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Chapter 31 Computer Program for Water Surface Profiles

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Preface

Chapter 31 is an updated version of Technical Release 61, which was prepared by hydraulic engineers from the Soil Conservation Service (SCS) Central Technical Unit in Hyattsville, Maryland. This chapter was developed by the SCS Technology Development and Support Staff, Washington, DC, and reviewed by personnel from the Engineering Division, Washington, DC, the National Technical Centers, and the SCS state offices.

This chapter of the National Engineering Handbook will assist engineers in preparing data for the WSP2 computer program. It will also help them understand the programmed procedures and consequently interpret answers properly.

Acknowledgments

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630.3100 Introduction

The Water Surface Profile 2 (WSP2) computer program can aid in the determination of flow characteristics for a given set of stream and flood plain conditions. More specifically, it can compute water surface profiles in open channels. The program also can estimate head losses at restrictive sections, including roadways with either a bridge opening or culverts.

WSP2 was initially written in FORTRAN IV computer language and was developed on an IBM 360/65 computer. The three subprograms (HROFDA, DATE, and REREAD) were written in assembly language.

Various field locations have adapted WSP2 to CDC and Univac systems. It has since been revised to operate on microcomputers with DOS or MS-DOS operating systems. Operating procedures for the microcomputer version are included in a text file on the program diskette.

Because the computations require a large amount of physical data on valley shape, roughness, and flow restrictions, an attempt was made to make data entry as easy and flexible as possible. Output records saved in a computer file provide direct input to SCS flood routing and economic analysis computer programs.

To use this program effectively, an understanding of basic hydraulic principles and procedures contained in the list of references is recommended.

630.3101 Capabilities

WSP2 can provide information on elevation, discharge, flow area, and flooded area at specified locations along a valley. The program computes up to 15 water surface profiles for a combined total of 50 valley and road cross sections. The discharge rate for each profile can be constant, variable, or user-selected. A job can be extended beyond 50 sections by the LINK feature and beyond 15 profiles by the CHANGE feature. The use of these features is described in detail in another section. More than one job can be processed in one run by putting the ENDJOB record after each job and the ENDRUN record after the last job. Results of computations from up to 20 cross sections can be saved for later computations by using TRIB records.

The shape of each valley cross section can be defined by up to 48 horizontal and vertical points, which can be entered in order or randomly. The vertical coordinate can be given in either elevation or rod reading. If points are entered randomly, WSP2 automatically reorders them according to increasing horizontal distance, except for points that have identical horizontal distance. Such points must be entered in the correct order because WSP2 will not change their order of entry. A cross section can be divided into a maximum of six segments representing different characteristics. The segments must begin and end on points that appear in the section table.

Manning's roughness coefficient *n* can be changed at user-specified values of elevation or hydraulic radius.

At any one road cross section, WSP2 can compute head losses through one bridge opening and up to four culvert openings with different configurations. If there is no bridge opening at a road cross section, up to five culvert openings with different configurations can be analyzed. Each of the culvert openings may have an unlimited number of identical culverts. Although one bridge opening along with several culvert openings can be defined for one road cross section, the user should be aware of certain limitations (see Section 630.3102(c), Road restriction analysis).

WSP2 may be used to compute water surface profiles for encroached valley and road cross sections. The user must input encroachment stations for each cross section where encroachment is desired.

WSP2 is capable of computing flow profiles for subcritical and critical flow. In natural channels and flood plains, most flow regimes are of these types. There are limitations on some procedures used in WSP2 to preclude analyzing supercritical flow. These are the bridge head loss procedures and the use of the critical flow equation in lieu of minimum energy to determine if flow is actually supercritical.

630.3102 Methodology

(a) Valley section analysis

The standard step method, with some modifications, is used to compute profiles between valley sections. All profiles are computed in the upstream direction. The letter "C" appears on the output when critical flow occurs for a profile. After defining a starting valley section, the program can start computations from given elevations, from given slopes, or if no starting information is given, from critical depths. All profiles at a given beginning point must be started in the same manner. Once the downstream starting information is developed, the following steps are needed at the upstream section to extend the profile upstream.

Step 1. Determine a set of elevation values at the upstream section corresponding to the following depths:

0.0			
0.2	5.6	18.2	38.0
0.4	6.4	19.6	40.0
0.6	7.2	21.0	42.0
0.8	8.0	22.4	44.0
1.2	9.0	24.0	46.2
1.6	10.0	25.6	48.4
2.0	11.0	27.2	50.6
2.4	12.0	28.8	52.8
3.0	13.2	30.6	55.2
3.6	14.4	32.4	57.6
4.2	15.6	34.2	60.0
4.8	16.8	36.0	62.4

For sections more than 62 feet deep, each of the depths is doubled before computing the elevations. Depths at both ends of channel segments and the low point of the cross section outside the channel segments (low ground elevation) are inserted into the table above. This is done to reflect rapid changes of hydraulic characteristics at these elevations.

For any elevation, WSP2 interpolates area values on a linear basis and KD values on a log basis. Conveyance may be computed based on changing roughness with respect to hydraulic radius or elevation. To utilize this option, enter the *n* values and hydraulic radius or elevation break points on NVALUE records. Enter an **E** in column 61-70 of the SEGMENT record to indicate variation by elevation. Leave that field blank to indicate variation by hydraulic radius. These options can be used for any or all segments within a cross section. It is possible to use elevation-roughness data for some segments and hydraulic radius-roughness data for other segments within the same cross section. Form SCS-ENG-18 shows input format and directions (appendix 31-B).

An example is shown with the maximum four elevation breakpoints to define the *n* relation of a segment.

SEGMENT	ABC	1	D	300		E
NVALUE	.05	100.0	.04	103.0	.03	105.0
NVALUE	.025	108.0				

Step 2. Compute area and conveyance (KD) values for each segment for the elevations chosen in step 1. The KD values for flood plain segments are adjusted to reflect their different reach lengths. This technique is described in chapter 14 of NEH-4.

Step 3. For each of the elevations chosen in step 1, WSP2 computes and saves critical discharge and velocity head. Critical discharge is computed using the following equation:

$$Q = \sqrt{32.2\frac{A^3}{T}}$$

where:
- Q = Discharge, cfs
- A = Valley section area, ft^2
- T = Top width, ft

WSP2 computes the velocity head for an assumed slope of 0.0001 foot per foot and weights the head by the percentage of flow in each segment. The actual velocity head for any assumed upstream elevation is the tabulated value times the ratio of the actual slope (see step 5) to 0.0001. WSP2 interpolates or extrapolates velocity head and critical discharge on a linear basis.

Step 4. Calculate flow rate (chapter 14 of NEH-4 for csm adjustments) for the profile being considered. The cubic feet per second per square mile (csm) adjustment is made on a drainage area basis so that each water surface profile closely matches a flood profile. WSP2 interpolates from the table developed in step 3 to determine the elevation at which the flow rate is critical.

Step 5. Figure 31–1 shows how the energy principle is used in WSP2. Energy is considered balanced when the trial elevation plus velocity head for that elevation (from the table developed in step 3) at the upstream section is within 0.1 foot of the energy level at the downstream section plus losses. Losses include friction loss and contraction/expansion loss. Friction losses are found by Manning's equation:

$$Sf = \left(\frac{Q}{KD}\right)^2$$

using Q and KD at the upstream section. The rate of friction loss is Sf, and the total loss is then Sf times the length (L). The critical elevation from step 4 is used first in the trial-and-error energy balance procedure. Energy losses are calculated by multiplying the expansion or contraction coefficient by the difference in velocity heads between upstream and downstream cross sections.

Step 6. If the initial upstream energy level (using critical elevation) is more than the downstream energy level plus losses, WSP2 assumes supercritical flow and takes critical elevation as the answer. If the reverse is true, WSP2 assumes subcritical flow, chooses a higher elevation, and recomputes the energy balance. The program repeats until an elevation is found at which the energy equation will balance within 0.1 foot.

For profiles with nearly equal discharges, it is possible to get more flow at a lower elevation than at a higher elevation on a rating table. A reversal of as much as 0.2 foot is possible within the 0.1-foot accuracy limit of the energy balance equation. Note that only the total energy elevation at the downstream section is needed to balance energy at the upstream section.

The section rating table contains information at bankfull, low ground, and zero-damage elevations. Zero-damage elevation is the lowest point in the damage segments. Bankfull elevation is the lowest of all first and last points defining channel segments. Low ground elevation is the lowest elevation outside or including channel banks. Discharge and cross sectional areas at these elevations are found by interpolation. For the program to compute bankfull, low ground, and zero-damage discharges more accurately, it is advisable to include discharges for which the water surface profile will be near (above and below) those elevations.

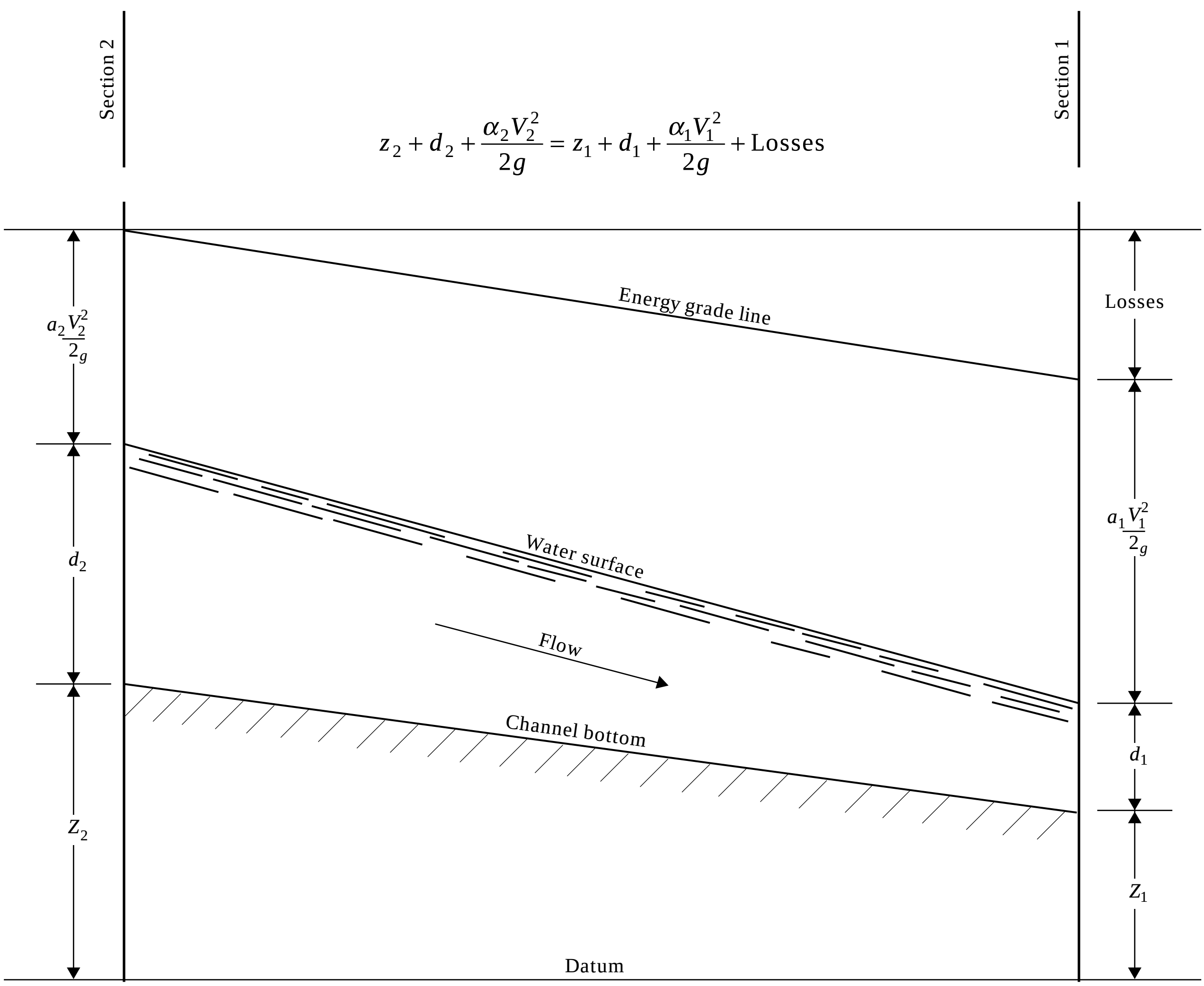
Cross sectional areas are interpolated linearly from the table developed in step 1. Discharges are interpolated linearly from data contained in the output RATING TABLE.

Bankfull, low ground, and zero damage will be printed if damage and nondamage segments are used and there is at least one profile higher than those elevations.

In developing conveyance, cross sectional area, and top width tables, a horizontal water surface is assumed over the entire cross section. If levees, spoil banks, or high points through a reach are not continuous on the flood plain, they are assumed to be ineffective in containing floodwater within the channel. If water for any or all profiles is confined within levees which are continuous through the reach, several options are available to compute profiles.

Figure 31–1 Energy balance equation

$$z_2 + d_2 + \frac{\alpha_2 V_2^2}{2g} = z_1 + d_1 + \frac{\alpha_1 V_1^2}{2g} + \text{Losses}$$



- If levees are assumed effective at all profiles and are not overtopped, enter the cross section coordinates between the tops of levees only or use the encroachment option with left and right stations at the tops of the levees.
- If levees are assumed effective at low profiles but ineffective at high profiles, enter an artificially high Manning *n* value for segments outside the levee at elevations below the top of the levee. This will essentially eliminate conveyance in these segments, and flow will be confined between the levees. The Manning *n* for these segments can be reduced from the artificially high value to an estimated actual value at an elevation near the top of the levee to allow flow outside the levee at high profiles. A limitation of this approach is that flow area outside the levees is included in the total flow area, and acres flooded outside the levees are included in total acres flooded.
- An alternative to the above option is to make two computer runs. For profiles contained within the levees use the encroachment option with left and right stations at the tops of the levees. For profiles which exceed the top of levee elevations, make a second computer run using the full cross section with the estimated actual roughness. Combine the results of the two computer runs for a final rating curve.

Analysis of levee hydraulics and hydrology is complicated and requires good engineering judgment. WSP2 and the SCS Computer Program for Project Formulation-Hydrology, Technical Release 20 (TR-20), should be used in a complementary manner. If the land behind the levee has a significant volume of storage, it may not fill to the elevation indicated by the WSP2 run. The volume of the hydrograph above the levee capacity needs to be compared with the volume behind the levee to be able to determine this. In addition, the outlet of the water which crosses the levee needs to be determined to calculate valid profiles. For example, if an area is completely bordered such that the only outlet is back to the river, this area is dead storage. The volume of water needed to fill the area should be determined and the flood hydrograph at the location adjusted to account for filling of the area. It is difficult to program all of the choices and judgments involved with this type of analysis. In complicated cases like this, either the input to WSP2 and TR-20 needs to be modified to reflect the actual flow conditions, or a more complex model, such as a dynamic routing model (which combines hydraulics and hydrograph routing), should be used.

Cross sections containing flow areas that will not carry active flow, such as depressions in the flood plain, should be revised to eliminate the cross section coordinates defining these inactive flow areas.

(b) Valley section location

Valley sections can serve many needs (geologic, engineering, economic, hydraulics), and all of them should be considered when selecting the location. For hydraulic purposes, valley sections are surveyed at points along the valley length and need to be representative of parameters, such as flow area, wetted perimeter, and roughness.

WSP2 considers energy losses due to friction and expansion or contraction and uses the rate of friction loss at the upstream section as the rate throughout the reach. Therefore, valley sections should be located as follows: divide the valley length into reaches with nearly constant parameters that affect hydraulics and locate the valley section near the upstream end of the reach. In addition to these sections, locate valley sections about 50 to 100 feet both upstream and downstream from road-type restrictions. These sections may be farther away from the road as long as they are representative of the channel and valley shape near the road. Survey sections perpendicular to the direction of flow and not necessarily straight across the valley. The Manning *n* values used for the reach should be representative of the channel and flood plain downstream of the cross section.

(c) Road restriction analysis

WSP2 analyzes a road restriction by determining tailwater, the surface elevation at the downstream face of the opening through the road embankment, head loss due to the restriction, and headwater elevation at the upstream face of the opening. These are labeled TW, HL, and HW on the computer output, respectively. Each step is explained.

Step 1. The value for tailwater is found by balancing energy between the exit valley section and a new section manufactured by the program at the center line of the bridge or the downstream face of the culvert. The reach length between the new section and the exit section is the channel length on the ROAD record. The shape of the new section is the same shape as the exit section. The exit section is moved vertically so that the low point on the new section is the same as the low point on the road section for a bridge and the same as the outlet invert for a culvert.

Step 2. The head loss or headwater elevation is found by assuming head losses beginning with zero loss and continuing in small increments. For each assumed loss, WSP2 finds the flow through the bridge opening or culvert(s), calculates the flow over the road, and adds these flows. The final head loss is the assumed loss at which the summed flows agree within 0.02 foot for bridge and 0.04 foot for culverts. The different procedures used to compute flow for a given head loss at a bridge opening and a culvert are described in Section 630.3102(c)(2), BPR bridge loss analysis; Section 630.3102(c)(3), Culvert loss analysis; and Section 630.3102(c)(4), Contracted opening bridge loss analysis.

Step 3. After the headwater elevation is determined, energy is balanced from the center line of the bridge or the upstream face of the culvert to the approach section. In order to do this, a velocity head must be calculated and added to the headwater elevation to get an energy grade line elevation at the upstream face of the bridge or culvert. WSP2 manufactures another section at the upstream face with the same shape as the approach valley section. The approach section is moved vertically so that the low point on the new section is the same as the low point on the road section for a bridge, and the same as the inlet invert for a culvert. Using this new section, WSP2 finds the area, by segment at the headwater elevation and computes a weighted velocity head. Once this velocity head is found, the water surface profile at the approach section is determined. The length to the approach section is the channel length on the REACH record for the approach section.

The analyses for flow over the embankments, flow using the BPR bridge loss analysis methods, flow with culvert losses, and flow through contracted openings are discussed in the following sections. In addition, road section output is shown.

(1) Flow over embankment analysis

The flow rate over a road is derived using a weir equation. Because of the irregular shape (across the valley) of most road surfaces, a common geometric shape can be assumed and a specialized weir equation developed. Therefore, a modification is made to the rectangular weir equation:

$$Q = CLh^{\frac{3}{2}}$$

where:
C = weir coefficient
L = length of weir, ft
h = depth of water, ft

The modification is the substitution of A (area) for Lh, which yields the equation:

$$Q = CAh^{\frac{1}{2}}$$

At a road cross section with a bridge entered, the road crest is divided into three weirs (over the girder, to the left of the girder, and to the right). The discharge for each is computed, then summed to get the total weir discharge. The elevation difference (h) is between the water surface and the lowest weir elevation. At a road cross section with only culverts entered, the road crest is treated as a single weir.

If the tailwater elevation is higher than the lowest elevation of the weir, the flow rate is reduced due to submergence. The procedure to adjust for submerged weir flow is contained in SCS NEH-11, Drop Spillways, and is used in WSP2.

(2) BPR bridge loss analysis

WSP2 uses a ratio of conveyances (M) to predict losses in the vicinity of a bridge (BPR Manual). To obtain this ratio, divide the conveyance of the approach section for a width equal to the bridge opening width at the bridge tailwater elevation by the total approach section conveyance. If the bridge has a skew angle, the bridge opening width is multiplied by the cosine of the skew angle.

The BPR Manual projects bridge abutments in the upstream direction to define the portion of the approach section that will be used for the numerator of the conveyance ratio. This is valid only if the channel near the bridge is straight. Because most channels near bridges are not straight, a "workable" technique had to be developed for WSP2. The program uses the station for the lowest elevation on the approach section as the center of the bridge opening width. If the width of the bridge opening is less than the approach channel width, the portion of the approach section used is within the channel segment limits. If the bridge opening width is greater, then the portion of the approach section used is centered over the channel segment. In other words, WSP2 uses all of the channel before any part of the flood plain.

Table 31–1 shows values used in the BPR bridge loss analysis and is included as standard output. Head loss calculation can be checked using these values.

The calculation of head loss at the bridge is based on two coefficients (three if there are piers). On the BPR record, the user needs to input the skew type, base curve, and pier curve (if there are piers). The skew type is either A or B as shown on figure 31–2 (fig. 10 in the BPR Manual). The skew angle is entered on the **GIRDER** record. The base curve depends on abutment type and angle and is either 1, 2, or 3 as shown on figure 31–3 (fig. 6 in the BPR Manual).

The use of the curves in figure 31–3 should be as follows:

- The bottom curve (No. 1) is for all spillthrough abutments, abutments with angles between 45 and 60 degrees, and bridges with openings more than 200 feet wide
- The upper curves are for less efficient abutment angles; the middle curve (No. 2) should be used for angles that approach 30 degrees
- The top curve (No. 3) should be used for angles that approach 90 degrees
- The user should judge which curve is most appropriate for other abutment angles, realizing that the highest head loss is associated with base curve 3. The type of pier determines which pier curve in figure 31–4 (fig. 7 in the BPR Manual) to select.

If the pier is not oriented parallel to the direction of water flow, the input value used for pier width is the projected pier width (BPR Manual). For some bridges this would completely close off the opening, which is obviously unrealistic. Therefore, the maximum projected pier width used should be about three times the actual pier width. Pier dimensions are entered on the PIER record. Up to three piers may be entered for each bridge. If there are more, pier widths should be combined so that no more than three are entered.

