE CREEK
T4 LOW FLOW PROFILE

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J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		2							30	
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
BT		475	38		625	43		700	50	

All bridge sections eliminated. Total loss defined on X5 record.
Losses computed in Special Bridge Example.

X1	4				360	360	360			
X5	-3	0.90	1.97	2.47						

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PAGE 2

SECNO	DEPTH	QWSEL	CRIBS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XLN	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 4.000									
WATER EL=X5	CARD=	30.900							
4.000	11.90	30.90	.00	.00	31.26	.36	.82	.03	30.00
2000.0	2.9	1954.0	43.1	6.1	402.5	42.0	3.4	.7	28.00
.02	.47	4.85	1.03	.080	.050	.080	.000	19.00	311.50
.001871	360.	360.	360.	0	0	0	.00	92.50	404.00

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PAGE 3

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

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PAGE 4

SECNO	DEPTH	CWSEL	CRISW	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	I'TRIAL	IDC	ICONT	CORAR	TOPWID	ENDST	

*PROF 2

CCHV=	.300	CEHV=	.500							
*SECNO 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 4.000
WATER EL=X5 CARD= 35.970

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.45

4.000	16.97	35.97	.00	.00	36.35	.38	.62	.10	30.00	
4500.0	395.6	3584.7	519.6	276.7	656.0	317.6	8.7	1.7	28.00	
.02	1.43	5.46	1.64	.080	.050	.080	.000	19.00	216.05	
.001236	360.	360.	360.	0	0	0	.00	238.65	454.70	

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PAGE 5

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									

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SECNO	DEPTH	CWSEL	CRISW	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	I'TRIAL	IDC	ICONT	CORAR	TOPWID	ENDST	

*PROF 3

CCHV=	.300	CEHV=	.500							
*SECNO 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 4.000
WATER EL=X5 CARD= 38.470

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 1.56

4.000	19.47	38.47	.00	.00	38.77	.30	.48	.11	30.00	
6000.0	985.5	4074.4	940.2	658.5	781.0	550.3	13.4	2.5	28.00	
.02	1.50	5.22	1.71	.080	.050	.080	.000	19.00	128.55	
.000893	360.	360.	360.	0	0	0	.00	360.55	489.10	

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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

SIMPLE CREEK

SUMMARY PRINTOUT TABLE 150

SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRISW	EG	10*KS	VCH	AREA	.01K
1.000	.00	.00	.00	19.00	2000.00	30.00	.00	30.47	28.53	5.54	377.50	374.42
1.000	.00	.00	.00	19.00	4500.00	34.00	.00	34.70	26.03	7.11	857.50	882.08
1.000	.00	.00	.00	19.00	6000.00	36.00	.00	36.66	21.73	7.26	1257.50	1287.06
*	4.000	360.00	.00	.00	19.00	2000.00	30.90	.00	31.26	18.71	450.63	462.34
*	4.000	360.00	.00	.00	19.00	4500.00	35.97	.00	36.35	12.36	1250.32	1279.92
*	4.000	360.00	.00	.00	19.00	6000.00	38.47	.00	38.77	8.93	1989.78	2008.02

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SIMPLE CREEK

SUMMARY PRINTOUT TABLE 150

SECNO	Q	CWSEL	DIFWSP	DIFWSX	DIFKWS	TOPWID	XLCH
1.000	2000.00	30.00	.00	.00	.00	70.00	.00
1.000	4500.00	34.00	4.00	.00	.00	170.00	.00
1.000	6000.00	36.00	2.00	.00	.00	240.00	.00
* 4.000	2000.00	30.90	.00	.90	.00	92.50	360.00
* 4.000	4500.00	35.97	5.07	1.97	.00	238.65	360.00
* 4.000	6000.00	38.47	2.50	2.47	.00	360.55	360.00

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SUMMARY OF ERRORS AND SPECIAL NOTES

NOTE SECNO= 4.000 PROFILE= 1 WSEL BASED ON X5 CARD
 NOTE SECNO= 4.000 PROFILE= 2 WSEL BASED ON X5 CARD
 WARNING SECNO= 4.000 PROFILE= 2 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
 NOTE SECNO= 4.000 PROFILE= 3 WSEL BASED ON X5 CARD
 WARNING SECNO= 4.000 PROFILE= 3 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

Appendix IV

Application of the HEC-2 Culvert Option

Appendix IV

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Chapter 1

Introduction

The HEC-2 program offers three methods for computing head losses through bridge or culvert structures: the **Normal Bridge Method**, the **Special Bridge Method**, and the **Special Culvert Method**. The normal bridge method is based on Manning's equation and uses the standard step method to determine bridge losses. The special bridge method, on the other hand, utilizes a series of hydraulic equations to analyze flow through bridges for a number of different flow conditions. Both of these methods are described in Appendix III.

The special culvert method is similar to the special bridge method, except that the Federal Highway Administration's (FHWA) standard equations for culvert hydraulics are used to compute losses through the structure. This appendix describes the application of the special culvert method.

Figure 1.1 illustrates a typical box culvert road crossing. As shown, the culvert is similar to a bridge in many ways. The walls and roof of the culvert correspond to the abutments and low chord of the bridge, respectively.

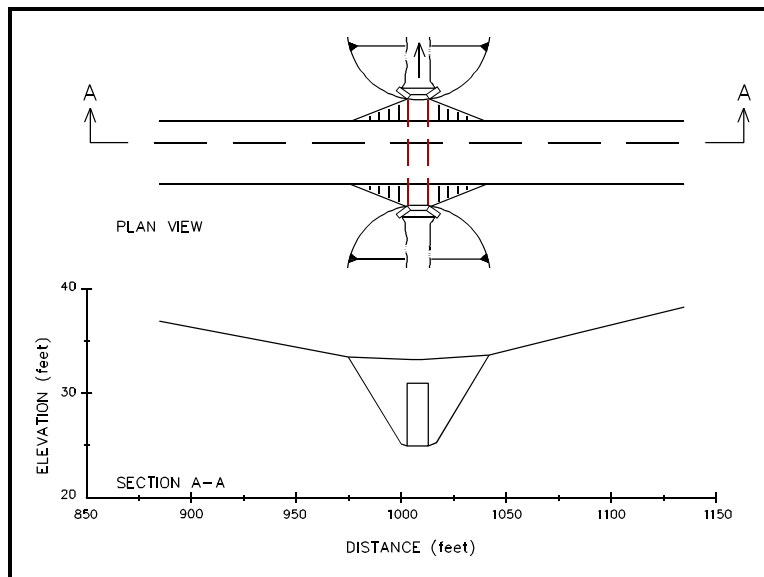


Figure 1.1
Typical Culvert Road Crossing

Because of the similarities between culverts and other types of bridges, the normal bridge and special bridge methods available in the HEC-2 computer program can often be applied to the analysis of culverts. The layout of cross sections, the use of the effective area option, the selection of loss coefficients, and most other aspects of bridge analysis apply to culverts as well.

1.1 Advantages of the Special Culvert Option

The special culvert method offers the following advantages for modeling flow through culverts, when compared with the normal bridge or special bridge methods:

- **Reduced Data Requirements:** For the special bridge or normal bridge methods, the culvert shape must be defined using the ground elevation coordinates (GR records) and the low chord coordinates (BT records). This can be tedious, especially for circular culverts. For the special culvert method, the culvert shape is defined using the pipe diameter for circular culverts, or the height and width of the opening for box culverts.
- **Familiar Hydraulic Coefficients:** The hydraulic capacity of the culvert is described using familiar terminology and coefficients, such as the Manning's roughness coefficient and the entrance loss coefficient.
- **Similarity to FHWA Nomographs:** The HEC-2 special culvert method is based on the same equations as the familiar FHWA culvert nomographs. Therefore, the results of the special culvert option can be easily confirmed using the nomographs.
- **Flexibility in Hydraulic Modeling:** The HEC-2 special culvert method provides a good solution for head loss through a roadway crossing under a wide variety of flow conditions, including low flow conditions.

1.2 Limitations of the Special Culvert Option

The HEC-2 special culvert option is subject to the following limitations:

- **Constant Cross Section:** The culvert cross section, flow rate, and bottom slope are assumed to be constant throughout the length of the culvert.
- **Positive or Horizontal Culvert Slope:** The culvert bottom slope is required to be positive or zero. That is, the invert or flow-line of the culvert cannot be lower in elevation on the upstream side of the culvert than on the downstream side.
- **No Mixed Sizes or Shapes:** Each culvert road crossing is assumed to be composed of only one culvert or a number of identical culverts.
- **No Super-Critical Profiles:** The special culvert option may be used in subcritical profile computations only.

1.3 Converting Special Bridge Models to Special Culvert Models

The special culvert option has been designed to operate like the special bridge option whenever possible. This similarity makes it easy to convert existing special bridge models to special culvert models. The following steps are required:

- 1) Change the value of the variable IBRID in Field 3 of the X2 record from 1 to 2 to indicate that the special culvert option will be used in place of the special bridge method.

- 2) Delete the value of the variable CMOM in Field 8 of the X2 record. This variable is used only for the special bridge option and is not required for the special culvert option. Although the program will ignore any value entered for this variable, it is good practice to leave Field 8 blank when using the special culvert option, in order to avoid confusion.
- 3) Replace the SB record with an SC record. Copy the values of variables COFQ (Field 3), RDLEN (Field 4), ELCHU (Field 9), and ELCHD (Field 10) from the SB record to the SC record. These variables are used by the special culvert method as well as the special bridge method. Make sure that ELCHU is equal to or higher than ELCHD.
- 4) Enter the appropriate values for the number of identical culverts (CUNO) and the culvert n-value (CUNV) in Field 1 of the SC record. Also enter the culvert entrance loss coefficient (ENTLC) in Field 2, the height of the culvert opening (RISE) in Field 5, the length of the culvert (CULVLN) in Field 7, and the Federal Highway Administration chart number (CHRT) and scale number (SCL) in Field 8 of the SC record. For box culverts, the width of the culvert opening (SPAN) should also be entered in Field 6 of the SC record. Chapter 3 of this appendix describes all of these input values.
- 5) Check the remaining input data to be sure that the modeling guidelines described in Chapter 3 of this appendix have been followed. Important items to check include the cross section layout and spacing, the definition of the top of road for weir flow, and the specification of effective flow areas.

The converted culvert model should now be ready for analysis using the special culvert method.

1.4 Using this Appendix

This appendix is intended to get you started in using the HEC-2 special culvert option quickly and easily, and also to provide a reference should questions or problems arise in the future. Chapter 2 of this appendix provides background information on culvert hydraulics and the terminology associated with culverts. Chapter 3 provides a complete discussion of the HEC-2 special culvert option, including the layout of all required cross sections, the sources of all required data for the culvert, and the appropriate values for all hydraulic coefficients. Chapter 4 presents three complete examples of the HEC-2 special culvert option, including complete listing of input data, results, and a discussion.

All equations and other material in this appendix are presented using standard English or American units of measurement. However, the special culvert option has been designed and implemented to work equally well with corresponding metric (S.I.) units.

Chapter 2

Culvert Hydraulics

This chapter introduces the basic concepts of culvert hydraulics which are used in the HEC-2 special culvert option.

2.1 Introduction to Culvert Terminology

A **culvert** is a relatively short length of closed conduit which connects two open channel segments or bodies of water. Two types of culverts are most commonly used: **pipe culverts**, which are circular in cross section, and **box culverts**, which are rectangular in cross section. Figures 2.1 and 2.2 illustrate pipe culverts and box culverts, respectively.

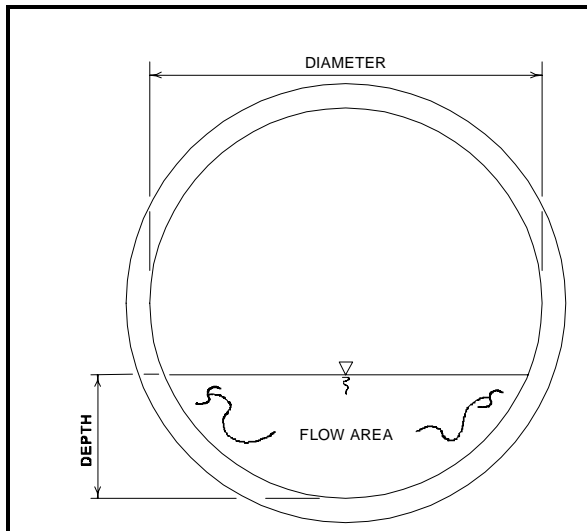


Figure 2.1
Cross-Section of a Pipe Culvert

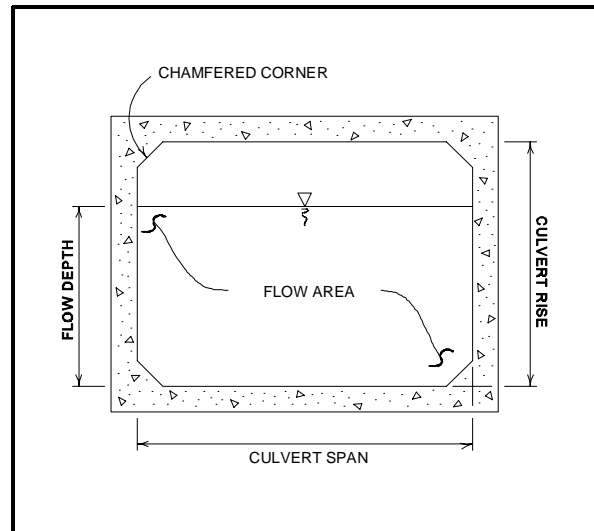


Figure 2.2
Cross-Section of a Box Culvert

Culverts are made up of an **entrance** where water flows into the culvert, and a **barrel**, which is the closed conduit portion of the culvert. The total flow capacity of a culvert depends upon the characteristics of the entrance as well as the culvert barrel.

The **tailwater** at a culvert is the depth of water on the discharge or downstream side of the culvert, as measured from the downstream flow-line of the culvert. The **flow-line** is the lowest point on the inside of the culvert at a particular cross section. It is sometimes called the **invert**. The tailwater depth depends on the flow rate and hydraulic conditions downstream of the culvert.

The **headwater** at a culvert is the depth of water on the entrance or upstream side of the culvert, as measured from the upstream flow-line of the culvert. The headwater is related to the tailwater as follows:

$$\begin{aligned} & \text{Tailwater} \\ + & \text{Energy Loss Through Culvert} \\ - & \underline{\text{Drop in Flow-Line Elevation Through Culvert}} \\ = & \text{Headwater} \end{aligned}$$

2.2 Flow Analysis for Culverts

The analysis of flow in culverts is quite complicated. It is common to use the concepts of "inlet control" and "outlet control" to simplify the analysis. **Inlet control** flow occurs when the flow capacity of the culvert entrance is less than the flow capacity of the culvert barrel. **Outlet control** flow occurs when the culvert capacity is limited by downstream conditions or by the flow capacity of the culvert barrel. The HEC-2 special culvert method computes the headwater required to produce a given flow rate through the culvert for inlet control conditions and for outlet control conditions. The higher headwater "controls" the design and determines the type of flow in the culvert for a given flow rate and tailwater condition.

For inlet control, the required headwater is computed by assuming that the culvert inlet acts as an orifice or as a weir. Therefore, the inlet control capacity depends primarily on the geometry of the culvert entrance.

For outlet control, the required headwater is computed by taking the depth of flow at the culvert outlet, adding all head losses, and subtracting the change in flow-line elevation of the culvert from the upstream to downstream end. The HEC-2 special culvert option considers the entrance losses, the friction loss in the culvert barrel, and the loss of velocity head at the outlet in computing the outlet control headwater of the culvert.

2.3 Computing Inlet Control Headwater

For inlet control conditions, the capacity of the culvert is limited by the capacity of the culvert opening, rather than by conditions farther downstream. Extensive laboratory tests by the National Bureau of Standards, the Bureau of Public Roads, and other entities resulted in a series of equations which describe the inlet control headwater under various conditions. These equations form the basis of the FHWA inlet control nomographs shown in the exhibit [FHWA, 1972].

The FHWA inlet control equations are used by the HEC-2 special culvert option in computing the inlet control headwater. The equations are adapted slightly to allow the use of metric units.

The nomographs in the exhibit of this appendix are considered to be accurate to within about 10 percent in determining the required inlet control headwater ([FHWA, 1972]. The nomographs were computed assuming a culvert slope of 0.02 feet per foot (2 percent). For different culvert slopes, the nomographs are less accurate because inlet control headwater changes with slope. However, the special culvert option of HEC-2 considers the slope in computing the inlet control headwater. Therefore, the special culvert option should be more accurate than the nomographs, especially for slopes other than 0.02 feet per foot.

2.4 Computing Outlet Control Headwater

For outlet control flow, the required headwater must be computed considering several conditions within the culvert and downstream of the culvert. Figure 2.3 illustrates the logic of the outlet control computations:

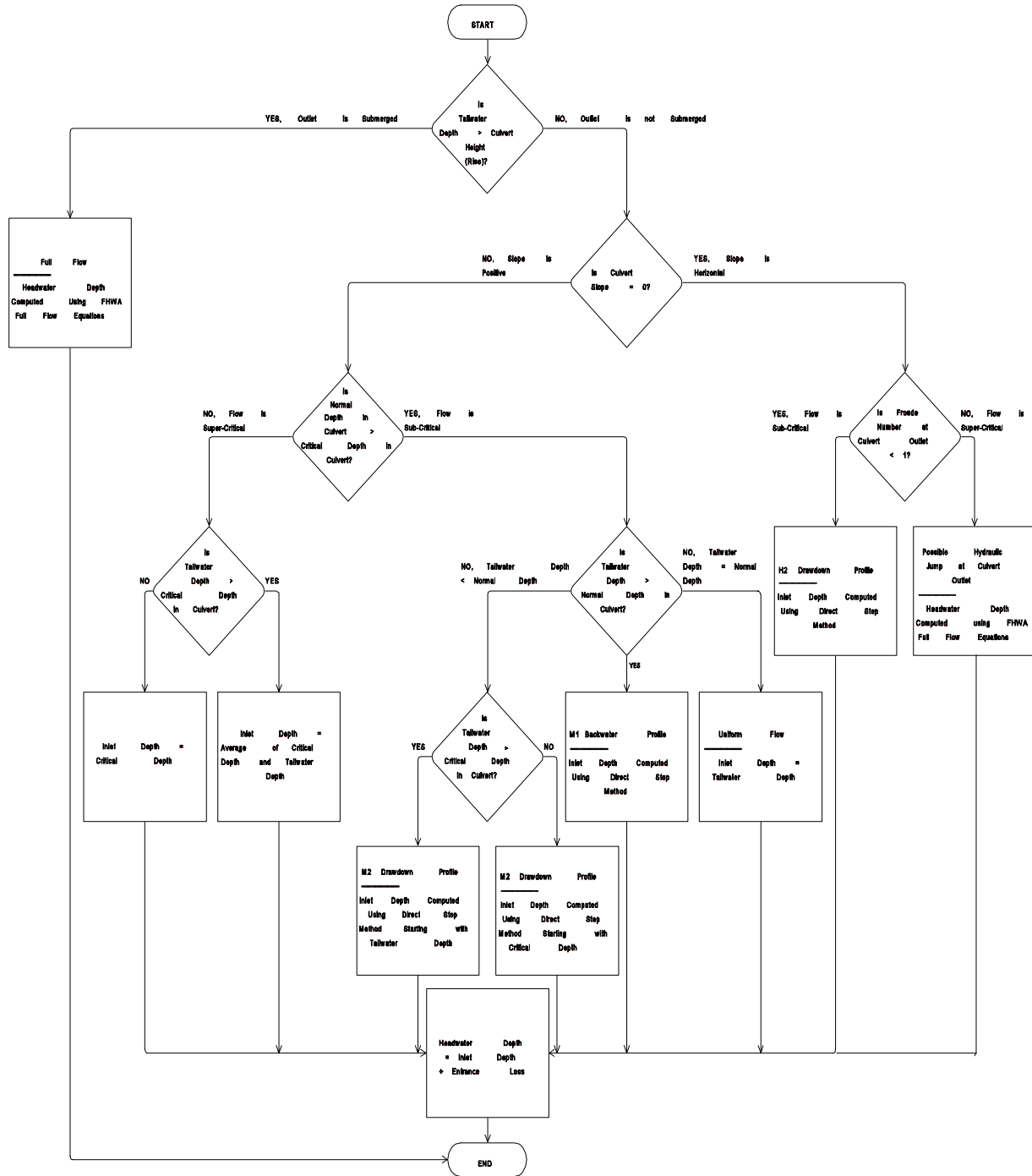


Figure 2.3
Flow Chart for Outlet Control Computations

2.4.1 FHWA Full Flow Equations

For culverts flowing full, the total **head loss**, or energy loss, through the culvert is measured in feet. The head loss, L_H , is computed using the following formula:

$$L_H = L_E + L_F + L_X \quad (IV-1)$$

in which:

L_F = friction loss (feet)

L_E = entrance loss (feet)

L_X = exit loss (feet)

The friction loss in the culvert is computed using Manning's formula, which is expressed as follows:

$$L_F = L \left(\frac{Qn}{1.486AR^{2/3}} \right)^2 \quad (IV-2)$$

in which:

L_F = friction Loss (feet)

L = culvert length (feet)

Q = flow rate in the culvert (cfs)

n = Manning's roughness coefficient

A = area of flow (square feet)

R = hydraulic radius (feet) = $\frac{\text{flow area}}{\text{wetted perimeter}}$

The entrance loss is computed as described in Section 3.2.3 of this appendix. The exit loss is assumed to equal the velocity head in the culvert.

2.4.2 Direct Step Water Surface Profile Computations

For culverts flowing partially full, the water surface profile in the culvert is computed using the direct step method. This method is very efficient, because no iterations are required to determine the flow depth for each step. The water surface profile is computed for small increments of depth (usually between 0.01 and 0.05 feet). If the flow depth equals the height of the culvert before the profile reaches the upstream end of the culvert, the friction loss through the remainder of the culvert is computed assuming full flow.

The direct step method computes the flow depth in the culvert at the inlet. The entrance loss, computed as described in Section 3.2.3 of this appendix, is added to the computed flow depth in the culvert to compute the outlet control headwater.

2.4.3 Normal Depth of Flow in the Culvert

Normal depth is the depth at which uniform flow will occur in an open channel. In other words, for a uniform channel of infinite length, carrying a constant flow rate, flow in the channel would be at a constant depth at all points along the channel, and this would be the normal depth.

Normal depth often represents a good approximation of the actual depth of flow within a channel segment. For inlet control conditions, the depth of flow within the culvert is assumed to be equal to normal depth. This assumption is only valid if the culvert barrel is sufficiently long to allow the flow depth to stabilize at normal depth.

For both box culverts and pipe culverts, the program computes normal depth using an iterative approach to arrive at a value which satisfies Manning's equation:

$$Q = \frac{1.486}{n} AR^{(2/3)}\sqrt{S} \quad (\text{IV-3})$$

in which:

Q = flow rate in the channel (cfs)

n = Manning's roughness coefficient

A = area of flow (square feet)

R = hydraulic radius (feet) = $\frac{\text{flow area}}{\text{wetted perimeter}}$

S = slope of energy grade line (feet per foot)

2.4.4 Critical Depth of Flow in the Culvert

Critical depth occurs when the flow in a channel has minimum specific energy. **Specific energy** refers to the sum of the depth of flow and the velocity head. At critical depth, the velocity head is equal to one-half the average depth of flow. Critical depth depends only on the channel shape and flow rate.

The depth of flow at the culvert outlet is assumed to be equal to critical depth for culverts operating under outlet control with low tailwater. Critical depth may also influence the inlet control headwater for unsubmerged conditions.

The special culvert option computes the critical depth in a pipe culvert by an iterative procedure, which arrives at a value satisfying the following equation:

$$\frac{Q^2}{g} = \frac{A^3}{T} \quad (IV-4)$$

in which:

- Q = flow rate in the channel (cfs)
- g = acceleration due to gravity (32.2 ft/sec²)
- A= cross-sectional area of flow (square feet)
- T= top width of flow (feet)

Critical depth for box culverts is computed by the following equation [AISI, 1980]:

$$y_c = \sqrt[3]{\frac{q^2}{g}} \quad (IV-5)$$

in which:

- y_c = critical depth (ft)
- q = unit discharge per linear foot of width (cfs/ft)
- g = acceleration due to gravity (32.2 ft/sec²)

2.4.5 Super-Critical Culvert Flow

The special culvert option allows super-critical flow in the culvert as a temporary condition in an otherwise sub-critical stream profile. The simple assumptions shown in Figure 2.3 are used to compute the headwater depth for super-critical culvert flow.

2.4.6 Horizontal Culvert Slope

The special culvert option also allows horizontal culvert slopes. The primary difference is that normal depth is not computed for a horizontal culvert. Outlet control is either computed by direct step for partial full tailwater or the full flow equation.

Chapter 3

Using the Special Culvert Method

HEC-2 computes the energy losses caused by culverts in two parts:

- 1) the losses due to expansion and contraction of flow on the downstream and upstream sides of the structure
- 2) the energy loss through the roadway structure itself.

The special culvert method has the capability to compute energy losses at a roadway culvert crossing for a number of different flow conditions, including inlet control flow, outlet control flow, weir flow over the roadway, or any possible combination of these flow conditions. The special culvert method uses hydraulic formulas to determine what flow conditions exist, what portion of the total flow rate falls into each condition, and what change in energy head and water surface elevation will occur through the culvert structure for a given total flow rate.

This chapter describes the use of the HEC-2 special culvert method for computing both types of energy losses. The layout of channel cross sections around the culvert is described, as is the information required to describe the culvert and roadway structures.

3.1 Cross Sections for Culvert Modeling

The number of HEC-2 cross sections required to analyze a given bridge, culvert, or related structure varies according to the modeling method selected.

The special culvert method requires the same cross sections as the special bridge method. Four cross sections are required for a complete bridge model. This total includes one cross section sufficiently downstream of the culvert that flow is not affected by the culvert, one at the downstream end of the culvert, one at the upstream end of the culvert, and one cross section located far enough upstream that the culvert again has no effect on flow. Figure 3.1 illustrates the cross sections required for a special culvert model.

3.1.1 Cross Section 1 of Special Culvert Model

Cross section 1 for a special culvert model should be located at a point where flow has expanded from its constricted top width within the culvert to its unrestrained top width downstream of the culvert. The cross section spacing downstream of the culvert should be based on a 4 to 1 expansion of flow. In other words, the maximum rate at which flow can expand after being constricted in the culvert is assumed to be one foot laterally for every four feet traveled in the downstream direction. (See Appendix III, "Application of HEC-2 Bridge Routines" for a more complete discussion of cross section locations.) The entire area of cross section 1 is usually considered to be effective in conveying flow.

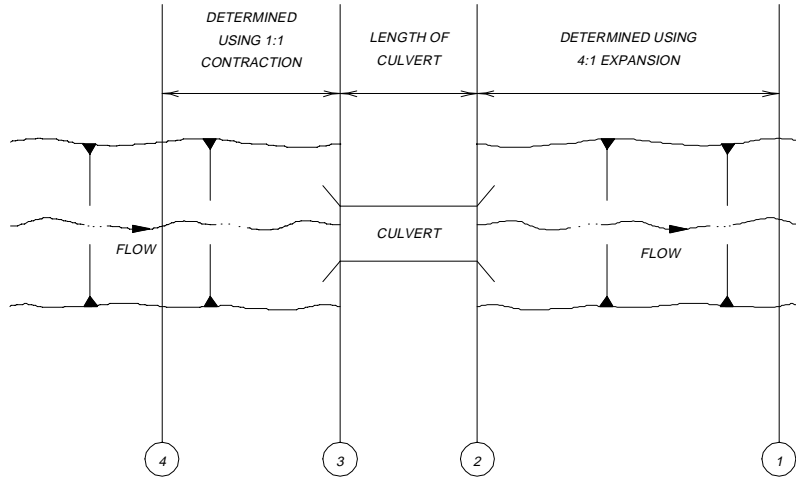


Figure 3.1
Cross Section Layout for Special Culvert Method

3.1.2 Cross Section 2 of Special Culvert Model

Cross section 2 of a special culvert model is located at the downstream end of the culvert. It does not include any of the culvert structure or embankments, but represents the physical shape of the channel just downstream of the culvert. The shape of the culvert itself is entered on an SC record between cross sections 2 and 3 of the special culvert model. No BT (bridge table) records are included for cross section 2.

The HEC-2 effective area option is used to restrict the effective flow area of cross section 2 to the flow area allowed by the edges of the culverts, until flow overtops the roadway. An NC record is placed just before cross section 2 to change the expansion and contraction coefficients, as described in Section 3.1.5. Figure 3.2 illustrates cross section 2 of a typical special culvert model of a circular culvert. As indicated, the GR records are not required to define the culvert shape for the special culvert model. On Figure 3.3, the channel bank locations are indicated by small circles and the stations and elevations are indicated by triangles.

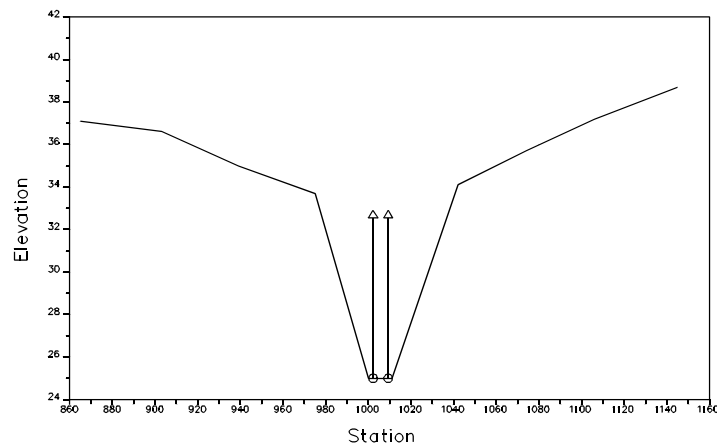


Figure 3.2
Cross Section 2 of Special Culvert Model

Cross sections 1 and 2 are located so as to create a channel reach downstream of the culvert in which the HEC-2 program can accurately compute the friction losses and expansion losses downstream of the culvert.

3.1.3 Cross Section 3 of Special Culvert Model

Cross section 3 of a special culvert model is located at the upstream end of the culvert, and represents the physical configuration of the channel immediately upstream of the culvert.

The special culvert method uses a combination of BT records, an SC record, and an X2 record to describe the culvert or culverts and the roadway embankment. The SC record describing the culvert crossing is located between the data for cross section 2 and cross section 3. The data for cross section 3 includes an X2 record which instructs the HEC-2 program to perform culvert loss computations. In addition, cross section 3 includes BT records describing the top of roadway profile for weir flow computations. The BT records used for the special culvert method are not required to include low chord elevations, since the special culvert method does not use these elevations.

The HEC-2 effective area option is used to restrict the effective flow area of cross section 3 to the flow area allowed by the edges of the culverts, until flow overtops the roadway. Figure 3.3 illustrates cross section 3 of a typical special culvert model of a circular culvert, including the roadway profile defined on BT records, and the culvert shape defined on the SC record. As indicated, the GR records are not required to define the culvert shape for the special culvert model. On Figure 3.3, the channel bank locations are indicated by small circles and the stations and elevations of effective area control are indicated by triangles.

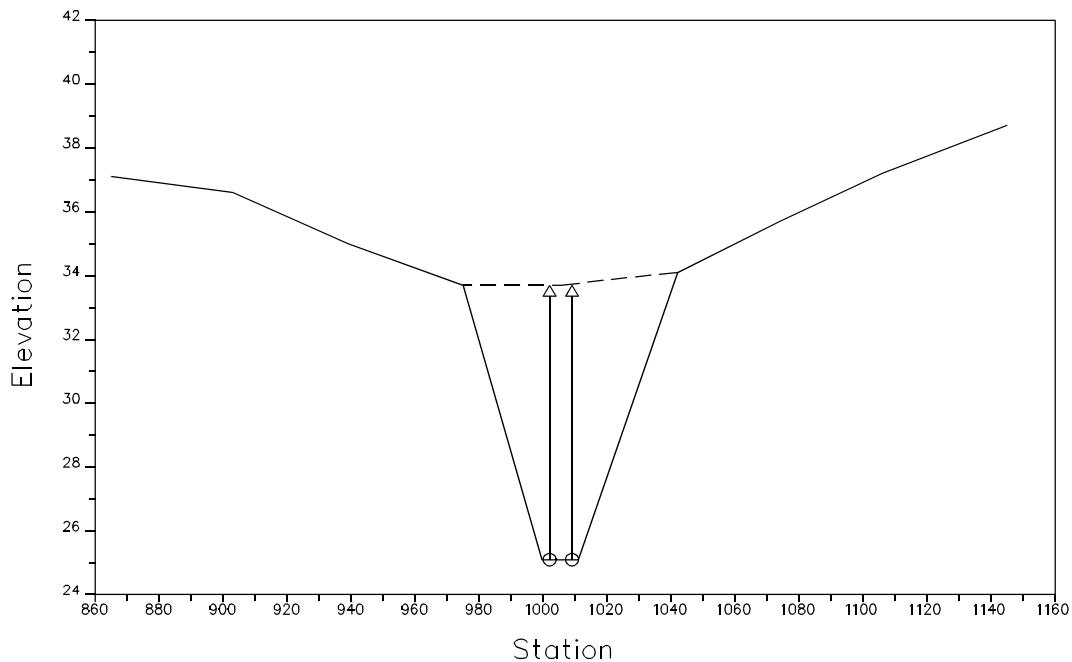


Figure 3.3
Cross Section 3 of Special Culvert Model

3.1.4 Cross Section 4 of Special Culvert Model

The final cross section in the special culvert model is located at a point where flow has not yet begun to contract from its unrestrained top width upstream of the culvert to its constricted top width in the culvert. This distance is determined assuming a one to one contraction of flow. In other words, the maximum rate at which flow can contract to pass through the culvert opening is assumed to be one foot laterally for every one foot traveled in the downstream direction.

The entire area of cross section 4 is usually considered to be effective in conveying flow. An NC record is placed just after cross section 4 to change the expansion and contraction coefficients, as described in Section 3.1.5.

3.1.5 Expansion and Contraction Coefficients

User-defined coefficients are required to compute head losses due to the contraction and expansion of flows upstream and downstream of a culvert. These losses are computed by multiplying an expansion or contraction coefficient by the absolute difference in velocity head between two cross sections. Normally, the greatest expansion loss occurs between the first two cross sections of a bridge model, as flow expands from the width of the culvert opening to the full width of the channel or floodplain. Similarly, the greatest contraction loss occurs between the last two cross sections of the bridge model, as flow contracts from the full width of the channel or floodplain to the width of the culvert opening.

If the velocity head increases in the downstream direction, a contraction coefficient is applied. When the velocity head decreases in the downstream direction, an expansion coefficient is used. Some recommended values of the expansion and contraction coefficients are indicated in Table 3.1. As indicated by the tabulated values, the expansion of flow causes more energy loss than does contraction, and head losses increase with the abruptness of the transition.

**Table 3.1
Expansion and Contraction Coefficients**

Description of Transition	Contraction Coefficient	Expansion Coefficient
No Transition Loss Computed	0.0	0.0
Gradual Transitions	0.1	0.3
Bridge Cross Sections	0.3	0.5
Abrupt Transitions (including most culverts)	0.6	0.8

When redefining expansion and contraction coefficients for a culvert, the coefficients should be changed to the desired values for the culvert just after the first cross section in the culvert model and changed back to the previous values just after the final cross section.

3.2 Defining the Culvert with the SC Record

The special culvert (SC) record is required to input coefficients for inlet control, outlet control, and weir flow for analysis by the special culvert method. Geometric properties of the culvert such as diameter (in the case of pipe culverts) and span and rise (in the case of box culverts) are also input on the SC record. The SC record is only required when using the special culvert method. Appendix VIII summarizes the information provided on the SC record. The following sections of this appendix provide a more complete description of each item.

3.2.1 CUNO: Number of Identical Culverts

The number of identical culverts is the value left of the decimal point in Field 1 of the SC record. For example, a value of 3.012 in Field 1 of the SC record indicates that three identical culverts are present at the current cross section. (Note: the 0.012 value right of the decimal point indicates that the culvert n-value is 0.012, as described in Section 3.2.2.)

If multiple culverts are specified, HEC-2 automatically divides the flow rate equally among the culverts and analyzes each culvert separately. All of the culverts must be identical; they must have the same cross-sectional shape, upstream and downstream invert elevations, roughness coefficients, and inlet shapes.

3.2.2 CUNV: Manning's Roughness Coefficient

The Manning's roughness coefficient is the value right of the decimal point in Field 1 of the SC record. For example, a value of 3.012 in Field 1 of the SC record indicates that the culvert has a roughness coefficient of 0.012. (Note: the 3 value left of the decimal point indicates that there are three identical culverts at this location, as described in Section 3.2.1.)

HEC-2 uses Manning's equation to compute friction losses in the culvert barrel, as described in Section 2.4 of this appendix. The roughness of the culvert is represented by Manning's roughness coefficient, commonly called the **n-value**. Suggested values for Manning's n-value are listed in Table 3.2 and Table 3.3, and in many hydraulics reference books. Roughness coefficients should be adjusted according to individual judgment of the culvert condition.

3.2.3 ENTLC: Entrance Loss Coefficient

The entrance loss coefficient is input in Field 2 of the SC record.

Entrance losses are computed as a fraction of the **velocity head** or kinetic energy of flow in the culvert. The velocity head in the culvert is computed as:

$$H_v = \frac{V^2}{2g} \quad (\text{IV-6})$$

in which:

- H_v = velocity head in the culvert (feet)
- V = flow velocity in the culvert (ft/sec)
- g = acceleration due to gravity (32.2 ft/sec²)

Table 3.2
Manning's 'n' for Corrugated Metal Pipe

Type of Pipe and Diameter	Unpaved	25% Paved	Fully Paved
Annular 2.67 x 1/2 in. (all diameters)	0.024	0.021	0.021
Helical 1.50 x 1/4 in.:			
8 inch diameter	0.012		
10 inch diameter	0.014		
Helical 2.67 x 1/2 in.:			
12 inch diameter	0.011		
18 inch diameter	0.014		
24 inch diameter	0.016	0.015	0.012
36 inch diameter	0.019	0.017	0.012
48 inch diameter	0.020	0.020	0.012
60 inch diameter	0.021	0.019	0.012
Annular 3 x 1 in. (all diameters)	0.027	0.023	0.012
Helical 3 x 1 in.:			
48 inch diameter	0.023	0.020	0.012
54 inch diameter	0.023	0.020	0.012
60 inch diameter	0.024	0.021	0.012
66 inch diameter	0.025	0.022	0.012
72 inch diameter	0.026	0.022	0.012
78 inch & larger	0.027	0.023	0.012
Corrugations 6 x 2 in.:			
60 inch diameter	0.033	0.028	
72 inch diameter	0.032	0.027	
120 inch diameter	0.030	0.026	
180 inch diameter	0.028	0.024	

[AISI, 1980]

The velocity head is multiplied by the **entrance loss coefficient** to estimate the amount of energy lost as flow enters the culvert. A higher value for the coefficient gives a higher head loss. As shown in Table 3.4, entrance losses can vary from about 0.2 to about 0.5 times the velocity head for box culverts. Table 3.5 indicates that values of the entrance loss coefficient range from 0.2 to about 0.8 for pipe culverts. For a sharp-edged culvert entrance with no rounding, 0.5 is recommended. For a well-rounded entrance, 0.2 is appropriate. An example of a fairly well-rounded entrance is the socket end of a concrete pipe section.

**Table 3.3
Manning's 'n' for Closed Conduits Flowing Partly Full**

Type of Channel and Description	Minimum	Normal	Maximum
Brass, smooth:	0.009	0.010	0.013
Steel:			
Lockbar and welded	0.010	0.012	0.014
Riveted and spiral	0.013	0.016	0.017
Cast Iron:			
Coated	0.010	0.013	0.014
Uncoated	0.011	0.014	0.016
Wrought Iron:			
Black	0.012	0.014	0.015
Galvanized	0.013	0.016	0.017
Corrugated Metal:			
Subdrain	0.017	0.019	0.021
Storm Drain	0.021	0.024	0.030
Lucite:	0.008	0.009	0.010
Glass:	0.009	0.010	0.013
Cement:			
Neat, surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
Concrete:			
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016
Unfinished, rough wood form	0.015	0.017	0.020
Wood:			
Stave	0.010	0.012	0.014
Laminated, treated	0.015	0.017	0.020
Clay:			
Common drainage tile	0.011	0.013	0.017
Vitrified sewer	0.011	0.014	0.017
Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
Vitrified subdrain with open joint	0.014	0.016	0.018
Brickwork:			
Glazed	0.011	0.013	0.015
Lined with cement mortar	0.012	0.015	0.017
Sanitary sewers coated with sewage slime with bends and connections	0.012	0.013	0.016
Paved invert, sewer, smooth bottom	0.016	0.019	0.020
Rubble masonry, cemented	0.018	0.025	0.030

[Chow, 1959]

**Table 3.4
Entrance Loss Coefficient for Box Culverts**

Type of Structure and Design of Entrance	Coefficient
Headwall Parallel to Embankment (no wingwalls):	
Square-edged on three edges	0.50
Three edges rounded to radius of 1/12 barrel dimension	0.20
Wingwalls at 15 to 45 degrees to Barrel:	
Square-edge top corner	0.40
Top corner rounded to radius of 1/12 barrel dimension	0.20

Source: "Street and Highway Drainage," Institute of Transportation and Traffic Engineering, University of California at Berkeley, 1969.

**Table 3.5
Entrance Loss Coefficient for Pipe Culverts**

Type of Structure and Design of Entrance	Coefficient
Concrete Pipe Projecting from Fill (no headwall):	
Socket end of pipe	0.20
Square cut end of pipe	0.50
Concrete Pipe with Headwall or Headwall and Wingwalls:	
Socket end of pipe	0.10
Square cut end of pipe	0.50
Rounded entrance, with rounding radius = 1/12 of diameter	0.10
Corrugated Metal Pipe:	
Projecting from fill (no headwall)	0.80
With headwall or headwall and wingwalls, square edge	0.50

3.2.4 COFQ: Weir Flow Coefficient

Weir flow over a roadway is computed in the special culvert method using exactly the same methods used in the HEC-2 special bridge method. The standard weir equation is used:

$$Q = CLH^{1.5} \tag{IV-7}$$

in which:

- Q = flow rate (cfs)
- C = COFQ = weir flow coefficient
- L = weir length (feet)
- H = weir head (feet)

For flow over a typical bridge deck, a weir coefficient of 2.6 is recommended. A weir coefficient of 3.0 is recommended for flow over elevated roadway approach embankments. The weir flow coefficient will generally be near 3.0 for special culvert models because the roadway embankment for a culvert is often similar to a roadway approach embankment. More detailed information on weir discharge coefficients may be found in Tables 3.6 and 3.7.

**Table 3.6
Broad-Crested Weir Coefficients**

Breadth of Crest of Weir in Feet	Measured Head in Feet (H)				
	1.0	2.0	3.0	4.0	5.0
5	2.68	2.65	2.66	2.70	2.79
10	2.68	2.64	2.64	2.64	2.64
15	2.63	2.63	2.63	2.63	2.63

[Brater/King, 1976]

When the weir (roadway) is submerged by high tailwater, the weir flow coefficient is automatically reduced by the HEC-2 program. The program adjusts for weir submergence based on either the curves in "Hydraulics of Bridge Waterways" [FHWA, 1978], or the Waterways Experiment Station's Design Chart 111-4 [U.S. Army Corps of Engineers, 1953]. The "Hydraulics of Bridge Waterways" method, the default method of the program, is based on a trapezoidal-shaped roadway embankment, whereas the WES method is based on a ogee-shaped spillway.

Use of the WES method is designed by a negative weir coefficient COFQ in Field 3 of the SC record. The "Hydraulics of Bridge Waterways" method is designated by a positive weir coefficient COFQ.

