Modified Level II Streambed-Scour Analysis for Structure I-65-81-5523 Crossing Big Blue River in Shelby County, Indiana

By ROBERT L. MILLER, BRET A. ROBINSON, and DAVID C. VOELKER

Prepared in cooperation with the
INDIANA DEPARTMENT OF TRANSPORTATION

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
square foot (ft^2)	929.0	square centimeter
feet per second (ft/s)	0.3048	meters per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Abbreviations used in this report:

D_{50}	median diameter of bed material
Q100	100-year discharge
FEMA	Federal Emergency Management Agency
HEC	Hydraulic Engineering Circular
IDNR	Indiana Department of Natural Resources
INDOT	Indiana Department of Transportation
USGS	U. S. Geological Survey
WSPRO	Water Surface PROfile model

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By Robert L. Miller, Bret A. Robinson, *and* David C. Voelker

ABSTRACT

Level II scour evaluations follow a process in which hydrologic, hydraulic, and sediment-transport data are evaluated to calculate the depth of scour that may result when a given discharge is routed through a bridge opening. The results of the modified Level II analysis for structure I-65-81-5523 on Interstate 65 crossing Big Blue River in Shelby County, Indiana, are presented. The site is near the town of Mt. Auburn in the southwestern part of Shelby County. Scour depths were computed with the Water Surface PROfile model, version V050196, which incorporates the scour-calculation procedures outlined in Hydraulic Engineering Circular No. 18. Total scour depths at the piers were approximately 30.8 feet for the modeled discharge of 23,900 cubic feet per second and approximately 35.7 feet for the modeled discharge of 31,300 cubic feet per second.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the Indiana Department of Transportation (INDOT), is conducting Level II scour analyses at a number of bridges throughout Indiana. This report describes the methods applied and the modeling results for bridge I-65-81-5523.

Background and Scope

Level I scour assessment is a process where a large number of bridges are studied as a group. Assessments usually are made by evaluating a combination of geomorphic, hydrologic, and bridge-characteristic data. The results help investigators determine which bridges appear to be most likely to experience streambed-scour problems and which bridges appear to be relatively immune to problems brought on by streambed scour (for example, bridges built on bedrock).

When applied correctly, Level I scour assessments provide an investigator with information to identify those bridges that appear to be relatively safe and those bridges that fall into higher risk categories.

Level II scour evaluations describe the process for an investigator to apply a model to a bridge site and calculate the potential depth of scour that may result from a given flood event. Level II analyses involve the application of basic hydrologic, hydraulic, and sediment-transport engineering concepts and may include an evaluation of flood history, channel hydraulic conditions (for example, water-surface profile analysis), and basic sediment-transport analyses such as scour calculations (Lagasse and others, 1995).

The methods and model outlined in Hydraulic Engineering Circular (HEC) No. 18 (Richardson and Davis, 1995) formulate the basis for Level II scour evaluations. Methods used in this study for Level II scour evaluations are a modification of the HEC-18 standards. These modifications were made to comply with the methodology requested by INDOT (Merril Dougherty, Indiana Department of Transportation, oral commun., 1996). Descriptions of the specific modifications are given in the "Evaluation Methods" section of this report.

This report presents the methods followed for modeling, special considerations for this study site, and the input for and the output from the Water Surface PROfile (WSPRO) model.

Site Description

The study site is located near the town of Mt. Auburn in the southwestern part of Shelby County. The drainage area for the site is approximately 575 mi^2 (estimated using Hoggatt, 1975, and USGS 7.5-minute topographic data). The predominant land use in the basin is agricultural; in the immediate vicinity of the bridge, the land is predominantly forest.

Within the immediate vicinity of the bridge, Big Blue River has a channel-bed slope of approximately 0.00077 ft/ft. The channel-bed material is gravelly sandy silt-clay, and the channel banks consist of sandy silt-clay. At the time of the Level I site visit on September 25, 1995, the banks were observed to have 0 to 50 percent woody vegetative cover; the field report noted that the banks were experiencing some fluvial erosion.

The Interstate 65 crossing of Big Blue River is a 416-ft-long, multi-lane bridge consisting of five spans supported by concrete and steel piers and riprap covered spill-through abutments. Additional details describing conditions at the site are included in the Level I data base (Hopkins and Robinson, unpub. data, 1997). Photographs of the site, taken at the time of the Level I site visit, are archived at the USGS office in Indianapolis.

EVALUATION METHODS

The methods described in this section apply to a number of bridge sites in Indiana being evaluated for scour and outline the procedures requested by INDOT for these modified Level II scour analyses. The principal modification requested by INDOT was that the input data to the model come from or be estimated from existing data sources; no additional field data were collected. Actual methods used in the scour evaluation at this particular bridge site use the most applicable method possible, given the data available.

To determine drainage area, either published values found in Hoggatt (1975) or 7.5-minute topographic maps with Hoggatt's original drainage-area delineations were used. Where there are no published data, drainage-area segments measured from the maps produced by Hoggatt were either subtracted from downstream sites or added to upstream sites published by Hoggatt (1975).

In Indiana, flood discharges are coordinated by agreement among State and Federal agencies. At sites where flood discharges officially are coordinated among State and Federal agencies in Indiana, the coordinated 100-year discharge (Q100) was modeled. INDOT also provided an additional flood discharge for these coordinated sites in excess of the Q100 to be modeled.