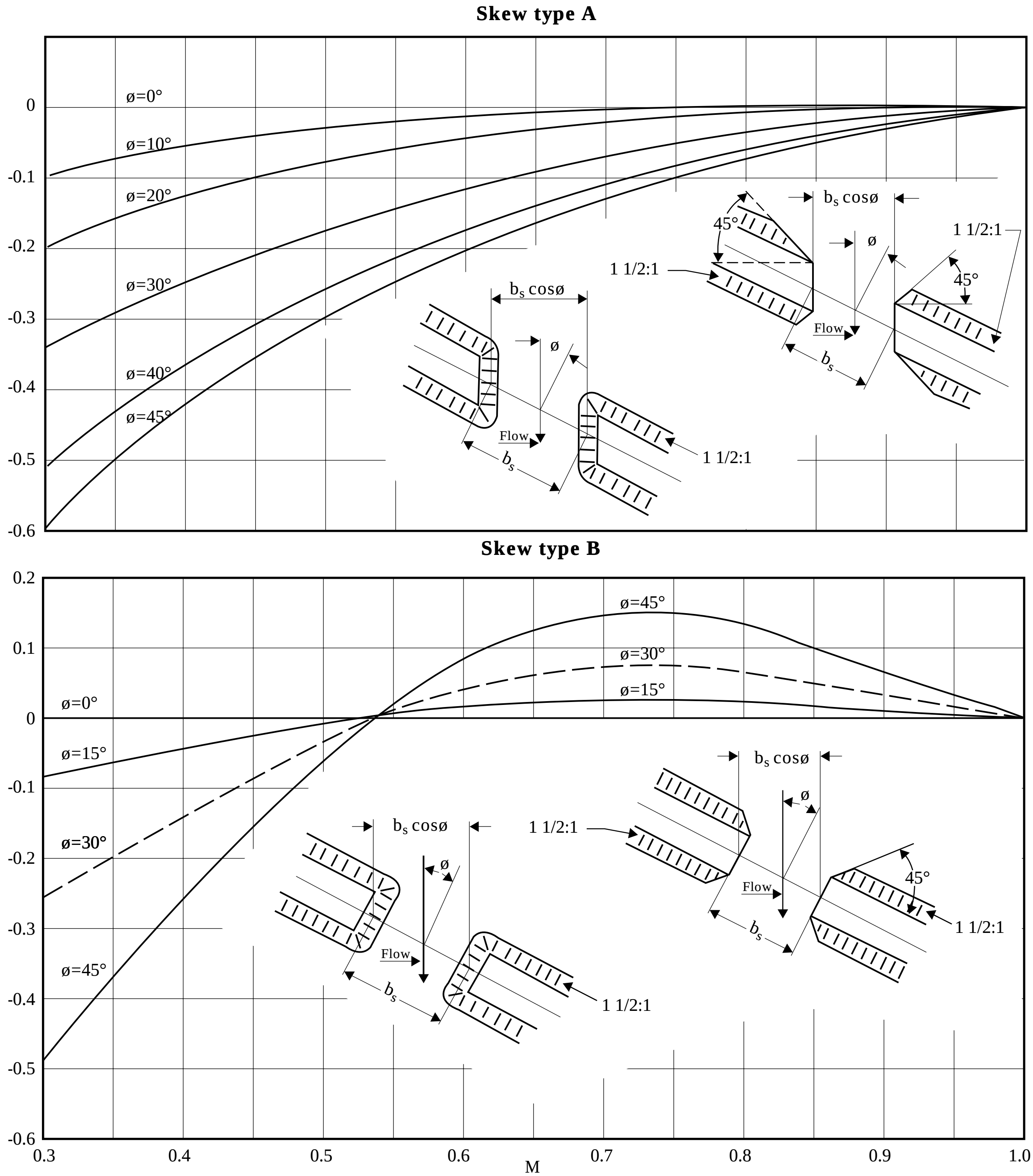
As described in the BPR Manual, the loss coefficients from the three figures are added. Loss for flow eccentricity is ignored in WSP2. The equations representing curves in figures 31–2 and 31–3 are very accurate. The pier curves in figure 31–4 are represented by linear equations and are not very precise below a ratio of pier area to total bridge area of about 0.02.

For values beyond the limits of figures 31–2, 31–3, and 31–4, the curves are extrapolated. When any curve is extrapolated for a particular bridge profile, it is noted in table 31–1.

Table 31–1 Values for BPR equation

Field	Description
1	**Profile number**.
2	**M**—Ratio of conveyances.
3	**AKB**—Backwater base coefficient (fig. 31–3).
4	**DLTAK**—Incremental backwater coefficient that relates to piers (fig. 31–4).
5	**SIGMA**—A factor used to modify DLTAK (fig. 31–4).
6	**DKS**—The value of the skew coefficient (fig. 31–2).
7	**COEFK**—The total backwater coefficient. COEFK = AKB + DLTAK x SIGMA + DKS
8	**VN2**—Average velocity at bridge, feet per second.
9	**ALPHA**—The velocity head correction coefficient at the approach section.
10	**ALPHA2**—The velocity head correction coefficient at bridge.
11	**ALPHA3**—The velocity head correction coefficient at the exit section.
12	**AEXIT**—Flow area at exit section, ft^2.
13	**APPAR**—Flow area at approach section, ft^2.
14	**DCRIT**—Critical flow elevation at bridge, ft.
15	**CRIT COEFF**—Coefficient from figure 34 of BPR manual. Equations on page 58 of the BPR Manual apply when there is critical flow.

Figure 31–2 Incremental backwater coefficient for skew



An * is placed beside values in fields 3, 4, 5, 6, and 15 of table 31–1 if they are beyond the limits of curves in the BPR Manual. If the head loss is more than 1 or 2 feet, check results carefully. High head losses are most likely associated with high velocity heads at the exit section and at the bridge itself. Values of M below the limits of figures 31–2, 31–3, and 31–4 combined with high velocity heads may result in unreliable head loss computations. Possible actions:

- Consider if routing the hydrograph through the storage area upstream of the bridge will reduce the peak significantly.
- Expand and contract exit and approach cross sections using the encroachment procedure to account for flow expansion and contractions.
- Consider whether Manning *n* values are too low or discharges too high resulting in unusually high velocities.
- Use a computer model which has been developed for use in areas with wide flood plains and considers flow contraction and expansion.

WSP2 uses a variation of equation 30 on page 95 of the BPR Manual for the basic loss relationship. The equation in the BPR Manual assumes the velocity head correction coefficient is the same at both approach and exit sections. The variation of equation 30 used in WSP2 uses the actual velocity head correction coefficients at the approach and exit sections, which in many cases are significantly different. Another difference between equation 30 of the BPR Manual and the head loss equation used in WSP2 is that flow through the bridge opening may not equal the total profile discharge if there is weir flow over the road. Since the approach area (**APPAR**) and exit area (**AEXIT**) represent total flow areas at approach and exit sections, it is appropriate to use the total profile discharge to calculate velocity head. Velocity head in the bridge itself is based upon the discharge through the bridge opening.

Figure 31–3 Backwater coefficient base curves (subcritical flow)

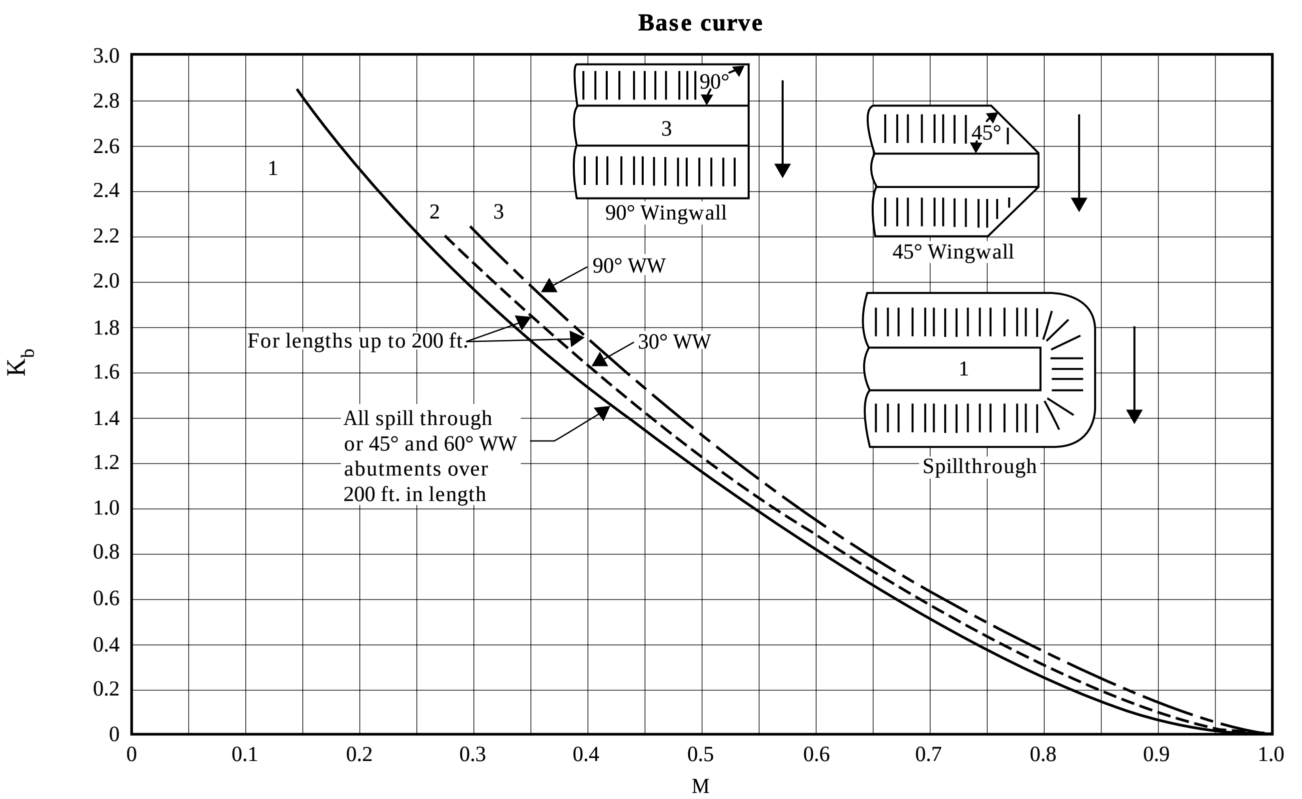
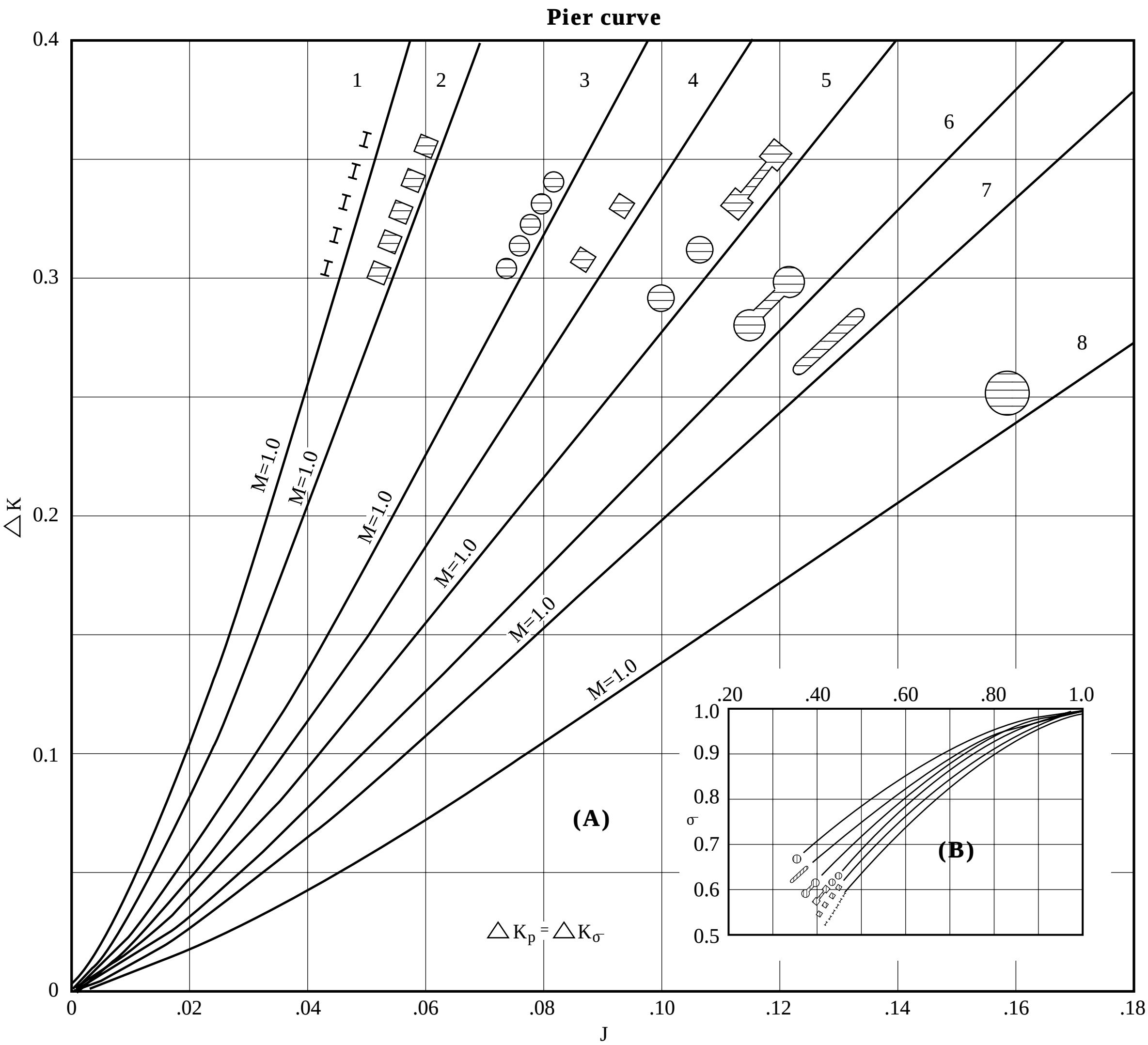


Figure 31–4 Incremental backwater coefficient for piers



(i) Calculation of head loss (subcritical flow)—These values may be combined according to the following equation to calculate the head loss at the bridge:

$$HL = COEFK \times \frac{ALPHA2}{64.4} \times (VN2)^2 + \frac{ALPHA3}{64.4} \times \left(\frac{CFS}{AEXIT}\right)^2 - \frac{ALPHA}{64.4} \times \left(\frac{CFS}{APPAR}\right)^2$$

where:
HL = head loss
CFS = the total profile discharge, cfs.

In this form, the HL equation is an energy balance with velocity heads at the approach, bridge, and exit sections multiplied by the respective coefficients. If HL should by chance be negative, it is changed to zero.

(ii) Calculation of head loss (critical flow)— The procedure in WSP2 follows closely that in the BPR Manual (pp. 98-100). Output data contained in tables 31–1, Values for BPR equation, and 31–2, Road section rating table can be used to verify or check the head loss for critical bridge flow:

$$HL = \frac{ALPHA2}{64.4} \times (VN2)^2 \times (1 + CRITCOEF) + DCRIT - TW - \frac{ALPHA}{64.4} \times \left(\frac{CFS}{APPAR}\right)^2$$

where:
TW = Tailwater elevation (from table 31–2)

Table 31–2 Road section output — A maximum of one bridge is permitted for any road cross section

Field	Description
1	**Profile number**.
2	**HW**—Headwater elevation upstream side of road crossing, ft.
3	**CFS**—Total profile discharge, cfs.
4	**HL**—Head loss, difference of headwater and tailwater elevations, ft.
5	**TW**—Tailwater elevation, ft.
5a	If a **C** appears, then the Froude number is greater than 0.7, and critical flow is assumed.
6	**Starting CSM**—cfs/mi²
7	**Bridge CFS**—Flow in cfs through bridge opening. If no flow or no bridge is at this cross section, a 0.0 is printed. If no head loss, – – – is printed because bridge flow is not computed.
8	**Bridge area**—Bridge area in square feet applicable to the bridge flow equation used. The bridge area is the area of the opening below the girder multiplied by the cosine of the skew angle for the BPR and contracted opening equations. Pier area is not subtracted for the BPR procedure because the backwater coefficient already accounts for head loss at piers. Bridge area is computed at the tailwater elevation. For orifice flow, the bridge area is the area of the opening below the girder minus the pier area. For critical flow, it is the area of the opening below the critical elevation minus the pier area. Orifice and critical flow areas are not adjusted for bridge skew.
9	**Culvert CFS**—Flow in cfs through all culverts at the particular road cross section. If there is no flow or no culvert at a road cross section, a 0.0 is printed. If no head loss, – – – is printed because culvert flow is not computed.
10	**Culvert area**—Flow area (ft²) of all culverts at the particular road cross section at the headwater elevation.
11	**Weir CFS**—Total weir flow at the road cross section. Includes weir flow over the road and over the top of girder if any.
12	**Weir area**—Total weir flow area in ft² corresponding to the headwater elevation.
13	**Weir top width**—Total top width of weir flow over the road and girder (ft). Top width of water surface is printed.

(iii) Calculation of head loss (orifice flow)— Head loss is computed from the equation:

$$HL = \left(\frac{BRIDGE\ CFS}{8.02 \times ORIFICE\ COEF \times BRIDGE\ \ AREA} \right)^2$$

where:

BRIDGE CFS	=	Flow under bridge
BRIDGE AREA	=	Flow area below tailwater elevation minus pier area, if any
ORIFICE COEF	=	Value entered on the GIRDER record

The HL calculated from these formulas will in general be ±0.02 feet when compared to the HL printed in the WSP2 output. This is because the solution procedure is trial-and-error, and the error tolerance is 0.02 feet.

It may occasionally happen that the HL from the orifice equation will be significantly less than that printed in the road rating table. If the bridge opening cannot carry the flow according to the BPR technique at the elevation where the orifice flow begins, then the flow condition switches to orifice flow. Using the orifice flow equation, the bridge opening can easily carry the flow with the associated head loss. Selection of the elevation where orifice flow begins can be important. It should be set slightly above the elevation where all the girders are submerged.

The lengths important to bridge analysis are found in the input as follows:

- The reach length on the ROAD record is the distance from the road center line to the exit section.
- The reach length on the approach section REACH record is the distance from the approach section to the center line of the road.

(3) Culvert loss analysis

In one road restriction, WSP2 can analyze losses through as many as five culvert openings of different shapes or elevations and an unlimited number of culvert openings with each configuration. Only rectangular, circular, and standard metal-pipe arch shapes can be analyzed. The capability to analyze open channel flow in multiple culverts with different configurations has caused the solution to be a double trial-and-error procedure.

The problem is to find the amount of flow that will go through each culvert for the head loss increment or headwater elevation assumed in step 2 of Section 630.3102(c), Road restriction analysis. WSP2 solves the problem as follows:

Step 1. Assume a discharge.

Step 2. Compute an open channel flow profile from the tailwater point through the culvert with the assumed discharge. Solve for open channel flow by the direct step method using the reach length found for a change in depth of 0.2 foot. If this extends the profile past the upstream end of the culvert, WSP2 interpolates the water surface at the entrance and adds an entrance loss. If this water surface elevation does not closely match the headwater elevation (step 2, Road restriction analysis), WSP2 assumes a new discharge and repeats this step.

Step 3. If open channel flow is impossible for this headwater elevation, WSP2 assumes full flow. For full flow, the water surface elevation at the culvert entrance for the assumed discharge is found from a form of the equation:

$$Q = A\sqrt{\frac{2gh}{\sum losses}}$$

If this water surface elevation does not closely match the headwater elevation (Step 2, Road restriction analysis), WSP2 assumes a new discharge and repeats this step.

Step 4. The headwater elevation is found by assuming inlet control. The water surface elevation required to pass the assumed discharge through the culvert entrance is found from a numerical representation of the nomographs in exhibits 14-6 through 14-13 of chapter 14 of NEH-4. (See also the FHWA publications listed in the references.) If this water surface elevation does not closely match the headwater elevation (Step 2, Road restriction analysis), WSP2 assumes a new discharge and repeats this step.

Step 5. The discharge that will pass each culvert opening at the assumed headwater elevation is the lowest discharge derived from the computations of open channel flow, full flow, and inlet control.

Step 6. If there are identical culverts, WSP2 multiplies the discharge from step 5 by the number of culverts that are identical. The lengths important to the culvert analysis are in the input as follows:

- The reach length on the ROAD record is the distance from the downstream end of the culvert to the exit section.
- The third data field of the CULV2 record is the culvert length.
- The reach length on the approach section REACH record is the distance from the approach section to the upstream end of the culvert.

When a pipe arch culvert is encountered, the product of input values of rise and span is used to select a standard dimension pipe arch culvert. Standard dimensional pipe arches are contained in Electronic Computer Program for Hydraulic Analysis of Pipe Arch Culverts (BPR Program HY-2) developed by the Bureau of Public Roads, Federal Highway Administration, revised May 1969.

(4) Contracted opening bridge loss analysis

The WSP2 computer program can analyze bridge losses by a contracted opening method based on the following equation:

$$Q = C(CA)\sqrt{\frac{2gh}{1-\left(\frac{CA}{AA}\right)^2}}$$

Table 31–3 Values for contracted opening equation

Field	Description
1	**Profile number**.
2	**COEF**—Contraction coefficient entered on CONTR record.
3	**APPAR**—Flow area of cross section upstream of bridge. This area is computed at the approach section at an elevation corresponding to the flow depth at the upstream face of the bridge. Example: If the flow depth at the upstream face of the bridge is 8.0 ft, then the approach area is computed at the approach section at a depth of 8.0 ft.
4	**RATIO**—This is the ratio of bridge area (corrected for skew) divided by the approach area. If this ratio is greater than 0.98, no head loss through the bridge is shown for this profile. This ratio is a measure of relative contraction of the flow. For profiles within the channel banks high values approaching 1 can be expected. For large flows inundating flood plains, low values should be expected. The equation arranged to compute head loss is $$HL = \left(\frac{BRIDGE\ CFS}{BRIDGE\ \ AREA \times COEF}\right)^2 \times \left(\frac{1-\left(RATIO^2\right)}{64.4}\right)$$ BRIDGE CFS and BRIDGE AREA are printed in table 31–2, Road section output. The contracted opening equation is used to calculate head loss whenever the headwater elevation is below the elevation where orifice flow begins. At that elevation WSP2 assumes orifice flow. Head losses may vary ± .02 feet from the values in table 31–2 because of the trial and error solution procedure and the trial depth increment of 0.02 feet.

where:
C = the coefficient of discharge
CA = the area within the contracted section
AA = the approach section area

The PIER record may not be used with the contracted opening procedure (table 31-3). If there are piers, they may be included in the cross section of the stream under the bridge.

The C value at most bridges ranges from 0.7 to 0.9. If flow turbulence approaching the bridge opening is relatively low, the C value is about 0.9. If flow turbulence is high, C value may be as low as 0.4 to 0.5. In determining C value, consider the following:

- shape of abutments (square cornered or shaped to reduce turbulence)
- number and shape of piers
- degree of skew
- number and spacing of pile bents (closely spaced bents increase turbulence)
- presence of trees, drift, or other obstructions at or approaching the bridge
- C value may decrease as discharge increases

Even though the head loss equation is somewhat different, the contraction coefficient (COEF) may be estimated from procedures contained in Matthai, 1967.

Perhaps the best use of the contracted opening procedure is for cases where high water marks are available which indicate head loss during a past flood. The contraction coefficient can be calibrated to give the appropriate head loss. It is more complicated trying to calibrate the BPR procedure because the head loss coefficients are determined by the physical data.

(d) Assumptions and limitations of bridge head loss procedures

Important assumptions to the BPR bridge analysis procedure are:

- The channel in the vicinity of the bridge must be nearly straight.
- Cross sectional area of the stream must be fairly uniform.
- Stream gradient between the exit and approach sections must be approximately constant.
- Flow must be free to contract and expand.
- No appreciable scour can be present at the bridge.
- Head loss through the bridge is computed by different procedures depending on whether flow is subcritical or critical. This can cause one profile at critical flow to be significantly lower than a profile at subcritical.

The limitations of the BPR figures, multiple openings, weir flow, and flow near critical depth head loss procedures are discussed in the following sections.