**Table 3.7
Trapezoidal Weir Coefficients**

Slope of Upstream Face (H:V)	Slope of Downstream Face (H:V)	Width of Crest (feet)	Measured Head in Feet (H)						
			0.50	1.00	1.50	2.00	3.00	4.00	5.00
1:1	1:1	0	4.14	4.08	3.75	3.75	3.75	3.75	3.75
2:1	2:1	0	3.81	3.87	3.87	3.87	3.87	3.87	3.87
2:1	2:1	.67	3.13	3.43	3.61	3.56	3.58	3.62	3.68

[Brater/King, 1976]

Note: A weir crest width of zero indicates a triangular weir.

3.2.5 RISE: Pipe Culvert Diameter or Box Culvert Height

The value in Field 5 of the SC record is used as the inside diameter of a pipe culvert or the inside height of a box culvert.

Box culverts are described by the **span** and **rise**, which are the horizontal and vertical dimensions of the culvert opening, respectively. For example, a "4 by 3 box culvert" has a span of 4 feet and a rise of 3 feet.

The inside height of the culvert opening is important not only in determining the total flow area of the culvert, but also in determining whether the headwater and tailwater elevations are adequate to submerge the inlet or outlet of the culvert.

3.2.6 SPAN: Box Culvert Span (Width of Opening)

Box culverts are essentially rectangular in cross section. For analysis of box culverts, the horizontal dimension of the rectangle, measured in feet, is input in Field 6 of the SC record. If Field 6 contains a zero or is blank, the culvert is assumed to be a circular culvert with the diameter provided in Field 5.

Most box culverts have **chamfered** corners on the inside, as indicated in Figure 2.2. The chamfers are ignored by the special culvert option in computing the cross-sectional area of the culvert opening. Some manufacturers' literature contains the true cross-sectional area of each size of box culvert, considering the reduction in area caused by the chamfered corners. If you wish to consider the loss in area due to the chamfers, then you should reduce the span of the culvert. You should not reduce the rise of the culvert, because the program uses the culvert rise to determine the submergence of the culvert entrance and outlet.

3.2.7 CULVLN: Culvert Length

The culvert length is input in Field 7 of the SC record. It is measured in feet along the center-line of the culvert. The culvert length is used to determine the friction loss in the culvert barrel and the slope of the culvert.

3.2.8 CHRT and SCL: FHWA Chart Number and Scale Number

The culvert FHWA chart number and scale number are input in Field 8 of the SC record. The FHWA chart number is entered left of the decimal point and the FHWA scale number is entered right of the decimal point. For example, a value of 1.2 in Field 8 of the SC record indicates FHWA chart number 1 and FHWA scale number 2.

The FHWA chart number and scale number refer to a series of nomographs published by the Bureau of Public Roads (now called the Federal Highway Administration) in 1965 [BPR, 1965], which allowed the inlet control headwater to be computed for different types of culverts operating under a wide range of flow conditions. These nomographs and others constructed using the original methods were republished [FHWA, 1985]. The exhibit of this appendix contains copies of all the pipe culvert and box culvert nomographs from the 1985 FHWA publication.

Each of the FHWA charts has from two to four separate scales representing different culvert entrance designs. The appropriate FHWA chart number and scale number should be chosen according to the type of culvert and culvert entrance. Tables 3.8 and 3.9 may be used for guidance in selecting the FHWA chart number and scale number.

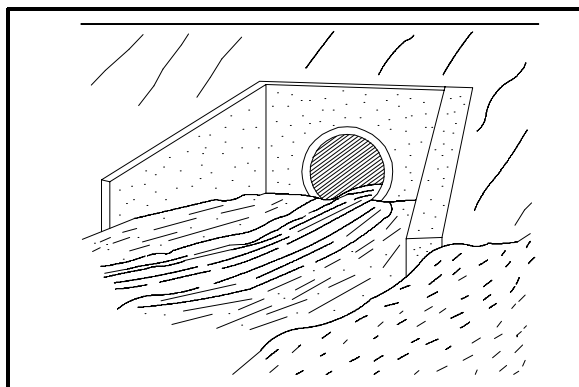
**Table 3.8
FHWA Chart and Scale Numbers for Pipe Culverts**

Chart Number	Scale Number	Description
1		Concrete Pipe Culvert
	1	Square edge entrance with headwall (See Figure 3.4)
	2	Groove end entrance with headwall (See Figure 3.4)
	3	Groove end entrance, pipe projecting from fill (See Figure 3.6)
2		Corrugated Metal Pipe Culvert
	1	Headwall (See Figure 3.4)
	2	Mitered to conform to slope (See Figure 3.5)
	3	Pipe projecting from fill (See Figure 3.6)
3		Concrete Pipe Culvert; Beveled Ring Entrance (See Figure 3.7)
	1(A)	Small bevel; $b/D = 0.042$; $a/D = 0.063$; $c/D = 0.042$; $d/D = 0.083$
	2(B)	Large bevel; $b/D = 0.083$; $a/D = 0.125$; $c/D = 0.042$; $d/D = 0.125$

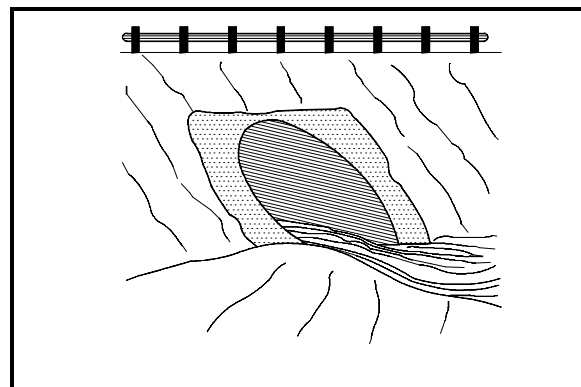
NOTE: For chart 3, enter scale number 1 for scale A and scale number 2 for scale B. See chart 3 in Exhibit A of this appendix for detail.

Chart numbers 1, 2, and 3 apply only to pipe culverts. Similarly, chart number 8, 9, 10, 11, 12, and 13 apply only to box culverts. The HEC-2 program checks the chart number to assure that it is appropriate for the type of culvert being analyzed. HEC-2 also checks the value of the Scale Number to assure that it is available for the given chart number. For example, a scale number of 4 would be available for chart 11, but not for chart 12.

Table 3.8 lists the FHWA chart and scale numbers for pipe culverts. Figures 3.4 through 3.7 can be used as guidance in determining which chart and scale numbers to select for various types of culvert inlets.



**Figure 3.4
Culvert Inlet with Headwall and Wingwalls**



**Figure 3.5
Culvert Inlet Mitered to Conform to Slope**

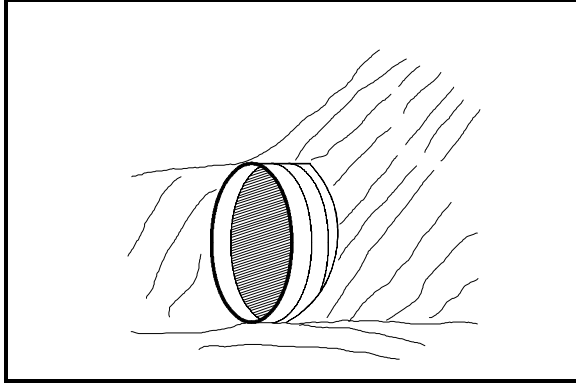


Figure 3.6
Culvert Inlet Projecting from Fill

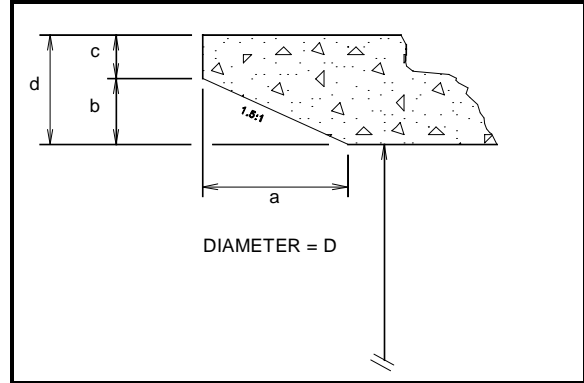


Figure 3.7
Culvert Inlet with Beveled Ring Entrance

Table 3.10 lists the FHWA chart and scale number for box culverts. Figures 3.8 through 3.13 illustrate the culvert inlets corresponding to various box culvert charts.

Table 3.9
FHWA Chart and Scale Numbers for Box Culverts

Chart Number	Scale Number	Description
8		Box Culvert with Flared Wingwalls (See Figure 3.8)
	1	Wingwalls flared 30 to 75 degrees
	2	Wingwalls flared 90 or 15 degrees
	3	Wingwalls flared 0 degrees (sides extended straight)
9		Box Culvert with Flared Wingwalls and Inlet Top Edge Bevel (See Figure 3.9)
	1	Wingwall flared 45 degrees; inlet top edge bevel = 0.43D
	2	Wingwall flared 18 to 33.7 degrees; inlet top edge bevel = 0.083D
10		Box Culvert; 90-degree Headwall; Chamfered or Beveled Inlet Edges (See Figure 3.11)
	1	Inlet edges chamfered 3/4-inch
	2	Inlet edges beveled 1/2-in/ft at 45 degrees (1:1)
	3	Inlet edges beveled 1-in/ft at 33.7 degrees (1:1.5)
11		Box Culvert; Skewed Headwall; Chamfered or Beveled Inlet Edges (See Figure 3.11)
	1	Headwall skewed 45 degrees; inlet edges chamfered 3/4-inch
	2	Headwall skewed 30 degrees; inlet edges chamfered 3/4-inch
	3	Headwall skewed 15 degrees; inlet edges chamfered 3/4-inch
	4	Headwall skewed 10 to 45 degrees; inlet edges beveled
12		Box Culvert; Non-Offset Flared Wingwalls; 3/4-inch Chamfer at Top of Inlet (See Figure 3.12)
	1	Wingwalls flared 45 degrees (1:1); inlet not skewed
	2	Wingwalls flared 18.4 degrees (3:1); inlet not skewed
	3	Wingwalls flared 18.4 degrees (3:1); inlet skewed 30 degrees
13		Box Culvert; Offset Flared Wingwalls; Beveled Edge at Top of Inlet (See Figure 3.13)
	1	Wingwalls flared 45 degrees (1:1); inlet top edge bevel = 0.042D
	2	Wingwalls flared 33.7 degrees (1.5:1); inlet top edge bevel = 0.083D
	3	Wingwalls flared 18.4 degrees (3:1); inlet top edge bevel = 0.083D

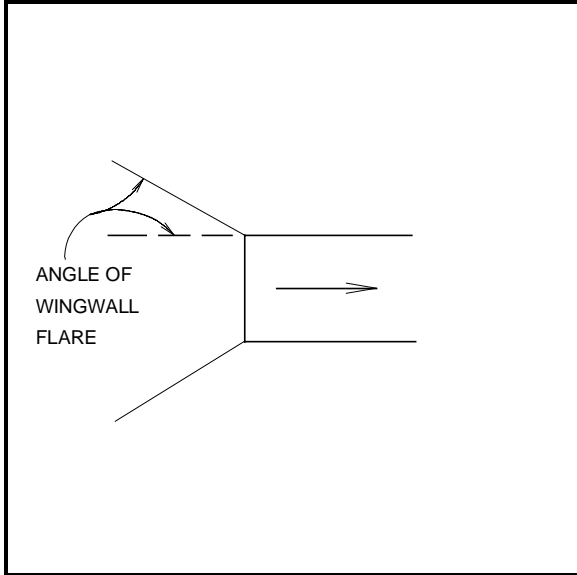


Figure 3.8
Flared Wingwalls (Chart 8)

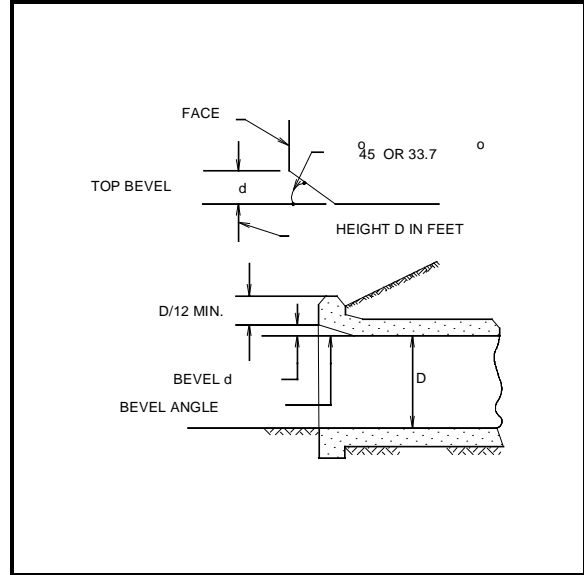


Figure 3.9
Inlet Top Edge Bevel (Chart 9)

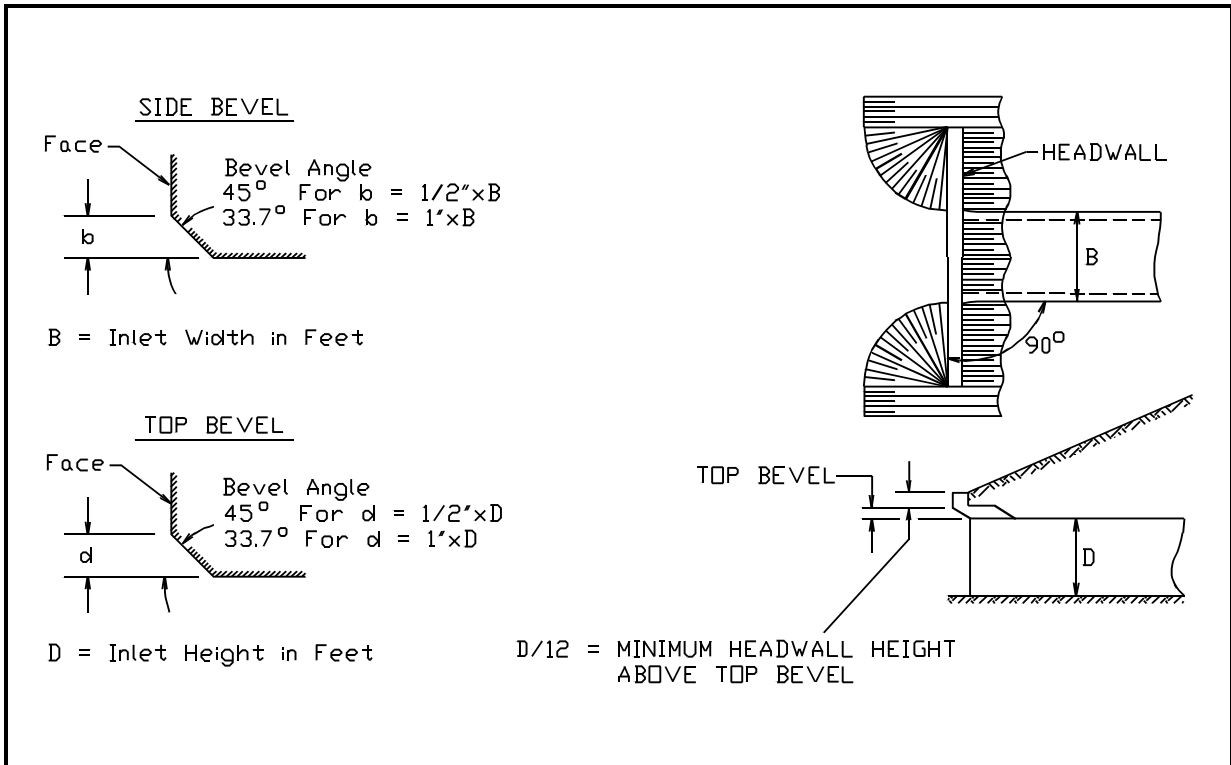


Figure 3.10
Inlet Side and Top Edge Bevel with Ninety Degree Headwall (Chart 10)

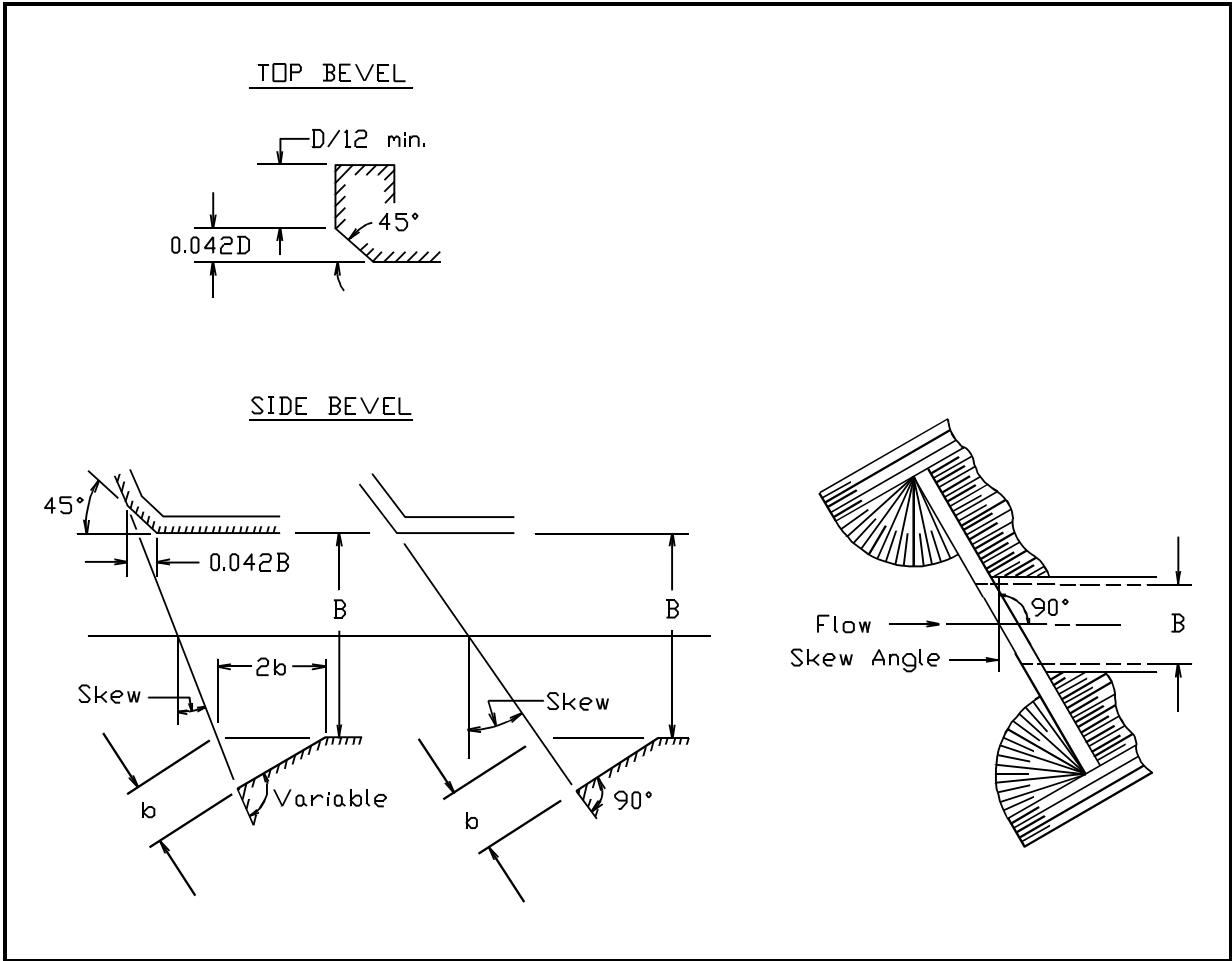


Figure 3.11
Inlet Side and Top Edge Bevel with Skewed Headwall (Chart 11)

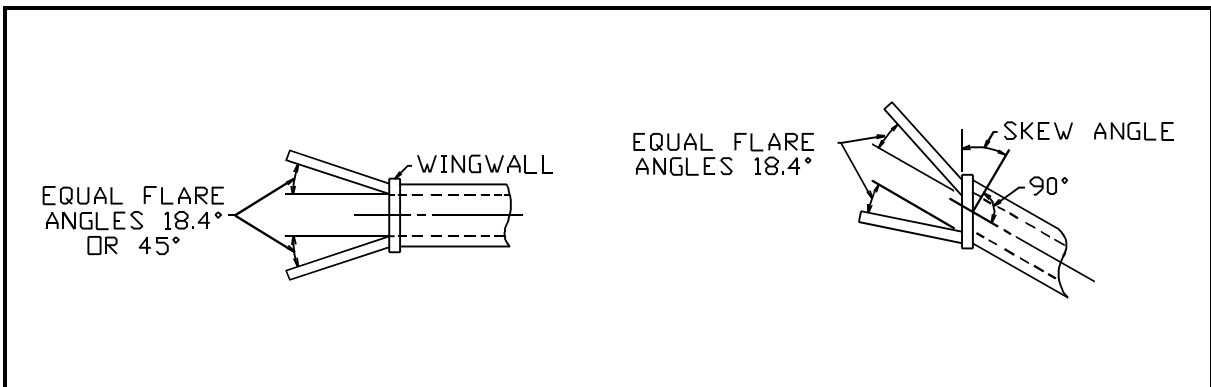


Figure 3.12
Non-Offset Flared Wingwalls (Chart 12)

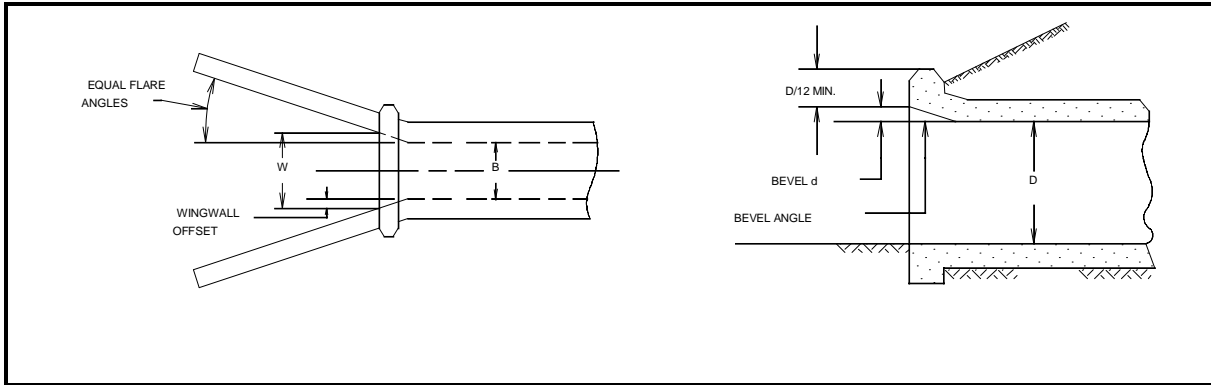


Figure 3.13
Offset Flared Wingwalls (Chart 13)

3.2.9 ELCHU and ELCHD: Culvert Invert Elevations

The culvert flow-line slope is the average drop in elevation per foot of length along the culvert. For example, if the culvert flow-line drops 1 foot in a length of 100 feet, then the culvert flow-line slope is 0.01 feet per foot. Culvert flow-line slopes are sometimes expressed in percent. A slope of 0.01 feet per foot is the same as a one percent slope.

The culvert slope is computed from the upstream flow-line elevation input in Field 9 of the SC record, the downstream flow-line elevation input in Field 10, and the culvert length input in Field 7. The following equation is used to compute the culvert slope:

$$S = \frac{ELCHU - ELCHD}{\sqrt{CULVLN^2 - (ELCHU - ELCHD)^2}} \quad (IV-8)$$

As already noted, HEC-2 cannot analyze culverts with adverse (negative) slopes. Most culverts are installed with some "positive slope"; that is, the flow-line of the culvert is slightly lower on the downstream end than the upstream end, so that some flow velocity can be maintained in the culvert even under low flow conditions. A sufficient slope to maintain a minimum flow velocity of 3 feet per second is often required.

The slope of the culvert is used by the program to compute the drop in flow-line between the upstream and downstream ends of the culvert. It is also used to compute the normal depth of flow in the culvert under inlet control conditions.

3.3 Defining the Weir Profile With the BT Records

Weir flow occurs when water begins to flow over the roadway. The HEC-2 program performs weir flow calculations using the standard weir flow equation. Total weir flow is computed by subdividing the roadway crest into segments, computing the discharge for each segment, and summing the discharges.

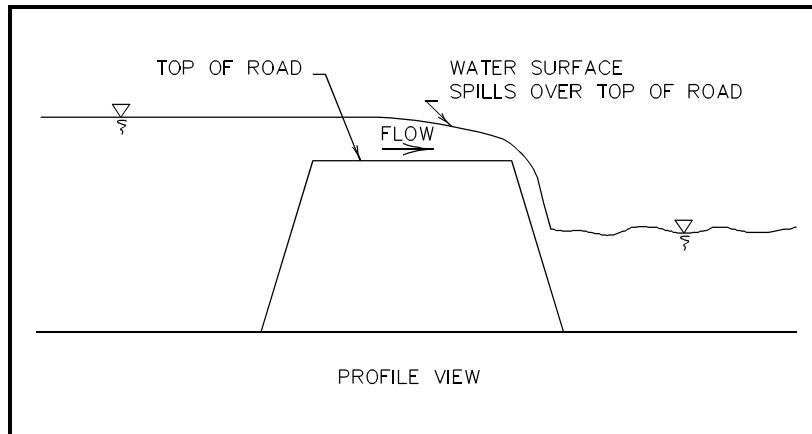


Figure 3.14
Illustration of Weir Flow Conditions

Combinations of culvert flow and weir flow are analyzed by HEC-2 using an iterative procedure. Energy elevations are assumed and discharges computed for each type of flow until the total computed flow rate is within one percent of the actual total flow rate at the roadway crossing.

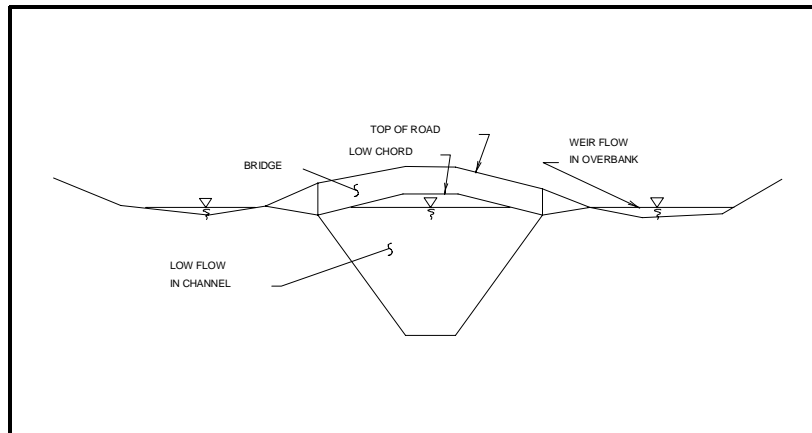


Figure 3.15
Illustration of Combination Flow Conditions

The top-of-road profile for weir flow computations is defined using BT records at cross section 3 of the special culvert model. For the special culvert method, BT stations do not have to match GR stations, because the standard step method is not used for the special culvert method. However, the entire top-of-road profile **must** be coded on the BT records, even if the top-of-road and ground elevations are the same for a portion of the cross section. Weir flow computations are based on the road profile as represented on the BT records **only**. Therefore, if only a portion of the road profile is included on the BT records, the length of the roadway for weir flow computations will be less than the actual length.

Proper definition of the top of roadway is a crucial step in assembling an accurate and reliable HEC-2 culvert model. **Actual top-of-road elevations should always be used in defining the top of roadway at cross section 3 in the special culvert method.** The natural ground elevations in the overbank should not be used to represent the top-of-roadway profile, even though there is a tendency to do so when copying a natural channel cross section for use in the culvert model. An exception to this

rule is that natural ground elevations should be used instead of top of road elevations when the roadway is in a cut, i.e., when natural ground is higher than the top of the roadway. Figure 3.16 illustrates this situation.

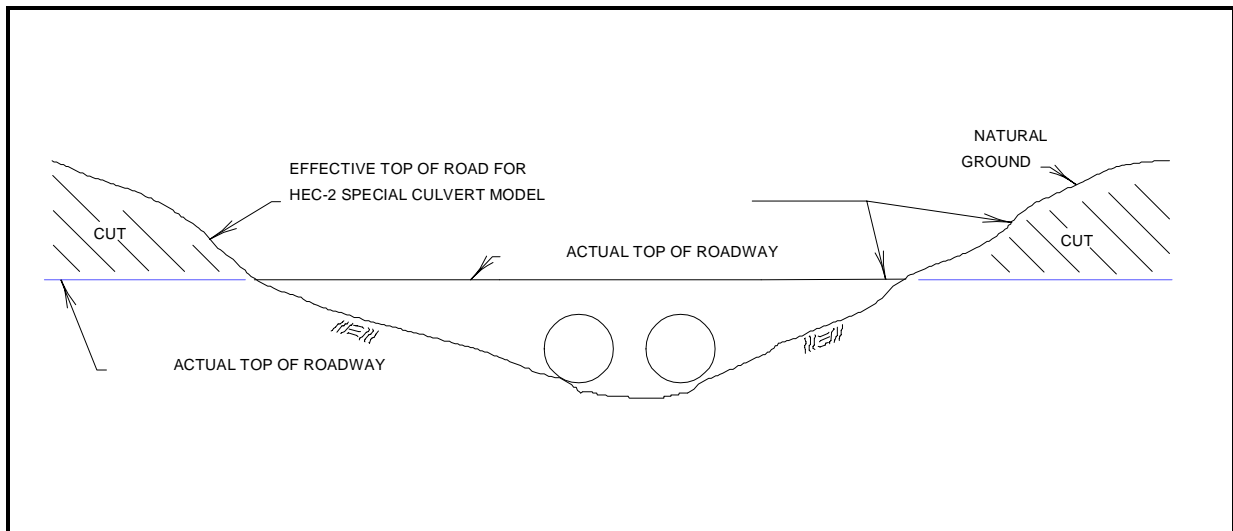


Figure 3.16
Defining the Top-of-Road for Roadways in Open Cuts

Bridge railings or curbs should sometimes be considered when defining the top of roadway. If a railing or curb forms a substantial obstruction to flow over the roadway, the top of the rail or curb should be considered as the effective top-of-road. Figures 3.17 and 3.18 illustrate roadways with solid and open rails.

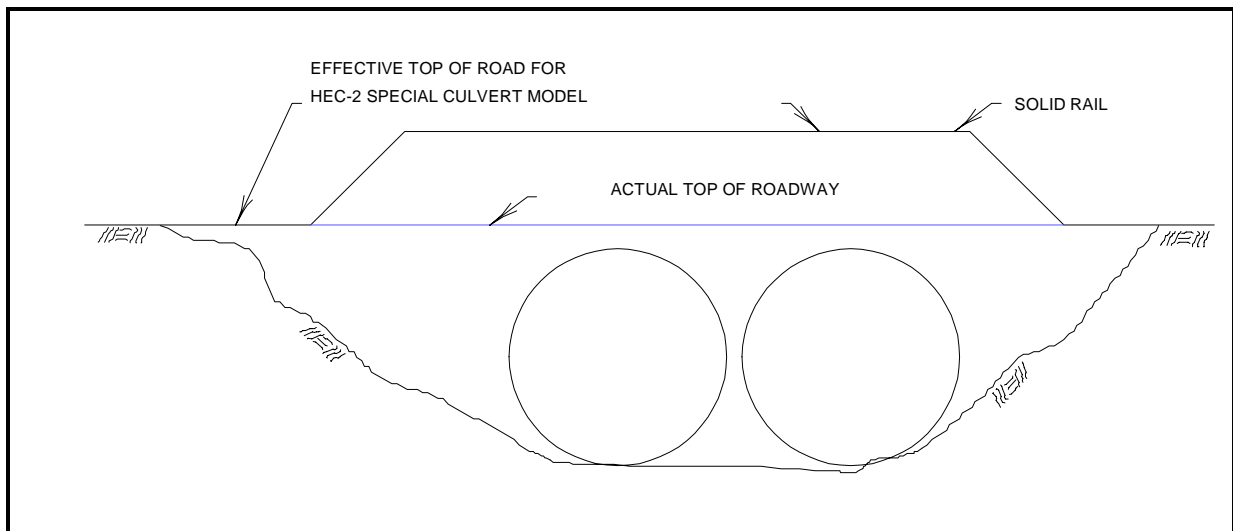


Figure 3.17
Defining the Top-of-Road for Roadways with Solid Rails

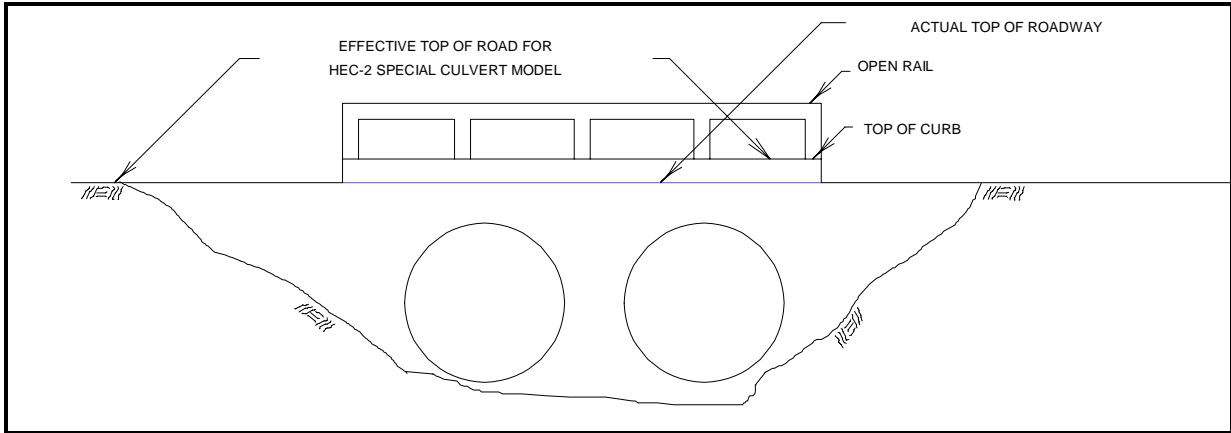


Figure 3.18
Defining the Top-of-Road for Roadways with Open Rails

In lieu of BT records, a horizontal weir may be specified using Field 4 of the SC record and Field 5 of the X2 record. However, this option should be used carefully, because the same weir length will be used for all flow rates. This contrasts with most bridges, in which longer and longer segments of the roadway are inundated as flow rates increase. Figure 3.19 illustrates a horizontal weir.

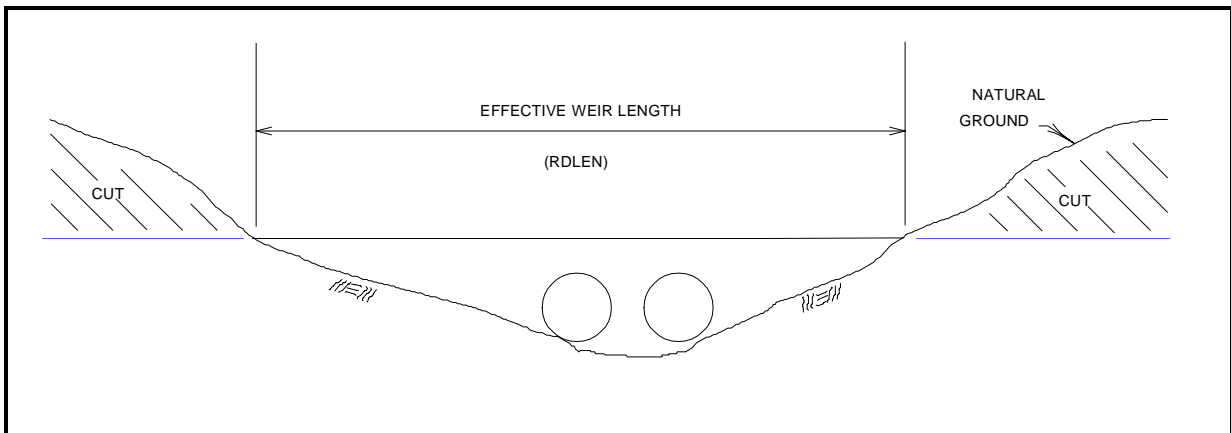


Figure 3.19
Defining a Horizontal Weir for the Special Culvert Method

3.4 Controlling the Special Culvert Option With the X2 Record

An X2 record is required at cross section 3 of the special culvert model. Field 3 of the X2 record should contain a "2" to indicate to HEC-2 that special culvert computations are to be performed.

Other variables on the X2 record are used in the special culvert method as they are in the special bridge method. Field 5 of the X2 record is used to define the minimum top-of-road elevation for use by the HEC-2 program in testing for weir flow. Therefore, when the energy grade line upstream of the roadway exceeds the elevation specified in Field 5 of the X2 record, the program begins to compute weir flow.

3.5 Special Culvert Output

The special culvert method generates detailed output for each cross section. This output includes the following:

- 1) A listing of the data values read from the SC record.
- 2) A description of the selected FHWA chart and scale.
- 3) A statement of whether the culvert operates under inlet control or outlet control.
- 4) The values of four important variables:
 - EGIC - the computed energy grade line elevation for inlet control;
 - EGOC - the computed energy grade line elevation for outlet control;
 - PCWSEL - the water surface elevation computed by HEC-2 for the previous cross section; and
 - ELTRD - the minimum top of road elevation for weir flow.

Summary Table 101 is available to provide the results of the special culvert option. Summary Table 101 includes the following variables:

- SECNO - the cross section number
- EGOC - the computed energy grade line elevation for outlet control
- EGIC - the computed energy grade line elevation for inlet control
- H4 - the difference between the computed energy grade elevation upstream and downstream of a culvert.
- ELTRD - the minimum top-of-road for weir flow.
- QCULV - the computed flow through the culvert. Equivalent to the QCH variable used in special bridge models.
- CLASS - an indicator of the type of flow occurring at the roadway crossing. The CLASS variable has several values relating specifically to the special culvert option. Table 3.10 lists these CLASS values.

**Table 3.10
CLASS Values for Special Culvert Option**

CLASS Value	Description
6	Inlet control, all flow is passing through the culvert.
7	Outlet control, all flow is passing through the culvert.
16	Inlet control, combination of culvert flow and weir flow.
17	Outlet control, combination of culvert flow and weir flow.

The variables QWEIR, CWSEL, VCH, and EG are also used in Summary Table 101 and have the same significance for special culvert models as special bridge models. The special bridge Summary Table 105 is also applicable to special culvert models. In Summary Table 105, the QCH variable contains the value for QCULV.

The special culvert examples in Section 4 of this Appendix illustrate the detailed and summary output for the special culvert option.

Error messages and warnings are also provided for special culvert computations. See special notes 5105 through 5185 in Appendix V (pages V-6 through V-7) for error messages and warnings which pertain to the special culvert option.

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.

4.1 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, 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 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 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 percent.

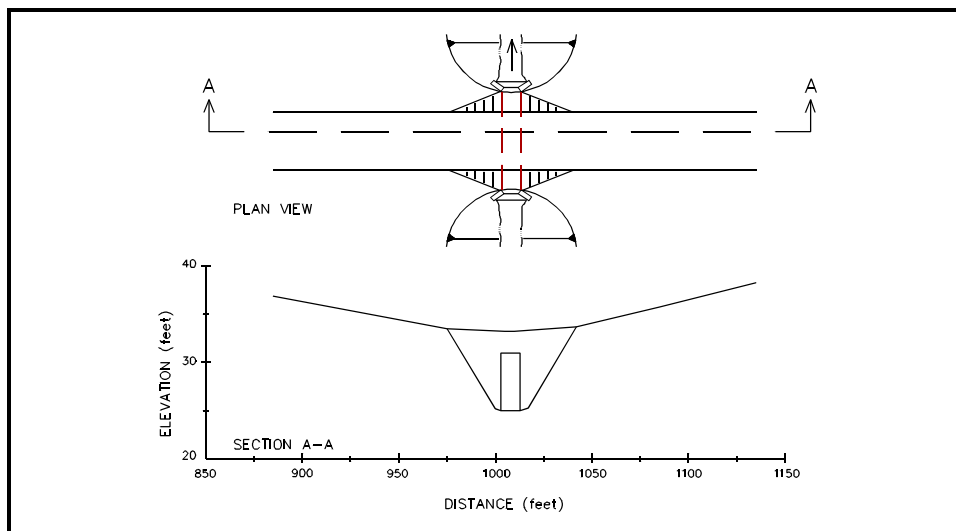


Figure 4.1
Illustration of Box Culvert Example

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 10 feet in the culverts to a maximum of about 60 feet downstream, the spacing between cross sections 1 and 2 should be about $4 \times (30 - 5) = 100$ 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 32. 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.

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 120 feet at cross section 4 to a top width of 10 feet in the culvert, the spacing between cross sections 3 and 4 should be about $60 - 5 = 55$ feet. An example output of the box culvert option is shown in Exhibit B of this appendix.

4.2 Example of Pipe Culvert Analysis

This example deals with a roadway crossing over a reinforced concrete pipe culvert. As shown in Figure 4.2, 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.

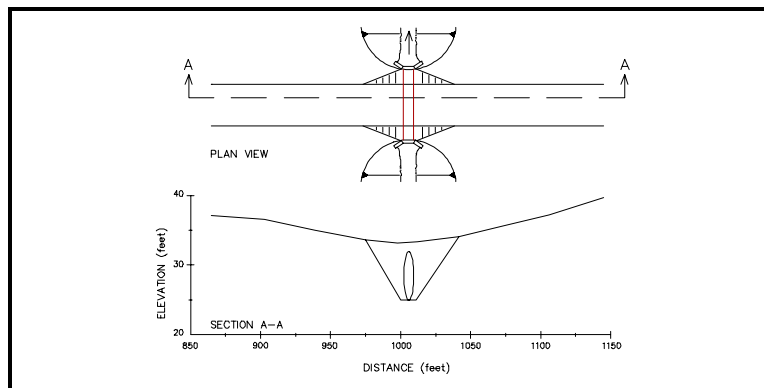


Figure 4.2
Pipe Culvert Example

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 percent.

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.

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. An example output of the pipe culvert option is shown in Exhibit C of this appendix.

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 4.3, 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 (page IV-21), Scale 1 of FHWA Chart 1 is appropriate for this type of culvert. According to Table 3.5 (page IV-18), the entrance loss coefficient for this type of entrance is about 0.5, assuming that the top edge of the entrance is not rounded.

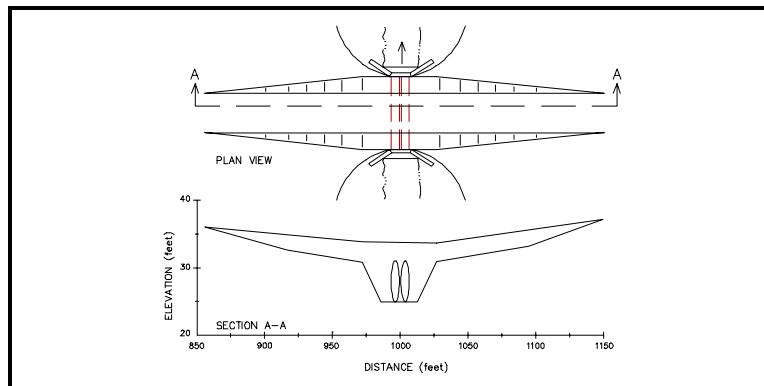


Figure 4.3
Illustration of Multiple Culverts Example

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 percent. 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 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 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.

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. An example output of multiple culverts is shown in Exhibit D of this appendix.

Chapter 5

References and Bibliography

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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.