If a flood discharge was not coordinated, the USGS examined Federal Emergency Management Agency (FEMA) studies for Q100 determinations. Where FEMA studies did not produce a Q100, the USGS contacted IDNR for an estimated Q100 in the vicinity of the site being studied. If IDNR did not have a Q100, data from nearby USGS streamflow-gaging stations were analyzed with nearby and similar drainage basins that have been coordinated. At sites having no coordinated discharge data, the two discharges used in the model were 1) the approximated Q100 and 2) a discharge equal to 1.7 times the approximated Q100.

Most of the cross-section and bridge-opening geometry data were taken from the bridge plans (Indiana State Highway Commission, 1968) provided by INDOT. Bridge plans are presumed to be representative of current conditions at the site. To determine the cross-section geometry, a line was drawn on the bridge plans parallel to the bridge stationing and approximately one bridge width from the bridge. For sites where the bridge plans did not extend far enough laterally for collection of all cross-section data required for WSPRO model analysis, additional data were collected from 7.5-minute topographic maps.

The roadway and embankment profile was taken from the bridge and highway plans for those sites where roadway overtopping was expected. The INDOT bridge plans and 7.5-minute topographic maps were used as a guide, based on the water-surface elevations calculated by the WSPRO model, to determine if roadway overtopping might occur.

Roughness values (n-values) for the main channel were estimated by viewing photographs archived from the Level I scour assessments. The n-values for the overbanks were assigned on the basis of the surface-cover data summarized in the Level I data base (Hopkins and Robinson, unpub. data, 1997). From those data, the following roughness values were assigned to the surface-cover categories: urban—0.050, suburban—0.035, row crop—0.045, pasture—0.035, brush—0.120, forest—0.100, and wetland (any area covered by standing water)—0.100. The n-values for the overbanks were adjusted if the Level I photographs provided sufficient detail to warrant an adjustment.

WSPRO version V050196 was used to model flow through the study site. Starting water-surface elevation was obtained with a slope-conveyance computation. The channel-bed slope in the immediate vicinity of the bridge was estimated from the 7.5-minute topographic map and was used as the slope of the energy grade line for this computation.

WSPRO version V050196 includes a field that allows the input of up to four scour-adjustment factors (K1 to K4). For this modeling, the default value for K4 (bed armoring) was chosen. For scour-adjustment factors K1 and K2 (pier-nose shape and angle of attack, respectively), input values were determined by evaluating the data archived in the Level I data base (Hopkins and Robinson, unpub. data, 1997). For the K3 factor (bed forms), a value of 1.1 was applied in all cases.

In some cases, piers set on the overbanks are constructed with footings that are higher in elevation than pier footings in the main channel. In these situations, if the channel position changes, the piers that were initially constructed on the overbank may become part of the main channel. Therefore, to evaluate total potential scour, the model results obtained for contraction scour and deepest local scour in the main channel were added and applied to all piers in the bridge opening. This methodology allowed for an evaluation of potential undermining of pier supports in the event that future channel movement placed overbank piers in the main channel.

Where bridge pairs have a continuous abutment or fill between the bridges that does not allow expansion of flow, the bridge pair was modeled as one bridge. Sites with discontinuous abutments, allowing expansion between the bridges, were modeled as two separate bridges. In those cases, a valley cross section was measured between the bridges and used as the approach section for the downstream bridge and as the exit section for the upstream bridge.

At sites with no embankment to function as a weir or at sites where the tailwater drowns out the embankment, a composite bridge and road section was used to compute flow. Those sites were computed with friction-loss equations rather than with a bridge routine.

Total scour is taken as the sum of local scour plus contraction scour. If the model predicted negative contraction scour (aggradation), the contraction-scour value was assumed to be zero in determining the total scour depth (table 1). This assumption was made so that a negative contraction scour would not mask the potentially detrimental effects of local scour at a pier. No abutment scour evaluations were made in this study.

Table 1. Cumulative scour depths for the modeled discharges at structure I-65-81-5523 crossing Big Blue River in Shelby County, Indiana

[--, no value]

Pier number[1]	Stationing from bridge plans[2]	Initial bed-elevation at pier (feet)	Main-channel contraction scour depth (feet)	Local scour depth (feet)	Worst-case total-scour depth[3] (feet)	Bottom elevation of pier (feet)	Worst-case bed elevation after scour[4] (feet)
Modeled discharge[5] is 23,900 cubic feet per second							
1	80+33	669	8.5	22.3	30.8	663	634.6
2	81+22	665	8.5	22.3	30.8	660	634.6
3	82+14	665	8.5	22.3	30.8	660	634.6
4	83+05	669	8.5	22.3	30.8	663	634.6
Modeled discharge is 31,300 cubic feet per second							
1	80+33	669	11.6	24.1	35.7	663	629.7
2	81+22	665	11.6	24.1	35.7	660	629.7
3	82+14	665	11.6	24.1	35.7	660	629.7
4	83+05	669	11.6	24.1	35.7	663	629.7

[1]Pier numbers were assigned from left to right as shown on the bridge plans.

[2]Stationing is the center line of the pier as determined from the bridge plans. Stationing from bridge plan, 80+33, represents a point 8,033 feet from an arbitrary starting location referenced on the bridge plans.