(1) Figures in the BPR Manual

Figures in the BPR Manual used in WSP2 to compute bridge backwater are based on experimental and field measurements. The limits of these measurements determined the limits of curves in the figures. If coefficients (particularly M) are much beyond the limits, reduced accuracy can be expected. Very low values of M indicate severe contraction of the flow and possible two dimensional flow, which is not properly handled by WSP2.

(2) Multiple openings

To calculate the bridge opening ratio, M, for the BPR method, the total approach conveyance is used. If there are also culvert openings, the computed M could be too small. This would tend to overestimate bridge head loss. WSP2 does not proportion the approach section among all openings.

To calculate the ratio of areas for the contracted opening method, the total approach area is used. If there are also culvert openings, the ratio could be too small and the head loss overestimated. Depending on the size of culverts in relation to the bridge, this limitation can have a large or small impact.

(3) Weir flow

The BPR and contracted opening procedures use total approach conveyance and area, respectively, to calculate their major parameters. WSP2 does not reduce approach conveyance or area to account for flow going over the road. This limitation causes a trend to overestimate head loss. Depending on the relative size of the weir flow and bridge flow, this limitation can have a large or small impact.

The limitation concerning the weir flow elevation below the bridge orifice flow elevation is discussed under output messages in section 630.3111(c). If at a certain headwater elevation the weir and/or culverts carry the total profile discharge, no flow is shown for the bridge opening for that profile.

(4) Flow near critical depth

Bridge hydraulics procedures may give unrealistic head losses for high velocities as reflected in the Froude number of flow in the bridge opening. The Froude number (F) is defined as:

$$F = \sqrt{\frac{Q^2 T}{gA^3}}$$

where:
Q = bridge flow, cfs
T = top width of water surface, ft
g = acceleration of gravity, 32.2 ft^2/s
A = area of bridge opening minus pier area, ft^2

The BPR procedure is based on limited data for high Froude numbers. The user is encouraged to read chapters 1, 10, 12, and appendix A of the BPR manual for a more complete discussion of critical bridge flow.

To illustrate what can happen at high velocities, at 11 feet per second the velocity head is 2 feet. If the bridge backwater coefficient is 2, the head loss at the bridge could be near 4 feet (which appears unrealistic). The user is cautioned to check results carefully under these conditions.

As described on pages 1 to 6 of the BPR Manual, there is a transition area where flow can be Type I (subcritical) or Type II (flow passes through critical depth). Depending on which computational technique is used, there can be a significant difference in head losses. The Froude number at which the transition occurs has been set at 0.7. The contracted opening procedure, which is similar to the procedure of Matthai (1967), is limited to Froude numbers below 0.8.

(e) Field survey of culverts and bridges

Survey data needed for culverts include the road profile, culvert inlet and outlet invert elevations, and culvert length, height, and width (or diameter). Notes should include a description of culvert shape, inlet and outlet type, wingwall angle, culvert materials, and number of culverts.

Standard survey data needed for bridges include road profile, cross section of stream, girder (top, bottom, and end points), bottom elevation and width of piers (if any), and the angle of skew between the bridge opening and the channel. Survey notes should include bridge abutment type, pier type, and skew type (see figs. 31–2, 31–3, and 31–4 and associated text).

The cross section surveyed under the bridge should extend from one bridge abutment to the other. It should represent an average cross section under the bridge if the channel width and side slopes change between the upstream and downstream bridge faces. It may be important to survey scour holes at bridge and culvert outlets for channel protection projects. If the scour holes are localized (just under the bridge or near the culvert outlet), these low areas should not be included in the WSP2 cross section because the scour holes act as energy dissipators and are not active flow areas. Guard rails and low steel of the bridge should be included in the girder survey because they represent a flow obstruction. The skew angle represents the angle between the channel flow direction and a perpendicular line to the bridge opening (see fig. 31–2). For example, if the channel is perpendicular to the bridge, the skew angle is zero. Photographs of bridges and culverts which are surveyed greatly aid in the coding of input data for WSP2.

(f) Evaluation of acres flooded

For any reach, information for three types of flooded areas can be found. The three types are damage (D), nondamage (N), and channel (C) areas. The letter designation D, N, or C on the SEGMENT records determines in which category a segment will be placed. In the rating table output for valley cross sections, acres damaged, channel acres, and total acres are printed for low ground, zero damage and bank full elevations (if present), and each profile.

Acres flooded are computed using the four reach lengths on the REACH and ROAD records and the top width data at the current cross section. Figure 31–5 indicates what each reach length on the REACH or ROAD record represents.

Damage acres =

$$\frac{\left[\left(TOPC + TOPD\right) \times DMLGT - \left(TOPC \times DLGT\right)\right]}{43560}$$

where:
TOPC= top width of channel segment(s), ft
TOPD= top width of damage segment(s), ft
TOPT= the total flow top width of all segments, ft

If damage acres is less than zero, it is set to zero.

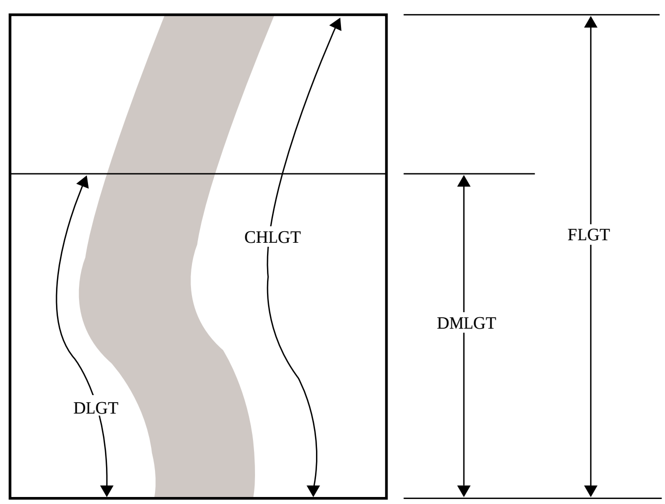
$$\text{Channel acres} = \frac{TOPC \times CHLGT}{43560}$$

$$\text{Total acres} = \frac{TOPT \times FLGT}{43560}$$

Channel acres and total acres are based on hydraulic lengths and give an estimate of acres flooded between cross sections. The top widths at the upstream section are assumed to be representative of the channel and flood plain between cross sections. For a meandering channel, the channel acres flooded may be computed to be greater than the total acres flooded. If this happens, total acres flooded is set equal to channel acres flooded. The damage length can be different than the flood plain length if there is some nondamaged area, such as woods or swamp, between the cross sections. The calculation of damage acres is based on input values for damage length and channel length in damage reach and is independent of the calculation of channel acres and total acres flooded.

Notes:
- In order to get damaged acres calculated, there must be a damage length on the REACH record (col. 51-60) and at least one D segment at the cross section.
- Acres flooded which are printed at road approach sections include those acres between the exit section and the road section (a damage length and channel length in a damage reach can be entered on a ROAD record). For road sections with culverts only, acres between the exit section and the culvert outlet are added to the acres from the culvert inlet to the approach section.
- It is recommended that if a damage length (**DMLGT**) is entered then channel length in damage reach (**DLGT**) also be entered to be consistent with assumptions in figure 31–5.

Figure 31–5 Channel and flood plain lengths



Input data for reach lengths on REACH and ROAD records

Columns	Variable name	Description
31-40	CHLGT	Hydraulic length of channel
41-50	FLGT	Hydraulic length of flood plain
51-60	DMLGT	Flood plain damage length
61-70	DLGT	Channel length in damage reach

630.3103 Cross section encroachment

An option to insert encroachment limits (to represent a floodway) at cross sections is operational in WSP2. At the encroachment limits, the program places vertical walls and no flow is calculated outside the limits. This option may be used on valley and road cross sections.

To use this option enter the left encroachment limit in columns 41 to 50, on the SECTION record, and the right encroachment limit in columns 51 to 60. One or both values may be entered. If these fields are blank, the program assumes no encroachment is desired. The left and right convention used is that the right encroachment limit must be a greater number than the left encroachment limit (only if both are entered). The program reads a blank field differently than a zero (since zero may be in the cross section stations). For no encroachment, the fields should be blank.

The only restrictions placed on encroachment limits are:

- The right limit must be greater than the left limit (otherwise a fatal error message is printed).
- If a limit is entered, it should be within the stations defining the original cross section. If not, the entered limit is ignored and a warning message appears.

(a) Valley section encroachment

The vertical walls placed at the encroachment limits are assumed to have friction (i.e., the wetted perimeter of the wall is included for conveyance computations). Section data outside of the limits are ignored in the conveyance computations.

The encroachment limits placed on a particular cross section also apply at locations where that cross section is transferred (REACH2 locations).

An example of valley section encroachment is shown in figure 31–6.

WSP2 will not indicate where encroachment limits should be set in order to allow a certain rise in the water surface. These limits may be estimated using the SCS Floodway Computer Program (TR-64).

(b) Road section encroachment

Encroachment limits at road cross sections can reduce the weir length associated with flow over a road. In certain situations, encroachment limits at a road crossing can be similar to those of the upstream and downstream cross sections, recognizing that active flow area is important in determining water surface elevations in WSP2.

Culvert and bridge data are not altered when encroachment limits are entered at a road cross section. If a culvert is outside a proposed encroachment limit, it may be appropriate to delete the CULV1 and CULV2 records for that culvert. Items to be considered when entering encroachment limits at road cross sections include:

- The left and right encroachment limits must be to the left of the left girder station and to the right of the right girder station, respectively.
- If both encroachment limits are entered, the right limit must be a greater number than the left. (Otherwise, an error message occurs.)
- If a limit is entered, it should be within the stations defining the original cross section coordinates. If not, the value is ignored and a warning message is printed.

An example of road cross section encroachment is shown in figure 31–7.

Figure 31–6 Valley section

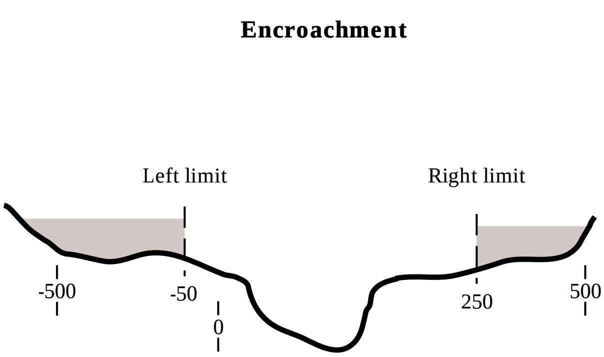
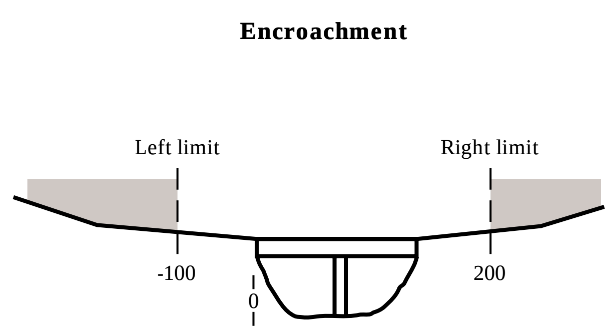


Figure 31–7 Road section



630.3104 Energy loss coefficients (expansion/contraction)

When flow along a reach expands or contracts, there is energy loss. The way in which this is accounted for in water surface profile computations is to multiply a coefficient by the difference in velocity heads between two cross sections. Using the terminology of figure 31–1 for expanding flow, the energy loss due to expansion is:

$$E_L = C_E\left(\frac{\alpha_2 V_2^{\,2}}{2g} - \frac{\alpha_1 V_1^{\,2}}{2g}\right)$$

where:
C_E = expansion coefficient.
Subscripts 1 and 2 refer to the downstream and upstream cross sections, respectively.

For contracting flow, it is:

$$E_L = C_c\left(\frac{\alpha_1 V_1^{\,2}}{2g} - \frac{\alpha_2 V_2^{\,2}}{2g}\right)$$

where:
C_c = contraction coefficient.

This loss is added to the friction loss in order to balance the energy at the upstream cross section. It is evident that consideration of expansion and contraction losses can result in slightly increased water surface profile elevations. Also, consideration of these losses would have more impact on profiles for streams with moderate to high velocities and change of cross section. The LOSS record can be used to enter energy loss coefficients for expansion and contraction of flow at valley sections.

An example follows:

```
LOSS     0.3     0.1
```

The expansion coefficient is entered in columns 11 to 20 and the contraction coefficient in columns 21 to 30. LOSS coefficients are initialized to zero when the program begins. When a LOSS record is read, those coefficients are used for all following REACHes until a new LOSS record is read. For example, a single LOSS record entered before the first REACH record is all that is needed to have the same coefficients for all REACHes in the job. For gradual changes in cross section, an expansion coefficient of 0.3 and a contraction coefficient of 0.1 are recommended. For abrupt changes 0.8 and 0.6 are recommended. The upper limit is 1.0 for these coefficients.

The loss coefficients also apply to transitions from the section downstream of a road to the tailwater section and from the headwater section up to the approach section upstream of the road. In order to change coefficients at a road, enter the LOSS record with appropriate coefficients just before the ROAD record. After the REACH record for the section upstream of the road, enter a new LOSS record to revise the coefficients again.

630.3105 Average rating table computation

If there are several cross sections in a hydrologic routing reach, an average rating table can be computed to represent the reach. This table will be saved in an output file for later use with SCS TR-20. A summary of operation follows.

Input examples

Specify the beginning and ending cross section of the reach by WSP2 names. Specify the *key* section where the name, elevations, and discharges will be retained. Specify an integer from 1 to 200 as a name for the reach. (This number will appear in the appropriate columns of the 2XSECTN record for the TR-20 program.) Use standard 10 column fields. Either of the examples below may be used as an input format. It is recommended that either 4 names (example A) or two names (example B) be used. If three names are used, the third name is ignored. The first two names are mandatory.

Example 31–A

AVERAGE AA BB CC 111

AVERAGE is the control word. Section AA is the beginning section (farthest downstream). Section BB is the ending section (farthest upstream). Section CC is the *key* section. Section 111 is the designated TR-20 reach name.

Example 31–B

AVERAGE AA BB

Section AA is both beginning and *key* section. If section AA has a TR-20 name on the SECTION record, it will be used. Section BB is the ending section.

- An *R* or *T* output option should be entered on the OUTPUT record. This will result in the *key* section rating tables being saved in an output file. The *key* section average rating table will take precedence, and no individual sections within that designated reach will be saved in the output file. Average rating tables will not be saved in the output file associated with the *E* option (See Section 630.3109, Output options).
- AVERAGE records need to be in the same order as the REACH and ROAD records. The logical location for these records would be with the reach input data. They should be entered before the COMPUTE records. AVERAGE reaches should not overlap each other. For example, cross sections labeled alphabetically could be averaged from A to E, from F to J, and from K to M.
- Because these tables can be used directly by TR-20, it is recommended the array of discharges begin with the lowest and proceed to the highest.
- Average rating tables will contain profile elevations, discharges, flow areas, and acres damaged for each profile. Bank full, zero damage, and low ground values will not be interpolated from the profiles. Bank full and low ground elevations for the *key* section will appear on the 2XSECTN record.
- Acres damaged are accumulated by profile. The sum is saved with the average rating table. The zero damage elevation for this table is the highest profile with zero acres damaged. This elevation will be saved in the appropriate columns for the 2XSECTN record for input to TR-20.
- The averaging or weighting of cross sections is accomplished by weighting the flow velocity at a cross section by its channel length. These are summed for all cross sections in the given averaging reach. A weighted velocity is computed by dividing the sum by the sum of channel lengths. This velocity is then divided into the discharge at the *key* section to get a weighted area. The short length between the exit section and a road section and the length between the road section and approach are included in the weighting.
- A maximum of 50 average rating reaches may be entered per job.
- The last average rating should be completed (the ending section computed) before the ENDJOB record is read.

- An average rating table may be incomplete at a COMPUTE or LINK record. The starting section needs only to be within a COMPUTE sequence and computed before the LINK record.

630.3106 Transferring cross section data using REACH2

If the valley is uniform in cross section, a surveyed cross section may be transferred upstream or downstream and displaced by a vertical distance increment. This is particularly useful in transferring a section from the upstream to downstream side of a road (or vice versa) if the valley shape is similar. An example of this follows.

If road cross section B and valley cross section C (50 feet upstream) are surveyed and a cross section downstream of B with a shape similar to cross section C is desired, enter:

			Distance			
REACH	A	5.0				
REACH2	C	-0.5				
ROAD	B	2.5	50.	50.	50.	50.
REACH	C	4.9	50.	50.	50.	50.

Cross section A only represents a location. No SEGMENT or SECTION data are entered for cross section A. The elevation of every point on cross section C is lowered by 0.5 feet, and the horizontal distances are not changed when the section is transferred to cross section A. The distances entered on the REACH and ROAD records represent the distance from that location to the next section downstream.

630.3107 Limitations

This section indicates important limitations of WSP2. If a given problem demands more accuracy than these limits allow, a different method of solution must be used.

Because data entry was made as easy as possible, WSP2 cannot check for many sources of input errors. For example, the capability of sorting the cross section station-elevation points precludes WSP2 from checking the integrity of station values. Survey information needs to be transferred accurately from notes to data records.

When supercritical flow occurs, WSP2 uses the elevation that corresponds to critical depth for that profile at the section and continues upstream in this manner until subcritical flow recurs. WSP2 does not recompute downstream to determine supercritical flow elevations.

Critical depth is found by using the equation:

$$\frac{Q^2}{g} = \frac{A^3}{T}$$

This relationship is valid for irregular, single-segment valley cross sections. It does not give the water surface elevation for multisegmented sections where energy is minimum. Errors of as much as 2 feet can occur, compared with the minimum elevation shown on a specific energy diagram, because of the area-top width relationship.

The WSP2 energy balancing procedure assumes gradually varied flow in a reach. Since WSP2 is based on the law of conservation of energy, the limits of gradually varied flow should be related to kinetic energy (velocity head) rather than directly to velocity. If velocities in a reach are less than 6 feet per second, the maximum change in velocity head would be about 0.5 foot. Certain evaluations could be significantly affected by this change, but they would normally be within the degree of accuracy of other hydrologic estimates.

If velocities are more than 6 feet per second, output should be carefully examined to determine the adequacy. At a velocity of 8 feet per second, the maximum change in velocity head would be about 1 foot. Therefore, results that include velocities of 8 feet per second or more should be carefully verified. A warning message will be printed if the velocity is greater than or equal to 8 feet per second.

WSP2 culvert analysis is limited to rectangular, circular, and standard arch shapes. A culvert that is deformed by settlement, partially filled with sediment, or of a different shape must be represented by one of the three standard shapes. Of all parameters estimated, a close similarity should be maintained between the actual area and the area of the culvert chosen as most representative.

The mysteries of computer processing along with the form of computer output sometimes suggest more accuracy than is justified. In examining WSP2 output, consider the following limitations:

- Accuracy of estimated input parameters. A Manning's *n* roughness value can be estimated to be 0.04. Over a period of time, it may range from 0.025 to 0.045. This might correspond to a variation in water surface elevation of -0.3 to +0.1 foot.
- Precision of technical procedures applied to input data. For example, energy is balanced to the nearest tenth of a foot, so a digit in the hundredth position has little meaning.

630.3108 Input

Control words in columns 1 though 10 of the input records direct the storage of data and the operation of the program. Spelling must be exact and upper case, but the user can insert blanks in control words as desired. Some data are optional. For example, if acres damaged information is unimportant, only the first two length fields on the REACH or ROAD record need to be coded.

All input is in standard 10 column fields. Data may be located anywhere in the field since the program disregards blank columns. For example, both 2379bbbbbb and b2379bbbbbb are read as 2379.b (b represents a blank column in an input field). If the correct input is 23.79 the user must insert the decimal point. Commas should never be included in numeric data, nor should blank lines occur in the data set.

A summary of input differences with the 1982 WSP2 version follows.

- **WSP2** record—Enter optional watershed identification (up to 8 characters) in columns 21 to 30. This will appear on output page headings and output files.
- **OUTPUT** record—Additional output options E, T, H, W, X, and C have been added.
- **SECTION** record—Enter optional integer section name (between 1 and 200) in columns 31 to 40. This identification will appear in output files. Enter optional left and right encroachment limits in columns 41 to 50 and 51 to 60, respectively.
- **AVERAGE** record—Enter beginning cross section name in columns 11 to 20, ending cross section name in 21 to 30, key cross section name in 31 to 40, and integer section name (between 1 and 200) in 41 to 50.
- **LOSS** record—Enter expansion coefficient in columns 11 to 20 and contraction coefficient in columns 21 to 30.
- **COMPUTE** record—Enter optional alternate identification (up to 8 characters) in columns 41 to 50. This will appear in output page headings and output files.

The user is referred to the blank input forms (appendix 31B) and sample job (appendix 31A) for detailed descriptions and examples of input data coding and organization.

The general input data categories are:

I. Preliminary data
- A. WSP2
- B. TITLE
- C. DISCHARGE
- D. STARTS or STARTE
- E. TRIB
- F. OUTPUT

II. Length and drainage area data
- A. REACH
- B. REACH2
- C. ROAD

III. Cross section data
- A. SECTION
- B. SEGMENT
- C. NVALUE

IV. Bridge data
- A. SECTION
- B. BPR
- C. PIER
- D. GIRDER
- E. CONTR

V. Culvert data
- A. SECTION
- B. CULV1
- C. CULV2

VI. Miscellaneous
- A. COMPUTE
- B. AVERAGE
- C. LOSS
- D. LINK
- E. CHANGE-END
- F. ENDJOB-ENDRUN
- G. COMMENT

(a) Data entry order

The input data forms have been organized such that they assist in ordering data in a WSP2 job.

Form SCS-ENG-16	Preliminary data
Form SCS-ENG-22	Reach length and drainage area data
Form SCS-ENG-17	Bridge and culvert data
Form SCS-ENG-18	Segment and *n* value data
Form SCS-ENG-19	Cross section data
Form SCS-ENG-20	Define computing sequence

Forms 22, 17, 18, and 19 may be used as many times and in any order needed according to the number of cross sections. The data should be followed by form 20.

For jobs with more than 50 cross sections, enter a LINK record after the COMPUTE record and continue with more data from forms 17, 18, and 19. Data from form 20 should follow that.