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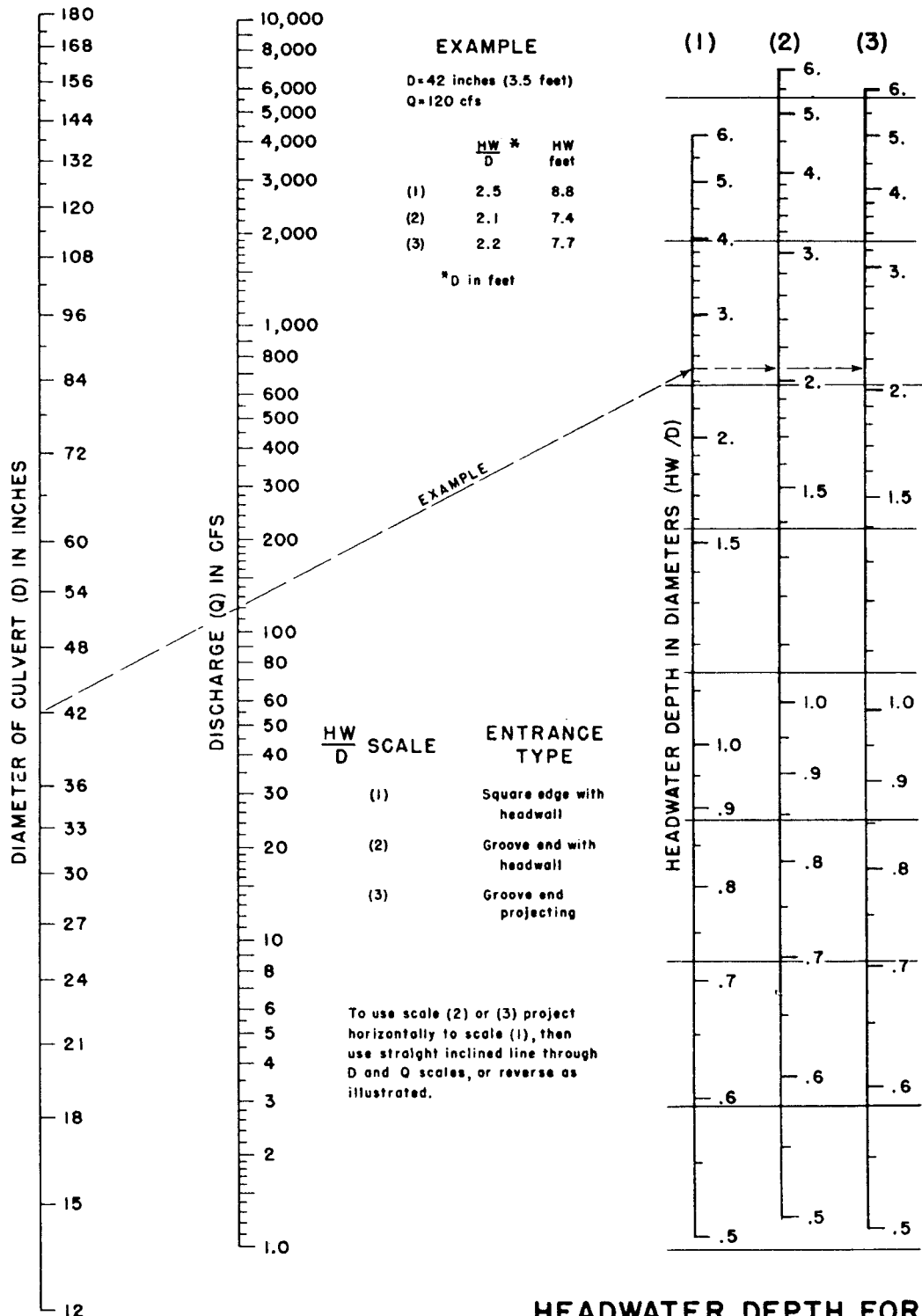
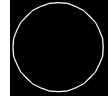
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Exhibit A

Federal Highway Administration

Culvert Charts

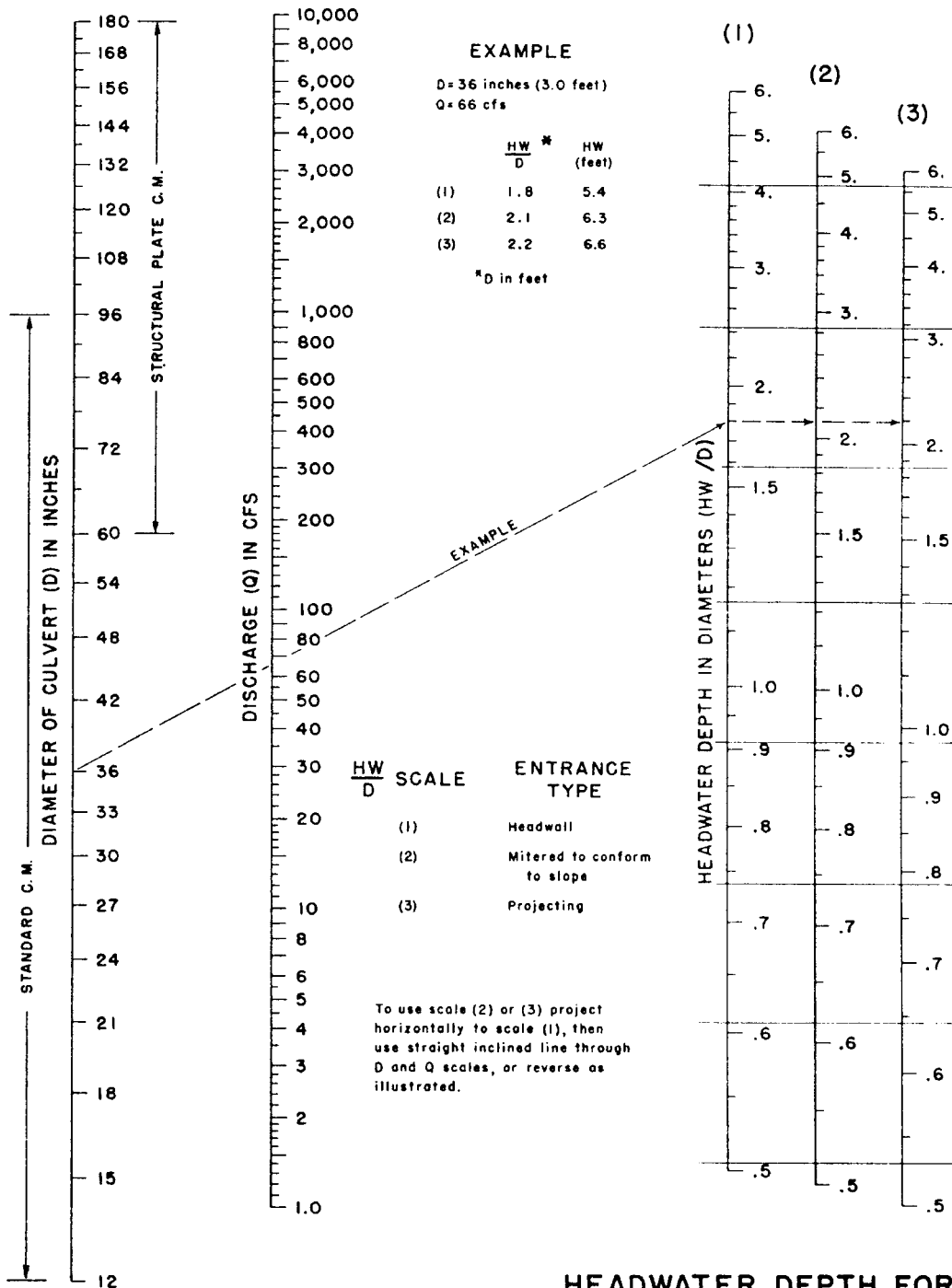
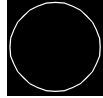
CHART 1



HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

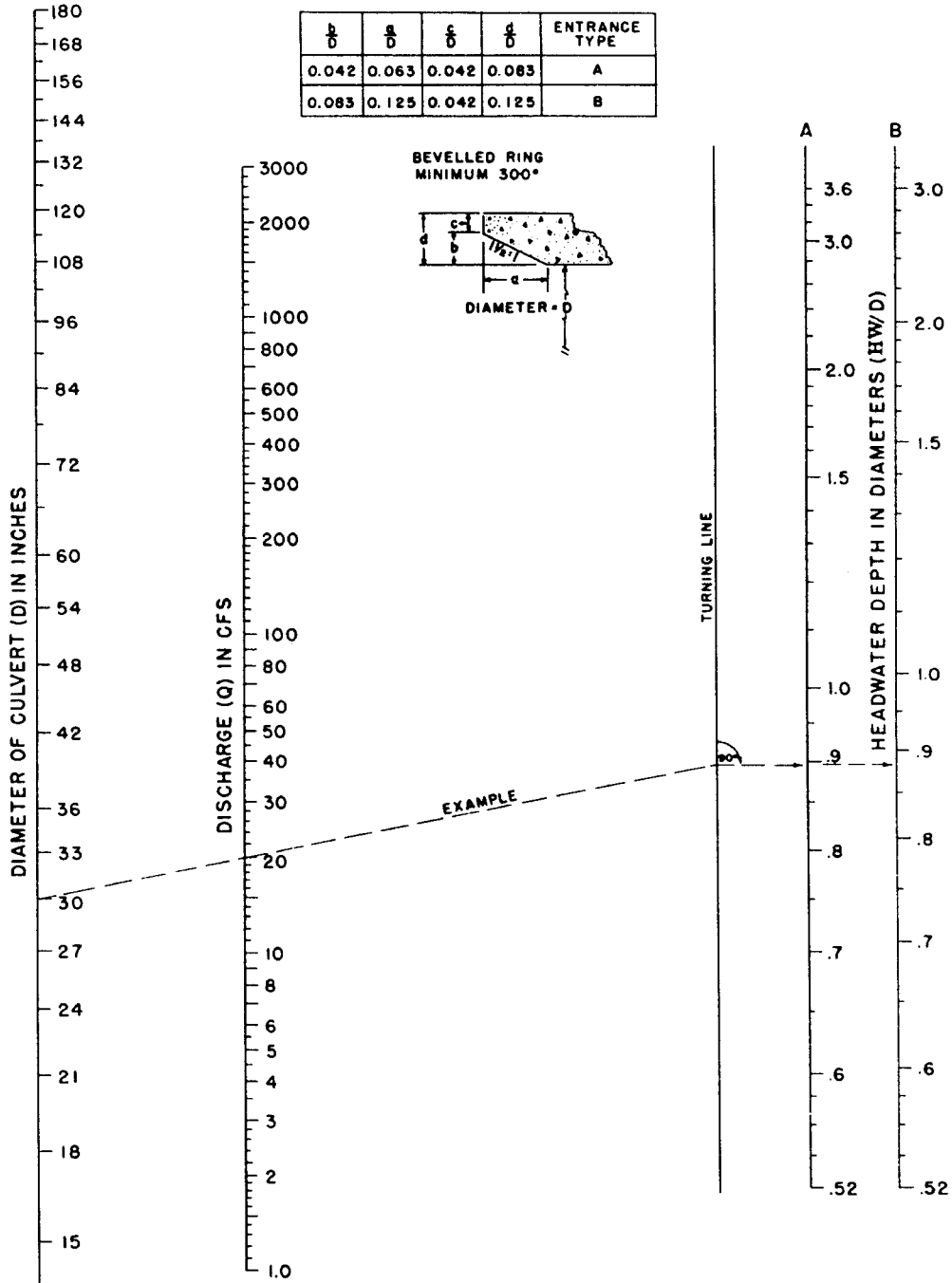
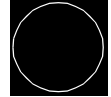
HEADWATER SCALES 2 & 3
 REVISED MAY 1964

CHART 2



HEADWATER DEPTH FOR
 C. M. PIPE CULVERTS
 WITH INLET CONTROL

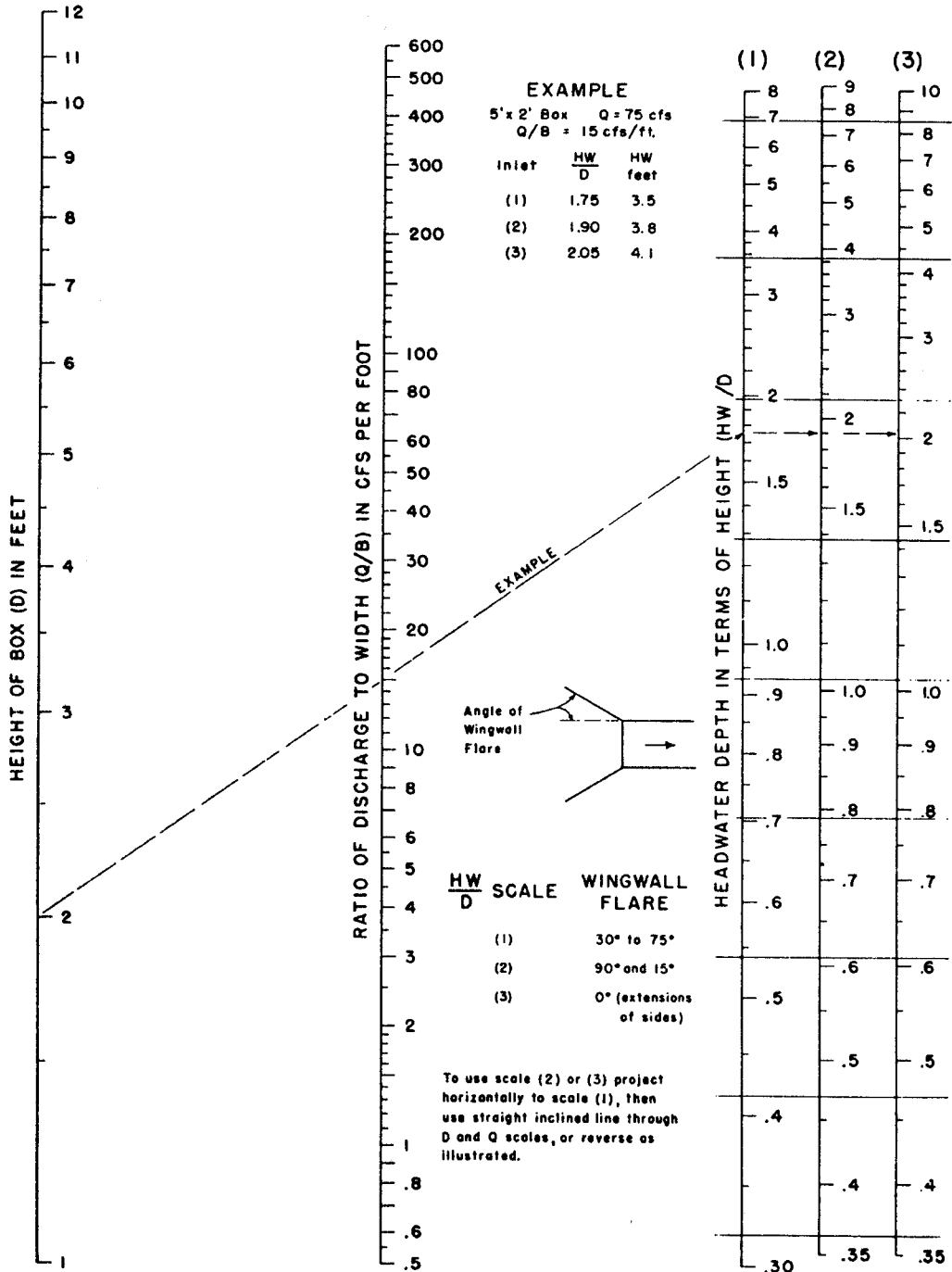
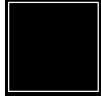
CHART 3



HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING INLET CONTROL

FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

CHART 8



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

CHART 9

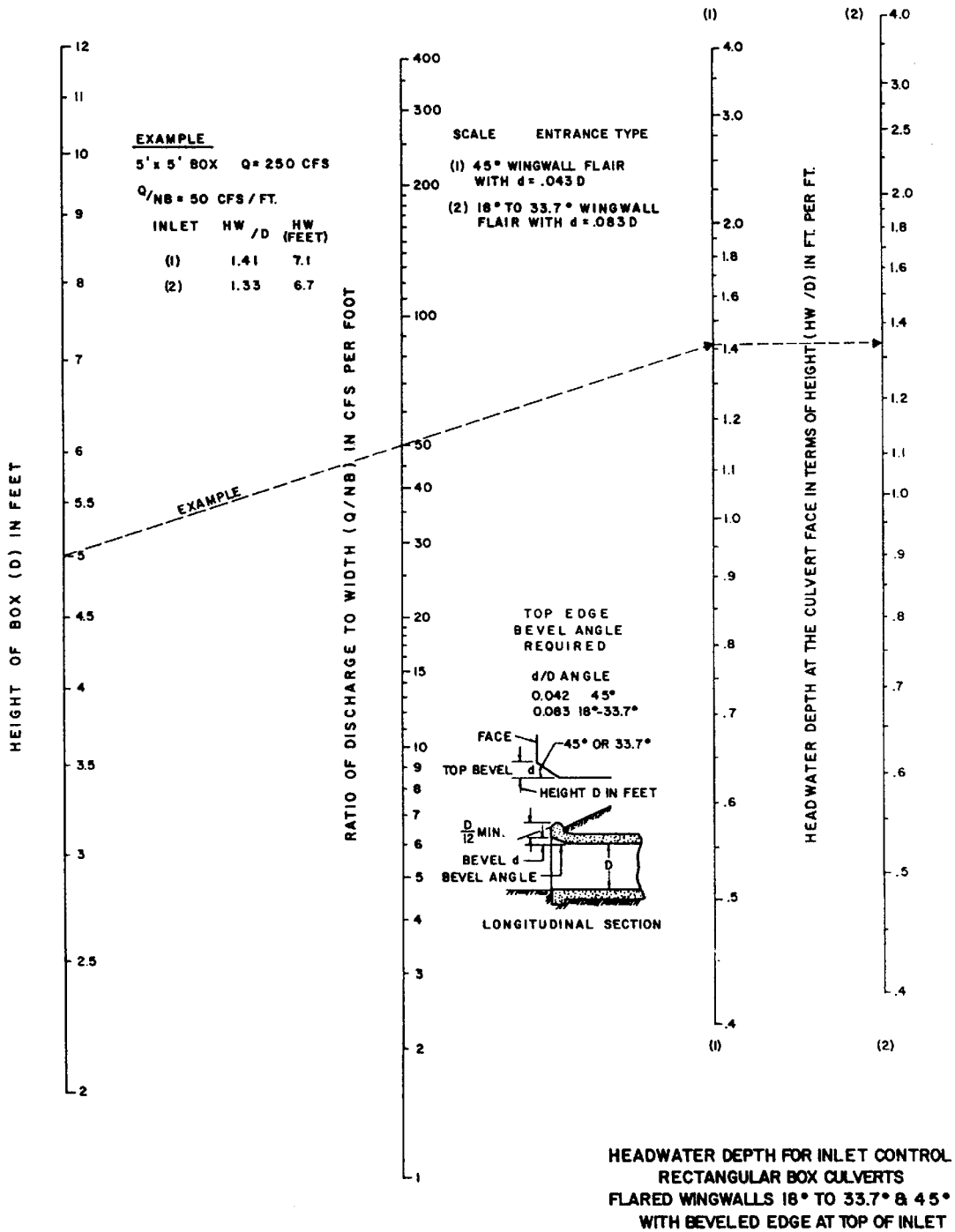
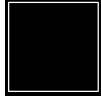


CHART 10



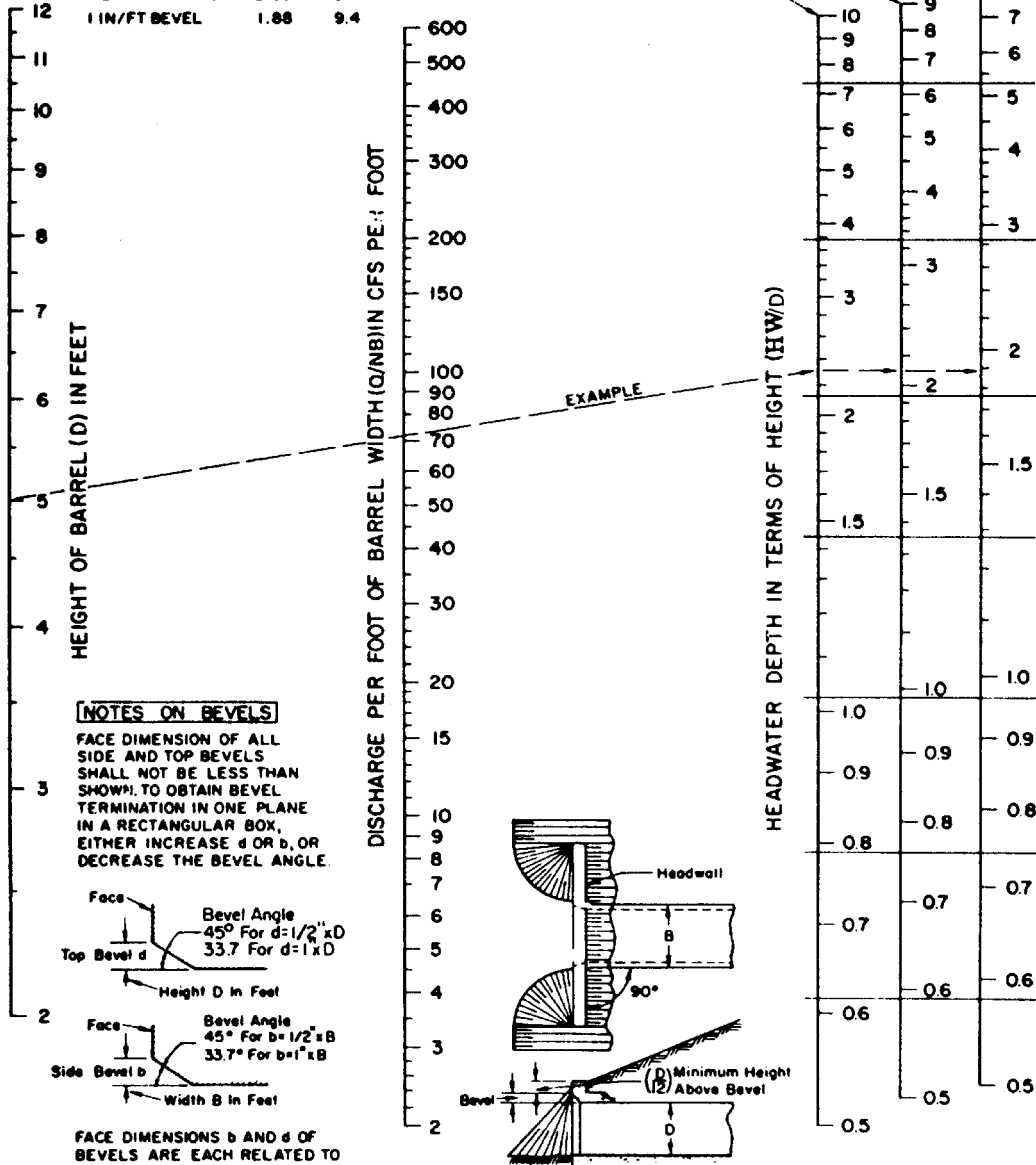
EXAMPLE

B=7 FT. D=5 FT. Q=500 CFS Q/NB =71.5

ALL EDGES	HW D	HW feet
CHAMFER 3/4"	2.31	11.5
1/2 IN/FT BEVEL	2.09	10.4
1 IN/FT BEVEL	1.88	9.4

INLET FACE-ALL EDGES:

- 1 IN/FT. BEVELS 33.7° (1:1.5)
- 1/2 IN/FT BEVELS 45° (1:1)
- 3/4 INCH CHAMFERS



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
90° HEADWALL
CHAMFERED OR BEVELED INLET EDGES

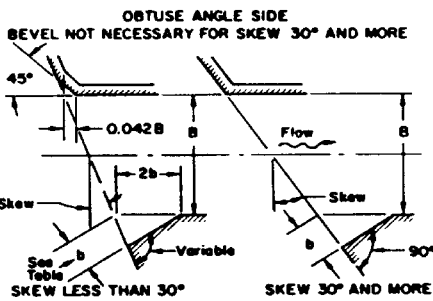
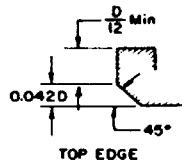
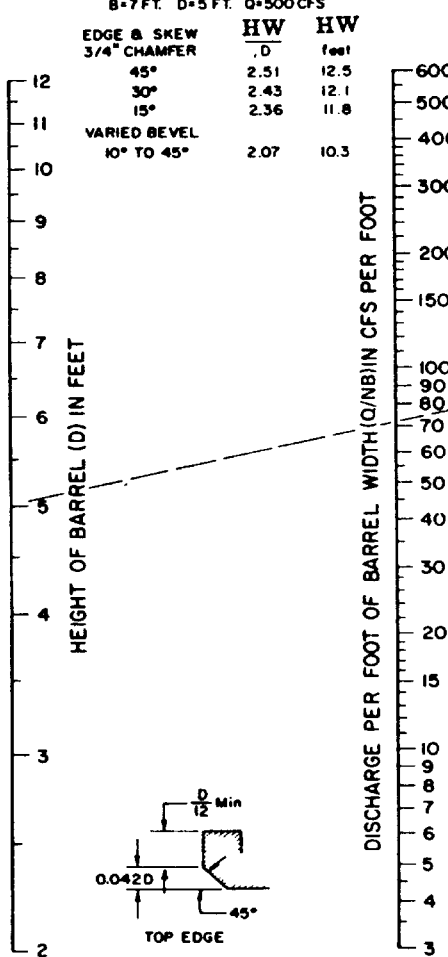
FEDERAL HIGHWAY ADMINISTRATION
MAY 1973



EXAMPLE

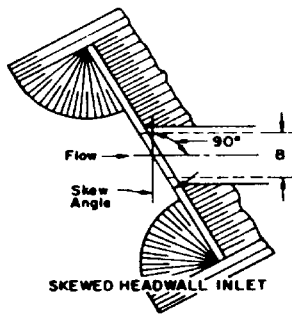
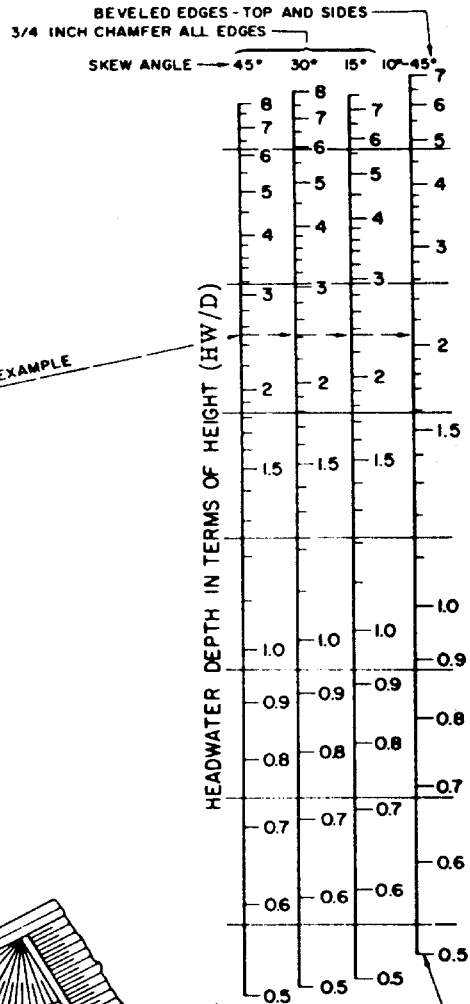
B=7 FT. D=5 FT. Q=500 CFS

EDGE & SKEW	HW D	HW feet
3/4" CHAMFER		
45°	2.51	12.5
30°	2.43	12.1
15°	2.36	11.8
VARIED BEVEL		
10° TO 45°	2.07	10.3



DESIGNED FOR SAME CAPACITY AT ANY SKEW

FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

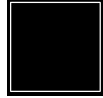


BEVELED EDGES AS DETAILED

SKEW ANGLE	SIDE BEVEL b
10°	3/4" x B (M)
15°	1" x B
22-1/2°	1-1/4" x B
30°	1-1/2" x B
37-1/2°	2" x B
45°	2-1/2" x B

HEADWATER DEPTH FOR INLET CONTROL
SINGLE BARREL BOX CULVERTS
SKEWED HEADWALLS
CHAMFERED OR BEVELED INLET EDGES

CHART 12

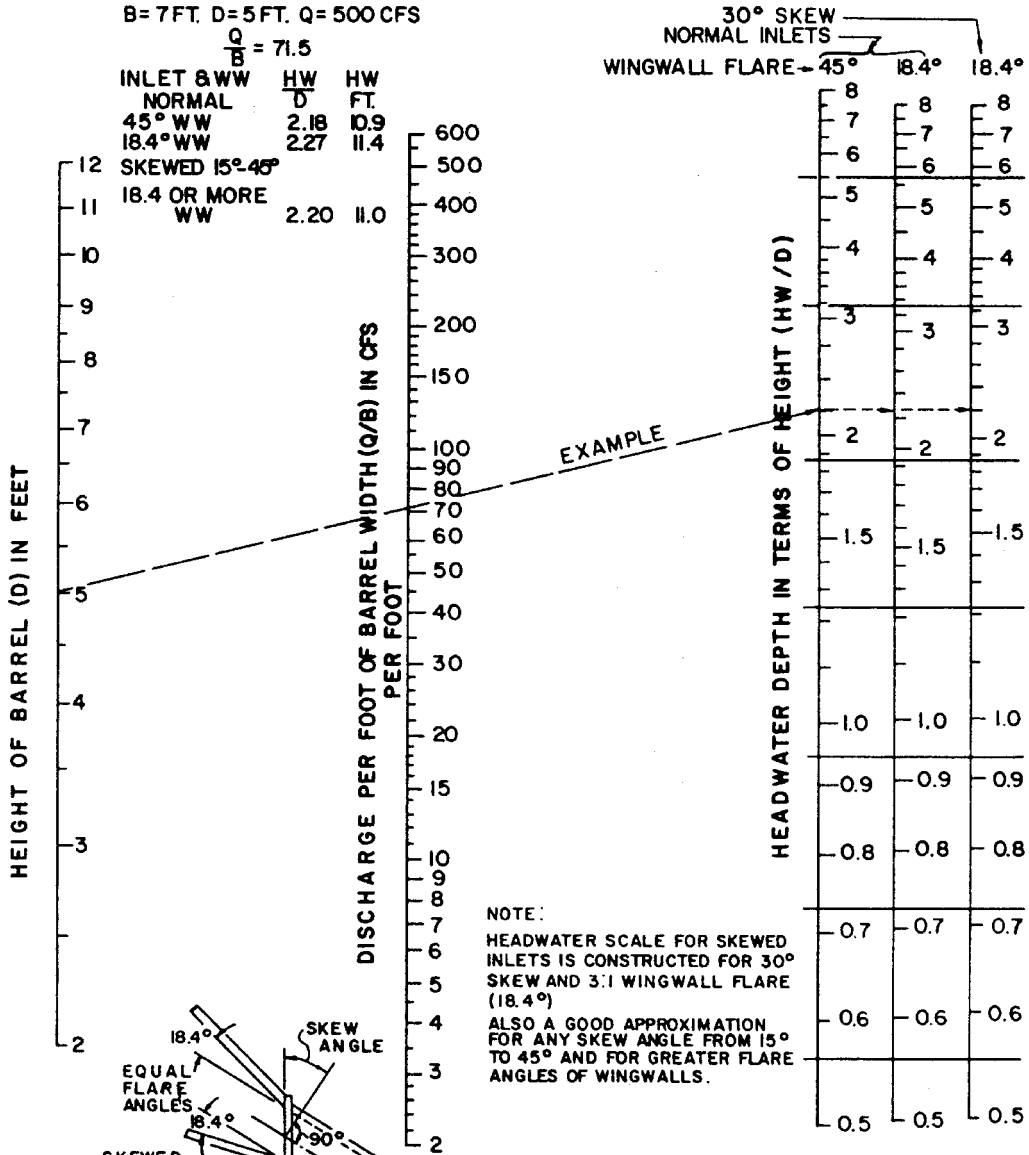


EXAMPLE

B = 7 FT. D = 5 FT. Q = 500 CFS

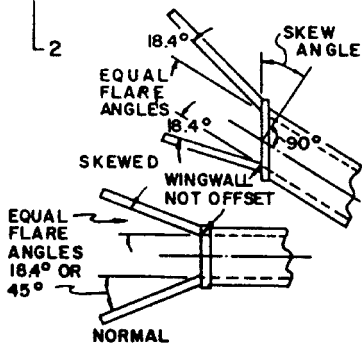
$$\frac{Q}{B} = 71.5$$

INLET & WW	HW D	HW FT.
NORMAL		
45° WW	2.18	10.9
18.4° WW	2.27	11.4
SKEWED 15°-45°		
18.4 OR MORE WW	2.20	11.0



NOTE:

HEADWATER SCALE FOR SKEWED INLETS IS CONSTRUCTED FOR 30° SKEW AND 3:1 WINGWALL FLARE (18.4°) ALSO A GOOD APPROXIMATION FOR ANY SKEW ANGLE FROM 15° TO 45° AND FOR GREATER FLARE ANGLES OF WINGWALLS.



WINGWALL INLETS

BUREAU OF PUBLIC ROADS
OFFICE OF R & D AUGUST 1968

HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS
NORMAL AND SKEWED INLETS
3/4" CHAMFER AT TOP OF OPENING

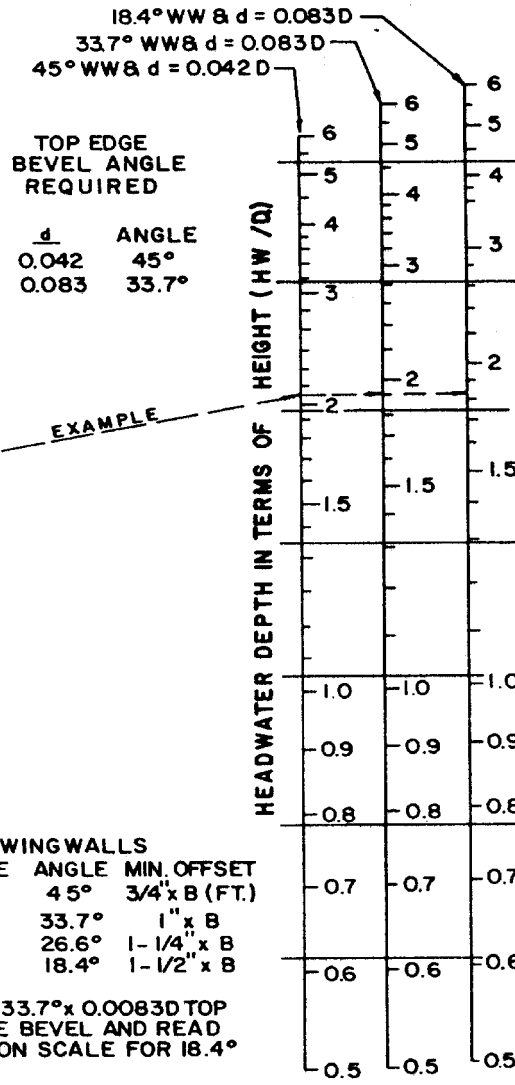
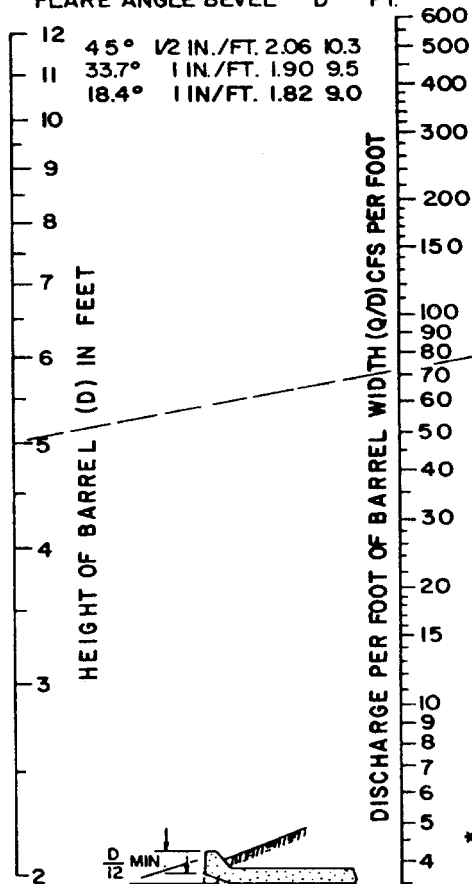
CHART 13

EXAMPLE

B = 7 FT. D = 5 FT. Q = 600 C.F.S

$$\frac{Q}{B} = 71.5$$

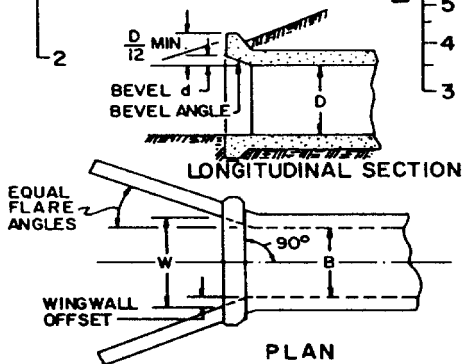
WINGWALL TOP EDGE FLARE ANGLE BEVEL $\frac{HW}{D}$ $\frac{HW}{FT.}$



WINGWALLS

FLARE	ANGLE	MIN. OFFSET
1:1	45°	3/4" x B (FT.)
1:1.5	33.7°	1" x B
* 1:2	26.6°	1-1/4" x B
1:3	18.4°	1-1/2" x B

* USE 33.7° x 0.0083D TOP EDGE BEVEL AND READ HW ON SCALE FOR 18.4° WW



BUREAU OF PUBLIC ROADS
OFFICE OF R & D AUGUST 1968

HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
OFFSET FLARED WINGWALLS
AND BEVELED EDGE AT TOP OF INLET

Exhibit B

Box Culvert Example

Computer Run

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*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 13:50:28 *
*****

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

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06FEB91 13:50:28

PAGE 1

THIS RUN EXECUTED 06FEB91 13:50:28

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*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****

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T1 SINGLE BOX CULVERT EXAMPLE - with 10 x 6 foot box
T3 SIMPLE CREEK 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 RIVER 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

06FEB91 13:50:28

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						33.3	33.3		
BT	-8	885	36.9		938	34.9		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

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PAGE 3

SECNO	DEPTH	CWSEL	CRISW	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	COFO	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 = 28.021 EGOC = 30.452 PCWSE= 30.272 ELTRD= 33.300

SPECIAL CULVERT

EGIC	EGOC	H4	QWEIR	QCULV	VCH	ACULV	ELTRD	WEIRLN
28.02	30.45	.05	0.	150.	2.871	60.0	33.30	0.

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PAGE 4

SECNO	DEPTH	CWSEL	CRISW	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	

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 33.30 ELREA= 33.30

3.000	5.22	30.32	.00	.00	30.45	.13	.05	.00	25.20
150.0	.0	150.0	.0	.0	52.2	.0	.3	.1	25.30
.01	.00	2.87	.00	.000	.040	.000	.000	25.10	1003.00
.000686	50.	50.	50.	2	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	151.0	.0	.4	.1	34.10
.02	.00	.99	.00	.000	.040	.000	.000	25.10	984.37
.000150	25.	25.	25.	2	0	0	.00	45.15	1029.52

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PAGE 5

T1 SINGLE BOX CULVERT EXAMPLE - Profile 2

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE

2 -1

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PAGE 6

SECNO	DEPTH	CWSEL	CRISW	WSELK	EG	HV	HL	OLOSS	L-BANK	ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK	ELEV
TIME	VLOB	VCH	VROB	XLN	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	25.20
300.0	.0	300.0	.0	.0	72.0	.0	.4	.1	.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	COFO	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 = 29.865 EGOG = 32.787 PCWSE= 32.203 ELTRD= 33.300

SPECIAL CULVERT

EGIC	EGOC	H4	QWEIR	QCULV	VCH	ACULV	ELTRD	WEIRLN
29.86	32.79	.32	0.	300.	4.035	60.0	33.30	0.

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PAGE 7

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

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 33.30 ELREA= 33.30

3.000	7.43	32.53	.00	.00	32.79	.25	.32	.00	.00	25.20
300.0	.0	300.0	.0	.0	74.4	.0	.5	.1	.1	25.30
.01	.00	4.03	.00	.000	.040	.000	.000	25.10	1003.00	
.000845	50.	50.	50.	2	0	0	.00	10.00	1013.00	

*SECNO 4.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 2.67

4.000	7.75	32.85	.00	.00	32.86	.02	.01	.07	.00	33.70
300.0	.0	300.0	.0	.0	275.7	.0	.6	.1	.1	34.10
.02	.00	1.09	.00	.000	.040	.000	.000	25.10	977.48	
.000119	25.	25.	25.	2	0	0	.00	60.20	1037.68	

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PAGE 8

T1 SINGLE BOX CULVERT EXAMPLE - 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
	3		-1							

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PAGE 9

SECNO	DEPTH	CWSEL	CRISW	WSELK	EG	HV	HL	OLOSS	L-BANK	ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK	ELEV
TIME	VLOB	VCH	VROB	XLN	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	.00	33.70		
	400.0	.0	400.0	.0	.0	312.5	.0	.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										
*SECNO	2.000												
	2.000	8.33	33.33	.00	.00	33.36	.03	.01	.00	.00	25.20		
	400.0	125.3	150.4	124.3	111.5	83.3	111.3	.7	.1	.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		
30.93	34.37	.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	

*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	

06FEB91 13:50:28

PAGE 10

THIS RUN EXECUTED 06FEB91 13:50:34

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

SIMPLE CREEK

SUMMARY PRINTOUT

SECNO	CUMDS	ELMIN	CWSEL	CRISW	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	30.32	.00	150.00	2.87	10.00	1.00
3.000	150.00	25.10	32.53	.00	300.00	4.03	10.00	1.07
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	45.15	2.14
* 4.000	175.00	25.10	32.85	.00	300.00	1.09	60.20	2.67
4.000	175.00	25.10	33.96	.00	400.00	1.15	73.56	.96

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PAGE 11

SIMPLE CREEK

SUMMARY PRINTOUT TABLE 101

SECNO	EGOC	ELLC	EGIC	ELTRD	QCULV	QWEIR	CLASS	H4	DEPTH	CWSEL	VCH	EG
3.000	30.45	.00	28.02	33.30	150.00	.00	7.00	.05	5.22	30.32	2.87	30.45
3.000	32.79	.00	29.86	33.30	300.00	.00	7.00	.32	7.43	32.53	4.03	32.79
3.000	34.37	.00	30.93	33.30	315.60	87.11	17.00	.62	8.85	33.95	1.59	33.98

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SIMPLE CREEK

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	30.32	.05	.00	10.00	.00	150.00	.00
	3.000	32.53	.32	.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	45.15	.00	150.00	.00
*	4.000	32.85	.01	.07	60.20	.00	300.00	.00
	4.000	33.96	.00	.00	73.56	.04	399.96	.00

06FEB91 13:50:28

PAGE 13

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

Exhibit C

Pipe Culvert Example

Computer Run


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*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 13:52:23 *
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*****
* U.S. ARMY CORPS OF ENGINEERS *
* HYDROLOGIC ENGINEERING CENTER *
* 609 SECOND STREET, SUITE D *
* DAVIS, CALIFORNIA 95616-4687 *
* (916) 756-1104 *
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06FEB91 13:52:24

PAGE 1

THIS RUN EXECUTED 06FEB91 13:52:24

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*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****

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T1 SINGLE PIPE CULVERT EXAMPLE - Seven foot pipe
T3 EASY CREEK 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	42	1	2	43	26	4	58
101	105							

USE NC RECORD TO SET RIVER 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							32.2	32.2	
GR	37.1	865	36.6	903	35	939	33.7	975	25	1000
GR	25	1003	25	1010	25	1011	34.1	1042	35.7	1074
GR	37.2	1106	38.7	1145						

SC RECORD DEFINES A SINGLE 84-INCH CONCRETE PIPE CULVERT

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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 AT UPSTREAM CULVERT FACE - FLOW LIMITED TO CULVERT WIDTH									
X1	3	12	1003	1010	50	50	50			
X2			2		33.3					
X3	10							33.3	33.3	
BT	-10	865	37.1		903	36.6		939	35	
BT		975	33.7		1003	33.7		1010	33.7	
BT		1042	34.1		1074	35.7		1106	37.2	
BT		1145	38.7							
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 - A FULL-FLOW SECTION UPSTREAM FROM THE 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

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SECNO	DEPTH	CWSEL	CRISW	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
	200.0	.0	200.0	.0	.0	185.5	.0	.0	.0
	.00	.00	1.08	.00	.0000	.040	.0000	.0000	24.90
	.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	.0000	.040	.0000	.0000	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 = 30.515 EGOE = 31.746 PCWSE= 30.921 ELTRD= 33.700

SPECIAL CULVERT

EGIC	EGOC	H4	QWEIR	QCULV	VCH	ACULV	ELTRD	WEIRLN
30.52	31.75	.46	0.	200.	4.513	38.5	33.70	0.