[3]Worst-case total-scour depths are generated by summing the calculated contraction-scour depth with the worst case of local scour.

[4]Worst-case bed elevation is computed by subtracting the worst-case total-scour depth from the lowest initial bed elevation in the bridge opening (665.4 feet).

[5]Coordinated discharge.

SPECIAL CONSIDERATIONS

Model runs indicate the water-surface elevation at the bridge is lower than the low-steel elevation for the modeled discharges. Therefore, there should be no pressure flow through the bridge opening for the discharges modeled.

RESULTS

Scour depths were computed with a version of WSPRO (Larry Arneson, Federal Highway Administration, written commun., 1996) modified from Shearman (1990). This version of WSPRO includes scour calculations in the model output. Scour depths were calculated assuming an infinite depth of material that could erode and a homogeneous particle-size distribution. The results of the scour analysis are presented in table 1; a complete input file and output results are presented in the appendix.

REFERENCES

Hoggatt, R.E., 1975, Drainage areas of Indiana streams: U.S. Geological Survey, Water Resources Division, 231 p.

Indiana State Highway Commission, 1968, Bridge plans Interstate Route 65: Bridge File I-65-81-5523.

Lagasse, P.F.; Schall, J.D.; Johnson, F.; Richardson, E.V.; and Chang, F., 1995, Stream stability at highway structures (2d ed.): Federal Highway Administration, Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Richardson, E.V., and Davis, S.R., 1995, Evaluating scour at bridges (3d ed.): Federal Highway Administration, Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Shearman, J.O., 1990, User's manual for WSPRO, a computer model for water-surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 177 p.

APPENDIX

WSPRO INPUT FILE

```
T1          I-65 over Big Blue River in Shelby Co.  I-65-81-5523
T2          County: Shelby                          Quad: Marietta 138A
T3          06-02-97                                  Robert Miller
SI          0
Q             23900  31300
SK               .00077 .00077
XS   EXIT    0  52
GR          2768 690  2830 680  4450 680  5664 680  5878 670
GR          7920 670  7935 669
GR          7945 669  7954 670  7961 671  7966 672  7993 673
GR          8000 674  8037 674
GR          8121 674  8132 667  8148 666  8168 666  8212 667
GR          8222 672  8227 673
GR          8285 673  8303 672  8314 671  8321 671  8330 674
GR          8425 670  9027 670
GR          10616 680  10766 690
N                .100         .038         .100
SA                     7887          8156
XS   FULLV    350 52
GR          2768 690  2830 680  4450 680  5664 680  5878 670
GR          7920 670  7935 669
GR          7945 669  7954 670  7961 671  7966 672  7993 673
GR          8000 674  8037 674
GR          8121 674  8132 667  8148 666  8168 666  8212 667
GR          8222 672  8227 673
GR          8285 673  8303 672  8314 671  8321 671  8330 674
GR          8425 670  9027 670
GR          10616 680  10766 690
N             .100           .038         .100
SA                    7887         8156
BR   BRDGE  350     685.5  30
GR          7962 685.8  7963 684.3  7965 684.2  7990 672.7  8000 672.7
GR          8008 668.9  8102 668.8  8110 665.3  8229 665.4  8236 668.9
GR          8332 668.9  8341 672.8  8351 672.6  8374 683.7  8376 683.6
GR          8377 685.1  7962 685.8
N               .032
PD 1            665.4  6  1
PD 1            668.9  6  2
PD 1            668.9  12 3
CD             3  156  2  685
DC 0 BRDGE     8102 8236 7887 8156  *   12
DP   BRDGE     7962 8377   3.0  *  *  1.0  2.9 1.1
DP   BRDGE     7962 8377   3.0  *  *  1.0  2.9 1.1
DP   BRDGE     7962 8377   3.0  *  *  1.0  2.9 1.1
DP   BRDGE     7962 8377   3.0  *  *  1.0  2.9 1.1
XS   APPR     850
GR          6511 690  6573 680  7943 675  7980 675
GR          8021 672  8031 671
GR          8035 671  8053 672  8067 671  8076 670  8084 669
GR          8099 668  8108 667
GR          8111 666  8125 665  8131 665  8133 666  8134 667
GR          8143 672  8146 673
GR          8165 673  8206 672  8211 671  8214 671  8223 672
GR          8233 673  8249 673
```

WSPRO INPUT FILE

```
GR          8278 673   8295 673   8300 672   8309 672   8338 673
GR          8380 670
GR          9961 680   10075 690
N               .100         .038         .100
SA                     7887           8156
EX
ER
```