The major requirement is that all data needed to perform a compute instruction must precede the COMPUTE record. The order of REACH and ROAD records establishes the order of computations that follow after a COMPUTE record is read. The user must place these records in the desired order, but the records need not be adjacent to each other in the input file. The input records that must be in a specific location are:

- The first record of any job must be a WSP2 record.
- REACH and ROAD records must be in the order of computation. Expansion and contraction loss entered on the LOSS record applies to all following REACH records until a new LOSS record is entered.
- For bridge openings, the BPR or CONTR record must be first. If a PIER record is used, it must follow the BPR record. The GIRDER records must be next followed by an ENDTABLE record.
- A CULV2 record must follow each CULV1 record.
- An NVALUE record must follow each SEGMENT record.
- A REACH2 record (if used) must follow the REACH record. The REACH2 record should be used only if the valley section of that reach has the same shape and roughness as the valley section of another reach. The valley section that is displaced and copied may be either upstream or downstream from the reach under consideration.
- All information necessary to compute profiles, such as DISCHARGE, STARTE, or TRIB, for a given compute sequence must precede the COMPUTE record.
- A LINK record must be used if a job exceeds a combined total of 50 valley and road sections. The section that precedes the LINK record must be identified on a TRIB record.
- An END record must follow the records associated with a CHANGE record.
- AVERAGE records should be placed before COMPUTE records and must be in same order as ROAD and REACH records.

(b) Updating

When updates are made, the old data are not saved. For example, update section MAIN 5 replaces data for old MAIN 5. The old data points are lost. Any piece of input data can be updated. Most common is updating of cross section coordinates to reflect channel improvement. This usually requires updating the corresponding segment data and, if channel lengths were shortened, the reach file (list of reaches by order of computation saved in computer memory). Updating is done as follows:

- **CHANGE BPR, CULV1, or CONTR**—This is used to update BPR, PIER, GIRDER, culvert, or CONTR data.

  A BPR bridge may be changed to a CONTR bridge and vice versa. To update BPR bridge data, BPR, PIER (if any piers) and GIRDER records must be reentered; even if, for example, there is no change in GIRDER data. These records follow the CHANGE BPR record. To change culvert data, any CULV1 and CULV2 records must follow the CHANGE CULV1 record. CONTR and associated GIRDER records must follow the CHANGE CONTR record.

- Any third, fourth, and so forth, TITLE record updates the second TITLE record. CHANGE and END records are not needed.
- **CHANGE DISCHARGE**—All the discharge file is lost, so all new discharge values must be entered.
- **STARTE or STARTS**—This information can be updated without using a CHANGE record if a new cross section name is used. If the same section name is used, a CHANGE STARTE or CHANGE STARTS record must be used.
- **CHANGE SEGMENT**—N-values must be reentered. Segments within the same cross section can be updated independently of each other.
- **CHANGE REACH From (XSEC) To (XSEC)**—If From (XSEC) and To (XSEC) are both filled in, then all cross sections between (including the From (XSEC) and To (XSEC) sections) are replaced with the new reach records that follow.
- **CHANGE SECTION**—If the section name(s) that follows this record is in the file, the data are replaced. If the section name is not in the file, these cross section data are added to the file.
- **CHANGE TRIB**—The number of cross sections where profiles are saved for later use may be increased over the limit of 20 by using the CHANGE TRIB capability. Since CHANGE records are normally used after COMPUTE records, the compute sequence is broken. If desired, one of the cross sections in the original TRIB file may be repeated as the **first** cross section in the changed TRIB file so that the following compute sequence will have starting data and profile computations can continue.

For example, cross sections labeled alphabetically:

TRIB	C	E	L	M	
COMPUTE	A	M	A		
CHANGE	TRIB				
TRIB	M	P	R	V	Y
END					
COMPUTE	N	Z	M		

- An END record must follow the last data for CHANGE record.

(c) Input for given discharge values

Three methods can be used to determine flow rates at each cross section. One method uses cubic feet per second per square mile (csm) values as input which are then converted to cubic feet per second (cfs) values by the computer program. The second method, based on direct input of cfs values by the user, is explained in the following example, which shows the discharge and reach records for a job using given cfs values.

DISCHARGE	-2	0.7	0.9	1.0	1.2	1.5
REACH	1	1375	0.0	0.0		
REACH	2	1345	450	450		
REACH	3	1290	700	700		

Five profiles are calculated. At valley section 1 the discharges are:

Profile 1 $0.7 \times 1{,}375 =$ 962 cfs
Profile 2 $0.9 \times 1{,}375 =$ 1,238 cfs
Profile 3 $1.0 \times 1{,}375 =$ 1,375 cfs
Profile 4 $1.2 \times 1{,}375 =$ 1,650 cfs
Profile 5 $1.5 \times 1{,}375 =$ 2,062 cfs

At valley section 2 the discharges are 0.7, 0.9, 1.0, 1.2, and 1.5 times 1,345.

The third method is to set all drainage areas on REACH and DISCHARGE records to 1.0 and enter discharges directly. An example follows. For sections labeled alphabetically and three profiles:

DISCHARGE	1.0	500.	1000.	1600.
COMPUTE	A	E	A	
CHANGE DISCHARGE				
DISCHARGE	1.0	400.	900.	1500.
END				
COMPUTE	F	M	E	

Section E needs to be identified on a TRIB record. This method allows the most flexibility in entering discharge values.

630.3109 Output options

A list of all input data up to the first COMPUTE record is printed first (see sample job output). The end of the input list is noted END OF DATA LISTING. This means that a COMPUTE record has been encountered and computations will follow. The standard output (valley section and road section rating tables) appears next. Requested optional output (segment and KD tables and rating curve plots) is intermixed with the rating tables. Only one bridge and one culvert rating are reproduced in the sample.

The velocity under the total column in the segment table (requested by **S** output option) is a weighted velocity. It is the velocity that, when squared and divided by 2g, yields the velocity head (see step 3, Section 630.3102, Valley section analysis). Stated another way, it is the average section velocity adjusted (usually increased) for nonuniform velocity distribution within the valley section.

Each output sheet has its own page identification. The standard output contains only the page number. The other sheets contain the same number plus a letter identification. **K** is for KD table, **P** for plotted rating table, and **S** for segment information table. All output sheets pertaining to the same cross section have the same page number. The title part of the identification is indicated by the input TITLE records. The points on the plotted rating table are labeled **0** for lowest cross section elevation, **1** to **9** for profiles 1 to 9, and **A** to **F** for profiles 10 to 15.

There are 10 output options associated with code letters for the WSP2 OUTPUT record. These letters may be entered in any order in columns 11 to 20. The letters may be separated by blank spaces, but not by any character, such as a comma or dash.

- **E**—All valley cross section rating tables are saved in an output file for use in the SCS ECON2. Elevation, discharge, area, and acres damaged are placed in 10 column fields.
- **K**—Conveyance table will be printed with output. Total top width and conveyance and segment conveyances are in the table.

- **P**—Rating tables (elevation vs. discharge) will be plotted for all sections with standard printer output.
- **R**—Average rating tables and rating tables for all other valley sections not in an averaging reach will be saved in an output file for later use as input to the TR-20 and/or ECON2 program (12 column fields). If any cross sections have designated TR-20 names (see **T** option below), these names will appear on the 2XSECTN records (col. 13 to 15).
- **S**—The segment table will be included in standard printer output. Segment conveyance, discharge, and velocity for each profile will be printed.
- **T**—This option will allow the user to select and name valley cross sections and/or average rating tables to be saved in an output file for later use with TR-20 and/or ECON2 (12 column fields). If the **T** option is selected and a valid TR-20 name (an integer between and including 1 and 200) is entered in columns 31 to 40 on the SECTION record, then that rating table will be saved. It is recommended that options **T** and **R** not be used on the same job execution. (If so, the *R* option is assumed.)
- **W**—Water surface profile data will be saved in a file for later use in microcomputer graphics software.
- **X**—Cross section data saved in a file for later use with graphics.
- **H**—Hydraulic (rating) tables will be saved in a file for later use with graphics.
- **C**—Conveyance tables will be saved in a file for later use with graphics.

Note: The 10 options are active only for cross sections where profiles are computed.

630.3110 Helpful hints

Quite often it is necessary for someone other than the person who prepares the input to study the output. For a person unfamiliar with the data, it is much easier to find specific pieces of information if a set input pattern is followed. Therefore, the pattern shown in the sample job is recommended. The standard forms can aid in coding input in this manner.

The sample job was put together as follows. The information on form SCS-ENG-16 was entered first. The complete REACH and ROAD file was entered next on form SCS-ENG-22. The complete reach and road file should be put here even if the section information is split by LINK records. This was followed by the SEGMENT, SECTION, and BPR or CULV information for cross sections beginning with the one located farthest downstream. The last information was COMPUTE information followed by ENDJOB and ENDRUN records.

WSP2 requires a large amount of input data. The user should make every possible check to eliminate errors. Use of the sort-routine precludes WSP2 from checking for correct station (x) values. A plot of the valley section input data is an excellent data check.

In WSP2, the hydraulic length of channels and flood plains is measured from the section under consideration to the next downstream section. The Manning *n* entered should represent the channel and flood plain to the next cross section downstream.

A few coding and data entry errors can be eliminated if optional information is omitted. For example, the elevations on segment boundary points can be left blank if the station value is unique.

The name of roads and reaches should contain no more than six characters because this is all that is retained by the program. Upper or lower case letters may be used, but the name must be the same in all places used (SECTION, SEGMENT, COMPUTE, REACH).

Examine all WSP2 output to determine the adequacy of the results. Use USGS rating curves, high water marks, and all other available information to check WSP2 ratings. Pay careful attention to BPR bridge head losses and to valley section ratings, particularly if velocities exceed 8 feet per second. A water surface reversal can occur between sections. This may be due to a large change in velocity head. When this occurs, compare the input data and the physical situation to determine the cause and proceed accordingly.

Always request the segment table if you run seven or fewer profiles. This generates no more pages of output and adds only minimal time for printing. The KD table that gives values at even foot increments should rarely be needed because KD values at profile point elevations are provided in the segment table.

A large block of run time in the sample job was used to analyze the head loss through the culverts and bridges. The amount of run time used in analyzing the head loss through a road restriction with bridge and/or culverts depends mainly on the number of profiles being processed, the amount of head loss for each profile, type of culvert being analyzed, and number of openings of different configuration.

A circular culvert uses about 2 times more computer time and a pipe arch culvert uses about 8 times more than a box culvert.

If you are in doubt as to whether a restricted opening should be analyzed as a bridge or a culvert, analyze the opening as a culvert. Culvert loss analysis is more reliable than the BPR bridge loss analysis. Therefore, if there is a choice, call the opening a culvert.

It is recommended that the array of discharges used in computations be entered from smallest to largest. This will insure a more accurate interpolation of bankfull and zero damage discharges and will result in the output rating table being properly ordered for entry into the hydrology program, TR-20.

630.3111 Data checking and output messages

All input data are edited for detectable errors when they are read. The three types of detectable errors are:

- **Error** in data that must be corrected. When this type of error is detected, computations will not proceed. The program continues to edit the data as much as possible in order to detect additional errors. Other errors can be detected only when computations are being performed. All error messages are made to stand out by asterisks.

*****BLANK IS NOT ALLOWED IN FIELD NO. 5*****

- **Warning** that may not result in erroneous results, so computations continue.
- **Message** to alert user to possible data problem.

Review of this section will provide background on many commonly made errors, program limitations, and data requirements.

(a) Errors

BLANK IS NOT ALLOWED IN FIELD NO XX.

Certain data fields cannot be left blank. If zero is intended, the zero must be included and entered on the record. This is because certain types of data must be present for the program to be run. The absence of data would indicate an oversight or an error.

BLANK OR ZERO DRAINAGE AREA ENTERED.

Enter a drainage area on the DISCHARGE record.

CHECK CULVERT DATA FOR ROAD CROSS SECTION XXXXX.

Check all culvert data at this section for reasonableness.

CONTR COEFFICIENT NOT BETWEEN 0 AND 1.0 FOR ROAD SECTION XXXXX.

This coefficient must be greater than zero and less than or equal to 1.0.

DISCHARGE RECORD MISSING.

A DISCHARGE record must be entered before the first COMPUTE record in order to specify what discharges and how many profiles are to be computed.

ENCROACHMENT STATION BETWEEN GIRDER ENDPOINTS FOR SECTION XXXXX. CHECK INPUT DATA.

The left and right encroachment stations may not be within the girder stations.

ENDTABLE RECORD EXPECTED.

ENDTABLE record missing at the end of the SECTION or GIRDER table.

GIRDER POINTS DO NOT MATCH ROADWAY ON BRIDGE.

The program matches the first and last points on the GIRDER record with points on the road cross section records in order to separate the road section into weirs and to get bridge-opening areas. The X-values are the ones that must be matched. The road section does not contain any X-values corresponding to the first and last girder X-values.

IMPROPER COMBINATION OF N-VALUES AND R OR E ON SEGMENT NUMBER XX XSEC NUMBER XXXXX.

The number of n-values provided for a segment in the input data must be equal to or one greater than the number of hydraulic radii or elevations provided.

INVALID CHARACTER IN FIELD XX ON THE ABOVE RECORD.

The field named in the record listed above has an invalid character. A letter, number, or other character is incorrectly entered. Check record and control words to determine correct notation for this field.

INVALID CULVERT CODE ENTERED, REFER TO USER MANUAL.

The culvert codes are listed on the back of form SCS-ENG-17.

INVALID NUMBER ENTERED IN FIELD XX ON ABOVE RECORD. REFER TO USER MANUAL.

A number outside prescribed limits for the field on the above record has been entered. Refer to the input data form for that record type.

LAST POINT ON SEGMENT XX DOES NOT MATCH ANY POINT ON CROSS SECTION XXXXX.

The data point named as the last station and last elevation on a segment record must correspond to one of the survey points for this cross section.

LEFT ENCROACHMENT STATION GREATER THAN RIGHT STATION.

Job is terminated. Check encroachment stations entered on SECTION record.

LESS THAN THREE GIRDER POINTS ENTERED FOR SECTION XXXXXX.

A minimum of three girder points may be entered. The first and last represent the left and right tops of the girder respectively.

LESS THAN TWO CROSS SECTION POINTS ENTERED FOR SECTION XXXXXX.

A minimum of two cross section points are needed for a road or valley cross section.

MORE THAN 50 AVERAGE RATING REACHES ARE ENTERED.

50 is the maximum number accepted.

NEGATIVE OR ZERO DISCHARGE ENTERED.

Enter a positive discharge on the DISCHARGE record.

NEGATIVE OR ZERO SLOPE ENTERED.

Starting slopes must be positive to prevent computer system errors.

NEGATIVE OR ZERO VALUE ENTERED IN FIELD X ON ABOVE RECORD.

A positive value is needed in the specified field.

NO VALID NVALUE FOR SEGMENT XX OR SECTION XXXXX.

WSP2 expects an NVALUE record to follow a SEGMENT record. The NVALUE record either is missing or has invalid data entered on it.

NO VALUE GIVEN FOR PIER CURVE ON BRIDGE XXXXX.

Pier curve number is missing on BPR record.

NUMBER OF ALLOWABLE GIRDER POINTS EXCEEDED.

The maximum number is fifteen.

NUMBER OF BRIDGE SECTIONS EXCEEDS LIMIT.

WSP2 accepts only 25 bridge sections on BPR, CONTR, or CULV records (before a LINK record is used).

NUMBER OF SECTIONS EXCEEDS FILE SIZE. USE LINK.

WSP2 can hold data on 50 cross sections entered on SECTION records. If more are entered, WSP2 simply ignores them. This may cause an error message later in the calculations, indicating that a particular section is missing.

NUMBER OF STARTING VALUES LESS THAN NUMBER OF PROFILES TO BE RUN.

The number of profiles to be run under the current COMPUTE record (determined by number of values entered by a DISCHARGE record) is more than the number of values in the STARTS or STARTE data for the cross section. Critical depths will be used for all starting values.

ORIFICE COEFFICIENT NOT BETWEEN 0 AND 1.0 FOR ROAD SECTION XXXXX.

This coefficient must be greater than 0 and less than or equal to 1.0.

PIPE ARCH DIMENSIONS EXCEEDS MAX. SIZE (**RISE × SPAN > 272 SQ. FT.**).

This message will be printed if the product of rise and span of a pipe arch culvert is greater than 272 square feet. Convert culvert to a bridge if product is exceeded. Formulas may not be extrapolated for pipe arch culverts. The culvert entered is approximated by one of 61 standard sizes stored by the program.

REACH—NAMED XXXXX IS NOT IN THE REACH FILE.

The cross section name XXXXX that appears in the first field in the COMPUTE record has not been located in the reach file. This cross section either has not been named as a reach and has been omitted from the reach file, or the name in this compute is incorrect.

RECORD OUT OF SEQUENCE.

The program expected a girder record or a CULV2 record.

ROAD WEIR COEF FOR SECTION XXXXXX OUTSIDE OF RANGE 1 TO 4.

SECTION XXXXXX IDENTIFIED AS A ROAD. BRIDGE AND/OR CULVERT DATA MISSING.

The named section is identified on a ROAD record. BPR, CONTR, and/or CULVERT data are missing.

SECTION XXXXXX IDENTIFIED AS A VALLEY. BRIDGE AND/OR CULVERT DATA ENTERED.

The named section is identified on a REACH record. BPR, CONTR, and/or culvert data have been entered.

SECTION UPSTREAM OF ROAD XXXXXX MAY NOT BE ANOTHER ROAD SECTION.

A ROAD section may not follow another ROAD section. Insert a valley section or use REACH and REACH2 to transfer a valley section to a location between the two ROAD sections.

SEGMENT NUMBER NOT IN RANGE OF 1 TO 6.

SEGMENT TYPE NOT C, D, OR N.

SEGMENTS X AND X OVERLAP ON SECTION XXXXX.

The endpoint value specified for a segment is smaller than the endpoint value specified for a segment that has a smaller segment number. For example, segment number 1 ends at a station 600; segment number 2 ends at station 400.

THE ABOVE RECORD IS OUT OF ORDER OR INCORRECTLY ENTERED, LIMITED EDITING CONTINUES.

Certain records must follow other records. For example, an NVALUE record must follow a segment record. The data on a record that is out of order are lost. This error may not be fatal at this point, but will probably be fatal before the run is through.

THIS STARTING DATA NOT YET COMPUTED.

The starting elevations were to have been computed and retained. However, the profiles for the required cross section have not been computed.

T**OO MANY BRIDGE AND CULVERT TYPES XSEC XXXXX. MAXIMUM OF 5 ALLOWED**.

A maximum of one bridge with four culvert types or no bridge and five culvert types are program limits.

TOO MANY BRIDGE OPENINGS AT ROAD CROSS SECTION XXXXX. ONE ALLOWED.

Only one bridge opening of the contracted opening or BPR type is accepted.

TOO MANY CROSS SECTION POINTS.

The program will hold 48 points per cross section.

TOO MANY SECTION NAMES WITH SEGMENT DATA. USE LINK.

There are more than 50 cross sections named on SEGMENT records.

TOO MANY SEGMENTS FOR THIS SECTION.

More than six segments have been named or entered for this cross section. The limit is six. Only the first six are used.

TOO MANY STARTING POINTS GIVEN.

The maximum number of entries on the STARTE or STARTS records is 15.

TOO MANY TRIBUTARY NAMES GIVEN.

The program can hold values for only 20 tributaries.

TOO MANY VALUES GIVEN FOR DISCHARGE—ONLY THE FIRST 15 ARE USED.

The program can run only 15 profiles at one time.

TYPES OF STARTING INFORMATION MAY NOT BE MIXED ON THE SAME CROSS SECTION.

A STARTE record has been entered following a STARTS record with the same cross section name, or vice versa. If either elevations or starting slopes are given for one profile, they must be given for all profiles. The last type entered is the one retained by the program. Later in the calculations this may cause an unequal match between the number of profiles and the number of starting elevations.

VALUES ON THE RECORD ABOVE MUST BE POSITIVE.

If values are entered on the above record, they must be positive.

WIDTH NOT NEEDED FOR CIRCULAR CULVERTS.

If the culvert code is for a circular culvert, then the width field on the CULV2 record should be blank.

WSP2 RECORD MISSING AT BEGINNING OF INPUT DATA FILE.

When reading the WSP2 record, the program initializes many factors. This record is needed at the beginning of each WSP2 job. If multiple jobs are entered, the WSP2 record should be at the beginning of each.

XSEC XXXXX DOES NOT HAVE SEGMENT FILE.

WSP2 found no segment data for the named cross section. It could be that the section is to be a bridge. If so, then bridge data are also missing.

XSEC XXXXX DOES NOT HAVE A SEGMENT NO. X NEXT TO NO=X.

Some segment data are missing for the named cross section.

CROSS SECTION XXXXX HAS TWO SEGMENTS NUMBER XX.

In trying to set up the segments for this cross section, the program found two segments with the same number. The first segment found with this number is used, and the other is disregarded.

XSEC XXXXX WAS NOT IN FILE.

The named cross section was not in the section file. The cross section either was not entered, or an error was made in entering the name.

XSEC NAME BLANK ON ABOVE RECORD.

The program expected to read a cross section name in a field on the above record.

XSEC NAME XXXXX ON COMPUTE RECORD NOT IN REACH FILE.

All three cross section names on the COMPUTE record need to be identified on REACH records previously entered.

XSEC WAS NOT ON THE FILE FOLLOWING CROSS SECTION NAMED XXXXX.

In an attempt to update the reach file, the To XSEC was not in the reach file after the From XSEC was located. In updating the reach file, both the From XSEC and To XSEC must be in the old file.

XSEC ON CURRENT COMPUTE RECORD CANNOT BE A ROAD.

The cross section named in the From XSEC or To XSEC field on a compute record may not be a road name because each road must have both an exit section and an approach section. Therefore, all profiles must start and end on a section other than a road section.

(b) Warnings

BOX CULVERT HEIGHT EXCEEDS 12 FEET OR AREA EXCEEDS 144 SQ. FT. FOR SECTION XXXXX.

Box culvert hydraulic formulas apply to heights of 12 ft or less and areas of 144 square feet or less. If openings are larger than 12 feet by 12 feet, the user may either treat the opening as a bridge or divide the opening into 12 feet by 12 feet or smaller box culverts with total area equal to that of the original opening. Solution to culvert backwater is extrapolated beyond limits of FHWA design charts.

COMPUTATIONS FOR AVERAGE RATING TABLE NOT COMPLETE AT END OF JOB.

This warning is printed when profiles for all cross sections in an average rating table reach have not been completed. Check cross section names on COMPUTE and AVERAGE records with reach file cross section sequence.

CULVERT DIAMETER EXCEEDS 15 FEET FOR SECTION XXXXX.

Circular culvert hydraulic formulas apply to diameters 15 feet or smaller. Solution to culvert backwater is extrapolated beyond limits of FHWA design charts.

ENCROACHMENT STATION XXXXX OUTSIDE CROSS SECTION, VALUE IGNORED.

An encroachment limit specified on the SECTION record is not within distance stations defined for the cross section. The value is ignored and profile computations continue.

FLOW DEPTH LESS THAN 0.2 FT.

For very shallow depths, conveyance interpolation may be inaccurate resulting in an inaccurate water surface profile.

ILLEGAL CHARACTER IN FIELD X ON THE ABOVE RECORD, DATA IGNORED.

Nonnumeric character found in a field where there is supposed to be a number or blank.

MORE THAN XXXX ESTIMATES OF HEADWATER MADE, SOLUTION TAKEN AT THIS POINT.