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PAGE 4

SECNO	DEPTH	CWSEL	CRISW	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

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 33.30 ELREA= 33.30

	3.000	6.33	31.43	.00	.00	31.75	.32	.46	.00	25.10
	200.0	.0	200.0	.0	.0	44.3	.0	.3	.1	25.10
	.01	.00	4.51	.00	.0000	.040	.0000	.0000	25.10	1003.00
	.001260	50.	50.	50.	2	0	0	.00	7.00	1010.00

*SECNO 4.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 3.56

	4.000	6.73	31.83	.00	.00	31.84	.01	.01	.09	33.70
	200.0	.0	200.0	.0	.0	217.9	.0	.4	.1	34.10
	.02	.00	.92	.00	.0000	.040	.0000	.0000	25.10	980.44
	.000099	25.	25.	25.	2	0	0	.00	53.74	1034.18

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T1 SINGLE PIPE CULVERT EXAMPLE - 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

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SECNO	DEPTH	CWSEL	CRISW	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	COFO	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 = 31.888 EGOC = 33.204 PCWSE= 31.875 ELTRD= 33.700

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SECNO	DEPTH	CWSEL	CRISW	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
31.89	33.20	.80	0.	280.	5.205	38.5	33.70	0.

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 33.30 ELREA= 33.30

3.000	7.68	32.78	.00	.00	33.20	.42	.80	.00	25.10
280.0	.0	280.0	.0	.0	53.8	.0	.4	.1	25.10
.01	.00	5.20	.00	.000	.040	.000	.000	25.10	1003.00
.001294	50.	50.	50.	2	0	0	.00	7.00	1010.00

*SECNO 4.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 4.05

4.000	8.22	33.32	.00	.00	33.33	.01	.01	.12	33.70
280.0	.0	280.0	.0	.0	304.9	.0	.5	.1	34.10
.02	.00	.92	.00	.000	.040	.000	.000	25.10	976.11
.000079	25.	25.	25.	2	0	0	.00	63.20	1039.31

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T1 SINGLE PIPE CULVERT EXAMPLE - 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
		3			-1					

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SECNO	DEPTH	CWSEL	CRISW	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	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	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		
34.17	36.00	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	

*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	

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THIS RUN EXECUTED 06FEB91 13:52:30

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

EASY CREEK

SUMMARY PRINTOUT

SECNO	CUMDS	ELMIN	CWSEL	CRISW	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
*	2.000	100.00	25.00	31.87	.00	280.00	5.82	7.00
	2.000	100.00	25.00	33.28	.00	400.00	1.80	63.04
	3.000	150.00	25.10	31.43	.00	200.00	4.51	7.00
	3.000	150.00	25.10	32.78	.00	280.00	5.20	7.00
	3.000	150.00	25.10	34.46	.00	400.00	1.43	95.83
*	4.000	175.00	25.10	31.83	.00	200.00	.92	53.74
*	4.000	175.00	25.10	33.32	.00	280.00	.92	63.20
	4.000	175.00	25.10	34.47	.00	400.00	1.05	95.53

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EASY CREEK

SUMMARY PRINTOUT TABLE 101

SECNO	EGOC	ELLC	EGIC	ELTRD	QCULV	QWEIR	CLASS	H4	DEPTH	CWSEL	VCH	EG
3.000	31.75	.00	30.52	33.70	200.00	.00	7.00	.46	6.33	31.43	4.51	31.75
3.000	33.20	.00	31.89	33.70	280.00	.00	7.00	.80	7.68	32.78	5.20	33.20
3.000	36.00	.00	34.17	33.70	265.68	132.80	17.00	1.17	9.36	34.46	1.43	34.48

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EASY CREEK

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	31.43	.46	.00	7.00	.00	200.00	.00
3.000	32.78	.80	.00	7.00	.00	280.00	.00
3.000	34.46	1.17	.00	95.83	156.79	93.82	149.39
* 4.000	31.83	.01	.09	53.74	.00	200.00	.00
* 4.000	33.32	.01	.12	63.20	.00	280.00	.00
4.000	34.47	.00	.00	95.53	.58	399.36	.06

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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

Exhibit D

Multiple Culverts Example

Computer Run

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*****
* HEC-2 WATER SURFACE PROFILES *
* *
* Version 4.6.0; February 1991 *
* *
* RUN DATE 06FEB91 TIME 13:53:59 *
*****

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

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THIS RUN EXECUTED 06FEB91 13:53:59

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*****
HEC-2 WATER SURFACE PROFILES
Version 4.6.0; February 1991
*****

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T1 MULTIPLE PIPE CULVERTS EXAMPLE - Two six foot culverts
T3 Sample Creek

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
		2			.00015				30.0	
J2	NPROF	IPLLOT	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			
X3	10									
GR	36.1	856	32.7	917	30.9	972	25	32.3	32.3	
GR	25	1007	25	1013	31	1027	33.2	986	25	993
GR								1095	37.2	1150

SC RECORD DEFINES DUAL 72-INCH CONCRETE PIPE CULVERTS

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SC	2.013	0.5	3.0	6.0	50	1.1	25.1	25.0
----	-------	-----	-----	-----	----	-----	------	------

CROSS-SECTION 3 AT UPSTREAM CULVERT FACE WITH EFFECTIVE FLOW OPTION

X2.3 = 2 INDICATES CULVERT OPTION - ROAD OVERFLOW AT 33.7 FEET

BT DATA DEFINE ROAD PROFILE FOR OVERFLOW CALCULATIONS.

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									
BT	-8	856	36.1	917	34.8		33.7	33.7		
BT		993	33.8	1007	33.8		972	33.9		
BT		1095	35.7	1150	37.2		1027	33.7		
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

CROSS-SECTION 4 IS A FULL FLOW SECTION UPSTREAM FROM CULVERT

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				

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SECNO	DEPTH	CWSEL	CRISW	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
	250.0	.0	250.0	.0	.0	217.0	.0	.0	.0
	.00	.00	1.15	.00	.000	.040	.000	.000	24.80
	.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
 EGIC = 29.499 EGOE = 30.843 PCWSE= 30.275 ELTRD= 33.700

SPECIAL CULVERT

EGIC	EGOC	H4	QWEIR	QCULV	VCH	ACULV	ELTRD	WEIRLN
29.50	30.84	.39	0.	250.	3.197	56.5	33.70	0.

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SECNO	DEPTH	CWSEL	CRISW	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

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

3.000	5.58	30.68	.00	.00	30.84	.16	.39	.00	25.10
250.0	.0	250.0	.0	.0	78.2	.0	.8	.2	25.10
.02	.00	3.20	.00	.000	.040	.000	.000	25.10	993.00
.000748	50.	50.	50.	2	0	0	.00	14.00	1007.00

*SECNO 4.000

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

4.000	5.78	30.88	.00	.00	30.90	.02	.01	.04	30.90
250.0	.0	250.0	.0	.0	236.1	.0	.9	.2	31.00
.03	.00	1.06	.00	.000	.040	.000	.000	25.10	972.05
.000122	50.	50.	50.	2	0	0	.00	54.67	1026.72

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T1 MULTIPLE PIPE CULVERTS EXAMPLE - Profile two

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

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SECNO	DEPTH	CWSEL	CRISW	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	30.90
	400.0	1.1	398.1	.8	10.9	295.8	8.6	.0	31.00
	.00	.10	1.35	.09	.100	.040	.100	.000	24.80
	.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 = 31.125 EGOG = 32.955 PCWSE= 31.678 ELTRD= 33.700

SPECIAL CULVERT

EGIC	EGOC	H4	QWEIR	QCULV	VCH	ACULV	ELTRD	WEIRLN
31.12	32.96	.99	0.	400.	3.740	56.5	33.70	0.

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SECNO	DEPTH	CWSEL	CRISW	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

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

3.000	7.64	32.74	.00	.00	32.96	.22	.99	.00	25.10
400.0	.0	400.0	.0	.0	106.9	.0	1.1	.3	25.10
.02	.00	3.74	.00	.000	.040	.000	.000	25.10	993.00
.000674	50.	50.	50.	2	0	0	.00	14.00	1007.00

*SECNO 4.000

3302 WARNING: CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE, KRATIO = 2.99

4.000	7.91	33.01	.00	.00	33.02	.02	.01	.06	30.90
400.0	9.7	382.2	8.0	67.2	353.0	62.2	1.4	.4	31.00
.03	.14	1.08	.13	.100	.040	.100	.000	25.10	911.50
.000075	50.	50.	50.	2	0	0	.00	177.52	1089.02

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T1 MULTIPLE PIPE CULVERTS EXAMPLE - Profile three

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

3

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SECNO	DEPTH	CWSEL	CRISW	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	WIN	ELMIN	SSTA	
SLOPE	XLOBL	XLCH	XLOBR	I TRIAL	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	
32.34	34.47	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	298.1	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

*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

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THIS RUN EXECUTED 06FEB91 13:54:05

 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

Sample Creek

SUMMARY PRINTOUT

SECNO	CUMDS	ELMIN	CWSEL	CRISW	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
*	2.000	200.00	25.00	31.68	.00	400.00	4.28	14.00
	2.000	200.00	25.00	32.48	.00	500.00	1.71	148.64
	3.000	250.00	25.10	30.68	.00	250.00	3.20	14.00
	3.000	250.00	25.10	32.74	.00	400.00	3.74	14.00
*	3.000	250.00	25.10	34.15	.00	500.00	1.21	217.23
*	4.000	300.00	25.10	30.88	.00	250.00	1.06	54.67
*	4.000	300.00	25.10	33.01	.00	400.00	1.08	177.52
	4.000	300.00	25.10	34.15	.00	500.00	1.07	217.22

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Sample Creek

SUMMARY PRINTOUT TABLE 101

SECNO	EGOC	ELLC	EGIC	ELTRD	QCULV	QWEIR	CLASS	H4	DEPTH	CWSEL	VCH	EG
3.000	30.84	.00	29.50	33.70	250.00	.00	7.00	.39	5.58	30.68	3.20	30.84
3.000	32.96	.00	31.12	33.70	400.00	.00	7.00	.99	7.64	32.74	3.74	32.96
* 3.000	34.47	.00	32.34	33.70	458.93	43.14	17.00	1.65	9.05	34.15	1.21	34.16

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Sample Creek

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	30.68	.39	.00	14.00	.00	250.00	.00
3.000	32.74	.99	.00	14.00	.00	400.00	.00
* 3.000	34.15	1.65	.00	217.23	180.25	153.27	166.48
* 4.000	30.88	.01	.04	54.67	.00	250.00	.00
* 4.000	33.01	.01	.06	177.52	9.73	382.23	8.04
4.000	34.15	.00	.00	217.22	27.95	445.81	26.24

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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=	3.000	PROFILE=	3	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

Appendix V

Special Notes

Appendix V

Special Notes

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 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 14.
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 and NC.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 19.
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.
- 1530 MANNINGS N VALUES FOR CHANNEL COMPOSITED. The criterion described in Section 2.3 is used to determine whether a composite 'n' value should be computed. This message indicates a composite value was computed, and the value is printed as the channel 'n' (variable XNCH). (See J6.3 for user control.)
- 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.

Statement Number	Notes and Remarks
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.
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, page II-6.
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 50 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.

Statement Number	Notes and Remarks
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).
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 (IARA) 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 800.
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 20. 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 20 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 (IARA = 10). Check results for reasonableness.

Statement Number	Notes and Remarks
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.
3790	DATA ERROR. 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 50 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.

Statement Number	Notes and Remarks
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.
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 and SB.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 subcritical flow. Change IDIR (J1.4) to zero.
5120	INCORRECT VALUE FOR FHWA CHART NUMBER. An incorrect value of the FHWA Chart Number (SC.8) 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.8) is entered for the specified chart number (SC.8). 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 30 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.

Statement Number	Notes and Remarks
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 supercritical flow condition. Therefore, the job has been terminated.
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.8) 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.

Statement Number	Notes and Remarks
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.
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 50 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, 100 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.

Statement Number	Notes and Remarks
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.
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.

Appendix VI

Output Data Description

Appendix VI

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.

Variable	Description																														
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.																														
CEHV	Expansion coefficient.																														
CHRT	Chart number for FHWA culvert nomographs																														
CHSLOP	Channel slope.																														
CLASS	Identification number for following types of bridge/culvert flow.																														
	<table border="1"> <thead> <tr> <th>Class</th> <th>Type of Flow</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Low Flow - Class A</td> </tr> <tr> <td>2</td> <td>Low Flow - Class B</td> </tr> <tr> <td>3</td> <td>Low Flow - Class C</td> </tr> <tr> <td>6</td> <td>Culvert Analysis, Inlet Control</td> </tr> <tr> <td>7</td> <td>Culvert Analysis, Outlet Control</td> </tr> <tr> <td>10</td> <td>Pressure Flow Alone</td> </tr> <tr> <td>11,15</td> <td>Weir and Low Flow - Class A</td> </tr> <tr> <td>12</td> <td>Weir and Low Flow - Class B</td> </tr> <tr> <td>13</td> <td>Weir and Low Flow - Class C</td> </tr> <tr> <td>16</td> <td>Culvert Analysis, Weir Flow & Inlet Control</td> </tr> <tr> <td>17</td> <td>Culvert Analysis, Weir Flow & Outlet Control</td> </tr> <tr> <td>30</td> <td>Pressure Flow and Weir Flow</td> </tr> <tr> <td>59</td> <td>Special Bridge Reverts to Normal Bridge Method</td> </tr> <tr> <td>67</td> <td>For Encroachment Methods 3 through 6</td> </tr> </tbody> </table>	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
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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.																														

Variable	Description
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.
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 energy elevation from upstream to downstream using culvert analysis option.

Variable	Description
HL	Energy loss due to friction for standard-step solutions. For all others it is the change in energy elevation.
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.
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.

Variable	Description
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.
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.

Variable	Description
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).
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.

Variable	Description
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).
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 VII
Input Data Description

Appendix VII

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HEC-2 Input Description Introduction

1. Introduction

This appendix contains a detailed description of the data input requirement for each variable on each input record. It also contains a Functional Use Index which can be used to determine which input variables are required for specific tasks. The Summary of Input Records shows the sequential arrangement of records. Many of the records described can be omitted if the options to which they apply are not required.

The location of the variables for each input record is shown by field number. Each record is divided into ten fields of eight columns each, except Field 1. A variable in Field 1 may only occupy record Columns 3 through 8 since record Columns 1 and 2 (called Field 0) are reserved for required identification characters. The values a variable may assume and the conditions for each are described. Some variables simply call for use of program options by using the numbers -1, 0, 1, 10, and 15. Other variables contain numbers which express the magnitude of the variable. For these a plus or minus sign is shown in the description under "value" and the numerical value of the variable is entered as input. Where the value of a variable is to be zero, the variable may be left blank since a blank field is read as zero.

Any number without a decimal point must be right justified in its field. Any number without a sign is considered positive.

The location of variables on records is often referred to by an abbreviated designation; for example, J1.5 refers to the fifth field of the J1 record.

HEC-2 Input Description
Functional Use Index

2. Functional Use Index

Task	Records Used
Basic Applications	T1, T2, T3, J1.4 - J1.9, NC, X1.1-X1.9, GR, EJ, ER
Archival Option	AC
Data Comment Records	C_
Multiple Profiles, Summary Printout	J2.1, J3
Printout Control	J5
Traces & Input Data Printout	J1.1, J2.10, X2.10
Storage-Discharge Output	J4
Printer Plots of Cross Sections and Profiles	J2.2 - J2.5, X1.10
Optional Friction Loss Equations	J6.1
Flow Distribution	J2.10, X2.10
Critical Depth Option	J2.7
Direct Solution for Manning's 'n'	J1.3, X2.2
Optional Records for Specifying Manning's 'n'	J2.6, NH, NV
Equivalent Roughness 'k'	KH
Options for Specifying Discharge	J1.2, J1.8, J1.10, X2.1, QT
Specifications of Ineffective Flow Areas & Encroachments	X3, ET
Additional Ground Points	X4
Channel Modification Due to Excavation	J2.8, J2.9, CI
Bridge and Culvert Losses	X2.3 - X2.6, BT, SB, SC, X5
Use of HEC-2 Data Edit Program	ED
Use of Free Format Input	FR, FIX, FREE
Use of the Flow Under Ice Option	IC
Water Surface Based on a Rating Curve	J1.5, JR, RC
Basic Applications of Split Flow Option	SF, TW, WS, WC, EE

HEC-2 Input Description EDIT2

ED

3. ED Record (HEC-2 Data Edit Program (EDIT-2) - Optional

Controls certain run options for data edit program. Does not need to be removed for HEC-2 runs.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	ED	Record identification characters.
1	LIST	YES (Blank)	Produce listing of input data before editing it (default).
		NO	Suppress listing.
2	CC	YES (Blank)	Produce 81 column output with carriage control in Column 1 suitable for line printer output or other wide carriage devices (default).
		NO	Limit output width to 80 columns without carriage control (i.e., for eighty column interactive terminals).
3	GRANGE	0 (Blank)	Use default value (150) for GR record elevation difference test.
		+	Value to use for GR record elevation difference test.

The HEC-2 data edit program (EDIT-2) is designed to accept as input any HEC-2 data file exactly as set-up for input to HEC-2. It will handle stacked jobs and all other features which are available in the September 1988 release of HEC-2.

The edit program will function with default run parameters for any HEC-2 data file. There are three parameters which may be entered on an optional ED record. If used, the ED record must be the first record in the data file and there may be only one. The format of the ED record is similar to HEC-2 data records; i.e., the letters ED in Columns 1 and 2 and the three values in the first three fields right justified to Columns 8, 16, and 24.

Suggestion for Using the EDIT2 Program. When RECORD OUT OF ORDER errors occur, many subsequent fallacious error messages may be triggered. It is suggested that the user correct the RECORD OUT OF ORDER errors first and rerun the edit program.

SF JC

HEC-2 Input Description Split Flow Records

4 Split Flow Records

4.1 SF Record - Split Flow Title

The SF record is used to flag the split flow option. Only one SF record can be used. This record is **required** if the split flow option is going to be used. The SF record has to be the first record in an HEC-2 file.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	SF	Record identification characters.
1-10			Alphanumeric title data.

4.2 JC Record - Title Job

The JC record is used to indicate that JP record follows. The JP record must follow the JC record. This record is optional.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	JC	Record identification characters.
1-10			Alphanumeric title data.

HEC-2 Input Description Split Flow Records

JP

4.3 JP - Job Parameter

The JP record is used to set several job parameters dealing with the split flow computations. The JC and JP records are optional and can be placed anywhere in the split flow data or completely left out. They should be placed normally after the SF records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	JP	Record identification characters.
1	ISFTR	0	Printout control of split flow computations will be held to a minimum.
		1	Trace each split flow iteration.
		10	Trace both the split flow and backwater iterations.
2	AEROR	0	The program will use a value of two percent allowed error for convergence.
		+	The user may specify the allowed percent tolerance for convergence.
3	NAITER	0	The maximum number of iterations for split flow to be executed per profile (20 is the default value).
		+	The user may specify the maximum number of iterations.
4	IUEG	-1,0	The program will use the water surface to determine the overflow.
		1	The program will use the energy grade line to determine the overflow.
5	PERFR	0	One hundred percent of the overflow is to be returned at SNOFR (WS.4, NS.4, and CS.4).
		+	Percent of overflow to be returned at SNOFR (WS.4, NS.4, and CS.4).

TW WS

HEC-2 Input Description Split Flow Records

4.4 TW Record - Title for Weir Location

The TW record is required for each set of weir outflow data set. The TW record must be followed by a set of WS and WC records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	TW	Record identification characters.
1-10			Alphanumeric title data.

4.5 WS Record - Weir Parameter Data

The WS record is required for each TW record used and must follow it. The WS record contains information dealing with the number of points describing the weir, weir flow coefficient, location of the upstream and downstream limits of the weir in relation to section numbers as used in the X1 records, and the section number where the flow returns. If the flow does not return, a value of negative one should be used. It is required that the section numbers used to set-up the backwater model increase from downstream to upstream. The same rule applies for supercritical models.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	WS	Record identification characters.
1	NWPL	+	Number of coordinate points that describe the weir on the WC record.
2	DSSNO	+	Downstream section number where the first weir coordinate applies.
3	USSNO	+	Upstream section number where the last weir coordinate applies.
4	SNOFR	+	Section number where the lost weir flow returns.
		-1	The weir flow does not return.
5	COEFL	+	Coefficient of discharge for use in weir flow equation.
6-10			Not used.

HEC-2 Input Description Split Flow Records

WC

4.6 WC Record - Weir Coordinate Data

The WC record is used to input the weir coordinates. The weir coordinates must start at the downstream end and proceed upstream. The maximum number of coordinates is 100.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	WC	Record identification characters.
1,3,5, 7,9	STA(I)	+	Station value of weir coordinate.
2,4,6, 8,10	ELO(I)	+	Elevation value of weir coordinate.

TN NS

HEC-2 Input Description Split Flow Records

4.7 TN Record - Title for Normal Depth Location

The TN record is required for each set of normal depth outflow data set. The TN record must be followed by a set of NS and NG records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	TN	Record identification characters.
1-10			Alphanumeric title data.

4.8 NS Record - Normal Depth Parameter Data

The NS record is similar to the WS record with the exception that instead of having the weir flow coefficient, it has the energy slope and 'n' value.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	NS	Record identification characters.
1	NWPL	+	Number of coordinate points that describe the normal depth flow cross section on the NG record.
2	DSSNO	0,+	Downstream section number where the first coordinate point on the NG record applies.
3	USSNO	0,+	Upstream section number where the last coordinate point on the NG record applies.
4	SNOFR	0,+	Section number where the lost flow returns.
		-1	The lost flow does not return.
5	XNVND	+	The 'n' value to be used for normal depth calculation.
6	SLOPND	+	The energy slope to be used for normal depth calculations.
7-10			Not used.

HEC-2 Input Description Split Flow Records

NG

4.9 NG Record - Ground Coordinate Data

The NG record is used to input the normal depth cross section coordinates. The coordinate must start at the downstream end and proceed upstream. The maximum number of coordinates is 100.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	NG	Record identification characters.
1,3,5, 7,9	STA(I)	+	Station value of cross section.
2,4,6, 8,10	ELO(I)	+	Elevation value of cross section.

TC CS

HEC-2 Input Description Split Flow Records

4.10 TC Record - Title for Rating Curve Location

The TC record is required for each set of rating curve outflow data set. The TN record must be followed by a set of CS and CR records.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	TC	Record identification characters.
1-10			Alphanumeric title data.

4.11 CS Record - Rating Curve Parameter Data

The CS record is similar to the WS record with the exception that the location (upstream and downstream) is a point location and therefore the value entered for USSNO and DSSNO should normally be equal.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	CS	Record identification characters.
1	NWPL	+	Number of discharge elevation pairs to be read from the CR records to follow.
2	DSSNO	0,+	Downstream section number where the rating curve applies.
3	USSNO	0,+	Upstream section number where the rating curve applies.
4	SNOFR	0,+	Section number where the lost flow returns.
		-1	The lost flow does not return.
5-10			Not used.

HEC-2 Input Description Split Flow Records

CR
EE

4.12 CR Record - Rating Curve Data

The CR record is used to input the rating curve of outflows. The location of the rating curve has to be at a specific location on the river. Therefore the location has to be specified at only one point. The variables DSSNO and USSNO should be set equal. If they are not, the program will use the mean of the two locations. The maximum number of rating curve points is 100.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	CR	Record identification characters.
1,3,5, 7,9	STA(I)	+	Discharge values for rating curve.
2,4,6, 8,10	ELO(I)	+	Elevation values for rating curve.

4.13 EE Record - End of Split Flow Data

The EE record is required to terminate the reading of the split flow data. The EE record should be in front of the first regular HEC-2 record, such as the AC, C, or T1 records.

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

AC

HEC-2 Input Description Documentation Records

5 Documentation Records

5.1 AC Record - Archival Option

To use the Archival Option, one or more AC records must be inserted at the beginning of a data file (i.e., before C records or first T1 record if C records are not used). Columns 3 through 80 of each AC record are available for alphanumeric comments to document the archival tape. As many AC records as required may be used. It is the users responsibility to provide the required job control statements to insure that the file written to Unit 96 will appear on magnetic tape or otherwise be saved by the system after execution. On an Archival execution cross section plots **should not** be requested. Also, the maximum number of summary tables is reduced by two for an Archival run.

RECORD NUMBER	FIELD	VARIABLE	VALUE	DESCRIPTION
1	0	IA	AC	Record identification characters.
1	1-10	--	--	Blank.
2 - as many records necessary	0	IA	AC	Record identification characters.
	1-10			Alphanumeric comments to document the Archival tape.

Example Application

```
AC Flood plain determination -- Spring Creek, Baker, CA
AC Cross sections from FEMA 2 foot contour map dated 6/18/90
AC ACE Engineers Contract No. 19675848, 11/7/90
T1
T3
J1
.
.
.
.
ER
```

HEC-2 Input Description Documentation Records

C_

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
    
```

T1 - T9

HEC-2 Input Description Documentation Records

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

HEC-2 Input Description Job Control Records

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).

6.2 JR Record - Starting Rating Curve

The JR records are used to input a starting rating curve. A set can be placed for each profile being run. They must follow the J1 record and the number of rating curve points must be greater than two. It is required that the number of rating curve points be entered on the J1 record, Field 5. A maximum of 20 discharge elevation values is allowed. The program linearly interpolates between given rating curve values and extrapolates for values outside the rating curve.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	JR	Record identification characters.
1,3,5, 7,9	QJ1(i)	+	Discharge values.
2,4,6, 8,10	XJ1(i)	-,0,+	Water surface elevation values.

Example Application

```

T1
T3
J1  0      3      0      0      7      0      0      0      0      0
JR  50  204.3  100  204.8  200  205.1  350  206.2  500  207.3
JR 1000 208.5  2000 210.5
J2
.
.
.
ER
    
```

6.3 JS Record - Starting Split Flow Assumption

The JS record is used to specify the starting assumed lost discharges for each reach defined in the split flow data set. If the JS record is not entered for a profile, then the program assumes that the first trial assumed lost flow is zero for all the split flow reaches. The JS record should follow the J1 record or the JR record if used. A maximum of 100 values are allowed.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	JS	Record identification characters.
1	N	+	Number of assumed lost discharges to read.
2	ARLQ(4,1)	+	Assumed lost discharge for first reach.
3	ARLQ(4,2)	+	Assumed lost discharge for second reach.
.	.	.	.
.	.	.	.
.	.	.	.
	ARLQ(4,N)	+	Assumed lost discharge for last reach.

Continue on in field one of additional JS records up to ARLQ(4,N).

Example Application