WSPRO OUTPUT

```
   ************************* W S P R O ****************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
         Run Date & Time:  8/ 4/97  3:16 pm     Version V050196
          Input File: 5523.dat       Output File: 5523.LST
   *-------------------------------------------------------------*
T1         I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
T2         COUNTY: SHELBY                          QUAD: MARIETTA 138A
T3         06-02-97                                  ROBERT MILLER
SI         0
Q            23900  31300

 ***   Processing Flow Data; Placing Information into Sequence  1   ***

SK              .00077 .00077

   ************************* W S P R O ****************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
       I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
      COUNTY: SHELBY                          QUAD: MARIETTA 138A
        06-02-97                                  ROBERT MILLER

          *-------------------------------------------------*
          *      Starting To Process Header Record EXIT     *
          *-------------------------------------------------*

XS   EXIT   0  52
GR         2768 690  2830 680  4450 680  5664 680  5878 670
GR         7920 670  7935 669
GR         7945 669  7954 670  7961 671  7966 672  7993 673
GR         8000 674  8037 674
GR         8121 674  8132 667  8148 666  8168 666  8212 667
GR         8222 672  8227 673
GR         8285 673  8303 672  8314 671  8321 671  8330 674
GR         8425 670  9027 670
GR         10616 680  10766 690
N               .100        .038        .100
SA                   7887         8156

 ***   Completed Reading Data Associated With Header Record EXIT    ***
 ***  Storing X-Section Data In Temporary File As Record Number  1  ***

 ***              Data Summary For Header Record EXIT               ***
 SRD Location:        0.   Cross-Section Skew:  52.0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (30 pairs)
     X          Y          X          Y          X          Y
----------  ----------  ----------  ----------  ----------  ----------
  2768.000    690.000    2830.000    680.000    4450.000    680.000
```

WSPRO OUTPUT

5664.000	680.000	5878.000	670.000	7920.000	670.000
7935.000	669.000	7945.000	669.000	7954.000	670.000
7961.000	671.000	7966.000	672.000	7993.000	673.000
8000.000	674.000	8037.000	674.000	8121.000	674.000
8132.000	667.000	8148.000	666.000	8168.000	666.000
8212.000	667.000	8222.000	672.000	8227.000	673.000
8285.000	673.000	8303.000	672.000	8314.000	671.000
8321.000	671.000	8330.000	674.000	8425.000	670.000
9027.000	670.000	10616.000	680.000	10766.000	690.000

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 2768.000 (associated Y-Elevation: 690.000)
Maximum X-Station: 10766.000 (associated Y-Elevation: 690.000)
Minimum Y-Elevation: 666.000 (associated X-Station: 8168.000)
Maximum Y-Elevation: 690.000 (associated X-Station: 2768.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
2768.000	4843.428	2830.000	4881.599	4450.000	5878.971
5664.000	6626.384	5878.000	6758.135	7920.000	8015.316
7935.000	8024.551	7945.000	8030.708	7954.000	8036.249
7961.000	8040.558	7966.000	8043.636	7993.000	8060.259
8000.000	8064.569	8037.000	8087.348	8121.000	8139.064
8132.000	8145.836	8148.000	8155.687	8168.000	8168.000
8212.000	8195.089	8222.000	8201.246	8227.000	8204.324
8285.000	8240.032	8303.000	8251.114	8314.000	8257.887
8321.000	8262.196	8330.000	8267.737	8425.000	8326.225
9027.000	8696.854	10616.000	9675.140	10766.000	9767.488

Roughness Data (3 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.100	---
	---	7994.999
2	.038	---
	---	8160.612
3	.100	---

--
* Finished Processing Header Record EXIT *
--

********** W S P R O **********
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English
--

I-65 OVER BIG BLUE RIVER IN SHELBY CO. I-65-81-5523
COUNTY: SHELBY QUAD: MARIETTA 138A

WSPRO OUTPUT

06-02-97 ROBERT MILLER

```
*-------------------------------------------------*
*      Starting To Process Header Record FULLV    *
*-------------------------------------------------*

XS   FULLV   350 52
GR        2768 690  2830 680  4450 680  5664 680  5878 670
GR        7920 670  7935 669
GR        7945 669  7954 670  7961 671  7966 672  7993 673
GR        8000 674  8037 674
GR        8121 674  8132 667  8148 666  8168 666  8212 667
GR        8222 672  8227 673
GR        8285 673  8303 672  8314 671  8321 671  8330 674
GR        8425 670  9027 670
GR        10616 680  10766 690
N            .100          .038        .100
SA                   7887        8156
```

*** Completed Reading Data Associated With Header Record FULLV ***
*** Storing X-Section Data In Temporary File As Record Number 2 ***

*** Data Summary For Header Record FULLV ***
SRD Location: 350. Cross-Section Skew: 52.0 Error Code 0
Valley Slope: .00000 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (30 pairs)

X	Y	X	Y	X	Y
2768.000	690.000	2830.000	680.000	4450.000	680.000
5664.000	680.000	5878.000	670.000	7920.000	670.000
7935.000	669.000	7945.000	669.000	7954.000	670.000
7961.000	671.000	7966.000	672.000	7993.000	673.000
8000.000	674.000	8037.000	674.000	8121.000	674.000
8132.000	667.000	8148.000	666.000	8168.000	666.000
8212.000	667.000	8222.000	672.000	8227.000	673.000
8285.000	673.000	8303.000	672.000	8314.000	671.000
8321.000	671.000	8330.000	674.000	8425.000	670.000
9027.000	670.000	10616.000	680.000	10766.000	690.000

Minimum and Maximum X,Y-coordinates

Minimum X-Station: 2768.000 (associated Y-Elevation: 690.000)
Maximum X-Station: 10766.000 (associated Y-Elevation: 690.000)
Minimum Y-Elevation: 666.000 (associated X-Station: 8168.000)
Maximum Y-Elevation: 690.000 (associated X-Station: 2768.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
2768.000	4843.428	2830.000	4881.599	4450.000	5878.971
5664.000	6626.384	5878.000	6758.135	7920.000	8015.316
7935.000	8024.551	7945.000	8030.708	7954.000	8036.249