WSP2 builds a headwater table based on small increments of depth. If a solution that provides a sufficient amount of discharge through the opening has not been found after 250 tries, an error in input data is likely.

NO SOLUTION TO BACKWATER EQUATION, GIVE UP TAKE THIS ANSWER, ELEV. = XXX.X.

WSP2 made 1,000 trials to determine estimated water surface elevation at the head of the reach. The last three trials have been printed. The last figure printed is taken as an answer and processing continues. This figure may or may not be correct. To check, the user should compare the last three values printed.

PROFILE NO. XX EXCEEDS SURVEY DATA BY XX FT. COMPUTATIONS BASED ON VERTICAL EXTENSION OF ENDPOINTS.

Extending cross section data to a higher elevation using survey or topographic information is recommended.

SECT. XXXXX KD VALUES REVERSED ON SEGMENT X AT ELEV. XX.X. VALUE CHANGED TO EQUAL PREVIOUS VALUE.

When calculating conveyance for a segment, it is possible for the conveyance to decrease with elevation if the wetted perimeter increases rapidly with respect to flow area. This indicates that the segment may need to be divided into two segments near the elevation given in the warning.

SKEW ANGLE GREATER THAN 45 DEGREES.

Skew angle entered on GIRDER record greater than 45 degrees. Computations continue based upon an angle of 45 degrees.

STARTING ELEV. BELOW CRITICAL ELEV. FOR PROFILE XX. PROFILE STARTING AT CRITICAL ELEV.

The starting elevation on the STARTE record is below the critical elevation for the profile. WSP2 will not compute supercritical profiles.

STARTING SLOPE GREATER THAN CRITICAL FOR PROFILE XX. PROFILE STARTING AT CRITICAL.

The starting slope on the **STARTS** record is greater than critical slope for the profile. WSP2 will not compute supercritical profiles.

VELOCITY EXCEEDS 8 FT/SEC. PROFILE MAY BE IRREGULAR DUE TO VELOCITY HEAD CHANGES.

Velocity at bridge or valley section exceeds 8 feet per second. Check water surface elevations at the current section and the upstream and downstream sections for large differences due to velocity head changes. If this is true, then there is a rapid expansion or contraction of flow at these sections. More detailed study of flow at these sections may be needed.

(c) Messages

ABUTMENT TYPE IS BLANK. DEFAULT IS A.

The BPR abutment type should be A or B. The program assumes an A if this field is left blank.

BRIDGE HEADWATER BELOW CRITICAL DEPTH ON APPROACH SECTION. HW PRESUMED CRITICAL FOR PROFILE XX.

The depth of water at the upstream face of the bridge (bridge headwater elevation) is less than critical depth at the same location. This occurs if the bridge opening and exit section have much more discharge capacity than the approach section related to the same depth.

CHANNEL LENGTH IN DAMAGE REACH GREATER THAN CHANNEL LENGTH FOR REACH XXXXX.

A damage length has been set longer than the channel length. See Section 630.3102(f), Evaluation of acres flooded, for impact on acres flooded calculation.

DAMAGE LENGTH GREATER THAN FLOOD PLAIN LENGTH FOR REACH XXXXX.

A damage length has been set longer than the flood plain length. See Section 630.3102(f), Evaluation of acres flooded, for impact on acres flooded calculations.

DATA POINTS ON SECTION XXXXX REORDERED BY PROGRAM ACCORDING TO X VALUES. DUPLICATE X POINTS NOT CHANGED.

The distances (x values) for cross section points have not been entered in increasing order. The sort routine in WSP2 puts the points in order; however, if two or more points have the same x value, the order of these values is not changed.

ELEV. BELOW FIRST PROFILE. FLOW INTERPOLATED LINEARLY FROM CHANNEL BOTTOM.

This message is printed when low ground, zero damage, or bankfull elevations are below the first profile. The flow value printed is such that the velocity is the same as that for the first profile. For a more accurate estimate of bankfull, zero damage, or low ground discharge, add profiles which will better define the cross section rating curve near that elevation.

MAX. ELEV. DIFFERENCE BETWEEN POINTS EXCEEDS XX FEET.

Difference in elevation between two succeeding cross section coordinates is more than XX feet. WSP2 will default XX to a value of 20 feet unless specified otherwise on the WSP2 record. A check for a coding or keypunching error should be made before accepting these data as correct.

REACH XXXXX HAS A DAMAGE LENGTH BUT NO DAMAGE SEGMENT and REACH XXXXX HAS A DAMAGE SEGMENT BUT NO DAMAGE LENGTH.

In order for damage acres to be computed, both a damage length and damage segment must be present.

SEGMENT NO. X ADDED TO SECTION XXXXX.

When updating segment data, this message will appear if the updated data have more segments than the original data.

WEIR AND CULVERTS (IF PRESENT) CARRY TOTAL FLOW FOR PROFILE XX. NOT ENOUGH HW ENERGY TO HAVE BRIDGE FLOW.

Weir and culvert flow formulas do not account for upstream velocity head whereas bridge formulas do. Bridge flow is based on the energy balance principle. To have bridge flow, the headwater elevation plus approach velocity head must exceed tailwater elevation plus exit velocity head. Weir and culvert flow are not based on the energy balance principle. Weir flow and culvert flow begin as soon as the headwater elevation exceeds the tailwater elevation. This is a program limitation in effect whenever the lowest weir elevation is below the elevation where orifice flow begins for the bridge opening. This message would most likely occur when the exit velocity head is large. If there is a large difference in elevation between the low point of the road section and low point of the downstream section, high velocities may occur because WSP2 raises the elevations of the downstream section by this difference. If there is a large velocity or elevation change, the profile should be plotted and the channel bottom elevations revised so that a smooth transition is made.

XSEC XXXXX EXCEEDS DEPTH OF 125 FEET. CHECK INPUT DATA CAREFULLY.

The elevation difference between the highest cross section point and lowest is more than 125 feet. Check for possible data entry errors.

630.3112 References

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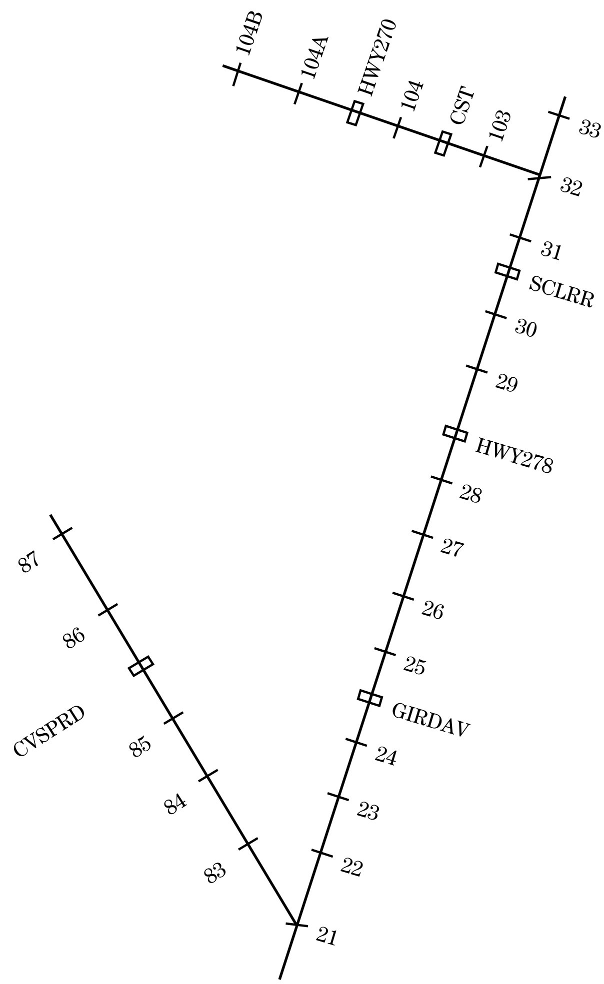
Terms and Notations

A	Cross section area ft^2
α	Velocity head correction coefficient
g	Acceleration of gravity (32.2 ft/s^2)
h	flow depth (ft)
KD	Conveyance equal to $\frac{1.486\,A\,r^{\frac{2}{3}}}{n}$
M	Ratio of conveyances in the BPR bridge loss analysis
n	Manning's coefficient of roughness
P	Wetted perimeter—the length of wetted surface measured along a cross section
Q	Discharge (cfs)
r	Hydraulic radius or the ratio of area to wetted perimeter
T	Flow top width at the free water surface (ft)
csm	Cubic feet per second per square mile
cfs	Flow rate in cubic feet per second
Energy level	Elevation of energy grade line, which is water surface elevation plus velocity head.
Segment	A part of the valley section that has uniform roughness and no rapid change in wetted perimeter with a small change in depth.
Damage segment	The part of the cross section where economic losses occur.
Nondamage segment	The part of the cross section that is not a part of the channel system and where economic losses are not considered.

Appendix 31–A

Cross section location schematic



Input data

```
WSP2                        CEDAR_GA
TITLE       BIG CEDAR CR GA,URBAN AREA
TITLE          EXAMPLE DATA SET FOR WSP2 PC VERSION
DISCHARGE   85.78       11.0        22.         37.03       58.0        88.87
DISCHARGE   85.78       105.        133.31      229.58      370.3
STARTS      21          0.00073     0.00073     0.00073     0.0008      0.00095
STARTS      21          0.001       0.00105     0.0012      0.00133
TRIB        21          32
OUTPUT      T
LOSS        0.3         0.1
REACH       21          85.78       10.         10.
REACH       22          77.68       1550.       1550.       1550.       1550.
REACH       23          77.32       2800.       2800.       2800.       2800.
REACH       24          76.75       900.        900.        900.        900.
ROAD        GIRDAV      2.7         50.         50.
REACH       25          76.56       1200.       1200.       1200.       1200.
REACH       26          76.38       600.        600.        600.        600.
REACH       27          76.28       600.        600.        600.        600.
REACH       28          76.14       950.        950.        950.        950.
ROAD        HWY278      2.7         50.         50.
REACH       29          76.09       400.        400.        400.        400.
REACH       30          76.05       200.        200.        200.        200.
ROAD        SCLRR       2.7         50.         50.         50.         50.
REACH       31          76.01       350.        350.        350.        350.
REACH       32          75.95       400.        400.        400.        400.
REACH       33          69.70       550.        550.        550.        550.
REACH       83          7.67        2500.       2500.       2500.       2500.
REACH       84          6.77        2800.       2800.       2800.       2800.
REACH       85          6.62        450.        450.        450.        450.
ROAD        CVSPRD      2.7         50.         50.         50.         50.
REACH       86          6.36        800.        800.        800.        800.
REACH       87          6.20        500.        500.        500.        500.
REACH       103         6.13        1750.       1750.       1750.       1750.
ROAD        CST         2.7         100.        100.
REACH       104         5.78        1350.       1350.       1350.       1350.
ROAD        HWY270      2.7         50.         50.         50.         50.
REACH       104A        5.78        50.         50.         50.         50.
REACH2      104         -.5
REACH       104B        5.56        600.        600.        600.        600.
REACH2      104         -.5
AVERAGE     24          30          24          15
AVERAGE     86          87          87          191
AVERAGE     103         104A
SEGMENT     21          1           D           1448.                               67
NVALUE       .105                                                                   69
SEGMENT     21          2           C           1535.                               70
NVALUE       .04                                                                    71
SEGMENT     21          3           D           2230.                               72
NVALUE       .105                                                                   73
SECTION     21                      1
            1000.        774.7      1180.       761.5       1320.       760.8       75
            1430.        760.0      1448.       758.8       1474.       749.0       76
            1520.        749.3      1535.       758.6       1635.       763.8       77
            1730.        764.8      1790.       763.4       1990.       764.0       78
            2080.        767.6      2230.       772.8                               79
```

ENDTABLE							80
SEGMENT	22	1	D	2250.			82
NVALUE	.105						84
SEGMENT	22	2	C	2335.			85
NVALUE	.035						86
SEGMENT	22	3	D	3995.			87
NVALUE	.105						88
SECTION	22		19				
	800.	775.4	1200.	761.8	1500.	759.3	90
	1660.	764.0	2095.	762.5	2250.	756.2	91
	2258.	748.7	2330.	748.8	2335.	757.8	92
	2400.	764.0	2585.	763.8	2750.	765.3	93
	2945.	767.7	3155.	767.7	3285.	765.7	94
	3505.	764.8	3660.	765.9	3995.	775.0	95
ENDTABLE							96
SEGMENT	23	I	D	1967.			98
NVALUE	.11						100
SEGMENT	23	2	C	2042.			101
NVALUE	.038						102
SEGMENT	23	3	D	3518.			103
NVALUE	.11						104
SECTION	23						105
	0.	776.3	120.	774.1	430.	762.9	106
	675.	762.6	810.	766.4	1040.	764.9	107
	1160.	764.6	1350.	766.5	1430.	764.5	108
	1770.	763.7	1810.	765.3	1925.	761.5	109
	1937.	759.1	1949.	759.8	1967.	759.1	110
	1975.	753.8	1985.	750.8	1990.	748.2	111
	1995.	747.2	2012.	746.6	2021.	746.0	112
	2027.	746.6	2042.	759.6	2089.	764.9	113
	2120.	764.0	2205.	764.1	2698.	771.4	114
	2878.	769.5	3058.	772.0	3118.	775.3	115
	3238.	772.8	3518.	777.0			116
ENDTABLE							117
SEGMENT	24	1	D	1697.			119
NVALUE	.13						121
SEGMENT	24	2	C	1761.			122
NVALUE	.06						123
SEGMENT	24	3	D	2900.			124
NVALUE	.13						125
SECTION	24		2				
	900.	775.0	1055.	764.6	1220.	766.8	128
	1435.	765.3	1595.	762.2	1697.	760.3	129
	1713.	755.2	1715.	748.5	1757.	748.5	130
	1761.	758.1	1881.	762.5	1966.	764.8	131
	2151.	766.1	2256.	769.7	2421.	771.9	132
	2900.	775.0					133
ENDTABLE							134
BPR	GIRDAV	B	1	2			136
PIER	757.0	3.	758.0	3.			138
GIRDER	770.0	769.2	0.	0.8	2.7		140
	1650.	774.7	1650.	769.2	1820.	769.3	141
	1820.	774.8					142
ENDTABLE							143
SECTION	GIRDAV						
	1200	778	1400	775.5	1600	775	144.1
	1650.	774.7	1650.	758.0	1705.	758.0	145

	1713.	755.2	1715.	748.5	1757.	748.5	146
	1758.	751.0	1761.	758.0	1820.	758.0	147
	1820	774.8	2000	775	2400	778	148
ENDTABLE							149
SEGMENT	25	1	D	4033.			151
NVALUE	.04						153
SEGMENT	25	2	C	4240.			154
NVALUE	.06						155
SEGMENT	25	3	D	4370.			156
NVALUE	.04						157
SECTION	25						158
	3941.	790.0	4015.	765.3	4033.	764.9	159
	4048.	761.8	4083.	758.8	4101.	754.0	160
	4105.	752.0	4112.	750.7	4135.	750.6	161
	4146.	751.4	4153.	756.7	4240.	763.0	162
	4370.	790.0					163
ENDTABLE							164
SEGMENT	26	1	D	1740.			166
NVALUE	.04						168
SEGMENT	26	2	C	1850.			169
NVALUE	.06						170
SEGMENT	26	3	D	1918.			171
NVALUE	.04						172
SECTION	26						174
	1634.	790.0	1720.	761.4	1740.	759.6	175
	1755.	750.5	1820.	750.5	1822.	754.7	176
	1825.	750.5	1832.	750.5	1850.	761.5	177
	1870.	764.5	1918.	790.0			178
ENDTABLE							179
SEGMENT	27	1	D	4173.			181
NVALUE	.04						183
SEGMENT	27	2	C	4320.			184
NVALUE	.06						185
SEGMENT	27	3	D	4384.			186
NVALUE	.04						187
SECTION	27		4				
	3997.	790.0	4173.	764.5	4203.	761.1	189
	4226.	756.3	4229.	755.2	4231.	752.5	190
	4238.	751.1	4245.	750.4	4257.	749.7	191
	4268.	749.6	4275.	751.2	4276.	752.7	192
	4280.	754.3	4285.	759.2	4297.	759.6	193
	4311.	758.6	4320.	758.5	4384.	790.0	194
ENDTABLE							195
SEGMENT	28	1	D	1365.			197
NVALUE	.04						199
SEGMENT	28	2	C	1540.			200
NVALUE	.06						201
SEGMENT	28	3	D	1591.			202
NVALUE	.04						203
SECTION	28						204
	720.	790.0	780.	771.2	1135.	771.4	205
	1365.	773.	1397.	757.4	1420.	756.1	206
	1433.	754.2	1448.	751.9	1452.	752.7	207

	1470.	752.2	1482.	754.7	1540.	772.9	208
	1591.	790.0					209
ENDTABLE							210
BPR	HWY278	B	1	2			212
PIER	752.0	2.					214
GIRDER	777.0	766.0	45	0.8	2.7		216
	1365.	779.0	1365.	776.8	1383.	769.0	217
	1400.	775.5	1420.	775.5	1442.	766.0	218
	1444.	766.0	1460.	774.0	1490.	774.0	219
	1501.	770.0	1510.	777.8	1510.	779.0	220
ENDTABLE							220.1
SECTION	HWY278						221
	800	782.	1000.	779.5	1200.	779.	221.1
	1365.	779.0	1365.	773.0	1397.	757.4	222
	1420.	756.1	1433.	754.2	1448.	751.9	223
	1452.	752.7	1470.	752.2	1482.	754.7	224
	1495.	759.4	1501.	770.0	1510.	777.8	225
	1510.	779.0	1700.	779.0	2000.	783.	226
ENDTABLE							227
SEGMENT	29	I	D	2548.			229
NVALUE	.04						231
SEGMENT	29	2	C	2645.			232
NVALUE	.06						233
SEGMENT	29	3	D	2722.			234
VALUE	.04						235
SECTION	29						236
	2420.	790.0	2548.	760.2	2552.	752.2	237
	2627.	752.2	2645.	764.5	2722.	790.0	238
ENDTABLE							239
SEGMENT	30	1	D	500.			241
NVALUE	.04						243
SEGMENT	30	2	C	600.			244
NVALUE	.06						245
SEGMENT	30	3	N	694.			246
NVALUE	.04						247
SECTION	30						
	85.	790.0	130.	774.7	180.	773.5	249
	240.	771.1	300.	769.4	355.	768.6	250
	420.	768.4	475.	768.0	500.	765.4	251
	523.	760.3	530.	757.5	533.	754.4	252
	537.	752.5	542.	751.6	547.	750.9	253
	554.	750.1	557.	750.2	564.	751.4	254
	571.	751.3	573.	754.8	580.	756.4	255
	589.	758.9	600.	764.0	604.	764.1	256
	614.	766.2	632.	771.4	650.	775.5	257
	694.	790.0					258
ENDTABLE							259
BPR	SCLRR	B	1.	2.			261
PIER	760.7	5.5	756.0	5.5			263
GIRDER	780.7	780.5	0.	0.8	2.7		265
	50.	781.8	105.	780.5	650.	780.5	266
	650.	782.0					267
ENDTABLE							268
SECTION	SCLRR						269
	48	781.8	49	781.8	50	781.8	269.1

	105.	780.5	130.	774.7	180.	773.5	270
	240.	771.1	300.	769.4	355.	768.6	271
	420.	768.4	475.	768.0	500.	765.4	272
	523.	760.3	530.	757.5	533.	754.4	273
	537.	752.5	542.	751.6	547.	750.9	274
	554.	750.1	557.	750.2	564.	751.4	275
	571.	751.3	573.	754.8	580.	756.4	276
	589.	758.9	600.	764.0	604.	764.1	277
	614.	766.2	632.	771.4	650.	780.5	278
	650	782	651	782			278.1
ENDTABLE							279
SEGMENT	31	1	D	2460.			281
NVALUE	.04						283
SEGMENT	31	2	C	2655.			284
NVALUE	.06						285
SEGMENT	31	3	D	2715.			286
NVALUE	.04						287
SECTION	31						288
	2395.	790.0	2460.	767.7	2485.	763.6	289
	2537.	755.3	2610.	755.5	2655.	769.8	290
	2715.	790.0					291
ENDTABLE							292
SEGMENT	32	1	D	1390.			294
NVALUE	.13						296
SEGMENT	32	2	C	1549.			297
NVALUE	.06						298
SEGMENT	32	3	D	1645.			299
NVALUE	.13						300
SECTION	32		32				
	0.	782.0	110.	777.3	210.	775.2	302
	290.	774.0	410.	772.9	460.	771.4	303
	550.	771.2	610.	772.8	670.	772.8	304
	790.	771.1	845.	769.5	955.	768.5	305
	1245.	768.4	1375.	767.3	1390.	765.8	306
	1395.	764.4	1445.	763.3	1535.	762.8	307
	1536.	754.4	1548.	754.4	1549.	767.6	308
	1556.	769.8	1596.	772.0	1616.	773.3	309
	1645.	782.0					310
ENDTABLE							311
SEGMENT	33	1	D	1608.			313
NVALUE	.13						315
SEGMENT	33	2	C	1724.			316
NVALUE	.06						317
SEGMENT	33	3	D	4040.			318
NVALUE	.13						319
SECTION	33						320
	955.	785.0	1000.	772.0	1250.	771.5	321
	1608.	770.7	1635.	759.9	1700.	759.9	322
	1705.	765.1	1724.	770.0	1870.	772.5	323
	1920.	766.5	2040.	765.9	2160.	768.0	324
	2270.	768.1	2580.	766.4	2920.	770.5	325
	3470.	772.3	3740.	774.7	4015.	777.5	326
	4040.	785.0					327
ENDTABLE							328
SEGMENT	83	1	D	1202.			545
NVALUE	.12						547