```

SF
.
.
.
EE
T1
T3
J1
JS      5      404      0      1118      150      650
J2
.
.
.
ER
    
```

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

HEC-2 Input Description Job Control Records

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 NC.2) are not modified. (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).

J3

HEC-2 Input Description Job Control Records

6.5 J3 Record - Selection of Variables for Summary Tables (optional)

Optional record (up to five records may be used). Used on the first profile of a multiple profile run to select variables for the summary printout. If a summary printout is requested (J2.1) and a J3 record is not supplied, a pre-defined table (Table 150) is printed.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	J3	Record identification characters.
1-10	IVAR(I)		Codes to specify summary tables. Pre-defined tables may be called as shown below (100 and 200 series). User-defined tables may be generated by specifying up to 13 variable codes per table. Where two or more user-defined tables are specified, a blank field should be used to separate the tables. Tables are printed in order specified. Pre-defined tables are printed in numerical order after any user-defined table. A maximum of five tables may be generated.

Codes for Pre-Defined Tables

Code	Table
100	Hydraulic calculations for special bridges only.
101	Hydraulic calculations for culverts only.
105	For cross section output at special bridge or culvert.
110 115	Encroachment data.
120	Channel improvement data.
150	Standard summary (two tables produced).
200	Floodway data (FIA Table 1) ¹ .

¹Flood Insurance Study, Guidelines and Specifications, Federal Emergency Management Agency, 1987.

J3 Record (continued)

Variable Codes for User Defined Tables

Variable Name	Code Number	Variable Name	Code Number	Variable Name	Code Number
Cross section and Reach Variables from Input		Water Surface and Energy Related Variables		Culvert Variables	
SECNO	38	CWSEL	1	H4	85
STCHL	21	CRIWS	2	EGOC	83
STCHR	22	WSELK	9	EGIC	84
XLBEL	23	EG	3	QCULV	86
RBEL	24	HL	11	Encroachment Variables	
ELMIN	42	OLOSS	12	PERENC	36
XLCH	39	IHLEQ	62	STENCL	27
CUMDS	66	Difference Variables		STENCR	28
CHSLOP (K*CHSL)	33	DIFEG	61	ELENCL	31
Velocity Variables		DIFWSP	50	ELENCR	32
VLOB	55	DIFWSX	51	Channel Improvement (CHIMP) Variables	
VROB	56	DIFKWS	52	CLSTA	29
VCH	26	Discharge Variables		BW	30
HV	10	Q	43	VEXR	64
ALPHA	57	QLOB	13	VEXT	65
TIME	6	QCH	14	Flow Under Ice Variables	
Calculated Geometric Variables		QROB	15	TH1	70
DEPTH	8	QLOBP	35	XICE1	71
TOPWID	4	QCHP	60	XSTAB1	72
AREA	25	QROBP	59	XFCH1	73
TWA	37	.01K	34	ZINCH	74
VOL	7	Manning's 'n' Variable		TVOLI	75
SSTA	53	XNL (K*XNL)	16	VOLIL	76
ENDST	54	XNR (K*XNR)	18	VOLIR	77
TELMX	63	XNCH (K*XNCH)	17	VOLICH	78
Hydraulic Parameters		WTN (K*WTN)	19	NICE	79
CASE	20	Bridge Variables		ZITL	80
SLOPE (10K*S)	5	CLASS	49	ZITR	81
KRATIO	58	QWEIR	46	ZITCH	82
SHEAR	67	QPR	47		
FRCH	68	EGPRS	44		
POWER	69	EGLWC	45		
		H3	48		
		ELTRD	40		
		ELLC	41		

See following pages for descriptions of variables.

J3

HEC-2 Input Description Job Control Records

J3 Record (continued)

Summary Printout Data Description

Code Number	Variable Name	Description
1	CWSEL	Computed water surface elevation.
2	CRIWS	Critical water surface elevation.
3	EG	Energy gradient elevation for a cross section which is equal to the computed water surface elevation CWSEL plus the discharge-weighted velocity head HV.
4	TOPWID	Cross section width at the calculated water surface elevation.
5	SLOPE (10K*S)	Slope of the energy grade line for the current section (times 10,000).
6	TIME	Travel time from the first cross section to the present cross section in hours.
7	VOL	Cumulative volume of water in the stream from the first cross section (in acre-feet for English units or 1000 cubic meters in Metric units).
8	DEPTH	Depth of flow.
9	WSELK	Known water surface elevation.
10	HV	Mean velocity head across the entire cross section.
11	HL	Energy loss due to friction.
12	OLOSS	Energy loss due to expansion or contraction.
13	QLOB	Amount of flow in the left overbank.
14	QCH	Amount of flow in the channel.
15	QROB	Amount of flow in the right overbank.
16	XNL (K*XNL)	Manning's 'n' for the left overbank area (time 1,000).

J3 Record (continued)

Summary Printout Data Description

Code Number	Variable Name	Description
17	XNCH (K*XNCH)	Manning's 'n' for the channel area (times 1,000).
18	XNR (K*XNR)	Manning's 'n' for the right overbank area (times 1,000).
19	WTN (K*WTN)	Weighted value of Manning's 'n' for the channel based on the distance between cross sections and channel flow from the first cross section. Used when computing Manning's 'n' from high water marks (times 1,000).
20	CASE	An internal program control variable. It provides no information to the user.
21	STCHL	Station of the left bank.
22	STCHR	Station of the right bank.
23	XLBEL	Left bank elevation.
24	RBEL	Right bank elevation.
25	AREA	Cross section area.
26	VCH	Mean velocity in the channel.
27	STENCL	The station of the left encroachment.
28	STENCR	The station of the right encroachment.
29	CLSTA	The centerline station of the trapezoidal excavation.
30	BW	The bottom width of the trapezoidal excavation.
31	ELENCL	Elevation of left encroachment.
32	ELENCR	Elevation of right encroachment.

J3

HEC-2 Input Description Job Control Records

J3 Record (continued)

Summary Printout Data Description

Code Number	Variable Name	Description
33	CHSLOP (K*CHSL)	Channel slope (times 1,000).
34	.01K	The total discharge (index Q) carried with $S^{1/2} = .01$ (equivalent to .01 times conveyance).
35	QLOBP	Percent of flow in the left overbank.
36	PERENC	The target of encroachment requested on ET record.
37	TWA	The cumulative topwidth area (acres or 1000 square meters).
38	SECNO	The cross section identification number.
39	XLCH	Channel reach length.
40	ELTRD	Minimum elevation for top of road profile.
41	ELLC	Maximum low chord elevation.
42	ELMIN	Minimum elevation in cross section.
43	Q	Discharge.
44	EGPRS	Energy elevation assuming pressure flow.
45	EGLWC	Energy elevation assuming low flow.
46	QWEIR	Total weir flow at the bridge.
47	QPR	Total pressure or low flow at the bridge.
48	H3	Change in water surface elevation from Yarnell's equation.
49	CLASS	Controlling flow type for bridge solution.
50	DIFWSP	Difference in water surface elevation for each profile.
51	DIFWSX	Difference in water surface elevation between sections.

J3 Record (continued)

Summary Printout Data Description

Code Number	Variable Name	Description
52	DIFKWS	Difference between known and computed water surface elevations.
53	SSTA	Starting station where the water surface intersects the ground (on the left side of the cross section).
54	ENDST	Ending station where the water surface intersects the ground on the right side.
55	VLOB	Average velocity in the left overbank area.
56	VROB	Average velocity in the right overbank area.
57	ALPHA	Velocity head coefficient.
58	KRATIO	Ratio of the upstream to downstream conveyance.
59	QROBP	Percent of flow in the right overbank.
60	QCHP	Percent of flow in the channel.
61	DIFEG	Difference in energy elevation for each profile.
62	IHLEQ	Friction loss equation index.
63	TELMX	Elevation of the lower of the two end points of cross section.
64	VEXR	Volume of excavation in reach.
65	VEXT	Volume of excavation, total.
66	CUMDS	Cumulative channel distance from first cross section.
67	SHEAR	Boundary shear stress within the channel.
68	FRCH	Froude number for main channel.
69	POWER	Stream power within main channel.

J3

HEC-2 Input Description Job Control Records

J3 Record (continued)

Summary Printout Data Description

Code Number	Variable Name	Description
70	TH1	Ratio (T/H) of ice thickness (T) to maximum depth (H) in channel.
71	XICE1	Calculated ice stability factor X based on TM.
72	XSTAB1	Ice stability factor based on Pariset curve based on TH1.
73	XFCH1	Froude number (for ice stability analysis) for the channel based on H equal to the maximum depth in the channel.
74	ZINCH	Channel N value based on Belokon-Sabaneev Formula.
75	TVOLI	Cumulative volume of ice in cubic yards or cubic meters.
76	VOLIL	Cumulative volume of ice on left bank.
77	VOLIR	Cumulative volume of ice on right bank.
78	VOLICH	Cumulative volume of ice in the channel.
79	NICE	ICE N value read in.
80	ZITL	Ice thickness for the left bank.
81	ZITR	Ice thickness for the right bank.
82	ZITCH	Ice thickness for the channel.
83	EGOC	Computed energy grade elevation for outlet control.
84	EGIC	Computed energy grade elevation for inlet control.
85	H4	Energy elevation difference from downstream to upstream of the culvert.
86	QCULV	Flow through the culvert.

6.6 J4 Record - Storage-Outflow Records for HEC-1 (optional)

Optional record used only on the first profile of a multiple profile run to obtain storage-discharge output in a form that can be used as input to the HEC-1 program for modified-Puls routing. A KK record is generated by HEC-2 for each routing reach. Storage and corresponding discharge values are written to SV and SQ records, respectively. KK and KM records are printed to identify the reach, and an RS record is printed without data. The storage-routing variables required on the RS record must be added by the HEC-1 user. Routing reach cross section numbers, REACH(I), specified on this record must correspond to an X1 record SECNO value. Output is written to TAPE7.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	J4	Record identification characters.
1-10	REACH(I)	+	<p>Defines routing reaches by pairs of cross section numbers representing downstream and upstream ends of reaches. REACH(I), when I is an odd number, indicates a downstream end. An even number for I indicates an upstream end. Fifty reaches can be specified.</p> <p>A blank field indicates that no more cross section numbers will follow.</p> <p>Zeros in a field are read as a cross section number, not a blank.</p>

J5

HEC-2 Input Description Job Control Records

6.7 J5 Record - Printout Control

The optional J5 record can be used to suppress detailed (cross section by cross section) and summary printout. The J5 record(s) may be used for single or multiple profile jobs. For multiple profile jobs, the J5 record(s) is inserted with job records for the first profile. Printout of the data input list, flow distribution data, and profile and cross section plots are unaffected by this option; for printout control of these options refer to the J1, J2, X1, and X2 records. Use of the J5 record for various printout options is illustrated in the following table.

Field					Desired Printout
0 (IA)	1 (LPRNT)	2 (NUMSEC)	3 (SECNOS(I))	4 .. N	
J5	-10	-10			Summary printout only for all cross sections
J5	-10		X		Detailed and summary printout beginning at cross section X
J5	-10	+	X ₁	X ₂ .. X _n	Detailed and summary printout for cross sections (X ₁ , ... X _n)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	J5	Record identification characters.
1	LPRNT	-10	and NUMSEC = -10, suppress detailed printout for all cross sections.
			and NUMSEC equals zero or plus, print detailed and summary printout for only those cross sections indicated by NUMSEC and SECNOS(I) (J5.2 and J5.3).
		-1	Same as -10 except a list of cross section numbers is furnished to aid in debugging runs that do not run to completion.

J5 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
2	NUMSEC	-10	Suppress detailed printout for all cross sections. Requested summary printout is not suppressed.
		0	Suppress all detailed and summary printout from the first cross section to the cross section indicated in J5.3.
		+	Any positive number indicates that the following fields will contain cross section numbers SECNOS(I).
3-10	SECNOS(I)	-,0,+	<p>If NUMSEC is plus, one hundred cross section numbers can be specified. If additional records are required, all ten fields should be used for SECNOS(I).</p> <p>A blank field indicates that no more cross section numbers will follow.</p> <p>Zeros in a field are read as a cross section number, not a blank.</p>

J6

HEC-2 Input Description Job Control Records

6.8 J6 Record - Friction Loss Equations (optional)

The J6 record is an optional record which can be utilized to select equations for computation of friction losses, transfer control of output print files to computer system control, choose the method of evaluating subdivision of conveyance within the channel, and select the station of the cross section at the downstream end of the model. These options may be used for single or multiple profile jobs. For multiple profiles the J6 record is inserted with job records for the first profile only.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	J6	Record identification characters.
1	IHLEQ	0	Average conveyance equation used to compute friction losses. This equation has been utilized in the preceding version of HEC-2 and is recommended for general application.
		1	Program selects, on a reach by reach basis, one of the following equations: average friction slope, geometric mean friction slope, or harmonic mean slope. Selection is based on flow conditions. ¹
		2	Average friction slope equation used to compute friction losses.
		3	Geometric mean friction slope equation used to compute friction losses.
		4	Harmonic mean friction slope equation used to compute friction losses.
2	ICOPY	0	The program will internally handle the disk/tape units containing the output print files.
		1	The program will transfer control of disk/tape units for output print files to the computer.

¹See Table 2, Chapter 4, page 22, of the User's Manual for details.

J6 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
3	SUBDIV	0	Default value. Allow subdivision of the channel if both bank side slopes are flatter than 5H:1V (horizontal to vertical). The slope is computed from the bank station to the point of 'n' or 'k' value change.
		-1	Allow the program to subdivide if 'n' or 'k' is changed in the channel cross section for any side slope.
		+	Value defining the side slope criterion for subdividing instead of the default value of five (5).
4	STRTDS	-,0,+	Station of the first cross section of the downstream end of the model. The units of STRTDS can be either in feet or meters or in miles or kilometers as indicated by the variable RMILE (J6.5).
5	RMILE	0	Units for STRTDS are in feet or meters.
		+	Units for STRTDS are in miles or kilometers.

EJ ER

HEC-2 Input Description Job Control Records

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.

7 Change Records

7.1 IC Record - Ice Data (optional)

Used to input or change ice data. Calculations with floating ice cover will start at the first cross section (X1 record) following the IC record and will continue until an IC record is read that has .01 for SPGR (Field 5). Insert IC records with other change records (NC, NH, ET, etc.) immediately ahead of record X1.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	IC	Record identification characters.
1	ZITL	+	Ice thickness for the left overbank.
		0	No change in ice thickness for the left overbank.
		-1	Open water in left overbank.
2	ZITR	+	Ice thickness for the right overbank.
		0	No change in ice thickness for the right overbank.
		-1	Open water in right overbank.
3	ZITCH	+	Ice thickness for the channel.
		0	No change in ice thickness for the channel.
		-1	Open water in the channel.
4	ZIN	+	Manning's 'n' value for ice.
		0	No change in Manning's 'n' value for ice.
5	SPGR	+	Value of ice specific gravity.
		.01	No ice calculations until another IC record is read. (Used to terminate ice calculations.)
		0	No change in ice specific gravity if a value was entered on a prior IC record or if none has been previously specified, the default value of 0.916 will be used.

IC

HEC-2 Input Description Change Records

IC Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
6-10 ¹	FZ	+	Factor to multiply ice thickness values (ZITL, ZITR, ZITCH) by.
		0	Ice 'n' values and ice thickness will not be modified.
		-	Factor to multiply ice 'n' value (ZIN) by.

¹ Field use (6-10) for a profile corresponds to the field specified in Field 8 (variable IBW) of the J2 record.

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.

NH

HEC-2 Input Description Change Records

7.3 NH Record - Horizontal Variations of Manning's 'n' (optional)

Used to permanently change the roughness coefficients (Manning's 'n') to values which vary with horizontal distances from the left side of the cross section. Roughness coefficients should be redefined for each cross section with new geometry. **The NH record should not be used at cross sections employing the NV record or when utilizing the channel improvement (CI) option.** If 'n' values change within the channel, the criterion described in Section 2.3 (page 4) is used to determine whether 'n' values should be converted to a composite value using Equation 5.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	NH	Record identification characters.
1	NUMNH	1-20	Total number of Manning's 'n' values (maximum 20) entered on NH records. If NUMNH is greater than four, multiple NH records are required and, the first field of the second and subsequent NH record, should contain a STN(N) value.
2,4,6, 8,10...etc	VALN(N)	+	Manning's 'n' coefficient between stations STN(N-1) and STN(N). The first 'n' value applies from the starting left station up to STN(N) (Field 3).
3,5,7, 9,11...etc	STN(N)	+	Station corresponding to VALN(N). Each stations should equal one of the stations on the next GR records. Stations must be in increasing order. Station values will not be adjusted by X1.8 PXSECR.

7.4 NV Record - Vertical Variations in Manning's 'n' (optional)

Used to change the channel roughness coefficient 'n' based on water surface elevations. Program interpolates channel 'n' value for each calculated water surface elevation based on 'n' versus elevation data. **This option should not be used at cross sections employing the NH record or CHNIM (J2.9) option.**

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	NV	Record identification characters.
1	NUMNV	2-20	Total number of Manning's 'n' values entered on NV records (maximum 20). If NUMNV is greater than four, multiple NV records are required and, the first field of the second and subsequent NV records should contain an ELN(N) value.
2,4,6, 8, 10, 12...etc.	VAL(N)	+	Manning's 'n' coefficient for area below ELN(N). The overbank 'n' values specified on the NC record will be used for the overbank roughness regardless of the values in this table.
3,5,7, 9, 11, 13 ... etc.	ELN(N)	+	Elevation of the water surface corresponding to VALN(N) in increasing order.

KH

HEC-2 Input Description Change Records

7.5 KH Record - Horizontal Description of Equivalent Roughness 'k' (optional)

Used to specify equivalent roughness coefficients (k values on feet or meters) which vary with horizontal distances from the left side of the cross section. These specifications remain in effect unless changed by new KH, NH, or NC records at subsequent cross sections. Roughness coefficients should be redefined for each cross section with new geometry. The KH record should not be used for cross sections employing the NV record or channel improvement (CI) option.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	KH	Record identification characters.
1	NUMKH	1-20	Total number of equivalent roughness values of 'k' (maximum of 20) entered on KH records. If NUMKH is greater than four, multiple KH records are required, and the first field of the second and subsequent KH records should contain a STK(N) value.
2,4,6 8,10,etc.	VALK(N)	+	Equivalent roughness 'k' coefficient between stations STK(N-1) and STK(N). The first 'k' value applies from the starting left station up to STK(1) (Field 3).
3,5,7 9,11,etc.	STK(N)	+	Station corresponding to VALK(N). Each station should equal one of the stations on the next GR record. Stations must be in increasing order. Station values will not be adjusted by X1.8 PXSECR.

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.

7.7 ET Record - Encroachment Table (optional)

This record is used to specify the Method 1 through 6 and target of the encroachment. The method and target will be used until changed by another ET record, except for Method 1, which only applies to the next cross section. A zero on the first ET record indicates no encroachment, while a zero on succeeding ET records indicates no change in encroachment. The field of the ET record that is being used for a particular profile is specified by variable INQ (J1.2). Methods 3 through 6 require a natural profile for the first profile and thus require reading a zero on the ET record of the "INQ" field for the first profile. If Methods 2 through 6 are being used and it is desired to terminate the encroachment option, use Method 1 with the encroachment stations specified near the two ends of the cross section. Each method is capable of evaluating the effects of encroachments on bridges.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	ET	Record identification characters.
1	None	None	Blank field.
2-10	ENCFP(N)	0	No encroachment or no change in encroachment.
		+ or -	Encroachment method used. The number X.Y is used to specify that method Y is being used and X is the target to be used for that method. Up to nine values may be specified. The encroachment method or target may be changed at any cross section or on different profiles.

Encroachment Methods

Positive values of X.Y for Methods 3 through 6 provide an encroachment based on a reduction of conveyance equally in both overbanks. Negative values of X.Y for Methods 3 through 6 provide an encroachment based on a reduction of conveyance in proportion to the distribution of natural overbank conveyance. For instance, if the natural cross section had twice as much conveyance in the left overbank as in the right overbank, a 10.3 would reduce conveyance by five percent in each overbank, whereas a -10.3 would eliminate 6.7 percent from the left overbank and 3.3 percent from the right overbank.

Bridge encroachments may be evaluated by adding .01 to the code X.Y for any of the methods. Thus a 9.11, 100.21, 10.31, 10.41, 10.51, or 10.61 would request the bridge encroachments for Methods 1 through 6, while a 9.1, 100.2, 10.3, 10.4, 10.5, or 10.6 would not. The table on the following page describes how each method handles encroachments on bridges.

HEC-2 Input Description
Change Records

ET

ET Record (continued)

Method	Description
1	Bridge encroachments set as indicated by target values of Method 1.
2	Bridge encroachments set as indicated by target values of Method 2.
3 - 6	Bridge encroachments defined by encroachments determined at the cross section immediately downstream of the bridge.

METHOD	ET CARD VALUE	DESCRIPTION
1	X.1 or X.11	The Xth and Xth + 1 fields of the ET record will be used for the encroachment stations STENCL and STENCR. STENCL should not be zero.
2	X.2 or X.21	The top width of X will determine encroachment stations such that the center of the top width will be centered halfway between bank stations.
3	X.3 or X.31	The natural cross section will be encroached so that X percent of the total conveyance will be eliminated equally (X/2 percent) from each overbank.
	-X.3 or -X.31	Same as X.3 except the reduction of conveyance in each overbank will be in proportion to the conveyance in the overbanks.
4	X.4 or X.41	The natural cross section will be encroached based on a (X/10) foot increase in water surface elevation. The reduction of conveyance will be equal in both overbanks. A 1 foot increase in water surface elevation would require a 10.4 and a .5 foot increase would require a 5.4.
	-X.4 or -X.41	Same as X.4 except the reduction of conveyance in each overbank will be in proportion to the conveyance in the overbanks under natural conditions.
5	X.5 or X.51	Operates much like Method 4 except that an iterative solution scheme attempts to obtain the desired difference in water surface elevations as closely as possible to the specified target difference.
	-X.5 or -X.51	Same as X.5 except the reduction of conveyance in each overbank will be in proportion to the conveyance in the overbanks under natural conditions.

ET

HEC-2 Input Description Change Records

ET Record (continued)

METHOD	ET CARD VALUE	DESCRIPTION
6	X.6 or X.61	Uses an optimization scheme to obtain a desired difference in energy grade line elevations as closely as possible to the specified target.
	-X.6 or -X.61	Same as X.6 except the reduction of conveyance in each overbank will be in proportion to the conveyance in the overbanks under natural conditions.

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. NOTE: When using the Split Flow Option, cross section ID numbers must increase downstream to upstream.
		-	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

HEC-2 Input Description Cross Section Records

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.

8.2 RC Record - Rating Curve for Inputting Water Surface Elevations

The RC record can be entered at any cross section and the program will determine the water surface elevation based on the rating curve and not on backwater computations. The RC record should be placed after the X1 record. A maximum of 20 discharge elevation values are allowed. The program linearly interpolates between given rating curve values and extrapolates for values outside the rating curve.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	RC	Record identification characters.
1	NRCP	+	Number of rating curve points being read in.
2	QRC(1)	+	Discharge value.
3	XRC(1)	-,0,+	Water surface elevation value.
4	QRC(2)	+	Discharge value.
5	XRC(2)	-,0,+	Water surface elevation value.
.			
.			
.			
.			
.			
	QRC(NRCP)	+	Last discharge value.
	XRC(NRCP)	-,0,+	Last water surface elevation value.

Continue on in Field 1 of additional RC records up to QRC(NRCP) and XRC(NRCP).

CI

HEC-2 Input Description Cross Section Records

8.3 CI Record - Channel Improvement (optional)

This optional record provides input for the channel improvement (CHIMP) option of the program. This option simulates the modification of cross section data (GR records) by a trapezoidal excavation. The modification begins at the first cross section with a CI record and continues until a CI record specifying a bottom width equal to 0.01 (variable BW, Fields 6-10) is encountered. Up to five bottom widths can be specified for analysis during multiple profile runs. Multiple CI records may be used to model improved channel sections with pilot channels; up to three CI records may be used at a single cross section. The channel improvements are performed in the order that the records are specified. The natural channel may be filled prior to excavation if desired. (See variable BW.) Low areas of the natural cross section may be filled by the sediment option (variable ELSESED X3.2). See J2 record, Fields 8 and 9 for further information.

Note: **The CI record cannot be used in conjunction with NH records.**

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	CI	First two columns of record for record identification.
1	CLSTA	0	Value on previous cross section's CI record is used.
		+	Station of the centerline of trapezoidal channel excavation which is expressed in terms of the stations used in the natural cross section description (GR records).
		-1	CLSTA is determined by program as halfway between bank stations.
2	CELCH	0	Value on previous cross section's CI record is used.
		+ or -	Elevation of channel invert (but not -1).
		-1	Elevation of channel invert is equal to minimum elevation in cross section. (For pilot channel excavations, second and third CI records, the channel invert elevation should be specified).
		$.1 \geq \text{CELCH} \geq .00001$	Elevation of channel invert is based on $\text{CELCH} (\text{Slope}) \cdot \text{XLCH} (\text{Channel Reach Length}) + \text{PELMN} (\text{D.S. Minimum Elevation})$.

HEC-2 Input Description
Cross Section Records

CI

CI Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
3	XLCH.CNCH	0 or +	The value to the left of the decimal point is the channel reach length (XLCH). If 0, the channel reach length specified on the X1 record will be used. The value to the right of the decimal point is the new channel 'n' value (CNCH). If 0, the previously specified 'n' (CI or NC record) will be used.
4	XLSS	0 +	Value on previous cross section's CI record for left side slope of trapezoidal excavation is to be used, or, if not previously specified, the left side slope will be vertical. Left side slope of excavation expressed as number of horizontal units per one vertical unit (i.e., 2.0 for two horizontal to one vertical).
5	RSS	0 or +	Same as XLSS except for right side of trapezoid.
6-10	BW	0 .01 + -	Value on previous cross section's CI record is used. End of channel improvement. If multiple CI records are being used, then all the CI records must have .01 to turn off the channel improvement. If not all of the CI records have a .01, then the records that do not have a .01 will be used to do the channel improvement. Note the channel 'n' value must be redefined if CNCH (CI.3) was used. Bottom width of channel. Field used (6-10) for this profile determined by variable IBW (J2.8). Same as + but the old channel will be filled up to an elevation equal to the minimum bank elevation.

X2

HEC-2 Input Description Cross Section Records

8.4 X2 Record - Optional Items for Each Cross Section (Bridge, etc.)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	X2	Record identification characters.
1	QNEW	0	No change in flow.
		+	Value of the new flow in the river. This value will be used for all remaining cross sections unless changed by another X2 record or by a QT record.
2	WSELK	0	High water mark elevations are not being used.
		+	Elevation of known water surface elevation (i.e., high water mark) at this cross section. Required if NINV(J1.3) equals one.
3	IBRID	0	Special bridge method will not be used.
		1	Special bridge method will be used. SB record is required just ahead of the X1 record for the current cross section.
		2	Special culvert will be used. SC record is required just ahead of the X1 record for the current cross section.
4	ELLC	0	Bridge or culvert methods are not being used.
		+ or -	Elevation of a horizontal low chord for the bridge for use by the normal bridge method. For the special bridge or culvert method, the maximum upstream low chord elevation within the bridge span which is used to help distinguish between pressure flow and low flow.
5	ELTRD	0	Bridge or culvert methods are not being used.
		+ or -	Elevation of a horizontal top of roadway for use by the normal bridge method. For the special bridge or culvert method, the minimum roadway elevation on the BT records which is used to determine if weir flow exists.
6	BLOSS	0	Change in water surface elevation will not be entered.
		+	Change in water surface elevation to be used between current and previous cross sections.

X2 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
7	REPBT	0	Do not repeat bridge table (BT records) used from previous cross section.
		1	Previous bridge table (BT records) is repeated for use at the current cross section. PXSECE (X1.9) may be utilized to modify the low chord elevations of the repeated BT records (top of roadways remain the same). This option is used in describing the top of a fixed diameter culvert for several cross sections. Horizontal stations cannot be changed when a bridge table is repeated.
8	CMOM	0	Drag coefficient for calculating pier losses with momentum equation is equal to 2.00 (square piers).
		+	Drag coefficient to be used for calculating pier losses with momentum equations (1.33 for piers with semicircular ends).
9	BSQ	0	No bridge skew is used. Factor of 1.0 will be used.
		+	This factor is used to modify (skew) the horizontal dimensions of the bridge profile (BT records). The value of the first RDST on the BT records to be skewed should be equal to the station (STA) of the first GR data point for the current cross section (see X1.8 to skew GR data).

Trace and Flow Distribution

10	ITRACE	0	No trace for this cross section unless ITRACE on J2 record (J2.10) is specified.
		1	Minor trace for current cross section.
		10	Major and minor trace for current cross section.
		15	Flow distribution printout for current cross section.

X3

HEC-2 Input Description Cross Section Records

8.5 X3 Record - Optional Items for Each Cross Section (Effective Area, etc.)

FIELD	VARIABLE	VALUE	DESCRIPTION
1	IA	X3	Record identification characters.
	IEARA	0	Total area of cross section described on GR records below the water surface elevation is used in the computations.
		10	Only the channel area (as defined by STCHL, X1.3 and STCHR, X1.4) is used in the computations, unless the water surface elevation exceeds the elevations of the bank stations. This option can be utilized to contain flow between levees until overtopping occurs, if the bank stations are coded at the top of the levees. Overtopping can occur on either side since the elevations of STCHL and STCHR are tested independently. The elevations can also be extended with ELLEA (X3.8) and ELREA (X3.9) to define artificial levees for bridge applications.
2	ELSEED	0	A sediment elevation is not specified.
		+ or -	Elevation of sediment deposition. All elevations below ELSEED are set equal to ELSEED. This elevation is not modified by PXSECE (X1.9).
3	ENCFP	0	Width between encroachments is not changed or is not specified.
		+	Width between encroachments is centered in the channel, midway between the left and right overbanks. Flow areas outside this width are not included in the computations. This width will be used for all cross sections unless changed by a positive ENCFP on the X3 record of another cross section or on an ET record or unless overridden by the use of STENCL (X3.4).
4	STENCL	0	Encroachments by specifying station and/or elevation will not be used on the left overbank.
		+	Station of the left encroachment. Flow areas to the left of (less than) this station and below ELENCL are not included in the computations. This option will override the option using ENCFP when both are used.

X3 Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
5	ELENCL	0	An encroachment elevation on the left side is not applicable and is therefore assumed very high or STENCL = 0.
		+ or -	Elevation of the left encroachment. Flow areas below this elevation and less than STENCL are not included in the computations.
6	STENCR	0	An encroachment station on the right is not used.
		+	Station of the right encroachment. Flow areas to the right of (greater than) this station and below ELENCR are not included in the computations.
7	ELENCR	0	An encroachment elevation on the right side is not applicable and is therefore assumed very high or STENCR = 0.
		+ or -	Elevation of the right encroachment. Flow areas below this elevation and greater than STENCR are not included in the computations.
8	ELLEA	0	The elevation (XLBEL) on the GR records corresponding to STCHL (X1.3) is used to decide if the left flow area is effective or not when using the effective area option (IEARA = 10).
		+ or -	This elevation is used instead of XLBEL. This option, when used with IEARA = 10, defines artificial levees for effective flow applications at bridges.
9	ELREA	0	Same as ELLEA except for right bank flows.
		+ or -	Same as ELLEA except for right bank flows. Left bank value (ELLEA) must be nonzero for program to use the right bank value.
10			Not used.

X4

HEC-2 Input Description Cross Section Records

8.6 X4 Record - Additional Points for Cross Section (optional)

An additional input record X4 may be inserted following records X1, X2 or X3 in order to add additional points, up to twenty, to describe the ground profile of the cross section. Stations of X4 data points must fall within the range of GR stations. The X4 data point is an **added point** and cannot be used to replace any GR data point. The sum of GR and X4 data points at a cross section must not exceed 100. This option is useful when modifying data records for a proposed obstruction as it allows points to be added anywhere in the cross section.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	X4	Record identification characters.
1	NELT	1-20	Total number of X4 data points (maximum of 20) to be added to the current cross sections GR data set. If NELT is greater than four, multiple X4 records are required, and the first field of the second and subsequent X4 records should contain a STAT(N) value.
2,4,6, 8,10 ... etc.	ELT(N)	+ or -	Elevation of additional ground point corresponding to STAT(N). Elevations added by X4 records are adjusted by PXSECE (X1.9), if input with GR data.
3,5,7, 9,11, 13 ... etc.	STAT(N)	+	Station of additional ground point. All stations must be less than the maximum station on the GR records. The pairs of elevations and stations do not have to be in any particular order. Station values are adjusted by PXSECR (X1.8), if input with GR data.

8.7 X5 Record - Use of Input Water Surface Elevations (optional)

An X5 record is used to input a water surface elevation at a cross section, or to input an increment of elevation to be added to the water surface elevation of the previous cross section to obtain the water surface elevation of the cross section. The X5 record can be inserted for any cross section, including a bridge cross section, and the desired elevation or elevation increment can be specified differently for each profile of a multiple profile job. The field of the X5 record that is used for a particular profile is controlled by variable INQ (J1.2).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	X5	Record identification characters.
1	N	1 to 19	Number of fields (maximum of 19) used on X5 record for desired water surface elevations. If the number of fields (N) is greater than nine, a second X5 record is required, and the first field of the second X5 record should have a SBWS(N) value.
		-1 to -19	Number of fields used on X5 record for desired increments of water surface elevation.
2-20	SBWS(N)	+ -	Water surface elevation (if N is positive) or elevation increment (if N is negative). Variable INQ (J1.2) indicates which field is used for a particular profile.

GR

HEC-2 Input Description Cross Section Records

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.

9 Bridge and Culvert Records

9.1 SB Record - Special Bridge (optional)

This special bridge record is used to specify data for use in the special bridge method and is only required when using the special bridge method. This record should be entered between cross sections that are upstream and downstream of the bridge. See X2 record, Fields 3 through 9, for additional input for the special bridge option.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	SB	Record identification characters.
1	XK	+	Pier shape coefficient, "K", for use in Yarnell's energy equation for Class A flow.
2	XKOR	+	Total loss coefficient, "K", between cross sections on either side of bridge, for use in orifice flow equation. Should not be less than 1.0.
3	COFQ	+	Coefficient of discharge "C" for use in weir flow equation. Weir flow will be corrected for weir submergence based on the curves in "Hydraulics of Bridge Waterways" (Reference 13, Figure 24). The "Hydraulics of Bridge Waterways" method is based on a trapezoidal-shaped roadway embankment.
		-	The absolute value of COFQ will be used as the coefficient of discharge "C" for use in weir flow equation. Weir flow will be corrected for weir submergence based on the Waterways Experiment Station's (WES) Design Chart 111-4. The WES method is based on a ogee-shaped spillway.
4	RDLEN	0	Flow over roadway is not being considered or a table of roadway elevations and corresponding stations will be read in on the BT record for determining "L" in the weir flow equation.
		+	Average length of roadway "L" in feet for use in the weir flow equation. Use a constant value of "L" only if the length of weir does not change with depth of flow. Otherwise, use the BT record to read in the top of roadway. Weir elevation defined on Field 5 of X2 record.

SB

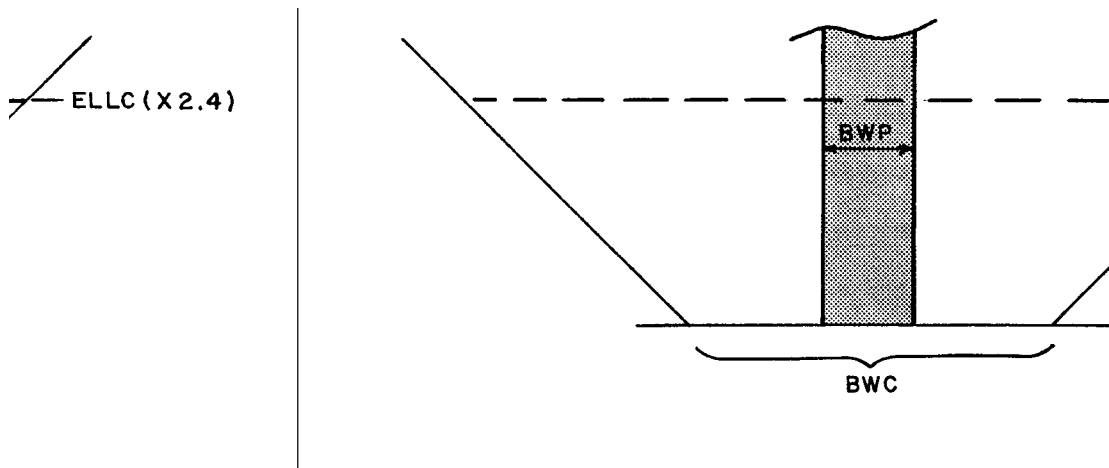
HEC-2 Input Description Bridge and Culvert Records

SB Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
5	BWC	+	Bottom width of bridge opening including any obstruction.
6	BWP	0	No obstruction (pier) in the bridge. Normal bridge method will be used in this case if low flow controls.
		+	Total width of obstruction (piers).
7	BAREA	+	Net area of bridge opening below the low chord in square feet or square meters.
8	SS	0	Vertical side slopes.
		+	Number of horizontal units per one vertical unit for the side slopes of the trapezoidal channel under the bridge.
9	ELCHU	0	Channel invert beneath bridge will be equal to the minimum elevation in the previous cross section. This value will not be adjusted by PXSECE (X1.9).
		+ or -	Elevation of the channel invert at the upstream side of the bridge.
10	ELCHD	0	Channel invert will be assumed equal to the minimum elevation in the previous cross section.
		+ or -	Elevation of the channel invert at the downstream side of the bridge. This value will not be adjusted by PXSECE (X1.9).

SB Record (continued)

The diagram below defines the six variables: BWC, BWP, SS, ELCHU, and ELCHD that define a trapezoid for low flow calculations. Variable BAREA provides the net area of the bridge opening for pressure flow calculations. For typical applications the net area of the trapezoid (special bridge output variable TRAPEZOID AREA) should be close to the actual net area (BAREA). If BWP is zero, standard step calculations will be used for low flow.



Trapezoidal Approximation of Bridge Opening

SC

HEC-2 Input Description Bridge and Culvert Records

9.2 SC Record - Special Culvert

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	SC	Record identification characters.
1	CUNO.CUNV	+	The value left of the decimal point is the integer number of identical culverts installed at this location. The value to the right of the decimal point is Manning's roughness coefficient for the culvert barrel.
2	ENTLC	+	Entrance loss coefficient for culvert.
3	COFQ	+	Coefficient of discharge "C" for use in weir flow equation. Weir flow will be corrected for weir submergence based on the curves in "Hydraulics of Bridge Waterways" (Reference 13, Figure 24). The "Hydraulics of Bridge Waterways" method is based on a trapezoidal-shaped roadway embankment.
		-	The absolute value of COFQ will be used as the coefficient of discharge "C" for use in weir flow equation. Weir flow will be corrected for weir submergence based on the Waterways Experiment Station's (WES) Design Chart 111-4. The WES method is based on a ogee-shaped spillway.
4	RDLEN	0	Flow over roadway is not being considered, or a table of roadway elevations and corresponding stations will be input using BT records for determining "L" in the weir flow equation.
		+	Average length of roadway "L" in feet for use in the weir flow equation. Use a constant value of "L" only if the length of the weir does not change with depth of flow. Otherwise, use the BT record to input the top of roadway. The weir elevation is defined on Field 5 of X2 record.
5	RISE	+	Rise (height) of box culvert opening, or diameter of pipe culvert opening in feet.
6	SPAN	0	Culvert is circular. Diameter must be entered in Field 5.
		+	Span (width) of box culvert opening in feet.

SC Record - (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
7	CULVLN	+	Length of the culvert barrel in feet.
8	CHRT.SCL	+	Value left of decimal point is the Federal Highway Administration chart number for the culvert. Value right of the decimal point is the Federal Highway Administration scale number for the culvert.
9	ELCHU	0	Culvert invert elevations ELCHU and ELCHD will be assumed equal to the minimum elevation in the previous cross section.
		+ or -	Elevation of the culvert invert at the upstream side of the roadway crossing. ELCHU must be greater than or equal to ELCHD.
10	ELCHD	+, 0, or -	Elevation of the culvert invert at the downstream side of the roadway crossing. This value will not be adjusted by PXSECE (X1.9). ELCHD must be less than or equal to ELCHU. This value will be ignored if ELCHU (SC.9) equals zero.

BT

HEC-2 Input Description Bridge and Culvert Records

9.3 BT Record - Bridge Table of Elevations and Stations (optional)

The bridge geometry described by this record may be used by either the normal bridge, special bridge, or culvert methods.

Normal bridge method computes conveyance in the bridge section with the data from BT and GR records defining the bridge section. Each BT station must correspond to a GR or X4 station. The program eliminates the area between top-of-road and low-chord profile defined by the BT data. If the ground and the top-of-road profiles are the same in the overbank portion of the cross section, the BT data does not have to duplicate the GR data. If the top-of-road is above the overbank ground profile, the low-chord elevations should be equal to the ground (GR) elevation to fill in the overbank area between road and ground.

For the **special bridge and culvert methods**, the BT data define a top-of-road profile for weir calculations. The BT data must define the entire weir length of the roadway. For culverts, and special bridges with piers (BWP > 0), the low-chord values are not required and BT stations do not have to equal GR stations. The ELLC variable (X2.4) defines the low-chord value required by these methods. However, if the special bridge (BWP = 0), the low-flow solution is based on conveyance calculations, and the BT input data must conform to the normal bridge requirements.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	IA	BT	Record identification characters.
1	NRD	+	Number of points describing the bridge roadway and low chord to be read on the BT records. Entered only on first BT record. The maximum number of points is 100.
		-	Same as a positive NRD except an optional data format is utilized for the second and subsequent BT records.
2	RDST(1)	+	Roadway station corresponding to RDEL(1) and XLCEL(1).
3	RDEL(1)	+	Top of roadway elevation at station RDST(1). Should be greater than the estimated energy elevation for special bridge applications, since weir flow calculations are based on energy elevations.
4	XLCEL(1)	+	Low chord elevation at station RDST (1).
5	RDST(2)	+	Roadway station corresponding to RDEL(2) and XLCEL(2).
6	RDEL(2)	+	Top of roadway elevation at station RDST(2).

BT Record (continued)

FIELD	VARIABLE	VALUE	DESCRIPTION
7	XLCEL(2)	+	Low chord elevation at station RDST(2).
8	RDST(3)	+	Roadway station corresponding to RDEL(3) and XLCEL(3).
9	RDEL(3)	+	Top of roadway elevation at station RDST(3).
10	XLCEL(3)	+	Low chord elevation at station RDST(3).

Format for Additional BT records

Standard Format

If NRD is positive (+) BT data RDST, RDEL, and XLCEL is to be input starting in the second and subsequent BT records, all ten fields are available for data.

Optional Format

If NRD is negative (-) BT data is to be input in the second through the tenth fields of the second and subsequent BT records, only nine fields are available for data.

For special bridge method, the last roadway elevation RDEL (NRD) should be greater than the estimated energy elevation.

FR

HEC-2 Input Description Optional FREE Format Records

10 FR - Free Format Indicator Record

The FR record must be the first record in the input file if free format input is used. The free format input option allows the user to enter data using commas (,) or blank space as a delimiter between field input. A blank should separate the record ID and the first field input data. A blank should be used to delimit a field that is full (i.e., 8 digits, or 6 if the first field). If a comma is used to delimit a field that is full, the next field will be blank. Multiple commas are interpreted as blank fields. If the last fields of an input record are blank, you can limit your input to those fields that contain input data, i.e., you do not have to define the ending blank fields.

With free format, more, or less, than 10-fields of input can be entered on a single line if the record-type has continuous data (e.g., GR or BT records). The data will be processed into 10-field records of data. This option can be used to add data into an existing data set without extensive editing to maintain the fixed-field format.

EDIT2 will create a fixed-field input file from free-format data. The fixed-field file will be saved as TAPE10. You can rename and save the TAPE10 file for use as the input file in HEC-2.

- *FREE** input record turns on the free-format option. This record must appear before the first free-format data.

- *FIX** input record turns off the free-format option. This record must appear before the first fixed-field input, if free-format option is active.

HEC-2 Input Description Input Record Summary

11 HEC-2 Input Record Summary

Records are listed in their relative order of input in a data file.

Record	Description	Page
Data Edit Record		
ED	Optional Record for HEC-2 Data Edit Program (EDIT-2)	3
Split Flow Data Records		
SF	Split Flow Title	4
JC	Title Job	4
JP	Job Parameter	5
TW	Title for Weir Location	6
WS	Weir Parameter Data	6
WC	Weir Coordinate Data	7
TN	Title for Normal Depth Location	8
NS	Normal Depth Parameter Data	8
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*Required for basic applications.

HEC-2 Input Description Input Record Summary

Change Records

IC	Ice Data	35
*NC	Starting Manning's 'n' Values & Shock Losses	37
NH	Horizontal Variations of Manning's 'n'	38
NV	Vertical Variations of Manning's 'n'	39
KH	Horizontal Description of Equivalent Roughness 'n'	40
QT	Table Discharges for Multiple Profiles	41
ET	Encroachment Table	42

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SB	Special Bridge	57
SC	Special Culvert	59

Cross Section Records

*X1	General Items for Each Cross Section	45
RC	Rating Curve for Inputting Water Surface Elevations	47
CI	Channel Improvement	48
X2	Optional Items for Each Cross Section (Bridges, etc.)	50
X3	Optional Items for Each Cross Section (Effective Area, etc.)	52
X4	Additional Points for Cross Section	54
X5	Use of Water Surface Elevations	55
BT	Bridge Table of Elevations & Stations	61
*GR	Ground Profiles Elevations & Stations	56

End of Records

*EJ	End of Job (marks end of river reach data)	34
*ER	End of Run	34

*Required for basic applications.



**US Army Corps
Engineers**

Hydrologic Engineering Center

Computing Water Surface Profiles with HEC-2 on a Personal Computer

Training Document No. 26

March 1992

REPORT DOCUMENTATION PAGE

Form Approved
 OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution of this document is unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Training Document # 26 (NTIS:AD-A209-458)		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION Hydrologic Engineering Center	6b. OFFICE SYMBOL (if applicable) CEWRC-HEC	7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) 609 Second Street Davis, CA 95616		7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO.	PROJECT NO.
		TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Computing Water Surface Profiles with HEC-2 on a Personal Computer (Unclassified)			
12. PERSONAL AUTHOR(S) Vernon R. Bonner			
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) September 1990 Revised March 1992	15. PAGE COUNT 72
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	
		Water surface profiles, computer program, personal computer	
19. ABSTRACT (Continue on reverse if necessary and identify by block number) A package of computer programs has been developed to compute water surface profiles and to display the results in tabular and graphical form. The package is based on the Corps' Water Surface Profile Program, HEC-2. This document presents each program in the package and provides user guidance.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Vernon R. Bonner, Chief, Training Division		22b. TELEPHONE (Include Area Code) (916) 756-1104	22c. OFFICE SYMBOL CEWRC-HEC

Computing Water Surface Profiles with HEC-2 on a Personal Computer

March 1992

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TD-26

Computing Water Surface Profiles with HEC-2 on a Personal Computer

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Chapter 1

Introduction

A package of computer programs have been assembled to compute water-surface profiles and display the results on a personal computer (PC). The package is based on the HEC-2 Water Surface Profile computer program. The User's Manual provides detailed information for the HEC-2 program. This document provides installation information and presents a description of each component of the PC package.

1.1 Program Development

The HEC-2 computer program was originally developed at the Hydrologic Engineering Center (HEC) by Bill S. Eichert. The present version is the product of development involving several HEC engineers. The basic computational capabilities for calculating water surface profiles remain essentially unchanged; however, numerous supplemental capabilities have been added over the years.

In response to a high demand from both the Corps and private engineering sectors, HEC implemented HEC-2 for MS-DOS compatible microcomputers (PC) in 1984. The edit program for HEC-2 data (EDIT2) was also converted at that time. The PC program distribution started in the fall of that year. The programs were modified in 1986 to meet FORTRAN77 standards. The 1984 PC versions maintained all the capabilities of the original mainframe version of the program, except for internal trace and comment information.

In 1986 a package of programs was provided that brought together all the necessary tools to accomplish a complete computation and display of water surface profiles on a personal computer. This Training Document was developed in support of that package of programs.

The 1988 version of HEC-2 was created with a number of added features, with an emphasis on hydraulic design applications. The 1990 Version 4.6 includes error corrections 01-04 to the 1988 version, plus culvert hydraulics. Additionally, some improvements have been made to each program in the PC package.

1.2 Overview of the HEC-2 Package

Once the cross section and field information has been gathered, the basic steps for computing water surface profiles include: (1) develop a data file that represents the physical reach under study, (2) check the data file for proper format and data errors, (3) compute water surface profiles, (4) review and evaluate computed results, and (5) produce required displays of computed results. The computational process is illustrated in Figure 1. The programs provided with the HEC-2 package provide the necessary tools to accomplish all the basic steps on a PC.

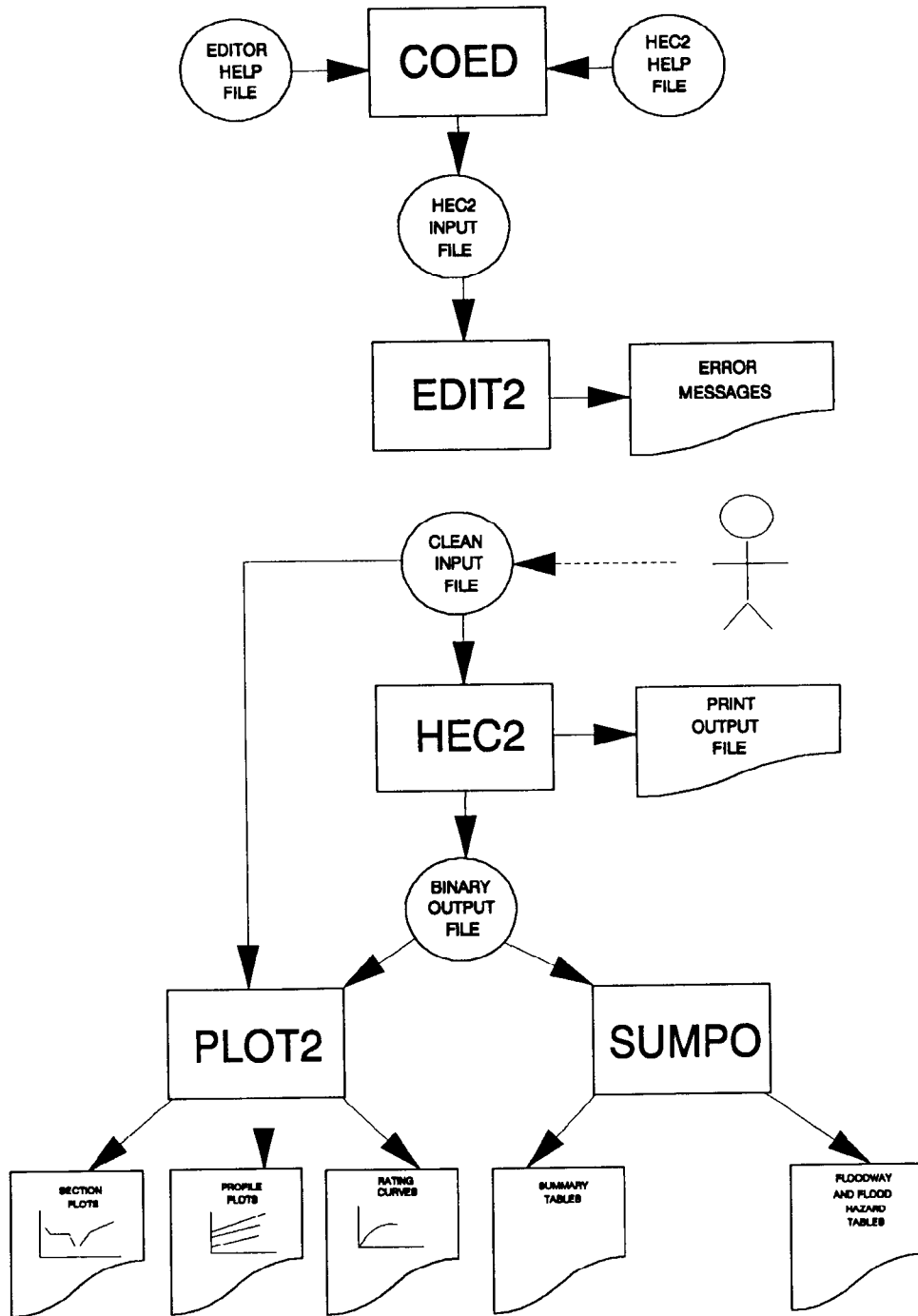


Figure 1
HEC-2 Computational Process

A menu program, MENU2, has been developed to provide program users convenient access to the HEC-2 package of programs and related files, when operating a PC with hard disk storage. The menu, described in Chapter 3, eliminates repeated typing of program and filenames in order to use the programs in the package.

Text editors can be used to create and modify an input data file for the HEC-2 program. The Corps' editor, COED, has been developed with some features specifically designed around the HEC format for computer program input. COED will place the input data in the format expected for HEC-2 as the data file is created. It also has help file information on HEC-2 variables. Chapter 4 provides information on creating and editing HEC-2 input files.

Checking an HEC-2 data input file is facilitated with the EDIT2 computer program. The program provides tests for proper input sequence, format, and data ranges. Running the input data file with EDIT2 is recommended to assist in locating input errors. Chapter 5 describes the EDIT2 program, the types of error messages, and the typical corrections required.

The HEC-2 program operates with the input data file to compute the water surface profiles. The optional capabilities, provided in the program, can also be used to solve many floodplain hydraulic problems. Chapter 6 provides information on running HEC-2 on a PC.

Once the HEC-2 program has been executed, the job of reviewing the results begins. Chapter 7 describes the HEC-2 output and gives some guidelines for output review. The use of computer program SUMPO to create summary tables of results is presented in Chapter 8, and the use of computer program PLOT2 for graphical displays is presented in Chapter 9. PLOT2 duplicates most of the capabilities of the Hydraulics Graphics Package, which produces HEC-2 cross section and profile plots in interactive or batch modes on the Corps' mainframe computers.

1.3 Acknowledgments

Vern Bonner, Chief, Training Division, is the author of this document. Dan Hoggan provided document revisions for the updated 1988 versions of the programs. Some of the concepts presented were derived from training materials on HEC-2, developed over the past decade. John Peters, Richard Hayes, and Alfredo Montalvo were major contributors to those training materials.

The HEC-2 computer program was developed by Bill S. Eichert, a past Director of HEC. The program is the product of development, primarily involving those HEC engineers mentioned above. The PC version of the program was created in 1984 by Alfredo Montalvo. The 1988 version was developed by Randy Hills. The 1990 version includes culvert hydraulics added by Dodson & Associates, Houston, TX.

The SUMPO program was developed, from the HEC-2 output routines, by Al Onodera. The program was converted for the PC by Alfredo Montalvo. The menus for the current PC version of the program were developed by Keith B. Knight.

The PLOT2 program was developed by Bob Barkau. Keith B. Knight added new menus, scaling options, rating curve routines and restructured the program. PLOT2 uses plot subroutines developed by Microcompatibles, Inc.

The menu program, MENU2, was developed by Keith B. Knight. It provides convenient access to the HEC-2 package and the utilities LIST, PROUT and COED.

The PC version of COED, with full-screen edit capability, was developed at HEC by Art Pabst and Bill Charley from the command-line editor in use on the HARRIS computers in the Corps of Engineers since 1980.

The LIST program is a public domain utility written by Vernon D. Bueg, AAI Systems, Inc. The program is presently distributed as shareware with a request for a gift to support development.

1.4 Program Documentation

The primary documentation for the HEC-2 program is the User's Manual. The manual provides a complete description of the HEC-2 program capabilities, theoretical basis for computations, program input and program output. A careful review of the User's Manual should be made before using the computer program. There are no user's manuals for the EDIT2, SUMPO, or PLOT2 computer programs. This material is the only documentation for those programs.

Supplemental information is available through the following HEC publications:

Training Document No. 5, Floodway Determination Using Computer Program HEC-2
(Presents FEMA based floodway procedures in HEC-2)

Training Document No. 18, Application of the HEC-2 Split Flow Option
(Present concepts and procedure for using option to compute overflow from water surface profiles).

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

Technical Paper No. 20, Computer Determination of Flow Through Bridges
(Description of HEC-2 bridge hydraulics)

Technical Paper No. 69, Critical Water Surface by Minimum Specific Energy Using the Parabolic Method
(Description of the HEC-2 critical depth computation procedure)

Research Document No. 26, Accuracy of Computed Water Surface Profiles.

The supplemental material, as well as other HEC publications, is listed in the Publication Catalog; along with prices and ordering information. This free catalog is available from:

**Hydrologic Engineering Center
609 Second Street
Davis, CA 95616-4687**

HEC provides training in HEC-2 in Basic and Advanced HEC-2 courses and in a Floodplain Hydrology Course. HEC also provides user assistance for Corps offices and other federal agencies. There are several university extension short courses on the use of the HEC-2 program. A one-week course provides a good overview of the basic program capabilities.

For those unable to attend a course, there are video tapes of most lectures given in HEC training courses on HEC-2. The tapes are distributed only in the USA by a contractor, which may vary from year to year. A Video Tape Catalog with ordering information is available from HEC at no charge.

1.5 Computer Equipment Requirements

The following equipment is required to run the HEC-2 package of programs on MS- DOS microcomputers.

DOS 2.0 (or later) Operating System
450K RAM Memory available
Two 5 1/4 inch floppy-disk drive (360 KB or 1.2 MB), or
One 5 1/4 inch floppy-disk drive and one 10 MB (or larger) hard-disk drive

(NOTE: a hard-disk is required for MENU2 use)

The graphic displays from PLOT2 can be sent to the screen or an HP 7475A pen plotter. Files can also be created for use by word processors. One of the following graphics cards (or their equivalent) is required:

Color Graphics Adapter (CGS), or
Enhanced Color Graphics Adapter (EGA), or
Video Graphics Array (VGA)

The programs will take advantage of a math coprocessor (8087, 80287, or 80387) if present in your computer. This coprocessor greatly speeds up program run time and is recommended, but it is not necessary for program accuracy.

1.6 Program Distribution

Corps of Engineers offices and other U.S. Federal agencies may receive copies from HEC at no charge. Other offices may obtain the program from NTIS or a number of private distributors. A list of these private distributors is available from HEC.

A free Computer Program Catalog is available from HEC. The catalog provides a description of all available computer programs and program support information. The catalog can be ordered at the HEC address shown above.

Chapter 2

Loading Programs on Your Computer

The floppy diskettes you receive are double-sided, double density, capable of holding approximately 360K bytes of information. Many of the program files have been written in an archive form and are labeled with the **.ZIP** extension. These files must be processed with the PKUNZIP program before they can be used.

2.1 Contents of the HEC-2 Package Diskettes

The HEC-2 package of programs, example input data, example output, menu system and full screen editor (COED) are provided on four 5 1/4 inch double-sided 360 KB floppy diskettes as follows:

INSTALL Diskette:	UTILPROG.ZIP PKZIP.EXE PKUNZIP.EXE PKZIPMAN.ZIP COEDHEC2.ZIP ASKME.COM INSTALL2.BAT TEMP2INS.BAT CONFIG.SYS
HEC2EXE Diskette:	HEC2EXE.ZIP HEC2DAT.ZIP README.DOC
SUP2EXE Program Diskette:	SUP2EXE.ZIP
COED Diskette:	COEDEXE.ZIP COEDHLP.ZIP COEDDOC.ZIP COED.TRM COED.XTK

NOTE: All files with the **.ZIP** extension are archived files. They must be unpacked by the program PKUNZIP provided on the INSTALL DISKETTE. PKZIPMAN.ZIP contains documentation for the program.

2.2 Program Installation on a Hard-Disk System

Installation is accomplished through the execution of an interactive procedure called INSTALL2. To install the HEC-2 Package onto your hard disk, do the following:

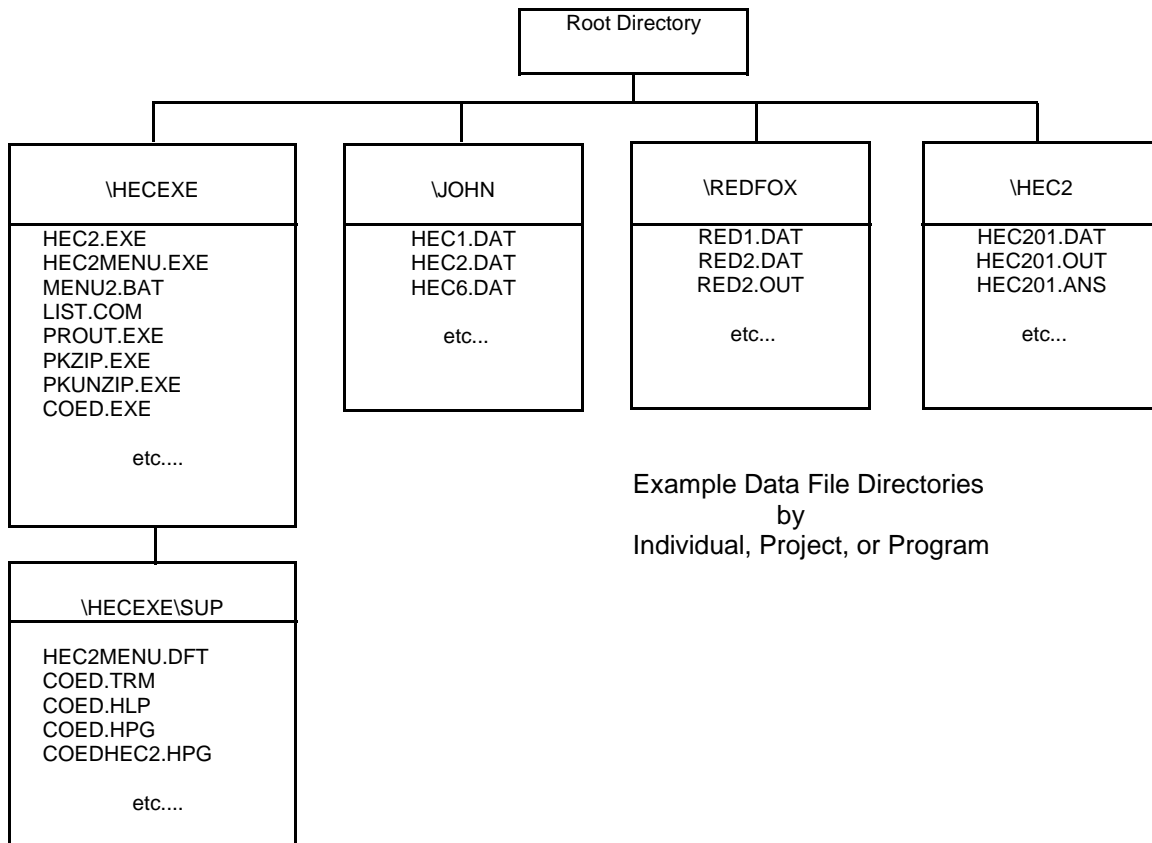
1. Start your computer and go to the drive (e.g., C: or D:) on which you would like to install this

software.

2. Place the INSTALL DISKETTE into the A: drive.
3. Type **A:INSTALL2** and then press the **<ENTER>** key.
4. At this point the INSTALL2 program will lead you through the installation of the HEC-2 Package.

The following is a summary of what the INSTALL2 program accomplishes:

1. Allows the user to select the drive (e.g., C: or D:) on which directories will be created and to which files will be copied.
2. Creates directories \HECEXE and \HECEXE\SUP. The \HECEXE directory is used to store all the executable programs and the \HECEXE\SUP subdirectory is used for any supplemental files required by the executable programs. Also creates, if the user wishes, the directories for input and output for each program.
3. The recommended directory configuration that INSTALL2 creates is shown in Figure 2.



Example Data File Directories
by
Individual, Project, or Program

Figure 2
PC Hard Disk Organization Using HEC Application Programs

2.2.1 Alternative Installation

As stated previously, the preferred method for installation is to use the INSTALL2 procedure, which will install the software using the HEC recommended directory configuration. If for some reason you do not use INSTALL2, you will need to do the following to install the HEC-2 Package.

1. You will need to create three directories. One of the directories should be labeled \HECEXE. This directory will be used to store all of the HEC executable programs. A second directory should be labeled \HECEXE\SUP. This directory will be used to store all of the supplemental files required by the executable programs. A third directory should be created to store data files. This data directory can be given any name. As shown in Figure 1, you may want this data directory to represent a specific project, person, or program. To accomplish these tasks do the following:

- * Go to the drive (e.g. C:) on which you would like to install the software.
- * Type **MD\HECEXE** then press the **<ENTER>** key.
- * Type **MD\HECEXE\SUP** then press the **<ENTER>** key.

2. Place the INSTALL Diskette into the A drive. You will need to copy the PKUNZIP.EXE file from this diskette to the root (C:\) directory. Use the following MS DOS command:

- * Type **COPY A:PKUNZIP.EXE** then press the **<ENTER>** key.

The PKUNZIP.EXE program will be used to dearchive the HEC-2 Package of programs into the correct directory.

3. The next step is to dearchive the utility programs if you want to. If you do not wish to use the utility programs, skip this step and proceed with Step 4. To dearchive the utility programs use the following command:

- * Type **PKUNZIP A:UTILPROG \HECEXE** then press the **<ENTER>** key.

4. The next step is to dearchive the HEC-2 COED help file. If you use COED then you must dearchive this file. To do so, use the following command:

- * Type **PKUNZIP A:COEDHEC2 \HECEXE\SUP** then press the **<ENTER>** key.

5. The next step will be to dearchive the HEC2 program. Place the HEC2EXE Diskette into the A drive. This diskette has a file labeled HEC2EXE.ZIP. This file contains the executables of a HEC2, HEC2MENU and the MENU2.BAT file which executes the MENU2 system. To dearchive use the following command:

- * Type **PKUNZIP A:HEC2EXE \HECEXE** then press the **<ENTER>** key.

6. The next step will be to dearchive the test input and output files that have been provided. If you do not want these files on your hard disk, skip this step and proceed to Step 7. For the data directory name, we are using the program name (i.e., HEC2) as an example. The user can use any name they prefer. If you would like these files copied do the following command:

- * Type **MD\HEC2** then press the **<ENTER>** key.
- * Type **PKUNZIP A:HEC2DAT \HEC2** then press the **<ENTER>** key.

Place the SUP2EXE Diskette into the A drive. This diskette has a file labeled SUP2EXE.ZIP. This file contains the executables for the previously listed programs. To dearchive use the following commands:

- * Type **PKUNZIP A:SUP2EXE \HECEXE** then press the **<ENTER>** key.
8. The next step will be to install the Full Screen Editor COED onto your hard disk. Not only does COED have several advanced editing features, but it also has several capabilities that aid in generating input files specifically for HEC programs. To install COED, place the COED Diskette into the A drive and do the following commands:

- * Type **PKUNZIP A:COEDEXE \HECEXE** then press the **<ENTER>** key.
 - * Type **PKUNZIP A:COEDHLP \HECEXE\SUP** then press the **<ENTER>** key.
 - * Type **PKUNZIP A:COEDDOC \HECEXE\SUP** then press the **<ENTER>** key.
9. To allow access of the executable programs from any directory, it will be necessary to edit the AUTOEXEC.BAT file to include a path to the \HECEXE directory. The AUTOEXEC.BAT file should be in your root (C:\) directory. The following is an example PATH command that would allow access to the \HECEXE directory as well as the root (C:\) directory:

PATH C:\;C:\HECEXE

You may want to include a path to other directories on your system. If so, just add the names of the directories to this command. For more information on the PATH command and the AUTOEXEC.BAT file, consult your DOS manual.

10. The final step will be to modify your CONFIG.SYS file. Many HEC programs require the capability to open more than eight (8) files at any one time. Because eight is the system default, you will need to modify your CONFIG.SYS file to include the following two lines:

FILES=20

BUFFERS=20

For more information concerning the CONFIG.SYS file, consult your DOS manual. Use COED or another text editor to make these changes. **AFTER THE CHANGES ARE MADE YOU WILL NEED TO RE-BOOT YOUR MACHINE.**

2.3 Program Execution on a Hard-Disk System

After installation and prior to execution, your system must be rebooted. This will provide the computer the revised information from your CONFIG.SYS and AUTOEXEC.BAT files. You are now ready to test the computer program. The preferred mode of execution is through the menu system, although you can run the individual programs in the package separately.

2.3.1 Executing HEC-2 Through the Menu System

1. Go to the directory containing the HEC-2 data files (e.g., **CD \HEC2**).
2. Type **MENU2** and press the **<ENTER>** key. This will invoke the batch file (MENU2.BAT) used to run the menu system of programs. You must operate the menu system through this batch file or the menu programs will not function correctly.

3. The MENU2 menu will appear on the screen and you are ready to use the programs in the package. See Chapter 3 for a description of the MENU2 program options. Each of the individual programs is described in the chapters that follow.

2.3.2 Executing HEC-2 Without the Menu System

To run the individual programs, the program name is entered along with the associated filenames. If the filenames are not given, the program will prompt you for the files. For example, to run HEC-2, enter the following at the DOS prompt:

```
HEC2 IN=A:HEC2##.DAT OUT=TEST##.OUT TAPE95=TEST##.T95
```

where: HEC2## is the test input data file (use A: if it's on the A Drive) and ## is the test number 01 through 17.

If you do not specify the files on the execution line, the program will request the filenames as follows:

```
ENTER THE FILENAME FOR INPUT [CON]  
ENTER THE FILENAME FOR OUTPUT [CON]  
ENTER THE FILENAME FOR TAPE95
```

By pressing the <ENTER> key in response to the questions, the default option will be selected.

The computed results from your output file can be compared with the output files provided for each test. Once you have verified that the program indeed runs on your computer, you can begin creating your own input data for the program. See Chapter 4 for information on input file creation. To run the program with your own data, issue the same commands using the filenames for your data.

Most of the HEC computer programs create and delete their own scratch files. If a program should terminate abnormally, you may see files on your system called TAPE92, TAPE93, etc. You may delete or rename these files as needed.

2.4 Running on a Two Floppy-Diskette System

Before you can use the HEC-2 package programs, you will have to dearchive the programs with PKUNZIP. The following assumes two diskette drives labeled **A:** and **B:**.

1. First the PKUNZIP program must be copied onto a blank, formatted diskette. Insert the **INSTALL** diskette into the default drive (this example assumes **A:**) and the formatted diskette into the other drive. At the DOS prompt, enter the following:

```
COPY PKUNZIP.EXE B:
```

2. Remove the **INSTALL** diskette, and insert the **HEC2** diskette into drive **A:**. At the DOS prompt, enter:

```
B:PKUNZIP A:HEC2EXE B:"program"
```

where "program" is the program to dearchive. The default is all programs; however, all programs will not fit on the target diskette. The same procedure can be used to dearchive programs from the SUP2EXE diskette.

3. To run HEC-2, put the diskette with HEC-2 into drive B.
4. Put the diskette to receive output data and scratch files into drive A.
5. Be sure drive A is the default drive, the prompt will be "**A>**".
6. Start the execution of HEC-2 by entering

B:HEC2

7. The computer will return:

ENTER THE FILENAME FOR INPUT [CON]

At this time, remove the HEC-2 diskette from drive B, and put the diskette with the input file into drive B.

8. In response to the question, enter the name of the input file. For example,

B:HEC201.DAT

9. The computer will now return:

ENTER THE FILENAME FOR OUTPUT [CON]

To select the default, press the **<ENTER>** key and the output will be displayed on the screen. Otherwise enter PRN for printer or a filename for disk storage (e.g., B:TEST01.OUT). Remember that the provided output file for the test data is HEC2##.OUT, so do not use that name or the file will be overwritten.

10. The program will then respond with:

ENTER THE FILENAME FOR TAPE95

To select the default, TAPE95, press the **<ENTER>** key. This option is usually selected.

11. The program is now executing and will display a message:

**Starting profile number #
CWSEL for cross section xx is yy**

where: # is the sequential number of the profile.
 xx is the cross section number.
 yy is the computer water surface elevation (CWSEL).

When complete, the following message will be displayed:

Normal program termination

The following chapters provide information on creating input data files and executing all the programs in the HEC2 package. Please refer to the appropriate chapter for program instructions.

2.5 Files Associated with the Programs

Besides INPUT (TAPE5) and OUTPUT (TAPE6), up to nine files may be created in an HEC-2 application. They are as follows:

	File Data	Type
TAPE7	FORMATTED	Storage-outflow data for streamflow routing
TAPE10	FORMATTED	Reformatted data from the free format option
TAPE16	FORMATTED	Modified input data file with GR records only.
TAPE90	SCRATCH	Split flow data
TAPE91	SCRATCH	Cross section data file
TAPE92	SCRATCH	Cross section plots
TAPE93	SCRATCH	Information for profile plots
TAPE94	SCRATCH	Comment records
TAPE95	UNFORMATTED	Computed profiles
TAPE96	FORMATTED	Archive data

Scratch files are deleted when the program terminates normally. The other files are retained for later use.

Chapter 3

HEC-2 Package Menu Program

3.1 Program Purpose

A menu program, MENU2, has been created to provide convenient access to all the programs in the HEC-2 package, including COED and LIST, when operating on hard-disk systems. All of the programs in the package can operate independently without the menu; however, the menu makes it more convenient to define and transfer filenames among the various programs in the package. The following provides a description of the menu operation.

3.2 Program Set-Up

For a hard-disk system, the executable programs in the HEC-2 package would be stored in a directory (e.g., \HECEXE), along with the menu batch file (MENU2.BAT). Refer to Chapter 2 of this document for installation instructions. The DOS PATH command is used to list the directories to be searched for commands or batch files. The installation instructions include adding **\HECEXE** to the PATH. Usually the PATH command is included in the AUTOEXEC.BAT file so that it automatically enters the command when you boot the system. Refer to your DOS manual for information on the PATH command and the AUTOEXEC.BAT file.

The data files for HEC-2 should be developed in a separate working directory (e.g., \HEC2). The test data can be copied into this directory if you want to run the standard tests. Program execution will occur in this directory; therefore, all input, output and scratch files will be in this directory.

3.3 Program Operation

The HEC-2 programs in the \HECEXE directory can be called while operating in any other directory because the PATH includes \HECEXE. To operate the HEC-2 package, change into the working directory (e.g., \HEC2), and execute the MENU2 program.

```
C:>CD \HEC2  
C:>MENU2
```

The menu, shown in Figure 3, will appear. All the programs in the HEC-2 package can be executed from this menu, as well as defining input and output filenames. The **background and text colors** can be changed for color monitors by pressing the **F9 and F10** keys, respectively. The program will save the selected colors and filenames.

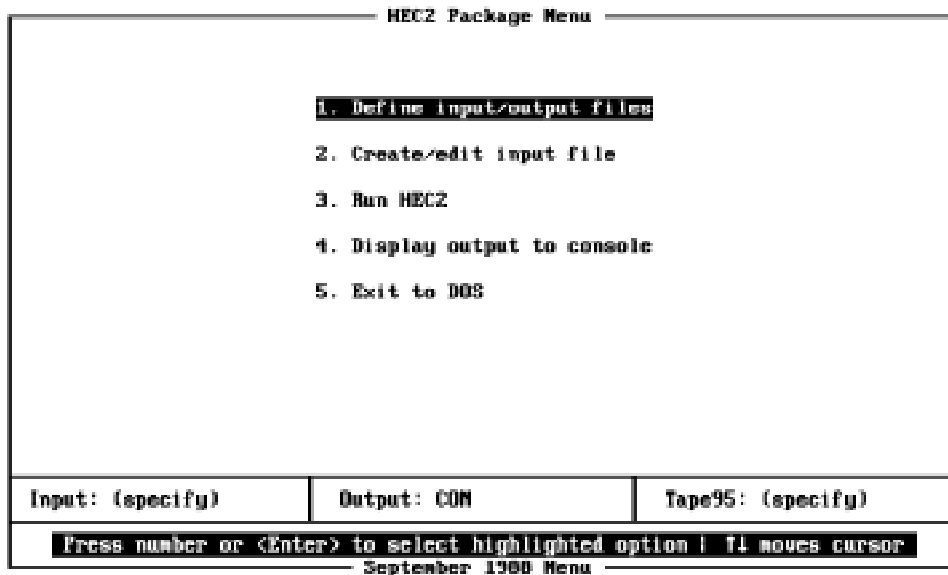


Figure 3
HEC-2 Package Menu, MENU2

1. Define input/output files

This option is used to define the target input and output filenames that will be used when executing HEC-2, and the support programs. When this option is selected, a pop-up menu will appear as shown in Figure 4.

2. Create/edit input file

This option will only function if you have also installed the full screen editor COED on your system. Selecting this option will call COED with the previously defined input filename, call the COED help file for HEC-2 (COEDHEC2.HPG) and open the file in full screen mode.

3. Run HEC2

This option executes HEC-2 and the support programs EDIT2, PLOT2, and SUMPO. The program selection is made by moving the cursor to this line and pressing the space bar until the desired program is displayed.

4. Display output to console

This option is used to display output to the console or the printer. To switch from console to printer, press the space bar while option 4 is highlighted. Program LIST is called with the output filename to provide console display, and PROUT is called to send output to the printer.

5. Exit to DOS

Selecting this option will exit you from the MENU2 program and return control to DOS. The defined filenames and screen colors will be saved.

The menu operates by using the cursor arrow keys to move to the desired operation and then pressing the <ENTER> key, or by pressing the number of the option desired. The menu options are listed in the order of a typical application. The following sections describe each option. First the input and output filenames must be defined.

If the filenames have been defined in a previous session, the input and output files are shown at the bottom of the menu. The filenames are stored when you exit MENU2 and recalled when you return to the menu. At the start, the input filename will show "(specify)".

To define, or change the files, move the cursor to "1. Define Input/output files" and press <ENTER> or enter <1>. A menu will pop up (see Figure 4) for the INPUT, OUTPUT, and TAPE95 files. Also, note the **default extensions** and **data directory** options.

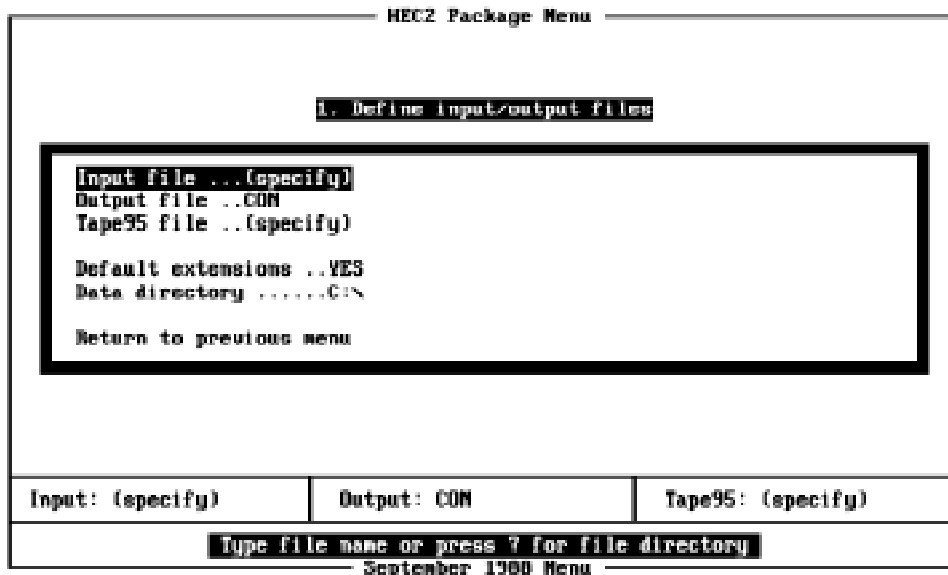


Figure 4
Define Input/Output Files Menu

With **Default extensions .. YES**, you only enter the filename (without extension) for the input file. This feature provides the same filename for all the files with the following extensions for HEC-2 files:

- .DAT for input data files
- .OUT for output "Print" files
- .T95 for the binary TAPE95 files

The automatic extension feature can be turned off by moving the cursor to **Default extensions** and pressing the space bar to toggle the choice to **NO**.

The default directory for file definition is shown next to **Data directory**. The directory can be changed by moving the cursor to that location and editing/entering the directory name. This allows access to data files in different drive and directory locations.

The filename can be entered, or enter a question mark <?>. For the <?> entry, a list of files on the current directory will be displayed, see Figure 5 below. The cursor keys can be used to highlight the desired file, and pressing <ENTER> will select the highlighted file. The **default extension** option, described above, will limit the file listing to those with the appropriate assumed extension, e.g., **.DAT** for data files.

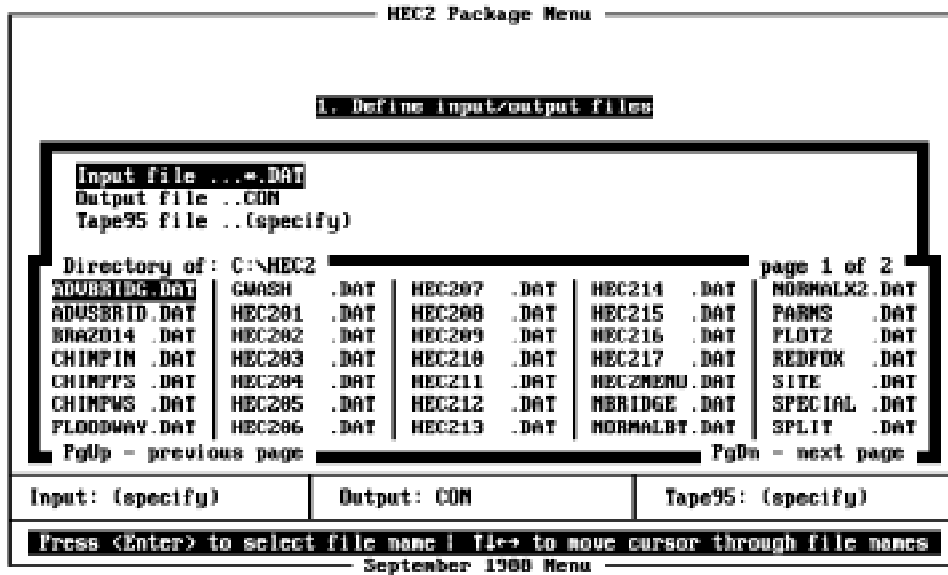


Figure 5
MENU2 Data File Listing

If you enter an input filename that does not exist, the program will echo:

File does not exist.
Would you like to create it (y/n)?

Enter <y> and the filename will be created.

When all the filenames have been defined, move the cursor to **Return to previous menu** and press <ENTER>. This will return you to the main menu. With **default extensions** option on, the cursor will automatically move to the return position after the input filename is defined; you only have to press <ENTER>.

After the files have been defined, you may want to enter data in a new input file or edit an existing file. Move the cursor to **2. Create/Edit Input file**, or enter <2> to call COED. The program will echo:

Edit "filename" (y/n)?

to check the "filename" before calling COED with the defined input filename. Enter <y> or press <ENTER> to proceed. Enter <n> if you want to change "filename"; then enter the desired filename to edit.

COED is called with the HEC-2 help file **<HP HEC2>** and the full screen option **<FS>**. This will load the HEC-2 input variables help file, set the tab setting for input to the HEC-2 program, and put you in the full screen edit mode. As each record ID is entered in columns 1 and 2 of a line, the variables for that ID are displayed at the bottom of the screen. Also, the input description for each variable is available within COED. Within COED the **<F1>** key provides on-screen help, or refer to the HP command instructions in the COED manual. Chapter 4 of this document also provides additional information. If the automatic HEC2 help file does not load, carefully review the COED installation. The assumed configuration is shown in Figure 2.

When you have completed the edit session, exit COED (usually with the SAVE option). With the completion of COED, or any program in the package, the screen will display:

Strike a key when ready . . .

This allows you to see if there are any error messages written to the screen from the current program operation. Pressing any key will return you to the main menu.

After the input file has been created or edited, it is a good practice to check the file with EDIT2. To run one of the programs, move the cursor to **"3. Run HEC2"**. The program to run can be changed by pressing the **<SPACE BAR>**. (The instructions are shown at the bottom of the menu.) Press the **<SPACE BAR>** until **EDIT2** is displayed, and then press **<ENTER>**. The defined input file will be processed with **EDIT2**, and the output will be written to the specified output file. When the job is complete, press any key to return to the main menu. The specified output file will contain the **EDIT2** output.

If a filename was given, item **"4. Display Output to console"** can be used to display the output file with program LIST. Simply enter the number **<4>**, or move the cursor to that line and press **<ENTER>**. LIST provides a screen display of the output file, using the cursor keys to move through the file. The **<END>** and **<HOME>** keys are convenient for moving to the bottom or beginning of the file. Press **<F1>** to see the LIST commands.

If the input file needs correction, move the cursor to **"2. Create/edit input file"** and press **<ENTER>**, or enter **<2>** and the input file will be directed to COED for editing. If the input file is ready to run with HEC-2, move the cursor to **"3. Run HEC2"** and toggle the program to **HEC2**, with the **<SPACE BAR>**, and press **<ENTER>**. The input will be passed to HEC-2 and the job executed. When complete, press any key to return to the main menu.

After running HEC-2, programs SUMPO and PLOT2 can be used to examine the results from the job. They are called from **"3. Run HEC2"**, in the same manner as HEC-2, described above. Chapters 8 and 9 provide detailed descriptions of the SUMPO and PLOT2 programs.

The HEC-2 output file can be reviewed on the screen with LIST by entering **<4>**, as described above. Also, LIST can also be used to print portions of the output file. A complete printing of the output file can be obtained by pressing the **<SPACE BAR>** to display **"4. Display output to printer"**. A utility program, PROUT, will print the output file with the carriage controls. PROUT will print with either 80- or 132-character line length. However, you must set the printer prior to starting the MENU2 program.

When complete, press number **<5>** or move the cursor to **"5. Exit to DOS"** and press **<ENTER>**. That will take you out of the Menu and return you to the DOS prompt.

Chapter 4

Creating an Input Data File

The HEC-2 program is a batch program, that means the necessary data for the program is provided as input at program execution and the program processes the entire job to completion. The program user does not interact with the program during execution. This section describes the sequence of an HEC-2 computation process, the input data format, and the basic steps for creating and storing an input data file.

4.1 Sequence of HEC-2 Computations

The HEC-2 program is designed to compute multiple water surface profiles with a given data set describing a river reach. The data set for the first profile defines the starting conditions and the physical river reach. If additional profiles are to be computed, the starting conditions for the subsequent profiles are provided at the bottom of the input data file that defines the first profile. Title plus job records (J1 & J2) are required for additional profiles. **NOTE: Since 1988, HEC-2 does not require three title records.**

As HEC-2 computes water surface elevations for each given cross section, the results are written to a file, TAPE95. There is also a sequential writing of results to the output file. When the program has completed one profile, the starting conditions are determined (if provided) for the next profile. The program repeats the process of computing the water surface profile with the new starting conditions and the original river reach data. The multiple profiles are computed for as many profiles as are defined in the input data set. The data set ends with an ER record. **NOTE: Since 1988, HEC-2 does not require three blank records.**

Once all the profiles are computed, the program reads TAPE95 and formats the summary tables requested by the input data. (See Section 6.1 for more information on HEC-2 operation and Section 6.2 for descriptions of program output files.)

4.2 Input Data File Format

The structure of the HEC-2 input data file can be seen by reviewing any of the test data sets provided with the program. The detailed input description is provided in Appendix VII of the User's Manual.

The format for the HEC-2 data is a "standard" HEC format. The concept is based on the eighty-column data card associated with batch input. The term card is used here even though the cards are more appropriately defined as records in a file. The first two columns are used for record identifier (ID); the program reads and sorts through the data based on the record ID. Each record is divided into ten (10) fields of eight columns each. However, a variable in field one may only occupy record columns 3 through 8 because the record ID is in columns 1 and 2. The HEC-2 User's Manual, and this text, refer to the individual records by their ID and the variable location of the record by the field number (1 through 10).

Data entry into fields requires careful counting of columns to ensure that the data are located in the correct fields. If a datum is entered across a boundary (column) between fields, the program will read part of the value as one variable and the remainder of the datum as the value for the variable in the next field.

There are several options available to assist the program user to enter data into fields without counting record columns to space data entries into the correct fields. The HEC-2 and EDIT2 programs will accept input data in "FREE" format and convert the data into fixed-format. However, the Corps' interactive edit program, COED, will automatically place input data into HEC standard (fields of eight) format. COED also provides on-screen help features that enhance the data entry function of the editor. The use of COED is assumed in the following sections.

4.3 COED Application

Creating or editing an input file from MENU2 calls COED. Calling COED from MENU2 also includes two parameters: **FS** and **HP HEC2**. If you run COED separately, these parameters can be entered while in COED. Entering **HP HEC2** will cause the HEC-2 input help file to be loaded, providing the tab settings for data entry and the input variables for HEC-2. Entering **FS** puts you into the Full Screen working environment. COED operates as a command editor (where you enter edit command codes and parameters) and also as a full screen editor (like a word processor). See the COED User's Manual for detailed documentation. Figure 6 shows an input data file in COED full screen edit mode, which is better for data entry.

```

TOP . .
T1  WATER SURFACE PROFILES WORKSHOP SOLUTION
T2  COED INPUT PREPARATION FOR PC VERSION
T3  RED FOX RIVER Q = 1000 cfs
J1  0      2      0      0      0      0      0      0      0      3.0
QT  3      1000   6500   10000
NC  0      0      0      .1     .3
NH  5      .1     415    .05    650    .03    710    .05    1020   .10
NH  1635
X1  1      11     650    710
GR  25     20     10     110    17     415    14     650    1      675
GR  0      650    1      710    13     710    14     1020   14     1590
GR  25     1635
NH  4      .1     415    .05    575    .03    640    .1     1250
X1  2      10     575    640    500    500    500
GR  25     30     20     110    20     200    17     415    10     575
GR  4      500    4      615    10     640    10     1195   25     1250
NC  .1     .05    .03
X1  3      10     370    400    400    400
GR  25     40     22     260    10.7   370    15     420    7.1    500
GR  7.5    530    17.3   560    20     600    22     850    25     875
NH  5      .1     130    .05    330    .036   460    .05    610    .1

```

T1 FIRST TITLE RECORD
 Help=F1 Caps-Lk Col=1 Line=1

Figure 6
 HEC-2 Input Data File in COED Full Screen Mode

Once in COED, with HEC-2 help file and full screen edit mode, data entry will automatically use the first two columns for ID, the next six columns for Field 1, and the remaining nine sets of eight columns as Fields 2 through 10. With the cursor at the first column, enter any appropriate HEC-2 ID (e.g., T1). The bottom of the screen will display a line of input information for the entered ID (e.g., FIRST TITLE RECORD for T1). If the ID is not appropriate for HEC-2, you will get the message:

ID >> >>> Record ID not valid for HEC-2 input <<< <<<

For title record information the entire line is available to enter text; there are no fields. For data records, most fields represent variables, and the variables are shown on the line at the bottom of the screen. For example, enter J1, and the variables for the J1 record are shown on the bottom line. Use the **<TAB>** key (usually shown with two horizontal arrows) to move the cursor from field to field. The cursor automatically moves to the right of each field. Data entry will also fill the field from the right. Therefore, the data are always right justified.

Data entry only affects the field that the cursor is on. Therefore, inserting or deleting data in a field only works in the one field. If you continue to enter data in a field, the previously entered data is displaced to the left until it is moved completely out of the field. Use the **<TAB>** key, or a cursor key, to move to another field. Use the **<SHIFT><TAB>** to move the cursor to the left.

Help information for COED is provided by pressing **<F1>**. The function keys are defined, and a list of additional help information is provided, as shown in Figure 7. The COED User's Manual is essentially provided through the help file.

F1	Help	Restore	F2	COED - Help Screen
Ctl-F1	-	PC Setup		
Shf-F1	-	-		
Alt-F1	Help Var	-		
F3	Delete-Ln	Insert-Ln	F4	PC Function Key Usage
Ctl-F3	-	-		Help - Request help/Resume editing
Shf-F3	Erase Fld	-		Restore - Restore line
Alt-F3	-	-		Delete-Ln - Delete current line
F5	-	-	F6	Insert-Ln - Insert line mode (toggle)
Ctl-F5	-	-		Command - Single line edit command
Shf-F5	-	-		Line-Edit - Go into line edit mode
F7	-	-	F8	Quit - Exit without saving file
Ctl-F7	-	-		Save - Save file and resume edit
Shf-F7	-	-		File - Save file and exit COED
Alt-F7	-	-		Help Var - Help for program variable
F9	Command	Line-Edit	F10	Erase Fld - Erase characters in field
Ctl-F9	-	Quit		
Shf-F9	-	Save		
Alt-F9	-	File		

Press <ENTER> for next help screen

Press <F1> to resume edit

Figure 7
COED Help Screen

Help

information for HEC-2 variables is provided by pressing **<ALT><F1>**. The HEC-2 ID in columns one and two provides the line of variables, for that record type, listed at the bottom of the screen. Moving the cursor to any field on the data input line and pressing **<ALT><F1>** provides the input description for that field's variable. Therefore, while you are entering data, you can obtain the input description for any input variable in the HEC-2 program.

With the HEC-2 help file loaded, COED can recognize legal input types. That is, the program will not accept a letter <O> for an entry that requires a number. This feature should reduce illegal input data errors.

4.4 File Creation and Storing

Basically, the input file is made up of the title records, the job records that define starting conditions and program options, and a series of cross sections that define the river reach. Refer to the User's Manual, Appendix VII, for input descriptions. A Functional Use Index in Appendix VII shows the records to use for various program options.

The first profile data usually begins with the title records (1988 version allows any number of title records) and ends with the EJ record. For multiple profiles, three more title records and a J1 and J2 record are provided to define the starting conditions for each succeeding profile. After the EJ record, only title records, J1, J2, and JR are allowed to define each succeeding profile. An ER record ends the input data file; blank records are not required with the 1988 version. See Test 2 input for an example of a four-profile job.

To create an input file, the editor program COED is executed along with an input filename. If the file does not exist, the file is created and is then available for data entry. The data are entered, starting with the first record, and sequentially entered through the required data set for the reach. For subcritical water surface profiles, the cross section data starts with the most downstream section, and the cross sections are defined sequentially upstream to the end of the reach, which would represent the first profile.

The input data file is saved with the appropriate command. Usually, the **FILE** command is used. It saves the edited file and exits the COED program. The **FILE** command can be invoked by pressing the <ALT><F10> keys. While in full screen mode, a single COED command can be entered for the **E>** prompt, which can be obtained by pressing the <F9>. Pressing <F10> will change COED into the command mode of operation. Entering <FS> will take COED back to full screen mode.

When completed, exit the text editor; the input data file is now available to use with the various programs. Chapter 5 describes how to check the input data file. Before running HEC-2 with your data, it is strongly recommended that the input data file be checked with EDIT2.

Chapter 5

Checking an Input File for Errors

Once an HEC-2 input data file has been developed, the data should be checked for format errors and possible input errors. The HEC-2 program provides input data checks; but if there is a fatal error, the program will stop. If there are several fatal data errors, it would require several attempts with HEC-2 before each error is found. Therefore, the input data file should first be checked with the EDIT2 program.

5.1 Purpose of EDIT2 Program

The EDIT2 program will process an entire HEC-2 input data file and provide a list of all the data errors found. Not only does the program identify fatal errors, it also identifies data inconsistencies and possible input errors.

The EDIT2 program will also process free-format data and create a fixed-format file, as described in Section 4.2. The fixed-format data are written to a file (TAPE10), which can be renamed and used for subsequent processing. Generally, it is easier to read and work with the fixed-format file because the data are all in their record fields and line up in columns.

5.2 EDIT2 Program Execution

The EDIT2 program can be conveniently run from MENU2. Move the cursor to "**3. Run HEC2**", press the **<SPACE BAR>** until the line indicates **RUN EDIT2**, and then press **<ENTER>**.

The EDIT2 program uses the HEC-2 input data file as its input; no additional input is required. There are three control variables that can be changed by using the optional ED card (see HEC-2 Input Data Description, Appendix VII). The ED card must be the first card in the data file. With it, you can: (1) suppress the listing of the input data, (2) set the column width of the output to 80 without carriage control (default 132), and (3) change the range of elevation difference (default 150) that is used to check for possible errors in input elevations for cross sections. If the difference in elevation in a cross section exceeds the test value, a message is printed indicating a possible input error. If you have an eighty-character printer, you may want to use the ED card to set the EDIT2 output to eighty.

The HEC-2 input data listing (unless suppressed) and error messages are written to an output file. It is more convenient to direct the output to disk via an output file name; MENU2 will transfer the defined input and output filenames. Then, when EDIT2 is finished, press a key and MENU2 will display the output file using program LIST. If there are error messages, you can print them from LIST by turning on the print option **<P>**. The screen display will be sent to the printer. Press **<X>** or **<ESC>** to exit program LIST and return to MENU2. The entire output file can be sent to the printer from MENU2 by pressing the space bar to toggle to "**4. Display output to printer**" and pressing **<ENTER>**. Also, LIST is useful when reviewing the input file because it will display illegal characters that may be in the file.

To execute the EDIT2 program as a separate program, at the DOS prompt enter:

EDIT2 INPUT="filename" OUTPUT="filename"

where: "filename" = the input and output filenames
e.g., HEC205.DAT for input, and HEC205.OUT for output

use: OUTPUT = CON for screen
PRN for printer

This assumes that the program and data are in the current default drive. Otherwise, also indicate the proper drive for the program and data. If the input and/or output filenames are not given, the program will request the name of the file, in response, enter the filename.

5.3 Types of Data Checks Performed

There are three basic levels of data checks and error messages provided by the EDIT2 program: **ERROR, CAUTION, and NOTE.**

ERROR messages are provided for those errors that are definitely wrong and probably will stop the HEC-2 program or cause erroneous results. **CAUTION** messages are provided when there may be an error because the data are inconsistent with typical applications of the program. These checks cannot be absolute because there may be situations where the input data are correct. **NOTES** are mostly informational to alert the user to some data entry that may be inconsistent or different than expected. Notes do not necessarily mean the data entry is wrong.

5.4 Error Messages Provided

The program provides numerous checks, and the messages are, hopefully, complete enough to focus the user on the source of the problem. There is no separate list of error checks and messages. The user must interpret the information based on the input data. If some messages do not make sense, correct the ones that do and check the data again.

The general format for the messages is: **Section number - Error type - Card identifier - Message.** (e.g., 51925.000 - NOTE - GR RECORD - STA = 260.000 MINIMUM ELEVATION NOT WITHIN CHANNEL) Generally, the minimum elevation of a cross section would be within the channel. For this section, the minimum elevation is at station 260, which is not between the left and right banks. This may be an error or it may be what the user wants. Obviously, only the person developing the data can make the final determination.

Often the message will focus on the variable that appears to be the problem source (e.g., 51500.00 - NOTE - QT RECORD - NUMQ = 8 DOES NOT EQUAL NUMBER OF Q READ = 7). If you are not familiar with the variable, refer to the HEC-2 Input Description. Review the card description, variable definition and input description. Usually the variable description will be sufficient to understand the error message. In the example above, the NUMQ variable defines the number of flow values, which was given as eight. However, the QT card only had seven flow values defined.

5.5 Correcting Input Data Errors

When **CARD OUT OF ORDER** error messages occur, many subsequent error messages may be generated. The **CARD OUT OF ORDER** error messages should be dealt with first. If in doubt about card order, refer to the foldout page at the end of the User's Manual. This Summary of Input Cards shows the cards in their relative order of input. Carefully review your input file, and arrange the card sequence to follow the sequence shown in the summary.

After correcting the input order, recheck the data file with EDIT2. If there are error messages, try to correct the errors. There may be some messages, including **ERRORS**, that are given even when you have the data set the way you want it. Be sure you understand why your data are causing the message. If the data are the way you want them, go ahead and run the data with HEC-2. However, you may want to place a message in your input file, using the comment card, to explain any apparent discrepancy. This would help any reviewer, testing your data set with EDIT2, understand why there were still error messages generated from your input data file.

Chapter 6

Computing Water Surface Profiles

After the input data file for HEC-2 has been created, checked with EDIT2 and the errors corrected, the data can be submitted to the HEC-2 program to compute water surface profiles. This section describes the basic operation of the HEC-2 program, the program output files, and program options for output.

6.1 HEC-2 Program Execution

The HEC-2 program can be easily executed from MENU2. Move the cursor to option **<3>**, press the **<SPACE BAR>** until **Run HEC2** is displayed, and then press **<ENTER>**. The files defined at the bottom of the menu display will be used by HEC-2. If the same output filename is used for an EDIT2 run and then with HEC-2, the output file will be written over. This should not be a problem because most people do not save their EDIT2 output once they have eliminated the input data errors.

The HEC-2 program uses the input data file as its input. If the ED record, described in Section 4.2, was used for EDIT2, it can remain in the data file. HEC-2 will ignore the record. If a free-format data file is used (described in Section 4.2), the HEC-2 program will convert the data into fixed-format, the same as EDIT2. The program user should save the fixed-format file for use with HEC-2 because it saves the added time for format conversion every time you execute the program.

To execute HEC-2 as a separate program, at the DOS prompt enter:

HEC2 INPUT= "filename" OUTPUT="filename" TAPE95="filename"

where: "filename" = the input, output, and TAPE95 filenames
(e.g., HEC2 INPUT=HEC205.DAT OUTPUT=HEC205.OUT TAPE95=HEC205.T95)

This assumes that the program and data are in the current default drive. Otherwise, also indicate the proper drive for the program and data. If the input and/or output filenames are not given, the program will request the names for the files. If you respond with the **<ENTER>** key, the default filename will be used.

As HEC-2 computes water surface profiles, it will send messages to the screen. The first is the "Title" from fields two through four on the third title record (T3). Following the "Title," the message:

**Starting profile number #
CWSEL for cross section xx is yy**

where: # is the sequential number of the profile.
xx is the cross section number.
yy is the computed water surface elevation.

These messages are written to the screen so you will know how far your job has progressed. When the job is complete, the following message will be displayed:

Normal program termination

If you are operating from MENU2, the following message will also be displayed:

Strike a key when ready . . .

This allows you to see any error messages that may be written to the screen from an abnormal termination. Missing input data or illegal data characters can cause FORTRAN error messages, which are written to the screen.

6.2 Program Output Files

As indicated above, there are several input/output files associated with HEC-2. Besides the standard INPUT and OUTPUT, there are TAPE95 and TAPE10. TAPE95 is an unformatted output file with all the variables, listed in the User's Manual Input Description under the J3 record, written for each section and every profile computed. TAPE10 is the file containing the fixed-format input data, if a free-format data file was read as INPUT.

There are two additional output files you can request. The archive option (see AC input description in the HEC-2 User's Manual) provides a formatted output file, similar to the intermediate output file TAPE95. The archive file is written to TAPE96 and contains the input plus the same output variables as TAPE95, except they are formatted. This means they can be read with LIST or printed like any other standard ASCII file.

An HEC-2 modified input file can be created and saved for subsequent computations. (See the J2 record, Field 8, IBW, input description of the HEC-2 User's Manual.) The intent is for applications using the CHIMP routine, where the user can request the data set, as modified by the channel modification routine. The file contains the input data, as modified by all the HEC-2 options used. The modified input file is written to TAPE16.

To save any HEC-2 generated file, such as TAPE96 or TAPE16, you can specify the filename on the command line, or you can rename the file. Use the DOS COPY or REN (RENAME) commands. For example, from the DOS prompt enter:

REN TAPE96 REDFOX.ARC

This will rename TAPE96 to REDFOX.ARC. The TAPE files are rewritten every time HEC-2 is run, so you must change the name of any file you want to save before running HEC-2 again.

6.2.1 OUTPUT - Formatted Output File

OUTPUT is the "print" file from HEC-2. Generally, this file would go directly to the printer or to a disk file. Because the printer is usually very slow, it is often easier to write the HEC-2 output to a disk file and review it with a program like LIST. There may be several computer runs required before the final results are obtained. By using the disk file approach, only the final results would be sent to the printer.

The OUTPUT file is easy to review from MENU2. Move the cursor to **"4. Display output to console"**, and press **<ENTER>**. This will call LIST with the output filename. To help locate specific areas in the output file, there are labels of ***PROF #** (where # is the number of the profile) at the start of each profile. At the start of the output for each cross section, there is a ***SECNO #** (where # is the cross section number). By using the appropriate find command to locate a character string (e.g., **F** in LIST), the user can find the start of any profile's output and the start of any cross section's output. Portions of the output file can be printed from LIST; **P** turns the printer on or off. Press **<F1>**, while in LIST, to see available LIST commands.

The entire output file can be sent to the printer from MENU2. At **"4. Display output to console"**

press the **<SPACE BAR>** to display "**Display output to printer**", and press **<ENTER>**. This will send the output file to the printer with the utility program PROUT. PROUT will recognize the carriage control characters in the output file and thus provide spacing and paging as a high-speed printer would. PROUT output can be set to eighty or 132 columns. PROUT does not set the printer width; that must be done external to the program.

The DOS COPY command can be used to send the output file to the printer (e.g., COPY A:TEST5.OUT PRN). However, this will tie up the computer while the file is printing. Alternatively, the DOS PRINT command can be used, (e.g., PRINT A:TEST5.OUT). The system will request the name of the print device; simply press **<ENTER>** to send the output to the printer. This approach does not tie up the computer. However, neither of the above approaches will allow your printer to recognize the print control characters in column one of the output file. Therefore, the printed output will not start a new page or skip lines the way the file would be normally printed if directed to the printer at the time of execution.

To use PROUT as a separate program, at the DOS prompt enter:

PROUT "filename" "column width"

where: "filename" is the output file to print
"column width" is the column width for the printer

(e.g., PROUT A:TEST5.OUT 132)

6.2.2 TAPE95 - Intermediate Profile Results

This file contains the results of the profile calculation written for summary output displays. When HEC-2 is computing the profile, it is also writing the results to TAPE95 after each cross section computation is complete. When the last profile is complete, the program develops requested summary tables by reading the results from TAPE95 and writing the requested data in the summary table format. Refer to the J3 record description in the User's Manual for a description of the summary table capability of HEC-2.

The TAPE95 file is a binary file and cannot be read with a text editor. However, the summary output portion of the HEC-2 program has been converted to a separate program SUMPO, and graphical displays can be developed with program PLOT2. These programs use TAPE95 as the "input" and interactively provide output. Chapter 8 provides a description of the SUMPO program, and Chapter 9 provides a description of PLOT2. Also, utility program READ95 can be used to convert a binary TAPE95 file to an ASCII text file.

The MENU2 default extension option automatically provides for an extension of **".T95"** for the TAPE95 file. However, if you did not define an alternative file name for TAPE95, you will need to rename TAPE95 to avoid writing over it with a subsequent execution of HEC-2. Every time HEC-2 is run, TAPE95 is written over again. If you are running more than one HEC-2 model, use the DOS command RENAME to save the file under a new file name.

To save TAPE95 under a new name enter:

RENAME TAPE95 "filename" (e.g., RENAME TAPE95 TEST5.T95)

The DOS COPY command can also be used to save TAPE95 under a different name and, if desired, in a different location.

6.3 Output Control

The HEC-2 User's Manual describes program output in Chapter 6. Table 4, in that Chapter, lists various output options and the control records required to activate those options. Standard Test 5 illustrates the use of the options to suppress the printer plot of profiles (J2.3 = -1), to develop summary tables (J3 record) and to control the sequential output (J5 record). You can review the input and output for Test 5 by looking at files HEC205.DAT and HEC205.OUT, respectively. These files are provided on the diskettes with the HEC-2 program package.

The HEC-2 program automatically prints a plot of the computed profile at the end of each profile computation, if there are five or more cross sections. Cross section printer plots must be requested (variable IPLOT on J2.2 or X1.10). Test 1 provides an example of cross section and profile printer plots (see file HEC201.OUT). With the availability of PLOT2 to provide a graphic display of cross sections and profiles, there is little value to the printer profile plot. By setting the PRFVS variable to minus one (J2.3) for each profile, the printer plots will be suppressed.

The J3 record is provided in the input data file to define the desired summary tables. The Input Description in the User's Manual describes the options available. There are predefined tables that are called with a single code number, and there are user-defined tables that are created by listing the code number for the variables desired. Test 5 shows an example of each.

The advantage of using the summary tables is the convenience of seeing the computed results for all the profiles displayed together for each cross section. The summary tables are at the end of the OUTPUT file. By looking at the end of the output first, the user can get an overview of the computed results. Chapter 6 provides some suggestions for reviewing the HEC-2 output. If there are tables that were not requested at the time of execution, they can be developed using the SUMPO program described in Chapter 7.

The J5 record can be used to selectively eliminate or request sequential output for cross sections. The J5 option is sometime used to reduce printed output from HEC-2 to a minimum. A better approach is the use of a disk file for the HEC-2 output. The sequential output contains helpful information for the analysis of the computed profile. If there are inconsistencies in the computed results, the sequential file is usually necessary to analyze the problem.

6.4 Model Calibration

Model calibration is an important phase of the initial model development. The number and accuracy of the cross sections and the loss coefficients are the most important (significant) input items. The calibration process should start with the best estimates for loss coefficients and a reasonable range for their values. By computing profiles for historic floods and checking computed results with observed values, some measure of the model accuracy can be determined.

If loss coefficients are to be adjusted during the calibration process, it is reasonable to assume that the absolute value of the coefficients are not known, but the relative magnitude among the coefficients may be reasonable. The input variable FN (J2.6) is a factor to multiply all the Manning's 'n' values in the model. By using the FN factor, the 'n' values can be proportionally raised and lowered. This approach is convenient for calibration and sensitivity analysis.

The other major model adjustments are with the cross sections. The spacing of the cross sections is one of the most important factors in the accuracy of the computed profile. Results from the Water Surface Profile Accuracy Study indicate that the spacing between sections is more important than the absolute accuracy of the sections themselves (USACE, 1986). Typically, there is an insufficient number of sections. If more sections cannot be obtained from the field, the repeat section capability and available topographic mapping should be used to add cross sections where needed in the model.

Chapter 7 provides some suggested items to review in the HEC-2 output. Generally, the initial model will require adjustment to the input parameters and additional data. The program user should never assume that the model is adequate just because the program can execute the data set.

6.5 File Archives

The entire HEC-2 INPUT, TAPE95 and OUTPUT files for a project can be maintained on a diskette for future reference or computations. By using the DOS COPY command, the files can be transferred to a diskette, which can be stored with other project documents. Also, the diskette could be a part of the project report. The HEC-2 archive option, described in Section 6.2, can also be used to provide a complete input/output file.

A filename convention, like that used in the MENU2 package, provides a convenient, easily recognized, set of information. Assuming all the information was on a hard-disk (drive C), the following DOS commands can be used to copy the information to a diskette:

```
COPY C:PROJECT.DAT A:  
COPY C:TAPE95 A:PROJECT.T95  
COPY C:PROJECT.OUT A:
```

where: **PROJECT** is the filename used for the study.

With all the project files on a diskette, the information is readily available for review. The original input data could be used to make additional profile computations. Selected portions of the HEC-2 output file can be printed by writing them to a separate file and then copying that file to the printer. Another way possibly, is to use the SUMPO program to extract the desired summary tables from TAPE95 for printing. Also, PLOT2 can be used to plot cross sections with the input file and profiles with TAPE95.

Chapter 7

Reviewing the HEC-2 Formatted Output File

The HEC-2 output file contains information that cannot be obtained from the TAPE95 file. This chapter describes the HEC-2 output file and gives some guidelines for the review of output. Because the program is basically designed to continue computations if possible, the fact that the program executes a complete job does not necessarily mean that the results are good. The user must carefully review the results to ensure that they represent the study reach and that they are reasonable and consistent.

7.1 Printout Sequence

The HEC-2 output file starts with a banner blocked off with an asterisk (*). The banner gives the program's release date, last update, and an error corrections and modifications list. The error corrections represent updates that corrected deficiencies or errors in the program. As errors are discovered, they are corrected and documented. After several have been found, the program is updated, and all program users are notified. The modifications represent enhancements to the program. The Foreword in the User's Manual gives a summary of the program modifications.

The data input for the first profile (T1 through EJ records) is listed below the banner. There is an input option to suppress the input listing, but this is discouraged. Most problems with the program execution come from input problems. Therefore, it is extremely helpful to have the input data for the job listed with the output.

Following the input listing, the output for the first profile is printed, starting with the ***PROF 1** note. The printout for each section consists of a block of forty variables that are displayed at the top of the page. The values for those variables are displayed in the same spatial arrangement as the variable list. Appendix VI Output Data Description, gives the definition of all the variables displayed. The section number (SECNO) is listed in the upper left-hand corner for easy reference; also ***SECNO #** is printed before the output display for each section.

Following the printout for each section, the program provides a printer plot of the profile. Output for Test 1 gives an example of the profile printer plot. With the availability of PLOT2 to plot profiles graphically, there is little added value to the printer plots. They can be suppressed by setting the variable PRFVS (J2.3) to minus one for each profile computed.

The second and subsequent profiles start with an input listing for that profile, which consists of the title and job records. There are no other data for the subsequent profiles; the remainder of the data are the same as the data listed at the beginning. After the input listing, the sequential output for the second, or subsequent, profile is printed. The sequence is repeated until the last profile output is printed.

Following the last profile, the summary printout is provided. The summary tables are defined by the data provided on the J3 record, or there is a default table if the J3 record is omitted. For

additional summary tables, the program SUMPO can provide the same tables interactively using the TAPE95 file from HEC-2.

The output file will also contain printer plots of cross sections, if requested. The IPLOT variable (J2.2

or X1.10) requests the cross section plot for all the sections in a profile or a single section, respectively. However, with the graphic cross section plots available from PLOT2, the printer plots are not usually requested.

7.2 Special Notes

Throughout the sequential cross section printout there may be informational notes. Some notes provide general comments like the initialization of contraction and expansion coefficients (e.g., CCHV= 0.100 CEHV= 0.300) or use of the NH record (1490 NH RECORD USED). Other notes indicate potential computation problems (e.g., 1340 RECORD NOT RECOGNIZED).

The notes are usually printed with a number and message. The number is the statement number in the HEC-2 program where the message is generated. To locate the message source, the program source listing would be required. However, the User's Manual Appendix V, Special Note Listing, explains special notes that commonly appear as part of the normal sequential output. The notes are listed in the order of their statement number.

The Special Notes should be carefully reviewed to assure there are no computational problems identified by the program. If the note message and the explanation in Appendix V are not sufficient for you to understand the problem, contact HEC for additional explanation.

7.3 Reviewing Output File with Program LIST

The LIST program is a public domain utility that provides a convenient way of viewing text (ASCII) files on the screen. It has the advantage of allowing you to shift your view of the output from left to right, as well as up and down. Because the standard output file from HEC-2 is 132 characters wide, the ability to shift your view of the output file in all four directions makes it easy to scan an entire output file on an eighty-character screen.

The program uses the cursor control keys in a logical manner. **<Page Up>** and **<Page Down>** moves you up and down through the file in blocks of text. **<Up>** and **<Down Arrows>** move you one line at a time. **<Left>** and **<Right Arrows>** shift the text left and right twenty columns. **<Home>** and **<End>** keys move you to the beginning and to the end of the file.

Help is called with the **<F1>** key or a question mark **<?>**. The Help file list includes the commands and the control keys to call the commands. Often, several logical choices of control keys are used to call a command.

Escape key **<ESC>**, as well as the letters **<Q>** and **<X>**, will terminate the program.

MENU2 calls LIST when you select **"4. Display output to console"**. To execute LIST as a separate program, from the DOS prompt enter:

LIST "filename" (also enter: drive: and \pathname\ if required)

If you don't include the "filename", the program will respond:

Enter file name:

Input the filename, and the program will display the first block of text in the file. Also, there is a partial list of program commands shown at the bottom of the screen. The program makes it easy to view the output file on the screen. There is also a print on/off switch, called by the letter **<P>**, which sends the viewed output to the printer. This feature makes it easy to print selected portions of the output file.

7.4 Output Review

Generally, **the summary tables are the first place to review output** for a large job. The summary gives a total view of the multiple profile job; it would also show whether the entire job executed. If you did not request a summary table, the program SUMPO can be used to generate summary tables from the TAPE95 written by the HEC-2 run. See Chapter 8 for a description of the SUMPO program.

The end of the summary table has the **SUMMARY OF ERRORS**. This listing provides some of the more important error messages and notes from the sequential output. The notes are written with the section number, profile number and error message. These error messages are the same as the special notes provided in the sequential cross section printout. **Review the notes** to see if there are computational problems. Some notes, like "**Critical Depth Assumed**," may be an indication that there are problems with some of the section solutions.

From the data provided by **Summary Table 150**, review the computed water surface elevations (CWSEL), the CWSEL difference for each profile (DIFWSP), and the CWSEL difference between sections (DIFWSX). If increasing discharges were used in each profile, one would expect to see the water surface elevation at a section increasing. As the solution steps upstream, for a subcritical profile, the water surface should generally increase. The increase between sections should be similar for the profiles. The review process should look for inconsistencies. The reviewer should be able to predict and explain the solution obtained.

Top width (TOPWID) is another important variable to review. The HEC-2 program does not check on consistency of top width between cross sections. It is possible to obtain a solution that shows a width of 5,000 feet at one section and five hundred feet at the next section, a short distance away. Often the varying top width is a result of the flow being in the channel at one section and in the overbanks at the next section. The reviewer must decide whether the transition is physically possible.

In cases where the overbank flow only appears at one section, and not at the adjacent upstream or downstream sections, it is obvious that the flow cannot be fully utilizing the overbank area at the one section. At locations where radical changes in top width occur, determine with the aid of a topographic map the path that the flow is likely to follow. Compare the mapped path with the cross section location and orientation used in the model. There may be a need to add or modify the cross section definition based on the initial model results. Remember that the model should only have the conveyance portion of the cross section. Ponding areas should not be included unless developing storage-outflow data for flow routing.

Another way to check the continuity of flow between sections is by comparing the flows in the three flow elements (QLOB, QCH, QROB) from section to section. An alternative approach is to look at the percentage of flow (QLOBP, QCHP, QROBP). Flow distribution should not vary too greatly from one cross section to the next. It would be unreasonable for seventy percent of the flow to be in the left overbank portion of one cross section and none of the flow in the left overbank of an adjacent section. If that occurs because of ponding, then that area should not be included in the conveyance calculations. The effective area option, IEARA (X3.10 = 10), is often used to eliminate ineffective overbank areas from conveyance calculations.

Review the energy loss computation. A good variable to review, from section to section, is the energy slope (SLOPE). The slope is very sensitive to changes in conveyance. No matter which method is used for averaging energy slope between sections, the change of slope between sections should not be too large. If, from one cross section to the next one upstream, SLOPE decreases by more than fifty percent, or increases by more than one hundred percent, the reach length may be too long for accurate determination of energy losses. Adding more cross sections would be advisable.

The **conveyance for a section (.01K)** is also a good variable to review, in the manner described above for SLOPE. The conveyance ratio between upstream to downstream cross sections is provided by variable KRATIO. The 1988 version of HEC-2 provides a warning message if KRATIO is less than 0.7 or greater than 1.4. Additional cross sections should be added when the ratio is outside this range and the length between the sections is large. In some cases, such as near structures, this warning may be generated yet the solution may be valid; the engineer performing the application must make the final judgement.

The review of summary output often raises a number of questions. The sequential output file should be examined to determine the reasons for the observed inconsistencies. The review process must answer the "why did it happen" and "is it reasonable" questions.

The **Special Notes** should all be reviewed. Often they will provide clues to computational problems.

Critical Depth solutions should be examined. The program will often revert to a critical depth solution when the computation process cannot find a balance between the assumed and computed water surface elevation. Many times this is a result of large changes in conveyance between cross sections that are too far apart. The usual solution is to add more cross sections. Also, there is an option (J6.1) to have the program select the equation for computing the friction losses based on the flow conditions. Sometimes this approach will provide a solution balance, but it is not a substitute for a sufficient number of cross sections.

Interpolated cross sections should be carefully reviewed. Using the program option (J1.7) for providing interpolated cross sections is generally discouraged. The interpolated section is only provided when the change in velocity head between sections exceeds the given value for HVINS. This means that there may be interpolated sections in one profile and not in the next. The interpolated sections will be based on the current given section adjusted in elevation and width-based change in elevation between the two sections and the area ratios for the channel portion of the cross sections. Sometimes the adjustments are not reasonable. It is generally recommended that interpolated sections be inserted by the user.

Check the **velocities** in the cross sections. Very high velocities and large changes in velocities between sections may indicate problems with the model data. Are the velocities shown realistic for the study reach?

Review every bridge solution carefully. The sequential cross section output displays are the most complete presentation of the bridge solution. The HEC-2 predefined Tables 100 and 105 are helpful for a summary table review of special bridge solutions. Table 100 provides the variables associated with the energy loss computations at the special bridge. Table 105 provides the distribution of flow and energy losses for the four cross sections in the vicinity of the special bridge. Both tables will provide the information for every special bridge in the data set.

Special Bridge results in the sequential cross section output should be reviewed for the transition of flow up to and away from the bridge. The computation sequence and total structural losses, computed within the special bridge routine, should be reviewed. Appendix IV, in the HEC-2 User's Manual, describes the application of the bridge routines. Program users should be familiar with the material in that text. In Appendix IV, "Figure 3. Special Bridge Method General Logic Diagram", shows the solution process. By following the diagram, the special bridge solution can be traced. If there is a problem with the solution, the basis for the critical decision in the routine and the necessary input changes to alter the solution can be determined.

Normal Bridge solutions need to be carefully reviewed too. The bridge is processed as a cross section, and the output is essentially the same as any other section in the sequential output. There are no checks for pressure or weir flow conditions. Therefore, the user must carefully review the solution with respect to the water surface elevation and where it is within the bridge. The program distributes flow in the section based on the distribution of conveyance. The computed water surface elevation could be within the bridge or over the bridge deck. No special notes or messages are provided to indicate the pressure or weir flow condition.

Look at the input data first for the source of errors. If the data ran before, assume that some change you made caused the problem you see. With the input and editing process, it is easy to make mistakes. If there is a read error, look at your input file with program LIST. It will show illegal characters. Look at the input listing from HEC-2. That shows what the program used for the solution at hand. While a program error is possible, usually the source of your errors is in that listing.

Sketch the cross sections and the computed flow path on a topographic map. This will give a general picture of the model results. It is also a convenient way of checking the output from the program, by comparing it with the map representation of the study reach.

The program user should **treat the input data for the study reach as an initial model.** It is reasonable to expect several iterations before the data are properly assembled. The first level is usually based on the physical nature of the study reach. The basic input errors should be mostly found by the EDIT2 program. Then the HEC-2 results are reviewed for consistency and reasonable results. The initial model was based on the expected flow of water through the study reach. Sometimes the results are not consistent with the initial assumption. The model then must be redefined to reflect the added information gained from the initial results.

Chapter 8

Creating Summary Output Tables

Summary tables offer the advantage of presenting the computed results from HEC-2 multiple water surface profiles all together for each cross section. If a range of discharges were used, or if profiles were computed for before and after conditions in the reach, the summary tables provide a convenient display for comparing the computed results for all those profiles.

8.1 Purpose of SUMPO Program

Computer program SUMPO is a separate version of the summary printout routines from HEC-2. All the basic capability of the HEC-2 program summary output can be obtained from the binary HEC-2 output file TAPE95. The program is menu driven to provide convenient interactive access to TAPE95 results.

The two basic capabilities in SUMPO are: (1) selecting a standard HEC-2 defined summary table (as described in the J3 record description) and (2) creating summary tables by defining the variables to display in the table. The program also allows the user to store the created summary table variable lists for future use. With this capability, the user can create, store, and recall variable lists for frequently used summary tables.

8.2 Program Operation

To run program SUMPO you must first run HEC-2. HEC-2 produces the binary output file, TAPE95, which is the input data file for SUMPO. TAPE95 is the default filename from HEC-2, but a different filename can be provided when running HEC-2 (see Chapter 6).

In MENU2, call SUMPO by moving the cursor to "**3. Run HEC2**", and press the space bar until you see "**3. Run SUMPO**"; then press **<ENTER>**. The TAPE95 file name will be transferred to SUMPO. With the automatic extension feature in MENU2, the "given name" plus the extension "**.T95**" will be used.

If you have not assigned a filename to TAPE95, you can rename it before you run HEC-2 again because each HEC-2 execution will write over the information on TAPE95. To change the filename, use the DOS RENAME or COPY command (e.g., COPY [d:][path] TAPE95 [d:][path]MYJOB.T95).

To execute SUMPO as a separate program, from the DOS prompt enter:

SUMPO

The program will respond with the SUMPO menu. The menu, shown in Figure 8, allows you to: 1) Define files and printer width, 2) Select pre-defined summary tables, 3) Create Summary tables, 4) Display output to console/printer, and 5) Exit SUMPO. To make a selection, use the **<Up>** or **<Down Arrows>** to move the cursor and press **<ENTER>**, or enter the line number. (The instructions are printed at the bottom of the menu frame.)

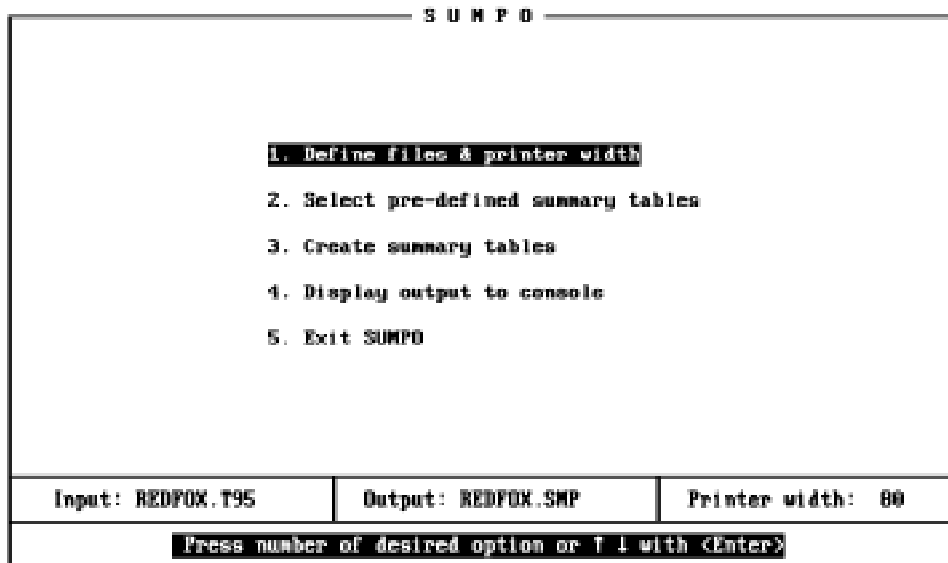


Figure 8
SUMPO Main Menu

The **background and text color can be changed by using the <F9> and <F10>** keys, respectively, to toggle through the color choices. The screen color will change as you go through the choices so you can see the choice. The defaults for files are: TAPE95 for the input file, CON (console) for the output file, and 80 for the printer width. The files and printer width setting are shown at the bottom of the menu. **If you are running SUMPO from MENU2, the screen colors and filenames will be transferred to SUMPO.**

To change the files or printer width, press **<ENTER>** while the cursor is on line "1. Define files & printer width", or enter **<1>**. A window will appear with **Input file, Output file, Printer width, and Return to menu** (see Figure 9). For **Input file** the default, TAPE95, can be changed by entering the desired file name or a **<?>** and **<ENTER>**. With the **<?>** entry, a window will appear showing the files in the default directory. Use the cursor key to move to the desired file name, and press **<ENTER>**; the selected file will be transferred opposite the **Input file**.

For **output file**, the automatic extension option assigns **".SMP"** to the filename. This prevents writing summary tables over the HEC-2 printed output file, which has the extension of **.OUT**. SUMPO provides the MENU2 output display capability with LIST and PROUT. Therefore, it is better to write summary tables to an output file instead of "CON" and "LPT1" for a filename. To make a selection, use the cursor arrows to move the cursor to **output file** in the menu, and enter the new name or **<?>**. As described above, the **<?>** will cause the files in the directory to be displayed, and the desired file can be selected by moving the cursor to the filename and pressing **<ENTER>**. Remember to include the drive and path, if necessary.

Printer width can be defined as eighty or 132 columns. Move the cursor to that line, and use the space bar to toggle between the two choices. The choice depends on your printer size and setting. (Note: This does not change the printer; printer settings must be made directly with the printer.)

When the filenames and printer width are correct, move the cursor to **Return to Menu**, and press **<ENTER>**. The window will vanish, and the new settings will be shown at the bottom of the menu.

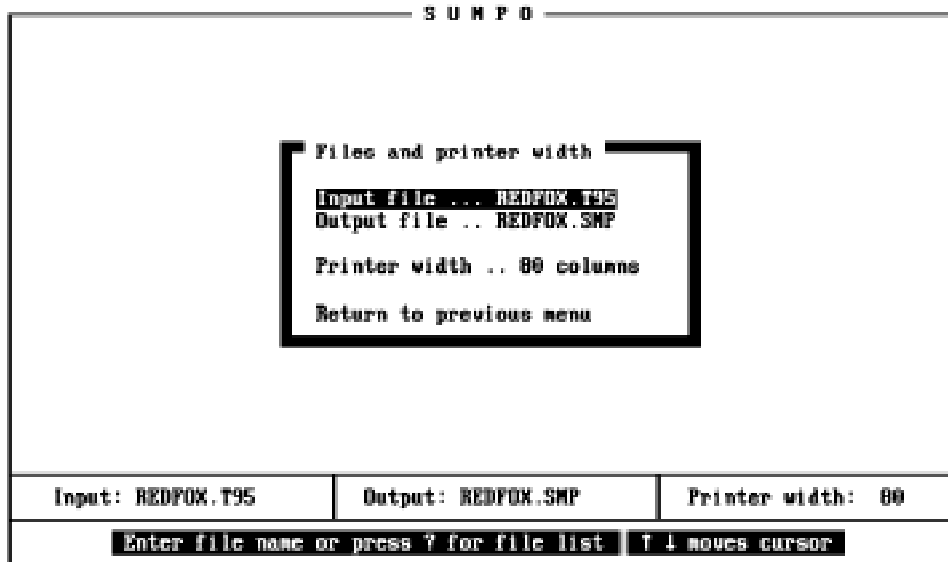


Figure 9
SUMPO Define Files and Printer Width Menu

From the main menu you can go to menus for "2. **Select pre-defined summary tables**" or "3. **Create summary tables**", which are the two options available in SUMPO. If you want one of the HEC-2 pre-defined tables, described in the HEC-2 User's Manual Input Description for the J3 record, move the cursor to "2. **Select pre-defined summary tables**", and press **<ENTER>**, or enter **<2>**. If you want to create a summary table by selecting the variables to be displayed in the table, move the cursor to "3. **Create summary tables**", and press **<ENTER>**, or enter **<3>**. To exit the program and return to DOS or MENU2, move the cursor to "5. **Exit SUMPO**", and press **<ENTER>**, or enter **<5>**.

8.3 Select Pre-Defined Summary Tables

The pre-defined summary tables menu provides the HEC-2 pre-defined summary tables. The HEC-2 User's Manual Input Description for the J3 record lists the available tables, which are the same as those provided in the Menu, shown in Figure 10. The tables are defined by a single code number that calls the variable list within HEC-2 and SUMPO.

To select a table, use the **<Up>** or **<Down Arrows>** to move the cursor to the code number desired, and press **<ENTER>**. **If the input data file is not properly defined, the program will respond:**

**File does not exist -- [filename]
press <ESC>**

With this response, press the **<ESC>** key and return to the main menu to redefine the input filename. The file may not have been located because the default drive is not the same as the drive where the input file is located. If that is the problem, redefine the input filename, making sure that the drive and path for the file has been correctly specified (e.g., [d:] [path] TAPE95). If you cannot see the problem, exit the program, and use the DOS DIRECTORY command to check the filenames (e.g., DIR [d:] [path]).

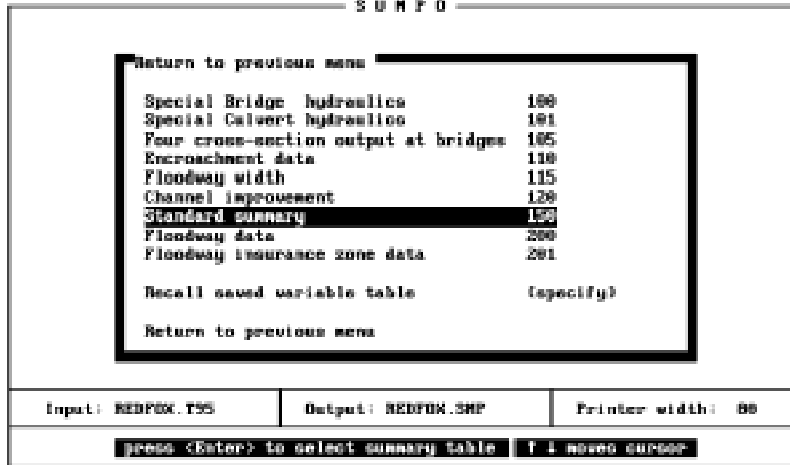


Figure 10
Pre-Defined Summary Tables Menu

After the data file has been read, for those tables that normally list all cross sections, the program will respond:

Output all cross sections (y/n) ?

If output for all cross sections is desired, press the **<y>** key. If limited output is desired, press the **<n>** key, and the Cross Section Selections Menu will appear, shown in Figure 11.

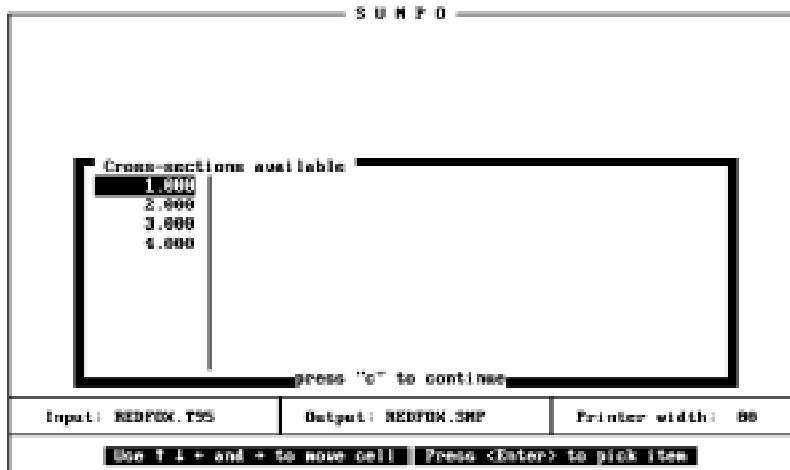


Figure 11
SUMPO Cross-Section Selection Menu

The cursor location is indicated by the highlighted section number. To select the cross sections to be used in the summary table, move the cursor to the desired section numbers, and press **<ENTER>**. The selected section numbers will have a pointer on them. When all the desired section numbers to be printed have been selected, press the letter **<C>** to continue. The program will respond:

Output all profiles (y/n) ?

If output for all profiles is desired, press the letter **<y>**. If only some of the profiles are desired, press the letter **<n>**. The program will display the Profile Selection Menu; see Figure 12.

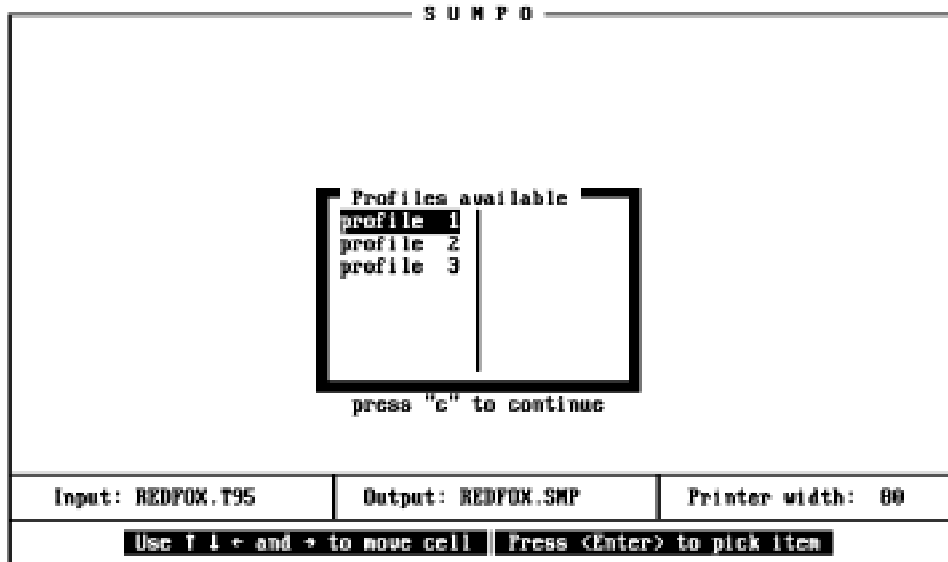


Figure 12
SUMPO Profile Selection Menu

As

with the cross-section selection, the cursor location is indicated by the blinking profile number. Move the cursor to the profile numbers desired, and press **<ENTER>**. The selected profile numbers will remain highlighted. When the desired selections have been made, press the letter **<C>** to continue. The program will respond:

Include summary errors in output (y/n)?

The summary of errors provides error messages for those cross sections that had some computation problem. Enter **<y>** for the messages (the recommended choice), or **<n>** for no messages. The program will respond:

Append output to output file (y/n)?

A **<y>** entry will add the current summary table to the end of the existing output file. A **<n>** entry will write the current summary table over the existing output in the file. This choice allows you to add to or delete the previous summary information in the file. The program will then respond:

```
----- SUMPO ready to output ---  
* press <ENTER> to continue  
* press <ESC> to abandon output
```


This gives you the option to stop the process, <ESC> and make another choice. Press <ENTER> and the summary table will be written to the designated output file. When complete, the main menu is displayed, and the cursor is located on "4. Display output to console". This provides for a review of the summary table with program LIST, or press the space bar to toggle the choice to "4. Display output to printer".

The pre-defined summary tables menu (shown in Figure 10) also has an option; "Recall saved variables". This option provides a user-defined, variable list file created and saved with the create summary tables option. Section 8.4, below, provides a description of the SUMPO create table menu and instructions for the available options.

8.4 Create Summary Tables

The SUMPO create table menu provides the output variables available for you to create a summary table. See Figure 13 for an example of the menu. User defined tables are created in two steps. First, the variables desired are selected. The selected variables are shown at the top of the Menu, in the section labeled "Selected Variables". There will be indicator bars for the undefined variables and positions for up to eight or thirteen possible variables in a table, depending on the page width defined in the main menu. The second step is the actual writing of the summary table to the designated output filename.

SUMPO									
Selected variables		Available variables							
SECNO	CWSEL								
SECNO	DEPTH	CWSEL	CRWS	WSELX	EG	HU	HL	QLOSS	CLASS
Q	QLOB	QCH	QROB	TOPWID	AREA	TWA	VOL	XLBEL	RBEL
TIME	ULOB	ULCH	UROB	K-XNL	K-XMCH	K-XNR	K-WTH	STCHL	STCHR
10+KS	K-CHSL	XLCH	PERENC	STENCL	ELENCL	STENCR	ELENCR	SSTA	ENDST
ALPHA	QLOBP	QCHP	QROBP	BM	CLSTA	VEKR	VEKT	ELMTH	TELMX
0.0LK	KRATIO	DIFWSX	DIFWSF	DIFWS	DIFEG	CASE	INLEQ	CUMDS	SHEAR
H3	EGLMC	EGPRS	QFR	QWEIR	ELLC	ELTRD	FRCH	POWER	
TH1	NICE1	XSTAB1	XFCH1	ZINCH	TVOLI	VOLIL	VOLIR	VOLICH	NICE
ZITL	ZITR	ZITC							
a	O - Output summary data								
e	S - Save selected variables								
n	R - Recall saved variables								
u	X - eXit to previous menu								
Input: REDFOX.T95			Output: REDFOX.SMP			Printer width: 80			
<Enter> to select variable <Ctrl> ++ to change field Tl=> moves cell									

Figure 13
SUMPO Create Table Menu

To select a variable for the summary table, use the cursor keys to move among the "Available variables", and press <ENTER> when the desired variable is highlighted. For example, to select SECNO, press <ENTER> when it is highlighted, and SECNO will appear in the "Selected variables" list. The highlighted location marker in the "Selected variables" will automatically advance to the next position in the list. Continue to use the cursor arrow keys to move the cursor through the array of variables, and press <ENTER> when the cursor is on the desired variable. Each selected variable will appear in the "Selected variables" list, and the highlighted location marker will continue to advance to the next position in the list.

If you make a mistake and want to change a variable in the "**Selected variables**" list, hold the **<CTRL>** (control key) , and use the **<Left>** or **<Right Arrow>** keys to move the highlighted position marker in the "**Selected variables**" list. (The program will not allow you to move the cursor beyond locations of defined variables, which could leave blanks in the summary table.) When the position marker is over the variable you want to change, release the **<CTRL>**, and use the arrow keys to move the cursor to the desired variable in the "**Available variables**" array and press **<ENTER>**. The selected variable will replace the highlighted variable in the "**Selected variables**" list.

Below the "**Available variables**" array there is a selection menu that provides options to: Output summary data, enter **<O>**; Save selected variables, enter **<S>**; Recall saved variables, enter **<R>**; make Ice variable table available, enter **<I>**; and eXit to previous menu, enter **<X>**. All these options are called by pressing the letter associated with the option. Each option is described in the following paragraphs.

Once you have selected the variables you want for your summary table, simply press the letter **<O>**. The program will respond with the same series of questions:

Output all cross sections (y/n)?
Output all profiles (y/n)?
Include summary errors in output (y/n)?
Append output to output file (y/n)?

After you have entered the desired response to the questions, the program will respond:

----- **SUMPO ready to output ---**
* **press <ENTER> to continue**
* **press <ESC> to abandon output**

This gives you the option to stop the process, **<ESC>** and make another choice. If you press **<ENTER>**, the summary table will be written to the location defined as the "Output File" in the main menu. Then the main menu will appear, and the cursor will be on "**4. Display output to the console**". Press **<ENTER>**, and the output file will be displayed with program LIST.

If you want to save a variable list for future use in generating summary tables, press the letter **<S>**. The menu will prompt you:

File to Save to -

Enter the filename desired; the program will add the extension ".**VAR**". On a hard disk system, it is best to save the file in the default directory; otherwise, include the appropriate drive and path, if you do not want the default drive (e.g., A:TABLE1). The saved file will contain the code number and the variable name for the variables selected. The file can be displayed on the screen from the DOS prompt, as any text file, using the DOS TYPE command, or the program LIST.

To recall a saved file of variables in SUMPO, press the letter **<R>**. The program will respond:

File to Read from -

Enter the filename (e.g., A:TABLE1) or a question mark **<?>**. With the **<?>** entry, a window will appear showing the files in the default directory with the **.VAR** extension, as shown in Figure 14. Move the cursor to the desired filename, and press **<ENTER>** to select the file. Once entered, the variables from the file will be displayed in the "**Selected variables**" section of the menu. If there are more variables than positions (e.g., thirteen variables and only eighty columns for output), only the first variables of the list will be included.

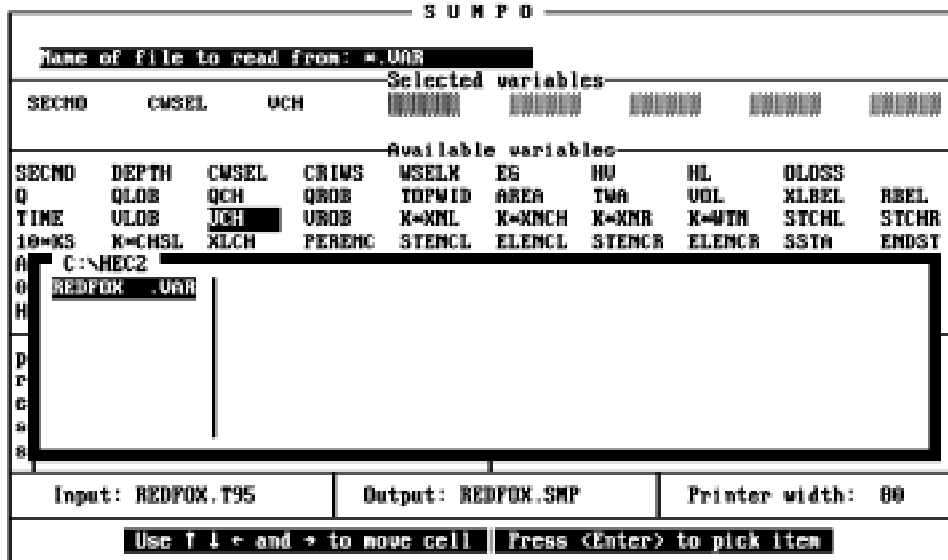


Figure 14
SUMPO Saved Variables Menu

The variables listed in the **"Selected variables"** list can be edited by moving the cursor (using the **<CTRL>** key and arrows) to the variable to be changed. Then move the cursor to the variable desired, and press **<ENTER>**. Changing the variables in the **"Selected variables"** list will alter the variables written to summary output, but it will not change the variables list saved on the disk. To transfer the new variables list to the saved file, the variables must be written to a file again (i.e., enter **<R>** and then enter the same file name to write over the old file, or enter a new file name to save the modified list of selected variables separate from the original).

Ice variables are not frequently used, so they were not included with the variables array. By pressing the letter **<I>**, the ice variables are displayed in the empty box area, in the lower right of the create table menu; see Figure 13. When the **"Ice variables"** are displayed, the cursor will only operate within the lower box. The variables selection process, described above, is the same except now the ice variables are selected. To return to the variables array again, simply press the letter **<I>** again. The ice option operates as an on/off switch.

To return to the main menu, enter the letter **<X>**. The Escape Key **<ESC>** can also be used.

To exit the SUMPO program and return to DOS, or MENU2, move the cursor to **"5. Exit SUMPO"** in the main menu, and press **<ENTER>**.

Chapter 9

Plotting with PLOT2

Graphical displays are often the most effective method of presenting input data and computed results. Plots of the cross-sectional data can often provide helpful information for screening the input and for analysis of computed results. Profile plots of water surface elevation, or other variables, provide an overview of the results, distributed over the study reach in a way that tables of numbers cannot. The following chapter describes the capabilities of the PLOT2 program and the procedures for obtaining graphical displays of HEC-2 cross sections, computed profiles, and rating curves.

9.1 Purpose of PLOT2 Program

Computer program PLOT2 was developed to provide a quick and simple graphical display of cross-sectional data and computed results from HEC-2. The PLOT2 program provides the capability to plot cross-sectional data, including the changes to the section caused by the HEC-2 options that modify section data. Also, profiles and rating curves of the output variables, available on TAPE95, can be plotted. Default settings for options allow plotting with a minimum of effort. Plots can be displayed on the screen or directed to an HP 7475A (or equivalent) pen plotter. Screen displays of plots can be printed on DOS GRAPHICS compatible printers using the print screen <PrtSc> option. Files can also be created for use by word processors. The program was developed using GRAPHMATIC and PLOTMATIC subroutines by Microcompatibles, Inc.

9.2 Program Operation

Cross section plots can be developed from HEC-2 input data files. For cross section plots, the water surface elevation can also be plotted from the HEC-2 computed results on TAPE95. Profile plots and rating curves are developed from the TAPE95 file; therefore, **you must first run HEC-2 before plotting profiles with PLOT2.**

PLOT2 is called from MENU2 by moving the cursor to line **3.** and pressing the <SPACE BAR> until **Run PLOT2** is displayed; then press <ENTER>. To execute PLOT2 as a separate program, from the DOS prompt enter:

PLOT2

The program will respond with a PLOT2 Title Page. Press any key and the PLOT2 Menu will appear; see Figure 15. The PLOT2 Menu allows you to call the menus for the Profile, Cross-section, or Rating Curve plot routines. The up and down arrows move the cursor through the options. Pressing the <ENTER> key selects the highlighted option. Also, the number of the option can be entered to make a selection. The screen colors can be changed by using the function keys F9 and F10 for background and foreground colors, respectively.



Figure 15
PLOT2 Main Menu

9.3 Output Devices

The graphic displays from PLOT2 can be directed to the screen or an HP 7475A pen plotter. Either of the following graphics cards (or their equivalent) is required: Color Graphics Adapter, or Enhanced Color Graphics Adapter, or Video Graphics Array. The plot device is set in the Plotting Options Menu, which can be called from the Profile, Cross-section, or Rating curve Menus (see Figure 19). The options are selected by using the <SPACE BAR> to toggle through the **Plot device** options. The choices are:

VIDEO GRAPHICS ARRAY
ENHANCED GRAPHICS ADAPTER
COLOR GRAPHICS ADAPTER for the console

and: **HP7470, 7475, 7550, 7580, 7585/86 Series Plotters**

A printed copy of the plot on the screen can be obtained, provided your printer is set to graphics mode. For IBM Graphics compatible printers, use the DOS **GRAPHICS** command prior to executing PLOT2. Also, there are several commercial programs to set your printer to graphics mode for high resolution graphics. Then generate the desired plot on the screen, and use the Print Screen <PrtSc> entry on your keyboard to copy the plot on your printer.

9.4 Pen Plotter Setup

Pen plotter graphics are directed to the plotter via COM1. The output port can be changed in the Plotting Options Menu by setting the **Plot device** to HP7475A and then moving the cursor to **Plot sent to** and using the <SPACE BAR> to toggle through the choices: two COM ports (COM1 or COM2) or an output file PLOT.HP. The PLOT.HP file allows you to create the plots on a computer without a plotter, and then transfer the file to another computer for plotting. Also, the plotter **Baud rate** default setting of 2400 can be set from 1200 to 9600. Just before the plots are written, the switch settings are displayed to the screen; see Figure 16. Press the <SPACE BAR> to plot, or press <Esc> to cancel the plot.

The plot operation uses PLOTMATIC routines from Microcompatibles, Inc. The following instructions for the printer settings are from their documentation. The plotter can be switched for certain parameters (e.g., BAUD rate, length of word, parity, programmed on state, paper dimensions) on the rear panel of the plotter, as described in the Operator's Manual. The switches should be set for a 2400 BAUD transmission rate, 8 bit word, one stop bit, no parity, programmed on state (Y/D switch set to D), and the US - A4 switch should be set to US (indicating 8.5 X 11 inch paper). The A4 size paper can still be used with your plotter even with the dip switch set to US. This switch just defines the active plotting region. Review the Operator's Manual for switch selection, and insure that the specified choices have been made.

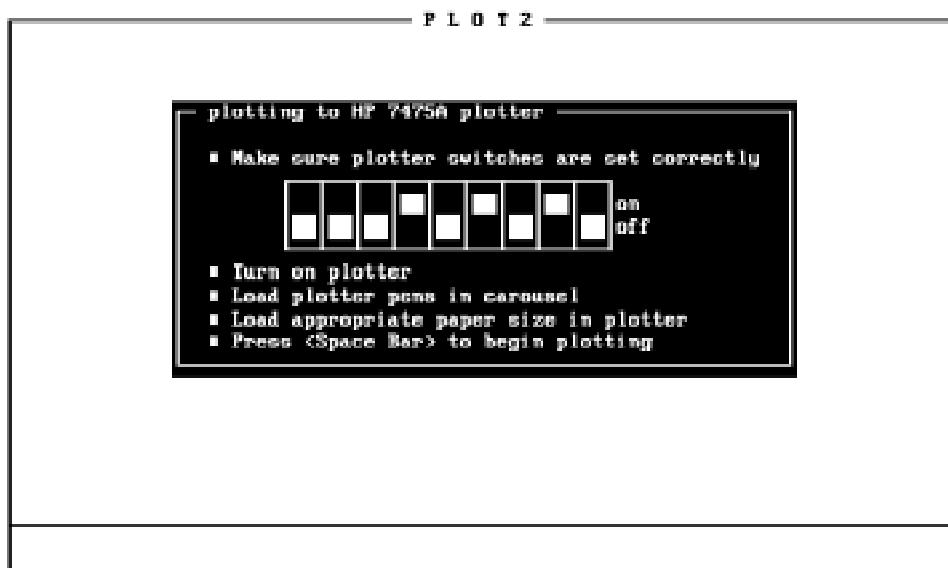


Figure 16
Pen Plotter Switch Setting

9.5 Profile Plots

Profile plots can be developed for any of the variables written to TAPE95. The default settings in the menus for profile plots assume that water surface profiles will be plotted. To develop profile plots, move the cursor to **1. Plot profiles** in the Main Menu, and press <ENTER>, or enter <1>. The Profile Plots Menu, shown in Figure 17, will appear.



Figure 17
PLOT2 Profile Plots Menu

In the **Profile Plots Menu**, **Profile options** and **Plotting options** provide menus to specify what will be plotted, what options will be used, and to title and label your plot. The menus are called by moving the cursor to the choice desired and pressing <ENTER>. The menu for **Profile options** is shown in Figure 18, and the menu for **Plotting options** is shown in Figure 19.

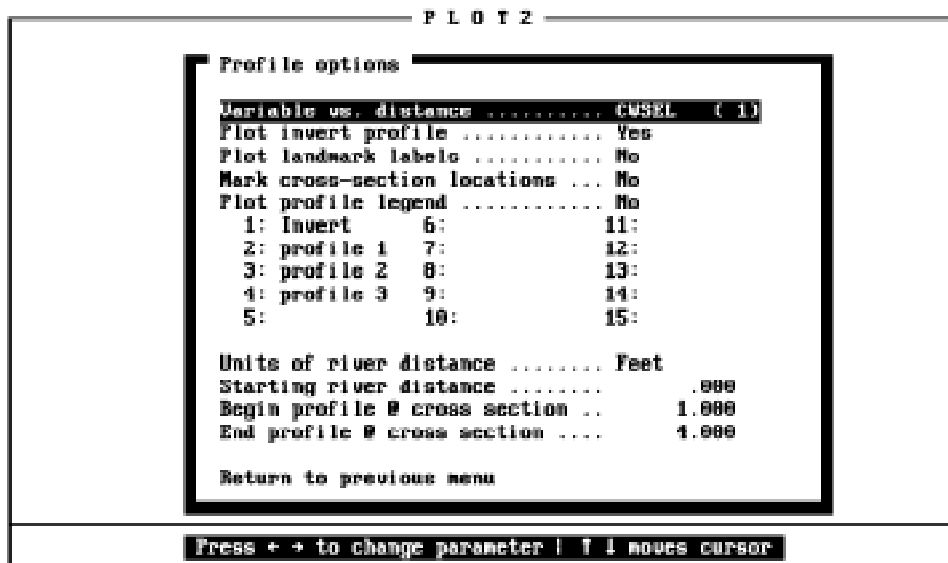


Figure 18
PLOT2 Profile Options Menu

There are two files indicated at the bottom of the Profile Plots Menu. The **HEC2 TAPE95 file name** is the HEC-2 program intermediate output file TAPE95, which is the input file for Profile Plots. The file name can be changed by entering a new file name in its place, or by entering a question mark <?>. The question mark entry will provide a menu of file names in the default directory. Use the cursor keys to highlight the desired file, and press <ENTER>. The selected file name will transfer into the Menu location. The **Landmark Label filename** has no default value. If this option is requested (see Figure 18. PLOT2 Profile Options Menu), then the file name must be entered.

The input file names should be defined before entering either options menu because data are obtained from the HEC-2 binary file to define default values for several options. To enter the **Profile options**, move the cursor to that location, and press <ENTER>.

The first line in the Profile Options Menu is for selecting the **Variable vs. distance** to plot. The default variable for this selection is CWSEL for Computed Water Surface Elevation. The variable code number is (1), as defined in the HEC-2 User's Manual Input description for the J3 record. To select a different variable to plot, the right and left cursor arrows may be used to toggle through the entire list of variables available. The variable name and code number are displayed for each variable.

Once the desired variable to plot is displayed, the up and down cursor keys can be used to move through the options in the menu. The **Plot invert profile** option has a default choice of **Yes**, which means that the invert profile will be plotted with the profile plot of the selected variable.

The **Plot landmark labels** option has a default choice of **No**. To change these options, move the cursor to the option, and use the <SPACE BAR> to toggle the choices between **Yes** and **No**.

The landmark label requires a file containing: distance, variable code number, and label. An example of the landmark file is shown below:

4000 1	{Distance Variable}
UNKNOWN BRIDGE	{Label to display}
6000 1	{Distance Variable}
USGS GAGE	{Label to display}

This file can be created with any text editor.

Mark cross section locations option has a default value of **No**. You can toggle to **Mark** or **Mark & number** using the <SPACE BAR> while the option is highlighted. The profile plot will then show arrow marks, or marks and numbers, at cross section locations.

Plot profile legend has a default value of **No**. If legends for the profile plots are desired, move the cursor to that option, and press the <SPACE BAR> to change the option to **Yes**. The cursor keys can then move the cursor to profile 1:, etc. At each location enter the appropriate legend; up to eight characters are allowed. If the **Plot invert profile** option is set to **Yes**, the legend label **Invert** will be shown for the first profile.

The **Units of river distance** has a default value of **Feet**; but this can be changed to **Miles**, **Meters**, or **Kilometers** using the <SPACE BAR> to toggle through the choices. The 1988 version of HEC-2 reads the units and starting distance, if given, on TAPE95.

Starting river distance is set to **0.000**. A different starting value can be entered. The entered value is added to the channel reach lengths to define the horizontal distance along the profile plot. Care should be taken to ensure that the **Units of river distance** and **Starting river distance** are consistent with the units used for the model reach lengths.

Begin profile @ cross section and **End profile @ cross section** options have the starting and ending cross section numbers for the data set (SECNO on the X1). The values are read from the binary output file, TAPE95. The default values provide a plot for the entire study reach. The starting and ending section numbers for the profile plot can be changed by using the vertical cursor arrow keys to the option and then using the horizontal cursor arrow keys to toggle through the section numbers. The program will not allow the starting section number to be equal, or upstream from the ending section number.

After all the profile options have been set, move the cursor to **Return to previous menu** and press <ENTER>. The **Profiles Plots Menu** will be displayed. The second option on the menu is **Plotting options**. Move the cursor to that option, and press <ENTER>. The Plotting Options Menu, shown in Figure 19, provides for two titles on the plot. The **Title 1**: displays the title information input on the third title record (T3), as read from TAPE95. The title can be edited, or replaced, depending on the insert mode setting; press <Ins> to change from insert to overwrite. **Title 2**: allows you to enter a second title.

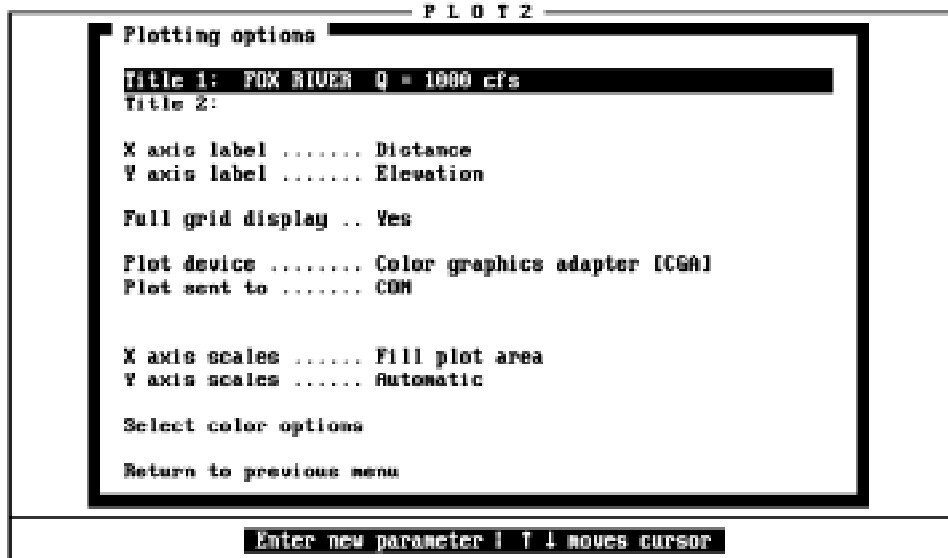


Figure 19
PLOT2 Plotting Options Menu

If the plot axes need a different label, move the cursor to the appropriate axis and enter, or edit, the label. A plotted grid can be added to the plot by moving the cursor to **Full grid display** and pressing the <Space Bar> to change the **No** to **Yes**.

The **Plot device** can be changed, as described in Section 9.3. For screen displays, the correct graphics adapter for your computer should be displayed. If it is not correct, the screen plot will appear as assorted characters. If an HP pen plotter is selected as the plot device, the **Plot sent to** will display **COM1**, the default. The output port can be toggled to **COM2**, by using the <SPACE BAR>. Also, a file **PLOT.HP** can be selected.

The **X axis scales** default is **Fill plot area**, while the **Y axis scales** are set to **Automatic** for each plot. Press the <SPACE BAR>, and the following options are provided: scales set to 1, 2, or 5 times a power of 10, Fill plot area, and Max scale for all. Fill plot area would normally be used for one scale while fixing the other scale. Max scale for all provides a fixed scale based on the maximum range of the data values.

Select color options provides a menu to set the pen number for pen plots and the line colors for **EGA color screen** displays. The **Color options** menu is shown in Figure 20. For profile plots, the options are for the Text, Axis, and the profiles to be plotted.

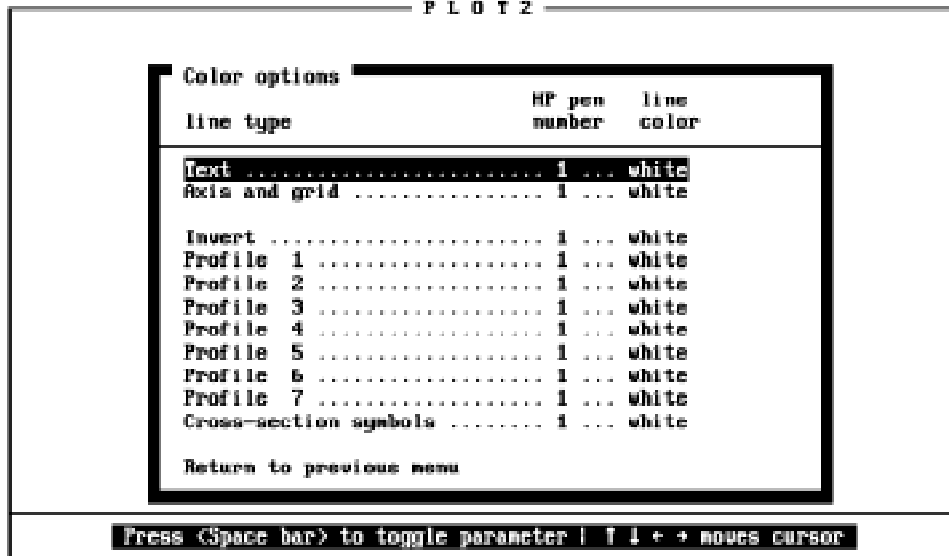


Figure 20
PLOT2 Profile Colors Options Menu

When complete, move the cursor to **Return to previous menu** and press <ENTER>. The Escape Key <Esc> will also return you to the previous menu. The Profile Plots Menu, shown in Figure 17, will be displayed.

When all desired options are set, move the cursor to **Plot profiles** to initiate the plot. The program will respond:

Plot all profiles (y/n)?

If yes, enter <y>, and the plot will go to the plot device defined in the Plotting Options Menu. If no, enter <n>, and a profile selection menu, as shown in Figure 21, will appear indicating the profiles available. The cursor location highlights the profile number. Use the cursor arrow keys to move through the choices, and press <ENTER> to select profile numbers to plot. The selected profile numbers will show an arrow marker. After selecting the desired profiles, press <c> to continue the plot.

If the **Plot profile legend** option was selected, a choice between the legend at the top or bottom of the plot is offered with the following:

Legend box top or bottom (t/b)

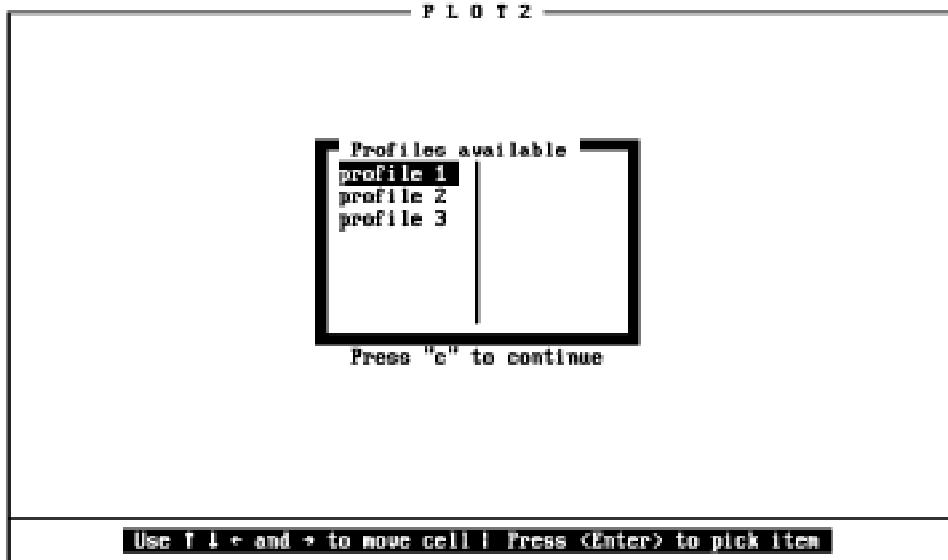


Figure 21
Profile Selection Menu

Enter your choice, and then the plot will be sent to the designate output device. If the plot is displayed to the screen, it will stay there until you press <ENTER>. If you want to copy the plot to your printer, press the Print Screen key <PrtSc> while the plot is on the screen. **Remember that you must enter the DOS GRAPHICS command** before entering PLOT2. Check your DOS manual, the GRAPHICS command may be limited to CGA graphics. Figure 22 provides an example EGA graphics profile plot, with the legend on top.

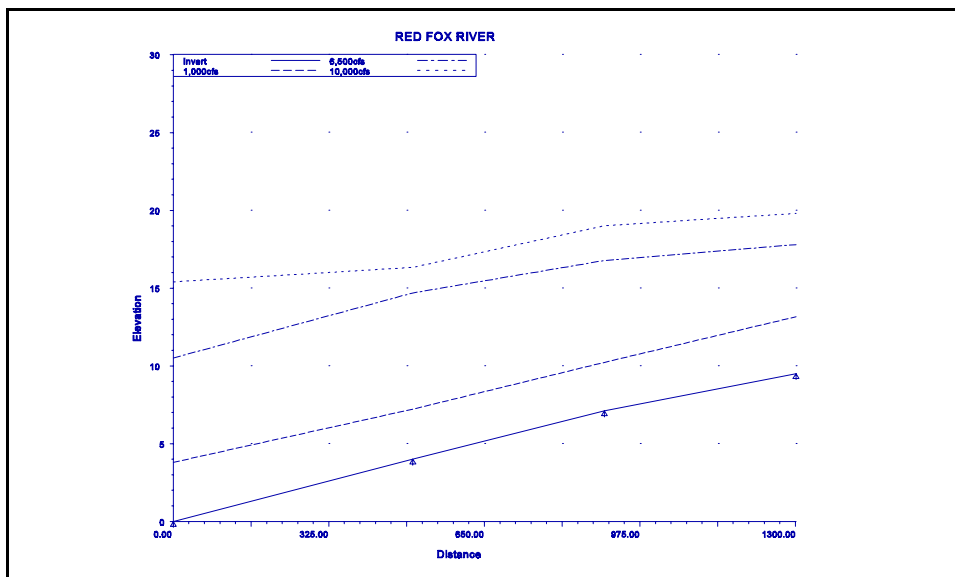


Figure 22
Example Profile Plot

When you have completed all the desired profile plots, return to the Main Menu by moving the cursor to that location and pressing <ENTER>. The Escape Key <Esc> will also return you to the Main Menu.

From the Main Menu, you can call cross-section plots or exit the program.

9.6 Cross-Section Plots

You enter cross-section plots from the Main Menu by moving the cursor to **2. Plot cross sections** and pressing <ENTER>, or by entering <2>. A sample **Cross-Section Plots Menu** is shown in Figure 23. From the menu you can call menus to define **Cross-section options** and **Plotting options**.

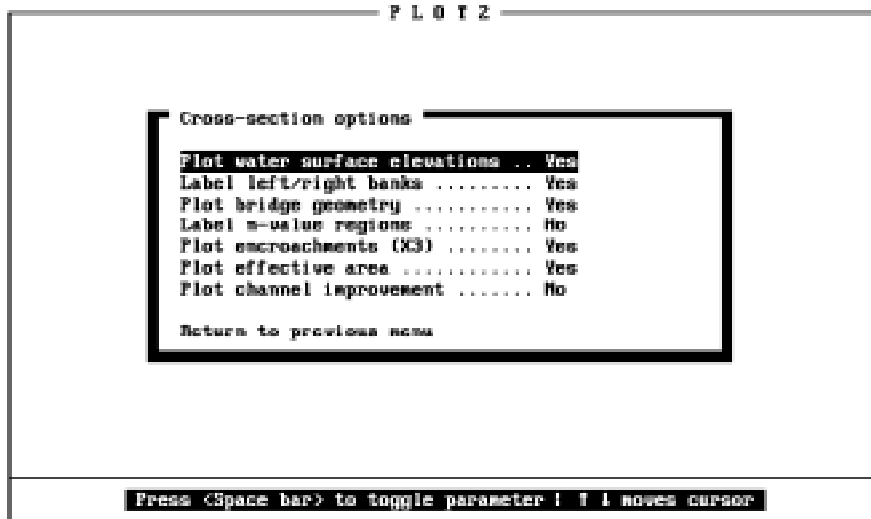
The **HEC2 input file name** must be entered for cross-section plots. There is no default; the menu will display **(specify)**. (If you are operating from MENU2, the file names will be transferred to PLOT2.) The input file name can be entered from the keyboard or a question mark <?> can be entered. The question mark entry will provide a menu with the file names available in the directory. The cursor keys will move the cursor around the file names, and pressing <ENTER> will transfer the highlighted filename into the menu.

The **HEC2 Tape95 file name** is only required if the water surface elevation is to be plotted with the cross section. The default file name, TAPE95, can be changed, as described above for the input file name.



Figure 23
PLOT2 Cross-Section Plots Menu

Move the cursor to: **Cross-section options**, and press <ENTER> to select the items to plot. The **Cross-section Options Menu** is shown, with the default settings, in Figure 24. Use the up and down cursor keys to select an option, and press the <SPACE BAR> to toggle between **Yes** and **No**.

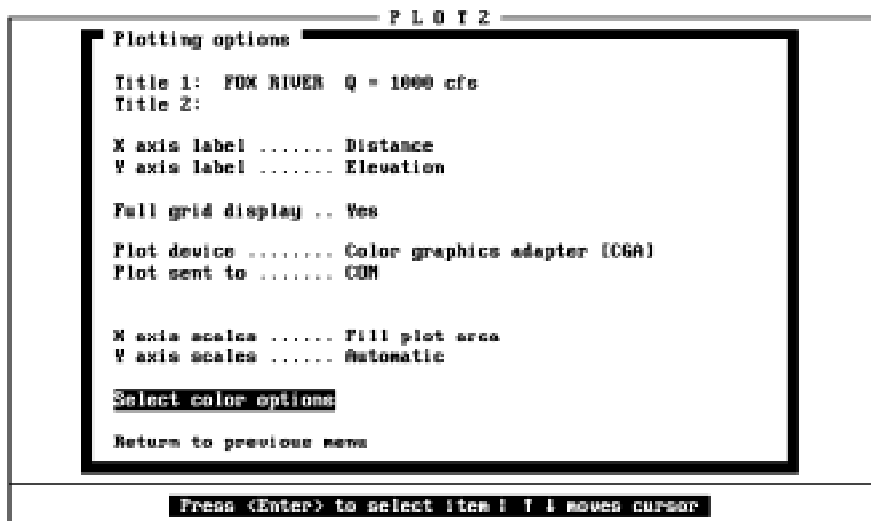


**Figure 24
PLOT2 Cross-Section Options Menu**

If channel improvement is to be plotted, there are five choices: Field 6 to Field 10. The field number defines the field of the CI record to obtain bottom width information. (See HEC-2 Input Description for the CI record for a complete description.)

When the plotting options are properly set, move the cursor to **Return to previous menu**, and press <ENTER>. Pressing <Esc> will also return you to the **Cross-section plots** menu.

In the **Cross-section plots** menu, move the cursor to **Plotting options**, and press <ENTER> to define titles, axes labels, and add a grid to the plot. Figure 25 shows the **Plotting options** menu with its default settings.



**Figure 25
PLOT2 Plotting Options Menu**

With the cursor positioned at **Title 1:**, type in the first title line. Then move the cursor to **Title 2:**, if desired, and enter the second title line. For **X axis label**, the default label **Distance** may be used, or an alternative label may be written over the default label. Units, if appropriate, can be added on the same line. Similarly, for the **Y axis label** the default label **Elevation** may be used, modified with units added, or replaced by entering a new label. A **Full grid display** is provided with the plot. To turn off the grid, move the cursor to that line, and press the <SPACE BAR> to toggle the choice from **Yes** to **No**.

As described in Section 9.4, options for graphics adapter and output device can be selected. For HP pen plotters, the output port can be set to COM1 or COM2, as appropriate.

The **X axis scales** default is **Fill plot area**, and the **Y axis scales** default is **Automatic** for each plot. To change the scale, press the <SPACE BAR> and the following options are provided: scales set to 1, 2, or 5 times a power of 10, Fill plot area, and Max scale for all. Fill plot area would normally be used for one scale while fixing the other scale. Max scale for all provides a fixed scale based on the maximum range of the data values.

Select color options provides a menu to set the pen number for pen plots and the line colors for EGA color screen displays. The **Color options** menu is shown in Figure 26. For cross-section plots, the options are for the Text, Axis, and the section features to be plotted.

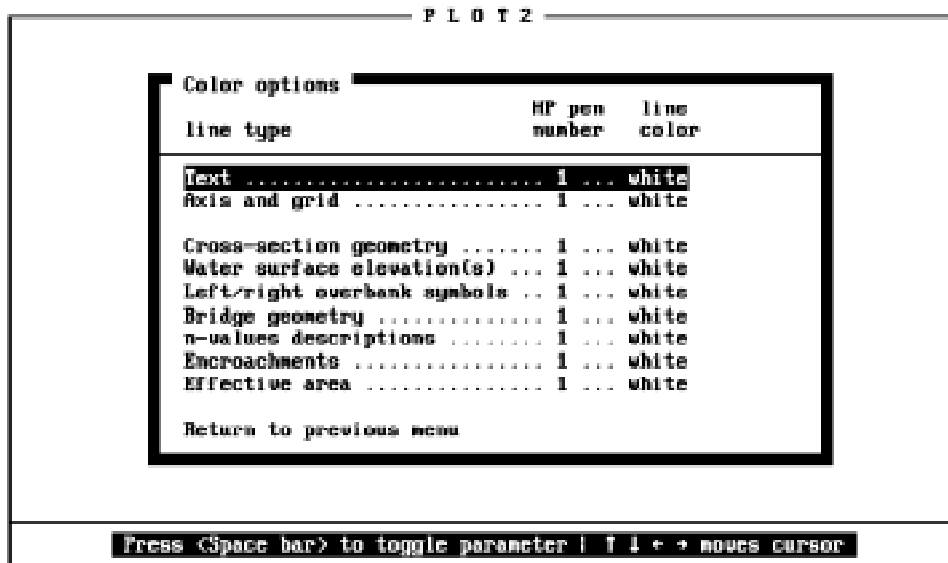


Figure 26
PLOT2 Cross-Section Color Options Menu

After the plotting options have been defined, move the cursor to **Return to previous menu** and press <ENTER>. Or press <Esc> to return.

In the Cross-section Plots menu, move the cursor to **Plot cross sections**, and press <ENTER>. If the input data file name is not defined correctly, the program will provide the following message:

**PLOT2 cannot continue until the
appropriate input files have been
specified.**

Press <ESC> to continue.

Return to the Cross-section Plots menu and check the file names. Remember to provide the drive and directory, if necessary. You can enter <?> to review the files in the default directory.

If the file names are correct, the program will provide the following message:

Plot all cross-sections (y/n)?

If all cross sections are to be plotted, enter <y>, or press <ENTER> and the program will start plotting with the first cross section in the data set. If you enter <n>, the program will provide a menu of cross sections available. The cursor arrow keys will move the cursor around the listing of cross-section numbers. To plot a cross section, press <ENTER> while the cursor is on the desired cross section. Figure 27 is an example cross-section plot with Manning's n values and water surface elevations plotted for three profiles.

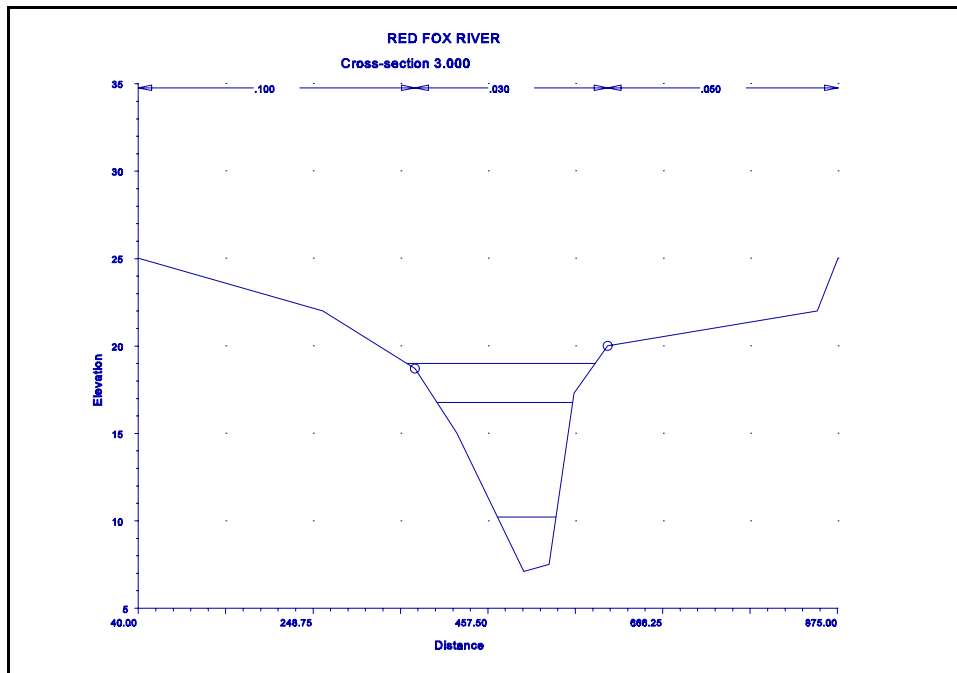


Figure 27
Example Cross-Section Plot

With the cross-section plot on the screen, you can obtain a printed copy of the display by entering <PrtSc>. Be sure that you have set your printer to graphic mode. Check your DOS manual, the GRAPHICS command may be limited to CGA graphics. To clear the plot from the screen, press <ENTER>. If you are selecting cross sections to plot from the menu of available cross sections, the program will return to that menu. If you are plotting all cross sections, the program will plot the next section.

When plotting has been completed, press <Esc> to return to the Cross-section Plots menu. To return to the main menu, press <Esc> or move the cursor to **Return to previous menu** and press <ENTER>.

From the PLOT2 Main Menu, you can enter <4> or move the cursor to **4. Exit PLOT2** and press <ENTER> to leave the PLOT2 program. Or you can plot Rating curves by pressing <3>. The **Rating Curve Plot Menu**, shown in Figure 28, will appear.



Figure 28
PLOT2 Rating Curve Plot Menu

9.7 Rating Curve Plots

The rating curve option is called from the PLOT2 Main Menu by moving the cursor to **3. Plot rating curves** and pressing the <ENTER> key, or by entering <3>. The rating curve menu, shown below, appears. The two options menus have default values, so you can start plotting rating curves immediately. However, selecting **Rating curve options** will display the menu shown in Figure 29, with the default settings as shown.

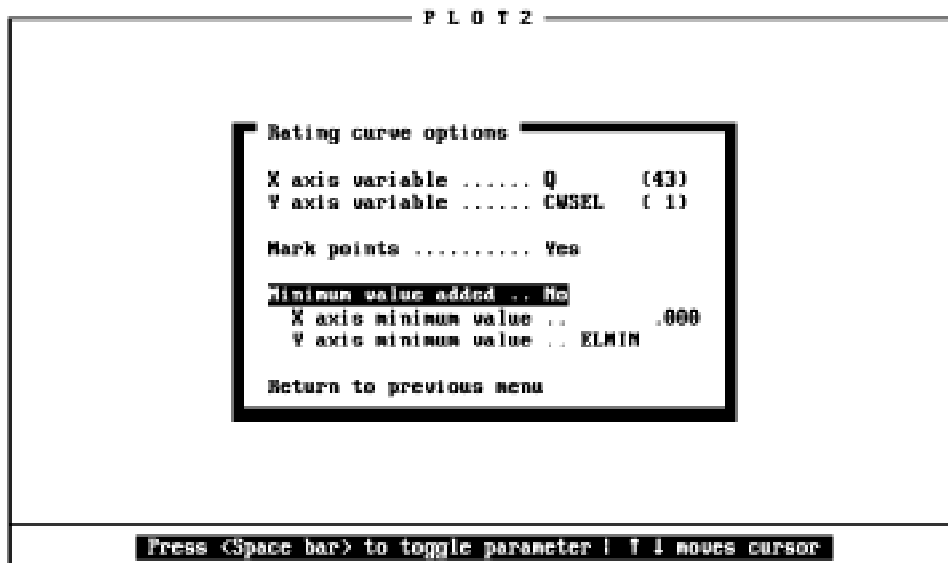


Figure 29
PLOT2 Rating Curve Options Menu

The **Rating curve options** menu allows you to define the variables to plot, mark the computed points, and add a minimum value. Default minimum values are 0.0 for most variables and the minimum cross-section elevation (ELMIN) for elevation variables. The default variables to plot, shown in Figure 29, are flow (**Q** variable 43) versus computed water surface elevation (**CWSEL** variable 1). The variables can be changed by pressing the left cursor arrow to decrease, or the right cursor arrow to increase, the variable number. The sequential order of the variables is listed in the input description for the **J3** record. The order is the same as the order of the variables in TAPE95. Refer to the input description to see the sequential order of the variables.

Move the cursor down to **Mark points** by pressing the down arrow. The default is to mark the computed points with a circle. The option can be turned off by pressing the <SPACE BAR> to change **Yes** to **No**.

The minimum value can be added by moving the cursor down to **Minimum value added** and pressing the <SPACE BAR> to change **No** to **Yes**. The default is 0.00 for variables that would typically have a zero minimum. The zero minimum can be modified by entering a numeric value. The alternate default is the minimum cross-section elevation (**ELMIN**) for elevation variables like water surface and energy elevation.

If the default settings are acceptable, you can quickly return to the rating curve menu by pressing escape <Esc>. After setting the options, you can return by moving the cursor to **Return to main menu** and pressing <ENTER>. Pressing <Esc> does not save the changes you make.

The **Plotting options** menu is called by moving the cursor to that line and pressing <ENTER>. The menu shown in Figure 30 will appear.

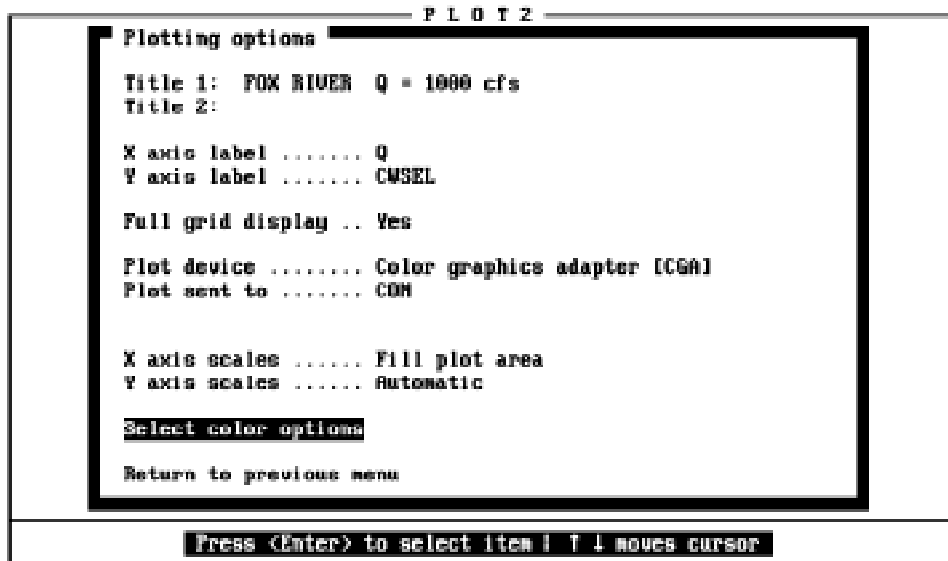


Figure 30
PLOT2 Rating Curve Plotting Options Menu

The rating curve **Plotting options** menu is similar to the other menus for plotting options. The default **Title 1:** is the title from the **T3** record, fields 2-4. The title can be edited using insert and delete keys, or replaced by typing over it.

The **X** and **Y axis labels** are set to the variable names selected for plotting in the rating curve options menu. The label can be changed by using the cursor to highlight the line, and entering a new label. For example, you may want to change **Q** to **Flow in cfs**.

A **Full grid display** is provided, by default. To eliminate the grid, highlight that option, and press the <SPACE BAR> to change **Yes** to **No**.

The **Plot device** and **Plot sent to** options are the same as described in Section 9.4. Also, the scales options are the same as previously described. The pen number, for pen plots, and the line color, for EGA color graphics display, can be set by moving the cursor to **Select color options** and pressing the <SPACE BAR>. The menu shown in Figure 31 will be displayed.

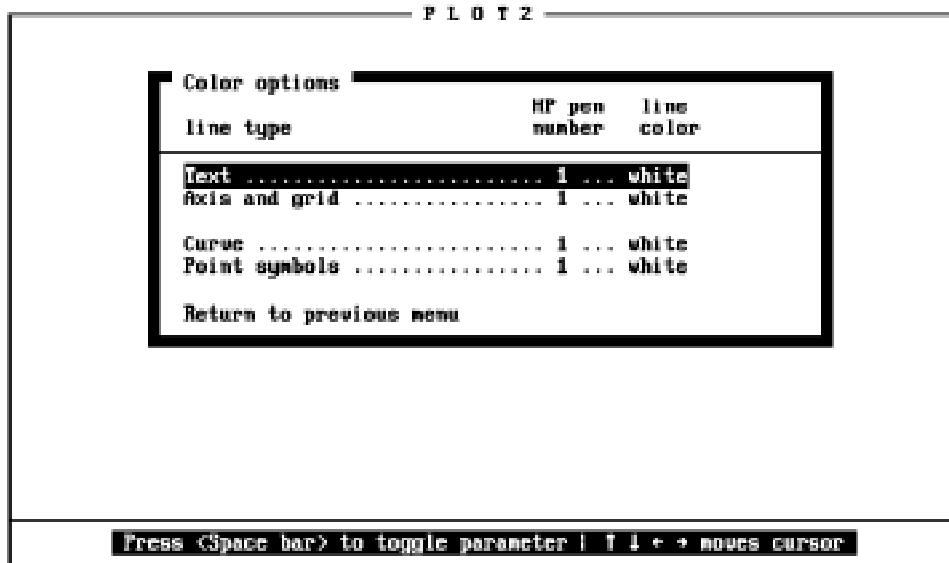


Figure 31
PLOT2 Rating Curve Color Options Menu

The cursor location is indicate by the highlighted line and a blinking marker. One column is for the pen number, and the other is the color of the plot lines for the screen display. The <SPACE BAR> is used to toggle through the choices. The left and right cursor arrows move the marker between columns, and the up and down arrows move the highlighted line.

Pressing escape <Esc> will return you to the **Plotting options** menu without any changes to the default color settings. If you change the settings, move the cursor to the bottom line, **Return to previous menu**, and press <ENTER>.

From the rating curve menu, move the highlighted line to **Plot rating curves** and press <ENTER>. The following message will be displayed:

Plot all cross-sections (y/n)?

Pressing <y> or <ENTER> will give you a rating curve for every cross section. Pressing <n> will give you a menu of available cross sections. Use the up and down cursor arrow keys to highlight the section numbers, and press <ENTER> to select the desired cross sections. When you have selected the desired section numbers, press <c> to start plotting. Figure 32 is an example of the EGA graphics plot. After each plot, press the <SPACE BAR> or <ENTER> to obtain the next plot. If you are plotting to the screen, you

can use the print screen option <PrtSc> to obtain a copy of the plot on a graphics compatible printer set to graphics mode. Check your DOS manual, the GRAPHICS command may be limited to CGA graphics.

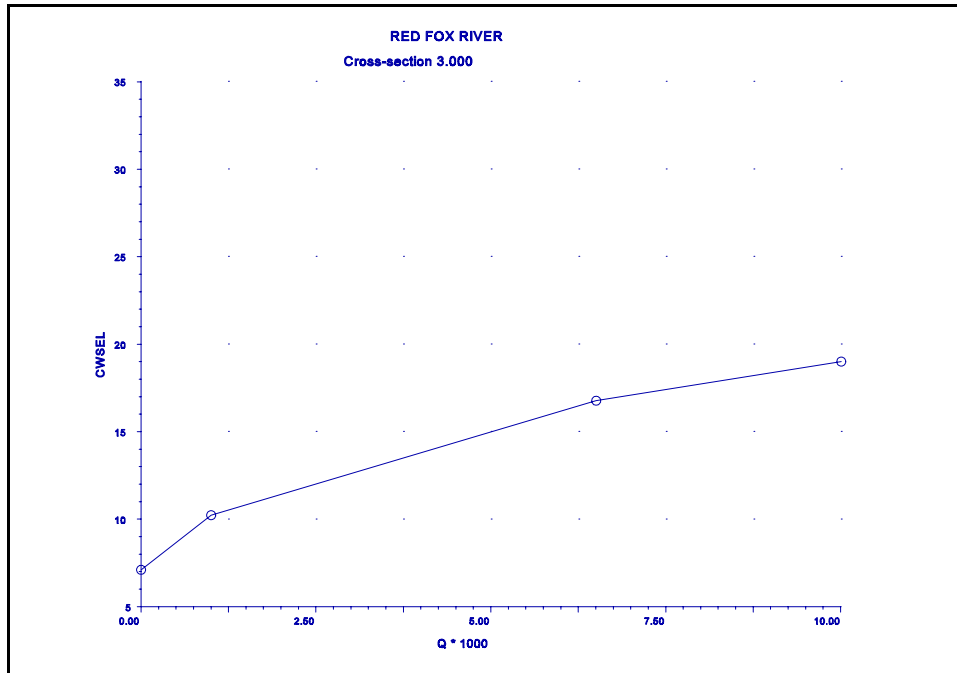


Figure 32
Example Rating Curve

After you have completed plotting, return to the PLOT2 main menu, and move the cursor to line **4. Exit PLOT2** and press <ENTER>, or simply press the <4> key. If you called PLOT2 from MENU2, you will be returned to MENU2. If you called PLOT2 from DOS, you will be returned to the DOS prompt.

Chapter 10

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