WSPRO OUTPUT

```
  7961.000    8040.558     7966.000    8043.636     7993.000    8060.259
  8000.000    8064.569     8037.000    8087.348     8121.000    8139.064
  8132.000    8145.836     8148.000    8155.687     8168.000    8168.000
  8212.000    8195.089     8222.000    8201.246     8227.000    8204.324
  8285.000    8240.032     8303.000    8251.114     8314.000    8257.887
  8321.000    8262.196     8330.000    8267.737     8425.000    8326.225
  9027.000    8696.854    10616.000    9675.140    10766.000    9767.488
---------- ----------   ----------  ----------   ----------  ----------

                    Roughness Data (  3 SubAreas )
                             Roughness   Horizontal
                   SubArea  Coefficient  Breakpoint
                   -------  -----------  ----------
                      1         .100         ---
                                ---        7994.999
                      2         .038         ---
                                ---        8160.612
                      3         .100         ---
                   -------  -----------  ----------

          *--------------------------------------------------*
          *      Finished Processing Header Record FULLV     *
          *--------------------------------------------------*

   ************************* W S P R O ****************************
      Federal Highway Administration  -  U. S. Geological Survey
            Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
       I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
      COUNTY: SHELBY                        QUAD: MARIETTA 138A
        06-02-97                               ROBERT MILLER

          *--------------------------------------------------*
          *      Starting To Process Header Record BRDGE     *
          *--------------------------------------------------*

BR   BRDGE  350    685.5  30
GR        7962 685.8  7963 684.3  7965 684.2  7990 672.7  8000 672.7
GR        8008 668.9  8102 668.8  8110 665.3  8229 665.4  8236 668.9
GR        8332 668.9  8341 672.8  8351 672.6  8374 683.7  8376 683.6
GR        8377 685.1  7962 685.8
N             .032
PD 1          665.4  6  1
PD 1          668.9  6  2
PD 1          668.9  12 3
CD           3  156  2  685

 ***   Completed Reading Data Associated With Header Record BRDGE   ***
 ***   Storing Bridge Data In Temporary File As Record Number  3    ***

 ***              Data Summary For Bridge Record BRDGE              ***
 SRD Location:      350.   Cross-Section Skew:  30.0   Error Code   0
 Valley Slope:  *******    Averaging Conveyance By Geometric Mean.
```

WSPRO OUTPUT

Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (17 pairs)

X	Y	X	Y	X	Y
7962.000	685.800	7963.000	684.300	7965.000	684.200
7990.000	672.700	8000.000	672.700	8008.000	668.900
8102.000	668.800	8110.000	665.300	8229.000	665.400
8236.000	668.900	8332.000	668.900	8341.000	672.800
8351.000	672.600	8374.000	683.700	8376.000	683.600
8377.000	685.100	7962.000	685.800		

Minimum and Maximum X,Y-coordinates

Minimum X-Station:	7962.000	(associated Y-Elevation:	685.800)
Maximum X-Station:	8377.000	(associated Y-Elevation:	685.100)
Minimum Y-Elevation:	665.300	(associated X-Station:	8110.000)
Maximum Y-Elevation:	685.800	(associated X-Station:	7962.000)

X-coordinates & Horizontal Breakpoints Translated by Skew Angle

X Input	X Skewed	X Input	X Skewed	X Input	X Skewed
7962.000	7981.828	7963.000	7982.694	7965.000	7984.426
7990.000	8006.077	8000.000	8014.737	8008.000	8021.666
8102.000	8103.072	8110.000	8110.000	8229.000	8213.057
8236.000	8219.119	8332.000	8302.258	8341.000	8310.052
8351.000	8318.712	8374.000	8338.631	8376.000	8340.362
8377.000	8341.229	7962.000	7981.828		

Roughness Data (1 SubAreas)

SubArea	Roughness Coefficient	Horizontal Breakpoint
1	.032	---

Discharge coefficient parameters

BRType	BRWdth	EMBSS	EMBElv	UserCD
3	156.000	2.00	685.000	**********

Pressure flow elevations

AVBCEL	PFElev
*********	685.500

Abutment Parameters

ABSLPL	ABSLPR	XTOELT	YTOELT	XTOERT	YTOERT
*******	*******	*********	*********	*********	*********

Pier/Pile Data (3 Group(s))