SEGMENT	83	2	C	1229.			548
NVALUE	.05						549
SEGMENT	83	3	D	1827.			550
NVALUE	.12						551
SECTION	83						552
	0.	768.5	240.	766.0	290.	766.0	553
	365.	766.7	520.	766.4	575.	767.1	554
	800.	763.4	842.	761.0	900.	759.9	555
	1065.	758.9	1117.	759.8	1202.	758.2	556
	1213.	755.5	1215.	753.8	1220.	753.3	557
	1223.	753.3	1227.	753.8	1229.	757.0	558
	1252.	757.1	1285.	761.3	1402.	761.2	559
	1522.	762.9	1632.	766.9	1827.	770.2	560
ENDTABLE							561
SEGMENT	84	1	D	2219.			563
NVALUE	.12						565
SEGMENT	84	2	C	2248.			566
NVALUE	.05						567
SEGMENT	84	3	D	2788.			568
NVALUE	.12						569
SECTION	84						571
	970.	780.0	1000.	770.6	1140.	770.9	572
	1640.	765.7	1700.	768.1	1885.	768.1	573
	1974.	765.8	2004.	764.6	2219.	766.2	574
	2225.	761.7	2243.	761.3	2248.	765.8	575
	2258.	764.3	2398.	767.3	2523.	767.6	576
	2553.	768.3	2763.	771.3	2788.	780.0	577
ENDTABLE							578
SEGMENT	85	1	D	1580.			580
NVALUE	.12						582
SEGMENT	85	2	C	1610.			583
NVALUE	.05						584
SEGMENT	85	3	D	1970.			585
NVALUE	.12						586
SECTION	85						587
	960.	780.0	1000.	766.5	1380.	766.5	588
	1420.	769.6	1560.	769.5	1580.	767.0	589
	1590.	761.4	1600.	761.2	1610.	766.6	590
	1740.	771.6	1775.	773.8	1960.	776.7	591
	1970.	780.0					592
ENDTABLE							593
BPR	CVSPRD	B	3.	2.			595
PIER	764.0	2.	763.5	2.	763.0	2.	597
GIRDER	766.9	766.5	0.	.8	2.7		599
	1463.	770.0	1464.	766.5	1542.	766.5	600
	1543.	770.0					601
ENDTABLE							602
SECTION	CVSPRD						603
	0.	776.5	200.	773.0	400.	771.0	604
	800.	770.5	1462.	769.0	1463.	770.0	605
	1464.	764.0	1484.	763.8	1486.	762.0	606
	1498.	761.8	1520.	764.0	1542.	762.9	607
	1543.	770.0	1544.	769.0	1610.	768.6	608
	2140.	777.0					609

ENDTABLE							610
SEGMENT	86	1	D	1410.			612
NVALUE	.12						614
SEGMENT	86	2	C	1435.			615
NVALUE	.05						616
SEGMENT	86	3	D	1880			617
NVALUE	.12						618
SECTION	86						619
	975.	780.0	1000.	771.8	1340.	769.4	620
	1410.	767.0	1415.	762.9	1430.	762.8	621
	1435.	766.9	1790.	775.4	1880.	779.2	622
ENDTABLE							623
SEGMENT	87	1	D	248.			625
NVALUE	.12						627
SEGMENT	87	2	C	260.			628
NVALUE	.05						629
SEGMENT	87	3	D	808.			630
NVALUE	.12						631
SECTION	87						632
	-18.	780.0	0.	774.0	95.	772.6	633
	133.	771.4	150.	769.6	248.	766.4	634
	250.	765.5	253.	763.2	254.	765.8	635
	260.	767.2	313.	768.9	425.	769.8	636
	490.	772.1	550.	771.5	655.	775.9	637
	800.	777.7	808.	780.0			638
ENDTABLE							639
SEGMENT	103	1	D	844.			739
NVALUE	.12						741
SEGMENT	103	2	C	869.			742
NVALUE	.05						743
SEGMENT	103	3	D	1680.			744
NVALUE	.12						745
SECTION	103						
	0.	778.7	145.	775.5	360.	773.8	747
	375.	774.1	390.	771.6	600.	770.1	748
	665.	768.5	800.	767.7	840.	768.5	749
	844.	768.4	848.	766.2	850.	764.2	750
	856.	764.1	859.	764.0	864.	764.3	751
	869.	768.6	912.	769.3	975.	771.7	752
	1020.	771.5	1110.	773.1	1180.	772.5	753
	1265.	772.6	1400.	774.3	1475.	774.7	754
	1550.	776.4	1680.	782.9			755
ENDTABLE							756
CULV1	CST	3	41111.				758
CULV2	8.	12.	80.	763.2	762.8		760
SECTION	CST						761
	2919.	781.0	2920.	775.7	3220.	775.0	762
	3740.	774.7	4015.	777.5	4016.	781.0	763
ENDTABLE							764
SEGMENT	104	1	D	1354.			766
NVALUE	.12						768
SEGMENT	104	2	C	1407.			769
NVALUE	.O5						770
SEGMENT	104	3	D	1870.			771
NVALUE	.12						772
SECTION	104						773

```
           0.          790.0     100.      786.0     400.      782.5     774
           800.        780.0     1200.     778.0     1353.     777.4     775
           1354.       781.3     1359.     774.6     1360.     769.8     776
           1364.       769.8     1365.     768.7     1393.     768.7     777
           1394.       769.8     1402.     769.3     1403.     774.6     778
           1407.       781.3     1408.     777.4     1500.     777.2     779
           1600.       778.0     1700.     778.5     1835.     780.5     780
           1840.       781.8     1870.     782.2                         781
ENDTABLE                                                                 782
CULV1      HWY270      3         21548
CULV2      10.                   45.       767.      766.9
SECTION    HWY270                                                        790
           900.        790.0     1000.     778.6     1335.     777.2     791
           1559        777.1     1729.     777.8     1830.     790.0     795
ENDTABLE                                                                 796
TITLE      SKEETER BRANCH AFTER C & S
COMPUTE    21          33        21        ALT NO 2
TITLE      NORTH BRANCH AFTER C & S
COMPUTE    83          87        21        ALT NO 2
TITLE      TANYARD BRANCH, MILL DAM IN, AFTER C & S
COMPUTE    103         104B      32        ALT NO 2
ENDJOB
ENDRUN
```

Partial output list

1 WSP2 XEQ 09/06/91 06:17:27 BIG CEDAR CR GA,URBAN AREA WS : CEDAR GA PAGE
REV 11/01/90 VERSION 2.0 SKEETER BRANCH AFTER C & S ALT: ALTNO2 9

RATING TABLE FOR SECTION 21 DA= 85.8 SQ MI EXP COEF= .30 CONT COEF= .10

NO.	ELEV FT	AREA SQ FT	Q CFS	------ACRES FLOODED------ FLOODPLAIN DAMAGE	CHANNEL	TOTAL	STARTING CSM FT	CRIT ELEV FT/FT	FRICTION SLOPE FT	FLOW TOP WIDTH

***** MESSAGE REACH 21 HAS A DAMAGE SEGMENT BUT NO DAMAGE LENGTH CHECK INPUT DATA****

NO.	ELEV FT	AREA SQ FT	Q CFS	FLOODPLAIN DAMAGE	CHANNEL	TOTAL	STARTING CSM FT	CRIT ELEV FT/FT	FRICTION SLOPE FT	FLOW TOP WIDTH
0	749.0	0.0	0.0							
1	755.0	340.4	943.6	.00	.02	.02	11.00	751.4	.00072	70.9
2	757.7	549.9	1887.2	.00	.02	.02	22.00	752.7	.00073	82.6
LOW GRND	758.6	626.7	2273.7	.00	.02	.02				86.5
ZERO DMG	758.6	626.7	2273.7	.00	.02	.02				86.5
BANK FULL	758.6	626.7	2273.7	.00	.02	.02				86.5
3	760.2	806.2	3176.4	.00	.02	.04	37.03	754.0	.00073	162.6
4	762.2	1480.5	4975.2	.00	.02	.10	58.00	755.6	.00080	428.9
5	764.0	2401.3	7623.3	.00	.02	.16	88.87	757.4	.00095	675.3
6	764.7	2975.6	9006.9	.00	.02	.18	105.00	758.3	.00099	803.8
7	765.8	3917.1	11435.3	.00	.02	.21	133.31	761.5	.00104	913.8
8	768.4	6434.5	19693.4	.00	.02	.23	229.58	763.0	.00120	1017.8
9	771.2	9453.7	31764.3	.00	.02	.26	370.30	764.6	.00133	1136.9

1 TABLE OF VALUES FOR BPR EQUATION

IF AN * SYMBOL APPEARS BESIDE A VARIABLE IN THIS TABLE. IT IS
EXTRAPOLATED FROM FIGURES 6, 7, 19, OR 34 OF THE BPR MANUAL.

NO.	M	AKB	DLTAK	SIGMA	DKS	COEFK	VN2 FPS	ALPHA	ALPHA2	ALPHA3	AEXIT SQ FT	APPAR SQ FT	DCRIT FT	CRIT COEF
1	.96	.02	.00	.00	.00	.02	2.38	1.00	1.00	1.00	372.17	462.18	750.88	.00
2	1.00	.00	.07	1.00	.00	.07	2.30	1.00	1.00	1.15	607.60	932.96	752.26	.00
3	1.00	.00	.11	1.00	.00	.11	2.42	1.01	1.01	1.96	1165.36	1487.44	753.80	.00
4	.96	.02	.13	.99	.00	.15	2.85	1.02	1.02	3.30	2211.37	2070.17	755.66	.00
5	.90	.08	.14	.98	.00	.22	3.59	1.03	1.02	4.88	4107.89	2602.63	757.85	.00
6	.89	.11	.14	.97	.00	.24	3.99	1.02	1.02	4.80	4970.12	2796.25	759.67	.00
7	.86	.14	.14	.96	.00	.27	4.68	1.02	1.02	4.52	6235.15	3078.63	760.43	.00
8	ORIFICE FLOW FOR THIS PROFILE. COEF = .80													
9	ORIFICE FLOW FOR THIS PROFILE. COEF = .80													

1 WSP2 XEQ 09/06/91 06:17:27 BIG CEDAR CR GA.URBAN AREA WS : CEDAR_GA PAGE
REV 11/01/90 VERSION 2.0 SKEETER BRANCH AFTER C&S ALT: ALTNO2 13B

ROAD SECTION GIRDAV

NO.	HW FT	CFS	HL FT	TW FT	STARTING CSM	BRIDGE CFS	BRIDGE AREA SQ FT	CULVERT CFS	CULVERT AREA SQ FT	WEIR CFS	WEIR AREA SQ FT	WEIR TOP WIDTH FT
0	748.50	0.0	0.00	748.50	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	756.74	884.2	.04	756.70	11.00	884.2	371.5	.0	.0	.0	.0	.0
2	760.06	1768.5	.12	759.94	22.00	1768.5	770.2	.0	.0	.0	.0	.0
3	762.81	2976.7	.16	762.65	37.03	2976.7	1232.3	.0	.0	.0	.0	.0
4	765.22	4662.3	.18	765.04	58.00	4662.3	1638.8	.0	.0	.0	.0	.0
5	767.27	7143.8	.16	767.11	88.87	7143.8	1990.7	.0	.0	.0	.0	.0
6	767.99	8440.4	.14	767.85	105.00	8440.4	2115.4	.0	.0	.0	.0	.0
7	769.00	10716.1	.12	768.88	133.31	10716.1	2291.4	.0	.0	.0	.0	.0
8	773.18	18454.8	1.60	771.58	229.58	18454.8	2283.5	.0	.0	.0	.0	.0
***** WARNING - VELOCITY EXCEEDS 8 FT/SEC. PROFILE MAY BE IRREGULAR DUE TO VELOCITY HEAD CHANGES *****												
9	777.03	29766.6	2.54	774.49	370.30	23249.1	2283.5	.0	.0	6517.5	1602.9	992.7
***** WARNING - VELOCITY EXCEEDS 8 FT/SEC. PROFILE MAY BE IRREGULAR DUE TO VELOCITY HEAD CHANGES *****												

MIN ROAD ELEVATION = 774.70 FT

BRIDGE TYPE = BPR GIRDER BOTTOM ELEVATION = 769.20 FT OPENING NO.=1

```
1       WSP2    XEQ 09/06/91    06:17:27      BIG CEDAR CR GA,URBAN AREA        WS : CEDAR,GA                 PAGE
                REV 11/01/90    VERSION 2.0   SKEETER BRANCH AFTER C & S        ALT:ALTNO2                      23

                         RATING TABLE FOR SECTION 32        DA=        76.0 SQ MI   EXP COEF= .30  CONT COEF=.10
```

N0.	ELEV FT	AREA SQ FT	Q CFS	-----ACRES FLOODED----- FLOODPLAIN DAMAGE	CHANNEL	TOTAL	STARTING CRIT CSM	FRICTION ELEV FT	FLOW TOP SLOPE FT/FT	WIDTH FT
0	754.4	0.0	0.0							
1	764.2	252.4	880.2	.00	1.33	1.33	11.00	759.8	.01011	144.6
2	765.7	483.3	1760.4	.00	1.46	1.46	22.00	764.1	.00567	158.5
LOW GRND	765.8	497.4	1822.2	.00	1.46	1.46				158.9
ZERO DAMG	765.8	497.4	1822.2	.00	1.46	1.46				158.9
BANK FULL	765.8	497.4	1822.2	.00	1.46	1.46				158.9
3	767.4	758.6	2963.0	.26	1.46	1.72	37.03	764.8	.00384	187.1
4	769.4	1647.7	4640.9	4.76	1.46	6.22	58.00	765.6	.00245	677.3
5	771.6	3368.3	7111.0	7.27	1.46	8.73	88.87	766.7	.00154	950.2
6	772.6	4436.7	8401.7	9.02	1.46	10.48	105.00	767.2	.00130	1141.5
7	774.2	6321.3	10667.0	10.76	1.46	12.22	133.31	768.9	.00100	1330.9
8	779.7	14518.7	18370.1	13.07	1.46	14.53	229.58	769.8	.00037	1582.9
9	784.4	22237.3	29630.0	13.65	1.46	15.11	370.30	771.0	.00028	1645.0

WARNING*****PROFILE NO 9 EXCEEDS SURVEY DATA BY 2.4 FT. COMPUTATION BASED ON VERTICAL EXTENSION OF END POINTS****

```
1     WSP2    XEQ 09/06/91   06:17:27        BIG CEDAR CR GA,URBAN AREA                       WS :CEDAR,GA      PAGE
              REV 11/01/90   VERSION 2.0     TANYARD BRANCH, MILL DAM IN, AFTER C & SALT:     ALT:NO 2           35B

                                             ROAD SECTION CST
```

NO.	HW FT	CFS	HL FT	TW FT	STARTING CSM	BRIDGE CFS	BRIDGE AREA SQ FT	CULVERT CFS	CULVERT AREA SQ FT	WEIR CFS	WEIR AREA SQ FT	WEIR TOP WIDTH FT
0	763.20	0.0	0.00	762.80	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	768.01	160.3	.02	767.99	11.00	.0	.0	160.3	173.0	.0	.0	.0
2	769.15	320.7	.03	769.11	22.00	.0	.0	320.7	214.1	.0	.0	.0
3	770.17	539.8	.14	770.02	37.03	.0	.0	539.8	250.8	.0	.0	.0
4	771.46	845.4	.21	771.25	58.00	.0	.0	845.4	288.0	.0	.0	.0
5	773.13	1295.4	.48	772.65	88.87	.0	.0	1295.4	288.0	.0	.0	.0
6	774.12	1530.5	.70	773.41	105.00	.0	.0	1530.5	288.0	.0	.0	.0
7	775.28	1943.0	.58	774.70	133.31	.0	.0	1416.8	288.0	526.3	256.9	696.9
8	779.89	3346.4	.08	779.81	229.58	.0	.0	598.9	288.0	2747.5	5029.3	1096.5
9	784.61	5397.5	.10	784.51	370.30	.0	.0	535.6	288.0	4861.9	10205.8	1097.0

WARNING****PROFILE NO. 9 EXCEEDS SURVEY DATA BY 3.6 FT. COMPUTATION BASED ON VERTICAL EXTENSION OF END POINTS****

MIN ROAD ELEVATION = 774.70 FT

OPENING NO.	NO. CULVERTS	CULV. CODE	HEIGHT	WIDTH OR DIAM	LENGTH	U/S INVERT	D/S INVERT	(N) COEFF
1	3	41111.	8.00	12.00	80.00	763.20	762.80	.012

```
1     WSP2    XEQ 09/06/91   06:17:27        BIG CEDAR CR GA,URBAN AREA                       WS : CEDAR,GA     PAGE
              REV 11/01/90   VERSION 2.0     TANYARD BRANCH, MILL DAM IN, AFTER C & S         ALT: ALTNO2         36

                     RATING TABLE FOR SECTION 104            DA=    5.8 SQ. MI   EXP COEF = .30  CONT COEF = .10
                     ----------------------------------
```

NO.	ELEV FT	AREA SQ FT	Q CFS	--------ACRES FLOODED-------- FLOODPLAIN DAMAGE	CHANNEL	TOTAL	STARTING CSM	CRIT ELEV FT	FRICTION SLOPE FT/FT	FLOW TOP WIDTH FT
0	768.7	0.0	0.0							
1	770.8	77.1	160.3	.00	1.41	1.41	11.00	769.7	.00243	42.5
2	772.0	127.6	320.7	.00	1.43	1.43	22.00	770.2	.00194	43.0
3	773.1	174.6	539.8	.00	1.44	1.44	37.03	770.7	.00205	43.4
4	774.3	227.1	845.4	.00	1.46	1.46	58.00	771.3	.00223	43.9
5	776.0	304.5	1295.4	.00	1.53	1.53	88.87	772.1	.00218	45.9
6	776.8	341.6	1530.5	.00	1.56	1.56	105.00	772.4	.00217	47.0
LOW GRND	777.2	359.5	1562.1	.00	1.58	1.58				47.5
ZERO DAMG	777.2	359.5	1562.1	.00	1.58	1.58				47.5
7	778.0	574.5	1943.1	10.28	1.62	12.66	133.31	773.0	.00210	380.4
8	780.9	3037.4	3346.4	34.90	1.75	39.23	229.58	774.8	.00082	1178.5
BANK FULL	781.3	3462.6	3497.6	36.68	1.76	41.48				1246.1
9	784.9	8805.2	5397.5	50.17	1.76	55.65	370.30	777.0	.00018	1671.7

WARNING*****PROFILE NO 9 EXCEEDS SURVEY DATA BY 2.7 FT. COMPUTATION BASED ON VERTICAL EXTENSION OF END POINTS****

1 WSP2 XEQ 09/06/91 06:17:27 BIG CEDAR CR GA,URBAN AREA WS : CEDAR,GA PAGE
REV 11/01/90 VERSION 2.0 TANYARD BRANCH, MILL DAM IN, AFTER C & S ALT: ALTNO2 39

RATING TABLE FOR SECTION 104B DA= 5.6 SQ MI EXP COEF=.30 CONT COEF = .10

NO.	ELEV FT	AREA SQ FT	Q CFS	-------ACRES FLOODED------ FLOODPLAIN DAMAGE	CHANNEL	STARTING TOTAL	CRIT CSM	FT ELEV	FRICTION SLOPE FT/FT	FLOW TOP WIDTH FT
0	768.2	0.0	0.0							
1	771.4	121.8	155.7	.00	.59	.59	11.00	769.2	.00053	42.9
2	772.7	178.7	311.4	.00	.60	.60	22.00	769.7	.00064	43.4
3	774.0	237.4	524.2	.00	.61	.61	37.03	770.2	.00075	44.1
4	775.5	304.1	821.0	.00	.63	.63	58.00	770.8	.00088	45.9
LOW GRND	776.7	359.5	907.6	.00	.65	.65				47.5
ZERO DAMG	776.7	359.5	907.6	.00	.65	.65				47.5
5	777.5	583.6	1258.0	4.76	.67	5.43	88.87	771.5	.00087	394.4
6	778.2	939.3	1486.3	7.87	.68	8.55	105.00	771.9	.00082	620.5
7	779.0	1523.9	1887.1	11.06	.70	11.76	133.31	772.5	.00077	853.5
BANK FULL	780.8	3462.6	2836.9	16.43	.73	17.16				1246.1
8	781.4	4305.6	3249.9	17.90	.73	18.63	229.58	774.2	.00038	1352.5
9	785.1	10053.2	5241.8	23.05	.73	23.78	370.30	776.3	.00012	1726.1

WARNING****PROFILE NO 9 EXCEEDS SURVEY DATA BY 3.4 FT. COMPUTATION BASED ON VERTICAL EXTENSION OF END POINTS*****

1 WSP2 XEQ 09/06/91 06:17:27 BIG CEDAR CR GA,URBAN AREA WS : CEDAR,GA PAGE
REV 11/01/90 VERSION 2.0 TANYARD BRANCH, MILL DAM IN, AFTER C & S ALT: ALTNO2 39

-------------LIST OF INPUT DATA WITH LIMITED EDITING-----------------------------
ENDJOB

********************NORMAL END OF JOB---------------------------

1 WSP2 XEQ 09/06/91 06:17:27 BIG CEDAR CR GA,URBAN AREA WS : CEDAR,GA PAGE
REV 11/01/90 VERSION 2.0 TANYARD BRANCH, MILL DAM IN, AFTER C & S ALT: ALTNO2 1

-------------LIST OF INPUT DATA WITH LIMITED EDITING--------------------------------------
ENDRUN

****

SCS WSP2 VERSION 11/01/90
FILE SUMMARY

INPUT = f:\dsk2wsp2\sample.job
OUTPUT = f:\dsk2wsp2\sample.OUT DATED 09/06/91 06:17:27

OPTIONAL FILES SAVED

OPTIONT = f:\dsk2wsp2\sample.WRT DATED 09/06/91 06:17:27

****

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-16
6-89

WATER SURFACE PROFILE INPUT DATA

Cedar Cr. (JOB OR PROJECT) BY WM CHECKED DW DATE 1/8/93

Control Word	Data Fields 11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	DELTA ELEV.	WSID					
WSP2		Cedar_GA					
	ANY ALPHAMERIC TITLE WILL BE PRINTED AT TOP OF EACH PAGE MAY NOT BE CHANGED IN JOB						
TITLE	Big Cedar Cr., GA,	Urban Area					
	ANY ALPHAMERIC TITLE WILL BE PRINTED AT TOP OF EACH PAGE MAY BE CHANGED AT ANY TIME						
TITLE	Example Data	Set for WSP2 PC V	ersion				
	TOTAL D.A.	CSM	CSM	CSM	CSM	CSM	
DISCHARGE	85.78	11.0	22.	37.03	58.0	88.87	
DISCHARGE	85.78	105.	133.31	229.58	370.3		
~~DISCHARGE~~							
	XSEC NAME	SLOPE	SLOPE	SLOPE	SLOPE	SLOPE	
STARTS	21	0.00073	0.00073	0.00073	0.0008	0.00095	
STARTS	21	0.001	0.00105	0.0012	0.00133		
~~STARTS~~							
	XSEC NAME	ELEVATION	ELEVATION	ELEVATION	ELEVATION	ELEVATION	
~~STARTE~~							
~~STARTE~~							
~~STARTE~~							
	XSEC NAME	XSEC NAME	XSEC NAME	XSEC NAME	XSEC NAME	XSEC NAME	
TRIB	21	32					
~~TRIB~~							
~~TRIB~~							
~~TRIB~~							
	OUTPUT OPTIONS						
OUTPUT	T						
	ANY ALPHAMERIC MESSAGE						
COMMENT							
	SAME AS COMMENT						
*							

PAGE 1 OF 7

Record	Field	Columns	Description
WSP2		1-10	Resets all program variables to program defined values for beginning of a new job. This must be the first record of a job.
	DELTA ELEV	11-20	Maximum elevation difference between X-section coordinates without a message statement resulting in printout. Default is 20 feet.
	WS_ID	21-30	Eight character watershed identification.
TITLE		1-10	
	TITLE	11-70	Any alphameric data. The first title entered will be retained for the entire job, and will be printed at the top of each page. It may not be altered. The second title entered will also be printed at the top of each page. It may be altered at any time.
DISCHARGE		1-10	Enters basic csm values to be used.
	TOTAL DA	11-20	The drainage area at the lower end of the watershed. (see note 1.)
	CSM	21-70 by 10 col. fields	The csm values for each profile desired. These values set the order of computations, i.e. the first csm value entered is the first profile run. A maximum of five values may be entered on one record. Up to 3 Records may be used. Entering csm values from lowest to highest is recommended.
STARTE		1-10	Used to enter the starting elevations for each profile to be run. Up to 3 records per section may be used but only one section may be entered at one time.
	XSEC NAME	11-20	The name of the cross section for which the starting elevations apply. The name must be entered in each record used. (See note 2.)
	ELEVATION	21-70 by 10 col. fields	The starting elevation for each csm. The first elevation entered refers to the first csm, etc.
STARTS		1-10	Same as STARTE except that slopes in ft/ft are entered instead of elevations. If neither STARTE nor STARTS records are entered, computations begin at critical depth.
TRIB		1-10	
	XSEC NAMES	11-70 by 10 col. fields	The names of cross sections where data are to be held for use as starting data on later profiles. These names cannot be road names. Up to 20 names may be used. (See note 2.)
OUTPUT		1-10	This record sets the output switches for the type of output desired. Each time an output record is entered all previous output options are turned off. The printed valley section and bridge rating tables are standard output.
	OUTPUT OPTIONS	11-20	R = Save rating tables for input to hydrology program. P = Plot rating tables S = Print segment table K = KD table T = Save selected rating tables for input to hydrology program E = Save rating tables for economic programs W = Water surface profile graphics file X = Cross section data graphics file H = Hydraulic tables graphics file C = Conveyance tables graphics file These options may be entered in <u>any</u> order. Enter letters only in this field
COMMENT	OR *	1-10	Provides list of desired comments on the output listing of input data. Do not use within groups of records that go together such as SEGMENT and NVALUE.
		11-70	The desired text.