Code Indicates Bridge Uses Piles

Group	Elevation	Gross Width	Number

WSPRO OUTPUT

```
                1       665.400       6.000        1
                2       668.900       6.000        2
                3       668.900      12.000        3
              ------  ---------  -----------  ------

          *--------------------------------------------------*
          *      Finished Processing Header Record BRDGE     *
          *--------------------------------------------------*

   ************************  W S P R O  ***************************
      Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
            Input Units: English  /  Output Units: English
   *-------------------------------------------------------------*
       I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
      COUNTY: SHELBY                          QUAD: MARIETTA 138A
        06-02-97                                  ROBERT MILLER
DC 0 BRDGE    8102 8236 7887 8156  *   12
DP   BRDGE    7962 8377   3.0  *  *  1.0  2.9 1.1
DP   BRDGE    7962 8377   3.0  *  *  1.0  2.9 1.1
DP   BRDGE    7962 8377   3.0  *  *  1.0  2.9 1.1
DP   BRDGE    7962 8377   3.0  *  *  1.0  2.9 1.1

          *--------------------------------------------------*
          *      Starting To Process Header Record APPR      *
          *--------------------------------------------------*

XS   APPR    850
GR         6511 690  6573 680  7943 675  7980 675
GR         8021 672  8031 671
GR         8035 671  8053 672  8067 671  8076 670  8084 669
GR         8099 668  8108 667
GR         8111 666  8125 665  8131 665  8133 666  8134 667
GR         8143 672  8146 673
GR         8165 673  8206 672  8211 671  8214 671  8223 672
GR         8233 673  8249 673
GR         8278 673  8295 673  8300 672  8309 672  8338 673
GR         8380 670
GR         9961 680  10075 690
N              .100       .038        .100
SA                  7887         8156

 ***   Completed Reading Data Associated With Header Record APPR    ***
 ***  Storing X-Section Data In Temporary File As Record Number  4  ***

 ***              Data Summary For Header Record APPR               ***
 SRD Location:      850.   Cross-Section Skew:    .0   Error Code   0
 Valley Slope:   .00000    Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients ->   Expansion:   .50   Contraction:   .00

                    X,Y-coordinates (35 pairs)
     X          Y           X          Y           X          Y
----------  ----------  ----------  ----------  ----------  ----------
  6511.000     690.000     6573.000     680.000     7943.000     675.000
```

WSPRO OUTPUT

```
   7980.000     675.000     8021.000     672.000     8031.000     671.000
   8035.000     671.000     8053.000     672.000     8067.000     671.000
   8076.000     670.000     8084.000     669.000     8099.000     668.000
   8108.000     667.000     8111.000     666.000     8125.000     665.000
   8131.000     665.000     8133.000     666.000     8134.000     667.000
   8143.000     672.000     8146.000     673.000     8165.000     673.000
   8206.000     672.000     8211.000     671.000     8214.000     671.000
   8223.000     672.000     8233.000     673.000     8249.000     673.000
   8278.000     673.000     8295.000     673.000     8300.000     672.000
   8309.000     672.000     8338.000     673.000     8380.000     670.000
   9961.000     680.000    10075.000     690.000
 ---------- ---------- ---------- ---------- ---------- ----------

                  Minimum and Maximum X,Y-coordinates
   Minimum X-Station:    6511.000  ( associated Y-Elevation:  690.000 )
   Maximum X-Station:   10075.000  ( associated Y-Elevation:  690.000 )
   Minimum Y-Elevation:   665.000  ( associated X-Station:   8131.000 )
   Maximum Y-Elevation:   690.000  ( associated X-Station:   6511.000 )

                    Roughness Data (  3 SubAreas )
                            Roughness   Horizontal
                  SubArea  Coefficient  Breakpoint
                  -------  -----------  ----------
                     1         .100        ---
                               ---        7887.000
                     2         .038        ---
                               ---        8156.000
                     3         .100        ---
                  -------  -----------  ----------

Bridge datum projection(s):  XREFLT  XREFRT  FDSTLT  FDSTRT
                            ******* ******* ******* *******

          *-------------------------------------------------*
          *      Finished Processing Header Record APPR     *
          *-------------------------------------------------*

    ************************* W S P R O ***************************
       Federal Highway Administration  -  U. S. Geological Survey
             Model for Water-Surface Profile Computations.
           Input Units: English  /  Output Units: English
    *-------------------------------------------------------------*
        I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
      COUNTY: SHELBY                        QUAD: MARIETTA 138A
        06-02-97                               ROBERT MILLER
  EX

          *=================================================*
          *     Summary of Boundary Condition Information    *
          *=================================================*

            Reach       Water Surface   Friction
     #    Discharge       Elevation      Slope          Flow Regime
    --    ---------    -------------   --------   --------------------
```

WSPRO OUTPUT

```
 1    23900.00       ********         .0008         Sub-Critical
 2    31300.00       ********         .0008         Sub-Critical
--    ---------    -------------    --------    --------------------

      *=================================================*
      *         Beginning  2 Profile Calculation(s)     *
      *=================================================*


*************************  W S P R O  ***************************
   Federal Highway Administration  -  U. S. Geological Survey
          Model for Water-Surface Profile Computations.
         Input Units: English  /  Output Units: English
*-------------------------------------------------------------*
    I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
   COUNTY: SHELBY                          QUAD: MARIETTA 138A
     06-02-97                                  ROBERT MILLER

                   WSEL     VHD       Q          AREA       SRDL       LEW
                   EGEL      HF       V            K         FLEN       REW
                   CRWS      HO     FR #          SF        ALPHA       ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: EXIT      675.476   .031  23900.000  19203.210 *********  5760.818
Header Type: XS    675.506 ******      1.245  860843.00 *********  9897.100
SRD:       .000    671.742 ******       .115     ******     1.269     ******

Section: FULLV     675.742   .028  23900.000  20309.580   350.000  5755.127
Header Type: FV    675.769   .247      1.177  939780.50   350.000  9939.356
SRD:    350.000    671.742   .000       .107      .0007     1.290      .016

       <<< The Preceding Data Reflect The "Unconstricted" Profile >>>

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
      KRATIO:   .29

Section: APPR      676.536   .672  23900.000   5758.271   500.000  7522.088
Header Type: AS    677.208  1.103      4.151  275468.60   500.000  9413.372
SRD:    850.000    675.219   .322       .664      .0022     2.509      .013

       <<< The Preceding Data Reflect The "Unconstricted" Profile >>>

        <<< The Following Data Reflect The "Constricted" Profile >>>
          <<< Beginning Bridge/Culvert Hydraulic Computations >>>


                   WSEL     VHD       Q          AREA       SRDL       LEW
                   EGEL      HF       V            K         FLEN       REW
                   CRWS      HO     FR #          SF        ALPHA       ERR
                 --------- ------ ---------- ---------- --------- ---------
Section: BRDGE     675.878  1.750  23900.000   2886.801   350.000  7983.090
Header Type: BR    677.629   .762      8.279  518626.60   350.000  8357.793
SRD:    350.000    673.235  1.359       .674     ******     1.642     -.003

Specific Bridge Information   C     P/A   PFELEV    BLEN     XLAB     XRAB
```

WSPRO OUTPUT

```
Bridge Type 3   Flow Type 1 ------ ----- -------- -------- -------- --------
Pier/Pile Code  1            .7805  .036  685.500 ******** ******** ********
--------------------------- ------ ----- -------- -------- -------- --------

                     WSEL     VHD       Q         AREA      SRDL      LEW
                     EGEL      HF       V           K       FLEN      REW
                     CRWS      HO     FR #         SF      ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: APPR       678.972   .200  23900.000  11646.310   344.000  6854.728
Header Type: AS     679.172  1.160      2.052  636589.50   395.886  9798.441
SRD:     850.000    675.219   .384       .318      .0022     3.059     -.015

            Approach Section APPR  Flow Contraction Information
           M( G )   M( K )     KQ       XLKQ     XRKQ     OTEL
          -------- -------- --------- -------- -------- --------
              .802     .523 304903.8 8023.071 8397.787  678.972
          -------- -------- --------- -------- -------- --------

              <<< End of Bridge Hydraulics Computations >>>


    ************************* W S P R O ****************************
       Federal Highway Administration - U. S. Geological Survey
             Model for Water-Surface Profile Computations.
            Input Units: English / Output Units: English
    *-------------------------------------------------------------*
        I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
      COUNTY: SHELBY                      QUAD: MARIETTA 138A
        06-02-97                              ROBERT MILLER

                     WSEL     VHD       Q         AREA      SRDL      LEW
                     EGEL      HF       V           K       FLEN      REW
                     CRWS      HO     FR #         SF      ALPHA      ERR
                   --------- ------ ---------- ---------- --------- ---------
Section: EXIT       676.336   .039  31300.000  22828.420 *********  5742.408
Header Type: XS     676.375 ******      1.371 1127479.00 ********* 10033.800
SRD:        .000    672.095 ******       .121     ******     1.333    ******

Section: FULLV      676.594   .036  31300.000  23940.170   350.000  5736.894
Header Type: FV     676.630   .251      1.307 1213661.00   350.000 10074.750
SRD:     350.000    672.095   .000       .114      .0007     1.350      .004

       <<< The Preceding Data Reflect The "Unconstricted" Profile >>>

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS AT SECID "APPR ".
      KRATIO:   .31

Section: APPR       677.326   .759  31300.000   7387.297   500.000  7305.616
Header Type: AS     678.085  1.084      4.237  372319.40   500.000  9538.277
SRD:     850.000    675.834   .361       .677      .0022     2.717      .010

       <<< The Preceding Data Reflect The "Unconstricted" Profile >>>

        <<< The Following Data Reflect The "Constricted" Profile >>>
```

WSPRO OUTPUT

<<< Beginning Bridge/Culvert Hydraulic Computations >>>

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: BRDGE	676.605	2.566	31300.000	3160.216	350.000	7981.511
Header Type: BR	679.171	.754	9.904	599464.20	350.000	8359.299
SRD: 350.000	674.290	2.044	.783	******	1.682	.004

Specific Bridge Information	C	P/A	PFELEV	BLEN	XLAB	XRAB
Bridge Type 3 Flow Type 1						
Pier/Pile Code 1	.7711	.036	685.500	********	********	********

	WSEL	VHD	Q	AREA	SRDL	LEW
	EGEL	HF	V	K	FLEN	REW
	CRWS	HO	FR #	SF	ALPHA	ERR
Section: APPR	680.485	.172	31300.000	16545.860	344.000	6569.995
Header Type: AS	680.657	1.001	1.892	981265.80	402.249	9966.526
SRD: 850.000	675.834	.485	.266	.0022	3.097	.018

Approach Section APPR Flow Contraction Information

M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.831	.587	403484.4	8018.313	8396.087	680.485

<<< End of Bridge Hydraulics Computations >>>

********** W S P R O **********

Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: English / Output Units: English

I-65 OVER BIG BLUE RIVER IN SHELBY CO. I-65-81-5523
COUNTY: SHELBY QUAD: MARIETTA 138A
06-02-97 ROBERT MILLER

*** Live-Bed Contraction Scour Calculations for Header Record BRDGE ***

Constants and Input Variables

Bed Material Transport Mode Factor (k1): .64
Total Pier Width Value (Pw): 12.000

	Scour	-- Flow --		-- Width --		--- X-Limits ---		
#	Depth	Contract	Approach	Contract	Approach	Side	Contract	Approach
--	------	---------	---------	--------	--------	------	--------	--------