Note 1: See section on input for given cfs values for optional methods of entering discharges.

Note 2: Names may consist of from 1 to 6 alphanumeric characters. Imbedded blanks are ignored so a - should be used to separate characters if desired. The name may be anywhere within the name field.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-22
6-89

WATER SURFACE PROFILE INPUT DATA

Cedar Cr. (JOB OR PROJECT) BY WM CHECKED DW DATE 1/8/93

Control Word	Data Fields 11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	XSEC NAME	DRAINAGE AREA	CHANNEL LENGTH	FLOOD LENGTH	DAMAGE LENGTH	CHANNEL LENGTH	
~~REACH~~							
	XSEC NAME	DISPLACEMENT					
~~REACH2~~							
	XSEC NAME	WEIR COEF	CHANNEL LENGTH	FLOOD LENGTH	DAMAGE LENGTH	CHANNEL LENGTH	
~~ROAD~~							
LOSS	0.3	0.1					
REACH	21	85.78	10.	10.			
REACH	22	77.68	1550.	1550.	1550.	1550.	
REACH	23	77.32	2800.	2800.	2800.	2800.	
REACH	24	76.75	900.	900.	900.	900.	
ROAD	GIRDAV	2.7	50.	50.			
REACH	25	76.56	1200.	1200.	1200.	1200.	
REACH	26	76.38	600.	600.	600.	600.	
REACH	27	76.28	600.	600.	600.	600.	
REACH	28	76.14	950.	950.	950.	950.	
ROAD	HWY 287	2.7	50.	50.			
REACH	29	76.09	400.	400.	400.	400.	
REACH	30	76.05	200.	200.	200.	200.	
ROAD	SCLRR	2.7	50.	50.	50.	50.	
REACH	31	76.01	350.	350.	350.	350.	
REACH	32	75.95	400.	400.	400.	400.	
REACH	33	69.70	550.	550.	550.	550.	
	BEGIN XSEC	END XSEC	KEY XSEC	NUMBER			
~~AVERAGE~~							
	EXP. COEF	CONT. COEF					
~~LOSS~~							

PAGE 2 OF 7

		Columns	
REACH		1-10	Defines the elements of a reach. The road and reach records must be in the order of computations since only the first and last section names are shown on the compute record.
	XSEC	11-20	The name of the reach, each must be unique. (See note 1–SCS-ENG-19.) This must be the same name as the cross section to be used, unless followed by a REACH2 record.
	DRAINAGE AREA	21-30	The drainage area (sq. miles) at the cross section (reach head).
	CHANNEL LENGTH	31-40	The hydraulic length of the main channel segment (to next **downstream** section).
	FLOOD LENGTH	41-50	The hydraulic length of the main flood plain (to next **downstream** section).
	DAMAGE LENGTH	51-60	The length to be used in computing flood plain damage acres in the reach.
	CHANNEL LENGTH	61-70	The length of channel in the damage reach. (See technical procedures for method of use.)
REACH2		1-10	Use this record only if the following data is needed. This record must follow a reach record.
	XSEC NAME	11-20	The name of the cross section to be transposed for the preceding reach. This section must be in the current data. It may not be used if a link record has been read since the XSEC was entered.
	DISPLACEMENT	21-30	The elevation change to be applied to each surveyed point on the cross section. Use negative value if section is to be lowered, positive if it is to be raised.
ROAD		1-10	Enters the elements for a road section.
	XSEC NAME	11-20	The name of the road, each must be unique. (See note 1 - SCS-ENG-19).
	WEIR COEF	21-30	The coefficient to be used for flow over the roadway (usually 2.7).
	REACH LENGTHS	31-70	See channel and flood length descriptions on the REACH record.
AVERAGE		1-10	Specifies cross sections used to develop an average rating table.
	BEGIN XSEC	11-20	Beginning valley cross section (furthest downstream).
	END XSEC	21-30	Ending valley cross section (furthest upstream).
	KEY XSEC	31-40	“Key” valley cross section.
	NUMBER	41-50	Designated TR-20 reach number (integer from 1 to 200).
LOSS		1-10	Enters expansion and contraction loss coefficients.
	EXP. LOSS	11-20	Expansion loss coefficient.
	CONT. LOSS	21-30	Contraction loss coefficient.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-22
6-89

WATER SURFACE PROFILE INPUT DATA

CEDAR CR (JOB OR PROJECT) BY WM CHECKED DW DATE 1-8-93

Control Word	11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	XSEC NAME	DRAINAGE AREA	CHANNEL LENGTH	FLOOD LENGTH	DAMAGE LENGTH	CHANNEL LENGTH	
~~REACH~~							
	XSEC NAME	DISPLACEMENT					
~~REACH2~~							
	XSEC NAME	WEIR COEF	CHANNEL LENGTH	FLOOD LENGTH	DAMAGE LENGTH	CHANNEL LENGTH	
~~ROAD~~							
REACH	83	7.67	2500	2500	2500	2500	
REACH	84	6.77	2800	2800	2800	2800	
REACH	85	6.62	450	450	450	450	
ROAD	CVSPRD	2.7	50	50	50	50	
REACH	86	6.36	800	800	800	800	
REACH	87	6.20	500	500	500	500	
REACH	103	6.13	1750	1750	1750	1750	
ROAD	CST	2.7	100	100			
REACH	104	5.78	1350	1350	1350	1350	
ROAD	HWY270	2.7	50	50	50	50	
REACH	104A	5.78	50	50	50	50	
REACH2	104	–.5					
REACH	104B	5.56	600	600	600	600	
REACH2	104	–.5					
AVERAGE	24	30	24	15			
AVERAGE	86	87	87	191			
AVERAGE	103	104A					
	BEGIN XSEC	END XSEC	KEY XSEC	NUMBER			
~~AVERAGE~~							
	EXP. COEF	CONT. COEF					
~~LOSS~~							

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		Columns	
REACH		1-10	Defines the elements of a reach. The road and reach records must be in the order of computations since only the first and last section names are shown on the compute record.
	XSEC	11-20	The name of the reach, each must be unique. (See note 1–SCS-ENG-19.) This must be the same name as the cross section to be used, unless followed by a REACH2 record.
	DRAINAGE AREA	21-30	The drainage area (sq. miles) at the cross section (reach head).
	CHANNEL LENGTH	31-40	The hydraulic length of the main channel segment (to next **downstream** section).
	FLOOD LENGTH	41-50	The hydraulic length of the main flood plain (to next **downstream** section).
	DAMAGE LENGTH	51-60	The length to be used in computing flood plain damage acres in the reach.
	CHANNEL LENGTH	61-70	The length of channel in the damage reach. (See technical procedures for method of use.)
REACH2		1-10	Use this record only if the following data is needed. This record must follow a reach record.
	XSEC NAME	11-20	The name of the cross section to be transposed for the preceding reach. This section must be in the current data. It may not be used if a link record has been read since the XSEC was entered.
	DISPLACEMENT	21-30	The elevation change to be applied to each surveyed point on the cross section. Use negative value if section is to be lowered, positive if it is to be raised.
ROAD		1-10	Enters the elements for a road section.
	XSEC NAME	11-20	The name of the road, each must be unique. (See note 1 - SCS-ENG-19).
	WEIR COEF	21-30	The coefficient to be used for flow over the roadway (usually 2.7).
	REACH LENGTHS	31-70	See channel and flood length descriptions on the REACH record.
AVERAGE		1-10	Specifies cross sections used to develop an average rating table.
	BEGIN XSEC	11-20	Beginning valley cross section (furthest downstream).
	END XSEC	21-30	Ending valley cross section (furthest upstream).
	KEY XSEC	31-40	“Key” valley cross section.
	NUMBER	41-50	Designated TR-20 reach number (integer from 1 to 200).
LOSS		1-10	Enters expansion and contraction loss coefficients.
	EXP. LOSS	11-20	Expansion loss coefficient.
	CONT. LOSS	21-30	Contraction loss coefficient.

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WATER SURFACE PROFILE INPUT DATA

Cedar Cr (JOB OR PROJECT) BY WM CHECKED DW DATE 1/8/93

Control Word	Data Fields 11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	XSEC NAME	SEGMENT NO.	SEGMENT TYPE	LAST STATION	LAST ELEV.	n VS EL	
SEGMENT	21	1	D	1448.			67
	'n'	'r' OR 'EL'	'n'	'r' OR 'EL	'n'	'r' OR 'EL'	
N VALUE	.105						69
SEGMENT	21	2	C	1535.			70
N VALUE	.04						71
SEGMENT	21	3	D	2230.			72
N VALUE	.105						73
~~**SEGMENT**~~							
~~**N VALUE**~~							
~~**SEGMENT**~~							
~~**N VALUE**~~							
~~**SEGMENT**~~							
~~**N VALUE**~~							

NOTE: TWO "'N VALUE" RECORDS CAN BE USED PER SEGMENT. FOUR SETS OF 'n'-'r' OR 'EL' VALUES IS THE MAXIMUM.

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		Columns	
SEGMENT		1-10	Describes elements of a segment of a cross section. Each segment record must be followed by its associated ‘NVALUE’ records. Up to 6 SEGMENT records may be entered for each cross section.
	XSEC NAME	11-20	The name of the cross section of which this segment is a portion.
	SEGMENT NO.	21-30	Enter any number between 1 and 6. A total of 6 segments may be used. They must be numbered consecutively, but not necessarily entered consecutively, i.e., if 4 segments are used they may be entered 4, 2, 3, 1 but may not be numbered 4, 2, 5, 1.
	SEGMENT TYPE	31-40	Three segment types may be used: C - It’s a channel segment and this width is used to determine channel acres flooded. KD values are used as computed. D - It’s a damage segment. Its area is included in flood plain damage acres and KD values are modified by the square root of the meander factor. N - It’s a non damage segment that is included in total acres flooded. Its KD values are modified the same as the 'D' segment.
	LAST STATION	41-50	The station on the cross section which marks the end of the segment. This must be a surveyed point. This also indirectly marks the beginning of the segment number that is 1 higher than this number.
	LAST ELEVATION	51-60	The elevation associated with the 'last station' above (optional). If there is only one station with the 'last station' value as given in columns 41-50, the elevation value is not necessary. However, if the segment ends on a vertical bank this value will indicate whether the segment ends at the top or bottom of the bank.
	n VS EL	61-70	Enter an E in this field if 'n' varies with elevation for this segment.
NVALUE		1-10	Enter the ‘n’ values and associated hydraulic radii or elevation. **Note: This record must always follow the SEGMENT record or another NVALUE record.
	'n'	11-20, 31-40, 51-60	Enter the ‘n’ values to be used. Up to 4 ‘n’ values may be used.
	'r' or 'E'	21-30, 41-50, 61-70	The hydraulic radius (‘r’) or elevation associated with the above 'n' value.

If only 1 'n’ value is entered, it is used for all flow depths. If 2 'n' values and 1 'r' is entered, all flows with 'r' lower than the 'r' given use the first 'n' value. All flows with an 'r' greater use the 2nd 'n' value. If 2 or more 'r's are given, the ‘r' value is interpreted on a straight line basis for all values of 'r' which lie between the given ones. If the actual 'r' is less than the first 'r' given, the first 'n' value is used. If it is greater than the last 'r' given, then the last 'n' value is used. One more 'n' value than 'r' values are permitted, such as 3 'n's and 2 'r's or 4 'n's and 3 'r's. In such case, the last ‘n' is used at all 'r's greater than the last ‘r’. Elevations and roughness are handled in the same manner as hydraulic radius and roughness.

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WATER SURFACE PROFILE INPUT DATA

Cedar Cr (JOB OR PROJECT) BY WM CHECKED DW DATE 1/8/93

Control Word	Data Fields 11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	XSEC NAME	HI	TR20 XSEC ID	LEFT ENCR.	RIGHT ENCR.		
SECTION	21		1				
	STATION	ELEV.	STATION	ELEV.	STATION	ELEV.	
	1000.	774.7	1180.	761.5	1320.	760.8	75
	1430.	760.0	1448.	758.8	1474.	749.0	76
	1520.	749.3	1535.	758.6	1635.	763.8	77
	1730.	764.8	1790.	763.4	1990.	764.0	78
	2080.	767.6	2230.	772.8			79
ENDTABLE							

NOTE: IF ROD READINGS ARE GIVEN TURN RECORDS MAY BE NEEDED

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		Columns	
SECTION		1-10	Enters the data for a cross section or road.
	XSEC NAME	11-20	The name of the section or road (See note 1).
	HI	21-30	The height of instrument if rod readings are given. Cross section data may be entered in any order as it is sorted by the x distance after entry. If 2 points have the same x distance they must be entered in the proper order as these points will not be reversed. (See note 2.)
	TR-20 XSEC ID	31-40	If rating table is to saved in TR-20 format, enter an integer number between and including 1 and 200. See also OPTION record (options R or T).
	LEFT ENCR.	41-50	Enter left encroachment station. Flow is not computed outside this station. (See note 3.)
	RIGHT ENCR.	51-60	Enter right encroachment station. Flow is not computed outside this station. The program checks for the right station to be a larger number than the left encroachment station if entered. (See note 3.)
	DATA RECORDS	11-70 by 10 col. fields	The X and Y coordinates of the cross section. These are entered X1, Y1, X2, Y2, etc. Use only the number of records actually needed. Road Sections are described the same as valley sections. With BPR and Contr bridges the points would be entered as the section would look with the bridge deck, as defined by the girder records, removed. With culverts the points are entered as the road surface above the culvert. A maximum of 48 points (16 records) may be entered.
ENDTABLE		1-10	Indicates the end of a section table.
TURN		1-10	Indicates a turning point in the survey. (See note 2.)
	BS	11-20	The backsight on the turning point.
	FS	21-30	The foresight on the turning point.

Turn records are inserted after any complete data record and are used to calculate elevations for the following Y coordinates.

Note 1 Names may consist of from 1 to 6 alpha numeric characters. Imbedded blanks are ignored so a hyphen (-) should be used to separate characters if desired. The name may be anywhere within the XSEC name field.

Note 2 Use TURN record only if instrument is moved during cross section survey.

Note 3 Encroachment at road cross sections cannot be within stations defining girder end points.

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Cedar Creek (JOB OR PROJECT) BY WM CHECKED DW DATE 1-8-93

Control Word	11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	XSEC NAME	SKEW TYPE	BASE CURVE	PIER CURVE			
BPR	GIRDAV	B	1	2			136
	BOTTOM ELEV	AVG WIDTH	BOTTOM ELEV	AVG WIDTH	BOTTOM ELEV	AVG WIDTH	
PIER	757.0	3.	758.	3.			138
	XSEC NAME	COEF OF CONTR					
CONTR							
	ELEV FULL	ELEV GRDR BOT	SKEW ANGLE	ORIF COEF	WEIR COEF		
GIRDER	770.0	769.2	0.	0.8	2.7		140
	STATION	ELEV.	STATION	ELEV.	STATION	ELEV.	
	1650.	774.7	1650.	769.2	1820.	769.3	141
	1820.	774.8					142
ENDTABLE							
	XSEC NAME	NO. OF PIPES	CULV CODE				
CULV 1	HWY 270	3	21548				
	DIA OR HEIGHT	WIDTH	LENGTH	ELEV US INVERT	ELEV DS INVERT	CULV 'n'	
CULV 2	10.		45.	767.	766 .9		
~~CULV 1~~							
~~CULV 2~~							
~~CULV 1~~							
~~CULV 2~~							
~~CULV 1~~							
~~CULV 2~~							
~~CULV 1~~							
~~CULV 2~~							

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		Columns	
BPR		1-10	Enters data to be used for computing BPR bridges.
	XSEC NAME	11-20	The name of the cross section associated with this bridge. (See note 1 - SCS-ENG-19).
	SKEW TYPE	21-30	A or B according to figure 31–2.
	BASE CURVE	31-40	Reference figure 31–3. Curves are numbered 1-3 from bottom to top.
	PIER CURVE	41-50	Reference figure 31–4. Curves are numbered 1-8 from left to right.
PIER		1-10	Defines the pier sizes if present. (This record must follow the BPR record if used.) Max. of 3 piers (1 record) may be entered. (If more are present, combine dimensions.)
	BOTTOM ELEV.	11-20, 31-40, 51-60	The elevations where the piers intersect the channel bottom.
	AVG. WIDTH	21-30, 41-50, 61-70	The average widths of the piers (See fig. 31–4).
CONTR		1-10	Gives the needed data if the bridge is to be computed by the contracted opening method.
	XSEC NAME	11-20	The name of the cross section associated with this bridge.
	COEF OF CONTR	21-30	The contraction coefficient to use in the contraction formula.
GIRDER		1-10	Describes the individual items pertaining to an opening (must follow CONTR or PIER, if PIER is not used, it must follow BPR).
	ELEV FULL	11-20	Elevation where orifice flow begins. Based on the individuals best judgment, it is usually slightly above the point where the girders are all submerged.
	ELEV GRDR BOT	21-30	The elevation where the girders first begin to reduce flow area from the channel.
	SKEW ANGLE	31-40	The angle of the flow in degrees with the perpendicular to the center line of the roadway.
	ORIF COEF	41-50	The coefficient to be used in the orifice flow formula when orifice flow controls.
	WEIR COEF	51-60	The weir coefficient for flow over the bridge deck. This is computed separate from the flow over the roadway proper.
	DATA RECORDS 1-5	11-70 by 10 col. fields	The X and Y coordinates are needed to describe the shape of the bridge girder. These points are used to deduct net flow area from the section when flow encounters the girder. The first and last girder points define the weir when flow overtops the girder. These are entered X1, Y1, X2, Y2, etc. the horizontal distances of first and last points must coincide with points on the cross section (road). The order of entry of girder points begins with the upper left point and proceeds counter clockwise and ends at the upper right point. See appendix 31A for example of girder input. Use only the number of records actually needed.
END TABLE		1-10	Indicates the end of a girder table.
CULV1		1-10	Enters data to be used in computing losses through culverts.
	XSEC NAME	11-20	The name of the cross section associated with this culvert. (See note 1 - SCS-ENG-19.)
	NO. OF PIPES	21-30	The number of identical openings - no limit on this number.
	CULV CODE	31-40	Select the appropriate code from the table below.
CULV2		1-10	This is a continuation of CULV1 and "must" follow it.
	DIA OR HEIGHT	11-20	The diameter of a circular culvert in feet or the height in feet of a box culvert or pipe arch.
	WIDTH	21-30	The width in feet of a box culvert or piper arch. (Leave blank for circular culverts.)
	LENGTH	31-40	The total length of the culvert in feet.
	ELEV US INVERT	41-50	The elevation of the upstream invert of the culvert.
	ELEV DS INVERT	51-60	The elevation of the downstream invert of the culvert.
	CULV 'n'	61-70	The culvert 'n' value, if a value other than that assigned by the table is desired. (0.01 ≤ 'n' ≤ 0.1)

Culvert code table

Corrugated metal pipe							Concrete pipe or box			
Circular					Pipe arch		Circular		Square edge R. C. Box	
Inlet type	Riveted 'n'=.021	Riveted 25% Paved 'n'=.021	Struc. Plate 'n'=.032	Struc. Plate 25% Paved 'n'=.026	Paved 25% 'n'=.026	Unpaved 'n'=.032	Inlet type	Code 'n'=0.12	Inlet type	Code 'n'=.012
Projection	12311	12411	12111	12211	32211	32111	Socket-end		30 to 75 Degree	
Mitered	13322	13422	13122	13222	33222	33122	projection	22551	Wingwall flair	41111
Headwall	12333	12433	12133	12233	32233	32133	Headwall	22552	90 to 15 degree	
End section	12335	12435					Square edge		Wingwall flair	41122
Bevel (A)	12346	12446	12146	12246			Projection	22533	Parallel wingwalls	41133
Bevel (B)	12347	12447	12147	12247			Headwall	22534		
Tapered	11348	11448					End section	22535		
							Bevel (A)	22546		
							Bevel(B)	22547		
							Tapered	21548		

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Control Word	11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	Data Fields						
	FROM XSEC	TO XSEC	STARTING XSEC	ALT ID			
~~COMPUTE~~							
	ANY ALPHAMERIC TITLE WILL BE PRINTED AT TOP OF EACH PAGE MAY BE CHANGED AT ANY TIME						
TITLE	Skeeter Branch after C & S						
COMPUTE	21	33	21	Alt. No. 2			
TITLE	North Branch after C & S						
COMPUTE	83	87	21	Alt. No. 2			
TITLE	Tanyard Branch, Mill Dam IN, after C & S						
COMPUTE	103	104B	32	Alt. No. 2			
~~LINK~~							
	CONTROL WORD	FROM (XSEC)	TO (XSEC)				
~~CHANGE~~							
~~END~~							
ENDJOB							
ENDRUN							

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		Columns	
COMPUTE		1-10	This signals computations to start.
	FROM XSEC	11-20	The first cross section name in the series of names to be used in computations.
	TO XSEC	21-30	The last cross section name in the series of names to be used.
			Intermediate names will be selected as they appear in the reach file.
	STARTING XSEC	31-40	The name of the cross section where starting elevations are to be taken. This may be the same name as the from field, or the current name in the STARTS or STARTE file or a name in the TRIB file. In the case that this name occurs in both the START file and TRIB file the START file is used. WSP2 checks the three names on the compute record for matching names in the REACH file.
	ALT ID	41-50	Optional eight character alternate identification. Should be changed for each pass through the watershed.
TITLE		1-10	Optional record to change TITLE for the following compute sequence. See also SCS-ENG-16.
LINK		1-10	If the number of sections in a watershed is larger than the program limit this will allow the watershed to be divided into subareas with each subarea having less sections than the program limit. The single junction point between subareas is always a cross section. This junction section must be listed on the TRIB record. The compute record which follows would normally be compute NAME1 (first reach in the new subarea), NAME2, NAME3 (TRIB record). Since the link records make all cross section data read before that point unavailable, such things as a REACH2 displacement with a section downstream from the link to upstream from the link is impossible.
CHANGE		1-10	Used when updating data files (see special section on updating).
	CONTROL WORD	11-20	Enter the name of the control word to be changed. Control words that may be changed are: REACH (includes ROAD), SECTIONS, DISCHARGE, SEGMENT, TRIB, CONTR, BPR, CULV1.
	Note: The following from and to fields are used for the "REACH" file only.		
	FROM (XSEC)	21-30	The first XSEC name to be changed.
	TO (XSEC)	31-40	The last XSEC name to be changed. All reach data between and including the "from" and "to" names will be deleted. If new data are desired they must be entered directly after the change record in the order that computations will take place. If the "to" field is left blank then any new reach (or road) records that follow will be inserted immediately after the name in the from field and the data associated with the "from" name are not altered. If data for only one reach needs to be changed that name will appear in the "from" and "to" fields.
END		1-10	To be used when the updates are completed.
ENDJOB		1-10	To be used between two WSP2 jobs.
ENDRUN		1-10	To be used after the last job in the run (calls exit).