WSPRO OUTPUT

```
 1   8.517 13949.150  9841.987  122.000  269.000  Left:  8102.000 7887.000
    ..... Approach Channel Depth:    6.913 .....  Right: 8236.000 8156.000
 2  11.557 17700.250 11629.050  122.000  269.000  Left:  8102.000 7887.000
    ..... Approach Channel Depth:    8.426 .....  Right: 8236.000 8156.000
--  ------ --------- --------- -------- --------  ------ -------- --------
```

```
     ************************* W S P R O ***************************
        Federal Highway Administration - U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
     *-------------------------------------------------------------*
         I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
       COUNTY: SHELBY                        QUAD: MARIETTA 138A
         06-02-97                               ROBERT MILLER

         ***  Pier Scour Calculations for Header Record BRDGE  ***

                      Constants and Input Variables

                          Pier Width:   3.000
                   *-----------------------------------------*
                     Pier Shape Factor            (K1):   1.00
                     Flow Angle of Attack Factor  (K2):   2.90
                     Bed Condition Factor         (K3):   1.10
                     Bed Material Factor          (K4):   1.00
                     Velocity Multiplier          (VM):   1.00
                     Depth Multiplier             (YM):   1.00
                   *-----------------------------------------*
```

	Scour	Localized Hydraulic Properties				X-Stations	
#	Depth	Flow	WSE	Depth	Velocity	Froude #	Left	Right
1	22.29	23900.000	676.262	10.962	9.330	.497	7962.000	8377.000
2	24.14	31300.000	677.090	11.790	10.969	.563	7962.000	8377.000

```
     ************************* W S P R O ***************************
        Federal Highway Administration - U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English  /  Output Units: English
     *-------------------------------------------------------------*
         I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
       COUNTY: SHELBY                        QUAD: MARIETTA 138A
         06-02-97                               ROBERT MILLER

         ***  Pier Scour Calculations for Header Record BRDGE  ***

                      Constants and Input Variables

                          Pier Width:   3.000
                   *-----------------------------------------*
                     Pier Shape Factor            (K1):   1.00
                     Flow Angle of Attack Factor  (K2):   2.90
```

WSPRO OUTPUT

```
                Bed Condition Factor          (K3):   1.10
                Bed Material Factor           (K4):   1.00
                Velocity Multiplier           (VM):   1.00
                Depth Multiplier              (YM):   1.00
              *-----------------------------------------*
```

#	Scour Depth	Localized Hydraulic Properties — Flow	WSE	Depth	Velocity	Froude #	X-Stations — Left	Right
1	22.29	23900.000	676.262	10.962	9.330	.497	7962.000	8377.000
2	24.14	31300.000	677.090	11.790	10.969	.563	7962.000	8377.000

```
     ************************* W S P R O ****************************
        Federal Highway Administration - U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English / Output Units: English
     *-------------------------------------------------------------*
         I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
       COUNTY: SHELBY                        QUAD: MARIETTA 138A
         06-02-97                               ROBERT MILLER

         ***  Pier Scour Calculations for Header Record BRDGE  ***

                      Constants and Input Variables

                           Pier Width:   3.000
                  *-----------------------------------------*
                    Pier Shape Factor             (K1):   1.00
                    Flow Angle of Attack Factor   (K2):   2.90
                    Bed Condition Factor          (K3):   1.10
                    Bed Material Factor           (K4):   1.00
                    Velocity Multiplier           (VM):   1.00
                    Depth Multiplier              (YM):   1.00
                  *-----------------------------------------*
```

#	Scour Depth	Localized Hydraulic Properties — Flow	WSE	Depth	Velocity	Froude #	X-Stations — Left	Right
1	22.29	23900.000	676.262	10.962	9.330	.497	7962.000	8377.000
2	24.14	31300.000	677.090	11.790	10.969	.563	7962.000	8377.000

```
     ************************* W S P R O ****************************
        Federal Highway Administration - U. S. Geological Survey
              Model for Water-Surface Profile Computations.
             Input Units: English / Output Units: English
     *-------------------------------------------------------------*
         I-65 OVER BIG BLUE RIVER IN SHELBY CO.  I-65-81-5523
       COUNTY: SHELBY                        QUAD: MARIETTA 138A
         06-02-97                               ROBERT MILLER
```

WSPRO OUTPUT

*** Pier Scour Calculations for Header Record BRDGE ***

Constants and Input Variables

Pier Width: 3.000

Pier Shape Factor	(K1):	1.00
Flow Angle of Attack Factor	(K2):	2.90
Bed Condition Factor	(K3):	1.10
Bed Material Factor	(K4):	1.00
Velocity Multiplier	(VM):	1.00
Depth Multiplier	(YM):	1.00

#	Scour Depth	Localized Hydraulic Properties Flow	WSE	Depth	Velocity	Froude #	X-Stations Left	Right
1	22.29	23900.000	676.262	10.962	9.330	.497	7962.000	8377.000
2	24.14	31300.000	677.090	11.790	10.969	.563	7962.000	8377.000

ER

********** Normal end of WSPRO execution. **********
********** Elapsed Time: 0 Minutes 6 Seconds **********