Appendix 31–B

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WATER SURFACE PROFILE INPUT DATA

______________________ BY ______________ CHECKED ______________ DATE ______________
(JOB OR PROJECT)

Control Word	Data Fields 11-20	21-30	31-40	41-50	51-60	61-70	Record Ident.
	DELTA ELEV.	WSID					
WSP2							
	ANY ALPHAMERIC TITLE WILL BE PRINTED AT TOP OF EACH PAGE MAY NOT BE CHANGED IN JOB						
TITLE							
	ANY ALPHAMERIC TITLE WILL BE PRINTED AT TOP OF EACH PAGE MAY BE CHANGED AT ANY TIME						
TITLE							
	TOTAL D.A.	CSM	CSM	CSM	CSM	CSM	
DISCHARGE							
DISCHARGE							
DISCHARGE							
	XSEC NAME	SLOPE	SLOPE	SLOPE	SLOPE	SLOPE	
STARTS							
STARTS							
STARTS							
	XSEC NAME	ELEVATION	ELEVATION	ELEVATION	ELEVATION	ELEVATION	
STARTE							
STARTE							
STARTE							
	XSEC NAME	XSEC NAME	XSEC NAME	XSEC NAME	XSEC NAME	XSEC NAME	
TRIB							
TRIB							
TRIB							
TRIB							
	OUTPUT OPTIONS						
OUTPUT							
	ANY ALPHAMERIC MESSAGE						
COMMENT							
	SAME AS COMMENT						
*							

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Record	Field	Columns	Description
WSP2		1-10	Resets all program variables to program defined values for beginning of a new job. This must be the first record of a job.
	DELTA ELEV	11-20	Maximum elevation difference between X-section coordinates without a message statement resulting in printout. Default is 20 feet.
	WS_ID	21-30	Eight character watershed identification.
TITLE		1-10	
	TITLE	11-70	Any alphameric data. The first title entered will be retained for the entire job, and will be printed at the top of each page. It may not be altered. The second title entered will also be printed at the top of each page. It may be altered at any time.
DISCHARGE		1-10	Enters basic csm values to be used.
	TOTAL DA	11-20	The drainage area at the lower end of the watershed. (see note 1.)
	CSM	21-70 by 10 col. fields	The csm values for each profile desired. These values set the order of computations, i.e. the first csm value entered is the first profile run. A maximum of five values may be entered on one record. Up to 3 Records may be used. Entering csm values from lowest to highest is recommended.
STARTE		1-10	Used to enter the starting elevations for each profile to be run. Up to 3 records per section may be used but only one section may be entered at one time.
	XSEC NAME	11-20	The name of the cross section for which the starting elevations apply. The name must be entered in each record used. (See note 2.)
	ELEVATION	21-70 by 10 col. fields	The starting elevation for each csm. The first elevation entered refers to the first csm, etc.
STARTS		1-10	Same as STARTE except that slopes in ft/ft are entered instead of elevations. If neither STARTE nor STARTS records are entered, computations begin at critical depth.
TRIB		1-10	
	XSEC NAMES	11-70 by 10 col. fields	The names of cross sections where data are to be held for use as starting data on later profiles. These names cannot be road names. Up to 20 names may be used. (See note 2.)
OUTPUT		1-10	This record sets the output switches for the type of output desired. Each time an output record is entered all previous output options are turned off. The printed valley section and bridge rating tables are standard output.
	OUTPUT OPTIONS	11-20	R = Save rating tables for input to hydrology program. P = Plot rating tables S = Print segment table K = KD table T = Save selected rating tables for input to hydrology program E = Save rating tables for economic programs W = Water surface profile graphics file X = Cross section data graphics file H = Hydraulic tables graphics file C = Conveyance tables graphics file These options may be entered in any order. Enter letters only in this field
COMMENT	OR *	1-10	Provides list of desired comments on the output listing of input data. Do not use within groups of records that go together such as SEGMENT and NVALUE.
		11-70	The desired text.

Note 1: See section on input for given cfs values for optional methods of entering discharges.

Note 2: Names may consist of from 1 to 6 alphanumeric characters. Imbedded blanks are ignored so a - should be used to separate characters if desired. The name may be anywhere within the name field.

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WATER SURFACE PROFILE INPUT DATA

______________________ BY ______________ CHECKED ________________ DATE ______________
(JOB OR PROJECT)

Control Word	Data Fields						Record Ident.
	11-20	21-30	31-40	41-50	51-60	61-70	
	XSEC NAME	DRAINAGE AREA	CHANNEL LENGTH	FLOOD LENGTH	DAMAGE LENGTH	CHANNEL LENGTH	
REACH							
	XSEC NAME	DISPLACEMENT					
REACH2							
	XSEC NAME	WEIR COEF	CHANNEL LENGTH	FLOOD LENGTH	DAMAGE LENGTH	CHANNEL LENGTH	
ROAD							
	BEGIN XSEC	END XSEC	KEY XSEC	NUMBER			
AVERAGE							
	EXP. COEF	CONT. COEF					
LOSS							

PAGE ______ OF ______

Record	Field	Columns	Description
REACH		1-10	Defines the elements of a reach. The road and reach records must be in the order of computations since only the first and last section names are shown on the compute record.
	XSEC	11-20	The name of the reach, each must be unique. (See note 1–SCS-ENG-19.) This must be the same name as the cross section to be used, unless followed by a REACH2 record.
	DRAINAGE AREA	21-30	The drainage area (sq. miles) at the cross section (reach head).
	CHANNEL LENGTH	31-40	The hydraulic length of the main channel segment (to next **downstream** section).
	FLOOD LENGTH	41-50	The hydraulic length of the main flood plain (to next **downstream** section).
	DAMAGE LENGTH	51-60	The length to be used in computing flood plain damage acres in the reach.
	CHANNEL LENGTH	61-70	The length of channel in the damage reach. (See technical procedures for method of use.)
REACH2		1-10	Use this record only if the following data is needed. This record must follow a reach record.
	XSEC NAME	11-20	The name of the cross section to be transposed for the preceding reach. This section must be in the current data. It may not be used if a link record has been read since the XSEC was entered.
	DISPLACEMENT	21-30	The elevation change to be applied to each surveyed point on the cross section. Use negative value if section is to be lowered, positive if it is to be raised.
ROAD		1-10	Enters the elements for a road section.
	XSEC NAME	11-20	The name of the road, each must be unique. (See note 1 - SCS-ENG-19).
	WEIR COEF	21-30	The coefficient to be used for flow over the roadway (usually 2.7).
	REACH LENGTHS	31-70	See channel and flood length descriptions on the REACH record.
AVERAGE		1-10	Specifies cross sections used to develop an average rating table.
	BEGIN XSEC	11-20	Beginning valley cross section (furthest downstream).
	END XSEC	21-30	Ending valley cross section (furthest upstream).
	KEY XSEC	31-40	“Key” valley cross section.
	NUMBER	41-50	Designated TR-20 reach number (integer from 1 to 200).
LOSS		1-10	Enters expansion and contraction loss coefficients.
	EXP. LOSS	11-20	Expansion loss coefficient.
	CONT. LOSS	21-30	Contraction loss coefficient.

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Control Word	Data Fields						Record Ident.
	11-20	21-30	31-40	41-50	51-60	61-70	
	XSEC NAME	HI	TR20 XSEC ID	LEFT ENCR.	RIGHT ENCR.		
SECTION							
	STATION	ELEV.	STATION	ELEV.	STATION	ELEV.	
ENDTABLE							

NOTE: IF ROD READINGS ARE GIVEN TURN RECORDS MAY BE NEEDED

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		Columns	
SECTION		1-10	Enters the data for a cross section or road.
	XSEC NAME	11-20	The name of the section or road (See note 1).
	HI	21-30	The height of instrument if rod readings are given. Cross section data may be entered in any order as it is sorted by the x distance after entry. If 2 points have the same x distance they must be entered in the proper order as these points will not be reversed. (See note 2.)
	TR-20 XSEC ID	31-40	If rating table is to saved in TR-20 format, enter an integer number between and including 1 and 200. See also OPTION record (options R or T).
	LEFT ENCR.	41-50	Enter left encroachment station. Flow is not computed outside this station. (See note 3.)
	RIGHT ENCR.	51-60	Enter right encroachment station. Flow is not computed outside this station. The program checks for the right station to be a larger number than the left encroachment station if entered. (See note 3.)
	DATA RECORDS	11-70 by 10 col. fields	The X and Y coordinates of the cross section. These are entered X1, Y1, X2, Y2, etc. Use only the number of records actually needed. Road Sections are described the same as valley sections. With BPR and Contr bridges the points would be entered as the section would look with the bridge deck, as defined by the girder records, removed. With culverts the points are entered as the road surface above the culvert. A maximum of 48 points (16 records) may be entered.
ENDTABLE		1-10	Indicates the end of a section table.
TURN		1-10	Indicates a turning point in the survey.
	BS	11-20	The backsight on the turning point.
	FS	21-30	The foresight on the turning point.

Turn records are inserted after any complete data record and are used to calculate elevations for the following Y coordinates.

Note 1 Names may consist of from 1 to 6 alpha numeric characters. Imbedded blanks are ignored so a hyphen (-) should be used to separate characters if desired. The name may be anywhere within the XSEC name field.

Note 2 Use TURN record only if instrument is moved during cross section survey.

Note 3 Encroachment at road cross sections cannot be within stations defining girder end points.

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Control Word	Data Fields						Record Ident.
	11-20	21-30	31-40	41-50	51-60	61-70	
	XSEC NAME	SKEW TYPE	BASE CURVE	PIER CURVE			
BPR							
	BOTTOM ELEV	AVG WIDTH	BOTTOM ELEV	AVG WIDTH	BOTTOM ELEV	AVG WIDTH	
PIER							
	XSEC NAME	COEF OF CONTR					
CONTR							
	ELEV FULL	ELEV GRDR BOT	SKEW ANGLE	ORIF COEF	WEIR COEF		
GIRDER							
	STATION	ELEV.	STATION	ELEV.	STATION	ELEV.	
ENDTABLE							
	XSEC NAME	NO. OF PIPES	CULV CODE				
CULV 1							
	DIA OR HEIGHT	WIDTH	LENGTH	ELEV US INVERT	ELEV DS INVERT	CULV 'n'	
CULV 2							
CULV 1							
CULV 2							
CULV 1							
CULV 2							
CULV 1							
CULV 2							
CULV 1							
CULV 2							

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		Columns	
BPR		1-10	Enters data to be used for computing BPR bridges.
	XSEC NAME	11-20	The name of the cross section associated with this bridge. (See note 1 - SCS-ENG-19).
	SKEW TYPE	21-30	A or B according to figure 31–2.
	BASE CURVE	31-40	Reference figure 31–3. Curves are numbered 1-3 from bottom to top.
	PIER CURVE	41-50	Reference figure 31–4. Curves are numbered 1-8 from left to right.
PIER		1-10	Defines the pier sizes if present. (This record must follow the BPR record if used.) Max. of 3 piers (1 record) may be entered. (If more are present, combine dimensions.)
	BOTTOM ELEV.	11-20, 31-40, 51-60	The elevations where the piers intersect the channel bottom.
	AVG. WIDTH	21-30, 41-50, 61-70	The average widths of the piers (See fig. 31–4).
CONTR		1-10	Gives the needed data if the bridge is to be computed by the contracted opening method.
	XSEC NAME	11-20	The name of the cross section associated with this bridge.
	COEF OF CONTR	21-30	The contraction coefficient to use in the contraction formula.
GIRDER		1-10	Describes the individual items pertaining to an opening (must follow CONTR or PIER, if PIER is not used, it must follow BPR).
	ELEV FULL	11-20	Elevation where orifice flow begins. Based on the individuals best judgment, it is usually slightly above the point where the girders are all submerged.
	ELEV GRDR BOT	21-30	The elevation where the girders first begin to reduce flow area from the channel.
	SKEW ANGLE	31-40	The angle of the flow in degrees with the perpendicular to the center line of the roadway.
	ORIF COEF	41-50	The coefficient to be used in the orifice flow formula when orifice flow controls.
	WEIR COEF	51-60	The weir coefficient for flow over the bridge deck. This is computed separate from the flow over the roadway proper.
	DATA RECORDS 1-5	11-70 by 10 col. fields	The X and Y coordinates are needed to describe the shape of the bridge girder. These points are used to deduct net flow area from the section when flow encounters the girder. The first and last girder points define the weir when flow overtops the girder. These are entered X1, Y1, X2, Y2, etc. the horizontal distances of first and last points must coincide with points on the cross section (road). The order of entry of girder points begins with the upper left point and proceeds counter clockwise and ends at the upper right point. See appendix 31A for example of girder input. Use only the number of records actually needed.
END TABLE		1-10	Indicates the end of a girder table.
CULV1		1-10	Enters data to be used in computing losses through culverts.
	XSEC NAME	11-20	The name of the cross section associated with this culvert. (See note 1 - SCS-ENG-19.)
	NO. OF PIPES	21-30	The number of identical openings - no limit on this number.
	CULV CODE	31-40	Select the appropriate code from the table below.
CULV2		1-10	This is a continuation of CULV1 and “must” follow it.
	DIA OR HEIGHT	11-20	The diameter of a circular culvert in feet or the height in feet of a box culvert or pipe arch.
	WIDTH	21-30	The width in feet of a box culvert or piper arch. (Leave blank for circular culverts.)
	LENGTH	31-40	The total length of the culvert in feet.
	ELEV US INVERT	41-50	The elevation of the upstream invert of the culvert.
	ELEV DS INVERT	51-60	The elevation of the downstream invert of the culvert.
	CULV ‘n’	61-70	The culvert ‘n’ value, if a value other than that assigned by the table is desired. (0.01 ≤ ’n’ ≤ 0.1)

Culvert code table

Corrugated metal pipe							Concrete pipe or box			
Circular					Pipe arch		Circular		Square edge R. C. Box	
Inlet type	Riveted ‘n’=.021	Riveted 25% Paved ‘n’=.021	Struc. Plate ‘n’=.032	Struc. Plate 25% Paved ‘n’=.026	Paved 25% ‘n’=.026	Unpaved ‘n’=.032	Inlet type	Code ‘n’=0.12	Inlet type	Code ‘n’=.012
Projection	12311	12411	12111	12211	32211	32111	Socket-end		30 to 75 Degree	
Mitered	13322	13422	13122	13222	33222	33122	projection	22551	Wingwall flair	41111
Headwall	12333	12433	12133	12233	32233	32133	Headwall	22552	90 to 15 degree	
End section	12335	12435					Square edge		Wingwall flair	41122
Bevel (A)	12346	12446	12146	12246			Projection	22533	Parallel wingwalls	41133
Bevel (B)	12347	12447	12147	12247			Headwall	22534		
Tapered	11348	11448					End section	22535		
							Bevel (A)	22546		
							Bevel(B)	22547		
							Tapered	21548		

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Control Word	Data Fields						Record Ident.
	11-20	21-30	31-40	41-50	51-60	61-70	
	XSEC NAME	SEGMENT NO.	SEGMENT TYPE	LAST STATION	LAST ELEV.	n VS EL	
SEGMENT							
	'n'	'r' OR 'EL'	'n'	'r' OR 'EL	'n'	'r' OR 'EL'	
N VALUE							
SEGMENT							
N VALUE							
SEGMENT							
N VALUE							
SEGMENT							
N VALUE							
SEGMENT							
N VALUE							
SEGMENT							
N VALUE							

NOTE: TWO '"N VALUE" RECORDS CAN BE USED PER SEGMENT. FOUR SETS OF 'n'-'r' OR 'EL' VALUES IS THE MAXIMUM.

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		Columns	
SEGMENT		1-10	Describes elements of a segment of a cross section. Each segment record must be followed by its associated 'NVALUE' records. Up to 6 SEGMENT records may be entered for each cross section.
	XSEC NAME	11-20	The name of the cross section of which this segment is a portion.
	SEGMENT NO.	21-30	Enter any number between 1 and 6. A total of 6 segments may be used. They must be numbered consecutively, but not necessarily entered consecutively, i.e., if 4 segments are used they may be entered 4, 2, 3, 1 but may not be numbered 4, 2, 5, 1.
	SEGMENT TYPE	31-40	Three segment types may be used: C - It's a channel segment and this width is used to determine channel acres flooded. KD values are used as computed. D - It's a damage segment. Its area is included in flood plain damage acres and KD values are modified by the square root of the meander factor. N - It's a non damage segment that is included in total acres flooded. Its KD values are modified the same as the 'D' segment.
	LAST STATION	41-50	The station on the cross section which marks the end of the segment. This must be a surveyed point. This also indirectly marks the beginning of the segment number that is 1 higher than this number.
	LAST ELEVATION	51-60	The elevation associated with the 'last station' above (optional). If there is only one station with the 'last station' value as given in columns 41-50, the elevation value is not necessary. However, if the segment ends on a vertical bank this value will indicate whether the segment ends at the top or bottom of the bank.
	n VS EL	61-70	Enter an E in this field if 'n' varies with elevation for this segment.
NVALUE		1-10	Enter the 'n' values and associated hydraulic radii or elevation. **Note: This record must always follow the SEGMENT record or another NVALUE record.
	'n'	11-20, 31-40, 51-60	Enter the 'n' values to be used. Up to 4 'n' values may be used.
	'r' or 'E'	21-30, 41-50, 61-70	The hydraulic radius ('r') or elevation associated with the above 'n' value.

If only 1 'n' value is entered, it is used for all flow depths. If 2 'n' values and 1 'r' is entered, all flows with 'r' lower than the 'r' given use the first 'n' value. All flows with an 'r' greater use the 2nd 'n' value. If 2 or more 'r's are given, the 'r' value is interpreted on a straight line basis for all values of 'r' which lie between the given ones. If the actual 'r' is less than the first 'r' given, the first 'n' value is used. If it is greater than the last 'r' given, then the last 'n' value is used. One more 'n' value than 'r' values are permitted, such as 3 'n's and 2 'r's or 4 'n's and 3 'r's. In such case, the last 'n' is used at all 'r's greater than the last 'r'. Elevations and roughness are handled in the same manner as hydraulic radius and roughness.

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Control Word	Data Fields						Record Ident.
	11-20	21-30	31-40	41-50	51-60	61-70	
	FROM XSEC	TO XSEC	STARTING XSEC	ALT ID			
COMPUTE							
	ANY ALPHAMERIC TITLE WILL BE PRINTED AT TOP OF EACH PAGE MAY BE CHANGED AT ANY TIME						
TITLE							
COMPUTE							
TITLE							
COMPUTE							
LINK							
	CONTROL WORD	FROM (XSEC)	TO (XSEC)				
CHANGE							
END							
ENDJOB							
ENDRUN							

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		Columns	
COMPUTE		1-10	This signals computations to start.
	FROM XSEC	11-20	The first cross section name in the series of names to be used in computations.
	TO XSEC	21-30	The last cross section name in the series of names to be used.
			Intermediate names will be selected as they appear in the reach file.
	STARTING XSEC	31-40	The name of the cross section where starting elevations are to be taken. This may be the same name as the from field, or the current name in the STARTS or STARTE file or a name in the TRIB file. In the case that this name occurs in both the START file and TRIB file the START file is used. WSP2 checks the three names on the compute record for matching names in the REACH file.
	ALT ID	41-50	Optional eight character alternate identification. Should be changed for each pass through the watershed.
TITLE		1-10	Optional record to change TITLE for the following compute sequence. See also SCS-ENG-16.
LINK		1-10	If the number of sections in a watershed is larger than the program limit this will allow the watershed to be divided into subareas with each subarea having less sections than the program limit. The single junction point between subareas is always a cross section. This junction section must be listed on the TRIB record. The compute record which follows would normally be compute NAME1 (first reach in the new subarea), NAME2, NAME3 (TRIB record). Since the link records make all cross section data read before that point unavailable, such things as a REACH2 displacement with a section downstream from the link to upstream from the link is impossible.
CHANGE		1-10	Used when updating data files (see special section on updating).
	CONTROL WORD	11-20	Enter the name of the control word to be changed. Control words that may be changed are: REACH (includes ROAD), SECTIONS, DISCHARGE, SEGMENT, TRIB, CONTR, BPR, CULV1.
	Note: The following from and to fields are used for the "REACH" file only.		
	FROM (XSEC)	21-30	The first XSEC name to be changed.
	TO (XSEC)	31-40	The last XSEC name to be changed. All reach data between and including the "from" and "to" names will be deleted. If new data are desired they must be entered directly after the change record in the order that computations will take place. If the "to" field is left blank then any new reach (or road) records that follow will be inserted immediately after the name in the from field and the data associated with the "from" name are not altered. If data for only one reach needs to be changed that name will appear in the "from" and "to" fields.
END		1-10	To be used when the updates are completed.
ENDJOB		1-10	To be used between two WSP2 jobs.
ENDRUN		1-10	To be used after the last job in the run (calls exit).